THE CONTEMPORARY GUITAR

JOHN SCHNEIDER

The more means an artist has at his disposal,
the more use will be found for them.

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Contents

Preface

During the last twenty-five years, increased use of the guitar in solo, chamber, and orchestral music, combined with innovative approaches to instrumentation and performance, have produced an entirely new kind of literature for the guitar. For the first time in the history of the instrument, most of the important music has come from the pens of non-guitarists—a fact that has been almost entirely responsible for the great changes in the complexion of the repertoire. The growing importance of timbre as a compositional element in twentieth-century music, and in particular in music since 1945, has persuaded composers and performers alike to reevaluate the role of the musical instrument as a sound-generating entity; as a result, the technique and the vocabulary of traditional instruments have been considerably extended. For both acoustic and electric guitar, this reexamination has resulted in an entirely new sound world: a world of experimentation, whose sounds are now being incorporated into the existing musical language during this, the second Golden Age of the Guitar.

Throughout its history, the guitar has been treated as a second-class instrument, not because of its lack of timbral variety, but mostly due to its poor dynamic range. Since the instrument does lack dynamic contrast, some other aspect of its tone must be varied in order to create musical interest. This is where the vast timbral repertoire of the guitar becomes important. In 1934, the eminent guitarist/composer Emilio Pujol wrote a book misleadingly titled *The Dilemma of Timbre on the Guitar.* In it he deals with the pros and cons of nail use in trying to achieve a "pure" tone on the guitar. Practically every guitar tutor ever written has dealt with this quest for the perfect tone, but none of them deals with the actual musical problem of tone production on the instrument. The *real* dilemma of timbre for the guitar is not in the search for a good, pure tone but in the search to produce as many different tone-qualities as possible for the purpose of creating the musical contrast that is not available from the instrument's dynamic range. This is the purpose of the Rational Method of Tone Production (introduced in Chapter 2), which is the theme of this book.

In order to understand fully the techniques of sound production on the guitar, it is first necessary to devise an accurate method for describing the sound the instrument makes, in order that a connection can be made between the mechanical actions of the player/instrument and the resultant sound. First, a brief history of the guitar from 1800 to the present is given (Section One); then the musical parameter of timbre is subdivided into five parameters (Chapter 2), in order to describe the tone quality of the guitar more objectively. The instrument is described as a sound-generating system consisting of string/s, soundboard, and soundbox. Next, the relationship between the player and the instrument is examined, and the ways in which the player can alter individual parameters of timbre, in order to transform the sound of the instrument, are shown. Chapter 3, "The Electric Guitar," uses the same systems approach to describe the electric instrument (string/s, pickup/s, amplifier, speaker), and discusses the result of the player's electronic control of the timbral parameters of the final tone. Because much of the information dealt with in these chapters is technical, those who wish only to get an overview of the material should read the italicized paragraphs at the head of each section to understand the concepts dealt with throughout the volume (although this is certainly no substitute for understanding the "nuts and bolts" of the instrument).

Section Two deals primarily with the Rational Method of Tone Production. This is both a physical technique for deriving contrasting sounds from the guitar and a conceptual approach to playing that emphasizes awareness of the relationships among the various sounds of the guitar. Both performers and instruments vary enormously, so it would be naive to try to predict the exact outcome of the techniques listed in these chapters on the instruments. For this reason, exact data (e.g., difference in harmonic amplitudes when plucking angles are changed) are rarely given. Fortunately, it is not the sounds themselves that are important; it is the relationship *between* sounds that is musically significant. This qualitative approach allows the player to concentrate on the wide spectrum of sounds available within the limits of his own instrument rather than trying to copy the exact sound of another player/instrument combination. Of course, this approach is equally applicable to the electric instrument and to the classic guitar.

Section Three describes the music that the composers of our time have written for both the electric and classic instruments. Since the music of the post-1945 era has utilized many kinds of sound-production, ranging from the traditional to the highly unconventional, musical examples of guitar techniques have been cited according to the quality of the sounds they produce, on a scale ranging from pitched to non-pitched sounds. First, the techniques of normal tone-production are examined; then sounds involving a higher amount of inharmonicity, such as microtones and quasi-pitched clusters, are discussed. Finally, the non-pitched sounds of percussion techniques and use of the prepared guitar are considered.

Much of the repertoire since 1945 has exhibited an increasing interest in sound-for-sound's-sake, often with little attention being paid to more traditional forms of composition. Many of the examples included in this book are mentioned either because they have introduced new timbres into the repertoire or because they have used old techniques in new ways, rather than because of their merits as music. The purpose of this collection of advanced techniques is to make composers aware of the colors available to them, so that they can incorporate these timbres into their musical styles. Of course, these techniques are not all equally valuable. I have included what seem to me to be the most important and interesting trends of the last thirty years, and I hope that the composers of today will use them to their advantage. As the American composer Gunther Schuller has said:

> [After] years of nearly unrelenting experimentation, often it seemed for experimentation's sake, one might think the pace would slow a little. And perhaps that is happening. Perhaps we are moving into a period when the innovations of the recent past will be assessed, weighed for their *real* value and long-term durability, and then, hopefully, the residue will be assimilated into the mainstream of compositional activity.[1]

For the performer, much of this repertoire will probably be unfamiliar; it is the opinion of the majority of players with whom I have come in contact over the last five years that there simply is *no* modern repertoire except the Britten *Nocturnal* (1963) and the pieces recorded by Julian Bream and John Williams. For this reason the music bibliography should be of great interest to those seeking new musical paths for the guitar. Also, this survey of techniques will familiarize the player with some modern trends in guitar writing, so s/he will not be surprised when a post-1945 piece of music appears on the music stand. But most important is the development of an awareness of the guitar's sound in terms of the parameters of timbre—an approach to the instrument that is applicable to the performance of *all* guitar music, not just that of the twentieth century. I hope that this method of increasing "tone awareness" will help to raise musical standards to the highest level that modern guitars and guitarists are capable of achieving.

Many people, by sharing their skills, music, etc., helped to make this book a reality. I would like to offer my appreciation to William Bland, Stephen Dodgson, Ho Wai On, Edward McGuire, Eric Forder (Universal Edition, London), Karl-Aage Rasmussen, Michael Blake-Watkins and Tessa Watkins of J. and W. Chester, London, for supplying scores. I especially thank Reginald Smith-Brindle, Gilbert Biberian, Tim Walker, David Starobin, Danlee Mitchell, and Erling Møldrup for making their personal music available to me.

In regard to the investigation into the acoustics of the instrument, I would like to thank Dr. Michael Greenhough and Bernard Richardson for their technical expertise and sympathy toward the musical problems of the guitar's technology, John Taylor for his dedication to the performance aspects of guitar acoustics, and Mark Griffiths and Dr. Jeff Bloom for their guidance and high standards of research and musicality. A special vote of thanks is due to Professor Charles Taylor and the Department of Physics at University College, Cardiff, South Wales, U.K., for providing the technical facilities and aesthetic climate that made my research possible; I offer my moral support to the Acoustics Group in their search for a greater understanding of the "quality of sound."

My thanks must go to Bert Turetzky, Barney Childs, and Richard Swift for their support and advice during the final stages of this manuscript's preparation. My greatest hopes and aspirations go with the composers and guitarists who use this volume.

J.S.
Santa Monica, California
September 1978

1. Quoted in Gardner Read, *Contemporary Instrumental Techniques* (New York: Schirmer Books, Macmillan, 1976), p. viii.

Section I
HISTORICAL BACKGROUND

CHAPTER I
Overview: 1800 to the Present

The history of an instrument's music is always inextricably related to the development of its construction: the instrument often inspires the performer, who in turn inspires the composer. One can hardly imagine the great Italian string music of the mature Baroque without Corelli, or Corelli without Stradivarius. Developments similar to those in the Cremona school of violinmakers occurred in the guitar manufacture of the mid-1700s. Changes were made to improve both the projection and the sustain of the instrument, which at that time had five double-strung courses.[1] By the beginning of the 1800s in Paris and Vienna, the two centers for guitar performance, the instrument used six single strings and tended to be wider and sturdier than its five-course predecessor. At that time several schools of guitar-playing had developed, and the instrument was assuming an important role in the concert life of these two musical capitals.

Guitarists such as Mauro Giuliani, Dionisio Aguado, Matteo Carcassi, and Fernando Sor were performing throughout Europe and were writing solo and ensemble music for their instrument, both to enlarge the repertoire and to satisfy the demands of a growing public. It was during this period that Schubert, who was known to play the instrument each morning and who wrote many of his *lieder* at the guitar, rearranged a trio by a local guitarist in his *Guitar Quartet* (1814) for flute, guitar, viola, and cello, D. 96. Weber, who also played the guitar, included it in his opera *Oberon* (1826), as well as composing a few guitar-accompanied songs and a piano and guitar duet. Hector Berlioz supported himself for some years by teaching the guitar in Paris; it was, in fact, one of the few instruments at which he was truly proficient. The great violinist Paganini was equally talented on the guitar, and it was only discovered posthumously that a great percentage of his compositions were solo and small-ensemble works for the guitar. Even Beethoven has been quoted as

1. The development of the guitar from its beginnings in the fifteenth century through the Baroque era is well documented in Bellow (1970), Evans and Evans (1977), Grunfield (1969), and Turnbull (1974).

having said that the guitar is a "miniature orchestra" and is reported to have written a small ensemble piece (now lost) that included a guitar.

The idea of the guitar as a small orchestra has been reinforced by descriptions of several guitar concerts of the period, in which some of the players were favorably recognized by critics for their ability to imitate the oboe, violin, and other orchestral instruments, to the delight of their audiences. Clearly, the most advanced players of the day knew the "colors" that were available to them; the technical manuals by Sor and Aguado mention many of these techniques. In fact, Sor, who began his musical career as an opera and orchestral composer, made a direct comparison between the guitar and the orchestra in his discussions of the techniques of accompaniment:

> If a portrait be made as large as life, it may exhibit all the details that exist in the original: *this is the orchestra.*
>
> Let a copy be made of this portrait in dimensions only one-third of the former, many of the little details will be suppressed; other parts, which in full size were developed, will be represented perhaps by a single point, the relative proportion of the features will always be the same, and although each will receive fewer touches of the pencil, the same object will be seen: *this is the pianoforte.*
>
> If this be copied again and reduced one-third, it will be necessary to suppress more. A small circle of the original may be represented by a point, and yet produce the effect of a small circle; so that the means of seizing the resemblance being fewer in detail, the likeness will be perfect if the features preserve the same relative proportions: *and this is the guitar.*[2]

Apparently Sor was well aware of the timbral and textural connections among the musical media for which he wrote, connections that clearly influenced his musical thinking. Although the player/composers of Sor's day were also aware of these connections between orchestral colors and guitar technique, the music of the time rarely requested these colors in the score, since they were part of the conventions of the contemporary technique.

The instrument and the style of playing developed during the early 1800s, known as the Golden Age of the Guitar, perfectly suited the language of Viennese classicism. With the growing scale and texture of romanticism, however, came demands for stronger contrasts and a wider dynamic range than the guitar was capable of producing, contrasts which were, however, easily within the means of the piano. By mid-century, Berlioz stated in his *Treatise on Modern Instrumentation* (1843):

> Without being able to play the guitar, one can hardly write for it pieces in several parts, containing passages demanding all the resources of the instrument. . . . Since the introduction of the pianoforte into all houses where the least musical taste exists, the guitar has been little used, save in Spain and Italy. . . . Composers employ it but little, either in the church, theatre, or concert room. Its feeble sonority, which does not allow its union with other instruments, or with many voices possessed even of ordinary brilliancy, is doubtless the cause of this. Nevertheless, its

2. F. Sor, *Méthode pour la Guitare* (1830); trans. A. Merrick, ed. F. Harrison as *Method for the Guitar* (London: Robert Cooks, 1896), p. 26.

> melancholy and dreamy character might more frequently be made available; it has a real charm of its own, and there would be no impossibility in so writing for it as to make this manifest.[3]

The piano and the violin, under the hands of Liszt and Paganini, became the instruments of the Romantic Age, while the guitar retained a small circle of devotees (including such composers as Saint-Saëns, Gounod, Moscheles, and Diabelli) but failed to produce any solo or ensemble music of any importance until the next century.

The seeds that were planted in Vienna and Paris were not lost, however. It was exactly this "dreamy and melancholy" character that Berlioz described which found its way into his operatic works—*Eight Scenes from Faust* (1829), *Benvenuto Cellini* (1838), and *Béatrice et Bénédict* (1862)—and into those of Rossini, Verdi, Bizet, and Donizetti. Even more important historically is Mahler's Symphony No. 7 in e (1905), in which the guitar is used orchestrally as an extension of the harp. It was by playing the part of a "treble harp" in the Viennese symphonic literature that the guitar, along with the mandolin, found its way into the modern symphonic repertoire, where all three members of the New Vienna School used it in their ensemble and orchestral textures.

In the first half of this century, although it suffered from a mediocre repertoire, the solo guitar went through changes similar to those that had occurred at the turn of the previous century. In Germany, Heinrich Albert (1870–1950) was reacquainting the public with the instrument through his series of publications *Die Gitarre in der Haus und Kammermusik vor 100 Jahren*[4] for and through the performance of ensemble guitar music, first with his Munich Guitar Quartet and later with the Molino Trio. He actively encouraged development of the instrument and continued the use of the Terz and Quarte guitars, as well as helping to develop the Quinte-Basse Guitar (1900) with Alfred Cottin.

Further south, the modern classic guitar was born through the efforts of the composer/guitarist Francisco Tarrega (1852–1909) and the luthier Antonio de Torres Jurado (1817–1892). The Torres instrument had a larger body and a longer scale-length than its predecessors, and it employed a new interior design of fan-strutting (still in use today) which resulted in a considerable improvement of the guitar's projection and tonal response. Tarrega not only helped to develop the instrument but also extended the techniques and repertoire of the day by adopting the technique of holding the right hand perpendicular to the strings, using the apoyando or rest stroke, and composing a vast number of pieces and studies as well as making guitar transcriptions of compositions of high quality, especially those of Bach and Chopin. His transcriptions of Bach showed that the guitar was capable of maintaining a polyphonic argument, an aspect which the earlier music did not often exploit. This helped to widen the instrument's vocabulary, and also made it a more attractive prospect for composition. Tarrega's achievements and teaching methods inspired a new generation of guitarists, the most notable of whom are Andres Segovia and Emilio Pujol.

3. Berlioz, *Treatise on Modern Instrumentation* (1843); trans. M. Clarke (London: Novello, 1904), pp. 69-70.

4. (Frankfurt: Musikverlag W. Zimmerman).

The classic guitar as we know it today is very much due to the efforts of Segovia in the first half of this century. In keeping with the tradition of Tarrega, he has constantly endeavored to extend the instrument and its music in a manner best described in his own words:

> I have dedicated my life to four essential tasks:
> 1. to separate the guitar from the mindless folklore type of entertainment.
> 2. to endow it with a repertoire of high quality, made up of works possessing intrinsic musical value, from the pens of composers accustomed to writing for orchestra, piano, violin, etc. . . . Assisted by professional musicologists, I also dedicated myself to capturing delightful works written for the vihuela and lute. . . .
> 3. to make the beauty of the guitar known to the philharmonic public of the entire world.
> 4. influencing the authorities at the conservatories, academies and universities to include the guitar in their instruction programs on the same basis as the violin, cello, piano, etc.[5]

I think that it can be conceded that this is close to a description of the position of the guitar in the musical world at present, and that Segovia's dedication, performances, and commissions have been a prime factor in bringing the classical guitar to the attention of the public.

From the early 1900s until World War II, the use of the solo guitar increased, thanks to the commissions of Segovia and some lesser-known European players, while the instrument was used coloristically in the ensembles of Schoenberg and Webern, and dramatically as well as musically in Berg's *Wozzeck* (1914–1921). The guitar also found its way into the works of Paul Hindemith, Kurt Weill, Sibelius, Henry Cowell, Alois Hába, Julian Carrillo, Frank Martin, Virgil Thomson, Stravinsky, and Elliot Carter.

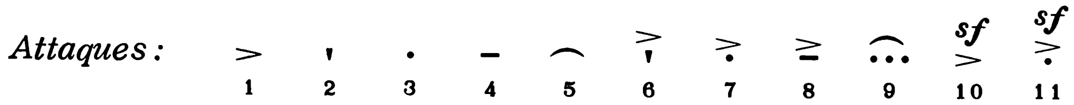
After World War II, when the search for new timbres and instrumental contrasts become of paramount importance, there was a spate of compositions calling for the guitar—usually in the setting of a small ensemble—the most notable of which is Boulez's *Le Marteau sans Maître* (1954). Solo works came from the pens of such non-specialist composers as Petrassi, Bartolozzi, Krenek, and Poulenc, while the guitar was used in ensemble and orchestral compositions by Lutyens, Henze, Musgrave, Seiber, Berio, Stravinsky, and many others. Harry Partch and Maurice Ohana have written microtonal music including a guitar, and the 1950s saw the introduction of the electric guitar into the realm of art music.

Once the guitar reentered the concert hall, the instrument's sounds and techniques became subject to the same principles of extension that the piano, oboe, flute, and other solo instruments had experienced in the change of aesthetic climate that followed the Second World War. Throughout Europe composers were reexamining the roles of performers, their instruments, and sound itself in the light of the two most influential compositional techniques of the day: total serialism and electronic music.

The serialization of all the musical parameters of sound brought new awareness of the timbral possibilities of individual instruments. One of the earliest and best examples of

5. Andres Segovia, *The Guitar and I*, MCA Records 2535.

quantification of timbre is the number of specific types of piano attacks required in Messiaen's *Mode de valeurs et d'intensités* (1949):



Ex. 1. Piano attacks from *Mode de valeurs et d'intensités* (1949), O. Messiaen. Used by permission of Theodore Presser Co.

Composers began to work with individual performers to see what sorts of sounds could be produced. With the experimental spirit of a "sound laboratory," writers and players worked together to extend both the range and the character of musical expression:

> Composers are again involved *in* performance, *with* performance. . . . As a result, new instrumental discoveries have antiquated every existing orchestration treatise, traditional limitations of voice and instrument have proved to be mythical. . . . Paradoxically, it is the advent of electronic music which sparked the performance renaissance. Electronic music introduced untried possibilities, and in so doing presented a challenge, shocked live music out of its inertia, kindled in musicians the desire to prove that live music can "do it too."[6]

Some of the music of that period became

> an attempt to demonstrate at that time that the human orchestra was capable of out-classing, in the matter of new sonorities and finesse, the new electronic techniques which were threatening to oust them.[7]

Instrumental techniques and the solo repertoire began to alter drastically, with much of the music being written at the Darmstadt Summer Courses for New Music and, independently, in Italy. Everywhere, musicians were looking for new modes of expression—

> generators, tape recorders, loudspeakers should yield what no instrumentalist could ever give: notation, performer, instrument should produce what no electronic apparatus could either deliver, imitate or repeat. . . . Writing instrumental music—after this—involves unleashing the performer's activities through optical signs and making a direct approach to the musician's [*sic*] living organism.[8]

—and new sounds—

> in general, makers and performers have always aimed at as great a degree of timbric unity as is possible throughout the compass of the instruments. . .. These are the causes which have made traditional techniques become a closed system, a system

6. Lukas Foss, "The Changing Composer-Performer Relationship," *Perspectives of New Music* (Spring 1963): 46.

7. Xenakis, program notes for 1975 English Bach Festival, British première of *Metastasis for Orchestra* (1953/54), p. 76.

8. K. Stockhausen, "Electronic and Instrumental Music," *Die Reihe* no. 5, trans. Ruth Koenig (Bryn Mawr, Pennsylvania: Theodore Presser, 1961), p. 67.

> which deliberately excludes any possibility which does not contribute to its own objectives, and thereby eliminates from the outset so many latent possibilities which we are only now discovering.
>
> This situation has been quite satisfactory as long as musical requirements were limited to the purity and "beauty" of sound obtained through uniformity of timbre. But such ideals have become more and more inadequate to the needs of contemporary music. . . .
>
> Contemporary music requires means of expression which can no longer be exclusively provided by "beauty" of sound or "tunefulness." In fact, there are no longer "false notes" now that the electronic sound spectrograph has allowed the frequency of any sound to be determined, so there are no longer sounds which are "ugly," "unpleasant," "hard," etc. Rather are there only sound phenomena which are useful in proportion to how much they lend themselves to organized musical usage.
>
> It is precisely in this direction that those more adventurous instrumentalists have directed their efforts in their search for new sounds designed to satisfy the needs of contemporary composers.[9]

In the 1960s, the guitar's musical personality seemed to splinter. One general development that was an outgrowth of the avant-garde movements of the fifties was the exploration of musical instruments as sources of non-traditional sound material. The guitar, rising in popularity during this period of exploration, was certainly not excluded from this type of experimentation. The introduction of the electric guitar to the concert stage during this period expanded its musical potential and forged a strong link with electronic music (since both media must be amplified through loudspeakers to be heard). Meanwhile, traditional composers found the acoustic guitar to provide a subtle and satisfying palette for their expressive needs; as one may well imagine, the repertoire from this period is even more diversified than was that of the previous decade.

By the 1970s, most works involving the guitar proved that the instrument had finally been accepted by the musical community. It was honored with substantial parts that were skillfully written to take advantage of the guitar's attributes rather than accentuating its weaknesses. The full acceptance of the electric guitar in the seventies was due in part to an acclimatization of the listening audience to this ubiquitous instrument, but was due also to the technological refinement of an instrument that had once been thought capable only of producing a loud "twang."

The increasing sophistication of the guitarist's repertoire must be met by a parallel development of the players who are to perform it. The new guitar music, solo, chamber, or orchestral, demands a wider range of sounds, colors, and techniques than ever before. To see how the player makes these sounds, we must look into the workings of the instrument. An understanding of the mechanics and acoustics of the guitar will enable both performers and composers to control these sounds for an optimum range of musical expression.

9. B. Bartolozzi, *New Sounds for Woodwind*, trans. and ed. R. Smith-Brindle (London: Oxford University Press, 1967), p. 5.

Section II
THE INSTRUMENTS

CHAPTER II
The Acoustic Guitar

Most of the literature for the guitar has been written for the Spanish or classical guitar (see Plate I). This instrument differs from the acoustic flat-top guitar in that the classical instrument uses nylon strings and a thin, responsive soundboard, whereas the flat-top guitar uses steel strings and has a stiffer soundboard. The classical instrument is strung with six strings: the three treble strings which were, until the 1940s, traditionally made of twisted gut, are now made of monofilament nylon, and the three bass strings consist of wire wrapped around a core of multifilament nylon, as opposed to the traditional core of silk threads. When a player plucks a string, the string vibrates, and most of the energy is transferred to the soundbox via the bridge. Resonance in the soundbox and the efficient radiation of the soundboard then amplify the weak sound of the string so that it carries through the surrounding air.

The guitar, when conceived as a sound-generating system, can be broken down into its component parts—string, soundboard, and soundbox. At each stage of sound production a finite number of activities occur in each of these components; if the player is aware of these phenomena and the principles behind them, he can better control the instrument. After all, that is what technique is all about: acquiring the *technical* skills required to facilitate musical expression. Here, this means understanding the mechanics of the system known as "guitar."

Because the guitar, a plucked instrument, is incapable of producing a constant or steady-state tone, the most important part of the note is the attack. At that moment the listener receives the most information about the note—its pitch, loudness, location, and timbre. The remaining parameter, duration, is determined by the instrument's reverberation time (RT), i.e., how long it takes the sound to die away. (Of course, the player can shorten the instrument's RT by damping the note before it has died away.) The attack is also the most important moment for the player, because at that instant he is touching the string with both hands; determining the pitch with his left and controlling the loudness and timbre with his right. As we shall see, timbre is the most variable musical parameter within the guitarist's control.

TIMBRE AND THE DESCRIPTION OF SOUND

The basic building-block of any musical language is sound, but until this century an accurate vocabulary dealing with this material has been conspicuously absent. As composers and performers have become increasingly interested in the subtleties of their art, the need has grown for a common language permitting an efficient description of musical ideas.

In the past, timbre was defined as that characteristic of a tone differentiating it from another which shared the same loudness, pitch, and duration, the characteristic which could be grossly stated as "violin" or "guitar." But what about the subtle differences within these instrumental categories, i.e., differences between a Stradivarius and a Guarnerius violin, or a Ramirez and a Rubio guitar? And even more important from the performer's point of view, what is the timbral difference between a note played (pont.) and (tast.) on the same instrument?

J.F. Schouten has subdivided the musical parameter of timbre into five subparameters:

1. The *time envelope* in terms of rise time, duration, and decay.
2. The *prefix*—the onset of a sound, quite dissimilar to the ensuing lasting vibration.
3. The *spectral envelope*— (amplitude of the partials of a sound).
4. *Change*: of spectral envelope (formant glide) and fundamental frequency (micro-intonation).
5. The range between tonal and noiselike character (the scale ranging from perfect periodicity through imperfect periodicity to random noise).[1]

The timbral parameters can be used to describe accurately *any* sound, from a slammed door to a violin trill, but it usually takes scientific equipment to analyze sound into these components. The human ear can hear the pitch of objects vibrating anywhere from about 20 times per second (20 Hz) up to approximately 20,000 times per second (20 kHz). If an object vibrates faster than 20,000 Hz, the sound cannot be perceived as pitch, and if it vibrates any slower than about 20 Hz, the sound is heard as a collection of discrete events rather than as pitch. That is to say, 20 Hz is the time constant of the ear, the point at which the brain integrates discrete events. This phenomenon is analogous to what happens when a motion picture is slowed down: individual frames are seen and motion is "frozen" from one frame to the next. As the film speeds up, a point is reached at which the brain interprets the rapidly repeating still pictures as fluid motion. In order to analyze the timbre of a sound, one must comprehend what is happening to the vibrating object during these vibrations. Once the performer understands these actions, s/he can then manipulate the manner in which the instrument vibrates in order to control these parameters of timbre more exactly.

1. J.F. Schouten, "The Perception of Timbre," *Reports of the Sixth International Congress on Acoustics* (Tokyo: GP–6–2, 1968), p. 42. Only the first four parameters are useful for describing a guitar tone since, on the whole, guitar notes approach perfect periodicity, and the noise element during the duration and decay of a note is negligible.

From the guitarist's point of view, timbre is determined almost completely by the relationship of the right hand to the string. Because the string is the first component in the sound-generating system and because it is the component with which the player has the most intimate contact, the player should first understand how the string itself works. Then, by understanding how the string interacts with the rest of the system, the player can learn how to control his relationship with the string/s, in terms of the separate parameters of timbre, so that he can fully utilize the musical possibilities inherent in this versatile system.

THE STRING

The manner in which a string vibrates is determined by its length, its tension, and the material from which it is made. A vibrating string generates many frequencies simultaneously, and these frequencies are produced by the string vibrating in 2, 3, 4, 5 . . . equal sections (see Fig. 1). The frequency of each of these equal divisions is 2, 3, 4, . . . times the fundamental frequency of the string. For example, if the fundamental frequency of the string in Figure 1A is the same as that of the A-string on a guitar (110 Hz or cycles per second), when the string vibrates in two equal sections (Fig. 1B), its frequency will be 220 Hz; when it vibrates in three equal sections (Fig. 1C), the frequency of each third will be 330 Hz.

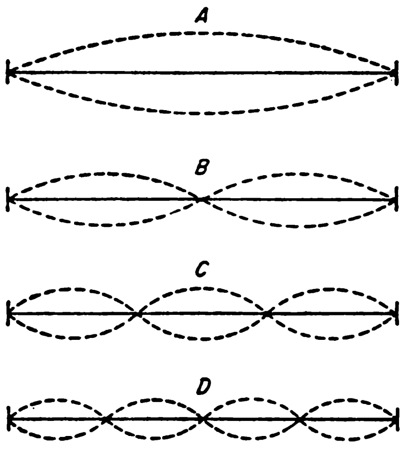


Fig. 1 First four modes of string vibration. Used by permission of McGraw-Hill.

When the vibrations are in this simple mathematical relationship of 1 : 2 : 3 : 4 . . . , they are called harmonics, *and their frequencies are described by the harmonic series (see Recorded Ex. 1):*

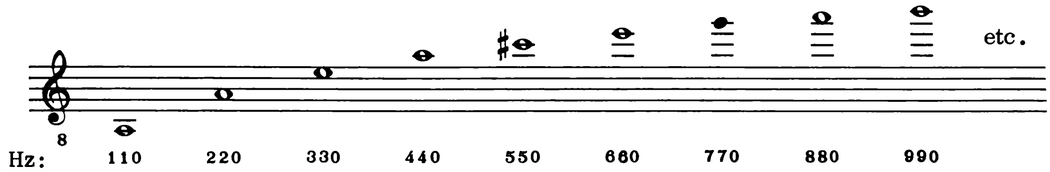


Fig. 2 The harmonic series of the A-string (110 Hz).

By plucking the strings at different points along its length, the player can suppress some frequencies and enhance others, thus changing the harmonic content (spectral envelope) of the overall string vibration.

Several terms often used interchangeably in describing musical vibrations in fact have very specific meanings. These terms are *mode*, *partial*, *overtone*, and *harmonic*. *Mode* is used to describe the manner of vibration of an object, whereas a *partial* is a component of a tone, i.e., part of a whole. The lowest frequency vibration is called the *fundamental* and is the first mode or first partial. An *overtone* is any partial found above the fundamental, and *harmonics* are those partials whose frequencies are in simple ratios to each other, as defined by the harmonic series. Thus, the first harmonic of a tone is the fundamental and not the first overtone, while the frequency components of a bell sound, for example, are not harmonics but partials, as they are, in fact, usually *in*harmonic.

Once the string has been plucked, the resulting sound depends in part on the number and strength of the partials in the tone—the quality called the tone's *spectral envelope*. How does plucking the string determine which partials will be present? Classical string theory tells us that when a string is plucked, two pulses or waves are sent travelling in opposite directions down the length of the string:

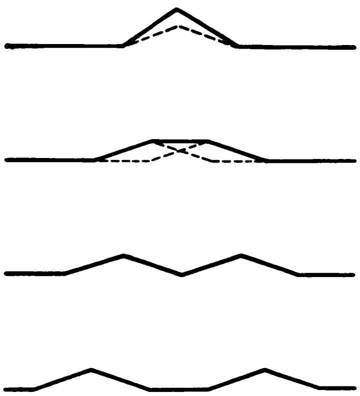


Fig. 3. Motions of a plucked string.[2] Used by permission of McGraw-Hill.

When each of these travelling waves reaches its boundary, it is reflected back again in the opposite direction, inverted:

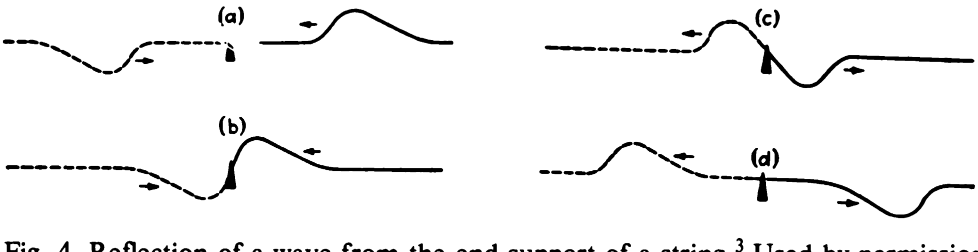


Fig. 4. Reflection of a wave from the end support of a string.[3] Used by permission of McGraw-Hill.

2. From P. M. Morse, *Vibration and Sound* (New York: McGraw-Hill, 1948), p. 73.
3. Ibid., p. 76.

Each wave then travels to the other end of the string, where the process is repeated.

Since these two traveling waves are moving on the same string, they will cross and interfere with each other as they travel from one end of the string to the other. Whenever the waves meet, their amplitudes are added together; if at a certain point both waves are positive, the combined value will be larger than that of either one alone. If at another point one is positive and one is negative, they will cancel each other out, so that the combined value will be zero.

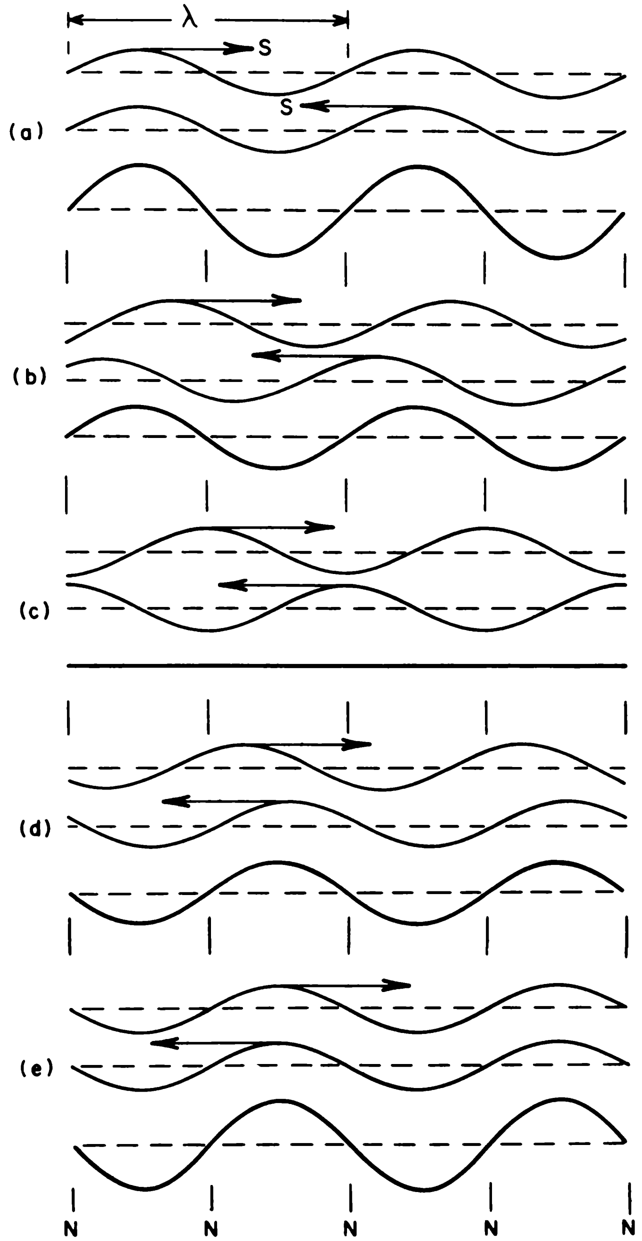


Fig. 5. Production of a standing wave in a string. (a), (b), (c), (d), and (e) are one-eighth of a cycle apart. Reproduced from *The Acoustical Foundations of Music* by John Backus, by permission of W.W. Norton and Co., Inc., N.Y., and John Murray, London. © 1977, 1969 by W.W. Norton and Co., Inc.

In Figure 5a, the travelling waves are in phase (their crests and troughs coincide), and the resulting amplitude is shown by the heavy curve directly below. Figure 5b shows the resulting amplitude a moment later, as the waves begin to move out of phase, and Figure 5c illustrates how the two waves cancel each other out when they are completely out of phase (the crests of one wave coincide with the troughs of the other). The result of this superposition of waves is called a *standing wave*, because the resulting wave does not move along the string. In fact, certain points, the *nodes* of a standing wave, do not move at all; these are labeled *N* in Figures 5 and 6. The vibrating sections of the string between the nodes are called *loops*, with the center of each loop designated as the *antinode*:

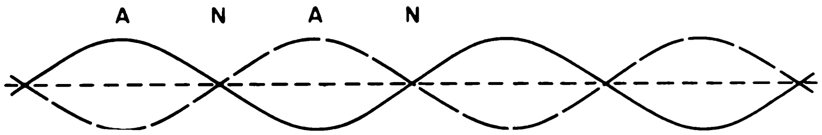


Fig. 6. Nodes (N) and antinodes (A) of a standing wave on a string. Reproduced from *The Acoustical Foundations of Music* by John Backus, by permission of W.W. Norton and Co., Inc., N.Y., and John Murray, London. © 1977, 1969 by W.W. Norton and Co., Inc.

When a guitar string is vibrating, a node will of course occur at the supports at both ends; thus, the first or fundamental mode of oscillation (Fig. 1A) is a standing wave with the antinode at the center and a node at either end. The second mode of vibration (or second harmonic—Fig. 1B) occurs when a standing wave is produced with three nodes and two loops; the third mode has four nodes and three loops, etc. For just *one* mode of vibration to occur on a real string, the travelling waves that create the standing wave would have to be the same shape as the loop of one of these modes. This is what happens when a harmonic is produced: the left-hand finger produces a node and the plucking finger creates a loop.

When a string is plucked in the usual manner, many modes of vibration are excited simultaneously because the plucker activates only the loops or antinodes of any particular mode, which also means that it does not produce any modes that have a node at that plucking point. This principle is best demonstrated by the special case of a string plucked at its midpoint. Fourier, a nineteenth-century French physicist, showed that any waveform can be reproduced by the superposition of suitably chosen sine waves (simple harmonic waves). Figure 7 shows a string displaced to form the triangle ACB, which is then analyzed into its first four sine components:

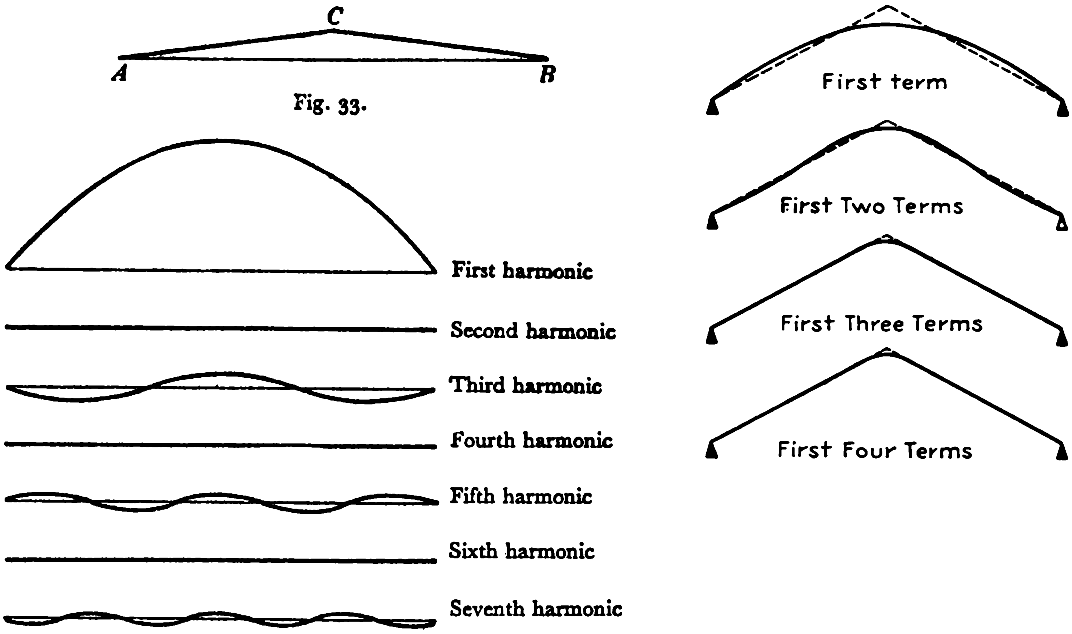


Fig. 7. Fourier-series representation of a waveform on a string. Solid figures on the right show the effect of adding successive sine components to the series; dotted figures show the actual form given by the entire series.[4] Used by permission of McGraw-Hill.

All the components have in common an antinode at point C, which means that the wave is composed of only odd-numbered harmonics, since all even-numbered harmonics have a node at the midpoint (see Fig. 1). It is also evident that in order to flatten the sides of the triangle (i.e., reconstitute the initial shape of the string), higher harmonics must be added to the series until the *loop* of the antinode of the highest component is comparable to the width of the plectrum. Of course this phenomenon actually occurs the other way around; the string will tend not to produce harmonics that have a loop which is smaller than the plectrum tip,[5] nor to produce modes with nodes at the point of plucking.

There is a method of determining which harmonics will be absent for any plucking point. For the midpoint pluck ($l = ½$), the harmonic numbers n missing are $2n$—in other words, all of the even harmonics are absent. When the string is plucked at a point one-third down its length ($l = ⅓$), every third harmonic, or $3n$, will be missing; when $l = ¼$, $4n$ will be missing. In general, for an ideal string plucked with an infinitely thin plectrum, the multiples of the denominator of the plucking length will be the numbers of the harmonics missing in that spectrum. Such an ideal string is, among other things, completely flexible. In the real world, since all strings have stiffness and imperfections and all plectra

4. Ibid., p. 88; J. Jeans, *Science and Music* (London: Cambridge University Press, 1943), p. 81.

5. Since the loop of a standing wave is equal to one-half of the wavelength, it can be said that the highest harmonic will have a wavelength equal to twice the width of the plectrum. Therefore, the plectrum acts as a low-pass filter: the thinner the width, the higher the harmonics.

have finite width, it is much more realistic to say that the partials with nodes at the plucking position will be suppressed, not completely absent. Also, the series of upper partials present, as well as their relative intensities, will depend on the diameter and the material of the string. The difference between the tone of steel and of nylon strings is due to the relatively poor elasticity of nylon, which tends to quench the higher upper partials. Nonuniformity also occurs along the length of the wound strings of the guitar; after a period of use, the fret wire tends to indent the winding, changing the string's performance.

THE SOUNDBOARD

So far, we have dealt only with a vibrating string. Sound is transmitted by fluctuating air pressure. Since a thin string is not very efficient at moving air, we need a means of communicating the string's vibrations to the surrounding air. This is achieved by attaching the strings to a soundboard whose greater surface area is more efficient at radiating vibrations. The link between the strings and the soundboard is the bridge, *which not only holds the strings but also helps to determine the sound of the instrument by influencing how much of the string vibration is transmitted to the soundboard. The construction of the soundboard is a prime factor in determining the character of an instrument.*

A string can be considered to be a one-dimensional system; that is, its length is far more important than its diameter. The soundboard is a two-dimensional system: it has length and width (we shall ignore its depth for the moment). This kind of surface is called either a membrane or a plate, depending on its stiffness, and it too can vibrate in a number of simple and complex modes simultaneously, just like a string.

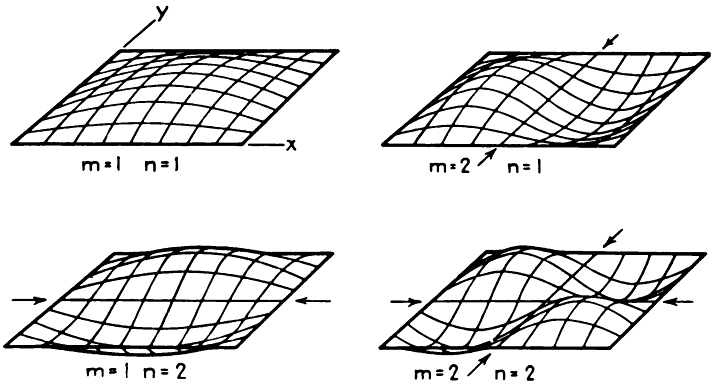


Fig. 8. Shapes of the first four normal modes of a rectangular membrane. (Arrows point to nodal lines.)[6] Used by permission of McGraw-Hill.

A rectangular membrane vibrates in in*harmonic modes: the frequencies will not be in simple ratios as they are in a string. A circular plate, which is much more closely related to a guitar plate, also vibrates in a number of modes:*

6. Morse, op. cit., p. 180.

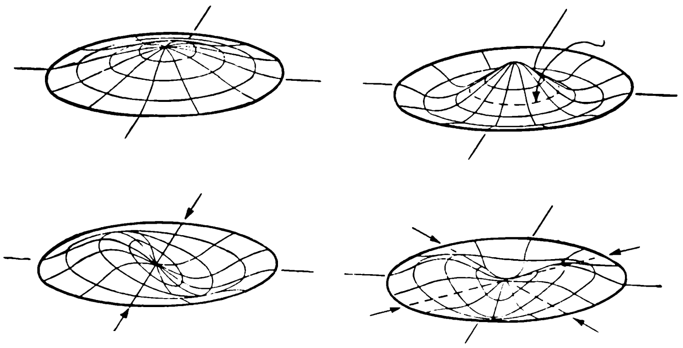


Fig. 9. Shapes of a few of the normal modes of vibration of a circular plate clamped at its edge. (Arrows point to nodal lines.)[7] Used by permission of McGraw-Hill.

Because the soundboard must withstand the tremendous tension of the strings as well as vibrate as sympathetically as possible, the strutting or bracing that underlies the surface is of great importance. It must be strong enough to support the stress applied by the bridge, but it must not inhibit any important modes of vibration. The luthier's art lies in balancing these two objectives to produce a strong and vibrant sound board. Two modern types of strutting are shown below:

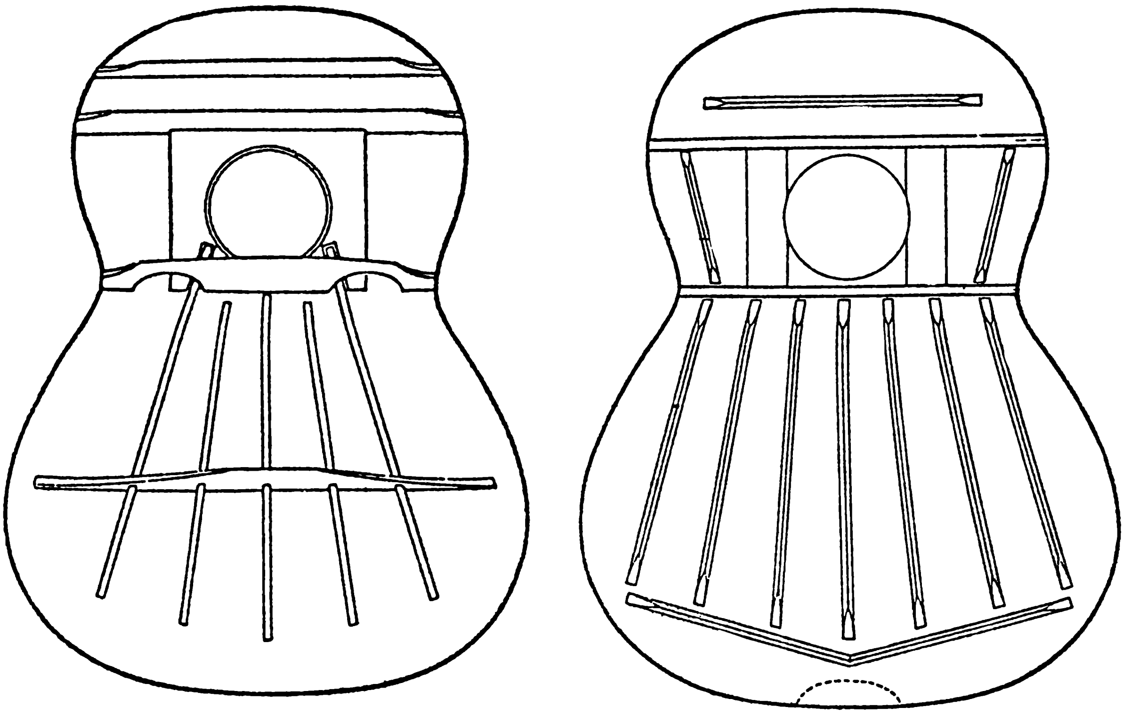


Fig. 10. Bouchet strutting. Traditional Torres strutting.[8]

Researchers have used holographic techniques to record the vibration patterns of guitar tops at various resonances.

7. Ibid., p. 211.
8. G. Clinton, "Robert Bouchet," *Guitar* (February 1973): 16.

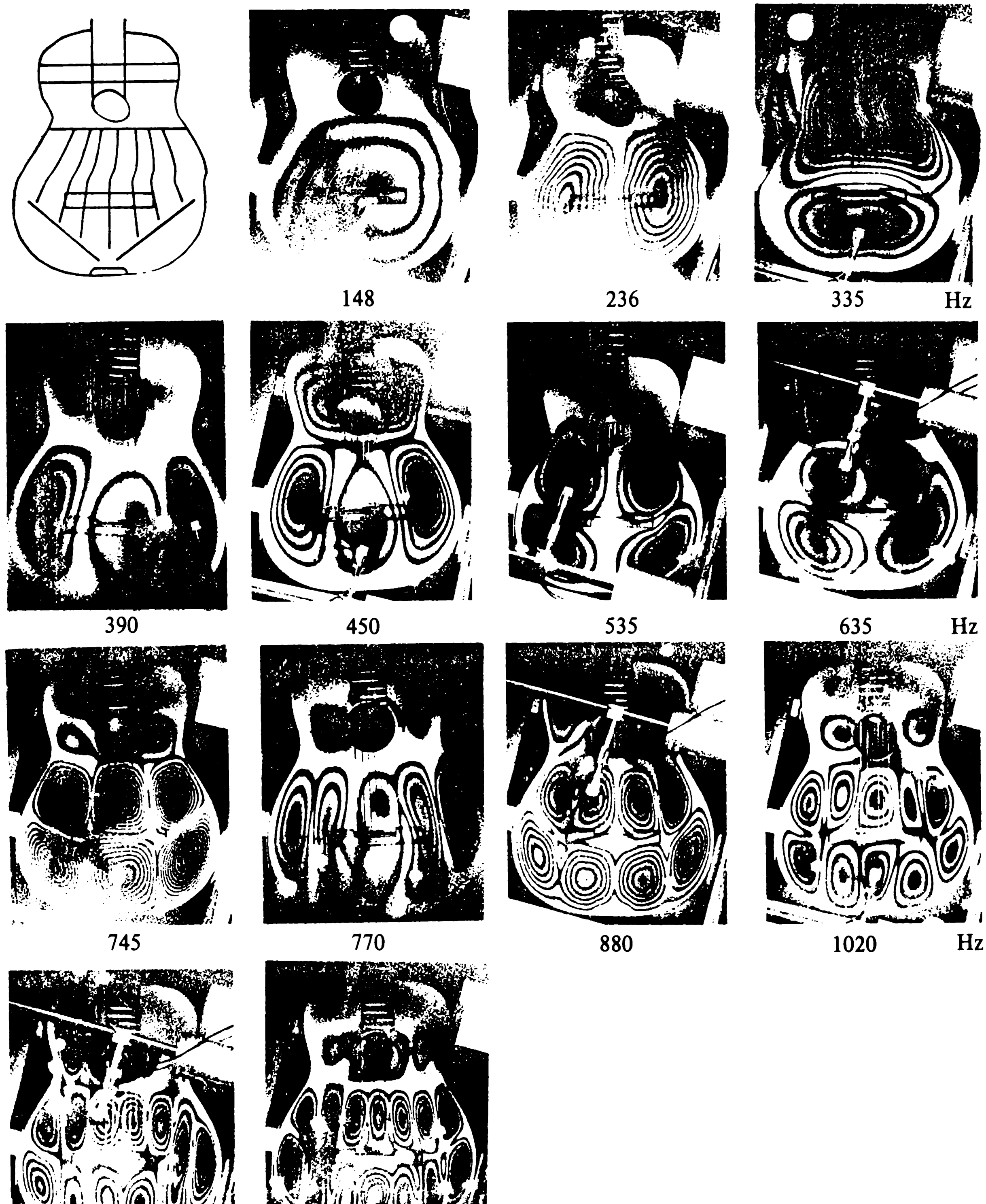


Fig. 11. Holograms of a Levin LG17 guitar top vibrating at some of its resonant frequencies. Made at the Royal Technical University, Stockholm, by Dr. Ian Firth, University of St. Andrews, Scotland. Used by permission.

Each pattern of vibration in Figure 11 is a holographic record of a guitar being vibrated, by a transducer, at a single frequency. The optical fringe patterns of the images of the guitar indicate displacement of the top plate. These fringes are contour lines that represent movement in three dimensions. Maximum displacements (antinodes) occur within the closed fringes, and lines or areas of no displacement (nodes) are shown by the white areas.[9] Each hologram of Figure 11 represents the soundboard vibrating at a single frequency, but just as a string can carry many waves simultaneously, a plate can also vibrate in a complex manner, producing a composite tone consisting of more than one mode and therefore containing more than one partial.

These holograms are records of the soundboard vibrating in its natural modes or resonances, which are determined by its size, shape, and material. A plate can be forced to vibrate at any frequency, but its response to some frequencies will be greater than its response to others. The guitar's frequency-response curve can be determined by creating sine wave motion in the body (by exciting the bridge with a mechanical transducer). The resulting sound-pressure levels are measured with a microphone and a level recorder. The input frequency gradually sweeps from 40 Hz to 20,000 Hz (20 kHz), while the input amplitude remains constant, and the microphone and recorder register the sound-pressure level of the guitar body's responses to the different frequencies. Guitar makers do not universally agree on materials, bracing, or even the instrument's overall size and shape; guitars vary widely, as is shown by the frequency-response curves of two instruments of different national origins:

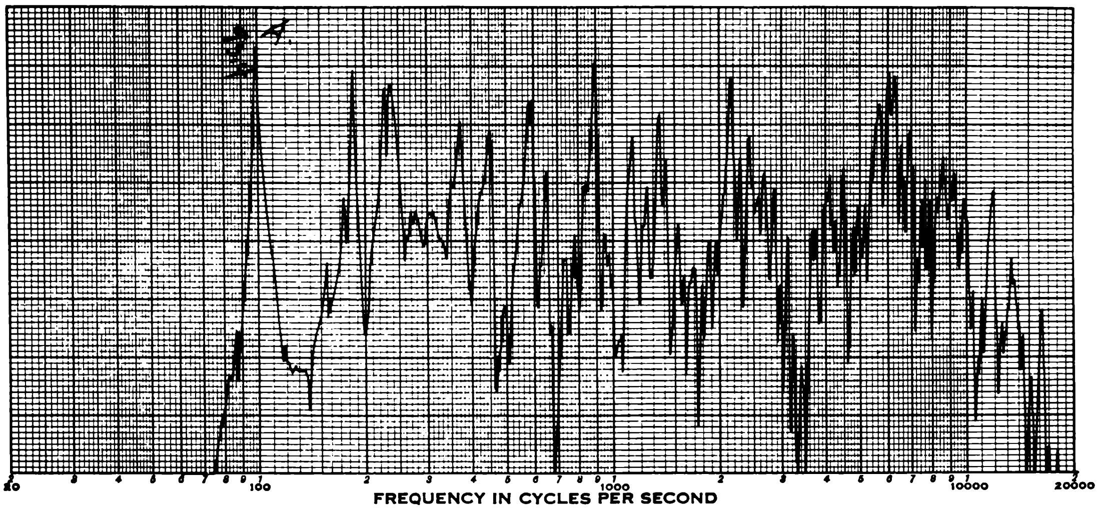


Fig. 12. a. Northern-style guitar.

9. Ian Firth, "Barring in the Guitar" (unpublished paper, School of Physical Sciences, University of St. Andrews, Fife, Scotland).

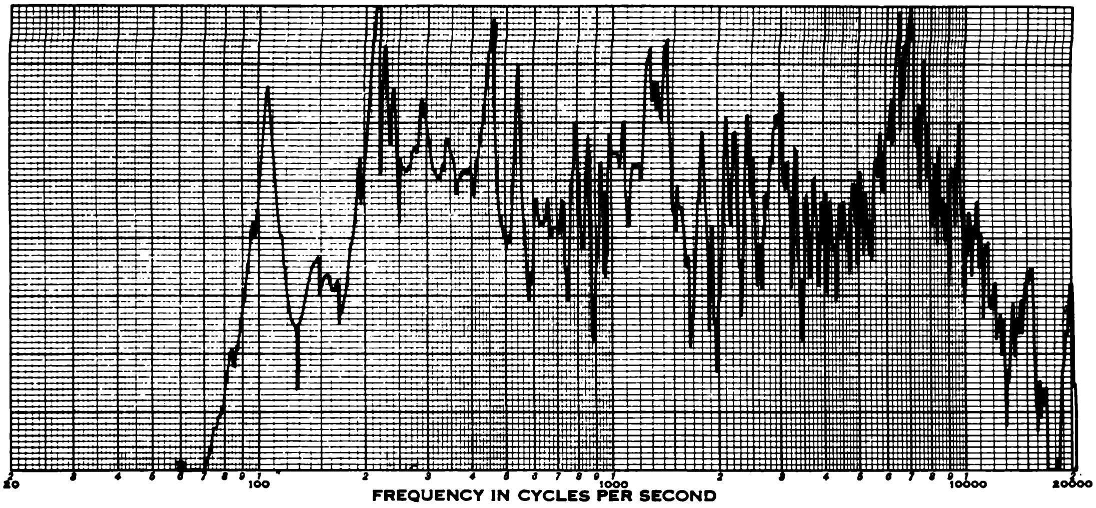


Fig. 12. b. Spanish guitar by Manuel Reyes (Cordoba, 1966).[10]

One other important factor is involved in the resonance of the plate, and that is the air within the soundbox. The guitar body acts as a Helmholtz resonator (named after the German physicist); the air resonance results from a standing wave created within the soundbox. The frequency of the air resonance is often around 100 Hz, and is usually more than a perfect fifth below that of the first plate resonance.

When a resonator such as a guitar body is excited by a complex tone such as a vibrating string's tone, the resonator's response curve will shape the spectrum of the incoming string signal, and therefore affect the spectrum of the output:

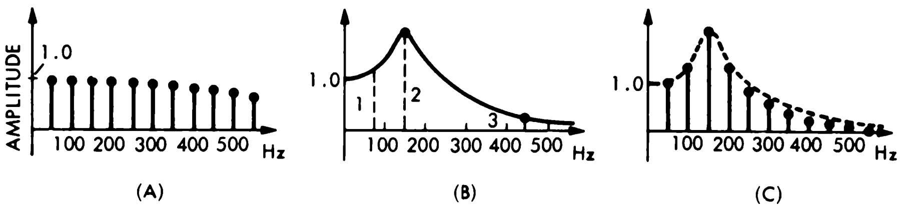


Fig. 13. A. Fourier spectrum of a train of pulses.
B. Resonance curve of the resonator.
C. Spectrum of the response of the resonator to the pulse train input.[11]

The sound of two guitars with differing response curves (e.g., those in Fig. 12) will thus differ in quality even if they are strung with the same strings and played by the same person.

10. J. Huber, "Application of Acoustical Testing Methods to the Guitar," *Catgut Acoustical Society Newsletter* no. 11 (1969): 16.

11. From A. Wayne Slawson, "Sound, Electronics, and Hearing," in *The Development and Practice of Electronic Music*, ed. Appleton and Perera, p. 41. © 1975. Reproduced by permission of Prentice-Hall, Inc., Englewood Cliffs, N.J.

STRING AND SOUNDBOARD: A COUPLED SYSTEM

The string transmits its vibrations to the soundboard by the force it exerts on the bridge. The direction in which the string moves will determine the motion of the soundboard, but the soundboard's flexibility will also determine the movement of the string. The two systems affect each other, i.e., they are coupled, *and the player can control the amount and quality of the force applied to the soundboard by the manner in which the string is plucked.*

Helmholtz showed that the force exerted on the bridge by the string waveform shown below has the form of an asymmetric square-wave:

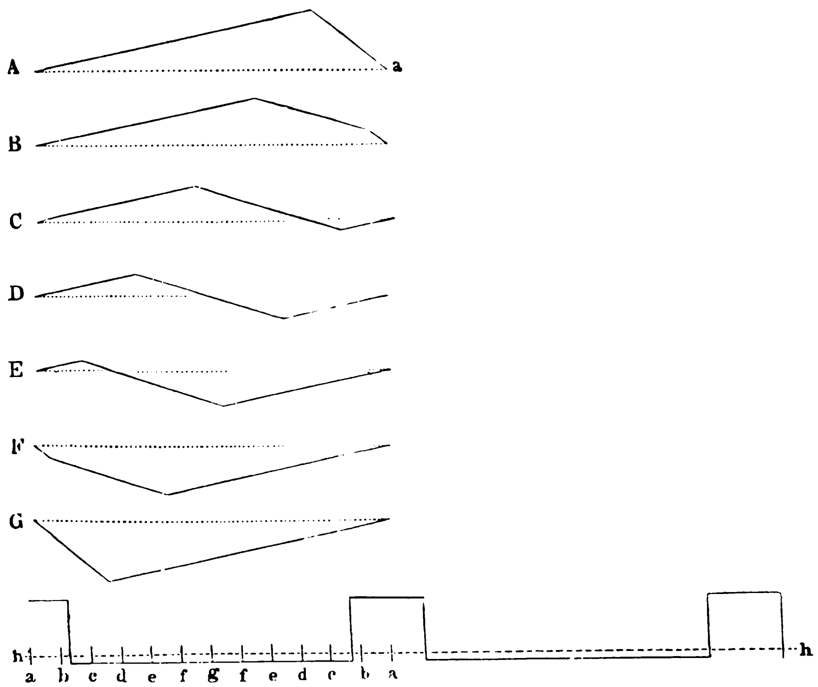


Fig. 14. String movement from initial shape A, and waveform of the string's force on the bridge.[12]

The movement of the string is cyclical, progressing from A to G and back to A, then repeating. By following the corresponding lower-case letters, it is easy to see that the time at which the force on the bridge changes from a higher to a lower value is dependent upon the length of the string on either side of the plucking point. For example, if the string had been plucked in the middle, the high and low (or on and off) values would have equal duration, creating a square wave. (Any rectangular waveform is called a pulse wave and is defined by the *duty cycle*, the ratio of the on portion to the entire cycle. The duty cycle of a square wave, for example, is 1 : 2.) The question arises: How is the spectrum of the string's vibration transmitted to the soundboard, if it must first be transformed into rectangular waves of force?

Figure 7 showed that the spectrum of the waveform of a string plucked at its

12. H. Helmholtz, *On the Sensations of Tone* (New York: Dover, 1954), p. 54.

midpoint consists of odd harmonics only. The resultant force from the bridge movement is a square wave (duty cycle of 1 : 2), which can be analyzed into its sine components.

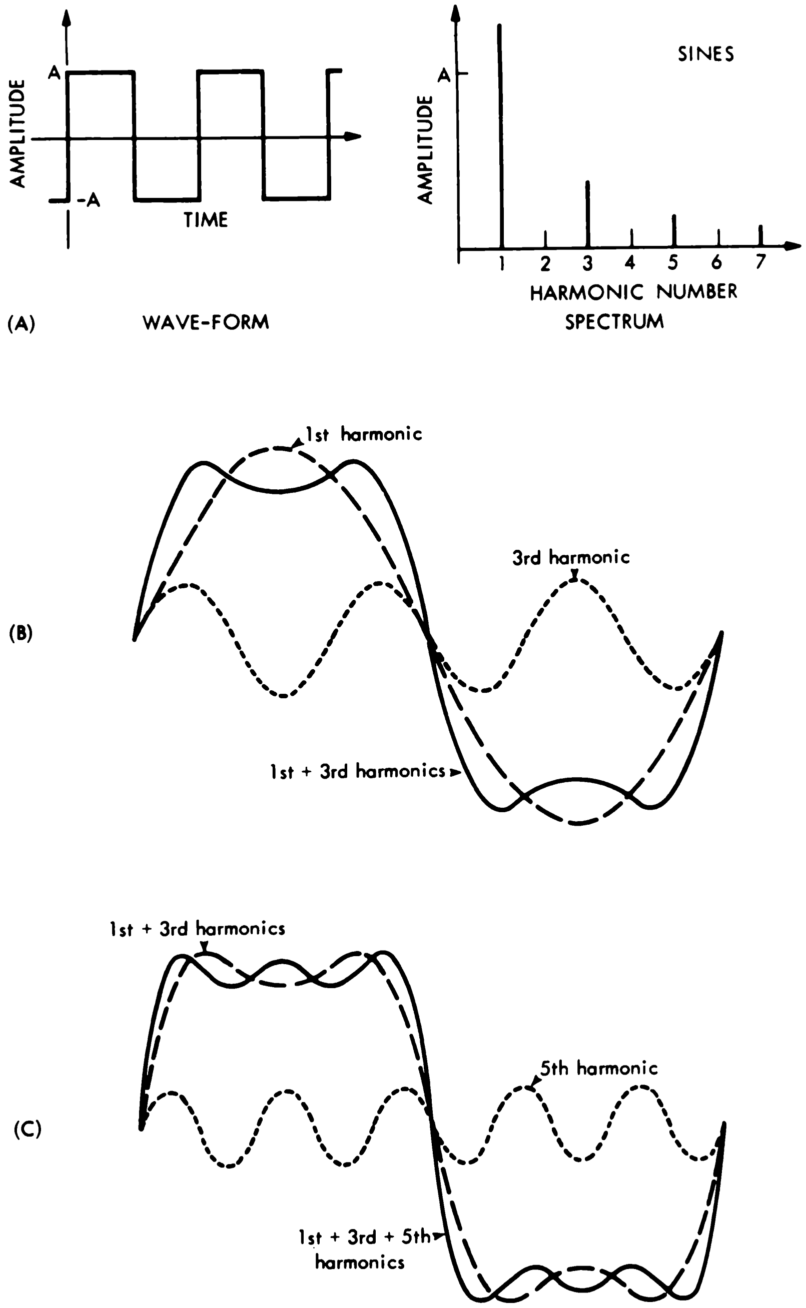


Fig. 15. Fourier analysis and synthesis. (A) The waveform and Fourier spectrum of a square wave. (B, C) The contributions of the first three and the first five harmonics, respectively.[13]

13. Slawson, op. cit., p. 37. Reproduced by permission of Prentice-Hall, Inc., Englewood Cliffs, N.J.

By comparing Figures 7 and 15, it can be seen that the spectra of the string and bridge/force waveforms are very similar, in that each consists of odd harmonics only. The amplitude and phase relationships between the harmonics differ, however.[14] When a guitarist plucks a string, he hears, not the waveform of the string; but the vibrations of the soundbox. These vibrations are determined by the force waveform on the bridge, the magnitude of which is controlled by the distance the string is displaced before release and the spectrum of which is determined by the length of string on either side of the plucker:

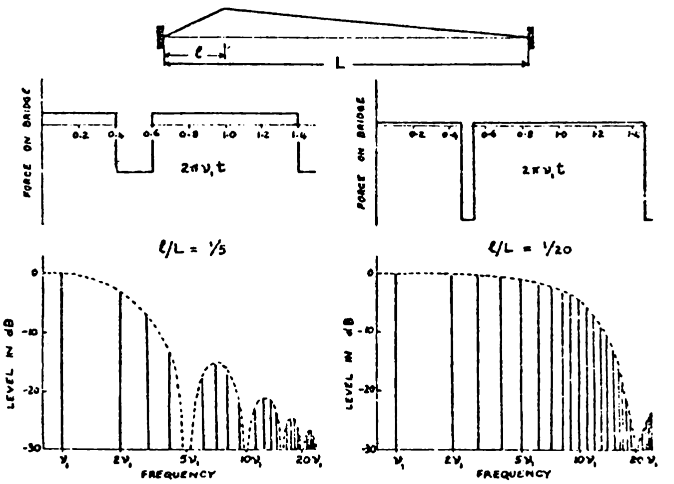


Fig. 16. The form of the transverse force on the bridge and the frequency spectra of this force for a string plucked at a distance of (A) one-fifth and (B) one-twentieth of its length from the end.[15]

Either the string-motion or the duty-cycle model can be used to determine accurately which harmonics are present, but the duty-cycle model gives much the more realistic description of the harmonic content of the resultant sound.

When an ideal string is set into motion between two completely stationary bridges, the only energy loss is due to friction within the string and friction between the string and the surrounding air. But when one end of a string is coupled to a resonator, such as the soundbox of a guitar, energy is exchanged between the two systems. The plate will radiate most of the energy at its resonant frequencies very efficiently, but some of the energy at those frequencies will be fed back into the original vibrating string, and also into the other five strings, through the movement of the bridge. If one or more of the unplucked strings happen to resonate sympathetically with the driven string, the sound will be enhanced; if

14. The amplitude of the square-wave components (i.e., the force waveform) diminishes in the relationship of $1/n$, whereas the amplitude of the triangle-wave components (i.e., the string waveform) diminishes in the relationship of $1/n^2$. Also, the square-wave components begin in a positive direction at the beginning of each cycle, whereas alternate components of the triangle wave begin in the negative direction.

15. N.H. Fletcher, "Plucked Strings—A Review," *Catgut Acoustical Society Newsletter* no. 26 (1976): 14.

not, that energy loss will simply hasten the decay of the plucked string. In fact, some players give greater sustain to high first-string notes by silently doubling a note at the octave below on the fourth string and allowing the sympathetic resonance to create the effect of a longer sustaining note.

THE TRANSIENT

All musical instruments are coupled systems. In stringed instruments the string is driven, and by the motion of the string the soundboard is forced to vibrate, but it takes time for the string to "convince" the soundboard to change from its state of rest. This "argument" creates complex interactions between the two members of the coupled system, and these interactions result in the complications of the waveform that can be heard at the beginning of the sound. This sound is called the transient *because it happens very quickly, at the beginning of a tone, and it disappears as soon as the string has convinced the soundboard to vibrate at the string's frequency rather than its own.*

An example of the complexity that a transient adds to a tone is shown in Figure 17 where, for the sake of convenience, the transient and steady-state tones are both assumed to be vibrations at single frequencies. It is easy to see how the combination of the two modes of vibration complicates the beginning of the sound, creating a *prefix*:

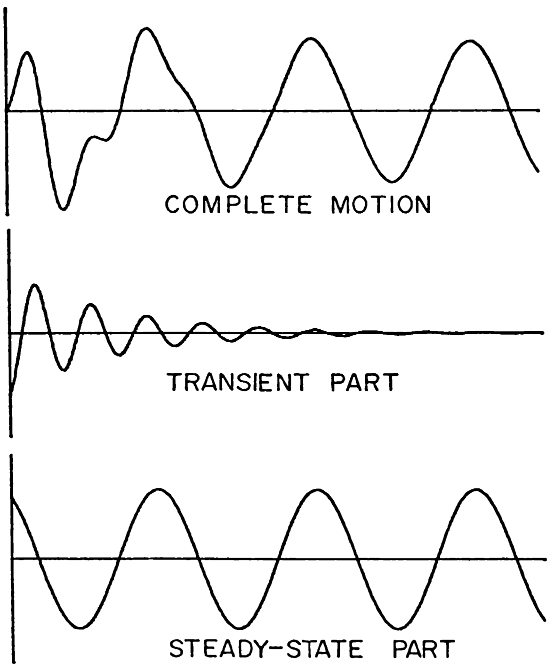


Fig. 17. Analysis of the complex interactions during the beginning of a two-frequency tone.[16]

16. A. Benade, *Fundamentals of Musical Acoustics* (London: Oxford University Press, 1976). p. 155. Reprinted by permission.

In plucked stringed instruments, the soundboard does not start its vibrations from a state of rest; rather, it begins its motion from the shape into which it is deformed by the string, which is *displaced* before it is released. When the string is released from the plucker (finger or plectrum), first the top begins to vibrate in a mode that is determined by the initial deformation of the soundboard, and then it begins forced vibrations determined by the frequencies of the driving string. These top deformations (*TD*) are always the same when the string is displaced in a particular direction: using x, y, and z to describe the three dimensions of the guitar with the center of the bridge as the origin,

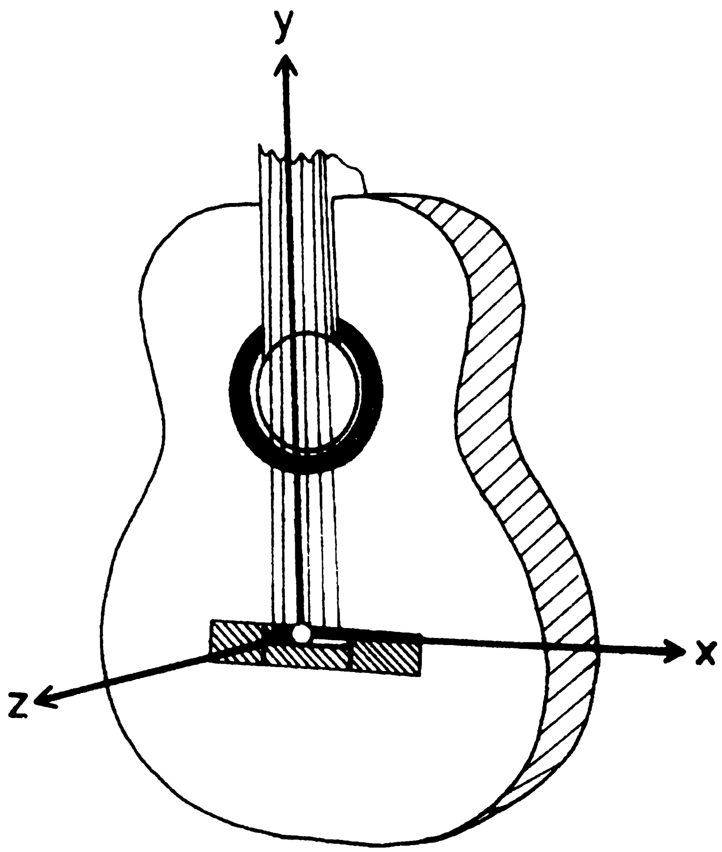


Fig. 18. Definition of a coordinate system.
x parallel to soundboard, perpendicular to strings;
y parallel to soundboard, parallel to strings;
z perpendicular to soundboard, perpendicular to strings.[17]

Jansson has shown the TD modes for forces (F) applied in these three directions. Figure 19a, for example, shows the TD2 mode created when the sixth string is displaced and held in the $-x$ direction, i.e., parallel to the soundboard and toward the player:

17. E.V. Jansson, "Coupling of String Motions to Top Plate Modes in a Guitar," *Quarterly Progress and Status Report* (Speech Transmission Laboratory, Royal Institute of Technology, 100 44, Stockholm 70, Sweden, 4/1973): 28.

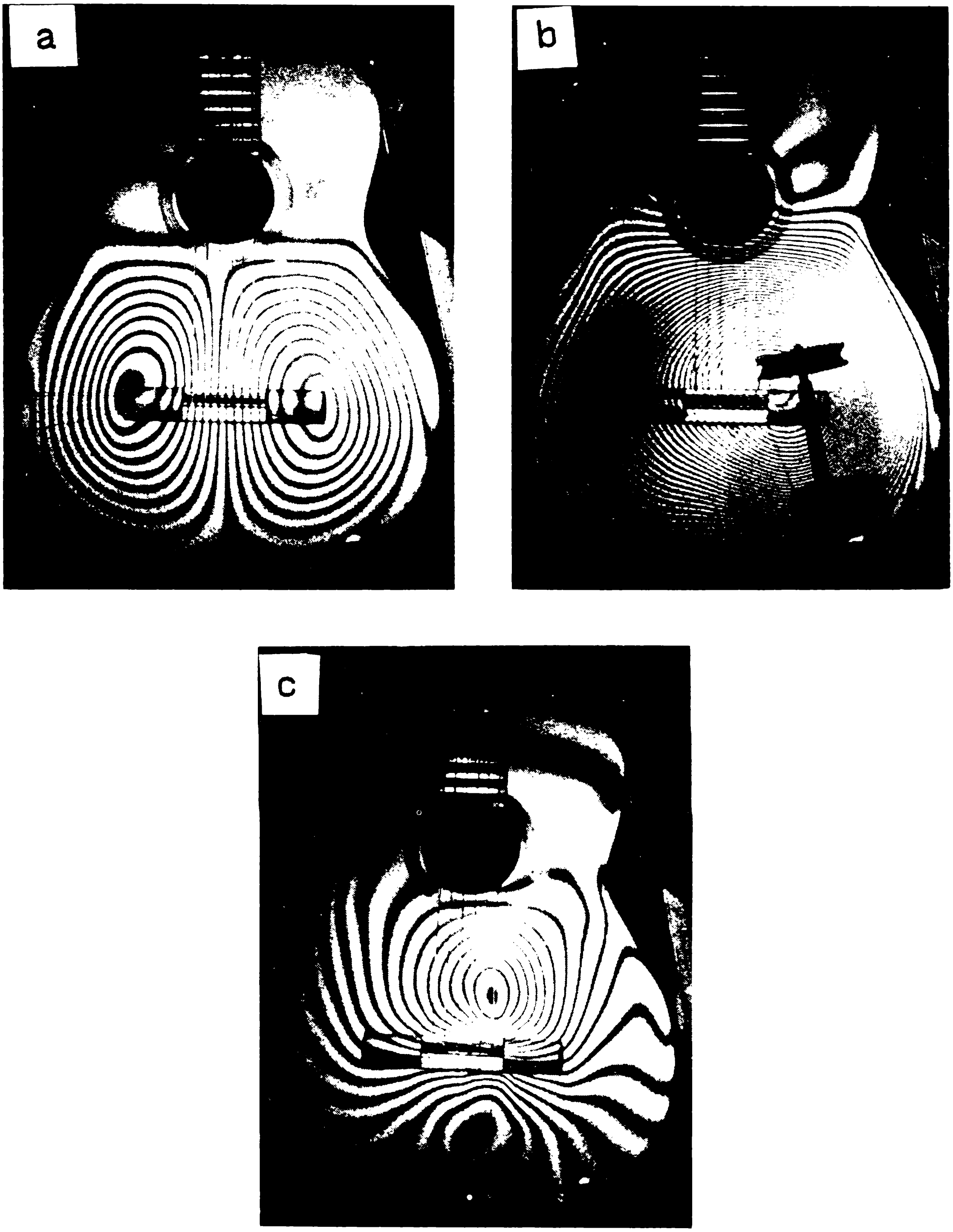


Fig. 19. Examples of interferograms.

a. $2F$ force applied in $-x$ direction to string 6 at the saddle = TD2.

b. F force applied in z direction to string 1 at the saddle = TD1.

c. $4F$ force applied in $-y$ direction to string 1 at the saddle = TD3.[18]

18. Ibid., pp. 29-33.

These illustrations, like those of Figure 8, show the contour lines of three-dimensional movement (the deformation shown in Fig. 19c is the same as that in the third quadrant of Fig. 8).

Obviously, few string displacements will occur only in one of these directions: most displacements can be described by the string's movement in a combination of the *x*, *y*, and *z* directions, so that the resulting top deformations will be combinations of the three modes TD1, TD2, and TD3.[19] Figure 20 shows TD2 for string displacement in the *x* direction; the solid black line depicts the actual shape of the soundboard:

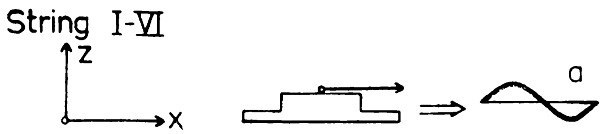


Fig. 20. Force F_x excites TD2 only.[20]

Moving the string in the *z* direction creates combinations of TD1 and TD2:

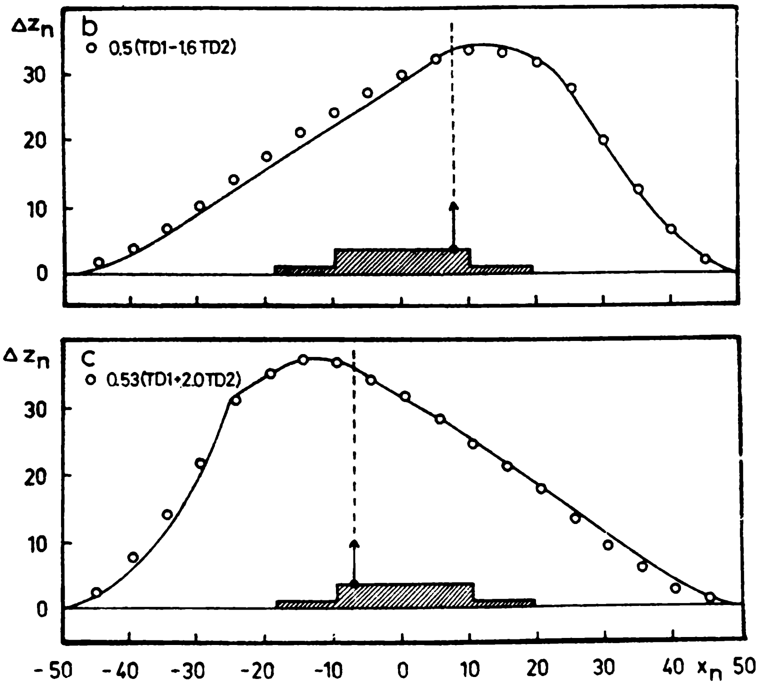


Fig. 21. Recorded deformations from force F_z, measured by number of holographic "white fringes" along the *x* axis, with F_z applied to the middle of strings 1 and 6.[21]

19. In fact, *y*-displacement and the resulting TD3 are negligible in comparison to the other two modes. This is illustrated by the fact that in order to produce TD3, one needs at least four times the force that it takes to produce TD1.

20. Jansson, op. cit., p. 33.

21. Ibid., p. 31.

Plucking one of the lower strings tirando (free-stroke or upstroke) with the thumb at approximately 30° gives the combination of TD1 and TD2 shown in Figure 22, where the total deformation can be analyzed into (1) TD2, depending on the *x* component [labeled (a) in the diagram], and (2) a combination of TD2 (b) and TD1 (c), depending on the *z* component (which in this case is positive):

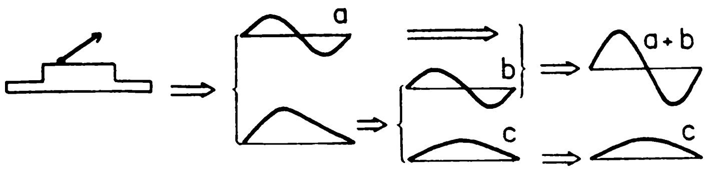


Fig. 22. Qualitative result of a force applied transversely to one of the lower three strings at 30°.

Figure 23 is an analysis of what happens when the same string is plucked apoyando (downstroke). The *z* component is then negative, which changes (b) to a negative value, and the resulting combination of (a) and (b) is a much smaller value for TD2, so the prefix of that note will contain much less of that mode.

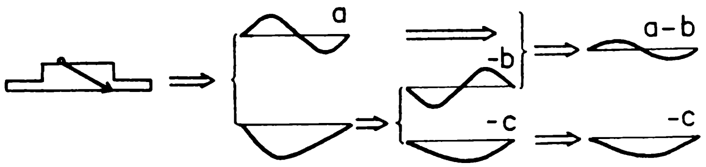


Fig. 23. Qualitative result of a force applied transversely to one of the lower strings at −30°.

The same rules apply to the first three strings:

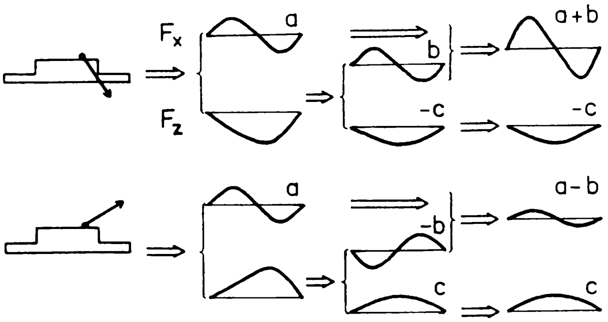


Fig. 24. Qualitative result of forces applied transversely to one of the upper three strings at (A) −30° and (B) 30°.[22]

22. If any of the plucking forces were reversed by 180°, e.g., if the strings 1–3 and 4–6 were played by the fingers instead of the thumb, or vice versa, the deformations would also be reversed, so there would be no change in the relationship between the different modes.

The air resonance of the soundbox also plays an important part in the prefix of a tone. (The pitch of this resonance can be quickly discovered by humming a scale glissando into the soundhole.) The resonance is usually between two fretted notes on the guitar; whenever either of these notes is played, the vibrations of the top plate excite this mode and that frequency is strongly reinforced from within the instrument. More important, every time TD1 is excited by a vertical component of string displacement, the volume of the soundbox changes, and this has the same effect that blowing over the hole of a bottle does: the air mode becomes excited and vibrates at its resonant frequency. Thus, each time TD1 is excited, the air resonance will be a part of the sound being produced.

Strictly speaking, the frequencies of TD1 and TD2 (along with the air resonance) constitute a noise component in the prefix of a guitar note (*noise* can be defined as any frequencies not harmonically related to the fundamental of a tone). A glance at Figure 11 will show that, for that guitar, TD1 = 148 Hz and TD2 = 236 Hz. Since some combination of these frequencies will be present in the transient of every note on the instrument, a harmonic relationship between these components and the fundamental of the sounding string will be the exception rather than the rule. (The presence of these frequency components in the final sound helps to distinguish a guitar note from that of a piano or any other plucked/struck instrument.)

THE PLAYER: THE RATIONAL METHOD OF TONE PRODUCTION

Now that the mechanics of the guitar have been introduced, we are only a short step away from translating this information into a useful technique for the player. The guitar has always been known as an "orchestra in miniature." This is not only because, like the piano, it can sustain melody and accompaniment simultaneously and because it can play polyphonic music, but also because of the many possibilities of timbral differentiation it is capable of producing. Since the turn of the eighteenth century, guitar players have described how they are able to imitate orchestral instruments such as the oboe, harp, trombone, trumpet, horn, and flute. These are romantic claims, of course, but *within* the sound medium of the guitar, by altering one or more of the parameters of timbre a great number of different sounds or "instruments" can be produced.

The timbral parameters were created to describe any sound, whether musical or not, so the timbre of any instrument can be analyzed in terms of these criteria. The difference between the tone of a violin and that of an oboe, for example, can be explained not only by the difference between the spectral envelopes of the tones but also by the difference between the attacks or prefixes of the two instruments. (It is well known that the ear can mistake one of these tones for the other if the attacks have been edited out of a recording of the two instruments.) When nineteenth-century guitarists "imitated" an orchestral instrument, they were intuitively mimicking some aspects of that instrument's timbre. Fernando Sor's oboe-effect, which was achieved by plucking the string vertically to the soundboard with the nail very close to the bridge, could not copy the attack of the oboe, but the spectrum produced by this method does resemble the nasal tone of the oboe, at least as compared to the normal tone of the guitar.

The rest of this section is a guide to altering the timbre of a guitar tone rationally (as opposed to intuitively, as it was done in the last century). If the guitarist is aware of each of the timbral parameters that define the tone and is able to relate these parameters to the mechanical processes of the instrument and to his own actions, the player can change colors at will, rather than by chance. There is no hierarchy within the musical parameter of timbre, as there is in pitch and loudness; a timbre only becomes meaningful when it is *compared* to another (just as we have no way of describing the flavor of a peach, absolutely, but we can illustrate its properties by contrasting them with those of a pear or an apple). In order to discover and to develop the timbral possibilities of the guitar fully, all of its timbres must be described. By mastering the production of these sounds, the player can make them musically meaningful through comparison and contrast. This is the basis of the Rational Method of Tone Production.

The Time Envelope

Every sound takes a finite amount of time from start to finish. The *time envelope* of a sound is described by its rise time, duration, and decay. The time envelope is illustrated graphically by plotting the amplitude of a sound vs. time. Since the guitar is not a sustaining instrument, the note it produces is almost all decay:

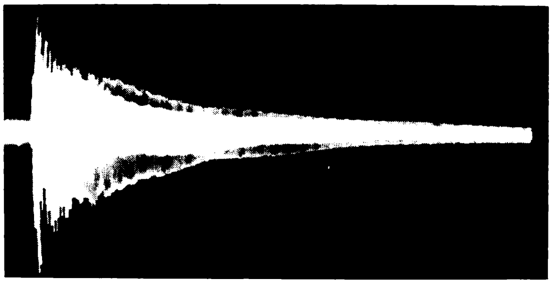


Fig. 25. Oscilloscope trace of the note produced by plucking the top (*e*, 330 Hz) string of a guitar.[23]

This means, effectively, that in the acoustic instrument the rise time is an unalterable part of the timbral structure of a tone; the only way the rise time of a guitar tone can be altered is by bowing the string instead of plucking it. Barring this rather awkward method, the only way to alter the time axis (as opposed to the sound-level axis) of the time envelope of a note is to shorten the decay time by damping the vibrations of either the string or the soundboard. This can be done by replacing the right hand on the string after plucking or, if

23. C.A. Taylor, *The Sounds of Music* (London: BBC, 1976), p. 36.

: is a stopped string, by releasing the pressure of the left-hand finger and damping the string with any available finger of the left hand.

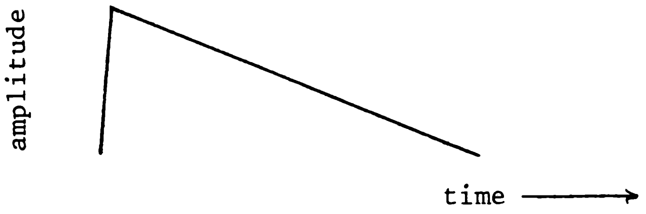


Fig. 26. Normal envelope. Fast decay.

The decay can be changed more subtly by altering the slope of the decay time or by adding an additional steeper ramp in the slope:

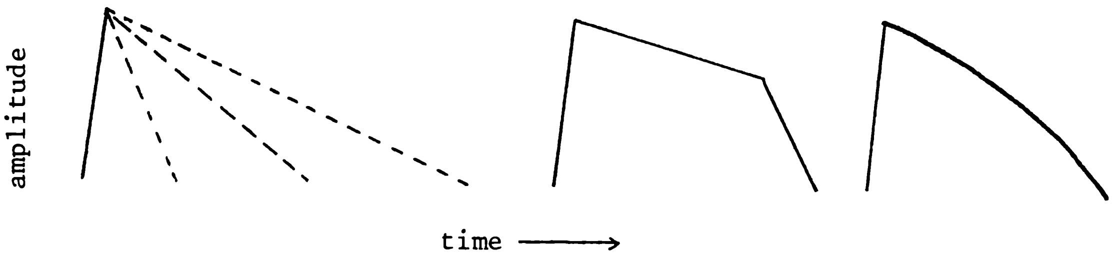


Fig. 27. Artificial decay times. Additional ramps.

These slower artificial decay times can be achieved by damping the string's vibrations at either end with one or both hands, or by damping the soundboard's movement by touching the bridge or any area of the lower bout with the right hand. The string method belongs to the pizzicato technique, although both techniques alter the spectral envelope (as will be demonstrated later).

The Prefix

The player can vary the amount of noise in the transient or prefix of a note by changing the angle of the string's displacement before its release. It is also the case that the further away from the bridge the string is plucked, the less energy is put into these noise elements; therefore, a left-hand pluck (ligado) produces a prefix so weak that it is masked by the string tone.

A change in the angle of string displacement alters the amount of the top deformation (TD) modes in the transient of a note. The two extremes are shown in Figure 28: the pluck that is perpendicular to the soundboard (no x component) enhances TD1 and the pluck parallel to the soundboard enhances TD2.

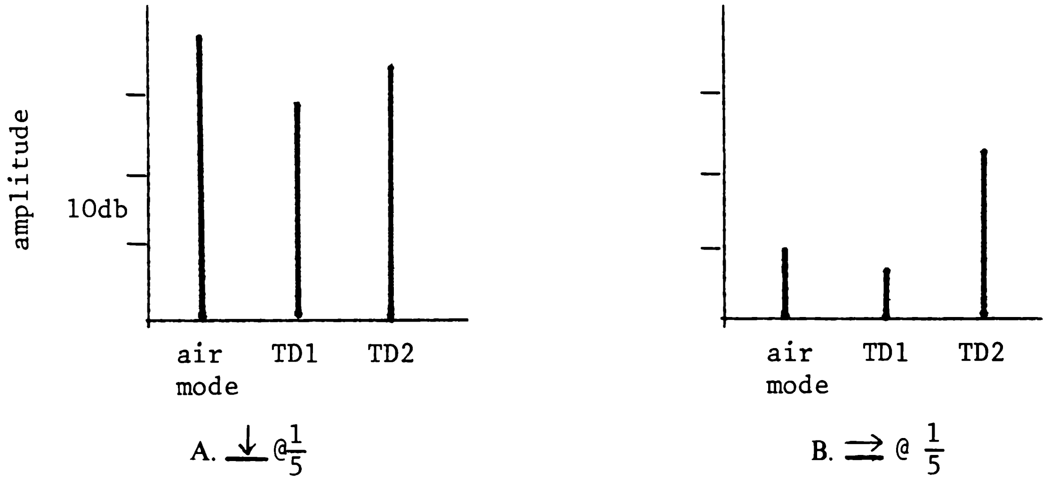


Fig. 28. Amplitudes of TD1 (154 Hz) and TD2 (216 Hz) of a Richardson No. 8 guitar when D^1 (588 Hz, first string) was mechanically plucked (A) perpendicularly and (B) parallel to the soundboard.

A change in the angle of string displacement also changes the amount of air resonance in the prefix. This is because the TD1 and the air resonance are so closely linked. Figure 29 shows a 26 db difference between two plucking angles for a first-string D^1 (588 Hz). Figure 29 also shows a difference of about 26 db in the intensity of the air resonance, as well as a difference in harmonic spectrum between the open first-string plucked perpendicularly, and plucked parallel to the soundboard.

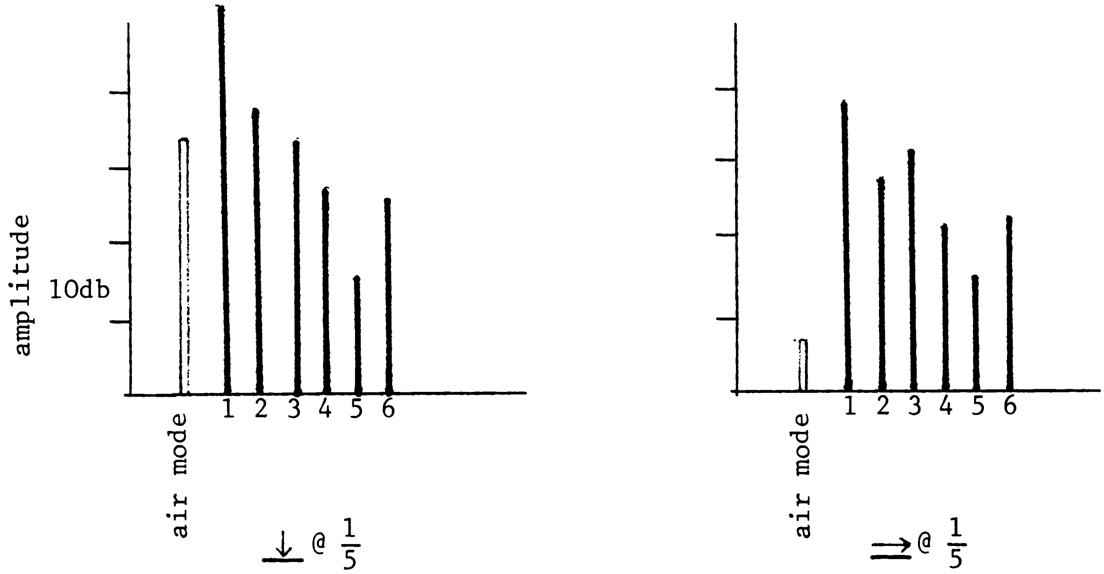


Fig. 29. Harmonics and air resonance of parallel and perpendicularly plucked E-string (330 Hz) tone, plucked mechanically at one-fifth of the string length from the bridge.

This effect occurs regardless of which string is plucked and how it is fretted. In selecting an "instrument," therefore, the amount of this component in the prefix can be varied by almost 30 db. The fact that the amount of air and the TD modes stay the same for a given plucking angle is one of the factors that tell the ear that the same "instrument" is playing when a melody or scale crosses strings or octaves. Although the harmonic spectrum changes from note to note and from string to string, the amount of air and the TD modes stay relatively the same, and this gives the notes timbral continuity.

If the left hand alone is used to initiate a string's vibration, the noise from the soundboard is entirely lost but is replaced by another sound, that of the vibrations of the length of string between the finger and the nut. The composite sound is called a *bi-tone* because the note has two pitches in it, defined by the lengths of the string on either side of the left-hand finger. Since the upper member of the bi-tone is often out of tune with the standard vibrating length and does not last as long as the soundboard tone, it becomes part of the prefix of this type of sound.

A string can also be put in motion by being struck rather than plucked. This is an inefficient way of getting a guitar string to vibrate; musically, the *tambura* (hitting the strings) and *golpe* (hitting the wood of the bridge or soundboard) techniques put more emphasis on the noise in the prefix than on the string itself.

Another way to color the prefix of a note is to use a *Bartók* pizzicato (designated by the symbol 𝆭), in which the string is picked up perpendicular to the soundboard and allowed to rebound against the fretboard. This adds to the prefix of a tone a "snap" that is unrelated to the ensuing tonal character of the note. A subtler range of prefixes is obtainable by a choice between using the flesh of the finger, or the nail or a plectrum; the latter two instruments add a small click to the beginning of the note.

All of the methods above affect the inharmonic elements that appear during the prefix of a sound. The harmonic content of the transient has the same spectral envelope as the rest of the tone, so its control will be discussed in the next section.

The Spectral Envelope

The spectral envelope *of a sound describes the amplitude relationships between the partials, and can be illustrated by plotting frequency (or harmonic number) against time. The player can change the spectral envelope of a tone by using a different string, plucking at a different point along the length of the string, altering the direction in which the string leaves the plucking finger, or damping the string or soundboard in various ways.*

Since the amplitudes of the harmonics in a guitar note are always in a state of change, the most realistic form of illustration is in three dimensions, plotting amplitude vs. frequency vs. time.

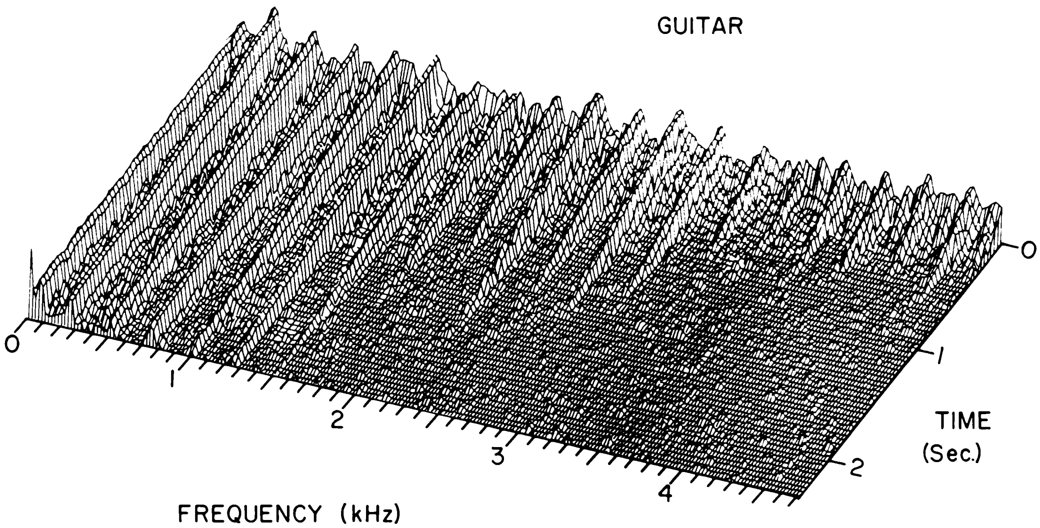


Fig. 30. "Perspective plot" of a guitar note (courtesy of Physics Dept., Brigham Young University).

However, because acoustic-guitar harmonics tend to decay at an even rate it is usually sufficient just to graph harmonic number vs. peak amplitude.

The spectrum of a note can be altered in several ways. Other than using a different string, the most effective method of color modulation of a tone is to change the point at which the string is plucked. We saw in Figure 16 that changing plucking positions changes the duty cycle of the rectangular waveform of force that excites the soundboard, which enhances some harmonics and damps others. The differences among the spectra produced by various plucking positions can be quite remarkable (see Fig. 31 and Recorded Ex. 2).

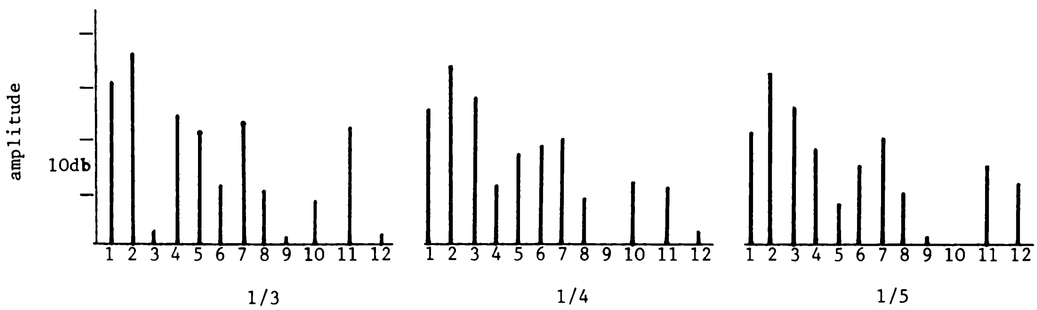


Fig. 31. Harmonic amplitudes of E-string (82.5 Hz) plucked with thumb and nail downstroke at three different positions (other strings damped).

Of course, when a melody is performed on a single string and the right hand stays at the same plucking position, the spectrum of each note is different. This is best illustrated by playing an octave diatonic scale on a single string with the right hand at one-sixth of the length of the open string throughout the scale. When the octave is reached, at the 12th fret, the right hand will be plucking at one-third of the vibrating length, having plucked at a different percentage of the length for each note of the scale. As was mentioned in the last section, when the right hand is stationary during the performance of such a line, the noise element in the prefix of each note remains the same and provides a connection between the different notes. In order to reverse this situation—to keep the harmonic amplitudes the same—some players mimic the left-hand movement with the right hand, as in playing artificial harmonics, but this is only effective when the right-hand position gives a particularly distinctive sound, such as at one-half or one-third of the string length.

Another effective alteration of the harmonic spectrum can be produced by changing the *angle* of the plucker, whether it is a finger, thumb, or plectrum. We have already seen how this alters the noise content of the transient. An angle change also affects the harmonic content of both the transient and the ensuing note. Figure 32 shows the difference between the harmonic amplitudes of a note plucked parallel to the soundboard and one that was plucked perpendicular to the soundboard. Most players believe that using flesh-and-nail (apoyando) rather than nail alone (tirando) accounts for this difference of harmonic spectrum; however, this experiment was made with a mechanical plucker to ensure that the result would not be influenced by the string's exciter.

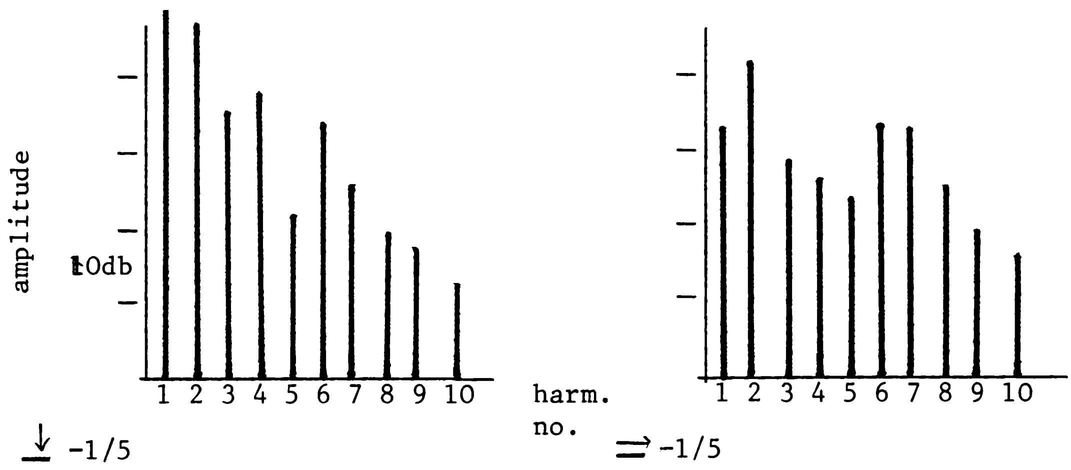


Fig. 32. The E-string (330 Hz) plucked (A) perpendicular to and (B) parallel to the soundboard at one-fifth of the string length from the bridge.

This is not to say, however, that the nail is not important in determining the angle of the string's displacement and motion. It is the exception rather than the rule that a string is drawn aside and then released from a stationary point. Generally, strings are never at rest during the plucking process, and the angle of the fingernail's edge (*ramp*) is very important in determining the speed with which and direction in which the string will travel as it leaves the finger.[24] This means that both the angle of the finger (nail) in the $x-y$ plane (Fig. 33A) and the angle of the string displacement in the $x-z$ plane (Fig. 33B) are available for a *continuous* alteration of the spectrum of a tone.

24. I would like to thank John Taylor for pointing out the importance of the ramp in string excitation.

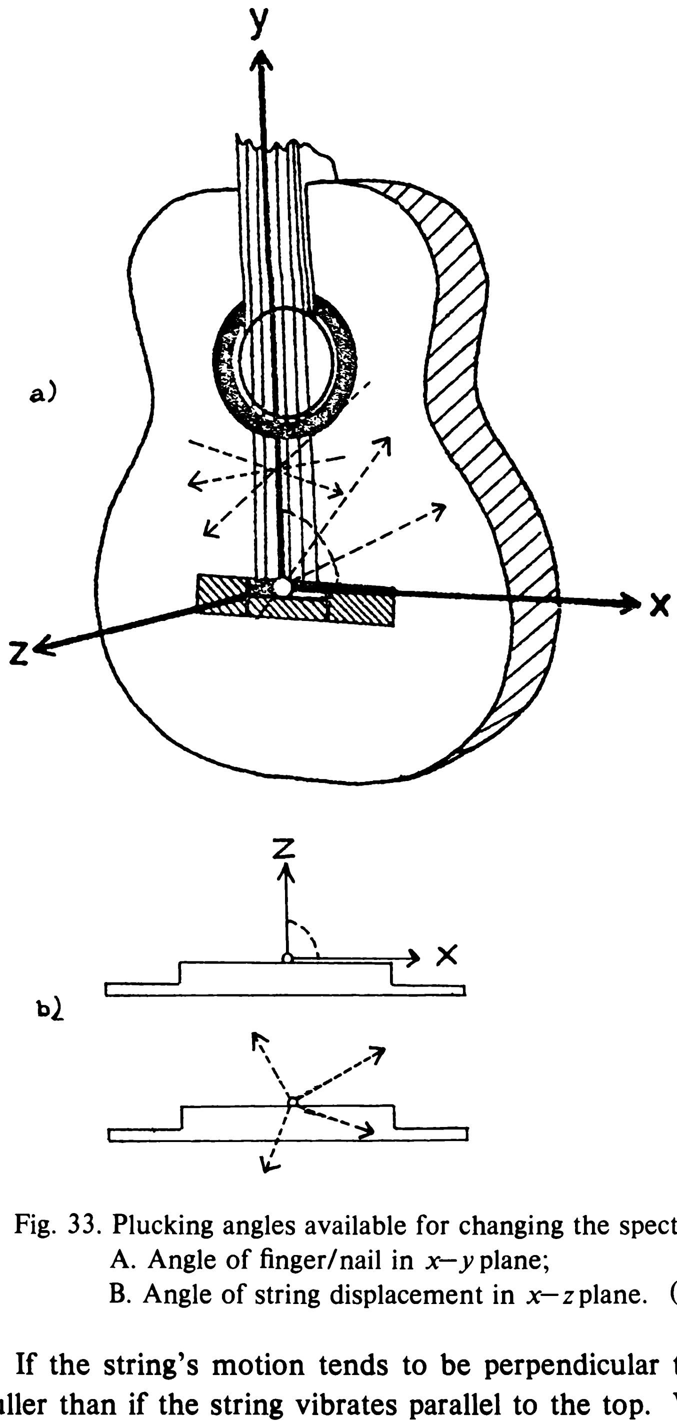


Fig. 33. Plucking angles available for changing the spectrum.
A. Angle of finger/nail in x–y plane;
B. Angle of string displacement in x–z plane. (See Recorded Ex. 3.)

If the string's motion tends to be perpendicular to the top, the tone will be richer and fuller than if the string vibrates parallel to the top. When a string is set into vibration parallel to the guitar top, it applies a kind of force to the bridge different from that which is usually measured. The graphs in Figure 12 show the frequency responses of two instruments when their soundboxes were excited, at the bridge, perpendicular to the plane of the bridge, which created transverse waves in the soundboard. (This is analogous to plucking the string perpendicular to the soundboard.) Figure 34 shows the frequency response of a guitar determined by driving the bridge with a sinusoidally varying force in two directions.

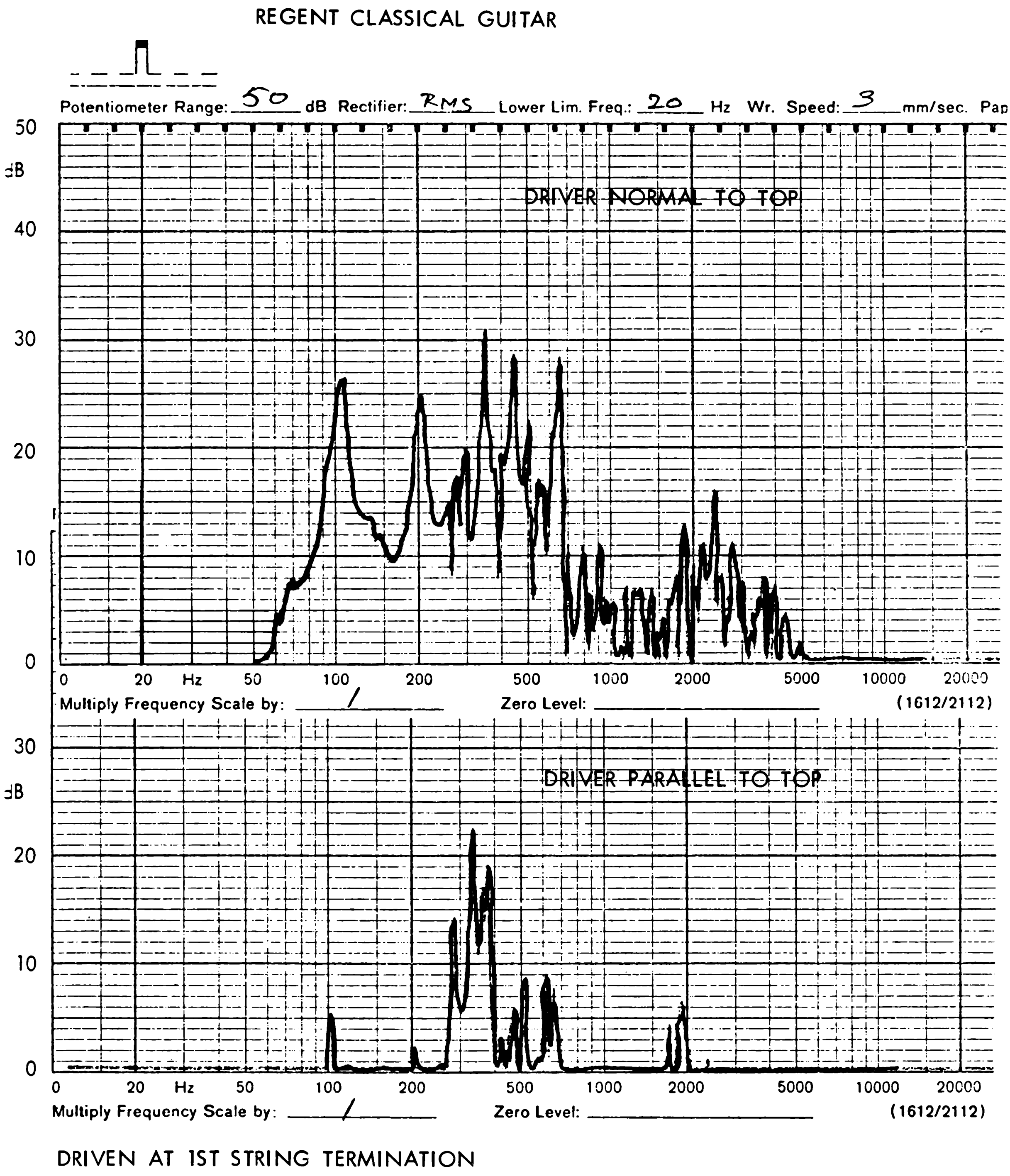
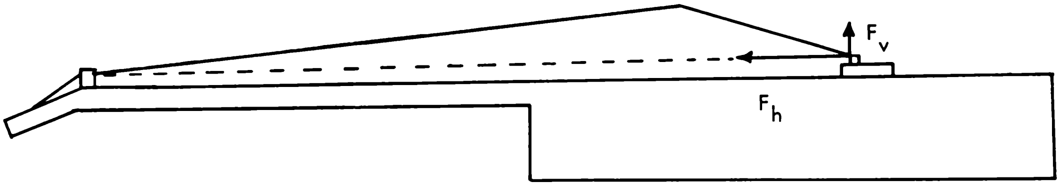
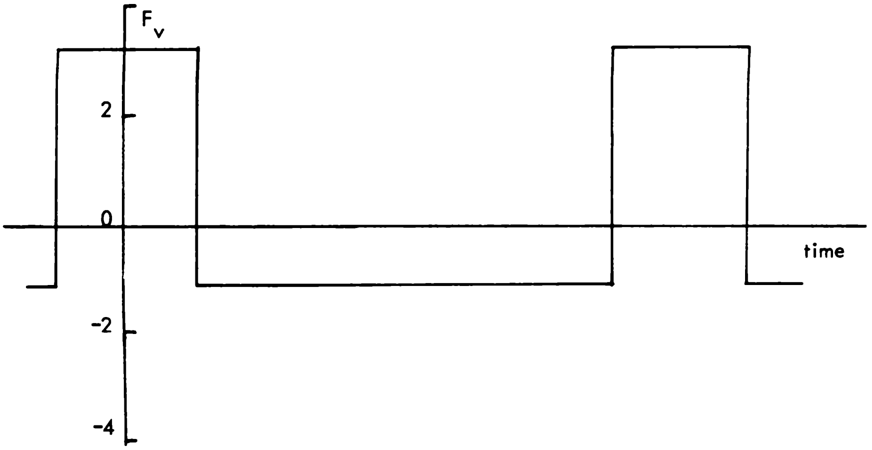


Fig. 34. Frequency response curves of a Regent Classical Guitar, driven (A) normally (perpendicularly) and (B) parallel to the top.

A. Houtsma et al. have shown that the normal and parallel components of force applied to the bridge from different directions of string vibration result in another type of force, double in frequency.





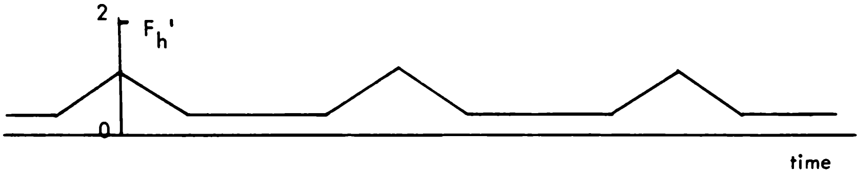


Fig. 35. Forces applied to the bridge by a string plucked at three-quarters of its length in the vertical (F_v) and the horizontal (F_h) directions.[25]

It follows, then, that the difference in sound between the rest-stroke and free-stroke occurs in part because the rest-stroke applies most of its force to the bridge perpendicular to the soundboard, while the free-stroke applies its force parallel to the soundboard, at twice the frequency, and with a different set of frequency responses.

The spectrum of a note can also be changed by varying the width of the plucker. Widening the plectrum, whether it is flesh, nail, or plastic, has the effect of damping the higher, more discordant harmonics, thus producing a less bright, "sweeter" sound. This occurs because the edges of the force waveform are rounded by the change in the initial curve of the displaced string:

25. Figures 34 and 35 are from A. Houtsma, R. Boland, and N. Adler, "A Force Transformation Model for the Bridge of Acoustic Lute-Type Instruments," paper given at the ninetieth meeting of the Acoustical Society of America, San Francisco, California, November 1975.

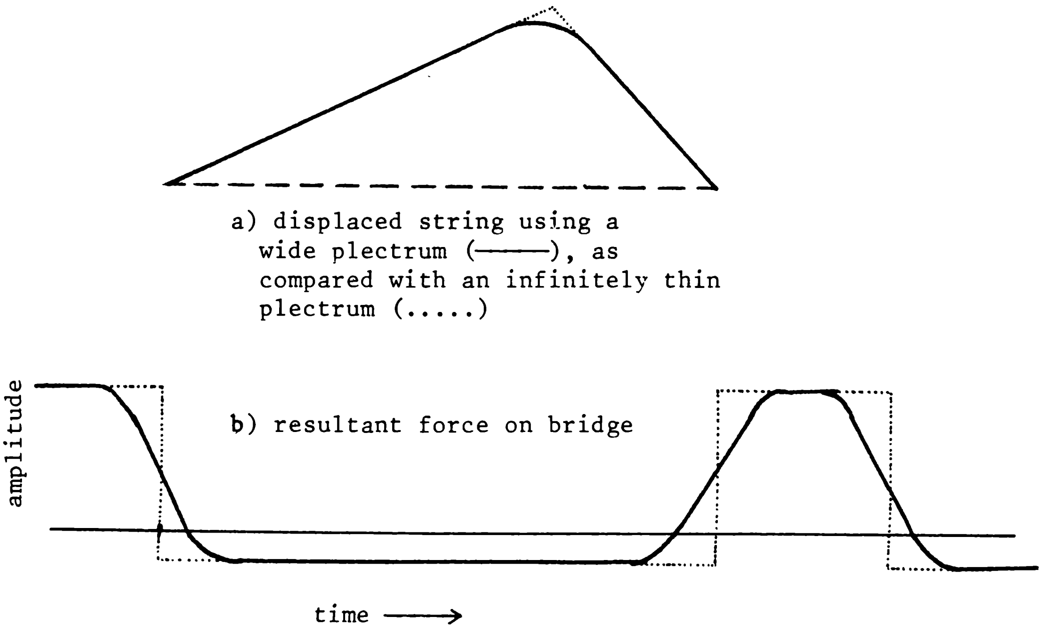


Fig. 36. Use of a wide, round plectrum smoothes the edges of the rectangular waveform of force (cf. Fig. 14).

The difference in area between a fingernail's edge and its corner is usually negligible, due to the stiffness of the string. A more pronounced contrast is that between nail and flesh. The fleshy tip of the finger is the widest practical finger-plectrum that a player can use; it produces a much softer sound (i.e., fewer high, discordant harmonics) than does the nail, or even nail and flesh.

The final method of changing the spectral envelope of a note is to alter the frequency response of the system by damping either the string or the soundboard. This absorbs the highest frequencies, dulling the tone much as in the process shown in Figure 36.[26] There are three kinds of string pizzicati (known also as *sons étouffées* or *apagado*). In the first, the heel of the right hand is held against the strings at the bridge to damp the string, while the right thumb plucks the string. This method is rather awkward, as the entire angle of the hand relative to the strings is different from the normal position, and also because plucking with the thumb limits the speed with which notes can be played. In an improvement on this method, the little finger of the right hand is held against the bridge end of the plucked string for damping, while the index and middle fingers are used for playing. This allows the hand and wrist angle to remain much the same as in normal playing, but it still anchors the right hand to the bridge, and also makes string crossing awkward, since the little finger has to be moved for each string change.

In the third method of string pizzicato, the left hand damps the string, either by placing on the fret-wire itself the left-hand finger that is fingering the note, or by using an adjacent finger for the same job. This method has the advantage of leaving the right hand

26. Of course, damping also absorbs low frequencies, but the higher frequencies of a guitar are much weaker and are absorbed more quickly.

free to determine the original harmonic content of the note by placement and plucking before the tone is altered by damping, but it does limit the speed with which the left hand can change notes.

Which method of pizzicato should be used will depend on the musical situation. It must be remembered that once the string tone has been changed, it can be allowed to ring on in its altered form (*étouffé resonant*); pizzicato need not shorten the decay time of a note.

Damping the soundboard of the instrument alters its frequency response, and hence will change any note that is played. This method can usually only be accomplished with the right hand after a note is already ringing, and is therefore time-dependent; it will be discussed in the next section.

Change: Formant Glide and Fundamental Frequency

This last parameter of timbre is concerned with changes that take place during the duration of a note. Changes in frequency or vibrato *are performed by pulling and/or pushing the string in order to change the string tension and hence the pitch. Changing the frequency response of the instrument during a note's duration can also be done, to add life to a note.*

The most familiar example of formant glide (change in spectral envelope) is the wah-wah effect created by trumpet players and electric guitarists. A *formant* (a peak in the spectral envelope of a sound) can be illustrated by showing the spectra for the vowel *ah* sung at two different pitches.

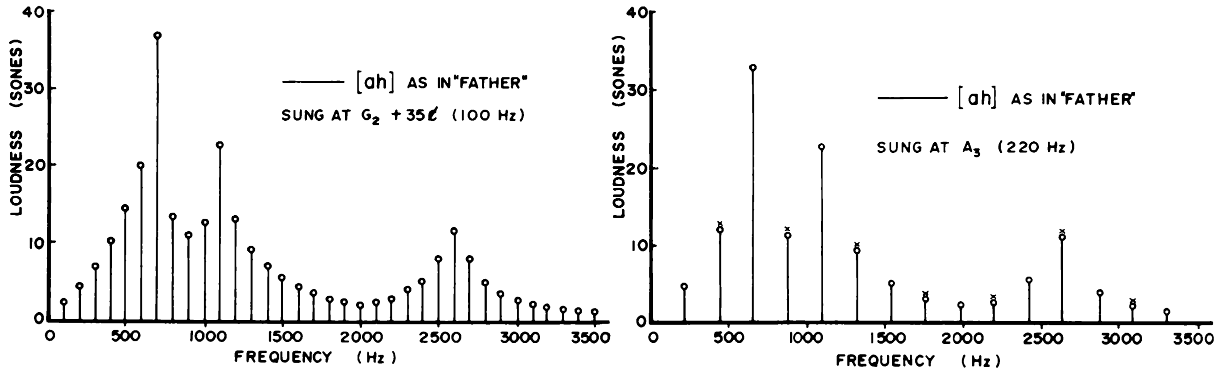


Fig. 37. Harmonic spectra of a vowel sung at two different pitches.[27]

The principle of the formant can be seen in the fact that the overall spectral envelope is the same for both tones, in spite of their differing pitches. A glide in formant means that the peaks of the envelope shift, and the quality of the sound (as determined by the amplitude of the harmonics) changes without any pitch change in the tone. The change from *oo* to *ah* that occurs in *wah* looks like this:

27. Benade, op cit., p. 371.

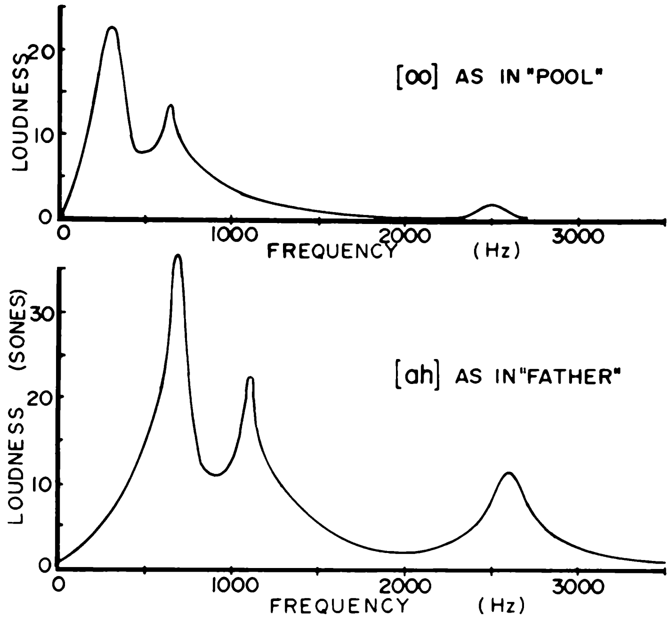


Fig. 38. Spectral envelopes for two vowels.[28]

A formant glide is best illustrated on a steady-state tone, and much will be said about its uses with the electric guitar, but it can also be effective in altering the tone of the acoustic instrument. If one of the lower three strings is plucked and then lightly damped (but not deadened as in pizzicato), the spectral envelope is transformed into one very closely resembling the *oo* spectral envelope of Figure 38—the damping finger absorbs all the harmonics except the fundamental and the first few overtones. This, the reverse of the *wah* effect, can be vocally described as *ah-oo.*

It is impossible to reverse this process by string-damping; once absorbed, the higher harmonics can only be regenerated by plucking the string again. Regeneration can take place, however, if only the soundboard is damped, since the string drives the soundboard whether or not the top is free to respond. Placing a hand on the lower bout of the soundboard temporarily alters the frequency response of the top, with an accompanying change in sound. The damper can then be removed to allow the string to drive the undamped soundboard (and the sound will, of course, change while the damping and undamping take place). This *wah-oo-wah* formant glide can be achieved only if the harmonic content of the string tone is high enough in both amplitude and frequency. (See Recorded Ex. 4.)

Vibrato

Small changes of fundamental frequency during the course of a note are called *vibrato.* On the violin, this is accomplished by altering the length of the string. On the guitar, however, because it is a fretted instrument, vibrato must be achieved by altering the string tension. For notes above about the 5th fret, the technique of pushing and pulling the string

28. Ibid., p. 373.

toward and away from the bridge is usually used; for those notes that lie closer to the nut, the string is pulled from side-to-side, perpendicular to the other strings.

Vibrato can be described by two parameters, amplitude and frequency, each of which has its own time envelope. The *amplitude* is the width of vibrato; in other words, it measures how far the fundamental moves from its original frequency. The full excursion of the guitar vibrato is normally no larger than a quarter-tone. Also, although a vibrato usually moves symmetrically on either side of its center, the pitch can be made just to flatten or just to sharpen, as is obviously the case with the side-to-side type of vibrato. The *frequency* of the vibrato is the number of times the pitch is altered per second, the norm being approximately seven changes per second.

The time envelopes of these two parameters can each be described by its rise, duration, and decay times, all of which can vary immensely. The envelopes can be made either to complement or to contrast with each other for musical effect. (See Recorded Ex. 5.)

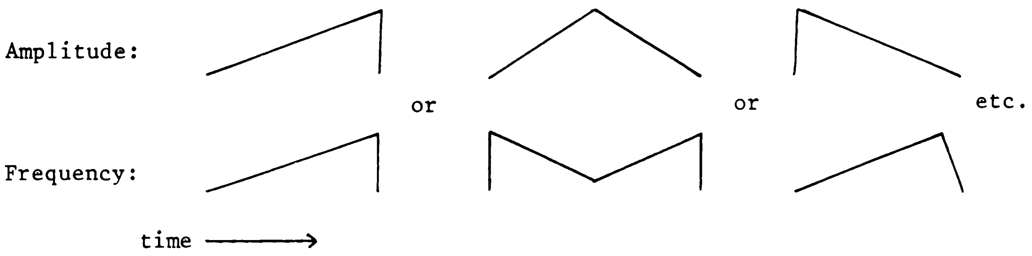


Fig. 39. Various time envelopes for the parameters of vibrato.

It is interesting to note that changes in fundamental frequency during vibrato are accompanied by changes in the spectral envelope of a sound, with the amplitudes of different harmonics changing at different rates. For example, Figure 40 shows the difference between the spectral envelopes of a violin's E played on the A-string when the frequency level of vibrato (FLV) is at its maximum and minimum:

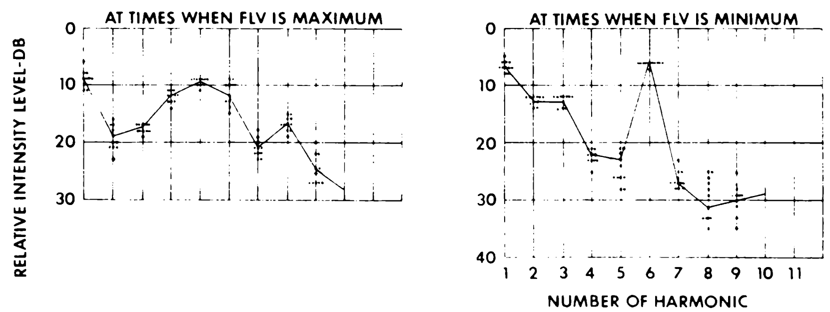


Fig. 40. Harmonic-structure curve for the violin note E played on the A-string when the frequency level of the vibrato (FLV) is at its (A) maximum and (B) minimum.[29]

29. H. Fletcher and L. Sanders, "Quality of Violin Vibrato Tones," *Journal of the Acoustical Society of America* 41, no. 6 (1967): 1542.

Thus the time envelopes of Figure 40 will also describe the spectral glide that accompanies the vibrato.

THE TECHNIQUES

This chapter has described how the player can alter each of the parameters of timbre to change the quality of a guitar note. In practice, however, many of these parameters are interdependent. If, for example, the plucking position is changed to alter the harmonic spectrum, the prefix is also changed; if the plucking angle is changed to diminish the amount of air resonance, the harmonic spectrum is also altered.

To construct a more realistic picture of the relationship between the player and the instrument, timbral changes are listed here according to the *techniques* that change them, so that the player and the composer can see how the results of these techniques overlap. Figure 41 gives a diagram of these relationships.

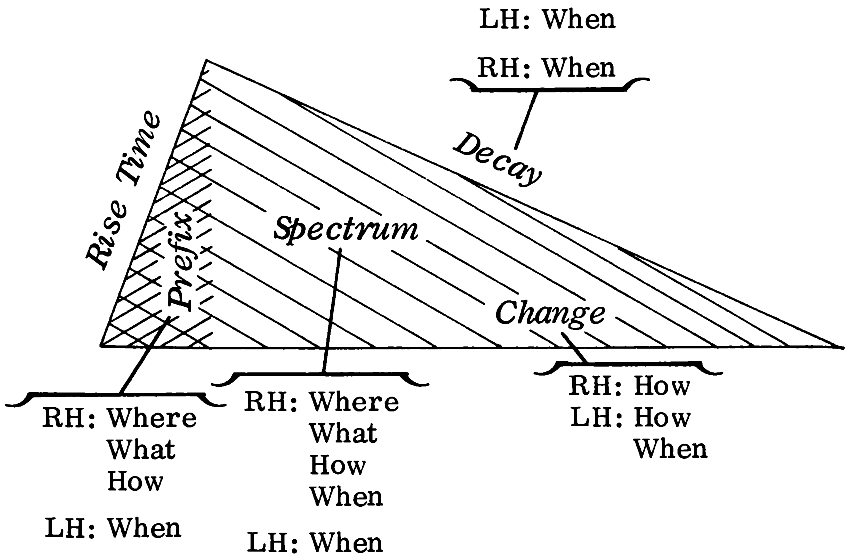


Fig. 41. The parameters of timbre for the acoustic guitar and the techniques that can be used to alter them.

Right Hand

WHERE the string is plucked along its length affects the

1. prefix: its amplitude in relation to the rest of the note;
2. spectral envelope: by changing the duty cycle of the force waveform.

WHAT the string is plucked with affects the

1. prefix; by adding extra surface noise if the fingernail or a pick is used:
2. spectral envelope: by filtering out higher partials according to the width of the plectrum.

HOW the string is plucked—the angle of string displacement and/or how the string leaves the plucker—affects the

1. prefix: by changing the amplitude relationships of the TD and air-resonance modes with each other and with the harmonic spectrum;
2. spectral envelope: by changing the direction of the force applied to the bridge.

WHEN AND WHERE the string is damped during or after it is plucked and how it is damped can affect the

1. spectral envelope: by filtering the high harmonics of the string tone either on the string or the body;
2. decay time: by absorbing much of the vibrational energy rather than using it for sound production;
3. formant glide: by making audible the filtering process of the pizzicato.

Left Hand

HOW the string is pulled can affect the

1. vibrato: by changing the time envelopes of both the frequency and amplitude of vibrato;
2. formant glide: which accompanies vibrato.

WHEN the string is held down by the finger/s can affect the

1. spectral envelope: by exciting the string with the left hand only;
2. formant glide: by using the left-hand pizzicato either with the finger placed on the fret of with an adjacent finger used as a damper;
3. decay time: by releasing or damping held notes;
4. prefix: by creating bi-tones.

SUMMARY

The acoustic guitar is a system containing, among other things, three sound-producing components: the strings, the soundboard, and the soundbox. The timbre of a guitar note can be described by four parameters: time envelope, prefix, spectral envelope, and change (formant glide and micro-intonation), all of which can be controlled by the performer's contact with the string. the first sound-producing component of the instrument. Because manipulation of the string produces almost all of the changes in timbre, many of the timbral parameters are interdependent. Control of these parameters has been explained from two points of view: first, each parameter was described and linked to a technique that could alter it; second, each technique was described and was linked to the effect(s) it produces.

With this information in his possession, the player should be able to control accurately the sounds he wishes to produce, in order to create any "instrument" within the "miniature orchestra" of the guitar.

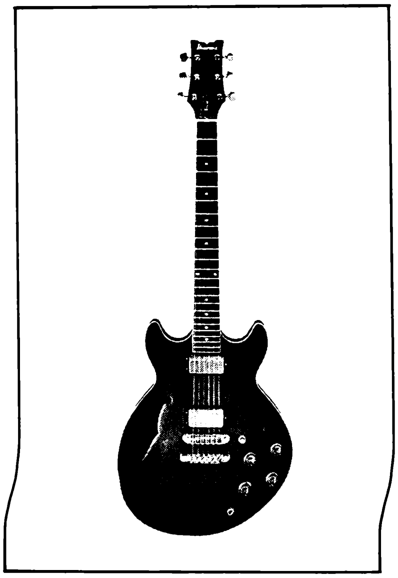
CHAPTER III
The Electric Guitar

The three types of electric guitar (solid-body, semisolid, and hollow-body) all use steel strings and magnetic pickups. Hollow-body, or cello-type, electrics are f-hole, movable-bridge instruments that are really acoustic guitars with pickups. The body serves to amplify the string vibrations in the normal manner, and the pickups "listen" to the string tone's acoustical characteristics, which are determined by the quality and design of the guitar top.

The solid-body guitar functions in an entirely different manner (see Plate II). The body is made of very dense heavy wood (sometimes even metal or plexiglass) in order to reflect the string vibrations rather than to absorb or radiate them; this creates a string tone which is very bright and long-sustaining. The sound production occurs magnetically and electronically. The semisolid, or semi-acoustic, instrument is a compromise between these two extremes. These instruments are usually about 1-1/2 to 2-1/2 inches thick (as opposed to the acoustic's measurements of 4 to 5 inches), and combine some of the long-sustaining characteristics of the solid body with the round, jazzy sound of hollow-body electrics.


Solid-body


Semisolid


Hollow-body

The electric guitar was developed when the danceband guitarists of the late 1930s wanted to be heard above the rest of the band. At that time, they played steel-strung cello-type guitars, so called because their design was based on the construction of the violoncello, with a carved, arched top, f-holes, and two bass-bars (longitudinal struts running almost the entire length of the guitar top). At first, the microphones were attached to the body, but that resulted in too much feedback, so magnetic pickups were developed through experimentation with Gramophone pickups. In the late 1940s, Les Paul, with the help of the Gibson Guitar Company, brought out the first commercial solid-body guitar, and the instrument has been climbing in popularity and versatility ever since.

The first appearances of the electric guitar in the field of contemporary art music were in the music of Harry Partch (1941), in Berio's *Nones* for Orchestra (1954), and in Stockhausen's *Gruppen* (1955/57), while the first piece to exploit the electric guitar as an individual instrument (rather than treating it merely as a louder acoustic instrument) was Kagel's *Sonant/. . .)*.

To understand how the electric guitar works, we will look at the component parts of the system (strings, pickup, amplifier, loudspeaker) and then discuss how the player controls the parameters of timbre using the techniques of electronic sound production.

THE STRINGS

The strings of an electric guitar adhere more to classical string theory (as described in the beginning of Chapter 2) than do nylon strings attached to a soundboard. The body and end supports of the electric instrument are very rigid, to keep the vibration in *the string and to radiate as little of the energy acoustically as possible. This is done by making the body of the instrument very heavy—it is usually made of very dense wood—and by using a metal bridge. Metal strings are more flexible and have less internal damping than do nylon strings, and they are able to vibrate much longer in high-frequency modes. The combination of these two factors results in the familiar "bright" sound accompanied by a longer sustain time than is attainable with nylon strings on an acoustic instrument.*

Because of the string's flexibility (especially the wire first and second strings), the size and shape of the plectrum and the width of the frets strongly affect the harmonic content of a note. Jazz guitarist Barney Kessel uses extra-wide fret wire because he "wanted a larger rounder sound. I want a high note to sound more like a trombone than a trumpet."[1] It is useful to think of a plectrum as a low-pass filter—because its width will determine the highest mode of vibration possible for the string (see p. 17)—and of the fret as a damper that also filters out high harmonics according to its width.

String gauge is also very important in determining the sound of an instrument. Heavy-gauge strings have a meaty sound (i.e., there is more emphasis on the lower partials in the tone) and offer more resistance to picking techniques, because of their higher tension, than do light-gauge strings. For any given string length and tension, increasing the string gauge increases the mass and therefore lowers the pitch. In order to compensate for

1. Quoted in K. Achard and C. Bradley, "Mainly Electric," *Guitar* (February 1973): 19.

this, the tension of the heavier string much be increased to match the pitch of a lighter string of the same length. This increase of tension can also affect the performance of the instrument body, since the amount of pull exerted by light-gauge strings is about 185 pounds, while a heavy-gauge set of strings can cause tension up to 240 pounds. (See Appendix II for some typical string gauges.)

The wrappings on the wound strings (the lower three) also affect the sound of a guitar. The simplest kind of wound string, known as *round-wound*, has a wire core with a round-wire wrapping. It has a very bright sound (many high harmonics), but also causes loud string-whistle (the squeaking sound made in sliding the fingers of the left hand from one note to the next). In order to reduce this whistle, the *flat-wound* string was invented. Its wire core is wound with metal tape so that the surface of the string is smooth; the overall sound is much duller than is that of the round-wound.

A compromise between these two designs is the half-round string, made by milling the surface of a round-wound almost smooth, so that the inside of the winding, which grips the core, is round and very flexible, while the outside is ground smooth so that the surface noise is reduced to a minimum. Another, similar solution is the compound string, which has two wrappings—an inner wrapping of round wire, for flexibility, and an outer wrapping of tape, for smooth fingering.

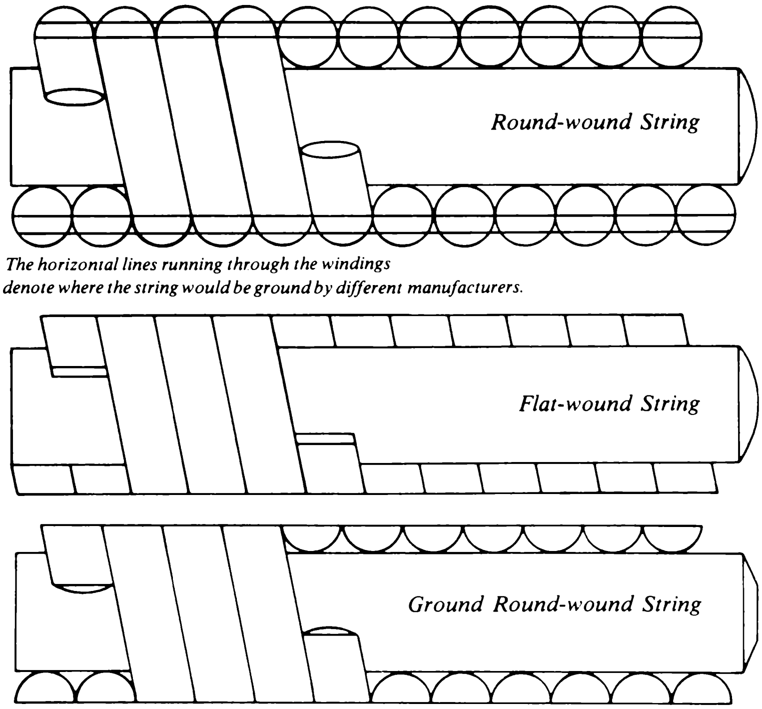


Fig. 42. Three types of winding for bass strings.[2]

The player must choose among these types of wrapping, as well as among at least six basic string gauges, ranging from heavy to extra-light.

2. R.S. Gollihur, "A Guide to Choosing Bass Guitar Strings," *Guitar Player* (July 1978): 30.

THE PICKUP

The next link in the audio chain is the magnetic pickup, which transforms the mechanical motion of a vibrating string into a varying voltage which is then amplified and turned into sound-pressure waves via a loudspeaker. The basic pickup consists of a magnet, one pole of which points toward and one points away from the strings, with a wire coil wrapped around the magnet. When the gap between the string and the pole piece changes, a voltage is created in the coil proportional to the velocity of the string's motion. (For this effect to occur, the string must contain some iron.) The quality of the signal produced can be changed by changing the location of the pickup along the string's length. Most guitars have two or more pickups, allowing the player to create composite sounds *(see p. 52)*.

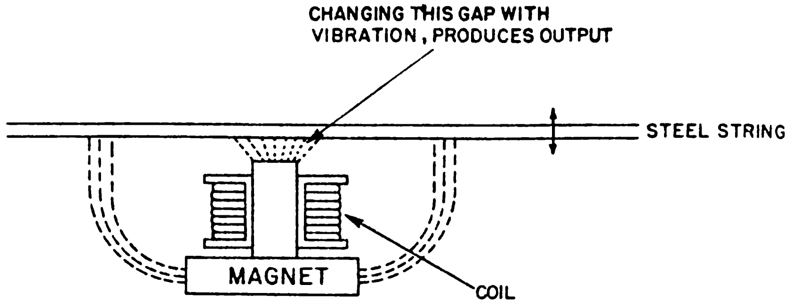


Fig. 43. Principle of the magnetic pickup.[3]

Placement of the pickup is one of the most important means of determining the tone of the guitar, because the pickup only "listens" to one point along a string, while the string's motion varies along its length. (In fact, pickup placement is analogous to the choice of plucking position along the length of the string of the acoustic guitar.) For example, if the pickup were placed at the center of the string in Figure 43, it would not pick up any even-order harmonics; if it were placed at a point one-third of the way along the string length from the bridge, it would not pick up the third harmonic or multiples of the third.

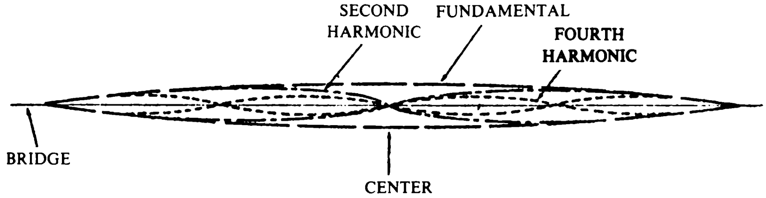


Fig. 44. Modes of string vibration.[4]

3. N. Crowhurst, *Electronic Musical Instrument Handbook* (Indianapolis: Howard W. Sams and Co., 1962), p. 44.
4. Ibid.

Table 1. Transmission of harmonics by pickup.[5]

Position of Pickup from Bridge	2nd Harmonic	3rd Harmonic	4th Harmonic	5th Harmonic
Halfway	0	.333	0	.200
One-third	.500	0	.250	.200
One-fourth	.707	.333	0	.166
One-fifth	.807	.538	.250	0
One-tenth	.989	.987	.942	.904

Table 1 shows the relative transmissions of harmonics by pickups at various positions along the string (in terms of transmission at the bridge). The closer the pickup is to the bridge, the brighter will be the sound, because more energy will be picked up from the high part of the string's spectrum.

The pickup also adds a few frequency components of its own, because it has non-linear characteristics (i.e., more frequencies come out than one puts in). Each string harmonic that is "heard" by the pickup may generate its own second-order harmonics. The signal of the pickup placed at the center of a string (a location which, theoretically, has no even harmonics) would look like this:

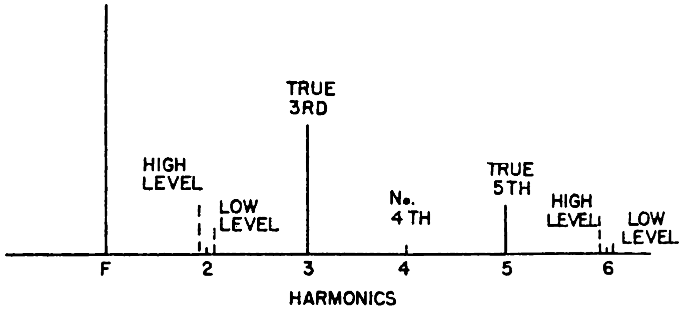


Fig. 45. Harmonics in center-of-string pickup output (______ = string harmonics; .... = pickup harmonics).[6]

The closer the pickup is to the string, the more non-linear the harmonics become.

The two basic types of pickups are single-coil and humbucking (double-coil). The first pickups were single-coil, a type known for their bright sound (meaning that they pick up a large percentage of the high-frequency content of the string motion), but they also tend to pick up electronic hum and extraneous electrical noise. In order to combat this problem, an engineer named Seth Lover invented the humbucking pickup by wiring two single coils together in series and out of phase, so that when electrical noise is picked up by both coils simultaneously, one coil describes it with a positive voltage and the other with a negative voltage. When the two signals are combined, they cancel each other out, thus eliminating hum (at least theoretically—since the two coils must be placed side by side,

5. Ibid., p. 45.
6. Ibid., p. 46.

however, the cancellation can never be complete). Also, because the coils are picking up string vibrations from two different points along the string, those high frequencies whose wavelengths are shorter than the gap between coils are cancelled, giving the humbucking pickup its characteristic broad or mellow tone.[7]

In the late seventies, more and more attention was paid to pickup efficiency and design, which had remained virtually unchanged for the previous twenty years. New ceramic magnets often replaced the alnico (a blend of *AL*uminum, *NI*ckel, *CO*balt, and iron) types originally used. These ceramics are cheaper to produce, as well as being more powerful. Another change has been in the use of the pickups themselves. Since the humbucking pickup uses two coils, many pickups now use a switch which allows the player to use only one of the coils at a time; thus a single pickup gives the guitarist a choice between the mellow humbucking sound or the bright single-coil sound. A guitar using two humbucking pickups therefore has four single-pole pickups to choose among, or to combine in any configuration, in or out of phase, with each combination giving a different quality of sound.

A traditional design problem has been the compromise between pickup output and frequency response: higher output is gained by wrapping more wire around the magnet, but increasing the number of wrappings cuts off higher frequencies. This problem has been at least partially solved by adding a small pre-amp to the pickup's circuit, making it possible to amplify the output and to tailor the frequency response electronically. Many instruments now contain this type of pre-amping, with its accompanying nine-volt battery, as a matter of course. As the prices of miniaturized electronics keep dropping, the future will surely see even more sophisticated "active" pickup circuitry developed.

How can pickups be used to change the timbre of a sound, once a design has been chosen? One obvious method of changing the tonal quality is to move the pickup. Several guitar companies make pickups that have movable positions, but the standard practice is to use two or more pickups permanently stationed at various positions along the string. Usually, each pickup has its own filter and volume control, permitting the player to change the sound of each pickup, as well as to operate a pickup by means of a selector (on-off) switch on the guitar itself. It is a short step from such tone control of individual pickups to tone synthesis—mixing the pickup outputs.

If the pickups are connected so that the polarities of their outputs are in phase at the fundamental frequency of the string, varying the proportion of output from each pickup provides a continuous change of quality from that delivered by one pickup to that delivered by the other. If the output of one of the pickups is reversed (i.e., the fundamental from one pickup is 180° out of phase with the fundamental from the other), then the combination of the two signals will cancel some frequencies and enhance others. At some settings the fundamental will be greatly reduced and many of the high harmonics will be greatly amplified.

7. For a more complete description of pickup types and designs, see T. Wheeler, "Pickups: A Primer," *Guitar Player* (February 1978): 32–34; and T. Evans and M. Evans, *Guitars* (London: Paddington Press, 1977), pp. 379–82.

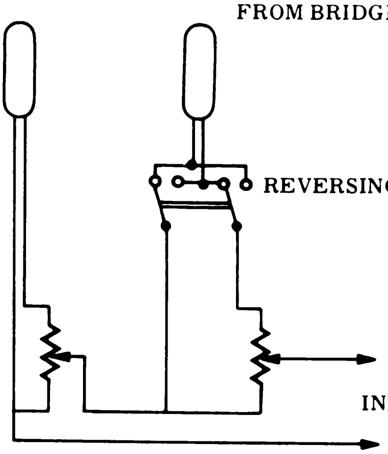


Fig. 46. Schematic for the phase-switch form of tone synthesis.[8]

It must be remembered that, like Spanish guitars, the electric instruments from different makers vary widely, and each has its own sound. There are at least forty different kinds of guitar pickups on the market today (the Gibson company alone makes seventeen!), all differing in the number of coils, size and shape of pole pieces, output voltages, impedances, cost, and, of course, sound. The player must sample in order to choose a combination of these various attributes that suits his "sound," just as the buyer of a Spanish guitar chooses an instrument that suits his style of playing. (See Recorded Ex. 6.)

THE AMPLIFIER

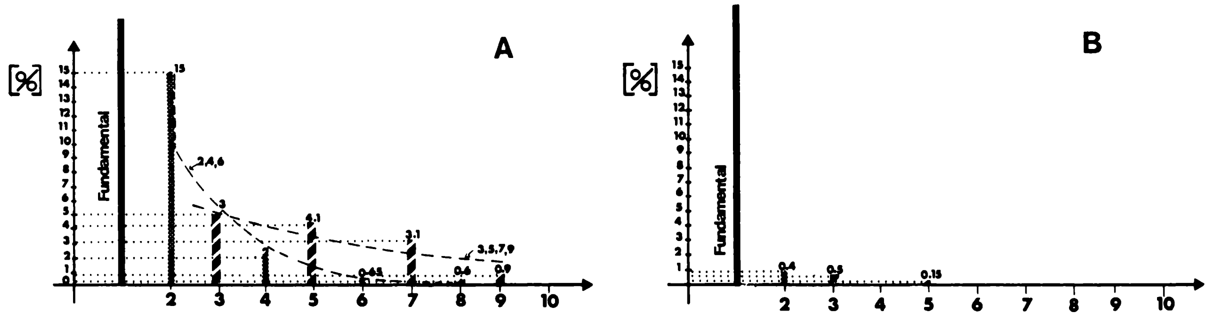
Once the pickup has produced a voltage whose frequency and amplitude are proportional to the string movement, the signal must be amplified in order to drive a loudspeaker. It is a common misconception that the original signal itself is somehow expanded electronically. What in fact happens is that the original signal controls another, much larger voltage (which usually comes from the main plug), and the larger power source drives the loudspeaker. The device known as the "amplifier" usually consists of two parts: the input part, or pre-amplifier, which contains tone-control circuitry, and the power amplifier.

The *pre-amplifier* (*pre-amp*) is designed to do several things. First, it amplifies the voltage from the pickup—ideally, without adding any distortion, extraneous noise, or hum from outside circuits. Next, it "equalizes" or compensates for any loss of high or low frequencies by giving that end of the sound spectrum some extra amplification, thus changing the frequency response of the system. This is the function of the tone controls—usually marked *Bass* and *Treble*—on a standard stereo or guitar amplifier. A more sophisticated kind of tone control is the graphic equalizer; this can individually amplify or attenuate small bands of the frequency spectrum, usually an octave at a time.

8. N. Crowhurst, *Electronic Musical Instruments* (No. 546; Pennsylvania: TAB Books, 1971), p. 46.

Since the mid-1960s, a controversy has raged over which type of amplifier is preferable: the kind that uses tubes, or the sort that uses transistors to amplify a signal. One is not necessarily better than the other, but the sound is definitely different, and this aspect of sound modification is a very real factor in determining the tonal character of the final sound of an instrument. It must be remembered that every component of an electric guitar's sound-system can influence the final sound, so each should be considered carefully before it is selected.

Any amplifier distorts signals; the difference among them is just a matter of degree. Transistor amps add less distortion than tube amps; in the sense that it gives a truer representation of what the pickup actually hears, the transistor amp is better.



Spectrogram showing harmonic distortion ref. 1 KHz. In a standard pentode 100W output (push-pull system)

Spectrogram showing harmonic distortion ref. 1 KHz. In a standard transistor 100W output (push-pull system)

Fig. 47. Spectrograms showing harmonic distortion of (A) tube and (B) transistor amps.[9]

Paradoxically, tube distortion is very pleasing to the ear—it gives a much meatier sound, by adding more harmonics (the second harmonic particularly). Since tube amplifiers came before transistor amps, when the technology finally became available for a non-distorting amplifier, most musicians weren't interested. In fact, many transistor amps are now designed to mimic the tube sound by adding distortion to the signal.

Once the signal has been amplified and equalized, it is ready for the output stage. The *power amplifier* receives signals of high voltage and relatively low power and releases signals of the same waveform but of sufficiently high power to drive a loudspeaker. The pre-amp and power amp are often housed together in a cabinet that sits near or on top of the speaker cabinet so that it is insulated from vibration. Small units that contain amps and speaker in a single cabinet are called combination amps.[10]

9. M. Sawicki, "The Technical Arguments," *International Musician and Recording World* (July 1976): 15.

10. For more information on amps, see B. Turetsky, *The Contemporary Contrabass* (Berkeley and Los Angeles: University of California Press, 1974), ch. 7.

THE LOUDSPEAKER

The loudspeaker performs one of the same functions as the soundboard of the acoustic guitar: it radiates the vibrations of the string into the surrounding air, so that they may be heard. The mechanical actions of the loudspeaker are almost exactly the reverse of the string-pickup process: the mechanical movement of a steel string induces a voltage in a coil of wire wrapped around a magnet, while the electrical signal applied to a loudspeaker coil induces a magnetic field that changes in value according to the amount of signal variation. The magnetic field moves the cone attached to the coil, and this motion is turn changes the sound pressure of the surrounding air, thus producing sound.

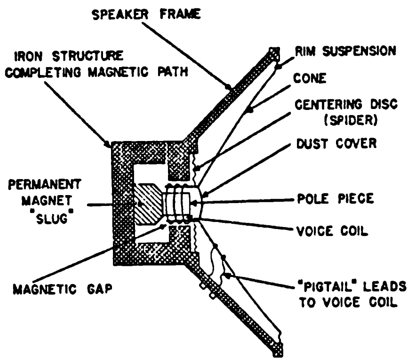


Fig. 48. Basic construction of a moving-coil loudspeaker.[11]

Every component of a sound-reproducing system should ideally have a flat frequency-response, i.e., it should respond to all frequencies equally. Often, however, a loudspeaker will display frequency characteristics which color the sound it is reproducing.

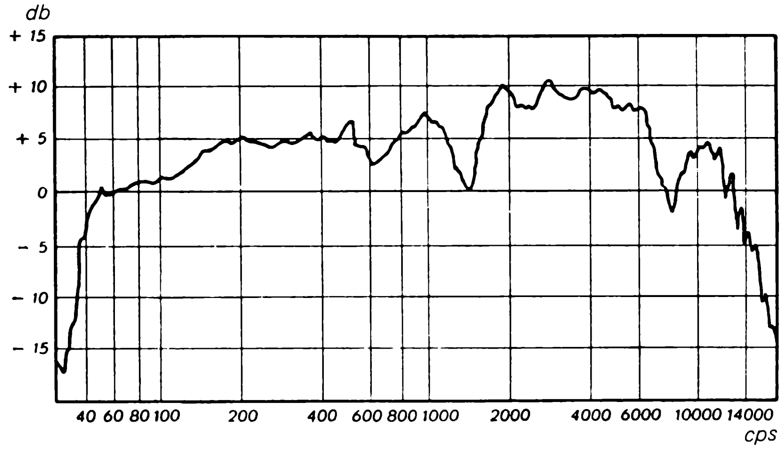


Fig. 49. Frequency curve of a loudspeaker.[12]

11. E. Villchur, *Reproduction of Sound* (New York: Dover, 1965), p. 71.

12. F. Winckel, *Music, Sound and Sensation*, trans. T. Binkley (New York: Dover, 1967), p. 377.

Also, different designs of loudspeaker favor different portions of the sound spectrum. In most modern systems, one speaker is not asked to do all of the work for all frequencies; instead, a crossover network divides the load between a woofer for low frequencies and a tweeter for high frequencies. Acoustical horns are also used, to increase the efficiency of changing mechanical vibrations into acoustical energy.

THE PLAYER

Now that the mechanics of the electric guitar have been systematically reviewed, the musical problems of the techniques of tone production can be more intelligently discussed. Because the timbral parameters are so interdependent in the acoustic instrument, the player has a limited—although still admirable—choice of methods that can be used to affect the guitar's tone. The possibilities for transforming the parameters of timbre are greater still with the electronic guitar, for the player has almost completely separate control of each individual timbral aspect of the sound.

Over the last fifteen years, the rock-and-roll division of the musical-instrument industry has developed scores of effects, pedals, and "magic boxes" to alter the guitar sounds of thousands of post-Beatles musicians. The fact that many of these effects were originally designed as gimmicks for pop groups who used them rather unsubtly does not diminish their usefulness for "serious" musicians. It is enough to say that a little taste goes a long way, and that careful and considered use of these techniques of tone modification can give very satisfying musical results—as many contemporary composers have already discovered.

Separate control of each timbral parameter, together with the sound-processing technology of the seventies, offers the guitarist and composer an incredible choice of sound qualities. The control of each of these parameters will be discussed in turn, with the same aesthetic goal as for the acoustic instrument: to offer a Rational Method of Tone Production.

The Time Envelope

The attack of a plucked string on the electric guitar has the same fast rise-time as that of the acoustic instrument; but because the player can now control when the sound is actually heard, the attack becomes a powerful variable that can be used effectively to change the character of a sound. The *rise time* can be altered at two places along the audio chain: by hand, with the volume potentiometer (*pot*) on the guitar; and by foot, with a volume pedal (*swell pedal*) between the instrument and the amplifier. A circuit called an *envelope shaper*, which controls the rise, duration, and decay time of the guitar's output, may also be placed between the instrument and the amplifier. This module is a standard part of the equipment of a synthesizer, and several shapers have been constructed especially to alter the rise time of the guitar according to the dynamic level of the input.

The *duration* segment of a guitar note can be altered considerably by electronics, and several techniques can be used to create sustain. One circuit (borrowed from the recording industry) is an amplifier designed to change its output level according to the input level of the signal. The job of this compressor-expander (*compander*) is to keep a constant output level; when the transient causes a large signal, the compander decreases its output, and when the guitar signal starts to decay, it increases amplification to keep the output steady.

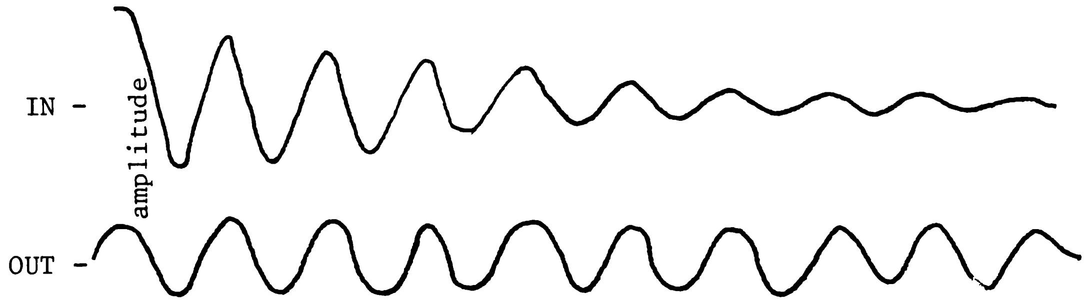


Fig. 50. Input and output levels of a compressor-expander (compander) circuit.

(One problem with this kind of circuit is that as the decaying input signal is amplified, the noise in the circuit is amplified as well, so the end of a note will be low in harmonic content but high in noise.) This kind of limiting and expanding can also be done by hand, with the volume knob on the guitar, or by foot, with a swell pedal.

Another form of sustain is obtained by overloading the input amplifier until the upper limits of the amplifier "clip" the output signal.

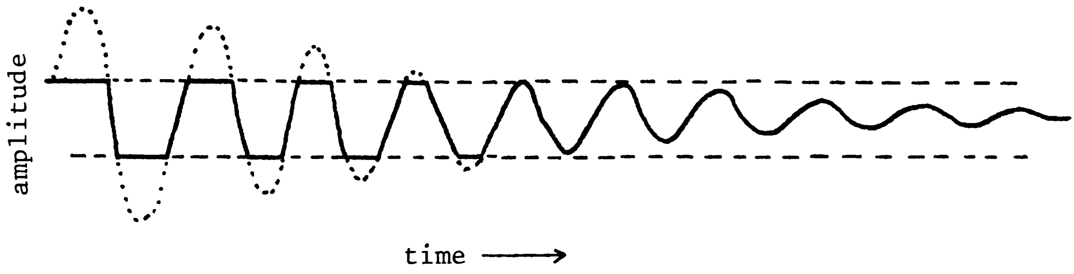


Fig. 51. A clipped signal. (........... = input; - - - - - - - = amp limits; ______ = output)

This also adds distortion: when the input is clipped, the waveform is changed, and the result sounds much like a squarewave or "fuzz-tone." The amounts of distortion and sustain are, of course, increased by increasing the amplitude of the input, and many amplifiers are now made with a master volume control so that even when the input volume is set at "10" for distortion, the overall sound level can still be kept low.

The *decay* is usually far less important to the electric guitarist than is sustain. Using clipping as a form of sustain lets the note decay naturally; however, many effects-boxes (such as fuzz-tones and octave-dividers, which boast a sustained-amplitude tone), simply cut off their outputs once the input signal has decayed beyond a certain point. Musically, this is very unsatisfactory, because pitch becomes the only parameter that a player using one of these devices can control (if we ignore any additional electronic spectral transformations). Such a limitation robs the guitarist of a great deal of potential expression. To overcome this difficulty, some manufacturers add an automatic decay at the end of the processed tone, but of course the sound of the tone is exactly that—processed. For the player, the answer is to use a swell pedal as the final treatment before the signal reaches the amplifier, so that there is kinesthetic control of the entire dynamic envelope, regardless of its content.

All these attempts at altering the time envelope have been aimed at controlling the point at which sections of the string's envelope will be revealed to the listener. The other approach is actually to determine the string motion by feeding energy back into the string, either acoustically or electro-magnetically, in order to sustain its vibrations.

The acoustic form of feedback occurs when the guitar body is held near the speaker of the amplifier: the string feeds the pickup, which feeds the amplifier, which drives the speaker, which causes the guitar body to vibrate, which drives the string, which feeds the pickup, and so on. This loop of energy is self-perpetuating, and can be controlled by altering the energy put into any part of the closed system. (See Recorded Ex. 7.)

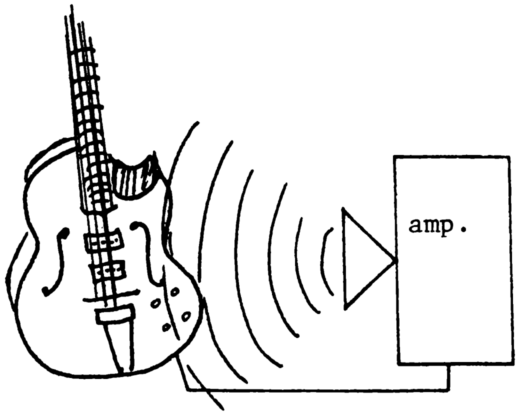


Fig. 52. Diagram of an acoustic feedback system.

This kind of system works best on electro-acoustic or semi-acoustic guitars because these bodies are relatively easily influenced by airborne sound; in fact, that is one reason why the solid-body guitar was developed—to inhibit unwanted feedback.[13]

The electromagnetic string-driver uses magnetic rather than acoustical feedback to keep the string vibrating after it has been plucked. The on-board string-driver used by the Roland GS-500 guitar has a driver transducer that uses the signal from the guitar pickup to feed energy back magnetically into the vibrating string (Fig. 53).

13. Of course, acoustic feedback methods can be used on a solid-body guitar if the acoustic signal is loud enough. Jimi Hendrix, a pioneer in this type of tone modification, used a solid-body guitar with several massive amplifiers.

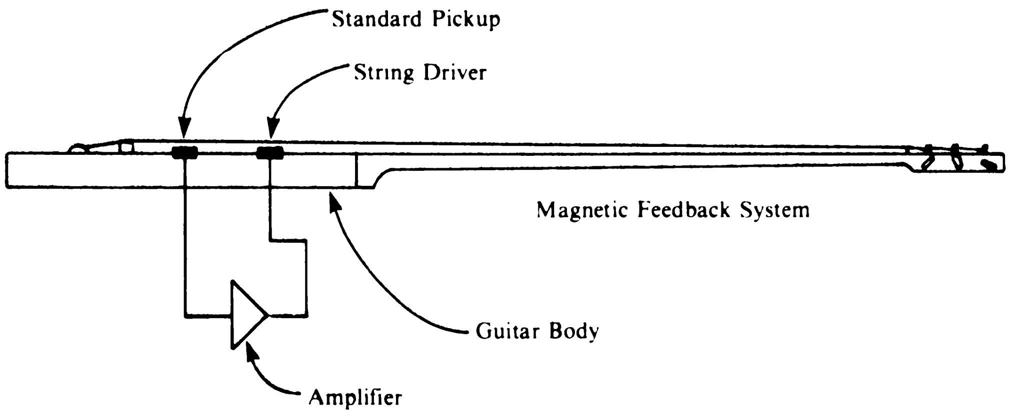


Fig. 53. On-board magnetic feedback system.[14]

The hand-held E-bow (Energy-bow) string-driver operates directly on the guitar string, rather than on the signal from the pickup. With the E-bow, the player not only controls the sustain of the note but also, by determining the proximity of the driver to the string, has complete dynamic control over the attack and decay. (See Recorded Ex. 8.) Moving the position of the driver along the string can also change the harmonic spectrum of the string signal.

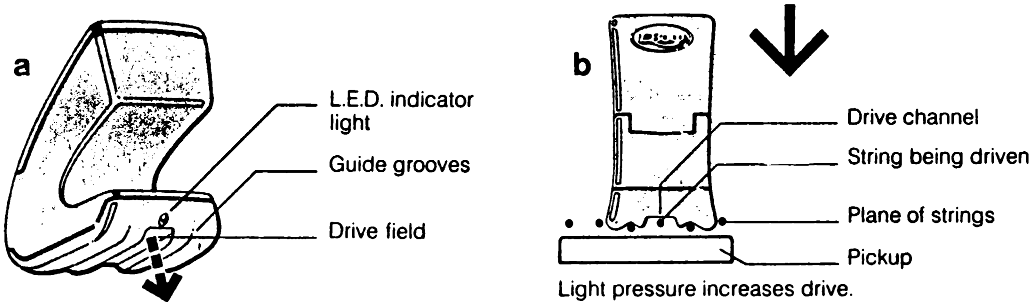


Fig. 54. E-bow hand-held electromagnetic string-driver.[15]

The Prefix

One of the most outstanding characteristics of the electric guitar tone is the twang at the beginning of the tone. This twang is the transient that occurs before the travelling waves excited by the pluck settle down into a standing wave and begin periodic vibration (see Chapter 2). By using a volume pedal to cut off this natural string attack, the character of the tone will be completely changed; it may even be mistaken for a flute or a clarinet tone (depending on the harmonic content of the rest of the envelope). Of course, this method of altering the prefix does not change the real string transient; it merely deletes it from the amplified sound, so that the prefix that is heard is a smooth crescendo of har-

14. D. Friend, "Guitar Synthesizers: Infinite Sustain," *Guitar Player* (April 1972): 160.
15. "Energy-Bow Instructions" (Los Angeles: Heet-Sound Products, 1976).

monics, without the inharmonic partials that are usually heard at the beginning of a tone. (See Recorded Ex. 9.)

A more versatile method of altering the prefix of a note is by changing its harmonic content. This can be done in the traditional manner—by altering the plucking position along the string—or electronically, by clipping the input signal. Most modern amplifiers include a master volume knob that controls the amount of power sent from the pre-amp to the amplifier. By turning the volume of the guitar and pre-amp up very high and keeping the speaker output low, a steady output level can be maintained while the amount of clipping on the guitar signal is controlled. A large amount of clipping (up to 75 percent) will alter the sustain of the note, but a small amount of clipping will only alter the spectrum of the transient (see Fig. 51).

The Spectral Envelope

The harmonic content is probably one of the most variable parameters of the electric guitar's timbre. As we saw earlier in the chapter, the spectrum can be altered both by changing the place where the string is plucked, and by the placement and settings of the pickup/s. (As a scale is played on a single string, both the plucking place and the pickup placement change their position in relation to the vibrating length of the string, thus changing the spectral envelope.) Varying the position of an electromagnetic string-driver will also change the spectrum of the steady-state tone, since it acts as a bow. All the string-oriented techniques used on the acoustic guitar (pizzicato, bi-tones, etc.) will work on the electric. In addition, two types of spectral transformation are specific to the electric instrument: subtractive transformation and additive transformation.

Subtractive Transformation

When the spectral envelope of a sound is transformed by a subtractive process, frequency components of the spectrum are either removed or attenuated. The simplest means of achieving this goal is to filter the signal by changing the frequency response of the system electronically. A *low-pass filter* like the tone control on a guitar lets through the low frequencies and attenuates the high frequencies; a *high-pass filter* attenuates low frequencies. (See Recorded Ex. 10.)

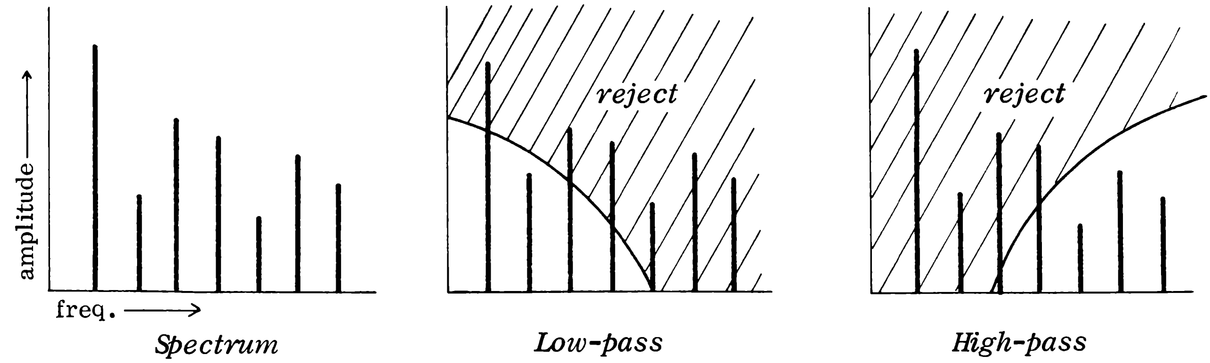
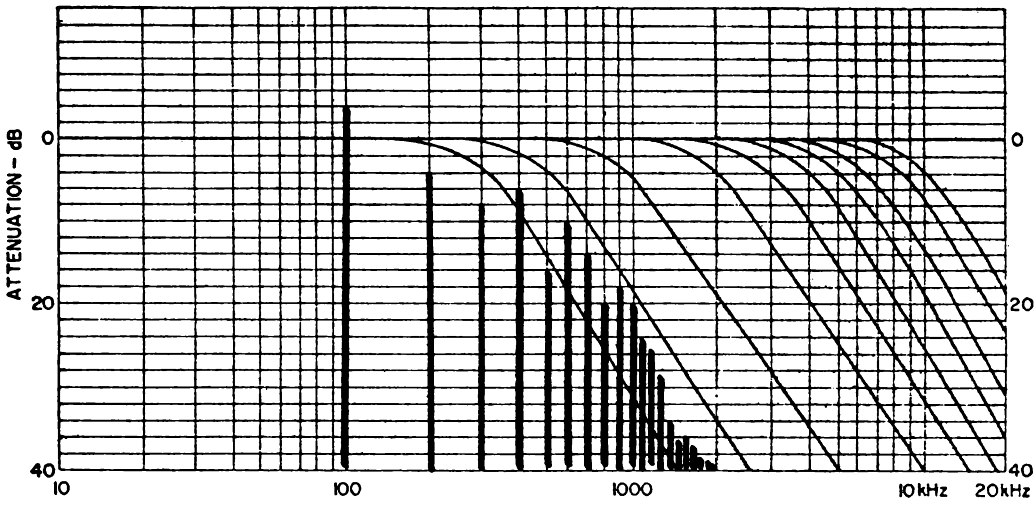
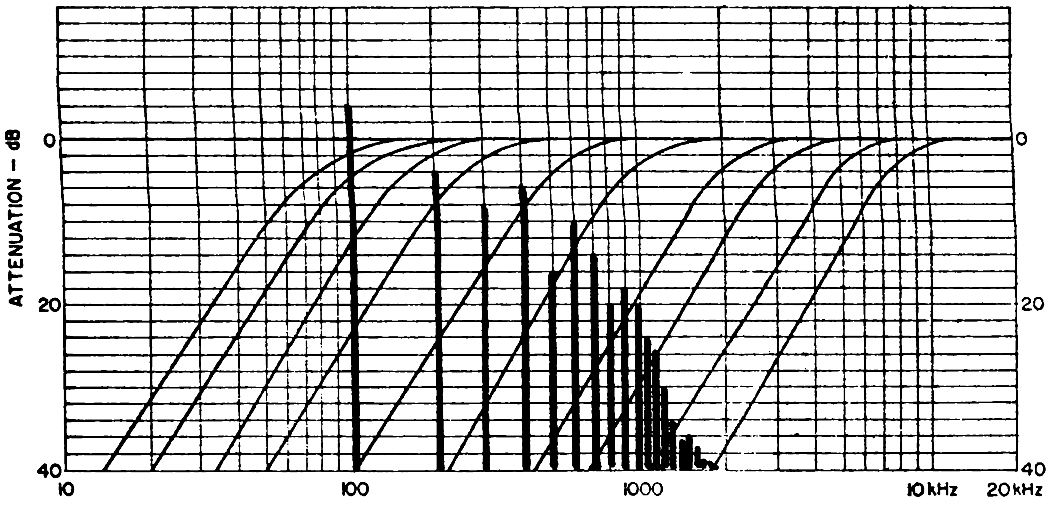


Fig. 55. Transmission characteristics of a high-pass filter and a low-pass filter.

The frequency above or below which the filter fails to pass any components is called the cutoff frequency; by varying the cutoff, the player can choose the part of the harmonic spectrum used.



(a) Used as a low-pass filter.

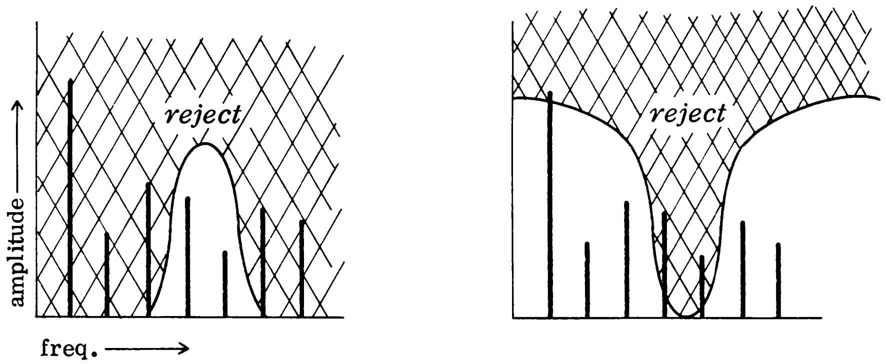


(b) Used as a high-pass filter.

Fig. 56. Cutoff frequencies for a high-pass filter and a low-pass filter.[16]

A *band-pass* or *band-reject filter* combines the functions of the high-pass filter and the low-pass filters in one circuit. The function of these circuits can be described by the band width (the width of the band of frequencies that are passed—band-pass filter—or rejected—band-reject filter); and the fixed center frequency of the band.

16. H. Tremaine, *Audio Cyclopedia* (Indianapolis: Howard W. Sams and Co., 1973), p. 358.



Bandpass *Band-reject*

Fig. 57. Transmission characteristics of a band-pass filter and a band-reject filter.

Band-pass and band-reject capabilities can be combined in a single circuit that controls the amplification or attenuation (±16 db) of a fixed band of frequencies with a single manual control—usually a sliding potentiometer. This *graphic equalizer* divides the approximately nine octaves of the audio spectrum into from one to three bands of fixed width and frequency per octave. The slider controls are then used to fix the amplitude of each of these bands; when they have been set, the control knobs give a visual representation of the frequency response of the equalizer—hence the name *graphic*.

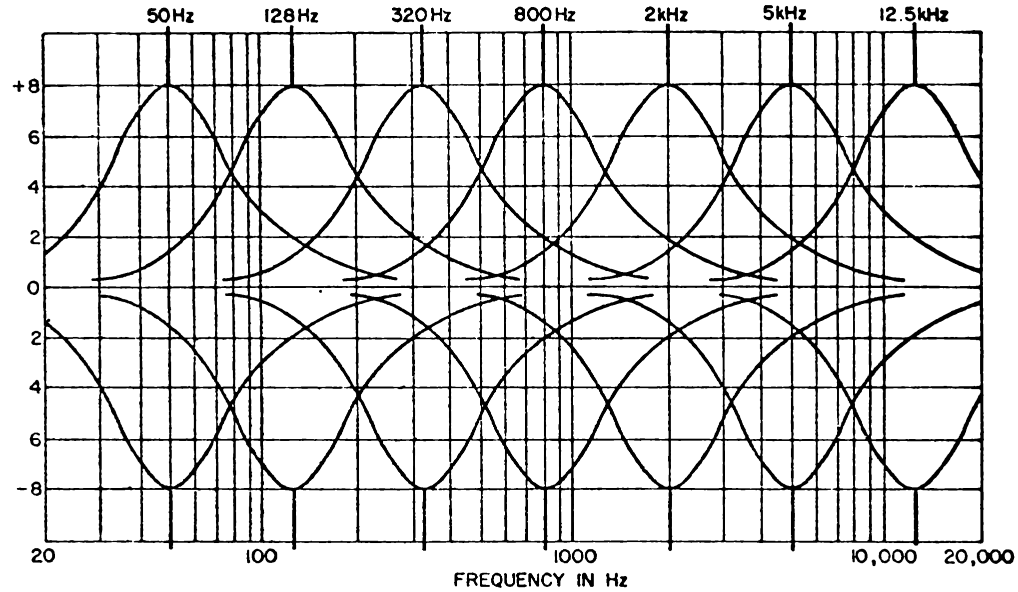


Fig. 58. Frequency-response curve of a seven-band graphic equalizer.[17]

There are several extremely small six-band equalizers, and some instruments are manufactured with two such equalizers (one for each pickup) in the guitar itself, as a replacement for traditional tone controls. (See Recorded Ex. 11.)

17. Ibid., p. 313.

An even more versatile system of equalization is a *parametric equalizer.* In this system, each parameter of equalization can be controlled separately. These instruments usually contain four control groups, each of which contains separate controls for level (±16 db), center frequency, and width of band to be equalized. Both graphic and parametric equalization systems give the performer and/or the recording engineer an enormous amount of control over the spectrum of a guitar signal, and these devices are also valuable for shaping the spectra of some of the harmonically rich transformed tones produced by many of the effects-pedals described in the next section.

It should now be clear that by altering the frequency response of any part of the system (guitar and/or amplifier and/or speaker), the spectral envelope of a tone can be changed with whatever degree of subtlety is permitted by the sophistication of the equipment used.

Additive Transformation

Any process that adds frequency components to the spectral envelope of a signal is called *additive transformation.* In addition to pickup or amplifier distortion, which have already been mentioned in this connection, a long list of guitar "effects" are included in this category. We are now entering the area of sound treatment, or sound processing; the techniques will be listed starting from the most subtle and ending with those techniques which leave the signal hardly recognizable. Once new frequency components have been added, the new composite signal can then be put through any of the previous subtractive transformations; in fact, additive sound treatments are nearly always used in conjunction with filtering circuits.

Fuzz-tone—In the mid-1960s a hit single, called "Heart Full of Soul" and featuring Jeff Beck of the Yardbirds, made the distorted tone of the lead guitar famous. The device Beck used, a *Tonebender,* clipped the input until it was almost a square wave; it soon became a very widely manufactured effect-box. Subsequently, a number of pedals came on the market which, rather than distort the input tone, simply converted it into a square wave, so that the player could mix the original and the treated signals at his discretion.

The fuzz-tone, or square wave, has a very bright, buzzy sound, due to the number of higher harmonics, and its rich spectrum makes it a very good signal to filter. (See Recorded Ex. 12.) Some devices now on the market boast three different kinds of fuzz-tone on a single device. In reality, the selection knob allows the guitar signal to be changed into either a square, a triangle, or a sine wave, which may then either be heard alone or mixed with the input.

Octave Divider/Multiplier—Just as it is possible to transform the spectrum of a note and add it to the original signal, it is possible to transform a tone in the pitch domain (octave transposition) electronically and then mix the altered note with the original to make a new composite sound.

The octave relationship is logarithmic: if the note A_5 (880 Hz) is to be lowered by one octave, its frequency must be divided by two; if it is to be lowered by two octaves, its four; if lowered by three octaves, it must be divided by eight, and so on. Thus, to lower the octave register of a note, a device is needed that, when fed a certain frequency, will output exactly a half, a quarter, or an eighth of that number. This is done by an electronic device called an *octave divider.* The signal to be transformed is dealt with in two stages. First, it is passed through a digital device[18] called a Schmitt trigger, the output state of which changes from on to off, or vice versa, whenever the input voltage crosses certain pre-set positive and negative thresholds. The incoming signal is thus transformed into a square wave:

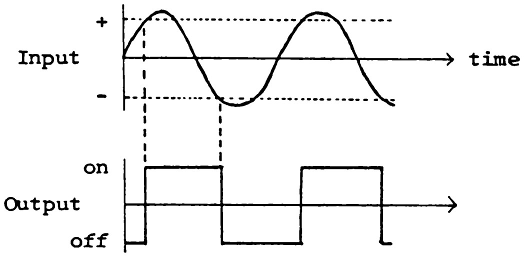


Fig. 59. Input and output of a Schmitt trigger.[19]

Next, the square-wave output of the Schmitt trigger is fed into the divider, also a digital circuit, the output state of which changes when a positive voltage is received at the input. Since a whole input cycle generates half an output cycle, the output frequency equals the input frequency divided by two. To divide by another octave, the divided signal is itself divided; and so forth:

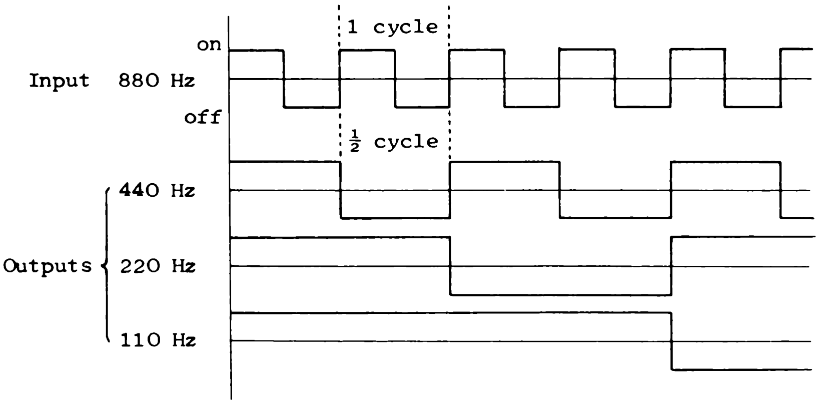


Fig. 60. Input and outputs of an octave divider.[20]

18. A *digital device* is one that can be in any one of a fixed number of discrete states. The Schmitt trigger has only two such states—"on" and "off." An *analogue device* can vary its output values continuously.

19. J. Schneider, "New Instruments through Frequency Division," *Contact* 15 (Winter 1976): 17–21. 20. Ibid.

By means of these two very simple devices, commonly found on the same IC (integrated circuit or chip), one can transpose an instrument's output down any number of octaves and transform its timbre to that of a square wave. In most commercial dividers, the output level of the divided signal is controlled by the level of the input signal so that the processed sound can follow the player's dynamic phrasing, and a control is usually available for mixing the balance of processed and "straight" sounds that finally leaves the circuit. (See Recorded Ex. 13.)

As we discussed in Chapter 2, the spectrum of a square wave consists of only odd-numbered harmonics, each of whose individual amplitudes is the reciprocal of its harmonic number [i.e. for harmonic number n of fundamental F, the frequency of the harmonic = nF, and its amplitude = $1/n$(amplitude of F); in other words, the seventh harmonic of the fundamental 110 Hz has a frequency of 770 Hz and one-seventh the amplitude of the fundamental]. Because of this harmonic construction, the sound of a square wave is quite harsh, much like a clarinet in the chalumeau register. Of course, through filtering, any of the characteristic harmonics can be amplified or attenuated and the timbre modified, and in this way a rich sound source may be produced that is related in pitch to the original input.

Once two or more octaves have been generated, they can be added to one another in various amplitude relationships to create a multitidue of waveforms. For example, if an input of 880 Hz (fist string at 17th fret) has been divided three times, four outputs are possible: 880 Hz (the squared input), 440 Hz, 220 Hz, and 110 Hz. If these square waves are added together in equal proportions, the harmonics will relate to the fundamental of the lowest tone at 110 Hz (hereafter F1). The spectrum of F1, shown in Figure 61, displays the diminishing amplitudes of the harmonics.

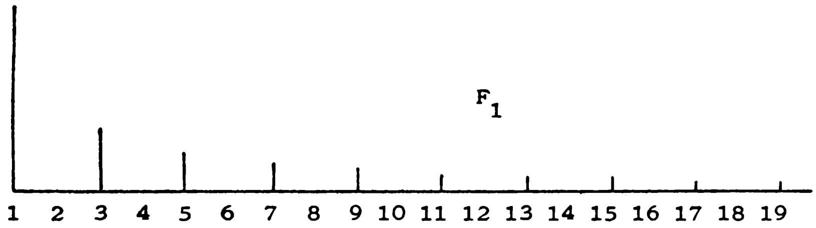


Fig. 61. Harmonic amplitudes of F_1.

Figure 62 shows the result of adding to this the octave above F_2:

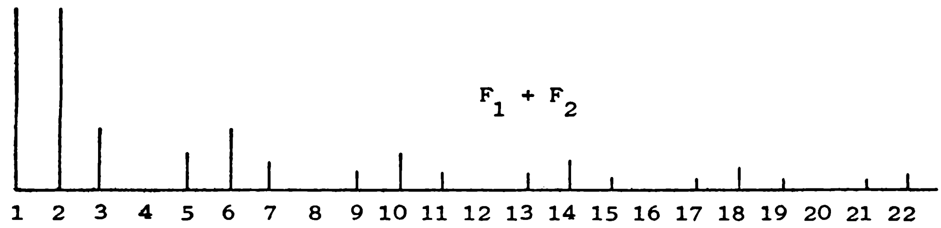


Fig. 62. Harmonic amplitudes of $F_1 + F_2$.

Figure 63 shows the spectrum produced when all four octaves are added in equal proportions:

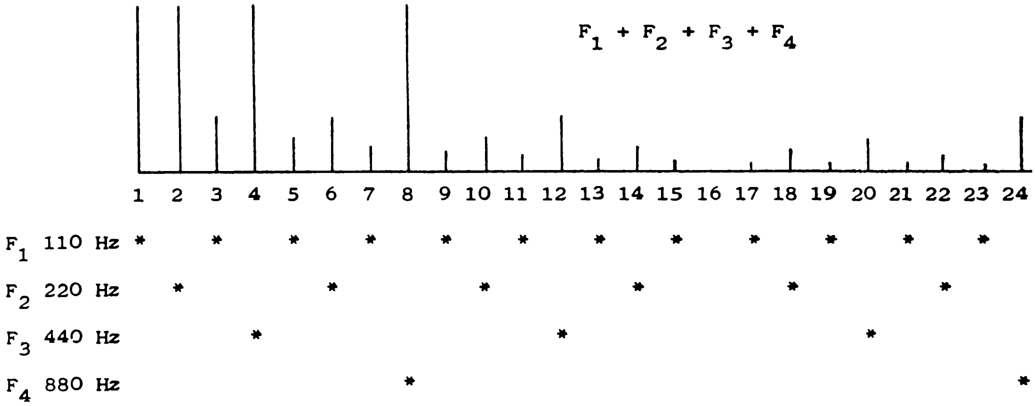


Fig. 63. Harmonic amplitudes of $F_1 + F_2 + F_3 + F_4$.

This distribution is quite unusual and, with such high amplitudes at the eighth, twelfth, twentieth, and twenty-fourth harmonics, creates a very live sound. If the four octaves are added with amplitudes descending in the proportions $F_1 + 1/2\ F_2 + 1/4\ F_3 + 1/8\ F_4$, the result is a staircase wave—equivalent to a ramp wave with every sixteenth harmonic missing[21] —in which both even and odd harmonics fall off steadily:

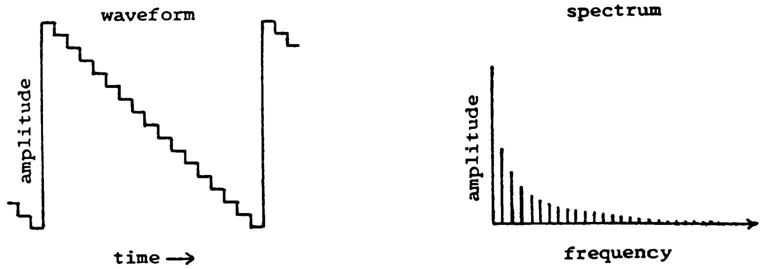


Fig. 64. Staircase waveform and harmonic spectrum of composite signal consisting of four octave-related square waves.

After these harmonics have been generated through addition, the composite waveform can then be subtractively transformed (filtered) to produce even more waveforms.

With the addition of one more circuit, *octave multiplication*, giving the input an infinite transposition range either up or down, is also possible. Theoretically, almost any

21. It is interesting to note that with octave square-wave addition, the harmonic that will be missing from the spectrum is determined by the formula 2^n, where n is the number of octaves added. In Figure 62 two octaves are added; hence $2^2 = 4$, and every fourth harmonic is missing. For Figure 63, in which four octaves are added, the formula is $2^4 = 16$.

harmonically related pitch (of course, *not* equal-tempered) can be produced for addition to the spectrum of the original tone. To add inharmonic partials, the frequency of the input can be shifted by 1, 2, 3 . . . as well as 2, 4, 8, ... For example, to shift the transformed wave a major third above the input, since the ratio of a major third is 5 : 4, the input should be multiplied by 5 and divided by 4. (The output from this sort of transformation is still intervallically related to the input; if the player wants truly inharmonic components, there are several devices that will do the job much more quickly.)

At this point the reader should be reminded of the principle of transposition of tones, since the next section deals with processes that alter the overtone structure of tones by using different methods of transposition. The ratio between the harmonics of a tone is 1 : 2 : 3 : 4 : 5 . . . . When the tone C_4 (261.6 Hz) is raised by a fourth, the fundamental and all overtones are *multiplied* by the same factor, 1.335, and the ratio remains intact (Fig. 65a). But when the tone is transposed using addition, that is, when the harmonics are raised by *adding* the value of 87.6 Hz (the amount it takes to raise the fundamental from C, 261.6 Hz, to F, 349.2 Hz), the ratio between the harmonics is disturbed and is no longer harmonic—1 : 2 : 3 : 4 : 5—but inharmonic—1 : 1.75 : 2.5 : 3.25 : 4 (Recorded Ex. 16):

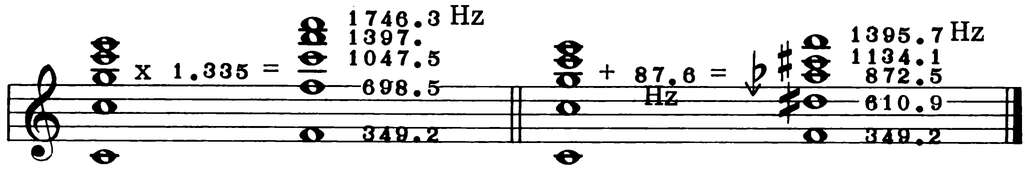


Fig. 65. Harmonic series of C_4 transposed up a fourth by (a) multiplication and (b) addition.

Thus, the degree of inharmonicity in an additively transposed tone can be controlled according to the number value added to each frequency.

Amplitude Modulation—One way to add frequencies to a signal is to modulate (change) its amplitude periodically with another signal (usually a sine wave). This can be done by voltage control of the amplifier that is processing the input signal. If sine-wave A is amplitude-modulated (AM) by sine-wave B, the result will be frequencies A, A+B, and A−B. These sum-and-difference tones on either side of the signal A are called *sidebands.* If, for example, A = 220 Hz and B = 110 Hz, the resulting sidebands will be harmonic; if B = 25 Hz, the sidebands will not be harmonically related to the input, and this of course alters the quality of the composite signal. When amplitude modulation is used to process a complex tone such as a guitar note, every harmonic of the input creates its own sidebands, so the end result will be a complex web of inharmonic components unless the modulating frequency is related harmonically to the input. (See Recorded Ex. 14.)

Ring Modulation—A *ring modulator* also has two inputs (a carrier and a program wave) and one output (the sum-and-difference tones) but it does *not* retain the original input. It is called a *ring* modulator because only the symmetrical ring of the sidebands around the input are heard. Again, if one of the inputs is a complex signal like a guitar note (which has well over twenty sine components), each of the sine components will produce its own sidebands, and because the frequencies are added together rather than multiplied, a very complex and inharmonic sound will result. Figure 66 shows the sidebands created by the first, second, and third harmonics of the chromatic scale tones A, 220 Hz, to A, 440 Hz, ring-modulated in this example by a 220-Hz sine tone (Recorded Ex. 15):

Fig. 66. Outputs of a chromatic scale A_3 –A_4 (220 Hz–440Hz) ring-modulated with a sine tone of 220 Hz.

The chordal nature of the output of the modulator, familiar to anyone who has worked with this circuit, is obvious from the composite signal. Although its complexity and tonal implications make it a very difficult device to control, ring-modulation repays the player for his trouble; a single note ring-modulated with a sine tone that is just marginally out of tune with the fundamental of the input gives many bell-like sounds.[22] The main problem in control is that the harmonic content varies so drastically from one diatonic step to the next that there is little, if any, continuity between the two sounds. However, another device is available that uses a ring modulator in its circuitry and inharmonically transforms the frequency components of a tone more subtly than a ring modulator.

Spectrum Shifter—The output of this electronic device, also called the *klangumwandeler* or *frequency shifter*, is one-half of a ring-modulator circuit, and is therefore technically termed a *single-sideband generator.* Figure 66 showed a signal being ring-modulated by 220 Hz; all frequencies above the fundamental were shifted up by 220 Hz, and all those heard below were shifted down by the same factor. Both sidebands heard simultaneously make a complex and inharmonic sound; if only one sideband were heard, however, the result would be the same sort of re-ordering of the harmonic relationships between the partials as was described in Figure 65b.

The higher the pitch of the input, the less drastic the spectrum shift will be, because the higher in the audio spectrum one goes, the more one has to shift a frequency (in terms of Hz) to get the same musical effect.[23] Commercial frequency-shifters, which can add anywhere from 1 to 1,000 Hz to the partials of a signal, can be very useful for introducing controlled inharmonicity. Unfortunately, this device usually stays in the studio; no commercially manufactured performing model is available as of this writing, but at the rate that industry is developing studio technology for on-the-road use, a working model should appear before long.

Change in Spectral Envelope and Fundamental Frequency

Again we come to one of the most important aspects of musical timbre, the change and "inner life" of a sound. An important part of classical guitar technique, this is even more central to electric-guitar playing, since for the first time, with the aid of electronics, a guitarist can produce a steady-state tone. This instrumental extension alone seems to be enough to satisfy most players, though they seldom realize the musical responsibilities inherent in the ability to sustain a note that does not change in amplitude, pitch, or timbre. This is an aspect of tone production on which those learning to play single-line sustaining instruments spend much of their time; the challenge lies in keeping the sound interesting throughout the duration of the note.

22. One main characteristic of a bell's timbre is the inharmonicity of its frequency components. The statement that RM guitar sounds are bell-like is literally true, since the time envelope of guitar and bell sounds are also similar.

23. For instance, the distance between C_4 and D_4 = 32.03 Hz, while the distance between C_5 and D_5 = 64.08 Hz and that between C_6 and D_6 = 128.2 Hz. Thus, an addition of 25 Hz in the first case will represent a 78 percent shift, in the second it will be 38 percent, and in the third, 19.5 percent.

It is a fact of nature that if anything continues unchanged, it loses its ability to stimulate our senses (e.g., it is a common experience not to notice that an electric fan has been on until it is switched off.) This rule also applies to steady-state tone. One of the first things a violinist does when the correct dynamic level on a played tone has been reached is to add vibrato, and then to change the rate of the vibrato, so that the listener will always get some new information about the note. This technique not only focuses the attention of the listener but also offers the player an extension of his musical vocabulary, in the form of yet more tools with which to express himself. As discussed earlier, the two areas of change available in the timbral domain are those of frequency and spectral envelope.

Vibrato was mentioned as a technique available on the classic guitar for micro-intonation of the frequencies of a tone. The string tension is varied with the left hand, either by pushing and pulling the string toward and away from the bridge or by bending the string from side to side. These techniques work on the electric guitar, and some electric instruments are manufactured with a "vibrato arm" to which the strings are connected, either directly or via the bridge. When moved, the arm changes the string tension, thus raising or lowering the pitch of all six strings. Again, the amplitude and frequency of the vibrato are continuously variable, as described in Chapter 2, and are extremely useful as expressive devices in changing the overall timbre of a steady-state tone. (Strictly speaking, frequency-shifting techniques also fall into this category of vibrato, in the sense that they are involved in micro-intonation, but they would only qualify musically as vibrato if these shifts were periodic.)

Tremolo is another device that introduces change in a signal. Technically, tremolo is amplitude modulation; the overall amplitude of the signal is made to rise and fall periodically, usually by means of a voltage-controlled amplifier. Like vibrato, tremolo can be described in terms of amplitude and frequency, and guitar amplifiers which have facilities for introducing this effect ususally call these two variables *Depth* and *Speed.* Controls for changing these attributes are usually pre-set, but they can also be controlled from a pedal, which means that they can be used expressively in the same manner as the vibrato envelopes of Figure 39.

Reverb and Echo—Another form of change within the duration of a tone is *reverberation*—the persistence of the reflections of a sound within an enclosure after the source has ceased to emit sound. Reverb can be considered as a series of multiple echoes so closely spaced in time as to merge into a single, continuous sound. An echo, on the other hand, is a reflected sound which is received at least 1/20 of a second after the original sound. The common principle behind these transformations is that of delay and re-addition of a reflected sound at some interval after the original's first appearance. Thus, individual harmonics' amplitudes constantly change as their reflections are re-added.

The reverb unit most familiar to the guitarist is the spring-line type, an electromechanical device that converts an audio signal into mechanical energy by means of a moving coil unit that drives a spring. The delay occurs because it takes time for the mechanical signal to reach the other end of the spring; there another transducer picks it up and sends it to the amplifier, where it can be mixed with the original signal. These units are often built into guitar amplifiers and are used to add depth to the sound.

An echo unit uses some sort of recording device (usually tape) that records the signal and then plays it back via a number of closely spaced playback heads. This sort of multiple playback mimics the acoustic effect of a signal bouncing off distant surfaces, the amount of perceived distance being determined by the speed of the playback tape, the choice of playback heads, and the distance between them (Recorded Ex. 18):

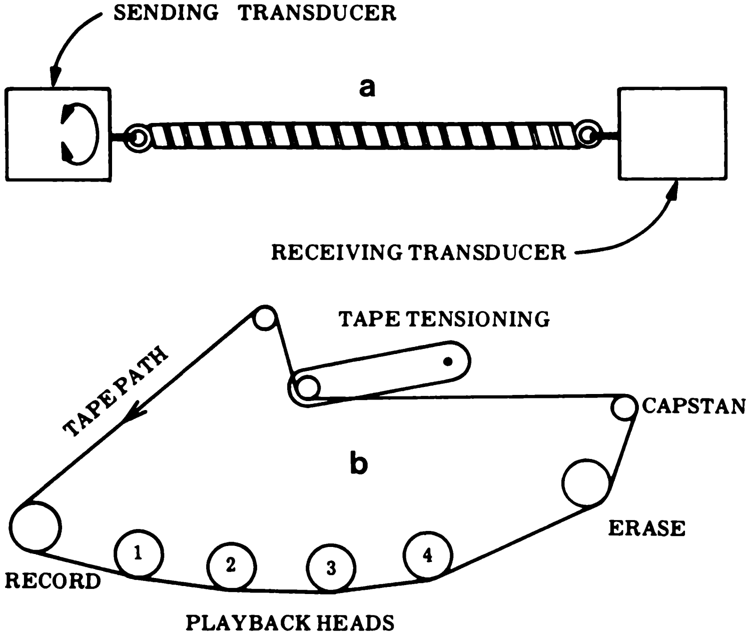


Fig. 67. Diagram of (a) mechanical reverb unit and (b) tape echo unit.[24]

A signal can be delayed electronically instead of mechanically. *Analogue* delay lines use analogue circuitry to slow the signal. Often, the amount of delay available is from 25 to 500 milliseconds (ms), and some units reduce the bandwidth with an increase of delay time to simulate the sort of signal degeneration that occurs during sound reflection in rooms. *Digital* delay lines convert analogue input signals into digital form and store the information in memory circuits, to be released later (after having been converted back to analogue form), either to be heard by itself or re-mixed with the original signal. The advantages of this method of signal delay are more precise control of delay times, less noise, and better preservation of signal quality, although this degree of sophistication is often unnecessary and is sometimes more expensive than mechanical forms of signal delay.

Reverberation can be used in many ways to alter the spectrum of a single sound. Since the decay time of a spring-line reverb unit is almost the same as that of the guitar string itself, reverberation can be used to add depth and distance to a note by subtly re-

24. Crowhurst, *Electronic Musical Instruments*, pp. 69–70.

adding frequency components to the sound. Another way to use the system is to play a staccato note into the unit and let the spring transmit its own decay, thus making a hybrid sound with a string-tone prefix and a spring-tone decay. If this is done with the tape-type (memory) units, the listener will hear the prefix of the string but the decay not of the string itself but of the regenerated signal.

The largest category of change is that of *formant glide*, the shifting of spectral envelope during the life of a tone. Any technique for electronically transforming the spectral envelope can be made a dynamic process by changing the quality of the transformations in time. Additive and subtractive transformations are usually used in conjunction with this type of processing, not only because the player then has more control over the final sound-product, but also because many subtractive effects, especially filtering and phasing, are not pronounced unless they are processing a harmonically rich signal.

One subtle type of spectral change becomes apparent with the use of the *compander*. If a clipped signal is being expanded, the output level will remain the same even when the input is no longer being clipped but is decaying normally. The result is a change in the amplitude of the harmonics in relation to each other, while the overall level stays the same. the effect is somewhat like a low-pass filter being swept downward toward the fundamental, since the higher frequencies are always the first to decay.

High-pass, low-pass, band-reject, and band pass filters can all be voltage-controlled: their cutoff frequencies can be swept up or down depending upon the amount of control voltage fed into them, and this voltage can be easily regulated by a foot pedal. The most elementary kind of dynamic filtering is the sweeping down and up of a low-pass filter's cutoff that is modifying a signal's spectrum. This alternately dulls and brightens the signal, creating an effect much like that made by turning the tone control on the instrument while the string is vibrating. An interesting variation of this technique is *resonant filtering*. If a filter set just on the brink of oscillation is swept over a signal, it resonates at the frequency of each partial that it passes. This ringing effect can be very melodious if the partials are harmonically related, and even more interesting if they are not, since this type of real-time spectral analysis reveals the harmonic content of the sound being filtered.

Phasing and *flanging* are popular effects that alter the spectral envelope of a sound periodically. The phasing effect originated in the recording studio: technicians fractionally delayed the playback of a signal and mixed it with the original, causing a swishing sound which is in fact a moving notch of frequencies being cancelled out from the top to the bottom of the spectrum. To mimic this effect, commercial phasers usually route the input through a periodically sweeping filter, often using a speed control that regulates the number of sweeps per second and an "intensity" control that determines the width and height of the notch. A *flanger* actually delays the input signal and re-mixes it with the original, creating a *comb filter* effect—a wide variety of harmonically spaced notches which increase in number and move to lower frequencies the longer the delay. The speed control on a flanger controls the periodicity with which the delay time is altered: a constant delay time results in a static filtering effect.

These moving notch or band-reject filters are very effective for altering a sound, but the reverse process, a sweeping band*pass* filter, is even more effective and is certainly more familiar. The ubiquitous wah-wah pedal is in fact a voltage-controlled bandpass filter with a single, movable formant. This circuit enhances some areas of the audio spectrum by rejecting all other frequencies; the vowel-like formants that mimic the vocal sound of "wah" are produced when the bandpass is swept upward through the spectrum (see Chapter 2).

The most imaginative technique for altering the spectral envelope of a sound uses one of the most sophisticated formant-filters ever developed—the human head. The guitar signal, fed into the mouth via a plastic tube which is driven by a horn driver, "replaces" the vocal chords. By changing the larynx and the oral and nasal cavities, the resonances of the head shape or articulate the spectrum of the guitar signal, which is then picked up by a microphone. This device is known as a *voice box* or *voice bag* (Recorded Ex. 20):

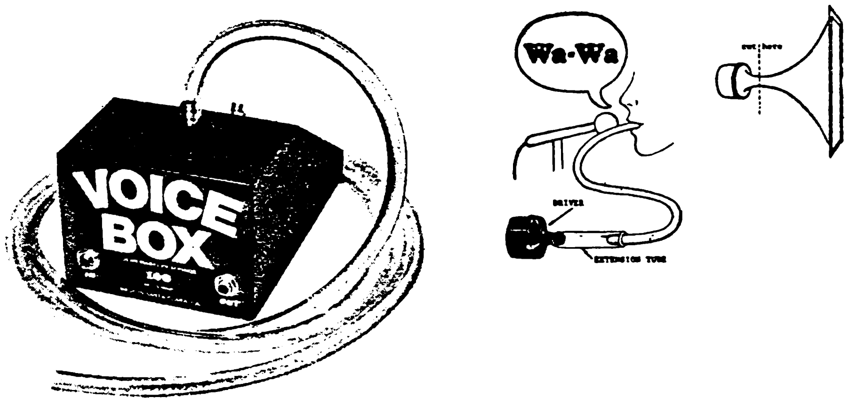


Fig. 68. Schematic and picture of a voice box.[25]

This is, incidentally, the only effect that is created between the amplifier and the loudspeaker in the audio chain. When switched on, the unit sends the amplified signal through the plastic tube to the player, and the speaker is silent. The possible combinations of human voice and "talking guitar" make this composite instrument truly one of the most versatile transformations available today. Normal vocal consonances can be mixed with guitar vowels, or the reverse. It is easy to play contrapuntal lines and voice and guitar pitch duets which share the same formants. Both the musical and lingual possibilities are almost limitless.[26]

All the electronic effects mentioned above can be used either alone or in various combinations. This modular approach is the natural outcome of a system with so many pos-

25. C. Anderton, "Build Your Own Talking Box,"' *Guitar Player* (December 1976): 99. ©1976 by Craig Anderton. Reproduced by permission.

26. A very expensive electronic processor now available does this same sort of transformation digitally. In the Vocoder, digital filters analyze the formant characteristics of the vocal input to the machine and filter the signal to be processed accordingly. By this method the integrity of the input is not degenerated through mechanical tranducing.

sible parts. Because some treatments tend to complement each other, many manufacturers make combination pedals such as "wah-swell," "wah-fuzz," "wah-fuzz-swell," "fuzz-phaser," and "fuzz-sustain-filter-volume." These sorts of pedals are on the way to becoming guitar synthesizers; in fact, some guitars have powered treatment modules in the bodies themselves. One American firm producing what they call a MPC guitar (Modular Powered Circuits) boasts of the ability to contain a phase shifter, fuzz, "tanktone," treble bass expander, and power overdrive within the instrument, not to mention the "tone spectrum circuitry" that is used to put the pickups in phase, out of phase, in series, or in parallel.

THE TECHNIQUES

The amount of timbral control available to the modern player is staggering, but most of the resulting sounds are either new or so seductive that it is difficult to make good musical sense of them. The Rational Method is designed to give modern musicians a logical approach to the new sound world that has been made available to them, an approach that will allow them to control these new sounds and not the other way around. A pictorial summary of the techniques that have been discussed and the parameters of timbre they modify may serve as a reference tool:

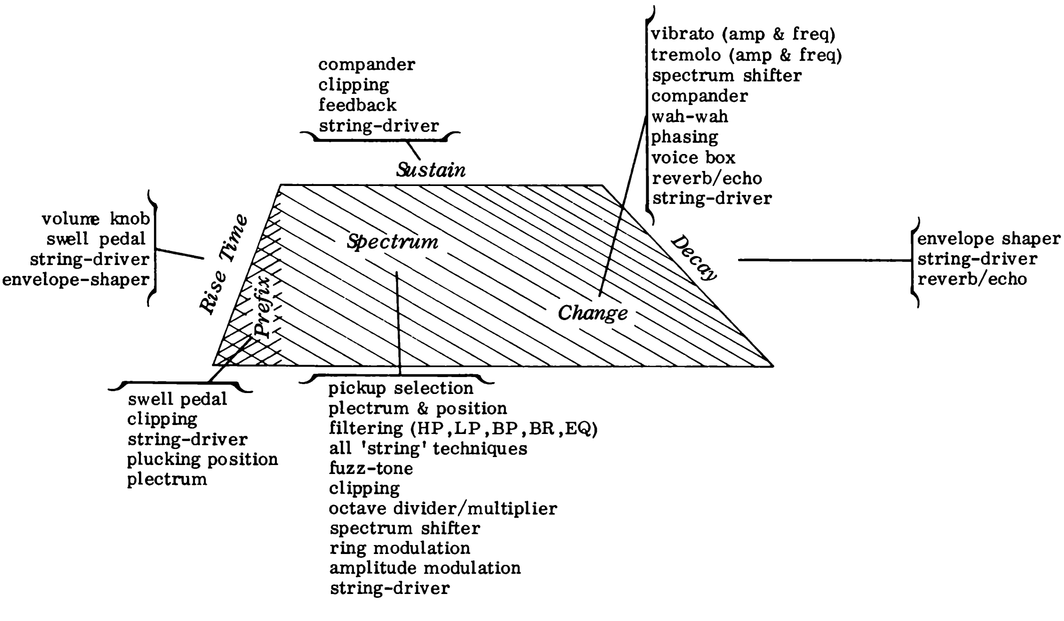
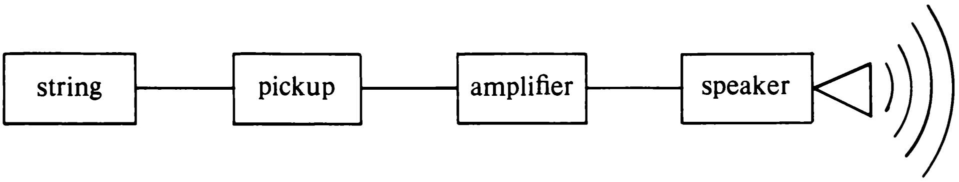


Fig. 69. The parameters of timbre and the techniques that can be used to alter them.

SUMMARY

The electric guitar can be described as a sound-system consisting of four components:



The player alters the timbral parameters of a note by changing the behavior of one or any combination of these four components. Besides possessing a much greater dynamic range, one of the principal musical advantages of the electric instrument is that the four timbral parameters (time envelope, prefix, spectral envelope, and change) can be varied independently, whereas they are often interdependent in the classical instrument.

CHAPTER IV
New Developments

The history of the guitar is filled withh efforts to change or extend the powers of the instrument. The nineteenth century produced such interesting instruments as the lyre-guitar, the upper bouts of which were extended upward toward the head of the instrument, in imitation of the ancient lyre; the guitarpa, which used thirty-five strings (twenty-six unfretted, which were played like a harp, on the body of the instrument, six on a standard fretted neck, and three bass strings on a second fretted neck); and the Terz and Octavina guitars, scaled-down versions of the standard six-string instrument, tuned a third and an octave higher, respectively. While many of these creations did not survive the decade of their invention, some of their principles have been carried on into this century—for example, the four extra fretted bass strings found on the ten-string guitar, and the use of four bass strings alone in both electric and acoustic bass guitars.

The last twenty-five years have also had their stringed monstrosities, but several truly important historical developments within this period will certainly affect the future of the guitar. For the classical guitar, these include new methods of construction which radically depart from the Torres methods, new tuning systems using interchangeable fingerboards, and external means of amplification. The electric guitar's range of usefulness has been extended through the invention of the cordless electric guitar and the guitar synthesizer. This new musical hardware offers composers and performers new and exciting sonic vistas, which must eventually affect the "software" written for guitar.

CLASSICAL GUITAR
Construction: The Kasha Model Guitar

The last major design change in the classical guitar took place at the end of the last century, when the luthier Antonio de Torres enlarged the body, extended the string length, and, most importantly, changed the internal strutting pattern from transverse barring (perpendicular to the body axis and grain of the top) to longitudinal barring (see Fig. 10). With this change of strut direction, string vibrations are transmitted to a larger area of the soundboard. However, the overall flexibility of the top is diminished, making necessary a compromise between tonal depth and acoustical power.

In the 1960s, Dr. Michael Kasha, director of the Institute of Molecular Biophysics at Florida State University, undertook a study of the construction of the classical guitar, considering its design from the point of view of the physical principles of sound production. He soon realized that tradition, rather than good engineering, had been the source of the standard guitar design, and that the concept of Torres's longitudinal barring was probably borrowed from Stradivarius. Stradivarius's use of the longitudinal bass bar in the violin performed a similar function, but since the violin's soundboard is constantly fed with energy, whereas the guitar's is not, the results were different. Using a mathematical model of the guitar soundboard based on the physics of vibrating circular plates and coupled oscillators (string to soundboard to cavity), Kasha designed a guitar that departs significantly from traditional instruments in both sound and appearance.

The main feature of the Kasha model is radial bracing of the soundboard. Because string vibrations are transmitted to the top of the guitar through the rocking motion of the bridge, Kasha added a transverse bar beneath the bridge as a pivot for these motions. Radial struts, placed in accordance with the normal vibrations of the lower bout, then distribute the vibrations over the area of that circular plate. The strutting of the lower bout is determined by certain frequency zones: the bass side has a few long struts and the treble side has a greater number of smaller bars, for high-frequency coupling. This pattern enhances the low-frequency modes of vibration without inhibiting the higher modes, as well as allowing control of the onset transient. The character of the instrument's attack can be changed by altering the shape and distance of overlap of the struts to the bridge profile. The transient can vary from a rapid rise of waveform which is perfect for flamenco, to a gradual onset which will give a round sound with great tonal purity for classical music. This is the most exciting aspect of designing guitars according to the principles of model physics: the instrument's sound can be chosen rationally, according to musical need.

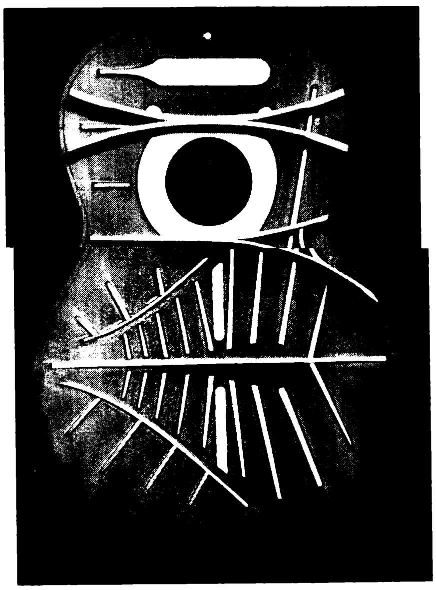


Fig. 70. Interior strutting of a Kasha model guitar. Photograph by Dennis Crawford.

Other structural changes in the Kasha guitar include the addition of an inertial mass (250 g of lead weight) in the neck and head. This added weight, which is counterbalanced by another weight in the tailblock, reflects back to the soundboard, where it can be radiated as sound, the string energy that is ordinarily wasted in the neck. In order to enhance the bass response, the lower bout of the soundboard is extended so that its curve is an ellipse with its foci at the bridge and the soundhole. Finally, a striking feature of the instrument is the ebony bridge, which is split in half, with the bass side considerably wider than the treble side. For ideal impedance-matching, the soundboard should be driven by slow high-amplitude motion for the bass register, and rapid low-amplitude motion for the treble register—hence the dual-function design.

The main proponent of Kasha's ideas for the last ten years has been luthier Richard Schneider of Michigan. His instruments have drawn both praise and scorn from the guitar community. Those of his guitars that I have played have displayed an unusual evenness both of tone color and volume throughout the entire register of the instrument, and they have had very good sustain. Schneider's Kasha models contain a microphone attached to the heel of the neck, inside the instrument above the soundhole. This microphone can be connected to the outside through the removable end pin, to reinforce the sound of the instrument when, for example, the guitarist is playing a concerto in a large hall. Schneider's Kasha model represents a new wave of guitar design that definitely belongs to the twentieth century.

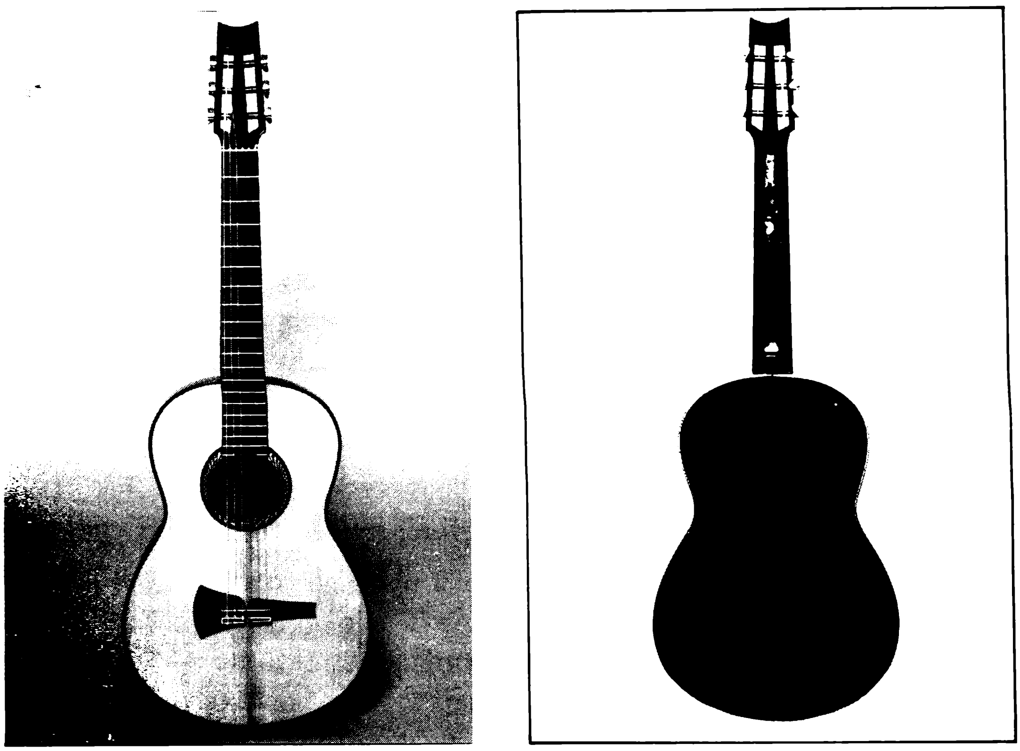


Fig. 71. Concert model Kasha guitar "Leah," created by Richard Schneider. Photograph by Dennis Crawford.

Tuning, Temperament and Interchangeable Fingerboards

Since their invention fretted instruments have used equal temperament almost exclusively as a system of tuning. This means that, like the modern piano, each of the semitones in the chromatic scale of the guitar is exactly one-twelfth of an octave. Even though it was invented in the 1500s, this system of tuning has won universal acceptance in Western music only within the last 150 years. Its value lies in its ability to modulate freely to any key, but it does have some drawbacks. Guitarists and lutenists since early times have had to make their semitones equal in size because each division of every string length is determined simultaneously by a single straight fret, which runs beneath all the strings. Other fixed-note instruments, such as keyboard instruments, can be tuned note by note since the pitch of each key is determined by one string or pipe. Historically, these instruments used other systems of tuning that were more acoustically correct and pleasing to the ear, for reasons which we shall see.

Interval size is described either in a ratio giving the relationship between the frequency of the two tones' fundamentals, or in decimal units called *cents.* (An equal-tempered semitone (C – C#) = 100 cents, a whole tone (C – D) = 200 cents, an octave = 1200 cents, etc.)

Table 2. Equal-tempered scale measured in cents

Note	C	C#/D*b*	D	D#/E*b*	E	F	F#/G*b*	G	G#/A*b*	A	A#/B*b*	B	C
Cents	0	100	200	300	400	500	600	700	800	900	1000	1100	1200

The intervals between the notes of the harmonic series also form a scale; in fact, these "just" intervals set an absolute standard for the correct value of all musical intervals, since they are derived from the ratios between harmonics which exist in all musical tones:

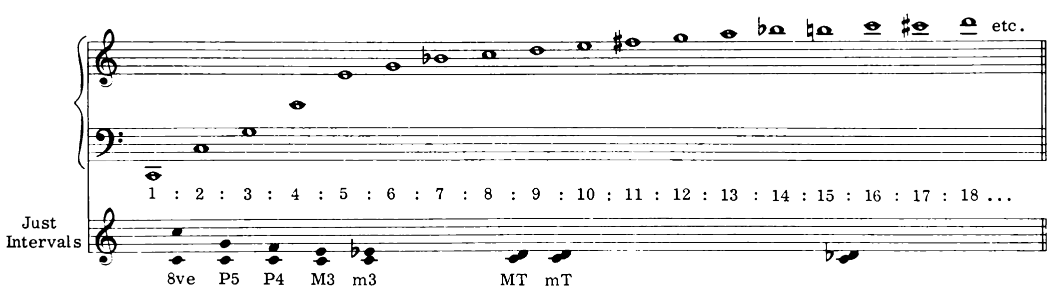


Fig. 72. Ratios between members of the harmonic series and the just intervals they create.

This just-interval scale is quite different from the equal-tempered diatonic scale.

Table 3. The just diatonic scale compared to the equal-tempered diatonic scale

Note	C	D	E	F	G	A	B	C
Equal tempered (¢)	0	200	400	500	700	900	1100	1200
Just (¢)	0	204	386	498	702	884	1088	1200
Ratio	1/1	9/8	5/4	4/3	3/2	5/3	15/8	2/1
Interval (¢)		204	182	112	204	182	204	112

The interaction between these two systems of tuning causes the acoustic impurity of the equal-tempered system. For example, if the major triad C-E-G (0/400/700¢) is sounded in equal-tempered tuning, the C-root of the chord generates an E_6 (as its fifth harmonic) with a just-interval size of 386¢, while the third of the chord (E) also generates an E_6 (as its fourth harmonic) which is 400¢ in size, 14¢ larger than the just third. The discrepancy between the frequencies of these two E's causes beats (see p. 169) which give a rough, mistuned sound to the interval C-E.[1] If this sharp third is combined with the flat fifth (700¢ instead of the just 702¢), one can see why equal temperament seemed excessively rough to Renaissance and Baroque ears used to just intervals.

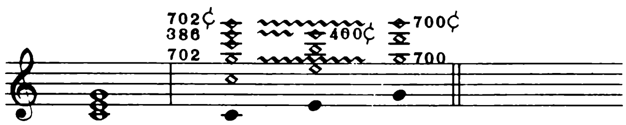


Fig. 73. Discrepancies (in cents) between harmonic series of notes in equal-tempered triads.

However, in the just major triad (4 : 5 : 6) the intervals between the fundamentals read 0/386/702¢ and will produce no beats (see Recorded Ex. 21).

The just diatonic scale produces acoustically perfect major (386/702¢) and minor (316/702¢) triads for six scale steps, excluding the supertonic minor triad D-F-A (294/680¢), whose thirds are flat by 22¢. This is clearly a very pure, but very limited, system of tuning: if the system were perfectly pure, one could generate the entire chromatic scale by adding perfect fifths. If this is attempted, the cycle C_4 -G_4 -D_5 -A_5 -E_6 results in an E_6 which is 22¢ sharp, this interval of 22¢ being called a *comma* or *syntonic comma.*

Renaissance musicians found a system of tuning by fifths which would ensure that a just third could be achieved. They simply tuned each of the fifths in the example above a quarter of the comma (22¢) flat, so that E_6 was 2,786¢ above C_4 (386¢ above C_6 —a just

1. The sharp third of equal temperament can easily be illustrated on the guitar. Tune the sixth-string E_2 in octaves with the open first-string E_4, then compare the fourth harmonic on the sixth string (5th fret) with the open first string. They should be exactly in tune, with no beats. Then compare the sixth-string fifth harmonic (4th fret) with the first-string G# (4th fret). The harmonic is the just major third and the fretted tone is the equal-tempered third, which is 14¢ sharp.

TABLE 4. Creation of 22¢ comma by adding four perfect fifths

					408¢
Note	C_4	G_4	(C) D_5 (1200)	A_5 (C) (2400)	E_6
Cents	0	702	1404	2,106	2,808
Interval (¢)		702	+ 702	+ 702	+ 702

third), and each fifth was approximately 5.5¢ flat. This created what is known as *quarter-comma meantone* tuning: "quarter-comma" because each fifth is tuned flat by that amount, and "meantone" because the size of the whole tone in the resulting scale is 193¢, the average or mean between the major tone (204¢) and the minor tone (182¢) of just tuning.

TABLE 5. Diatonic scale in quarter-comma meantone tuning

Note	**C**	**D**	**E**	**F**	**G**	**A**	**B**	**C**
Equal temperament (¢)	0	200	400	500	700	900	1,100	1,200
Quarter-comma meantone (¢)	0	193	386	503.5	696.5	889.5	1,082.5	1,200
Interval (¢)		193	193	117.5	193	193	193	117.5

In order to generate a chromatic scale in this system, eight consecutive fifths of 696.5¢ are added above the root C, producing G to G#, and three consecutive fifths of the same size are taken away to generate F, B*b*, and E E*b*[2] .

Table 6. Chromatic quarter-comma meantone scale

Note	C	C#	D	E*b*	E	F	F#	G	G#	A	B*b*	B	C
Equal temperament (¢)	0	100	200	300	400	500	600	700	800	900	1000	1100	1200
Quarter-comma meantone (¢)	0	75.5	193	310.5	386	503.5	579	696.5	772	889.5	1007	1082.5	1200
Interval (¢)		75.5	117.5	117.5	75.5	117.5	75.5	117.5	75.5	117.5	117.5	75.5	117.5

2. If eleven meantone fifths were taken up from C, this would generate a scale from C to E#, the acoustic tonality of A. An acoustic tonality allows for modulation to key signatures three sharps above and three flats below its own key signature; the acoustic tonality of C would therefore generate keys with up to three sharps (G, D, and A) and up to three flats (F, B*b*, and E*b*).

Meantone tuning, and all tuning systems that use unequal divisions, are *linear temperaments*: this means that after progressing around the circle of fifths, B# no longer equals C. *Cyclic temperaments* such as equal temperament are those which start and end on the same tone and use enharmonics, i.e., two or more names for the same note (C#/D♭, E#/F, etc.). The limitation of linear temperaments which use twelve notes per octave is that there are no enharmonics. In meantone tuning, for example, G#, tuned as the just third to E (386¢), will not serve as the A♭ a third below C, since that interval is 428¢. This means that music can be played in keys three sharps higher and two flats lower than the key signature of the beginning note of the tuning system. These restrictions were not really inhibitive until the 1700s, when music tended to go beyond these bounds and include a "compass" of more than twelve notes; for much of the modal music that was written during and before that time, cyclic temperament added a distinct charm. The clarity of harmony provided by the just thirds and slightly flat fifths of meantone tuning makes this system one of the most significant in the evolution of tuning.[3]

Several attempts have been made in the past to adapt the guitar to other tuning systems. In the early 1800s, General Perronet Thompson devised a method of tuning the guitar in just intonation, described in his treatise *Instructions to My Daughter for Playing on the Enharmonic Guitar* (1829). Thompson divided the octave into fifty-three parts, essentially a scale of commas which allows *all* enharmonic intervals to be correctly tuned within 1¢ of their just values. To accomplish this he divided the neck into fifty-nine parts, from the nut to the body, and provided each string with twelve individual frets, shaped like croquet hoops, to be placed in the two tiny holes that marked each of the fifty-nine divisions. This meant that for any key, 114 frets had to be placed (19 per string, if the entire one-and-a-half-octave string length was to be used), and of course the instrument had to be refretted for every key change! As one can imagine, these instruments, built by Louis Panormo of London, were not very popular.

A slightly more elegant solution to the problem of intonation was produced in Paris by the luthier René Lacôte in 1852. His instrument used twelve frets per octave, with each fret divided into six units, one per string. Each fret unit was mounted on a sliding block of ebony which travelled along a groove parallel to the string, so that each fret for every string could be individually placed to correct or create a particular tuning system. Of course, in this system, also, a change of key necessitated repositioning at least the majority of the seventy-two frets per octave.

Until the 1970s, all other instruments that used alternative tuning systems (with the exception of Harry Partch's guitar) have used fixed frets, limiting each instrument to one tuning system. In the 1970s, guitarist Tom Stone announced his invention of a guitar with *interchangeable fingerboards*. His Intonation System guitars use specially designed lightweight

3. For further information on the history of tuning, see J.M. Barbour, *Tuning and Temperament* (New York: Da Capo Press, 1972); O. Jorgenson, *Tuning the Historical Temperaments by Ear* (Marquette: Northern Michigan University Press, 1977), and L.S. Lloyd, *Intervals, Scales and Temperaments* (New York: St. Martin's Press, 1963).

aluminum channels in the guitar neck which fit into channels on the underside of the fingerboard. The board is locked into place by a system of pins and slots; once fitted, it is as secure as any built-in fingerboard. With these guitars any tuning system can be switched to any other in 6 to 10 seconds—a remarkable improvement over having to move 72 to 114 frets individually!

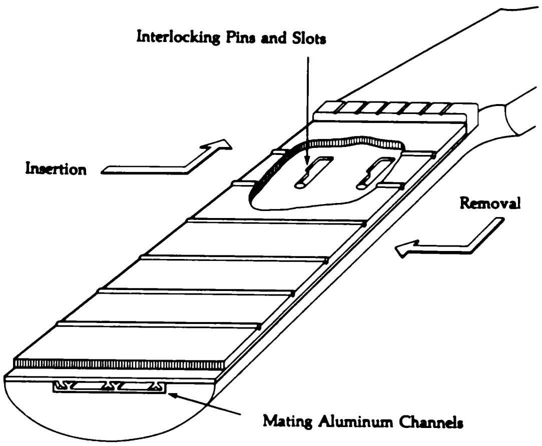


Fig. 74. Diagram of Intonation System's interchangeable fingerboard.[4]

Four categories of boards have been made available:

1. Pure Intonation series, a form of just intonation, in various keys, one board per key.

2. Experimental series, dividing the octave in the proportions of the harmonic series, including those between the eighth and sixteenth harmonics, twelfth and twenty-fourth harmonics, sixteenth and thirty-second harmonics, and twenty-fourth and forty-eighth harmonics. (These use either straight frets, so that each string will be divided proportionately, or varied frets so that the divisions can be taken from a single fundamental.) This series offers equal divisions of 17, 19, 22, 24, and 31 per octave (all straight frets), as well as a fretless board for infinite division, true glissandi, and true pizzicati.

3. Cultural series, including Japanese koto scales (Hiradioshi just), East Indian (Hindustani—22 sruti), and classical Arabian.

4. Historical series, including Pythagorean scales, (seven tones—straight and varied frets, twelve and thirteen tones—straight and varied frets), traditional just intonation (seven and twelve tones), quarter-comma meantone (acoustic tonalities of B♭ through E),[5] 17/18 Rule (Vincenzo Galilei's system for fretting lutes: 18 : 17 = 99¢), and, of course, equal temperament.

4. From a brochure on the Guitar with Interchangeable Fingerboards, courtesy of Intonation Systems, Box 932, Fairfield, Iowa.

5. To discover which meantone tonality to use for a piece, observe how many sharps and/or flats the music uses. If a piece has two sharps and one flat, its compass is ten notes (B♭ upward ten

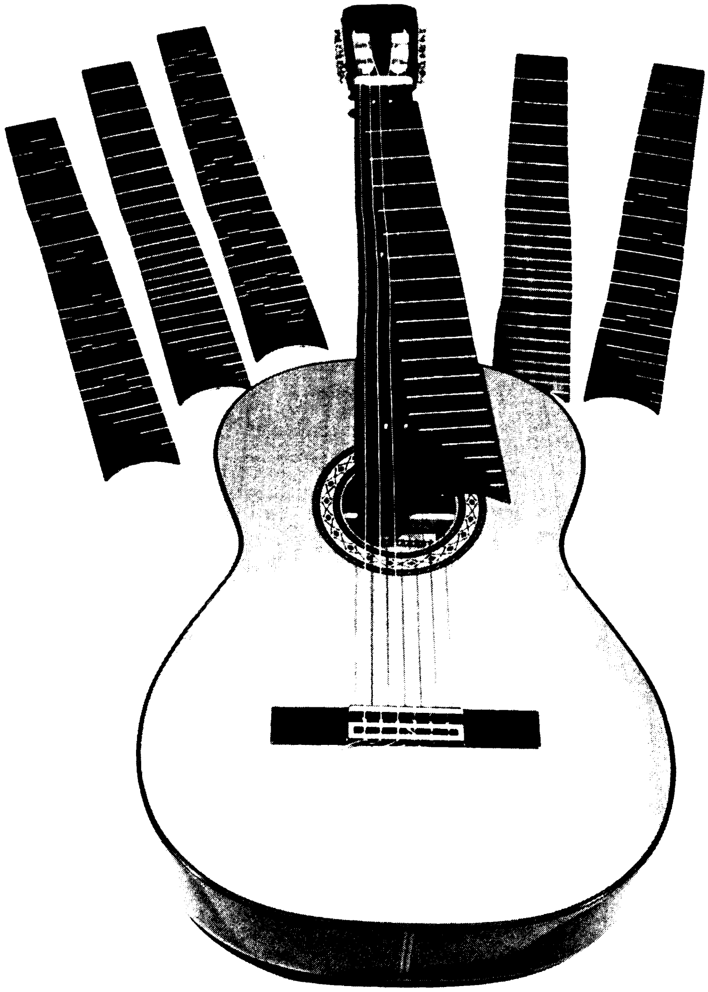


Fig. 75. Intonation System guitar with several interchangeable fingerboards.

This approach to tuning will undoubtedly have a great impact on the future of the guitar. Already, composers and players are discovering new musical possibilities for an instrument whose equal-tempered sound has been taken for granted for so long. The historical temperaments, although they are not historically correct for guitar compositions, do approximate the tunings of sixteenth, seventeenth, and eighteenth-century pieces transcribed for the instrument from the keyboard literature. The remarkable contrast that this allows the recitalist fills a need which some players have attempted to meet by playing lute, baroque guitar, and classical guitar in a single concert. The alternative tuning systems offer

fifths to C#) and can be played on the meantone scales of G, C, and F. If a piece has a compass of twelve notes (i.e., A♭–C#), then the acoustic tonality is F (three fifths higher than the lowest flat). Any piece with a compass larger than twelve cannot be performed with a twelve-note meantone scale without some sharp dissonances, since this scale is not enharmonic.

completely different sounds from one instrument. And, of course, the greatest advantage is that every system is pre-set in the fingerboard, rather than necessitating a keyboard player's retuning of most strings individually in order to attain a new intonation system.

Amplification

Throughout its history, the guitar's greatest problem has been that of volume and projection. These problems have traditionally been set at the feet of the luthier, whose knowledge of woods and construction techniques have always determined the sound of the guitar. In the last twenty-five years, however, the electrical engineer has stepped into the design picture, and has come very close to solving the problem of amplification of the classical guitar.

The problem of amplifying the steel-strung guitar was solved by using magnets that sensed the string's vibrations and changed them into electrical impulses, which could then be amplified. This technique does not work with the nylon-strung classical guitar, however. The first attempts at amplification of the classical guitar simply placed a microphone in front of the guitar, but this often caused feedback and distorted the sound; a more sophisticated technique of miking used today places a small condenser mike just inside the soundhole.

The other approach to amplification attempts to pick up the vibrations from the guitar itself with contact microphones. A contact mike is made of a piezoelectric material, a substance which, when it is deformed, produces a voltage. When the pickup is attached to the soundboard of a guitar, the vibrations of the top bend the unit, and the voltage produced corresponds to the motions of the top, just as the voltage produced by a steel string moving past a wound magnet corresponds to the harmonic motion of the string. Commercially available contact mikes (such as Barcus-Barry, FRAP, or Wooden Nickel) usually come with their own pre-amps to help boost the signal and match impedances. These mikes are usually attached to the top or bridge of the guitar with a special adhesive wax that does not injure the guitar's finish, although some pickups can be held to the bridge by wood screws. Barcus-Barry also makes "Hot-Dots," small round pickups disguised as pearloid (mother-of-pearl) bridge decorations.

Because the contact mike is attached to a particular spot on the body of the instrument, the vibrations that it senses must be biased in some way: in one position it may be lying on a node and in another on an antinode, so the sound product differs with each placement. This type of pickup gives a very bright sound because it "hears" only the transient of the guitar note, the loudest part of the sound. The contact pickup has no way of "hearing" the transient mixed with the air resonance of the guitar body, since it is attached to the guitar top.

One solution to this problem has been advanced by the Ovation guitar company: they put six piezoelectric pickups underneath the saddle so that the string's vibrations are picked up at the bridge, where the combination of string and top sound is produced. Because they are sensitive on both top and bottom, they pick up the string vibrations as well as the top vibration.

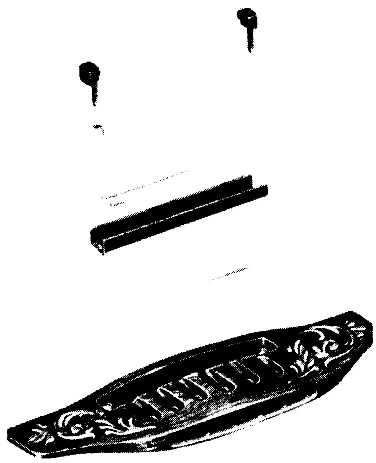


Fig. 76. Ovation's bridge pickup.[6]

The signal is then run through its pre-amp (installed inside the guitar body). The volume and tone controls are placed on a single split knob, usually mounted on the shoulder of one of the upper bouts for easy access.

The advantages of this system of amplification are those of minimal feedback, immediate control of both volume and tone, and, of course, the absence of dangling wires or cords running across the face of the instrument (as with contact mikes). Unfortunately, the sound is still not completely natural, both because the air resonance is still not picked up, and because there is a large proportion of actual string tone, whereas one normally hears the guitar top's interpretation of the string's vibrations. In spite of these drawbacks, this approach to amplification systems for the classical guitar will surely change the instrument's stature in the world of ensemble music.

ELECTRIC GUITAR

Guitar Synthesizers

For years, the electric guitarist has used various electronic effects to modify the sound of his instrument, but these treatments have always affected the actual string sound. The octave divider sensed the guitar signal and transformed it into a square wave through a complicated switching technique—the first step toward synthesizing a tone using the information from a vibrating string. In the late 1970s, a true guitar synthesizer was developed. It uses the guitar signal to control waveforms other than its own, giving the guitar all the techniques and timbres available to the keyboard synthesist.

In electronic tone synthesis, the musical parameters are voltage-controlled. Each parameter (pitch, amplitude, rise time, spectrum, etc.) can be controlled individually, although the performer must convey a great deal of discrete information to the machine concerning the creation of the final sound product. The waveform in a synthesizer is

6. Reprinted courtesy of Ovation Instruments, Inc., Bloomfield, Conn.

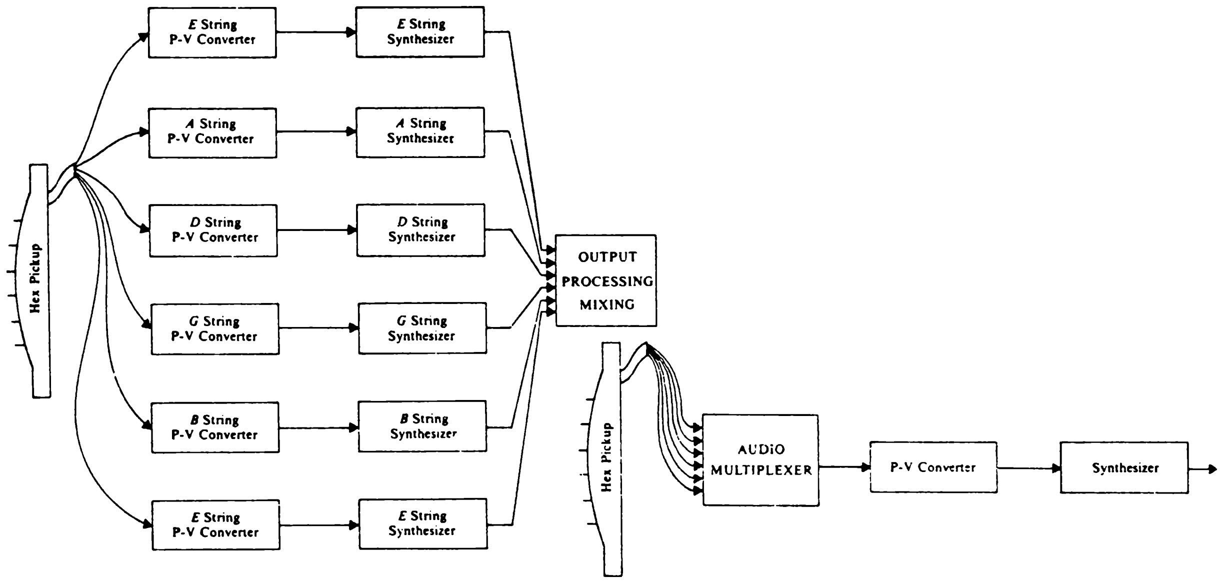
created by a voltage-controlled oscillator (VCO). This module often produces up to three waveforms (sine, sawtooth, and square waves) and the voltage applied controls the pitch of the waveforms. The amplitude of a waveform can then be determined by a voltage-controlled amplifier (VCA) whose rise time, duration, and decay time describe the envelope of a sound (hence the common name *envelope shaper*). The amplitude of the harmonics of a waveform can also be changed with a voltage-controlled filter (VCF), whose frequency cutoff is altered according to the amount of voltage fed to it. These are the three basic modules of synthetic tone-generation.

When a key on a monophonic (one note at a time) keyboard is pressed: (1) a pitch-controlling voltage is sent to the VCO; (2) a pulse is sent to the envelope shaper; and (3) a gating voltage is sent to the duration controls of the shaper to tell it how long the key is held down. The waveform from the oscillator is sent through a VCF for filtering, then the filtered waveform is sent to the envelope shaper, whose controls for attack, sustain, and decay have usually been pre-set. The pitch voltage tells the VCO what pitch to generate, the pulse begins the attack segment of the envelope shaper, and the gating voltage stays positive to hold the sustain portion of the envelope until the key is released. A similar series of events takes place when a guitar is used to control the synthesis modules, except that because the pitch information produced by an ordinary electric guitar signal is too complicated to be used for a pitch-controlling voltage, another type of pickup was developed.

A standard guitar pickup sums the signals from all six strings and presents a composite signal to the amplifier. When the pitch extractor (or *pitch-to-voltage converter*), located on the input to a guitar synthesizer, sees this signal, it does not know which one of the six strings to follow. Even if one string at a time is plucked, vibrations from the other strings tend to confuse the signal. For this reason, the *hexaphonic* pickup was developed. This is actually six independent pickups in a single unit, with six separate output wires, one per string, so that the output of each pickup will always be one pitch at a time. To eliminate any cross-talk between pickups due to string bending, the pickups are located next to the bridge, where string excursion is minimal regardless of the amount of bending.

The next task is to convert these pitches to voltages which can be used to run the synthesizer. Depending on cost, guitar synthesizers have anywhere from one to six pitch-to-voltage (P-V) converters, with the same number of synthesizers per string. A fully polyphonic system will use six of each: the player will have six separate "instruments," each consisting of a VCO, a VCF, and its own envelope shaper, and s/he will also be able to mix the original string signal with the output. A monophonic synthesizer uses one P-V converter and one synthesizer connected to one string at a time. The machine determines the last string plucked by using a circuit called an audio multiplexer, which scans all six strings and uses the highest-amplitude signal to run the synthesizer. The number of strings scanned can also be limited; for example, the bottom three strings can provide a synthesizer bass while the actual sound of the top three strings is reproduced.[7]

7. D. Friend, "Two Approaches to Guitar Synthesizer Systems," *Guitar Player* 12, no. 8 (July 1978): 158.



Fully polyphonic system architecture. *Illustration of Avatar architecture.*

Fig. 77. Schematic for (a) polyphonic synthesizer and (b) monophonic synthesizer. Used by permission of David Friend.

The hexaphonic pickup has made possible a new category of effect, *hex effects*, in which a separate effect circuit can be provided for each string. The hex fuzz, for example, uses six fuzz circuits: when a chord from a standard pickup is fed into one fuzz unit, the harmonics intermodulate and a muddy sound emerges. When six separate units are used, the resultant fuzz sound is clean and crisp for each of the notes in the chord. In a hex envelope follower, each string output controls the amplitude of its own envelope and the sweep of its own filter. These are, of course, sound modification techniques, not true synthesis, but they are valuable additions to the electric instrument's repertoire of sounds.

The combination of the hexaphonic pickup and the new guitar synthesizers has revolutionized the concept of the electric guitar. It is now possible to play six different instruments simultaneously, one per string, each with timbral characteristics that vary as much as those of any orchestral instrument. These new capabilities, which have already changed the role of the guitar in commercial music, are sure to alter the role of the electric guitar in art music as well.

Cordless Electrics

In the 1960s and 1970s wireless transmitters for guitarists have become commercially available. One drawback to the use of the electric guitar has always been the necessity of a cord to connect the instrument to the amplifier. At first glance, this annoyance may seem to be negligible, but there are three major problems inherent in the use of cords. First is the physical danger of tripping over the cord, a problem compounded when a number of electric-instrument performers share a stage. The number of effects desired determines the number of cords connected to each unit, and these can sometimes create a real tangle. Second is electrical shock—in the United States, only an annoyance, but in Europe and other places where amplifiers may use 220 volts, a serious problem. During the 1970s there were several fatalities from electrical shocks caused by musical instruments.

Finally, cords inherently have a limited frequency response, due to the electrical property of capacitance. This does not affect the studio player who sits several feet from his amplifier, but a cord longer than fifteen feet begins to act as a low-pass filter, and the longer the length, the lower the frequency response. Also, long cable lengths pick up extraneous electrical noise generated by lights, radio signals, power sources, etc. Replacement of the guitar cord by a wireless transmitter eliminates all these problems.

The cordless guitar system consists of a battery-powered transmitter and a receiver. The system can be the FM tunable type, using frequencies between 88 megaHertz and 108 megaHertz, or the VHF fixed-frequency type, which broadcasts either in the low-band area, between 54 and 88 megaHertz, or in the high-band range, 174 to 216 megaHertz. The broadcast unit is plugged into the guitar and is usually attached to the performer's guitar strap. It either uses the connecting cord as an antenna or has a small antenna already attached to it.

Once the guitar signal is broadcast, it is picked up by the receiver and fed into the amplifier (or mixer). Because transmitters are directional, signal dropout is possible if only one receiver is used, thus creating "dead spots" on stage where the receiver is unable to pick up the player's signal. Two methods of diversity can solve this problem. *Dual-receiver diversity* uses two receivers (each with one antenna) and a small computer that decides which of the two is receiving the strongest signal; *antenna diversity* uses one receiver and two or more antennae.

At present, most cordless guitar systems are used by rock groups who need the stage freedom afforded by this technology, but classical players have also benefited. Classical guitarist Turan-Mirza Kamal, for example, has very successfully performed concerti using a Kasha model guitar (with an internal microphone *and* transmitter) not for amplification but for sound reinforcement when playing in a very large hall. This technique eliminates the microphone and stand, which are often annoying to performer and audience alike.

One drawback of cordless instruments is that they are not connected to effects pedals or boxes. Special effects can always be switched into the circuit at the mixing board, however, and, in any case, the rapid rise of on-board electronics and effects is already eliminating this problem.

All in all, cordless electric guitars are a subtle but important breakthrough in the technology of the instrument, a development so new that the implications for the future cannot be foreseen.[8]

8. For information concerning manufacturers' specifications, etc., see T. Mulhern, "Wireless Transmitters for Guitar," *Guitar Player* 13, no. 3 (March 1979): 40.

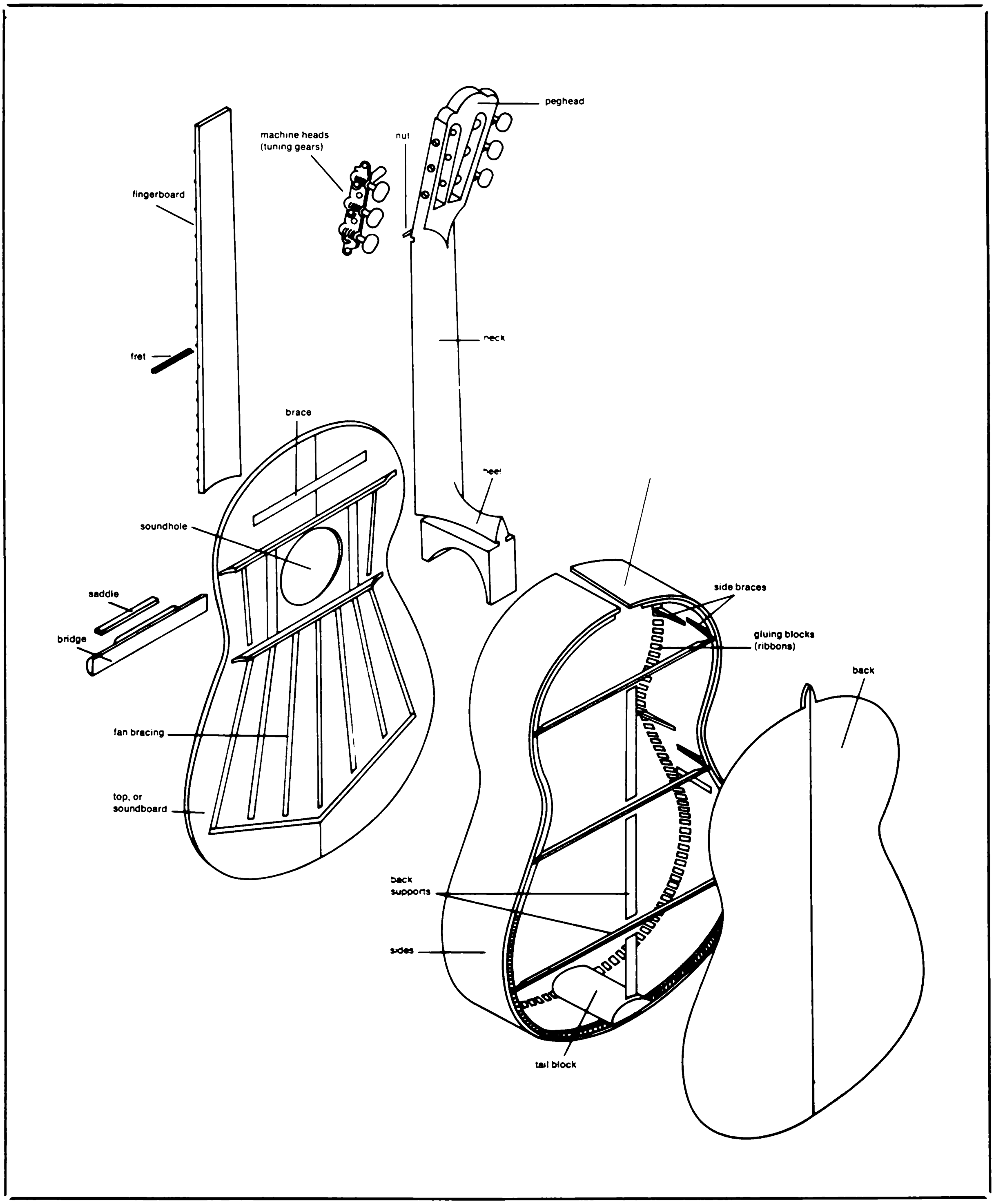
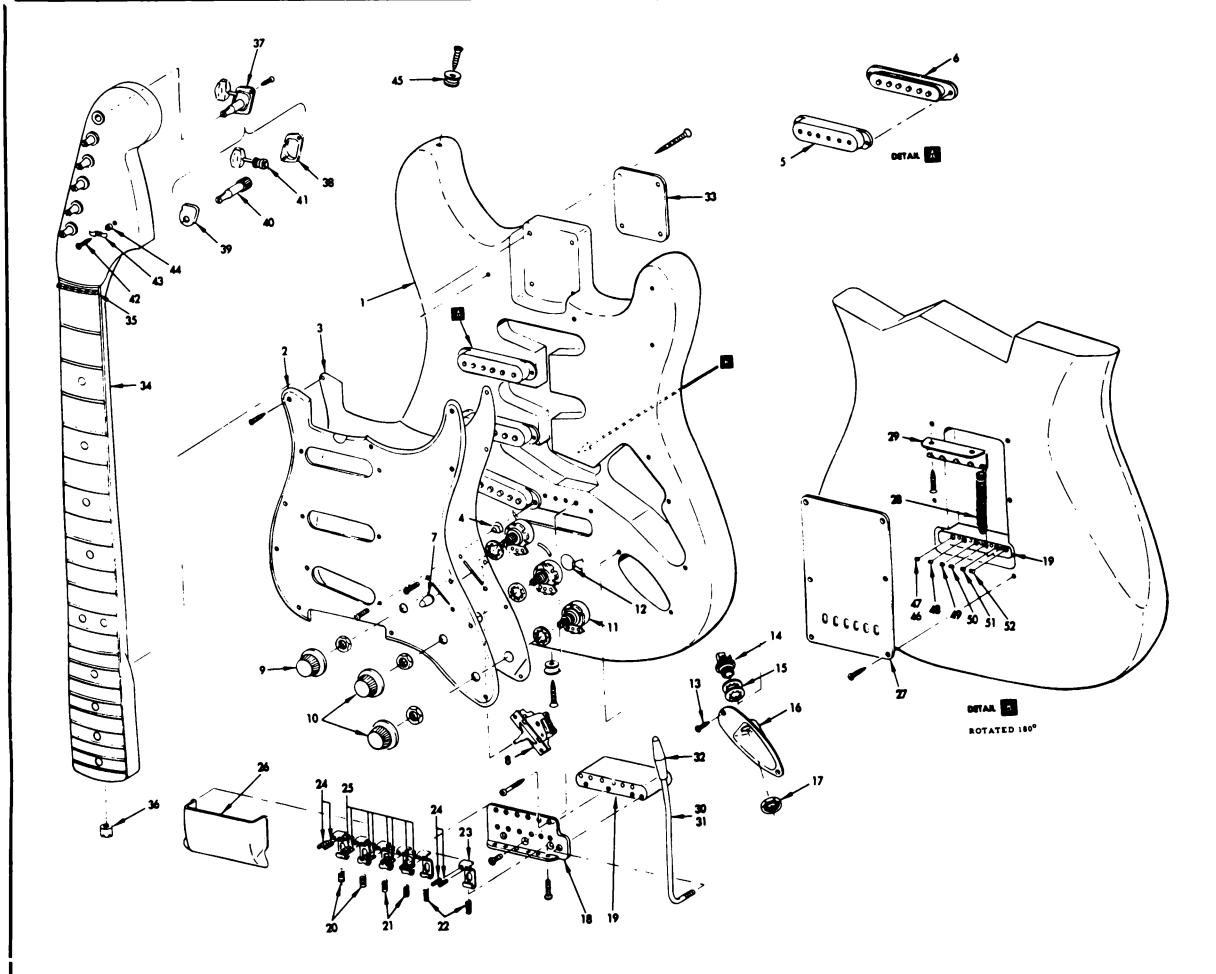


Plate I The classic guitar, exploded view. By Gerry Kana (after a drawing by Petrucelli) in *The Guitar Book: A Handbook for Electric and Acoustic Guitarists,* rev. and enl. ed. by Tom Wheeler. © 1974, 1978 Thomas Hutchin Wheeler. By permission of Harper and Row, Publishers, Inc.



1 Guitar Body

PICKGUARD ASSEMBLY

2 Pickguard
3 Pickguard Shield
4 Pickup Compression Spring
5 Pickup Cover
6 Pickup Core Assembly
7 Lever Knob
8 Pickup Selector Switch
9 Volume Knob
10 Tone Knob
11 Volume & Tone Potentiometers (Controls: 250K)
12 Ceramic Capacitor

13-17 OUTPUT PLUG ASSEMBLY

BRIDGE ASSEMBLY

18 Bridge Base Plate
19 Tremolo Block*
20 1/4" Compression Spring
21 5/16" Compression Spring
22 7/16" Compression Spring
23 Bridge Bar
24, 25 Set Screws
26 Bridge Cover
27 Rear Cover Plate
28 Tension Spring
29 Tremolo Tension Spring Holder
30-32 Lever Assembly

*"Tremolo" is used by Fender as a synonym for Vibrato.

NECK AND PEGHEAD ASSEMBLY

33 Neck Plate
34 Neck & Fingerboard, Frets & Position Markers
35 Nut
36 Neck Rod Adjusting Nut

TUNING KEY ASSEMBLY

37 Complete Key Assembly
38 Key Assembly Cover
39 Key Assembly Housing
40 Post and Gear
41 Head and Worm

MISCELLANEOUS

42-44 String Guide Assembly
45 Strap Button
46-52 Strings (Ball Ends)

Plate II Fender Stratocaster, exploded view.

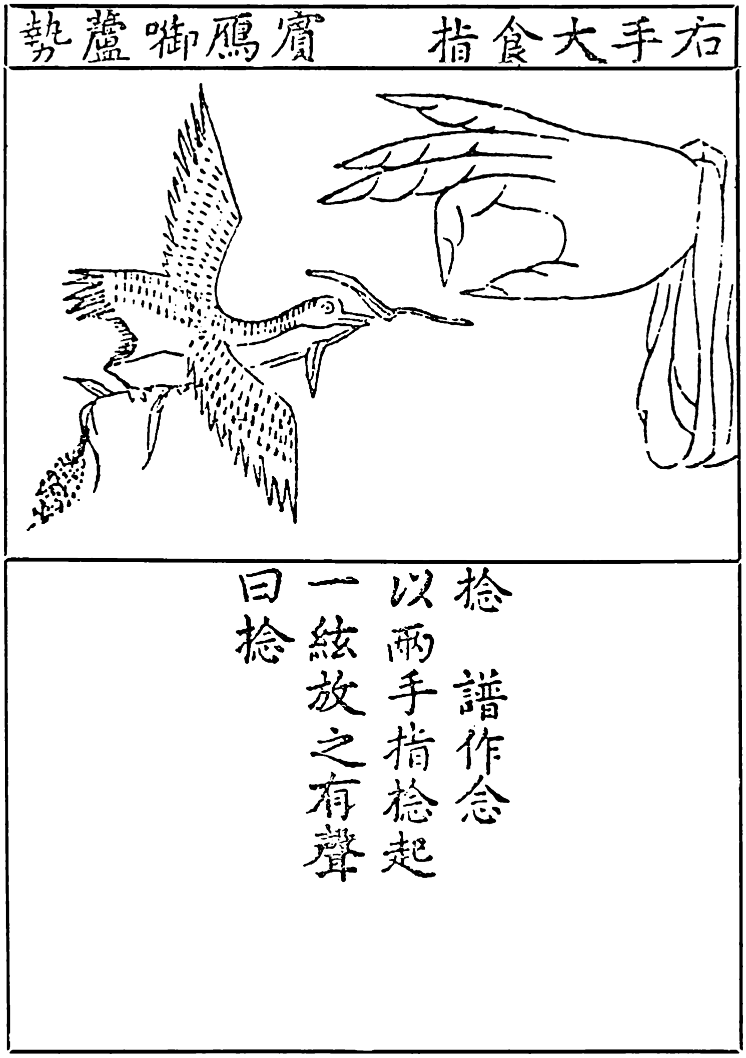


Plate III Symbolic picture illustrating finger technique for playing a note on the ch'in. R.H. vanGulik, *The Lore of the Chinese Lute,* Monumenta Nipponica Monograph, Tokyo, 1969.

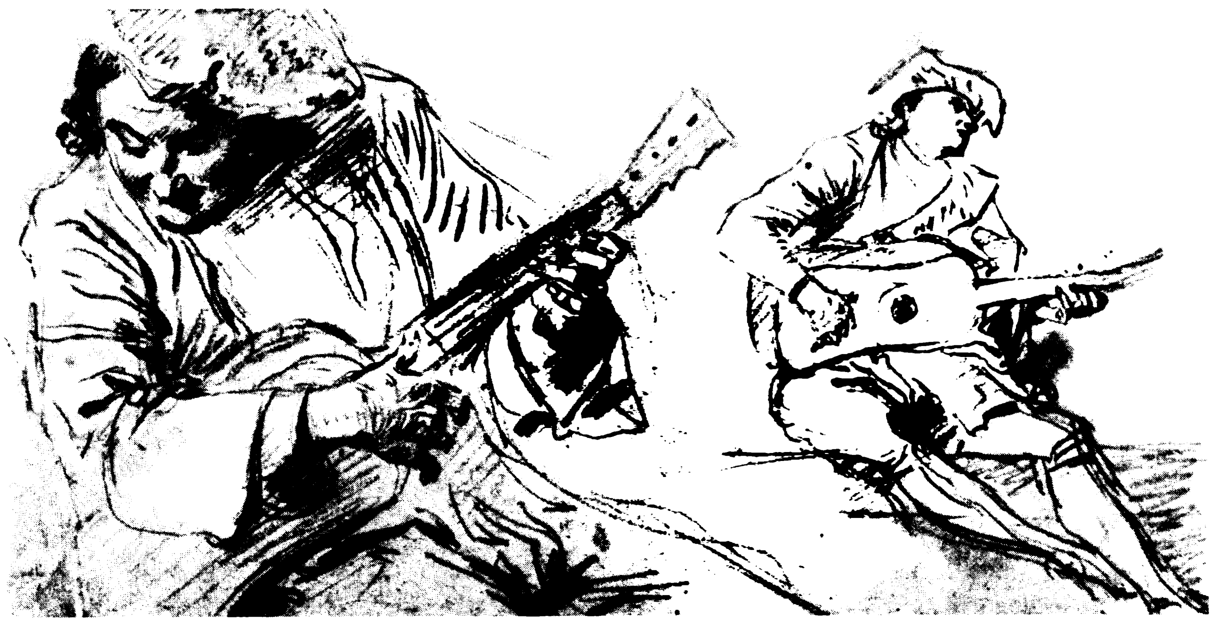


Plate IV Sketches of a Guitarist, by Antoine Watteau (1684–1721). Reproduced by courtesy of the Trustees of the British Museum.

CHAPTER V
Timbre and Notation

BACKGROUND

Of the five musical parameters—pitch, loudness, duration, location, and timbre—Western instrumental music has paid least attention to timbre. In many other cultures, however, timbre is of paramount importance. In the notation of music for the ch'in, the ancient seven-string Chinese lute, "an attempt is made to express in words that extremely elusive element that constitutes one of the chief charms of Lute music; the timbre, the colour of the tones."[1] The Chinese have developed a highly elaborate system of notation for the timbres of this plucked instrument. One of the earliest volumes, *Sixteen Rules for the Tones of the Lute*, by Leng Ch'ien (fourteenth century A.D.), describes in 150 to 200 special characters the techniques for performing the sixteen archetypical "touches" or tones of the lute, the titles of which include "The Gliding Touch," "The Crisp Touch," "The Empty Touch," and "The Profound Touch." Rather than describe finger technique exclusively in terms of direction and strength of plucking, the ch'in literature used symbolic pictures to relay the "spirit" of each technique (see Plate III).

All the information needed to perform a note on the ch'in was illustrated by a single character. For example: "*Kou:* 勹 *the middle finger pulls a string inward,* 'A lonely duck looks back to the flock.' The curve of the middle finger should be modelled on that of the neck of the wild duck: curved but not angular."[2] It must be remembered that the complexity of musical articulation reflects both a gradual evolution of technique and the fact that ch'in playing was considered a spiritual activity.

In the early 1600s, Western music began to assign particular instruments to specific parts, and dynamic markings appeared in the score. The first timbral effects were used for dramatic purposes in the operas of this period. These effects were usually given to the string parts, because stringed-instrument tone is easily varied by bowing and pizzicato techniques. In general, performance practice for an instrument was left to the discretion of the

1. R.H. van Gulik, *The Lore of the Chinese Lute* (Tokyo: Sophia Press, 1940), p. 103.
2. Ibid., p. 120.

performer, which means, of course, that the music of the past was never played exactly according to the printed page. An extract from J. J. Quantz's *Versuch einer Anweisung die Flöte zu Spielen* (1752) shows one interpretation of a written line:

Ex. 2. An Adagio graced in the Italian *galant* style. The expression marks, like the ornaments, are by Quantz himself.[3]

(It is worth noting that timbral changes are closely linked to dynamic changes and that many composers throughout the centuries have used dynamics alone to control the timbre of individual instruments.) By the end of the nineteenth century, orchestration had become an important aspect of composition—exemplified in the music of Debussy, Ravel, Stravinsky, and Richard Strauss—but timbre still functioned mainly as a carrier for the pitch information of a tone.

At the beginning of this century, Arnold Schoenberg began exploring the possibilities of exploiting timbre for its own sake. The most famous example is the "Farben" movement of his *Five Pieces for Orchestra* (1909), in which subtle orchestrational changes occur during the course of a single chord. This was the beginning of what Schoenberg called "*Klangfarbenmelodie*" (melody of tone colors), which he discussed in his *Harmonielehre* (1911):

3. From T. Dart, *The Interpretation of Music* (London: Hutchinson and Co., 1954), p. 167.

> I think . . . that sound makes itself evident through timbre, of which pitch is one dimension. Timbre is therefore the complete whole, whereas pitch is only a part of this whole, or rather, pitch is only timbre measured in a single direction. Now if it is possible to use timbres which are distinguished one from another by pitch so as to create structures which we call melodies (successions of sounds which by their relationships with each other give the impression of a logical discourse), then it must also be possible, using the timbres of the other dimension, those we simply call "timbre," to create sound successions whose interrelationship has the effect of a kind of logic, completely equivalent to the kind of logic which satisfies us in melodies made through pitch.[4]

The search for a scale or hierarchy of timbre analogous to the scales of pitch, loudness, and duration has held an increasing fascination for the composers of this century. A few years after *Harmonielehre* was published in Vienna, the American composer Henry Cowell put forward some similar concepts in his *New Musical Resources*, written in 1919:

> If tone-qualities were arranged in order, and a notation found for them, it would be of assistance to composer and performer alike. . . .
>
> Since early times, however, more and more music has been and is being written in which certain particular qualities are essential; music which becomes almost completely lost if the wrong quality is given in its production. Tone-quality thus becomes one of the elements in the composition itself and ceases to be only a matter of performance. Since there is no notation of tone-quality, a tradition has grown as to how the tone should be played in Chopin, Debussy, and others; but tradition is a vague thing and is subject to subtle alterations. Chopin and Debussy might be better performed if they had been able to write down the exact shades of tonal values they desired in their works.[5]

Cowell's aesthetic principles were certainly laudable, but his argument was limited technically by the state of acoustic theory at the time, which believed that "the only possible difference in tone-quality between tones having the same fundamental is through a different relation of dynamics in the overtone series."[6] This led Cowell to postulate that

> The problem of forming a related series of tone-qualities is the same as in other branches (of a musical tone) [*sic*]. A scale can be made by placing in the same group the tone-qualities in which overtones from the same portion of the series are most prominent; thus a quality in which the first overtone is most evident might be number one in the scale; a quality in which the second overtone is most plainly heard might be number 2, etc. A quality possessing both the first and the second overtones would be a bridge from number 1 to number 2 in the scale and might be classified as a "harmonic" quality, as it would be produced through a combination of sounds.
>
> The harmonic tone-qualities could be named by their chord names of the combinations of overtones forming them; thus, a quality produced by prominence

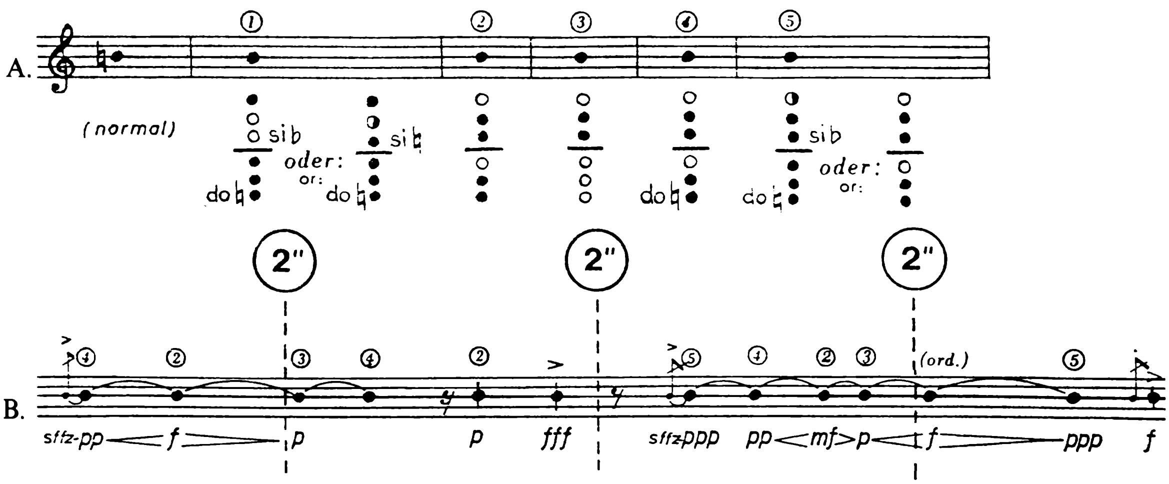
4. Quoted in B. Bartolozzi, op. cit., p. 50.
5. H. Cowell, *New Musical Resources* (New York: Knopf, 1930), pp. 34–35.
6. Ibid., p. 35.

of the fifth, sixth and seventh partials might be called a "diminished triad tone-quality," because these partials are found to produce a diminished triad, etc.[7]

Unfortunately, the ear does not perceive timbre exclusively in this manner; we have since learned that qualification of timbre is far more complex than the simple definition of overtone dynamics. But these attempts earlier in the century pose a very interesting question: can there be a scale of timbre? Chapter 2 revealed that the musical parameter of timbre is itself defined by a series of parameters which, counting the variations of vibrato and the elements of the time envelope, number at least ten. Any parameter varies only one value, so there can be a scale for that aspect of the sound. But if more than one value is altered at the same time, the overall timbral perception cannot be defined by a single term; therefore, there *cannot* be a scale of timbre, since timbre is a multidimensional phenomenon.

This raises an important question concerning the notation of timbre: how can the composer describe the quality of the sound he wants? Traditionally, the composer has had two choices: either to describe the desired sound-effect (metallic, bright, lontano, dark, pastoso) or to describe the mechanical action needed to make the sound (con sordino, ponticello, martelé). Both these methods assume a common understanding of the terms involved, though the technical approach also expects that all instruments will react in approximately the same way. Neither method can guarantee a truly objective reproduction of the composer's intentions.

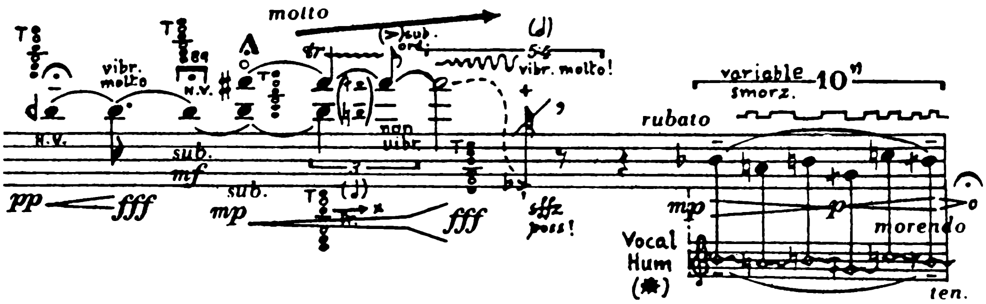
Luciano Berio, in his *Sequenza VIII* for oboe, has used the principle of contrast to notate timbral differentiation. He requests five tone qualities ranging from "bright and very near" to "dark and distant," gives the correct fingering for each, and numbers them from one to five. He then utilizes this arbitrary timbral scale to articulate a *Klangfarbenmelodie*:



Ex. 3. Excerpt from *Sequenza VIII* for oboe (1969), L. Berio: (A) Colors 1-5 for B-natural; (B) *Klangfarbenmelodie.* © 1971 by Universal Edition (London), Ltd., London, for all countries of the world excluding the Western Hemisphere. Used by permission.

7. Ibid.

Many composers have chosen to include the technique notation on the score itself, especially in those works which require many different multiphonics or new woodwind effects. In their complexity these scores often resemble the lute and organ tablatures of the Renaissance:



Ex. 4. *Cassandra's Dream Song* (1970), B. Ferneyhough. © 1975 by Hinrichsen Edition, Ltd. Reprinted by permission of C. F. Peters Corp.

Because much of today's music demands an unprecedented precision in performance, composers often combine verbal and technical descriptions to ensure that their sound ideas are adequately realized.

I stated at the beginning of this chapter that in Western instrumental music timbre has been relatively unimportant. One musical instrument, however, has relied almost entirely on timbral differentiation for its effectiveness; this instrument is, of course, the human voice. Since the beginnings of speech, humanity has organized the incredible number of possible vocal timbres into patterns that allow us to communicate with each other. In fact, the sentence you are now reading is little more than a timbral notation that represents the arbitrary collection of sounds the English language has chosen to convey its meanings. In this notation, pitch has traditionally been left to the discretion of the speaker/reader.

On the other hand, musical instruments have been designed to excel in the pitch domain of music, so of course the notation of instrumental music has developed a high degree of sophistication in this area, with duration and dynamics treated as of secondary importance, and the timbral quality as least important of all. One reason for this is that in the past, musical instruments have been unable even to approach the timbral complexity and versatility of the human voice. Now, however, the techniques of sound production (through analogue electronics, computers, and "extended" conventional instruments) have increased the possibilities of timbral articulation in instrumental music so greatly that a notation to organize them is definitely needed. Composer Donald Martino has in fact developed a symbolic notation system that uses phonetic models for differentiating the attacks of wind instruments, the instrumental technique borrowing from the vocal.[8] H. H. Stuckenschmidt has summed up these changes:

8. See D. Martino, "Notation in General—Articulation in Particular" (1966) in *Perspectives on Notation and Performance*, ed. B. Boretz and E. Cone (New York: W.W. Norton and Co., 1976), pp. 102–13.

> Early Western music centered round the human voice. The introduction of instruments marked the beginning of a new epoch. Instrumental music proper, with its own forms equal in status to those of vocal music, began to emerge about 1600. After 1750 instrumental music had a clear predominance over vocal music.
>
> We can thus speak of two eras in the history of music: the vocal and the instrumental. . . . Instruments brought in a new technical factor: mechanical possibilities increased, and dynamic and frequency ranges were expanded. . . .
>
> Electronic music constitutes the third era within this scheme. It stands in the same relation to instrumental music as instrumental music to vocal music. . . . There is room for hope that the newly-developed possibilities in sound will open up a realm of new musical forms, as well as endow vocal and instrumental music with fresh inspiration and vitality. This would vindicate our comparative scheme given above, in terms of which electronic music is the historical synthesis of organic and mechanical music.[9]

The present combination of vocal, instrumental, and electronic capabilities clearly constitutes a new voice for mankind, more facile in terms of pitch, loudness, and timbre than any before. We must now begin to invent a language that can harness these new sounds. The challenge is as great as was the ancient task of organizing natural human sounds into the kaleidoscope of national language which exists today.

TIMBRE IN GUITAR NOTATION

Until the middle of the eighteenth century, music for the guitar (which was still a double-strung, five-course instrument) existed only in tablature form. This tablature described two styles of playing: *punteado* (plucking) and *rasqueado* (strumming). In some general introductions to the instrument, a few references hinted at the possibilities of timbral variety; for instance, Pietro Millioni, in *Intavolatura de Chitarra Spagnola* (Rome, 1627), suggests strumming between the rose and the neck "for greater sweetness."[10]

When Michel Corrette published his *Les Dons d'Apollon: Méthode pour Apprendre Facilement à Jouer de la Guitarre* (Paris, 1763), he described the music both in tablature and in a primitive form of G-clef notation, with each line of clef notation above the corresponding line of tablature. Corrette recommended two right-hand positions: between the rose and the bridge, for plucking, and between the rose and the last fret (in mid-century Baroque guitars, the 10th), for rasqueado strokes.[11] These two "manières de pincer" are best illustrated in *Sketches of a Guitarist*, by Antoine Watteau (1684-1721) (see Plate IV).

The last half of the eighteenth century witnessed the greatest changes, changes that helped transform the Baroque guitar into the modern instrument. The guitar itself was

9. H.H. Stuckenschmidt, *Twentieth Century Music*, trans. K. Deveson (London: World University Library, 1969), pp. 178–79.

10. Quoted in H. Turnbull, *The Guitar: From the Renaissance to the Present Day* (London: Batsford, 1974), p. 44.

11. Quoted from Diderot and d'Alembert's *Encyclopedia*, in ibid., p. 60.

altered by the addition of the sixth string and use of single courses; a change in technique freed the little finger of the right hand from the table of the instrument; and a G-clef (octave-transposing) notation that distinguished various parts of the music by the direction of note stems was developed.[12] Virtually all guitar methods and illustrations of players made prior to the late 1700s show the little finger placed on the table next to the bridge in punteado playing. (In fact, this technique was practiced by some players well into the nineteenth century.) This position was probably borrowed from lutenists, who usually used the thumb and forefinger for playing fast passages.

Freeing the right hand from the bridge position had several far-reaching effects on guitar technique and, eventually, on the music itself. First, because the little finger acted as a damper, its removal from the top changed the resonance of the soundboard. Second, the right hand could now vary in height and angle of attack, so the player was able to use the index and middle fingers for scale passages while the thumb added a bass or other line to the musical texture. More generally, the right hand now had complete mobility for producing "an infinite gradation of tone color."[13]

At the end of the eighteenth century, the first method was published which taught the player to read music exclusively from notes on the G-clef, rather than from tablature. In *Arte de Tocar la Guitarra Española por Musica* (Madrid, 1799), Fernando Ferandière also makes one of the first allusions to the "orchestral" guitar: "It can easily imitate other instruments, such as flutes, trumpets or oboes, and has the ability to accompany singing as though it were a pianoforte."[14] It is perhaps significant that these two new developments (G-clef notation and acknowledgment of timbral differentiation) should occur during the same period of the guitar's history. From this point on, the subject of timbre appears in many writings concerning the guitar, but only in the works of those men who were masters of the instrument, those who had probably already conquered the mundane task of note production and were perhaps searching for other levels of musical expression. And yet, even though Aguado mentions several instrumental imitations in his *Nuevo Metodo* (Paris, 1843), and Sor gives explicit instructions as to the techniques for imitating the horn, oboe, trumpet, flute, and harp in the *Méthode* (Paris, 1830), neither made a practice of notating any of these timbres in their scores. Perhaps the reason is to be found in this comment by Sor:

> The imitation of other instruments is never the exclusive effect of the quality of the sound. It is necessary that the passage should be arranged as it would be in a score for the instruments to be imitated.[15]

Thus it must be assumed that an enlightened contemporary player, seeing a horn-like passage in the score, would understand by convention that he should use the appropriate

12. T. Heck, "Birth of the Classic Guitar" (Ph.D. dissertation, Yale University, 1970), p. 17.

13. Ibid.

14. Quoted in F. Grunfield, *The Art and Times of the Guitar* (New York: Collier-Macmillan, 1969), p. 140.

15. F. Sor, op. cit., p. 5.

color. Color was also used for compositional contrast, however, not just for instrumental imitation, in certain kinds of music.

One of the most popular forms in the chamber music, including the guitar repertoire, of the early nineteenth century was the Variation. In this type of composition, a familiar theme is stated and then "illustrated" musically and adorned through varied repetitions. The composer used various compositional devices to highlight certain aspects of the theme, and one of the most obvious aspects of a theme that could be varied was the timbre. On the rare occasions in the guitar music of this period when a particular timbre was asked for specifically, the piece was almost always a Theme with Variations [for example, in Giuliani's Op. 6 (1811), Variation IV: "right hand above the fifteenth fret, then imperceptibly returning to its place"; and his Op. 16, *16 Austrian Ländler*, No. 12: "ondeggiamenti," indicated by 〰].[16] The restriction of musical material may have forced the composer to search for material to vary once the other aspects of the theme had been explored (although Sor occasionally used *dolce* and *étouffez* in order to produce musical contrast in other contexts).

This "variation" colorism can be looked upon as the conceptual ancestor of today's timbral exploration of the guitar. Today the instrument itself has become the "theme," and today's players and composers, having (seemingly) exhausted the traditional sounds of the instrument, are now exploring every possible method of sound production for musical texture, to develop this "theme" to its fullest potential.

One interesting occurrence in the nineteenth century was the reemergence of the nails/no nails controversy that had plagued the players of plucked string instruments since the days of the lutenists. Of the reigning virtuosi of the day, Aguado, Giuliani and Carulli recommended the use of nails, while Sor and Carcassi deplored it. Unfortunately, as Pujol puts it, "It is not practicable for the same set of fingers to use two techniques, the player must make a choice: hence the dilemma."[17] The choice between these two methods was still important enough in 1934 to inspire Pujol to write *The Dilemma of Timbre on the Guitar*, in which he traced the historical precedents of the problem and presented a highly subjective argument favoring the no-nail technique. But in the nineteenth century this aspect of tone production was also left to the performer's discretion; even though Sor hinted at "the disadvantage in the use of nails, especially for my music which was conceived in a spirit utterly unlike the conceptions of the guitarists of the period,"[18] none of the music of the day specifically requested either method.

One outcome of the nineteenth-century efforts to improve the sound of the guitar was the development of many new instruments which expanded the range of the newly

16. Heck, op. cit., pp. 174–76.

17. E. Pujol, *The Dilemma of Timbre on the Guitar*, trans D. Gow and E. Giordan (Buenos Aires: Ricordi Americana, 1960), p. 43.

18. Ibid., p. 43.

standardized but not yet universally accepted six-string instrument. The harpolyre, guitarpa, and Doppelgittare (all of which soon became obsolete) added a large number of strings, necks, and tuning pegs. Of more lasting significance were the instruments that differed from the ordinary guitar only in size, retaining the same number of strings and the same interval pattern for their tunings.

The most popular of these instruments was the Terz guitar, developed by Giuliani; it was tuned a minor third higher than the normal guitar and had a string length of 55 cm. This instrument gave a more brilliant sound than the standard guitar, and Giuliani wrote many pieces for it, including a guitar concerto.[19] The two other types of instruments were the Quarte guitar (with a string length of 50 cm), invented by A. Schneider of Dresden, which was tuned a fourth higher than standard, and the Quinte-Basse guitar (with a string length of 70 cm), which was tuned one-fifth below the standard guitar. The Quarte guitar, also known as the *requinto*, was used by Diabelli in his *Grand Trio for Three Guitars*, Op. 62, and the Quinte-Basse instrument was used extensively by Heinrich Albert in his Munich Guitar Quartet.

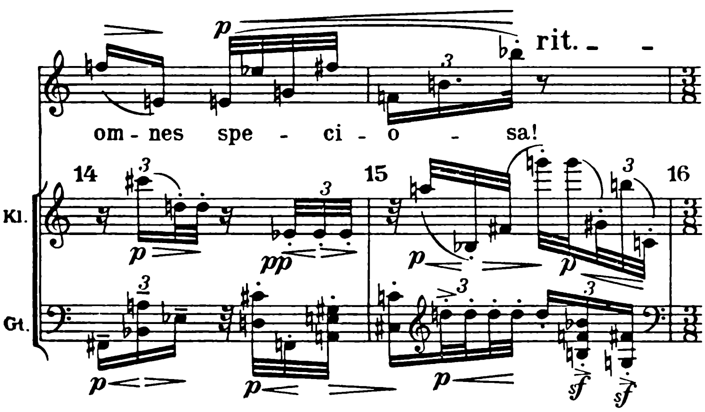
Another extended instrument was the Decacorde, developed in 1828 by the guitarist/composer Carulli and the luthier Lacôte, which had four extra bass strings. It was very popular in its own time and has been revived in this century by several players, notably Narciso Yepes and the American Vincenzo Macaluso.

The next mention of the "orchestral" guitar is by the father of the modern guitar, Francisco Tarrega (1852-1909), via his pupil Pascual Roch's *A Modern Method for the Guitar: School of Tarrega.* In the section entitled "Artistic and Beautiful Effects on the Guitar," Roch describes harp-tones, bell-tones, side-drum effect, bass-drum effect, trombone effect, and the clarinet or oboe effects and their production. There is even a section explaining how to "Imitate the Cracked Voice of an Old Man or Woman, To Imitate Sobbing, a Stammerer, and a Stammerer Singing"! Tarrega (who, incidentally, chose to play without nails) was particularly aware of the sound-producing capabilities of the guitar; he adopted a new style of right-hand technique which called for the fingers to be held perpendicular to the strings, and was the first teacher to develop the *apoyando* or downstroke technique. He was a prolific composer and arranger of music for the guitar, and his pieces take full advantage of many musical techniques that are idiomatic to the guitar, such as glissandi, tremolo, harmonics, and left-hand-only pizzicato. It is not surprising, then, to find that the first works in the repertoire that ask for color effects are by Tarrega. In his *Gran Jota de Concierto* (1872), he asks for tambura (snare-drum effect) and nails-only ponticello; and when transcribing *The Umbrellas* (a mazurka from the zarzuela "El Año Pasado por Agua" by

19. It is interesting to note that whenever this type of brilliant sound was called for but a Terz guitar was not available, the score would ask for a standard guitar (Primguitarre) to be played with a capo placed at the 3rd fret, perhaps an indication of the interest shown in transforming the tone quality, rather than just for ease in reading the transposed part.

Checa), he contrasts ponticello with the "trombone effect."[20] It was probably the fact that he was transcribing that tempted Tarrega to extend the timbral limits of the guitar to match more closely the contrasts of the instruments for which the music had originally been written.

It was not until the 1950s that the colors of the guitar began to be explored again. Of course, the drastic changes in the musical language by that time helped to renew interest in the instrument. The few pieces of creative composition for the guitar written in the years between the wars used the accents and expressive markings for timbral articulation common to all instruments:

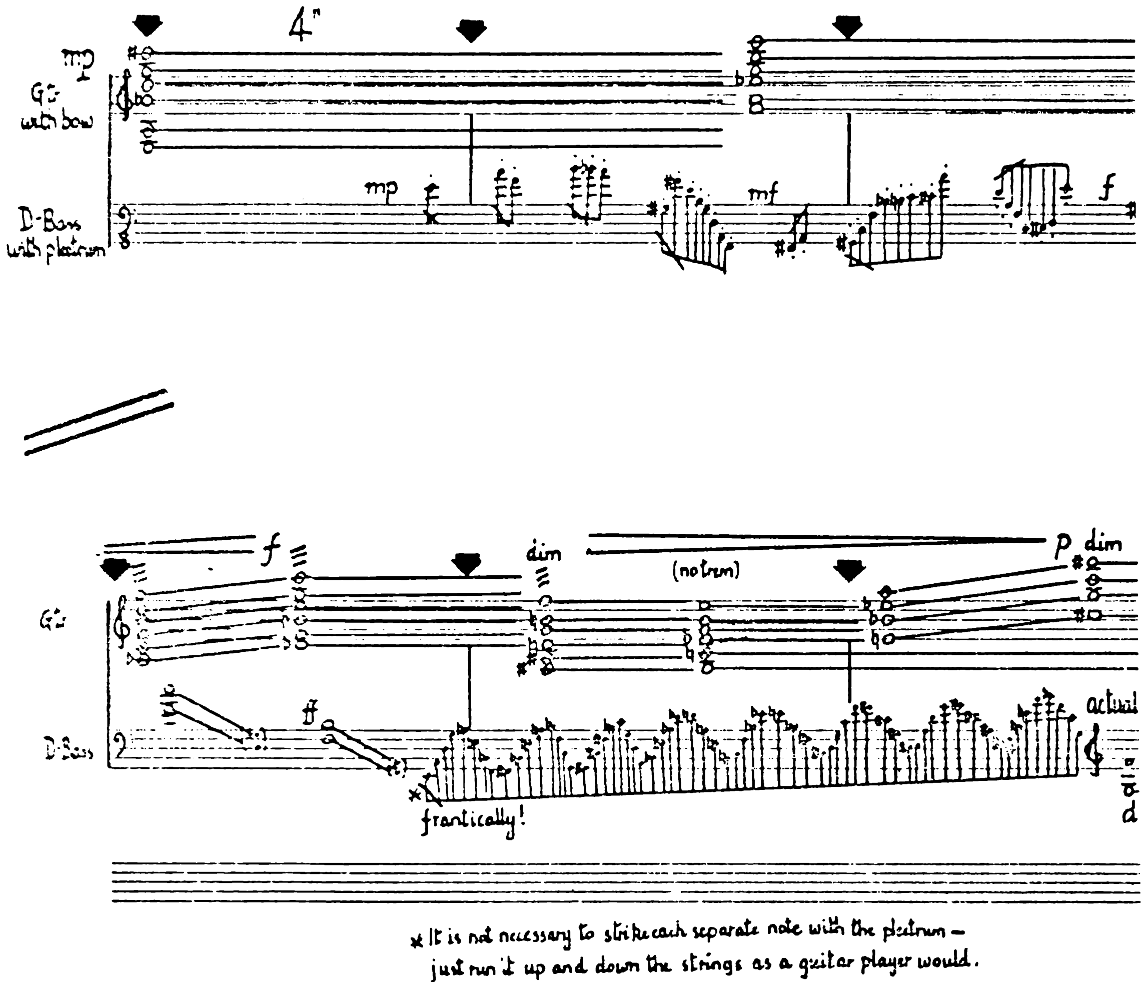


Ex. 5. *Drei Lieder*, Op. 18 (1925), A. Webern. © 1927 by Universal Edition, A.G., Vienna. Copyright renewed. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

After World War II the emphasis was no longer exclusively on tones per se, but on sound and its organization. What this meant for the instrumentalist was that a new approach was to be taken toward the instrument, an approach which included utilization of every part of an instrument to produce any possible sound of which the instrument *and* the performer, separately or together, were capable. Needless to say, neither the composer nor the performer could rely on the old conventions to communicate these new ideas, and it was this gap that fostered the new era of experimental notation.

Many new sound *ideas* for the guitar have been borrowed from other musical instruments, just as they had been in the 1800s; but in this century, some of the *physical* techniques have also been transplanted to the guitar. A very theatrical example of this musical cross-pollination occurs in a piece by David Bedford: the guitarist is instructed to "Walk to D-Bass player. Give him/her plectrum. Take Bass bow" and then the two instrumentalists swap sound-producing roles:

20. Roch, *A Modern Method for the Guitar: School of Tarrega* (New York: Schirmer, 1921), p. 141.



Ex. 6. *A Horse, His Name was Hunry Fencewaver Walkins* (1973), D. Bedford. © 1978 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

This is just one of the many ways in which modern composers have transcended the traditional musical identity of the guitar.

The remaining chapters review the textures and notations in guitar music since 1950, in an attempt to categorize the guitar's repertoire of sound objects. Each technique of sound production is discussed in turn, illustrated by a series of examples that begin with historical precedents and then progress from the technique's simplest to their most sophisticated musical uses. Each section ends with recommendations for the clearest possible notation of the technique presented.

Chapter 6 describes the classes of pitched sounds (ordered by increasing inharmonicity), ranging from the tonal production of pitched sounds to the quasi-pitched sound material of clusters. Chapter 7 discusses the production and notation of unpitched or inharmonic sounds, including percussion and extra-musical sounds, and Chapter 8 explains how to write for the electric guitar, including composing with the electronic extensions of the instrument. Throughout, each technique represents a new color, just as each instrument in a real orchestra is a different color: the skilled orchestrator can use these techniques to create the contrasts that are needed to articulate musical ideas effectively.

The guitar has always been criticized as musically insignificant because of its poor timbral and dynamic range, but the discoveries of the last thirty years have proven it to be a very powerful instrument indeed, and it is finally finding its proper place in solo, chamber, and orchestral music. These examples have been compiled in order to increase composers' and performers' awareness of the capabilities of the instrument and to encourage them to make intelligent use of an instrument that has, until very recently, been undeservedly neglected.

CHAPTER VI
Pitched Sounds

RUDIMENTS OF GUITAR COMPOSITION

Some of the advanced techniques described in the following pages will be new territory for many, but even the most basic techniques of composing for the guitar are not readily at the fingertips of many composers. This is because the instrument is not covered in most traditional orchestration classes or texts, due to its "secondary" or "folk" status. This section is designed to familiarize composers with the basic possibilities and limitations of the instrument, the first principles necessary for a complete understanding of the guitar and its music.

The problems of notation will be considered in terms of the musical parameters of pitch, dynamics, duration, and articulation, timbre having been explored in the earlier chapters of this book. I have tried to make these descriptions complete enough to allow the composer to write for the guitar without having ever touched one, but my sincere advice is to *get a guitar and play it!* The instruments are to be found everywhere—chances are that your neighbor's daughter or your brother-in-law has one. So long as it is a full-sized instrument (scale length approximately 25–26 inches), the problems of reaching notes and stretches can be accurately understood through first-hand experimentation.

Pitch

Usually, the first question that presents itself is, "What notes are available, and where are they played?" Figure 78 illustrates all the fretted and open notes on the guitar and where to find them. The guitar is a *transposing* instrument: its notes sound an octave lower than they are written. Its true range can easily be written with a bass and treble clef and two ledger lines, but the treble clef is traditionally used. Figure 79 illustrates the range of each string.

The left hand can usually stretch a span of four frets (one finger per fret) and can extend to six frets if needed. Keep in mind that big stretches need a little time to prepare for and to recover from. Remember also that open-string notes are available at any time, Notes Available on the Guitar

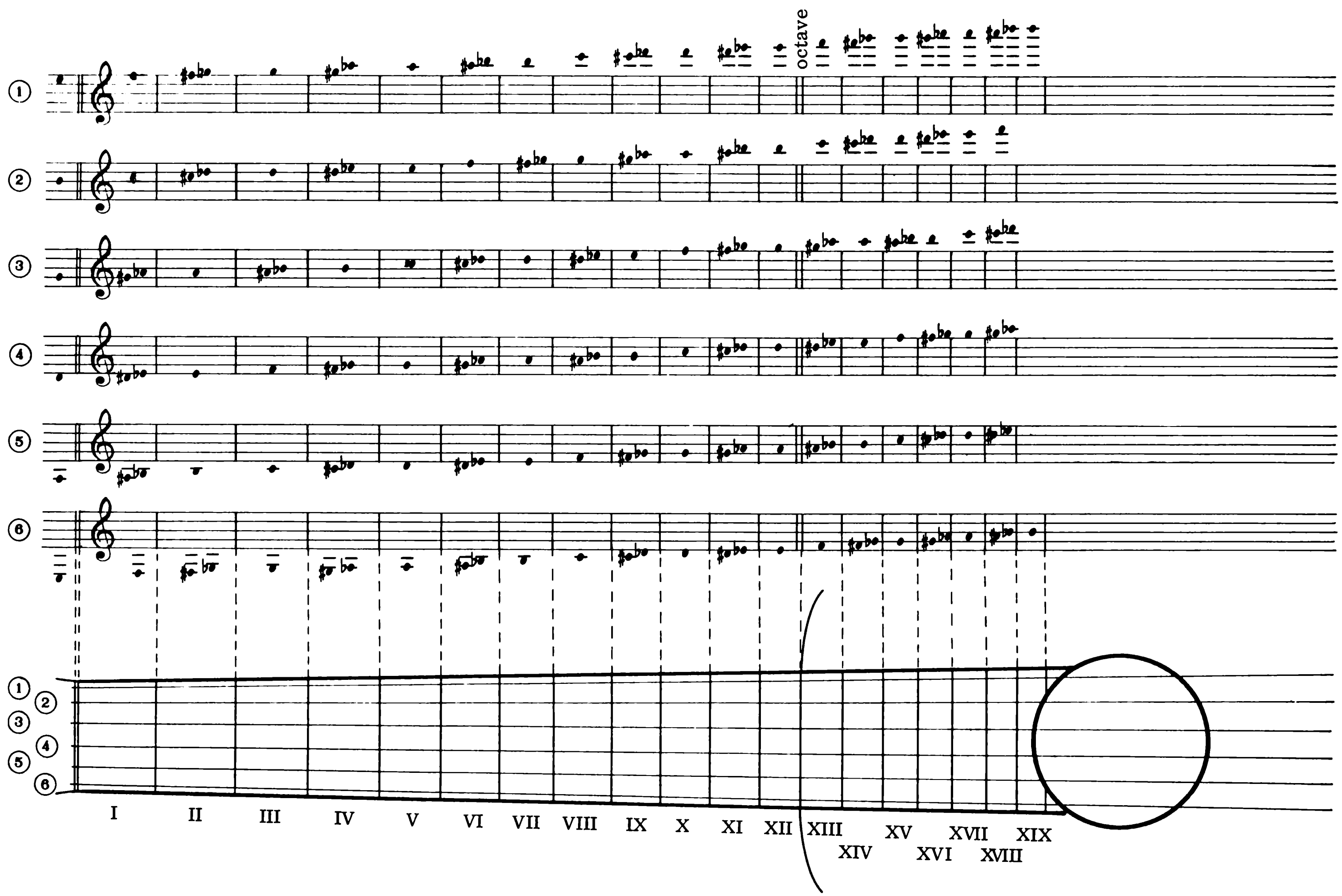


Fig. 78. Notes on the guitar.

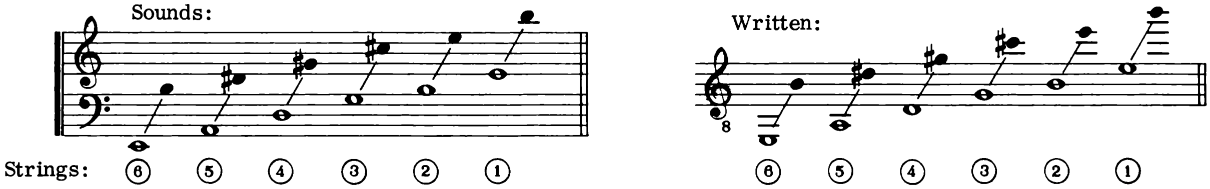


Fig. 79. Range of guitar strings in standard tuning.

and also that when a barre is used (that is, when the first finger holds down some or all strings at a particular fret) that a new set of open-string notes is available in that position.

The numbers and letters used for describing right-hand and left-hand fingerings are shown below:

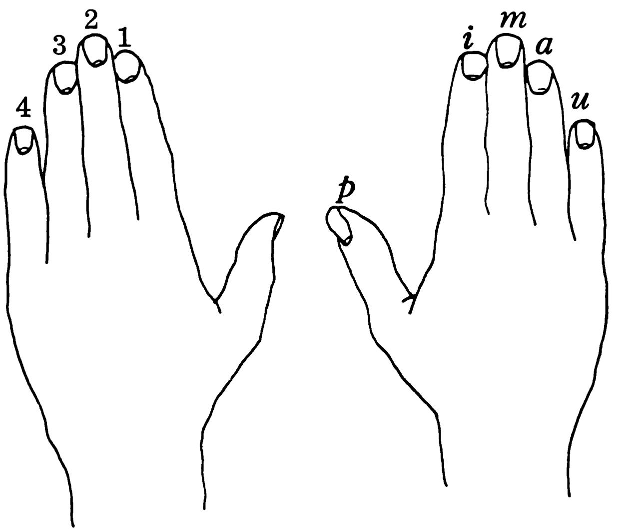
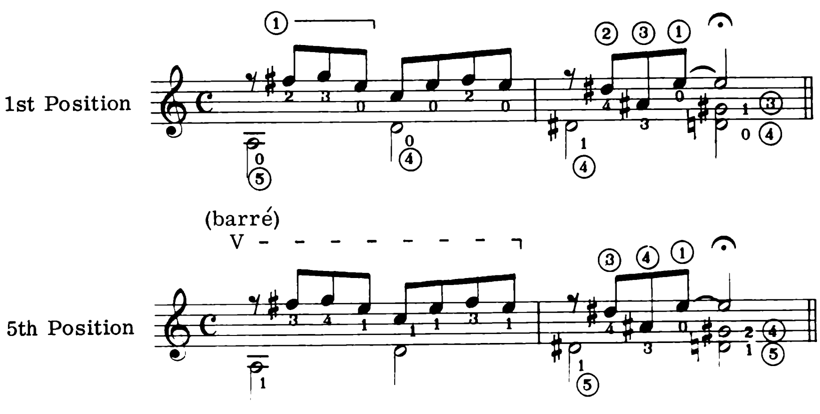


Fig. 80. Labeling conventions for guitar fingerings.

Roman numerals indicate the fret at which the first finger of the left hand is placed. In Example 7, the two-bar phrase is marked to be played in two ways, the first using open strings, and the second using a barre at the fifth fret for the first measure.



Ex. 7. Two methods of fingering the same phrase.

As an exercise, look at the note chart and try to imagine the difference between these two fingerings; even better, try them yourself and hear the difference in sound. (See Recorded Ex. 24.) Remember also that the range of the fretted pitches can be extended by scordatura and use of harmonics.

Dynamics

The practical dynamic range of the unamplified classic guitar is from *pppp* to *ff*, the fortissimo being somewhat questionable. Since a guitar note decays rapidly, a guitar played with other instruments becomes quieter and less expressive than when it is played alone, because its tone is easily masked by longer-sustaining instruments. This must be taken into account when writing for the instrument. Do not let recordings of ensemble music fool your ear; studio techniques of miking and mixing are usually used to bring the guitar up to the accompanying instrument's level, a balance which can rarely be achieved in live performance. Of course, all these problems disappear once amplification is introduced, but then those of tone coloring and feedback problems often replace them.

One acoustical distinction between two notes of differing dynamic level is that the louder note contains more high-frequency harmonics. Therefore, a player can in fact mimic a louder dynamic by using a brighter tone color (see "Tone Production") and increase the effective dynamic range of the instrument.

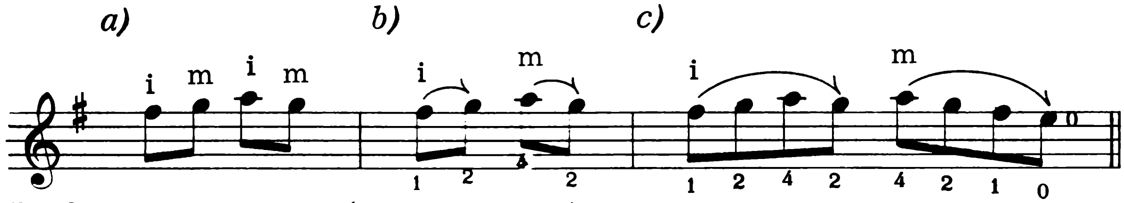
Duration

The length of time an individual tone will last depends not only on how loud the initial tone is played but also on the string on which it is played. Wound strings sustain longer than plain strings: an open sixth-string note will last approximately ten seconds, but a first-string twelfth-fret E will only last approximately five seconds even on a good instrument.

Very quick notes are easily obtained, and notes that are one-eighth of a second in duration are entirely possible. Repeating notes depend on the skill of the performer, and rest-strokes will be a bit slower than free-strokes. It is safe to write 16th notes at ♩ = 132, and tremolo technique can also be used to reach these speeds.

Articulation

The right hand determines the loudness and timbre of the guitar's musical tone, but through articulation, the guitar's version of the violin's bowing techniques, the left hand also controls much of the musical expression. Just as several notes can be played on a single bow, the guitarist can play several notes with a single pluck, using legato or *ligado* techniques in which the left hand continues to fret or unfret notes after the string has been plucked. In folk guitar, this technique is called *hammering on* when the finger strikes down on a fret above the originally plucked note, and *pulling off* when the left-hand finger replucks the string from the fret of the original note and lets the note vibrate from a lower fret. These techniques are illustrated below. In (a) each of the four notes is plucked with the right hand; in (b) the F# is plucked with the right hand, the G is hammered on with the second finger, the A is plucked with the right-hand middle finger, and the left-hand fourth finger pulls off to the G, which is fretted by the second finger; in (c) after the initial pluck with the right-hand index finger, G and A are hammered on and then the A is pulled off, then after the right-hand middle finger plucks the A, all fingers pull off to the open E-string:



Ex. 8. Ligado techniques (Recorded Ex. 25).

TONE PRODUCTION

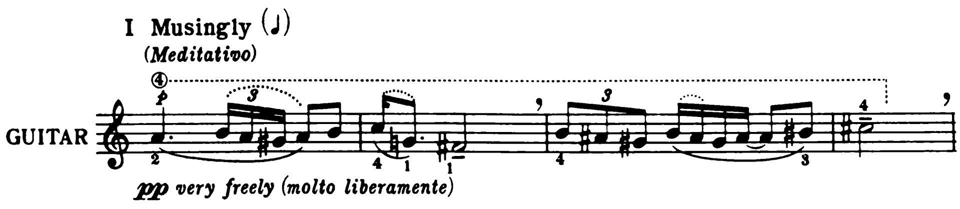
This section deals with the ways composers have designated specific timbres of string tone by requesting particular right-hand techniques. Chapter 2 described the acoustics of tone production in the classic guitar and ended by describing the right-hand techniques in terms of where, how, and with what object the string is plucked. This section will be divided into these same categories and will end with a new system of notation that takes all three of these aspects of tone production into account. All musical examples not illustrated will be cited by page, system, and bar numbers

page no:	system no.	bar nos.
↓	↓	↓
6:	4.	2–4

to help those who wish to refer to the works cited.

Which String

One of the first choices that a composer can make about timbre is on which string/s the notes are to be played. String choice is often left to the editor or the guitarist who eventually marks the fingering of the music for publication. One example of a creative use of editing is found in the opening of Britten's *Nocturnal*, Op. 70; Julian Bream has chosen to have the first two phrases played on the fourth (D) string.



Ex. 9. *Nocturnal*, Op. 70 (1963), B. Britten. © 1964 by Faber Music, Ltd. Reproduced by permission.

This gives the line a continuity that would be impossible if it were to be played by crossing strings in the first position.

String choice can also be used to color a single note, as in the *Klangfarbenmelodie* type of compositions.

Ex. 10. *Rives* (1975), J. Richer. Used by permission of Theodore Presser Co.

Ex. 11. *Solo for Electric Guitar* (1971/72), P. Gudmundsen-Holmgreen. By permission of Edition Wilhelm Hansen, Copenhagen.

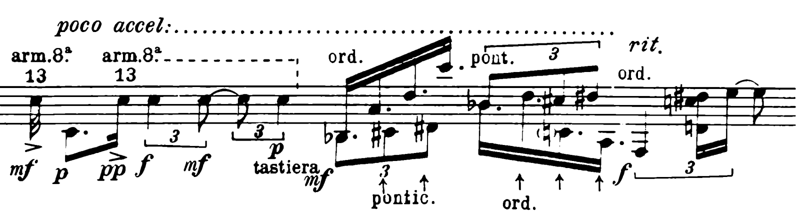
Where to Pluck

After the string has been chosen, the player must choose where that string is to be plucked. Sor suggests that the usual placement of the right hand should be approximately one-tenth of the whole length of the string:

> For a more mellow and sustained tone, touch the string at one-eighth part of its length from the bridge. . . . If a louder sound be desired, touch the string nearer the bridge than usual, and in this case use a little more force in touching it.[1]

When Tarrega uses ponticello in *Gran Jota* (1872), he comments that this is the way to obtain a "metallic sound," and in much of the early twentieth-century literature—Hindemith's *Rondo for Three Guitars* (1925), for example—the word *metallic* is also used to mean ponticello (4:5.1).

Ponticello is one of the most common methods of obtaining tonal contrast in guitar music. Goffredo Petrassi employs the ponticello sound and the normal position tone almost simultaneously in this difficult passage:

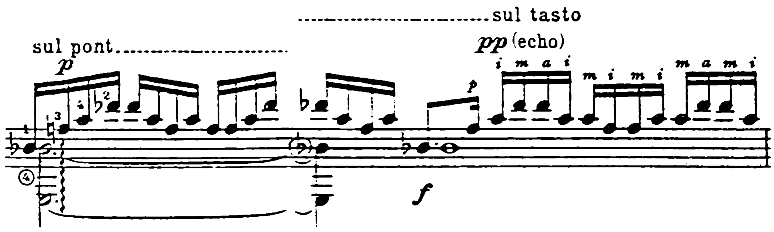


Ex. 12. *Suoni Notturni* (1959), G. Petrassi. © 1961 by G. Ricordi and Co., Milan. Used by permission.

1. Sor, op. cit., p. 4.

The opposing sonority to ponticello is called *sul tasto* (plucking over the fingerboard) or *flautando* (fluted tone), terms which are also borrowed from the terminology of bowed string instruments. Sor calls this the "harp tone" ("Pluck halfway between the 12th fret and the bridge"),[2] as does Tarrega/Roch ("Right hand plucks the strings at any point of the space between the 18th and 12th frets, the tones are quite like those of the harp, and the more so, the higher you go").[3] Henze specifically asks for the guitar to play "comme une harpe" in *El Cimarrón* (68 : 2.1)

Musically, ponticello and tasto are often used to change the meaning of the repetition of an event by presenting the material in a different color. Thus, when the music of the last movement of Smith-Brindle's *El Polifemo de Oro* is repeated, the first section is played ponticello (4 : 1–5). Ponticello used for the repetition of material often functions as an echo device, as in the "March" from Britten's *Nocturnal* (7 : 9.2), and the use of *sul tasto* is even marked "echo" by Fricker in his *Paseo*, Op. 61:



Ex. 13. *Paseo* (1971), P. Fricker. © 1971 by Faber Music, Ltd. Reproduced by permission.

Change of plucking position can also be used to give the impression that an event is changing character, as during the rhythmic decomposition of the theme at its last entrance in the "Allegro" from *El Polifemo*:

Ex. 14. *El Polifemo de Oro* (1956), R. Smith-Brindle. Courtesy of Aldo Bruzzichelli Editore, Florence, Italy.

Smith-Brindle has also used the three standard right-hand positions simultaneously in a small ensemble piece for three guitars.

2. Ibid., p. 4.
3. Roch, op. cit., p. 69.

Ex. 15. *Music for Three Guitars* (1970), R. Smith-Brindle. © 1977. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

He has also suggested that this practice be used when the guitars play a *forte* unison passage, as in the last few bars (9:3.1). Since each instrument will be putting all its energy into one area of the tone's spectrum, the combined effect will be a very full sound indeed.

On an electric guitar, the change in sound due to the movement of the right hand from the normal to the ponticello plucking position is not as dramatic as it is with the acoustic guitar; the analogous situation is to change the string pickup from the forward-position to the bridge-position pickup. David Bedford, in *18 Bricks Left on April 21* (1968), uses "N." and "P." to notate whether the position of the pickup switch is to be in the normal or the bridge position.

Many composers interested in a more exact description of right-hand placement have found ways to request the sound they want. For instance, Bartolozzi, in *Omaggio a Gaetano Azzolina* (1972), asks for "½ pont." (2:1) and "½ tast." (2:4); Karl-Aage Rasmussen marks "poco sul pont." (18:3.6) in *Protocol or Myth?* (1971) and Boulez notates "près de la rosace" (37:3.2) in *Le Marteau sans Maître* (1954). Francis Miroglio is a little more precise in *Choréiques* (1958), asking that the bass notes sound "near the bridge but sonorous" (4:2.2). A specialized language has already slowly evolved for dealing with these problems, but it is hard to describe some positions because they just are not exact. One exception is when the string is plucked exactly halfway along its vibrating length. Guitarist Tom Hartman says, "I somtimes play phrases in which my thumb or my fingers follow exactly the pitches of the left hand at the octave, which makes a very round, harplike sound."[4] Smith-Brindle calls this the "clarinet tone" (because theoretically a mid-string pluck produces only odd harmonics, like the tone of a clarinet), and asks for its production by name in his *Do Not Go Gentle* (1976, 3:6.3), as well as specifying "12.° tasto" in both *El Polifemo de Oro* (see Ex. 14) and *Concerto "de Angelis"* (1973, 10:2).

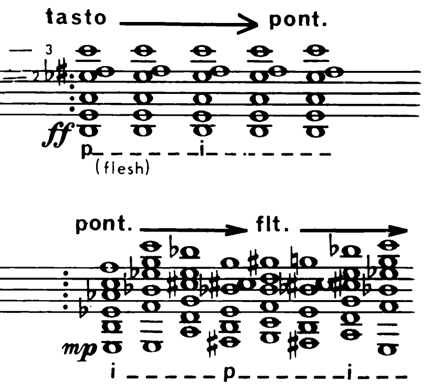
Gilbert Biberian goes one step further in his *Prisms II* (1970): he lists a catalogue of right-hand positions at the beginning of the work, and marks which fret of the fingerboard the player should play over for tasto (see Ex. 16). The position labels he uses are these:

4. "Tom Hartman," *Guitar* (November 1972): 14.

Fo.—Flautando; strike the note at the half-way nodal point (RH).
To.—Sul Tasto; RH placed between XIIth and XIXth frets, irrespective of pitch.
Bo.—Sul Boca; RH placed over the sound hole.
No.—Normale; RH between sound hole and bridge, nearer sound hole.
Po.—Ponticello; play as near the bridge as possible.
Fl.—strike with the flesh of the thumb.
Nl.—strike with the nail of the thumb.

Ex. 16. *Prisms II* (1970), G. Biberian. Used by permission.

The right-hand positions dealt with so far have been static, i.e., solely tasto or solely normal, but of course the right hand can change positions while plucking, producing corresponding changes of color. Giuliani first mentioned and described this technique in 1811. The change of the right-hand position can also be illustrated graphically, as in Tomás Marco's *Miriada* (1970), or an approximate indication can be given as to where the hand should be at any given moment, as in Bedford's *You Asked for It.*

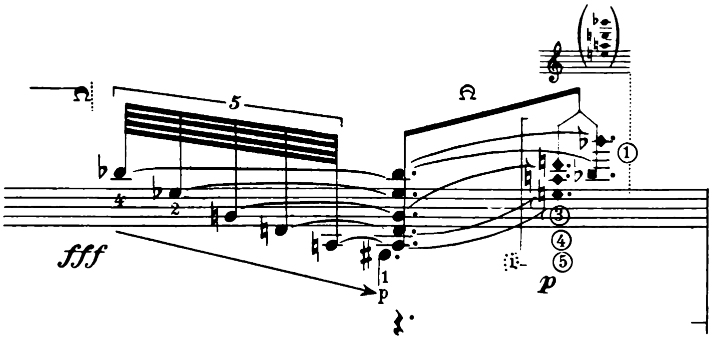


Ex. 17. *You Asked for It* (1969), D. Bedford. © 1973 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

These uses of the technique in a textural manner are special cases, however. A more melodic use can be found in *El Polifemo de Oro* (1:2-3) and in Richard Rodney Bennett's *Impromptus* (1968, 4:5-6), where the gradual transformation from the normal to the ponticello position prepares the listener for a ponticello section of music. A pictorial method of depicting changes of right-hand registration is given at the end of this chapter (p. 119).

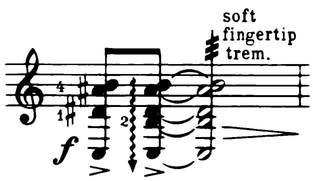
What to Pluck With

When a string and plucking position have been chosen for the production of a tone, the composer may choose the kind of object with which he wants the string to be plucked. During the nineteenth-century controversy over whether or not to use the nails, composers never specified in the score which method was to be used. In this century, the situation is quite different; it is common for the music to contain explicit directions pertaining to the material of the plucking object. Boulez often asks for certain passages to be played with the nails both in *Le Marteau* and in the orchestral piece *Pli selon Pli* (1958/62). In some cases, a special sound can be obtained by playing with the back of the nail. In Example 18, another percussive effect is added to the nail sound by playing a downward arpeggio *fff* with the back of the thumbnail touching the saddle of the bridge:



Ex. 18. *Las Seis Cuerdas* (1963), A. Company. © 1965. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

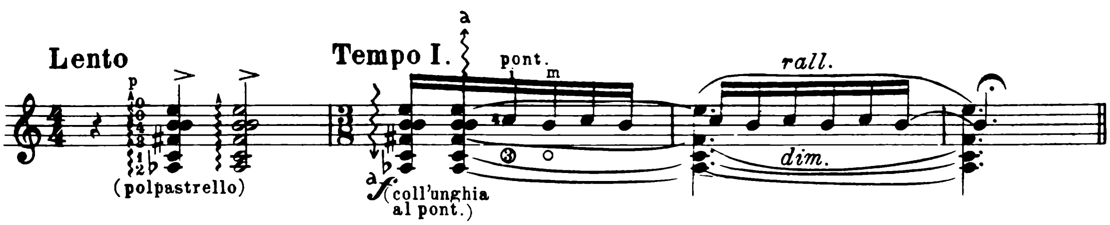
Players are often requested to play with only the flesh of the finger, which, because of the widening of the plectrum, produces a softer, rounder sound (see Chapter 2). This technique can be used effectively to create a dramatic diminuendo:



Ex. 19. *Do Not Go Gentle* (1976), R. Smith-Brindle. © 1976. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

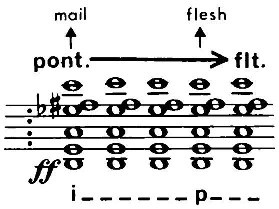
The flesh tone is also used by electric guitarists to contrast with the usual plectrum sound. Pelle Gudmundsen-Holmgreen asks in *Solo for Electric Guitar* (1971/72) that the third movement be played "without plectr. Use the soft part of the thumb near the bridge," while using a "dark timbre" setting on the guitar itself. Christian Wolff tells the guitarists in *Electric Spring III* (1967) to "pluck with fingers unless otherwise indicated," and in *Songs, Drones and Refrains of Death* (1968) George Crumb suggests that "the electric guitar is always to be plucked with the fingers unless a plectrum is specifically indicated." It is not surprising that Crumb uses the flesh tone predominantly, since he also asks that the reverberation control on the amplifier be set rather high, to suggest a "surreal quality," both effects lending themselves to the character of the text.

The opposite qualities of the flesh and the nail tone can be used to contrast a musical idea:



Ex. 20. *El Polifemo de Oro* (1956), R. Smith-Brindle. Courtesy of Aldo Bruzzichelli Editore, Florence, Italy.

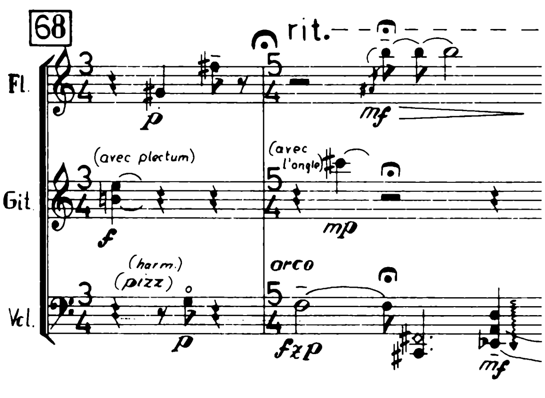
It can also be used to accentuate the differences between ponticello and tasto:



Ex. 21. *You Asked for It* (1969), D. Bedford. © 1973 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

Henze uses his own graphic signs for playing with the finger-tips or with fingernails in both *El Cimarrón* and its guitar solo counterpart *Memorias de "El Cimarrón."*

Use of the plectrum is now becoming commonplace in the guitar repertoire, especially when used with the classic guitar. One of the first post-war uses was by Stravinsky in the third movement of the *Four Russian Songs* (arr. 1954 for voice, flute, harp, and guitar), where the guitarist strums one chord throughout. Many composers ask for particular kinds of plectra, which change the quality of the sound. Henze asks the guitarist to play "sul tasto with soft plectrum" (*El Cimarrón*, 20:1); Walter Hekster calls for a "mandolin pick" in *Epicycle I and II* (1975); and Mauricio Kagel uses a metal plectrum and an "extremely hard" plectrum on the electric guitars used in *Sonant (1960/. . .)* and *Tremens* (1963/65). Ivan Tcherepnin even contrasts the sounds of nails and plectrum by using them in succession:

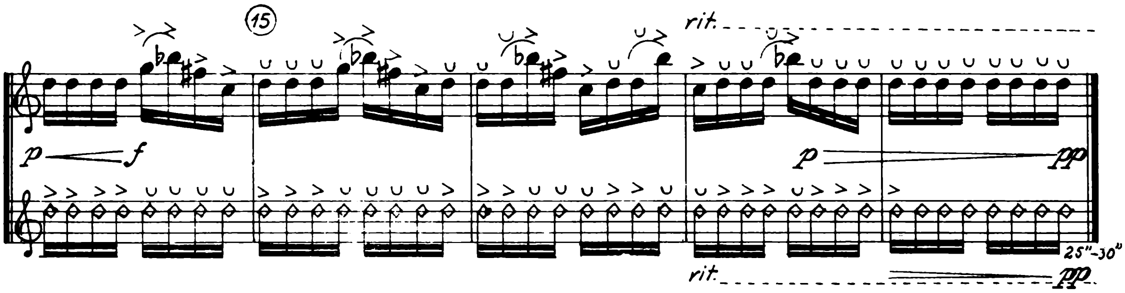


Ex. 22. *Sombres Lumières* (1964), I. Tcherepnin. © 1970 by M. P. Belaieff. By permission of C. F. Peters Corp., sole selling agents for the Western Hemisphere.

The most efficient way to notate use of nail, flesh, or plectrum is simply to mark the word above the passage in question (Recorded Ex. 26).

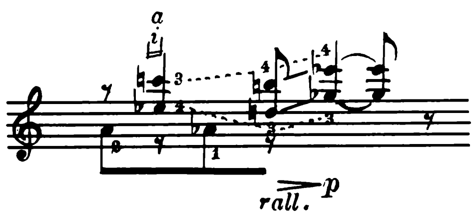
How to Pluck

Finally, after the string, placement, and plectrum have been chosen, the manner in which the string is plucked must be chosen by the performer. Since this choice affects the quality of the tone, the composer can also take this aspect of tone production into consideration when writing for the guitar. The notation of sound-production techniques for the guitar has, until the last decade, usually dealt with the sound produced rather than describing the exact action involved. The excerpt from Webern's *Drei Lieder* in Example 5 is a good illustration of that type of notation. The Dutch composer Bernard van den Boogaard has chosen to use dynamic markings to differentiate between two types of tone color in one section of his *Oilless Motors* (1973): "*mf* means for the two guitars a sharper point of touch on the strings than *mp*. For the harpsichord it means a subtle difference in registration (also in the sense of dull-sharp)." Boulez has marked the difference between accented and unaccented tones in *Le Marteau*, and Theodor Antoniou has used the tonal difference between two methods of note production to shift the emphasis away from the beginning of each bar:



Ex. 23. *Dialoge* (1963), T. Antoniou. Used by permission of Edition Modern, Munich.

How the guitarist chooses to create the differences between the accented and unaccented notes has usually been left up to the player, although it is usual for players to use a downstrike (apoyando) for an accented tone and an upstroke (tirando) for an unaccented tone. The acoustic difference between the two methods of string excitation is shown in Chapter 2; when a composer wants to differentiate between the two types of sounds, he should ask for them by using the violin notation for the different bowing directions: i.e., upstroke (tirando) = V , and downstroke (apoyando) = ⊓ . Peruzzi uses the downstroke sign inverted, and requests that three notes be played downstroke simultaneously:



Ex. 24. *Quattro Pezzi* (1974), A. Peruzzi. © 1974. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

Of course the two notes are played on strings one and two, because the method of downstroke dictates that the finger rest on the string below the one that is plucked.

The members of the Trio Chitarristico Italiano, who have been editing a guitar chamber-music series for Edizioni Suvini Zerboni of Milan, have invented terms to describe how the string should be plucked. After using "Tast.," "½ Tast.," "N.," "½ Pont.," and "Pont." to describe where the string should be plucked, they add:

> Whenever the above signs are followed by the letters A, D, and DD, the tone colour should be made harsh (Aspro), dolce (D), or dolcissimo (DD) by means of different angles [at] which the fingernails pluck the strings.[5]

This quite precise communication of musical interpretation can also be used by composers to orchestrate their guitar music more exactly.

One unconventional method of putting a string into vibration does not entail plucking it at all; instead, another string which shares the same pitch is plucked. The plucked string then excites the unplucked string through sympathetic vibration and creates a rather ghostly effect, a very different type of tone from the normal plucked-string sound:

Ex. 25. *Sonata* (1975), G. Biberian. Used by permission.

NEW SYSTEM OF RIGHT-HAND NOTATION: ALVARO COMPANY

The methods and notations discussed in this section have been the products of individual composers' expedient solutions to similar problems, some of which are more successful than others. It was not until the post-1945 era that someone tried to create a standardized right-hand notation that would take into account all aspects of right-hand technique: that person was Alvaro Company.

Company is an Italian guitarist who in the early 1950s became interested in expanding the timbral notation of the guitar. The culmination of this work can be found in his

5. A. Borghese, R. Frosali, and V. Saldarelli, "Signs and Symbols," from *Trio* per tre chitarre, Op. 26, by L. DeCall (Milan: Edizioni Suvini Zerboni, 1974).

composition *Las Seis Cuerdas* ("The Six Strings") (1963), one of the most fascinating works ever written for the solo guitar. It is not only a complex and rewarding musical statement written in the contemporary idiom, but it also manages to be an encyclopedia of the contemporary "extended" acoustic guitar techniques, using practically every sound-producing capability of the instrument. (Needless to say, this piece will be referred to often in the coming pages.)

In the section of "Signs and Symbols" committed to "Positions of the R.H. Fingernails on the Strings," Company states:

The symbol ——— represents the section of string between 12th fret and the bridge.

The symbol represents the fingernail.

The position of the sign on the line ——— indicates the point where the string must be plucked (from the 12th fret to the bridge).

The inclination of on ——— indicates the angle at which the fingernail plucks the string.

Fingernail inclined: *Fingernail straight:*

Side of the fingernail: *With the fingertips (without the nail):*

A FEW EXAMPLES:

Fingernail inclined at the 12th fret.

With the side of the nail at the soundhole.

Fingernail straight at the bridge.

(Without the nail) with fingertips at the fingerboard.

Pluck the string near the bridge, while touching the saddle of the bridge with the fingernail.

Pluck the string exactly midway along its vibrating length.

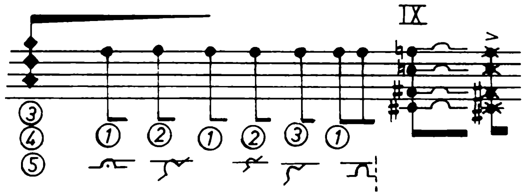
Examples of gradual and progressive changes.

The position of the r.h. fingernails shown in the above symbols remains unchanged until the sign: = end of fingernail position.[6]

The great advantage of this system of notation is that it transmits all the information at a single glance. One composite symbol tells the player where, with what, and how to pluck the string, as did the characters in the music for the ancient Chinese ch'in. Perfor-

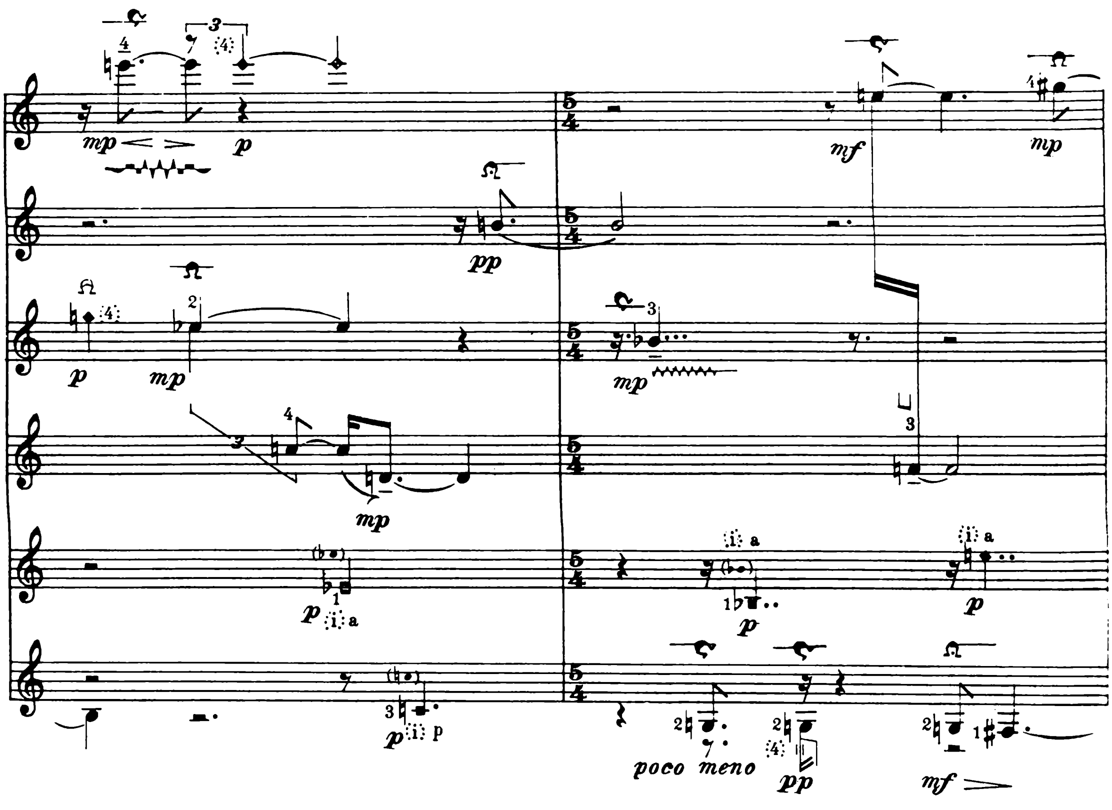
6. A. Company, *Las Seis Cuerdas* (1963) (Milan: Edizioni Suvini Zerboni, 1965).

mance of the following example of *Klangfarbenmelodie* would take much more space to describe in conventional word-symbols:



Ex. 26. *Omaggio a Gaetano Azzolina* (1972), B. Bartolozzi. © 1972. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

This sort of notation is by no means restricted to the contemporary repertoire. Alvaro Company uses this same system for editing many eighteenth- and nineteenth-century works. It is fitting to close this section on tone production with a few bars from *Las Seis Cuerdas*, which uses one stave per string:



Ex. 27. *Las Seis Cuerdas* (1963), A. Company. © 1965. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

PIZZICATO

The name of this technique, which literally means "plucked," is borrowed from the terminology of bowed string instruments. When a string is plucked, it is the pad of the left-hand finger, rather than a fret, that absorbs the highest frequencies of the vibrating string, and the soundpost inhibits the free vibration of the instrument top, producing a tone that is somewhat muffled. To imitate this tone on the guitar, the player must filter out these higher frequencies by using either the pad of the right hand on the bridge and strings or the pad of the left-hand finger on top of the fret (see Chapter 2). In the guitar literature, pizzicato is also called *apagado* or *sons étouffés.* The term *left-hand pizzicato* is sometimes mistakenly used to describe a tone produced by striking the string with the left-hand finger, the technique called *hammering on* in the folk tradition of guitar playing. This type of tone is really a *bi-tone* (discussed in the next section), and the term should be reserved for the sound it accurately describes.

Most guitarists believe that the right-hand palm technique is the best, if not the only, way to play pizzicato. It is interesting that as early as 1830 Sor suggested:

> To damp or check the sounds, do not employ the right hand, but place the fingers of the left hand, so as to take the string on the fret which determines the note, pressing it with less force than usual, but not so lightly as to make it yield an harmonic sound. The manner of damping or buffing requires great accuracy in the distances; but produces true suppressed sounds.[7]

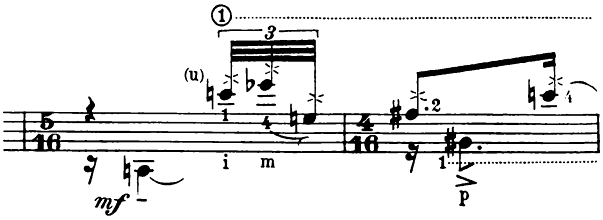
Pujol describes four kinds of right-hand pizzicati in his *Escuela Razonada de la Guitarra* (1956). *Pizzicato étouffé* and *pizzicato normal* differ only in the number of strings that are covered by the palm: both use the little finger on the soundboard as a support. *Pizzicato ouvert* places the hand on the bridge, but without touching the strings. The last type, *pizzicato strident* (or *harsh*), is said to imitate the bassoon or a muted trumpet. This effect is achieved by placing the palm of the hand halfway between the bridge and the soundhole and plucking the appropriate string with the thumb so that the string bounces against the hand, producing a nasal or harsh sound.[8]

Pizzicato should be notated by marking the word itself or its abbreviation *pizz.* over the appropriate passage, and the effect is cancelled by the marking *normale.* Britten uses the abbreviation *pizz.*, accompanied by the use of accent marks over each note to be played using this technique, in *Nocturnal* (1963, 12:4). In that piece, as in most others, pizzicato has been used in an either/or manner, but pizzicato and normale can also be employed simultaneously, with the bass strings muted and the treble free:

Ex. 28a. *Las Seis Cuerdas* (1963), A. Company. © 1965. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

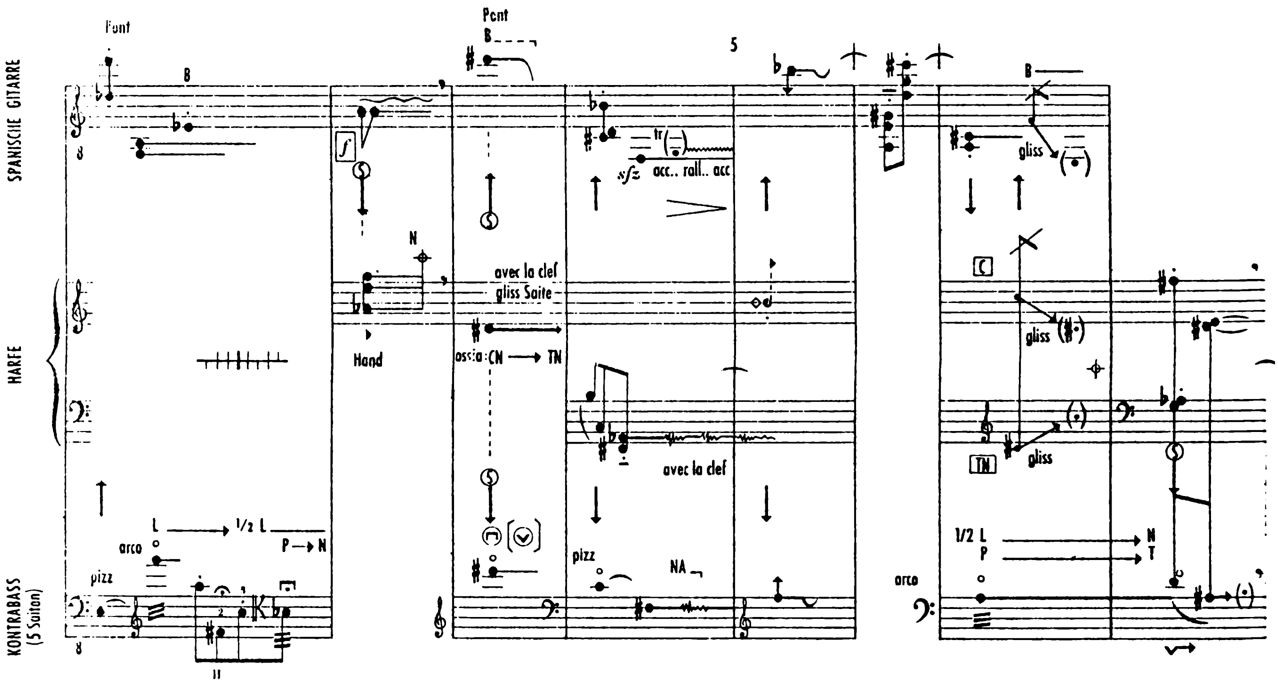
7. Sor, op. cit., p. 5.
8. Pujol, op. cit., book four, pp. 132–35.

Or vice versa:



Ex. 28b. *Las Seis Cuerdas* (1963), A. Company.

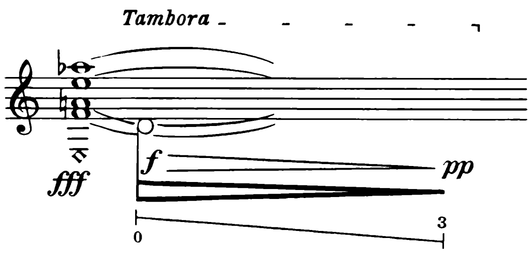
Company notates damped notes with an *x* on the stem ( ). To damp the treble notes, the little finger (u) of the right hand damps one string at a time near the bridge (see Ex. 28b). Guitarist Alexander Lagoya likens this effect to the lute stop on a harpsichord.[9] For the left-hand étouffé Kagel uses the abbreviation *B* for *Bund* (German for "fret") over the appropriate notes:



Ex. 29. *Sonant (1960/. . .)*, M. Kagel. © 1964 by Henry Litolff's Verlag. By permission of C. F. Peters Corp.

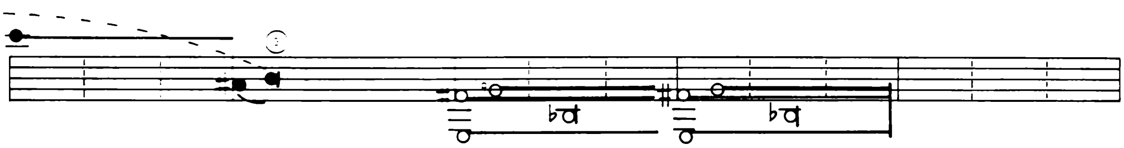
The act of filtering the string tone can be made audible, as was described in Chapter 2. Cristobal Halffter uses a double decrescendo sign for this effect, with the instruction. "Dampen slowly with the right hand, beginning at the bridge":

9. Interview with Peter Sensier on *The Classical Guitar,* BBC Radio 3, 12 April 1976.



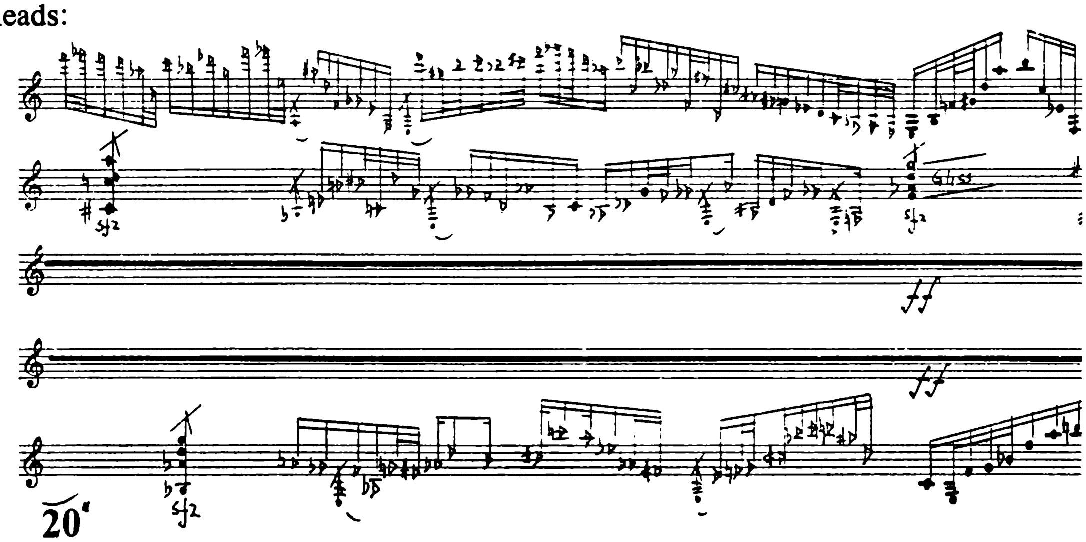
Ex. 30. *Codex I* (1963), C. Halffter. © 1968 by Universal Edition, Vienna. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

Once the higher harmonics have been filtered out, a note can then be allowed to ring on in its filtered version without the interference affecting the duration of the note. This effect, called *étouffé resonance*, is produced by removing the damping object from the string/s as soon as they are plucked. George Kröll notates this effect in *Estampida* (5:6–7) with a crescendo mark under the notes marked *pizz.* Company's notation uses two lines on either side of the note stem ( ), and if the damping is to be done with a finger of the left hand, the damping finger is given in dotted parentheses ((4)) (see Ex. 27). Bent Lorentzen uses a similarly graphic symbol ( ) for damping in his somewhat unconventional guitar notation:



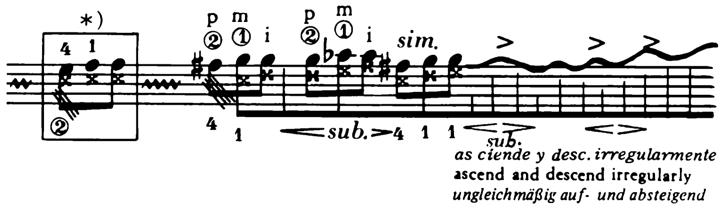
Ex. 31. *Umbra* (1973), B. Lorentzen. By permission of Edition Wilhelm Hansen, Copenhagen.

Another category of left-hand pizzicato produces pitched unfretted sounds. For this effect, the left-hand fingers rest lightly on the string without pressing the string to the fingerboard. Biberian calls this "surface pizzicato" and notates the effect with triangular note-heads:



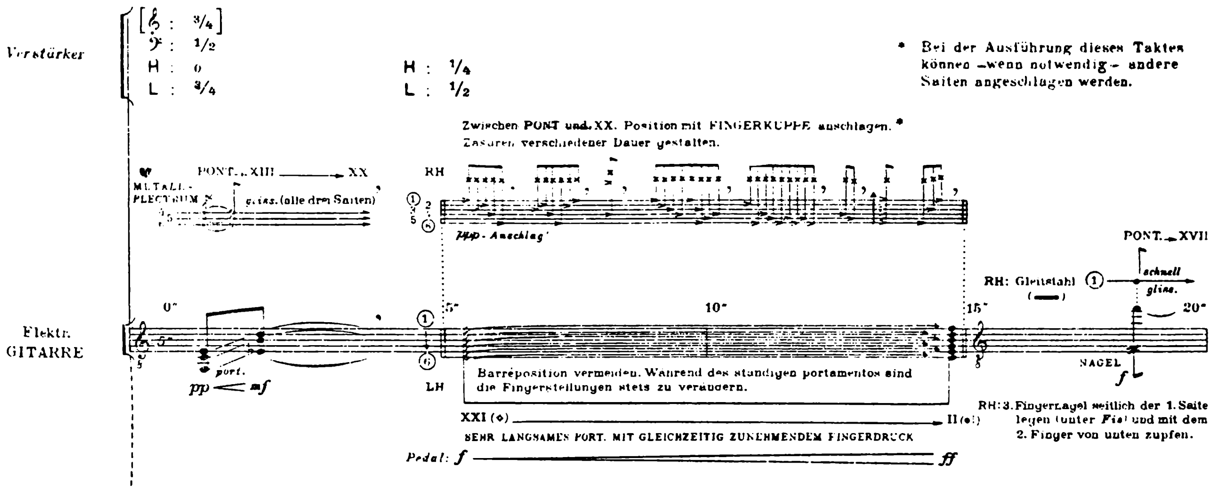
Ex. 32. *Prisms II* (1970), G. Biberian. Used by permission.

Leo Brouwer, who notates this effect by putting an *x* next to the note stem, uses it in an irregularly ascending glissando:



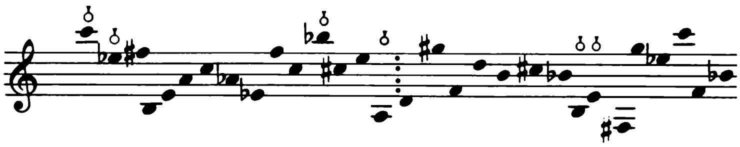
Ex. 33. *La Espiral Eterna* (1971), L. Brouwer. © 1973 by B. Schott's Söhne, Mainz. Used by permission of European American Music Distributors Corp., sole U.S. agent for B. Schott's Söhne, Mainz.

Because this figure involves sliding up the strings, Brouwer suggests that a better sound is achieved if the strings are touched with the left-hand fingernails. In *Tremens*, Kagel not only slowly changes the pitch when using this technique, but also indicates that the finger pressure should gradually increase:



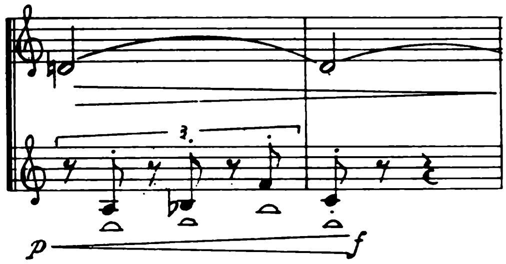
Ex. 34. *Tremens* (1963/65), M. Kagel. © 1973 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

Another type of pizzicato borrowed from the string literature is the *Bartók* or *snap pizzicato* (usually notated ⏁), in which the string is lifted perpendicular to the soundboard and allowed to rebound against the fingerboard with a snap. David Bedford makes good use of this effect as an alternating texture where the ⏁ are to be played *fff* and the ● *mp*:



Ex. 35. *You Asked for It* (1969), D. Bedford. © 1973 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

The Bartók pizzicato is often used as an either/or texture, as in the example above, but it also can be used in any dynamic range and can be musically phrased like any other sound, as Theodor Antoniou does in *Dialoge* (pizzicato notated):



Ex. 36. *Dialoge* (1963), T. Antoniou. Used by permission of Edition Modern, Munich.

When Pelle Gudmundsen-Holmgreen uses the snap pizzicato on electric guitar in *Solo for Electric Guitar* (1971/72, I), he says that the string should "attack the pickup directly."[10] This aggressive sound combines the noise content of percussion with the advantages of a pitched sound. Hifumi Shimoyama uses a special kind of snap pizzicato that directs the player to "push the string violently at the holes level (S) and take the finger off immediately. The sixth string sounds with a bang, and is notated by " in his *Dialogo No. 2* (4:3.3).[11]

Ho Wai On, in her *3:10 A.M.* for guitar and viola, calls for another kind of special snap pizzicato. She asks that the string be plucked up and toward the treble strings with the flesh of the thumb, so that the string bounces onto the fingerboard at an oblique angle. This type of sound (notated by the sign) is quite different from the standard snap pizzicato; the composer compares it to the sound of the koto.[12]

It should be remembered that pizzicato is a *treatment* of musical tones, and can be used on practically any tone the guitar can produce. For example, damping pizzicato has been used on harmonics (Britten, *Nocturnal,* 12:5.1), and on crossed strings and clusters (Jolivet, *Deux Etudes,* 1965, 6:6.3), and the Bartók pizzicato has also been used on har-

10. P. Gudmundsen-Holmgreen, *Solo for Electric Guitar* (Copenhagen: Editions Wilhelm Hansen, 1974).

11. H. Shimoyama, *Dialogo No. 2* per due chitarre (Milan: Edizioni Suvini Zerboni, 1969).

12. Ho Wai On, *3:10 A.M.* (unpub.), 2 : 2.

monics (Kröll, *Estampida*, 1968, 4:7–) and on crossed strings (Corghi, *Consonancias y Redobles*, 1973, 2:), and on anywhere from two strings (Brouwer, *La Espiral Eterna*, 9:4) to five (Kagel, "Faites votre jeu I," *Sonant (1960/. . .)*, 1:3.5). (See Recorded Ex. 27.)

BI-TONES

One other technique is often described as pizzicato: when a string is made to vibrate by hammering-on (i.e., by striking the string at the appropriate fret with a left-hand finger), two notes emerge—one from the length of string between the fingered fret and the bridge, and one from the length of string between the fret behind the left-hand finger and the nut. This double sound, a *bi-tone*, has been called *left-hand pizzicato* in most guitar literature.

The relationship between the upper bi-tone is not a chromatic scale from fret to fret, as it is for the normal vibrating portion of the string. To determine the distance between the frets, the luthier takes a certain percentage of the length of the vibrating string in order to raise the pitch by an equal-tempered semitone. To find the distance of the first fret from the nut, the whole (65 cm) length is divided by 1.059. . . .($\sqrt[12]{2}$). To find the location of the second fret, the new string length (between the first fret and the bridge) is divided in the same proportion, and so on. This explains why the distance between the frets diminishes from the nut to the end of the fingerboard. For the upper bi-tone, however, the shorter its string length becomes, the *further* apart the frets become, and this produces a rather uneven scale with microtones at one end and large intervals at the other. (See Recorded Ex. 28.)

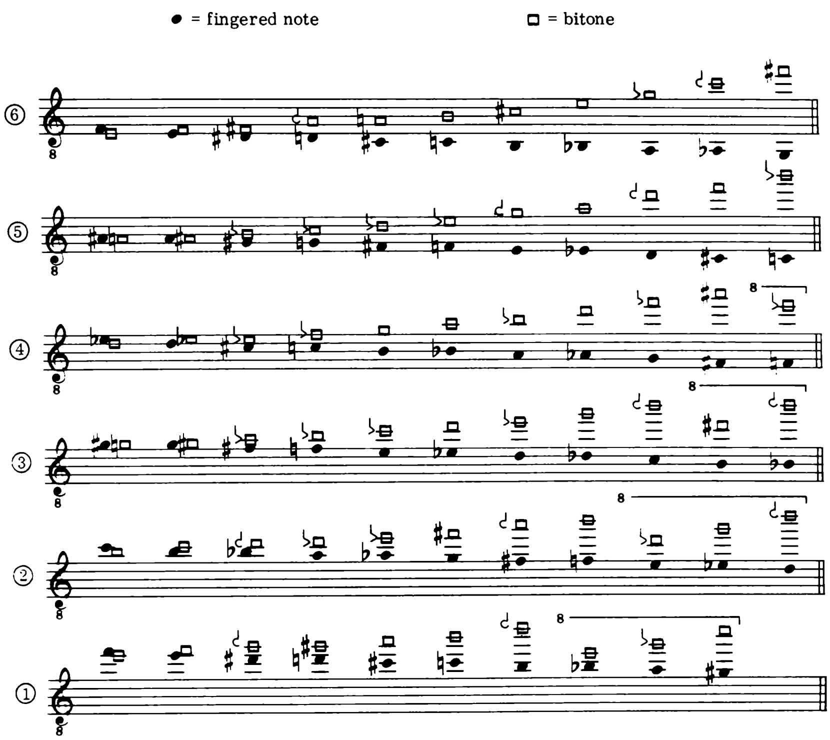
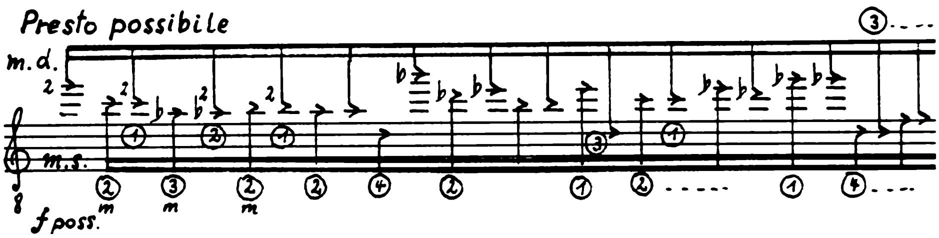


Fig. 81. The chart of bi-tones.

Fig. 82. The scale of bi-tones.

The infamous Futurist Luigi Russolo was one of the earliest to mention this technique. In 1926 he invented a device for bringing about the "simultaneous and independent vibration of two segments of the same string, thus producing a bitonal combination of two complementary sounds."[13] Left-hand pizzicato has of course been used in guitar music for a long time, but the bi-tonal aspect of this kind of tone production was not explored until the post-war era. This left-hand pizzicato is usually notated with a wedge-shaped note head:



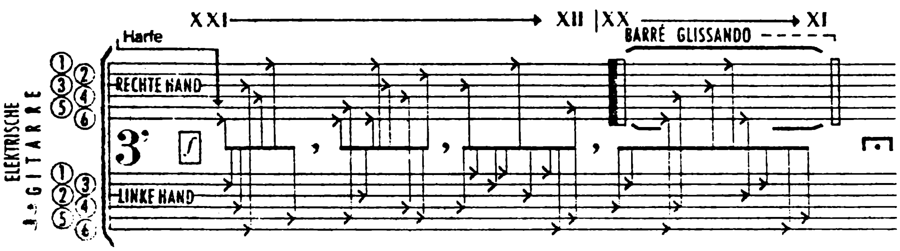
Ex. 37. *Estampida* (1968), G. Kröll. © 1970, Ars-Viva-Verlag, Mainz.

Right-hand and left-hand hammered-on pizzicato, a popular texture in many modern pieces, takes a good deal of practice for the performer because the right hand is not usually trained for this sort of activity, and the fingernails often get in the way.

Rather than notate the pitch placement of the right and left hands, some composers prefer using tablature. This is a reasonable approach. After all, even if left-hand placement is notated accurately, the pitch of the upper bi-tone is not indicated, so even that form of notation approaches tablature, in the sense that the symbols describe what is done rather

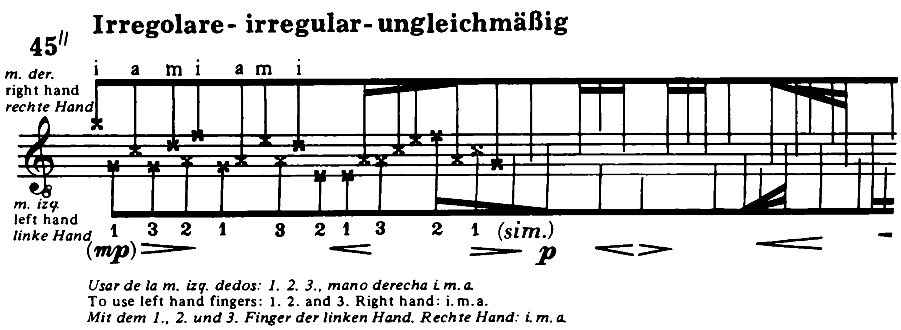
13. Quoted in B. Turetsky, op. cit., p. 100.

than what is heard. Kagel uses right-hand and left-hand pizzicato (sometimes referred to as "flutter fingers") in a purely textural manner, and gives a staff of tablature for each hand:



Ex. 38. "Faites votre jeu II," *Sonant (1960/. . .)*, M. Kagel. © 1964 by Henry Litolff's Verlag. By permission of C. F. Peters Corp.

Leo Brouwer uses the same texture, phrased more subtly:

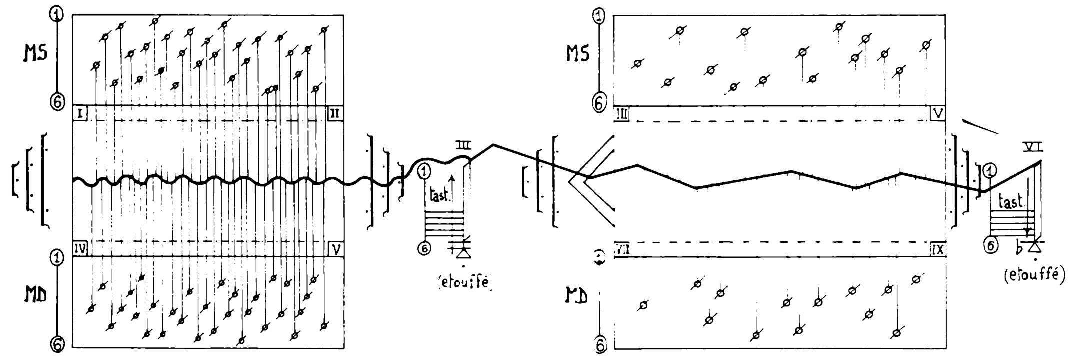


Ex. 39. *La Espiral Eterna* (1971), L. Brouwer. © 1973 by B. Schott's Söhne, Mainz. Used by permission of European American Music Distributors Corp., sole U.S. agent for B. Schott's Söhne, Mainz.

The musicality of this kind of technique cannot really be imagined; one must hear it to comprehend both the complexity and fragility of texture that it is capable of producing.[14]

Once bi-tones began to be used as musical material, many composers started using only the upper tone, that produced between the left hand and the nut. This tone has been found in non-fretted string music for several years, the most memorable use being in George Crumb's *Black Angels* for electric string quartet (1968), in which the violins are held like gambas, and notes are bowed above the fingers (AF). In *Tremens*, Kagel obtains the upper bi-tone by asking for a left-hand pizzicato and then damping the other half of the string with the right hand by notating *pizz.*; and in *Consonancias y Redobles* Azio Corghi compares the sounds of the left-hand pizzicati (bi-tones) with those of the right-hand-damped/left-hand-pizzicato (upper bi-tones) by using the right elbow (<<) to damp the strings from the bridge:

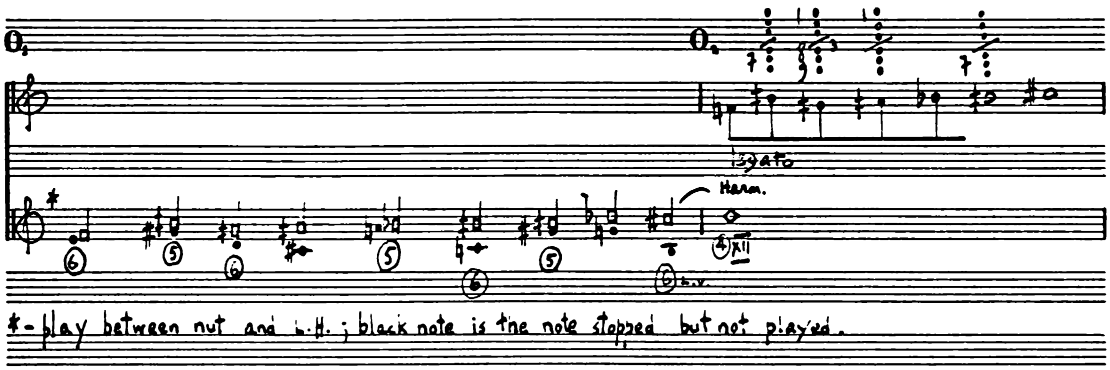
14. I strongly recommend listening to Brouwer's own rendition of this piece on the record *Les Classiques de Cuba*, Erato STU-70669.



Ex. 40. *Consonancias y Redobles* (1973), A. Corghi. © 1974. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

Of course, a gradual transition from left-hand pizzicato to the upper bi-tone alone can easily be achieved by slowly damping the right-hand portion of the string from the bridge.

Plucked upper bi-tones have also been used, notated either by left-hand finger placement, as Peruzzi does with a specially marked ① stem in his *Quattro Pezzi* (1974, 9:1), or by marking the finger placement *and* the sounding note:



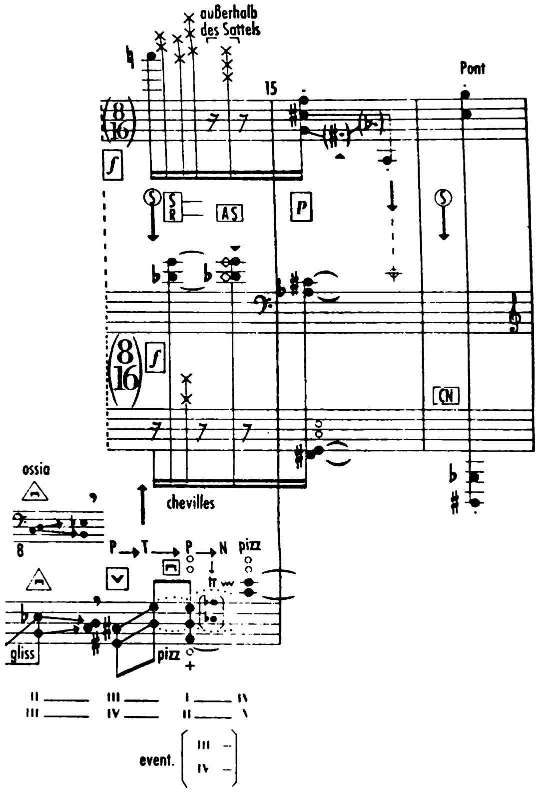
Ex. 41. *Sonata* (1975), G. Biberian. Used by permission.

The great limitation of the bi-tone is that the upper note is much quieter than the lower note: the latter has the soundboard to amplify it, whereas the former is heard only through the vibrations in the neck. Electric guitarist and improviser Fred Frith has designed a special pickup that swings down on the bridge from the nut and amplifies the upper bi-tone.[15] Plate V shows him bowing a drone note on the upper side of the capo-divided string and playing bi-tones and artificial harmonics on the other side. When the capo is not used, the upper bi-tones can be amplified to equal the volume of the signal from the normally vibrating segment of string.

There are two more sources of high-pitched low-dynamic notes on the guitar: the lengths of string above the nut, and those between the bridge and the string fastenings.

15. L. Bosman, "Fred Frith—Expanding Horizons," *Guitar* (April 1976): 17.

Biberian uses arpeggiated above-nut tones as texture in *Prisms II* (1970), as does Lukas Foss in the solo guitar part in *Fragments of Archilochos* (1965, 17:1.1–2). Kagel uses these tones as part of a phrase, contrasting them with indeterminate high pitches notated with *x* note-heads:



Ex. 42. "Marquez le jeu (à trois)," *Sonant (1960/. . .)*, M. Kagel. © 1964 by Henry Litolff's Verlag. By permission of C. F. Peters Corp.

Below-the-bridge notes are a viable source of fixed-pitch sounds on bridgepiece guitars and have been used extensively in music for violin and other bowed string instruments. Arne Mellnäs, in *Tombola* (1963), has used this type of sound inventively. Behind-the-bridge notes are notated by I and are both arpegiatted (13:4) and played individually (13:6). However, on the classic guitar the lengths of string between the saddle and the actual fastening point on the bridge are extremely short. Xavier Benguerel does ask for the strings behind the bridge to be strummed on the classical guitar in *Versus* (1974), but the effect is much more percussive than pitched (3:5.1).

The best notation for bi-tones is the wedge-shaped note-head (> or <), and the clearest notation for upper bi-tone only is to indicate both fingered and sounding notes.

HARMONICS

To use harmonics is one of the easiest ways to extend the range of the guitar. Just as pizzicato filters out the high partials in a string's tone, production of harmonics can be understood as isolation of certain partials in a note by cancelling out most of the other partials present. As Joseph Needham points out, this technique has been used throughout the history of stringed instruments:

> Recognition of individual harmonics, "floating sounds," using the same string, was already well advanced in the time of Hsi Khang [A.D. 223-262]. In Europe on the contrary this came very late, not before the eighteenth century. Indeed, the technique of playing the ch'in mainly depends on exploiting the production of different timbres at the same pitch, and this was already developed to perfection by the later Sung [twelfth century A.D.].[16]

Mauro Giuliani's use of the third, fourth, fifth, and sixth harmonics on the guitar A-string to play a triadic melody was in a variation (No. 7 of his Op. 6, 1811) whose musical context probably prompted the use of the technique. Fernando Sor spends several pages of his *Méthode* in describing the production and use of both natural (open-string) and artificial (stopped-string) harmonics, and his *Etude* 21, Op. 29, is entirely open-string harmonics. Besides the usual manner of producing the artificial octave-harmonic by plucking and stopping a string with the right hand, Sor suggests

> employing the same means as on a violin, by determining the note with the forefinger and doing with the little finger at four frets' distance what is done with another finger on the fourth to produce the double octave. This method is a little more promising, but there is the inconvenience of being obliged to contract the distance between the two fingers in proportion as the hand approaches the body of the instrument.[17]

Tarrega supplies a method for playing open-string harmonics with the left hand alone:

> Place finger 4 over the fret at which the harmonic is to be produced, and touch the string "harmonically," and let finger 1 (separated by two fingerbreadths from 4) pull the string back with its tip-joint; on releasing the string the harmonic tone will sound.[18]

Harmonics are produced by artificially introducing a *node* in a vibrating string, which forces the string to vibrate in one of its *modes* (see Chapter 2). Since a node divides the string into equal sections, a string vibrating in a mode of many sections has several nodes. For example, when the fifth harmonic is played, the string is divided by four nodes into five sections of equal length. Therefore, if the player creates a node at any one of these four points, the fifth harmonic will sound (a frequency five times as high as the open string). Figure 83 is a chart of the first five harmonics (nos. 2-6, the fundamental being no. 1) on all six strings, and Figure 84 shows the scale of open-string harmonics (see Recorded Ex. 29). It must be remembered that these notes really *are* harmonics and are not the

16. J. Needham, *Science and Civilization in China* (London: Cambridge University Press, 1962), p. 287.
17. Sor, op. cit., p. 24.
18. Roch, op. cit., p. 101.

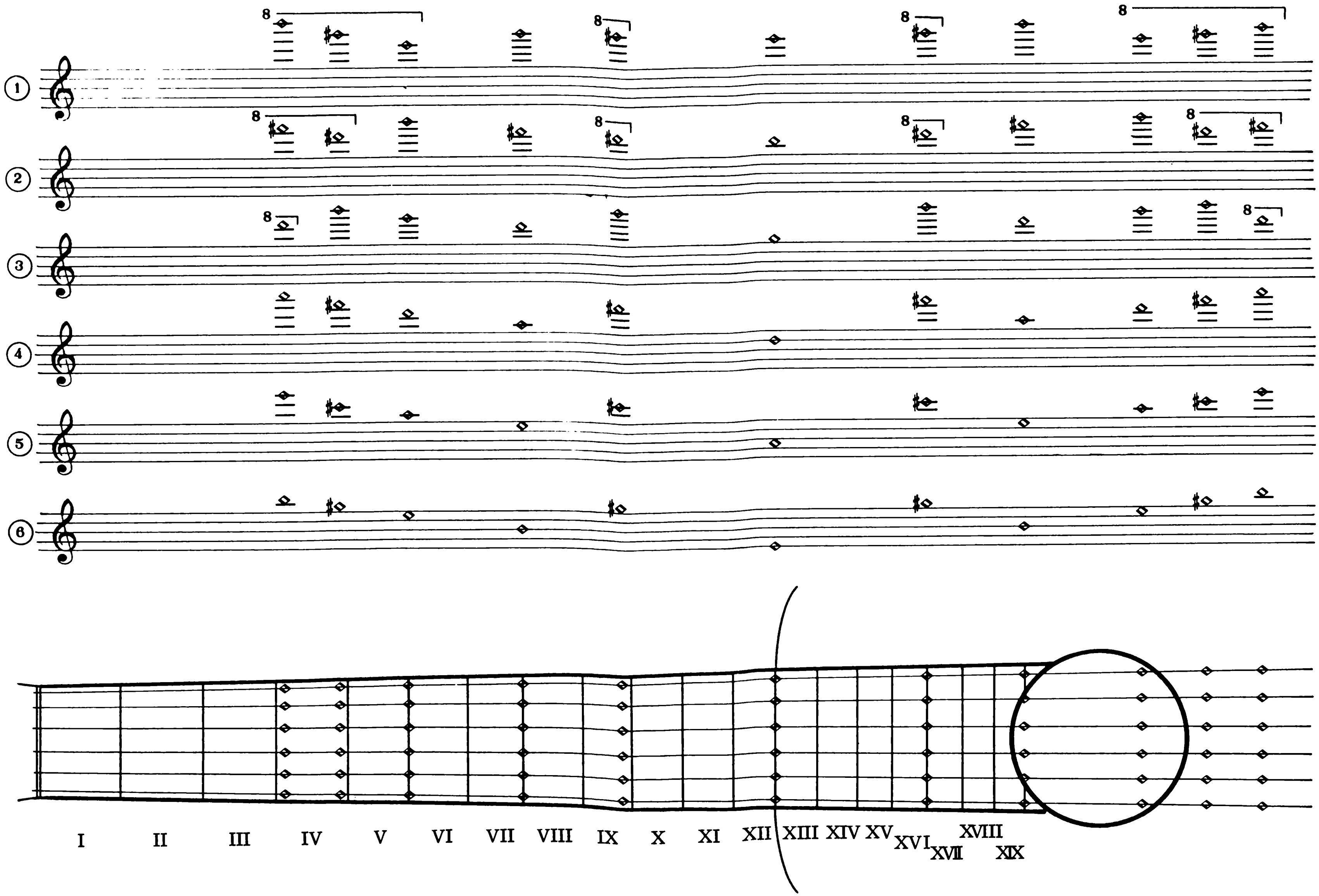


Fig. 83. Chart of open-string harmonics.

equal-tempered notes that the notation suggests. (A quick way to prove this is to compare the harmonic G#–IV⑥ with the fretted note G#–IV①. Harmonics should be notated by a diamond-shaped note-head at the pitch of the resulting sound; this information can be supplemented by including the string and/or fret number above the note-head.

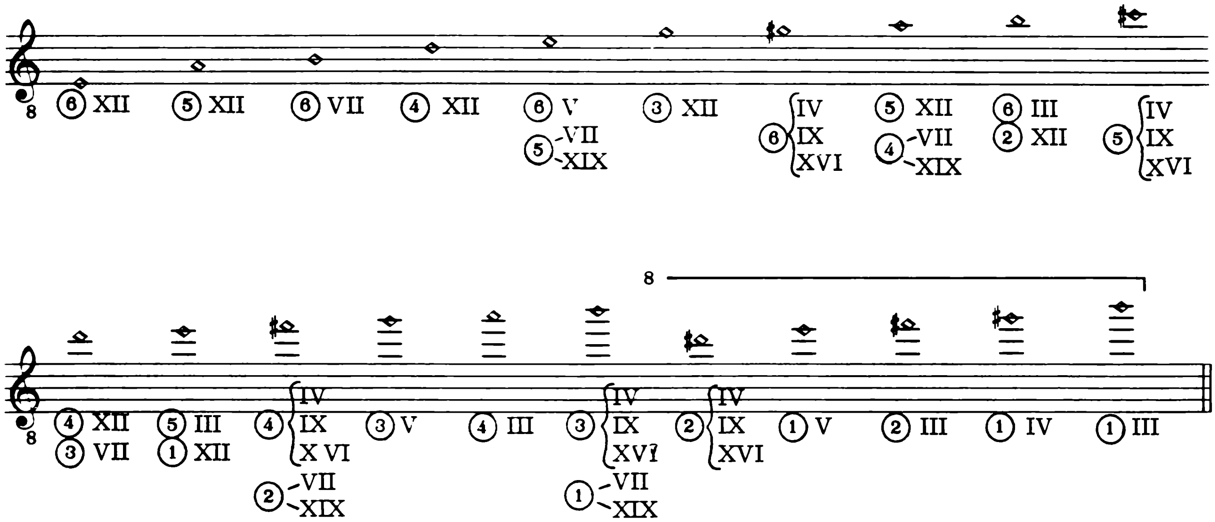
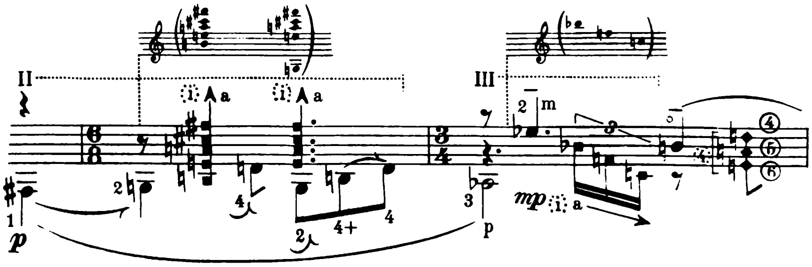


Fig. 84. Scale of open-string harmonics.

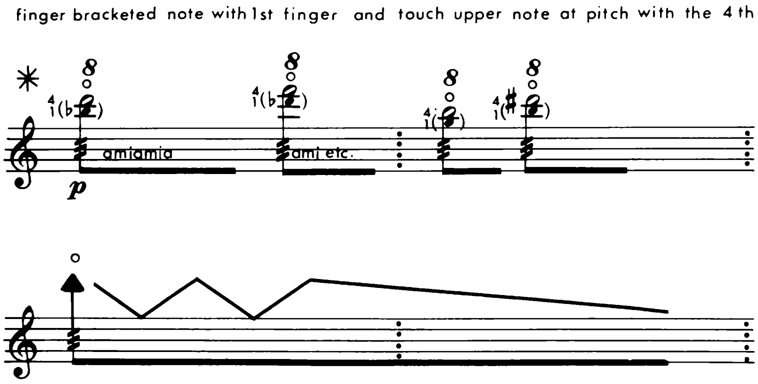
Any guitar pitch can be raised an octave by using artificial harmonics: the left hand stops the string at the desired pitch and the right hand produces the node at the string's midpoint with the index finger while plucking the string with the thumb or any other finger. An extremely beautiful effect with artificial harmonics can be produced by strumming upward or downward arpeggios with the "a" finger and creating nodes simultaneously with the "i" finger. If the left hand is playing a chord with notes held down on different frets, the right hand will play the sixth harmonic of some notes and perhaps the seventh or eighth of others. This effect is most pronounced when performed on steel strings (see Recorded Ex. 30).

Harmonics have always been valued for their distant and ethereal quality, often echoing thematic material; but in the second half of the twentieth century they have been used as musical material in their own right. One famous example by Britten contrasts first-position chords with a *pp* artificial-harmonic melody in the "Dreaming" section of his *Nocturnal* (8:1–6). Too few composers have managed to integrate artificial harmonics into a polyphonic texture. Alvaro Company again proves to be an exception, with his sprightly (♩= 112) second movement of *Las Seis Cuerdas*, which even includes arpeggiated artificial-harmonic chords:



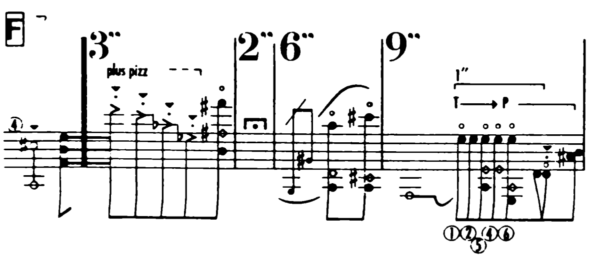
Ex. 43. *Las Seis Cuerdas* (1963), A. Company. © 1965. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

Other interesting uses of harmonics include Bedford's use of left-hand stopped fourth and fifth harmonics, and also his notation for very high harmonics (↑), which tend to sound like unfretted pizzicati when tremoloed and glissed:



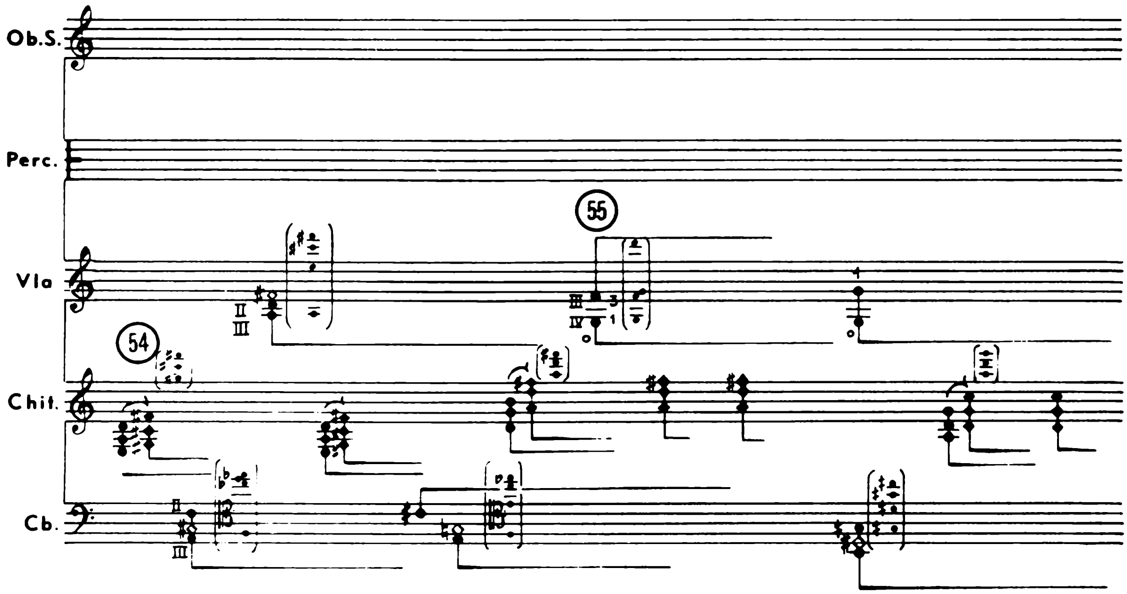
Ex. 44. *You Asked for It* (1969), D. Bedford. © 1973 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

Francis Miroglio uses the symbol ▲ to designate very high harmonics in the electric guitar part of *Tremplins* (1968, 10 : .4). Because harmonics of the same pitch but different timbres can be produced on several different strings, they can easily be used for the construction of *Klangfarbenmelodien*:



Ex. 45. "Faites votre jeu I," *Sonant (1960/. . .)*, M. Kagel. © 1964 by Henry Litolff's Verlag. By permission of C. F. Peters Corp.

The process of audibly filtering out harmonics from already plucked strings, a useful application of harmonic production, has been used by Bartolozzi as part of an ensemble texture:



Ex. 46. *Concertazioni per Oboe* (1965), B. Bartolozzi. © 1966. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

Right-hand plucking techniques can alter the tone quality of a harmonic; Petrassi has specified that the artificial harmonics in the Adagio of *Nunc* (1971) be played "with the nail."[19] George Crumb asks that the electric-guitar harmonics in "Casida Del Herido por El Agua" from *Songs, Drones and Refrains of Death* (1968) be played with the fingertips.[20]

A very subtle use of harmonics is achieved by playing several harmonics above a harmonically unrelated note. By altering the implied spectral envelope of the lowest tone, this gives the aural impression of a totally new timbre. The effect of this almost multiphonic timbre, which Bartolozzi would probably call a "sonoric amalgam," is further strengthened by that composer when he asks that the harmonics be played ponticello in his *Concertazioni per Oboe* (6 : 2).

In general, harmonics are a very versatile extension of the guitar's pitch and timbral range.

MULTIPHONICS

In the early 1960s, Bruno Bartolozzi published *New Sounds for Woodwind* (Eng. translation, 1967), a culmination of his exploration of new playing techniques and their applications. He and his fellow workers discovered that each member of the woodwind

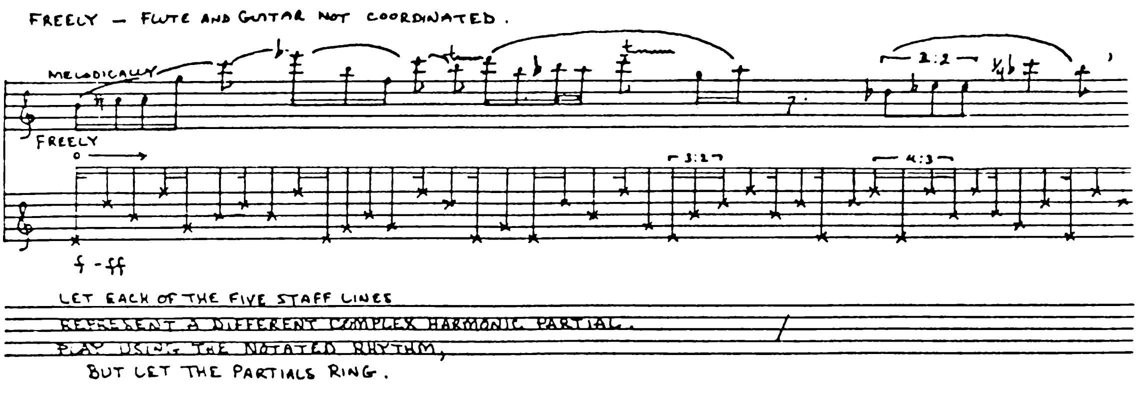
19. G. Petrassi, *Nunc* (Milan: Edizioni Suvini Zerboni, 1972), 7 : 2–3.
20. G. Crumb, *Songs, Drones and Refrains of Death* (New York: C.F. Peters, 1971), 21 : 2.

family could produce not only traditional monophonic music (one note at a time), but also chords and *multiphonics.* Multiphonics occur when, through the use of unusual performance techniques certain partials normally present in a tone are made to stand out or by changing embouchure or fingerings, new partials are created. That is, the traditional hierarchy within a tone's harmonic structure is changed so that the partial/s become more dominant than the fundamental of a tone and produce chords of equally loud frequencies. These multiphonics can also be produced on the guitar.

As was mentioned in the previous section, the higher harmonics on a vibrating guitar string create many equally spaced nodes, and some of the nodes will overlap if the harmonics are numerically related. For example, all even harmonics share the node at the midpoint of a string, and all harmonics that are multiples of four share a node at the fifth fret. It is also well known that the stronger lower harmonics will sound even if the node-producing finger is not touching exactly the right point on the string. The combination of these two phenomena enables the player to produce more than one harmonic—even up to five or six—on a string at a time. This effect works much better on the lower three wound strings than on the upper nylon strings.

Multiphonics should be notated by ✣ (a tilted double-sharp sign), with the string number and fret placement; the note-head should lie on the staff where the note would sound if the finger were pressed to the fingerboard. For example, ⑥ ¼ XIX means "touch the sixth string at the point that is one-fourth the length of the ninth fret from the nut"; ⑥ XIX tells the player to place his finger directly over the fret wire. Figure 85 is a chart of the multiphonics on the three wound bass-strings. In order to verify which partials are in any particular multiphonic, place the left-hand finger on the desired spot and play artificial harmonics with the right hand along the entire length of the string, from the 12th fret to the bridge. The left-hand finger will cancel any harmonics that do not have a node at that spot, so the right hand will pick out the partials one by one. (See Fig. 85.)

Multiphonics are quite rare in guitar literature, although William Bland, who has worked with guitarist David Starobin, has used them in several of his pieces. Bland calls these sounds "complex harmonic partials." He uses them singly in his *An Impression of Crumb* (1975); in an untitled duo, several occur in a repeating succession of rapid notes:



Ex. 47. *Untitled Composition in Three Sections* (1975), W. Bland.

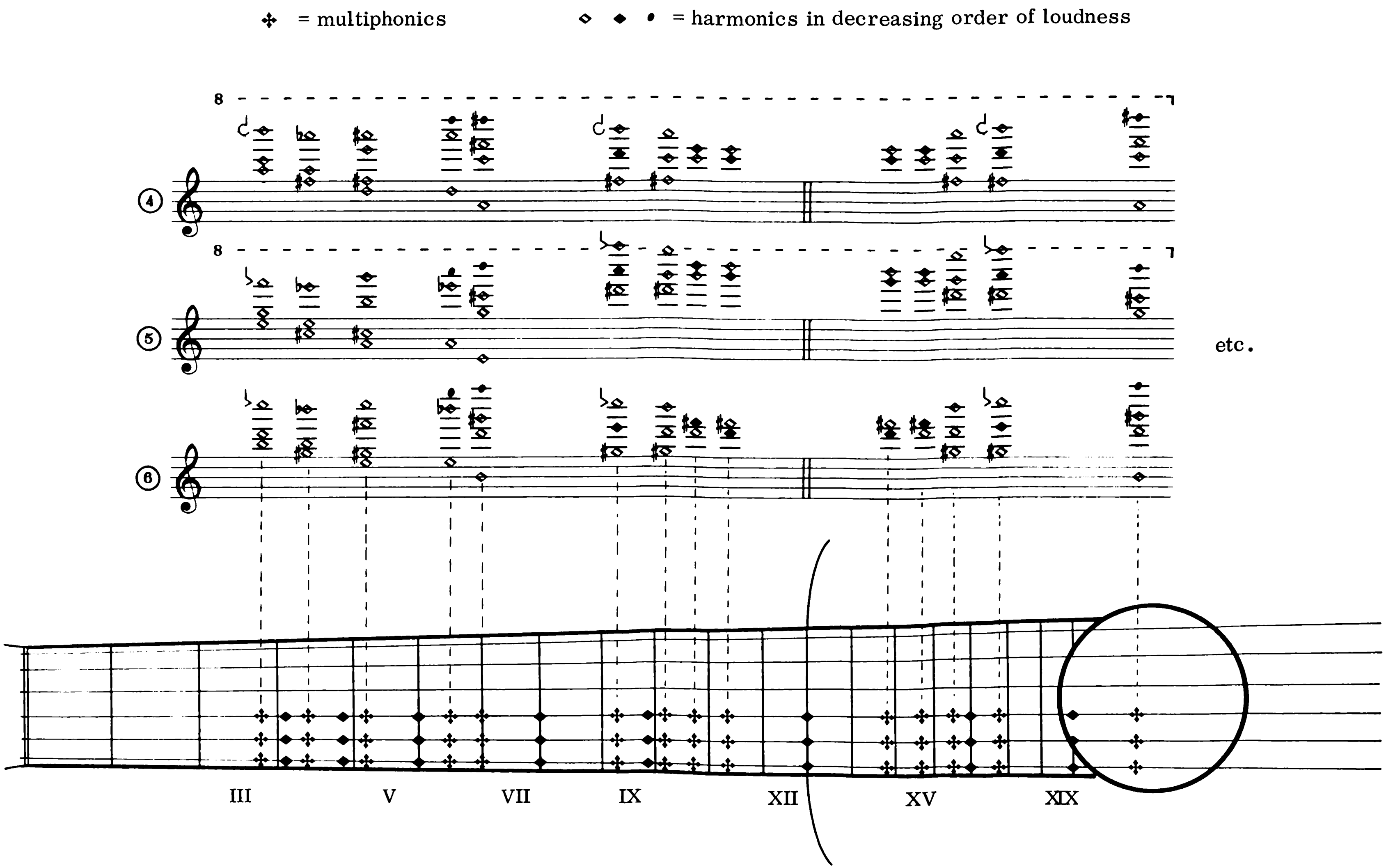


Fig. 85. Chart of multiphonics on the bass strings.

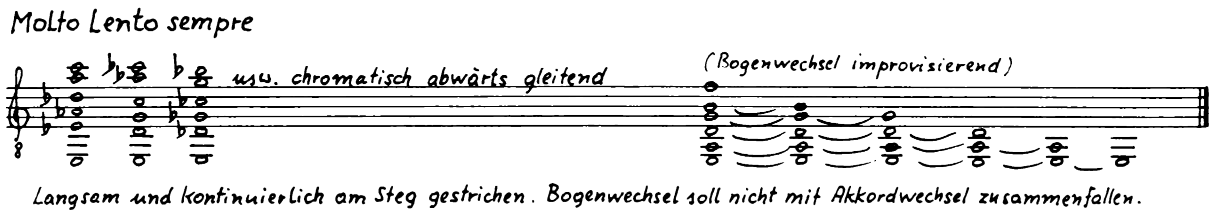
The quality of open-string multiphonics is quite chordal, but usually sounds bell-like (see Recorded Ex. 31). These new sounds should become a part of the guitar's vocabulary as composers find good musical uses for them.

ARCO

One definite drawback of the acoustic guitar is that it is incapable of producing sustained tone. The well-known nineteenth-century luthier J. G. Staufer, believing that a bow would solve this problem, invented the "Arpeggione" (also known as *chittara col arco* or *guitare d'amour) in 1823. This instrument had six strings, metal frets, and a curved finger*board, and closely resembled a viola da gamba. It did not survive the test of time, however, and its complete surviving repertoire consists of one *Sonata in A-minor*, (D. 821) (1824) by Schubert.

In this century the bow has reemerged as an extension of guitar technique; within the last twenty years it has been used in several pieces. In order to make this musical "transvestism" (as described in Ex. 6) complete, all of the bowing techniques belonging to the violin family can also be transferred to the guitar, with the result that terms such as *spiccato*, *martelé*, and *col legno* can become part of the bowing guitarist's new vocabulary.

However, the flat fingerboard means that the bowed guitar can only use either the first or sixth string alone or all six strings simultaneously. This makes the finale to Kröll's *Estampida* playable only if the left hand sequentially damps the first to the fifth string:



Ex. 48. *Estampida* (1968), G. Kröll. © Ars-Viva-Verlag.

One way out of this predicament is to raise the required bowed string/s above the others by using an artificial bridge (see Plate VI).

Henze prefaces his *Memorias de "El Cimarrón"* with performing directions that include a section called "For performance with the bow":

> The guitar is held between the legs like a violoncello.
> Because of its weight and size, a violoncello bow is to be preferred.
> It is recommended that one plays "sul ponticello" (on the bridge) with the bow throughout, so that the rosin does not affect the middle position of the right hand; furthermore, this style of playing produces a sound which is richer in upper partials.[21]

21. H.W. Henze, *Memorias de "El Cimarrón"* (Mainz: B. Schott's Söhne, 1973).

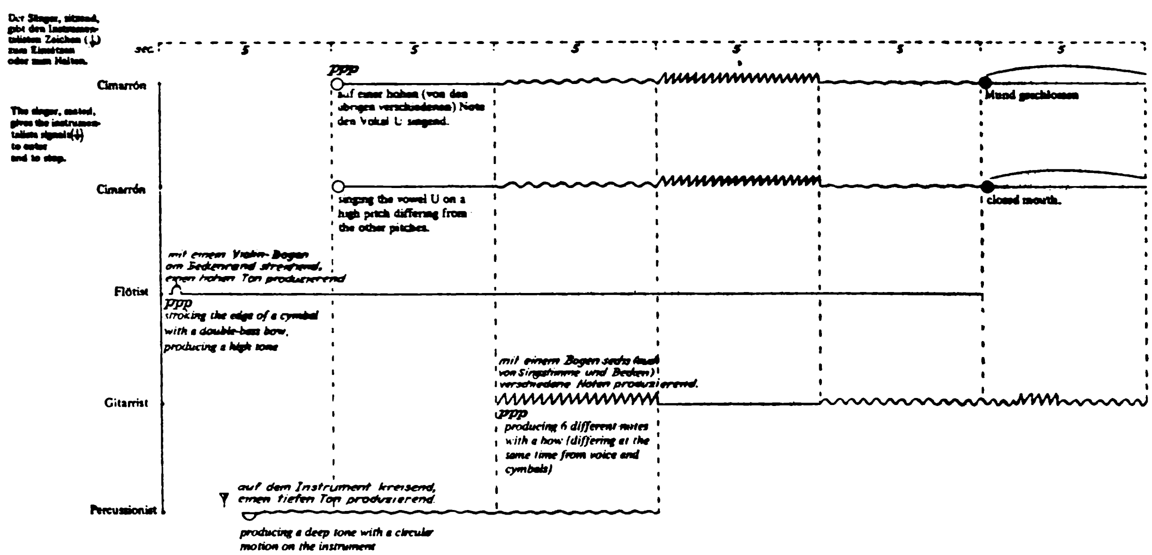
Roberto Gerhard also indicates that the guitar should be bowed at the ponticello position in *Concerto for Eight*, though he prefers another playing position:

> Guitar: *col arco*, holding the guitar flat on your lap, play with a cello bow closest to the ponticello. Begin down bow on the open sixth string, and then gradually flatten the position of the bow, to bring the other five strings into vibration, crescendo up bow to *ff* over the last three beats. The bow should be somewhat loosely strung and well resined.[22]

The type of bow is a matter of individual preference: Kagel asks for a violin bow in *Tremens*, and Christian Wolff recommends bowing the electric bass-guitar with either a cello or bass bow in *Electric Spring III* (1967).

The musical uses of the "chitarra col arco" also vary widely. Henze uses bowed chords to add to the very effective atmospheric texture which opens *El Cimarrón*:

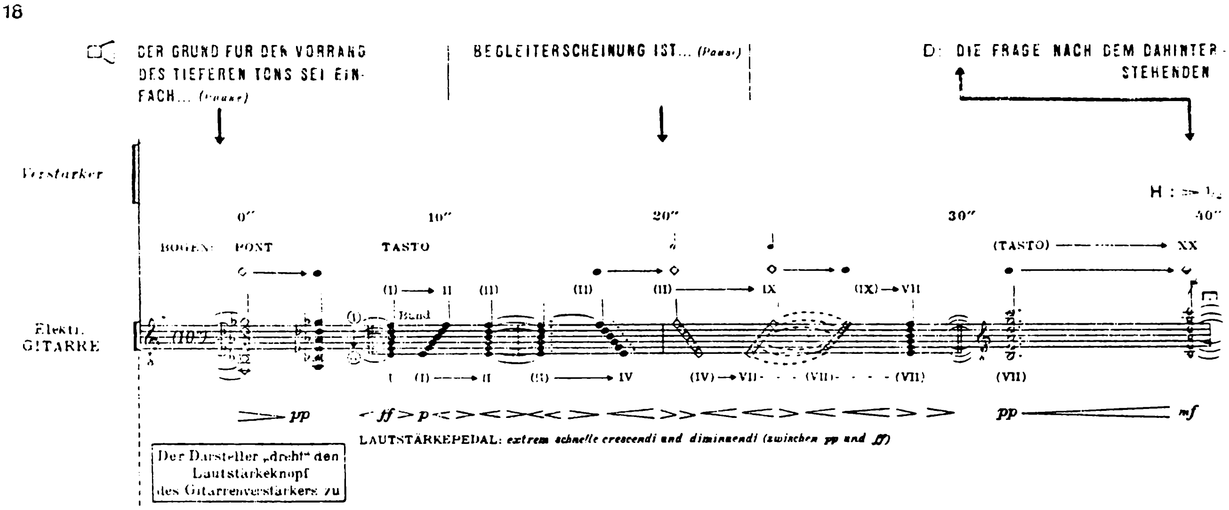
I Die Welt · The World



Ex. 49. "Die Welt," *El Cimarrón* (1969), H. W. Henze. © 1972 by B. Schott's Söhne, Mainz. Used by permission of European American Music Distributors Corp., sole U.S. agent for B. Schott's Söhne, Mainz.

Wolff, on the other hand, tends to use single notes in *Electric Spring II* (1966/70, 1:1). In *Tremens* Mauricio Kagel creates a very complex texture (including bass guitar, electric contrabass, Hammond organ, and percussion), in which the bowed electric guitar not only changes bowing position but also bottleneck glissandoes while changing the angle and pressure of the bottleneck and making extremely fast crescendi and diminuendi (between *pp* and *ff*) with the volume pedal:

22. R. Gerhard, *Concerto for 8* (London: Oxford University Press, 1962), 2 : 1–2.



Ex. 50. *Tremens* (1963/65), M. Kagel. © 1973 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

The bowed guitar offers some very interesting sonic possibilities, but it should be given careful musical consideration to avoid its use as just another avant-garde gimmick. For the electric guitar, use of the Energy-bow (see Chapter 3) could prove to be useful and creative, but until sustain technology is a part of most guitarists' techniques, composers and players alike will have to accept the mechanical awkwardness of a rosined bow if they want to extend the duration capabilities of the classical guitar. (See Recorded Ex. 32.)

VIBRATO

This effect, like pizzicato, is a treatment; it adds warmth and expression to a sound, but it is not an entity in itself. Vibrato can be described by two parameters, frequency and amplitude (see Chapter 2). This technique of tone modification was thoroughly described by the Chinese lute masters, who ranked it among the sixteen important aspects of tone production; they called it the "Loose Touch":

> The beauty of vibrato and vibrato ritardando lies in the loose touch. The left hand should move up and down over the string in a rounded-off movement, light and freely, without any jerks or hitches. . . . Heavy, thin, slow and quick vibrato and vibrato ritardando, all are based on the loose touch. Therefore, the wondrous music of the Lute entirely depends upon touch.[23]

In the lute music itself, vibrati, like so many other aspects of tone production, were described by metaphors of nature. The character asking for a quick left-hand movement literally means "A cold cicada bemoans the coming of autumn"; the swinging vibrato should evoke the image of "fallen blossoms floating down with the stream." Gulik describes one remarkable vibrato called the *ting-yin*:

23. Gulik, op. cit., p. 106.

> The vacillating movement of the finger should be so subtle as to be hardly noticeable. Some handbooks say, that one should not move the finger at all, but let the timbre be influenced by the pulsation of the blood in the fingertip, pressing the string down on the board a little more fully than usual.[24]

One type of vibrato was peculiar to nineteenth-century gypsies. Vladimir Bobri writes:

> [The instrument] had a narrow waist and a detachable neck fitted with a screw to hold it in position. This feature was especially liked by the gypsy guitarists since it afforded a certain amount of play between the neck and the soundbox, which permitted the guitarist to shake the guitar in both hands after striking a chord, producing a peculiar tone somewhat like that of a Hawaiian guitar.[25]

Vibrato notation is found in several seventeenth-century books of tablature and is used extensively in the sonatas of Ludovico Roncalli (1692). But in the repertoire of the nineteenth century, vibrato hardly ever appears on the printed page, though it would be naive to assume that it was not widely used in a period whose music dealt so much with the expression of emotion. The Russian historian Makaroff described one Spanish guitarist:

> The vibrato, when performed by Ciebra, was really divine—his guitar actually sobbed, wailed and sighed. Ciebra only showed these remarkable qualities in slow tempos as in largo, adagio or andante.[26]

One printed example can be found in Mauro Giuliani's *16 Austrian National Ländler*, Op. 16, No. 12, where he indicates *ondeggiamenti* over parts of the melody line with the symbol ∿∿∿∿.[27]

The composers of twentieth-century music have shown much more interest in vibrato and its notation. In violin music, vibrato is now so taken for granted that a non-vibrato tone must be marked *secco*. In guitar music, the situation is reversed; vibrato must be demanded. Many composers simply state "vib." (e.g., McCabe, in his *Canto for Guitar*, 1968, 4:1.2, 6:1.4), while others differentiate between "molto vib.," "vib.," and "con poco vib." (e.g., Lutyens, in *The Dying of the Sun*, 1969, 1:1–2). Hifumi Shimoyama distinguishes between the push-pull type of vibrato, "vib.," and the bending type of vibrato, which he calls "Gran vibrato" and designates with a wavy line in his *Dialogo* (1963) (1:1.1).

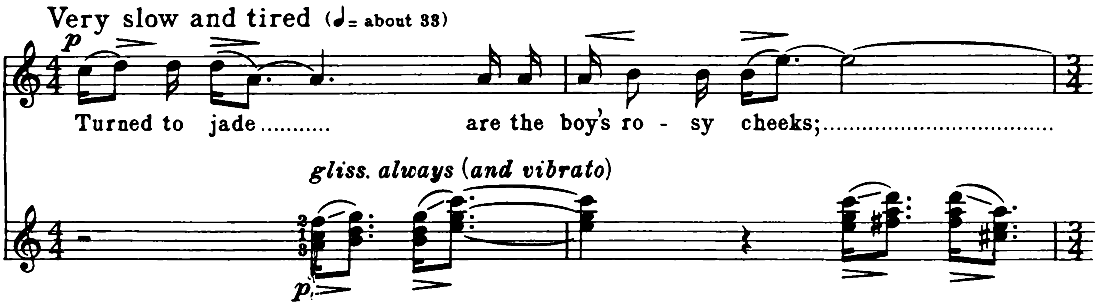
Musically, vibrato has been used to accentuate phrase endings or to make individual melodic notes stand out from their neighbors. Britten has used vibrato to highlight the emotional content of one of his *Songs*:

24. Ibid., p. 125.

25. V. Bobri, "'Gypsies and Gypsy Choruses of Old Russia," *Guitar Review* no. 20 (1956): 26.

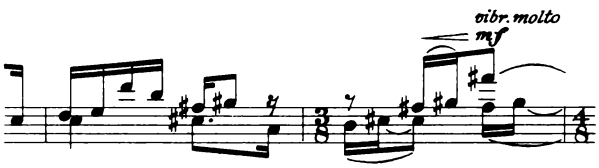
26. Quoted in P.J. Bone, *The Guitar and Mandolin* (2nd edition, London: Schott and Co., 1972), p. 79.

27. Heck, op. cit., p. 174.



Ex. 51. "Depression," *Songs from the Chinese* (1957), B. Britten. © 1959 by Boosey and Co., Ltd. Reprinted by permission of Boosey and Hawkes, Inc.

Henze uses *molto vibrato* to accentuate a crescendo:

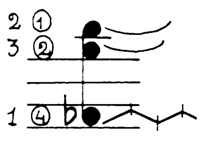


Ex. 52. *I Drei Tentos* (1958), H. W. Henze. © 1960 by B. Schott's Söhne, Mainz. Used by permission of European American Music Distributors Corp., sole U.S. agent for B. Schott's Söhne, Mainz.

So does Smith-Brindle:

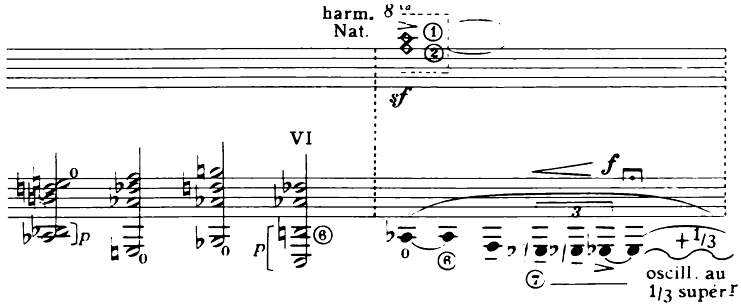
Ex. 53. *El Polifemo de Oro* (1956), R. Smith-Brindle. Courtesy of Aldo Bruzzichelli Editore, Florence, Italy.

Many composers have qualified their use of this effect by notating the parameters of vibrato. The amplitude of vibrato (i.e., how widely the pitch varies) has been notated graphically by Azio Corghi by the symbol [⌃⌃], representing "strong vibrato covering the range of ¼ tone":



Ex. 54. *Consonancias y Redobles* (1973), A. Corghi. © 1974. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

This contrasts two stable tones with the changing A♭. Maurice Ohana contrasts harmonics with a vibrato that oscillates at one-third-tone:



Ex. 55. "La Chevelure de Bérénice," *Si le jour paraît* (1963), M. Ohana. Published by permission of Gérard Billaudot éditeur, Paris.

Roman Haubenstock-Ramati uses a wavy line to notate "pronounced vibrato," which, he says in *Hexachord I*, should cover a quarter-tone.[28]

The examples above tend to treat vibrato as an off/on technique, an approach which seems to accompany most of the techniques discussed, although most players will phrase the dynamics of their vibrati according to musical need. Peter Fricker has notated a decrescendo of vibrato to accompany the falling dynamic level of a pizzicato phrase in *Paseo* (1971, 12:2.2), and, of course, Alvaro Company goes to great lengths to illustrate graphically the differences between vibrato normale, lento, and rapido:

and the changes from one to another,

musically contrasting them in close proximity (see Ex. 27).

The highly expressive musical tool of vibrato can be used on any string sound, from crossed strings to harmonics. Players and composers can use this effect to best advantage by applying its two parameters, frequency and amplitude, to their musical requirements.

GLISSANDI

This term comes from the French verb *glisser*, meaning "to slide," and it describes the technique of sliding the left hand along the string to change pitch. On the violin, a glissando provides a continuous pitch change, but the frets on the fingerboard of a guitar produce a discrete chromatic scale.[29] Glissando has usually been used to perform melodies legato, often using portamento (another version of the same technique). There are several different types of glissandi; here we discuss the fretted gliss, bending gliss, bottle-neck or slide-gliss, scordatura or scord-gliss, koto-gliss, and scratch-gliss, in which the string is scraped along its length to produce what is commonly known as "string whistle." (See Recorded Ex. 33.)

28. R. Haubenstock-Ramati, *Hexachord I and II* (Vienna: Universal Edition, 1976), A2.

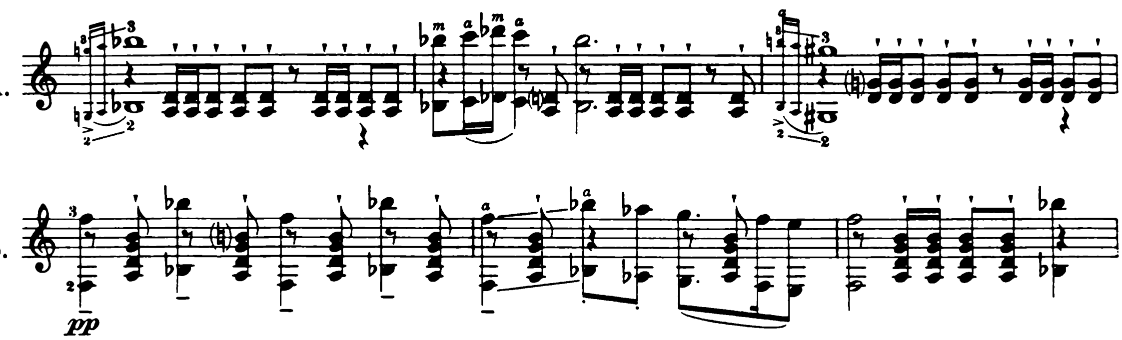
29. A true fretless gliss can of course be accomplished on a fretless fingerboard; these are available with Intonation Systems' Interchangeable Fingerboard guitars (see Chapter 4).

A guitar glissando has the psychological effect of creating a sustained tone: after the string has been plucked, the glissing tone is still giving the listener information as the pitch changes, engaging the attention throughout the decay time. This does not happen with a stationary note, because the normal plucked note gives most of its information at the beginning of the tone. The ear and brain process this information and then lose interest—unless something else is happening in the tone. (This is one reason why vibrato lengthens the apparent duration of the note.) The glissed tone can be considered a "musical object" which is different from the normal plucked tone of the guitar, and can be used as a musical contrast to the normal tone. Because the tonal resources of the guitar are relatively few in number, every contrast that *is* available should be used to its fullest advantage to expand the musical possibilities of the instrument.

In guitar music, fret-glissandi have been used extensively to add a "vocal" expressiveness. The music of Tarrega is full of portamenti and glissandi that perform this function, and, by extending the gliss over the bar lines, often give the impression of rubato. In fairly conventional post-war music, glissandi have been used dramatically—as in the music of Eduardo Falu—and as a contrasting musical texture, as in Britten's *Nocturnal*, where he contrasts the glissing figure both sequentially (A) and concurrently (B) with the other material:

A.

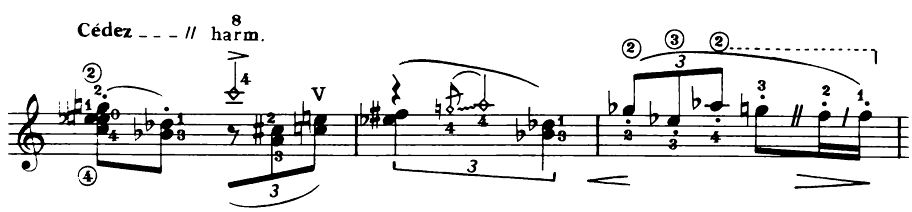
B.



Ex. 56. *Nocturnal* (1963), B. Britten. © 1963 by Faber Music Ltd. Reproduced by permission.

In *Oilless Motors* (1976), Bernard van den Boogaard simultaneously contrasts two fret-glissandi moving in contrary motion on a single guitar. In fact, fret-gliss is so distinct a sound that Bent Lorentzen prefaces his *Umbra* (1973) with the symbol , meaning "slow glissando with audible fret-sounds."

Any type of string tone may be glissed. Maurice Ohana glisses an artificial harmonic:

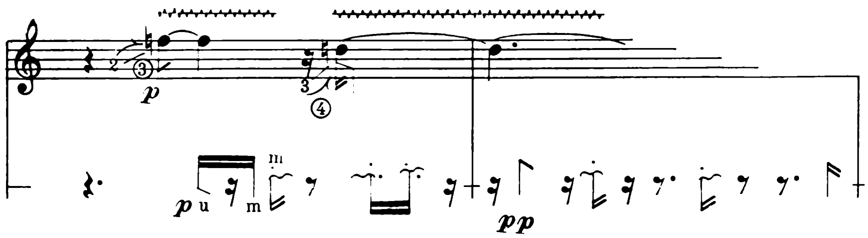


Ex. 57. "Temple," *Si le jour paraît* . . . (1963), M. Ohana. Published by permission of Gérard Billaudot, éditeur, Paris.

Alvaro Company glisses crossed strings (A), and even uses the fret-gliss as an attack for a note (B):

A.

B.

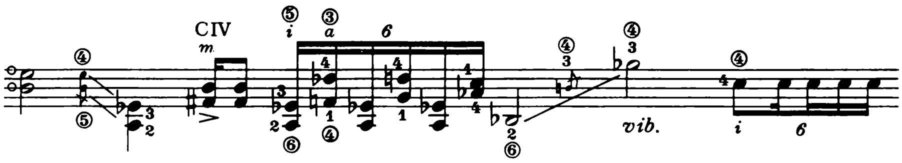


Ex. 58. *Las Seis Cuerdas* (1963), A. Company. © 1965. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

A treated tone may be glissed: Kagel asks the bass guitar to gliss and molto-vibrato simultaneously in *Tremens* (17:2.3–4), and Ekkehard Reiser even glisses a trill in *Masken* (1972, 7:5.2).

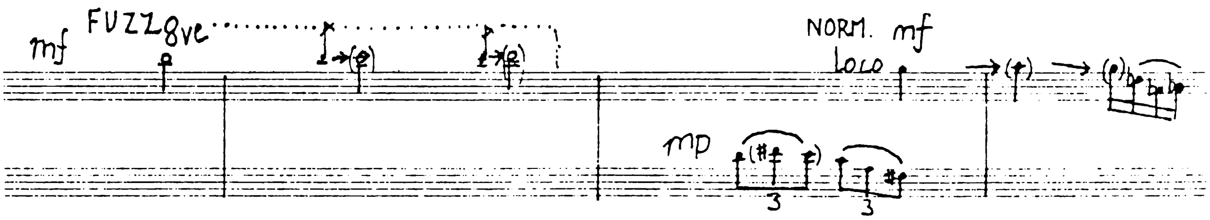
Since a portamento or glissando is notated by a line connecting the beginning and ending notes, the speed of the change can be notated by the slope of the line. Kagel uses this graphic indication for slide-glissing and also when he wants an extremely short portamento in *Tremens.*

Since a single guitar string covers a range of just an octave and a half, if a composer wants a longer gliss, the player must change strings. Humphrey Searle notates the string change with a grace note:



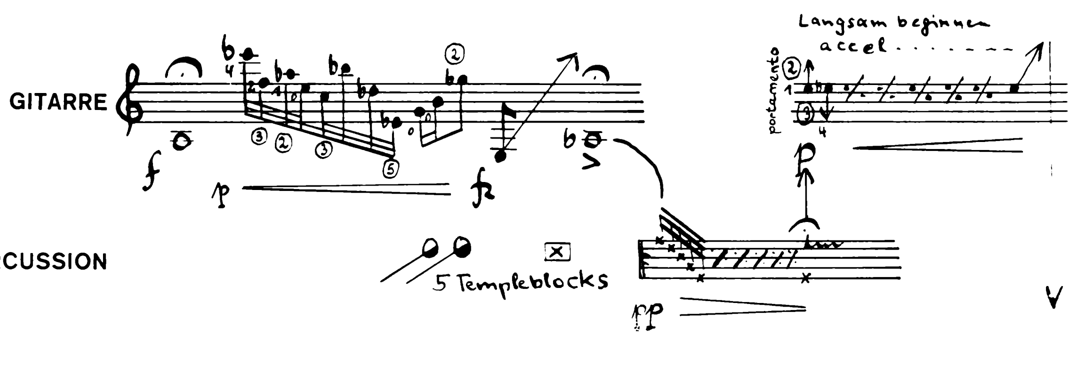
Ex. 59. *Five* (1974), H. Searle. © 1976 by Faber Music Ltd. Reproduced by permission.

The *bend-gliss* changes the pitch of a note by stretching or bending the string without the left-hand finger moving from its fret position. (The one exception to this method is the type of bend-gliss used by Christian Wolff in *Electric Spring III*, which uses the vibrato bar on the electric guitar.) The bend-gliss has always been very popular with electric guitarists, who tend to use light-gauge strings designed for this purpose. When David Bedford writes for this effect, he remarks in the score that the final note is to be obtained "by 'bending' from the previous note, i.e., not played on the correct fret," with the note that is not to be plucked given in parentheses:



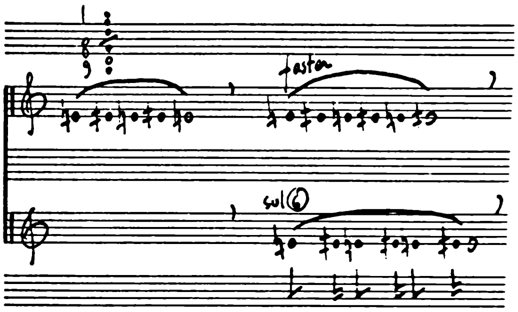
Ex. 60. *The Ones Who Walked Away from Omelas* (1976), D. Bedford. © 1976 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

Of course, notes can also be "bent down," by bending the string out-of-tune before it is plucked and slowly returning it to its original position during the ensuing vibration. Siegfried Fink has used the upward and downward bend-gliss to contrast with each other:



Ex. 61. *Dialoge* (1968), S. Fink.

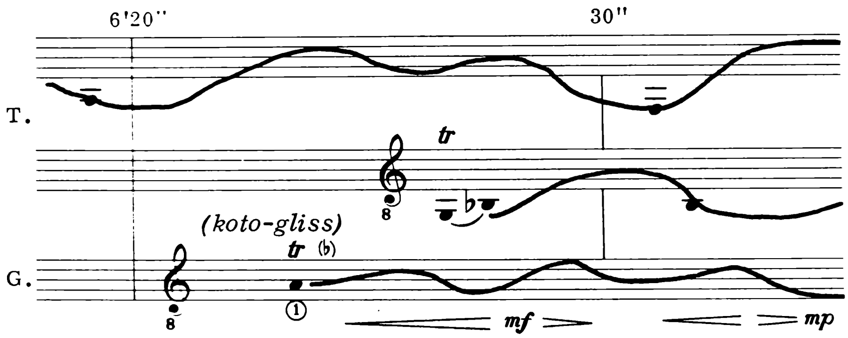
Gilbert Biberian, in *Prisms II* (1970), has the guitarist strike the string repeatedly while it is bent back and forth between two pitches, so that the pitch is sounded at various places along its excursion from one tone to the other. In *Sonata* (1975), he uses gliss that pulls the string out of tune:



Ex. 62. *Sonata* for flute and guitar (1975), G. Biberian. Used by permission.

This method is used because the music demands a quick return to the original pitch. Its range is not as great as that of the bend-gliss; it is usually measured in microtones rather than semitones.[30]

An unusual type of bend-gliss is called for in my *Voyage* (1976), which uses an electro-acoustic cello-type guitar. This *koto-gliss* requires a guitar that uses a separate tail-piece to hold the strings, so that an appreciable length of string is available between the bridge and the tailpiece. The first string is gradually tuned down one-and-a-half octaves (*scord-gliss*) during the piece, to lower the tension of the string. Then individual left-hand plucked notes are bent as much as a fourth, by changing the tension of the string with pressure from the right hand on the string section behind the bridge. The live guitar plays a trio with two koto-glissing instruments on tape. This gliss is notated graphically:



Ex. 63. *Voyage* (1976), J. Schneider.

30. Jazz guitarist John McLaughlin has borrowed from the Indian vina a method of glissing on an instrument with a scalloped fingerboard. The player can gliss simply by pressing the string toward the fingerboard. (Similar instruments were built in the nineteenth century.)

The principal musical difference between a fret-gliss and a bend-gliss is that the latter changes its pitch continuously. The only limitation of the bend-gliss is its range, which is usually no more than three semitones for the electric guitar (lightly strung) and two semitones for the classic guitar. To attain the range of the fret-gliss with the smooth transition of the bend-gliss, classical composers have borrowed a technique used by Hawaiian and blues guitarists, called the *slide guitar.* This is a method of stopping the string from above with a heavy object, rather than from below with a fret. This object, called a *steel* for the Hawaiian guitar and a *bottleneck* in folk guitar (for the obvious reason), must be heavy enough to shorten the vibrating length of the string by reflecting the string's vibrations without absorbing them. Because the surface of the strings is continuous, the steel gives a three-octave range of continuous pitch on *each* string and extends the range of the instrument from the usual three-and-a-half octaves to over five octaves (e^2 = 82.5 Hz to e^7 = 2637 Hz).

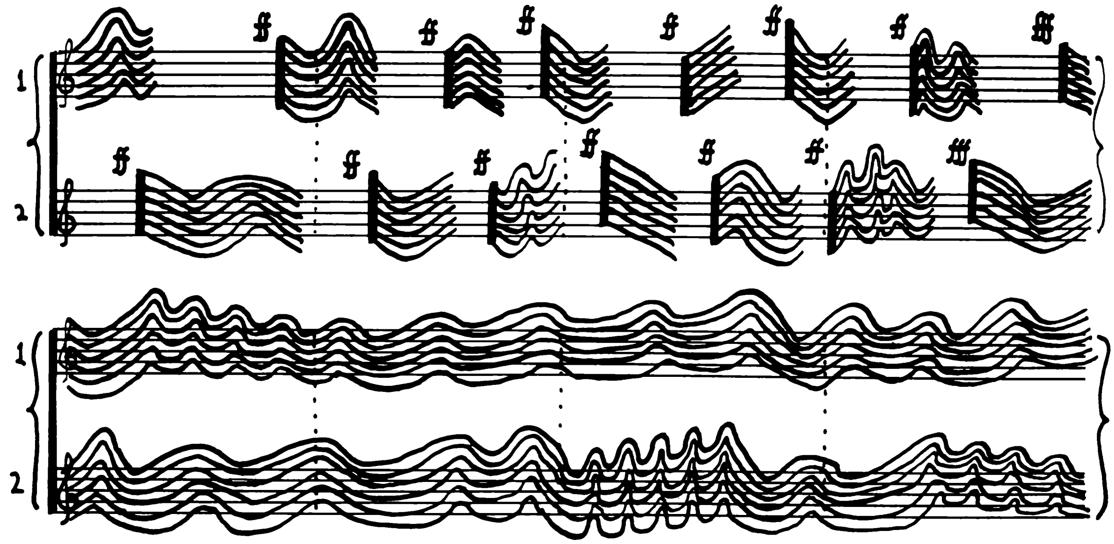
One of the first composers to use *slide-gliss* was the American Harry Partch, whose self-made instruments and their music have been strongly influenced by Oriental and ethnic music. His use of a forty-three tone-per-octave scale necessitates the use of microtuned and gliding-tone instruments. One of these is his Adapted Guitar II (1945), which has a raised nut, allowing a lead-weighted plastic rod to be pressed down on the strings without pushing them down to the fingerboard. Rather than using frets to mark divisions of the string length, Partch uses color-coded triangles painted on a fretless fingerboard (see Plate VII).

Describing the slide-gliss tone, Partch remarks: "The obnoxity of this tonal manipulation to some musicianly ears is due, I am convinced, more to the sugary and pseudo-South Seas music given to the instrument than to any ugliness or sentimentalism in the gliding sound as such."[31] He has used the Adapted Guitar II in *Plectra and Percussion Dances* (1949/50), *Oedipus* (1951), *Revelation in the Courthouse Park* (1960), and *Delusion of the Fury* (1965/66).

Most composers tend to use the slide-gliss sound first as a texture rather than to treat the gliding quality as an additional control over the pitch domain of a guitar note. Misha Mengelberg uses a Hawaiian guitar in *AMAGA* (1968), but most other composers have used conventional guitars, either electric or acoustic, and usually choose to gliss over all of the strings. (See Example 64.) To play Example 64, Bedford suggests using a "glass ashtray, jam jar, or similar glass object of appropriate width," as he does for *Star's End* (1974), in which the two unaccompanied soloists gliss up and down the full length of their bottom strings in contrary motion (142:1). In Example 50, all six strings are glissed simultaneously with a bow (*Tremens*, 18:1).

George Crumb creates a more delicate use of slide-gliss with a metal rod glissing single notes and single-note trills on the electric guitar. (See Example 65.) Lukas Foss

31. H. Partch, *Genesis of a Music* (1949; 2nd ed., New York, Da Capo Press, 1974), p. 105.



Ex. 64. *18 Bricks Left on April 21* (1968), D. Bedford. © 1968 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

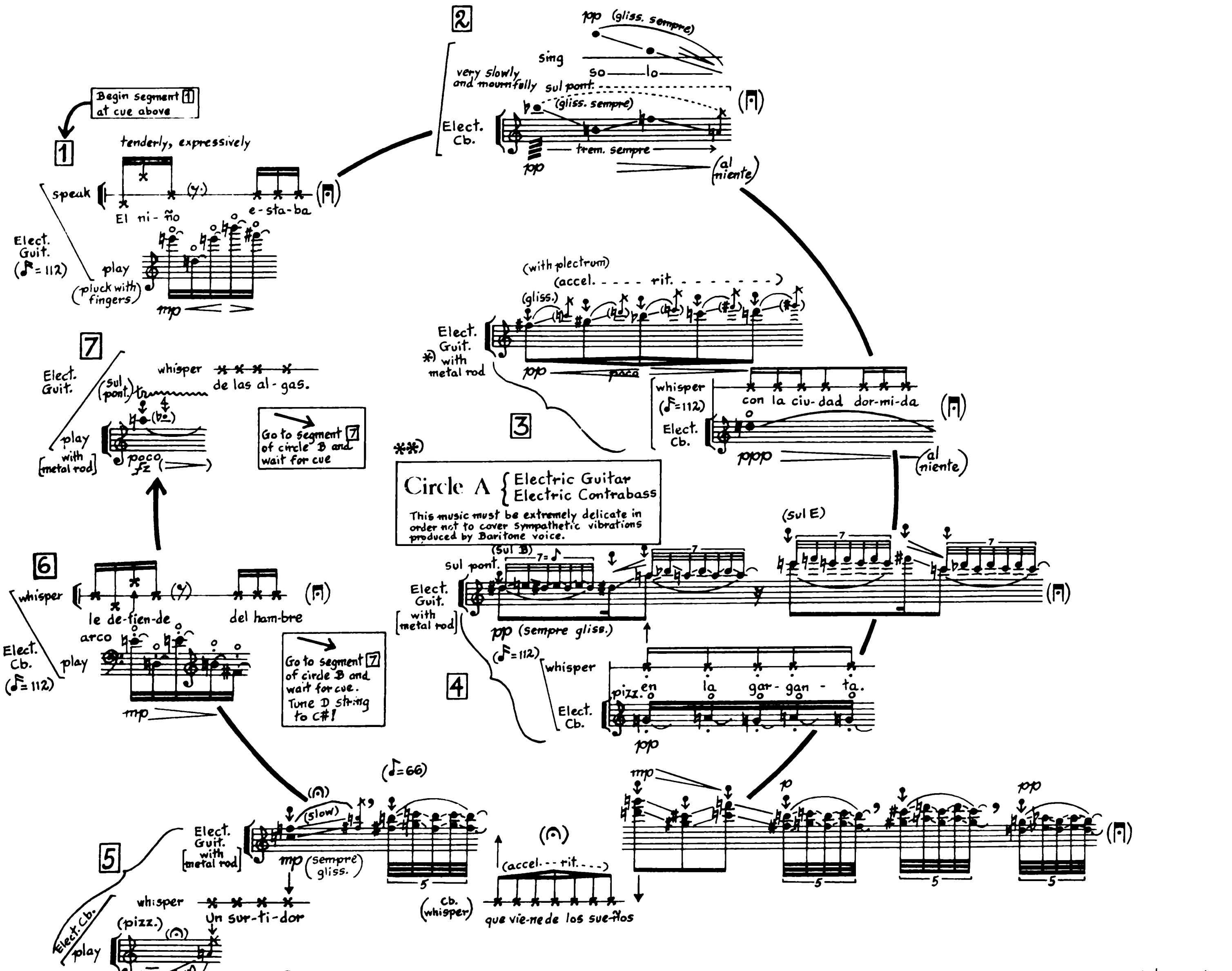
makes a very interesting use of this technique in *Paradigm* (1968), when he asks the electric guitarist to apply the movable slide "only beyond the fingerboard an inch or two from the pickup, barely allowing right hand the space to pluck the strings (upper three strings only). Keep moving slide (gliss.) to alter pitches."[32] This very high-pitched glissing is musically matched with the similar sound of the percussionist's flexaton, and the two converse over the frantic quaver and semiquaver activity of the other three players (4:2).

One of the leading exponents of classical slide-guitar is the German guitarist/composer Siegfried Behrend, who includes the technique in many of his own compositions and inspires its use in the many pieces that have been written for him, such as *Ultima Rara* (1969), by Sylvano Bussotti. In fact, Behrend insists that a glass bottleneck is the only technique which allows a true "molto dim. (a niente)" in the last line of McCabe's *Canto for Guitar* (1968). (See Example 66.) The composer agrees, and, as Behrend tells it, "When he wrote the piece, he didn't know it was possible to make such sounds with the glass, and when I showed it to him before I recorded it, he said, 'Oh fantastic! that's exactly what I wanted to hear.'"[33] (This is a good example of the type of communication between composer and performer that can result in forwarding both the art of the guitar and its music.)

When Behrend writes for the slide-gliss, he uses the abbreviation "m.G." (*mit Glas*) and cancels it with "o.G" (*ohne Glas*). In *Movimenti* (1969), he contrasts bend-gliss with slide-gliss (5:5). The American composer William Bland has written a piece exclusively for bottleneck guitar. It is called *Fantasy for Oscar Dominguez, "Nostalgia of*

32. L. Foss, *Paradigm* for percussion/conductor, electric guitar, and three sustaining instruments (1968) (Mainz: B. Schott's Söhne, 1969), 4 : 2.

33. S. Behrend, Interview with P. Sensier on *The Classical Guitar*, BBC Radio 3, 1976.



* Glissando with a metal (or glass) rod [so-called "bottleneck technique"]. Draw rod smoothly along the string to produce the indicated pitches. Use plectrum for all of these passages.

** Make a pause of 5-7 seconds between segments of "Circle-music."

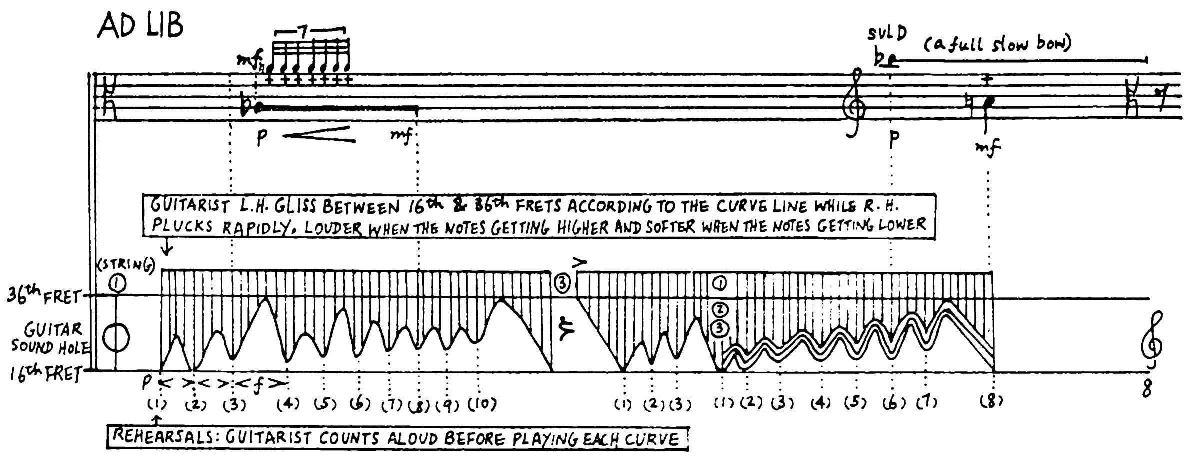
*** All notes marked as harmonics [o] (including the lower pitches, if possible) should be sung in a falsetto voice in order to project a surreal effect.

Ex. 66. *Canto for Guitar* (1968), J. McCabe. © 1970 by Novello and Co., Ltd. Used by permission.

Space" and in it he not only uses the standard texture of glissing chords but also exploits the bottleneck to perform one-fifth, one-fourth, two-fifths, one-sixth, and even one-eighth-tones. He also calls for bottleneck bi-tones, creating a breathless, eerie sound.

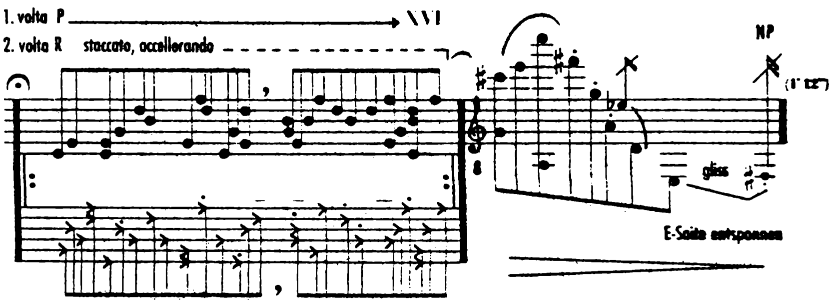
Real bottlenecks are not very efficient slides for the classical guitar, nor are the traditional steels, which are designed to be used on an instrument held in the lap. Several makes of metal-tube slide bars are commercially available today, but they lack the weight to sustain the string vibration. The best implement I have found for slide glissing is an extended socket from a socket wrench: 13/16 in. is weighty enough to sustain good vibration times on all strings, the approximately four-and-a-half-inch-long sockets are long enough to cross all the strings, and the metal finish on the Craftsman brand, for example, is smooth and durable enough to last a long time. In addition, the hexagonal or octagonal shape of the inside of the socket makes it easier to manipulate than a piece of metal or glass tubing.

In the section on pizzicato, Leo Brouwer's technique of a glissed figure damped by the left hand (Ex. 33) was discussed. The composer Ho Wai On has invented a very effective notation for this kind of activity (which can be considered a damped slide-gliss). She portrays the string/s to play, and both how high and how much to play them (see Ex. 67); her use of the damped-gliss is highly textural, so pitch information is not critical. Arrigo Benvenuti also uses this damped gliss texture, as a sectional contrast in a small ensemble in *FroBorSal's Trio* (1973).



Ex. 67. *3:10 A.M.* (1977), Ho Wai On.

Another type of gliss that changes the pitch of a note continuously is the scordatura, or *scord-gliss* (from a term meaning "out of tune"). This gliding tone is achieved by changing the pitch of a string by turning the tuning peg while the string is vibrating. I have used this technique in *Voyage* (1976) to gradually tune down over an octave and a half, but much smaller changes are more common. Bussotti tunes the sixth string down only a semitone in *Ultima Rara* (1969, 1:11.2); Kagel goes down the same distance and returns immediately, as part of a musical phrase:



Ex. 68. "Faites votre jeu II," *Sonant (1960/. . .)*, M. Kagel. © 1964 by Henry Litolff's Verlag. By permission of C. F. Peters Corp.

In *Abreuana* (1971), Angel Gilardino raises the pitch of the first string by a quarter-tone and then lowers it while playing a tremolo on the same string (5:2.4). Pelle Gudmundson-Holmgreen's use of the scord-gliss is rather esoteric: an entire section of his *Solo for Electric Guitar* (1971/72) consists of the instruction, "Tune the guitar *pp-p*, dur. 20″-50″"![34] A much more sensitive and meaningful use is that of William Bland in his *An Homage to Picasso—For Guernica* for constantly tuned guitar. The piece begins with the instructions:

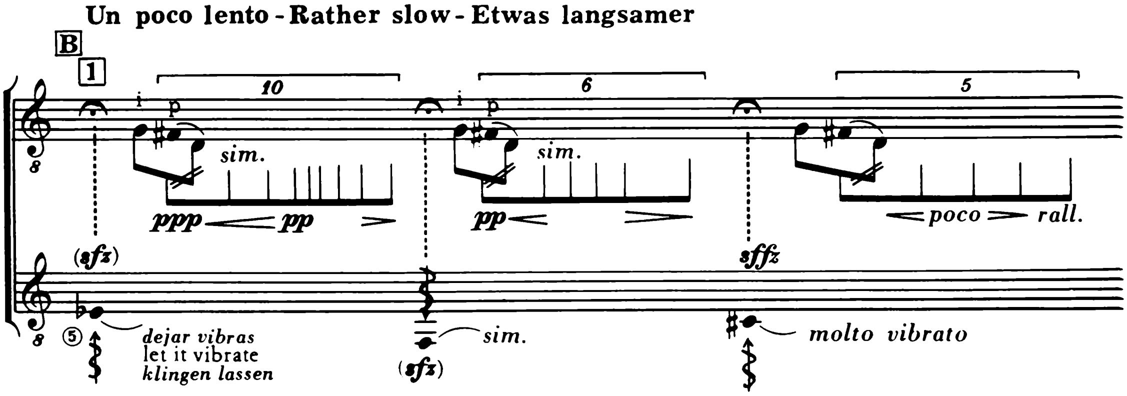
> Start with all strings extremely slack, so loose no discernible pitch is perceived. Intermix tones in an approximately continuous flow of 32nd's. After playing c.:15″ begin to gradually (and randomly) tighten all strings. Tune mostly upwards (very slowly), but add downward gliss. ad lib.

Later in the piece, natural harmonics are scord-glissed, and the last musical gesture is a slow second-string gliss that leaves the string totally slack.

The last type of glissando to be discussed is the *scratch-gliss*. Because the bass strings on a guitar are wound with wire, when the left-hand fingers change position and scrape along the strings, the strings produce a squeaking sound known as *string whistle*. Players spend a good deal of their time trying to avoid this sound, but many composers have used it as a sound source, and have even asked players to produce a more accentuated sound, with their nails or other objects. It has been used for centuries by Japanese koto players, and since its discovery in the West it has proven to be a very useful and popular color.

34. P. Gudmundsen-Holmgreen, *Solo for Electric Guitar*, section IV.

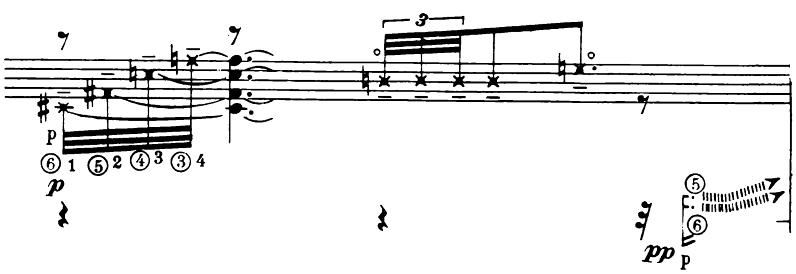
Kagel describes this technique as part of his "Fin II/Invitation au jeu, voix," *Sonant (1960/. . .)*: "Slide with fingernail or plectrum slowly along the 6th string. You know that the glissando is brightest when approaching the bridge, and you can emphasize this with the tone-switch, turned to maximum treble."[35] Brouwer has used the scratch-gliss to add color to the attack of a note in solo guitar music:



Ex. 69. *La Espiral Eterna* (1971), L. Brouwer. © 1973 by B. Schott's Söhne, Mainz. Used by permission of European American Music Distributors Corp., sole U.S. agent for B. Schott's Söhne, Mainz.

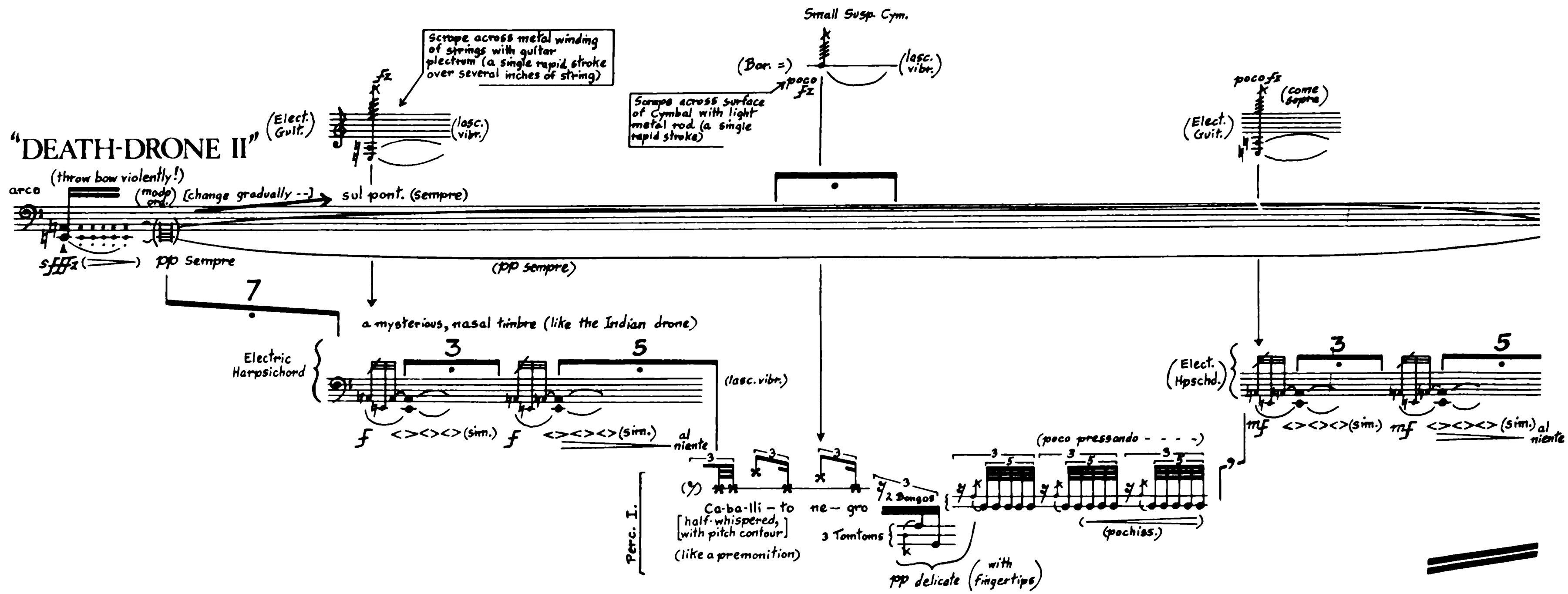
George Crumb has used this sound to add to the attack of the electric harpsichord, and has echoed it a few seconds later by having the percussionist scrape a cymbal with a metal rod. (See Example 70.)

Various attempts have been made to notate the sound produced by the scratch-gliss: the difficulty is that it is not a pitched sound in the traditional sense. In *Dialogo* (1963, 1:2.1), Shimoyama uses the onomatopoetic description "Su!" accompanying the notation of how quickly which string should be scraped, while Company prefers a more graphic representation of the action:



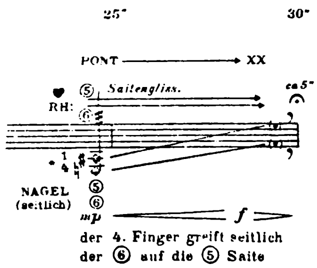
Ex. 71. *Las Seis Cuerdas* (1963), A Company. © 1965. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc.; Sole Agents, U.S.A.

35. M. Kagel, *Sonant (1960/. . .)* for guitar, harp, contrabass, and percussion (Frankfurt: C.F. Peters, 1964).



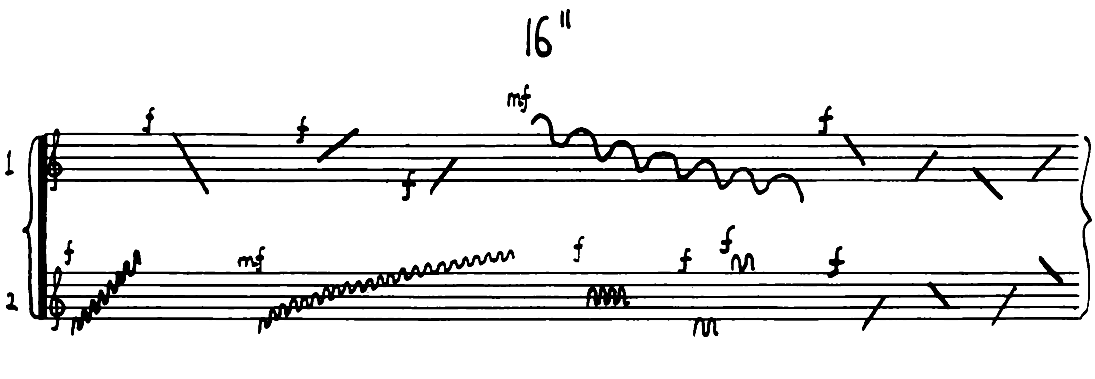
Ex. 70. *Songs, Drones and Refrains of Death* (1968), G. Crumb. © 1971 by C. F. Peters Corp. By permission.

Another choice is simply to direct the left and right hands without describing the sounds produced, as Kagel does when he asks the player to scrape the strings with a pick in tremolo fashion and damp-slide-gliss with the left hand:



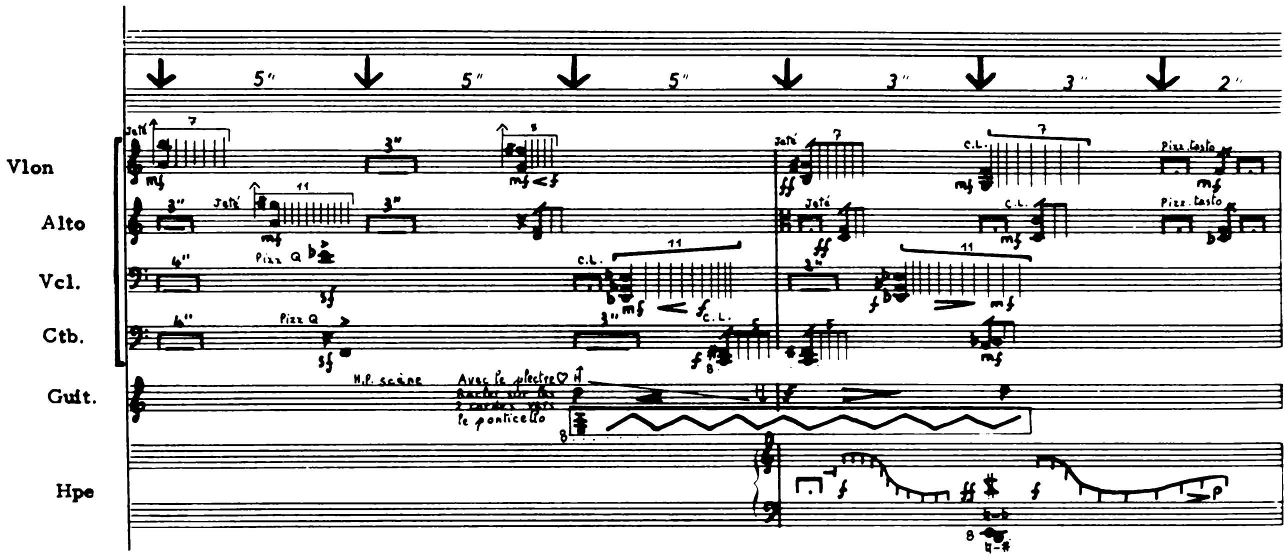
Ex. 72. *Tremens* (1963/65), M. Kagel. © 1973 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

The notation used by David Bedford in *18 Bricks* seems adequate, until we learn (from the preface) that the lines represent, *not* the pitch of the scraping sound, but the position of the finger on the string:



Ex. 73. *18 Bricks Left on April 21* (1968), D. Bedford. © 1968 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

Unfortunately, the pitch of a scratch-gliss is determined by the *speed* of the scraping instrument over the strings, not by its placement on the string—a fact which renders the above notation less helpful than it seems at first glance. Francis Miroglio seems to know exactly what kind of sound he wants when he assures the final sound by describing the strings, scraper, pitch, and dynamics to be used:



Ex. 74. *Tremplins* (1968), F. Miroglio. © 1975 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

SCORDATURA

Changing the tuning of a guitar is one obvious way to extend the lower range of the instrument, just as harmonics and slide-gliss are two methods of extending the top range. It is also an obvious method for changing the tuning relationship between the strings, which has been standardized for the last hundred and fifty years. In earlier days, lutenists and vihuelists often changed tuning to facilitate performance of music in one key or another, and the practice of lowering the sixth string to D has been fairly common in the tradition of folk and blues guitar.

Many nineteenth-century pieces of music ask for the bass notes to be altered; Sor, for example, changes the sixth string to D and the fifth string to G in the Menuet of his Op. 11, and in one piece he raises the sixth string to F. The most common change was to tune down the sixth string to D for performance of pieces in that key. Some players enjoyed the resonance and key-facility that the retuning gave them, which led several to advocate additional bass strings on the existing instrument. One such extended instrument was the Decacorde designed by Lacote and Carulli in 1828; its four added bass strings made it a ten-string guitar very similar to the type used by the contemporary Spanish guitarist Narciso Yepes.

In the first half of this century, Percy Grainger experimented with open tunings in several pieces, using the guitar played in the "Australian" way—tuning the guitar to a complete chord and using the left hand to stop all six strings at once. In his *Father and Daughter* for five men's single voices, double chorus, strings, brass percussion, and mandolin and guitar band, four separate groups of guitars are used, tuned in B♭, F, E♭, and D-minor chords. The parts are then written out using a double-tailed note that tells the player on which fret he should place the left-hand barre.[36]

In the post-war era, composers have tended to employ scordatura for the same reasons that writers and players of the previous century did. To extend their range, in *Dialogo No. 2* (1970) Shimoyama changes the tuning of the sixth string of one guitar to D, and the other to E♭. Smith-Brindle goes even further, tuning the sixth string down to C in *Do Not Go Gentle* (1976) and *Concerto "de Angelis"* (1973). The quality of the string tone changes dramatically when it is lowered by a major third, as in the last two examples; Brindle uses this new color to advantage in both pieces.

There are a few examples of extreme tuning-down altering the string tone completely; for instance, the first string in my *Voyage* (1976) sounds very much like a koto. An even more dramatic change in character occurs when Gudmundsen-Holmgreen asks that the sixth string be lowered by one octave in *Solo for Electric Guitar* (1971/72). He explains:

> The E-string (6) is tuned down an octave. All the notes on this string will have to be performed as written but the sound will only be approximately an octave below when the E is played. Other notes will be very unsecure. Higher, more or less, due to the slackness of the string.[37]

Perhaps even more distorted is the sound of the lowest string on the electric bass guitar when it is tuned down by "about an octave" in Tom Darter's *Dual* (1976). The guitarist is then directed to perform a "solo on E-string: glissandos, wide bending, scraping, picking, etc."[38] Of course, the most extreme use of tuning down is in William Bland's *An Homage to Picasso* (described in the previous section). It is interesting to note that many of these delicate sounds canot be heard on an acoustic instrument—it is only through electronic amplification that this micro-level of sound can be fully exploited (a theme which is more fully explored in a later chapter).

Another function of scordatura is to raise the open-string pitches. This is not usually advisable; the tension that results from over-tightening the strings can cause structural damage to an instrument. Historically, however, the *capo* or capotasto has performed this function, operating as a movable artificial bar that raises all string pitches simultaneously by altering their vibrating lengths. The capo, or *cejilla*, as it is known in Flamenco, is used extensively in that style of music but has not found a following in classical music, except when a standard guitar is requested to play Terz-guitar music (a minor-third higher). Incidentally, a brand of strings is now manufactured to produce the pitches of Terz-guitar tuning at normal-guitar string tension (see Appendix II). Use of a capo also alters the tone of an instrument, giving it a brighter sound the higher up the neck one clamps the strings, and it also improves the sustain on some instruments. This powerful tool should not be overlooked in future music for the instrument.

36. C. Forsyth, *Orchestration* (London: Macmillan, 1935), pp. 481–82.

37. P. Gudmundsen-Holmgreen, *Solo for Electric Guitar*, Notes.

38. T. Darter, *Dual* for electric guitar and electric bass guitar, in *Guitar Player* 10, no. 11 (November 1976): 36–38.

The other traditional function of scordatura has been to change the relationship of string pitches. George Crumb, in "Casida del Herido por el Agua" from *Songs, Drones* (1968), raises the third string to G-sharp and lowers the A-string and low E-string by two semitones in order to allow certain natural harmonics to be heard. For the same reason, José Encinar, in the last minutes of *Abhava* (1972), changes the second string to C, the third to F#, the fifth to B♭, and the sixth to E♭.

One very unusual request occurs in Jorge de Freitas Antunes's *Sighs* (1976). The second movement requires that the instrument be tuned as follows:

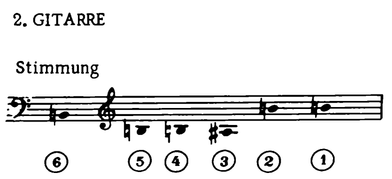
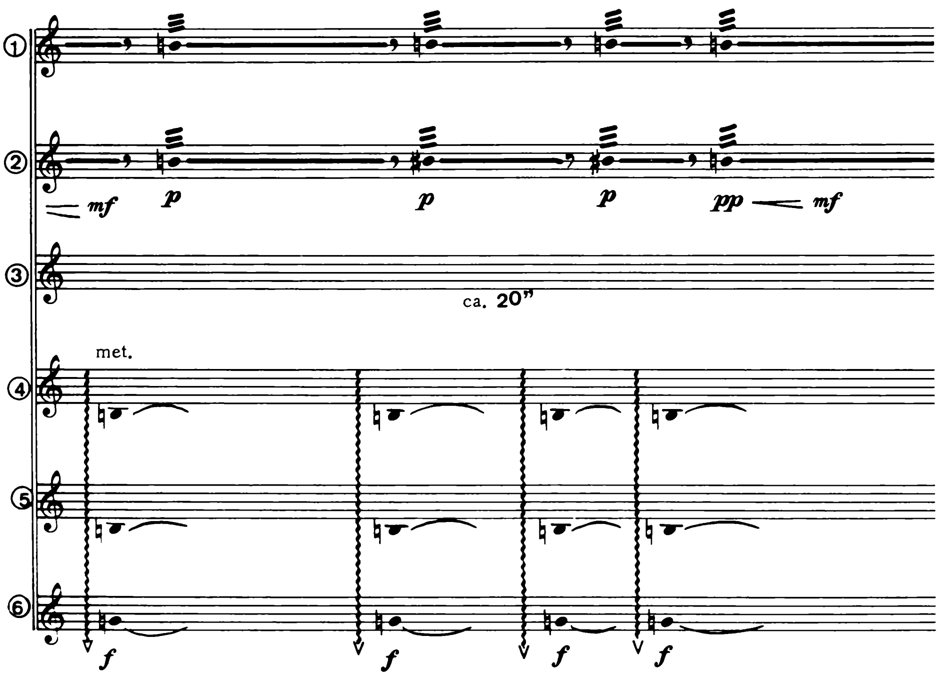


Fig. 86. Tuning for *Sighs* (1976), J. Antunes.

Because this unconventional tuning cannot be achieved on an ordinary set of strings, the composer tells the guitarist to obtain a second guitar strung with four fifth strings and two second strings to play the second movement, an invention on the note B:



Ex. 75. *Sighs* (1976), J. Antunes.

Another interesting use of scordatura is the basis of Swedish composer Sven-David Sandström's *Surrounded* (1972), in which the guitar is tuned in quarter tones (see Recorded Ex. 34):

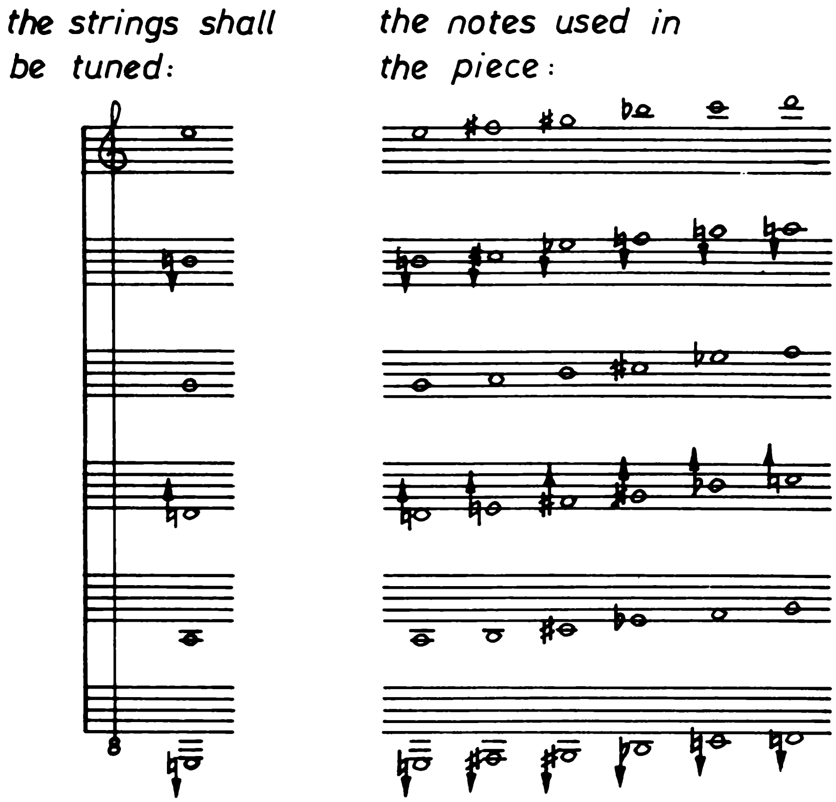


Fig. 87. Tuning for *Surrounded* (1972), S.-D. Sandström. © 1975 by AB Nordiska Musikförtlaget/Edition Wilhelm Hansen, Stockholm.

The entire piece is involved with the harmonic relationships created by this "mis-tuning" (to be discussed in the next section). The tuning is achieved by raising the fourth-string pitch until it lies *exactly* between the fretted D♮ and D# on the fifth string (5th and 6th frets). Then the second-string pitch is raised until its fretted D# (4th fret) is in octave unison with the newly tuned open fourth string. The sixth string is then lowered to octave unison with the fourth string fretted at the first fret.

As a general rule, a scordatura note should always be notated *at pitch*, not at the pitch fingered. If tuning changes before a new section, the change must be mentioned at the beginning of the piece. The music should only be transposed if a capo, which alters all string pitches simultaneously, is being used.

MICROTONES

In the guitar literature, vibrato was our introduction to out-of-tuneness within a musical framework. Bend-gliss and slide-gliss then entered the twilight world between the equal-tempered tones of the chromatic scale, but these techniques were used only as transitions from one tone to the next. Microtones have been used throughout history in the music of most countries of the world, and Western music is only now beginning to accept them as musical material within our own culture.

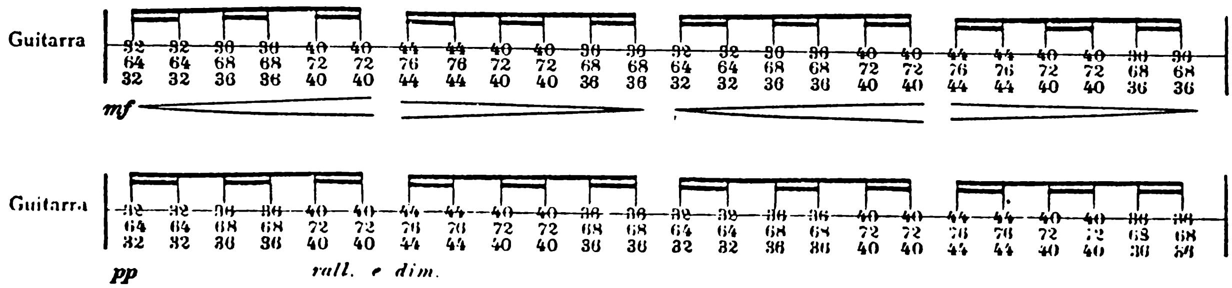
This change in attitude began at the end of the last century, when composers began taking an interest in alternative scale systems, which led to (among other things) the first quarter-tone piano, patented in 1892. In 1895, Mexican composer Julian Carrillo first approached the problem of microtones with his discovery of one-sixteenth tones—later introduced to the world in his theory of *Sonido 13* ("The 13th Sound"). The "13" is significant because it signals a step outside the traditional boundary of the twelve tones of the chromatic scale. In this theory Carrillo also advocated the use of quarter- and eighth-tones and, of course, combinations of all three of these sub-semitonal divisions.

Busoni discussed the possibilities of a sixth-tone system (each semitone divided into equal thirds) in his *Sketch of a New Aesthetic of Music*, although he never composed with it himself. Schoenberg remarked in *Harmonielehre* (1911): "The efforts made here and there to write music using third- and quarter-tones are destined to failure as long as the instruments capable of playing such music are so few."[39] Several composers of that era did take up the challenge, however: Alois Hába began his lifelong exploration of microtones in 1919, and Carrillo, Ives, Bartók (*Violin Concerto*, 1938, and *Sonata* for solo violin, 1944), Georges Enesco, Ben Johnson, Harry Partch, and Ernest Bloch all used intervals smaller than a semitone in their compositions.

Microtones have traditionally been used for two musical purposes: to adjust intervals for purer intonation in tonal music, and to create intervals to forge a new musical language. The guitar has been involved with the first type of microtonal music for over a century and a half—the creation of the enharmonic guitar (1826) and Lacôte's sliding-fret guitar have already been mentioned—but the instrument has also taken part in the exploration of atonal microtones, since its scale is so easily divided.

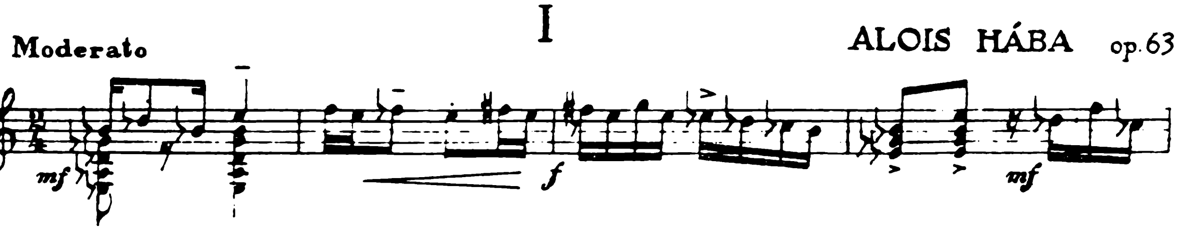
One of the earliest quarter-tone guitars was built by Baudelio Garcia at the turn of the century, for Julian Carrillo, who used it for, among other works, his *Sonata in Quarter-Tones* (1925) and *Concertino* (1926). His notation for the ninety-six tones per octave consists of numbering from 1 to 96; every eighth number represents an equal-tempered semitone, every fourth number is a quarter-tone, and so on. The system is difficult to sightread, but the composer has transcribed several works of Bach and Beethoven into his system. Recorded Example 35 is a solo guitar passage from his *Preludio*:

39. Quoted in Bartolozzi, op. cit., p. 26.



Ex. 76. *Preludio a Cristobal Colon* (1934), J. Carrillo. Used by permission of Theodore Presser Co.

Late in the first half of the century, Alois Hába also turned to the guitar to articulate some of his musical thoughts. He chose to restrict his octave division to quarter-tones, which he notates with quarter-tone accidentals (= quarter-tone sharp, = quarter-tone flat):



Ex. 77. *Suite für Vierteltongitarre*, Op. 63 (1946), A. Hába.

Harry Partch began working with steel-string guitars in 1934; his first use of the instrument was in *Barstow* (1941). He has developed two instruments: Adapted Guitar I, a six-string acoustic instrument played with a slide, and Adapted Guitar II, a ten-string acoustic instrument that uses electronic amplification and is also played with a slide. Partch uses ratios in his notation and treats the musical staff as a form of tablature in telling the player which string to play. His Adapted Guitar II is tuned to the following ratios, each string represented on ten spaces of an extended staff:

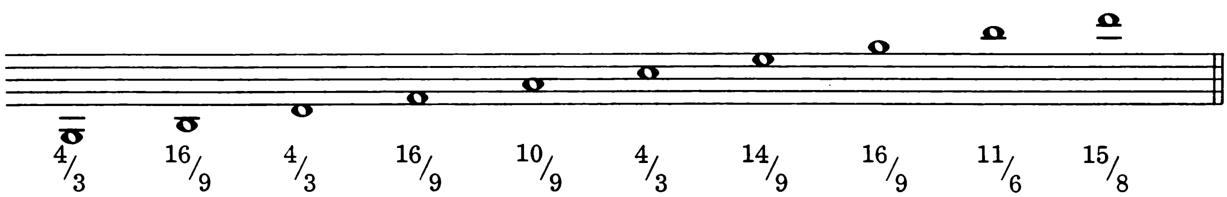
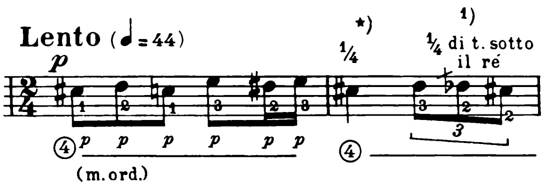


Fig. 88. Partch's ratio tuning of Adapted Guitar II.

In the music Partch then indicates, for the strings that are to be plucked, the ratios that determine the placement of the plastic slide bar for all ten strings:

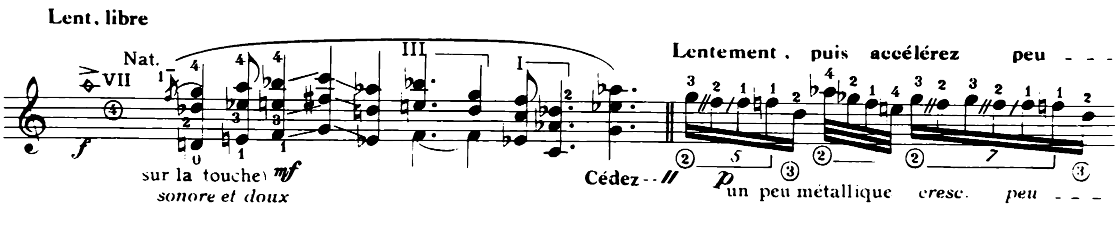
Ex. 78. "Ring around the Moon," *On the 7th Day Petals Fell in Petaluma* (1964), H. Partch.

Maurice Ohana used specifically composed microtones in his hauntingly beautiful *Concerto (Trois Graphiques)* (1950/57), and he has used them in all of his guitar compositions since. In his *Tiento* (1957), one very lyrical passage hovers microtonally around the note C#:



Ex. 79. *Tiento* (1957), M. Ohana. Published by permission of Gérard Billaudot *éditeur, Paris.*

By 1963, in his twenty-five-minute opus *Si le jour paraît. . .*, Ohana was using 1/3 tones, notated // = note + 2/3, / = note + 1/3:

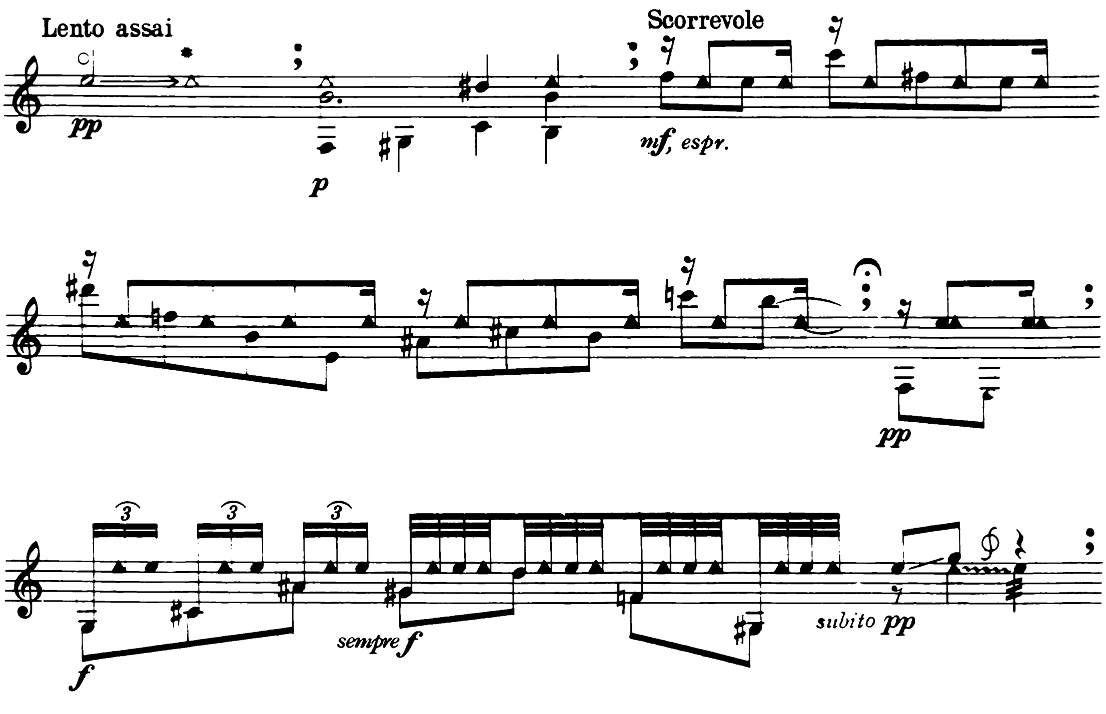


Ex. 80. "Maya-Marsya," *Si le jour paraît. . .* (1963), M. Ohana. Published by permission of Gérard Billaudot éditeur, Paris.

Much of Ohana's work is influenced by his Andalusian background; his use of microintervals seems to echo the vocal wailings of "cante flamenco," which often uses intervals smaller than a semitone. The composer has stated:

> I believe myself that in order really to enlarge the scope of a melodic line by the use of these intervals the ear requires to be carefully trained to a new approach. Monodic music offers vast possibilities for the use of third or quarter-tones. Two-part writing, and three-part, if carefully handled, can be very striking, as also certain clusters of tones struck or plucked.
>
> The use of these intervals is most striking, however, against a background of tempered instruments tuned in ordinary semi-tones (like a piano). After a short while the ear follows astonishingly well all the subtle changes in between the tones, whether in thirds or quarters. After all, one frequently hears intervals of third and quarter-tones in certain types of popular singing, e.g. the Cante Jondo, and although this is due rather to lack of pitch, it sounds quite acceptable to the ear.[40]

Another composer who has used fixed microtones in a melodic manner is Angel Gilardino, although he uses the sharpened first-string Δ more as a dissonant drone than as part of the melodic figure:



Ex. 81. *Abreuana* (1971), A. Gilardino. Used by permission of Editions Bèrben s.r.l.

40. M. Ohana, "Micro-Intervals," *Twentieth Century Music: A Symposium*, ed. R. Myers (London: John Calder, 1960), pp. 121–22.

Harmonic use of microtones is rare in guitar music, and almost all microtonality used in the repertoire is glissed. In "Faites votre jeu II," *Sonant (1960/. . .)*, Kagel uses an oblique glide-bar on an electric guitar which is played in the lap (Hawaiian-style) to introduce microtonal intervals between the strings, but even this example is glissed and not stationary. It is almost as though composers are admitting that the public's ears are not yet prepared for microtonal harmony, and that these pieces are slowly preparing the way by passing through microtonal intervals but that the composers are not yet willing to commit themselves by using these tones simultaneously, in a harmonic fashion.

A fascinating exception to this trend is *Surrounded* (1972) by Sven-David Sandström. It has already been shown how Sandström has achieved repeatable microtonal intervals on the guitar by altering the tuning (see p. 159). He begins this piece with a five-note arpeggiated chord, and the sonorities that emerge during the seven minutes of music which follow tell of a previously unexplored world filled with gong-like timbres and strangely weaving melodies that seem all the more sinewy because they avoid "normal" intervals, due to the "mis-tuning." The term "gong-like" is very accurate: part of the characteristic sound of struck quasi-pitched metal instruments is the inharmonicity of their partials. In bells and gongs, this inharmonicity is due to the shape of the instruments; in microtonal guitar music, it is a function of the tuning.

Sandström uses a fixed number of chords and melodic ideas in *Surrounded*, employing repetition and transposition as compositional devices. The effect sounds almost like a guitar-gamelan, each chord having its own special character due to the particular relationship of sharpened and flattened intervals within it. An excerpt from the first section (Recorded Ex. 34) illustrates the kinds of sonorities used. (See Example 82.)

The intonational aspects of microtonal intervals are just beginning to be explored in guitar literature. American composer Lou Harrison, however, has been using intonations in his music for many years. His *Serenade for Guitar* (1952) uses specific ratio tunings between strings; in his latest guitar works, *Suites for Tuned Guitars* (1978–), Harrison has used a different intonation for each suite. The first uses a just scale of eight tones:

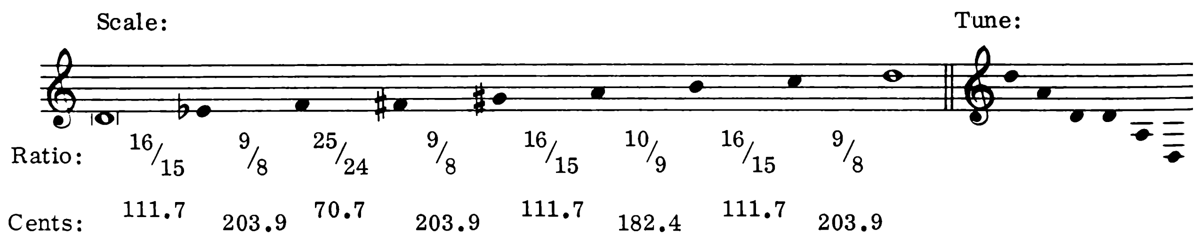


Fig. 89. Ratios and tuning for *Suite I for Tuned Guitar* (1978), L. Harrison.

The second *Suite*, "Ditone Set," uses Pythagorean tuning of the twelve-note compass, tuning perfect fifths (3/2) upward from E♭ to G#. Both movements, "Variations" and "Plaint," employ parallel fifths and fourths and very few thirds, which are 24¢ sharp in this

Ex. 82. *Surrounded* (1972), S.-D. Sandström. © 1975 by AB Nordiska Musikförlaget/Edition Wilhelm Hansen, Stockholm.

tuning. These pieces are written for instruments using interchangeable fingerboards on which these tunings can be accurately reproduced. Alan Hovhaness is also composing works for these instruments, and it is to be hoped that many composers will follow suit when they hear the intonational purity now achievable on the classical guitar.

On the other hand, the increasing use of noise elements in guitar music has involved the instrument in much of the sound exploration in the music of this century. Sounds with an increasing amount of inharmonicity appear in the repertoire with the use of microtones and clusters, finally culminating in the world of quasi-pitched and unpitched sounds (discussed in Chapter 7). Use of microtonality is a major advance toward creating a new musical language, and since it is so easily converted into a microtonal instrument, the guitar should take an active role in this development.

CLUSTERS

A new kind of "musical object" has appeared in the music of the twentieth century—the *tone cluster.* It was in the early nineteen hundreds that Cowell and Ives started to use clusters in their piano music. Clusters had been used by Beethoven and others at the turn of the nineteenth century in "battle music" for the piano, but the term was invented by Henry Cowell in the first decades of this century to describe these chords built out of seconds instead of the traditional intervals of thirds, fourths, and fifths.[41] The tendency is to hear this kind of chord as a tone with added "mass"; in other words, the new chord becomes an entity representing a wider area of the pitch spectrum than that of a single tone. Boulez calls this an "integration" of the intervals involved, which

> gives us, so to speak, sound "surfaces" using either the true continuum or a rough approximation of this continuum by the aggregation of all unitary intervals within the given limits; these are called *clusters* in the vertical sense, or *glissandi* in the diagonal sense. . . .
>
> Clusters and glissandi could be called frequency bands: the glissando being used as a function of length of time *x* to *y*, all the elements of the cluster functioning at a single time *x*. . . . The frequency band represents a field completely filled with an amorphous material.[42]

Clusters can be used both melodically and harmonically. To make an analogy: melodic use of clusters is not unlike an artist using a wider brush to articulate a line, while harmonic use of clusters can be compared to the use of block colors in painting. Cowell says that "the cluster must be treated like a single unit, as a single tone is treated."[43] Kagel adds, "If the tone-cluster is really treated as a single tone, one must add a new parameter to the other three (pitch-register, note duration, and intensity); the *breadth* of the cluster."[44]

In guitar music, clusters have been used in three ways: melodically, harmonically (in blocks) and texturally—a cluster is built up and sustained by arpeggiating. One of the first uses of dissonance in the literature is of the third type, in the famous *Fantasia que Contrahaze la Harpa en la Manera de Luduvico* ("Fantasia that imitates the harp in the manner of Luduvico"), by Alonso Mudarra. This piece, originally for solo vihuela, was one of the first pieces of musical parody ever written: the melodic line in the chromatic closing section imitate the sustaining characteristics of the harp. The composer comments in the score, "From here to the end there are some dissonances; if you play them well, they will not sound bad." Many modern performers (unhistorically) arpeggiate this melody to highlight these dissonances. (He also mentions at the beginning of the piece that the music may

41. H. Cowell, *New Musical Resources* (1919; New York: Alfred A. Knopf, 1930), p. 117.

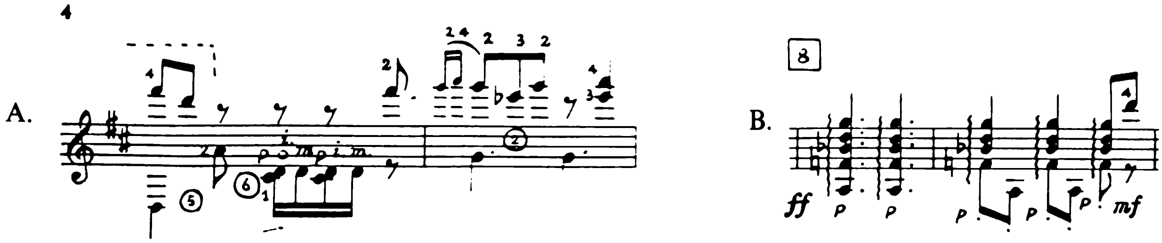
42. P. Boulez, *Boulez on Music Today*, trans. R.R. Bennett and Susan Bradshaw (London: Faber and Faber, 1971), p. 44.

43. Cowell, op. cit., p. 121.

44. M. Kagel, "Tone-Clusters, Attacks, Transitions," *Die Reihe* no. 5, trans. Ruth Koenig (Bryn Mawr, Pennsylvania: Theodore Presser, 1961), p. 45.

prove "difficult until understood," a comment which could apply to many works of the twentieth century.)

Diatonic use of the harmonic cluster is found in Rodrigo's *Concierto de Aranjuez* (1939), where the composer uses the leading tone of the scale almost as an acciaccatura to the tonic, adjacent to one another (A), or a minor-ninth apart (B):



Ex. 83. *Concierto de Aranjuez* (1939), J. Rodrigo.

Diatonic clusters have also been used by Milhaud, in *Segoviana* (copyright 1959).

Of course, non-diatonic clusters can also be used in all these ways. The melodic cluster has proven the least popular, but this texture is used very effectively by Maurice Ohana, who tremolos adjacent string semitones and whole tones:

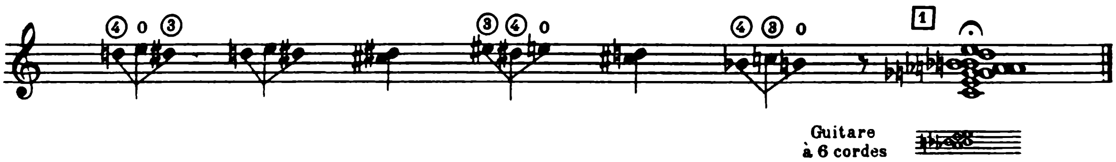
Ex. 84. "Maya," *Si le jour paraît . . .* (1963), M. Ohana. Published by permission of Gérard Billaudot éditeur, Paris.

And, of course, any treatment of a cluster will be easier to manage on two or more guitars, as Shimoyama shows when he asks two players to gliss a double cluster in *Dialogo No. 2* (1970, 3:1.3).

Harmonic use of clusters has proven very popular in mid-century guitar music: again, ensemble guitars are particularly well suited to this type of cluster production:

Ex. 85. *Music for Three Guitars* (1970), R. Smith-Brindle. © 1977. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

The quarter-tone harmonic clusters used by Sandström (Ex. 82) are a good example of how blocks or masses of sound can be created on a solo guitar by playing microtuned adjacent tones. Semitones are also very effective; in "Aube," Ohana contrasts bi-chords and tri-chords in crotchet motion (♩ = 50):



Ex. 86. "Aube," *Si le jour paraît* . . . (1963), M. Ohana. Published by permission of Gérard Billaudot éditeur, Paris.

In another section of the same piece, the composer uses a Bartók pizzicato to play a bi-chord cluster:

Ex. 87. "20 Avril," *Si le jour paraît* . . . (1963), M. Ohana. Published by permission of Gérard Billaudot éditeur, Paris.

When the C and D♭ in Ex. 87 are sounded together, another sound is generated that is not a frequency component of either of the individual notes. The juxtaposition of closely spaced pitches causes several acoustic phenomena that account for the difference in quality between the sound of a cluster and the sound of a more widely spaced interval. Probably the most important of these interference phenomena is the creation of *beats* between two tones, which results in a periodic waxing and waning of loudness of the composite sound. To illustrate this principle, two sine waves, with frequencies of 7 Hz and 8 Hz, respectively, are added in Figure 90. The darker line shows that at Point A the wave crests occur together, and the total amplitude of the combined wave crest is twice that of each individual crest. At B, where crest and trough coincide, they cancel each other out, producing zero amplitude and momentary silence. This alternating increase and decrease of amplitude (a double crest followed by silence) is heard as a *beat.*

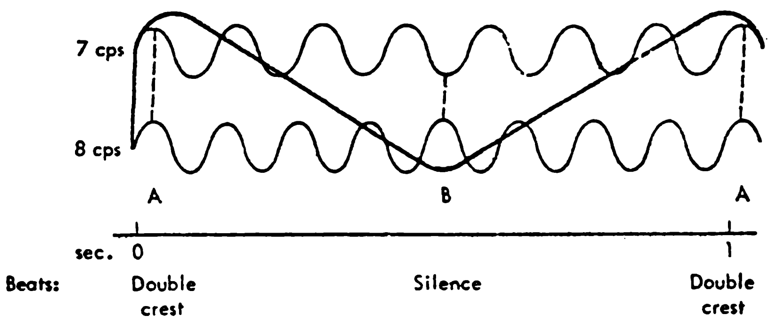
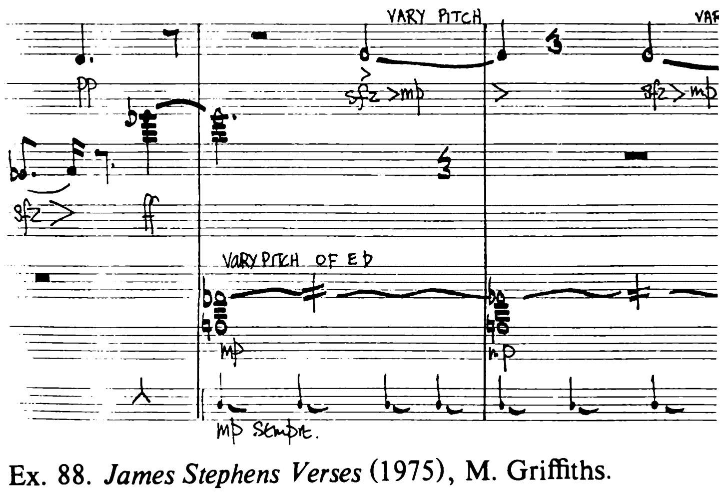


Fig. 90. Beats created by waves of slightly different frequencies.[45]

The beat frequency (beats per second, or *bps*) is always the difference between the frequencies of the two waves (8 Hz − 7 Hz = 1 bps). In Example 87, the C = 130 Hz and the D♭ = 138 Hz, so the combination of the fundamentals of these two tones will beat at approximately 8 bps. (See Recorded Ex. 36.)

Some composers have used beats as part of their music. Mark Griffiths, in his *James Stephens Verses*, has the guitarist play a major seventh, then bend-gliss the interval in and out of tune by a quarter-tone, producing beats that accelerando and ritard:

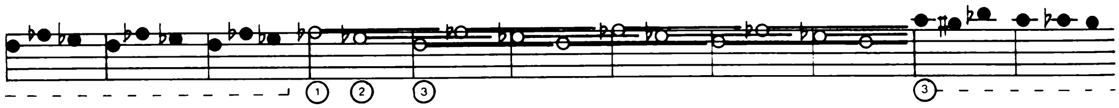


Ex. 88. *James Stephens Verses* (1975), M. Griffiths.

45. From R. Cogan and B. Escot, *Sonic Design: The Nature of Sound and Music* (Englewood Cliffs, N.J.: Prentice-Hall, 1976), p. 371. Reprinted by permission.

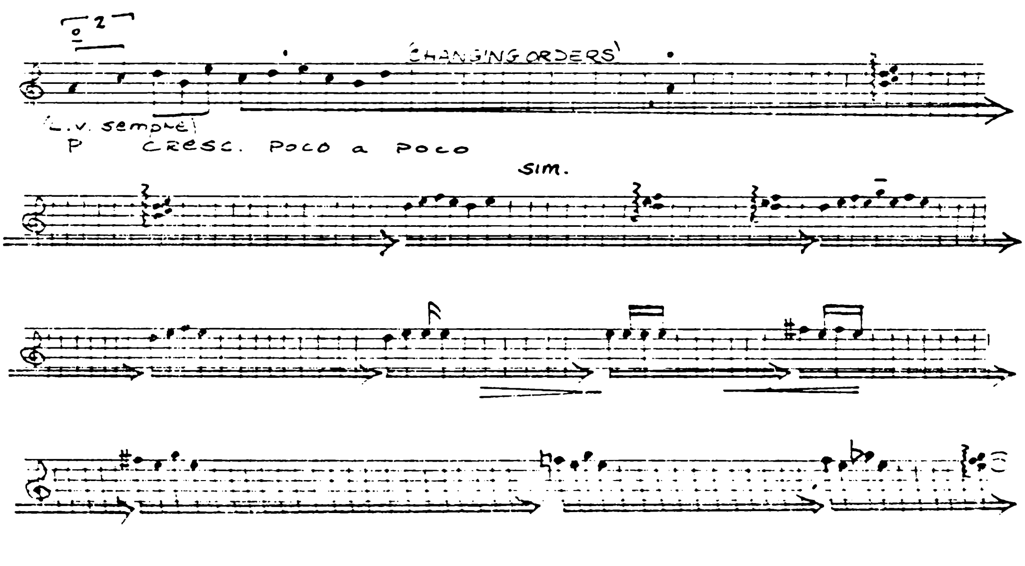
José Encinar achieves the same effect somewhat differently by allowing the octave string to vibrate in resonance with the plucked string, which is then glissed a quarter-tone away from the octave, in *Abhava* (1972).

The *textural* form of cluster writing usually begins with a single note, to which semitones are added above, below, or on either side. This procedure is illustrated graphically by Bent Lorentzen's line/duration notation:



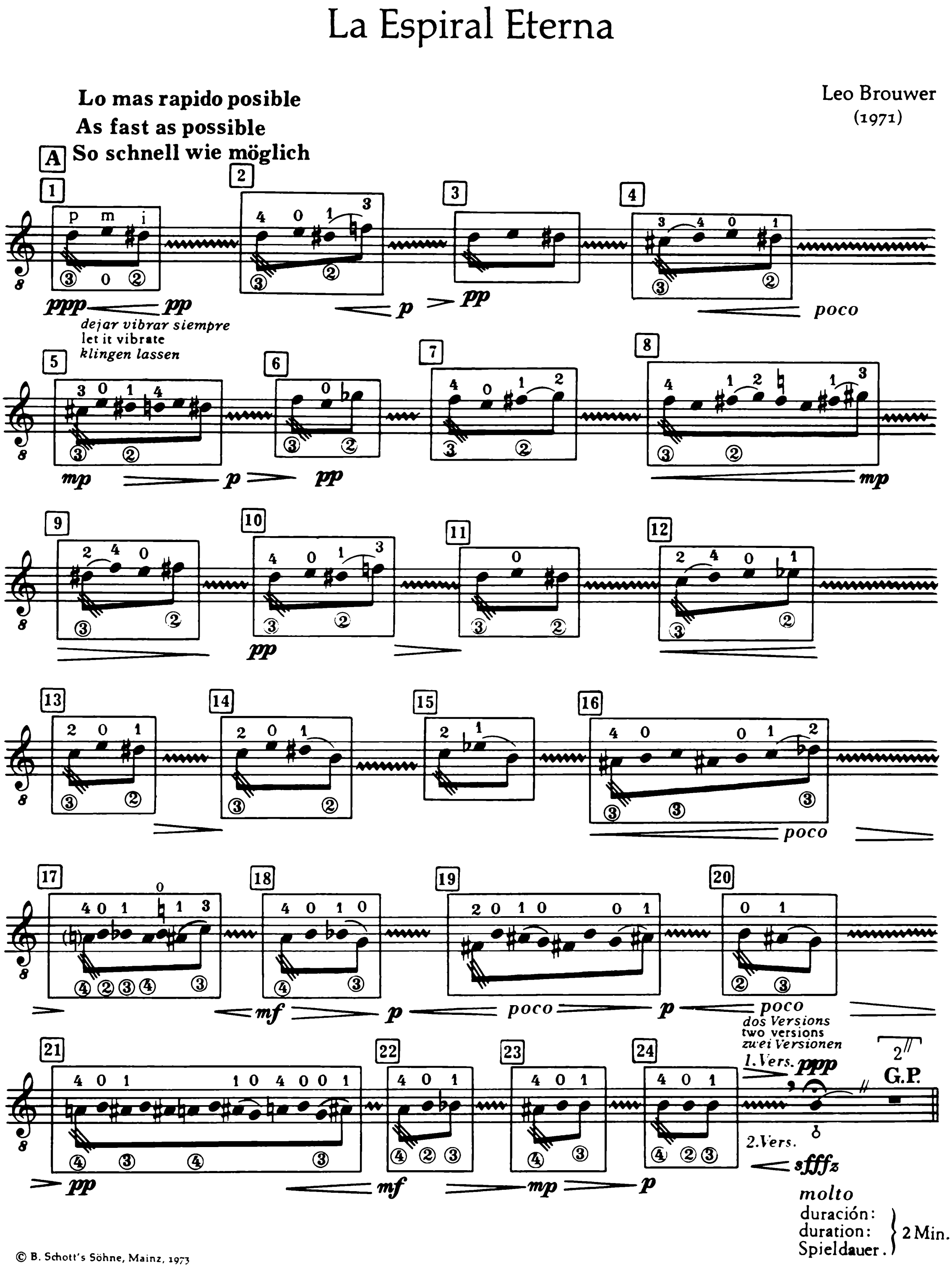
Ex. 89. *Umbra* (1973), B. Lorentzen. By permission of Edition Wilhelm Hansen, Copenhagen.

Once the texture has been built up, it can then be phrased dynamically or timbrally or can be transposed by adding notes in either direction. Leo Brouwer uses this kind of constantly transforming texture as the two-minute introduction in *La Espiral Eternal.* See Example 91. Complex textures are also built up in Edward McGuire's *Music for Four Guitars*, where much of the second movement, "Day Song," is built up of clusters arpeggiated in semiquaver motion. The interesting aspect of this example of cluster writing is that the four players are told to play this passage out-of-phase with each other, so that the distinctions between notes become extremely blurred.



Ex. 90. *Music for Four Guitars* (1973), E. McGuire. Used by permission of Editions Bèrben s.r.l.

Notation of clusters is a matter of personal preference, and the results from different pens vary widely. Multi-headed stems, as in Examples 86 and 87, are the most common solution; D. K. Libby and A. Company (Ex. 27) use a stave per string when the note values of closely spaced pitches differ. Some composers use a graphic symbol: Elisa-



Ex. 91. *La Espiral Eterna* (1971), L. Brouwer. © 1973 by B. Schott's Söhne, Mainz. Used by permission of European American Music Distributors Corp., sole U.S. agent for B. Schott's Söhne, Mainz.

beth Lutyens uses in *"Go, Said the Bird"* (1975, 5:2.1), and Siegfried Behrend uses for "bright-sounding clusters" and for "muted-sounding clusters" in both *Movimenti* (1969) and *Sechs Monodien* (1974).

Clusters represent the first use of quasi-pitched sound in guitar music. Kagel has said that "clusters have generally been used as a kind of anti-harmony, as a transition between sound and noise."[46] In guitar music, the next move toward unpitched sound comes with the use of the prepared guitar; finally, with the introduction of percussion techniques, unpitched sound and noise become a vital part of guitar sound.

46. M. Kagel, "Tone-Clusters, Attacks, Transitions," p. 46.

CHAPTER VII
Unpitched Sounds

Noise—unpitched and quasi-pitched sound—found its way into Western music in the form of percussion instruments used in the orchestral scores of the Romantic era. By the end of the nineteenth century, when the search for new musical material began, this aspect of sound production began to be more fully exploited. Due in part to the Industrial Revolution, the quality of European life had changed drastically in the latter half of that century, and the increasing use of machinery introduced a large amount of noise into the daily lives of most people. Perhaps it was this aspect of life, coupled with the avant-garde search for new means of expression, that inspired the Italian Futurist Luigi Russolo to propose a "Music of Noise" in 1913. This "bruitismo"' included:

1. Bangs, thunderclaps, explosions, etc.
2. Whistles, hisses, snorts.
3. Whispers, murmurs, rustling, gurgling.
4. Screams, shrieks, buzzing, crackling, sounds produced by friction.
5. Sounds produced by striking metal, stone, wood, china, etc.
6. Animal and human cries—roars, howls, laughter, sobs, sighs, etc.[1]

After the First World War, composed noise became a common element in much modern music, particularly in America, where George Antheil, in his famed *Ballet Mécanique* (1924), used percussion, electric instruments, ten pianos, and machines including an airplane engine and propeller as musical instruments. Of more lasting musical value was Edgard Varèse's *Ionisation* (1931), composed for thirteen percussionists. John Cage was also very interested in percussion timbres, and used them adventurously in *First Construction (in Metal)* (1939) and *Double Music* (1941) for percussion quartet playing water-buffalo bells, brake-drums, muted brake-drums, sistrums, thundersheet, water-gongs, and tam-tam. Cage "invented" the prepared piano during this period, though it is interesting to note that many continental pianos in the early 1800s used effects-pedals that lowered various materials onto the strings to alter the sound. For example, some used strips of

1. H. Stuckenschmidt, op. cit., pp. 50–51.

brass and parchment to imitate the cymbals and bassoon in performances of "Turkish" music.[2] Of course, Cage's preparations offer a much more abstract set of sonorities than these musical condiments did.

On the continent, Messiaen's fascination with Oriental scales and timbres prompted him often to turn to the percussion section of the orchestra, which, for new timbral contrasts, he had enriched with many Eastern gamelan-type instruments. Messiaen's influence on the Darmstadt generation is well known; his most famous pupils, Boulez and Stockhausen, have also written much music for quasi-pitched instruments. Boulez has considered the relationships between noise and sound:

> Western music has long excluded noise because its hierarchy has depended on the principle of the identity of sound relationships which are transposable on all the degrees of a given scale; noise, being a phenomenon not directly reducible to another noise, is thus rejected as contradictory to the system. . . .
>
> It seems that sensations of noise and sound arise primarily from the greater or lesser selective analytical ability of the ear. When it hears a rapid succession of complex chords, or a single complex chord of extreme brevity, the ear is incapable of even an intuitive analysis of the relations between the pitches; it is saturated with complexity and, *globally*, perceives noise. When it hears a reiterated succession of different noises in a simple and homogeneous context—the same family of instruments—it analyses them instantly and is able to specify, if only intuitively, the relations existing between them. . . .
>
> In my opinion, then, sounds and noises must be treated as a *function* of the formal structures which employ them, which reveal them for what they are.[3]

Today, noise is, to some degree, an integral part of almost all compositions, and it is particularly important in concrete and electronic music written since 1950. In some solo instrumental music, such actions as rattling keys, striking instrument bodies, and bowing tailpieces have provided composers with a new class of sounds—the unconventional use of conventional instruments. The guitar has also been extended in this manner. This chapter explores the methods players and composers have chosen to elicit quasi-pitched and unpitched sounds from electric and acoustic guitars.

PERCUSSION

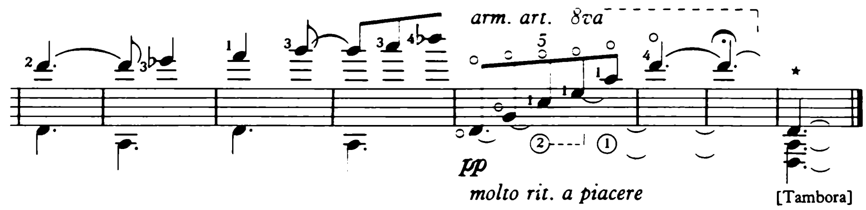
There are two kinds of percussion techniques for the guitar: those that strike the strings (*tambura* or *tambora*) and those that strike the wood (*golpe*). *Tambura* is the Italian term meaning "drum"—an accurate description of the sound attained when the player strikes the strings near the bridge with the side of his thumb or palm. This action activates the air resonance inside the body of the guitar, which responds with a tone whose pitch

2. A. Loesser, *Men, Women and Pianos: A Social History* (New York: Simon and Schuster. 1954), p. 172.

3. P. Boulez, op. cit., pp. 42–43.

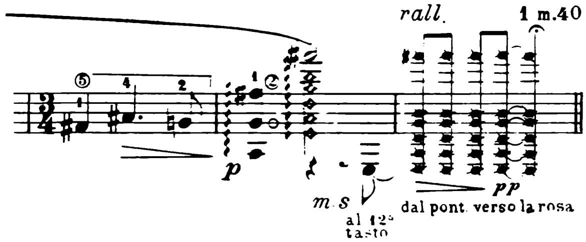
depends on the size and shape of the body (Chapter 2). Aguado describes this effect as *Tambourin* in his *Méthode Complète pour la Guitare*.[4] (See Recorded Ex. 37.)

Tambura is very popular in modern guitar music; it is often used at the end of phrase or a section to repeat chordal material in a transformed state. Because it cannot be played very loudly, the effect is usually reserved for this sort of function. Walton uses tambura to bring to a close the meditative ending of his *Second Bagatelle*:



Ex. 92. *Five Bagatelles for Guitar* (1972), W. Walton. © 1972 Oxford University Press. Used by permission.

The tambura effect can also be phrased timbrally as well as dynamically, by changing the position of the right hand while striking the strings:



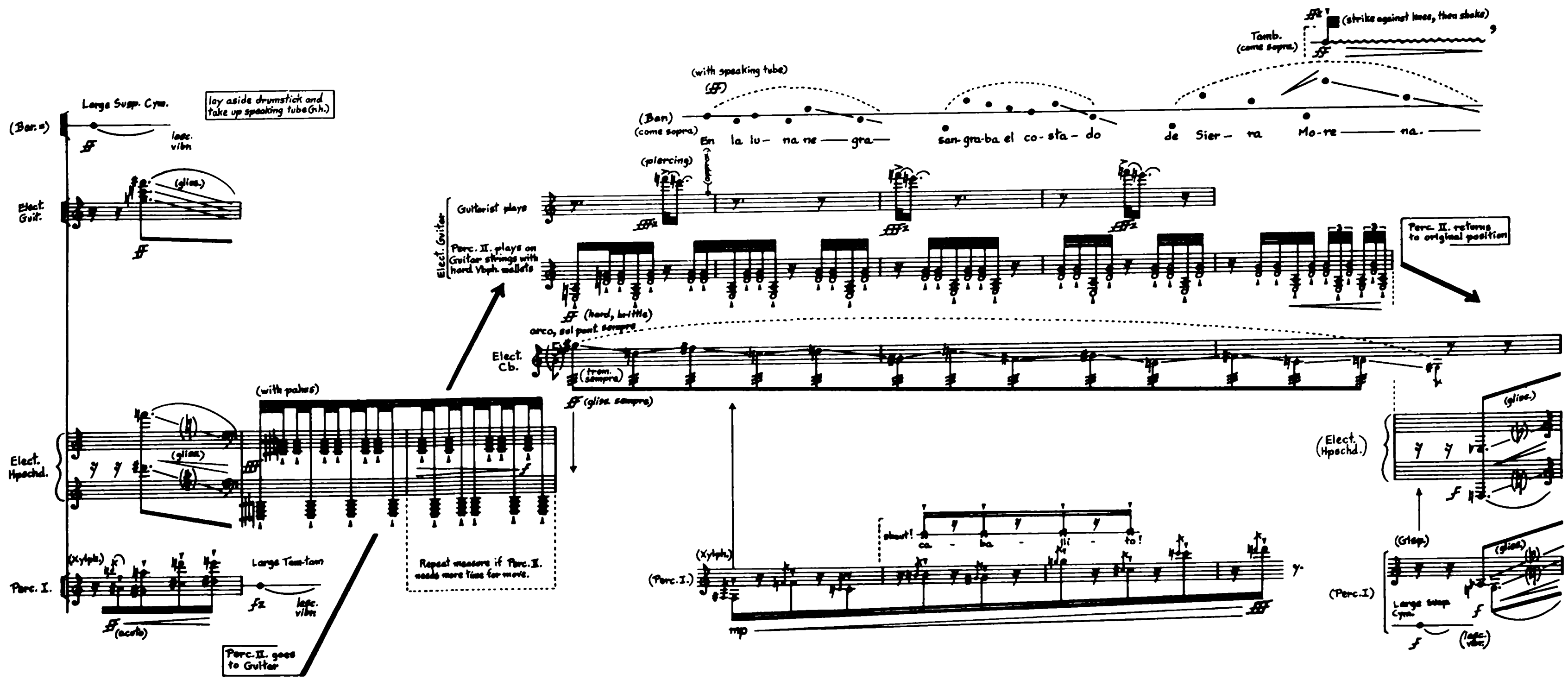
Ex. 93. *El Polifemo de Oro* (1956), R. Smith-Brindle. Courtesy of Aldo Bruzzichelli Editore, Florence, Italy.

Alvaro Company uses this effect very competently in a delicate interplay between plucked and struck chords in the last measures of the second movement of *Las Seis Cuerdas* (13b : 2–6).

Although it is the norm to use tambura on chords, the technique is equally effective on all types of string tones. Company asks for single strings to be struck with the flesh of either the "i" or "m" finger, calling the effect "timpano" because of its likeness to the sound of a kettledrum; he also uses this effect to produce harmonics. Siegfried Behrend uses tambura to play crossed strings in *Movimenti für Gitarre* (1969, 6 : 2.2).

So far I have been discussing striking the strings with the hand, but many composers of this century have requested that the strings be struck with anything from pencils to ping-pong balls. Kagel was one of the first to use an alternate method of striking, asking the guitarist in *Tremens* (27 : 1.1–4) to tremolo on the first, then the first and second strings with a xylophone mallet which is held in the right hand. David Bedford plays the electric bass guitar with a small mallet in *Those Who Walked Away from Omelas* (31 : 1.4), and George Crumb has one of the percussionists in *Songs, Drones* walk over to the electric

4. D. Aguado, *Méthode Complète pour la Guitare* (Paris: Richault, 1827), p. 79.

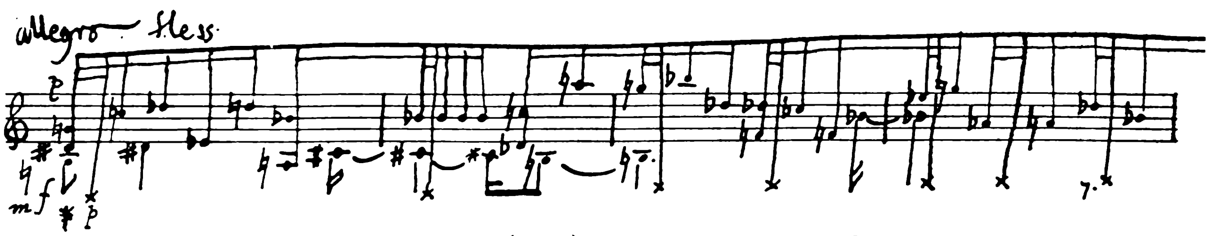


Ex. 94. *Songs, Drones and Refrains of Death* (1968), G. Crumb. © 1971 by C. F. Peters Corp. By permission.

guitarist and strike the four deepest open strings with hard vibe-mallets while the guitarist plays on the top strings (see Ex. 94).

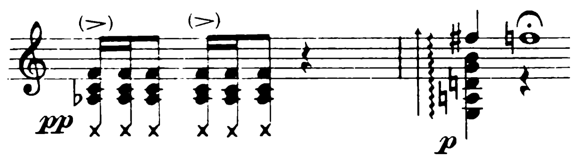
In *You Asked for It* (1969), Bedford asks the guitarist to produce a tremolo by bouncing a teaspoon on the required strings (see Plate VIII). When he wants this effect, in this piece or in his *Nurse's Song with Elephants* (1971), he simply writes "teaspoon." Other strange striking implements include a tuning fork, in Ohana's *Si le jour Si le jour paraît . . .* (II, 5 : 4) and Tomás Marco's *Albayalde* (1965, : 8), a triangle beater and triangle, in Kagel's *Tremens* (9 : 1 and 277 : 1), ping-pong balls, in Marco's *Albayalde* (: 9), pencil rubber and "resonant metal object," in Keith Humble's *Arcade IV* (1969, 6 : 1), and a felt-covered metal bar, in *Si le jour paraît*... (VI, 1:1). The tambura effect is notated by an *x* marked through the pitch/s to be played.

The other kind of percussion effect used in guitar music is the *golpe* stroke, in which the player strikes the wood of the body of the instrument. This technique is certainly not peculiar to classical guitar technique; in fact, it was borrowed from flamenco players, who must protect the tops of their guitars with plastic sheets called *golpeadores* because the table of the instrument is struck so often in this style of music. John Gavall has correctly stated that "from a percussion point of view, the guitar's soundbox may be considered as a small battery of wooden drums of varying resonance characteristics."[5] Many composers have used this aspect of the instrument, and there are several degrees of sophistication with which the golpe effect can be notated. Most writers simply use an X symbol without trying to define the tone's loudness or pitch. This type of golpe has been used as a contrapuntal line:



Ex. 95. *Lullaby for Illian Rainbow* (1972), P. Maxwell-Davies.

It has also been played simultaneously with a chord:

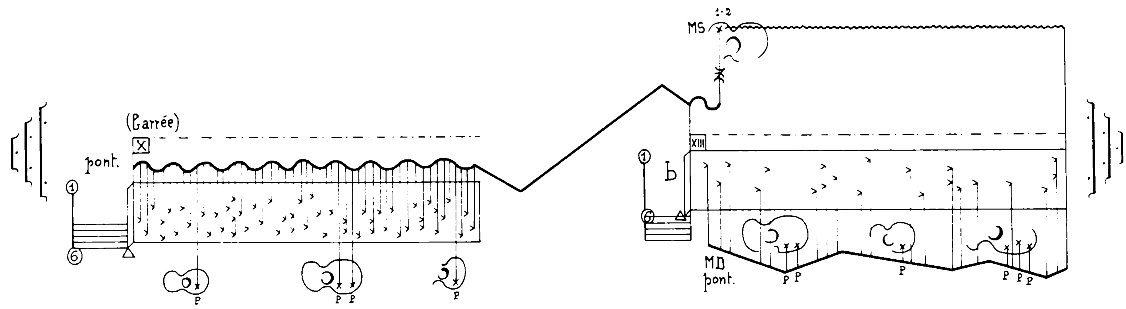


Ex. 96. *Canto for Guitar* (1968), J. McCabe.

5. J. Gavall, "The Guitar—An Evaluation," *Musical Times* 95 (November 1955).

The X method really evades the notation issue, however. One of two better approaches may be taken: one can either notate the relative pitch of the sound, or one can use a symbol to direct *where* the instrument should be struck.

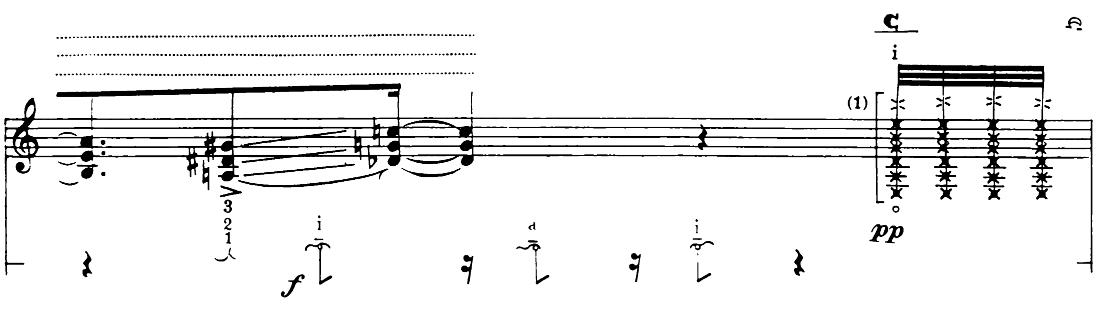
One of the few composers who has chosen the pitch method of notation is Siegfried Fink, who uses the relationship of dots to a line as the pitch determinant, and the size of the dots to define the dynamics, in *Dialoge* (1968). Most other composers who do not use the X method choose to illustrate where the guitar body is to be struck. Azio Corghi uses a picture of the guitar top:



Ex. 97. *Consonancias y Redobles* (1973), A. Corghi. © 1974. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

In *Grande Fantaisie* (1975), Hans Gefors even wants a chord to be excited by striking the back of the instrument; he directs the player, "Beat with the backside of the hand without using the knuckles to produce a soft, conga-like sound."
Henze uses several symbols to notate with what the body is to be hit, but leaves the pitch and loudness to the discretion of the player. In *El Cimarrón*, he uses ⚹ for knuckles, ⅄ for fingertips, and ⅄ for fingernails.

Several other systems of percussion notation have been invented, notably by Aurelio Peruzzi for *Quatro Pezzi* (1974), and by H. Shimoyama for *Dialogo No. 2* (1970), but perhaps the most thorough, and certainly the most elegant, system has been constructed by Alvaro Company. This system (see Fig. 91) uses a separate symbol for each part of the hand that can be used to strike (flesh, flat of finger, nail, back of nail), and a symbol for each place on the instrument to be struck (the soundboard, the bridge, the side of the upper or lower bouts). This allows Company to write a line of percussion (in rhythmic counterpoint to plucked and struck chords) with relative ease:



Ex. 98. *Las Seis Cuerdas* (1963), A. Company. © 1965. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

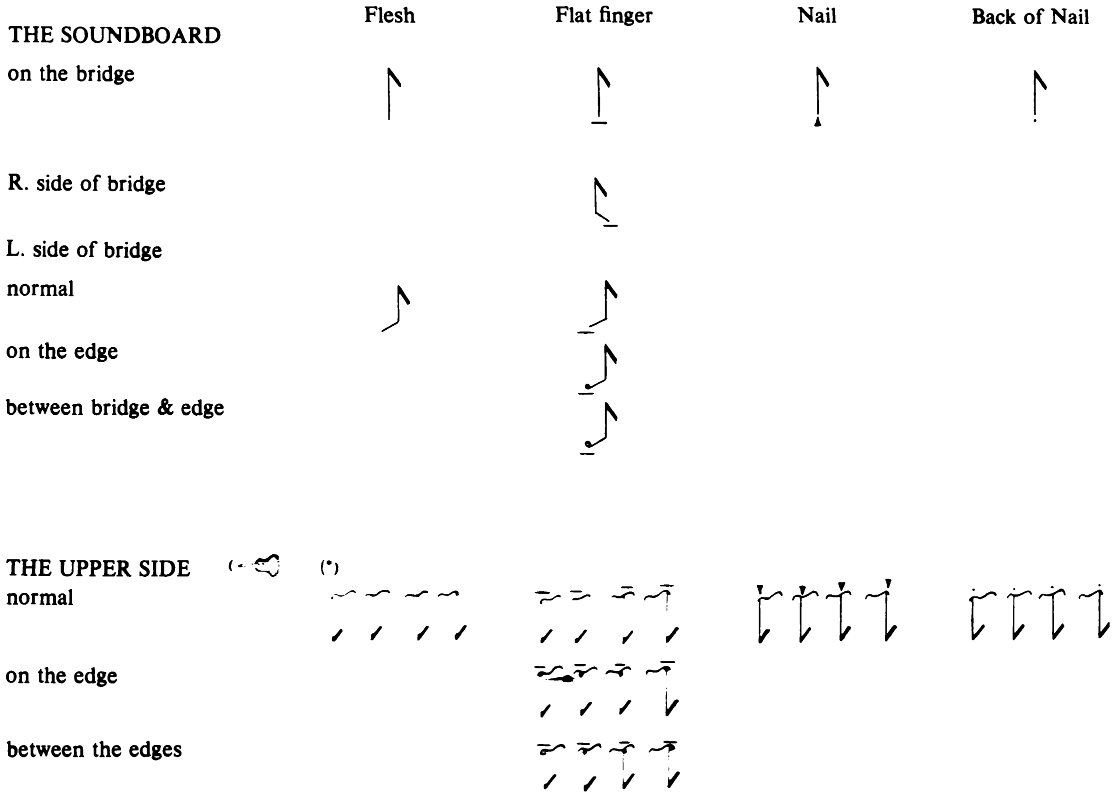


Fig. 91. Symbols for "indeterminate sounds" from *Las Seis Cuerdas* (1963), A. Company. © 1965. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

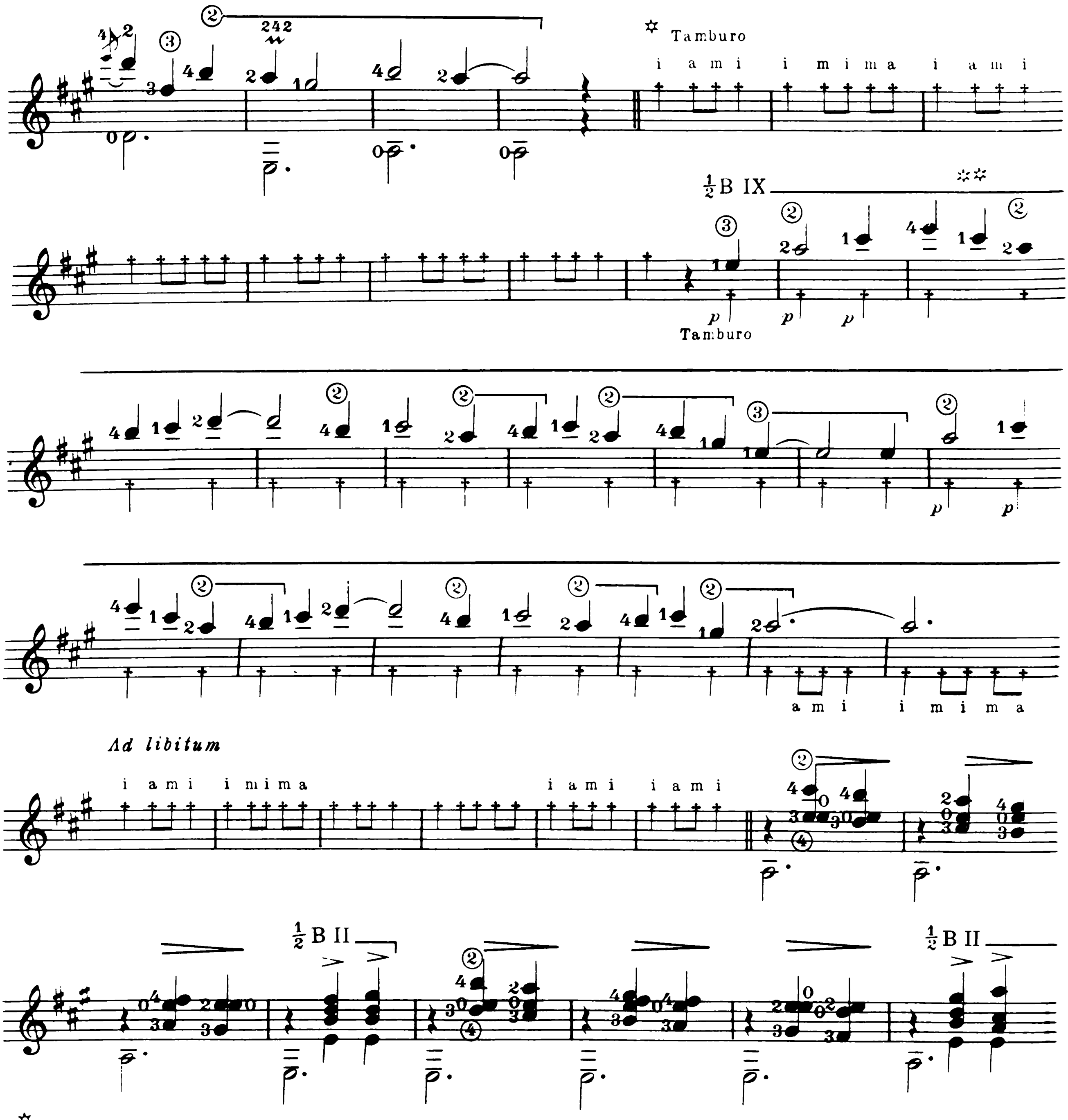
When using this system, however, one must remember that instruments *do* differ, and the composer should perhaps try each prospective technique with more than one player.

Percussive effects can be a powerful tool when used with taste. They should not be treated only as "a *function* of the formal structures which employ them," as Boulez suggests; they must also help to *determine* the musical structures. Henze has devoted part of a movement in his *Royal Winter Music* (1976) to a musical discussion of these types of sounds, and it is to be hoped that more composers of his calibre will follow suit.

PREPARATION

The practice of preparing musical instruments for non-tonal music began in 1938 with John Cage's extension of the timbral capacity of a piano by attaching bits of metal and rubber to its strings. This produced a sound not unlike a gamelan orchestra or a large orchestra of percussion instruments. In guitar music, preparation also means somehow interfering with the normal string vibration, by adding some object onto or next to the string/s involved.

The first example of preparation in guitar music was the use of one of the six strings themselves to interfere with the other strings. In Tarrega's *Gran Jota* (1872), the player is directed to twist the fifth and sixth strings at the ninth fret to obtain what he calls the "tamburo effect"' (crossed strings), which he then contrasts with a melody played ponticello with the nails:



☆ Per ottenere l'effetto del Tamburo si accavallano o sovrappongono la ⑥ e ⑤ corda all'altezza del IX tasto.
☆☆ Suonare con l'unghia sul ponticello per ottenere il suono metallico.

E. 1533 B.

Ex. 99. *Gran Jota* (1872), F. Tarrega. Used by permission of Editions Bèrben s.r.l.

This was later called the "side-drum" or "snare-drum" effect.[6]

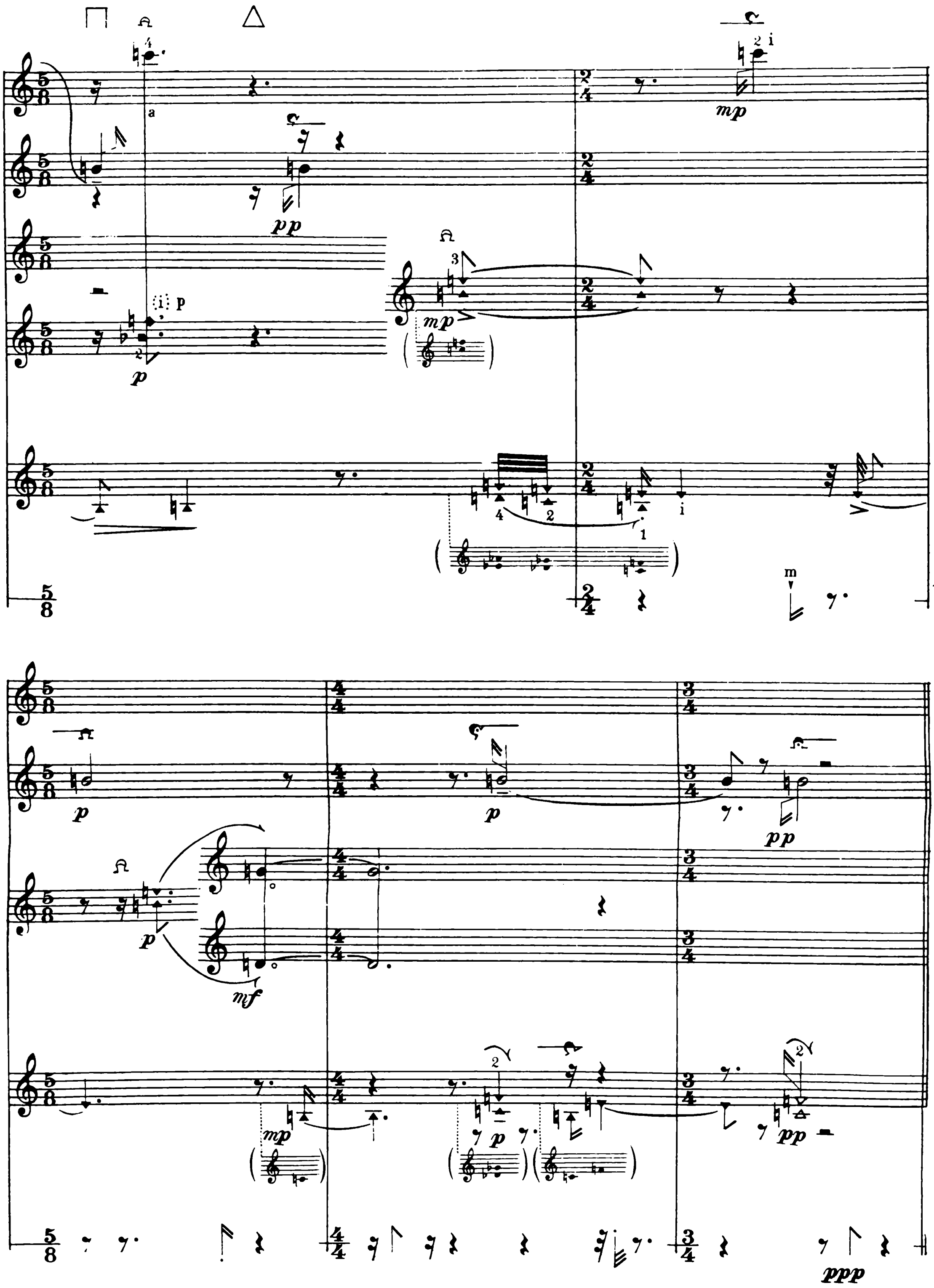
The crossed-string technique has been the most popular method of preparation for the classic guitar in this century. Wound strings give a resonant sound, but nylon strings can also be crossed to produce a light, rattling texture. Crossed strings are easiest to play when they are crossed near the center of the string length, because the strings are more easily bent at that point. One piece, however, asks that the fifth and sixth strings be crossed at the first fret, which is not only extremely difficult for the left hand to finger, but is almost impossible to prepare quietly [*Codex I* (1963), C. Halffter, 6 : 3].

Theodor Antoniou tremolos crossed strings in a dynamically phrased flute accompaniment in *Dialoge* (1963, 12 : 4.2), and Aurelio Peruzzi uses a repeating crossed-string figure to accompany an upper-string melody:

Ex. 100. "Recuerdos," *Quattro Pezzi* (1974), A. Peruzzi. © 1974. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

Alvaro Company uses two sets of crossed strings simultaneously, and makes the release of

6. Roch, op. cit., book two, p. 70.



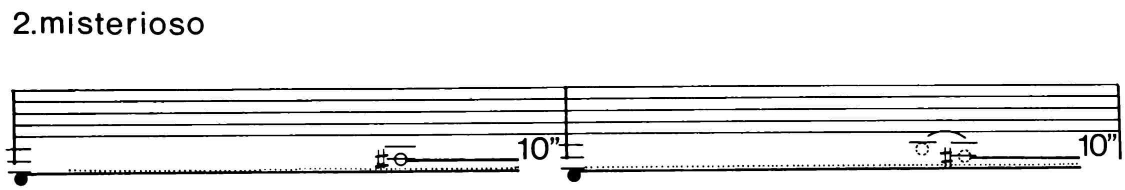
Ex. 101. *Las Seis Cuerdas* (1963), A. Company. © 1965. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

one pair a part of the musical phrase (see Ex. 101). This example shows that either member of the crossed-string pair can be plucked separately. (See Recorded Ex. 38.)

The Company notation shows the crossed notes as triangles; another method is to use an *x*-headed note for each string. David Nevens asks for a special crossed-string effect in *Soliloquium II* (1976): "'Bend' string(s) over edge of finger board at fret indicated."[7]

All other types of guitar preparation involve some sort of foreign object either being held against the strings while they are being plucked, or actually exciting the string as well as modifying the sound. In the "Nocturne" of *Arcade IV* (1969, 6 : 1), Keith Humble suggests a number of textures for guitar improvisation, two of which produce a buzzing sound—by holding a paperclip/nail file/pencil next to the string, in one instance, and a fingernail next to the string, in the other. For this type of sound, Bent Lorentzen uses a special symbol accompanied by the instructions:

> Strike the open string at the middle point, with maximum vibration; shortly after the attack, place nail of the first finger of the left hand sideways to the string in fret 1. The result will be a buzzing sound like the East Indian zither.[8]



Ex. 102. *Umbra* (1973), B. Lorentzen. By permission of Edition Wilhelm Hansen, Copenhagen.

In two of his pieces, David Bedford prepares the guitar in a way sometimes used by harpists: with paper. Harp players usually weave a piece of paper between the strings; in *You Asked for It* (1969), the guitarist is told to "place folded tracing paper beneath the strings at the bridge. The paper should be thick enough to touch and damp the strings."[9] In the piece itself, the section using this preparation is simply marked "paper."[10] In *Nurse's Songs with Elephants* (1971), Bedford asks for "folded newspaper (Sunday *Times* Business Section is about the correct size) under the strings to produce a damped, rattling sound."[11]

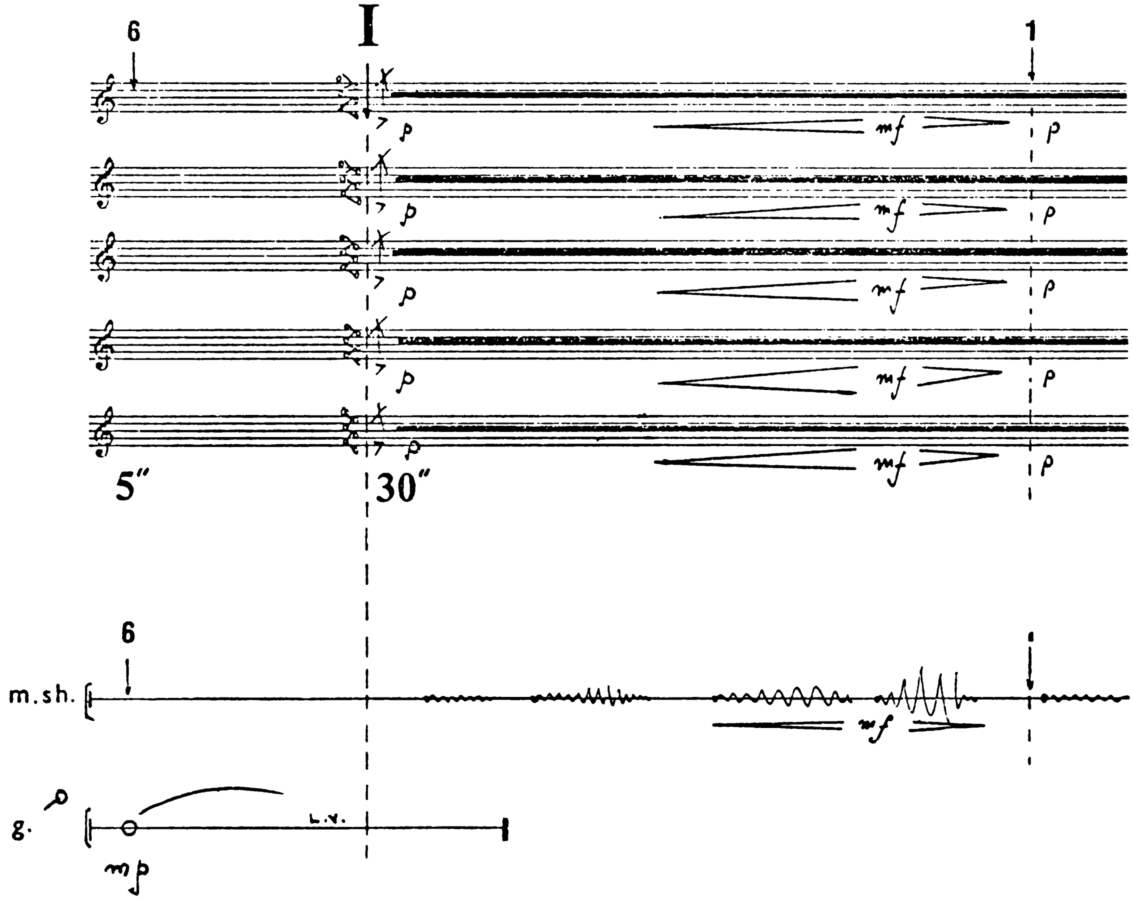
7. D. Nevens, *Soliloquium* for guitar (unpub., College of Music and Drama, Cardiff, South Wales).

8. B. Lorentzen, *Umbra* for guitar solo (Copenhagen: Editions Wilhelm Hansen, 1973), Instructions.

9. D. Bedford, *You Asked for It* (London: Universal Edition, 1969), Notes for Performer.

10. Ibid., 6 : 6.2 11. Ibid., 13 : 10.4.

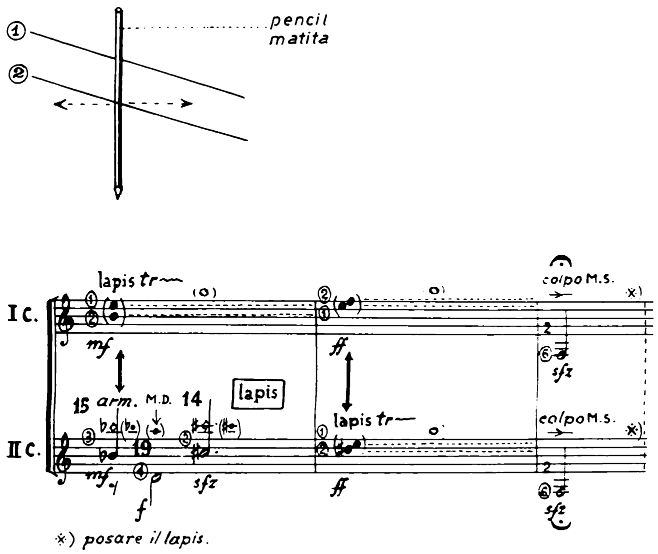
Another type of preparation involves setting the strings in vibration with the preparing object. Gilbert Biberian creates a ghostly atmosphere when all ten guitarists in *Prisms II* "insert paper knife between the strings (over and under alternatively) then on the sign > set it in vibration by pressing the near end down and releasing":



Ex. 103. *Prisms II* (1970), G. Biberian. Used by permission.

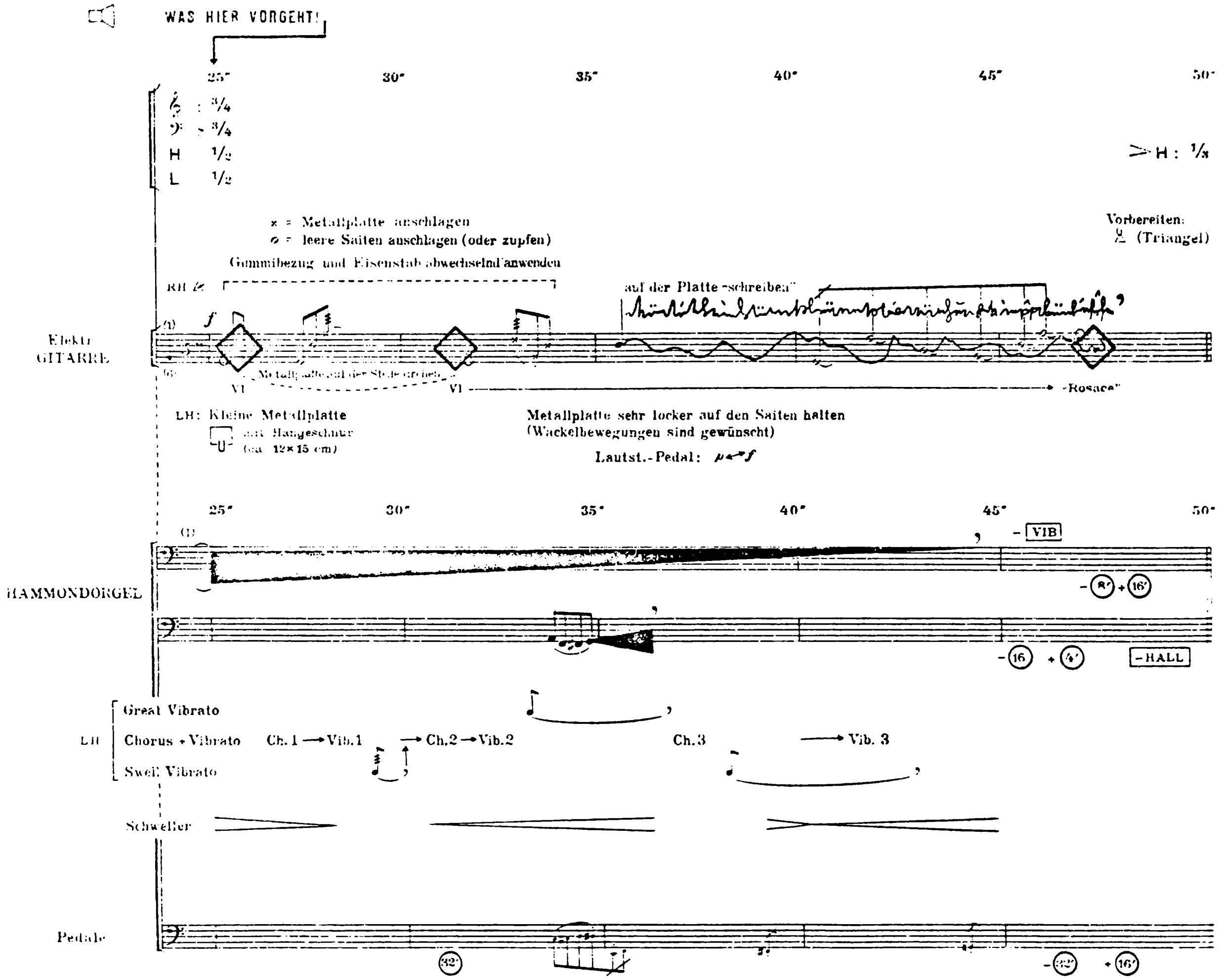
David Bedford uses a milk bottle to create a very delicate texture on the electric guitar. In both *18 Bricks* and *The Ones Who Walked*, the electric guitarists are asked to "place guitar on the floor. Put a milk-bottle (upright) on the strings above the pickup. If pushed gently, it will wobble on the strings, producing a gamelan-like sound." In fact, the bottle produces bi-tones when rocking on the strings, and the pickup amplifies both lengths of string, producing a beautiful, ethereal sound.

Another type of bi-toneproducing preparation is the "pencil-trill" used by Shimoyama. To perform this trill, one must "put a long pencil vertically between first and second strings, at the holes level (S). Make trill by shaking it between them":



Ex. 104. *Dialogo No. 2 per Due Chitarre* (1970), H. Shimoyama. © 1973. By permission of Edizioni Suvini Zerboni, Milano, and Bossey and Hawkes, Inc., Sole Agents, U.S.A.

Sounds such as those found in the Bedford examples above are only possible on the electric guitar. These delicate sounds need great amplification to be heard, and the microphonic ability of this instrument has made available to the progressive guitarist a whole new class of sounds. Mauricio Kagel, who utilizes many exotic and obscure instruments, has employed a number of these delicate sounds in *Tremens* as part of the ensemble texture. For one such sound, a thin metal spring about 20 cm long and 15 mm wide is held to the pickup by magnetic screws, which also amplify its vibrations (see Plate VI). This preparation permits a wide choice of "gong" and "boing" sounds, depending on where and how the spring is hit and how far along its length it is attached to the pickup. (English composer Hugh Davies has made several sophisticated instruments for this type of sound generation, with four magnetic pickups on a stand and a selection of various-sized springs.) Kagel asks that the spring be placed on the strings and moved constantly while being struck, rubbed, and scratched with a triangle beater. Accompanying this action is the electric six-string bass guitar, which is employing a heavy spring for much the same purpose; in the fourth bar a triangle is used a a glide-bar while the right hand strikes the spring. All this activity, added to the music of the electric contrabass, Hammond organ, and tape, combine in a very complex texture. *Tremens*, as well as several other Kagel works using electric guitars, is full of unusual instrumental treatments and highly inventive preparations. At one point Kagel asks the guitarist to place a small metal plate (12 cm x 15 cm) on the strings and to write on it while moving the plate from the 6th fret toward the bridge:



Ex. 105. *Tremens* (1963/65), M. Kagel. © 1973 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

These sorts of elaborate preparations are perhaps put to their best use in an ensemble texture: because of the time it takes to prepare these sounds and the relative awkwardness of changing from one kind of preparation to another, they have limited use in the solo repertoire.

Several preparations for electric guitar are both simple and very effective. David Toop, the "discoverer" of the Prepared Guitar (see Plate IX), suggests:

> Fastening (miniature) crocodile clips to the strings of the guitar has the effect of converting the guitar into a small orchestra of gong and bell sounds (a rather imprecise description—though the timbre is largely either ringing or deeply resonant, the struck quality of an idiophone is absent. The resultant spatial definitions peculiar to idiophones are replaced by a curious amorphous sound). These crocodile clips, used

normally by electricians, can be used on any type of plucked chordophone, acoustic or electric.[12]

The clips can also be used to attach additional material to the strings (rubber, pieces of metal, etc.) to extend the repertoire of sounds available.[13] Guitarist-composer William Hellerman uses paperclips to prepare all three instruments in *On the Edge of a Node* for guitar, violin, and cello (1974). He remarks that the preparations "give artificial 'nodes' that emphasize pitches in varying degrees of distant relation to the fundamental stopped pitch. Each note becomes a timbral event in itself made up of a family of pitches at a variety of amplitudes. What I especially like about clipping the strings is that it makes the surface of the sound particularly evident."[14]

Another easy and versatile preparation is found in my *Voyage* (1976). A plectrum is placed between the fourth and sixth strings 

This produces a gong-like sound that can be altered by plucking any or all of the strings touching the plectrum, or by changing the position of the plectrum along the strings. These last two types of preparation (clips and pick-between-strings) are very easily placed and removed, and can be moved quickly for timbral transformations. (See Recorded Ex. 39.)

VOCAL AND EXTRA-MUSICAL EFFECTS

One aspect of performance practice that has been developed in the last thirty years is the use of the instrumentalist as a sound source. American composer Donald Erb has said:

> Music is made by a performer. It comes from him rather than from his instrument, the instrument being merely a vehicle. Therefore it seems logical that any sound a performer can make may be used in a musical composition.[15]

As the following examples will illustrate, these sounds can include anything from spoken words to cries and finger-snapping.

Elisabeth Lutyens has used humming in a piece for speaker and ten guitars (see Ex. 106). The vocal parts appear in five staggered entries during a *tutti ff* chord, and literally appear from nowhere—a striking musical gesture, and a very dramatic one, because most audiences do not expect players to sing (or hum).

12. D. Toop, *New and Rediscovered Musical Instruments* (private publ., 1974), p. 9.

13. For some interesting preparations, see R. Bunger, *The Well-Prepared Piano* (Colorado Springs: Colorado College Music Press, 1973). Prepared electric guitar and electric bass guitar can be heard played by David Toop in "Divination of the Bowhead Whale," *New and Rediscovered Musical Instruments*, Obscure Records no. 4.

14. Sleeve notes on *Music from the American Academy in Rome*, CRI SD-336. The recording of *On the Edge of a Node* is an excellent example of the textures available from the prepared classic guitar.

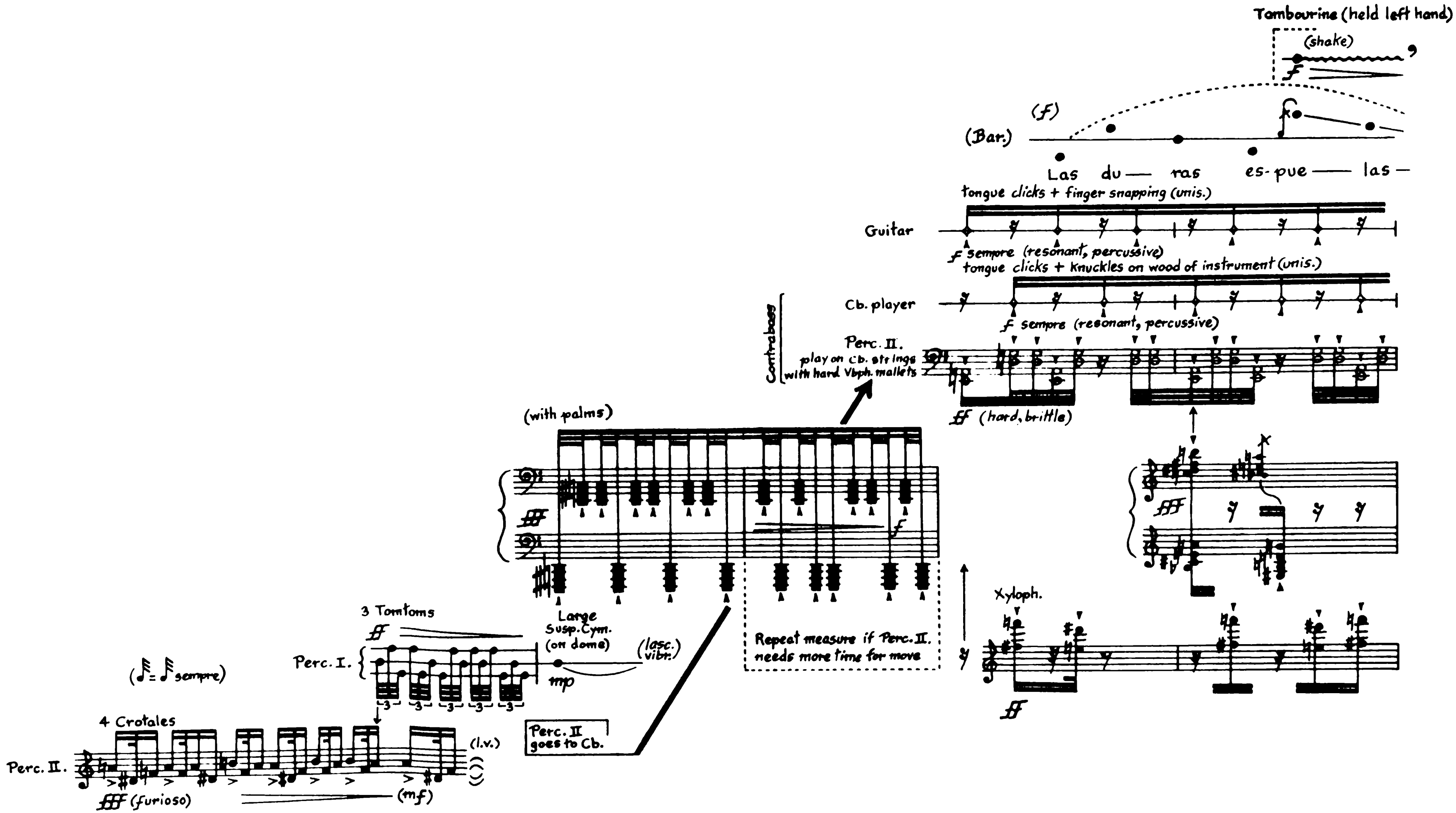
15. Quoted in Turetsky, op. cit., p. 44.

Ex. 106. *Anerca* (1970), E. Lutyens. Printed by permission of Olivan Press, London, England.

George Crumb often asks his performers to use their vocal and percussion-playing abilities. Throughout *Songs, Drones* the guitarist is asked to speak, shout, hum, and, at one point, even to play a jew's harp (18 : 1). In the second movement, the guitarist speaks ("eerily") while playing harmonics (see Ex. 107). At another point Crumb asks the guitarist to make tongue clicks and finger snaps in unison ("Canción de Jinete, 1860").

Henze also uses tongue-clicking and finger-snapping (notated by the symbol) to create the musical atmosphere of "The Forest" (see Ex. 108). The circled notes are whistled "*pp* always 8^{va} ," an example of a mixture of vocal and instrumental techniques producing the same sound simultaneously. Another application of the vocal/instrumental mix is in Kagel's *Sonant (1960/. . .)*, which calls for glottal attacks throughout. Kagel even uses a separate staff for vocal notation in "Pièce de Résistance" when the player is to perform "with every chord one or two glottal attacks; register and volume ad libitum."[16] He gives a special group of symbols just for vocal sounds (see Fig. 92).

16. Kagel, *Sonant (1960/. . .)*, Performance Instructions.



Ex. 107. "Casida de las Palomas Oscuras," *Songs, Drones and Refrains of Death* (1968), G. Crumb. © 1971 by C. F. Peters Corp. By permission.

Ex. 108. "The Forest," *El Cimarrón* (1969), H. W. Henze. © 1972 by B. Schott's Söhne, Mainz. Used by permission of European American Music Distributors Corp., sole U.S. agent for B. Schott's Söhne, Mainz.

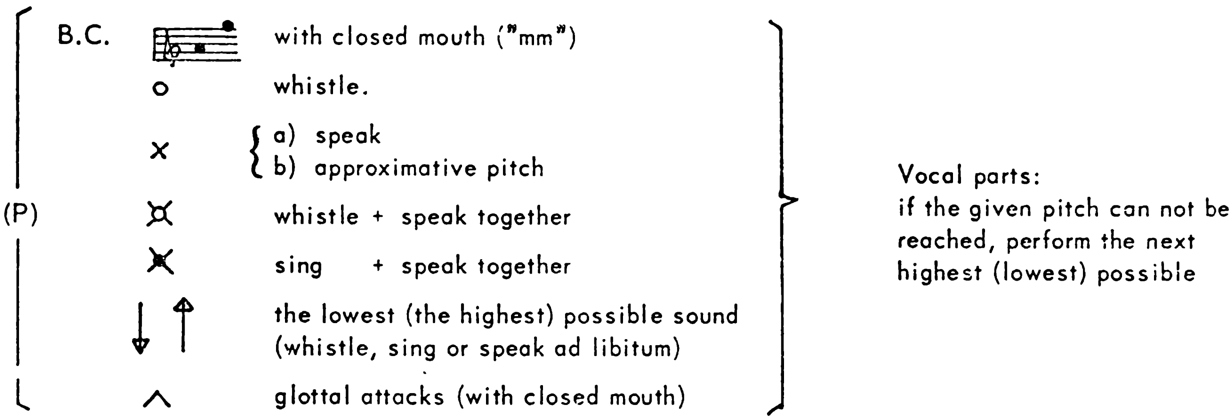
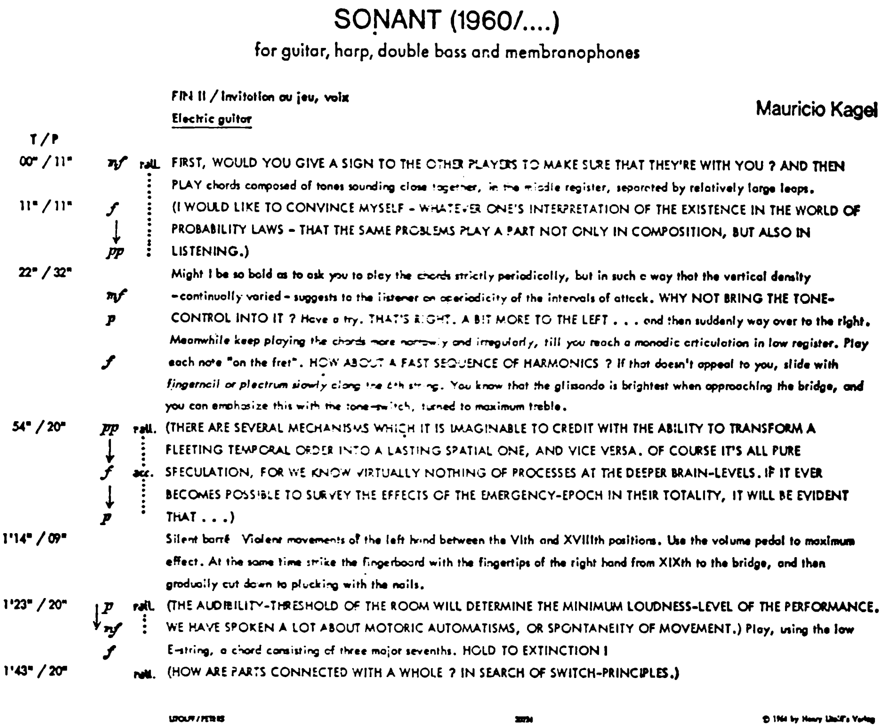


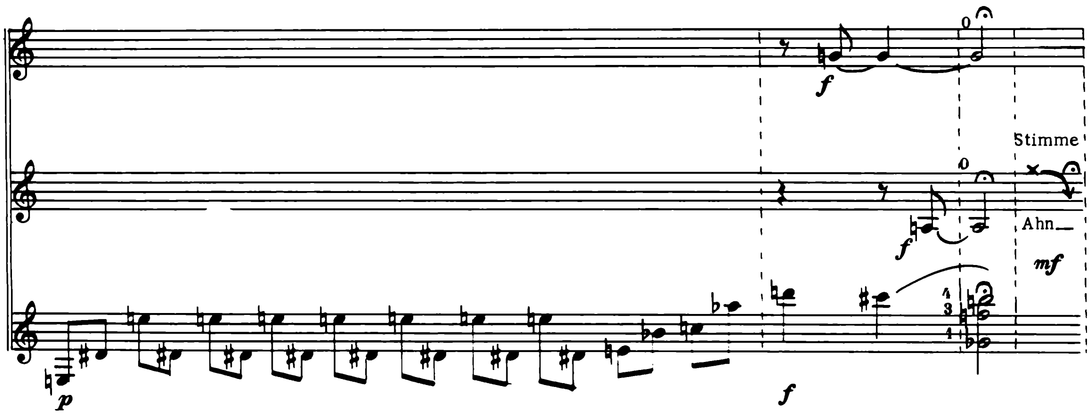
Fig. 92. Vocal symbols from *Sonant (1960/. . .)*, M. Kagel. © 1964 by Henry Litolff's Verlag. By permission of C. F. Peters Corp.

Of course, as soon as the voice becomes part of the score, use of language is obvious. One Dutch composer, Peter Schat, has chosen to use syllables for their sound value only; the guitarist chants monosyllabic consonants while playing different ad libitum sections in *First Essay on Electrocution* for violin, guitar, and metal percussion instruments (1966). Kagel has taken advantage of the theatrical possibilities inherent in the situation of speaking performers; he has written an hilarious commentary on contemporary composition in which the text printed in upper-case letters is to be read aloud and the lower-case text read silently (see Ex. 109).



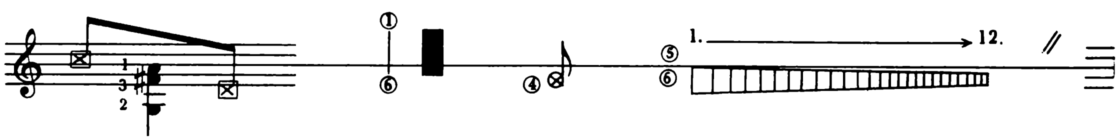
Ex. 109. "Fin II/Invitation au jeu, voix," *Sonant (1960/. . .)*, M. Kagel. © 1964 by Henry Litolff's Verlag. By permission of C. F. Peters Corp.

In his *Sighs* (1976), Jorge Antunes makes another interesting use of the voice. In the third movement he uses a vocal sigh—again, a very dramatic effect when it is the only movement in the piece (and very probably in an entire concert of this sort of solo guitar music) in which the player actually speaks *during* the music:



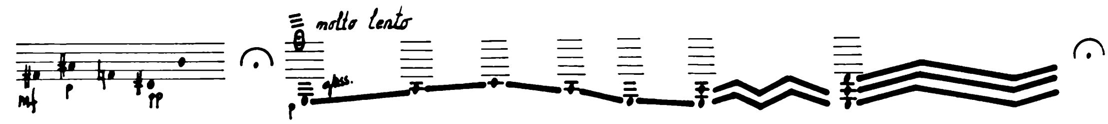
Ex. 110. *Sighs* (1976), J. Antunes.

Several *extra-musical* techniques have been used in guitar literature since mid-century—techniques that either produce sounds with a high noise content or are not useful in the pitch domain of music-making. Siegfried Behrend uses a sound produced "with the nail of the little finger, right hand, glissando over the frets between two strings":



Ex. 111. *Movimenti für Gitarre* (1969), S. Behrend. © 1972 by Universal Edition, Vienna. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

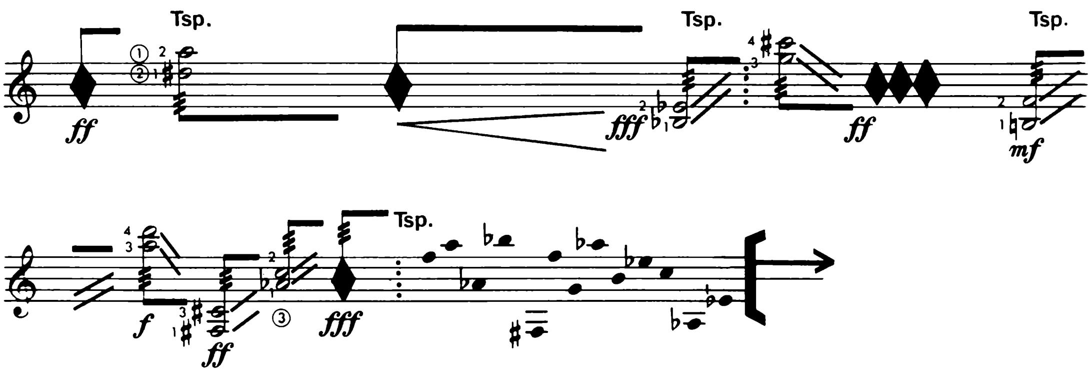
Another scratching sound is created when the player in Marco's *Albayalde* rubs the string-winding of the bass strings with a razor blade:



Ex. 112. *Albayalde* (1965), T. Marco.

Siegfried Fink employs this technique in *Dialoge* (1968). (It is significant that both these works were written for Siegfried Behrend, for this is one of his special techniques.)

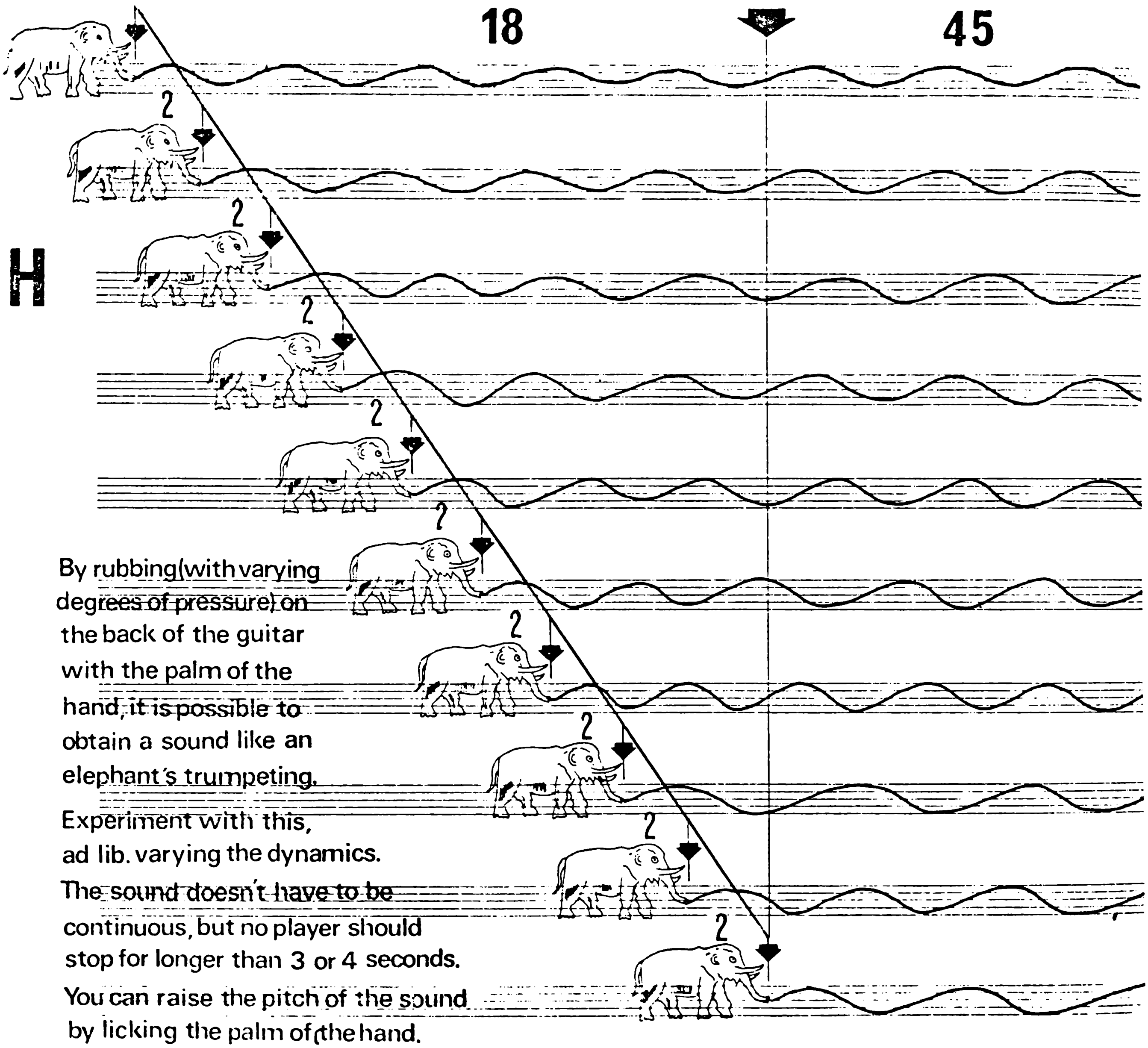
David Bedford has notated two types of *squeak-tones* produced by rubbing the wood of the guitar with the hand. The first is notated by the symbol ◆ accompanied by the directions: "Use the palm or heel of the hand on the body of the instrument to produce a squealing sound."[17] He contrasts this texture with the teaspoon tremolo in *You Asked for It*:



Ex. 113. *You Asked for It* (1969), D. Bedford. © 1973 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

17. Bedford. *You Asked for It*, Notes for Performer.

The other type of sound is made by sliding "a wettened finger lightly across the back of the instrument. With practice a sound like an elephant's trumpeting can be produced"[18] (see Plate VIII). In *You Asked for It*, Bedford notates this sound by the directions "improvise using wet finger" placed in the score, but I find the notation in his *Nurse's Song with Elephants* much more satisfactory (see Ex. 114).



Ex. 114. *Nurse's Song with Elephants* (1971), D. Bedford. © 1971 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

18. Ibid.

In the post-war decades, unpitched sound has proven to be a valuable source of musical material. Although these sounds are difficult to manage in any manner other than atmospheric, the challenge is there to be taken up by those who realize the potential of these materials in the repertoire of the contemporary guitar.

CHAPTER VIII
Electronics

Chapters 6 and 7 have shown the development of colorism in guitar music—from timbrally differentiated pitched sounds to completely unpitched sounds—for both the Spanish and electric guitar. The use of electronics has expanded these timbral possibilities, and since the art of electronics in music is only a little over half a century old, one can easily see that the musical potential of these powerful new tools is just beginning to be realized.

The first use of electronics in conjunction with the guitar in modern art music was simple amplification of the instrument so that it could be heard in a mixed instrumental setting. Harry Partch was the first to use magnetic amplification for his *Adapted Guitars I and II* (1945), and for the amplified guitar Berio uses three symbols (○ ◑ ●)—maximum, medium, and no amplification—in his *NONES* (1954/55). Even in the 1970s, amplification was used to highlight some of the subtle colors available on the acoustic instrument in a chamber-music setting. Vacchi prefaces his *Suite* (1973) with the instructions:

> The amplification of the piece is required inasmuch as it is only through these means that one can highlight such timbres. This amplification should not in any way change the characteristic timbre of the guitar but only raise its power. In order to obtain this result it is advisable to use a good microphone installed at a fair distance from the instrument (circa 40–50 cm.), and an amplifier of medium power used at low volume and with tonal regulations in the linear position; nevertheless in cases of performance in a small theatre, amplification can be eliminated without compromising the result.

Stockhausen used the soloing capability of the electric instrument in *Gruppen* (1955/57). Kagel's *Sonant (1960/. . .)* was the first attempt to explore the *electric* guitar per se rather than as an amplified acoustic guitar. In this piece, Kagel began a relationship with the instrument that has produced some of the most imaginative techniques to be found in the literature (as many of the examples in the previous chapters have shown).

The 1960s were a period of intense timbral exploration in music, and the electric guitar was certainly no stranger to this type of musical thinking. Due to the microphonic capabilities of the instrument, the tiniest and most subtle sounds (tonal *or* non-tonal) that the guitar produces can be amplified even to an *fff* dynamic. Kagel uses a type of "electronic golpe" in *Tremens*, asking the guitarist to strike the contact microphone attached to the instrument (23 : 1).

The sixties also produced a wide variety of tone-modification effects for rock-and-roll guitarists. These effects have made quite sophisticated sound-processing techniques inexpensive enough for the man-in-the-street and available even to players of the classical instrument who would previously have had to visit an electronic music or recording studio to obtain these sounds. These effects have developed rapidly—one firm now markets for under $600 a microprocessor (a very small computer) for extremely sophisticated sound filtering and processing, and guitar synthesizers are now available for as little as $500 that will completely transform the guitar's signal electronically. Needless to say, the Age of the Electronic Guitarist is just beginning; the evidence from the published musical literature indicates that composers are taking advantage of these techniques to extend the sound-producing capabilities of the guitar.

To review quickly the basics of the electric guitar: most electric guitars have two pickups, one next to the bridge and one near the fingerboard. Each of these pickups usually has its own volume control and tone control, and the guitar has a switch that enables the front, back (bridge), or both pickups to be used. A standard amplifier also has a volume and tone control for each of its channels, so the composer's basic technical vocabulary must be able to describe *which* pickup should be heard, *what* each pickup's individual settings are to be, and *what* settings should be used for the amplifier. Dynamics should always describe the perceived sound, although an instruction asking the guitar to be plucked *fff* but heard *mp* is obviously a possible timbral variation.

The existing repertoire will be discussed in terms of the timbral parameters outlined in Chapter 3, and will be followed by a short discussion of the music for tape and guitar.

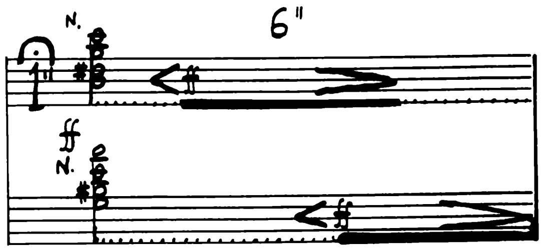
PREFIX

One of the first aspects of the guitar's tone that composers altered was the prefix. This is done by cutting off the attack of the string sound with the volume control. Berio notates the technique in the way shown in Example 115. Bedford uses dotted and solid lines to indicate whether the volume is on or off:

> Play the sound with the volume knob at zero (but strike the strings so that the written dynamic would be produced if the knob were turned up). Turn up the volume knob to full at the point where the dotted line becomes solid and turn it to zero again where the line becomes dotted again (or if the line remains solid, damp the sound). If there are crescendo or diminuendo signs, follow them with regard to the speed with which the knob is turned up or down. If not, turn knob as quickly as possible.[1]

1. D. Bedford, *18 Bricks Left on April 21* for two electric guitars (London: Universal Edition. 1968), p. 8.

Ex. 115. *NONES* (1954), L. Berio. © 19XX. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.



Ex. 116. *18 Bricks Left on April 21* (1968), D. Bedford. © 1968 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

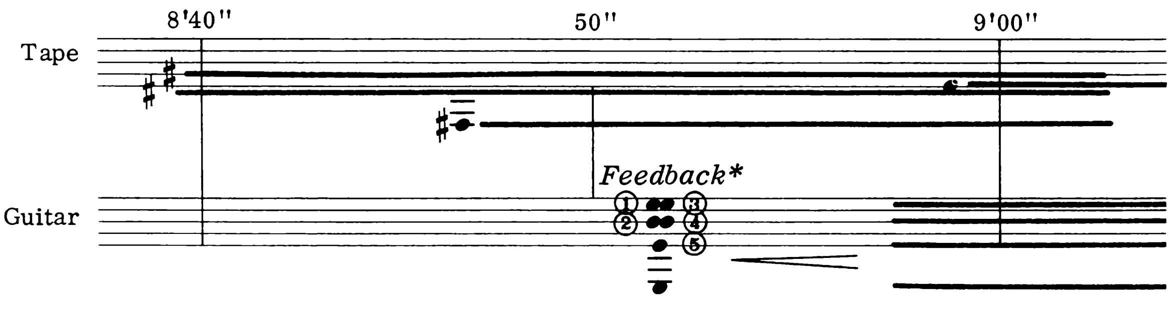
Arne Nordheim uses this method of changing the prefix of both chords and notes in *Parti II* (1969).

TIME ENVELOPE

Of course, the examples above also alter the time envelope of the guitar tone, bu the lack of string attack is a more important aspect of the timbral transformation than is th alteration of the rise time of the note. Feedback is the most popular method for alterin the duration section of the note's time envelope. In "Pièce touchée, pièce jouée" c *Sonant 1960/. . .)*, Kagel uses the letters *OF* under a passage to mean "turn out the filte (prolong the tone by feedback)," a technique which is applied to a tri-chord and three ha monics.

In *Voyage* (1976), I use acoustic feedback to produce the sustained-tone materi that makes up most of the second movement. The performer is asked to

> stand facing one of the loudspeakers (at a distance of 2′–4′) while holding th notated chord. By altering the volume knob on the instrument, allow the sixt string to start vibrating enough to periodically strike the frets, producing "grinding," pulsating sound.



Ex. 117. *Voyage* (1976), J. Schneider.

One piece of music uses the actual sound of electronic feedback as musical materia rather than just using the acoustic signal to sustain the string vibrations. Page 8 c

Bedford's *18 Bricks* consists of five blank, two-stave systems headed with the instructions:

> This page, lasting five minutes, should be filled in by the performers, if possible with collaboration with the composer since what is played will be determined to a large extent by the type of equipment being used. It should consist *entirely* of sounds obtained through various types of feedback. The only rules to be followed are:
>
> 1. there should be sound for the entire 5 minutes i.e. no silences,
> 2. the whole 5 minutes should be extremely loud.

Tim Walker, one of the piece's dedicatees, reminisces, "I remember at one concert, when we played the feedback we emptied half the hall. It's supposed to be played very loud. On another occasion, I felt sick and paralyzed through the volume of it."[2] The musical consequences of this sort of activity are somewhat dubious outside the confines of late-1960s experimentalism; in fact, the composer has said that he would not today insist on the duration or volume he originally requested.

SPECTRAL ENVELOPE

The versatility of the electric guitar has given composers the opportunity to be selective about the quality of sound they demand. Some instruments are associated with particular sounds; in fact, in *"Go, Said the Bird"* (1975), Elisabeth Lutyens specifically asks for a "light-strung guitar (Fender)." The spectral envelope of this brand of instrument is highly individual (due to its pickups and circuitry), but almost every electric guitar has a number of tone-modification controls on the instrument itself which can radically alter the sound. These controls, along with all the controls available on the amplifier, add another dimension of timbral differentiation for the composer who is aware of their existence.

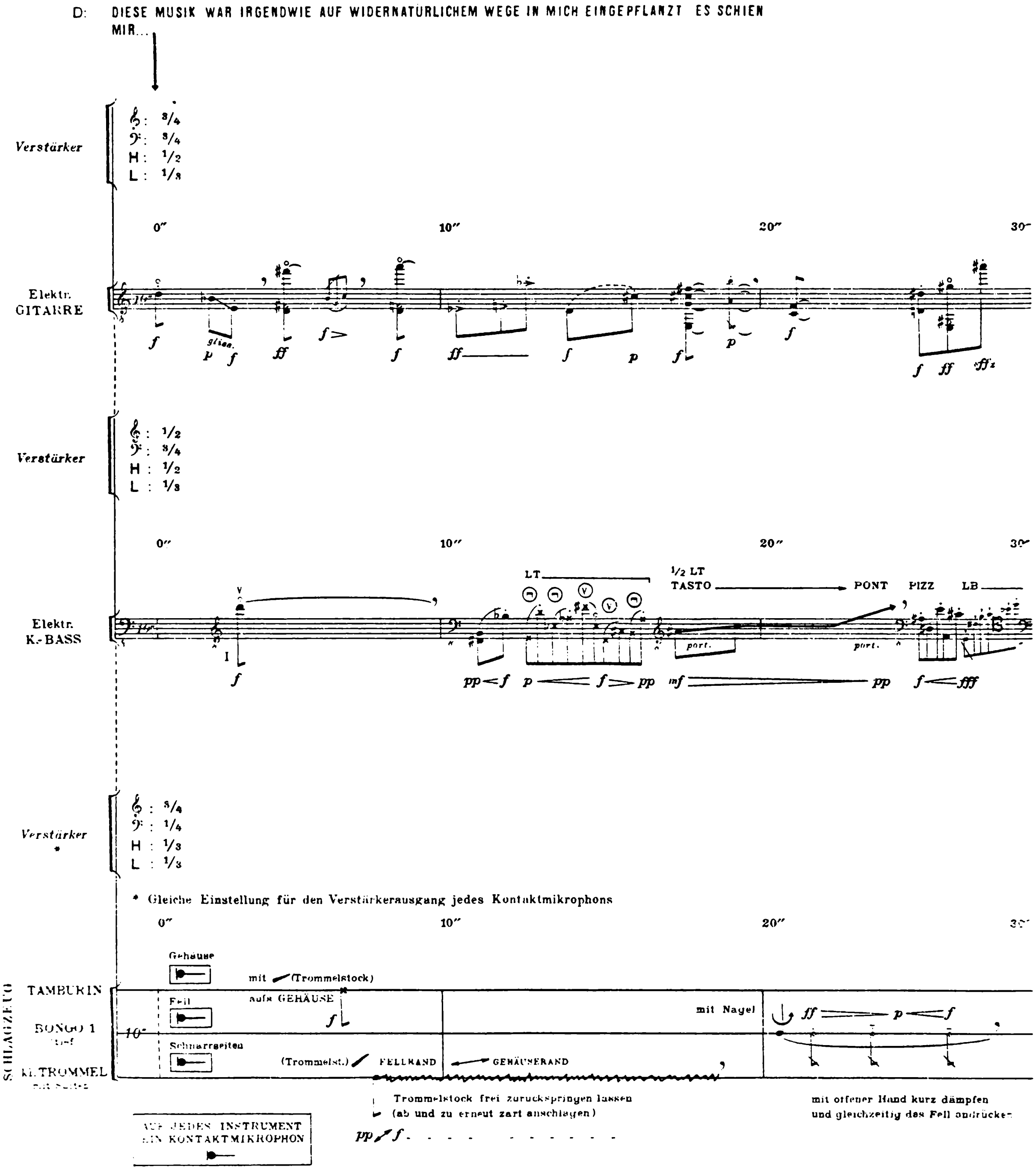
There are, however, three basic types of electric guitar, each of which has its distinctive class of sound. Solid-body instruments tend to have a bright, thinnish tone; acoustic-electric, or "jazz," guitars, which are amplified, full-bodied, F-hole guitars, have a much rounder, mellower sound. The third type, called a semi-acoustic guitar, is a hybrid. It is as thin as most solid-body guitars, but the instrument body is hollow. Generally, solid-body guitars tend to use lighter-gauge strings than semi-acoustic or acoustic instruments, and this, with the choice of pickup, is basic to the tone of the instrument (see Chapter 3).

In his *Solo for Electric Guitar* (1971/72), Pelle Gudmundsen-Holmgreen specifies the overall spectral envelope that is required for each movement. For example:

I.	II.	III.
min. vib.	dark timbre	senza vibr.
min. reverb.	(plectrum)	medium reverb.
medium timbre		medium light timbre

2. L. Bosman, "'The Guitar Is an Untapped Instrument,' Tim Walker," *Guitar* (January 1974): 23.

Timbre refers to the guitar's tone settings; "dark" means that all of the treble is to be cut off, and "medium light" indicates that just a portion of the treble should be attenuated. Kagel, in *Tremens*, is much more exact; he gives settings for the amplifiers' tone controls as part of the score (see Ex. 118).



Ex. 118. *Tremens* (1963/65), M. Kagel. © 1973 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

Almost all the rock-and-roll effects mentioned in Chapter 3 have also been used by contemporary composers. David Bedford uses fuzz-tone throughout both *Star's End* (1974) and *The Ones Who Walked Away from Omelas* (1976). The effect is also used in Kagel's *Tremens*, Lutyens' *"Go, Said the Bird"* (1975), Wolff's *Electric Spring III* (1967), and Schat's *First Essay on Electrocution* (1966). These composers just put the word "fuzz" next to the specific note or phrase, leaving the amount of distortion, etc., to be decided by the performers. They really have little choice in the matter, unless they are personally working with the players, because most fuzz units are not yet standardized and differ greatly both in their controls and in the quality of their output.

Use of other spectrum-modification devices is less common than use of fuzz-tone, but some composers have used ring-modulation and distortion to alter the spectral envelope of a sound. A most adventurous use of these devices can be found in Misha Mengelberg's *AMAGA*, which calls for five loudspeaker units, three amplifiers, one product-modulator (ring-mod), and one amplitude modulator (tremolo). The introduction includes a block diagram of the electronic set-up (whence the title of the piece):

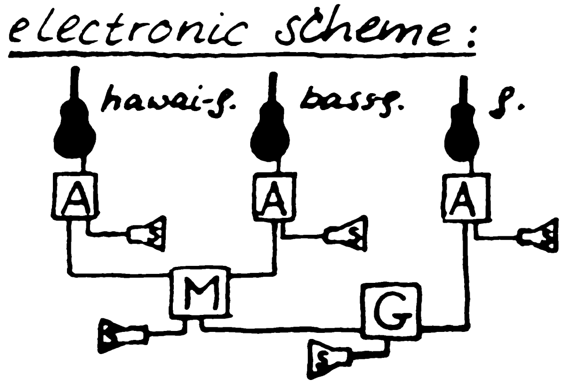
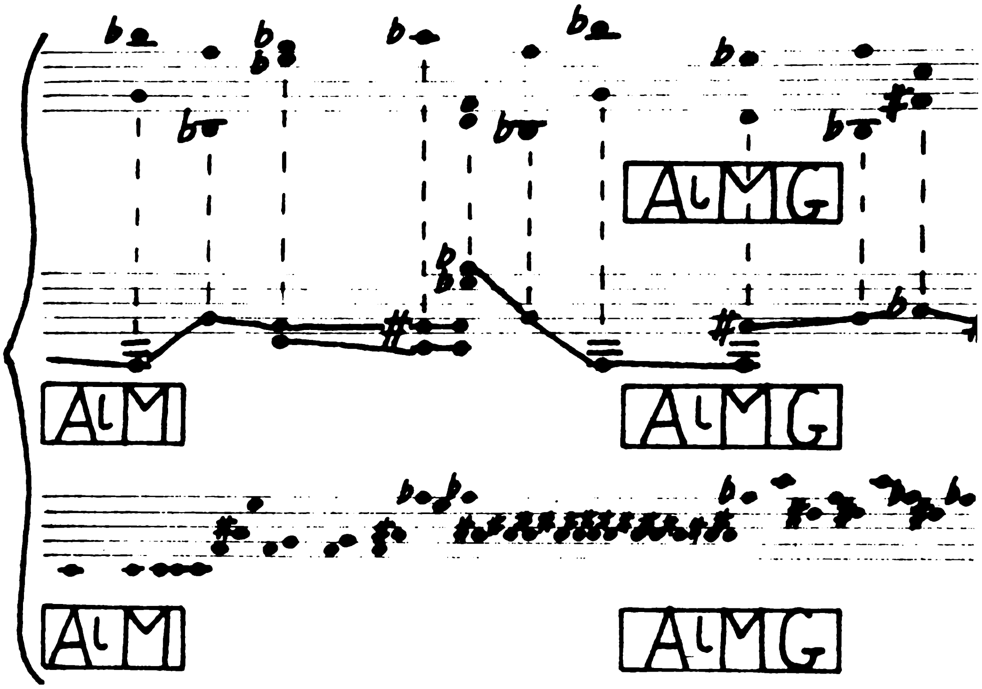


Fig. 93. Electronic Scheme for *AMAGA* (1968), M. Mengelberg. Reprinted by permission of C. F. Peters Corp., sole selling agents in the Western Hemisphere for Stichting Donemus, Amsterdam.

In this diagram, S = loudspeaker, A = amplifier, M = product-modulator, and G = amplitude modulator. Lower-case letter notate use of the amplifiers: h = low frequencies excluded, l = amplifier overmodulated, e = echo, m = dynamics to be played on the guitar. A typical section of music from this piece uses these symbols underneath the appropriate passages:



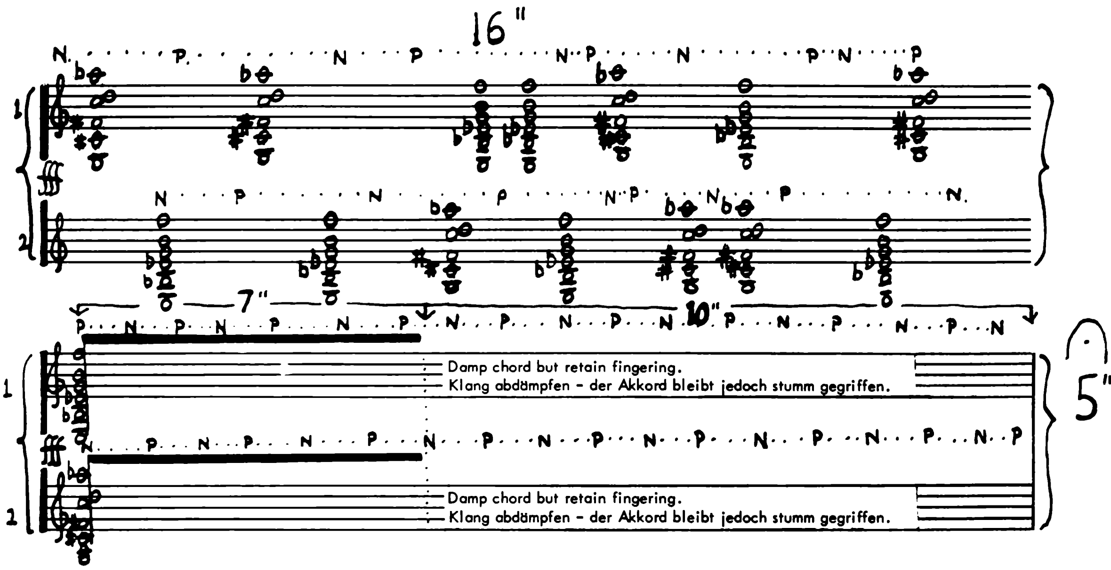
Ex. 119. *AMAGA* (1968), M. Mengelberg. Reprinted by permission of C. F. Peters Corp., sole selling agents in the Western Hemisphere for Stichting Donemus, Amsterdam.

CHANGE

The alteration of the spectral envelope during the duration of a guitar tone has become one of the aspects of timbre that a composer can now manipulate musically, with the aid of electronics. These changes can be dramatic—as in Example 119 when the Hawaiian guitar slide-glisses while ring-modulating the bass guitar—or subtle—as in Kagel's *Tremens,* in which the control knobs on the amplifier are turned while the guitar is being played.

In *"Go, Said the Bird,"* Elisabeth Lutyens uses the largest arsenal of tone modification gear to date. She requires the guitarist to use fuzz, wah-wah, and phaser pedals. Unfortunately, she only specifies "+wah-wah - - - - - - -," without marking any articulation. Because wah-wah is such a dramatic modification, the process of filtering becomes almost more musically significant than the pitch material that is being filtered, so care should be taken to shape its spectral glide. Since all wah-pedals produce the "oo" sound in the up position and the "ah" in the down position, there is no reason why the composer should not add pedalling instructions like those in piano music; this simple addition would make the effect much more controllable from the compositional point of view. Lutyens also marks the other effects in this on/off manner, notated simply "+ fuzz" and "+ phaser," but the lack of more specific instructions is less important for these modifications.

The use of pedal effects in a mixed chamber ensemble can produce some unexpected problems. Since most pedal effects are designed to be used in the production of fairly loud rock music and are switched on by foot during this music, the noise created by the switch itself has never been of any significance. In a chamber-music setting, however, the clicks and scrapes that accompany the use of these pedals often exceed the mezzo-forte level. The first performance of Lutyens' *"Go, Said the Bird,"* for instance, was given on a wooden stage, and the clicks produced by the three pedals involved almost ruined the performance. One way to get around this problem is to make the clicks a part of the music, as David Bedford does when he has guitarists change from one pickup to another with the directions, "The click as the switch from P to N is made should be made audible":[3]



Ex. 120. *18 Bricks Left on April 21* (1968), D. Bedford. © 1968 by Universal Edition (London), Ltd., London. Used by permission of European American Music Distributors Corp., sole U.S. agent for Universal Edition.

This very personal solution is certainly not applicable in most musical situations, however. The real answer is simply to change the mechanisms involved so that they will *not* emit noise when being used.

In order to control the changes of frequency and pitch during the life of a tone, many electric guitars have vibrato arms installed on the tailpiece. This mechanism changes the tension of the strings, which of course causes a change in pitch. This effect is used by Arne Nordheim (*Partita II*, 1975, 1 : 4) and Tom Darter (*Dual*, 1976, 6.3). But more often requested from the electric guitar is the "vibrato" effect available on most amplifiers, which is in actuality tremolo, or amplitude modulation. Christian Wolff says that "the guitar should use the vibrato built into its amplifier,"[4] but uses the vibrato bar for making

3. Bedford, *18 Bricks*, p. 7.
4. C. Wolff, *Electric Spring III* (1967) (New York, C.F. Peters, 1968), p. 2.

glissandi (*Electric Spring III*, 1967). In *18 Bricks*, Bedford graphically notates vibrato as "speed according to the way the wavy line is written," and says that if no vibrato control is available, the volume knob should be used.[5]

GUITAR AND TAPE

Since the beginnings of electronic music, pieces for live instrument/s and tape have become a part of the contemporary music scene, and the guitar has taken part in this. Only a handful of pieces have yet been produced for this combination, but these few do offer some insights into the musical possibilities made available by this medium.

Famed guitarist and singer Les Paul made multitrack recordings in the 1940s. This approach is now the basis of much of the recording industry: musicians accompany an earlier recording of themselves, mixing the new combination onto another tape. In contemporary music, several composers have used tape either to create another guitar part, as in Thea Musgrave's *Soliloquy I* (1969), or to create an accompanying ensemble. Barbara Kolb creates an ensemble by writing out the live-guitar part alongside the parts to be prerecorded on tape:

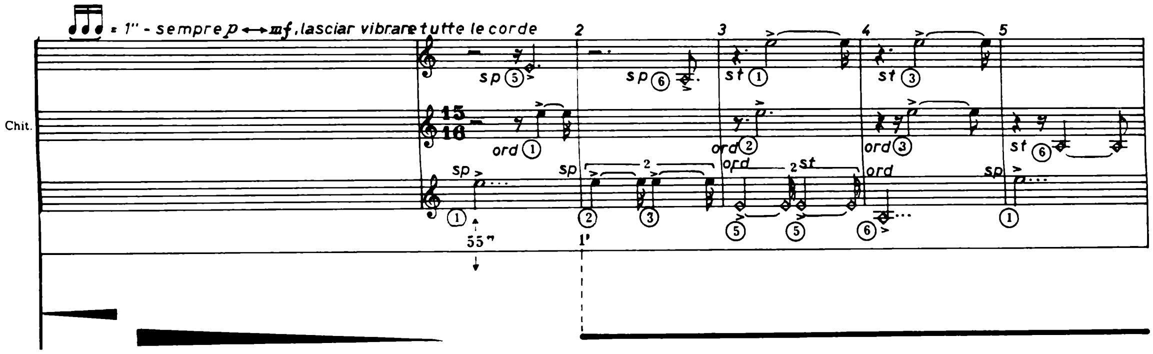
Ex. 121. *Looking for Claudio* (1975), B. Kolb. © 1978 by Boosey and Hawkes, Inc. Reprinted by permission.

She gives mixing instructions as part of the score, describing how echo and balance should be used in the final mix.

José Encinar also uses the tape medium to create a guitar ensemble through pre-

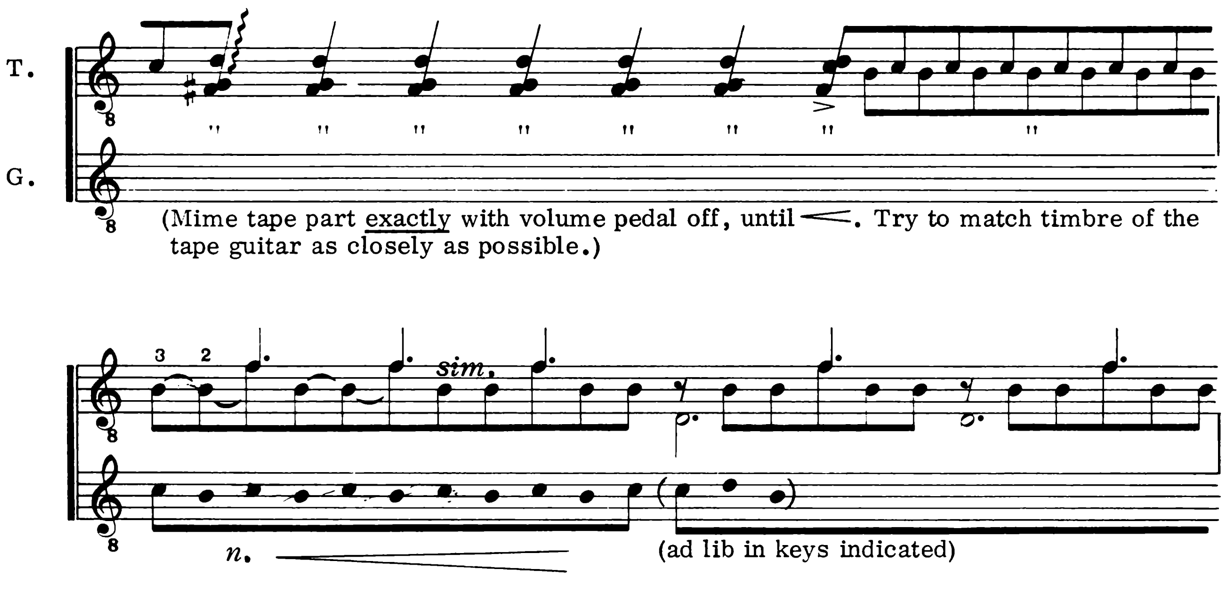
5. Bedford, *18 Bricks*, Instructions.

recording, and the two pre-recorded guitars, plus the live instrument, are accompanied by electronic sounds:



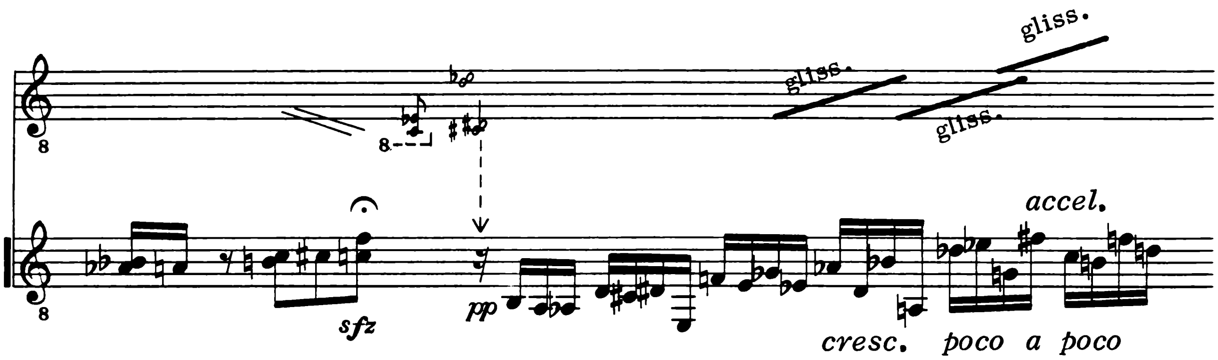
Ex. 122. *Abhava* (1972), J. Encinar. © 1973. By permission of Edizioni Suvini Zerboni, Milano, and Boosey and Hawkes, Inc., Sole Agents, U.S.A.

One of the main problems of all instrument and tape pieces is to create a balance between the acoustic and the electronic sound sources. The acoustic instrument always seems to lose; the power available to the electronic part inevitably seems to be used to its fullest. My *Voyage* (1976) is written for electro-acoustic guitar and tape; the guitar and tape come out of the same speakers, since both must be amplified to be heard. This situation creates an equality of musical forces that is rare in this kind of music, and it also allows a great deal of ambiguity concerning the actual origin of the music—the live guitarist, or the tape:



Ex. 123. *Voyage*, (1976), J. Schneider.

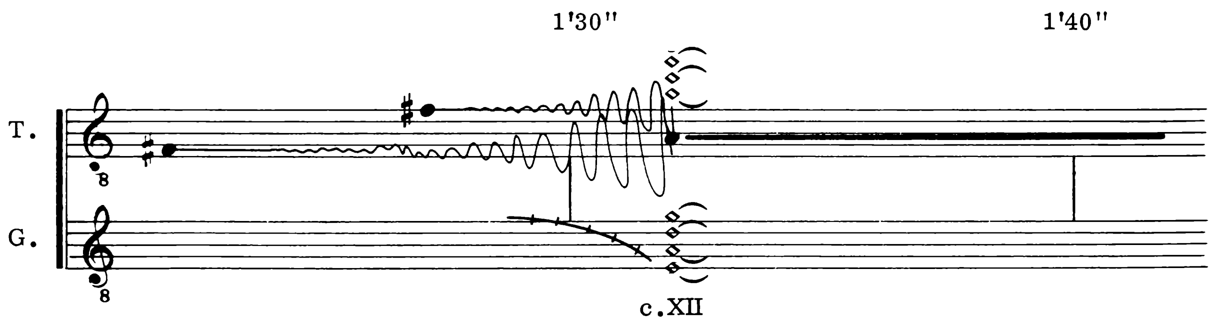
One great advantage the tape medium offers is the opportunity process a sound in the studio before it is heard by the audience—a technique used in popular music for decades. In fact, some groups only create their music for records and never perform "live." All the sound-transformation technology of the electronic music and recording studio can be used to accentuate or alter the timbral parameters of a sound. Thea Musgrave uses several tape techniques to transform the sound of the classic guitar that is the source of all the pre-recorded sound in *Soliloquy I.* These techniques mostly involve changing the timbre of chords and notes by tape-transposing them either up or down an octave. She also tape-glisses several notes by gradually increasing the speed of the tape recorder:



Ex. 124. *Soliloquy I* (1969), T. Musgrave. Used by permission of J & W Chester/Edition Wilhelm Hansen, London, Ltd.

She also transforms repeated notes and golpe attacks into the pulsing sound one achieves when using positive feedback to distort tape echo (11 : 7).

In *Voyage* (1976), I use the amplitude variations of the guitar tone to modulate the frequency of a sine tone of the same pitch. This exploding sound is then duplicated on tape, tape-transposed down an octave (which also doubles the duration), and mixed with the original. The new composite sound is then reversed to create a crescendo erupting into a great "explosion," all evolving out of the initially plucked F-sharp (see Recorded Ex. 40):



Ex. 125. *Voyage* (1976), J. Schneider.

This activity or "event" is later recapitulated by mechanical frequency modulation of the down-tuned first string (koto-gliss). This piece and others are filled with examples of this type of studio treatment of the guitar, an area that is just beginning to be explored by composers and players.

The use of electronics in guitar music is a very new development, especially compared to the five-hundred-year-old history of the instrument. As signal-processing techniques become more sophisticated, they should be more often adapted to the guitar. I am sure that the marriage of the guitar and electronics will be a long and happy one.

Conclusion

Only in this century have musical thinkers begun successfully to construct a theory of musical timbre. It has been suggested by Cogan and Escot that the reason for this state of affairs is simply that until now we have lacked the means to analyze sound objectively.[1] Previous attempts at codifying timbre, whether orchestral or instrumental, can be likened to trying to create a theory of harmony from the tablatures of various musical instruments without using a universal pitch notation. The advances that have been made in the science of musical acoustics in the last thirty years have enabled a first generation of new timbral theories to emerge. In the summer of 1977, for example, several international conferences on new aspects of musical acoustics were held in Europe[2] —a fact that illustrates the growing interest in this comparatively young field. Such research will undoubtedly affect the musical community as it makes progress toward the creation of a language through which instrument makers, music educators, performers, and composers can more completely describe that invisible product with which they are all involved—*sound.*

The purpose of this book has been to explicate a Theory of Timbre for the guitar. The Rational Method of Tone Production has shown how the parameters of timbre can be altered to change the tonal character of guitar notes. All the practical sound-producing aspects of both electric and acoustic guitars have been discussed and illustrated, in order to help performers better understand what is happening beneath their fingertips, and to give composers a conceptual approach to the instrument, since guitar is not discussed in most orchestration books or composition/orchestration courses.

Many of the pieces which have been chosen to illustrate the techniques of sound production discussed here are simply not good music; but, as the Preface warned, these examples have been included because they have introduced new techniques and sounds into the repertoire, not because of their musical value. (It is certainly not the fault of the sounds used in one of the avant-garde pieces cited, if the musical structure cannot justify

1. R. Cogan and B. Escot, op. cit., p. 328.

2. Conference on Musical Acoustics (Catgut Acoustical Society), Cambridge, England, June 1977; Ninth International Congress on Acoustics, Madrid, July 1977; IRCAM/GALF Symposium on Musical Psychoacoustics, Paris, July 1977; and the Second Workshop on Physical and Neurophysical Foundations of Music, Ossiach, Austria, July 1977.

the sounds produced by these techniques. This would be tantamount to blaming the color yellow for ruining a picture and not the artist for placing the yellow pigment where he did.) I have presented the "sound palette" of the guitar, accompanied by some remarks concerning the use of color and contrast in compositions for the guitar. It is now up to performers to use these colors to interpret existing music, and up to composers to use the timbres for creating a new music for an instrument that is in need of a wider repertoire of musical consequence.

This century has witnessed a great renewal of interest in the guitar; a second Golden Age of the Guitar is beginning, one which will surely outshadow its predecessor of the early 1800s. The guitar is also on its way to deposing the piano as the most common household musical instrument (a position which the latter has held for well over a hundred years), and it is also gaining popularity in the classroom, where teachers have enjoyed the ability to face their pupils while leading music-making activities. The next generation of guitarists will be better trained and better informed than the players who left music colleges even five years ago, thanks to this growing number of players and teachers, and thanks also to the growing interest in the instrument's history and to the efforts of those who are determined to develop the musical possibilities of the instrument to its fullest extent. A better understanding of the acoustics of the instrument and the musical application of these principles will soon be seen to be an important part of this evolution of both the instrument and its music.

The growth of the repertoire in the last thirty years has been nothing short of astonishing, and it is reassuring that a large proportion of the works being written today are of a very high musical standard. This is self-perpetuating: the higher the standard of the repertoire, the higher the performance standard becomes, which in turn attracts more composers and wider audiences, and so on—creating what should become an ascending spiral of activity involving audiences, players, and composers. The position of the contemporary guitar has been elegantly summarized by Hans Werner Henze in a comment on his collaboration with Julian Bream during the composition of *Royal Winter Music* (1976):

> I gained a more profound knowledge of the technicalities and of the sound-world of the guitar. I would even go so far as to say that this collaboration gave me a new concept of how to write for an instrument with an old and rich tradition. The guitar is a "knowing" or "knowledgeable" instrument, with many limitations but also many unexplored spaces and depths within these limits. It possesses a richness of sound capable of embracing everything one might find in a gigantic contemporary orchestra; but one has to start from silence in order to notice this: one has to pause, and completely exclude noise.[3]

When solo guitarists play to capacity audiences in the Royal Festival Hall, 3,000 people sit absolutely still for two hours without coughing or rustling their programs, transfixed by the sounds of six plucked strings. Audiences *are* ready to "start from silence," pause, and listen to the ever-expanding sound-world of the guitar.

3. H.W. Henze, Program notes to first London performance (1977) of *Royal Winter Music* (1976).

APPENDIX I
Partial Chronology of Repertoire since 1900

1905 Mahler *Symphony No. 7 in e*
1912 Villa-Lobos "Suite populaire Brasilienne"
1913 Webern *Orchestral Pieces*
1914 Webern *Three Orchestral Songs*
1917 Villa-Lobos *Sextour Mystique*
1920 de Falla *Homenaje*
Villa-Lobos *Chôro # 1*
1921 Chavez *Three Pieces for Guitar*
1923 Schoenberg *Serenade*, Op. 24
Webern *Five Orchestral Pieces*, Op. 10
1924 Roussel "Segovia", Op. 29
1925 Berg *Wozzeck*
Carrillo *Sonata in Quarter-Tones*
Hindemith *Rondo for Three Guitars*
Webern *Drei Lieder*, Op. 18
1926 Carrillo *Concertino*
Morena-Torroba *Suite Castellana*
Nocturno
Turina *Fandaguillo*
Webern *Zwei Lieder*, Op. 19
1929 Villa-Lobos *Etudes for Guitar*
1930 Ponce *Variations and Fugue*
1931 Morena-Torroba *Pièces caractéristiques*
1932 Castelnuovo-Tedesco *Variations*, Op. 71
1933 Martin *Pièces Brèves*
1934 Carrillo *Preludio a Cristobal Colon*
1936 Ibert *Entr'acte*
1938 Carter "Tell me Where Is Fancy Bred"
1939 Castelnuovo-Tedesco *Concerto in D*, Op. 99
Rodrigo *Concerto de Aranjuez*
1940 Villa-Lobos *Preludes*
1941 Partch *Barstow—Eight Hitchhiker Inscriptions from a Highway Railing at Barstow, California*
Ponce *Concierto del Sur*
1943 Castelnuovo-Tedesco *Serenade*, Op. 118
Hába *Sonate für Gitarre*, Op. 52
Suite für Vierteltongitarre, Op. 54
1944 Burkhard *Serenade*
Smith-Brindle *Fantasia I*
Serenata I
1945 Smith-Brindle *Chittareo*
Fantasia II
1946 Hába *Suite für Vierteltongitarre*, Op. 63
Smith-Brindle *Nocturne*
1948 Smith-Brindle *Sonatina Fiorentina*
1949 Smith-Brindle *Etruscan Preludes*
1950 Ohana *Concerto (Trois Graphiques)*
Partch *Plectra and Percussion Dances*
Eleven Intrusions
Smith-Brindle *Sonata Senesa*
1951 Villa-Lobos *Concerto for Guitar*
1952 Bartolozzi *Tre Pezzi per Chitarra*
Serenata

1953 Castelnuovo-Tedesco *Second Concerto in C*, Op. 160
Morena-Torroba *Sonatina*
Stravinsky *Tango*
1954 Boulez *Le Marteau sans Maître*
Rodrigo *Fantasia para un Gentilhombre*
Stravinsky *Four Russian Songs*
1955 Berio *Nones*
Lutyens *Nocturnes*, Op. 30
1956 Dodgson *Concerto*
Jolivet *Sérénade pour Deux Guitares*
Smith-Brindle *El Polifemo de Oro (Four Fragments for Guitar)*
3 Pieces for guitar and piano
1957 Berio *Divertimento*
Haubenstock-Ramati *Les Symphonies des Timbres*
Krenek *Suite*
Ohana *Tiento*
Seiber *The Owl and the Pussycat*
Smith-Brindle *10-String Music*
Stockhausen *Gruppen*
1958 Baumann *Duo*, Op. 62
Berio *Allelujah II*
Berkeley *Sonatina*, Op. 51
Britten *Songs from the Chinese*, Op. 58
Haubenstock-Ramati *La Petite Musique de Nuit*
Henze *Kammermusik 1958*
Miroglio *Choréiques*
1959 Krenek *Hausmusik: Sieben stücke für die sieben Tage der Woche*
Milhaud *Segoviana*
Petrassi *Suoni Notturni*
1960 Castelnuovo-Tedesco *Platero y Yo*
Kagel *Sonant (1960/. . .)*
Partch *Revelation in the Courthouse Park*
Poulenc *Sarabande*

1961 Feldman *The Straits of Magellan*
Sydeman *Fantasy for Guitar*
Takemitsu *Ring*
1962 Berio *Passagio*
Boulez *Pli selon Pli: Portrait de Mallarmé*
Castelnuovo-Tedesco *Concerto for Two Guitars*, Op. 201
Les Guitares bien tempérées, Op. 199
Gerhard *Concerto for Eight*
Petrassi *Seconda Serenata-Trio*
Sydeman *Music for Flute, Guitar, Viola, and Percussion*
Takemitsu *Sacrifice*
1963 Antoniou *Dialoge*
Apostel *Sechs Musiken*, Op. 25
Birtwhistle *The World Is Discovered*
Britten *Nocturnal*, Op. 70
E. Brown *From Here*
Bussotti "Mobile-Stabile" (from *Sette Fogli*)
Company *Las Seis Cuerdas*
Mellnäs *Tombola: Spiel Musik*
Nordheim *Epitaffio*
Ohana *Si le jour paraît . . .*
Shimoyama *Dialogo*
1964 Becker *Metathesis*
Tcherepnin *Sombres Lumières*
1965 Bartolozzi *Concertazioni per Oboe*
Foss *Fragments of Archilochos*
Jolivet *Deux Etudes de Concert*
Kagel *Tremens: Szenische Montage eines Teste*
Krenek *Quintina über die fünf Vokale*
Marco *Albayalde*
Takemitsu *Valeria*
1966 Partch *And on the Seventh Day Petals Fell in Petaluma*
1967 Biberian *Prelude and Fugue*
Bussotti *RARA*
Erb *String Trio*
Nordheim *Signaler*
Penderecki *Devils of Loudun*
Rasmussen *When I Was Happy I Wrote No Songs*
Rodrigo *Concierto Andaluz*
Wolff *Electric Spring III*

1968 Buck *Summertrio*
Crumb *Songs, Drones and Refrains of Death*
Dodgson *Duo Concertante*
McCabe *Canto for Guitar*

Mengelberg *AMAGA*
Stockhausen *Spiral*

1969 Takahashi *Metathesis 2*
Takemitsu *Stanza I*

1970 Bennett *Guitar Concerto*
Berkeley *Theme and Variations*
Biberian *Prisms II*
Bozza *POLYDIAPHONE*
Brouwer *Per Sonare a Tre*
Dodgson *Fantasy-Divisions*
Henze *El Cimarrón: Recital for Four Musicians*
Lutyens *Anerca*
Norgaard *Arcana*
Smith-Brindle *Music for Three Guitars*
Wolff *Electric Spring I and II*

1971 Bedford *Nurse's Song with Elephants*
Blake-Watkins *Psallein*
Brouwer *La Espiral Eterna*
Fricker *Paseo*, Op. 61
Gilardino *Abreuana*
Kucera *Diario: Homage a Che Guevara*
Maxwell-Davies *From Stone to Thorn*
Petrassi *Nunc*
Rasmussen *Protocol or Myth?*
Read *Canzone de Notte*, Op. 127

1972 Bartolozzi *Omaggio a Gaetano Azzolina*
Blake-Watkins *Double Concerto*
Guitar Quartet
Invocation
Brouwer *Concerto*
Buck *14 Preludes*
de Regt *Musica per Flauto, Viola, Violoncello e Chitarra*, Op. 17
Encinar *Abhava*
Haubenstock-Ramati *Frame*
Holmgreen *Solo for Electric Guitar*
Maxwell-Davies *Ara Coeli: Lullaby for Illian Rainbow*
Sandström *Surrounded*
Taverner *Celtic Requiem*
Walton *Five Bagatelles*

1973 Bedford *A Horse, His Name Was Hunry Fencewaver Walkins*
Benvenuti *FroBorSal's Trio*
Blake-Watkins *Clouds and Eclipses*
Brouwer *Parabola*
Per Suonare a Due
Corghi *Consonancias y Redobles*
Duarte *Ballade*, Op. 53
Haubenstock-Ramati *Hexachord I and II*
Lorentzen *Umbra*
Maxwell-Davies *Dark Angels*
Scottish Dances
Yesterday
McGuire *Music for Four Guitars*
Mellers *A Blue Epiphany for J. B. Smith*
Norgaard *Libra*
Smith-Brindle *Concerto "de Angelis"*

1974 Bedford *Star's End*
Behrend *Sechs Monodien*
Benguerel *Versus*
Bland *An Impression of Arp*
Song for David
Bolcom *Seasons*
Dodgson *Duo*
Henze *Carillon, Recitatif, and Masque*
Maxwell-Davies *Fiddler at the Wedding*
Points and Dances from Taverner
Rasmussen *Love Is in the World*
Searle *Five*
Takemitsu *Folios*

1975 Apostel *Studie*, Op. 29
Biberian *Eight Bagatelles*
Eight Valses
Sonata
Sonata No. 2
Bingham *The Light Phantastic*
Blake-Watkins *Solus*
Bland *An Impression by Crumb*
Untitled Duo for guitar and flute
Campo *Preludes*, Op. 51
de la Vega *Sound Clouds*
Emsley *Syntagm*
Gefors *La Boîte Chinoise*
Kessner *Array*
Six Aphorisms
Kolb *Looking for Claudio*
Lutyens *"Go, Said the Bird,"* Op. 105
Rawsthorne *Elegy*

1976 Antunes *Sighs*
Bedford *The Ones Who Walked Away from Omelas*
Benguerel *Vermelia*
Bland Untitled Duo for amplified guitar and piano
Boogaard *Oilless Motors*
Dodgson *Dialogues*
Duarte *Night Music*, Op. 65
Hovhaness *KHORHOORT NAHADAGATS*
Schneider *Voyage*
Smith-Brindle *Sonata No. 2*

1977 Biberian *Monogram*
Quartet No. 3
Fanshawe *African Sanctus*
Ho Wai On *Tai Ch'i*
3:10 A.M.
Smith-Brindle *Guitarcosmos* (Vols. 1–3)

1978 Carter *SYRINGA*
Dodgson *Merlin*
Harrison *Suites for Tuned Guitars*
Smith-Brindle *Sonata No. 3*
Sonata No. 4

1979 Hovhaness *Concerto*, Op. 325
Sonata for Guitar, Op. 329
Smith-Brindle *The Pillars of Karnak*
Sonata No. 5

APPENDIX II
String Gauges (Acoustic and Electric)

String Number	String Gauge (in inches) 1	2	3	4	5	6
CLASSICAL GUITAR						
Medium	.028	.032	.040	.028w*	.034w	.045w
Ophee lightweight (for Terz-guitar tuning on standard scale guitars, med. tension)	.0235	.0285	.037	.0268w	.0315w	.0375w
Savarez						
yellow	.0315	.035	.0415	.031w	.037w	.0455w
red	.0275	.033	.040	.030w	.0335w	.0435w
white (low tension)	.0265	.031	.038	.0305w	.0332w	.0418w
Aranjuez						
silver	.0285	.0332	.0405	.031	.0362	.0435
Augustine						
blue	.0279	.032	.042	.0302	.0365	.0448
ELECTRIC GUITAR						
"Extra Slinky"	.008	.011	.014	.022w	.030w	.038w
Extra light	.010	.014	.020w	.028w	.040w	.050w
Light	.011	.015	.022w	.030w	.042w	.052w
Medium light	.012	.016	.024w	.032w	.044w	.054w
Medium	.013	.017	.026w	.034w	.046w	.056w
Heavy	.014	.018	.028w	.038w	.048w	.058w

* w = wound string

Recorded Examples

1. Harmonic series on A-string (110 Hz) (first eight harmonics)
2. E-string plucked with thumb at three positions
3. Changing plucking angles in X-Y plane;
   changing plucking angles in X-Z plane
4. Wah-wah on soundboard
5. Time envelopes for some vibrato parameters
6. Pickups in and out of phase
7. Acoustic feedback
8. Magnetic feedback with E-bow
9. Note without attack by using swell pedal (chords, too!)
10. Low-pass filter scale; hi-pass filter scale
11. Five-band graphic equalizer's effect on low E-string tone
12. Fuzz-tone
13. Octave divider
14. Amplitude modulation
15. Ring-modulation
16. Spectrum shifter
17. Vibrato and tremolo
18. Reverb and echo
19. Phasing
20. Voicebox
21. Equal-tempered third and equal-tempered major chord; just third and just major triad
22. Quarter-comma meantone diatonic scale; quarter-comma meantone chromatic scale
23. Milan Pavane, equal-tempered, then meantone
24. Two fingerings for the same phrase
25. Ligado techniques
26. Scale in G-major: ponticello, normale, tasto
27. Pizzicato (played with thumb, hand on the saddle): left-hand pizzicato; pizzicato stridente; pizzicato resonance; surface pizzicato; Bartók pizzicato
28. Scale of bi-tones
29. Scale of open-string harmonics
30. Scale of artificial harmonics; artificial chords (left hand stationary)
31. Multiphonics for open sixth string
32. Bowed guitar
33. Glissandi: fretted gliss; bending gliss; bottle-neck gliss; scord-gliss; scratch-gliss; koto-gliss trill
34. Tuning for S.-D. Sandström's *Surrounded*; opening measures of Example 82
35. Guitar solo from Carrillo's *Preludio*
36. Beats between C and D*b*. M. Griffiths' *James Stephens Verses*: glissing beats
37. Percussion sounds: tambura; golpe (top, back, and sides)
38. Crossed strings: bass and treble
39. Prepared guitar: classic guitar (paper clips); electric guitar (crocodile clips)
40. *Voyage* (electric guitar and tape)

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Index