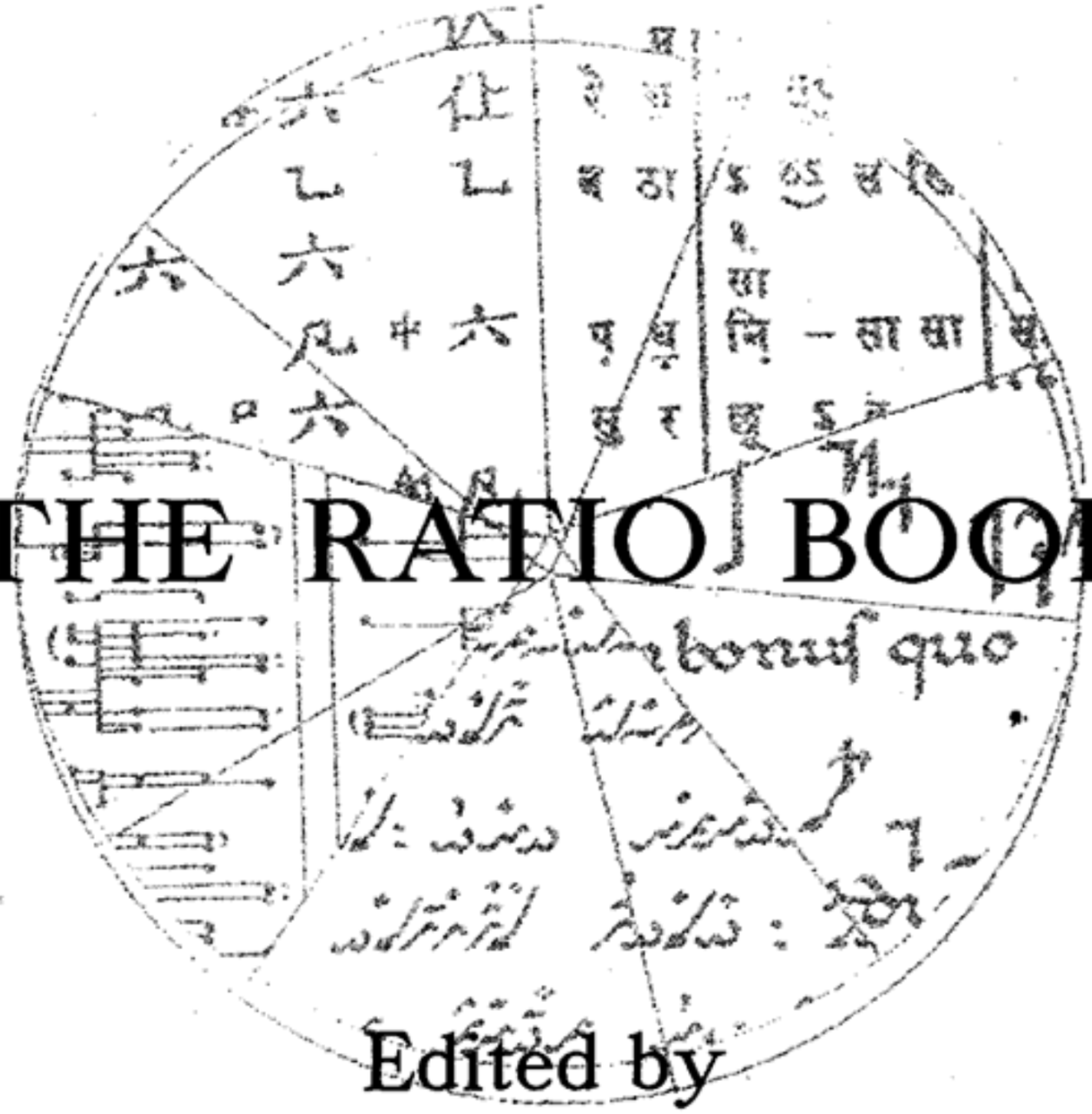

THE RATIO BOOK

Edited by

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Wim van der Meer

Theory and Practice of Intonation in Hindustani Music

The other day I was present at a concert of Hariprasad Chaurasia. As is common in Indian music he started out by tuning the tanpura, which takes quite a long time – like twenty minutes or so. He wants it really perfect. And then he says, as he picks up his bamboo flute, "thank God I don't have to tune this instrument". Now, that is indeed a very nice joke, because the bamboo flute has seven holes that are more or less equidistant, so you can imagine how much trouble it is to play that instrument in tune. And I assure you he is one of the most well attuned musicians in India. Just to give you an idea of what it sounds like I'll play a small piece of a relatively unknown but excellent young singer. This raga is in the Western major scale.

[Music example: Raga *Tilak Kamod* by Ashwini Bhide]

Indeed, it is often striking that Indian musicians achieve an uncanny exactness in intonation. We will come back to that in the course of this talk.

In this small piece you hear the drone. You don't hear it very clearly. It's supposed to be soft. You also hear the voice and the drum, and on top of that you might have heard a small harmonium that is actually tuned in more or less equal temperament. But that doesn't really disturb the Indian musicians so much. It's also played softly, and they refer to the tanpura, and in particular of course the major third is different in one instrument and the other.

Now, before I really go into this subject of how this intonation came about I want to say one thing, which is that people think that a culture like India's has undergone very little change over the ages; that the music is transmitted orally from teacher to student and that very often the student spends twenty-five years with his teacher and I mean not just spending in the sense of coming to him once a week but living with him and assimilating the whole music.

But you know there are at present approximately fifty ragas that are really very well known, big ragas, important ragas. There are surely another two hundred ragas that are reasonably well-known. Not to everyone, but at least some people know them. There is one book in which about seven hundred and fifty ragas are discussed. But in fact ragas are invented everyday and ragas are changed everyday.

Musicians try all sorts of things all the time, so if you would start counting the number of ragas that might have been in existence at any particular moment you are talking about thousands, many thousands. And there's really a Darwinian process of selection that goes on.

It's in the first place the musician himself who may say, "Well, I tried this". He may have tried it for a few days, he may have tried it for a few months, or even for a few years, but he may conclude in the end that it didn't really work. And in the second place of course it's the audience; and I'm not talking about once or twice, but it's going to take a process of ten years or twenty years that a certain raga came into being, was played for some time, and then disappeared again. And how it disappears is not because there is some committee, or some musicologists who say, "this raga's wrong". They have no influence on that. It just didn't work. And some other ragas have existed already perhaps for the past fifteen hundred years or so, because the whole raga principle got its main shape in about the Vth or VIth century A.D. Even then, ragas that are that old might have changed in the course of time. So the whole history of Indian music is very much an evolutionary process of trial and error. Most probably, various aspects of intonation also have been subject to this evolutionary process - trying and finding the best tuned solutions.

Towards the end of this talk I'll come back to that. I'll go first to the ancient theory of intonation in Indian music.

The man who is always cited on this is Bharata, a great scholar of two thousand years ago, who wrote a treatise on theatre in which there is an important part devoted to music. He explains different intervals of music and people have tried to understand his theory. I think by now there is a kind of general consensus on how it works.

Take his division of the octave in a tuning called *Sa grama*. He divided an octave of seven tones into a total of twenty-two *shrutis*, which one nowadays knows were not equal in size. He saw that you can tune perfect fifths (2:3) and perfect fourths (3:4) and if you tune an instrument (they used harps in those days), you get a problem with your fifths. Most probably he got that problem because he was aware of the existence also of the harmonic major third 4:5.

Put simply, he knew the octave, the perfect fifth, the harmonic major third as primary intervals, derived the fourth as an inverted fifth, then getting the *chatushruti* (meaning "four *shrutis*") which is the major whole tone 8:9 (204 cents), the difference between the fifth and the fourth. Then he recognized another slightly smaller interval called the *trishruti* ("three *shrutis*"), i.e. the minor whole tone 9:10 (182 cents), the difference between a harmonic major third and a major tone. Then came the *dvishruti* ("two *shrutis*"), the major semitone 15:16 (112 cents) or the fourth minus the harmonic major third. He was also aware of the syntonic comma 80:81 (22 cents, the difference between the major and the minor whole tones), which he called the *pramanashruti*. Now, by variously chaining together the *dvishruti* ([2] below), the *trishruti* ([3]) and the *chatushruti* ([4]), he arrived at the following seven-tone scale* (European note-names and cent equivalents are given below):

Sa	[3]	*Re*	[2]	*ga*	[4]	*ma*	[4]	*Pa*	[3]	*Dha*	[2]	*ni*	[4]	*Sa'*
do	182	re	112	mi♭	204	fa	204	sol	182	la	112	si♭	204	do'

Just add up the *shrutis* and you'll see they total twenty-two (the cents add up to 1200). Note that the perfect fifth is thirteen *shrutis*, the fourth is nine. You can also see that the interval *Re–Pa* (re–sol) is not a perfect fourth, something he was obviously aware of. What we are saying is that he somehow understood that the harmonic major third actually makes a mess of the beautiful system of fifths: when you tune an instrument you meet that problem naturally.

Let me go back a step here. This will be very much a repetition of what we saw this morning. I will first state a

General law of consonance:
Consonance decreases as the fractional relation between base frequency and the frequency of the related pitch becomes more complex.

Look now at the following figures:

1:1	1:2	2:3	3:4	3:5	4:5	4:7
I	VIII	V	IV	VI	III	--

You see the octave (VIII), fifth (V) and fourth (IV), followed by the sixth (VI) and third (III). Then you see 4:7 and here comes my first comment, which is just what Clarence Barlow said this morning:

Comment 1:
Prime numbers above 5 aren't part of a fraction.

Then you can go on and you come here to other known intervals:

5:6	5:8	5:9	8:9	9:10	8:15	9:16	15:16	16:25
iii	vi	vii	II	II-	VII	vii	ii	--

Having eliminated the numbers Clarence eliminated – 7, 11, 13 and so on, you arrive at 25/16, the next one in line. The 25 also poses a problem. (To C.Barlow) I don't know if you would know by heart the indigestibility factor of 25.

C.Barlow: I think about twelve.

W.v.d.Meer: Right, above ten. I'm sure we could easily apply the formula of Clarence's lecture this morning. As soon as you have a 25 you're putting thirds together, and that's difficult tuning. If you're singing, that's really out of the question. This leads to my

Comment 2:
The number 5 doesn't occur more than once in a fraction.

Thus no compound thirds.

* See page 70

D.Wolf: Question: are you making a distinction between 25 in relationship to the tonic? For example if you go from 5:6 over the tonic to 4:5, you're going 24:25 and that's quite common.

W.v.d.Meer: I would say in Indian music it's not. And I'm not eliminating these on the basis of some theory. I'm just going through all the possible intervals and already indicating which ones are not used in Indian music.

C.Barlow: I think you're talking about the relationship between a certain tone and the tonic, if I'm not mistaken. But, as Daniel Wolf says if you have both major and minor thirds you can indeed find the difference between them forming 24:25.

W.v.d.Meer: In that case I agree absolutely.

J.Tenney: The tuning you showed us looks like our minor scale.

W.v.d.Meer: Yes. That's a minor scale basically, the *Sa grama*. That's what they used as their basic scale. There was another one called *Ma grama*, in which the fifth (*Pa*) was lowered a bit to make it consonant with the second (*Re*); if I have time I'll come back to that. This is a fundamental scale from which, by transposition, all sorts of other scales were derived with basically seven tones of course, although later two more tones were added – the major third and the major seventh, on which basis again new scales were derived. You finally get quite a complex set of musical scales.

Going on with our intervals we get

16:27	20:27	27:32
VI+	IV♯	iii-

which I'll come back to.

Here I'll make another general observation:

Comment 3:
Inverted intervals are more difficult to tune and perform

I mean the fifth above the tonic is very easy to produce. A fifth below the octave is very difficult to produce – it would mean the fourth. The perfect fourth is really far more difficult than the perfect fifth. Similarly, the minor sixth is also much more difficult than the major third. It's very easy to understand why, because what really happens in this kind of natural tunings is that you're matching harmonics – the harmonics of the voice with those of the drone. And, if the harmonics of the drone are kept steady, you match the harmonics of the voice to them. It's much easier to do that above the drone than to do the inverted thing. It's like cutting your hair in a mirror, something like that.

H.Radulescu: Is it because your fourth is nearly your forty-third harmonic? It's very difficult to control. It's a prime number.

W.v.d.Meer: I wouldn't say that.

H.Radulescu: But why are primes bigger than 5 forbidden?

W.v.d.Meer: They're just not used in Indian music.

H.Radulescu: But they could come. Between the seventh and sixth is fantastic. A minor minor seventh, no?

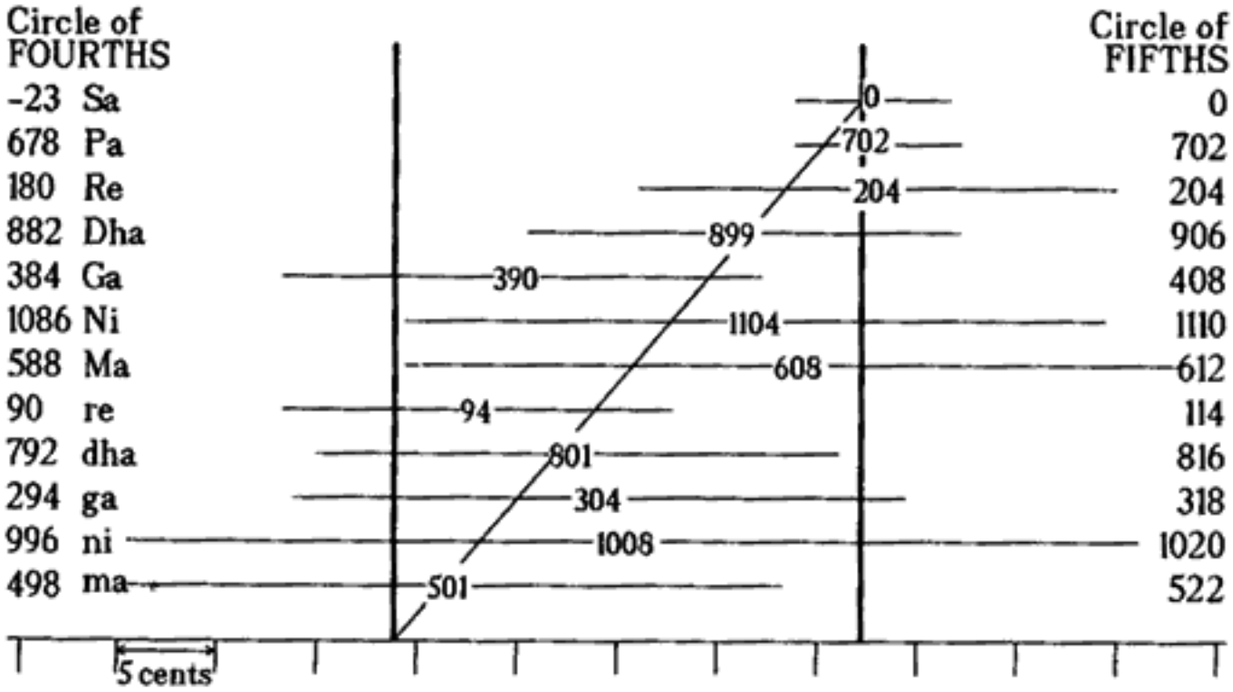
W.v.d.Meer: Oh yes, they could, but they don't!

Now these are some general outlines that we find in the interpretation of a natural scale in Indian music. Now here's my last comment – I'll have to come back to that in much more detail.

Comment 4: The semitone is an independent interval

The semitone is really an independent interval produced by some kind of acoustics of the instrument or the voice generating the melody and the drone. There is something funny going on there that is not explained in this theory of simple harmonic relations because we are talking about a strictly complex ratio. I will show you that the semitones used in Indian music are with great accuracy and dependability about ninety-five cents. They are certainly not the 15:16 we commonly find in books. What ratio the ninety-five cents is, you can figure out for yourself, of course – extremely complex.

[1 - Average intonation measured for the twelve scale-degrees shown in circles of fourths and fifths; all values in cents - note names in *sargam*



[1 shows an ascending cycle of fourths (with Indian note names) along the left vertical line opposite a descending cycle of fifths on the right, 23.46 cents (a Pythagorean comma) apart. The diagonal shows equal temperament, the horizontal lines the pitch spread (with the mean value centred) of the twelve chromatic notes found in about two hundred 5- to 15-minute compositions we computer-processed in the past twelve years. The fifth (*Pa*) averages at 702 cents, the major second (*Re*) at 204, beautifully. The major third (*Ga*) is a bit high at 390 cents instead of at 386, hardly noticeably. The major sixth (*Dha*) is tempered: the major third and the major whole tone pull on it about equally. The major seventh (*Ni*) 96 cents below the octave (*Sa'*), the augmented fourth (*Ma*) 94 below the fifth (*Pa*), the minor second (*re*) 94 above the tonic (*Sa*) all more or less follow the rule I mentioned that drone centres, here always tonic and fifth, tend to be flanked by semitones at about 95 cents. The minor sixth (*dha*) is interesting, a bit higher than expected (99 cents above *Pa*) and practically tempered. The minor third (*ga*) is relatively well spread; especially the minor seventh (*ni*) goes really wild. The perfect fourth (*ma*) is at 501 cents a bit high, known to Indian musicians who say this is because musicians are too greedy.

⌈2 - Tabulation and evaluation of the findings in ⌈1

Scale-degree Name	Semitones	Theoretical alternatives in cents with ratio (and derivation)			Measured average in cents (range and position* in % of a syntonic comma)
Sa (do)	0	0 1:1			0 (37/103)
re (re♭)	1	90 243:256(IVx5)	112 --schisma-- 114 15:16(IV-III)	2048:2187(Vx7)	94 (90/16)
Re (re♮)	2	180 --schisma-- 182 59049:65536(IVx10)	9:10(IV+III-V)	204 8:9(Vx2)	204 (110/102)
ga (mi♭)	3	294 27:32(IVx3)	316 --schisma-- 318 5:6(V-III)	16384:19683(Vx9)	304 (140/46)
Ga (mi♮)	4	384--schisma--386 6561:8192(IVx8)	4:5(III)	408 64:81(Vx4)	390 (110/20)
ma (fa♮)	5	498 3:4(IV)	520--schisma-- 522 20:27(Vx2-IV-III)	131072:177147(Vx11)	501 (150/13)
Ma (fa♯)	6	588 729:1024(IVx6)	612 512:729(Vx6)		608 (180/84)
Pa (sol)	7	678 177147:262144(IVx11)	702 2:3(V)		702 (40/100)
dha (la♭)	8	792 81:128(IVx4)	814--schisma--816 5:8(VIII-III)	4096:6561(Vx8)	801 (120/43)
Dha (la♮)	9	882--schisma--884 19683:32678(IVx9)	3:5(IV+III)	906 16:27(Vx3)	899 (100/69)
ni (si♭)	10	996 9:16(IVx2)	1018--schisma--1020 5:9(Vx2-III)	32768:59049(Vx10)	1008 (230/56)
Ni (si♮)	11	1086--schisma--1088 2187:4096(IVx7)	8:15(V+III)	1110 128:243(Vx5)	1104 (160/71) *

• distance from (where schismatically paired next to) lowest shown theoretical value

General observations:
Pa, *Re* clear preference for high, *Ga*, *ma* clear preference for low position
Dha almost tempered, *ga*, *dha* and *ni* also near-tempered
re, *Ma*, *Ni* approximately 95 cents from drone centres *Sa*, *Pa* and *Sa'*

Note by note:

Sa	although properly zero, often corrected in view of the other notes
re	easiest place in theory IV-III not used due to absence of IV in drone
Re	absolute and stable preference of 8:9 over 9:10 due to *Pa* tuning
ga	tempered between the two theoretical positions, not very stable
Ga	clearly naturally harmonic
ma	a bit above the inverted fifth, not so stable due to lack of *Pa*-support
Ma	high position
Pa	more stable than *Sa* because *Pa* is stronger in the tanpura - s. ⌈5
dha	tempered between the high VIII-III and its 95ct adjacency to *Pa*
Dha	tempered between the low III+IV and the high Vx3
ni	tempered between the low IVx2 and the high Vx2-III
Ni	clearly high in spite of the apparently simple low V+III choice

[2 - continued

Further observations
It could be expected that notes with an easy choice for low or high would a) follow that choice and b) be quite stable. This is so for *Re*, *Ga* and *Pa*
It could therefore be expected that notes with two accessible positions are tempered and unstable - this is the case with *ga* and *ni*
The instability of *ma*, is spite of an easy choice, is due to its lack of support by the tanpura - inverted harmonic matching is more difficult
The semitones adjacent to *Sa* and *Pa* are at a distance of 94-96 cents, but for *dha* at 99 cents above *Pa*, seeming to indicate a phenomenon unknown in literature
The temperament of *Dha* indicates balanced consonance with *Re* and *Ga*

J.Tenney: So if there were for example in your sample two different versions of the major sixth, you would lose that distinction by averaging them out.

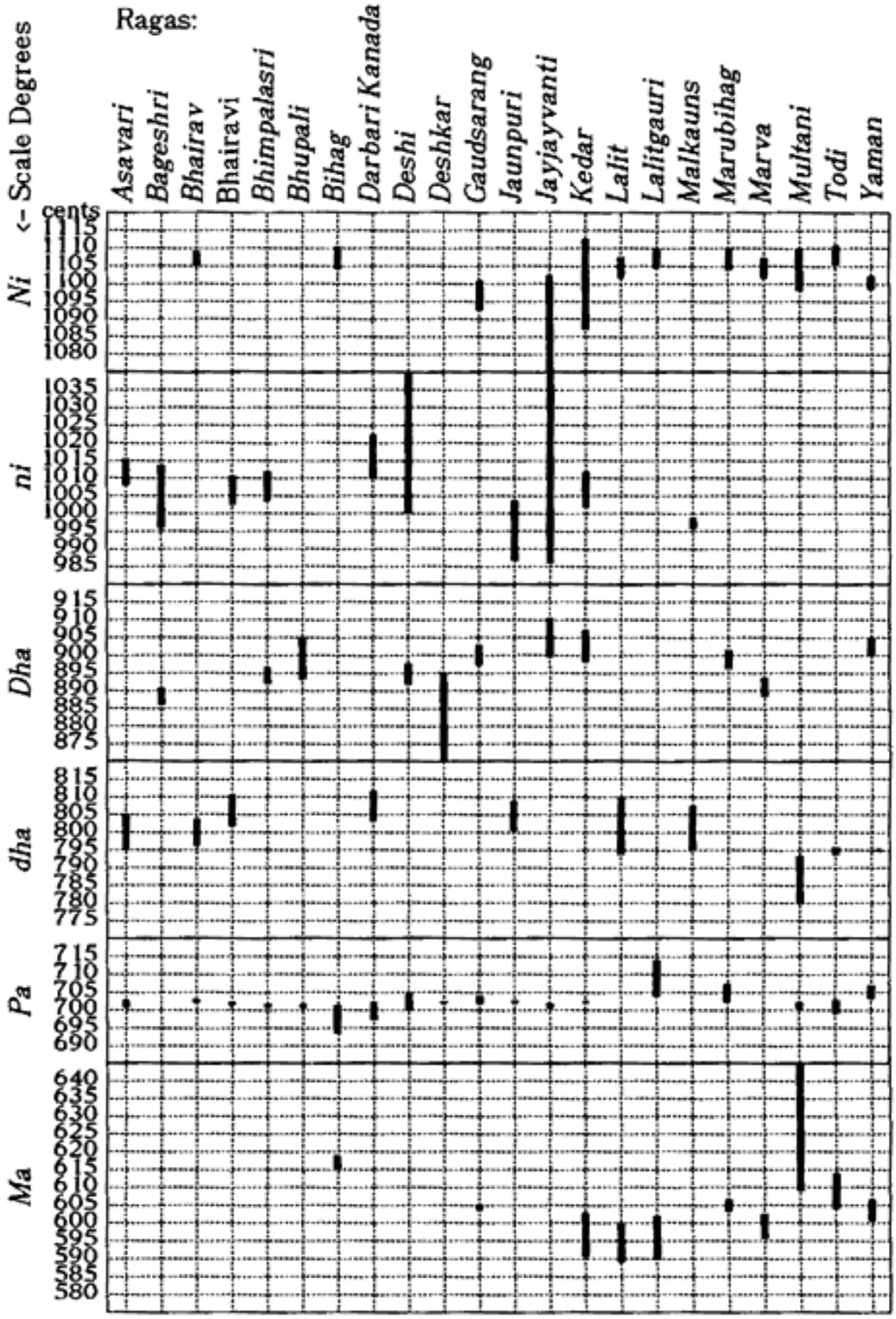
W.v.d.Meer: Absolutely. Of course. That is the next question that has to be raised.

Differentiation of intonation by raga

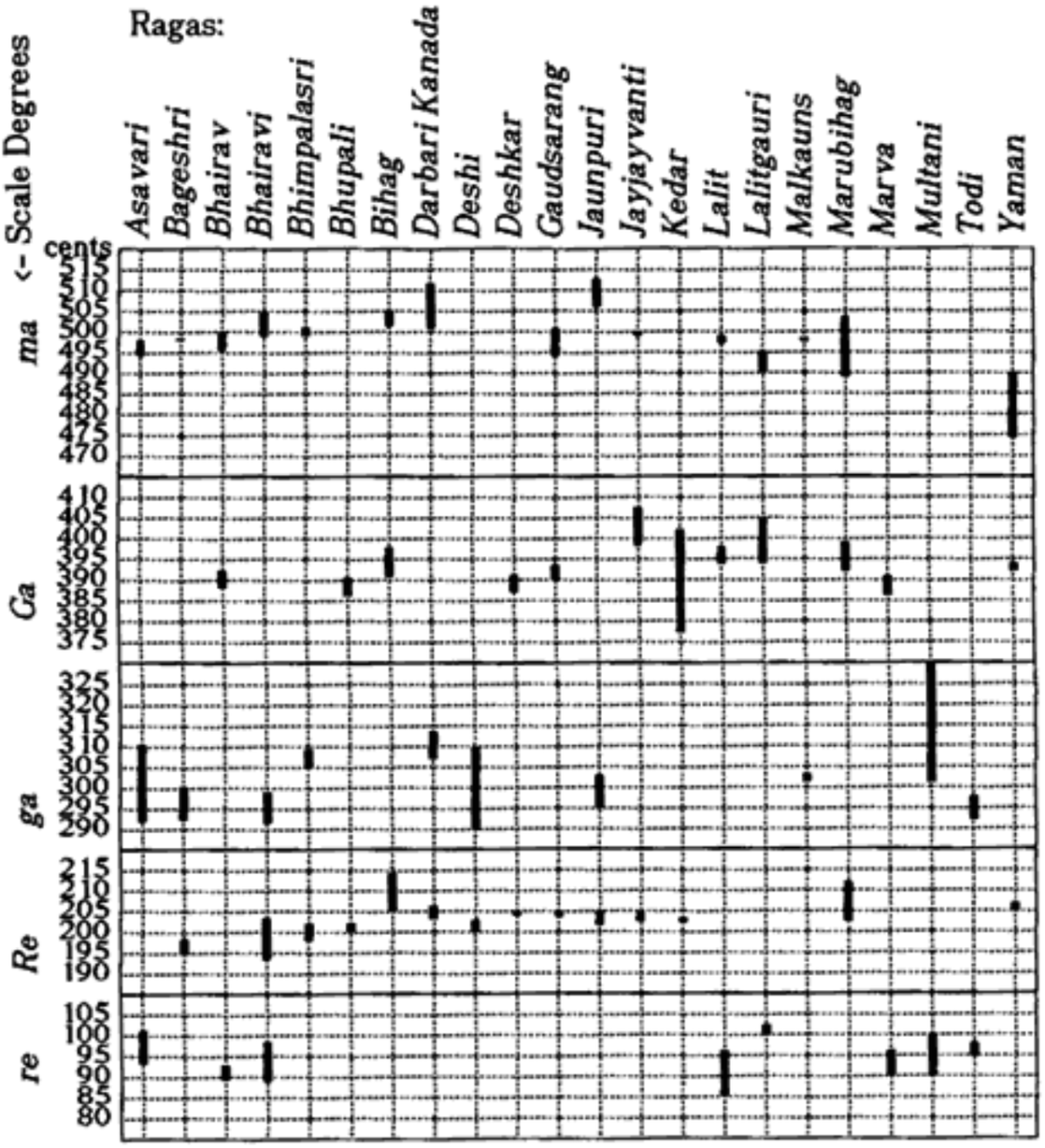
I must tell you that after studying the history of Indian music and discussing with many people this scheme of Bharata in which you make this distinction between the higher position and the lower position, a distinction which is discussed very often among Indian musicologists (not so much among musicians, as you value), I find that musicologists like to talk about the high position which is the bright position of the notes that relates to the day time, and the low position which is the dark position and relates to the night. You know; day ragas, night ragas. I must say, about ten or fifteen years ago, I staunchly believed that somehow some scheme like this was being followed by Indian musicians. So naturally, when you take this kind of general average of course it happens that sometimes musicians take the higher position, and sometimes they will get a lower position: you will get an average.

So naturally the next thing we did was to see, raga by raga, if one can find some ragas that really take the high position and some which take the lower position, because that would be the theory, originally.

[3 – Intonation of eleven scale degrees measured for twenty-two ragas



[3 continued



Watch these measurements, raga by raga, note by note. The minor second (*re*), for example, is found here in eight different ragas. The measurements speak for themselves – there is hardly anything significant here. The minor second is generally at 85 to 103 cents, always lower than the 112-cent 15:16. Now in Raga *Bhairav* it's supposed to be low. Nice. But you can't say this is significant.

C.Barlow: I remember hearing that the minor second in Raga *Marva* ought to be especially high. Isn't this a general belief?

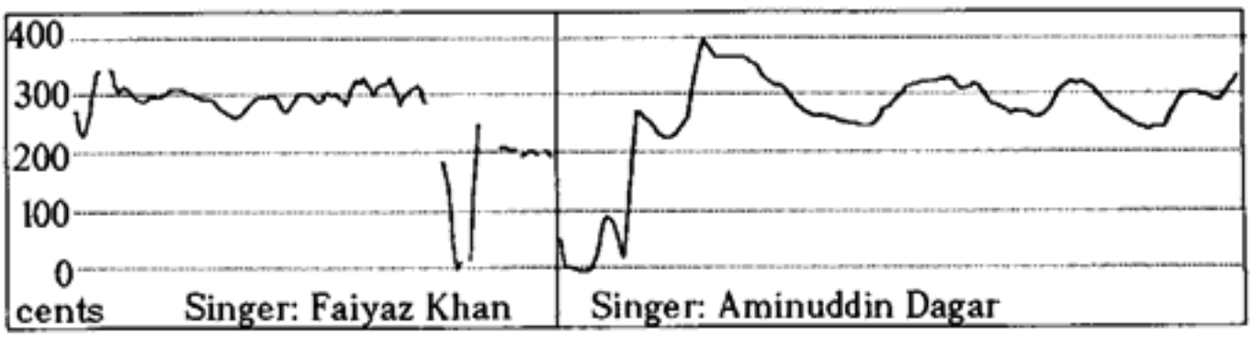
W.v.d.Meer: Exactly. But it's not true.

J.Tenney: How did you measure these intervals?

W.v.d.Meer: In a minute. Let's run through a few. An interesting case to attend to is the major second (*Re*) ranging in *Bhairavi* from 194 to 204 cents because both the minor and the major second are used. There tends to be a little play there; in measuring you're going to get some variability. For instance, here is one really on the low side: in *Bagesri*, a raga in which the drone tuning is not done with the tonic and the fifth, but the tonic and the fourth. You would indeed expect it to be a bit low, but again it's certainly not the 182 cents (9:10, the minor whole tone) you would theoretically expect. You see that most of the major seconds are around 204 cents, though, certainly in the general average. Quite clear cut.

The minor third (*ga*) is all over the place. Sometimes it doesn't even fit on this diagram: it goes from 300 to beyond 325 cents in Raga *Multani*. Interesting that in Raga *Darbari Kanada*, the minor third is supposed to be very low, and it is significantly higher here than what we would actually expect – see also [4.

[4 – Measured intonation of the *Darbari Kanada* minor third as sung by two prominent singers (about five seconds each)

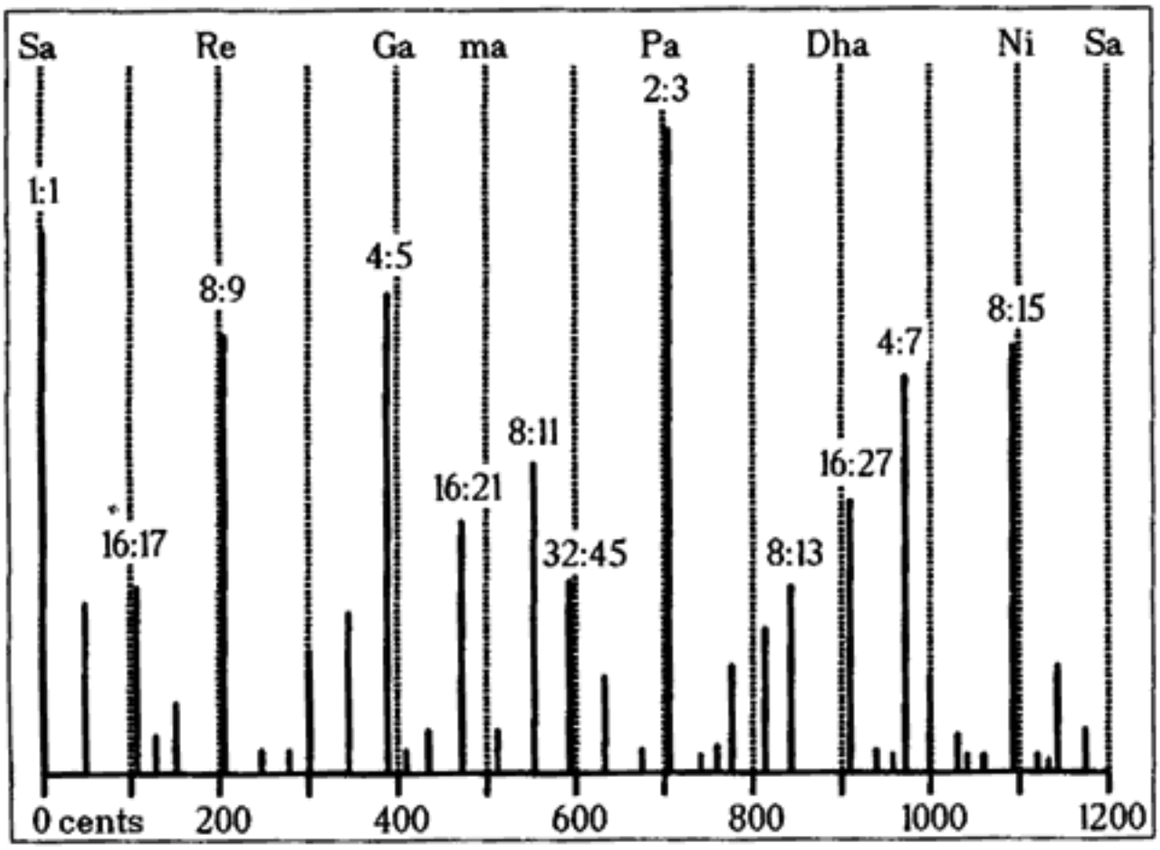


The major third (*Ga*) is also extremely spread out – a problem of measurement. In Raga *Kedar*, for instance, the major third is used very little and therefore isn't very dependable: measurements get more dependable if you have really steady notes used regularly in a performance. You will find large spreads either when the note is seldom used or if it oscillates strongly which happens in some cases. Or if both major and minor forms of one note are used. Yet this is hardly significant. A quick look at some of the others, e.g. the sixths (*dha*, *Dha*) and sevenths (*ni*, *Ni*), shows the same story. You hardly get any significant differences from one raga to another in intonation. I don't find it interesting to assess each case separately.

The seventh harmonic in the tanpura

Here's a picture that's of some interest – [5:

[5 - The cumulative spectrum of a lady's tanpura in *Pa*-tuning; Indian note-names at twelve-tone equal-tempered positions



This is a tanpura spectrum. You see very clearly the fifth (2:3) even stronger than the tonic. The major third (4:5) is also very clear, as is the major second (8:9). Very clear, too, the major seventh (8:15 or 1088 cents) a third above the fifth. But this is not the one preferred in practice which at 1104 cents is above the dotted line of equal temperament.

The 4:7 interval at 969 cents is very interesting. Very audible. Clear in the tanpura sound. But ask any Indian musician: "Do you hear that?". – "No...". You sing it. It's very clear. You soften your voice to hear the tanpura better. "No. It doesn't exist. What are you singing? It's out of tune!"

D.Lekkas: Excuse me, do you mean they have been trained away from hearing that harmonic, or how do you account for that?

W.v.d.Meer: I suppose so. I suppose the ear is so much trained to hear those set intervals that an interval that's out of ...

C.Barlow: Yes, but look at Western music: if you play a low note on the piano you hear the seventh harmonic very clearly. And none of our harmony has a natural seventh in it.

D.Lekkas: Well that's different from not being able to hear it. You might not use it but you should be able to hear it.

C.Barlow: I think it's a matter of openness, actually. It's probably lacking there in a certain respects.

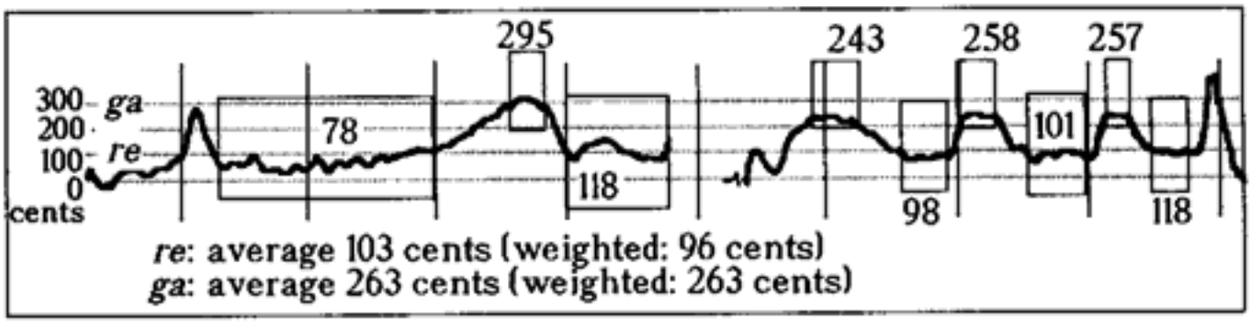
The problem of measurement

W.v.d.Meer: Now let us listen to just one small musical fragment.

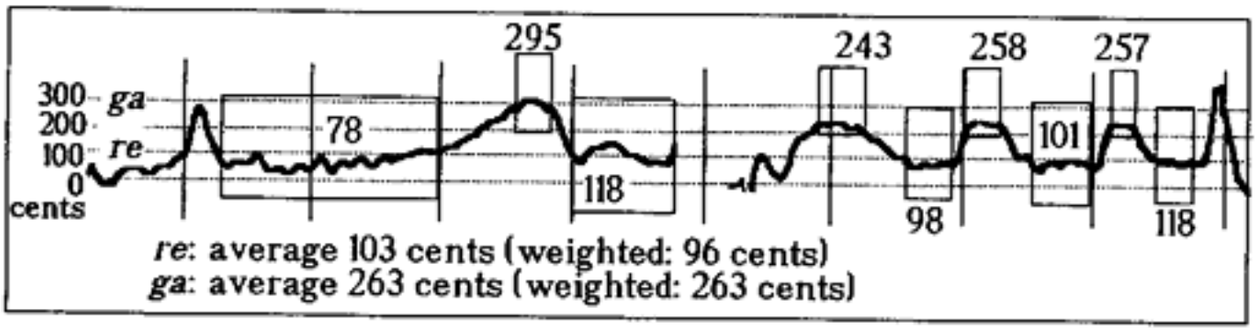
(Tape example)

In [6 (here below, repeated on next page) you see a line representing what you just heard, the minor second and the minor third in the Raga *Todi* sung by the great Mallikarjun Mansur, who died a few months ago. This picture is obtained by pitch extraction. A lot of the research we did was based on fundamental pitch extraction. It was done by a machine designed by Bernard Bel in Bombay, on which a large amount of material was processed. Of course I later used the techniques that were developed here in Holland for pitch extraction, a programme that's called LVS that's quite satisfactory to people nowadays. And I also developed a pitch extractor myself to be able to do this work at home and on a normal computer, because all those things work on special computers. Bernard's machines are in Bombay and the LVS machines are only available at phonetic labs and institutions of that kind. Whereas the one that I built works on a relatively simple Apple Macintosh.

[6 - A short fragment of Raga *Todi* sung by Mallikarjun Mansur



[6 - A short fragment of Raga *Todi* sung by Mallikarjun Mansur (repeated)



Now pitch extraction by itself is a complex matter. I don't think I should talk about that here. But here you see the problem of how to decide what really is the intonation of the minor second and third: see here the various windows in which they were measured. You get an average here of 103 cents for the minor second, and an average of 263 for the minor third. In one case, at 295 cents, the minor third's a bit higher, but it's otherwise at 243, 258 and 257; the minor second's at 78, 118, 98, 101 and 118 cents. This happens a lot in Indian music, this moving between notes from one to another. The crazy thing is you can never really measure these notes. Already making a window makes your measurement appear lower than what maybe it should be. At the present state of the art we cannot really measure a point with great certainty because even in producing this graph there was a certain amount of smoothing going on; actually very often these graphs look like lots of tiny steps. Which point are you exactly measuring? It's very difficult to say. Moreover, looking at such a narrow point in time, the question also arises as to what note is suggested, because notes are often much more suggested than actually produced, as is clear in [4.
[7 shows the overall spread of *re* and *ga* in *Todi*.

From the audience: I have one question about this problem, a question I came especially for. According to Daniélou, the minor third in *Todi* is a low 64:75, about 274 cents. What do you think? Did you find this interval?

W.v.d.Meer: Not really. Unless you say, "well let me find one here." If you see the variability in this kind of movement you could say "yes, well here look, he's using a 243 you know." But it makes no sense also because the pitch moves too much. And soon as the minor third is held steadily in *Todi* (which a number of musicians do, but some say you never should), it's very close to 310 cents.

C.Barlow: You have 263 as an average in that fragment.

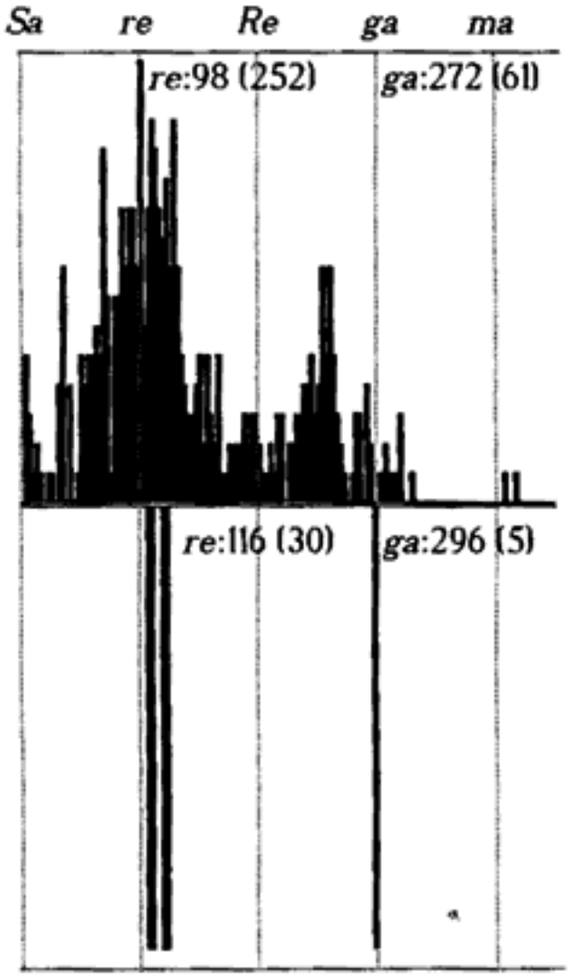
W.v.d.Meer: Yes, 263 here. But as I said, what does this really mean?

D.Lekkas: May I make a point of this? This 64:75 really shows up in a lot of Asian music decidedly not as a third, but always as an augmented second. So, if you don't have an augmented second with a tonic, I think it would be hardly probable that you would find it in practice. You might find it between *shrutis* further up, but not down there.

C.Barlow: Yes. It would have to function as an augmented second, being two major thirds minus a fourth.

D.Lekkas: It's conscious culture that counts whether it's a second or a third.

[7 - Pitch spread for the lower tetrachord of *Todi* as performed by Mallikarjun Mansur with position and weight of *re* and *ga* indicated



W.v.d.Meer: Now, if you listen to Indian music you'll in fact hear mostly that when notes are held steadily, they are very close to the twelve-tone system. With some adjustments you'll hear that the third is really harmonic. But for the rest it's a twelve-tone system.

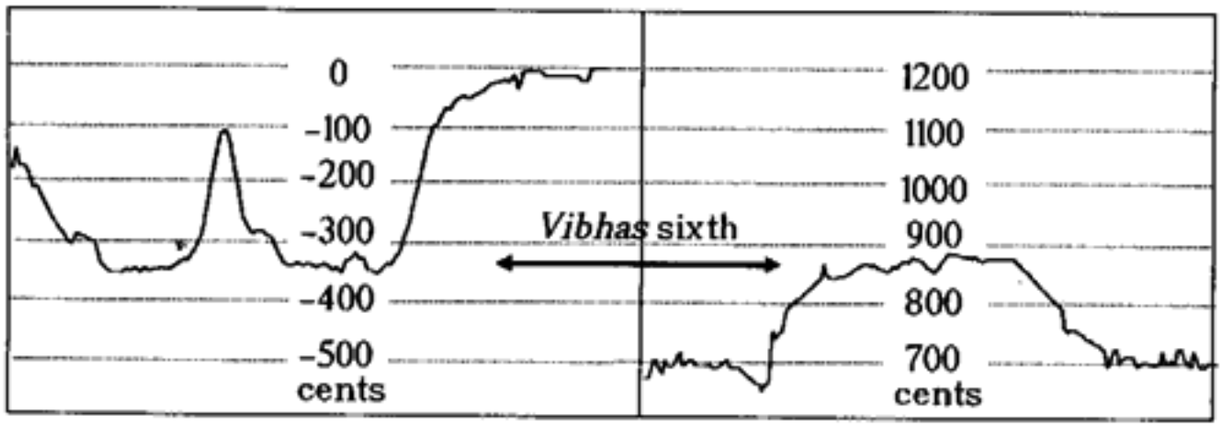
The major sixth of Raga *Vibhas*

However there is to my knowledge one clear exception:

(Tape example)

I was intending to play more of this example because it's really fantastic – this is Kishori Amonkar singing Raga *Vibhas*. And, as you've heard, there is a beautiful major sixth really way below the regular major sixth. You can see here in [8 how low it is.

[8 – Two examples (about three seconds each) of the *Vibhas* major sixth as sung by Kishori Amonkar



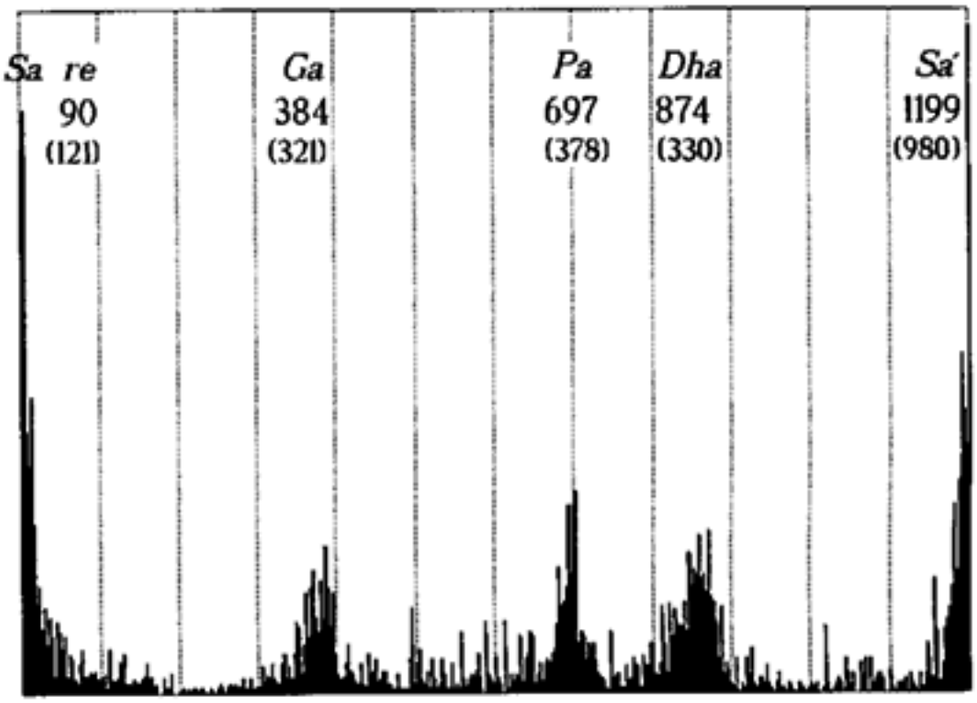
And it's interesting also to to tell you that when I discussed it with her she said, "I spent many years practising this," because it's really not easy. It's particularly difficult to get your perfect fifth in order after you've made this major sixth so much lower. The intention behind it is obvious – you see a certain consistency in the *Dha* averages measured on a number of different occasions ([9; see also [10).

[9 – Ten cases of measured averages for the five scale degrees of *Vibhas*

	a	b	c	d	e	f	g	h	i	j
Sa	2	0	-2	-1	0	0	0	0	0	-1
re	75	90	77	90	87	92	65	145	71	86
Ga	380	388	385	384	389	375	378	360	377	386
Pa	692	696	696	697	698	698	695	690	698	696
Dha	865	875	876	874	880	878	883	875	868	877

This table also includes data from Mallikarjun Mansur (case 'h'), the singer from whom we heard the *Todi*. Both Amonkar and Mansur are extremely reliable artists. Absolute top of the Indian tradition. And you see here a clear and blunt deviation from the general model of our system of twelve semitones.

[10 - Pitch spread for Raga *Vibhas* (positions in cents, weights bracketed)



J.Tenney: It's very close to a 3:5. It's almost right on it.

W.v.d.Meer: No. There is a very audible difference.

J.Tenney: Yes. A 3:5 is only a few cents down.

H.Radulescu: It's a thirteenth harmonic.

J.Tenney: You're within ten cents of a 3:5 in all cases.

W.v.d.Meer: I would say more like twenty cents.

A.La Berge: Well, what did she say?

W.v.d.Meer: Oh, this is absolutely of interest, because if you are talking about the 3:5, which is found quite commonly (and quite steady) in Indian music if you have the tanpura tuning in *ma*, the perfect fourth. If the tanpura is tuned to the perfect fourth, then

the major sixth will have that 886 cents position (see [11), but the one in *Vibhas* is definitely lower than that and she knows it very well, having to work hard to make it that low. It's so much more out of tune, in the Indian conception of intonation.

J.Tenney: Can we hear it again? I didn't hear it out of tune.

H.Radulescu: You're not an Indian!

(Repeat of the last tape example)

J.Tenney: That's a real good 3:5 I hear.

W.v.d.Meer: Very clearly not I'm afraid. I would never sing that *Dha* of *Vibhas*, not even try to, whereas the 3:5 is a piece of cake.

[11 - Tabulation and evaluation of raga tunings with a *ma*-tuned tanpura (Pa-tuning supplied for comparison)

Scale-degree Name	Semitones	Theoretical syntonic alternatives in cents with ratio (and derivation)		Measured average in cents (range and position in % of a syntonic comma)	
				ma-tuning	*Pa*-tuning
Sa (do)	0	0 1:1			0 (37/103)
re (re♭)	1	90 243:256(IVx5)	112 15:16(IV-III)	91 (100/2)	94 (90/16)
Re (re♮)	2	182 9:10(IV+III-V)	204 8:9(Vx2)	197 (30/67)	204 (110/102)
ga (mi♭)	3	294 27:32(IVx3)	316 5:6(V-III)	299 (60/23)	304 (140/46)
Ga (mi♮)	4	386 4:5(III)	408 64:81(Vx4)	396 (50/43)	390 (110/20)
ma (fa♮)	5	498 3:4(IV)	520 20:27(Vx2-IV-III)	498 (10/0)	501 (150/13)
Ma (fa♯)	6	588 729:1024(IVx6)	612 512:729(Vx6)	595 (140/27)	608 (180/84)
Pa (sol)	7	678 177147:262144(IVxII)	702 2:3(V)	690 (--/50)	702 (40/100)
dha (la♭)	8	792 81:128(IVx4)	814 5:8(VIII-III)	802 (170/43)	801 (120/43)
Dha (la♮)	9	884 3:5(IV+III)	906 16:27(Vx3)	889 (40/21)	899 (100/69)
ni (si♭)	10	996 9:16(IVx2)	1018 5:9(Vx2-III)	1001 (100/24)	1008 (230/56)
Ni (si♮)	11	1088 8:15(V+III)	1110 128:243(Vx5)	1105 (70/76)	1104 (160/71)

[ll continued

The few cases of *ma*-tuned ragas are interesting:	
re	remains, as with *Ma* and *Ni*, at about 95±4 cents from drone centres
Re	stable and surprisingly quite high
ga	slightly lower than with *Pa*-tuning
Ga	higher than in *Pa*-tuning, probably due to the 95ct proximity to *ma*
ma	very stable, exactly at the low position
Ma	see *re*
Pa	only one case was measured, not surprisingly low
dha	here the least stable, at the same pitch as with *Pa*-tuning
Dha	stable and low as expected
ni	slightly lower than with *Pa*-tuning (as with *ga*)
Ni	see *re*

Historical background of the *Vibhas* tuning

I will finish my talk here. You should still know in this particular case that there are three varieties of Raga *Vibhas*. One is just like the Raga *Bhup*, *Sa Re Ga Pa Dha* (*do re mi sol la*). Then there is *Sa re Ga Pa Dha* (*do re♭ mi sol la*), which you just heard with the minor second. The third is *Sa re Ga Pa dha* (*do re♭ mi sol la♭*) in which both the second and the sixth are lowered. Now it could be the case that this raga was imported from another culture where quarter-tones are used. I don't know for sure, because I don't know any other than Indian music. Perhaps this *Dha* (*la*) has been slowly trying in the process to find a place either in the higher or in the lower position. It could also be that what's happening is a transition from one to the other, a kind of transition seen very often in Indian music, of notes one by one slowly shifting by a semitone: that would be particularly probable in this case because there are already four ragas using these tones and it's really very confusing.

It has been shown to be a general principle, that when there are many ragas using the same tones, some modification starts taking place in one of them to differentiate it from the others. So it could be simply a process in which *Re* (*re*) and *Dha* (*la*) are slowly being lowered. One point perhaps in that direction is that Mallikarjun takes the second at 145 cents, higher than the normal minor second.

W.Swets: It sounds to me like the Turkish makam *Hicaz*. There you have the same thing. The high minor second and the third a little bit lower, and the sixth has about that pitch. But then of course *Hicaz* is heptatonic, not like *Vibhas*.

Some final conclusions:

Natural intonation is based on harmonic matching, the coincidence of the n-th harmonic of the drone with the m-th harmonic of the instrument.

Whenever harmonic matching offers two possibilities, temperament occurs.

Inverted matching is more difficult - you have to listen to whether the drone is in tune with the note you produce.

The combined spectrum of the drone with its adjacent semitones has a unique quality that defies the laws of consonance.

* Editor's Note: The note-names of North Indian music are based on the seven degrees of the major diatonic scale, named as follows (commonly used abbreviations in brackets): *Shadj* (*Sa*), *Rshabh* (*Re*), *Gándhár* (*Ga*), *Madhyam* (*Ma* or *ma*), *Pancham* (*Pa*), *Dhaivat* (*Dha*) and *Nishád* (*Ni*). Through the addition of the lowered (*komal*) second, third, sixth and seventh (notated *Re*, *Ga*, *Dha*, *Ni* or alternatively *re*, *ga*, *dha* and *ni*) and the raised (*tivra*) fourth (notated *Ma#* or *Ma* [here against *ma* for the perfect fourth]), one gets the complete twelve-tone chromatic scale as generally used in North Indian music. The notation system used here is *Sa - re - Re - ga - Ga - ma - Ma - Pa - dha - Dha - ni - Ni - Sa'*.