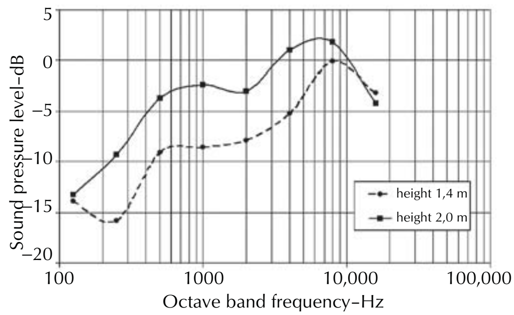


Figure 7-55. Influence of the vertical distance ear level-sound source level on the sound pressure level at a listener seat referred to free field radiation.

7.4 Variation of Room Acoustics by Construction or Electroacoustic Methods

7.4.1 Variable Acoustics

The manipulation of room acoustic properties is universally known by the term vario-acoustics as well as variable acoustics. What variable manipulations are possible in variable acoustics? The primary structures (volume, dimensions, shape) and the secondary structures (reflective, diffuse, absorptive) of a room have a huge influence on its acoustic properties.

Acoustical parameters describing the acoustical overall impression of rooms are determined by the utilization function (see Section 7.3.1). If this function is unambiguously defined, as is the case, for example, with auditoriums and concert halls for symphonic music, the result corresponds, provided an appropriate planning was carried out, to the utilization-relevant room-acoustical requirements. Things look quite different, however, for rooms having a wide utilization range—i.e., so-called multipurpose halls. For speech and music performances which use exclusively sound reinforcement, a short reverberation time with little rise in the low-frequency range as well as a reduced spaciousness of the natural sound field are desirable. For vocal and music performances with mainly natural sound sources, however, a longer reverberation time with enhanced spaciousness is aspired to. The timbre of the room should herewith show more warmth in the lower frequency range. As regards their room-acoustical planning, most multipurpose halls feature a compromise solution which is harmonized with their main utilization variant and does not allow any variability. The acoustically better solution lies in the realization of variable acoustics within certain limits. This aim can be achieved by architectural or electroacoustical means.

Another range of application for purposefully variable room-acoustical parameters is by influencing the reverberation time, clarity and spaciousness of rooms which owing to their form and size meet with narrow physical boundaries in this respect. This concerns mainly rooms with too small a volume index (see Section 7.3.2.1), or such containing a large portion of sound-absorbing materials. Architectural measures for achieving desirable modifications of room-acoustical parameters are applicable here only to a limited extent, since they are bound to implement methods allowing a deliberate modification of the temporal and frequency-dependent sound energy behavior of the sound field. The effectiveness of these methods is herewith determined by the correspondingly relevant sound energy component of the room-acoustical parameter. Achieving a desired reverberation-time and spaciousness enhancement requires a prolongation of the travel path of sound reflections and a reduction of the sound absorption of late sound reflections (enhancement of reverberant energy). In this respect, more favorable results can be obtained by electroacoustical means, particularly because in such rooms the sound-field structure does not contribute essentially to the manipulated parameters. From a practical point of view Section 7.4 is mainly dedicated to the presentation of electronic procedures for reverberation-time prolongation. Equivalent architectural measures will be explained only on fundamental lines.

7.4.1.1 Fundamentals of Variable Acoustics

In the planning and realization of measures enabling variation of room-acoustical parameters, it is necessary to comply with essential aspects so that the listener's subjective listening expectation in the room is not spoiled by an excessive range of variability:

1. The measures viable for realizing variable acoustics by architectural as well as electroacoustical means can be derived from the definitions of the room-acoustical parameters to be varied (see Section 7.2.2). Additional sound reflections arriving exclusively from the direction of the sound source surely enhance clarity, but boost spaciousness as little as an additional lateral sound energy prolongs reverberation time. Spaciousness-enhancing and reverberation-time prolonging sound reflections must essentially impact on the listener from all directions of the room. By means of appropriately dimensioned additional architec-

tural measures it is possible to achieve good results in this respect. Realization of the same, however, often implies high technical expenditure and costs. For influencing the reverberation time, for instance, these include the coupling or uncoupling of additional room volumes or the prolongation of the travel path of sound reflections with simultaneous reduction of the sound absorption of late sound reflections. A desired reduction of reverberation time and spatial impression can be achieved by means of variable sound-absorbing materials (curtains, slewable wall elements of different acoustic wall impedance) which have to be effective over the whole frequency range required by the performance concerned.

2. The coupling of acoustically effective room volumes has to be done in such a way that these acoustically form a unity with the original room. Otherwise there occur disturbing effects like timbre changes and double-slope reverberation-time curves. Incorrect dimensioning often results, owing to an acoustical orientation towards the additional room volume, in a heavily frequency-dependent spaciousness of the decay process in the sound field. The frequency-dependent reverberation time of the additional room volume must be a bit longer than or at least as long as that of the original room.

   In the opposite case of reducing the reverberation time by uncoupling the additional room volume, it is for the remaining room volume necessary to provide the sound-field structure required for the desired variation. For instance, there is more sound energy to be allocated to the initial reflections and in the decay process—which is now to be supplied with less sound energy—there must not occur any irregularities.

3. The variation depth achievable by means of variable acoustics must be acoustically perceptible to a significant degree. The distinctive threshold of, for example, subjectively perceived reverberation time changes is not independent of the absolute value of the reverberation time. Variations of 0.1 s to 0.2 s are at medium frequencies and a reverberation time of up to 1.4 s to 1.5 s is subjectively less clearly perceived than above this limit value. Thus a reverberation-time prolongation from 1.0 s to 1.2 s attained with much technical effort is almost not audible, whereas one from 1.6 s to 1.8 s is already significantly audible.

4. The listening experience has to tally with the overall visual impression of the room—too heavy deviations are perceived as disturbing and unnatural. This aspect has to be taken into account especially with small room volumes, if an excessively long reverberation time is produced by an electronic enhancement system (except for acoustic disassociation effects).

5. The sound-field structure of the original room has to remain unchanged if measures of variable acoustics are implemented. Additionally modified sound reflections have to correspond to the frequency and time structure of the room. This aspect holds true for architectural as well as electroacoustical measures—e.g., for reverberation enhancement. Coupled additional room volumes must not involve any distinctive timbre changes compared with the main room. Electroacoustical room sound simulators with synthetically produced sound fields are allowed to change the transmission function only in compliance with the original room, except if alienation effects are required for special play-ins.

6. An enhancement of reverberation time and spaciousness is possible only within permissible boundaries in which the overall acoustic impression is not noticeably disturbed. This boundary is all the lower the more the manipulation makes the sound field structure deviate from that of the original room.

Aspects to Be Considered with the Realization of Variable Acoustics. In keeping with the envisaged target, the following main realization objectives can be formulated for variable acoustics:

1. Large Room Volume (Large Volume Index) or Reverberant Rooms

   - **Task of variable acoustics:** Enhancement of clarity and definition. Reduction of reverberation time and spaciousness.
   - **Architectural solution:** Apart from an appropriate tiering arrangement of the sound sources, variable ceiling panels and movable wall elements have to be placed at defined distances for enhancing the clarity of music and the definition of speech. Modified inclinations of walls, built-in concert shells near stage areas in theaters, etc., create new primary reflections that are in harmony with the variants of purpose.

Broadband sound absorbers in the shape of variable mechanisms for low frequencies, combined with curtain elements or slewable boundary elements of differing acoustic wall impedance, reduce reverberation time and diminish spaciousness. When arranging variable sound absorbers it is necessary to pay attention to the frequency dependence of these elements. Slots between the installed slewable wall elements may, depending on the position of the elements, function as unwanted additional bass absorbers. In case of exclusive use of curtain arrangements, the low-frequency fraction is at a disadvantage giving rise to a brilliance-poor sound pattern.

An effective broadband reduction of the reverberation time can be achieved by deliberately influencing the late sound reflection mechanism. This may be realized by means of mobile room dividing wall parts which shorten the travel distances of sound reflections at the points of maximum length or width of the room and direct the reflections toward the sound-absorbing listener area. To this effect it is also possible to perform a room reduction, for example, by detaching the room volume above or below a balcony or a gallery.

- **Electronic solution:** An additional electronic architecture system serves for enhancing definition and clarity. Reducing reverberation time or diminishing spaciousness however, are not possible by electronic means.

2. Little Room Volume (Small Volume Index) or Highly Sound-Absorbent Rooms

- **Task of variable acoustics:** Enhancement of reverberation time and spaciousness.
- **Architectural solution:** One solution for enhancing reverberation time consists of the coupling of additional room volumes in acoustical unity with the main room. By means of a purposive sound reflection guidance at the point of maximum room length or width, it is possible to realize long travel paths by letting the sound repeatedly be reflected between the room boundary faces and the room ceiling, thus having it belatedly absorbed by the listener area (cf. large concert hall in the Neues Gewandhaus Leipzig). This way it is first of all the early decay time, which is mainly responsible for the subjectively perceived reverberation duration, which is prolonged.
- **Electronic solution:** Influencing reverberation time and spaciousness is quite possible by electronic means, if the physical and auditory-psychological limitations are observed. Viable solutions are described in detail in Section 7.4.2.

In general variable-acoustics is steadily losing ground because of its high costs and low effect in comparison with the use of correctly designed sound systems.

7.4.2 Electronic Architecture

Establishing good audibility in rooms, indoors as well as in the open air, has been and remains the object of room acoustics. This is the reason why room acoustics is called architectural acoustics in some countries.

The architectural measures have far-reaching limitations. These shortcomings are:

- The sound source in question has only a limited sound power rate.
- Changes of room acoustics may make huge changes in the architectural design and thus cannot always be optimally applied.
- The measures regarding room acoustics may make a considerable amount of constructional changes and these can only be done optimally for one intended purpose of the room.
- The constructional change, despite its high costs, results in only a very limited effect.

Because of these reasons sound systems are increasingly being used to influence specific room acoustic properties, thus improving audibility. This holds true regarding an improvement of intelligibility as well as of spaciousness. So one can speak of a good acoustic design if one cannot distinguish, when listening to an event, whether the sound quality is caused only by the original source or by using an electroacoustic installation.

Another task of sound installation techniques consists of electronically modified signals that remain uninfluenced by specific properties of the listener room. It is necessary to suppress, as far as possible, the acoustic properties of the respective listener room by using directed loudspeaker systems. It is also possible to create a dry acoustic atmosphere by using suitable supplementary room-acoustic measures.

Reverberation (the reverberation time of a room) cannot be reduced by means of sound systems. At the typical listener seat the level of the direct sound is of great significance. Also short-time reflections, enhancing intelligibility of speech and clarity of music, can be provided by means of sound reinforcement.

The following sound-field components can be manipulated or generated:

- Direct sound.
- Initial reflections with direct-sound effect.
- Reverberant initial reflections.
- Reverberation.

For this reason electronic techniques were developed that opened up the possibility of increasing the direct or reverberation time and energy in the hall—i.e., directly influencing the acoustic room properties.

Such a method for changing the room-acoustic properties of rooms is now called the application of electronic architecture.

7.4.2.1 Use of Sound Delay Systems for Enhancing Spaciousness

These procedures act in particular on the sound energy of the initial reflections affecting the reverberant sound.

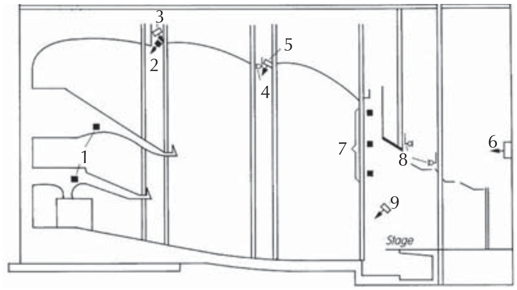
7.4.2.1.1 Ambiophony

This procedure, which is already obsolete, makes use of delaying devices reproducing not only the discrete initial reflections; but also the reverberation tail. The reflection sequences have herewith to be chosen in such a way that no comb-filter effects, such as flutter echoes, will be produced with impulsive music motifs. The functioning of a simple ambiophonic system can be described as follows: to the direct sound emanating directly from the original source and directly irradiated into the room, there are admixed delayed signals produced by an adequate sound delaying system (in the initial stages this was just a magnetic sound recording system) which are then irradiated like reflections arriving with corresponding delay from the walls or the ceiling. This requires additional loudspeakers appropriately distributed in the room for irradiating the delayed sound as diffusely as possible. For further delaying the sound it is possible to arrange an additional feedback from the last output of the delay chain to the input. A system of this kind was first suggested by Kleis[51] and was installed realized in several large halls.[52,53]

7.4.2.1.2 ERES (Electronic Reflected Energy System)

This procedure was suggested by Jaffe and is based on a simulation of early reflections used for producing so-called reverberant-sound-efficient initial reflections, Fig. 7-56.[54]

Thanks to the arrangement of the loudspeakers in the walls of the stage-near hall area and to the variability range available for delay, filtering and level regulation of the signals supplied to them, adapted lateral reflections can be irradiated. The spatial impression can thus be amply influenced by simulating an acoustically wider portal by means of a longer reverberation time or a narrower portal by using a shorter reverberation time.



1. One of the 14 pairs of the AR (assisted resonance)/ ERES loudspeakers under the balcony.
2. One of the 90 AR loudspeakers.
3. One of the four ERES loudspeakers in the third ceiling offset.
4. One of the 90 AR microphones.
5. One of the four ERES loudspeakers in the second ceiling offset.
6. ERES stage-tower loudspeaker.
7. Three of the six AR proscenium loudspeakers.
8. ERES microphones.
9. One of the two ERES proscenium loudspeakers.

Figure 7-56. ERES/AR system in the Sivia Hall in the Eugene Performing Arts Center, Eugene, Oregon.

This gives the capability of:

- Adaptation to acoustical requirements.
- Simulation of different hall sizes.
- Optimization of definition and clarity.

Jaffe and collaborators speak of electronic architecture. It is certainly true that this selective play-in of reflections does simulate room-acoustical properties the room in question is devoid of, so as to compensate shortcomings in its room-acoustical structure. After installing the first system of this kind in the Eugene Performing Arts Center in Oregon,[55] Jaffe-Acoustics have installed further ones in a large number of halls in the United Statres, Canada and other countries.

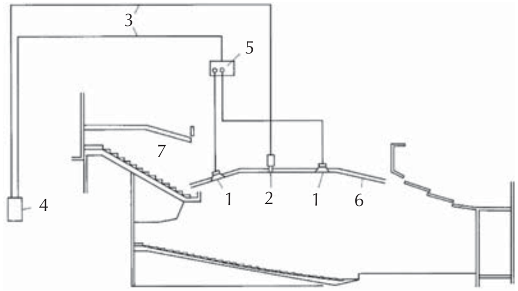
The electronic delay procedure in sound reinforcement systems has meanwhile become a general practice all over the world and is now the standard technique used for the play-in of delayed signals (e.g., for simulating late reflections). In this sense one may well say that electronic architecture is used in all instances where such reflections are used on purpose or unintentionally.

7.4.2.2 Travel-Time-Based Reverberation-Time Enhancing Systems

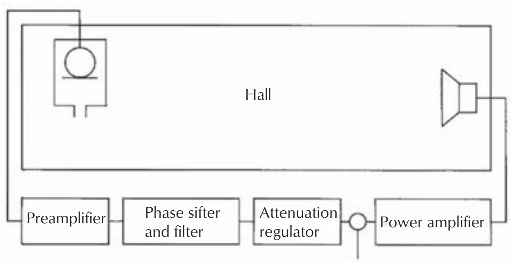
This procedure is mainly used for enhancing the late reverberant sound energy combined with an enhancement of the reverberation time.

7.4.2.2.1 Assisted Resonance

For optimizing the reverberation time in the Royal Festival Hall built in London in 1951, Parkin and Morgan[56,57] suggested a procedure permitting an enhancement of the reverberation time especially for low frequencies, Fig. 7-57.



A. Principal layout of a channel arrangement in a hall.



B. Components of an AR-Channel (Microphone in resonance chamber).

1. 60 loudspeaker boxes each in the ceiling area and in the upper wall region.
2. 120 microphones in Helmholtz resonator boxes.
3. 120 microphone and loudspeaker cables.
4. Remote control, phase shifter, amplifier for the 120 channels.
5. Distributor for loudspeaker boxes.
6. Movable ceiling for varying the volume of the room.
7. Balcony.

Figure 7-57. Assisted resonance system.

Parkin and Morgan proceeded on the assumption that in any room there exist a multitude of eigenfrequencies which give rise to standing waves with nodes and antinodes decaying by an e-function according to the absorption characteristics of the surface involved. This decay process is characteristic for the reverberation time of the room at the corresponding frequency. Any standing wave has its specific orientation in space and a microphone is installed at the point where a sound pressure maximum (vibration antinode) occurs for a given frequency. The energy picked up from the microphone is supplied via an amplifier to a loudspeaker installed at a distant antinode of the same standing wave, so that the energy lost by absorption is compensated. The energy at that frequency can thus be sustained for a longer period (assisted resonance). By enhancing the amplification it is possible to considerably prolong the reverberation time for this frequency (until feedback sets in). Thanks to the spatial distribution of the irradiating loudspeakers this applies accordingly to the spatial impression.

These considerations hold true for all eigenfrequencies of the room. The arrangement of the microphones and loudspeakers at the locations determined by the antinodes of the individual eigenfrequencies may, however, be difficult. The microphones and loudspeakers are therefore installed at less critical points and driven via phase shifters. In the transmission path there are additionally inserted filters (Helmholtz resonators, bandwidth approximately 3 Hz) which allow the transmission channel to respond only at the corresponding eigenfrequency. Care should be taken that the irradiating loudspeakers are not arranged at a greater distance from the performance area than their corresponding microphones, since the first arrival of the reverberant signal may produce mislocalization of the source.

This procedure, which has meanwhile become obsolete, was installed in a large number of halls. In spite of its high technical expenditure and the fact that the system required can be used only for the assisted resonance, it was for a long period one of the most reliable solutions for enhancing the reverberation time without affecting the sound, particularly at low frequencies.

7.4.2.2.2 Multi-Channel-Reverberation, MCR

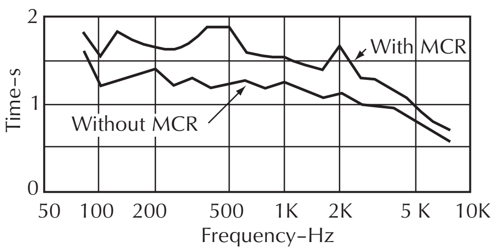
Using a large number of broadband transmission channels whose amplification per channel is so low that no timbre change due to commencing feedback can occur, was suggested first by Franssen.[58] While the individual channel remaining below the positive feedback threshold provides only little amplification, the multitude of channels is able to produce an energy density capable of notably enhancing the spatial impression and the reverberation time.

The enhancement of the reverberation time is determined by

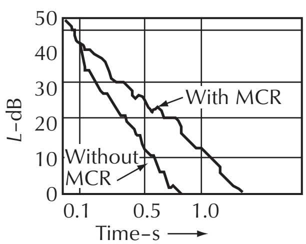
$$\frac{T_m}{T_o} = 1 + \frac{n}{50} \tag{7-73}$$

If the reverberation time is, for instance, to be doubled (which means doubling the energy density), there are $n = 50$ individual amplification chains required. Ohsmann[59] has investigated in an extensive paper the functional principle of these loudspeaker systems and has shown that the prognosticated results regarding enhancement of the reverberation time cannot be achieved in practice. He also quotes the fact that Franssen "did not sufficiently consider the cross couplings between the channels" as a possible reason for the deviation from theory.[1]

A system technologically based on this procedure is offered by Philips under the name of Multi-Channel Amplification of Reverberation System (MCR). It serves for enhancing reverberation and spaciousness.[60] According to manufacturer's specifications a prolongation of the average reverberation time from approximately 1.2 to 1.7 s is achieved for ninty channels. Even longer reverberation enhancements are said to be possible. There exist numerous implementations in medium-sized and large halls (the first was in the POC Theater in Eindhoven, Fig. 7-58).



A. Frequency response of the reverberation time with and without MCR.



B. Reverberation behavier at 400 Hz.

Technical data of the system: hall 3100 m^3, stage 900 m^3.
90 channels (preamplifier, filter, power amplifier).
90 microphones at the ceiling.
110 loudspeakers in the side walls, in the ceiling and under the balcony.
Remote control of the reverberation in 10 steps.

Figure 7-58. MCR system in the POC Theater in Eindhoven.

7.4.2.3 Modern Procedures for Enhancing Reverberation and Spaciousness

7.4.2.3.1 Acoustic Control System (ACS)

This procedure was developed by Berkhout and de Vries at the University of Delft.[61] Based on a wave-field synthesis approach (WFS) the authors speak of a holographic attempt for enhancing the reverberation in rooms. In essence, it is really more than the result of a mathematical-physical convolution of signals captured by means of microphones in an in-line arrangement (as is the case with WFS). The room characteristics are predetermined by a processor, which produces, in the end, a new room characteristic with a new reverberation time behavior, Fig 7-59.

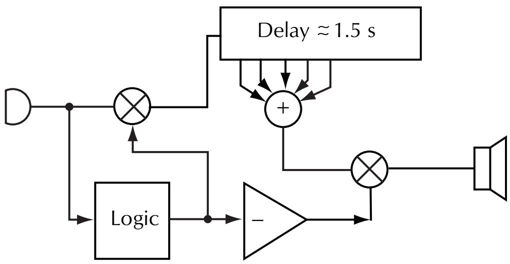


Figure 7-59. Principle of the Reverberation on Demand System (RODS).

The upper block diagram shows the principle of the ACS circuit for a loudspeaker-microphone pair. One sees that the acoustician formulates the characteristics of a desired room—e.g., in a computer model—transfers these characteristics by means of suitable parameters to a reflection simulator and convolutes these reflection patterns with the real acoustical characteristics of a hall. Fig. 7-60 shows the complete block diagram of an ACS system.

Unlike other systems, the ACS does not use any feedback loops—thus timbre changes owing to self-excitation phenomena should not be expected. The system is functioning in a series of halls in the Netherlands, Great Britain and in the United States.

7.4.2.3.2 Reverberation on Demand System, RODS

With this system a microphone signal is picked near the source and passed through a logical switching gate before reaching a delay line with branched members. This output is equipped with a similar gate. A logical control circuit opens the input gate and closes the output gate when the microphone signal is constant or rising.

Vice versa, it closes the input gate and opens the output gate when the microphone signal is falling, Fig. 7-60.[62]

An acoustical feedback is thus avoided, but this system fails to enhance the lateral energy with continuous music, which makes it unsuitable for music performances. It is no longer used.

7.4.2.3.3 LARES

The LARES system by the Lexicon Company uses modules of the standardized Room Processor 480L which, when fed by special software, simulates the desired decay curves, Fig. 7-61. A large number of loudspeakers are required in the wall and ceiling areas. The input signals are picked up by just a few microphones in an area near the source.[63,64] On account of the time-variant signal processing (a large quantity of independent time-variant reverberation devices), the adjustment of reverberation times is not exactly repeatable. Common computer-controlled measuring software (based, e.g., on MLS) is thus unable to measure decay curves. Apart from the ASC system, LARES installations are very widespread in Europe and the United States. Well known are the systems installed in the Staatsoper Berlin, the Staatsschauspiel Dresden, and the Seebühne (floating stage) in Mörbisch/Austria.

7.4.2.3.4 System for Improved Acoustic Performance (SIAP)

The basic principle of SIAP consists in picking up the sound produced by the source by means of a relatively small number of microphones, processing it appropriately (by means of processors which convolute, that is overlay electronically the room-acoustical parameters of a room with target parameters) and then feeding it back into the hall by an adequate number of loudspeakers, Fig. 7-62. The aim is to produce desired natural acoustical properties by electronic means. For obtaining spatial diffusivity a large number of different output channels are required. Moreover, the maximally attainable acoustic amplification is dependent on the number of uncorrelated paths. Compared with a simple feedback channel, a system with 4 inputs and 25 outputs is able to produce a 20 dB higher amplification before feedback sets in. This holds true, of course, only under the assumption that each and every input and output path is sufficiently decoupled from the other input/output paths. Each listener seat receives sound from several loudspeakers, each of which irradiates a signal somewhat differently processed than any of the others (!).[65]

7.4.2.3.5 Active Field Control, AFC

The AFC system by Yamaha[66] makes active use of acoustic feedback for enhancing the sound energy density and thereby also the reverberation time. When using the acoustic feedback it is, however, important to avoid timbre changes and to insure the stability of the system. To this effect one uses a specific switching circuit, the so-called Time Varying Control (TVC) which consists of two components:

- Electronic Microphone Rotator (EMR).
- Fluctuating FIR (fluc-FIR).

The EMR unit scans the boundary microphones in cycles while the FIR filters impede feedback.

For enhancing the reverberation, the microphones are arranged in the diffuse sound field and still in the close-range source area (gray dots in Fig. 7-63 on the right). The loudspeakers are located in the wall and ceiling areas of the room. For enhancing the early reflections there are four to eight microphones arranged in the ceiling area near the sources. The signals picked up by these are passed through FIR filters and reproduced as

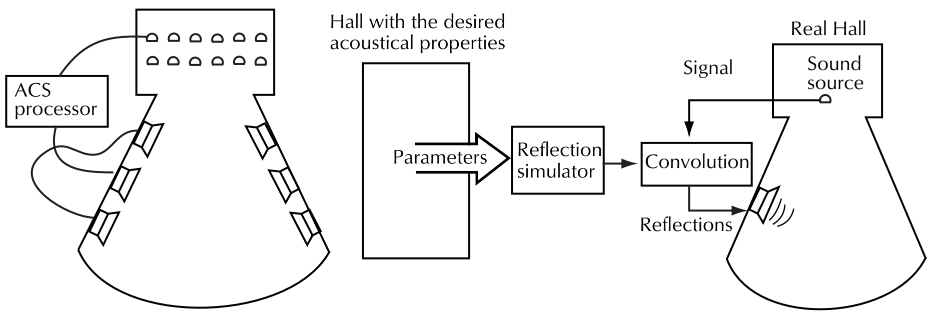


Figure 7-60. Basic block diagram of the Acoustic Control System (ACS) illustrated for a loudspeaker–microphone pair.

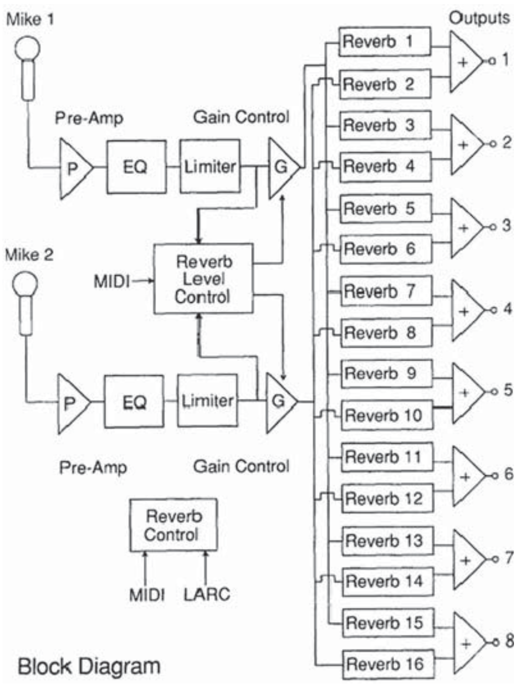


Figure 7-61. LARES block diagram.

lateral reflections by loudspeakers located in the wall and ceiling areas of the room. The loudspeakers are arranged in such a way that they cannot be located, since their signals are to be perceived as natural reflections.

Furthermore the AFC system allows signals to be picked up in the central region of the audience area and the reproduction of them via ceiling loudspeakers in the area below the balcony for the sake of enhancing spaciousness.

7.4.2.3.6 Virtual Room Acoustic System Constellation™

Constellation™ by Meyer Sound Inc. is a multichannel regenerative system for reverberation enhancement. Its development is based on ideas already considered in the sixties of last century by Franssen[58] when developing the above-mentioned MCR procedure.[67] The principle is already rather old and was described by users.[68] The biggest difference is that today Constellation™ uses, instead of the second reverberation room, an electronic reverberation processor which is more easily adaptable.

But modern electronic elements and DSPs have made it possible to design circuits which widely exclude timbre changes. This is achieved by coupling a primary room A (the theater or concert hall) with a secondary room B (the reverberant room processor). Simultaneously the number of reproduction channels is reduced along with the timbre change of sound events. An enhancement of the early reflections is obtained as well, cf. Fig. 7-64.

Contrary to other systems, Constellation™ uses a comparable number of microphones and loudspeakers in a room. To this effect the microphones are located in the reverberant or diffuse field of all sound sources within the room and connected via preamplifiers to a digital processor. Then the outputs of the processor are connected to power amplifiers and loudspeakers for reproduction of the signal.

With the Constellation™ system there is a multitude of small loudspeakers L_1 to L_N (40 to 50) distributed in

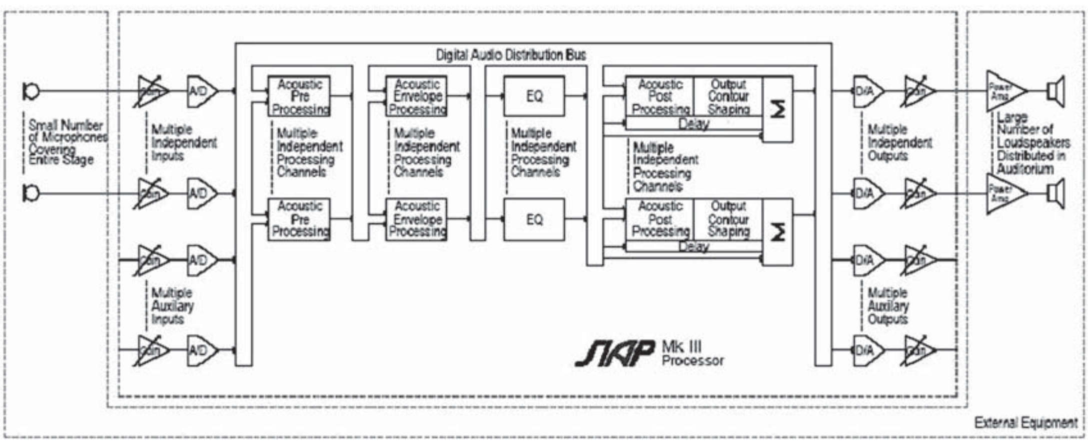


Figure 7-62. Schematic circuit diagram of SIAP.

the room, which, of course, may also be used for panorama and effect purposes. Ten to fifteen strategically located and visually inconspicuous microphones m_1 to m_N pick up the sound and transmit it to the effect processor $X(\omega)$ where the desired and adjustable reverberation takes place. The output signals thus obtained are fed back into the room. The advantage of this solution lies in the precise tuning of the reverberation processor enabling well-reproducible and thus also measurable results.

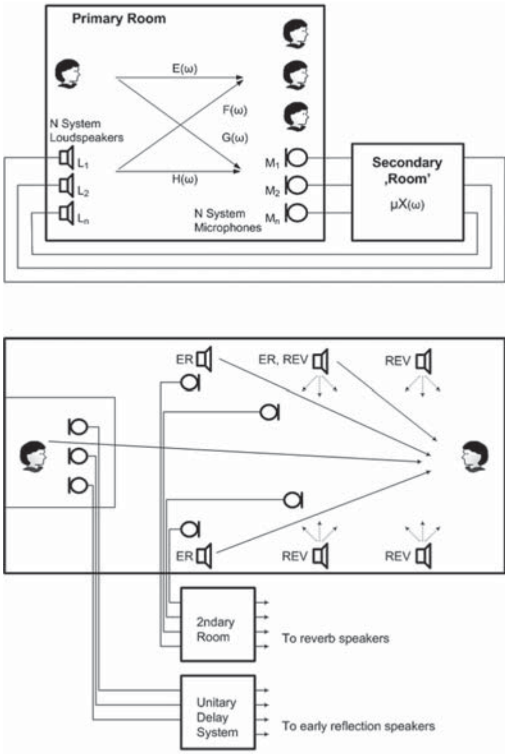


Figure 7-64. Principle of the Virtual Room Acoustic System, Constellation™.

7.4.2.3.7 CARMEN®

The underlying principle is that of an active wall whose reflection properties can be electronically modified.[69] The system was called CARMEN® which is the French abbreviation of Active Reverberation Regulation through the Natural Effect of Virtual Walls. On the wall there are arranged so-called active cells forming a new virtual wall. The cells consist of a microphone, an electronic filter device, and a loudspeaker by which the picked-up signal is irradiated, Fig. 7-65. The microphones are typically located at 1 m distance from the loudspeaker of the respective cell, i.e. at approximately ⅕ of the diffuse-field distance in typical halls. Therefore it might also be called a locally active system.

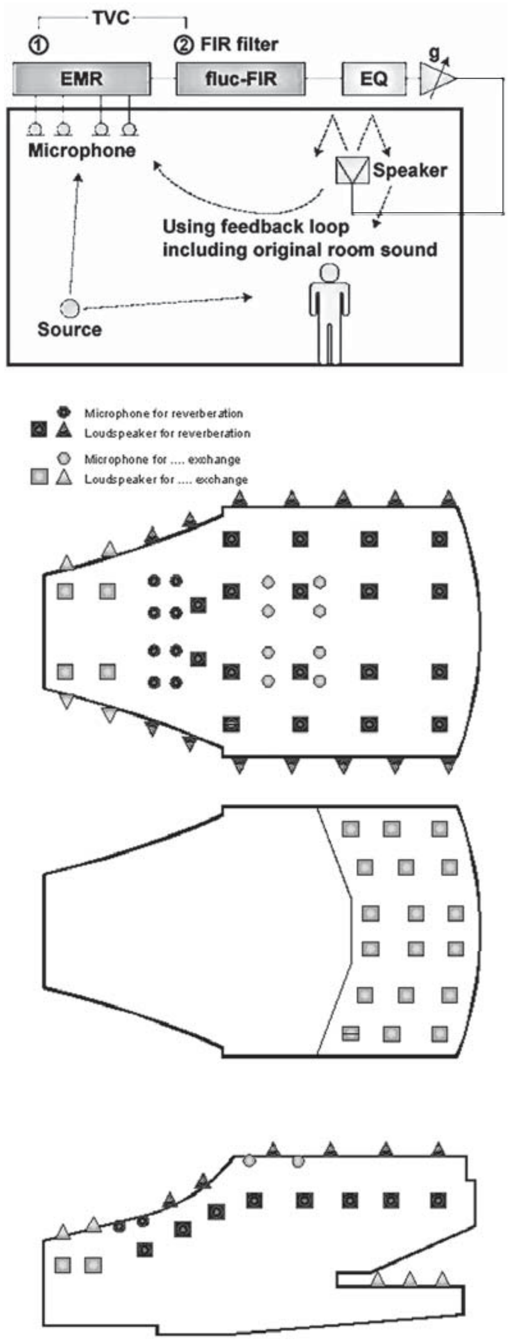


Figure 7-63. Active Field Control System (AFC) by Yamaha, Japan.

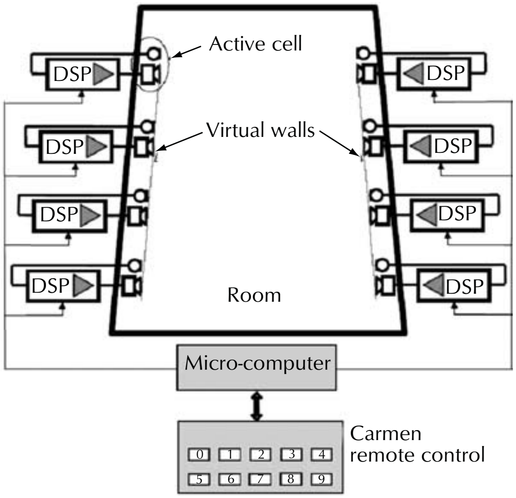


Figure 7-65. Principle of the Active Reverberation Regulation System, CARMEN®.

Every cell produces a desired decay of the artificial reflections, provided one does not choose an excessive cell gain liable to provoke feedback. To avoid feedback an adequate microphone directivity characteristic as well as internal echo canceling algorithms are used. In addition it is possible to delay the microphone signal electronically, a feature which allows the cell to be virtually shifted and the room volume to be apparently enlarged.

Since 1998 CARMEN® has been installed and tested in more than ten halls used by important orchestras. It has proven to be particularly effective in theaters which are also used for orchestra performances. In these rooms it best improves the acoustics in the distant areas under the balconies. In the Mogador Theater in Paris acoustics were significantly improved by installing CARMEN® cells in the side walls and in the ceiling of the balcony.

By means of twenty four cells in a room with a reverberation time of 1.2 s at 500 Hz, it was possible to enhance this reverberation time to 2.1 s. Additionally there resulted various spatial effects like a broadening of the sound source or an improved envelopment with lateral reflections, features often required for big orchestras, but also soloists.

7.4.3 Conclusions and Outlook

The above presented comparison shows that a large number of procedures exist for enhancing reverberation and spaciousness, part of which continue to be used today. Thanks to ever-increasing quality of the electronic transmission devices, the prejudices still existing especially among musicians against the electronic architecture will diminish, so that it will be increasingly possible to adapt concert halls even to the acoustical conditions characteristic of different creative and historic periods. Utilization in so-called multipurpose halls will, of course, prevail. The aim will have been achieved when musicians and audience perceive acoustical conditions established by means of electronic architecture as normal and natural. Simplicity of varying settings or security against acoustical feedback and unrelated timbre change will then be decisive factors in the choice of an enhancement system. Modern computer simulation will assist in banning the potential feedback risk.

Costly architectural measures for realizing the variable acoustic will be more and more discarded, particularly in view of their limited effectiveness.

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