Proceedings of the Institute of Acoustics

LARGE ROOM SOUND SYSTEM DESIGN TECHNIQUES FOR IMPROVED GAIN BEFORE FEEDBACK FROM OPEN MICROPHONES

Craig Janssen

Acoustic Dimensions, Dallas, Texas, USA

1. INTRODUCTION

The last decade has produced a considerable upsurge in audience expectations for high quality production values for many presentation facilities. This increased demand for production and audio quality has impacted houses of worship, entertainment facilities, stadia, performing arts venues and others where sound systems are utilized in conjunction with multiple open microphones. A typical West End or Broadway theatrical production for example uses more than 20 wireless microphones, often all active at the same time.

Many sound systems have been designed and implemented which meet the traditional expectations for good sound coverage consistency, loudness, intelligibility and perceived tonal quality. However these systems commonly present limited capability for achieving sufficient gain before feedback loudness margins with multiple or single open microphones.

The intent of this paper is to present various sound system design techniques which can improve gain before feedback margins. It is not expected that this paper will explore previously undeveloped techniques, but rather that a foundation can be laid of practical and real world design solutions. The techniques described have been developed to provide primarily for improved performance in large rooms (over 500 seats).

2. DESIGN ISSUES

The possibility of regenerative feedback between an open (active) microphone and a loudspeaker system can only exist if the microphone "hears" the loudspeaker system and re-amplifies this signal with sufficient level to support the regenerative feedback.

A plethora of physical conditions dictate the onset of feedback, and many solutions exist to maximize gain before feedback including the physical systems design, microphone capabilities and signal processing techniques. In recent times, a variety of signal processing devices have found their way onto the market which purport to reduce gain before feedback problems. Many of these adaptive filtering devices have merit, but it is the opinion of the author that the most significant and stable improvements in gain before feedback are achieved by attention to detail regarding loudspeaker system designs and loudspeaker/room acoustics interaction. Signal processing and microphone techniques and usage will not be covered in this paper.

The following general issues are considered to be the primary factors to be addressed with respect to optimizing gain before feedback:

2.1. A general reduction of the level of direct sound from the loudspeaker system to the staging area must be achieved.

This goal can only be achieved by increasing the directivity of the loudspeaker system which directs sound to the required seating areas, but not to the stage. While many commercially available loudspeaker products provide for some directional control of sound at higher frequencies, most commercially available products do not provide similar directivity at mid to low frequencies (typically below 800 Hz).

It is the authors experience that broadband direct sound level reductions on stage (compared to the main seating area) of 4 to 8dB can be achieved and will provide very good gain before feedback performance. Direct field level reductions higher than this may not provide improvements in gain before feedback unless the acoustical response of the room is completely non diffuse (ie. In a very large room). The primary danger to this design approach is that in a large room, the loudest signals on stage may be the specular reflections generated in the room by the sound system. These signal returns typically arrive back on stage well outside of the ear integration time and thus can be perceived as strong echoes due to the lack of early arriving signal energy from the main speaker systems.

2.2. The sound system must exhibit flat frequency response of the direct sound throughout all areas of the stage.

The reduction of sound levels onto the stage areas must be broadband (ie. Equal reduction in low, mid and high frequencies) in nature and consistent in frequency response throughout the area where microphones are to be used.

All loudspeaker systems interact significantly when placed in close proximity to each other. When the off-axis lobes are poorly controlled, it is largely an exercise in futility to effectively equalize the microphones for stable gain before feedback. These lobes result in narrow band peaks and dips in frequency response with divergent frequency response at differing microphone positions. These narrow band peaks and dips exhibit attendant sharp changes in phase response. Studies by others [1] have indicated that these rapid changes in phase response significantly compromise gain before feedback.

Most systems designers use loudspeaker products which individually exhibit constant directivity over a broad frequency range. However, studies published demonstrate the negative results of physical misalignment of clusters and the resulting narrow band off-axis projection of lobes when even these devices are used. Practitioners such as Carey, Alison and Thrasher have developed effective techniques [2] for arraying mid and high frequency horns for reduced problematic interaction. However, limited work has been done for practical and affordable solutions to control lobes and directivity of clusters and cabinets at lower frequencies (100Hz to 400Hz).

2.3. The reverberant sound level in the room (as excited by the sound system) must be kept as low as possible for good gain before feedback performance.

Cluster design techniques now exist which allow the level of the direct signal from the cluster to the microphone to be reduced substantially. While this in of itself will result in improved gain before feedback, one must also consider the loudness of the reverberant field in the space as generated by the sound system. Calculation of reverberant levels in most large rooms is very difficult due to the statistically non-diffuse nature of the spaces and thus it is difficult to predict with confidence the reverberant levels on stage. However specular reflection levels can more easily be accurately predicted. It is certainly possible that the microphone on stage will "see" a reverberant or specular field which is louder than the direct field sound from the cluster.

For the reasons mentioned above, it is desirable to implement loudspeaker system designs which do not excite the reverberant field or generate high level specular reflections. A sound system which projects sound onto the walls, ceiling and any surfaces other than the seating area (which is largely absorptive) will generate a higher reverberant level than a system designed to project sound largely onto the seating areas.

Fortunately the same techniques which result in minimal projection of sound onto the stage, will also tend to minimize projection of sound onto ceiling planes. The astute designer however will also ensure that the sound system does not generate high level specular reflections back to the stage.

3. LOUDSPEAKER SYSTEMS DESIGN AND LAYOUT

With respect to designing a speaker system which supports the design goals described above, the loudspeaker components must exhibit flat power response (ie. Flat frequency response both on and off axis) both individually and in arrays. Additionally the designer must ensure that the components are arrayed in such a way to result in minimal off axis destructive lobing. The designer must have knowledge of how to combine components together in such a way as to use the component interaction to result in broadband nulls in the direction of the stage and the ceiling while at the same time not generating nulls in the direction of the seating plane.

The appropriate design of a loudspeaker system is dependent on many elements including required loudness and frequency response levels, available budget, architecture of the space, production demands, etc. This paper is focused simply on sound system design techniques for improved gain before feedback, however it is acknowledged that real world conditions must also be accommodated. The following loudspeaker system design approaches are investigated with respect to their impact on gain before feedback.

3.1 Central Loudspeaker Cluster System

The center cluster design approach has many merits with respect to high performance and (potentially) cost effective implementation in a large space, providing that the structure can support the mass. However with respect to gain before feedback, this approach typically performs quite poorly. There are three primary reasons for this difficulty.

a. The close spacing of multiple components magnifies greatly the potential for problematic interaction and resultant non-linear off axis frequency response. The type of design requires the use of quite large speaker cabinets which are assembled together in a way which reduces energy projection towards the stage and the ceiling. Effective design of such a system requires a high level of design skill and the use of relatively costly loudspeaker components.

b. A central cluster, as a design approach, results in the longest aggregate projection distance to the seating areas. Thus for a given sound pressure level at the furthermost seating areas, the center cluster must produce considerably more energy in the near field than other design approaches. This tends to result in a higher level of reverberant field excitation and a higher potential loudness level on the stage (unless excellent vertical pattern control is achieved).

c. The sound projection from a center cluster must provide coverage of 180 degrees or more in the horizontal plane in order to provide coverage to the front most seating areas. The side firing loudspeakers which provide sound coverage to the front side seats will also project considerable energy onto the side stage areas, thus reducing gain before feedback from any microphone operated from these areas.

3.2. Central Loudspeaker Cluster System with Spaced Left and Right Speakers

This design approach is simply a design variation of the central cluster. Rather than attempting to provide sound coverage to the front side seating areas from the center cluster, thus requiring sound to be fired across the stage, this design spreads out a pair of short throw speakers to the left and the right of the center cluster. This provides improved gain before feedback for microphones used down stage right and left, and additionally provides the benefit of not projecting excessive energy onto the side walls. The improvement in gain before feedback with this approach can be 1-3dB.

3.3. Central Loudspeaker Cluster System with Spaced Left, Right Speakers and Delay Ring

This design approach is a further design variation of the central cluster. A ring of speakers (with appropriate delayed feed) supplements the center cluster to provide sound coverage to the rear most seating areas. As the center cluster is not required to generate sound coverage to this distant area, the output power of the long throw speaker components can be reduced, thus further improving gain before feedback margins by up to 3dB over the example above. Note that this improvement in performance will be achieved regardless of the front speaker cluster design approach. Multiple rings of loudspeakers will provide limited improvement on this gain. An additional benefit to this design approach is the reduction in reverberant field excitation and specular reflections due to the reduced projection of energy onto the rear walls of the space and reduced total energy projection into the space.

3.4. Spread Cluster Design

The center cluster can be split into multiple discreet clusters spread out across the front of the stage. Typically 4-6 clusters will be used for this approach. With respect to gain before feedback, this approach can yield 3dB to 6dB improvement over a single central cluster. This due to the fact that the microphone(s) will receive the maximum direct field sound levels from only one cluster at a time (due to physical proximity). The summation of sound from more distant clusters will be reduced in level.

This design approach must be used with caution as system intelligibility can be severely compromised if the signals from the various clusters arrive at the listeners ears with similar sound pressure levels over a wide time spread.

3.5. Center, Left, Right Clusters with signal matrixing

A number of entertainment venues utilize center, left, right speaker systems to support theatrical and musical events. The basic principle of this design is that individual clusters will each provide sound coverage to most of the seating areas (often in conjunction with a ring of delayed speakers and stage lip speakers). These systems typically allow signals to be routed not only to each of the clusters separately but also allow differing levels to be set between the long throw and short throw components within each cluster. This design approach provides considerable gain before feedback benefit when multiple microphones are routed through differing speaker systems. This can provide more than 6dB improvement in gain before feedback as the number of open microphones routed to each cluster is reduced and cross matrixing can route individual microphones though more distant loudspeaker elements.

This design approach must also be used with caution as system intelligibility can be severely compromised if the signals from the various clusters arrive at the listeners ears with similar sound pressure levels over a wide time spread.

4. CASE STUDIES OF TWO LARGE ROOM SOUND SYSTEMS

Tests were performed in two venues to ascertain the deviation of broadband sound levels between the mixing console location, the front row of seats and the center of the stage. Presumably the venue which projects the least amount of energy onto the stage will achieve the highest gain before feedback margins.

The measurements shown in Fig 1-4 were made by injecting Pink noise at constant level into each sound system and measuring the loudness and frequency responses at various seating areas as indicated. An omni directional Josephsen microphone was used and the information was captured by a Techron TEF 20 using RTA software. In all cases the measurements shown indicate the difference in frequency response between measurements at the mixing console (presumed to be a representative listening position) and the test position.

4.1. Split Cluster System in a 4,000 seat Theatre

This system implements four identical clusters spread across the front of the stage each spaced approximately 5 meters apart. Each cluster has been designed to provide broad band pattern control in both the vertical and horizontal planes. . The system is four way with sub-bass, low, high and mid range components. The low frequency cabinets incorporate a line array with custom signal processing on dual 12" direct radiating drivers and dual 15" direct radiating drivers. The mid range comprises of dual 10" drivers mounted on a horn, and the high frequencies are 2" compression drivers mounted on medium format horns. Sub-bass is provided by dual 18" direct radiator cabinets The system implements a delay ring of speakers to cover the rear of the room and stage lip speakers which provide supportive sound coverage to the very front seating areas.

Fig 1 indicates the frequency response deviation between the mixing position and the front row of seats. It should be noted that at almost all frequencies, the loudness at these seats are lower in level than at the mixing console position. In reality the stage lip speakers are used to increase this broadband level to be consistent with the mixing console location.

Fig 2 indicates the frequency response deviation between the mixing location and the front center of the stage. It should be noted that at almost all frequencies, the loudness at this position is lower in level than at the mixing console position by an average of 3-4 dB.

This system is known to exhibit excellent gain before feedback characteristics.

4.2. Single Center Cluster System in a 5,000 seat Church

This system implements a single center cluster above the front of the stage. The system is four way with discreet sub-bass, low, high and mid range components. The low frequency cabinets incorporate dual 12" direct radiating drivers. The mid range comprises of horn loaded mid range compression drivers, and the high frequencies are 2" compression drivers mounted on small format horns. Sub-bass is provided by dual 18" direct radiator cabinets. The system does not implement either a delay ring of speakers or stage lip speakers.

Fig 3 indicates the frequency response deviation between the mixing position and the front row of seats. It should be noted that at almost all frequencies, the loudness at these seats are higher in level than at the mixing console position. It is interesting to note that the crossover points and the changing directivity of the devices can be observed.

Fig 4 indicates the frequency response deviation between the mixing location and the front center of the stage. It should be noted that at almost all low and mid frequencies, the loudness at this position is higher in level than at the mixing console position. This indicates that the low/mid frequencies of the microphone will have to be reduced in level considerably in order to provide stable gain before feedback.

As might be expected, this design provides rather unnatural and thin sounding support of speech.

5. REFERENCES

[1] Sound System Engineering, Second Edition, Don Davis, Carolyn Davis

[2] Horns (Their function, measurement, arraying and alignment), supplement to Syn-Aud-Con newsletter Volume 20 number 2.

DESIGN TECHNIQUES FOR IMPROVED GAIN BEFORE FEEDBACK

Frequency response deviation between house mix console location (30m from cluster) and front row (12m from cluster)

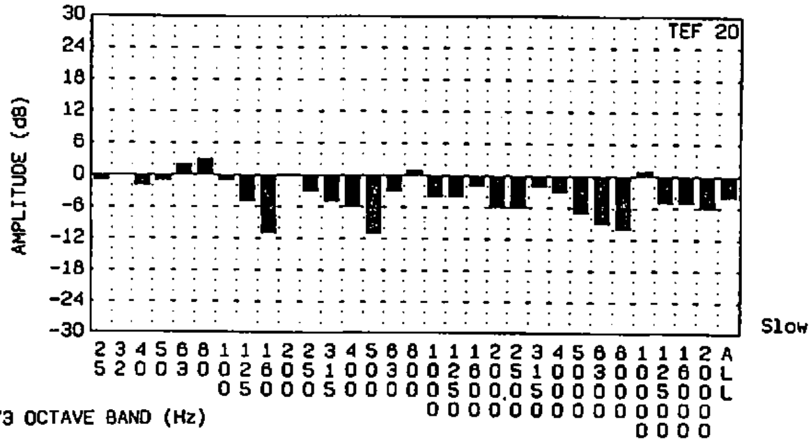

Fig #1

Frequency response deviation between house mix console (30m from cluster) and center stage (10m from cluster)

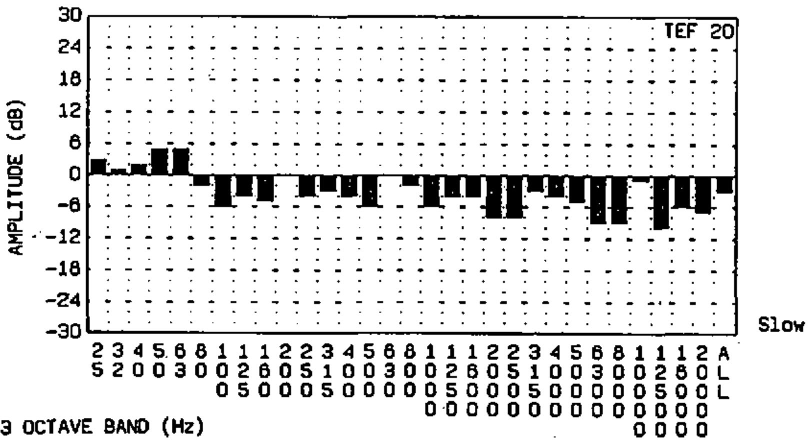

Fig #2

Frequency response deviations measured in a 4,000 seat theatre which implements an alternating left/right cluster (4 in total) system designed for broadband vertical pattern control. Note that stage lip speaker system is turned off.

DESIGN TECHNIQUES FOR IMPROVED GAIN BEFORE FEEDBACK

Frequency response deviation between house mix console location (30m from cluster) and front row (14m from cluster)

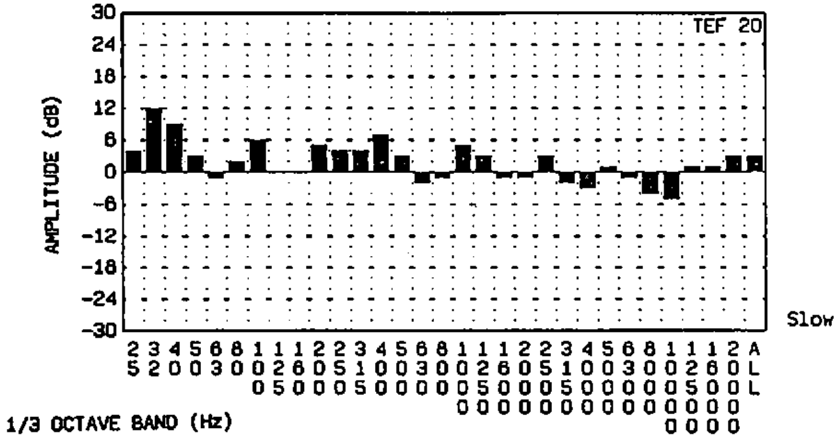

Fig #3

Frequency response deviation between house mix console (30m from cluster) and center stage (12m from cluster)

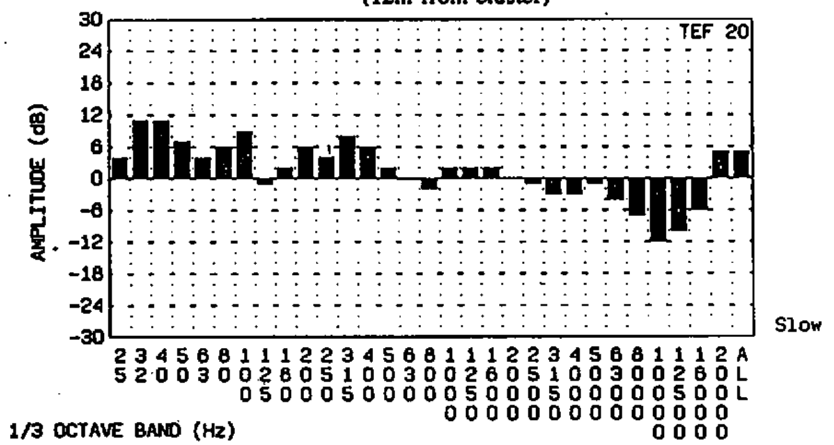

Fig #4

Frequency response deviations measured in a 5,000 seat church which implements a single centre cluster system based on traditional design techniques.