ALTEC ENGINEERING NOTES

TECHNICAL LETTER NO. 229

CONTROL OF FEEDBACK IN SOUND SYSTEMS WITH THE WHITE MODEL 3900 NARROW-BAND FILTER SET

Introduction

Every room has its own set of normal modes of acoustic resonance which may be predicted by theory. When a reverberant room is driven by a loudspeaker, the excitation of these normal modes depends on the response of the loudspeaker, its physical location in the room, and so on. Experiments have shown that the combined performance of the total electroacoustic system, consisting of a sound-reinforcement system with an open microphone plus the room itself, becomes self-oscillating at a series of these normal modes.

By inserting properly designed narrow-band filters in the link circuit of the sound system amplifier, each mode, one by one, can be rendered free from oscillation. The depth of the notch required to stop self-oscillation in the system varies from mode to mode; normally it lies somewhere between 3 and 10 dB. The process may be continued indefinitely, but a small number of filters will usually effect adequate improvement in system gain and quality.

In this usage, *narrow-band* applies to notch filters having a bandwidth of 10 Hz at the lower end of the control range and up to about 2% in the higher end of the control range.

Essentially, every room also has one or more *room-ring modes.* These are modes of the room that can be readily rung by the singing voice without a sound system. Of course they can also be rung by an audio oscillator driving a loudspeaker. These modes are related to the *bull notes* of the organ builder.

Increasing the sound-system gain may, or may not, feed back at *room-ring* frequencies. In either case, the unfavorable *room-ring mode* may be readily controlled by proper narrow-band filtering. When this filtering has been done, program material into the microphone results in improved quality of sound perceived by the audience than the sound obtained with the room persistently rung by program pulses.

When, on occasion, the frequency of a *room-ring mode* happens to coincide with a preferred frequency of oscillation in the total electroacoustic system of room and sound equipment, feedback becomes a paralyzing phenomenon. Insertion of the proper narrow-band filter in the amplifier link (see block diagram) will correct the difficulty and produce a vastly improved total result.

In excessively reverberant churches, for example, the *room-ring modes* and a limited number of self-oscillation modes of the total system appear to be the main problems to overcome in making speech easily understandable in the pews. Even with the amplifier gain set well below the feedback threshold, the response of the total system at the preferred modes is unduly high and is disturbing to speech. In most cases, troublesome *room-ring* or *feedback* modes are few in number.

In some cases, a narrow-band filter on each of several modes, occurring in succession and at random frequencies, may not appreciably improve system gain before feedback, or speech intelligibility. Eventually, however, a major mode will be uncovered, which, when brought into proper balance by its filter, will significantly improve system gain or quality.

When enough of these modes have been controlled with narrow-band filters, the speech in the reverberant room usually shows a marked and sometimes startling improvement in intelligibility, while the system retains the full-bass response characteristic of wide-range sound systems. The sound usually seems to be warm and full, and speech is clearly understood.

As the location of the sound-system microphone is varied, essentially the same frequencies of oscillation appear; however, the order of appearance of these modes tends to vary with microphone position, at least in the early stages of the equalizing procedure. The entire list of such modes seems to be a property of the total electroacoustic situation. As the number of narrow-band sections is increased, the feedback threshold is gradually raised above the normal operating range. In many rooms, the performance becomes nearly independent of microphone position. For equalized systems in such rooms, loudspeaker location is not critical. It may be behind, in front of, or beside the microphone as long as the microphone and loudspeaker are not in close proximity. The feedback threshold in distributed sound systems tends to become relatively independent of the number of distributed loudspeakers in operation at one time during the late stages of the equalizing procedure.

System Gain Before Feedback

System gain before feedback is defined as the difference in the sound pressure level (SPL) measured at the most distant seat in the room with the sound system turned off and then measured with the sound system turned on, but with the sound-system gain set just below the feedback threshold. The noise source should be located on the microphone axis at the same distance during both measurements. *System gain before feedback* may be measured as a function of frequency, or in any arbitrary manner desired. In many existing rooms, this difference in SPL, with the sound system in its original unequalized state, tends to lie between 2 and 8 dB.

When both house-curve tailoring and narrow-band equalizing procedures have been carried out satisfactorily, the *system gain before feedback* may be made considerably higher.

If this equalizing procedure is to succeed, the sound-system equipment must be of excellent quality, properly designed, and properly installed. Loudspeakers not fully capable, or in the wrong place, will not produce the desired listening results; nor will unstable and variable amplifiers. A good installation of high-quality equipment that has been properly equalized with broad-band equalizers is ready for improvement by narrow-band equalization.

Model 3900 Narrow-Band Filter Set

The preferred method of narrow-band equalization under the Boner patented process uses specially tapped toroidal inductors, manufactured under Boner patents. These inductors, tuned on the job, provide optimum results for major equalization problems. However, a pretuned filter set consisting of 168 filters has been designed to fill the need for filters that may be quickly and accurately installed. This is the Model 3900 Narrow-Band Filter Set. It meets the following specifications.

1. The filters are tuned LC circuits of controlled Q, packaged in octal plug-in cans for rapid installation in a prewired chassis.

2. The set of 168 filters is rationally spaced for full coverage from 100 Hz through 1200 Hz.

3. The spacing varies from 5 Hz at the low end up to 13 Hz at the high end.

4. Special sockets in the manifold provide two plug-in positions for an insertion loss in the control band of either 6 dB or 9 dB.

Preferred Test Procedure

Before application of the Model 3900 set, verify that the room response has been *contoured* by the use of either the Altec 9013 series of passive filters or the Altec 9860A Active Filter. The special test equipment required is a frequency counter, having a sensitivity of 100 mV, although a unit with less sensitivity may be used with somewhat less convenience. In the preferred test procedure, an audio oscillator is also required.

A special manifold is provided as a carrier for the Model 3900 set and must be used because of the special two-way sockets required. One of these manifolds must be wired into a 600-ohm link circuit. If a passive equalizer, working into 600-ohm loads is being used, the manifold may be wired in series with the equalizer as shown in the block diagram. No further terminations are needed.

If an active equalizer is used, a 600-ohm link must be established in the usual way by *building out* its input impedance to make it into a 600-ohm source. The 600-ohm load MUST be provided.

A resistor of 8 to 10 ohms, wired into the low side of the 600-ohm link, will facilitate the injection of a small sine wave signal as shown in the block diagram. For isolation, pad the audio oscillator as shown and set its output control to 0. Connect the counter across the audio oscillator as shown.

Position an open microphone to receive normal program pickup and carefully increase the sound-system gain to the feedback threshold. The gain control must be continuously adjusted by hand to bring out a single clean tone.

Next, turn up the amplitude control of the audio oscillator until a small sine-wave tone is mixed with the feedback oscillation of the system. Vary the frequency of the audio oscillator until it coincides exactly with the feedback frequency, using the *zero beat note* effect. THE MIXER GAIN CONTROL MUST BE HAND CONTROLLED AT ALL TIMES TO MAINTAIN EVEN FEEDBACK EFFECT AND PREVENT GROSS OVERLOAD OF THE SYSTEM.

Having adjusted the audio oscillator to the feedback frequency, reduce the system gain to 0. Open the switch on the audio oscillator and increase the output gain of the audio oscillator until a good count is obtained on the counter. The advantage of using this transfer technique is that is provides a clean count in high-noise situations, or where the system gain tries to feed back at two frequencies at once, and is slow in settling into one pure sine-wave mode.

Select a filter from the Model 3900 set nearest to the observed counter frequency and plug it into the pre-wired manifold. Try the 6 dB position first. If a feedback frequency within the control band of this unit returns at a later point in the test procedure, the filter may be reversed to provide 9 dB of attenuation.

Repeat this process to find the next frequency of self-oscillation. It will be different from the first and will require a new filter. After several filters have been installed, the system gain before feedback will normally be 4 to 6 dB higher, and the quality of the sound will be greatly improved.

If feedback modes occur at frequencies outside the 100 to 1200 Hz range of the Model 3900 set, the following procedure is recommended. CAREFULLY lower the response in the affected 1/3-octave band of the broad-banding equalizer. A decrease of only 1 or 2 dB should be tried. Lower the response in the 1/3-octave band of the equalizer only enough to stop oscillation, then proceed to the next feedback frequency.

Alternate Test Procedure

If no sine-wave audio oscillator is available, connect the counter across the loudspeaker output terminals of the power amplifier. As feedback is realized, CAREFULLY increase the gain until a clean tone is heard and an accurate frequency count can be repeated. The sensitivity of the counter MUST be adjusted so that no residual hum or room noise is counted. Select the necessary filters from the Model 3900 set in the PREFERRED TEST PROCEDURE previously described.

Identifying and Handling Room-Ring Modes

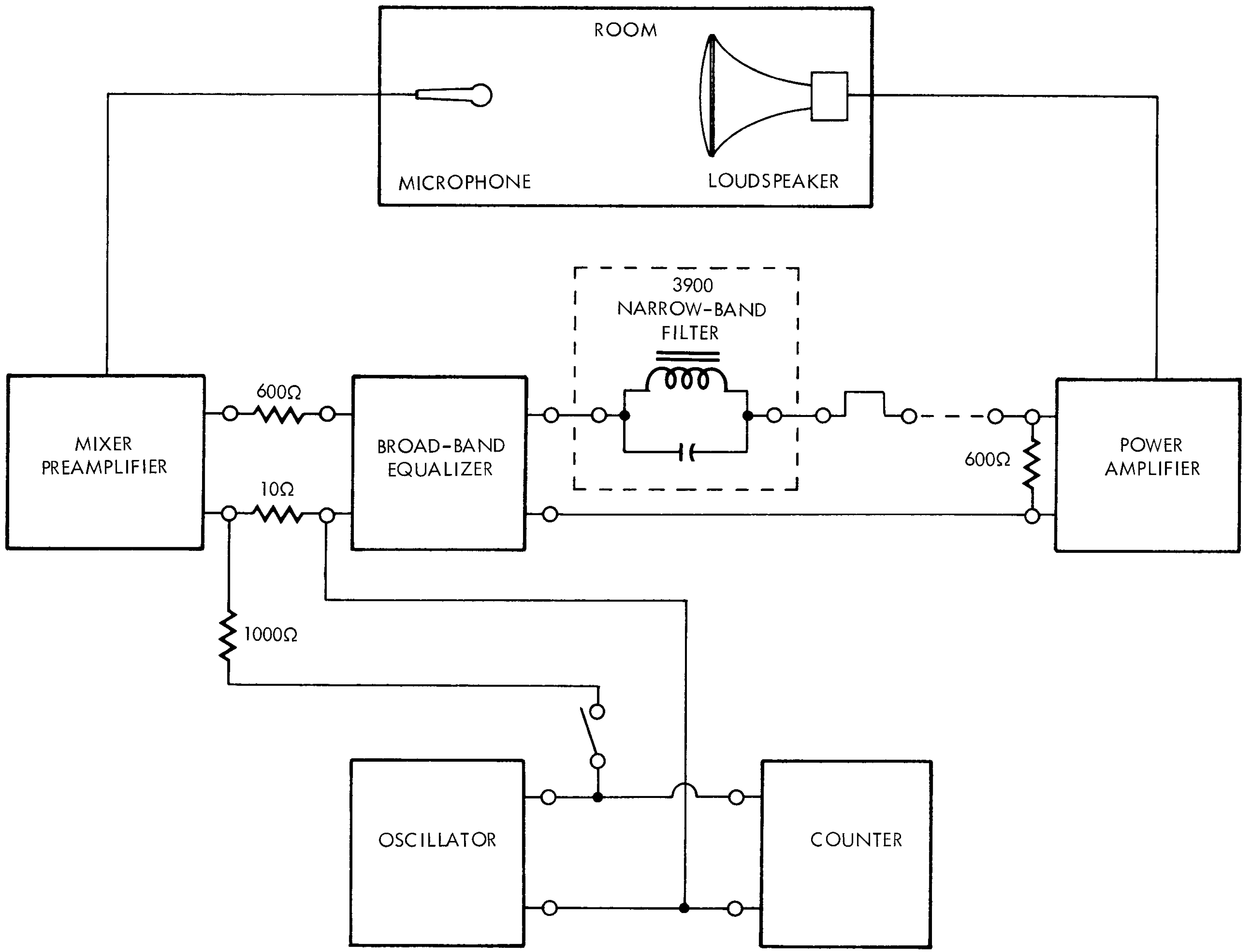
After several narrow-band filters have been installed (typically 6 to 9 units), the amplifier gain setting before feedback will be 4 to 6 dB higher. Improvements of the sound quality in the system is equally important, and this can be verified by talking tests. There may still be *room-ring modes* present, however, that can render an undesirable quality to the sound. Related to *room-ring modes* are certain *proximity modes* involving the microphone and nearby reflecting surfaces, such as podiums or lecterns. Use the following procedure to locate and treat both types of modes.

Set the amplifier gain control to just below feedback threshold. Set the audio oscillator output to drive the system in pulses at a rather high level. Remove the signal by switching off the audio oscillator output and observe (by ear, normally) the decay rate at that particular frequency. If the decay rate is very slow at a given frequency, but the system will not go into sustained feedback oscillation at that frequency, the mode is called a *room-ring mode.* Beats can be heard in the decay, and the audio oscillator can be carefully tuned to a zero-beat condition. Measure the frequency from the audio oscillator, and plug in the correct filter. The *room-ring modes* seriously interfere with speech intelligibility in a highly reverberant room; but generally they are few in number.

If insertion losses greater than 9 dB are required to take care of a *room-ring mode,* the situation often indicates mechanical coupling in the total system; e.g., loudspeaker shaking the structure and hence the microphone, or microphone mounted on a vibrating surface. Such conditions are remedied by mechanical isolation.

General Information

The Model 3900 Filter Set is manufactured under license from Dr. C. P. Boner under U. S. Patent number 3,256,391. Sale is made under restricted conditions by White Instruments, Inc., Box 698, Austin, Texas 78767; telephone 512-892-0752. Write or call for further information.



BLOCK DIAGRAM FOR NARROW-BAND EQUALIZATION