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THE REVERBERATION DILEMMA

(And How To Solve It)

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Looking over the reverberation market, one views everything from "space expansion" devices to gold foil models, with equipment costs ranging from about $100 to more than 50 times that amount. You can't help but ask, is there really that much difference in performance between the various manufacturer's equipment falling within these two extremes? Reverberation equipment seems to group itself in the general price ranges of (a) below $500, (b) $500-$1,000, (c) $1,000-$2,000, and (d) over $2,000. The higher range can easily exceed the cost of primary recording equipment that the reverb would be utilized with.

In the basic recording equipment, skillful usage can make recordings on budget equipment that are almost unnoticeably different in quality from those done on the most expensive equipment. But when dealing with reverberation equipment, one finds that the cost vs. quality required is not necessarily proportional to the overall equipment budget, nor does skillful usage have the same effect. Five thousand dollars worth of basic recording equipment can make excellent tapes, but reverberation equipment worth of such tapes will add at least ¼ more to the investment.

A lot of effort is being spent, even today, by individuals as well as manufacturers on ways to achieve high quality reverberation without spending this apparently disproportionate amount of money that good reverberation seems to cost. Over the years we have heard of many novel and often rather extensive schemes to try and bypass the requirements for the more expensive reverberation devices. Only a very few of these attempts have been capable of passing the listening test.

BASIS FOR CRITERIA

The primary problem with any approach is that the human ear is an extremely sophisticated device and is quite particular about the type of reverberation that it wants to hear. No special talent is required to make a listening test. With very little experience, almost anyone can pass judgement on a reverberation device and will probably find himself in general agreement with others.

This very fact determines the quality required in reverberation, regardless of the cost. It is almost as if poor reverberation is worse than none at all. Poor reverberation is readily apparent when transient material is involved, or, to put it another way, transient material always requires good reverberation.

To the already diverse product lines of reverberation devices now on the market, there will soon be appearing a group of low priced delay lines which can be recycled and thus form another type of reverberator which is very similar in performance to the recycled tape loop, an elementary set-up on the professional tape recorder. From this assortment of electro-mechanical and now all-electronic devices when taken in relationship to the sophistication of the human ear, what are the criteria for a reverberation device and how do they equate to money well-spent?

The primary consideration in reverberation is the somewhat elusive quality called diffusion. All reverberation devices contain standing waves in their output structure, with the difference being whether these standing waves are a large or small portion of the total output energy.

A poor quality machine will have a coarse comb filter effect with almost complete cancellation of signal at the comb minima points, while a good reverberator will have a fine comb filter effect and only a very small amount of cancellation at the comb minima points.

The old technique for plotting out the standing waves in a room or auditorium is very valid for assessing the diffusion capability of an artificial reverberation chamber. It is also a very easy test to perform. To make such a test, slowly (very slowly) sweep the chamber with a sine wave oscillator from about 50 Hz to 5,000 Hz. Count the number of output amplitude variations which occur, as measured with a VU or dBm meter, or plotted on a graphic recorder.

The resulting quantity of maxima points divided by the frequency range covered (in Hz) is referred to as

Resonances per Hertz

and provides a strong indication of the chamber's performance qualities. A good reverb will produce close to one, or even more, resonances per Hz, while a poor quality machine will result in a magnitude or more <u>fewer</u> resonances per Hz.

Figure 1 expresses this concept. The low quality machine will have a very well defined comb filter effect caused by the cancellations due to standing waves in the transmission path(s), resulting in a low figure (usually 0.01 to 0.20) of resonances per Hz. This effect is very well known, although not in those terms, and is responsible for the sound so often discussed and associated with an inexpensive spring reverb.

Most people refer to it a "Boint", but it is a characteristic property of delay lines, and not necessarily that of the spring itself which happens to be the transmission media most often used in electro-mechanical reverberation systems.

Because of this fact, it has been possible to design at least two very good reverberation devices using the basic spring as the transmission medium. One of these spring systems is generally referred to as the torsional transmission line system. The other is the Master-Room system which utilizes networks of specially designed 'springs', with the outputs being essentially summations of numerous interconnected and digitally tuned sections.

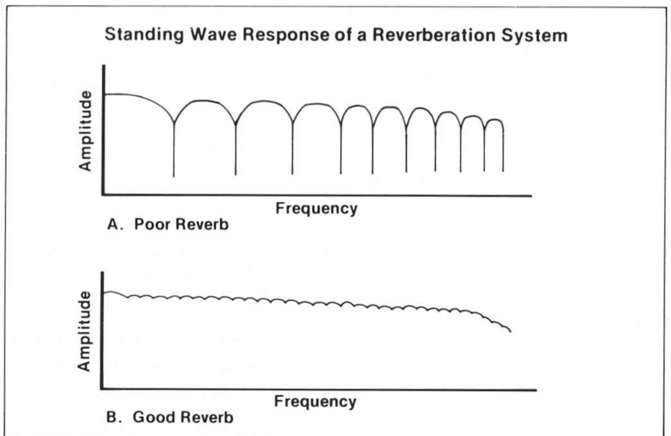

Figure 1. Sine wave sweep frequency test shows comb filter effect. A poor quality system has coarse comb response while high quality system will have a magnitude greater of maxima points. The small quantity of standing waves results in "boing" or flutter echo effects.

ELECTRONIC REVERBS

Because of its cost, the electronic delay line has not yet achieved the popularity of the more common reverberation device. However, there is probably not a person alive who, having the availability of a digital delay line, has not tried to duplicate some reverberation effect by making the line recycle itself. What is soon discovered, though, is that the recycled delay line is even more "boingy" than its electro-mechanical counterpart.

The reason for this rather weird fact is that the electronic line is a precision comb filter and exhibits no diffusion. The electro-mechanical device is not as precise in its physical design and therefore has some inherent which tends to reduce the 'boing' properties.

Since diffusion is the name of the game to a very great extent in reverberation, and it is this property which breaks up sound into the multiplicity of random echoes that please the ear, it will take a lot of design effort to make an electronic reverb that is as good as our present electro-mechanical systems. New concepts will have to be developed to provide diffusion in a digital system since the obvious multi-tapped delay line can sound worse than even the automobile "reverberators" which were popular a few years ago.

There will soon be on the market a formidable array of analog delay line units based on the bucket brigade devices (BBD's). This type of delay line, like its digital counterpart and the electro-mechanical systems, will still have to follow the same set of laws, however, when set for a recycling mode of operation.

In the recycling mode, the delay time determines the primary resonance while the method of feedback determines whether the reflections are odd or even multiples of the primary resonance. Various configurations of these systems are responsible for the "flanger" and other electronic sound modifiers. The comb filter which is formed by a recycled delay line can have two basic modes, depending upon the sign of the output summation. Figure 2 illustrates this effect.

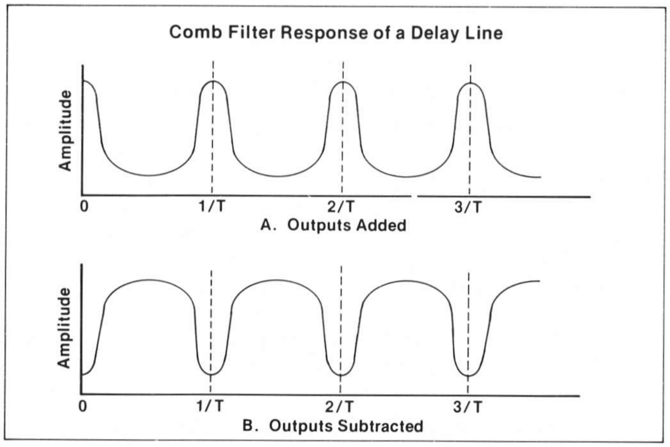

Figure 2. Recycled electronic delay lines have precise periodic amplitude reinforcement or cancellations at harmonics of the fundamental resonant frequency. Fundamental frequency is determined by the reciprocal of the delay time.

The primary resonant frequency is determined by $F = 1/T$, where T is the delay time. A delay time of one millisecond in a delay line would result in a primary resonant frequency of

$$F = 1/0.001 = 1{,}000 \text{ Hz},$$

with additional resonances occurring at all multiples of T (2T, 3T, etc.) to the bandwidth of the system. If the delay line was 50 milliseconds long, the primary resonance would be at 20 Hz.

PULSE TESTING

Any transient in the recycled line can shock excite the system to ring at the primary and/or at harmonic resonance points. These resonances are interpreted as "boing" when the frequency is within the range of approximately 50 Hz to 3,000 Hz, and as flutter echo when the resonance is below the lowest frequency that the ear can resolve.

It is this property of the basic delay line, not the material used, that has given the simple spring reverb its bad name and sound.

At MICMIX Audio Products, we developed (or at least significantly improved) another technique for room and reverberation device analysis which is similar to radar and sonar technology. With this system, a sharp narrow pulse is transmitted and the resulting echo pattern describes the time domain characteristics of the structure or device being tested.

Figure 3 illustrates this system as applied to an auditorium. The test pulse is transmitted and the resulting echoes are displayed on a storage type oscilloscope. The timing pattern displayed is capable of being interpreted as a good or bad reverberation system and the frequency of any trouble points can be located by the 1/T formula. It was from this type of studies that the parameters for the Master-Room reverberation chambers were determined.

One interesting aspect regarding these studies of both live rooms and artificial chambers is that all good reverberation systems have a common sound when pulse tested and monitored aurally. While I cannot readily describe this type of sound in print, it is possible for anyone to become familiar with its character after just a little experience, and thereafter be able to quickly spot a poor reverberation system. The pulse test also has the ability to shock excite any resonances in the reverberation system which 'color' the resulting echo pattern.

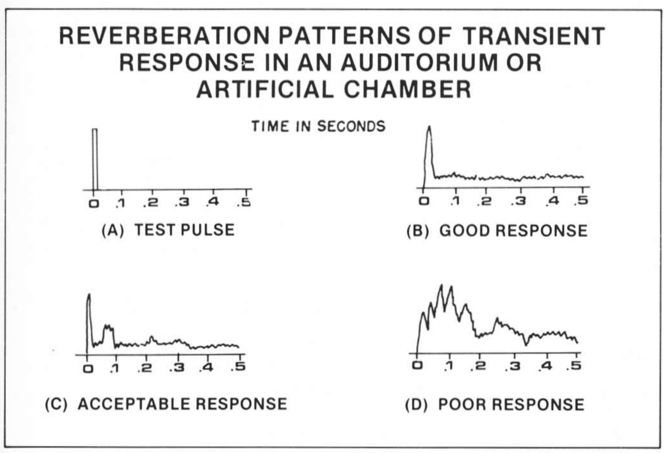

Figure 3. A good reverberation system will have only small variations in amplitude due to standing waves created when tested with a sharp pulse signal. First 500 milliseconds of reverberation time are most significant in this test.

Pulse testers for this purpose are extremely simple devices, Figure 4 is a schematic of one circuit using a unijunction transistor which can be built for just a few dollars worth of parts and which delivers a very usable pulse with more than adequate amplitude.

Care must be taken with this circuit in not using too much amplitude. Because the output has such a low duty cycle (manually operated push button) and a very sharp pulse, it is quite easy to use too much output and overload the input amplifier of the system being tested, whether a speech input system or an artificial reverberation device.

Such overloading will totally defeat the purpose of the test. A little experimentation with the pulser will soon give an idea of the proper pulse amplitude. From use of the pulse test, one can learn a substantial amount about reverberation devices and become a good judge of quality rather quickly. As an additional benefit, the pulse tester is an excellent aid in tweaking up EMT and AKG units to obtain best performance.

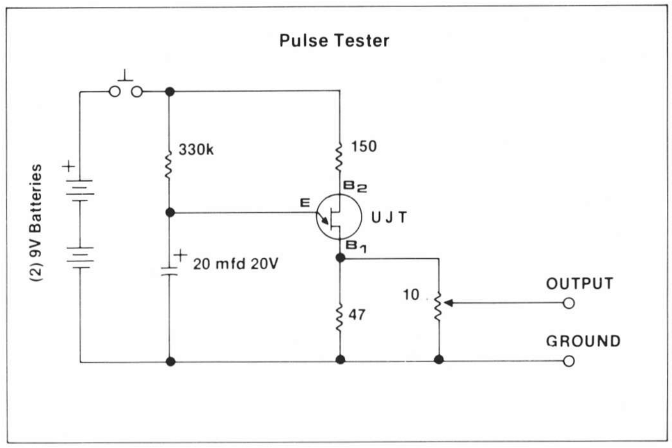

Figure 4. Simple pulse test circuit. Typical UJT's are 2N4851, HEP 210 or ECG 6401. A pair of standard 9 volt transistor batteries in series provides the power supply. The unit is operated by depressing the momentary switch until a pulse occurs. Set the output level low enough to avoid overloading the system being tested.

APPLYING THE CRITERIA

Purpose of this article was to try and clear up a little of the witchcraft that has surrounded reverberation devices for a number of years, and to provide a simple test method whereby one can have a standard for comparing not only artificial chambers but acoustic systems as well.

In the near future there will be many models of electronic delay lines and space expansion type systems. Some no doubt will be very good while others will be of questionable value to the professional. With these, as with existing devices, I would like to reiterate one point; i.e., reverberation is considerably different than a speech input system and the human ear is very sophisticated in the type of reverberation it likes to hear. It pays to evaluate a reverb system before spending one's cold hard cash, and thereby eliminate the oft-repeated lament that what was bought was not satisfactory for the desired effect.

The electronic reverb is somewhere in the future and it is probably safe to say that all of us in the manufacturing business have several systems running in development for evaluation. Other than as a novelty, however, the professional quality all-electronic reverb at a somewhat reasonable price may be quite some time in the future because it is so much more difficult to achieve our present quality in reverberation electronically than it is electro-mechanically. The electro-mechanical (passive) delay line is not a 'noise' generator and can be more easily produced on a cost-effective basis to achieve the diffusion that is so necessary for good reverberation quality.

New technology usually wins out in the end, but during the interim it is always wise to let quality be the determining factor in making a decision, rather than novelty or price.

— END —

PULSE MASTER™

AUDIO TEST GENERATOR

PULSE MASTER is a new and effective tool for determining the performance characteristics of artificial reverberation chambers as well as that of live chambers, control rooms and auditoriums.

The sharp, 1 ms wide pulse generated by PULSE MASTER is a much better transient for testing than a drum beat, hand clap or microphone tap. Non-electronic transient signals do not have the preciseness or repeatability of PULSE MASTER, and their lack of sharpness can easily mask any response measurements of the system under test. PULSE MASTER readily provides a standard of exactness when making repeated tests or when comparing one system against another.

While PULSE MASTER can be used in conjunction with a graphic recorder or storage type oscilloscope for sophisticated measurement data, mere listening to the sound produced by the system under test can, for all practical purposes, be just as effective. All good reverberation systems have a common type sound when pulse tested and monitored aurally. With a little experience, it is possible for almost anyone to quickly spot the differences between a good system and a poor system. PULSE MASTER also has the ability to shock excite resonances in reverberation systems which 'color' the resulting echo pattern and can be used as an aid in tweaking up AKG and EMT systems to obtain best performance.

Output of the PULSE MASTER is adjustable from 0 to 12 volts peak and impedance is less than 100 ohms. It is therefore capable of overdriving the input of most systems and care must be taken in testing that only the minimum pulse amplitude necessary is utilized. Overloading the system's input will result in incorrect data and totally defeat the purpose of the test. In some instances, overdriving could possible result in equipment damage. If pulse amplitude metering is not available, some experimentation starting at low levels will soon provide an indication of the proper pulse amplitude setting. One word of caution: VU meters have extremely poor response when measuring pulses of this nature and cannot be depended upon for amplitude indication.

In addition to reverberation systems, PULSE MASTER is also useful in establishing peak overload points in most types of recording and audio processing equipment when used in conjunction with a quality type peak program meter such as the MASTER AUDIO METER.

PULSE MASTER is battery powered and draws current only when the Test button is depressed, thus assuring long battery life. The button may be pressed only long enough for a single pulse or held down for repetitive pulses which occur at approximately 2 second intervals.

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