# REAL-TIME LOUDSPEAKER/ENVIRONMENT PERFORMANCE MANAGEMENT

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Real-time control of sound-reinforcement system frequency and power response by automated analyzer/equalizer systems was popular for a while several years ago. The limited success of these automated equalization systems points up the need for further and and more detailed consideration of the capabilities and limitations of loudspeakers and measurement systems in order to allow safe and effective correction of spectral imbalance to be carried out. This paper discusses the parameters used in the decision-making process of what to EQ and, perhaps more important, what not to EQ. A new system that is based on the principles outlined here is the subject of a second paper.

## 0.0 INTRODUCTION

As equalizers become computer controllable and spectrum analyzers become capable of storing, retrieving and transmitting frequency-response data, it was only a matter of time until someone said "Hey, why don't we let the analyzer measure overall system response, generate a correction and send it to an automated equalizer. Systems will automatically EQ themselves!" For anyone who has been in this business any appreciable amount of time, this is a familiar statement made at least once every two years. A good question is, "Why *doesn't* someone do this?" The answer is because we did, and we found that it didn't work very well. As a matter of fact, results ranged from highly amusing to downright catastrophic.

These automated systems did not possess expertise to recognize "unequalizable" spectra. Instead of accepting certain spectral idiosyncrasies as unfixable by equalization, these systems would gleefully pump power into loudspeaker arrays without regard to mechanical and thermal driver limits, or wave interference-induced frequency response nulls, etc. The result was driver failure (thermal and/or mechanical), clipping (at both line and power levels), tail chasing (positive feedback in the analysis-equalization loop), runaway and other types of schizophrenic behavior. The cure was worse than the disease.

## 1.0 A SYSTEMATIC APPROACH

Detailed knowledge of the spectral, thermal and interference-induced performance of loudspeaker drivers and/or arrays and of the behavior of the acoustic environment is required to determine whether to EQ or not EQ the system under scrutiny. A measurement topology based on this information, together with data networking and programmable equalizers, would make possible an automatic equalization system capable of making intelligent decisions about how to equalize a sound reinforcement system.

In order to accomplish this the system would have to:

a) Identify driver bandwidth limits
b) Identify system (interference-induced) nulls
c) Identify driver power compression limits and their signatures
d) Identify spectral anomalies caused by spurious absorptive mechanical vibration
e) Identify "unfixable" conditions and exclude such data as unreliable

The following information represents a brief discussion of what questions must be asked, whether a human or a machine is asking them, about “setting up” a loudspeaker system and maintaining the best possible performance in a real world environment. In some cases, not-so-obvious measurement questions are raised.

## 1.1 LOW FREQUENCY AND HIGH FREQUENCY LIMITS

The equalizable bandwidth of a transducer cannot be determined by simply stating the frequency where the amplitude vs. frequency curve is “3 dB down”. In reality, most (make that all) transducers, systems and arrays produce anything but flat response. The “norm” is usually a craggy series of juxtaposed peaks and troughs related to the transducer’s mechanical behavior, the environment in which the test is being conducted, and in some cases, the measurement system. This leaves the decision of where the $f_3$ (the high and low frequency limit of the equalizable band) is going to be as a subjective judgment. Smoothing algorithms make this job easier, but an “intelligence” still has to make the decisions. One obvious necessity is the elimination of human judgment as to where, amongst the ripply fray, one should assign the magical $f_3$ points. In automatic equalization equipment, graphic subjectivity must be eliminated and repeatability enhanced.

Unless they know where driver low-frequency and high-frequency limits are, as well as unequalizable interference-induced nulls, auto-equalization systems will dump enormous quantities of corrective energy into systems uncorrectable through equalization. Imagine trying to correct the frequency response of a 3" woofer down to 20 Hz, at 100 dB SPL, or a 15" woofer up to 15 kHz, or attempting to make a cancellation flat. The results would be the same: at best, spectral imbalance in the reverberant environment, and at worst, destroyed loudspeakers.

## 1.2 DRIVER THERMAL LIMITS

When determining what type of drivers and how many to use in a system, it is always crucial to know what the maximum SPL is going to be. It is at best difficult to incorporate manufacturer-specified maximum SPL limits because, while furnishing efficiency and maximum power dissipation information, they don’t include data concerning efficiency loss due to voice coil heating. The industry refers to this phenomenon as “power compression”. There is no apparent standard for conveying this type of driver behavior information to the public. Most drivers will produce less than half of their rated conversion efficiency (!) at their rated thermal limit. This behavior can manifest itself in many different ways. One of the most interesting is the likelihood that the different drivers in a multi-way system will have different thermal limits. If one pass band approaches its thermal limit while the others do not, all sorts of dynamic frequency response aberrations and polar pattern shifts will occur. Needless to say, all of the above are easily measurable and often audible.

If thermal limits are determined ahead of time, proper driver proportioning may be enacted so as to avoid or reduce such anomalies. It is also important to note that this is of concern only in systems where a high degree of accuracy is desirable. It may not be of concern to a user whose only interest is high SPL. Most modern cone-based low-frequency drivers employing cooling vents require adequate voice-coil excursion to insure proper heat transfer. Excessive high passing will render the heat transfer method ineffective and degrade the power performance of the driver.

It is assumed a the system’s upper dynamic range limit is established by the driver with the lowest thermal limit. This assumption is made because no dedicated process exists for electronically managing system thermal limitations.

In automatic equalization systems it is necessary to have complete knowledge of the loudspeaker system’s thermal limits for each frequency band (from the perspective of the reference microphone) to reduce any possibility of equalizing beyond the thermal capacity of the system, and to warn the operator that the maximum system power handling capacity has been reached. At this point an intelligent controller may (if given permission) invoke correction through reduction of gain in prescribed frequency bands to approach the target response within the known thermal limits. The more that the analyzer knows about the system it is managing ahead of time, the less the system operator has to contend with.

## 1.3 ARRAY NULLS

It seems inevitable that individual loudspeakers must sooner or later be used with others of different (in the case of a woofer and tweeter) or similar (in the case of an array) characteristics. When sizes of arrays of similar drivers exceed 1/2 wavelength of the signal to be reproduced, nulls will occur in the polar patterns. In the case of a non-coincident woofer/tweeter combination this occurs only through the crossover transition.The audibility of the nulls may be questionable, but we are more concerned how it affects the SPL from the perspective of the measurement microphone location.

Data may be divided into two categories: 1) equalizable dips and 2) unequalizable nulls. The dips are correctable in the frequency domain and the nulls (some of them) are correctable (or movable) in the time domain. The common problem in data interpretation is judging the relationships between amplitude and phase trends and inflection points, to arrive at a decision as whether to correct the measured anomaly in the frequency domain. Some correction may be effected through frequency equalization in the direct field, however, the amplitude anomalies will be merely displaced into the reverberant environment where they will be very pronounced in that they alter the total power radiated into the room. In the case of automatic equalization in the frequency domain, any frequency- response anomaly caused by interference should be thrown out as irrelevant.

### 1.4 NULLS DUE TO SYMPATHETIC VIBRATION

In analysis of the environment , it is important to differentiate between nulls caused by a vibratory absorption and nulls caused by interference. While the interference-caused anomalies may be affected via electronic means, vibratory anomalies are not. Their detection and correction require a different methodology than is usually used. A useful test would locate vibrating walls, door panels, glass panes or any other types of mechanco-acoustic narrow-band resonant absorbers. Any null caused by such absorbers would be designated as unequalizable, the operator should be notified of it so the data can be thrown out.

### 1.5 SPECTRAL CENTER

The spectral center of a driver or array is defined as the frequency that equally divides the system's energy output in the frequency domain. It is important to note that any tilting in a driver or array's frequency response biases the center toward the direction of the tilt's upward slope. This data could be used in the system initialization routine to normalize phase, gain and frequency.

### 1.6 EFFICIENCY

Efficiency is determined by the measured SPL at 1m distance. Compensation for different distances could be accomplished by inverse-square-law computations with absolute distance being determined by the first arrival in the ETC at the spectral center of the driver. This data, while not used in real time equalization, would be useful in the system setup. Shifts in efficiency vs. frequency are sometimes indicative of directivity changes in drivers or arrays and would be useful clues as to what spectra should be equalized.

### 1.7 CROSSOVER POINTS

In setting up a system, the crossover points could either be chosen and set manually or automatically. If the crossover points are known ahead of time (because they were possibly selected by the analyzer) then this data should almost universally be thrown out as dips in this region are not fixable in the frequency domain.

### 1.8 DRIVER BALANCE

The driver pass-band gains should be normalized after crossover points have been selected. In an active system, all driver pass-band gains should be set to be equal at their respective spectral centers from the perspective of the measurement microphone. In the case of a passive system, the most efficient drivers are padded back to match the sensitivity of the least efficient driver. Any relative frequency domain error in the system to be equalized should be minimized as this enhances the correction range.

### 1.9 MECHANICAL OFFSET

Offset in time is caused by misalignment of the horizontal displacement between two drivers reproducing common signals from the perspective of the measurement microphone location or the listening area. This may be corrected physically or electronically. The main benefit of corrected time offset is that excess phase (pure time) is practically eliminated, leaving only phase anomalies which we may be able to fix. Electronic alignment has limited off axis effectiveness when used with non-coincident drivers, however that is beyond the scope of this paper. Reducing occurrences of excess phase means that more spectra will be fixable via frequency equalization.

### 1.10 BAFFLE REFLECTIONS

Early reflections are usually baffle-assembly related and are characterized by juxtaposed energy peaks following closely behind the first arrival on the ETC from a single driver. Data affected by such early reflections is generally thrown out as unequalizable in the frequency domain

### 1.11 DIFFUSION

Diffusion is an indicator of how dispersive the boundaries of the listening environment are. The ideal situation for a non-absorptive boundary is to equally "scatter" all sound waves regardless of their angle of incidence. This condition would all but passivate "echoes" "flutter" "comb filtering" and other perceptually undesirable manifestations of discrete reflections. The character of diffusion is unrelated to problems fixable in the frequency domain so the data is not considered.

### 1.12 INTELLIGIBILITY

Intelligibility is a measure of how well the spoken word is understood. The higher the signal coherence the more understandable it is. Essentially, "signal" is coherent, while "noise" is incoherent. The previous statement assumes that incoherence may negatively affect intelligibility. If a coherent signal is summed with an incoherent (caused by rapid or random shift in phase vs. frequency) signal, the result is usually reduced intelligibility. Incoherent energy is essentially indistinguishable from noise, so it is treated as such and deemed as uncorrectable. Frequency data corrupted by incoherence, hence, is thrown out.

### 1.13 DYNAMIC RANGE:

Dynamic range is the difference, in dB, between the highest and lowest volume levels an audio program or system is able to produce. The top end of the dynamic range, at any given frequency, is set by the thermal limit of the active driver, by the onset of electronic clipping, or by unacceptable levels of distortion of the electro-acoustic system output. The bottom of the dynamic range at any given frequency is based on the noise floor established by residual electronic thermal or induced noise, mechanical or acoustic ambient noise. The only aspect of dynamic range important to an automatic system is the upper limits (thermal and clipping) which may be affected by necessary boost.

### 1.14 IMPEDANCE OVER USABLE RANGE

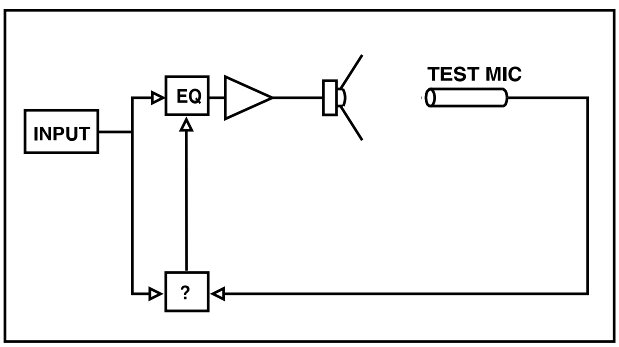
This data is not used in the equalization process.

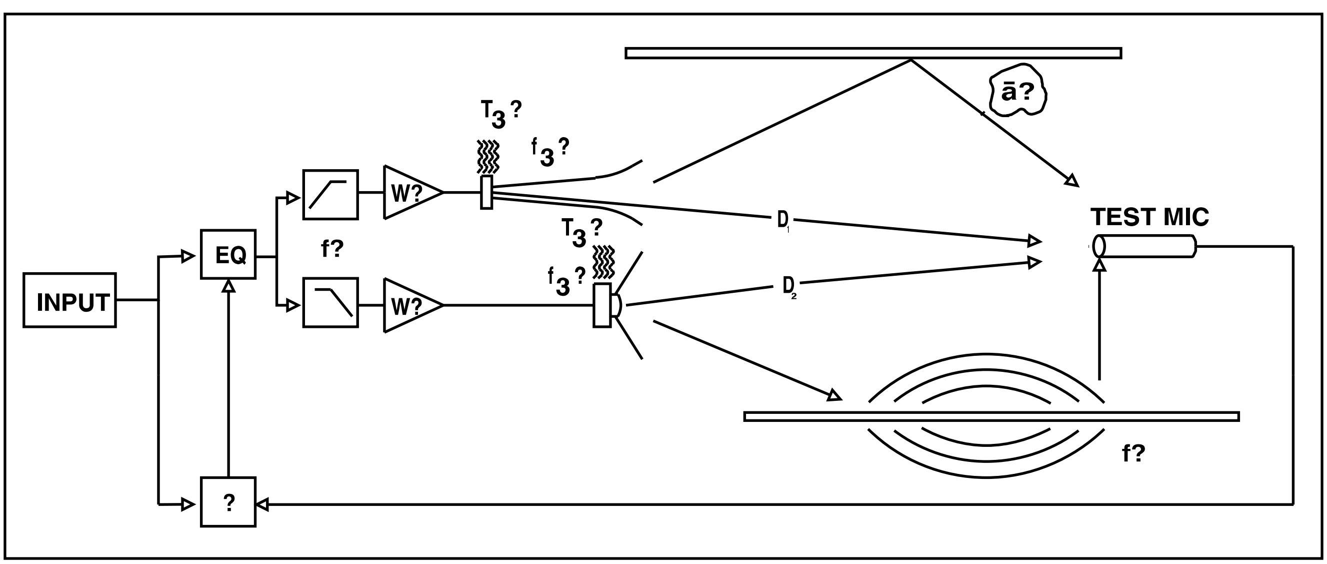
### 1.15 DI (DIRECTIVITY INDEX)

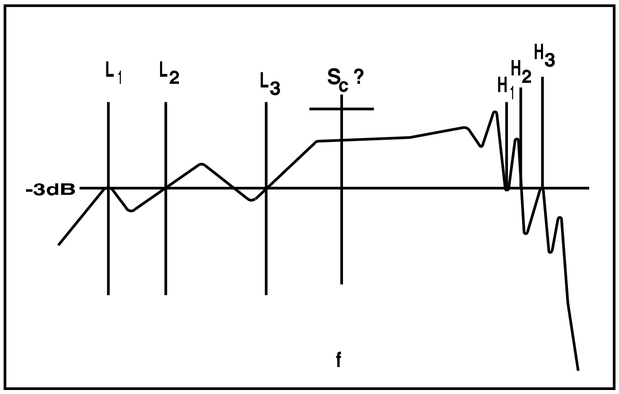
This data is not used in the equalization process

### 2.0 SUMMARY

Limiting parameters used in the equalization process based on a fixed measurement or listening perspective have been discussed. It is proposed that more information than frequency and phase response of the loudspeakers is necessary to define corrective equalization. It is further proposed that additional information concerning wave interference in loudspeaker arrays, spurious mechanco-acoustic absorption in the room, and driver thermal (power compression) data are necessary to enact "intelligent" equalization decisions. All this applies regardless of whether the decisions are made by human or machine.

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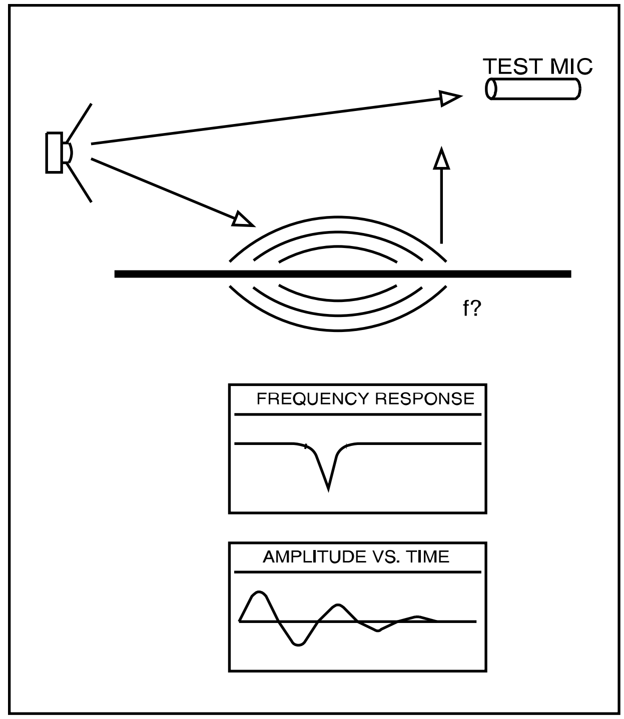
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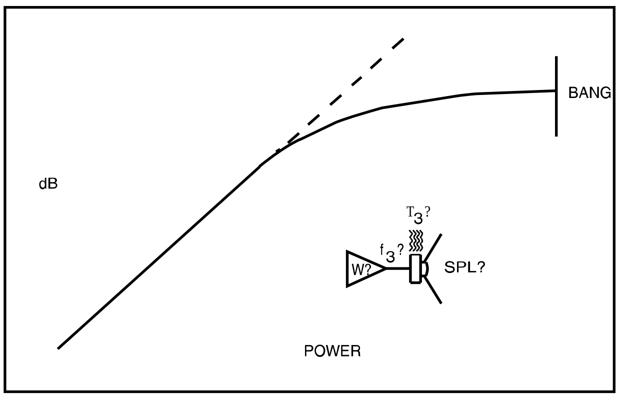
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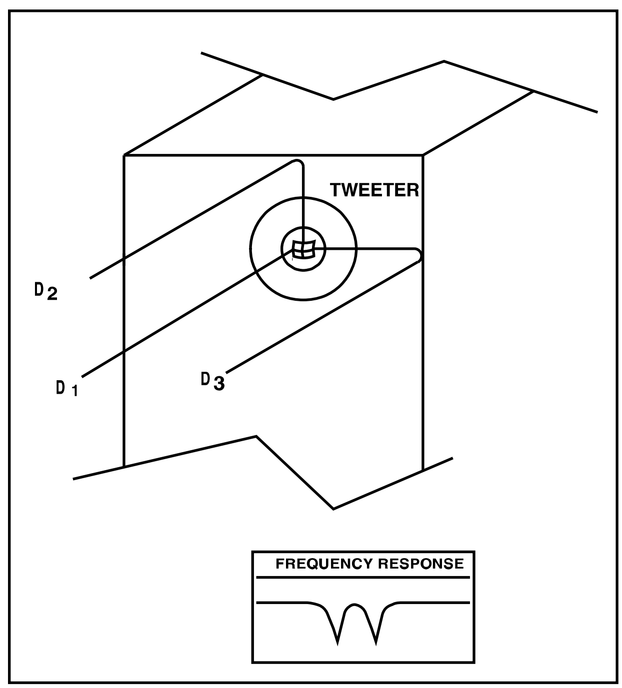
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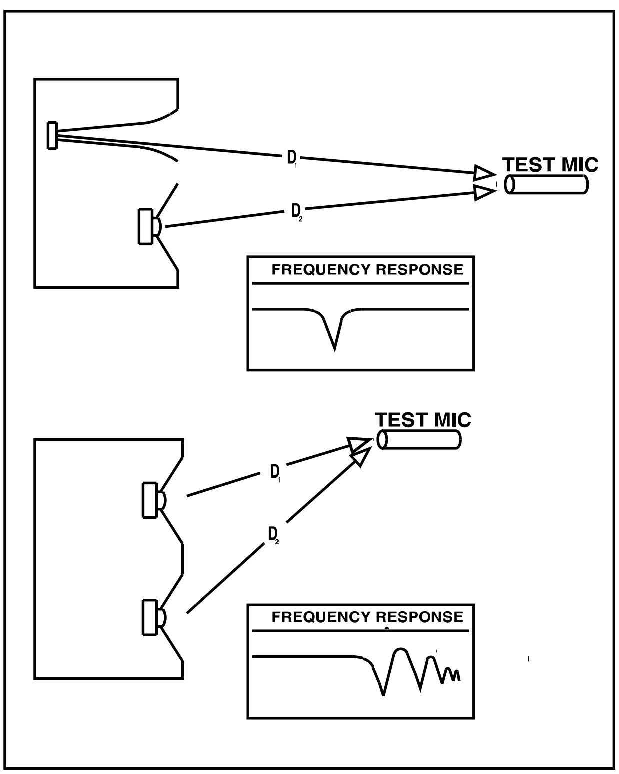
D2
D1
D3
FREQUENCY RESPONSE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TEST MIC
D2
FREQUENCY RESPONSE
TEST MIC
D1
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