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FAR FIELD TESTING OF LOUDSPEAKER SYSTEMS

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1. INTRODUCTION

Over its 25+ year history, Community has repeatedly gone to great lengths to test products in the most revealing and relevant way possible. Community also has a history of constructing large, bizarre-looking pieces of apparatus to accomplish these tests. Not wanting to break with a tradition that has consistently produced really usable information, we have taken a similar path in the design of our current the data gathering system.

2. BACKGROUND

When we devised this new test system, our guiding principles were "free field" and "far field". The reasons for these choices are simple and practical; they are inherent in the nature of the products being tested and in the applications for which those products are designed. In this case, the products are sound reinforcement speaker systems, and their purpose is to project sound over a distance.

Therefore, far more dependable and relevant data can be obtained by testing the speakers at measurement distances that correspond to the actual listening distances. In our experience, testing in the near field and then trying to extrapolate back out to realistic distances generally produces data with serious flaws when such data is superimposed on actual use conditions, especially with multi-way systems.

Further, as Mark Ureda points out in his paper, testing in the far field has significant benefits in terms of accuracy of data, particularly angular data. Several other well known papers have also dealt with the matter of the apparent apex of loudspeakers, the point around which the speaker must be rotated to obtain correct coverage information.

Even in a single device, such as a pattern control high frequency horn, apparent apex is not a simple matter, since it can change considerably with horn orientation - horizontal apex is very different from vertical apex. When the test speaker is a multi-way system incorporating several acoustical elements the question of apex becomes absurdly complicated. Not only is the apex of each element changing with frequency and orientation, but clearly each element is at a different location in the system and is operating in a different frequency range.

The effect of the coincidence (or lack thereof) of the rotational axis of the test and the apparent apex of the speaker being tested is very significant in the near field, but becomes far less significant as the measuring distance increases.

Fortunately, if the distance from the microphone to the speaker is sufficiently large, the effect of any offset between the apparent apex and the rotational axis of the test becomes relatively insignificant, and this complex problem is reduced to a point where it can reasonably be ignored entirely.

This was a major reason for our decision to test in the far field. We could obtain accurate pictures of the dispersion patterns even of fairly large systems, and we would also have the added benefit of being able to rotate them around their centers of gravity. This second benefit made it possible to design and construct a relatively simple and rugged rotator mechanism that could handle not only individual speaker systems but also arrays of speaker systems.

3. JUSTIFICATION

The advantages of far field measurements for accurate dispersion information are fairly easy to see. The advantages for sensitivity and response data are not quite so obvious, but are equally valid. Speaker sensitivity is usually quoted as a 1 Watt/1 meter SPL, although the function of that rating for sound reinforcement purposes is to use it as a basis to calculate output at other distances and other power levels. However, if you think about it at all, the output of a speaker at 1 meter does not mean much unless the speaker will actually be listened to at that distance.

Therefore, if you measure speaker sensitivity by applying one Watt and reading the SPL at one meter, even though it is an accepted, direct and technically correct method, it will almost surely lead to substantially erroneous results when the data is used in far field calculations.

We have found that a more useful and realistic sensitivity figure is obtained by making a far field measurement and then calculating back to a 1 meter SPL. In this way, when the calculation is reversed to predict performance in the far field, a correct result is obtained.

The frequency response of a loudspeaker is clearly different in the near field and in the far field. Systems such as studio monitors and domestic hi-fi speakers that are intended for near field applications should certainly have their response measured in the near field. Sound reinforcement speakers should not, and to do so will uniformly give an unrealistic and misleading picture of their performance. The only truly accurate depiction of a speaker will obtained by measuring it in a manner that is representative of its actual use.

To test in the far field and test over a wide frequency bandwidth, it is necessary to be at a considerable distance from any reflective surfaces. This is the "free field" aspect of our testing program, and it required either testing in a gigantic (60' cube) anechoic chamber or testing outdoors. We chose the second option, and constructed a test system that consists of an automated rotator mechanism that rolls out on a track that projects from the third floor of our manufacturing plant. Above the track a 13.5 meter (44.3ft) long horizontal mast also projects from the side of the building, and on this mast travels the microphone and its boom. This arrangement positions the speaker at a distance of 5 meters from the nearest reflective surface, and positions the microphone at a distance of 12 meters from the speaker, thus satisfying both the free field and the far field requirements.

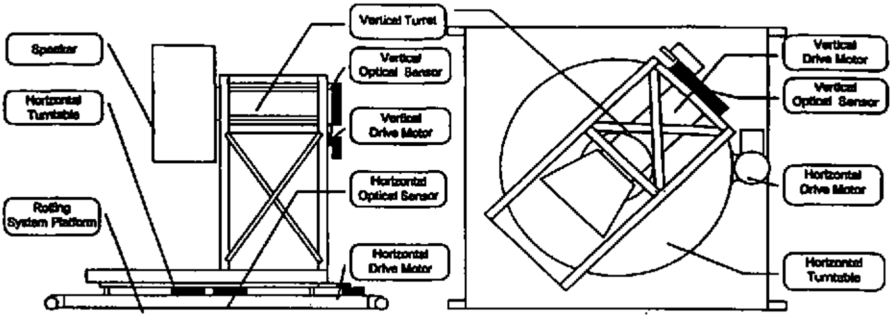

FIGURE 1 Pictogram of Rotator

4. PARAMETERS OF THE DATA GATHERING SYSTEM

The test system that was created for this project needed to be quite unique due to the variety of products to be tested. Its main function is accurate spherical positioning of everything in Community's current line of speakers. This includes products as diverse as small high frequency horns and systems weighing only a few pounds to large 253 lb. concert systems. The physical structure of the test system had to perform this function without presenting an acoustic obstruction. In addition, it also had to provide a means for easy mounting, dismounting, rotational positioning and measurement positioning of this wide variety of loudspeakers and systems.

Figure 1 shows the test apparatus. The vertical turret holds the speaker and rotates it axially. It is constructed of a open skeleton of square tubular steel designed to be as acoustically transparent as possible while being strong enough to support an array of large enclosures. This turret is mounted on skids to the horizontal rotation platform to allow for proper adjustment of the point of rotation for each system under test. Adjustable speaker mounting fixtures placed on the turret allow the speaker to be aligned axially.

5. COLLECTION OF DATA

Horizontal and axial rotation in five degree steps is accomplished via gear motors, optical position sensors and pneumatic brakes. This drive system is controlled via the TTL output of the TEF measurement system using Polar software. The Polar software collects a TDS amplitude response for each 5 degree rotation and stores it as an individual file. These files are grouped into 18 sets of 37 files each, one set for each horizontal rotation and one file for each 5 degree step (plus one header file). Each set can be viewed as a 3D waterfall. This means that 722 individual files requiring over 23 megabytes of storage space are collected and stored for each quarter sphere directivity measurement.

The TEF Polar software allows each of the 18 sets of files to be post-processed into 18 one third octave and 18 octave polar sets. These sets of polars are then imported into a custom Excel spreadsheet with custom Visual Basic modules that further post-process and display the data in horizontal and vertical polar, Isobar, beamwidth and DI / Q charts. These charts are then cut and pasted electronically into Corel Draw templates to give us graphically presentable data. Every step of the post processing process has been carefully written to assure the integrity of the data. Our guiding philosophy in this project has been to present detailed TEF data in a graphically pleasing and useful fashion without affecting the integrity of the data. To this end, all our Excel post-processing spreadsheets utilize the same algorithms for post-processing and displaying data as the TEF software. If you test the products yourself with a TEF measurement system under the same conditions you should get exactly the same result.

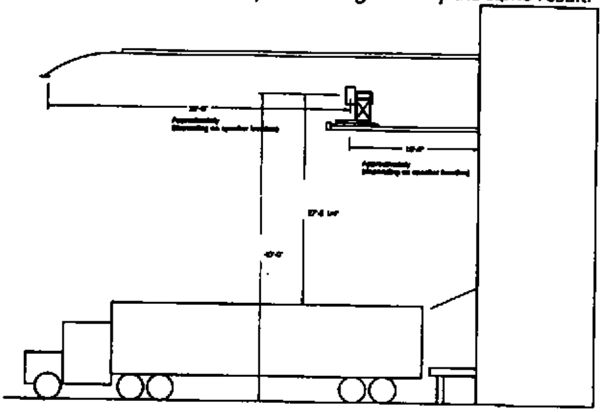

Figure 2. Pictogram of Test Environment

Our goal was to gather far field, free field measurements while achieving less than 10% error in three dimensional directivity tests.

Figure 2 shows our test environment with microphone 39 ft. (~12 M) from the loudspeaker. Using Mark Ureda's Isobar error probability equation we would have a maximum probability of error of 9.33% on our largest midrange horn and much less for the majority of our products, thus satisfying our far field and isobar accuracy goals.

To achieve a perfect free field measurement would require an environment completely free of reflective surfaces and completely free of any background noise. Since this is not practical, we placed the test system as far away from reflective surfaces as possible and choose test parameters for our TEF measurement system that would not allow these reflections to interfere with our measurements. We also utilized the noise immunity advantage of TDS measurements to reduce the interference of background noise.

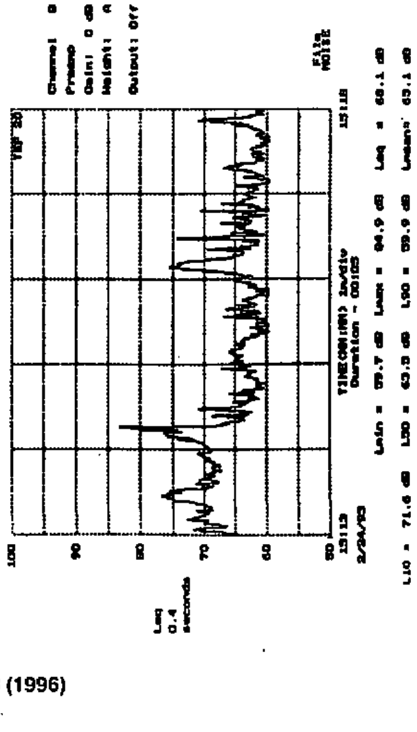

Figure 3a Background noise level vs. time

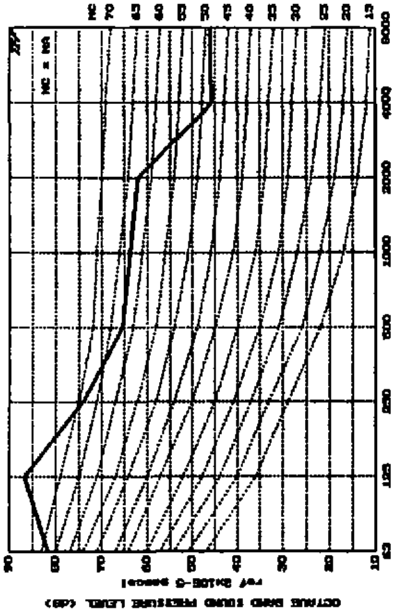

Figure 3b Background noise level vs. frequency

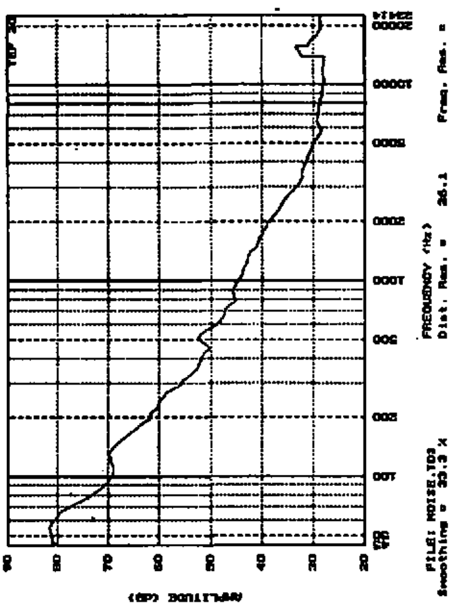

Figure 3c Background noise level vs. frequency (reduced by TDS measurement technique)

FAR FIELD TESTING

The first step in reducing the effects of background noise was to measure its level related to time. For this test we used the TEF NLA software that measures SPL vs. time. This can be seen in Figure 3a. Since the testing was done outside above a parking lot and quite close to a minor highway several noise events were measured as expected. They included a truck idling below the microphone, truck accelerating out of the parking lot, cars passing on the highway and then finally a truck passing on the highway. As you can see the noise level varies from 60 to 85 dB SPL. Since the noise varies significantly with time, tests to determine frequency content would have to be averaged over time to get an accurate picture of frequency content.

Figure 3b shows how the noise level varies with frequency as measured by the TEF NC software. This measurement is the average of six measurements taken during six extreme events; truck driving by, truck in parking lot, employees departing, etc.

You can see that the noise level is significantly greater at high frequencies compared to low frequencies. To test in this environment with a system that did not attenuate noise would require a sound pressure level at the microphone of 125 dB at low frequencies and 85 dB at the highest frequencies, 40 dB above the noise floor for accurate polar measurements. Since this is not practical, the advantages of TDS measurement were called upon once again to help us achieve our free field measurement goal.

It is easy to measure the background noise as seen by a TEF TDS measurement by disconnecting the loudspeaker under test and performing a TDS test. The result is a measurement of background noise reduced by the TDS tracking filter. Figure 3c shows the resultant noise floor measured using this technique with the TEF measurement system set for 50 Hz. frequency resolution.

As before, this measurement is the average of six measurements taken during six extreme events, truck driving by, truck in parking lot, employees departing etc. As you can see background noise is considerably lower than before. Also, background noise is more of a problem at lower frequencies and less of a problem at higher frequencies. This allowed us to measure high and mid frequency devices at a lower level than full range and subwoofer systems while maintaining an on axis SPL 40 dB above the noise floor. Figure 3b is very useful in evaluating the data presented in this binder.

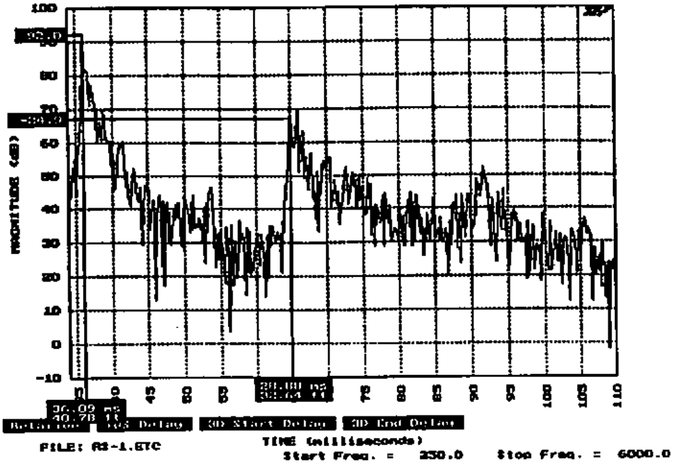

Figure 4 Energy Time Curve (ETC)

Figure 2 also shows the test environment with all acoustically significant boundaries. These boundaries include the building, parking lot, loading dock roof and any trucks that might be parked at the loading dock. These boundaries represent the limits of our TDS measurement window. They can be seen acoustically in the TEF Energy Time Curve (ETC) shown in Figure 4. This information guided us in selecting a maximum window of 26 ft. allowing 43 Hz. frequency resolution. There are varying opinions, but most people would agree that with this resolution, our measurements are accurate 86 Hz. and above.

Through use of TDS measurement techniques utilized in the TEF measurement system, an environment free of reflective surfaces close to the loudspeaker under test, and a long measurement distance, we are able to collect polar, SPL and harmonic data in an accurate and practical manner.