Abstract
A pseudo-isotropic source is presented. The source consists of an electrically large cavity with internal excitation (horn antenna), a variable internal boundary condition (a rotating paddle as in a reverberation chamber), and randomly placed apertures for external radiation. On average, the radiation pattern approaches that of an isotropic source. Data are presented for a non-optimized box realization showing +/- 3 dB isotropy over typical planar cuts. Simulations suggest that better than +/- 2 dB should be possible.

1. INTRODUCTION
Semi-anechoic chambers are typically qualified using site attenuation measurements. Similar site-qualification methods are being developed for fully anechoic chambers. The site attenuation technique compares the measured signal at a receiving antenna to an ideal value based on the assumption of no reflections from the absorber-lined walls. An implicit assumption in such a site-qualification measurement is that the signal being reflected by the absorber walls is equivalent in strength to the direct path signal between the transmit and receive antennas. This implies that the ratio of the two (reflected/direct) is related to the reflection coefficient of the absorber wall. If this is not the case, the site-qualification measurement is not useful. For example, if the direct path signal is zero then even small reflections from good absorber will result in large relative reflected/direct values. Conversely, if the signal to the absorber walls is zero then even poorly absorbing walls will result in small reflected/direct values. In short, an isotropic source is preferable when making qualification measurements of anechoic environments.

Dipole or biconical antennas are presently used for such measurements in the frequency range 30 to 1000 MHz. These antennas are omni-directional in the plane perpendicular to their long axis. Using two orientations, horizontal and vertical, the reflection properties of all walls in a chamber can be tested. Although not ideal isotropic sources, these antennas have proved suitable for chamber qualification. At frequencies above 1 GHz, standard antennas such as horns become more directional. This makes anechoic chamber qualification difficult since horn antennas are not omni-directional in any plane, let alone isotropic. The horn antenna may be rotated to illuminate various walls, but as noted above this results in a reduced direct-path coupling. It should be possible to continuously account for the antenna pattern of the horn as it is rotated, thereby correcting the direct path level; however, this would require care and precise knowledge of the full spherical pattern of the horn antenna. Back-wall illumination might still prove problematic if there is no usable direct-path coupling. Thus, horns are not an ideal antenna for anechoic chamber qualification.

Isotropic and null-free antennas have been considered in the past. An ideal isotropic source needs to be independent of direction and polarization. Unfortunately, a coherent source cannot be truly isotropic [1]. If a coherent source has a null-free radiation pattern, then the polarization will range over all values from linear to left- and right-circular [2]. A variation on this theme is a quarter-wave-type antenna with isotropic power densities in a half plane [3-4]. These are not well suited to our application here, however.

This paper explores a pseudo-isotropic source using a small reverberation chamber. Reverberation chambers rotate fields about an object, resulting in a near-isotropic illumination when the fields are averaged over time [5]. The time period for averaging is determined by the type of variable boundary condition used to vary the fields (stepped stirrer, continuous stirrer, variable walls, etc.). This principle can be applied to antenna excitation, creating isotropic radiation when averaged over time. The basic idea is to use an electrically large metal cavity with an internal source and stirrer (variable boundary condition). This will provide variable excitation. Randomly placed apertures in the cavity shield allow for radiation outside the cavity. As the stirrer rotates, the distribution of the aperture excitation is changed. If the number of apertures is reasonably large, the radiation pattern should approach an isotropic pattern when averaged over time. This average pattern should be suitable for anechoic chamber qualification owing to the reasons outlined above.

This paper presents measured data using a 30-hole rectangular cavity with internal stirrer and horn excitation. The cavity was constructed for another purpose (an investigation of shielding effectiveness) and not optimized for the purpose discussed here. Nonetheless, results obtained with this box demonstrate the desired isotropic radiation behavior. We also performed numerical simulations that demonstrate improved isotropy that should be realizable using this approach and a spherical geometry. The paper concludes with some summary remarks.

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2. MEASURED DATA: 30-HOLE RECTANGULAR CAVITY

As an example of a pseudo-isotropic source, we investigated a rectangular metallic box (0.73 x 0.93 x 1.03 m) with five holes 1.6 cm in diameter randomly placed on each face, making a total of 30 holes. A double-ridged horn antenna inside the box was connected to a network analyzer via coaxial cable and a feed-through connector on one face of the box. A double-ridged horn connected to the network analyzer was used to receive the external fields and determine the resulting insertion loss. The input power to the horn antenna inside the box was a few milliwatts. This gave more than enough dynamic range. A paddle stirrer was used to vary the field distribution inside the box and thereby the aperture excitation distribution. Photos of the box and its interior are shown in Figure 1.

![Figure 1. The 30-hole box: (a) the exterior, and (b) the interior, with horn excitation and paddle stirrer.](image)

In a first set of experiments, the external field distribution was measured in the three planes normal to the cavity faces at a distance of 3 m inside a fully anechoic chamber. This separation is in the radiating near field where the radiating fields dominate but the pattern is still depends on the separation. This may affect results slightly. The frequency was varied from 2 GHz to 4 GHz in steps of 40 MHz. Field measurements were performed at angular steps of 2° over the planar cut. Forty-eight stepped paddle positions were used to vary the internal excitation. Figure 2 shows the ratio of the received power to the average received power for an example planar cut at 2 GHz, averaged over the 48 paddle positions. The variation shown is on the order of +/- 3 dB. If the source were truly isotropic, then the ratio (in dB) would be zero at all angles. However, a reverberating source can be isotropic only in an average sense. Some variation will be introduced when using a finite sample size. This is on the order of +/- 1 dB for the 48 paddle positions used. Increasing the number of paddle positions should reduce the variation, as is done in the next section. Thus, the +/- 3 dB result is promising.

![Figure 2. Isotropy of the 30-hole box source using 48 internal paddle positions at 2 GHz for a typical planar cut.](image)

Figures 3 and 4 show the same results at 3 and 4 GHz respectively. In each case, the variation about zero is a few dB. Figure 5 shows data for all the frequencies combined. Again, the variation for the most part is on the order of +/- 3 dB.

![Figure 3. Isotropy of the 30-hole box source using 48 internal paddle positions at 3 GHz for a typical planar cut.](image)
cut more through the diagonal of the box. The isotropy is better than +/- 2 dB with the exception of a few points.

In a second set of measurements, multiple cuts were measured at a distance of 8 m in the NIST cylindrical near-field range (near-field extrapolations were not necessary at this separation). The frequency was varied from 2.2 GHz to 4.0 GHz in steps of 200 MHz. Angular steps of 2° were again used for field measurements over the planar cut. In this set of measurements, the paddle was rotated continuously and sampled 801 times. A standard-gain horn connected to a network analyzer was used to determine insertion loss. More details on the measurement setup can be found in [6-7]. Figure 6 shows an example of the data for a principal-plane cut with all ten frequencies plotted. The variation is on the order of +/- 2 dB. Due to the larger sample size from the internal excitation distribution and the larger separation between the box and probe, the data spread is less than in the first set of experiments. The data also show a cyclical behavior created by the periodic presentation of the box edges and faces toward the receiving antenna. Figure 7 shows similar data for a planar cut made through the box diagonal.

3. SIMULATED DATA: 25 POINT SOURCES ON A SPHERE
The above 30-hole rectangular cavity was not originally created with isotropy in mind. In using this cavity here, no attempt to improve isotropy was made. A spherical or cubical case with a more optimized array of holes is likely to give better results. Figure 8 shows simulated planar-cut isotropy data for a 50 cm sphere with 25 ideal point sources randomly placed on the sphere surface and randomly excited (phase and magnitude). More detail on the simulation method is given in [3]. The data in Figure 8 represent an average over 50 runs (50 random excitations) to simulate the effect of a variable excitation (e.g., a paddle). The resulting isotropy is better than +/- 2 dB. If the number of runs is increased, the isotropy should improve,
as was seen in the measured data when the sample size was increased from 48 points to 801 points. Figure 9 shows data for the same configuration when the number of runs is increased to 100. The data are now well within the +/- 2 dB range. We can speculate that perhaps better than +/- 1 dB could be achieved with optimization. Such a source should be relatively easy to realize (a sphere with an internal paddle) and would require no physical rotations. This could be a useful method for anechoic chamber qualification at frequencies where omni-directional antennas are not practical.

4. CONCLUSION
A 30-hole rectangular cavity was investigated as an isotropic source. An internal paddle varies the excitation of the apertures. Averaging over the internal paddle positions gives a radiation pattern that becomes more isotropic as the paddle-position sample size is increased. Measured data show that isotropy on the order of +/- 2 dB is achieved with this simple construction. Simulations suggest that isotropy on the order of +/- 1 dB should be possible through optimization of the same principle. The resulting source could be used to qualify anechoic chambers at higher frequencies where conventional antennas tend to become highly directional and not able to illuminate all the walls of the chamber. Directional antennas can also be rotated to illuminate all directions in a chamber, but physical rotations are time-consuming and costly. The source considered here, being near isotropic, does not need to be rotated. Topics for future work include optimizing the aperture array for better isotropy, realization of an optimal design, and reflection experiments in an anechoic chamber.

REFERENCES