Correlation of Fully Anechoic to OATS Measurements

A small, fully anechoic ferrite chamber with a 3-m site for CE compliance testing has been developed. A theoretical emission model for the correlation to OATS has been formulated and experimentally validated.

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INTRODUCTION

According to the latest CISPR 16 and ANSI C63.4 requirements, radiated emission measurements are performed at open area test sites (OATS). Any alternative measurement facility must be traceable to this procedure. The maximum calibration error may not exceed ± 4 dB in the range of 30 to 1000 MHz. The European Generic standard EN 50082-1/residential/ITE (information technology equipment) requires a 10-m measurement distance. If a semi-anechoic chamber with a 10-m integrated site is used, the potential financial investment can easily exceed $1 million. While using an OATS is much more cost-effective, ambients often make emission testing difficult.

The U.S. FCC accepts 3-m OATS data for Class B devices. However, a shielded enclosure is necessary to conduct some radiated immunity measurements, and the placement of additional absorber material on top of the ground plane is mandatory. Changing a semi-anechoic chamber to a fully anechoic chamber each time is a cumbersome exercise. Therefore, a fully anechoic chamber appears to be very attractive. Thus, in the ETSI telecom world, the use of a free space environment such as a fully anechoic chamber is the preferred procedure for transmitters and antennas.

Under far-field conditions it is easy to compute free space data for different measurement distances (from 3 m to 10 m, -10.46 dB is added; from 3 m to 30 m, -20 dB is added). Additional reflections must be accounted for over a ground plane. Assuming that this correction factor is 6 dB under all circumstances is incorrect.

To correlate the results of a fully anechoic room to an OATS, a small, fully anechoic ferrite chamber with a 3-m site for CE compliance testing has been developed. A theoretical emission model for the correlation to OATS has been formulated and experimentally validated.

THEORETICAL MODEL

The basic model for an OATS with two antennas over a ground plane is shown in Figure 1. The transmitting antenna height is h_1 and the receiving antenna height is h_2. In the case of horizontal polarization of the antennas, the direct path field strength in the receiving point is found to be:

$$E_{1h} = \frac{Ke^{-jk\sqrt{(h_2-h_1)^2 + d^2}}}{\sqrt{(h_2-h_1)^2 + d^2}} \tag{1}$$

where K is a constant and k is the wave number. The field strength of the indirect ray is:

$$E_{2h} = \frac{Ke^{-jk\sqrt{(h_2+h_1)^2 + d^2}}}{\sqrt{(h_2+h_1)^2 + d^2}} \tag{2}$$

The total field in the receive point is the superposition of E_{1h} and E_{2h}:

$$E_{3h} = E_{1h} + E_{2h} \tag{3}$$

Under free space conditions:

$$E_{fs} = E_1(h_1 = h_2) \tag{4}$$

Dividing the absolute values of E_{1h} over E_{fs} results in the ratio:

$$r_{1h} = \frac{d}{\sqrt{(h_2 - h_1)^2 + d^2}} \tag{5}$$

The ratio of field strength OATS to free space follows:

$$r_{2h} = r_{1h}\left|\frac{E_{3h}}{E_{1h}}\right| = r_{1h} \times r_{3h} \tag{6}$$

where:

$$r_{3h} = \sqrt{1+\frac{l_1^2}{l_2^2} - 2\,\frac{l_1}{l_2}\,\cos(k[l_2 - l_1])} \tag{7}$$

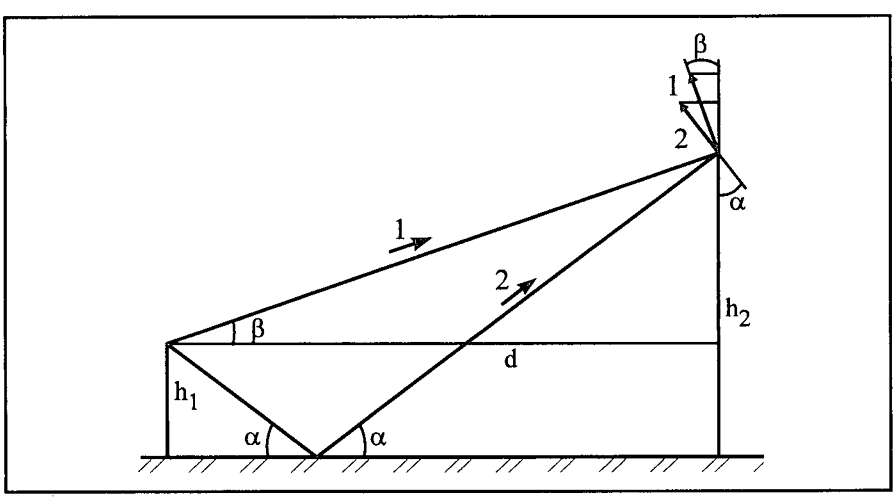

Figure 1. *OATS Model with Direct (1) and Indirect (2) Path.*

and $l_1 = \sqrt{(h_2 - h_1)^2 + d^2}$

$$l_2 = \sqrt{(h_2 + h_1)^2 + d^2}$$

In the vertical polarization case:

$$r_{3v} = \sqrt{1 + \frac{l_1^6}{l_2^6} + 2\frac{l_1^3}{l_2^3} \cos(k[l_2 - l_1])} \quad (8)$$

where

$E_{1v} = E_{1h} \times \cos^2\beta$ and $E_{2v} = E_{2h} \times \cos^2\alpha$
$r_{1v} = r^3_{1h}$ and $r_{2v} = r_{3h}$

Now the maximum r_2 factors over the given height scan range, measurement distance and the appropriate transmitter antenna height can be determined for all used frequencies (30 - 1000 MHz). Numerical simulations have been performed for 3 m, 10 m, and 30 m and are depicted in Figures 2 to 7. The assumptions are a radiating point source at a 1-m height and a receiving antenna height scanned from 1 m to 4 m.

An interesting comparison with ANSI C63.4/1992 is presented in Figures 8 and 9. The theoretical normalized site attenuation has been converted to the equivalent free space attenuation. The agreement between the four curves is excellent. This proves that ANSI's model assumes point sources.

To finalize the conversion from an OATS to a 3-m, fully anechoic chamber, one has to subtract the additional free space attenuation (from 3 m to 10 m, 10.46 dB is subtracted; from 3 m to 30 m, 20 dB is subtracted).

For the 3-m case, the first near-field term for checking the sensitivity had been considered. This effect was determined to be of minor importance.

To allow for arbitrary radiators to be measured, a reduced height scan of ±0.9 m is recommended to meet 10-m OATS requirements. This results from a trigonometry analysis. The negative scan is made to collect the potential contributions of radiator patterns directed downwards.

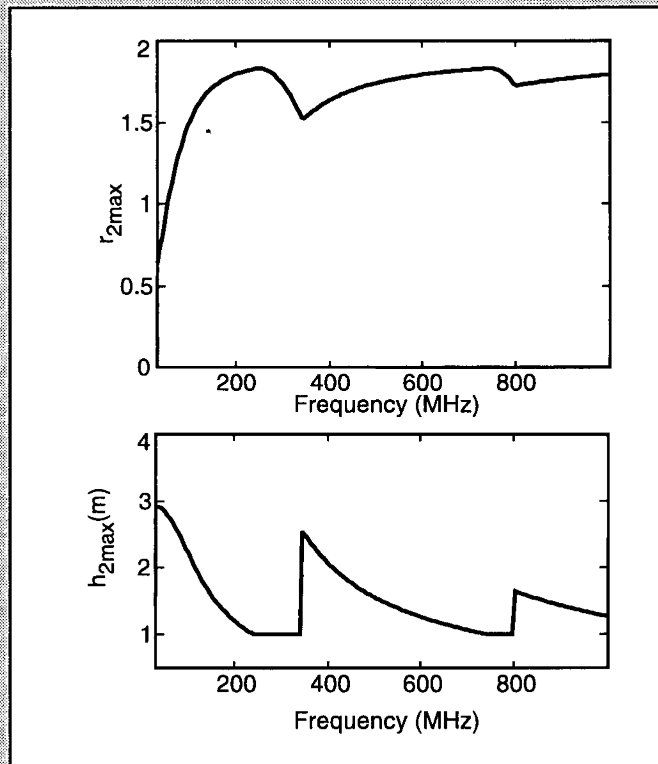

Figure 2. Conversion Factor from 3-m Free Space to 3m OATS and the Related Maximum Scan Height for Horizontal Polarization.

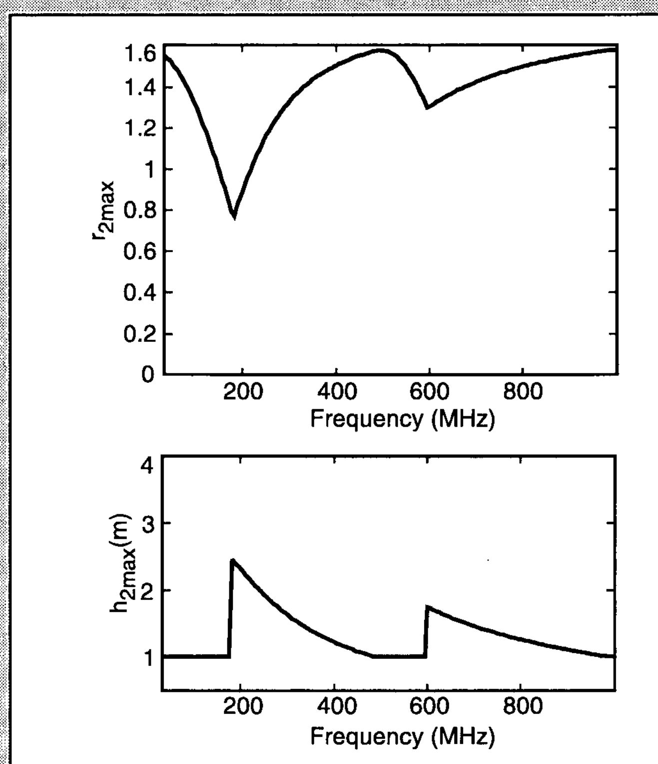

Figure 3. Conversion Factor from 3-m Free Space to 3-m OATS and the Related Maximum Scan Height for Vertical Polarization.

EXPERIMENTAL VERIFICATION

To verify this theory, a fully anechoic chamber (7 m x 4 m x 3 m) with a measurement distance of 3 m, in accordance with the ANSI C63.4/1992 calibration for alternative sites, was designed and tested. The antennas were basically free space calibrated and traceable to national standards. The ferrite material used for the chamber presents a typical reflectivity of 12 to 19 dB from 30 to 1000 MHz. The correlation to the 10-m OATS was better than ±4 dB (Figures 10 and 11).

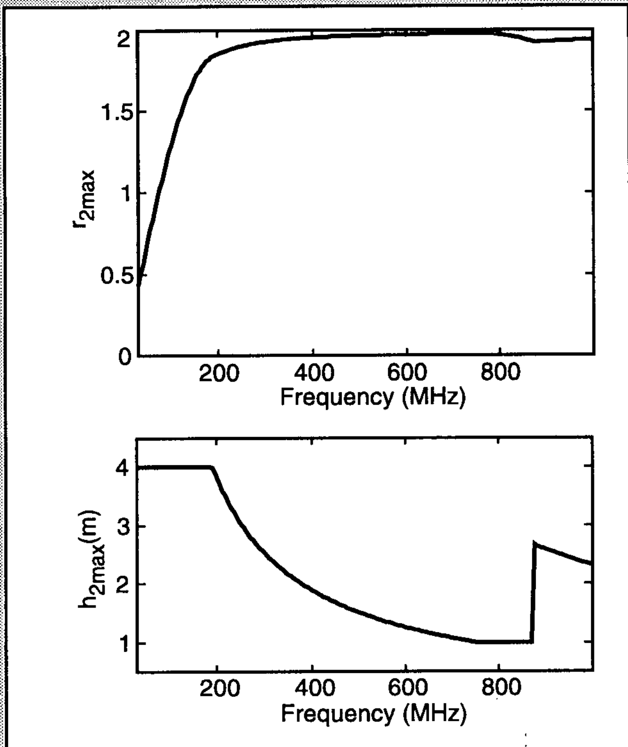

Figure 4. *Conversion Factor from 10-m Free Space to 10-m OATS and the Related Maximum Scan Height for Horizontal Polarization.*

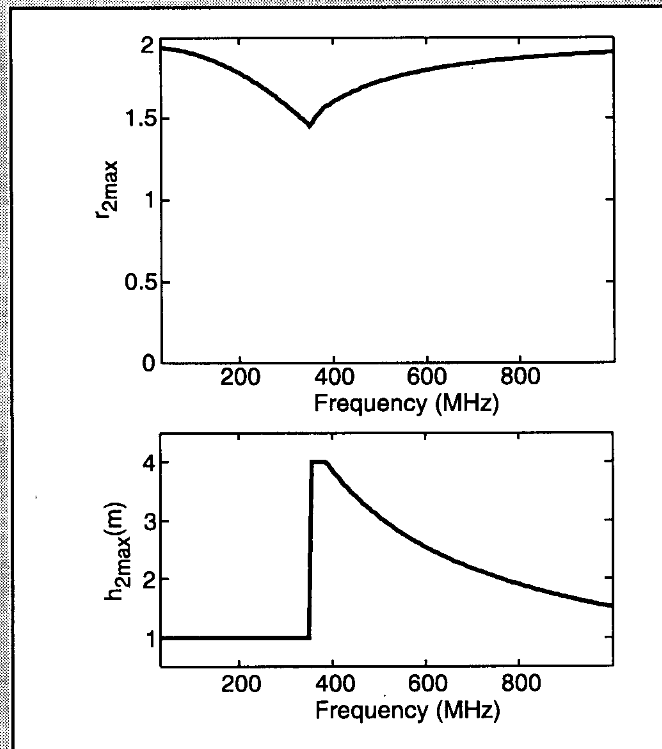

Figure 5. *Conversion Factor from 10-m Free Space to 10-m OATS and the Related Maximum Scan Height for Vertical Polarization.*

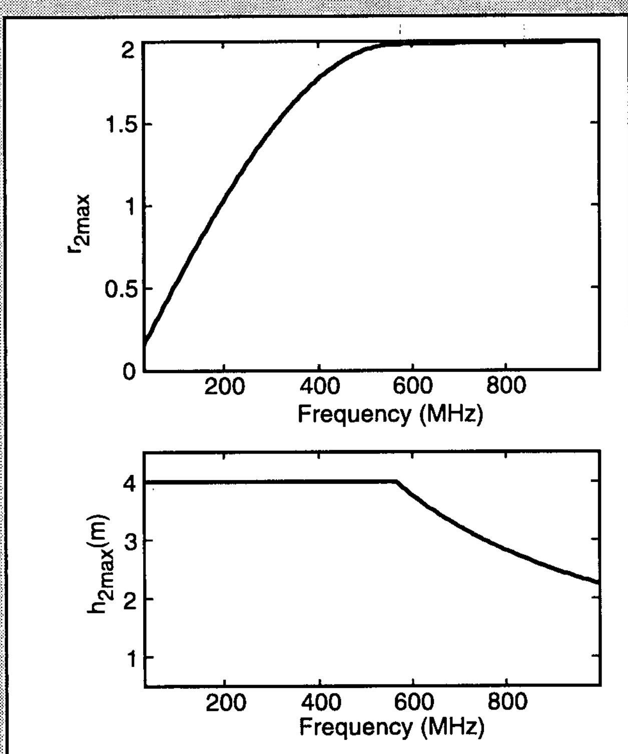

Figure 6. *Conversion Factor from 30-m Free Space to 30-m OATS and the Related Maximum Scan Height for Horizontal Polarization.*

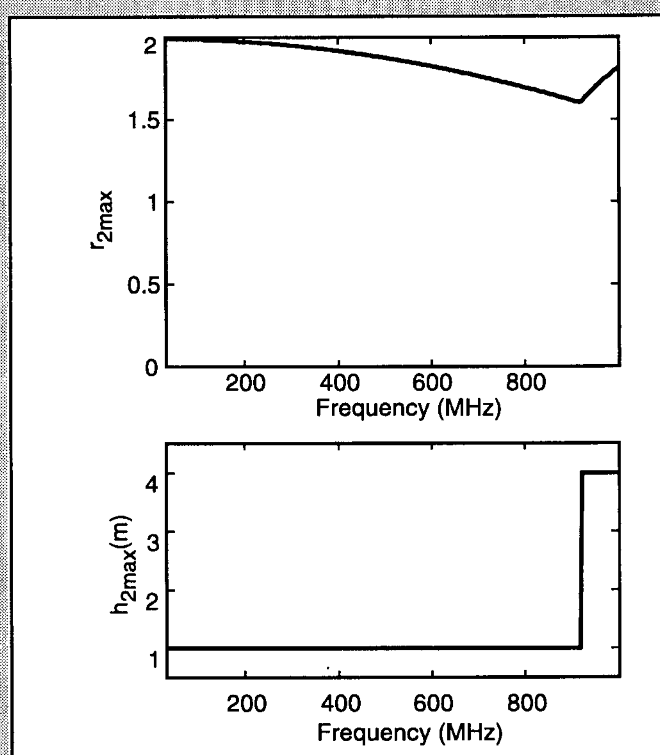

Figure 7. *Conversion Factor from 30-m Free Space to 30-m OATS and the Related Maximum Scan Height for Vertical Polarization.*

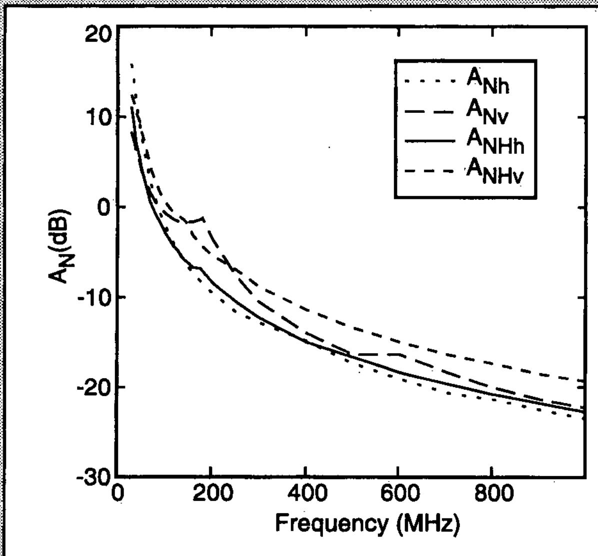

Figure 8. Theoretical Normalized ANSI 3-m Site Attenuation.

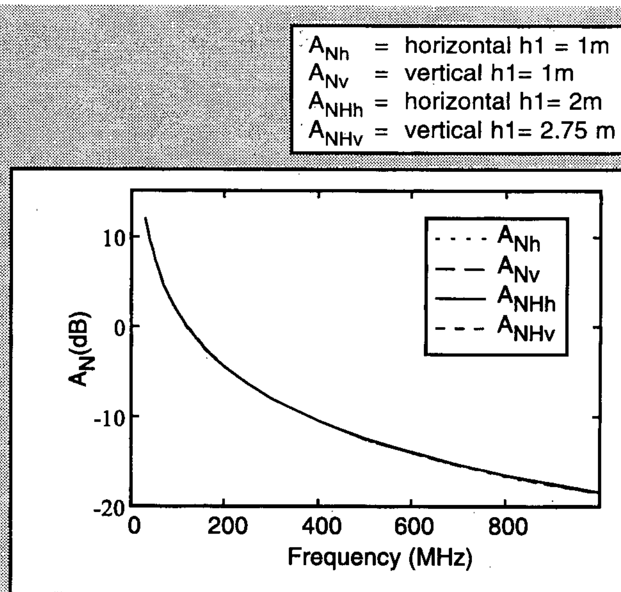

Figure 9. Theoretical Normalized ANSI 3-m Site Attenuation Converted to Free Space (nomenclature see Figure 8).

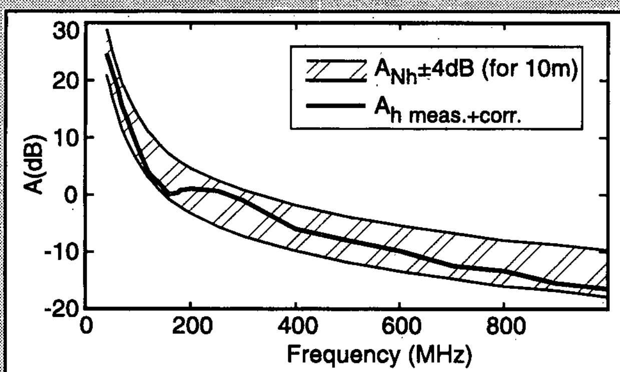

Figure 10. Horizontal Site Attenuation of a 3-m FALC Correlated to a 10-m OATS.

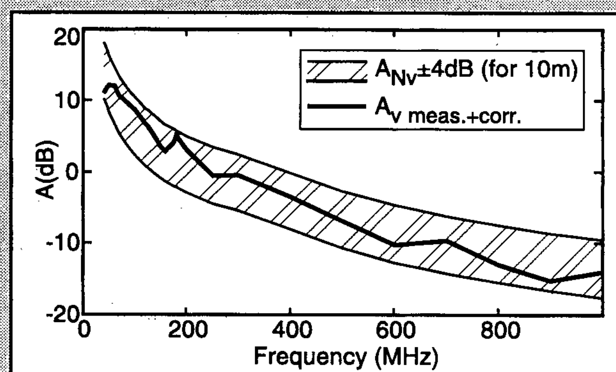

Figure 11. Vertical Site Attenuation of a 3-m FALC Correlated to a 10-m OATS.

In accordance with the ANSI requirement for alternative sites, a volumetric check was also done by moving the antenna 0.75 m from the center position. The diagonal distance was used for the measurements. The actual antenna mast and turntable were installed. The following equipment was used immediately after external calibration: a receiver, including a 50-ohm tracking generator, biconical antenna, and a log periodic antenna.

Additionally, many tests were performed at other accredited EMC labs, demonstrating excellent agreement within the known tolerances. The investment of the chamber was less than $300,000. The chamber also fulfills the immunity requirements (IEC 801-3, ENV 50140). The chamber has been successfully used for more than two years.

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SOURCES

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