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# Alternative Techniques for Some Typical MIL-STD-461/462 Types of Measurements

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Most testing for MIL-STD- 461/462 is performed in a shielded enclosure (screenroom) which leads to uncertainty in the measurement of emissions from electronic equipment, or the susceptibility of equipment to electromagnetic radiation. Possible alternative techniques for improved measurements in a screenroom have been developed by the National Institute of Standards and Technology (NIST). These techniques are covered in this report.

This report presents antenna factors determined in a screenroom which was partially loaded with radio frequency (rf) absorbing material, using the two-antenna insertion-loss technique. These antenna factors are compared with the antenna factors obtained in an unloaded screenroom, a fully loaded screenroom (anechoic chamber), and at an open field site. In addition, measurements at the eight corners of a cube were made in the partially loaded and fully loaded screenroom to determine the field deviation at the eight corners of the cube with respect to its center. Also, measurment improvements are quantified for the electric-field strength beneath a single-wire transmission line, in a partially loaded screenroom. Finally, electric-field measurements were made on top of the grounded table in a partially loaded screenroom to determine the field strength variation above the table.

Key words: antenna factor; electromagnetic compatability; field strength standards; loaded screenroom; military standards; screenroom measurements.

## 1. Introduction

This report describes a follow-on project to that which was covered in a previous National Bureau of Standards (NBS) report [1] to the same sponsor. That report of October 1986, NBS Tech Note 1300, is titled "Assessment of Error Bounds for Some Typical MIL-STD-461/462 Types of Measurements". The work was sponsored by the U.S. Army Aviation Systems Command (AVSCOM) in St. Louis, Missouri. NBS Tech Note 1300 deals with the instrumentation and equations for screenroom measurements which are used by the U.S. Army for electromagnetic compatability (EMC) testing and calibrations. The report relates to Military Standards 461 and 462, which are standards issued by the U.S. Department of Defense (DOD) for use by all departments and agencies within the DOD. MIL-STD-461A is titled "Electromagnetic interference characteristics, requirements for equipment" and includes the specified limits for radiated and conducted radio frequency (rf) emissions, both narrowband and broadband [2]. It is dated August 1, 1968 and supersedes MIL-STD-461. MIL-STD-462 was issued by DOD on July 31, 1967, and is titled "Electromagnetic interference characteristics, measurement of" [3]. These two standards, MIL-STD-461A and MIL-STD-462, will generally be referred to here collectively as MIL-STD-461/462.

Most EMC testing for MIL-STD-461/462 is performed in a shielded enclosure (screenroom) rather than at an open field site because of lower cost, shielding from ambient fields, and convenience. This MIL-STD, which is used in the procurement of many military and other government systems, has several recognized problems. Possible errors and large uncertainties can occur in the measurement of electromagnetic (EM) emissions from electronic equipment, or the susceptibility of this equipment to EM radiation. The uncertainty is increased when performing the measurements inside a screenroom where multiple reflections and antenna impedance perturbations occur. An assessment and discussion of the error bounds is covered in NBS Tech Note 1300 [1].

In the present report, measurement improvements have been quantified for generating standard (known) electric fields beneath a single-wire transmission line in a partially-loaded screenroom. That is, a typical screenroom was loaded with pieces of rf absorbing material at some of the surfaces of the screenroom. The MIL-STD describes a laboratory method for producing a field having known E and H magnitudes in a shielded room using a long-wire antenna. The objective of NIST testing was to evaluate the field level and uniformity in this partially loaded screenroom, and compare these measurements with theoretically calculated values and with measurements made previously [1].

Also, measurements have been performed in a partially loaded and a fully loaded screenroom (anechoic chamber) and on the NIST ground screen to determine antenna factors using the two-antenna method. Data of antenna factors determined in the partially loaded screenroom and in the fully loaded screenroom (anechoic chamber) are presented and compared with those determined in Tech Note 1300 [1] and at the NIST open field site.

In addition, measurements of electric field at the eight corners of a cube were made in the partially loaded and fully loaded screenroom to determine the electric field deviation at the eight corners of a cube with respect to its center. The electric-field strengths in the partially loaded screenroom were measured with and without a metal box inside the cube. In the anechoic chamber the electric-field strength was measured only on the eight corners of the empty cube. The data are evaluated and compared.

Finally, electric-field measurements were made on top of the grounded table of the partially loaded screenroom, to determine the field strength variations which may occur above this type of table.

## 2. EM Field of a Single-Wire Transmission Line in a Partially Loaded Screenroom

The long-wire antenna, as illustrated in figure 1, is fabricated in a shielded enclosure for use when the test items are too large to be placed in a parallel-plate line or other standard-field chamber. The objective of the NIST tests was to determine the electric field uniformity along the length of the long-wire line in a partially loaded screenroom and also to compare the measured field strengths with theoretically calculated values as a function of vertical distance below the wire. This long-wire antenna is actually the center conductor of a transmission line or TEM cell formed by the walls of the screenroom acting as the outer conductor. The technique for matching the generator source impedance to the characteristic impedance of the long-wire transmission line is described in NBS Tech Note 1300 [1] on pages 3.1-3.3.

The equation for calculating the magnitude of the E field beneath a long-wire antenna is given in MIL-STD-461[2]. The theoretical field strength at a distance c (see figure 1) vertically below the center of the long-wire in a screenroom is given approximately by [1]

$$E=\frac{60\ V}{(Z_0+Z_g)}\left[\frac{1}{c}-\frac{1}{c+2a}-\frac{1}{c-2b}+\frac{1}{c-2a-2b}\right.$$

$$\left.+\frac{1}{c+2a+2b}-\frac{1}{c-2a+4b}+\frac{1}{c+4a+2b}+\frac{1}{c-4a-4b}\right], \quad (1)$$

where E =electric field strength at a distance c below the center of the long-wire, V/m,

V =RMS voltage at the input to the transmission line, V,

$Z_0$= characteristic impedance of the line, Ω,

$Z_g$=impedance of the generator, Ω,

a =distance from the horizontal wire to the ceiling of the screen room, m,

b =distance from the wire to the floor, m, and

c =vertical distance from the wire to the field point P, m.

When measuring field strength using a calibrated transfer probe such as the NIST EFM-5 [4], the probe should not distort the field being measured. Equation (1) was used to calculate the electric field strength and this was compared with the measured field for signal frequencies of 1, 2, 3, 5, 7.5, 15, 22, and 30 MHz. The vertical distance (c) to the wire ranged from 0.2 m to 0.8 m below the center of the long wire. The differences between calculated field using eq. (1), and field strengths measured with the EFM-5 probe (in dB), were plotted versus distance to the wire. That is, the dB "differences" plotted in figure 2 were obtained from the expression [20 log (calculated E/measured E)].

Figure 2 is a graph of the calculated-to-measured field strength ratio as a function of distance below the center of the long-wire antenna, in a partially loaded screenroom. The three lowest frequencies in the figure (1, 2 and 3 MHz) are all close to the 0 dB line and thus show the least difference between the calculated and measured values. However, it can be seen that the variation of field strength as a function of distance from the wire (slope of the graph) is generally greater at these lower frequencies. The data indicate that the electric-field strength is frequency dependent,but does not vary in a systematic manner versus frequency.

## 3. Measurement of Antenna Factor in a Partially Loaded Screenroom

The measurement of electromagnetic fields in a shielded enclosure using the MIL-STD 461/462 approach has serious problems because of uncertain antenna factors caused by multipath reflections from conductive surfaces. The accuracy of measurements in a shielded enclosure and historical background dealing with the reliability of measurements in screenrooms, error bounds of antenna factors measured in a screenroom, and reliability of measured antenna factors for making screenroom measurements are discussed in NBS Tech Note 1300 [1] on pages 4.1-4.5.

In this report, measurements of antenna factors in partially loaded and fully loaded screenrooms are presented and compared with the antenna factors determined previously for the same antennas in an unloaded screenroom and at the NIST open-field site. To measure antenna factors in a screenroom, the two-antenna method described in MIL-STD-461A was used. Figure 3 shows the instrumentation and configuration used for making these measurements. The screenroom was loaded with rf absorbing material at the two ends of the room, with the pyramidal points facing parallel to the direction of propagation of the electromagnetic wave. Figure 4 shows this absorbing material as placed in the shielded room. The procedure described in the MIL-STD requires antennas with "identical" characteristics. The equation used for determining antenna factor is

$$K = 10 \ \ell og\left[\frac{F \ V_T}{d \ V_R}\right] - 16 \qquad (2)$$

where $K$ = antenna factor, dB,

$F$ = frequency, MHz,

$V_T$ = measured voltage at the position of the transmitting antenna when the antenna cables are directly connected, V,

$d$ = distance between the two antennas as shown in figure 3, m, and

$V_R$ = measured voltage of the receiving antenna when the radiated path is inserted, V.

Using eq (2) and the equipment configuration of figure 3, one can determine an in situ antenna factor for two identical antennas at any location in a given shielded enclosure. The derivation of equation (2) is given in reference [1], pp 4.5-4.6.

Figure 5 is a sketch of the screenroom layout used for measuring the antenna factors of two biconical antennas in the NIST screenroom. The two antennas were located in three different positions as shown in the figure. Figure 6 gives the results for the unloaded screenroom measurement, for the three positions of figure 5, with a separation distance of 1 m between antennas. Figure 7 gives the results for the partially loaded screenroom, for the same three positions with the same separation distance of 1 m between antennas. A comparison of figures 6 and 7 indicates that partial loading of the screenroom achieves a reduction in the screenroom (cavity) Q, thereby reducing the screenroom resonance effects and multipath reflections. As a consequence the maximum excursions in measured antenna factor are reduced by about 27 dB.

Antenna factors were also measured in the NIST anechoic chamber to determine the possible beneficial effect of measuring antenna factor in a fully loaded screenroom. Figure 8 shows the antenna factors measured at the following four sites: (a) in the partially loaded screenroom, (b) in the unloaded screenroom at position 1, (c) in the fully loaded screenroom (NIST anechoic chamber), and (d) at the outdoor field site above the NIST groundscreen. All these antenna factor measurements were made with an antenna separation of 1 m. As one progresses from an unloaded to a fully loaded screenroom, the antenna factor values approach those which were obtained at the NIST open field site above a groundscreen. These data indicate that a fully loaded screenroom (NIST anechoic chamber) is more likely to produce results which approach the free-space values, even though the rf absorbing material in the anechoic chamber is not designed for frequencies below 300 MHz.

## 4. Uniformity of Electric Field Generated by a Transmitting Biconical Antenna Within a Cubic Volume of a Partially Loaded Screenroom

One criterion for a good standard-field setup is the uniformity of the generated field as a function of field point position and frequency. Because a conventional screenroom has measurement problems due to multiple reflections, resonances, and distortion of the electromagnetic field, it is difficult to predict the field generated by a transmitting antenna at a given receiving point in the screenroom. Using the NIST designed EFM-5 probe, after calibrating it in a TEM cell [5], we measured the electric field in the partially loaded screenroom. The EFM-5 probe uses electrically short dipoles (5 cm long) that have a known response over the frequency range of 0.5 to 1000 MHz. The probe uses high resistance plastic leads and can be used to measure the field strength at a point location as a function of frequency without perturbing or distorting the field being measured.

To measure the electric field uniformity in the partially loaded screen room, a cubical volume midway between the two ends of the room was defined by the eight corners of an empty dielectric box. The selected position was with the center of the box 1 m above the floor and at a distance of 1 m from the center of the transmitting biconical antenna. The length of each side of the cubical box was 0.6 m. The location of the transmitting antenna was the same as that shown for the transmitting antenna in figure 5, position 1. Figure 9 shows the cubical box with the top four corners designated as 1A through 4A and the bottom four corners designated as 1B through 4B. A constant field strength was maintained at the center of the cube throughout the frequency range of 20 to 200 MHz; data were taken in 10 MHz increments. That is, with a constant field amplitude applied at the center of the cube, as measured with the EFM-5 probe, the field was then measured at the eight corners of the cube. Figure 10 shows the measured electric field strength differences at positions 1A through 4A, with respect to the strength at the center of the cube. Figure 11 shows the measured field differences at positions 1B through 4B.

Field scattering by items being tested for EM susceptibility may introduce additional error when determining the value of an electric field being generated. In order to ascertain the severity of field distortion caused by a nearby conducting object, a small metal box of dimensions 0.21 m wide by 0.16 m high by 0.28 m deep was placed in the center of the cubic test volume (large dielectric box). An EM field with the same unperturbed magnitude as that applied previously without the metal box was generated at the center of the test volume. The metal box was then introduced, and field strength measurements were made to determine the change in magnitude of the electric field at the 8 corners of the cubical volume. Figure 12 is a pictorial representation of this metal box in the center of the dielectric cube. Figure 13 is a graph of the electric field differences between the empty and loaded cube, measured at the top 4 corners of the cube. Figure 14 shows the differences measured at the bottom 4 corners of the cube. The data show that for this size of metal box, the field-strength perturbations at the 8 corners of the large empty cube, produced by introducing the small metal box in the center of the cube, were all less than ± 2 dB.

## 5. Uniformity of Electric Field Generated by a Transmitting Biconical Antenna Within a Cubic Volume of a Fully Loaded Screenroom

To measure the electric field perturbations in a fully loaded screenroom (anechoic chamber), the dielectric cube was placed inside the chamber at a 1 m distance from the transmitting biconical antenna. This cubic volume is the same as the one used in the partially loaded screenroom. A constant field was maintained at the center of the cube as measured with the EFM-5 probe. That is, with a constant field amplitude applied to the center of the cube, the field was measured at the eight corners of the cube. Figure 15 shows the measured electric field strength differences with respect to the center of the cube at positions 1A through 4A. Figure 16 shows the electric field differences at positions 1B through 4B. Comparison of the data of figure 10 with that of figure 15, and figure 11 with figure 16, indicate that a fully loaded screenroom has less perturbation than a partially loaded screenroom. Also, the measured field strength differences with respect to the center of the cubic volume, (0 dB reference) are much less for the fully loaded room, especially at frequencies above about 100 MHz.

## 6. Electric Field Distribution on the Grounded Table in a Screenroom

The purpose of the grounded table or "test stand" in a MIL-STD screenroom is to provide a convenient bench on which to place test equipment. MIL-STD-462 requires that the minimum table size be 2.25 m (24 ft ) and the depth be at least 0.76 m (2.5 ft). To assure electrical continuity of the ground plane of the table with the shielded enclosure, MIL-STD-462 states that the bonding points shall be placed at a distance no greater than 0.30 m (1 ft) apart. In practice, it is common to bond the seam along the entire length of the bench.

There are three recommended procedures for making susceptibility tests above the grounded table in a screenroom: (1) monitor the field strength with a receiving antenna at the test sample, (2) monitor at $180^0$ or another angle from the test sample, and (3) precalibrate and regenerate the electric field. To monitor the field with a receiving antenna at the test sample, the antenna factor of the receiving antenna must be known. Data were presented in a previous report to show that this technique is not very accurate and the error bounds are quite large [1]. Monitoring the field strength at $180^0$ has an even greater uncertainty and should thus be avoided. To precalibrate the receiving antenna after placing it in the position of the test sample, and then regenerate the field strength with the test sample in place of the antenna, will change the conditions of the field. Precalibration and regeneration of the electric fields are feasible only if the test sample is in place and the receiving probe is calibrated and does not perturb the electric field [4].

The NIST EFM-5 probe was used to plot the measured electric field strength generated by a transmitting biconical antenna at various positions on top of the grounded table. Figure 17 shows the locations of positions 1 through 0 on the table where field strength measurements were made. The transmitting biconical antenna was placed with its center at a distance of 2 m from the reference position R. This setup was used to assure that a constant field strength was generated at position R throughout the frequency range of 20 to 200 MHz. The EFM-5 probe was then placed at positions 1 through 0 and the field strength measured, with the same constant field applied at position R. These measurements were made under two conditions, with and without rf absorbing material placed on the wall above the table. The total area covered by the absorbing material was 3.25 m (35 ft ). The EFM-5 probe was placed at a height of 0.23 m (0.75 ft) above the top of the table.

The positions 1 through 5 and positions 6 through 0 had successive displacement distances of 0.5 m.

Figure 18 shows the measured electric field differences of positions 1 through 0 with respect to position R, with the screenroom wall loaded with absorber. Figure 19 shows the measured field strength differences with the wall unloaded. Figure 20 is a graph for position 0 in both the loaded and unloaded configurations. The data indicate that there is a maximum difference of 16 dB in field strength in the loaded configuration and a maximum difference of 20 dB in the unloaded configuration. These data indicate that it is important to carefully measure the field strength configuration when radiating a sample for immunity tests, rather than rely on theoretically calculated values for the field strength.

## 7. Summary

The measured E field levels directly beneath the center conductor of a long-wire antenna vary both with frequency and distance from the wire, in either an empty or partially loaded screenroom. Data were taken at distances varying between 0.2 and 0.8 m below the wire. This variation in field strength as a function of frequency, for a given measurement location, is up to 10 dB over the frequency range of 1 to 30 MHz. The <u>variation</u> of field strength difference between measured and calculated values, as a function of distance below the center conductor of the long-wire, is greater at the lower frequencies (up to 4 dB at 1 MHz) than at the higher frequencies. However, the average field values at a given distance below the wire are generally closer to the theoretical values at the lower frequencies.

The two-antenna insertion-loss method as described in MIL-STD-461A was used at NIST to determine in situ antenna factors in a partially loaded screenroom. Antenna factors were also measured in a fully loaded screenroom (anechoic chamber). The maximum antenna factor difference measured at a given frequency

and location between the unloaded and partially loaded screenroom, was about 30 dB. The maximum difference at a given frequency and location, between the partially loaded and fully loaded screenroom, was about 12 dB. Comparison of antenna factors between the fully loaded room and the NIST open field site indicates that the maximum difference in this case is only 2 dB.

Measurements of the electric field strength at the 8 corners of a cubical volume indicate a variability of about 24 dB with respect to the center of the cube when measured in the partially loaded screenroom. However, the variation of field strength when measured in a fully loaded room is reduced to about 14 dB. When the field strength is measured at the corners of the cube, and a metal box is placed at the center of the cube, the difference with/without the metal box is about ± 2 dB maximum over a frequency range of 20 to 200 MHz.

Measurements of the E field on top of the grounded table in a screenroom, for positions 1 through 0, indicate that variations may be as great as 28 dB with the wall above the table loaded with rf absorber. Without absorber, the variations of E field may be up to 32 dB.

## 8. Conclusions

The equation given in MIL-STD-462 for calculating the electric field magnitude beneath a single-wire transmission line in a typical screenroom is inadequate for either an unloaded or a partially loaded screenroom. The data obtained at NIST indicate that the field strength varies with frequency in a nonsystematic manner. The measured E field values beneath a single-wire line in a partially loaded screenroom indicate that reflections cause field perturbations which are frequency dependent. However, these variations of the field strength as a function of distance below the center conductor are not as pronounced as those in an unloaded screenroom [1].

Measurements of antenna factor in a screenroom by the two-antenna insertion-loss technique are not an accurate parameter for subsequent measurement of field strength with the calibrated antenna, either in free space or at another location in the screenroom. Large errors may occur even in a partially loaded screenroom because of room resonances, multiple reflections, and distortion of the field. Antenna factors determined in a partially loaded screenroom are slightly more accurate, relative to the open field site antenna factors, but they are still subject to variations as a function of antenna placement and size of the shielded enclosure. If the size of the screenroom could be increased and the enclosure fully loaded with rf absorbing material, the error bounds would diminish. In this case a measurement with the calibrated antenna would lead to a more accurate field strength determination.

Our general conclusion is that it is very beneficial to add absorbing material to the walls of a screenroom, both for measurement of emissions and for susceptibility testing. It is even more beneficial to work inside an anechoic chamber. This conclusion applies even when using microwave absorbers which are specified as "good" only above 500 MHz. The data indicate that the beneficial effects of this partial loading by microwave absorbers are noticeable at frequencies as low as 25 MHz.

Measurements of the E-field variation within a cubic enclosure and on top of the grounded table within a screenroom indicate the magnitude of the problems in properly determining field strength in a screenroom environment, both in the unloaded and partially loaded configurations.

## 9. Recommendations

EMC testing in a shielded room having highly conductive surfaces is accompanied by large measurement uncertainty, due to multiple reflections and antenna impedance perturbations. All of the experimental data show large variability of antenna factors and field strength in the screenroom as a function of frequency and location. Although the error bounds are reduced by partially loading the screenroom with rf absorbing material, there is still much ambiguity in determining field strength within the enclosure when using standard measurement procedures. The following recommendations with respect to the use of a shielded room are made in order to achieve greater accuracy when making EMC measurements.

1. A shielded room should be used only when it is not feasible to use other facilities, such as an open field site or a fully loaded screenroom.

2. To minimize the measurement uncertainty caused by making measurements in different types of shielded enclosures, all screenrooms should be standardized with respect to their dimensions and internal geometrical configuration. The standard dimensions should be large enough that the walls and other surfaces of the enclosure can be loaded with rf absorbing material. A partially loaded screenroom will minimize the uncertainty. However, the problem of reflections will still introduce significant errors in the measurements.

3. Because the fields in a shielded room change with placement of the equipment being tested, an E-field probe should be used as a transfer standard for checking the calculated fields in a screenroom environment. The E-field probe is a small electrically isolated antenna that has a known response over a given frequency range. Such a probe can be used to measure the field strength as a function of frequency at each desired test location.

## 10. References


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[2] MIL-STD-461A. Military Standard, Electromagnetic Interference Characteristics, Requirements for Equipment; 1968 August 1. Also Notice 1, 1969 February 7; Notice 2, 1969 March 20; Notice 3, 1970 May 1; Notice 4, 1971 February 9; and MIL-STD-461B, Notice 1, draft, 1983 January 5.

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[5] Crawford, M.L. Generation of Standard EM Fields using TEM Transmission Cells, IEEE Trans. Electromag. Compat., EMC-16 No. 4, pp 189-195 November 1970.

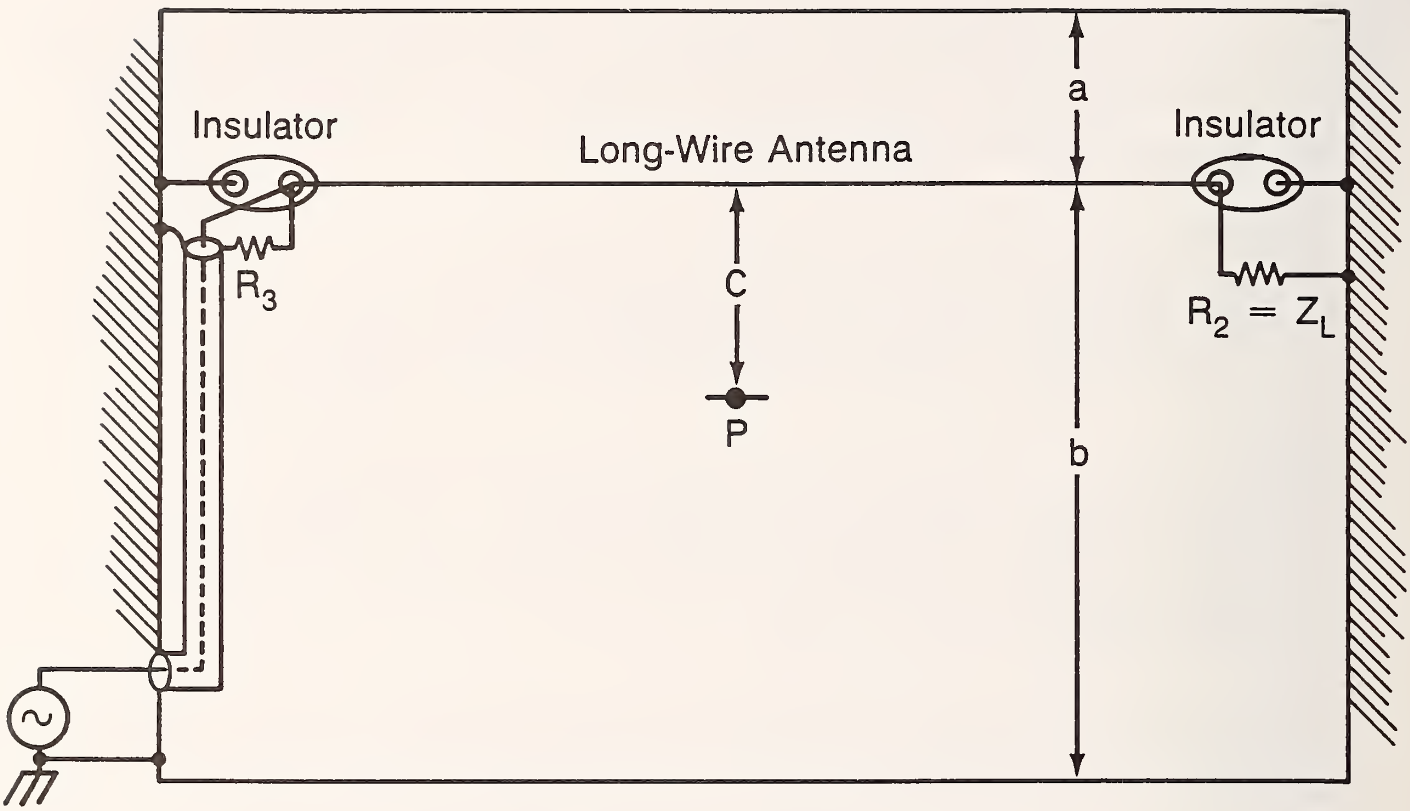



Figure 1. The long-wire antenna configuration in a screenroom.

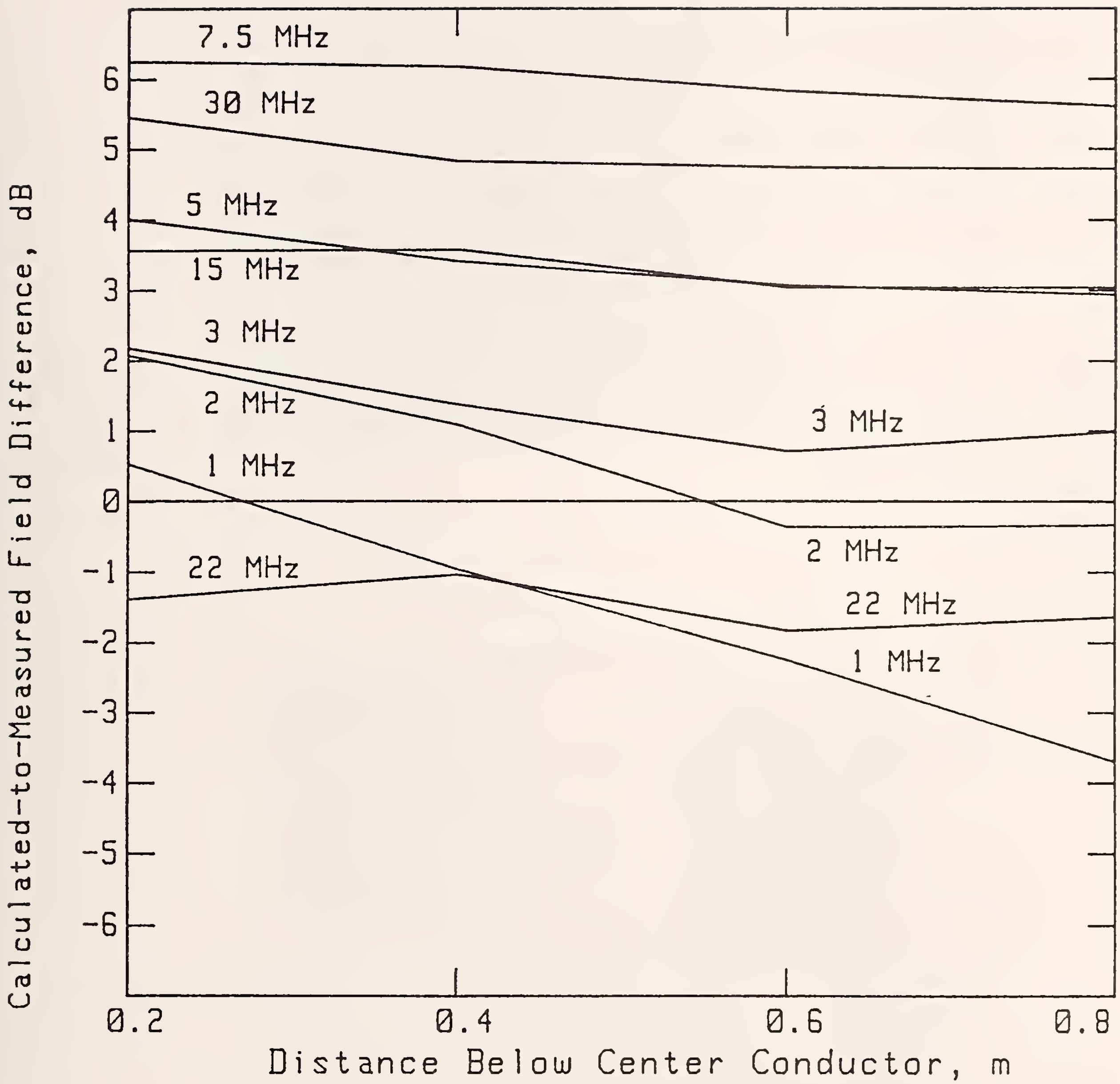



Figure 2. Calculated-to-measured field strength versus distance below the long-wire for selected frequencies in a partially loaded screenroom.

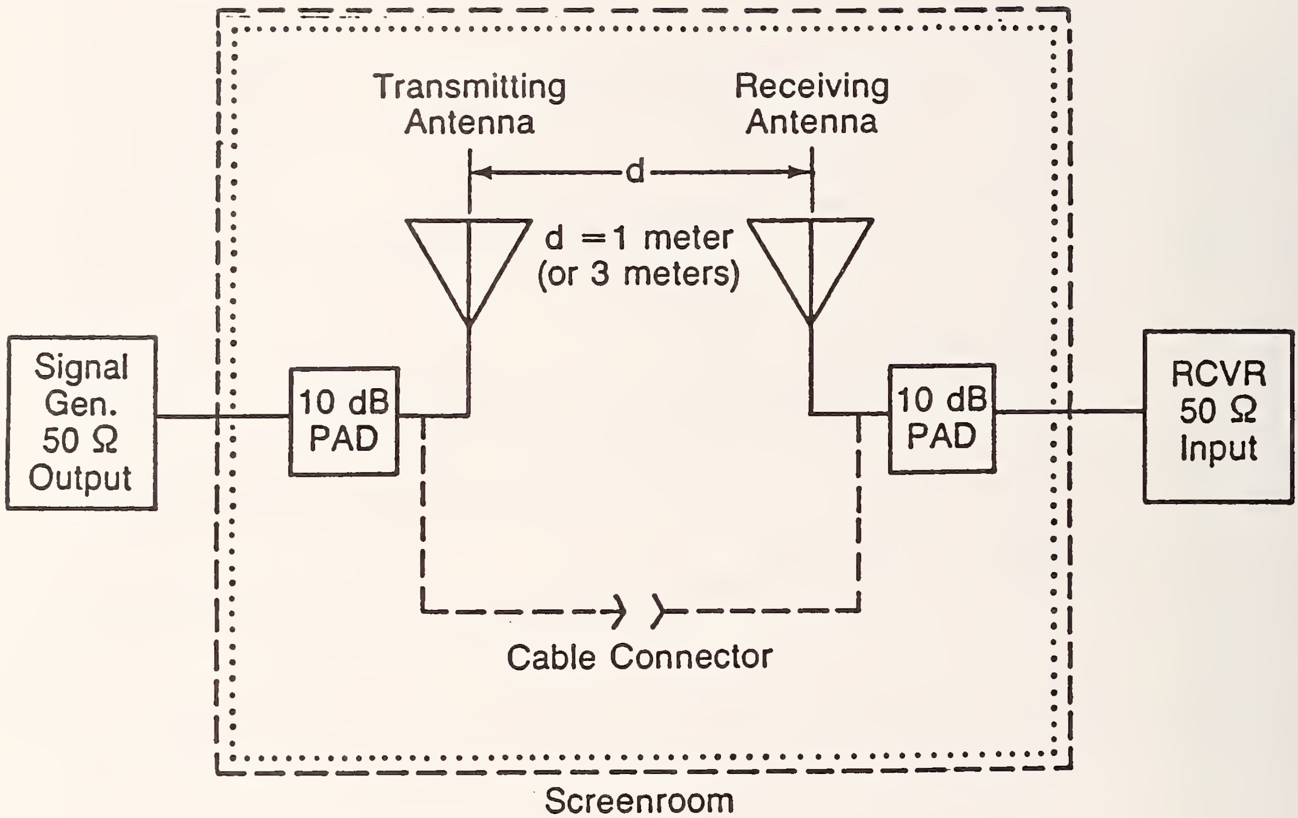
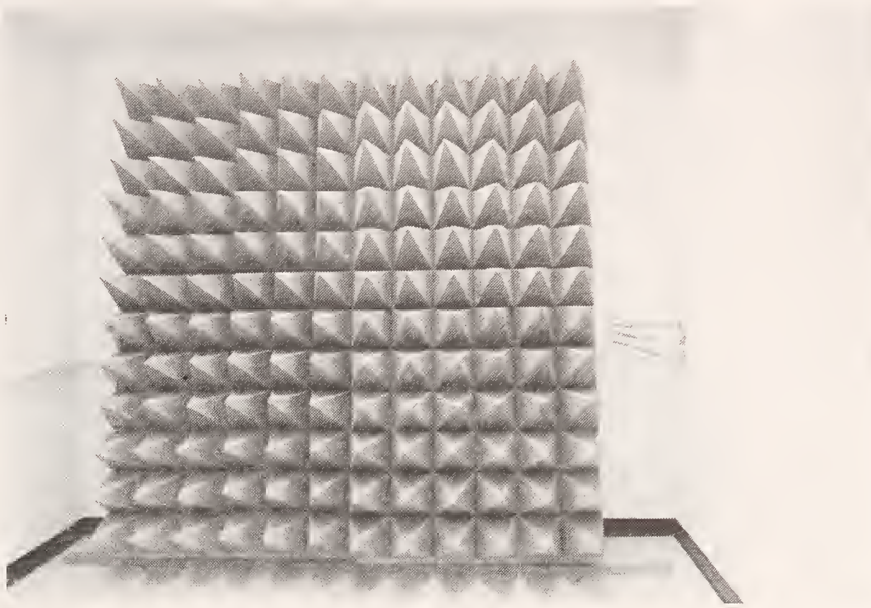
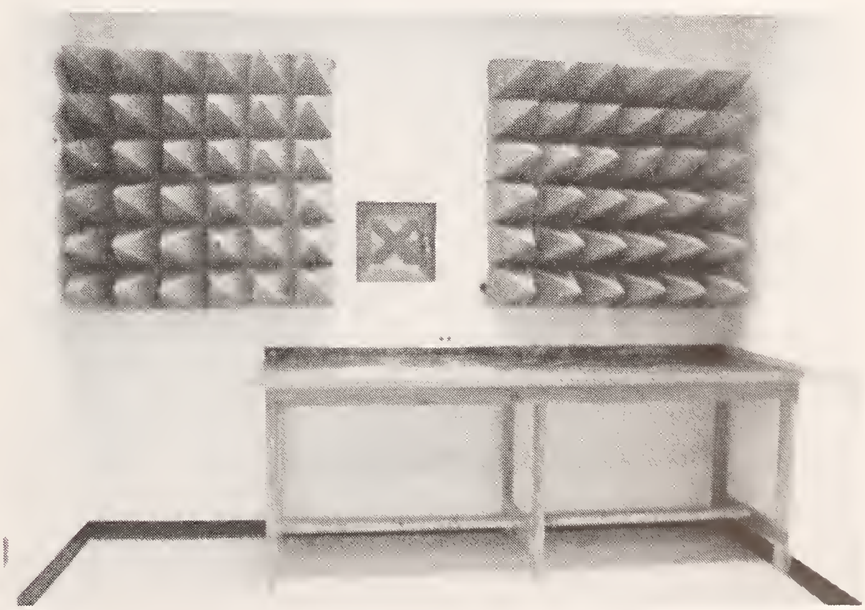



Figure 3. Test setup required by MIL-STD-461A for determination of antenna factors.

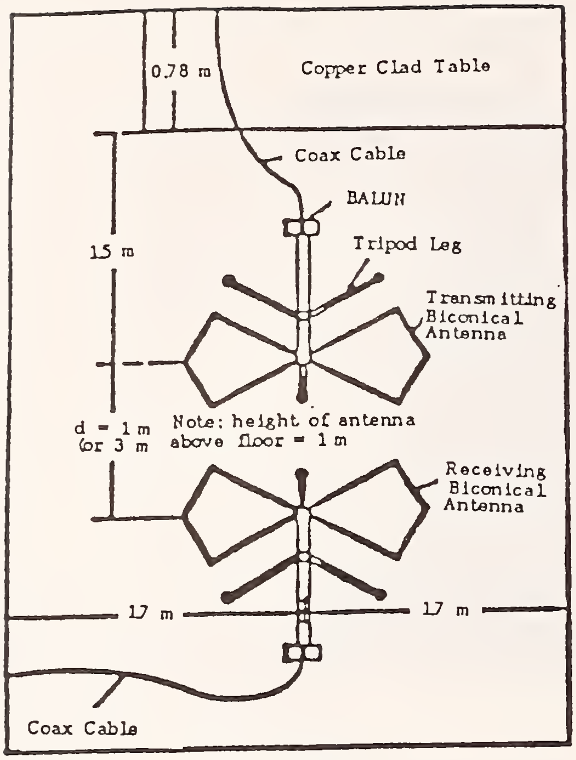


a. Rear end of screenroom

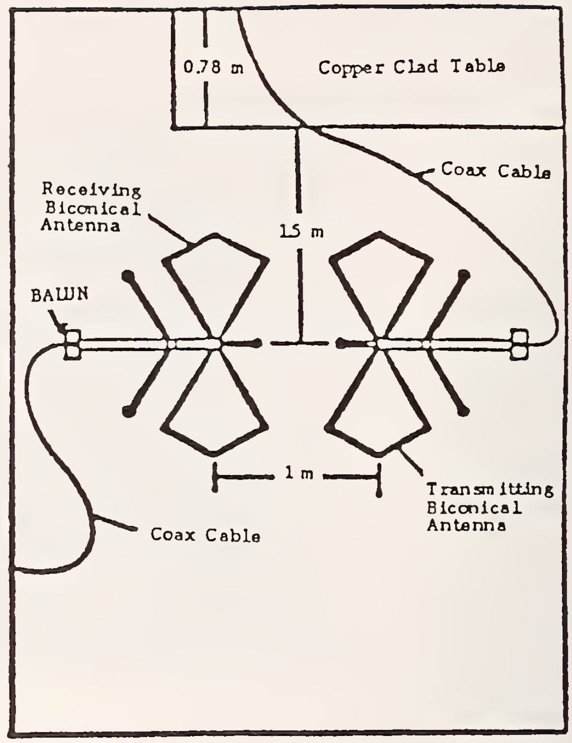


b. Front end of screenroom

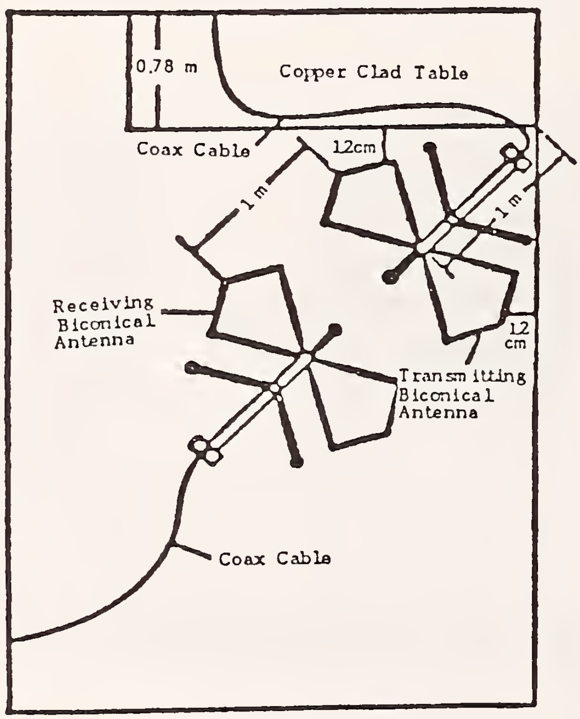
Figure 4. Placement of the rf loading (absorber material) in the NIST shielded room.




Position 1




Position 2




Position 3

Figure 5. Sketch of three screenroom configurations for measuring the antenna factor of two identical antennas.

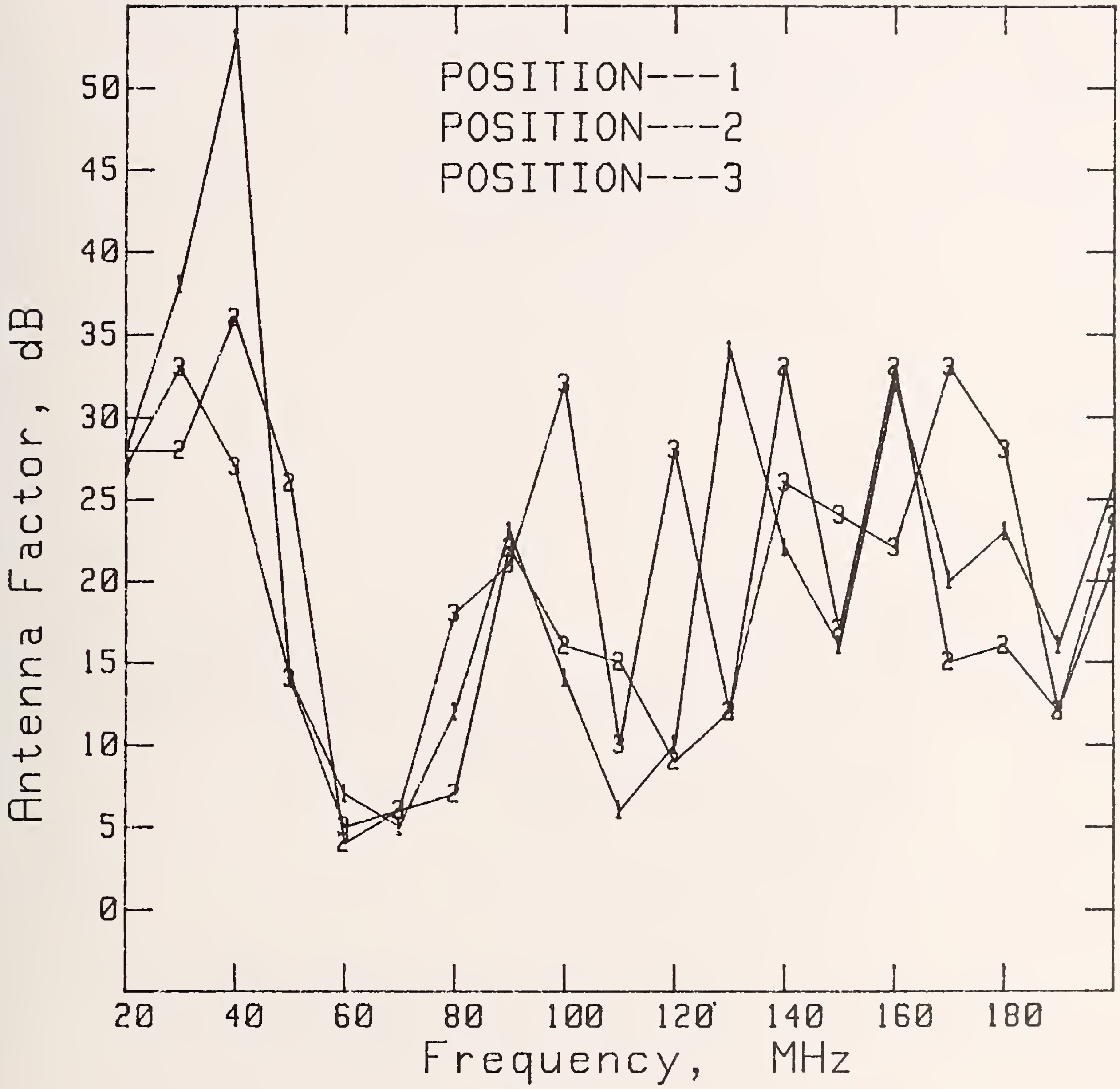



Figure 6. Antenna factors measured in an unloaded screenroom at a separation distance of 1 m, for three selected positions.

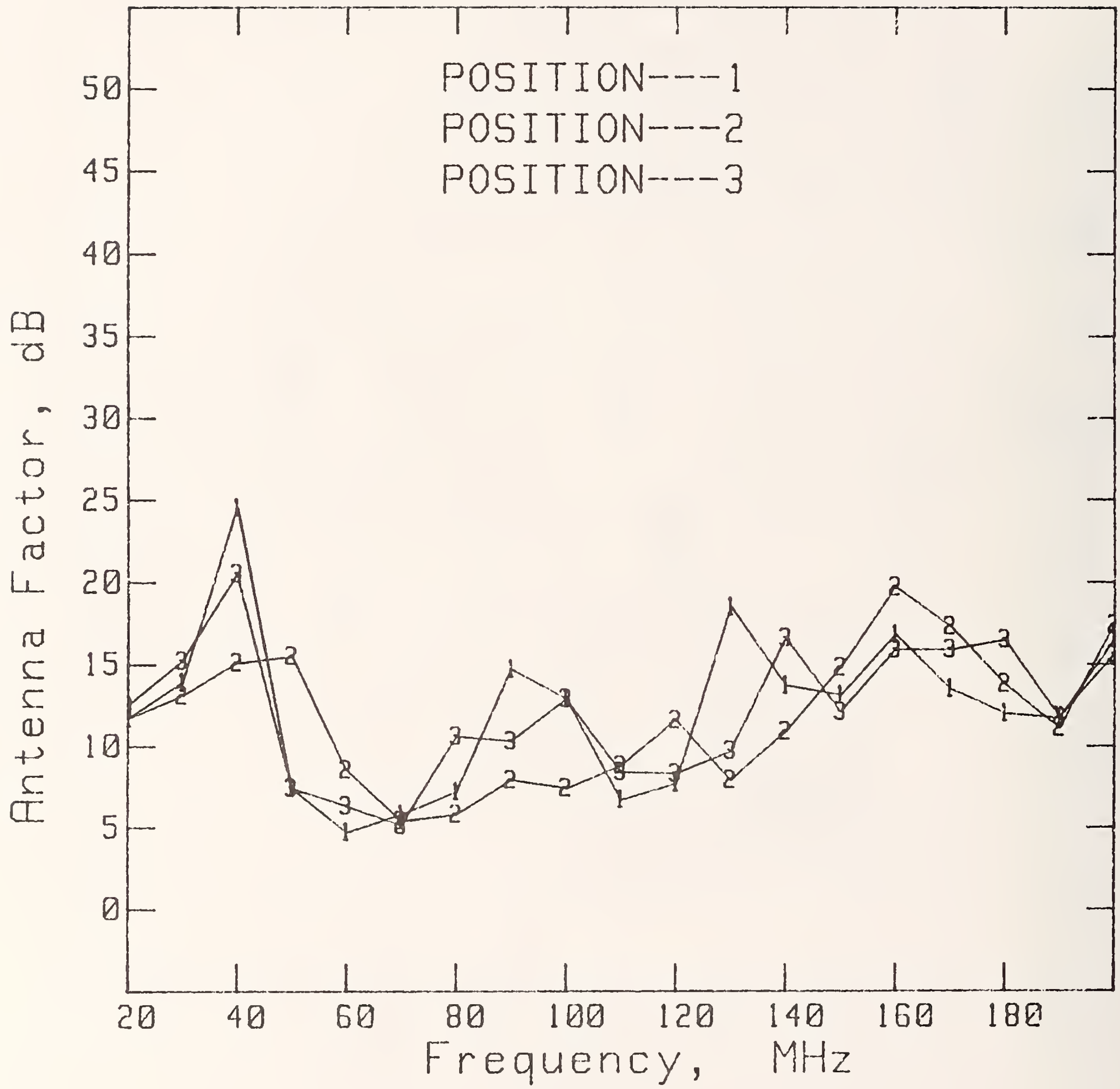



Figure 7. Antenna factors measured in a partially loaded screenroom at a separation distance of 1 m, for three selected positions.

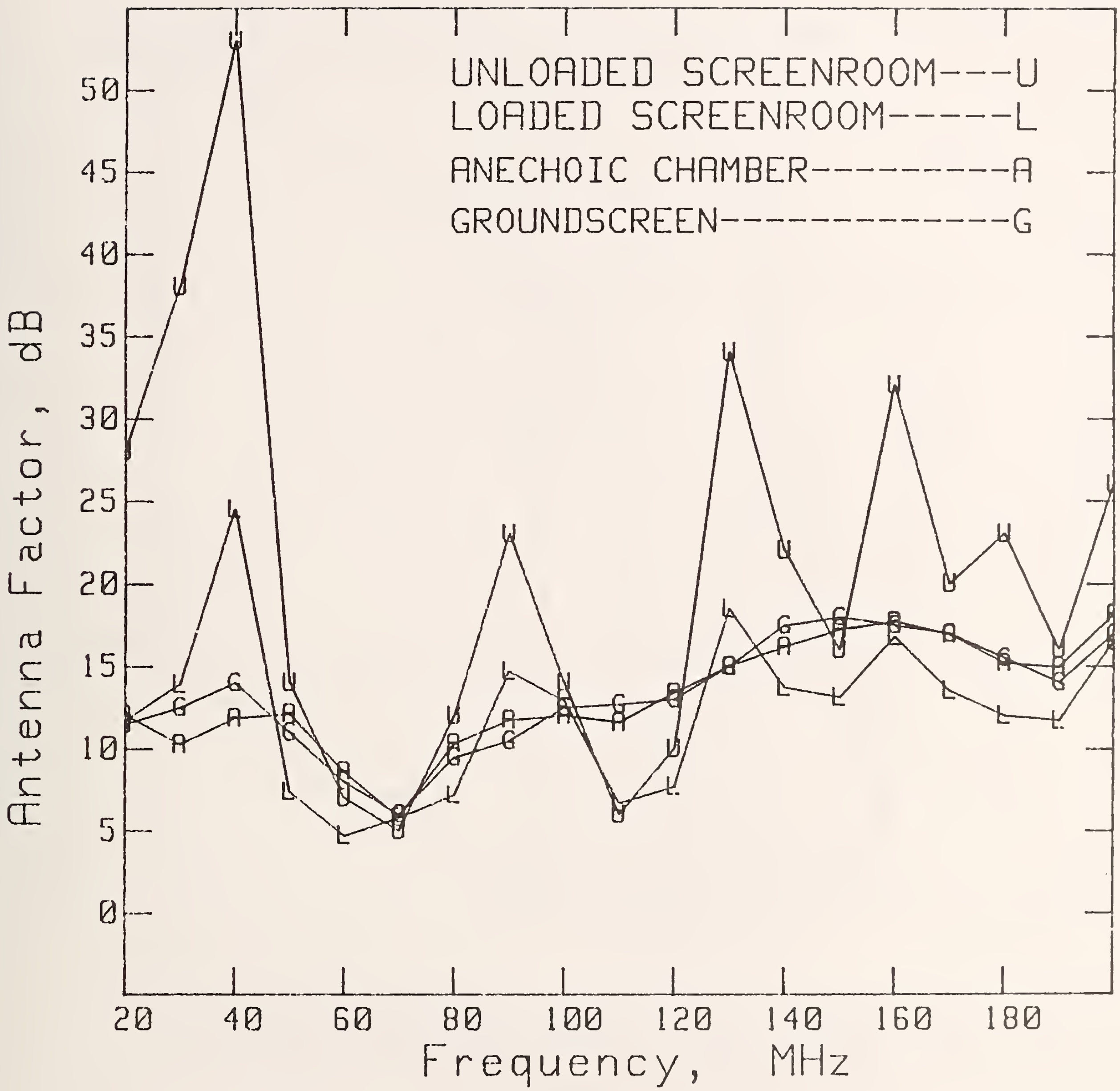



Figure 8. Comparison of antenna factors measured in four different facilities, with a 1 m separation between antennas.

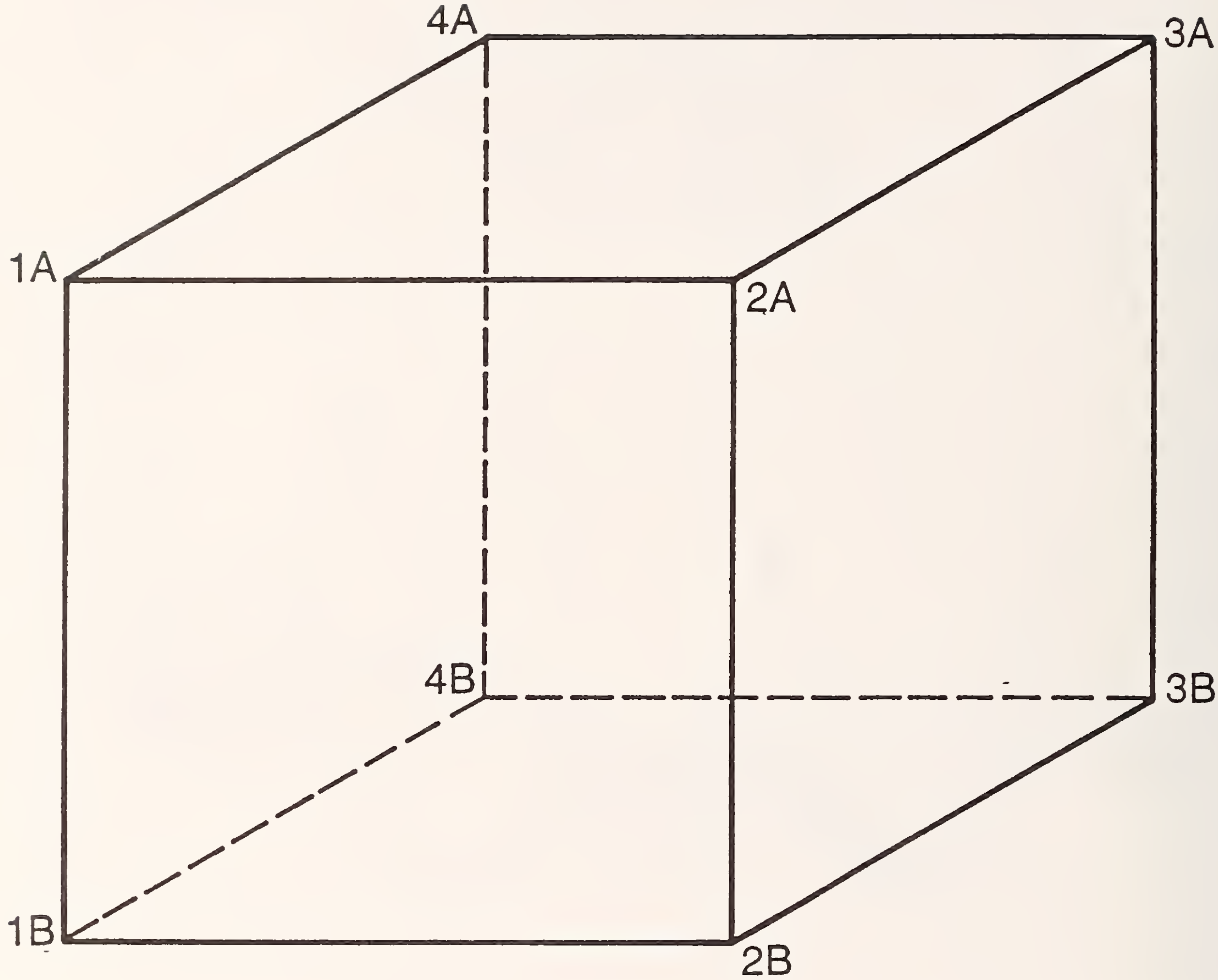



Figure 9. Identification of the eight corners of a cube for measuring the field strength differences with respect to the center of the cube.

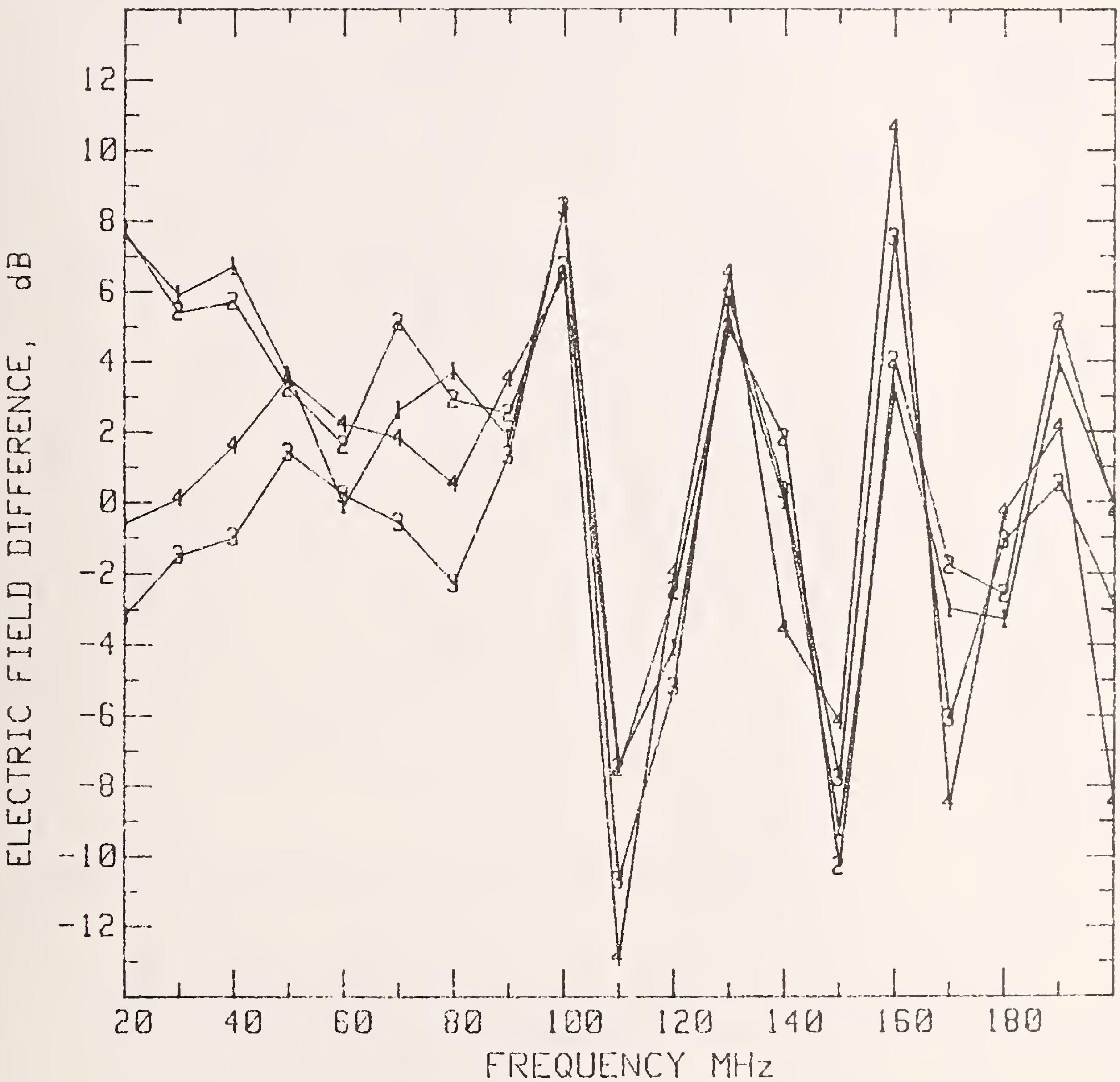



Figure 10. Electric field differences of the top 4 corners of a cube with respect to the center of the cube, in a partially loaded screenroom.

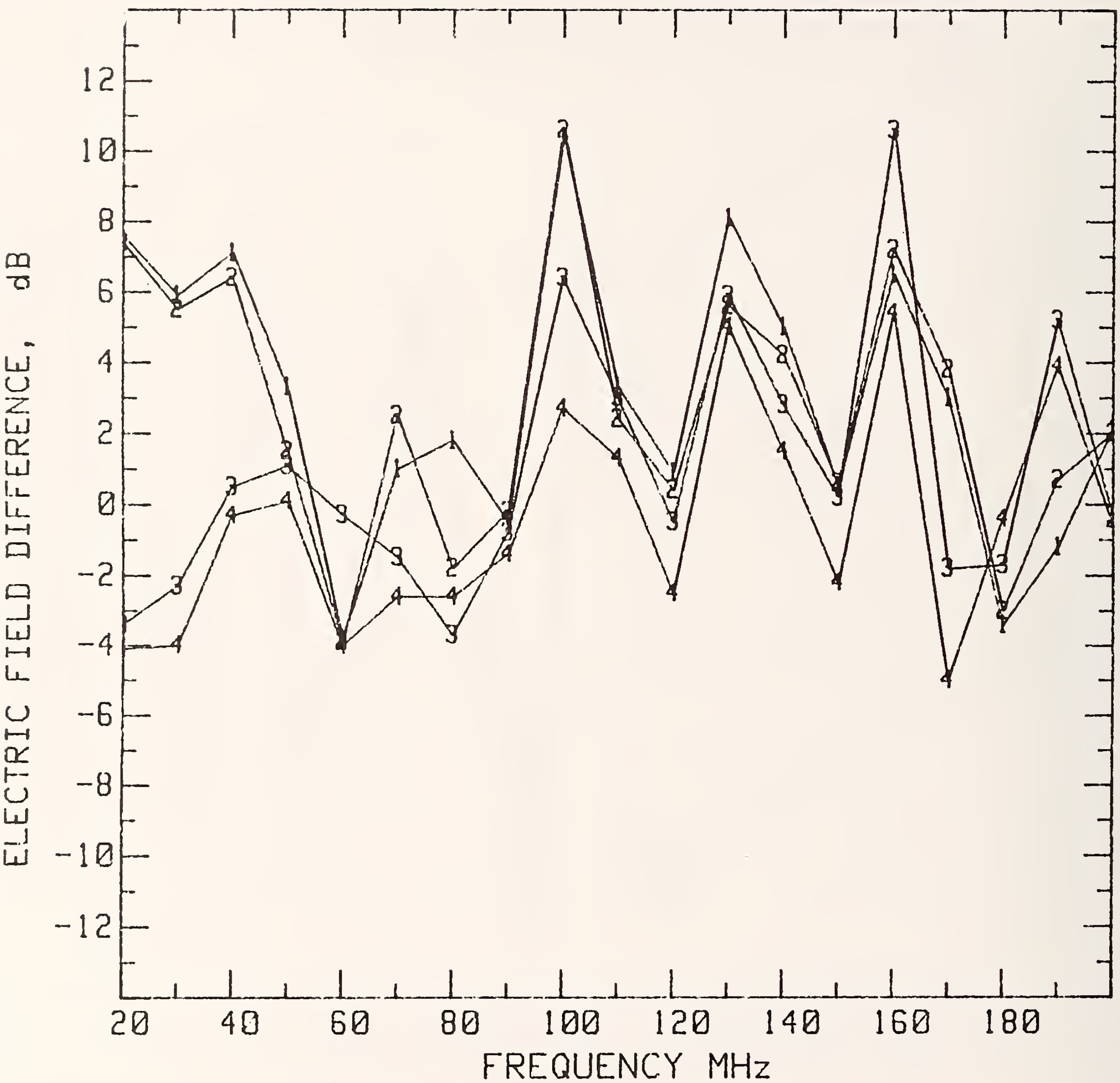



Figure 11. Electric field differences of the bottom 4 corners of a cube with respect to the center of the cube, in a partially loaded screenroom.

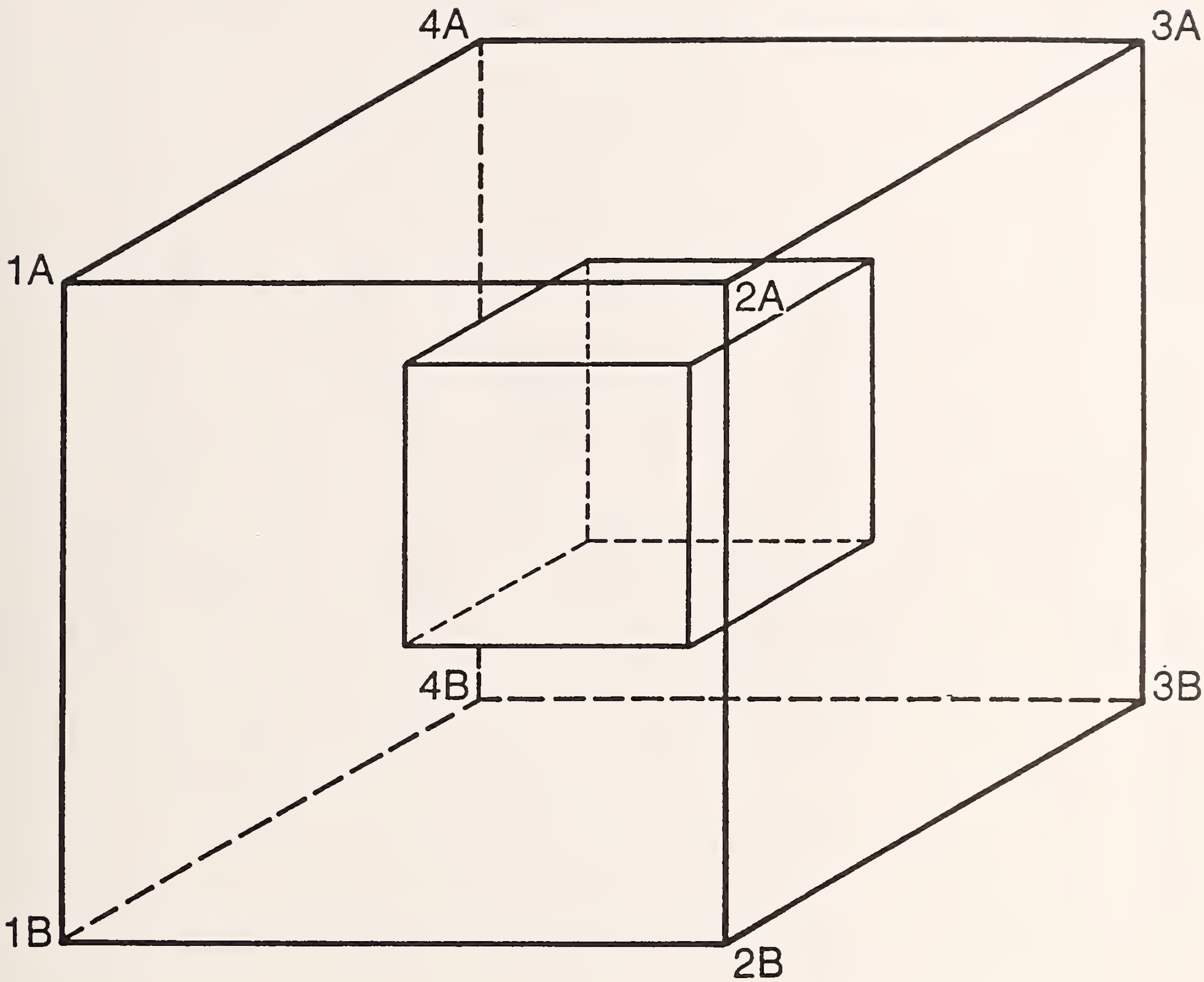



Figure 12. Sketch of a cubic volume with an enclosed metal box, for measuring the field distortion caused by the metal box.

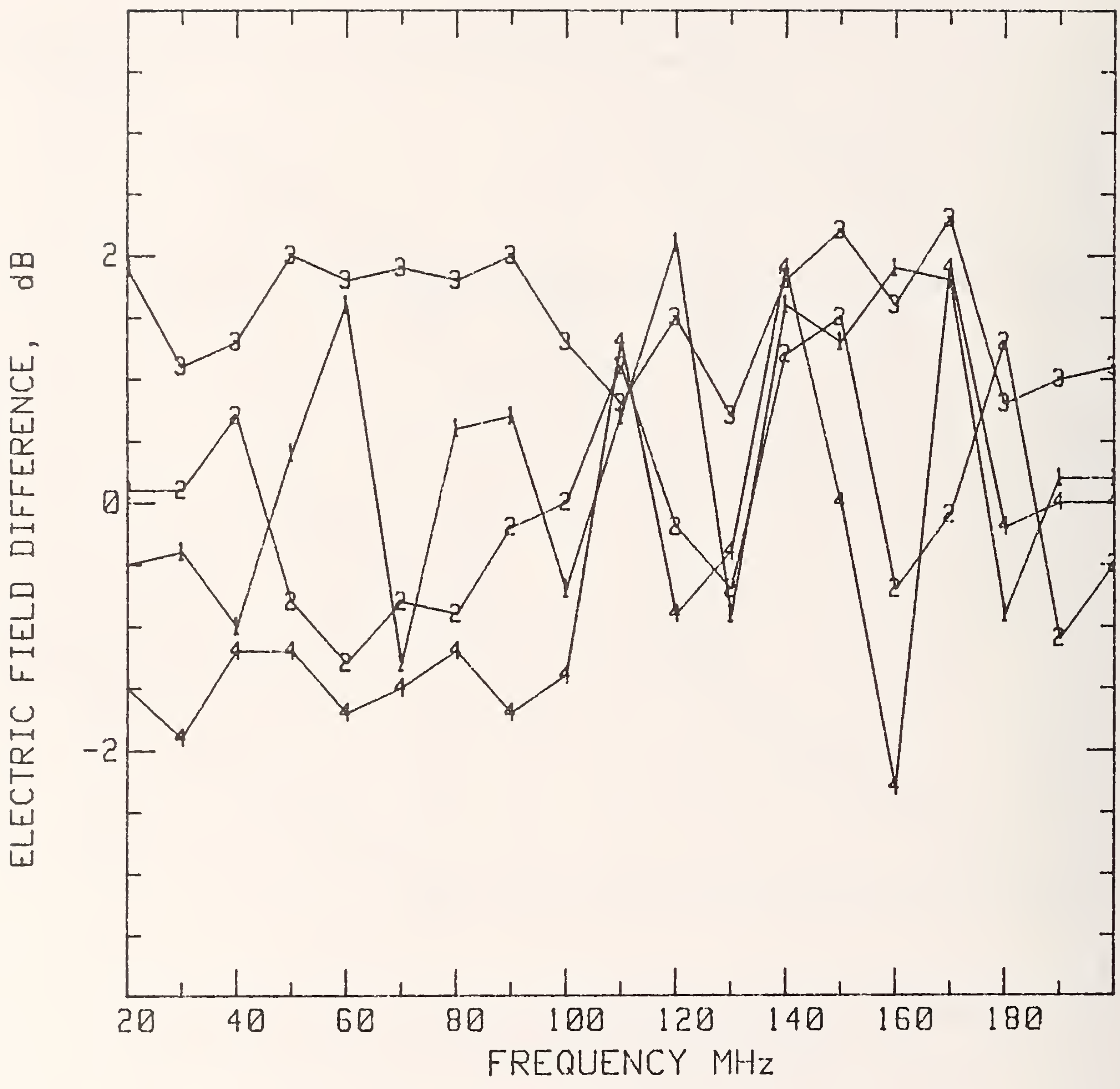



Figure 13. Electric field differences of the top 4 corners of a cube with respect to the center of the empty cube, caused by inserting a rectangular metal box.

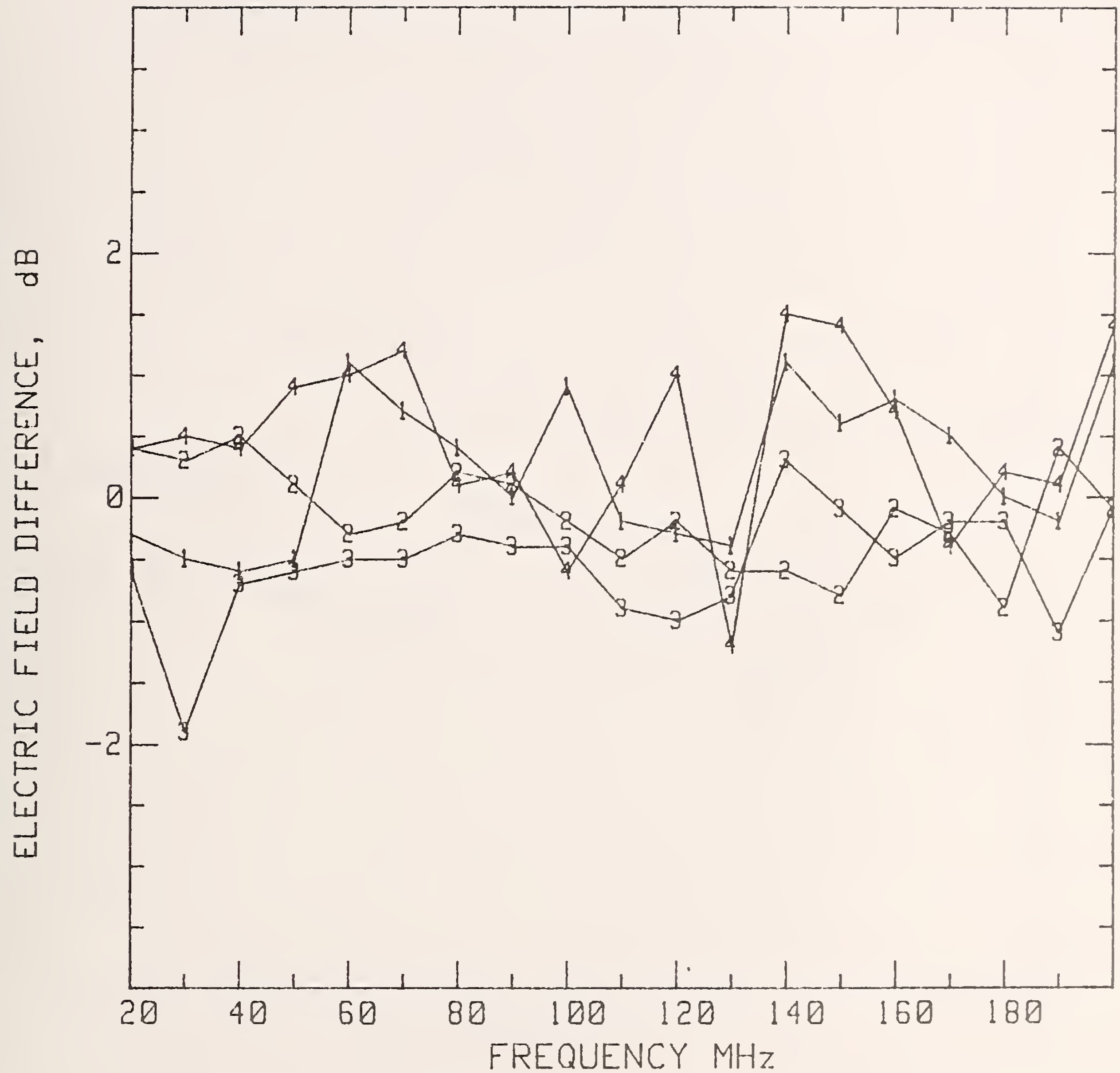



Figure 14. Electric field differences of the bottom 4 corners of a cube with respect to the center of the empty cube, caused by inserting a rectangular metal box.

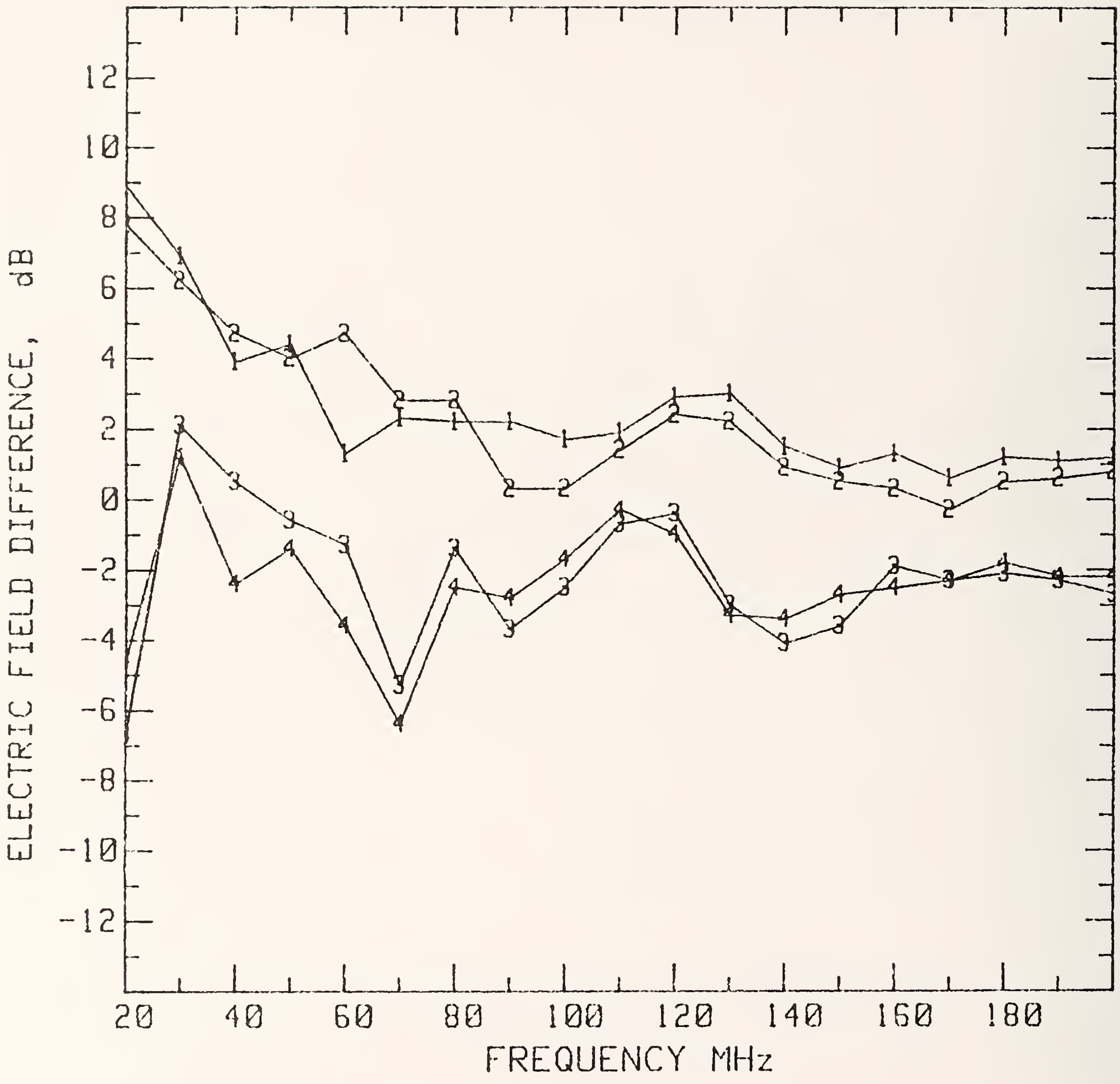



Figure 15. Electric field differences of the top 4 corners of a cube with respect to the center of the cube, in a fully loaded screenroom (anechoic chamber).

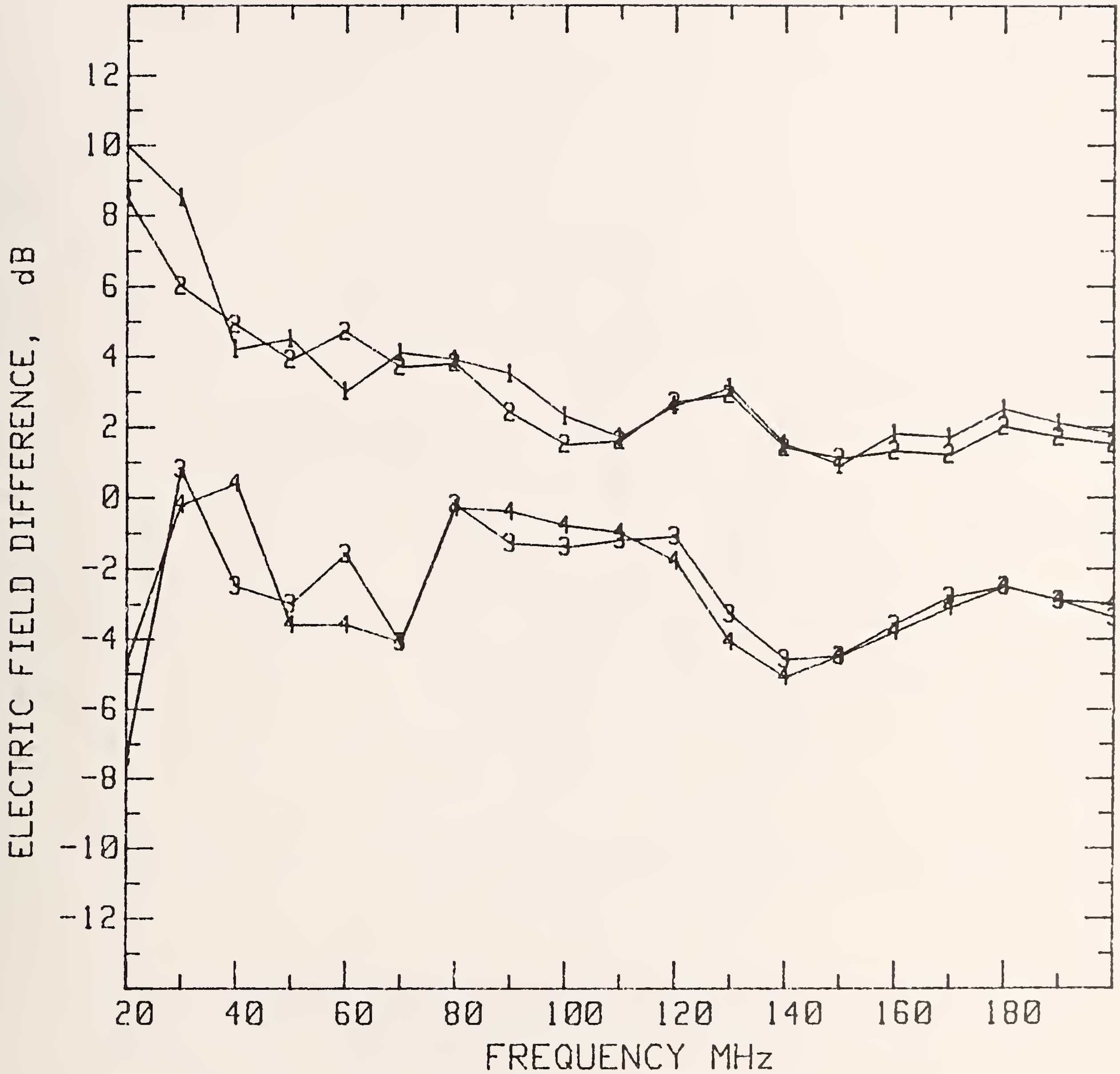



Figure 16. Electric field differences of the bottom 4 corners of a cube with respect to the center of the cube, in a fully loaded screenroom (anechoic chamber).

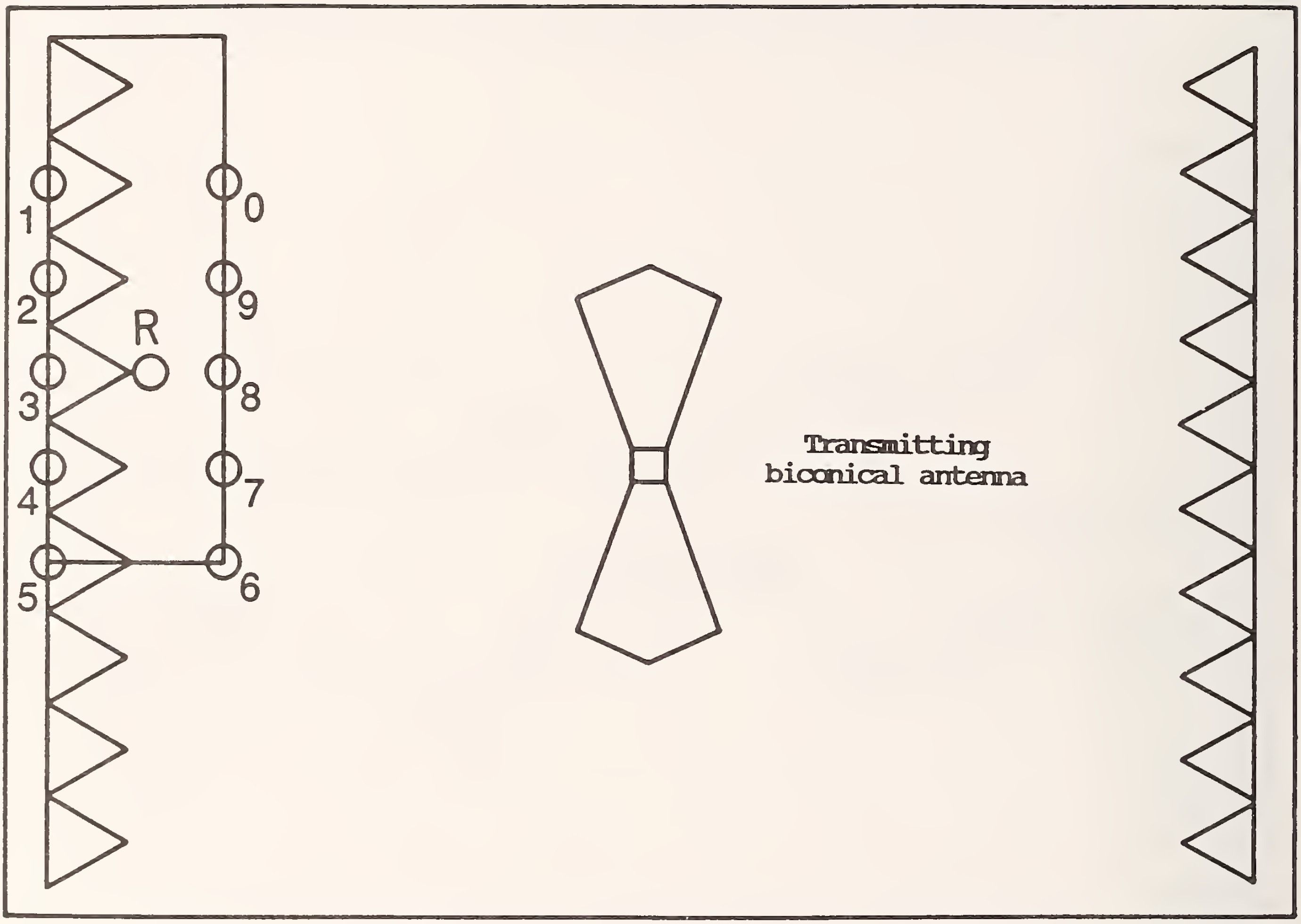



Figure 17. Measurement location in the screenroom for determination of the electric field above the grounded table.

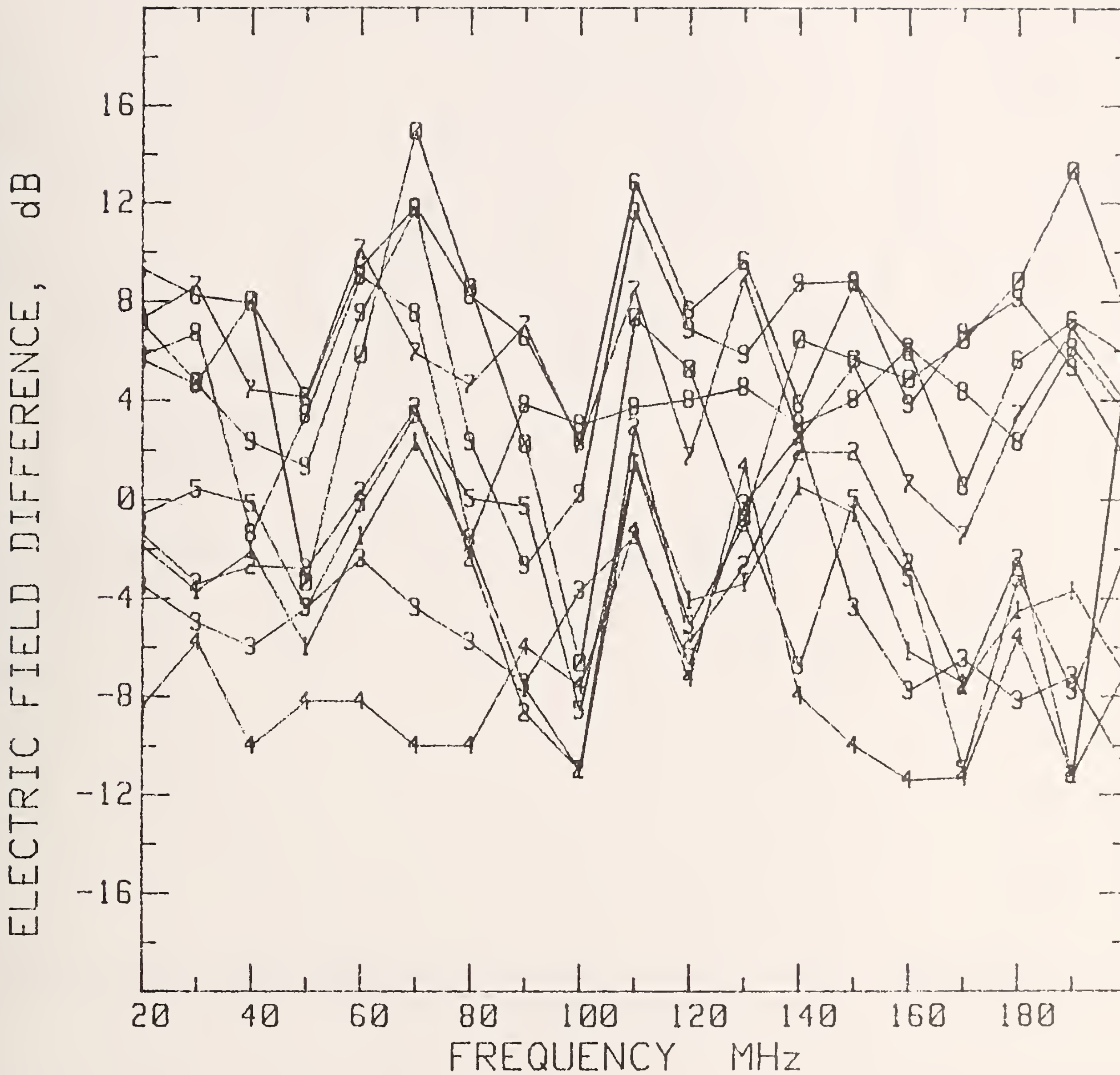



Figure 18. Electric field differences on the grounded table for 10 positions, using the center of the table (position R), with the wall loaded, as the 0 dB reference.

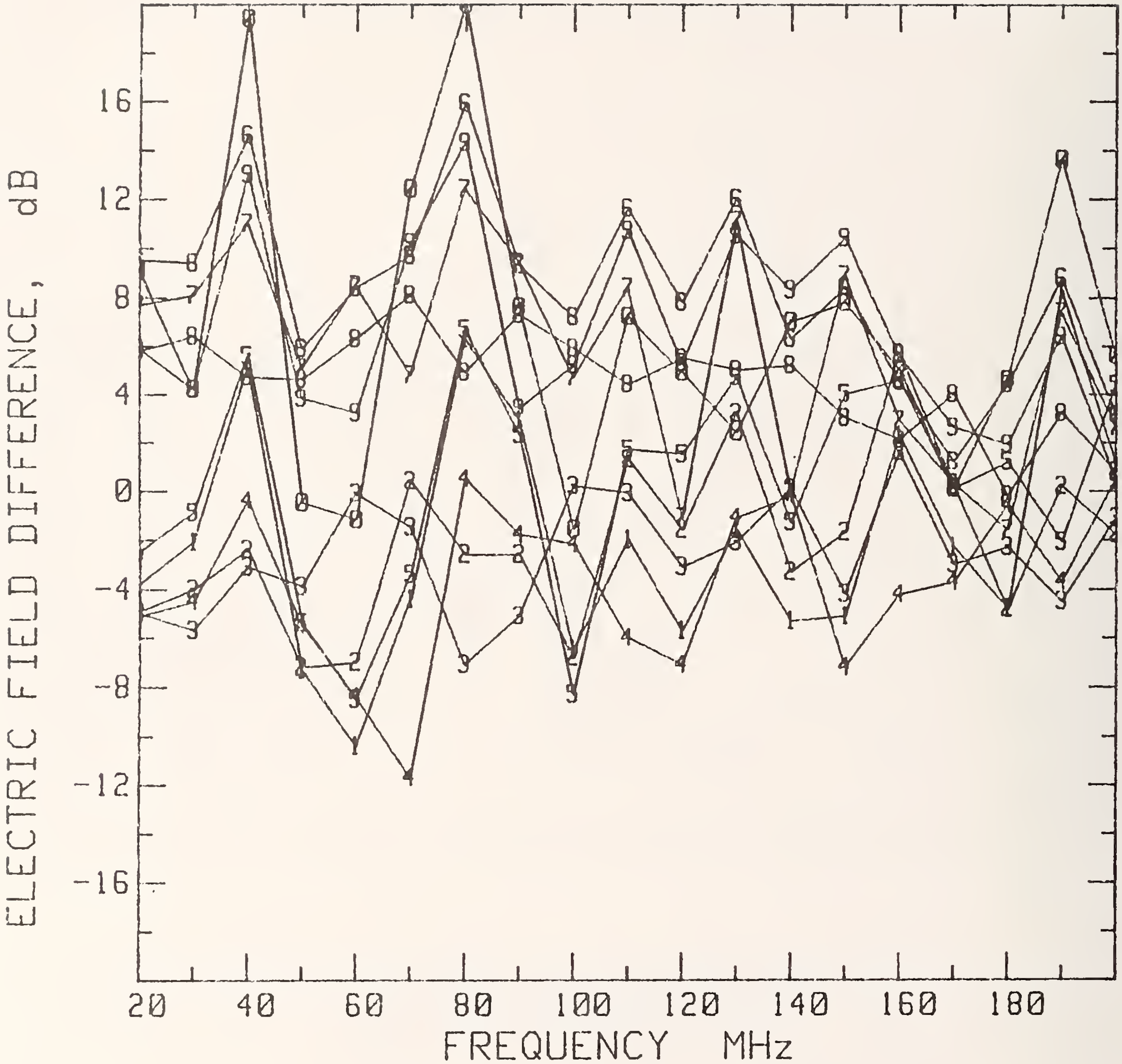



Figure 19. Electric field differences on the grounded table for 10 positions, using the center of the table (position R), with the wall unloaded, as the 0 dB reference.

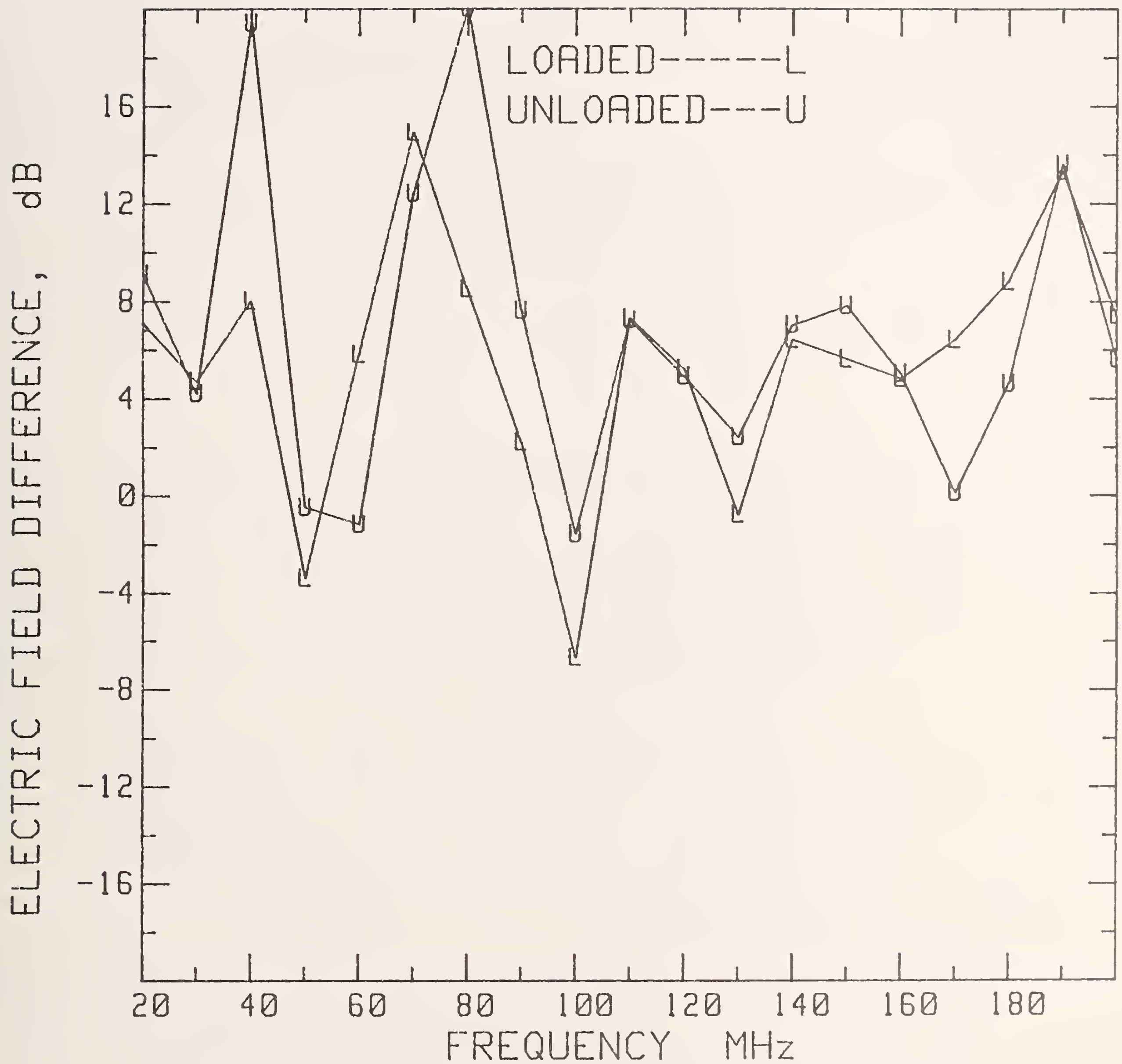



Figure 20. Electric field differences between position R and position 0 (of figure 17) on the grounded table, using position R as the 0 dB reference, with the wall either loaded or unloaded.

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**10. SUPPLEMENTARY NOTES**

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

**11. ABSTRACT** *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

Most testing for MIL-STD-461/462 is performed in a shielded enclosure (screenroom) which leads to uncertainty in the measurement of emissions from electronic equipment, or the susceptibility of equipment to electromagnetic radiation. Possible alternative techniques for improved measurements in a screenroom have been developed by the National Institute of Standards and Technology (NIST). These techniques are covered in this report.

This report presents antenna factors determined in a screenroom which was partially loaded with radio frequency (rf) absorbing material, using the two-antenna insertion-loss technique. These antenna factors are compared with the antenna factors obtained in an unloaded screenroom, a fully loaded screenroom (anechoic chamber), and at an open field site. In addition, measurements at the eight corners of a cube were made in the partially loaded and fully loaded screenroom to determine the field deviation at the eight corners of the cube with respect to its center. Also, measurement improvements are quantified for the electric-field strength beneath a single-wire transmission line, in a partially loaded screenroom. Finally, electric-field measurements were made on top of the grounded table in a partially loaded screenroom to determine the field strength variation above the table.

**12. KEY WORDS** *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

antenna factor; electromagnetic compatibility; field strength standards; loaded screenroom; military standards; screenroom measurements

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