Sample Site Attenuation Data Logbook
Data Log Sheet
With Sample Test Data

SITE ATTENUATION

DATA LOGBOOK

BOOK NO: _______

TEST LAB: _________________

____

Assigned To:______________________________	Date Assigned: _________________
Test Division:_____________________________	Date Completed:________________
NVLAP or LAP Code:________________________	Approved:_____________________

INSTRUCTIONS

All entries into this log should be made in ink or pencil. All the work of computations should be done in these books.

Each subject should begin on a new page. The subject and date along with all pertinent reference data should be plainly written at the top of each data page.

Work should be done systematically and neatly. This logbook is for convenience, but no unnecessary work should be done. Errors should be crossed off instead of erased.

In all cases, entries, sketches, diagrams, added data of any kind that is part of the data recording process must be signed by the test engineer/technician, witnessed, and dated.

All additional entries and/or sketches should be indexed on pages provided in the front of the book.

As pages are used they should be sequentially numbered in ink in reference to the index.

A record should be kept of all books issued, and the parties to whom they are issued will be held responsible for them.

Upon completion of a log book, it must be turned over to the supervisor of the test division for approval signature. Please ensure that proper archival of this log and associated logs are maintained.

Site Attenuation Logbook

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About This Log

A **logbook** is a means to record details of various records or data by written entries within a log. A logbook serves as a strong form of professionalism for you and your firm in attention to details that are pertinent to data collection for proof of compliance with test standards. An accurate, complete and neat logbook should be a matter of personal pride.

This logbook is bound so pages will not be lost. Pages should not be removed from this logbook. This logbook is designed for your convenient use. This logbook is your written diary of all test results obtained.

Starting the Log

First fill in and sign the box on the opposite page. Show the name of the Test laboratory and its location and the book number assigned. If the test lab is accredited, please indicate the corresponding code. The issuance of this logbook should be approved and signed for.

The index is provided to summarize all major entries. Each log sheet is divided up into the following categories:

- Header
- Data Entry Columns
- Note Block
- Remarks Section

The header requires entry of information pertinent to the test specification, test conditions, equipment under test (EUT), and personnel involved with the test. A space is provided for check-off of quality assurance/calibration checks by test personnel or by QA Personnel. All tests performed should be witnessed, whenever possible, and signed for in the space provided in the header section.

Data entry columns are provided for data entry relevant to the measurement task of this particular log. Data should be neat and clearly entered. The last data column is used to note any additional info or data entered.

The note block is to indicate the mathematical equations used to derive results for a selected column entry.

The remarks section is to allow entry of any additional info required to clearly define the data entered for each data sheet.

Entering Other Information

The reverse side of each data sheet of this log is left blank to allow room for sketches, diagrams, or added data of any kind that is part of the data recording process. Please adhere to the instructions found at the beginning of this logbook. Any additional sheets required should be inserted within this logbook or added as an appendix with pages labeled.

After the logbook is complete, the date of completion should be recorded at the front. Proper filing of this log should adhere to your company's policy.

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Site Attenuation
Data Logging

This logbook is for personnel involved with site attenuation measurements to facilitate their data entry and calculation requirements. This logbook is for the following models:

- FCC's Bulletin OET-55 (Formally OST-55)
- VDE 08777-2/..82 for Site Attenuation
- Albert A. Smith, Jr. of IBM
- ANSI C63.4 based on the Smith Model
- Normalized Site Attenuation

Please refer to the adjoining section entitled "Introduction to Site Attenuation" for more detailed information. It is recommended that the reader follow the references listed at the end of that section for an in-depth understanding of each model.

Guidelines For Logbook Entries

I. HEADER ENTRIES:

Specification/Model used: Please enter the test specification and/or site attenuation Model.

Date/Time: Please enter the date & time of the test.

Site/Location: Clearly identify the actual site and its geographical location.

XMIT ANT(S): Please enter the XMIT (transmit) antennas for this site attenuation. Ensure the model and serial numbers are recorded along with the last recorded calibration date.

RCVR ANT(S): Please enter the RCVR (receiving) antennas used for this set of measurements. Ensure the model and serial numbers are recorded along with the last recorded calibration date.

FIM: Identify the Field Intensity Meter (FIM) used for these measurements.

FIM BW: Identify the FIM Bandwidth used for these measurements.

Detector Used: Indicate the type of FIM detector used (i.e. Peak or Quasi-Peak).

Measurement Distance: Indicate the measurement distance in meters between the transmit and receive antenna.

Temp/Humidity: Indicate the temperature in degrees Celsius and the relative humidity in % at the time of testing.

Page/Book: Ensure that proper page numbers are used and the book number of the log is correctly entered for each data sheet.

Performed by: Indicate who has performed the testing and data entry for this sheet.

Witnessed by: All test entries must be witnessed and so signed.

Requested by: Please indicate the requesting party for this test performed.

QA/Cal CHK (Y/N): If all Quality Assurance & Calibration checks have been successfully performed please indicate that they have and the initials of the Test or QA Personnel.

Site Attenuation
Data Logging

II. Column Entries:

Column 1: Enter the frequency in MHz of the test frequency evaluated for site attenuation. The frequency range for this column is 20 MHz to 1 GHz.

Column 2: Enter (V) for vertical polarization or (H) for horizontal polarization used for this measurement. Only (H)orizontal polarization is considered for the FCC OET-FF model.

Column 3: Record the FIM (Field Intensity Meter, Receiver or Spectrum Analyzer) value in dBμV when the coaxial cables connected to each antenna are directly connected. This reading will later be used to calibrate out the overall cable loss of the measurement system. The total Balun Loss in dB must also be included in this measurement when using the FCC OET-55 Model.

Column 4: Record the maximum received value as indicated in dBμV on the FIM. This is accomplished by varying the height of the receive antenna (h_R) over the specified height scan range of h_1 to h_2. Please ensure that the proper scan range is used as specified for the site attenuation model that these measurements are being performed to. Please refer to the adjoining section entitled “Introduction to Site Attenuation” for the required scan range.

Column 5: Accurately record the ACF (Antenna Correction Factor) of the transmit (XMIT) antenna in dB/m.

Column 6: Accurately Record the ACF of the Receive (RCVR) antenna in dB/m.

Column 7: This column is used to record the correction factor for mutual coupling effects between antennas. This factor for all practical purposes is equal to 0 for vertical and horizontal site attenuation measurements made at measurement distances of 10 and 30 meters for tuned dipoles and for other measurements using broadband antennas. For horizontal site attenuation measurements made at 3 meters using tuned dipoles, please obtain the appropriate values from Table I.

This column is used in conjunction with the Normalized Site Attenuation model. Disregard this column for use with the other site attenuation models.

Column 8: Actual measured site attenuation can now be calculated by using the following expression(s):

For Normalized Site Attenuation:

$$\text{Site Attenuation} = \text{FIM}_{\text{Direct}} - \text{FIM}_{\text{Site}} - \text{Mutual Coupling Factor}$$

Or by Column Numbers

Site Attenuation = (Column 3 Value) – (Column 4 Value) – (Column 7 Value)

For the FCC OET-55 Model or ANSI C63.4:

$$\text{Site Attenuation} = \text{FIM}_{\text{Direct}} - \text{FIM}_{\text{Site}}$$

or by Column Numbers

Site Attenuation = (Column 3 Value) – (Column 4 Value)

NOTE: The user should be familiar with the adjoining section (Introduction to Site Attenuation) regarding the determination of site attenuation from measured values.

Column 9: This Column is used only for the Normalized Site Attenuation Model and can be disregarded for use with the FCC or ANSI Models.

Site Attenuation
Data Logging

Normalized Site Attenuation (NSA) is calculated by subtracting the ACF of both the transmit and receive antennas from the site attenuation value obtained in Column 8. This is expressed as follows:

$$NSA = \text{Measured Site Attenuation} - ACF_{TX} - ACF_{RF}$$

Or by Column

NSA = (Column 8 Value) – (Column 5 Value) – (Column 6 Value)

Column 10: Theoretical Site Attenuation (SA) can be obtained from tables 2 through 4 for NSA or from the equations found in Appendix A for the measurement geometries or other site attenuation models used.

Column 11: Deviation of calculated NSA from theoretical NSA is obtained by the differences of these two values. This is expressed as follows –

For NSA Model:

Deviation = Theoretical NSA – Calculated NSA

Or by Column:

Deviation = (Column 10 value) – (Column 9 Value)

For FCC or ANSI models:

Deviation = Theoretical SA – Measured Site Attenuation

Or by Column:

Deviation = (Column 10 Value) – (Column 8 Value)

Column 12: Note any additional information required that is relevant to the site attenuation measurements made for the frequency listed in column 1 for this data row.

<u>III. Remarks Entries:</u>

Use the remarks section to record any additional information required as to the operation of the EUT or the actual conduction of the Site Attenuation measurements performed. Use the blank page on the back of each data sheet to sketch any diagrams such as may be used to depict test configurations used during testing. If any additional sheets or information is pertinent to the gathering of data, please ensure that this information is so referenced on the respective data sheet and the information inserted within the proper logbook.

<u>Additional Information</u>

To order additional logbooks please specify this publication on the attached tear-out card at the end of this logbook.

A software package is also available for use with this logbook to plot measured site attenuation values against calculated values for the models listed at the beginning of this section. Please contact Liberty Labs for ordering, pricing, and additional information on EMC Software Tools Set No. 4 to use in combination with this logbook.

Sample Site Attenuation Data Logbook
With Sample Test Data Shown

Site Attenuation Data Logbook

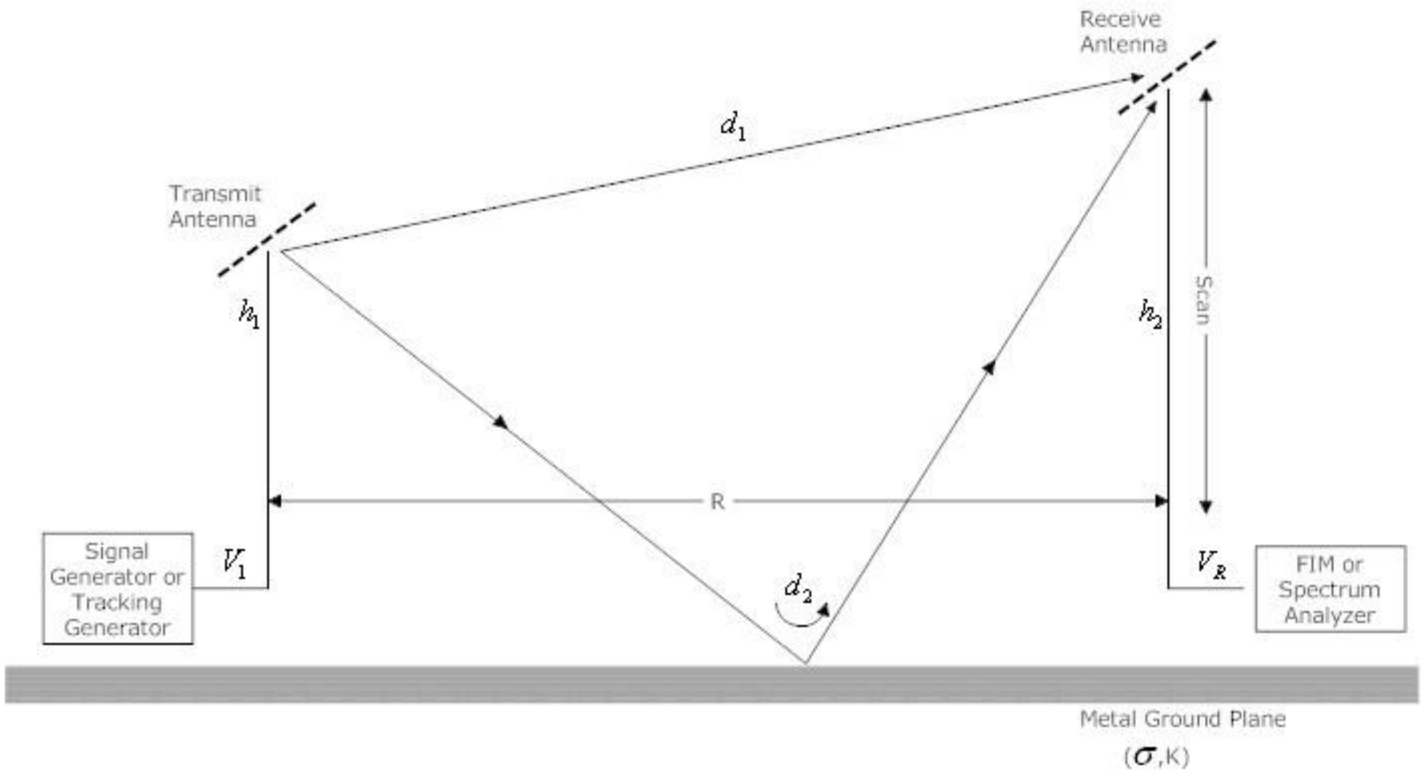
Specification/Model Used	Normalized	FIM	HP 8566B Spectrum Analyzer	Page	1	Book:	1
Date/Time	7/12/88 10:00 AM	FIM BW	100 kHz	Performed by:		John Smith	
Site/Location	Site #1, Anytown, US	Detector	Peak	Witnessed by:		John Doe	
XMIT ANT(s)	EMCO 3120, SN 76	Measurement Distance	3 Meters	Requested by:		ABC EMC Test Lab	
RCVR ANT(s)	EMCO 3120, SN 77	Temp/Hur	72˚F@65%RH	QA/CAL CHK (Y/N)		YES, JWS	

(1) FREQ. (MHz)	(2) POL (V/H)	(3) FIM DIRECT (dBµV)	(4) FIM Site (dBµV)	(5) ACF XMIT (dB/m)	(6) ACF RCVR (dB/m)	(7) AF_{TOTAL}, Ø or TABLE 1	(8) Site Atten (dB)	(9) NSA Actual (dB)	(10) Theoretical SA (dB)	(11) Deviation (dB)	(12) Notes
30	H	83.0	67.3	0.7	0.6	1.3	14.4	13.1	11.0	-2.1	H_1 = 2 m
40	H	83.0	66.7	2.5	2.7	2.7	13.6	8.4	7.0	-1.4	
50	H	83.0	68.6	4.3	4.3	0.0	14.4	5.8	4.2	-1.6	
60	H	82.5	67.7	6.5	6.3	-0.8	15.6	2.8	2.2	-0.6	
70	H	82.0	69.3	7.0	6.8	-1.9	14.6	0.8	0.6	-0.2	
80	H	81.5	67.5	8.3	8.1	-1.6	15.6	-0.8	-0.7	0.1	
90	H	81.0	62.5	10.9	10.7	-0.9	19.4	-2.2	-1.8	0.4	
100	H	81.0	65.4	10.1	10.0	-0.9	16.5	-3.6	-2.8	0.8	
120	H	80.5	58.9	13.2	13.3	0.7	20.9	-5.6	-4.4	1.2	
140	H	80.0	58.8	13.4	13.3	-0.7	21.9	-4.8	-5.8	-1.0	
160	H	79.5	49.7	18.7	18.5	-1.3	31.1	-6.1	-6.7	-0.6	
180	H	78.0	52.9	16.7	16.6	-1.4	26.5	-6.8	-7.2	-0.4	
200	H	77.5	52.0	16.6	16.4	0.1	25.4	-7.6	-8.4	-0.8	
300	H	75.0	47.5	20.0	19.6	0.0	27.5	-12.1	-12.3	-0.2	
400	H	74.5	38.8	25.3	25.5	0.0	35.7	-15.1	-14.9	0.2	
500	H	73.0	43.6	23.3	23.2	0.0	29.4	-17.1	-16.7	0.4	
1000	H	72.0	38.6	28.6	28.1	0.0	33.4	-23.3	-22.7	0.6	

Note: (8) = (3) - (4) - (7), (9)=(8)-(5)-(6),
(10)=Tables 2 through 4, (11)=(10)-(9)
*(EXCEL: only enter 2,3,4,5,6, & 7)

REMARKS

Figure 1
Configuration Used for Site Attenuation Measurement



$$A = V_1 / V_R$$

$$A(dB) = V_1(dB\mu V) - V_R(dB\mu V)$$

Introduction To Site Attenuation

Introduction:

The suitability of EMI/EMC test sites used for measurement of electromagnetic fields is determined by performing site attenuation measurements. Site Attenuation is a measure of performance of an open area test site (OATS) used to determine the levels of emissions from electromagnetic sources or to calibrate antennas used for field strength measurements. The frequencies measured for site attenuation typically range from 20 to 1000 MHz. An ideal site for performing radiated field strength measurements is a plane homogenous conducting surface of infinite extent. This conducting surface may be either good-earth or metal. ANSI C63.4 uses a metal ground plane for its reference. On an ideal site ground wave fields can be readily determined for simple radiating sources, such as a dipole antenna.

Sites may contain imperfections, which result in ground wave fields that differ from those found on the ideal site. Examples of site imperfections include, surface roughness, inhomogeneity of the site, finite ground plane size, and RF field scatterers such as: trees, people, fences, buildings, vehicles, power lines, soda cans, etc. The greater the imperfections found in the site, the more the fields will differ from those of the ideal site. The potential for errors occurring during emission measurements of a product are more likely when such imperfections exist.

Site imperfections can be fully characterized by performing site attenuation measurements. Differences between the measured site attenuation on an actual site and theoretical site attenuation of the ideal site can be a good indicator of the field strength measurement errors.

This section reviews only 3 models for the measurement and calculation of site attenuation. Additional models and methods can be utilized besides those presented. The reader is encouraged to review the models listed here and to refer to the list of references at the end of this section. It is for the reader to select the specific site attenuation model and procedures that best suit the particular measurement requirements.

Definition of Site Attenuation

Figure 1 shows a pair of antennas separated by a distance R and located over a plain surface with conductivity and relative dielectric constant. A signal generator or tracking generator with output voltage V_1 is connected to the transmitting antenna, which is placed at a height h_1 above the surface. The height of the receiving antenna is scanned over the range $h_2^{min} \leq h_2 \leq h_2^{max}$, and the maximum output voltage V_R is measured by a FIM (Field Intensity Meter, receiver or spectrum analyzer). The receiving antenna height is scanned to avoid nulls in the ground wave field and direct wave arriving at the receiving antenna. Site attenuation is defined as:

$$A = V_1 / V_R \quad [1]$$

Or

$$A(dB) = V_1(dB\mu V) - V_R(dB\mu V) \quad [2]$$

Site Attenuation Model: (Smith Model, Developed by Albert A. Smith, Jr. of IBM, REF. 1 & 7)

The theoretical site attenuation model developed in equation [1] is presented in terms of the antenna factors of the transmit and receive antennas and the ground wave propagation term as:

$$A = \frac{279.1\, AF_R\ AF_T}{f_M\ E_D^{max}} \quad [3]$$

Or, in decibels, as:

$$A(dB) = -20\log f_M + 48.92 + AF_R(dB/m) + AF_T(dB/m) - E_D^{\max}(dB\mu V/m) \quad [4]$$

Where:
f_M = Frequency in MHz
AF_r (dB/m) = antenna factor of receiving antenna in dB/m
AF_T(dB/m) = antenna factor of transmitting antenna in dB/m
E_D^{Max} (dBμV/m) = maximum electric field in receiving antenna height scan range $h_2^{min} \leq h_2 \leq h_2^{max}$ from a theoretical halfwave dipole with one picowatt of radiated power.

The expressions for E_D^{Max} for both horizontal and vertical polarizations are in Appendix A. Numerical values of E_D^{Max} are in Table V for some typical geometries.

Smith states that since the site attenuation model derived in [1] and given by [3] and [4] is expressed in terms of antenna factors, site attenuation measurements can be made with broadband antennas such as biconical and log-periodic antennas. This can be a significant advantage since broadband antennas have several advantages over tunable dipole antennas. Broadband antennas are compatible with automated instrumentation and can be used for swept frequency measurements. This results in significant reduction of test time compared to using the discrete frequency manually-tuned halfwave dipole. Broadband antennas exhibit less mutual coupling than dipoles at the lower frequencies and can be used for vertical polarization measurements in place of their dipole counterparts at frequencies less than 90 MHz. They can also be used in small semi-anechoic chambers. The Smith model may also be used with tunable dipoles. The model closely accounts for the antenna-to-antenna and antenna-to-ground plane mutual coupling between closely spaced horizontally polarized tunable dipole antennas.

Basic Measurement Method
(Smith Model)

The measurement method for determining site attenuation based on the Smith Model requires a signal generator and FIM, and may be used with either broadband antennas or tunable dipoles. The set-up is shown in figure 1. The signal or tracking generator is connected to the transmit antenna with an appropriate length of transmission line (coax cable). The transmit antenna is placed in the desired location, usually in the center of the area normally occupied by the equipment under test (EUT). Antenna height is set to h_1 and the desired polarization (vertical or horizontal) is selected. If a tunable dipole is used, the element lengths must be adjusted to the desired frequency.

The receive antenna is mounted on a mast, or antenna positioning tower, which allows scanning over the height range $h_2^{min} \leq h_2 \leq h_2^{max}$, placed at a distance R from the transmit antenna. The receive antenna is connected to the FIM by an appropriate length of transmission line. The appropriate polarization (vert/horz) is then selected. If a tunable dipole is used, the antenna element lengths must be adjusted for the required frequency. Vertically polarized measurements below approximately 80 MHz for the height scan range of 1 to 4 meters are not practical with tunable dipoles, because of their length (i.e., dipole length at 30 MHz = 5 meters).

The two methods for performing discrete and swept frequency measurements are presented next, based on the basic method presented here using the SMITH Model.

Discrete Frequency Method
(Smith Model)

The following steps apply when making discrete frequency measurements using a signal generator and a FIM. The signal generator should have a fairly stable output to perform these measurements. Discrete frequency measurements are to be made at 5

MHz intervals from 25 to 50 MHz, 10 MHz from 50 to 100 MHz, 25 MHz from 100 to 200 MHz, 50 MHz from 200 to 300 MHz, and 100 MHz from 300 to 1000 MHz.

1. The signal generator is tuned to the required frequency and the output adjusted to a level V_1 which gives a received voltage at least 10 dB above the RF ambient and receiver noise as indicated in the FIM output.

2. The receive antenna is scanned over the height range (h_2^{min},h_2^{max}) and the maximum received voltage is recorded over this height range as V_R.

3. The transmit and receive cables are disconnected at the antennas and a variable 50 ohm attenuator is inserted in series with the cables. The attenuator may be an integral part of the signal generator and should preferably have a 0.1 dB resolution and a dynamic range of at least 60 dB.

4. The signal generator output is set at the same level V_1 as in step (1) above, and the attenuator is varied until the FIM indicates the same level V_R recorded in step (2) above.

5. The measured site attenuation is then equal to the attenuator reading obtained in step (4). This method is commonly referred to as the substitution method in determining the final measurement results - the need to separately account for cable losses is thus avoided with this method.

6. The measured site attenuation may then be plotted on graph paper with site attenuation in dB as the ordinate (Y-axis) and frequency as the abscissa (X-axis). The theoretical site attenuation for the standard site from equation (4) should also be plotted on the same graph for comparative analysis.

Swept Frequency Method

(Smith Model)

The following steps are to be used when making swept frequency measurements for site attenuation. This method is performed using a tracking generator and a spectrum analyzer. This procedure is well suited for use with broadband linearly polarized antennas such as biconicals and log-periodic antennas.

1. First adjust the level of the tracking generator to produce a received voltage on the spectrum analyzer well above the RF ambient (10 dB is suggested here).
2. Place the spectrum analyzer in automatic sweep over the desired frequency range (30 to 200, 200 to 1000 MHz, etc). Then place the analyzer in MAX HOLD.
3. Next raise and lower the receiving antenna over the specified height range of h_2^{min} to h_2^{max} .
4. Record the maximum received voltage spectrum in Register B of the spectrum analyzer.
5. Disconnect the transmit and receive cables from the two antennas and connect the two cables together using a straight adapter.
6. Store the cable-loss spectrum in Register A of the spectrum analyzer
7. By using the tract arithmetic functions of the spectrum analyzer subtract the contents of register B from the contents of Register A and store the results in A. This function can be accomplished with most spectrum analyzers by simply depressing the A-b->A key.
8. The results stored in A is the measured site attenuation of the site. The results in A can then be outputted to either an X-Y plotter or other suitable plotter that is compatible with the spectrum analyzer.

Introduction To Site Attenuation

The following equipment types are listed as typical equipment that can be used for the swept-frequency measurements.

Tracking Generator – HP8444A with Option 59

Spectrum Analyzer – HP8558B or HP8568B

Site Attenuation
(FCC OET-55 Model)

The FCC OET-55 model for site attenuation is based on a plane-wave model. It has been based on horizontal site attenuation measurements only. The empirical results with this model show that it is not representative of what actually occurs below 80MHz. The measured attenuation below 80 MHz can be expected to be a few dB more than what the equation predicts.

This model is based on the following equation.

$$A = 20\log D + 20\log F_M - G_S - G_R + BL - 27.6 - R \qquad [5]$$

Where:
A = Site Attenuation
D = Distance in meters between the transmitting and receiving antennas
F_M= Frequency in megahertz of the transmitted signal
G_S= Gain in dB of the source antenna relative to isotropic.
G_R= Gain in dB of the receiving antenna relative to isotropic.
BL = Total balun loss in dB of both source and receiving antenna at Fm.
R = Contribution from ground reflected radiation.

The recommended values to use for R:

4.3 for 3 meter sites
5.7 for 10 meter sites
5.9 for 30 meter sites

For when 2 tuned dipoles used as the source and receiving antennas where G_s=G_R=2.15 dB, the equation then becomes:

$$A = 20\log + 20\log F_m - 31.9 - R + BL \qquad [6]$$

The ground reflection term, R, of this equation was obtained using a geometrical model which assumes that the field arriving at the receiving antenna is caused by a direct wave traveling a path r_1, and a ground reflected wave traveling a path, r_2 . The ground reflection term has been derived from the following equation assuming a perfect ground reflection.

$$20\log(1+\frac{r1}{r2}) \qquad [7]$$

The range of these values will change with the height scan of the receiving antenna. The actual range of these values are:

3.74 to 4.84 dB for 3 meter sites
5.46 to 5.86 dB for 10 meter sites
5.91 to 5.98 dB for 30 meter sites

Cable losses are not considered here, for if the measurement procedure used for site attenuation is followed as set forth in OET-55, then these losses are accounted for in the site attenuation measurements. Balun losses typically are found to be 1dB or less. However, if one wishes to obtain a more accurate measurement of site attenuation, then these balun losses should be measured.

Site Attenuation Measurement Procedure – FCC OET-55 Method:

The procedure for making site attenuation measurement per OET-55 calls for use of two half-wave dipole antennas. Other combinations of antennas may be employed to perform site attenuation measurements.

Introduction To Site Attenuation

A. See figure 1. Connect the output of a signal generator that is controlled by a standard attenuator to the half-wave dipole radiating antenna via a coaxial cable. Since a half-wave dipole is a balanced antenna, a balun must be used. An impedance matching transformer may also be necessary if the impedance matching is not accomplished with the balun.

B. The radiating antenna is set up for horizontal polarization at height Ht as specified in Step E and oriented for maximum radiation toward the location of the measuring instrument. The antenna should be adjusted to the proper length at each frequency of measurement.

C. Connect a field strength meter or a spectrum analyzer (FIM) to the receiving half-wave dipole antenna via coaxial cable, again using a balun. Adjust the antenna to the frequency of the generated signal and tune the FIM to that signal.

D. Set the output level of the signal generator and the standard attenuator at a value that gives an FIM reading significantly above the RF ambient noise level or interfering signals from other sources. Record the attenuator setting.

E. Measure the horizontal component of the field strength at the location of the FIM. Find the maximum value of the field strength by raising and lowering the measuring antenna over the search distance specified as shown below. Record the reading indicated by the FIM.

D= 3m, h_t=2m search (H_2) = 1–4m
D= 10m, h_t=2m search (H_2) = 1–4m
D= 30m, h_t=2m search (H_2) = 2-6m

F. Disconnect the coaxial cables from the two antenna terminals and connect these cables together. If the baluns can be disconnected at the antenna terminals, the baluns should be connected in the circuit as follows:

Cable > Balun > Balun > Cable

G. Adjust the standard attenuator to give the same FIM reading that was recorded in Step D. Record the attenuator setting.

The site attenuation is the difference in dB between the standard attenuator setting recorded in Step G and that in Step D. If the baluns or impedance matching transformers are removed or otherwise not included in the measurement described in Step F then the loss of these devices must be considered in the final site attenuation calculations.

The site attenuation measured from the above procedure is next compared to the calculated value derived from the FCC OET-55 model. The two values must be within 3dB to be acceptable. More than 3 dB of difference between these values is indicative of site abnormalities or measurement processes. This difference is also a good indicator that errors will exist in the measurement of emissions at this site.

Normalized Site Attenuation
(Based on Studies Performed by Don N. Heirmann of AT&T Information Systems, Reference No. 21)

As shown in the previous Smith Model, site attenuation was based on antenna factors and mutual coupling as shown in equation (4). If the antenna factors are subtracted from equation (4) then the concept called Normalized Site

Attenuation (NSA) is obtained as defined by Heirmann.

The NSA (A_N) term can be calculated as follows:

$$A_N(dB)=-20\log F_M+48.9-E_D^{MAX} \quad [8]$$

This equation is independent of antenna factors. Heirmann also states that the resulting NSA can be used to compare site attenuation without the need to know the antennas used for the measurement. This method will standardize means to compare site attenuation measurements between sites by providing similar range of data and within a recommended error from that predicted using the equation (8).

Equation 8 was expanded by Heirmann to have information presented in a more usable format. This equation is now shown as:

$$A_N(dB)=V_1-V_R-AF_{TX}-AF_{RX}-(C_T+C_R)-DF_{Total} \quad [9]$$

V_1= Output Voltage of the signal source in dBµV
V_R= Input voltage of the FIM in dBµV
AF_{TX}= Transmit antenna factor (dB/m)
C_T= Cable loss between the signal source and the transmit antenna in dB
C_R=Cable loss between the FIM and the receive antenna in dB
DF_{Total} = Correction for mutual coupling in dB

This can further be simplified by:

$$V_{direct} = V_1-C_T-C_R \quad [10]$$
$$V_{site} = V_R$$

Thus

$$A_N(dB)=V_{direct}-V_{site}-AF_{TX}-AF_{RX}-DF_{Total} \quad [11]$$

It is important to emphasize here the need to have accurate values for the transmit and receive antenna factors. These factors should be traceable to NBS standards. This was also stressed in the Smith Model presented previously. Standard values for NSA can be found in Tables I through IV.

Acceptability Criteria for Site Attenuation (Calculated VS Measured):
The ANSI C63.4 document on Open Area Test Sites considers the measurement site to be suitable for electromagnetic radiation measurements if the measured site attenuation is within 4 dB of the calculated or theoretical site attenuation for an ideal site. Field strength measurements on sites that meet these criteria are acceptable without correction or adjustment of the measured emissions data made on that site. The FCC model uses a 3 dB criteria for acceptance.

Antennas for Site Characterization:
Linearly polarized antennas can be used for site attenuation measurements. The use of broadband antennas is recommended based on the Smith Model. Biconicals for the 30 to 200 MHz range and log-periodic antennas for the 200 to 1000 MHz range are preferred. Broadband antennas are very compatible with automated instrumentation and permit swept measurements over a large frequency range, resulting in a significant reduction in test time compared to tunable dipoles. Broadband antennas, since they are shorter than tunable dipoles, exhibit significantly less mutual coupling and can be used for vertical polarization measurements and for measurements within indoor sites such as semi-anechoic or full anechoic chambers. Vertical polarization is more sensitive to detection of site imperfections than horizontal polarization.

Tunable dipoles may also be used for site attenuation measurements. However, their large size at the lower frequencies rules out vertical measurements and use in some indoor sites. In addition, mutual coupling effects for horizontally polarized tunable dipoles at close spacing are non-negligible at the lower frequencies and must be accounted for.

The antenna factors of antennas used to make site attenuation measurements should be traceable to a national standard such as NCS standards. Manufacturer's antenna factors may not be sufficiently accurate to achieve good agreement between measured and calculated site attenuations. In order to determine the accuracy of the antenna factors, a horizontal site attenuation measurement is made on a near-ideal site (preferably at a distance of 10 meters with antenna heights of h_1=1m and h_2=1 – 4 m) and compared with the calculated site attenuation of a standard site. Differences between measured and calculated curves can be mainly attributed to antenna factor errors. If the differences exceed 2 dB, calibration of the antennas is indicated.

The difference between the FCC OET-55 curve and the measured site attenuation at 30 MHz is approximately 10.5 dB. It has been shown that the 10.5 dB difference is due to three factors: 3.5 dB from neglecting mutual coupling; 3.5 dB from incorrectly accounting for the magnitude and phase of the ground reflected wave (by assuming a 4.7 dB average ground reflection factor); 3.5 dB due to antenna losses (which are included in the antenna factors but not the FCC curve, which assumes lossless matched dipoles).

Smith Model Versus FCC/OET-55 Model for Site Attenuation:

The theoretical site attenuation model developed by Smith in reference 1 allows for both horizontal and vertical polarizations over the earth and metal ground planes, and accounts for mutual coupling effects between closely spaced horizontal tunable dipoles. A major advantage of this model is that site attenuation is now expressed in terms of antenna factors, which allows broadband antennas to be used with their many advantages over the their tunable dipole counter-parts.

Site attenuation is also a measure of the accuracy of the transmit and receive antenna factors. The study conducted by Smith shows that the comparison of measured and theoretical site attenuations for a qualified open-field site is largely a measure of antenna factor errors.

The model developed by the FCC in OET-55 assumes an average ground reflected component below 80MHz and measurements are restricted to horizontal polarization only. The FCC model neglects the mutual coupling factor for horizontal polarization with measurement distances of 3 meters. The results obtained for site attenuation below 60 MHz using the assumed values of the ground reflected component is prone to error (see references 1 & 34). Studies conducted by Smith and the work for the ANSI C63.4 committee have shown that vertical site attenuation measurements are more suited to indicate test site imperfections or abnormalities than horizontal site attenuation measurements.

VDE 0877-2/..82 Site Attenuation

Section 7.1.3 of VDE 0877-2//..82 specifies the calibration of Measurement Test Sites. The test site is calibrated over the frequency range of 30 to 1000MHz by measuring and evaluating the attenuation existing between the voltage applied to the terminals of a transmitting antenna and the voltage measured at the terminals of a receiving antenna. VDE specifies the use of dipole antennas for these measurements. Both horizontal and vertical site attenuation measurements are to be performed. The test site is considered suitable when the measured and the calculated values do not deviate more than 3 dB from each other. If the values exceed 3 dB, then correcting action is taken to determine the cause of this variance. Please refer to figures 2 through 5 at the end of this logbook to obtain the calculate values for site attenuation. These figures have the ACF and cable losses subtracted out.

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NOTE: The reader is urged to consult with the following references for additional information relating to Site Attenuation.

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Appendix A

Mathematical Expressions for Site Attenuation
(Please Refer to Figure 1)
I. Smith Model

Site Attenuation $A = V_1/V_R$

Or

$$A(dB)=V_1(dB\mu V)-V_R(dB\mu V)$$

Where:

V_1 = Signal Generator Output Voltage (which drives the transmit antenna)

V_R = Maximum Output voltage as measured by a FIM over the range of h_2 ($H_2^{Min} \leq h_2 \leq h_2^{Max}$)

-Site Attenuation expressed in terms of the antenna factors of the transmit and receive antennas and a ground wave propagation term is given as –

$$A = \frac{279.1 AF_R AF_T}{f_M E_D^{\max}}$$

Or, in decibles, as

$$A(dB) = -20\log f_M + 48.92 + AF_R(dB/m) + AF_T(dB/\mathrm{m}) - \mathrm{E}_D^{\max}(dB\mu V/\mathrm{m})$$

Where:

f_m = Frequency in MHz

$AF_R(dB/m)$ = Antenna factor of receiving antenna in dB/m

AF_T = Antenna Factor of Receiving antenna in dB/m

E_D^{max} = Maximum electric field in receiving antenna height scan range $h_2^{min} \leq h_2 \leq h_2^{max}$ from a theoretical halfwave dipole with one picowatt of radiated power.

Appendix A

The following expressions for E_D^{max} are derived in [1].
Please refer to Figure 1 for the geometry used.

For Horizontal polarization, E_D^{max} is given by –

$$\mathrm{E}_{DH}^{\max} = \frac{\sqrt{49.2}[d_2{}^2 + d_1{}^2 \mid \rho_h \mid^2 + 2d_1 d_2 \mid \rho_h \mid \cos(\phi_h - \beta[d_2 - d_1])]^{\frac{1}{2}}}{d_1 d_2} \quad [1]$$

Maximized over the interval $h_2^{min} \leq h_2 \leq h_2^{max}$

Where:

$$\beta = \frac{2\pi}{\lambda} \quad [2]$$

ϕ_v = reflection coefficient phase angle for vertical polarization.
ϕ_h = reflection coefficient phase angle for horizontal

$$d_1 = [R^2 + (h_1 - h_2)^2]^{\frac{1}{2}} \quad [3]$$

$$d_2 = [R^2 + (h_1 + h_2)^2]^{\frac{1}{2}} \quad [4]$$

$$\rho_h = \frac{\sin\gamma - (\mathrm{K} - \mathrm{j}60\lambda\sigma - \cos^2\gamma)^{\frac{1}{2}}}{\sin\gamma - (\mathrm{K} - \mathrm{j}60\lambda\sigma - \cos^2\gamma)^{\frac{1}{2}}} \quad [5]$$

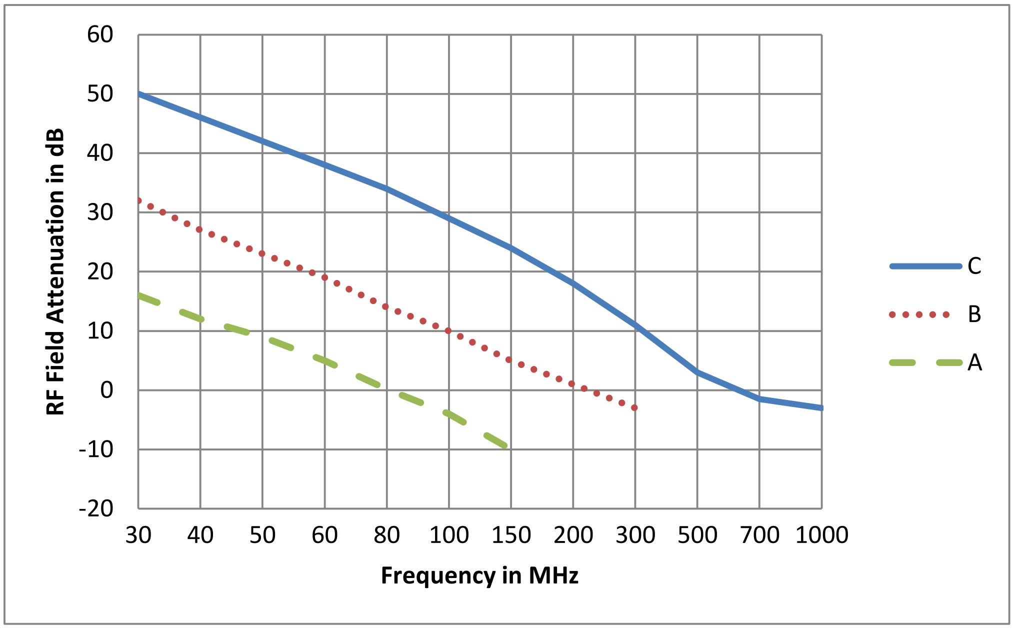
$$\rho_h = \frac{(\mathrm{K} - \mathrm{j}60\lambda\sigma)\sin\gamma - (\mathrm{K} - \mathrm{j}60\lambda\sigma - \cos^2\gamma)^{\frac{1}{2}}}{(\mathrm{K} - \mathrm{j}60\lambda\sigma)\sin\gamma - (\mathrm{K} - \mathrm{j}60\lambda\sigma - \cos^2\gamma)^{\frac{1}{2}}} \quad [6]$$

K = Relative dielectric constant
σ = conductivity, Siemens/meter

Equations [5] and [6] are just the maximum values over the receiving antenna height scan range [h+2+^{min},h_2^{max}] of the space wave fields radiated by a half-wave dipole antenna with one picowatt of radiated power. The transmitting dipole and the receiving antenna are spaced a distance R apart and the transmitting antenna is at height h_1.

Appendix A

VDE Site Attenuation Requirements



Attenuation Requirements
Figure 2 – Measurement Site Attenuation with Fixed Antenna Heights for Measurement Distance, d, and Receiving Antenna Height, h_e, for Horizontal Polarization. Note: Transmit Antenna Height for Figures 2-5 is 1 meter.

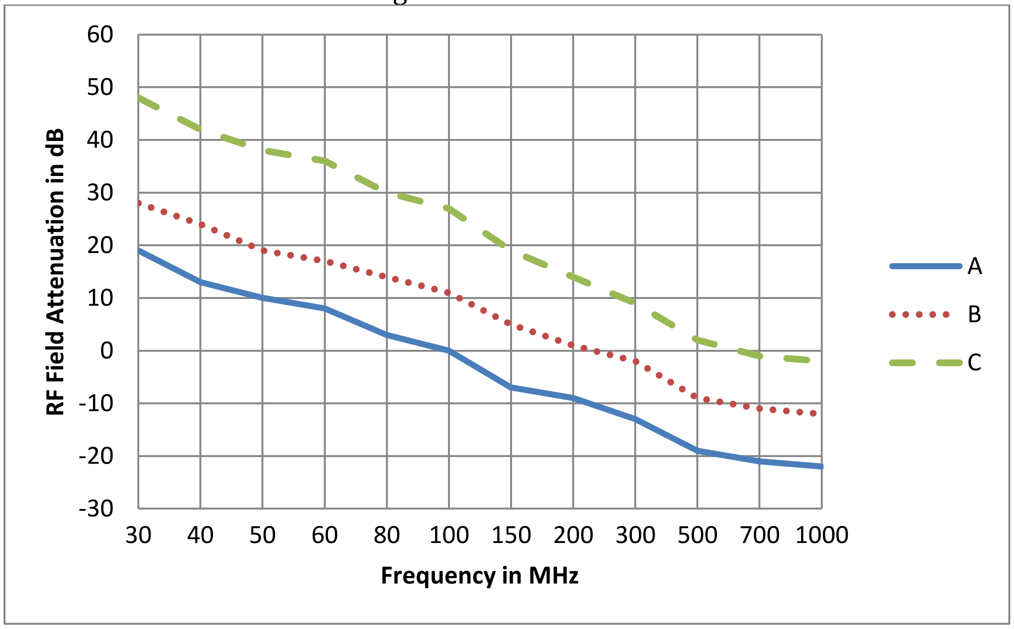


Figure 3 – Measurement Site Attenuation with Variable Antenna Height for Horizontal Polarization.

Appendix A

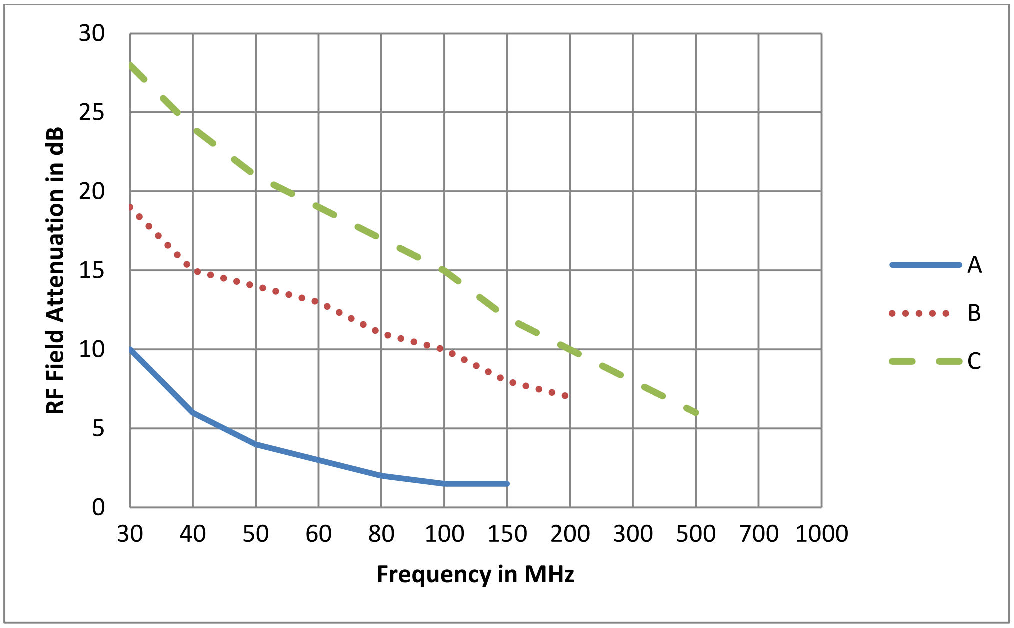


Figure 4 – Measurement Site Attenuation with Fixed Antenna Heights for Vertical Polarization

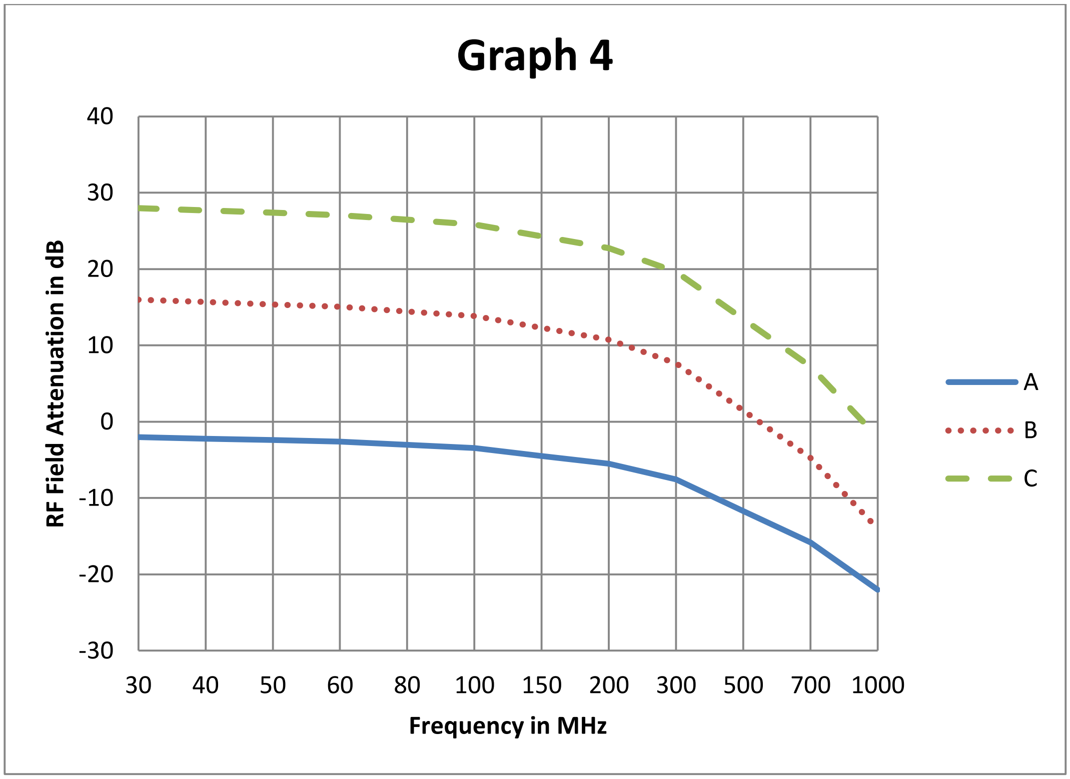


Figure 5 – Measurement Site Attenuation with Variable Antenna Heights for Vertical Polarization

Appendix A

TABLE I	
Mutual Coupling Factors For Horizontally Tuned Dipoles Spaced 3 Meters Apart	
Table Parameters: R=3m, h_1=2m, h_2=1 to 4 meter scan height	
F_{TOT} = Total Antenna Factor Correction in dB	
Freq in MHz	Correction Factor for Pair of Resonant Dipoles
30	1.3
35	2.7
40	2.7
45	1.7
50	0.0
60	-0.8
70	-1.9
80	-1.6
90	-0.9
100	-0.9
125	0.7
150	-0.7
175	-1.4
200	0.1
Note: Above 200 MHz, no mutual coupling corrections are required	

Tables I-IV: Reprinted from the 1987 IEEE EMC Symposium Records, Copyright © 1987 IEEE, The institute of electrical and Electronics Engineers, Inc., by Permission of the IEEE Copyrights and Trademarks Division. Reference pages by Donald N. Heirman entitled "Definitive Open Area Test Site Qualifications", August 1987, pp 127-134.

Appendix A

Table II

Polarization	Horz	Horz	Horz	Vert	Vert	Vert
R Meters	3	10	30	3	10	30
h_1 Meters	1	1	1	1	1	1
h_2 Meters	1 - 4	1 - 4	2 - 6	1 - 4	1 - 4	1 - 4
Freq in MHz	A_N(dB)	A_N(dB)	A_N(dB)	A_N(dB)	A_N(dB)	A_N(dB)
30	15.8	29.8	44.4	8.2	16.7	26.1
35	13.4	27.1	41.7	6.9	15.4	24.7
40	11.3	24.9	39.4	5.8	14.2	23.6
45	9.4	22.9	37.3	4.9	13.2	22.5
50	7.8	21.1	35.5	4	12.3	21.6
60	5	18	32.4	2.6	10.7	20.1
70	2.8	15.5	29.7	1.5	9.4	18.7
80	0.9	13.3	27.5	0.6	8.3	17.6
90	-0.7	11.4	25.5	-0.1	7.3	16.6
100	-2	9.7	23.7	-0.7	6.4	15.7
120	-4.2	7	20.6	-1.5	4.9	14.1
140	-0.6	4.8	18.1	-1.8	3.7	12.8
160	-7.4	3.1	15.9	-1.7	2.6	11.7
180	-8.6	1.7	14	-1.3	1.8	10.8
200	-9.36	0.6	12.4	-3.6	1	9.9
250	-11.7	-1.6	9.1	-7.7	-0.5	8.2
300	-12.8	-3.3	6.7	-10.5	-1.5	6.8
400	-14.8	-5.9	3.6	-14	-4.1	5
500	-17.3	-7.9	1.7	-16.4	-6.7	3.9
600	-19.1	-9.5	0	-16.3	-8.7	2.7
700	-20.6	-10.8	-1.3	-18.4	-10.2	-0.5
800	-21.3	-12	-2.5	-20	-11.5	-2.1
900	-22.5	-12.8	-3.5	-21.3	-12.6	-3.2
1000	-23.5	-13.8	-4.5	-22.4	-13.6	-4.2

Appendix A

Table III

Polarization	Horz	Horz	Horz
R Meters	3	10	30
h_1 Meters	2	2	2
h_2 Meters	1 - 4	1 - 4	2 - 6
Freq in MHz	A_N(dB)	A_N(dB)	A_N(dB)
30	11	24.1	38.4
35	8.8	21.6	35.8
40	7	19.4	33.5
45	5.5	17.5	31.5
50	4.2	15.9	29.7
60	2.2	13.1	26.7
70	0.6	10.9	24.1
80	-0.7	9.2	21.9
90	-1.8	78	20.1
100	-2.8	6.7	18.4
120	-4.4	5	15.7
140	-5.8	3.5	13.6
160	-6.7	2.3	11.9
180	-7.2	1.2	10.6
200	-8.4	0.3	9.7
250	-10.6	-1.7	7.7
300	-12.3	-3.3	9.1
400	-14.9	-2.8	3.5
500	-16.7	-7.6	1.6
600	-18.3	-6.3	0
700	-19.7	-10.6	-1.3
800	-20.8	-11.8	-2.4
900	-21.8	-12.9	-3.5
1000	-22.7	-13.8	-4.4

Note: See Table I for additional information regarding site attenuation using horizontally polarized antennas separated by 3 meters

Appendix A

Table IV						
Normalized Site Attenuation for Vertically Polarized Tuned Dipole Antennas						
R	3m		10m		30m	
h_1	2.75m		2.75m		2.75m	
Freq in MHz	h_2(m)	A_N(dB)	h_2(m)	A_N(dB)	h_2(m)	A_N(dB)
30	2.75 - 4	12.4	2.75 - 4	18.8	2.75 - 6	26.3
35	2.39 - 4	11.3	2.39 - 4	17.4	2.39 - 6	24.9
40	2.13 - 4	10.4	2.13 - 4	16.2	2.13 - 6	23.8
45	1.92 - 4	9.5	1.92 - 4	15.1	2 - 6	22.8
50	1.75 - 4	8.4	1.75 - 4	14.2	2 - 6	21.9
60	1.5 - 4	6.3	1.5 - 4	12.6	2 - 6	20.4
70	1.32 - 4	4.4	1.32 - 4	11.3	2 - 6	19.1
80	1.19 - 4	2.8	1.19 - 4	10.2	2 - 6	18.0
90	1.08 - 4	1.5	1.08 - 4	9.2	2 - 6	17.1
100	1 - 4	0.6	1 - 4	8.4	2 - 6	16.3
120	1 - 4	-0.7	1 - 4	7.5	2 - 6	15.0
140	1 - 4	-1.5	1 - 4	5.5	2 - 6	14.1
160	1 - 4	-3.1	1 - 4	3.9	2 - 6	13.3
180	1 - 4	-4.5	1 - 4	2.7	2 - 6	12.8
200	1 - 4	-5.4	1 - 4	1.6	2 - 6	12.5
250	1 - 4	-7.0	1 - 4	-0.6	2 - 6	8.6
300	1 - 4	-8.9	1 - 4	-2.3	2 - 6	6.5
400	1 - 4	-11.4	1 - 4	-4.9	2 - 6	3.8
500	1 - 4	-13.4	1 - 4	-6.9	2 - 6	1.8
600	1 - 4	-14.9	1 - 4	-8.4	2 - 6	0.2
700	1 - 4	-16.3	1 - 4	-9.7	2 - 6	-1.0
800	1 - 4	-17.4	1 - 4	-10.9	2 - 6	-2.4
900	1 - 4	-18.5	1 - 4	-12.0	2 - 6	-3.3
1000	1 - 4	-19.4	1 - 4	-13.0	2 - 6	-4.2
Note: See Table I for additional information regarding site attenuation using horizontally polarized antennas separated by 3 meters						

Appendix A

The Values of E_d^{Max} listed below were calculated from (A-1) and (A-2) for the indicated geometries using K=15, σ = 0.001 for earth ground planes and K = 1, σ = ∞ for metal ground planes.

Table V								
E_D^{max} for Typical Geometries								
Polarization	H	H	H	H	V	V	V	V
R Meters	3	10	30	30	3	10	30	30
h_1 Meters	1	1	1	2	1	1	1	2
h_2 Meters	.5 - 1.5	1-4	1-4	1-4	1-1.5	1-4	1-4	1-4
plane	Metal	Metal	Earth	Earth	Metal	Metal	Earth	Earth
Frequency in MHz	**E_D^{max} dBμV/m**							
30	1.6	-10.4	-26.9	-21.8	11.2	2.7	-14.7	-13.8
35	2.7	-9.1	-25.9	-20.7	11.1	2.7	-14.7	-13.8
40	3.7	-8	-25.0	-19.7	11.1	2.7	-14.7	-13.8
45	4.6	-7	-24.2	-18.8	11	2.7	-14.7	-13.8
50	5.3	-6.1	-23.5	-18	10.9	2.6	-14.7	-13.8
60	6.7	-4.7	-22.1	-165.6	10.7	2.6	-14.7	-13.7
70	7.8	-3.5	-21.0	-15.4	10.5	2.6	-14.7	-13.6
80	8.8	-2.4	-19.9	-14.4	10.3	2.6	-14.6	-13.5
90	9.6	-1.6	-19.0	-13.5	10	2.5	-14.5	-13.4
100	10.2	-0.8	-18.1	-12.6	9.6	2.5	-14.5	-13.3
120	11.2	0.4	-16.7	-11.3	8.8	2.4	-14.5	-13.1
125	11.4	0.6	-16.3	-11	8.6	2.4	-14.3	-13
140	11.9	1.2	-15.4	-10.2	7.8	2.3	-14.1	-12.8
150	12.1	1.5	-14.9	-9.8	7.2	2.3	-14	-12.7
160	12.2	1.8	-4.3	-9.3	6.5	2.2	-13.9	-12.6
175	12.3	2.1	-13.6	-8.8	5.4	2.1	-13.8	-12.4
180	12.4	2.1	-13.4	-8.6	5	2.1	-13.7	-12.4
200	12.5	2.3	-12.6	-8.1	3.2	1.9	-13.5	-12.2
250	12.7	2.5	-10.9	-7.3	7.2	1.5	-13	-11.7
300	12.7	2.6	-9.7	-7.1	9.7	0.9	-12.5	-11.4
400	12.8	2.7	-6.0	-7	10.9	1	-11.7	-10.8
500	12.8	2.8	-7.2	-7	11.3	1.7	-11.2	-10.5
600	12.5	2.8	-7.0	-6.9	9.5	2	-10.7	-10.2
700	12.6	2.8	-7.0	-6.9	10.4	2.2	-10.4	-10
800	12.7	2.8	-6.9	-6.9	10.9	2.4	-10.1	-9.9
900	12.7	2.6	-6.9	-6.9	11.2	2.4	-9.9	-9.8
1000	12.8	2.7	-6.9	-6.9	11.3	2.5	-9.7	-9.7

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