

Short Papers

Site Attenuation

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Abstract—Site attenuation is a measure of performance of an open test site at frequencies below about 1 GHz. These sites typically consist of a large obstruction-free ground plane and the hemisphere above it. Calculations of site attenuation are presented which provide a reference for measurements made on a 30- by 60-m wire-mesh ground screen. Measured data are compared to the calculated results.

Key Words—Site attenuation.

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I. INTRODUCTION

Site attenuation is a measure of performance of an open test site used to determine the levels of emissions from electromagnetic sources or to calibrate monopole and dipole antennas used for field-strength measurements. An ideal site consists of obstruction-free plane ground and the hemisphere above it, both infinite in extent. Ground constants may range from typical earth values to values for good conductors. Site-attenuation measurements are used to compare performance of real sites to some standard or reference site. Calculations presented here provide a reference for the measurement results obtained from a 30- by 60-m wire-mesh ground screen.

Site attenuation is defined as the minimum relative insertion loss measured between the terminals of two polarization-matched antennas located on the test site when one antenna is moved vertically over a specified height range. The following parameters must also be specified: separation distance between the two antennas, *measured horizontally*; antenna type and polarization; and impedance of the receiving and transmitting systems attached to the antenna terminals. Note that this definition includes mismatch losses but not balun or cable losses.

II. CALCULATIONS

Relative insertion loss between two thin half-wave dipole antennas in free space may be calculated using mutual impedance between the dipoles [1]:

$$Z_{21} = -\frac{V_{21}}{I_{1b}}$$

By calculating the mutual impedance Z_{21} , the open-circuit voltage V_{21} at the terminals of the receiving dipole can be determined if the base current I_{1b} in the transmitting dipole is known. Only the positions of the dipoles are needed to compute all the required mutual impedances for two half-wave dipoles over a plane perfect conductor. The test-range geometry and mutual-impedance relations are shown in Fig. 1 for horizontal polarization. The value of I_{1b} is calculated assuming 1 W of power is delivered to the transmitting dipole that has an input impedance equal to its self-impedance [2] properly combined with the

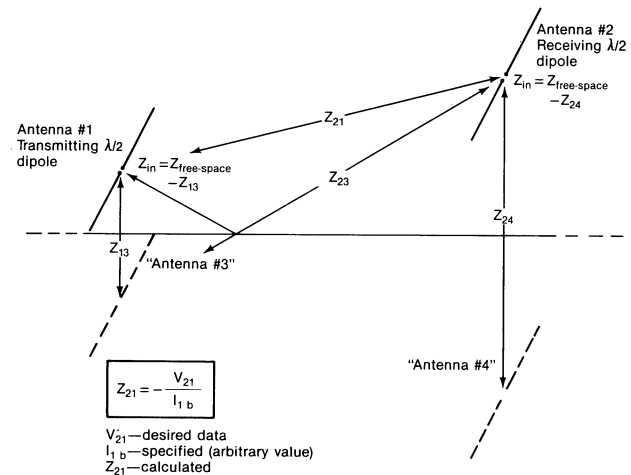


Fig. 1. Test-range geometry and the impedance relationships for horizontal dipole antennas.

mutual impedance between it and its image in ground. Input impedance of the receiving dipole is calculated in the same way, and used with Z_{21} and Z_{23} to calculate the received power. The impedance of the transmitting dipole is assumed to be unaffected by the current in the finite load impedance of the receiving dipole.

Relative insertion loss is the ratio of the power delivered to the transmitting dipole terminals to the power received at the receiving dipole terminals and is a positive quantity. Site attenuation is the minimum insertion loss occurring when the receiving dipole is scanned in height. The height-scan patterns in Fig. 2 show calculated insertion loss for horizontally polarized (HP) and vertically polarized (VP) dipoles with a 3-m separation distance. The transmitting dipole is 2 m above perfectly conducting ground. Site attenuation is the single minimum value of each pattern. Fig. 3 shows site attenuation versus frequency for horizontal-separation distances (S) of 1, 10, and 30 m. Heights scanned are 1–4 m at the 3- and 10-m separation distances and 2–6 m at the 30-m separation distance, except for vertical polarization when the half-length of the receiving dipole would touch the ground. The lower tip of the VP dipole is always positioned at 5 cm, or more, above the ground.

Calculated site attenuation provides an ideal reference. Deviations of measured data from the reference indicate site imperfections.

III. MEASUREMENTS

Fig. 4 shows the measurement procedure used for determining site attenuation. The reference relative insertion loss, shown in Fig. 4(a), is a received signal level, expressed in dBm, dependent upon the output level of the signal generator and balun, cable, and attenuator losses. The output level remains fixed during the measurement procedure and is somewhat arbitrary. It is less than the maximum level acceptable by the receiver, but great enough so the signal level in Fig. 4(b) is well above the ambient noise level.

The dipole antennas used to measure site attenuation at the National Bureau of Standards (NBS) have hybrid junctions for antenna baluns. Equal-length coaxial cables from the dipole terminals to the hybrid junction form a 100- Ω balanced shielded transmission

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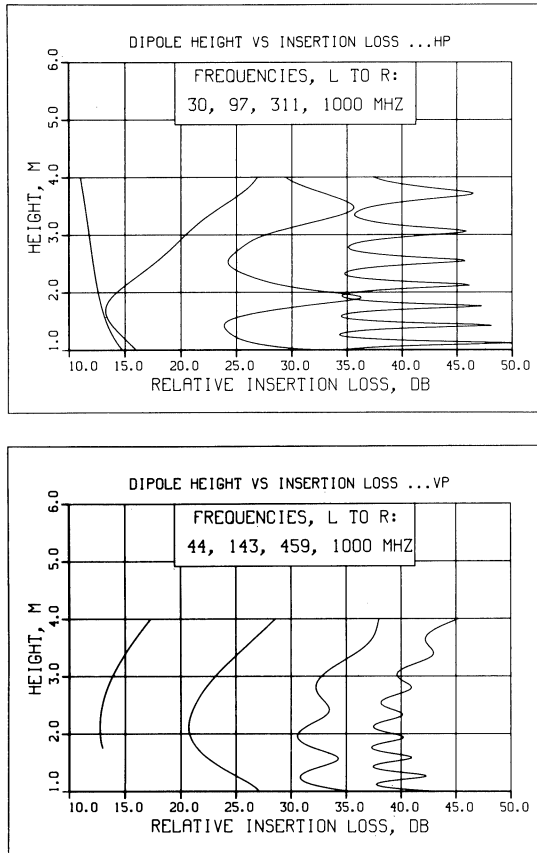


Fig. 2. Selected relative-insertion-loss data calculated for horizontally polarized (HP) and vertically polarized (VP) dipoles over perfect ground. Site attenuation is the single minimum relative-insertion-loss value of each curve. Horizontal separation distance is 3 m; transmitting dipole height is 2 m.

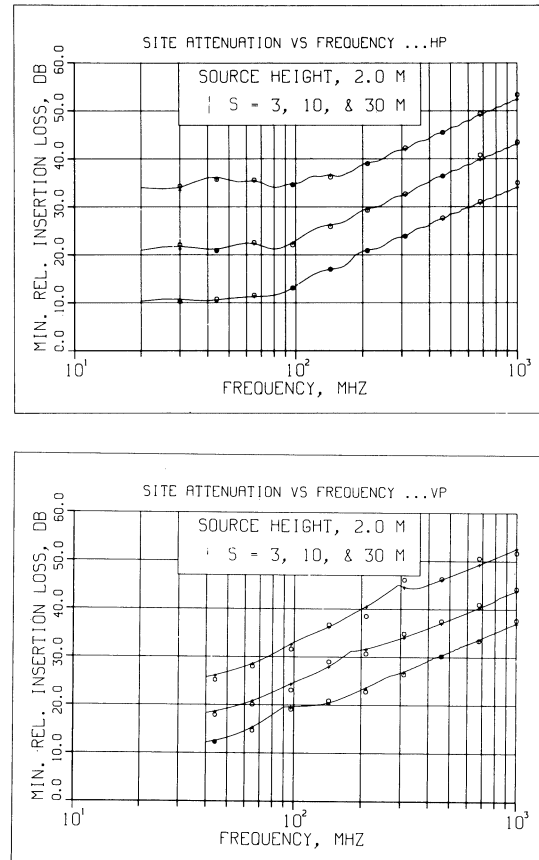


Fig. 3. Site attenuation for horizontally polarized (HP) and vertically polarized (VP) dipoles over perfect ground. Solid curves are calculated for half-wave dipoles with radius = $1.E-30$ m; + points are calculated for dimensions of actual dipoles. Measured data are shown as o.

line. As a result, the receiving and transmitting system impedances are 100Ω . This value is used to calculate the reference site attenuation data shown in Fig. 3, as the solid lines for very thin dipoles and (+) points for dipoles with dimensions of those actually used for the measurements. To insure that this impedance is 100Ω , miniature 3-dB attenuators are permanently installed in the four separate cables at the point of attachment to the dipole terminals.

The receiving dipole is moved up and down over the specified height range by a person below the ground screen who observes the receiver display. The maximum received signal level is recorded by a peak sample-and-hold circuit in the receiver. The magnitude of the difference between the reference insertion loss value and this maximum measured value gives site attenuation directly. No additional measurement or correction is required. The measured data are represented by circles in Fig. 3.

IV. ERROR ESTIMATE

Test-range antenna heights and separation distances are set within ± 1 cm, assuming the ground-screen surface is perfectly flat. Dipole height is measured at the dipole feed point. The extensible dipoles used at 97 MHz and lower frequencies droop about 16 cm at the tips at 30 MHz. No effort is made to keep these dipoles straight. Calculated errors in site attenuation are at most ± 0.09 dB as a result of possible positioning errors (neglecting dipole droop).

The stability of the receiver, signal generator, hybrid junctions, and cable combination is determined by the repeatability of the reference insertion-loss measurements (Fig. 4(a)) performed before and after each subset of measurements. (The three subsets of

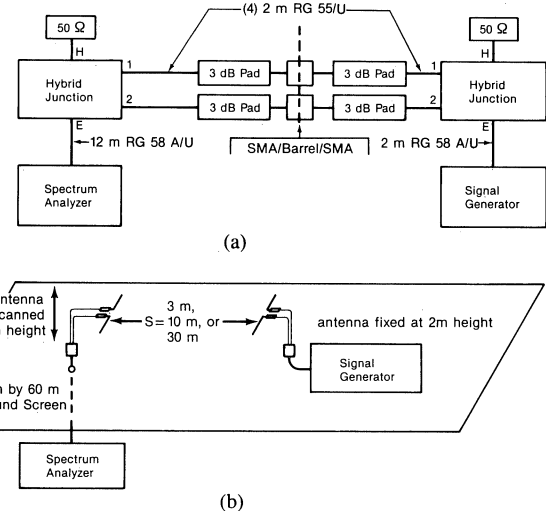


Fig. 4. Schematic diagram of measurement procedure. (a) Measure reference insertion loss. (b) Measurement reference insertion loss plus site attenuations.

measurement frequencies are determined by the frequency ranges of the three sets of hybrid junctions.) Over these typically 2-h time periods, the difference between the initial and final reference insertion-loss data is at most ± 0.11 dB. This variability appears to be predominantly caused by cable handling, connector mating, and moving the signal generator. Since this is a *relative* insertion-loss measurement, not an absolute one, the primary accuracy limitation is

TABLE I
MEASURED AND CALCULATED SITE ATTENUATION DATA (dB)

Horizontal Polarization						
Frequency, MHz	3 m Distance		10 m Distance		30 m Distance	
	meas.	calc.	meas.	calc.	meas.	calc.
30.0	10.3	10.182	22.1	21.238	34.3	33.461
44.0	10.8	10.357	20.9	20.912	35.7	35.850
65.0	11.6	11.389	22.6	22.332	35.6	35.350
97.0	13.1	13.124	22.1	22.446	34.6	34.689
143.0	17.0	17.142	25.9	26.261	36.2	36.630
210.0	20.9	20.954	29.3	29.527	39.0	39.057
311.0	23.9	23.903	32.7	32.455	42.3	41.977
459.0	27.7	27.401	36.4	36.370	45.5	45.435
677.0	31.1	30.720	40.8	39.777	49.4	49.078
1000.0	35.0	34.045	43.5	43.112	53.4	52.439

Vertical Polarization						
Frequency, MHz	3 m Distance		10 m Distance		30 m Distance	
	meas.	calc.	meas.	calc.	meas.	calc.
44.0	12.3	12.312	17.9	18.507	25.2	26.014
65.0	14.7	15.286	20.1	20.782	28.0	28.508
97.0	19.1	19.438	23.1	24.295	31.6	32.530
143.0	20.9	20.268	29.0	27.909	36.7	36.152
210.0	22.8	23.412	30.7	31.529	38.5	40.437
311.0	26.4	26.798	34.9	33.998	46.1	44.459
459.0	30.2	30.212	37.5	36.998	46.3	46.068
677.0	33.4	33.531	41.0	40.202	50.6	49.230
1000.0	37.7	36.961	44.2	43.779	51.7	52.576

the manufacturer's specified "cumulative fidelity" for the receiver (spectrum analyzer) of " $\leq \pm 1.0$ dB over 0 to 80-dB display, 20–30°C." Therefore a simple worst-case error estimate is $(\pm 0.09 \pm 0.11 \pm 1.0) \leq \pm 1.2$ dB.

The statistics of the measured data imply that the uncertainty may be less than half of this worst-case estimate if it is assumed that the calculated data are correct. The average difference between the measured and calculated (calculated – measured, decibel) data for horizontal polarization is -0.2 dB with a standard deviation of 0.4 dB calculated using the decibel values.

The data for the single measurement set upon which this paper is based are shown in Table I. This was the first set of data measured after the preliminary set used to determine the suitability of the various test components. Failure of the air-supported fabric cover over the NBS ground screen facility has temporarily halted further measurements.

The greatest difference between measured and calculated site attenuation is 1.02 dB for horizontal polarization, where the effect of feed-cable reflections is negligible, and 1.94 dB for vertical polarization.

V. CONCLUSIONS

The agreement between measured and calculated site attenuation data is good, even for vertical polarization. The agreement for vertical polarization is believed to result from the use of commercial hybrid junctions as dipole-antenna baluns. These devices split the E -port power $180^\circ \pm 1^\circ$ at the 1 and 2 ports. Little or no unbalanced (common-mode) current flows on the feed cables and produces unwanted radiation.

Implementation of the deceptively simple mutual-impedance equations is actually a fairly straightforward computer-programming exercise. To relieve interested readers of this exercise, the author will provide a 400-line listing of the FORTRAN 4 code used to calculate site

attenuation. No claim is made for the efficiency or structure of the code, nor for its accuracy beyond the comparison of measured and calculated results presented here.

The actual measurement technique is certainly not new. It is basically a "two-identical-antenna" gain measurement that stops short of the last step, subtracting the path loss and mismatch loss from the measured data to obtain the product of the gain of two identical antennas over ground.

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Peripheral Cable-Shield Termination: The System EMC Kernel

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Abstract—This paper presents experimental data that show an overwhelming dependence of system electromagnetic compatibility (EMC) on system cable effects, rather than leakage through cracks, seams, and other box (LRU and WRA) openings. A laboratory experiment compares cable-shield RF leakage from a pigtail-terminated cable with that of one

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