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IEEE Std 473™-1985 (Withdrawn 2006)

IEEE Recommended Practice for an Electromagnetic Site Survey (10kHz to 10 GHz)

Sponsor

**Technical Committee 3 on Electromagnetic Environments
of the
IEEE Electromagnetic Compatibility Society**

Withdrawn 3 February 2006

IEEE-SA Standards Board

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Foreword

(This Foreword is not a part of IEEE Std 473-1985, IEEE Recommended Practice for an Electromagnetic Site Survey (10 kHz to 10 GHz).)

In the field of radio engineering the need for practitioners to perform an electromagnetic site survey is common. The specific objectives of site surveying vary widely as do the details of the sites where they are executed. Thus, while surveys also have much in common, allowance for these variances must be preserved in a standard practice. The objective of this recommended practice is to preserve necessary freedom of choice and to make due allowance for individuality in survey practice while carefully articulating those elements of radio-frequency surveying that can and should be common to all undertakings. Only by standardizing the essential survey procedures and equipments can coherent representations of the radio-frequency environment emerge and become beneficial to the radio-engineering community.

This recommended practice draws from a wealth of technical material, far too extensive to be addressed except by reference. All users are urged to make generous use of the citations which have been carefully screened for relevance.

The Committee is indebted to the many anonymous members of the IEEE and other technical societies who have unselfishly contributed to this effort.

It is the hope and request of the Committee that, as use is made of this recommended practice, its flaws will be brought to our attention so that it may be improved to better serve the engineering community.

At the time this standard was approved, the members of Technical Committee 3 on Electromagnetic Environments of the IEEE Electromagnetic Compatibility Society were as follows:

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Letter Symbols for Quantities

A	antenna aperture area
AF	antenna factor
AF _c	antenna factor of a calibrated reference antenna

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B	noise bandwidth
D_1	lower decile value of a random variable
$\hat{D}$	deflection of a trace
D_s	dimension of a radiating source
D_u	upper decile value of a random variable
$\tilde{d}$	antenna dimension (usually diameter)
$d\hat{\alpha}(N)$	confidence bound for sample size N
$d\hat{a}$	confidence bound
E	electric field strength (V/m)
E_{dB}	electric field strength, decibels (ref 1 $\mu\text{V/m}$)
F	$10 \log f$, noise figure for a receiving system
F_a	external (antenna) noise figure, $F = 10 \log f_a$
F_{am}	median value of F_a
$F_o(x)$	theoretical cumulative distribution of the random variable x
f	operating noise factor for a receiving systems
f_a	external noise factor
f_p	impulse repetition rate
f_r	receiver noise factor
Δf	scan frequency interval
Δf_{6dB}	6 dB bandwidth
Δf_{imp}	impulse bandwidth
G	antenna gain expressed in decibels
g	antenna gain
$\hat{h}$	physical length of a linear antenna
H	magnetic field strength in amperes per meter
k	Boltzmann's constant, $1.38 \cdot 10^{-23}$ J/K
L_u	largest dimension of an antenna
l	added receiver circuit attenuation factor
l_c	antenna circuit loss factor
l_t	transmission line loss factor
MR_c	output voltage of a calibrated reference antenna expressed in decibels relative to 1 W
MR_t	output voltage of a test antenna expressed in decibels relative to 1 W
N	sample size
N_t	number of threshold levels
P_n	noise power in decibels relative to 1 W
p_n	noise power
μP	power per megahertz in decibels relative to 1 μW
$p_o(v_i)$	probability the i th threshold voltage will be exceeded
$\Delta p_o(v_i)$	incremental probability
p_r	detected power in watts
$p(\alpha)$	probability α to $\epsilon \chi \chi \epsilon \delta \epsilon \delta$
R	frequency scanning rate in hertz per second
R_c	charging time constant resistance
R_d	discharging time constant resistance
r	resistance in ohms
S	noise power flux density, dB (W/m ²) Hz
$S_N(x)$	observed cumulative distribution of a sample size, N , of random variable x
S_r	slew rate of a recorder
T	measurement time interval
T_a	antenna temperature
T_e	effective noise temperature of a receiver
T_o	reference temperature, 288 K
t_m	minimum frequency scan time

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V	$10 \log v$, v in volts
V_{av}	mean value of v
V_d	voltage deviation
V_i	incremental value of v_i
V_{peak}	peak voltage
V_{rms}	root mean square voltage
$v_{1,2}$	envelope voltage values
v_i	i th threshold voltage value
Δv	difference between the i th and the $(i+1)$ threshold voltage
w	power density, in watts per centimeters squared
$\bar{x}$	median of true population, x
x_i	i th value of the random variable x
x_m	median value of a subset of random variable x
Z_o	impedance of free space, 377Ω
α	circuit parameter: see [27]
α	statistical significance level
Γ	slope or the cumulative distribution of a random variable in the vicinity of the median value
$\hat{I}$	antenna efficiency
η	allowable fractional increase in system noise temperature
λ	radio signal wavelength in a vacuum
λ_m	free space wavelength of the lowest measurement frequency
$\bar{\sigma}_s$	median vlaue of the root-variance of building attenuation
T	time

Unit Symbols

K	Kelvin
ms	milliseconds
dBw	dB (ref 1 w)
V	volts
dB(μ V/MHz)	spectral intensity expressed in decibels
kHz	kilohertz

Abbreviations

ACR	average crossing rate of the envelope voltage
APD	amplitude probability distribution. <i>See</i> $D(v)$
BFO	beat frequency oscillator
BLK	black
cw	continuous wave
cm	common mode
crt	cathode ray tube
dm	differential mode
EMC	electromagnetic compatibility
FSK	frequency shift keying
GRN	green
if	intermediate frequency
PDD	pulse duration distribution
PSD	pulse spacing distribution
rf	radio frequency
RTT	radio teletype
WHT	white
ISM	instrument, scientific, and medical
NCFSK	noncoherent frequency shift keying

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IEEE Recommended Practice for an Electromagnetic Site Survey (10 kHz to 10 GHz)

1. Introduction

An electromagnetic (em) site survey is a systematic, documented investigation of the amplitudes of radio-frequency (rf) em fields found at one or more locations with respect to frequency, time, and position. Although these ambient em fields may have intrinsic interest, more commonly they will be regarded as radio noise or simply as interference. This *noise level* establishes the minimum useable signal strength for satisfactory service. Furthermore, it often dictates equipment design decisions intended to reduce any adverse effects of this interference on system performance. Survey sites of interest may be at virtually any indoor or outdoor location. Radio-frequency sampling may involve either airborne or surface platforms.

Electromagnetic nonionizing radiation studies are generally initiated for one of two reasons

- 1) To characterize the performance of an existing or planned electronic system
- 2) To examine the potential contribution to short- and long-term biological effects

Recognizing the potentially diverse uses of survey results, a systematic approach has been developed allowing accurate cross-comparison of data collected at different times and locations.

This practice addresses periodic and random radiated electric and magnetic fields and conducted interference within the frequency range of 10 kHz to 10 GHz. Several aspects of radioemission investigations are not addressed directly in this text including signal identification and discrimination, field emission from regularly occurring, low-frequency, pulses sources, and test enclosure fields. However, much information pertinent to these areas is provided here.

Throughout this recommended practice letter symbols for quantities are in accordance with ANSI/IEEE Std 280-1985 [10]¹ and letter symbols for units of measurement are in accordance with ANSI/IEEE Std 260-1978 [9]. See ANSI Y1.1-1972 (R 1984) [6] for abbrevitions.

¹The numbers in brackets correspond to those of the references in Section 3.

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2. Definitions

Specialized terms and expressions used throughout this recommended practice and not found in ANSI/IEEE Std 100-1984 [7] are listed here.

average crossing rate (ACR). The average number of crossings in the positive direction of a given level v_i per unit time. (See Fig 1.)

amplitude probability distribution (APD). A distribution showing the probability (commonly a percentage of time) that an amplitude is exceeded as a function of amplitude v_1 .

decile, D_L . The ratio of the lower decile value (the value of x exceeded 90% of the time) of the random variable x to its median value, expressed in decibels.

decile, D_U . The ratio of the upper decile value (the value of x exceeded 10% of the time) of the random variable x to its median value, expressed in decibels.

envelope voltage or voltage envelope. The magnitude of the complex representation of the observed instantaneous voltage.

NOTE — Envelope voltage is always a positive quantity permitting the logarithmic operation to be performed upon the value.

impulse bandwidth. The ratio of the maximum value of the voltage at the output of a network (when properly corrected for network sinewave gain at the stated reference frequency) to the spectrum amplitude of the pulse applied at the input. In networks with a single-humped response the reference frequency is taken as that at which the gain is maximum.

pulse duration distribution (PDD). The fraction of pulse duration at level v_i that exceeds time T . (See Fig 1.)

pulse spacing distribution (PSD). The fraction of pulse spacing time, at level v_i that exceeds time T . (See Fig 1.)

receiver 1 dB gain compression point. The input signal level to an otherwise linear receiver for which the gain has been decreased 1 dB below the value measured for the minimum detectable input signal (within the linear response range).

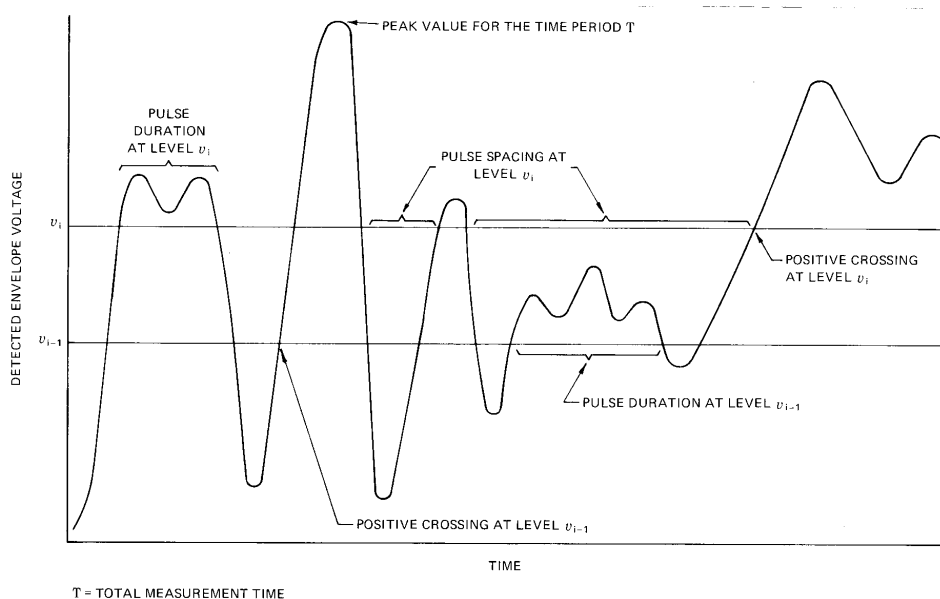


Figure 1— Typical Noise Envelope of a Man-Made Radio-Noise Process

receiver linear dynamic range. The interval between the minimum detectable signal and the 1 dB gain compression point within which the receiver gain deviates from a constant value by less than 1 dB.

voltage deviation, V_d . The ratio of the root mean squared envelope voltage to the average envelope voltage of a signal expressed in decibels.

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3. References

When the American National Standards referred to in this recommended practice are superseded by a revision approved by the American National Standards Institute, Inc, the revision shall apply.

[1] ANSI C63.2-1980, American National Standard Specifications for Electromagnetic Noise and Field Strength Instrumentation, 10 kHz to 1 GHz.²

[2] ANSI C63.4-1980, American National Standard Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 10 kHz to 1 GHz.

[3] ANSI C95.1-1980, American National Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz.

[4] ANSI C95.3-1973 (R 1979), American National Standard Techniques and Instrumentation for the Measurement of Potentially Hazardous Electromagnetic Radiation at Microwave Frequencies.

[5] ANSI C95.5-1980, American National Standard Recommended Practice for the Measurement of Hazardous Electromagnetic Fields—RF and Microwave.

[6] ANSI Y1.1-1972 (R 1984), Abbreviations for Use on Drawings and in Text.

[7] ANSI/IEEE Std 100-1984, IEEE Standard Dictionary of Electrical and Electronics Terms.³

[8] ANSI/IEEE Std 149-1979, IEEE Standard Test Procedures for Antennas.

[9] ANSI/IEEE Std 260-1978, IEEE Standard Letter Symbols for Units of Measurement (81 Units, Customary Inch-Pound Units, and Certain Other Units).

[10] ANSI/IEEE Std 280-1985, IEEE Standard Letter Symbols for Quantities Used in Electrical Science and Electrical Engineering.

[11] ANSI/IEEE Std 474-1973 (R 1982), IEEE Standard Specifications and Test Methods for Fixed and Variable Attenuators, DC to 40 GHz.

[12] ANSI/IEEE Std 488-1978, IEEE Standard Digital Interface for Programmable Instrumentation.

[13] CBEMA-ESC5-1977, Computer and Business Manufacturers Association Limits and Methods of Measurement of Electromagnetic Emanations from Electronic Data Processing and Office Equipment, May 20, 1977.⁴

[14] CCIR R 322-1963, Distribution and Characteristics of Atmospheric Radio Noise.⁵

[15] IEEE Std 291-1969 (R 1981), IEEE Standards Report on Measuring Field Strength in Radio Wave Propagation.

[16] IEEE Std 302-1969 (R 1981), IEEE Standard Methods for Measuring Electromagnetic Field Strength for Frequencies Below 1000 MHz in Radio Wave Propagation.

²ANSI publications are available from the Sales Department, American National Standard Institute, 1430 Broadway, New York, NY 10018.

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, Piscataway, NJ 08854.

⁴CBEMA publications are available from the Computer and Business Machine Manufacturers Association, 311 First St, NW, Suite 500, Washington, DC 20001.

⁵CCIR publications are available in the US from National Technical Information Service, Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

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- [17] MIL-STD-462 1967, Measurement of Electromagnetic Interference Characteristics.⁶
- [18] NCDRH 21 CFR, Part 1030.10, Performance Standard for Microwave and Radio-Frequency Emitting Products, Apr 1983.⁷
- [19] Reference Data for Radio Engineers. New York: Howard W. Sams Company, 1975.
- [20] SAE-AIR 1509-1978, EMC Antennas and Antenna Factors: How to Use them.⁸
- [21] Health and Welfare, Ottawa, Canada, Safety Code 6, *Recommended Safety Procedures for the Installation and Use of Radio Frequency and Microwave Devices in the Frequency Range 10 MHz to 300 GHz*, Feb 1979.
- [22] ANDREWS, B. H. The Flux Densities of Twenty Radio Sources at 31.1 Mc/s. *Journal of Astrophysics*, Feb 1967, pp 423–432.
- [23] BOISCHOT, A. Les Bruits Cosmiques. *AGARD Conference Proceedings for Electromagnetic Noise, Interference and Compatibility no 159*, Nov 1975, pp 4-1 and 4-12.
- [24] BULLINGTON, K. Radio Propagation Fundamentals. *Bell Systems Technical Journal*, vol 36, no 3, May 1957, pp 593–626.
- [25] COTTONY, H. V., and JOHLER, J. R. Cosmic Radio-Noise Intensities in the VHF Band. *Proceedings of the IRE*, vol 40, no 9, Sept 1952, pp 1053–1060.
- [26] DIETZ, J. Examination of the Feasibility of Conventional Land Mobile Operations at 950 MHz, Phase I, Base-to-Mobile. *FCC Report*, R-1702, Mar 1971.
- [27] GESELOWITZ, D. B. Response of Ideal Radio Noise Meter to Continuous Sine Wave, Recurrent Impulses, and Random Noise. *IRE Transactions on Radio-Frequency Interference*, vol RFI-3, no 1, May 1961, pp 2–11.
- [28] GREENE, F. M. Influence of the Ground on the Calibration and Use of VHF Field-Intensity Meters. *Journal of Research of the National Bureau of Standards*, vol 44, no 2, Feb 1950.
- [29] HABER, F. Response of Quasi-Peak Detector to Periodic Impulses with Random Amplitudes. *IEEE Transactions on Electromagnetic Compatibility*, vol EMC-9, no 1, Mar 1967, pp 1–5.
- [30] HAGN, G. H. Calibration of 9-ft Rod Antenna for MF and HF EMC Measurements. *IEEE International Electromagnetic Compatibility Symposium Record*, vol EMC-S, June 1978, pp 160–168.
- [31] KRAUS, J. D. *Radio Astronomy*. New York: McGraw-Hill, 1966.
- [32] LARSEN, E. B. and RIES, F. X. Design and Calibration of the NBS Isotropic Electric-Field Monitor (EFM-5), 0.2 to 1000 MHz. *National Bureau of Standards Technical Note 1033*, Mar 1981.
- [33] LARSEN, E. B. and SHAFER, J. F. Surveys of Electromagnetic Field Intensities Near Representative Higher-Power FAA Transmitting Antennas. *Federal Aviation Report*, FAA-RD-77-179, Dec 1977.

⁶MIL publications are available from the Director, US Navy Publications and Printing Service, Eastern Division, 700 Robbins Avenue, Philadelphia, PA 19111.

⁷NCDRH publications are available from the Technical Information Staff (HFX-28), National Center for Devices and Radiological Health, FDA, 5600 Fishers Lane, Rockville, MD 20857.

⁸SAE publications are available from the Society of Automotive Engineers, Inc, 400 Commonwealth Drive, Warrendale, PA 15096.

WITHDRAWN

- [34] LIN, JAMES C., GUY, ARTHUR W., and JOHNSON, CURTIS C. Power Deposition in a Spherical Model of Man Exposed to 1–20 MHz Electromagnetic Fields. *IEEE Transactions on Microwave Theory and Techniques*, vol MTT-21, Dec 1973, pp 791–797.
- [35] LONGLEY, A. G. Location Variability of Transmission Loss-Land Mobile and Broadcast Systems. *Office of Telecommunications Report*, ORT-76-87, May 1976.
- [36] LONGLEY, A. G., and RICE, P. L. Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain, A Computer Method—1968. *ESSA Technical Report*, ERL 79-ITS 67, July 1968.
- [37] MAGRAB, E. B., and BLOMQUIST, D. S. *The Measurement of Time Varying Phenomenon*. Washington, DC: Wiley Interscience, 1971.
- [38] MAHLUM, RONALD W. *Flight Measurements of Aircraft Antenna Radiation*. Final Report, USAF Flight Test Center, Edwards Air Force Base, CA AFFTC-TD-75-3, Oct 1975.
- [39] MASSEY, Jr, FRANK J. The Kolmogorov-Smirnov Test for Goodness of Fit. *American Statistical Association Journal*, Mar 1951, pp 68–78.
- [40] MATTOX, W. How to Select Minimum Sweep Time for Plotter Readout. *EDN/EEE*, vol 16, no 14, July 15, 1971, pp 46–47.
- [41] MIR, S., and WHITE, D. R. J. Building Attenuation and the Impact on Product Susceptibility. *IEEE Electromagnetic Compatibility Symposium Record*, July 1974, pp 76–84.
- [42] OKUMURA, Y., OHMORI, E., KAWANO, T., and FUKADA, K. Field Strength and its Variability in VHF and UHF Land-Mobile Radio Service. *Review of the Electrical Communication Laboratory*, vol 16, no 9–10, Sept 1968, pp 825–873.
- [43] RICE, L. P. Radio Transmission into Buildings at 35 and 150 Mc. *Bell Systems Technical Journal*, Jan 1959, pp 197–210.
- [44] RICE, P. L., LONGLEY, A. G., NORTON, K. A., and BARSIS, A. P. Transmission Loss Predictions for Tropospheric Communication Circuits. *National Bureau of Standards Technical Note 101*, vols 1 and 2, May 1965.
- [45] RUGGERA, P. S. Near-Field Measurements of RF Field. US Department of Health, Education, and Welfare Publication (FDA) 77-8026, *Symposium on Biological Effects and Measurements of Radio-Frequency and Microwaves*, Rockville, MD, Feb 16–17, 1977, pp 104–116.
- [46] RUGGERA, P. S., *E-Field Instrumentation and Calibration Below 500 MHz*. US Department of Health, Education, and Welfare, Publication (FDA) 77-8011, Dec 1976, Biological Effects of Electromagnetic Waves, Selected Papers of the USNC, URSI Annual Meeting, Boulder, CO, vol 2, Oct 1975, pp 281–296.
- [47] SHEPHERD, R. A. GADDIE, J. C., and NIELSON, D. L. *Improved Suppression of Radiation from Automobiles Used by the General Public*. Final Report, SRI International Project 2763, Jan 1975.
- [48] SKOMAL, E. N. The Dimensions of Radio Noise. *IEEE Electromagnetic Compatibility Symposium Record*, June 1969, pp 18–28.
- [49] SKOMAL, E. N. *Man-Made Radio Noise*. New York: Van Nostrand Reinhold, 1978.
- [50] SMITH, Jr, A. A. Attenuation of Electric and Magnetic Fields by Buildings. *IEEE Transactions on Electromagnetic Compatibility*, vol EMC-20, no 3, Aug 1978, pp 411–418.

WITHDRAWN

[51] SMITH, Jr, A. A. Power-Line Noise Survey. *IEEE Transactions on Electromagnetic Compatibility*, vol EMC-14, no 1, Feb 1972, pp 31–32.

[52] SMITH, Jr, A. A. Propagation of Interference Currents on Power Mains. *Third Symposium and Technical Exhibition on Electromagnetic Compatibility*, Rotterdam, May 1–3, 1979, pp 465–470.

[53] SMITH, Jr, A. A. Received Voltage Versus Antenna Height. *IEEE Transactions on Electromagnetic Compatibility*, vol EMC-11, no 3, Aug 1969, pp 104–111.

[54] SPAULDING, A. D., and DISNEY, R. T. Man-Made Radio Noise, Part I, Estimates for Business, Residential, and Rural Areas. *Office of Telecommunications Report*, OTR 74- 38, Boulder, CO, June 1974 (NTIS: COM-75-10798/7).

[55] WELLS, P. I., and TRYON, P. V. The Attenuation of UHF Radio Signals by Houses. *Office of Telecommunications Report*, OTR-76-98, Aug 1976 (NTIS: PB-258-447/2).

[56] YATES, R. W., and WIELEBINSKI, R. Intensity-Frequency Dependence of the Radio Sky Background. *Australian Journal of Physics*, vol 19, 1966, pp 389–407.

4. Test Planning

4.1 Site Electromagnetic Environment

An electromagnetic radiation survey may consist of measurements in which the rf environment is characterized, at one extreme, by a single frequency which varies little with time and slowly with position, and at the other extreme, by composites of periodic and random emissions of many frequencies varying greatly with time and observation point. In preparation for surveying a given site, the character of the radiation environment likely to be present should be determined. Electromagnetic radiation fields will include not only emissions from licensed transmitters, but also ambient noise from both natural and unintentional man-made sources. Information on US land-based sources may be obtained from national spectrum management authorities such as the Federal Communications Commission or the area frequency coordinator of the United States Department of Defense (in Canada consult the Department of Communications). Information requests might include source, location, output power schedule, antenna height, radiation pattern, polarization, effective radiated power, and frequency. The operating duty factor may be obtained directly from the license holder. Each investigator shall supplement these data with computed radio path losses to estimate the signal strength at the survey site. Sources of information aiding this calculation are available, such as [19], [24], [36], [42], and [44].

No comprehensive cataloging of transmitters in space is presently provided by any agency. However, the International Telecommunications Union in Geneva, Switzerland, maintains a file of voluntarily reported satellite launches with emitter characteristics and orbital parameters.

Unintended man-made radio noise which may be a significant contributor from at least 10 kHz to 5 GHz is a function of locale and frequency. The mean power of this interference p_n , in watts, observed at the output terminals of a lossless antenna is expressed by an external noise figure F_a , in decibels:

$$F_a = 10 \log_{10} f_a \quad (\text{Eq1})$$

where noise factor f_a is given as

$$f_a = p_n / (kT_o B) \quad (\text{Eq2})$$

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where

- B = the noise bandwidth, Hz
 k = Boltzmann's constant $1.38 \cdot 10^{-23}$ J/K
 T_0 = the reference temperature of 288 K

The median value of F_a designated as F_{am} is plotted in Fig 2, [49], and [54]. Figure 2 provides an estimation of the expected levels of this type of ambient noise for four classes of locales: urban, suburban, rural, and quiet rural. These surface sources also contribute to ambient noise levels above the earth. Some experimentally determined values, as a function of altitude above the earth's surface and degree of urbanization, are shown in Fig 3. Surface generated noise intensity decreases with altitude by 2 dB within the first 300 m (at 100 MHz) and by 0.6 dB/km above 300 m (at 100 MHz). The initial 2 dB decrease is less than the observed variability in surface noise levels. Figure 3 also displays observed surface median values F_{ao} , as derived from measurements in several world-wide urban areas, [54]. Upper bounds are shown in terms of the 84 percentile and 97.7 percentile geographical maximum values to be expected. Maximum weekday diurnal variations, due to changes in human activity, are shown in Fig 4. The degree of variation is primarily dependent upon frequency, not upon locale.

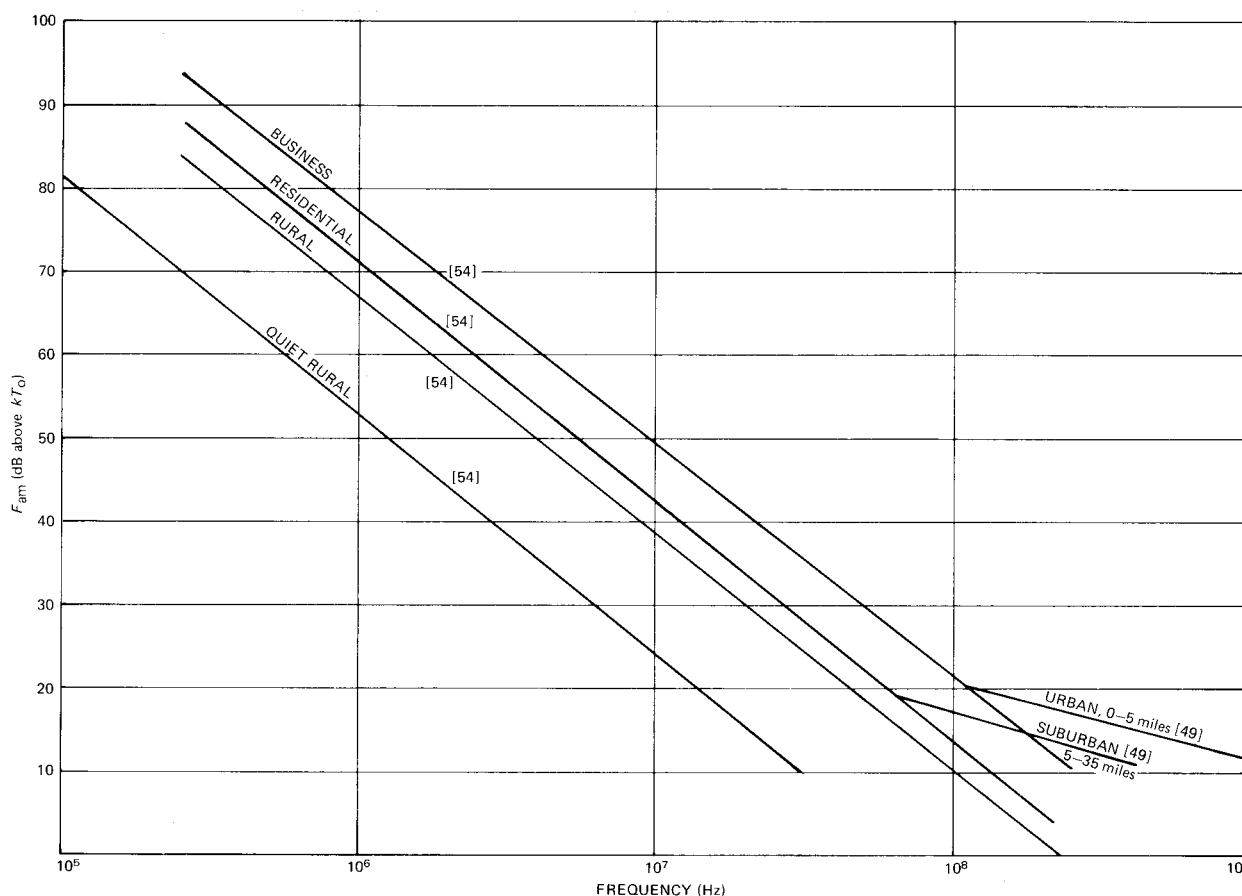


Figure 2— Median External Noise Figure for Surface Man-Made Incidental Median Ambients

Naturally occurring rf noise from atmospheric disturbances and from solar system and galactic sources may contribute significantly to background levels, especially in the quieter remote and rural locations. Figure 5 illustrates contributions above 10 MHz from several of these sources [22], [23], [25], [31], [49], [54], and [56]. For a survey application in which either antenna gain g , or the effective aperture area A (m^2), of the survey antenna is known, the

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noise power flux density S , plotted in Fig 5 may be used to compute the ambient noise power density P_n , (dB) for an antenna of gain g by means of

$$A = g\lambda^2/4\pi \quad (\text{Eq3})$$

$$P_n = S + 10 \log_{10} A, \quad \text{dB/Hz} \quad (\text{Eq4})$$

and therefrom, F_a by using

$$F_a = P_n + 204 - 10 \log_{10} B \quad (\text{Eq5})$$

Except for spatially distributed galactic noise, the source shall fall within the useful beam of the observing antenna to contribute significantly to the ambient level being recorded.

Naturally produced ambient noise levels at frequencies below 25 MHz are supplemented or dominated by atmospheric noise which is dependent upon frequency, location, time of day, and season [48]. The atmospheric noise contribution should be added to values determined from Fig 5 (for frequencies less than 25 MHz).

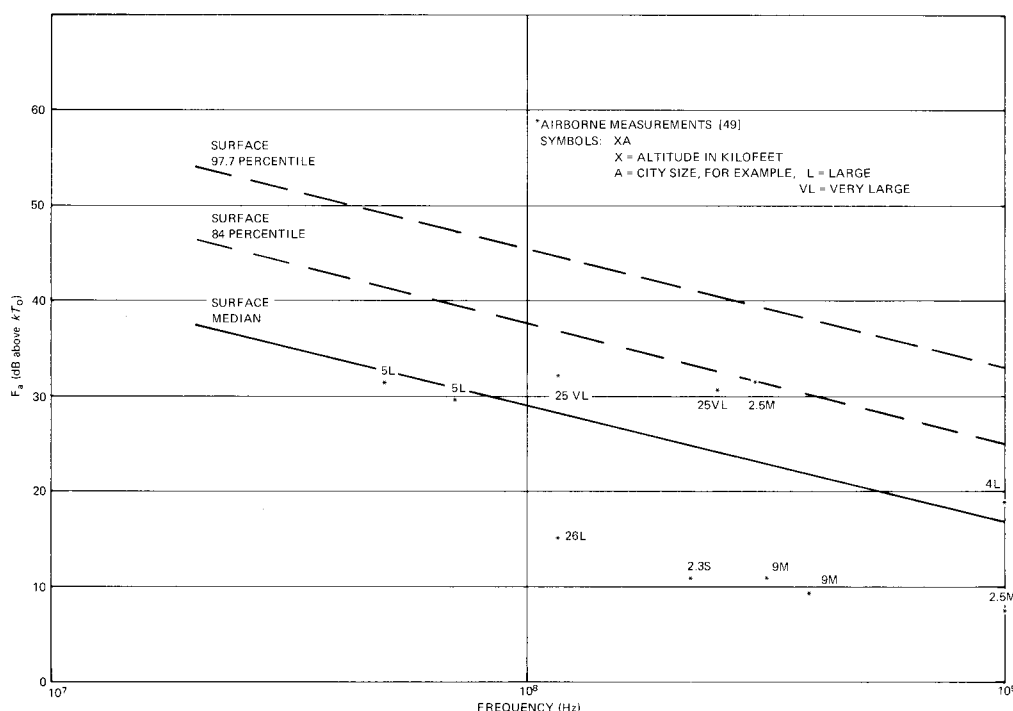


Figure 3— External Noise Figure for Man-Made Incidental Radio Noise as a Function of Urban-Center Size, Altitude of Measurement, and Frequency with Surface Distribution Percentile

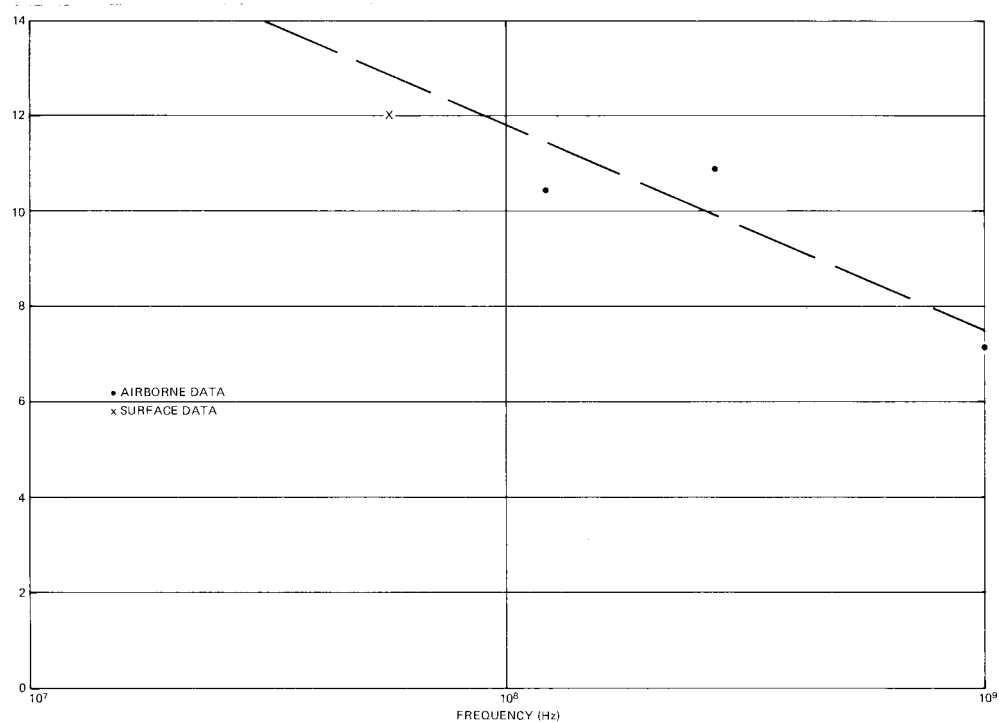


Figure 4— Maximum Weekday Diurnal Variation in F_a of Man-Made Noise [49]

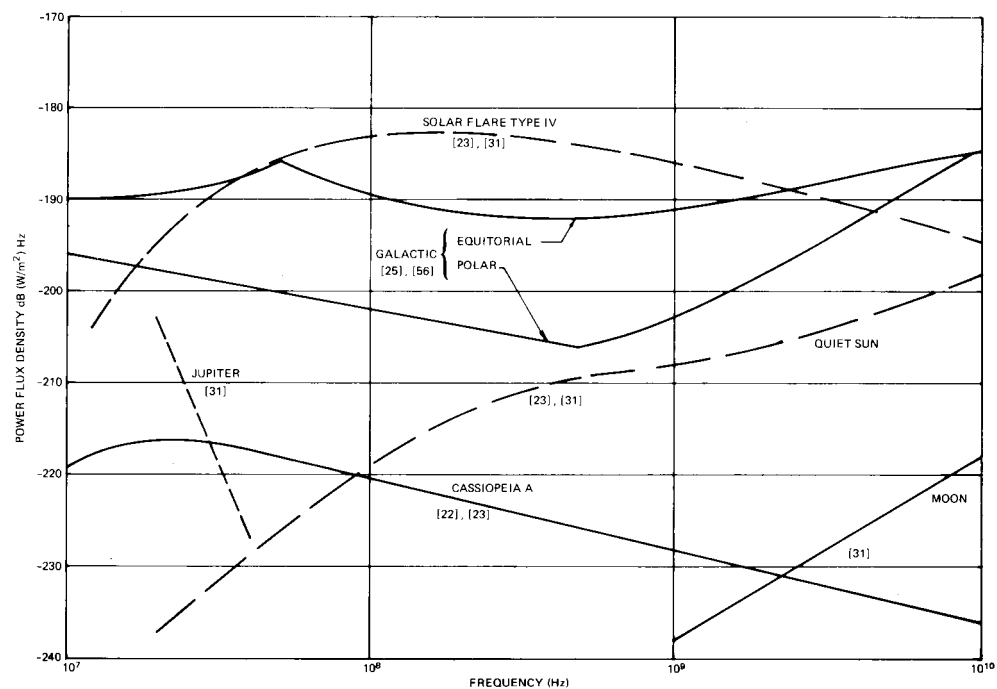


Figure 5— Power Flux Density for Natural Noise Sources

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4.2 Data Sampling

The survey of sites where essentially continuous radiation from local transmitters predominate may be conducted over shorter test periods than those where natural or man-made random emissions contribute significantly. A single 24 h sampling period is recommended to establish the variability of a periodic radiation source. If weather-dependent effects are expected to be significant, the survey duration should be long enough to include weather cycle extremes. Average power samples of 3 min should be recorded at least once an hour. Each 3 min sample provides a mean power level. The hourly power levels are constructed to determine a daily cyclical pattern.

Site conditions dominated by random noise sources require much longer observation intervals (listed in Table 1). A minimum test duration of two weeks ensures repeatable diurnal measurements. When man-made noise is dominant, sampling intervals should be spaced 1 h apart with 3 min minimum sample lengths. To ensure statistical confidence, a minimum of 11 data points is recommended. Referring to Table 2 and Fig 6, 11 samples are seen to yield an uncertainty of $\pm 0.352/\Gamma$ in a population mean at a confidence level of 0.9 (a level of significance of 0.1) [39]. Here Γ is the slope of the cumulative distribution formed by the set of 11 hourly samples in the vicinity of the median x_m . By increasing the 3 min sample set size above 11 the uncertainty interval about the set median containing the population median may be reduced in accordance with Table 2. As an example, suppose that a 3 min sample size of $N = 35$ data points were recorded. If a 90% confidence is desired, enter Table 2 at $\alpha = 0.1$ and $N = 35$ to obtain $d(35) 0.21$. The calculated median x_m of the 35 points is expected to lie within $\pm d\alpha(35) = \pm 0.21/\Gamma$ of the true population median, with a 90% confidence. By plotting the cumulative distribution of the set of 35 measured values, x_i , the value of the slope Γ is obtained allowing the limits $\pm 0.21/\Gamma$ to be calculated. These results are distribution independent, that is, they are not a function of the form of the distribution function characterizing the observed data. The only constraint that applies is that the data shall be reasonably representable by a continuous distribution function.

Table 1— Site Survey Observation Intervals

Predominant Type of Electromagnetic Radiation	Total Duration of Survey (d)	Inter-Sampling Interval (h)	Minimum Sample Length (min)	Minimum Number of Data Points per Sample
Periodic	1	1	3	11
Random noise natural sources	14	4 0600–2400	3	11
Man-made	14	1 Local Time	3	11

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Table 2— Critical Values $d\hat{\alpha}(N)$, of the Maximum Absolute Difference between Sample and Population Cumulative Distributions

Sample Size (N)	Level of Significance ($\hat{\alpha}$)*				
	0.20	0.15	0.10	0.05	0.01
1	0.900	0.925	0.950	0.975	0.995
2	0.684	0.726	0.776	0.842	0.929
3	0.565	0.597	0.642	0.708	0.828
4	0.494	0.525	0.564	0.624	0.733
5	0.446	0.474	0.510	0.585	0.669
6	0.410	0.436	0.470	0.521	0.618
7	0.381	0.405	0.438	0.486	0.577
8	0.358	0.381	0.411	0.457	0.543
9	0.339	0.360	0.388	0.432	0.514
10	0.322	0.342	0.368	0.410	0.490
11	0.307	0.326	0.352	0.391	0.468
12	0.295	0.313	0.338	0.375	0.450
13	0.284	0.302	0.325	0.361	0.433
14	0.274	0.292	0.314	0.349	0.418
15	0.266	0.283	0.304	0.338	0.404
16	0.258	0.274	0.295	0.328	0.392
17	0.250	0.266	0.286	0.318	0.381
18	0.244	0.259	0.278	0.309	0.371
19	0.237	0.252	0.272	0.301	0.363
20	0.231	0.246	0.264	0.294	0.356
25	0.21	0.22	0.24	0.27	0.32
30	0.19	0.20	0.22	0.24	0.29
35	0.18	0.19	0.21	0.23	0.27
over 35	1.07 $\sqrt{N}$	1.14 $\sqrt{N}$	1.22 $\sqrt{N}$	1.36 $\sqrt{N}$	1.63 $\sqrt{N}$

* $\hat{\alpha} = 1 - \text{confidence level}$ NOTE — Values of $d\hat{\alpha}(N)$ so that $p_r[\max|S_N(x) - F_o(x)| > d\hat{\alpha}(N)] = \hat{\alpha}$, where $F_o(x)$ is the theoretical cumulative distribution and $S_N(x)$ is an observed cumulative distribution for a sample of N .

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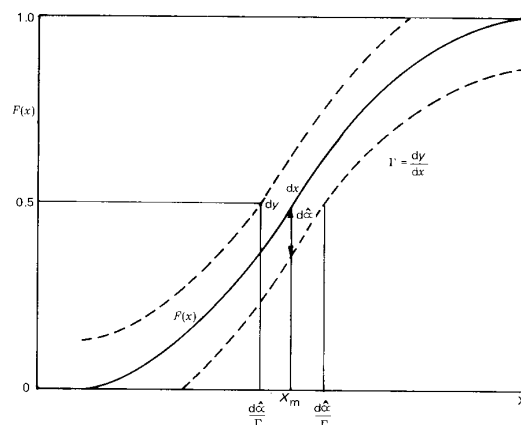


Figure 6— Distribution Function $F(x)$

4.3 Documentation of Site Characteristics

Any metallic, or, more generally, conducting object can affect an electromagnetic field. The degree of the effect is dependent upon the frequency of radiation and the size of the object. Reflection, scattering, and diffraction are primary mechanisms by which field measurements are upset. It is important to document any site features likely to affect the data. A scaled map should be used to record such features. Major reflecting surfaces and conductors, both above and below ground level, at least 100 m (up to one wavelength) from the site should be shown. Obstacles shown should include

- 1) Above ground structures, such as buildings (note type of construction), metallic fences, and broadcast antennas
- 2) Suspended cables, such as power, telephone, and those used for cable television (note the number of cables, routing, location of drop wires, power-line ratings, and the type, number, and location of supporting structures)
- 3) Underground conduits for water, power, gas, oil, etc
- 4) Other major obstacles associated with the terrain, including foliage (note density)

Photographs should be taken to document major features of the region.

Specific rf sources should be documented and located on the map, including known active transmitters which are considered primary sources. Local noise sources not specifically identified by a licensing agency should also be documented. The latter may have to be located by inspection of the area or by radio direction finding. For each specific rf source, information concerning schedule of operation, time pattern of emission, radiated power, antenna directivity, type of modulation, and signal polarization should be tallied.