SPECTRUM ANALYSIS . . .
Field Strength Measurement

Introduction

Field strength measurements are necessary to determine the amount of radiation emitted from electronic equipment. If a piece of equipment generates spurious signals which may interfere with equipment operating in the same vicinity, then a field strength measurement becomes necessary. For example, spurious radiation from a garage door opener could interfere with communication between pilot and control tower at an airport. Because of the possibility of interference, there is government regulation of the maximum amount of emission from electronic devices. Consequently, the manufacturer of the garage door opener must measure the field strength emitted from his device to insure compliance with government regulations.

Field Strength

A measurement of field strength is a measurement of the electronic field in volts/meter as given in equation (1):

Equation (1): $E = \sqrt{120\pi P}$ (Note 1)

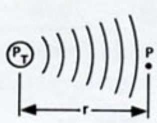
where: E = rms value of field strength in volts/meter
P = power density in watt/meter^2
120π = impedance of free space in ohms.

Power Density

Field strength is directly proportional to the square root of the power density. The power density, also referred to as spectral density, is a measurement of the electromagnetic field at a point in space. The unit for power density is watts/meter^2 as shown in equation (2):

Equation (2): $P = \frac{P_T}{4\pi r^2}$ (Note 2)

where: P = power density in watt/meter^2
P_T = transmitted power in watts
r = distance in meters.



Antenna Factor

To convert the voltage reading of the receiver to field strength in volts/meter, a conversion factor is added (in dB) to the receiver reading. This number is normally called the antenna factor and is usually supplied by the antenna manufacturer. Figure 1 illustrates the mathematical relationship of the antenna factor in linear and logarithmic form.

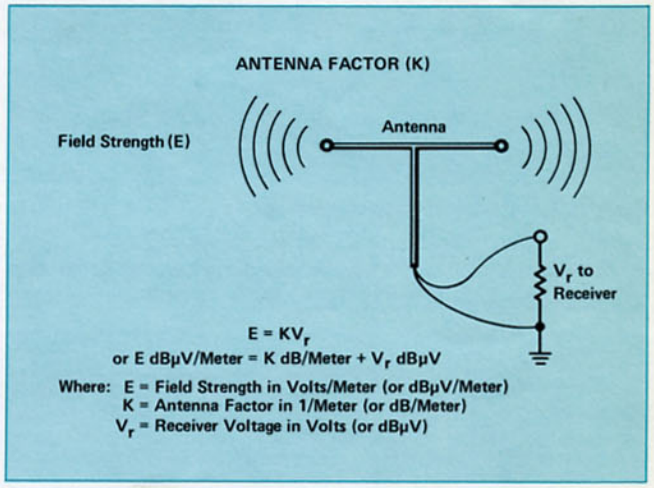


Figure 1: Antenna Factor is used to convert the receiver voltage reading to field strength in volts/meter or dBμV/meter.

Measurement Technique

In order to measure field strength, a calibrated antenna and a tuned receiver are required. The antenna is used to convert the radiated electric field from volts/meter to volts for the receiver to measure. A spectrum analyzer is a swept-tuned receiver that displays the antenna output voltage on the vertical axis and frequency on the horizontal axis. Also, since the spectrum analyzer is usually a broadband instrument, many different frequencies can be measured simultaneously.

Antenna Gain

If the gain of the antenna is given rather than the antenna factor, then the following equation will allow conversion from antenna gain to antenna factor:

Equation (3): $K = 20 \log f - G_{dB} - 29.8\,dB$
(for 50 Ω system)

where: K = antenna factor in dB/meter
f = frequency of measurement in MHz
G = antenna gain in dB. (power ratio)

Spectrum Analyzer Calibration

Spectrum analyzers are usually calibrated in dBm so a conversion to voltage is required. To read in dBμV (dB referenced to 1 μV) simply add 107 dB to the reading in dBm.

i.e., dBμV = dBm +107 dB (50 Ω system).

Example:

A field strength measurement was required to determine the amount of radiation emitted from a garage door transmitter. The transmitter was located 10 meters away from the measuring test set. The antenna had a gain of 8 dB.

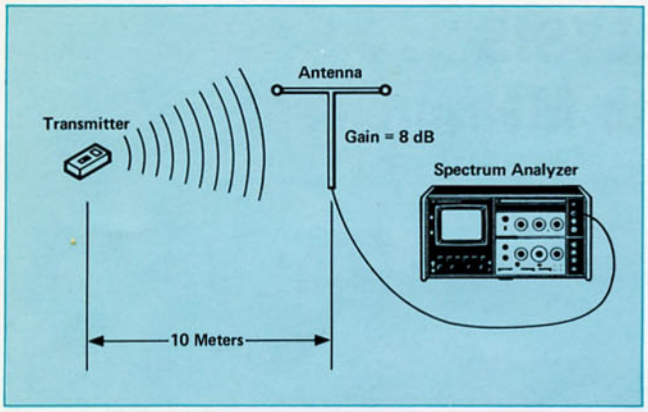


Figure 2: Field strength measurement set-up.

The signal measured by the spectrum analyzer in Figure 3 is −80 dBm at 320 MHz.

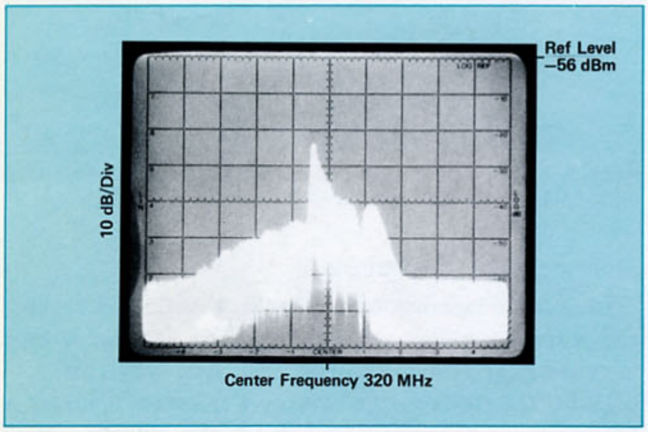


Figure 3: Radiation from transmitter.

Since only the antenna gain is given, we need to use equation (3) to convert to antenna factor:

Equation (3): $K = 20 \log f - G_{dB} - 29.8$ dB

$K = 20 \log (320) - 8 - 29.8$

$K = 12.3$ dB/meter.

To convert the spectrum analyzer reading to dBμV, we simply add 107 dB.

$$-80 \text{ dBm} + 107 \text{ dB} = 27 \text{ dB}\mu\text{V}$$

The field strength, E, is the sum of the adjusted spectrum analyzer reading and the antenna factor:

$$E = \underbrace{27 \text{ dB}\mu\text{V}}_{\text{Analyzer Reading}} + \underbrace{12.3 \text{ dB/meter}}_{\text{Antenna Factor}} = 39.3 \text{ dB}\mu\text{V/meter.}$$

Appendix

A. Antenna Factor Derivation

To determine the power received by the antenna, we multiply the power density by the receiving area of the antenna. The receiving area of the antenna is defined by equation (A_1):

Equation (A_1): $A_r = \dfrac{G\lambda^2}{4\pi}$ (meter^2) (Note 3)

The power received by the antenna is then defined by equation (A_2):

Equation (A_2): $P_r = PA_r = \dfrac{PG\lambda^2}{4\pi}$ (watts)

where: P = power density in watts/meter^2
G = antenna gain
λ = wavelength in meters.

Combining Equation (A_2) with the field strength equation, $E = \sqrt{120\pi P}$, yields

$$P_r = \frac{E^2 G\lambda^2}{480\pi^2}$$

Also, since: $P_r = \dfrac{V_r^2}{Z_0}$

where: V_r = received voltage
Z_0 = receiver input impedance

then: $\dfrac{V_r^2}{Z_0} = \dfrac{E^2 G\lambda^2}{480\pi^2}$,

knowing that: $\lambda = \dfrac{300 \text{ meter/sec}}{f \text{ (MHz)}}$,

we can simplify and rearrange terms to yield:

$$E = \frac{V_r f\pi}{75}\sqrt{\frac{30}{Z_0 G}}$$

Since antenna factor is defined as $K = \dfrac{E}{V_r}$,

then: $K = \dfrac{f\pi}{75}\sqrt{\dfrac{30}{Z_0 G}}$,

or, in log form: $K = 20 \log f \text{ (MHz)} - G_{dB} - 29.78$ dB ($Z_0 = 50\ \Omega$).

Similarly, K can be derived for a 75 Ω system which yields:

$K = 20 \log f \text{ (MHz)} - G_{dB} - 31.54$ dB ($Z_0 = 75\ \Omega$).

B. Spectrum Analyzer Conversion Factors

Z_0	dBm		dBmV		dBμV
50 Ω	0	=	47	=	107
75 Ω	0	=	48.75	=	108.75

Additional information on field strength measurement can be obtained from Hewlett-Packard Application Note 63E.

Note 1: "Reference Data for Radio Engineers," Fifth Edition, page 25-7.
Note 2: Ibid, page 25-7.
Note 3: Ibid, page 25-42.

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