An Extremely Broadband Antenna for EMI Measurements

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INTRODUCTION

Manufacturers are required to keep electromagnetic interference (EMI) levels to a minimum by using shielding and filtering techniques in their electronic products. The growth in microprocessor technology has made it necessary to measure this interference over an extremely wide frequency range: from 60 cycle power up to clock rate harmonics of 1 GHz and beyond. To keep products in compliance with government emissions standards, an extremely broadband measuring device is sometimes required.

GENERAL DESCRIPTION

One such antenna is an extremely broadband active receiving system that is designed around monopole and discone principles and operates in the frequency range of approximately 100 Hz to 1.0 GHz (Figure 1). Proper positioning results in a vertically polarized, omni-directional sensor. The antenna is individually calibrated at the factory and provided with antenna factor correction data. When connected to a measurement receiver or spectrum analyzer, the antenna can be used to obtain accurate electric field strength measurements. The dynamic range is sufficient to allow operation in many areas where strong signals would normally prohibit the use of such sensitive active antennas. Signal levels of up to 1 V/m can be easily tolerated.

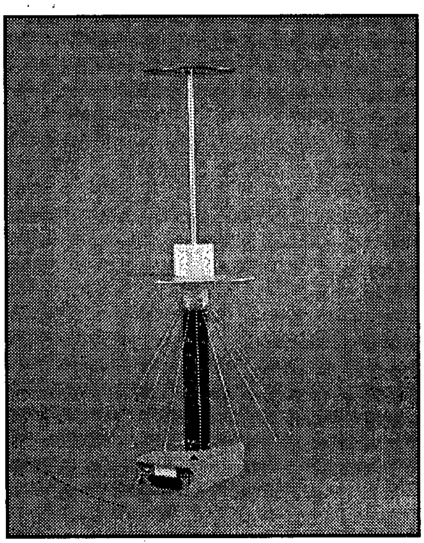

Figure 1. Extremely Broadband Antenna.

Manual band switching is not required with an extremely broadband antenna.

The antenna is portable and specially suited to indoor applications. It is 35 inches high and weighs approximately 13 pounds. Power for the active components comes from an internal 115/230 volt power supply or from rechargeable batteries located in the base of the unit. When fully charged, the batteries will operate the antenna continuously for about 8 hours. A threaded hole in the bottom of the housing is provided for convenience in mounting to a standard camera tripod. Flexible and removable elements allow almost instantaneous setup for use and rapid collapse for immediate storage or transportation.

THEORY

The antenna system consists of a combination of monopole and discone antennas functioning in two overlapping frequency bands (Figure 2). The signals received by the antennas are combined through a passive network to form a single output, thereby achieving a single frequency band design.

The monopole and discone antennas are referred to in subsequent sections as the low-band and high-band antennas, respectively. The low-band antenna affects the frequency response below 100 MHz, while the high-band antenna affects the frequency response above 100 MHz. Signals at frequencies as low as 5 Hz have been observed in the laboratory, but calibration normally stops at 100 Hz because of a rapid frequency response roll-off and consequent loss of sensitivity.

A schematic diagram shows the circuit interconnections between the main parts of the antenna system (Figure 3). The system consists of the following main components:

- 15-inch monopole with removable top hat, small ground plate and pre-amplifier
- removable metal ring which serves as the disc for the discone antenna
- set of long flexible wire elements which constitutes the cone section of the discone antenna
- mast section containing the baluns, the high band pre-amplifier and the power combiner network
- main housing assembly

*See Advertisement on Page 229.

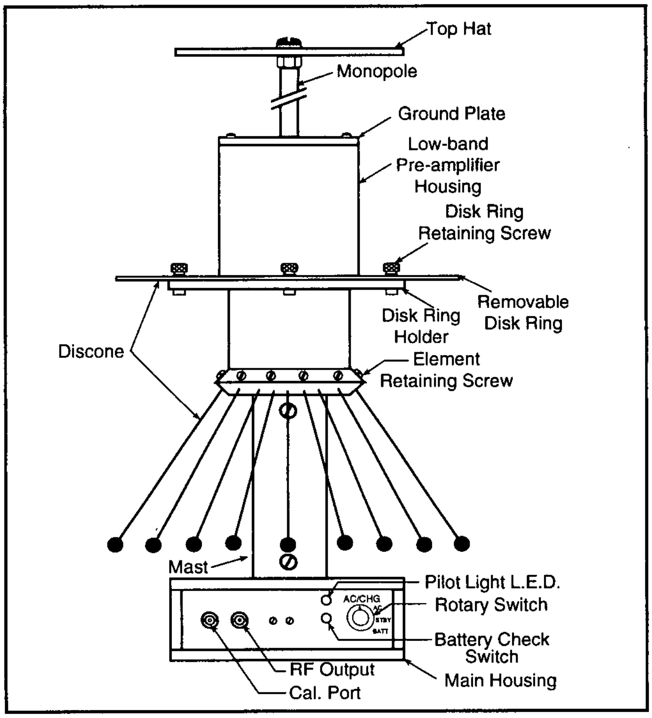

Figure 2. *Antenna System Components.*

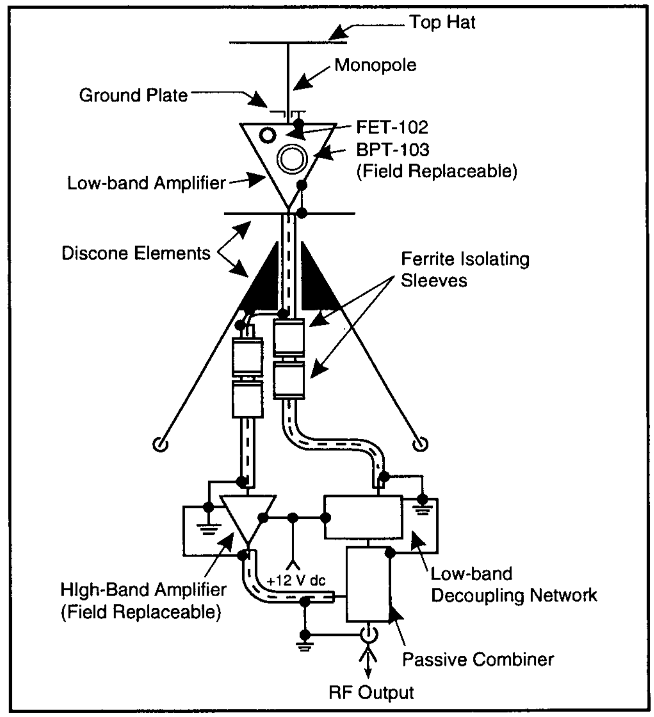

Figure 3. *Schematic of Extremely Broadband Antenna.*

Coaxial cables are used to achieve broadband access to the two antennas and to provide well-isolated connections at the inputs of the power combiner.

The low-band antenna is designed around an electrically short, top-loaded monopole working into an active network. The active network uses a field-effect transistor (FET) in a source follower mode and a bipolar transistor in a negative feedback common emitter mode. This combination is practically ideal for obtaining a nearly constant response (or antenna factor) over a wide frequency range. The monopole is so short electrically that its effective height, and hence the open-circuit voltage induced at its feedpoint, is essentially independent of frequency below 100 MHz.

As the frequency decreases, the self-impedance of the monopole rises until it eventually exceeds the high, constant input impedance of the source follower. At this point, the source follower begins to load the monopole significantly, thereby causing a reduction in the voltage available at the feedpoint of the monopole. This explains the roll-off in response at the low end of the band.

The source follower works into a line amplifier, which adds approximately 15 dB of gain to the system. The amplification is emphasized at the low frequency end of the band in order to partially compensate for the loss of voltage due to the rising self-impedance of the monopole. The result is a reasonably flat response over an exceedingly wide range of frequencies (Figure 4). The second stage adds very little noise to the already low-noise first stage, and it raises the overall response to a level where the full sensitivity of the antenna can be realized with most receivers used for field intensity measuring purposes (Figure 5).

The high-band antenna is designed around the discone principle, according to which the driving point impedance is a function of the geometric angle of the antenna at frequencies above cutoff and, therefore, has broadband characteristics. Cutoff occurs when the conical elements are on the order of 1/4 wavelength long, or in this case about 200 MHz. The antenna factor of the discone reaches a minimum (maximum response) at around 300 MHz, above which it tends to have constant gain properties.

The calibration factor is essentially the insertion loss between the calibration input port and the RF output port.

The discone has a 50-ohm driving-point impedance. A low-noise pre-amplifier is incorporated primarily to bring the signal response to a level that is suitable for most receivers.

The combiner, which is an RLC network, contains two passive filters; a low-pass filter for the low-band antenna and a highpass filter for the high-band antenna. The filtered signals are summed (combined) at the RF output. The filtering and summing scheme smoothes the transition between the low and high frequency bands.

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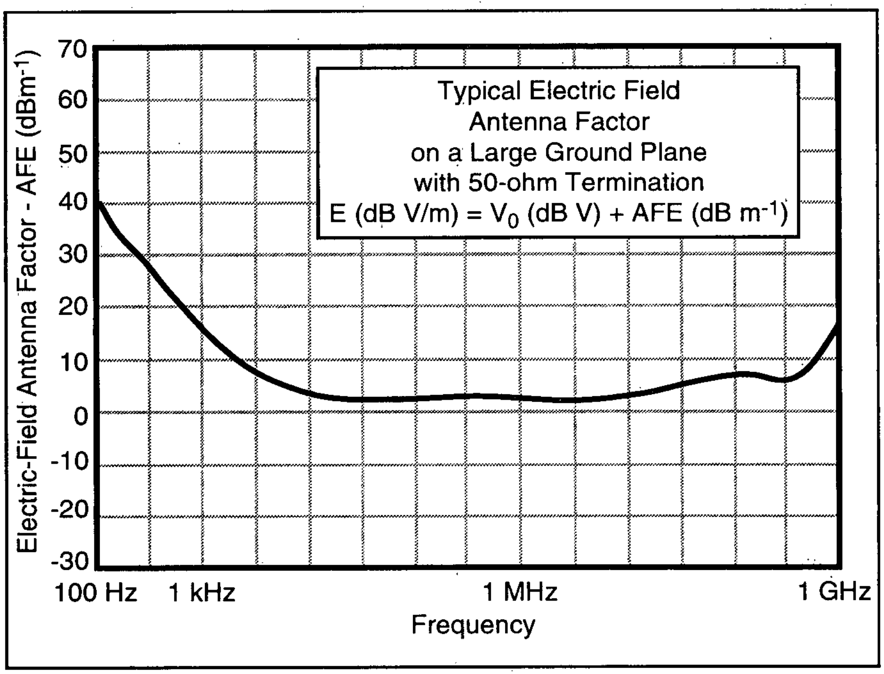

Figure 4. Typical Antenna Factor Curve.

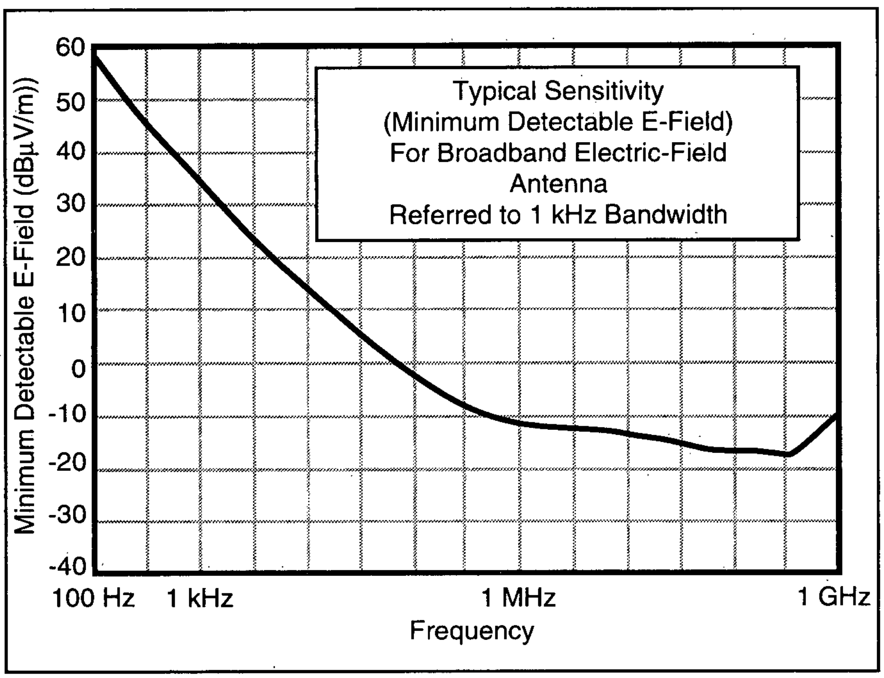

Figure 5. Typical Sensitivity Curve.

CALIBRATION PORT

The antenna is available with an optional calibration port which allows the injection of a known signal into the system in essentially the same way as an incident electromagnetic field, and provides an easy means of verifying that the antenna is functioning properly. When the antenna is calibrated at the factory, an additional calibration factor C is included for testing the active components and interconnections. The calibration factor is essentially the insertion loss between the calibration input port and the RF output port. A quick check is made of the insertion loss using a stable RF signal source and receiver. The measured insertion loss should match the factory-provided calibration factor data.

$$C = V_C/V_O$$

where

V_C = RF voltage at calibration input port

V_O = RF voltage at antenna RF output port

or in decibel form,

$$C(dB) = V_C(dBV) - V_O(dBV) = \text{insertion loss}$$

The calibration port also provides an input to check the entire receiving system path. This verifies operation and maintains setup repeatability of external cables, connectors and equipment.

OPERATION

Power for the active components in the antenna originates from an internal 115/230 volt power supply or rechargeable batteries located in the base of the unit. A front panel switch selects the power source used. Battery power is recommended when making accurate field strength measurements to avoid power line interference problems. When fully charged, the batteries will operate the antenna continuously for about 8 hours, and a discharged set of batteries can be completely recharged overnight. An indicator light at the front of the housing displays the status of power being applied to the antenna.

The antenna connects to a receiver or spectrum analyzer with coaxial cable of any convenient length up to about 100 feet. Low-loss coaxial cable should be used to reduce signal loss at the higher end of the frequency range. Although calibration is performed with the base of the housing resting on a large metal ground plane, the antenna can be used without a ground plane with a consequent change in antenna factor (AFE) of less than 2 dB over the entire operating frequency range.

To measure the electric field emissions from the device under test, the user simply connects the RF output of the antenna to the receiver via coaxial cable. The field strength is then determined from the voltage level at the receiver through the frequency dependent electric field antenna factor (AFE) by the equation:

$$E = AFE \times V_O$$

where
E = electric field strength at antenna
V_O = voltage at antenna output connector
AFE = electric field antenna factor

Converting this equation into decibel form gives:

$$E(dBV/m) = AFE(dBm^{-1}) + V_O(dBV)$$

An example showing the application of the second equation is given below. Assume the observed antenna output voltage at 1 MHz is 7.0 μV (-103.1 dBV) and that the antenna factor (AFE) at 1 MHz is 2.1.
Then,

$$E(dBV/m) = 2.1 + (-103.1) = -101.0 \text{ dBV/m}$$

It should be noted that external losses due to cables and connectors are not accounted for in the antenna factor equations.

SUMMARY

With the advancement of automated EMI test procedures, it is desirable to cover an extremely broad range of the frequency spectrum with one antenna so that manual band switching is not required. By combining the electrical properties of two proven antenna designs, the resulting antenna system, when calibrated, allows for accurate and efficient electric field intensity measurements over an extremely broad band.

BIBLIOGRAPHY

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