Active Antennas for EMC Measurements

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Although limitations exist when applying active antennas, they usually can be overcome through careful design.

INTRODUCTION

An active antenna is an antenna that incorporates one or more active devices or circuitries with the structure of the passive elements such that the passive element characteristics can be modified or controlled. Because of their nonreciprocal characteristic, general-purpose active antennas are used for receiving purposes only and hence are not suitable for EMC immunity tests. However, due to their distinctive features, they are desirable when conducting emission tests. These include an extremely broad bandwidth, excellent impedance match, a flat antenna factor (AF) curve in frequency, low noise figure (high sensitivity), compensation of the cable loss, and compact size. This article gives an overview of active antennas, including their advantages and disadvantages over the passive ones. A new design to overcome their major limitation will be introduced at the end of this article.

HISTORY

The earliest idea of an active antenna can be traced back to 1928, when small antennas with a wideband coupling tube were commonly used in radio broadcast receivers. People did not pay much attention to active antennas until the 1960s, when pioneer work on active antennas was reported and their attractive characteristics were revealed. Although reciprocity no longer applies for general active antennas, special designs and studies have been reported for small transmitting active antennas.[1] They are, however, not widely used in practice for EMC tests.

During the 1970s and 1980s a lot of effort was put on the integration of FET amplifiers with a small passive antenna. These efforts led to the studies of today's "active integrated antenna," which integrates the active circuits and the passive elements on the same substrate. This article is not intended to investigate the modern techniques and development regarding the active integrated antennas, but to focus on the benefits that can be obtained from general active antennas for EMC measurements. The term "active antenna" as used in the following paragraphs will thus be restricted to the general (receive-only) active antennas.

BASIC STRUCTURE AND CHARACTERISTICS

One of the earliest definitions of the active antennas is stated as follows:

The term "active antenna" could be taken to mean any antenna in which the power source or head amplifier is very closely associated with the radiating or receiving element. The term seems most appropriate when the active component is coupled directly to the element without an intervening match (or mismatch) to any sort of transmission line.

--- E. A. Killick, 1969[2]

Most of the active antennas used in EMC applications follow this definition. The most basic design principle of active antennas is the use of a pre-amplifier directly after the passive elements, such as monopoles, dipoles, loops, discones, etc., which are usually electrically small (Figure 1). This kind of structure has a low resonant frequency, higher radiation resistance, and consequently, wider bandwidth compared to its passive counterpart. For an active element, the input impedance variation is much less sensitive to the frequency variation than that of a passive element.[3] Thus, impedance matching over a wide frequency range is easier to achieve. This also contributes to the broad bandwidth

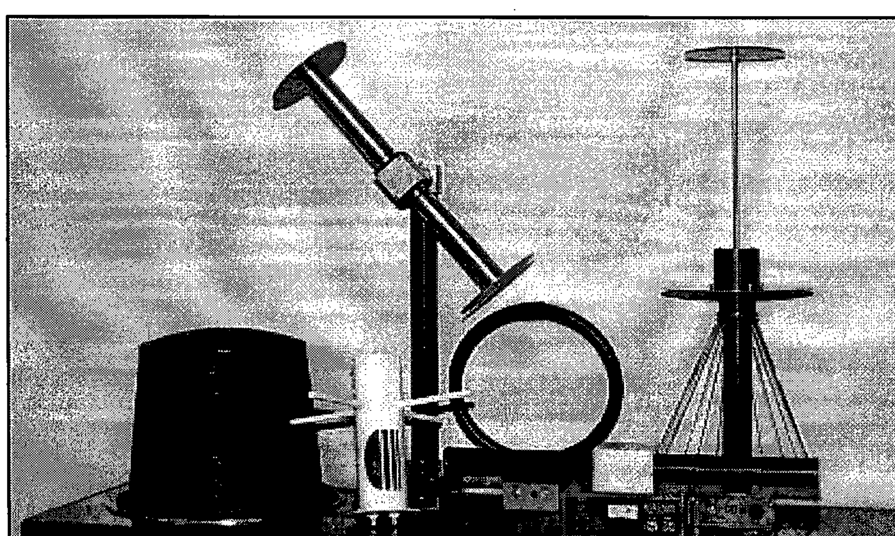

***Figure 1**. Active Antennas.*

of an active antenna. The broad bandwidth is the most attractive characteristic for EMC measurements.

An active antenna is desirable when a system with a low noise figure (NF) is required or maximum sensitivity is needed. In the application of a system with a passive antenna, a receiver with a high NF will result in a high system NF and poor system sensitivity. The solution to this problem can be found by investigating the Friis' equation:

$$NF_{total} = NF_1 + (NF_2-1)/G_1 + (NF_3-1)/(G_1G_2) + \dots + (NF_n-1)/(G_1G_2 \dots G_n)$$

where
NF_{total} = System noise figure
NF_1 = Noise figure of stage 1
NF_2 = Noise figure of stage 2
NF_n = Noise figure of stage n
G_1 = Gain of stage 1
G_2 = Gain of stage 2
G_n = Gain of stage n
(Note: all quantities are dimensionless ratios)

It is clear from the equation above that the system NF is determined mainly by the NF of the first stage of the system. In the design of active antennas, we can thus use a low noise amplifier (LNA) as the first stage device to improve the system NF and consequently improve the system sensitivity.

Other important features of active antennas include small size, flat antenna factor curve in frequency, accurate impedance match to the receiver,[4] and compensation of cable loss. In spite of the merits discussed above, active antennas had limited acceptance in the past due to the concern for the nonlinear distortion in a broadband amplifier. This concern no longer exists, since in recent years amplifiers have undergone great improvements with respect to third-order intermodulation distortion, which is the dominating nonlinear effect of the pre-amplifiers used with active antennas. This progress is obtained by advanced circuitry and superior active devices.

While the third-order intermodulation has been minimized with current devices, active antennas can suffer an overloading problem. A strong incident field can cause a large signal at the amplifier and thus force the amplifier into gain compression. The ideal solution to this problem involves retaining the active characteristics of the antenna. This can be accomplished by using an antenna that can operate either in the passive mode (as a passive antenna) or in the active mode (as an active antenna), depending on the field strength it will encounter in a measurement.

A NEW DESIGN

GENERAL DESCRIPTION

One such antenna is a portable broadband E-field receiving antenna system designed around the discone principle to operate over the frequency range of 20 MHz to 3 GHz in two bands (Figure 2).[5] The low band covers 20 MHz to 1 GHz and the high band covers 800 MHz to 3 GHz. This active antenna is provided

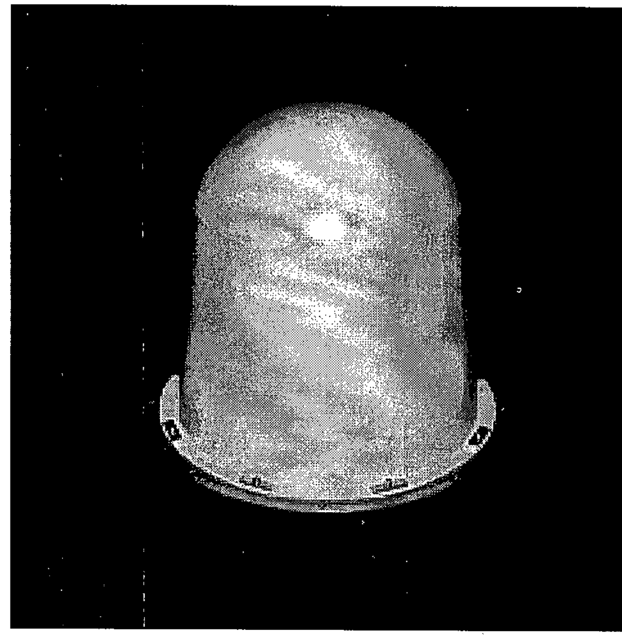

Figure 2. *Broadband E-field Receiving Antenna System with Two Operating Modes – Active and Passive.*

with a passive operating mode in either band in order to protect the antenna from overloading. It may be used with its calibrated antenna factors to make field strength measurements in radiated emission tests. The electrical dimensions are very small, especially for the lower portion of the band where wavelength can be several meters long. The performance, however, is comparable to full-scale antennas many times larger. The reception pattern of this antenna is omnidirectional in azimuth and monopole-like in elevation. A null exists at the zenith. The antenna is radome-enclosed and supplied with a base plate mounting hole pattern or an optional mast mount.

THEORY

This system consists of two antennas with separate outputs. Cutoff occurs at about 20 MHz for the low-band antenna and 800 MHz for the high-band antenna. Below its cutoff frequency the antenna continues to perform but has a roll-off effect similar to that of an ordinary fat dipole.

The system has a nominal 50-ohm input impedance. For each band, the signal is fed to a low noise pre-amplifier to enhance the overall response. The amplifiers are included primarily to raise the response to a level that is suitable to most receivers while introducing a negligible amount of noise, thus maximizing the antenna sensitivity. For measuring very large fields which could damage the internal pre-amplifiers, separate internal bypass switches are included at the front ends of the amplifiers. Through use of an external control line, the pre-amplifier can be either in-line or bypassed.

Typical antenna factors measured with the antenna on

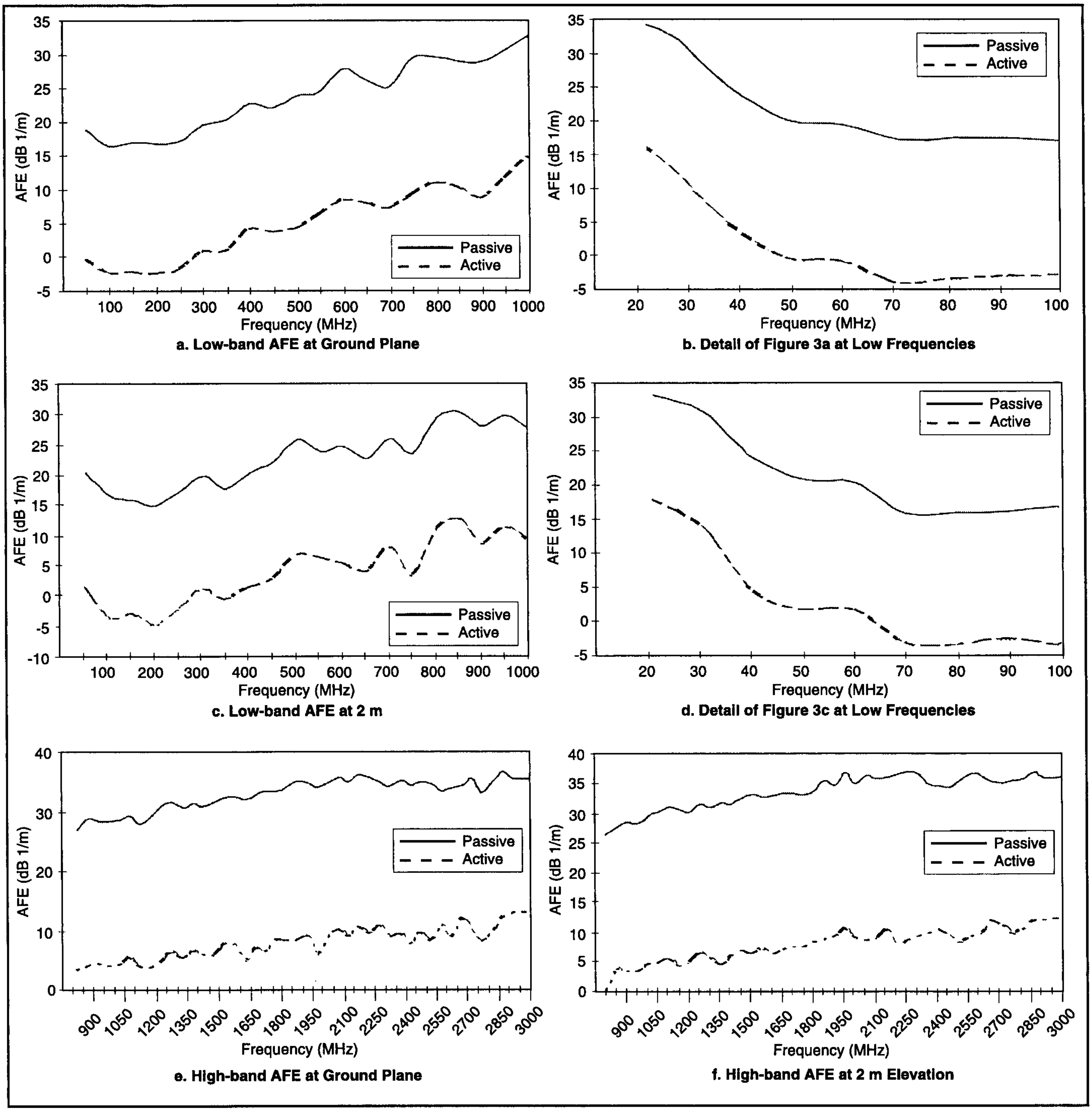

Figure 3. *Typical Antenna Factor Curves.*

a big ground plane and 2 meters above the ground plane are shown in Figure 3. Passive and active modes are both shown for comparison. The electric field can be calculated using the following formula:

$$E\ (\text{dBV/m}) = AFE\ (\text{dB/m}) + V_0\ (\text{dBV})$$

where

E = Incident electric field seen by the antenna

AFE = Electric field antenna factor

V_0 = Voltage at the output connector of the antenna when it is matched to 50 ohms

It is clear from Figure 3 that the antenna factors obtained from operating in the active mode are greatly improved. This improvement is achieved not only from the gain of the amplifier but also from the impedance match.

CONCLUSION

General active antennas are receive only and thus cannot be used for radiated immunity tests. For radiated emission tests, however, active antennas are desirable because of their broadband characteristic. Additional advantages include low noise figure, high sensitivity, small size, excellent impedance match, flat antenna factor curve in frequency, and compensation of cable loss. Although limitations exist when applying active antennas, they usually can be overcome through careful design. An extremely broadband receive-only antenna was designed to overcome the major limitation with the employment of amplifier-bypassing switches. With individual calibration, this antenna can be a powerful tool in radiated emission tests because of its broadband characteristic.

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