Utilizing FM and TV Transmitters for Characterizing Shielded Enclosures

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Abstract

Electromagnetic shielded enclosures provide an interference-free environment for testing high frequency small signal circuits. The shielding effectiveness can be different at different frequencies. Actual numbers vary from enclosure to enclosure depending on the material used and the design. One method to obtain the shielding performance is to place a variable frequency transmitter inside the enclosure and to monitor the signal strength outside. Another method is to measure the signal inside due to an outside source. In this paper, a novel method to utilize FM and TV transmitters in the vicinity to characterize the shielding effectiveness of an enclosure is described. Actual measurements, using this method at several spot frequencies, provide useful information within a certain frequency range.

Introduction

Shielded enclosures provide an interference-free environment for testing high frequency circuits and systems. In some situations, the enclosure is used to prevent electromagnetic radiation from test circuits that are intended to transmit or radiate and placed inside. The shielding effectiveness is frequency dependent. Enclosures with different levels of shielding, sizes, and frequency ranges are commercially available[1]. Most of the commercial enclosures are of modular design and can be assembled on site. It is helpful to have a method to recalibrate or verify the assembly of the enclosure with minimum equipment and time required.

Shielded Enclosure Characteristics

Electromagnetic shielding is achieved by using materials with high relative permeability, μ_r and/or materials with good conductivity such as copper for the sidewalls of the enclosure. High-μ materials are effective at low frequencies. At higher frequencies, copper sheets of reasonable thickness can shield such signals since the 'skin depth' of copper is small.

The amount of shielding is expressed as a ratio of the signals without the enclosure and inside the in dB. The characteristic is plotted as shielding in dB versus frequency. Manufacturers of the shielded enclosures provide such charts with the enclosures.

One such modular enclosure was available for tests at the College of Technology of the University of Houston, Houston, Texas. This was a 6' x 4' x 8' (W x D x H) with double-clad high-μ metal panels on all six sides. The metal door had double layers of beryllium copper contacts all around the door leaf and the doorframe, which improve protection against RF leakage.

Measurements

For the measurement of the effectiveness of shielding, we need an RF source that transmits or radiates at desired frequencies. A variable frequency source will enable us to characterize over the entire range of frequencies of interest. However, FCC restricts radiation at unauthorized frequencies. We will use a second method where the source is outside and measurements are done with the help of a receiver placed inside the enclosure. The sources in this method are the FM and TV transmitters in the vicinity. The FCC regulation is automatically taken care of in these cases.

Design and Construction of the Test Antenna

The constraints on the antenna test for this purpose are that they should be physically small, easy-to-build, and have known gain characteristics. Since the impedance of the measurement system is 50-Ohm unbalanced, a monopole antenna is selected. One can use empirical relations or charts[2] to obtain physical dimensions to achieve desired input impedance. Both length and diameter of the monopole wire are specified as a fraction of the wavelength.

Ground Plane

The dimensions of the ground plane compared to the wavelength determine the radiation characteristics of a monopole; however, deviations are minimal if the ground plane dimension is wavelength or larger.

Monopole

A 2-mm thick copper wire was used for the monopole. A ground plane using 90cm x 90cm square shaped copper-clad sheet with copper thickness 76.2 µm was fabricated. The largest skin depth[2] (which corresponds to the lowest frequency of interest) is about 2 µm, which is very small compared to the copper thickness. A coaxial connector is mounted at the center of the ground plane for soldering the monopole wire on the metal side and for connecting a coaxial cable on the other side.

Measurement Set-up

The antenna output is fed to a spectrum analyzer via a shielded coaxial cable as shown in Fig.1.

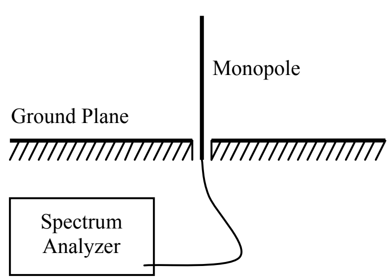

Fig. 1 Measurement set up

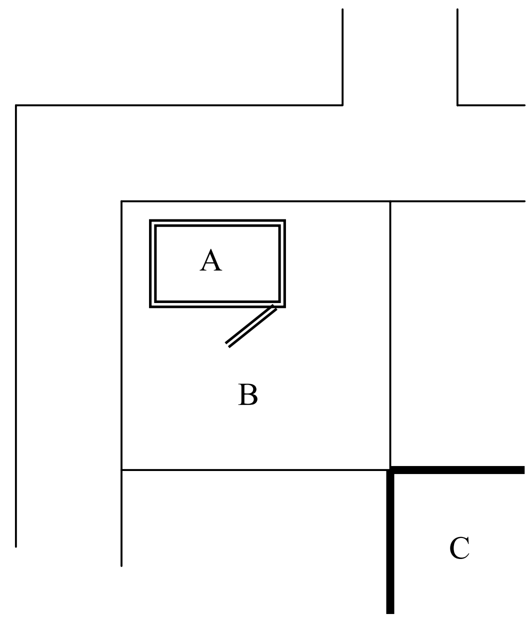

Fig. 2 Measurement locations relative to the enclosure

The spectrum analyzer used is the BK Precision[3] model 2630 with an operating frequency range of 150kHz to 1050 MHz. The sensitivity of the spectrum analyzer is – 99 dBm into 50 Ohm. For a few of the FM transmitters the signal level inside the enclosure was measured to be below – 99 dBm and thus did not provide accurate information on shielding effectiveness.

Fig. 2 shows measurement locations B and C relative to the enclosure A in the College of Technology building. Measurements at location B, outside the enclosure but within the laboratory and location C, outside the building, were also recorded. The shielding effectiveness at various frequencies was calculated based on measurements at A and B and are tabulated in Table 1. The data collected at location C provided information about the field strengths in the open ground due to various transmitters. The initial length of the test antenna was selected for the smallest frequency and was trimmed for each higher frequency at each location.

FM and TV Transmitters

In big cities such as Houston, Texas one can find a number of high power broadcast transmitters operating in the frequency range of interest. These operate at authorized carrier frequencies for either FM or TV signals radiating tens or hundreds of kW of RF power. Most of the transmitters are usually located in the outskirts of the city.

Signals from six FM transmitters were identified as stronger ones and were used for the characterization. In addition, five TV broadcast channels with stronger video carrier signals were selected. Measurements were performed at the three locations mentioned above at several other frequencies; however only those for the stronger eleven frequencies are tabulated here. Data was recorded at various times of the day since the operating power levels are changed during daytime and evenings.

TABLE I
Shielding Effectiveness Measurements

Carrier Frequency, MHz	Shielding Range in DB
88.7	25 – 30
90.9	45 – 50
93.7	25 – 30
96.5	25 – 30
100.3	15 – 30
102.9	35 – 45
211.25	24 – 34
507.25	24 – 26
543.25	24 – 27
621.25	20 – 23
693.25	20 – 29

Compilation of Data

The shielding effectiveness was calculated in dB and plotted for each transmitter frequency. Based on several samples, a range for the effectiveness was calculated. Due to the high μ metal construction, the shielding was higher at lower frequencies compared to that at higher frequencies. Some of the lower numbers at high frequencies were attributed to leakages in the gaps and air vent. Many of them were visible and were closed.

Scope and Limitations

Utilizing FM and TV transmitters in the vicinity provides a less expensive and quick method to characterize an enclosure. It is also useful in identifying RF leaks due to gaps in the joints of assembly as well as any air vents.

The sensitivity of the spectrum analyzer available can limit the range of effectiveness measurement. The size of enclosure to be tested will restrict the size of the test antenna. In the vicinity of metallic structures the radiation pattern of large antennas deform, which is likely to introduce errors.

Conclusions

In this paper, a novel method of utilizing FM and TV transmitters in the vicinity for evaluating the shielding effectiveness of an enclosure is described. Along with a spectrum analyzer operating in the desired frequency range, a set of simple antennas is required for such characterization. The range of shielding effectiveness measurement is limited by the transmitter power and the sensitivity of the spectrum analyzer available. This method provides easy recalibration of an enclosure after reassembling at a new location as well as helps detection of any leaks in the assembly at desired operating frequencies.

Reference

[1] Lindgren RF Enclosures, Inc., 400 High Groove Boulevards, Glendale Heights, IL.
[2] W.L. Stutzman and G.A. Thiele, Antenna Theory and Design, John Wiley, New York, 1997.
[3] BK Precision Spectrum Analyzer Model 2630 Instruction Manual

Biographical Information

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