Coaxial Magnetic Probes and Applications

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INTRODUCTION

A conference was recently held by the National Institute of Standards and Technology to discuss the problems presented by the electromagnetic compliance community in the United States.[1] Some of the most pressing problems presented could be addressed by the appropriate applications of shielded magnetic probes.[2]

The principles of magnetic probe design have been applied to both circular[3,4] and square probes.[5] Simply stated, a gap in the outer shield of the coaxial cable is introduced at equal distances from the point where the inner conductor is grounded to the outer shield and the point where the loop begins.[5-7] By the appropriate application of transmission line theory, the resonant frequency can be calculated and does not limit the upper frequency range of interest for most electronic products and loops smaller than 2 cm in diameter.[2] To minimize the errors in measurement, the diameter of the loop should be less than 0.01 times the wavelength.[4] For material reasons this may limit loops made from coaxial cable to tens of GHz. The smaller the diameter of the loop, the better resolution of the properties of the system of interest, but sensitivity may become an issue, especially at low frequencies. The sensitivity can be enhanced by matching the probe source impedance to the measuring instrument.[8]

Using shielded magnetic loops to illuminate a shield for testing represents a more realistic test than using plane waves for many configurations. Shields that are close to printed wiring boards are illuminated, for the most part, by magnetic fields that are perpendicular to the shield, and generated by the magnetic loops formed by paths on the circuit board. Testing such a shield with plane waves can lead to significant errors in the measurement of shielding effectiveness as it applies to the circuit being shielded.

> ***Although the principles of designing shielded magnetic probes have been well established for some time, new applications continue to be developed.***

APPLICATION OF SHIELDED MAGNETIC PROBES

Although the principles of shielded magnetic probe design are well known, application of the probe design is still a fruitful area for development. A review of recent patents shows quite a number of patents that are based on new applications. Both circular and rectangular shielded magnetic probes have been applied to the following:

- measurement of homogeneity in material properties[9] and shielding effectiveness of materials[10]
- measurement of shielding effectiveness and emissions from shielding enclosures[11] and electronic devices[12]
- measurement of shielding effectiveness of interconnections used in shielded enclosures[11]
- verification of circuit designs for undesirable emissions and immunity of circuits to impinging electromagnetic energy[6, 13, 14]

When measuring the first three items, two probes are placed at a fixed distance and the material or enclosure is inserted between the probes. The insertion loss is recorded. Measurements made in this manner are independent of the circuit and are for diagnostic purposes only.[2] The insertion loss is referenced to the coupling strength of the probes for the same conditions without the inserted item. The figure of merit is the shielding effectiveness. Such measurements have been made for a number of materials such as electroless Ni/Cu, vapor deposited Al (with and without a protective film), arc sprayed metals/alloys, conductive paints, meshed wires, formed metals and fiber-filled plastics.[10] Under the appropriate conditions, the resistance/square can be calculated.[9]

By using the contactless shielded magnetic probes, a more exact value of shielding effectiveness and derived values of resistance can be obtained. For materials that are sensitive to the contact pressures of the probes, as in the direct measurement of resistance, the measurement is usually not reproducible using the contact methods. Materials that are sensitive to contact probe pressures include filmed material such as oxidized Al, Ni and alloys and meshed wire composites. Materials such as fiber-filled plastics can yield very high resistance when using contact probes, but offer sufficient shielding effectiveness. In this case a high resistance surface film of plastic is present due to the material and processing conditions.

Measurements of the insertion loss of enclosures require high resolution to find the primary cause of the electromagnetic leakage, so smaller magnetic probes are used to advantage. A large frequency range is measured, even beyond the operating frequency, so small holes or other defects can be detected. Such information can then be given to the vendor so potential problems in processing and/or materials can be corrected early in the design cycle.

Verification of circuit designs is an art dependent on the availability of a good set of rectangular probes and an understanding of the various devices that can be potential radiators and receivers.[12,13] The area of testing of individual components and relating the relevance of such measurements to meet regulatory requirements should be expanded.[12]

CIRCULAR VERSUS RECTANGULAR SHIELDED MAGNETIC PROBES

For uniform fields, only the loop area (single turn loops) affects coupling strength. A circular and a rectangular loop of the same area should have the same open circuit output voltage. Rectangular loops will have more inductance, which will have some effect on the output voltage. For analysis of most circuits, rectangular loops have a better geometric fit than do circular probes, but at very large distances both are effectively the same. The better fit of rectangular probes to most circuits translates to better coupling between the circuit and the probe.

The lower size limit of fabrication of circular and rectangular probes using coaxial cable is better for circular probes than for rectangular ones due to the material properties of the cable.

Circular probes are bent to a small radius of curvature whereas rectangular probes have 90-degree bends, thus requiring a smaller radius of curvature than a circular probe of the same area. This limitation becomes important at very small probe sizes which approach tens of GHz frequency response.

SUMMARY

Circular probes are useful for many purposes but rectangular probes are most useful as all-purpose probes. Rectangular probes range in usefulness from measurement of shielding effectiveness of materials, enclosures and interconnection methods to detecting the source of noise and susceptibility of a working circuit.

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