MAGNETIC PROBE WITH EXTENDED GROUND PLANE FOR EMC MEASUREMENT

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1. INTRODUCTION

Nowadays, increasing functionalities of high speed digital circuitry and rapid development of wireless devices in a limited space introduce numerous design and fabrication issues. These neighboring circuitry modules sometimes cause electromagnetic interference in self equipment or excessive electromagnetic radiation to generate electromagnetic interference (EMI) problems [1]. The knowledge of the electromagnetic environment of circuitry is therefore essential and the use of near-field techniques in EMC applications increases rapidly.With a map of electromagnetic field intensity on the circuitry [2-3], one can find the whole field intensity distribution and find out the corresponding noise source. To predict far-field emission level or to position the source of electromagnetic noise, magnetic near-field measurement by a loop probe is a promising method . According to measuring requirements, considerations of broad operating bandwidth, high spatial resolution, and large isolation between sensed electrical field and magnetic field for the magnetic probe are respect. In ref. [4], a set of quasi-periodic notches was embedded into the connecting portion of a loop. The embedded notches, acted as a microstrip filter, effectively suppress the inherent resonances of the circular loop to up the usable frequency to 9 GHz. A stripline magnetic near-field probe for high frequency band up to 10 GHz achieved an improved spatial resolution [5]. The smaller sensor causes higher operation frequency and degraded sensing zone. However, three layer structure with 1 mm^2 dimension is seemly an uneasy fabrication. A shielded magnetic loop using CMOS–silicon-on-insulator (SOI) micro-fabricated technology obtains a further-miniature and high spatial-resolution function [6]. However, the sensing sensitivity is degraded because of the tiny IC scale. In addition, a rectangular magnetic field probe with air-bridge, which effectively suppresses resonance between probe and ground plane [7], was proposed to gauge much higher frequency region than conventional magnetic probe.

In this paper, we propose a magnetic field probe with a circular loop. In addition, an extended ground plane is used to effectively suppress self-resonance of the magnetic loop. It ups the usable frequency to larger than 9 GHz. Moreover, the extended ground plane acts as a reflector of E-field. The feature introduces a 20 dB isolation between sensed electrical and magnetic field.

2. PROBE DESIGN

Figure 1 shows the computer-aided design (CAD) layout of the proposed probe. In addition to easy fabrication, probe dimension compared with the device-under-test (DUT) in RF scale was considered. In this design, the proposed sensor is a planar circular loop with radius R and strip width of 1 mm on a PVC substrate, which is with permittivity of 2.27 and thickness h. The circular loop was connected to displayer (spectrum analyzer or receiver) through a coplanar-waveguide microstrip line. The positive of a 50-Ω SMA connector connects to point A, while the SMA chassis (negative) connects to an extended conductive plane in dimension of $L_G \times W_G$. Note that a gap of 1.5 mm between the microstrip line and ground plane is needed to separate the positive from negative. For real applications, the metal portions, including loop, microstrip line, and ground plane, can be easily fabricated by cut in a piece of conductor or directly printed on a microwave substrate. In this study, copper with thickness of 0.02 mm was chosen as the conductive material.

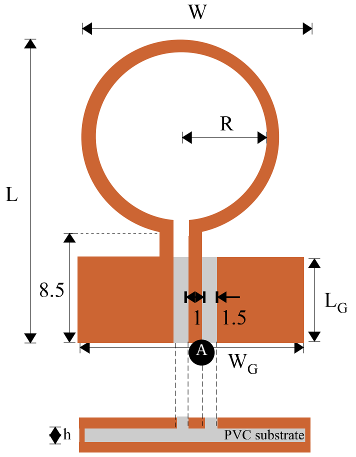

Figure 1: Configuration of the proposed probe

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

Figure 2 shows the configuration for measurements. The magnetic field measurement system consists of a 3-D positioner, network analyzer, test-fixture, and probe. Here, a microstrip line, which is with characteristic impedance of 50 Ω and terminated by a matching load, was used as device under test (DUT). The microstrip line was connected to the Network Analyzer through a SMA plug and a semi-rigid coaxial cable. The DUT was fabricated on a commercial FR4 substrate (permittivity ε_r = 4.4 and thickness h = 0.8 mm). For all directional field measurement, including H_x-, H_y-, and E-field, the magnetic field probes were placed 3 mm above the circuit, in order to have the central points of the probes at the same level. In addition, the reference probe, which was with same structure as the proposed except for the extended ground plane, is presented for clear comparison. The reference can be considered as a conventional loop probe. S-parameters of the proposed probe were measured to demonstrate the features of proposed probe. Firstly, Figure 3 shows the reflection coefficient S_{11} of the proposed probe and reference probe. The corresponding parameters are shown in Table 1. From the experimental results, the first resonance is at about 4.0 GHz with -4 dB reflection for the reference. This self-resonance possibly interferes to the magnetic field penetrated through the circular loop and limits the usable bandwidth of probe. However, S_{11} of the proposed probe has improved on the reference about 3 dB, that is, the resonance is successfully suppressed. Accordingly, the operating bandwidth determined by S_{11} less than 3 dB is largely raised from 3.5 GHz to larger than 9 GHz.

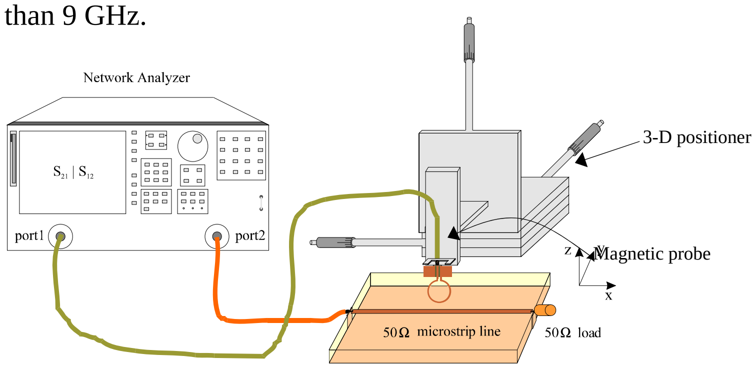

Figure 2: Structure for measurements.

Table 1: Parameters of the proposed magnetic probe (unit: mm)

R	L_G	W_G	L	W	h
4	6	16	20	20	0.02

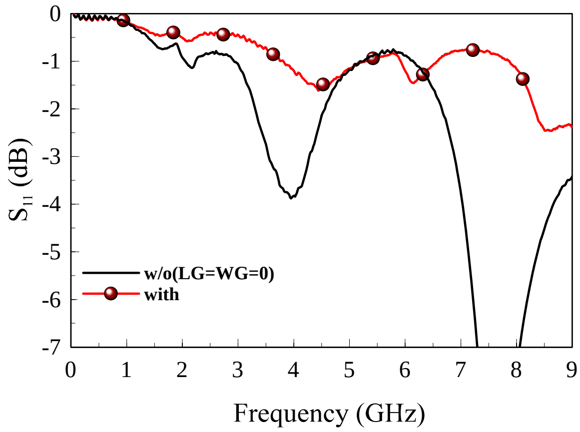

Figure 3: Measured S_{11} in frequency for the proposed in ground plane.

The effects of the ground plane dimension W_G and L_G on operating bandwidth were theoretically studied by Ansoft HFSS 10.0. Each investigation was performed on one varied parameter while others keep constant as shown in Table 1. From Figure 4 and Figure 5, it is seen that input impedance of the proposed probe at the first resonance is sensitive to both W_G and L_G. Larger ground plane diminishes the real impedance and suppress the resonance of the first mode. Also, longer ground plane (L_G↑) shifts the second resonant mode toward higher frequency and more broaden the operating bandwidth. Comparing with the measurement in Figure 3, disagreement in upper band is seen. It is possibly caused by the too large simulated frequency range.

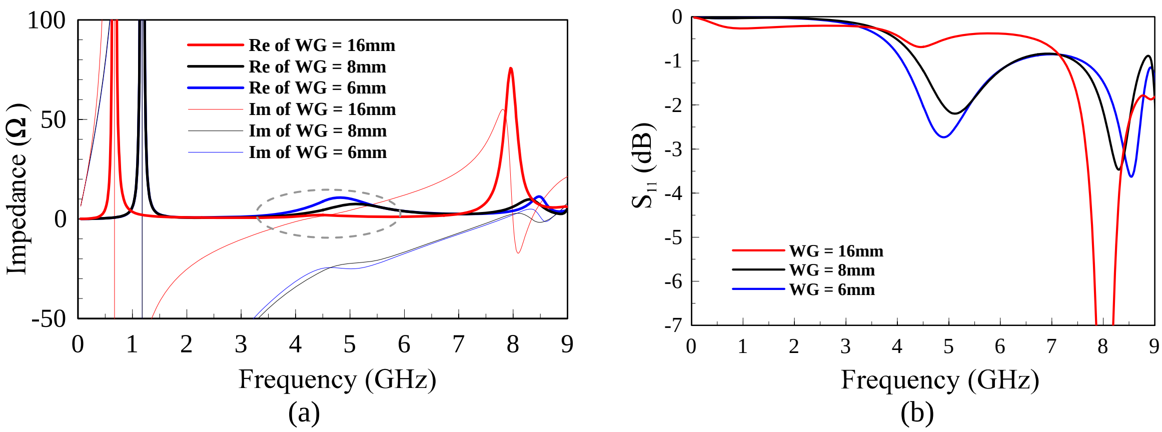

Figure 4: Simulated (a) input impedance, and (b) S_{11} against frequency with varied W_G.

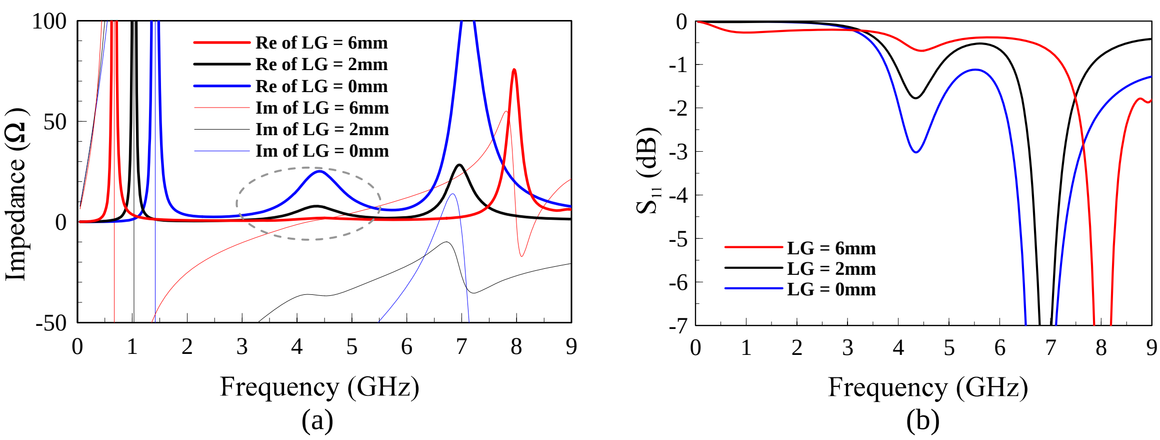

Figure 5: Simulated (a) input impedance, and (b) S_{11} against frequency with varied L_G.

To certify the magnetic noise, larger separation from E-field is expected. Figure 6 presents the measured E-field and H-field in frequency of proposed magnetic probe. Also, the reference is presented for clear comparison. For the reference, the isolation between E- and H-field is relative to frequency and E-field dominates the measurements for the worst. On the other hand, the experimental results indicate that the proposed probe has stably up to 20 dB enhancement in isolation by the extended ground plane.

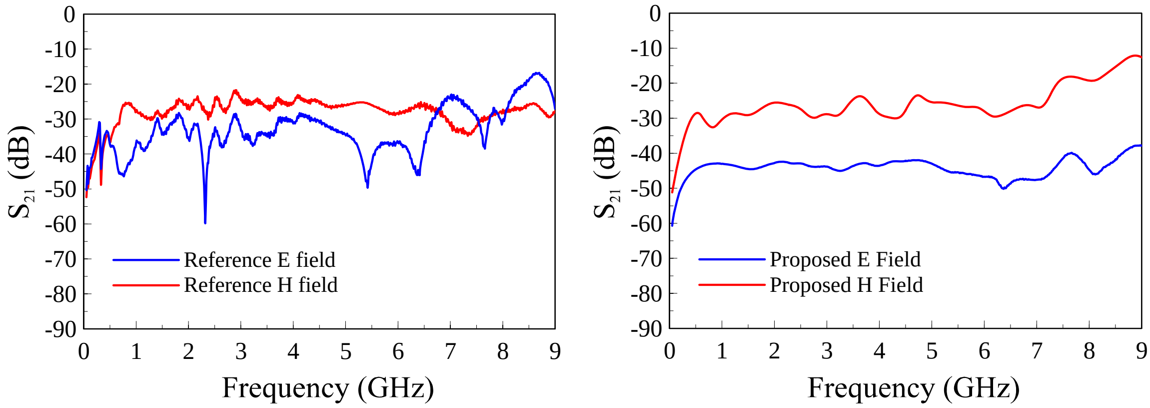

Figure 6: Measured E-field and H-field in frequency of (a) Reference probe and (b) Proposed probe.

4. CONCLUSIONS

We have developed a planar circular loop as magnetic field probe. An extended ground plane, lowers the real input impedance of the first self-resonance to largely broaden the operation bandwidth. Moreover, the ground plane shields the loop probe from E-field, greatly enhance the desired performance of isolation than the conventional circular loop probe.

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