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Extraction of Via Defects from Very-Near-Field Measuremets and A Source Reconstruction Method

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Abstract

Electric-field integral equation (EFIE) is solved in the planar very-near-field measurement of the substrate integrated waveguide (SIW) to reconstruct the equivalent sources on the surface that encompasses the structure and extract the position of the defective vias. In a two-step process, firstly, the region of interest where the defect is located is estimated. Secondly, the qualitative reconstructed fields in vicinity of the defects are improved through mesh refinement.

1. Introduction

As electronic devices evolve in the matter of functionality and complexity, the risk of electromagnetic interference problems grows. Thus, it is crucial to accurately measure and model the electromagnetic behavior of circuit boards.

The waveguide structure is one of the lowest loss transmission line types. Within the planar substrate structures, the integration of classical waveguides with solid walls cannot be achieved. An alternative is to use multilayer structures. In most of the academic research environment, the technical facilities are not sufficient to develop complex multilayer designs. Therefore, single layer (single substrate) substrate integrated waveguide (SIW) design is preferred that can come up with the similar performance of conventional waveguides and at the same time, the fabrication ease of planar circuits [1,2]. By choosing these designs, the cost of material, fabrication, shipment and installation can also be decreased. Thus, many SIW components such as bends, filters, couplers, duplexer, six port junction, circulators and phase shifters are developed for different applications. Evidently, an accurate reconstructed current can provide us with enough information about the location and the sort of the problem for defected vias and internal elements that are not fabricated satisfactorily.

Near-field (NF) scanning has emerged as a successful technique to examine the electromagnetic behavior of the electronic systems [3-5]. NF data allows development of equivalent radiation sources. Furthermore, it does not need a (semi) anechoic camber, makes it very cost-effective for a designer to access the EMC behavior of their product before running a (pre-) compliance test. The required time to perform a full NF scan varies depending on the size of the device, but quickly takes up to several hours for a comprehensive data set and multiple frequencies. RFxpert is a bench-top very-near-field measurement tool. It is a planar array of magnetic near-field probes which measures two orthogonal components of the magnetic field in real time [6-11]. In this paper source reconstruction algorithm (SRM) is used to extract the location of potential defective vias in SIW structures. The input data is the x and y components of the magnetic field at a plane above the SIW transmission line that is extracted from a full wave software (HFSS).

2. Extraction of via defects

The source reconstruction method that is explained in [6] is used here to reconstruct the magnetic and electric currents on the surface of the box that encloses the SIW transmission line (TL). An illustration of a SIW structure with two defective vias is depicted in Fig.1. (a). Here it is assumed that x and y component of magnetic fields can be measured (both magnitude and phase) as it is the case in RFxpert. These measured magnetic fields are linked to the equivalent sources on a closed surface that contains the structure via EFIE [7].

$$\bar{H}(\bar{r}) = -K(J;r) - \frac{1}{\eta_0}L(M) \quad (1)$$

where

$$K(J,r) = \int_{\Sigma_R} J(r')\times\nabla g(r,r')dS'$$

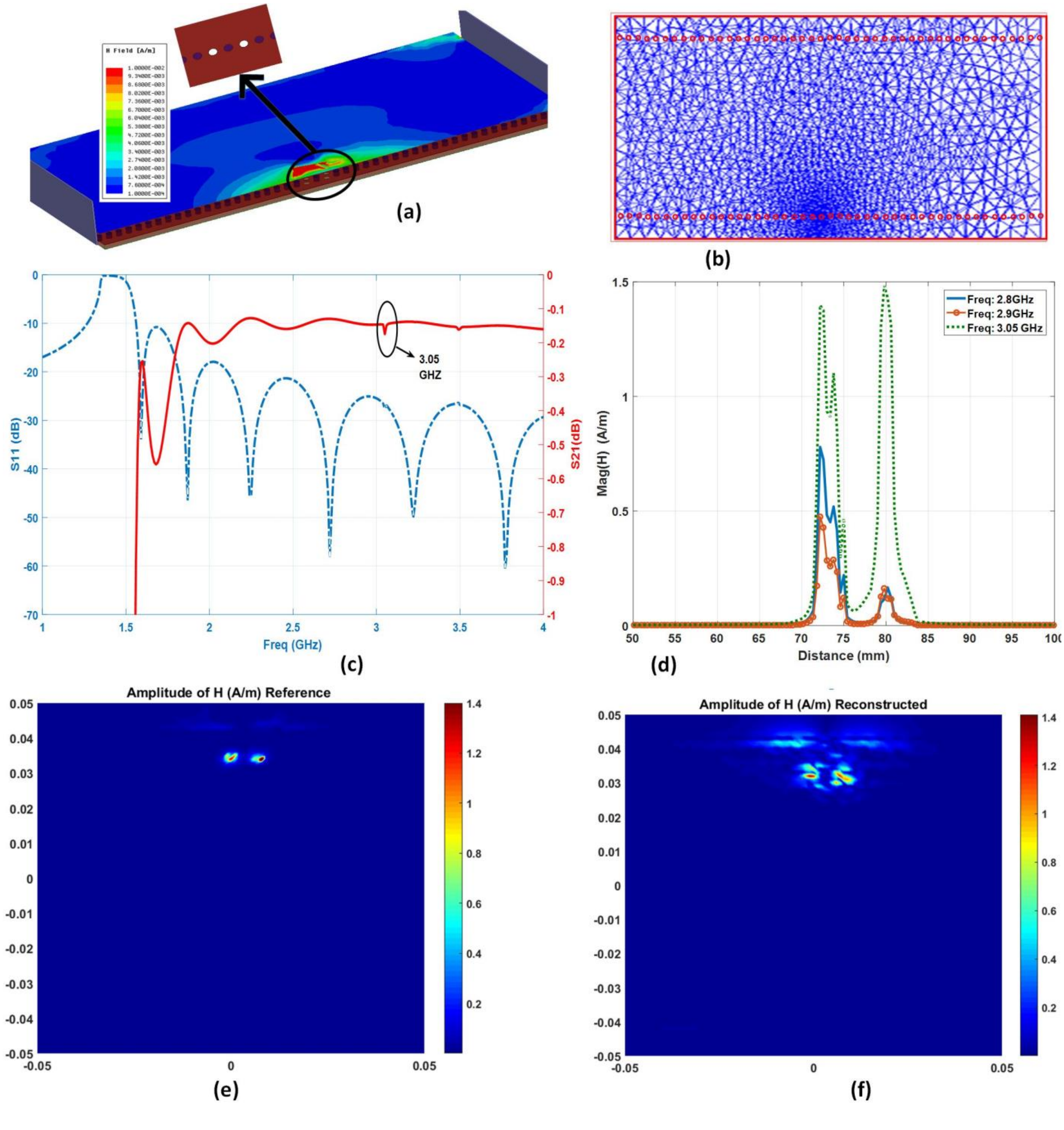

Fig. 1 (a) The magnitude of the magnetic fields over a plane 3mm above the structure, (b) the refined meshes at the position of the defective vias (c) S parameters of the simulated SIW TL, (d) the magnitude of the magnetic field along a line on top of the vias for different frequencies, (e) the amplitude of the magnetic field 1mm away from the SIW TL extracted from HFSS, (f) the amplitude of the magnetic field 1mm away from the SIW TL obtained using the reconstructed sources.

$$L(M;r) = jk_0 \int_{\Sigma_R} \left[M(r') + \frac{1}{k_0^2} \nabla \nabla'_S . M(r') \right] g(r,r') dS'$$

$$g(r,r') = \frac{e^{-jk_0|r-r'|}}{4\pi|r-r'|} \qquad (2)$$

where, $\eta_0 = \sqrt{\mu_0 / \varepsilon_0}$, $k_0 = \omega \sqrt{\mu_0 \varepsilon_0}$ and ∇'_s is the surface divergence operator. To solve the inverse problem, Tikhonov or TSVD method can be employed [12]. As it is demonstrated in Fig.1. (a), close to the position of the defective vias, there is some radiation on the measurement plane. As illustrated in Fig.1. (b) in the MoM, for the surface that includes the SIW TL, refined meshes can be used to have a more accurate representation of the reconstructed currents. Gmsh mesh generator is used to do mesh refinement [13]. By looking at the S parameters of the SIW structure we realize the frequency at which the radiation is more evident. For instance, as shown in Fig. 1. (c) it seems that the defective vias have more impact on the performance of the structure at 3.05GHz, and are more detectable at this frequency.

The magnitude of the magnetic field along the line that is exactly on top of the vias is plotted for three different frequencies (Fig.1. (d)). There is a clear distinction between the magnitude of magnetic field at 3.05 GHz and its magnitude at the other frequencies.

Some parameters such as the scanning resolution, mesh size, scanning plane area and scanning height impact simulation and measurement results.

Increasing the scanning resolution significantly decreases the condition number of the inverse problem therefore enhances the stability to measurement errors. When the scanning resolution is approximately finer than the maximum spacing allowed, the condition number almost converges to a constant. A fine enough scanning resolution assures the information adequacy. The maximum spacing between sampling points (ΔS) allowed to have adequate information for planar near-field measurement according to the sampling standard proposed by Joy and Paris [14] is

$$\Delta S = \frac{\lambda}{2\sqrt{1+\left(\frac{\lambda}{d}\right)^2}} \qquad (3)$$

Where *d* is the separation between the DUT and the probes. Thus, the additional refinement of the scanning resolution does not improve the accuracy.

The condition number of the inverse problem sharply increases by increasing the number of mesh elements. On the other hand, a fine enough resolution for the triangular patches is crucial to completely represent the PCB. Therefore, there is an optimum balance between the information sufficiency and numerical stability.

A near field plane where the maximum field on the edges is about 20dB lower than the maximum field is desired. Further increasing its size does not improve the accuracy of the equivalent source method remarkably.

Closer scanning distance results a more precise representation of the PCB but based on (3) it needs more samples. When scans are conducted at a higher distance the same sized measurement plane covers less data. The higher the measurement plane, the approximations are more probably inaccurate.

In this work, the scanning height, resolution and area are 3mm, 1.5mm, and 100mm×100mm respectively. The mesh size varies from 1mm to 6mm at the operating frequency of 3.05GHz. The diameter of vias is 2mm and the pitch is 3.57mm. The substrate is Rogers RT/duroid 5880. The amplitude of the magnetic field at the height 1mm above the SIW TL that is extracted from HFSS is depicted in Fig.1.(e). The amplitude of the magnetic field 1mm away from the SIW TL that is obtained using the reconstructed sources is shown in Fig.1 (f). There is a good agreement between the amplitude of the original fields and the reconstructed fields.

3. Conclusion

In the proposed method the planar near-field measurement and source reconstruction algorithm are utilized to find the precise position of the defective vias in SIW structures. The impact of the different parameters that are involved in the simulations and measurements such as the scanning resolution, mesh size, scanning plane area and scanning height are discussed. This algorithm is verified by using the radiated fields from a SIW transmission line with two defective vias. The data is extracted from a full wave solver (HFSS).

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