Visualization of Impedance-Mismatching and Electromagnetic-Coupling by Using a Radiowave Holography Method

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Abstract: A new method for evaluating microwave modules is proposed. The technique yields visualization of impedance mismatching points and electromagnetic coupling by using a radiowave holography method based on the near-field interference pattern measurement. Some results of the experiment are presented to demonstrate the validity of the proposed method.

1. Introduction

In the microwaves industry, more compact and more low-priced systems are required. Microwave engineer has distress, e.g., the problem of doing difficulty being of discovering even if it uses time-domain reflectometer (TDR), and the problem that a guess isn't stuck at all such as electromagnetic coupling. We have proposed a radiowave holography method for visualization of radiation [1][2] and propagation [3][4]. This paper presents a new technique to evaluate microwave modules: i.e., impedance mismatching and electromagnetic coupling. We also an apparatus of hologram observation for applying actual microwave systems such as digital cellular phone and active components.

2. Methodology

If impedance mismatching point exists in the circuit, an electromagnetic wave is radiated from the respect to the space. Moreover, if electromagnetic coupling exists in the circuit, induction field is observed in the part. Radiowave holography is a technology which does 3-D visualization based on the phase of 2-D observed electromagnetic waves. Therefore, using a wave information from the circuit which wants to be evaluated: i.e., the interference pattern of the radiated electromagnetic wave is recorded and wave source images can be reconstructed. Moreover, the radiation pattern which unnecessary coupling makes can be presumed.

3. Holography apparatus

Figure 1 shows the configuration of the measurement system constructed for observing the actual radiowave hologram. The signal is received by the scanning antenna. The frequency is selected by the spectrum analyzer (Advantest R3271), and the signal is converted to the IF frequency of 21.4 MHz.
MHz band filtering is applied. In order to cancel the phase variation in the time course of hologram measurement, the reference wave is received by another spectrum analyzer which is completely phase-locked. The reference wave is taken from a fixed antenna. The measured hologram signal and the reference signal, received by the two spectrum analyzers and converted to the IF frequency of 21.4 MHz, are further converted into 15.4 MHz and 14.4 MHz, respectively, and the two signals are multiplied by the multiplier. In the output signal from the above multiplier, the result of multiplication of the frequency component in the measured hologram signal and the corresponding frequency component of the reference signal, results in the signal frequency of 1 MHz. The phase of that 1 MHz signal has the information representing the phase difference between the measured hologram signal and the reference signal. This 1 MHz signal is sampled by the sampling clock synchronized to the local oscillator, and the coherent detection is applied using the Fourier integral. Then, the relative phase distribution and the amplitude distribution in regard to the reference wave on the hologram measurement plane is obtained.

![Block diagram of radiowave hologram observation system.](image)

**Fig. 1** Block diagram of radiowave hologram observation system.

### 4. Results

Figure 2 shows the direct measurement results of wave emission from a planer microwave circuit; frequency=20GHz, height of probe=6cm, extension=20cm x 20cm. Figure 3 shows the calculated reconstruction results of wave emission points by using the Figure 2 data based on the inverse Fresnel transforms. The planer circuit used in the observation is made of a directional coupler and low-pass filter, which are connected in series. The directly observed radio image pictures show that a strong wave is detected at a no-wave-source location because of wave interference. The calculated reconstruction image pictures clearly show the impedance mismatching points: i.e., input connector and terminator of the directional coupler.
Fig. 2  Measured interference data of microwave module.

Fig. 3  Reconstructed impedance-mismatching points of Figure 2.
Figure 4 shows the measurement results of current distribution of a digital cellular phone; frequency=940MHz, height of probe=2.7cm, extension=26cm x 26cm. A strong current distribution is observed by the antenna part. However, it is weak; an induction current to the box of the telephone, is observed in the wide area. Figure 5 shows the calculated reconstruction results of wave radiation pattern by using the Figure 4 data based on the Fresnel transforms; frequency=940MHz, height of reconstruction=60cm, reconstruction extension=52cm x 52cm. It finds that the induction current influences a radiation pattern mainly.

Figure 6 shows the far field radiation patterns of the digital cellular phone by using the measured current distribution data of Figure 4; in case of the antenna, in case of the box, and in case of the total. The radiation pattern which was calculated using the total current distribution, it breaks to two. But, the radiation pattern which was calculated using the case of antenna and the box, these like a dipole radiation. Thus, the phase difference about the current distribution in two parts made the division of the directivity occur.

In this experimental system can simulate the radiation pattern of the results of putting weight on the measured current distribution, respectively partial. The cause of the radiation pattern and the result, and the improve of the radiation pattern engineering change can be easily examined by this function.

![Fig. 4 Measured interference data of portable radiotelephone.](image-url)
Fig. 5  Reconstructed radiation pattern of Figure 4.

Fig. 6  Comparison of far field radiation pattern between partial current distributions and total current distribution.
5. Conclusions

A new evaluation method has been proposed and the effectiveness has been shown by the experiment for microwave modules based on the Fresnel transforms and the inverse Fresnel transforms (see Appendix). The proposed observation system is possible to measure a various actual signals such as continuous wave and modulated wave. By using the proposed technique and the experimental setup, the diagnosis and evaluation of the microwave modules can be carried out based on the non-contact testing.

References


Appendix: Hologram Reconstruction without Approximation

\[ J(R') : \] Current distribution \[ V(R) : \] Received voltage \[ \tilde{G}(R - R') : \] Dyadic Green’s function

\[ l^h_e : \] Effective vector length of H pol. antenna \[ \mathcal{F}[\cdot] : \] Fourier transforms

\[ l^v_e : \] Effective vector length of V pol. antenna \[ \mathcal{F}^{-1}[\cdot] : \] Inverse Fourier transforms

**Electric field vector** (Fresnel transforms):

\[ E(R) = -j \omega \mu_0 \int \frac{L}{2} \frac{L}{2} \int \frac{L}{2} \frac{L}{2} \tilde{G}(R - R') \bullet J(R') \cdot dx' \cdot dy' \]

**Received voltage vector** by using probing antennas:

\[ V(R) = \int \frac{L}{2} \frac{L}{2} \int \frac{L}{2} \frac{L}{2} \tilde{B}(R - R') \bullet J(R') \cdot dx' \cdot dy' \]

where

\[ \tilde{B}(R - R') = -j \omega \mu_0 \left[ l^h_e(R - R') \right] \bullet \tilde{G}(R - R') \]

\[ = \begin{bmatrix} A_{hh}(\theta h, \phi h) \sin \theta h & A_{hv}(\theta h, \phi h) \sin \theta v \\ A_{vh}(\theta h, \phi h) \sin \theta h & A_{vv}(\theta h, \phi h) \sin \theta v \end{bmatrix} \frac{e^{j2 \pi r/k}}{r} \]

**Current distribution** (inverse Fresnel transforms):

\[ \tilde{J}(R') : \] Current distribution \[ V(R) : \] Received voltage \[ \tilde{G}(R - R') : \] Dyadic Green’s function

\[ l^h_e : \] Effective vector length of H pol. antenna \[ \mathcal{F}[\cdot] : \] Fourier transforms

\[ l^v_e : \] Effective vector length of V pol. antenna \[ \mathcal{F}^{-1}[\cdot] : \] Inverse Fourier transforms

**Electric field vector** (Fresnel transforms):

\[ E(R) = -j \omega \mu_0 \int \frac{L}{2} \frac{L}{2} \int \frac{L}{2} \frac{L}{2} \tilde{G}(R - R') \bullet \tilde{J}(R') \cdot dx' \cdot dy' \]

**Received voltage vector** by using probing antennas:

\[ V(R) = \int \frac{L}{2} \frac{L}{2} \int \frac{L}{2} \frac{L}{2} \tilde{B}(R - R') \bullet \tilde{J}(R') \cdot dx' \cdot dy' \]

where

\[ \tilde{B}(R - R') = -j \omega \mu_0 \left[ l^h_e(R - R') \right] \bullet \tilde{G}(R - R') \]

\[ = \begin{bmatrix} A_{hh}(\theta h, \phi h) \sin \theta h & A_{hv}(\theta h, \phi h) \sin \theta v \\ A_{vh}(\theta h, \phi h) \sin \theta h & A_{vv}(\theta h, \phi h) \sin \theta v \end{bmatrix} \frac{e^{j2 \pi r/k}}{r} \]
\[ J(R') \cong Z^{-1} \left[ Z^{-1} B^{-1} (R - R') \right] \cdot Z[V(R)] \]