Microwave Field Measurement by using Semiconductor Scatterer with Optical Modulation

Takahiro Kurosawa
Akita Industrial Technology Center, 4-21, Sanuki, Araya, Akita, 010-1623, Japan

***Abstract* – Microwave electric field measurement system based on the modulated scattering technique with semiconductor scatterer has been developed. The scattered wave by the scatterer was modulated with the light which has higher energy than the band-gap energy of the semiconductor. By using undoped germanium disk as the scatterer, microwave field could be detected in the frequency range of 1-7 GHz. The sensitivity was 65 dBuV/m at the frequency of 1 GHz and was increased with increasing the frequency. On near field measurements, distribution of the in-plane field component on the microstrip line and the patch antenna could be measured.**

***Index Terms* — electric field measurement, modulated scattering, dielectric scatterer, semiconductor, EMC.**

1. Introduction

Near field measurements of antenna provide a fast and accurate method of determining the antenna gain, pattern, and other parameters of interest to develop the antenna. For this purpose, the modulated scattering technique (MST) was proposed [1]. The authors have been developing an electric field measurement system based on the MST with non-metal scatterer to map the electric field distribution radiated from the source [2][3]. The system introduces a dielectric or semiconductor probe as the modulated scatter, instead of the conventional metallic dipole.

When a semiconductor scatterer is illuminated the light which has higher energy than the band-gap energy of the semiconductor, resistivity of the scatterer is decreased. This leads increasing the dielectric loss of the scatterer and leads decreasing the amplitude of the scattered wave. Thus the light intensity modulates, the scattered wave amplitude of the semiconductor can modulates. Then the modulated scattered wave receives, and synchronous detection which refer to the light intensity modulation is carried out, scattered wave amplitude can be determined. Since the amplitude is proportional to the electric field strength at the scatterer, the field strength can be measured. In this report, the sensitivity and frequency response is evaluated. Near field measurements of the microstrip line and the patch antenna are also shown for application.

2. Experiment

Fig. 1 shows the block diagram of the experimental setup. Log-periodic dipole array antenna was used as the wave source and was fed the RF signal from the tracking generator of the receiver which has the same frequency of the receiving frequency of the receiver. Undoped germanium disk (diameter: 25 mm and thickness: 0.5 mm) was set in the field of the wave source and used as the scatterer. The diode laser was used as the light source and the amplitude of the light was modulated. The output of the laser was focused onto the scatterer with convex lens. The diameter of the light was set to 17 mm. Both the modulated scattered wave from the scatterer and direct wave from the source were received by the antenna and put to the receiver. In-phase and quadrature component of the received wave was obtained by using a quadrature demodulator from the IF signal of the receiver. Each in-phase and quadrature component of the wave was detected by two lock-in amplifiers and extract the signal components V_I and V_Q at the modulation frequency of the light. The amplitude of the scattered wave V_s and the phase of it θ can be written as $V_s = (V_I^2+V_Q^2)^{1/2}$ and $\theta = \tan^{-1}(V_Q/V_I)$, respectively . Since the polarization of the scattered wave is parallel to the field at the scatterer, the direction of the field can be determined from the polarization of the antenna.

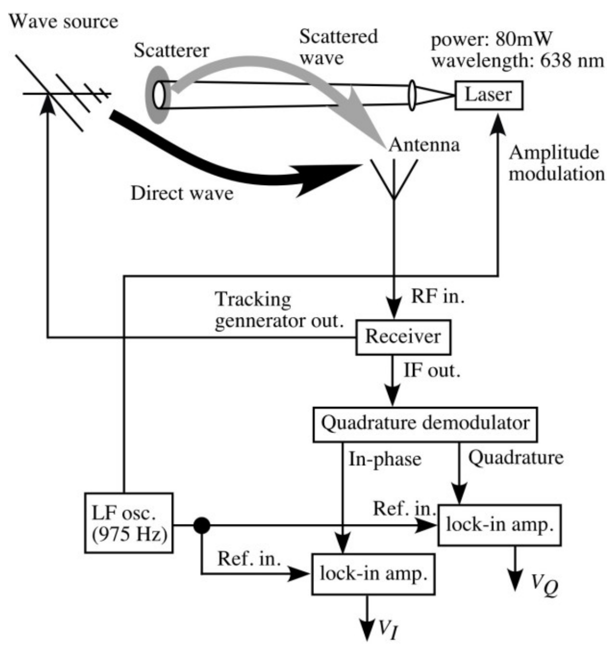

Fig.1. Schematic diagram of the field measurement system by using the optically modulated scatterer.

3. Far field measurements

Since the measured scattered wave amplitude increased linearly with an increase in the electric field at the scatterer, the signal to noise ratio (SNR) of the scattered wave amplitude was measured. The SNR was obtained from the ratio of average value of V_s and its standard deviation in 50 times measurements. The SNR also depends on the time constant τ of lock-in amplifiers, the τ dependence of the SNR was evaluated. Result is shown in Fig. 2. The SNR is proportional to the square root of the τ because the standard deviation of the V_s inversely proportional to the square root of the τ. The SNR was proportional to the field strength, the sensitivity (SNR = 0dB) can be determined from the Fig.2. The sensitivity at 1 GHz was 65 dBuV/m and the sensitivity at 3 GHz was 50 dBuV/m with τ=1s.

Fig.3 shows the frequency dependence of the normalized amplitude of the scattered wave. Scattered wave could be detected in the frequency range of 1-7 GHz. The amplitude increased with increasing the frequency. This property is desirable for higher frequency driving electronic devices.

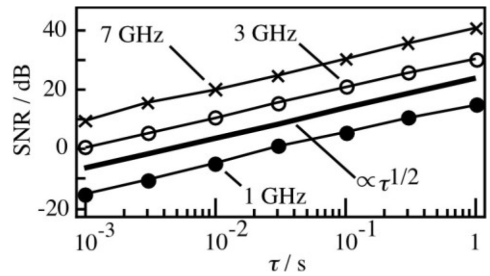

Fig.2. Time constant τ dependence of the signal to noise ratio SNR of the scattered wave signal. Electric field at the scatterer was set to 80 dBuV/m. Solid line denote the value which is proportional to the square root of the τ with dB unit.

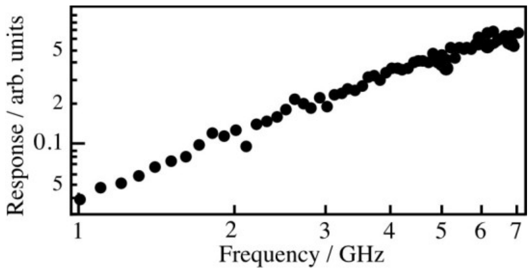

Fig3. Frequency dependence of the amplitude of the scattered wave. Each value was normalized by the applied field and antenna factor.

4. Near field measurements

Fig.4 shows the electric field distribution over the microstrip line (MSL) with open termination. The measured field direction is in-plane and perpendicular to the longitudinal direction of MSL. The amplitude and phase distribution of the standing wave on the MSL can be seen clearly. The wavelength shortening coefficient was determined by measuring the interval of null points of the standing wave, and it was 0.53. This value is in agreement with the analytical value.

Fig.5 shows the electric field distribution over the patch antenna with quarter wave impedance matching line. The field is mostly concentrated along the two edges.

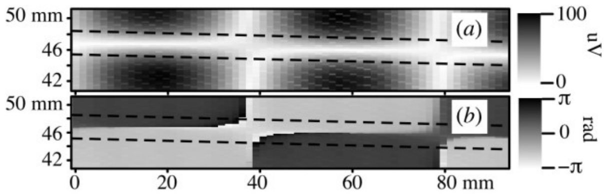

Fig. 4. Electric field amplitude (a) and phase (b) over the microstrip line with open termination. Measured frequency was 2 GHz. The outline of the conductor is shown with dotted lines.

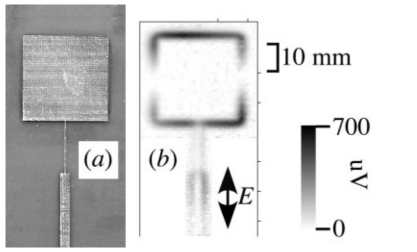

Fig.5. Patch antenna measurements : (a) photograph, and (b) field patterns over the patch antenna. Measured frequency was 2.476 GHz and measured field direction is shown in (b) as E with an arrow.

5. Conclusion

Microwave electric field measurement system based on the modulated scattering technique with semiconductor scatterer has been developed. By using undoped germanium disk as the scatterer, microwave field could be detected in the frequency range of 1-7 GHz. The sensitivity was 65 dBuV/m at the frequency of 1 GHz and was increased with increasing the frequency. On near field measurements, distribution of the in-plane field component on the microstrip line and the patch antenna could be measured.

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