Planar Near-Field Measurements of Microstrip Array Antenna Using Photonic Sensor at X Band

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1. Introduction

Planar near-field measurements (PNFM) are widely used as a technique for antenna pattern measurements of directive antennas. However the equipment becomes large and heavy below a few GHz because the size and the weight increase relating to the wavelength. To overcome the difficulties, we have proposed a photonic sensor as the probe for the PNFM and have shown its usefulness through the measurement of a horn antenna at 8 GHz [1]. In this paper, we also show that the photonic sensor can be used for antenna pattern measurements at 9.41 GHz, of a microstrip array antenna.

The antenna size of the photonic sensor is less than 0.1 wavelength (about 3 mm) and its weight is a few grams. Therefore the antenna can be considered as a linearly polarized electric infinitesimal antenna. Moreover the sensor consists of dielectric materials except tiny metals used for the antenna and a mirror (about 1 mm). This means that the mutual coupling between an antenna under test (AUT) and the sensor is negligible. Therefore we can measure the electric field in close proximity (0.3 wavelength, or 10 mm) to the aperture of the AUT without disturbing the original electromagnetic field created by the AUT.

To verify the characteristics, we have also measured the antenna patterns of the AUT by the PNFM using the conventional open-ended waveguide (OEW) as the probe and by the far-field method, and compared the measured results using the three methods. Because the measured results agreed within 1 dB on the main beam region of the antenna, we have confirmed that the photonic sensor can be treated as a linearly polarized electric infinitesimal antenna.

2. Measurement setup

The structure and size of the photonic sensor are shown in Fig. 1. Thickness of $LiNiO_3$ substrate is 0.5 mm. As the operation principle of the sensor is based on Mach- Zehnder interferometer [1], an instantaneous electric field applied to the sensor is measured. Therefore we can measure the amplitude and phase of the electric field at a frequency by using a conventional coherent detection such as a vector network analyzer.

Measurement setup is shown in Fig. 2. Since the photonic sensor, the laser, the detector, and the optical fiber are replaced with the OEW probe, the measurement procedure is the same as using the OEW probe. The measured quantity is S21 from the AUT to the photonic sensor including the measurement system characteristics such as the coaxial cable, the optical fiber, etc.

We use a planar near-field measurement system (Model 200V-3x3 manufactured by NSI) as measurement equipment. The scanning area is the square of 40 cm that is large enough to neglect the truncation error. The sampling interval is 4 mm. To improve the low

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sensitivity of the photonic sensor, a power amplifier of 30 dB gain is used between the vector network analyzer and the AUT as the transmitting antenna, and amplifiers of 55 dB gain are also used at the output of the photodetctor.

3. Measurement results

Figure 3 shows the structure of a microstrip antenna and its array structure used in the measurement. Each microstrip antenna is electromagnetically coupled through thin slotted apertures to the feeding microstrip lines at the opposite side of the microstrip antenna [2]. The amplitude excitations are equal along the x-axis and 1:1.6:1 along the y-axis. The E plane and the H plane of the array antenna are along the x-axis and the y-axis respectively.

The measured electric field on the plane near the aperture of the AUT is Fourier-transformed to the far-field pattern [3] because no probe compensation is needed. To verify the results, we also measured the antenna patterns using the conventional OEW probe and the far-field method. In comparison, the OEW results are used as the references.

Figure 4 shows the E-plane principal patterns obtained by the three methods. Each pattern is normalized by its peak value. Figure 5 shows the normalized H-plane principal patterns. From the figures, the results by the three methods agree within 1 dB in the main beam. The originally designed principal patterns of the E plane and H plane are shown in Fig. 6 and Fig. 7 respectively. They are slightly different from the measured patterns because the infinite substrate is assumed in the design whereas the measured one has the finite extent.

The cross-polarization patterns of the E plane and H plane are shown in Fig. 6 and Fig. 7 respectively. They are below –30 dB but do not agree with each other. This is because each alignment of the cross-polarization axis with the measured axis was incomplete and different with each other. However, those figures indicate that the antenna patterns from 0 dB to about –30 dB can be measured by using this photonic sensor system.

4. Conclusions

We have shown that the photonic sensor is ideal as a probe for the PNFM because it is small, light, and not disturbing the measured electronic field. Moreover, because it is considered as a linearly polarized electric infinitesimal antenna, it needs no probe compensation.

To demonstrate the characteristics, we have compared the antenna patterns using the photonic sensor with those using the conventional OEW probe and the far-field method. The principal polarization patterns using the three methods agreed within 1 dB on the main beam region. The corss-polarization patterns did not agree but were below –30 dB.

In the near future, we will improve the dynamic range and the sensitivity of this system. Then we will be able to measure the cross-polarization components correctly.

References

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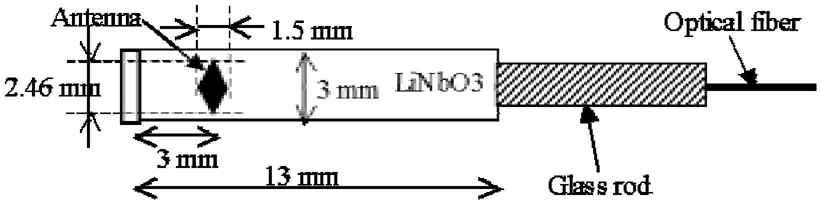

Figure 1. Structure of the photonic sensor used in the measurement

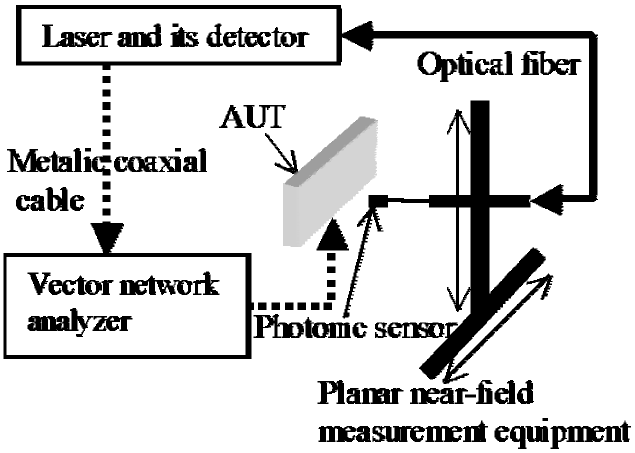

Figure 2. Measurement setup

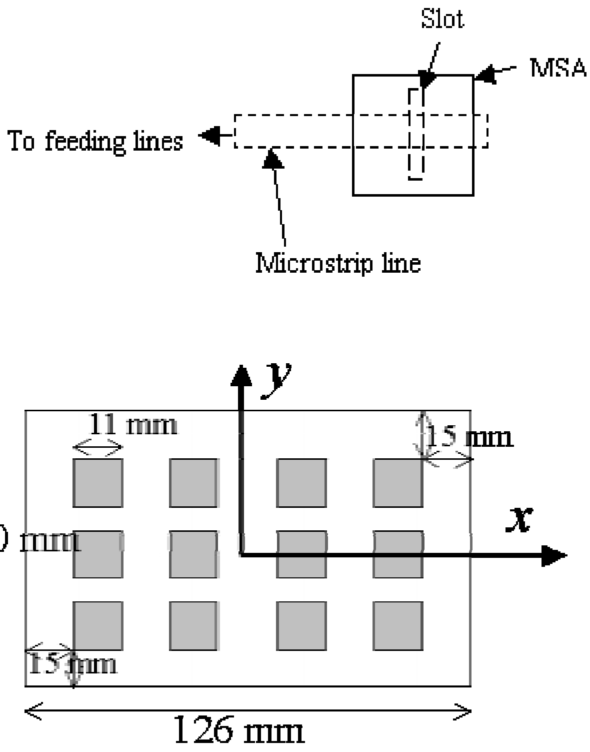

Figure 3. Structure of a slot-coupled microstrip antenna and its array

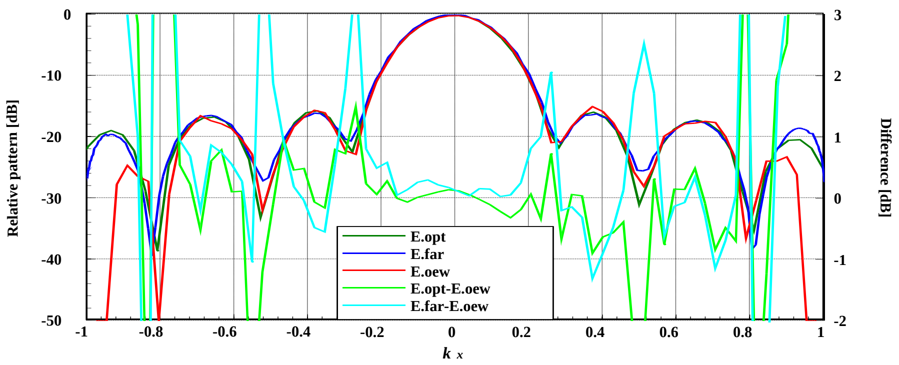

Figure 4. E-plane patterns of the principal polarization. E.opt, E.far, and E.oew correspond to the measured results using the photonic sensor, far-field method, and WR90 probe respectively. E.opt-E.oew and E.far-E.oew are the differences of E.opt and E.far relative to E.oew respectively.

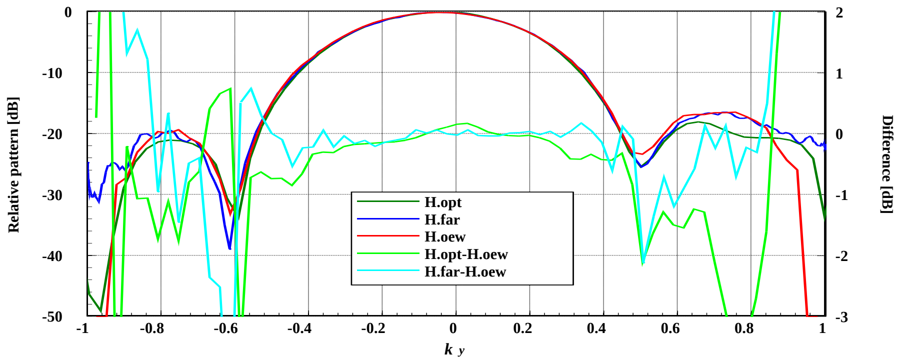

Figure 5. H-plane patterns of the principal polarization. All subscripts are the same as Fig. 4.

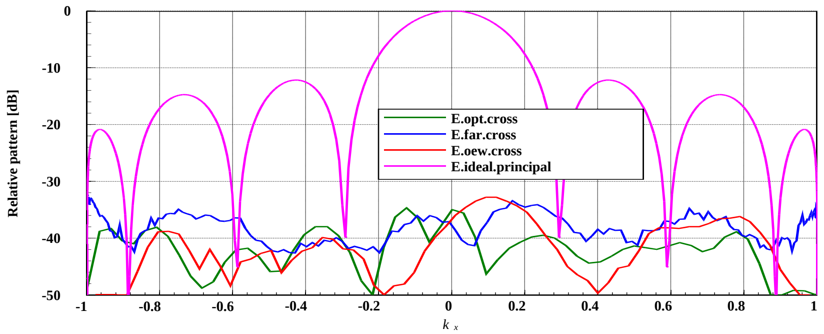

Figure 6. E-plane patterns of the cross-polarization. E.ideal.principal is the E-plane pattern of the principal polarization calculated by the designed condition.

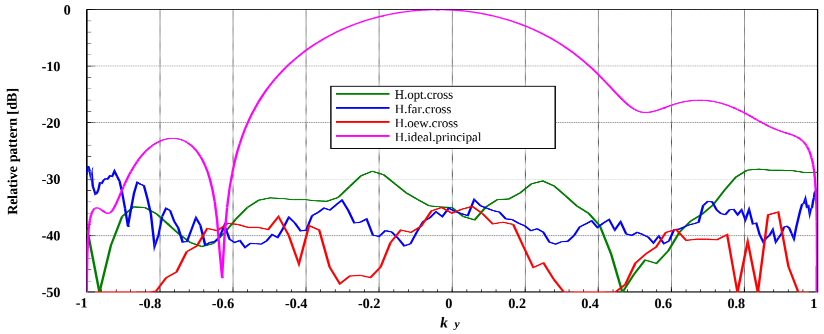

Figure 7. H-plane patterns of the cross-polarization and H.ideal.principal.