Development of a System for Measuring Power and Phase Distributions of Radio Waves

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***Abstract*—A system for measuring power and phase distributions of a radio wave incident on the surface of a thin metamaterial absorber is developed. By measuring the voltages on an array of lumped resistors interconnecting surface patches on a mushroom-type metasurface at its resonance frequency, incident power and phase distributions are obtained. The effectiveness of the technique is evaluated by measuring a radio wave transmitted from a dipole antenna, on the basis of the comparison between the simulation and the actual measurement.**

Keywords*—*metamaterial absorber; power distribution; phase distribution; measurement;

I. Introduction

In-situ measurement and visualization of spatial distributions of radio-frequency (RF) waves gives important information to identify RF noise sources in electronic devices, as well as to evaluate the performance of antennas installed on communication devices used in actual environment. So far we have developed an "RF power imaging system" to monitor 2-d power distributions of a radio wave at a few GHz incident on a thin metamaterial absorber [1-2]. The power distribution of the incident wave was measured as the power absorbed by an array of lumped resistors interconnecting the square patches on a mushroom-type metasurface, which were matched with the incident wave impedance at the resonance frequency. It was suggested that the phase distribution of the incident wave could also be obtained by measuring the voltages on the resistors, being proportional to the incident electric field components [3]. In this study, we develop a system to measure and visualize power and phase distributions of an RF wave incident on the surface of a metamaterial absorber.

II. RF Power and Phase Distribution Measurement System

Fig. 1 shows the configuration of an RF power and phase distribution measurement system developed in this study. The system is composed of a metamaterial absorber used as a sensor, a spectrum analyzer and a PC. We use a metamaterial absorber (304.5×304.5×1.6 mm) having 30×30 square metal patches on the surface of a grounded substrate (a mushroom-type metasurface), where geometrical and constitutional parameters were chosen to have a resonance frequency of 2.44 GHz (for detail, refer to [2]). A radio wave incident on the surface is absorbed by lumped resistors placed between the adjacent patches at the resonance frequency of the metasurface [1]. The resistors arranged in the horizontal (x) and vertical (y) directions absorb the incident waves with horizontal and vertical polarizations, respectively. Since the voltages induced on the resistors are proportional to the electric field components of the incident and absorbed wave, amplitude (power) and phase distributions are obtained by measuring the RF signals (voltages) on the individual resistors [3]. Here an 8×8 array of resistors were chosen as the "measurement points" on the surface for each of the two polarizations. At each measurement point the resistor was removed and the RF signal was directly fed to an RF switch network through a matching circuit and a balun. Controlled by a PC and an MCU, a total of 128 RF signals were sequentially selected and input at Ch.1 of a two-channel spectrum analyzer (Advantest U3851), while Ch.2 was fed with a reference RF signal obtained at a fixed point on the absorber surface. The spectrum analyzer measured simultaneously the RF power at Ch.1 and the phase difference between the RF signals at Ch.1 and Ch.2. The power and phase signals at all the measurement points were then transmitted to the PC and visualized as 2-d color maps of power and phase distributions on the PC display.

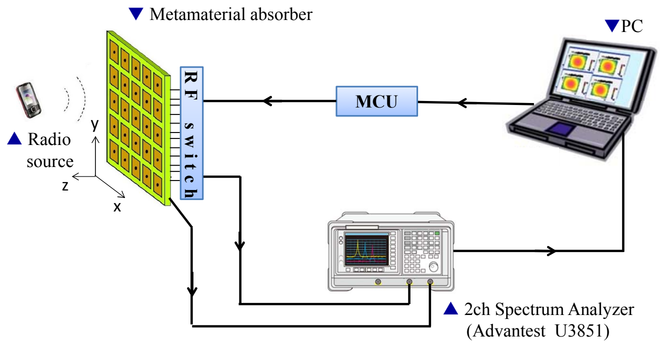

Fig 1. RF power and phase distribution measurement system.

III. Mesurement Results

The developed system was used to measure RF power and phase distributions radiated from a dipole antenna. Fig 2 illustrates an experimental setup. An RF wave of –5 dBm at

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2.44 GHz was transmitted from a standard dipole antenna with a horizontal polarization in an anechoic chamber, and absorbed by the metamaterial absorber placed on the *xy*-plane. The dipole was put at a distance *d* from the center of the absorber and at an angle θ from the *z*-axis on the *xz*-plane. Initially the received power and phase at each measurement point were calibrated by an almost far-field and plane wave pattern, created by the transmitting antenna placed at $d = 1$ m and $\theta = 0°$.

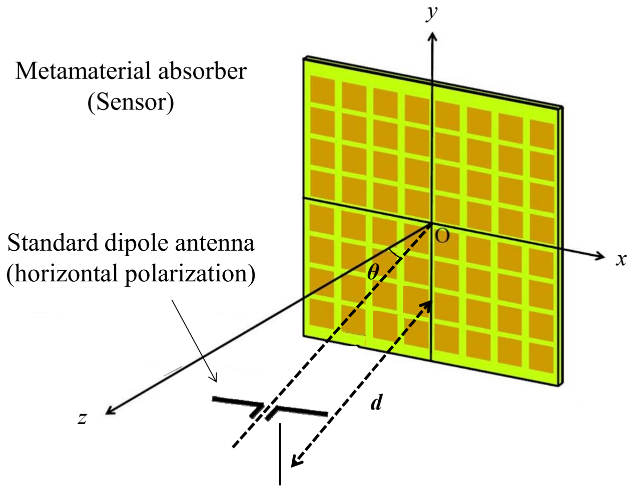

Fig 2. Setup for measuring an RF wave radiated from a horizontal dipole antenna.

In Fig. 3, we plot the power and phase distributions at antenna distances d = 0.1, 0.2, 0.3 and 0.6 meters at a fixed angle $\theta = 0°$. Fig. 3 (a) shows the absorbed power distribution of horizontal polarization measured on the absorber surface at d = 0.1 m, where the left and right panels are the profiles obtained by a simulation using CST MW-STUDIO and by the actual measurement. The two panels in Fig. 3 (b) plot the simulated and measured power profiles along the *x*- and *y*-directions indicated in Fig. 3 (a), respectively, where the lines and symbols are simulated and measured results and different colors correspond to different distances. Similarly, Figs. 3 (c) and (d) show the phase distributions obtained by simulation and measurement. Both the measured power and phase profiles practically agreed with the simulated profiles. As seen in Figs. 3 (b) and (d) the measurement errors in power and phase profiles were within ±1.0 dB and ±10°, respectively, around the center of the absorber. The error increased toward the edges of the absorber, up to +2.5 dB in power and –30° in phase, which were likely caused by the undesired reflection of incident waves from the edges [2].

Fig 4 shows the angular dependence of power and phase distributions at angles θ = 0, 30, 45 and 60° at a fixed antenna distance d = 0.2 m. Figs. 4 (a)-(d) compare the simulation with measurement in the same manner as in Fig. 3. The power and phase distributions shown in Figs. 4 (a) and (c) are for the case of θ = 30°. Again the measured profiles were practically in good agreement with simulated ones, with the power and phase errors within ±2.0 dB and ±10° but increasing to –3.0 dB and +20° around the edges possibly due to edge scattering.

IV. Conclusion

In this study, we have developed 2-d power and phase distribution measurement system of a radio wave incident on a thin metamaterial absorber. Measuring an RF wave transmitted from a dipole antenna, we were able to confirm the effectiveness of the system on the basis of the comparison between the simulation and the measurement. We are now extending the system to estimate the direction-of-arrivals and even the source locations of incident radio waves.

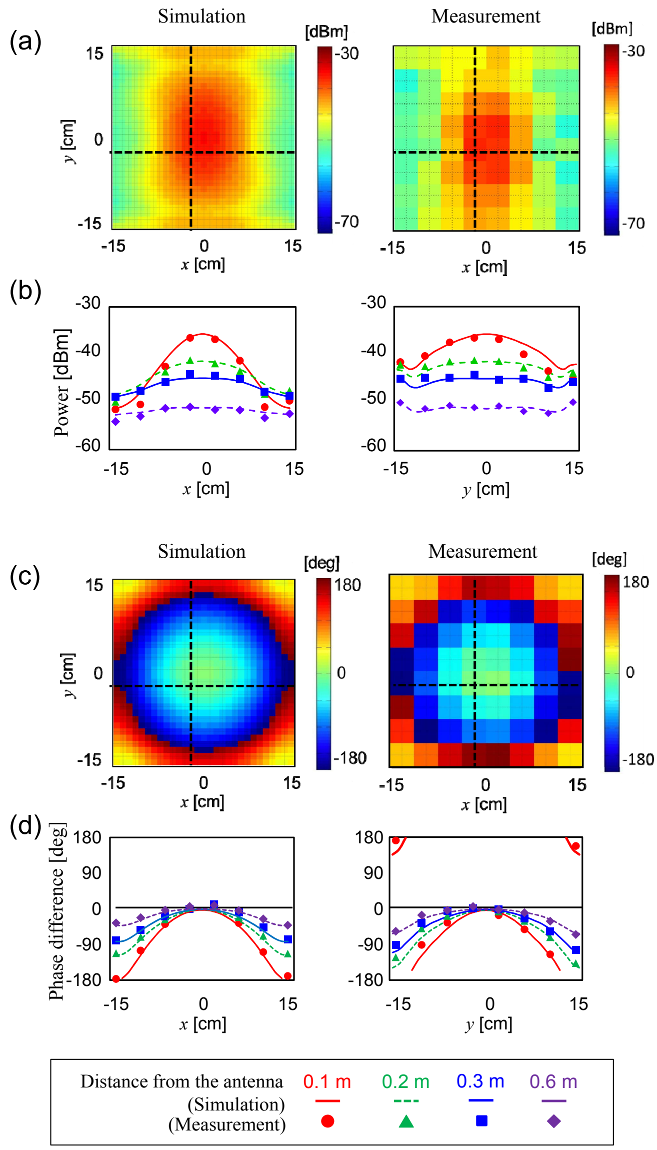

Fig 3. Distance dependence of RF power and phase distributions.

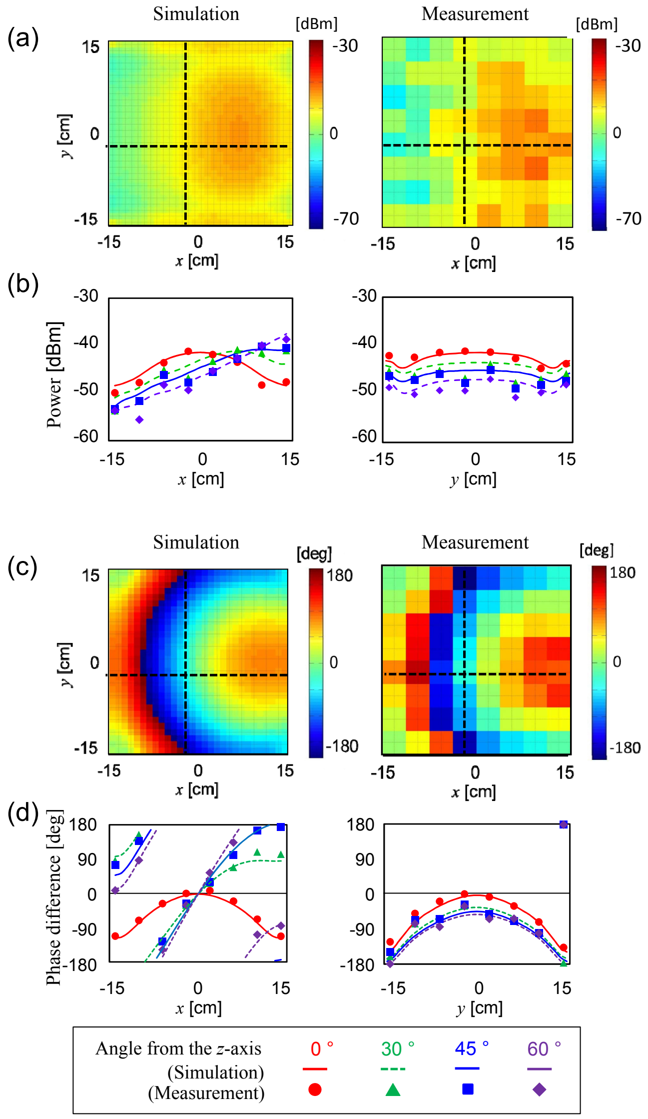

Fig 4. Angular dependence of RF power and phase distributions.

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References

[1] S. Yagitani, K. Katsuda, M. Nojima, Y. Yoshimura, and H. Sugiura, "Imaging radio-frequency power distributions by an EBG absorber," IEICE Trans. Commun., vol. E94-B, no. 8, pp. 2306-2315, August 2011.

[2] R. Hayashi, R. Kanaura, S. Yagitani, T. Imachi, M. Ozaki, Y. Yoshimura, and H. Sugiura, "Radio-frequency power distribution measurement system using thin metamaterial absorber," Proc. 2016 Int. Workshop on Antenna Technology, pp. 157-160, February-March 2016.

[3] S. Yagitani, T. Sunahara, T. Nakagawa, D. Hiraki, Y. Yoshimura, and H. Sugiura, "Radio-frequency field measurement using thin artificial magnetic conductor absorber," Proc. 2013 Int. Symp. on Electromagnetic Theory, pp. 691-694, May 2013.