C-7

Experimental Verification of the Beam Concentration Method Using Spherical Wave Synthesis

*Takashi Uno[1], Kuniaki Shibata[2], Kenji Saegusa[2], Tadashi Takano[2]

Abstract: Wireless power transmission at a relatively close distance have been studied. In this system, electromagnetic wave shaped beam are necessary, because more than 90% power should be received by a receiving antenna. In order to achieve this objective, we apply spherical wave synthesis using a phased array antenna. In this paper, we experimentally verify the design method for a wireless power transmission using beam concentration method.

1. Introduction

Wireless power transmission in a relatively close distance has been studied[1]. In this system, electromagnetic wave shaped beam are necessary, because more than 90% power should be received by a receiving antenna. In order to achieve this objective, we proposed a wireless power transmission using a beam concentration method. A phased array antenna is applied in this method. The beam was concentrated by controlling the excitation phases and amplitudes of element antennas.

In this paper, we investigated the beam concentration method experimentally. The experimental results of the beam concentration are compared with the analytical results.

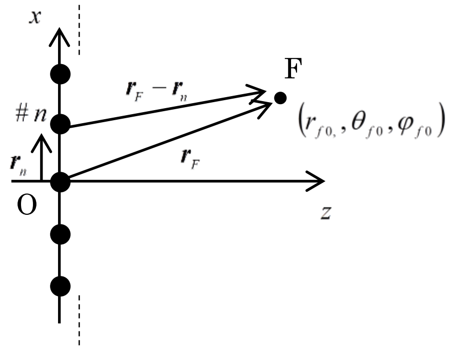


Fig.1 Calculation of phase

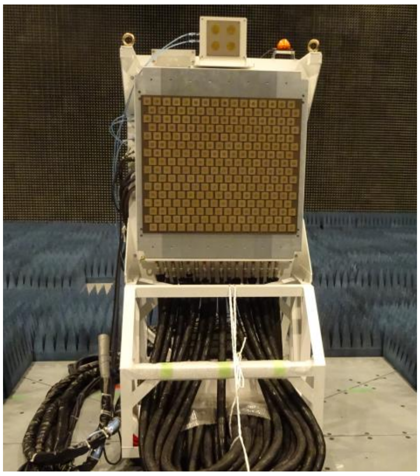


Fig.2 Outlook of the phased array antenna used in the experiment

2. Beam concentration method

We consider a phased array antenna which elements are arranged as in Fig.1. The $\boldsymbol{r}_f$ represents a vector drawn from the origin O to a focus F ($r_{f0}, \theta_{f0}, \varphi_{f0}$), $\boldsymbol{r}_n$ represents a vector drawn from O to the element labeled #n. The r_{f0}, θ_{f0} and φ_{f0} represent a distance between the origin to a focus, the zenith angle from z-axis, and the azimuth angle from x-axis, respectively. Considering that the vector drawn from the element #n to F is $\boldsymbol{r}_F - \boldsymbol{r}_n$, the excitation phase should be provided to the elements in correspondence to the distance $(|\boldsymbol{r}_F| - |\boldsymbol{r}_F - \boldsymbol{r}_n|)$ in order to concentrate the beam at F. Therefore, excitation phase Δ_n is represented as following equation,

$$\Delta_n = -k(|\boldsymbol{r}_F| - |\boldsymbol{r}_F - \boldsymbol{r}_n|) \tag{1}$$

where k is the wave number defined as $k = 2\pi/\lambda$.

3. Overview of experiment and analysis

In Research Institute for Sustainable Humanosphere of Kyoto University, the advanced phased array antenna for microwave power transmission was introduced in order to e wireless power transmission[2]. Elements are 256 in number, frequency is 5.8GHz, and polarization is right handed polarization. Each element is connected with a 5-bit digital phase shifter. The excitation phase can be controlled,

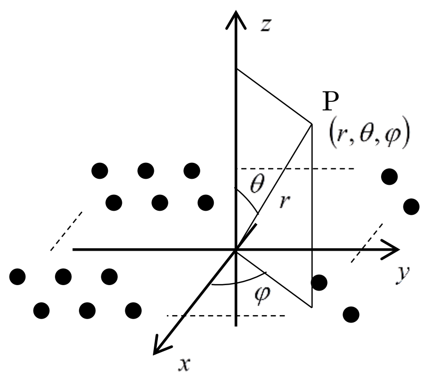


Fig.3 Model of experiment and analysis

1: Electronic Engineering, CST., Nihon-U, Master :　Electronic Engineering, CST., Nihon-U, Teacher

but is kept the same in the aperture. The outlook of the phased array antenna is shown in Fig.2.

Fig.3 shows coordinates used in the experiment and analysis. In the figure, the z-axis is perpendicular to the antenna surface, the radiation pattern is represented with two angles of θ and φ. The experimental pattern is fixed on $\varphi = 90\mathrm{deg.}$, because the experiments were conducted by using turn table. The excitation phase of each element was set as analog in analysis. On the other hand, it was set as 5 bit digital in the experiments considering phase shifters.

4. Experimental and analytical results

4.1 Beam patterns at various distance

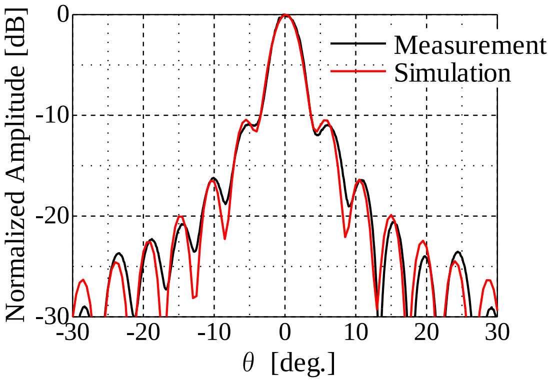
Fig.4 shows radiation patterns when the beam is designed to be concentrated at $r_{f0} = 6\mathrm{m}$. The black lines of Fig.4 (a), (b), and (c) show the pattern at the observance points, $r = 3\mathrm{m}$, $r = 5\mathrm{m}$ and $r = 6\mathrm{m}$, respectively. It is clear that the beam is narrowed at $r = 6\mathrm{m}$. From these results, a concentrating electromagnetic beam can be generated by a phased array antenna. Experimental results are compared with analytical results which is shown in red lines. The first side lobe in the experiment is larger by 1-2dB than that of analysis. This is partly because mutual coupling affect the side lobe level.

4.2 Tilting beam

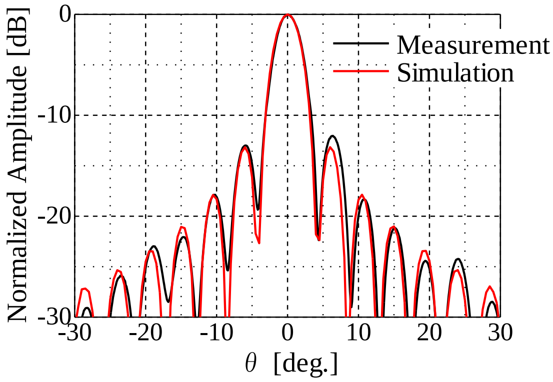
Fig.5 shows radiation pattern when a beam is concentrated $\theta_{f0} = 10\mathrm{degree}$ with the distance $r_{f0} = 6\mathrm{m}$. It is shown that the beam is tilted to 10.5degree and the radiation pattern within the first side lobe is agreeable with the analytical result. The difference between experiment and analysis is larger as θ is increase. The fact that the results of the experiment agree with analysis show the availability of the beam concentration method.

5. Conclusion

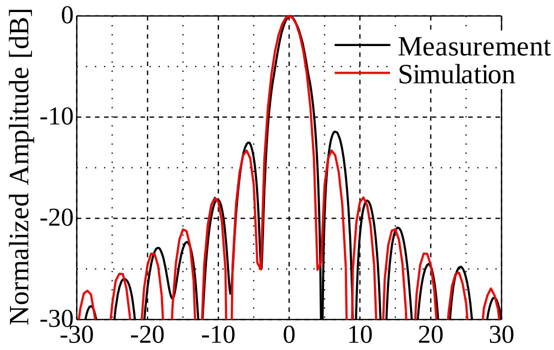
In order to generate an electromagnetic beam, we proposed beam concentration method, and considered efficiency of it from analysis and experiment. The results of experiment were theoretically agreed with analysis, we indicate that the beam can be concentrated by making the distribution of excitation phase in spherical form.



(a) $r = 3\mathrm{m}$



(b) $r = 5\mathrm{m}$



(c) $r = 6\mathrm{m}$

Fig.4 Radiation pattern($r_{f0} = 6\mathrm{m}$)

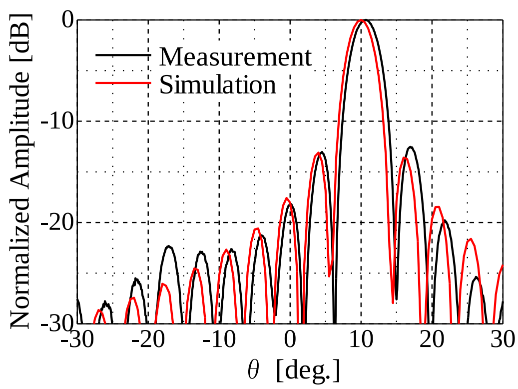


Fig.5 Radiation pattern($r_{f0} = 6\mathrm{m}, \theta_{f0} = 10\mathrm{deg.}$)

References

[1]Tadashi Takano, et al..: ‘Power Transfer System by a Beamed Radio for a Relatively Short Haul’, EMCJ WPT, IEICE-WPT2014-85

[2]Takaki Ishikawa, et al..: ’Study on Beam Forming with Phased Array System for Microwave Power Transmission’, IEICE Technical Report, WPT2012-40