# Experimental Study of a Partially Driven Array Antenna with a Reflector


[#]Tadashi Takano [1, 4], Takehiro Imura [2], and Midori Okumura [3]

[1] JAXA, The Institute of Space and Astronautical Science
3-1-1 Yoshino-dai, Sagamihara 229-8510Japan, ttakano@isas.jaxa.jp
[2] Electronics Engineering Department, University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656 Japan
[3] Electronics Engineering Department, Tokai University
1117 Kita-kaname, Hiratsuka 259-1592 Japan
[4] Department of Electronics and Computer Science, Nihon University
7-24-1 Narashino-dai, Funabashi, 274-8501 Japan


## 1. Introduction

Phased array antennas are quite attractive due to the agility of beam scan. Up to now, many attempts were studied to use this antenna in advanced radio communications [1], but almost all failed. The reasons may be disadvantages in cost, weight and size, and power consumption [2]. The phased array antenna is also available to construct quite a large aperture in addition to beam agility for microwave power transmission systems [3].

To solve the above-mentioned disadvantages, we proposed the concept of a partially driven-array antenna (PD-AA) [4]. Some elements in a fully driven array antenna are replaced with undriven elements or parasitic elements by means of the active utilization of electromagnetic coupling between array elements. The PD-AA scheme was verified using dipoles in space without a reflector which were coupled via a direct wave [5]. However, as an actual antenna should have a reflector to shield radiation in the back-side, a new type of PD technique is required.

This paper proposes and clarifies the coupling via a reflected wave in addition to a direct wave in order to realize a practical PD-AA with a reflector which may be called a PD-AAR.

## 2. Concept of PD-AAR

The configuration of two kinds of a PD-AA with two dipole elements is shown in the direction of the dipoles in Fig. 1. In the figure (a), the radiated wave from the driven element spreads, and a part of the wave reaches the parasitic element to excite a current on the surface. The induced current emits a re-radiated wave. If the distance between the elements is adjusted to make the radiated and re-radiated waves in phase, the combined wave is maximized. With proper design, the combined antenna gain can be almost the same as the array antenna with all elements driven. In this case, the amplitude and phase should be adjusted by a single parameter, the distance d.

In the figure (b), the coupling between two elements is accomplished through the reflected wave by a reflector as well as the direct wave. Therefore, the coupling is adjusted with two parameters: the d and the height h.

## 3. Characteristics of a Single Element Used for Test

The actual dipole element used in the experiment is a so-called ULPD (Ultra Low Profile Dipole) type with a simplified configuration shown in Fig. 2 where a coaxial mode of the current is converted to a dipole antenna mode by an elaborate transition at the end of a semi-rigid coaxial cable [6]. This type of a balun is effective regardless of the height h as is quite convenient in the present experiment [7]. As the frequency is 5.8 GHz, the length l is 24.0 mm, a bit shorter than a half wavelength of 25.9 mm. The height h corresponds to 0.63 $\lambda$ . The characteristic impedance of the cable is 50 Ω. The reflector is a square aluminium plate with size of 400 x 400 mm which can be considered as an infinite plate.

The radiation pattern was measured in an unechoic chamber in far field. The results are shown in solid lines in Fig. 3, with simulation results in broken lines which were calculated in a half wavelength dipole model regardless of the feeding structure. The lobe perpendicular to the reflector, or the main lobe is 6.7 dBi.

The lobes on both sides of the main lobe, or the side lobes in H-plane in Fig. 3(a) are at 65 deg, and higher than the main lobe. On the other hand, the side lobes in E-plane in Fig. 3(b) are asymmetrical on both sides of 0 deg due to the structure of the actual element shown in Fig. 2.

## 4. Characteristics of a PD-AAR with Three Elements

The configuration of three elements PD-AAR is shown in Fig. 4. The center driven element was realized using the aforementioned element. The adjacent two dipoles or parasitic elements were mere metallic rods with 2 mm diameter supported by a foamed material. The spacing between the center and each parasitic element is denoted d.

The radiation pattern was measured changing the element spacing d. The H-plane patterns are shown in solid lines in Fig. 5. The side lobes in d = 0.6 $\lambda$ are located at the same angle as the side lobes of a single element shown in Fig. 3(a), but have lower side lobes than those of the single element. The simulated results are added in the correspondent figures, and agree well with the experimental results.

The change of the main lobe level is summarized in Fig. 7. The experimental value indicated by black squares has the maximum of 12.7 dBi at d = 0.6 $\lambda$ and 0.7 $\lambda$, though the simulated value indicated by white triangles is 13.2 dBi at d = 0.7 $\lambda$. The change of the side lobe level is summarized in Fig. 9. The side lobes have the minimum at d = 0.5 $\lambda$ and 0.6 $\lambda$. Those minimum side lobe levels are higher than the simulation results.

The E-plane patterns are shown in solid lines in Fig. 8, which are almost symmetrical. The side lobe levels are almost the same as those of a single element shown in Fig. 3(b). The change of the side lobe level is summarized in Fig. 9, as remains constant.

## 5. Conclusions

A partially driven array antenna of one driven element and two parasitic elements with a reflecting plate were studied experimentally. A strong coupling between the driven and parasitic elements was realized so that the antenna gain is close to an array antenna of three equally driven elements with a penalty of - 1dB. The side lobes is - 8dB to the main lobe, and much lower than that of a single element. The experimental results agree well with the simulation results. Accordingly, a PD-AAR is basically confirmed for practical utilizations.

## Acknowledgments

This research was carried out in the contract research program granted by the Ministry of Interior Affairs and Communications.

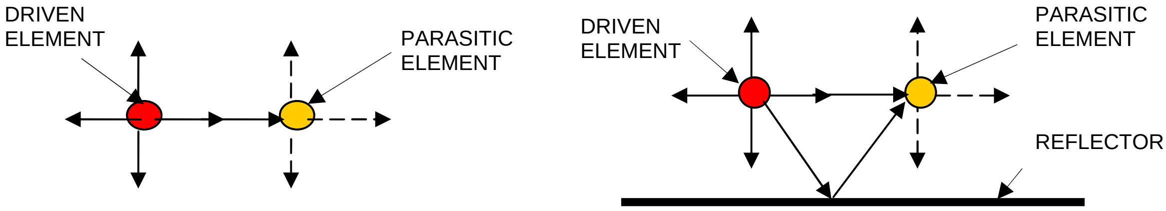
## References

[1] S. Liu, M. Lee, C. Jung, and F.D. Flaviis, "A frequency-reconfigurable CP patch antenna by integrating MEMS switches", IEEE, APS. Int. Symp., vol.2A, pp.413-416, July 2005.

[2] T. Takano, S. Kawasaki, H. Toshiyoshi, H. Ikeda and Y. Kazama, "The R&D of Active Phased Array Antennas with Significant Cost Reduction and Usage Convenience", ISAP07, 4B3-3, Niigata JAPAN, 2007.

[3] G.M.Hanley. "Satellite power systems (SPS) concept definition study I-Executive summary", NASA, CR-3317, (1980).

[4] T. Takano, N. Kamo and A. Sugawara, “Gain Enhancement of an Array Antenna Using Coupling Optimization between Elements ”, IEEE AP-S & URSI 2005, Washington DC, 2005.
[5] M. Okumura, T. Imura, N. Kamo, A. Sugawara and T. Takano, “Theoretical and Experimental Study on a Partially Driven Array Antenna with Simplified Dipole Elements”, IET Microwaves, Antennas & Propagation, Vol.2, No.7, pp696-703, March 2008.
[6] A. Thunvichit, T. Takano and Y. Kamata, “Characteristics Verification of a Half-wave Dipole Very Close to a Conducting Plane with Excellent Impedance Matching", IEEE Transactions on Antennas and Propagation, Vol.55, No.1, pp.53-58, 2007.
[7] A. Thunvichit, T. Takano and Y. Kamata, “Ultra Low Profile Dipole Antenna with a Simplified Feeding Structure and a Parasitic Element”, Trans. of Institute of Electronics, Information and Communication and Communication Engineers, vol.89-B, no.2, pp. 576-580, 2006.




(a) Coupling a by direct wave

(b) Coupling by reflected and direct waves

Fig.1 Types of coupling between a driven and parasitic elements.

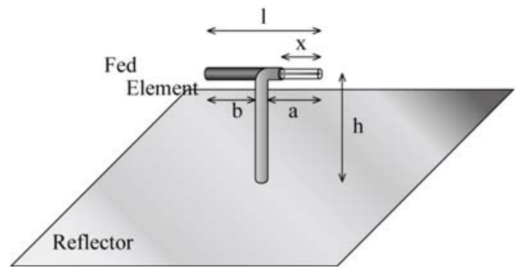
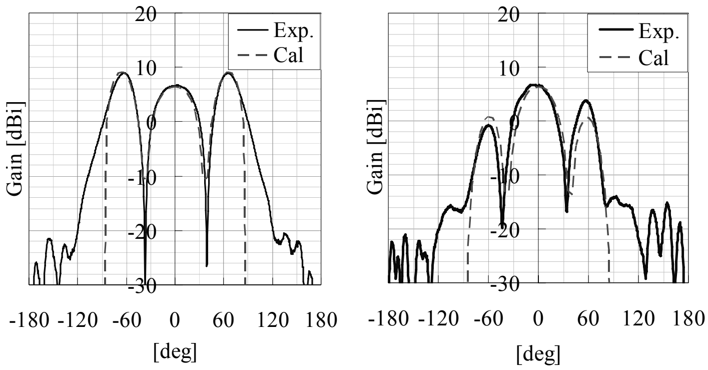



Fig.2 Configuration of an element antenna used for experiment.




(a) H-plane

(b) E-plane

Fig.3 Radiation pattern of the element antenna (h = 0.63λ).

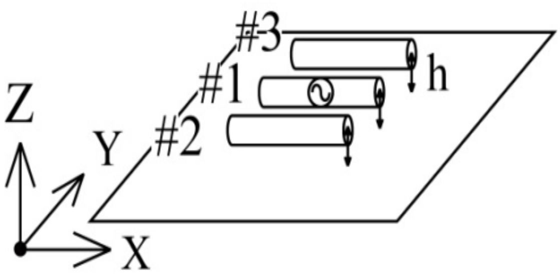
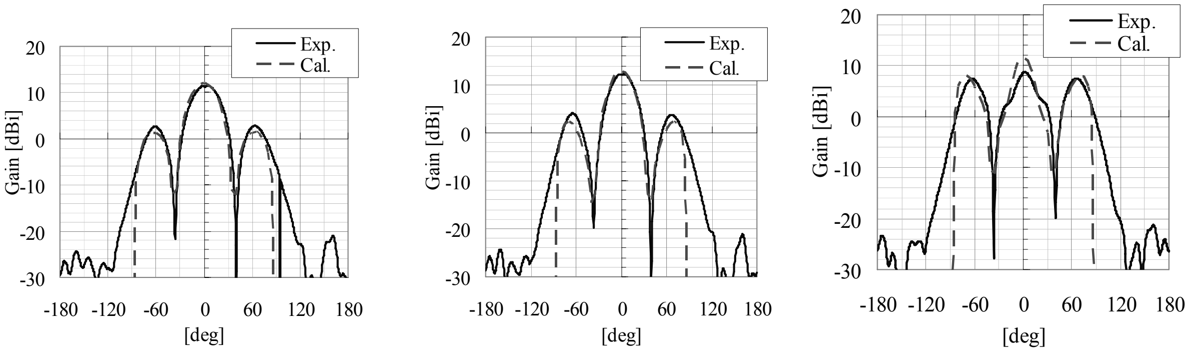



Fig.4 Configuration of three elements array antenna with two parasitic elements




(a) d=0.50λ　　(b) d=0.60λ　　(d) d=0.80λ

Fig.5 Radiation patterns in H-plane for several values of the distance d

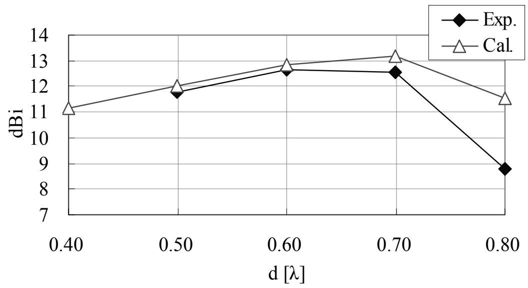



Fig.6 Gain change by distance d (h = 0.63λ)

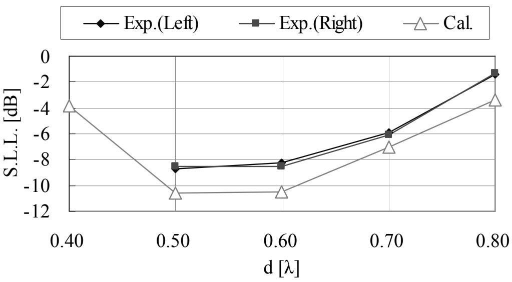
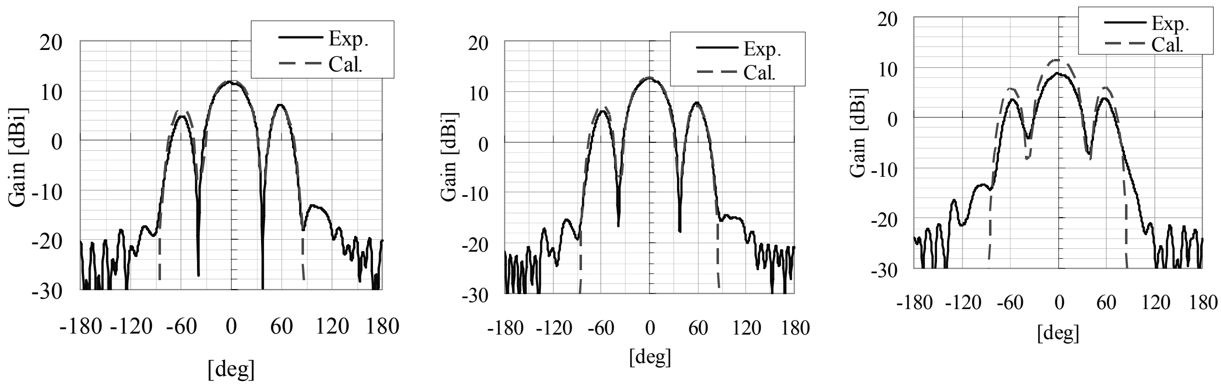



Fig.7 Change of side-lobe level in H-plane by distance d (h =0.63λ)




(a) d=0.50λ　　(b) d=0.60λ　　(d) d=0.80λ

Fig.8 Radiation patterns in E-plane for several values of the distance d

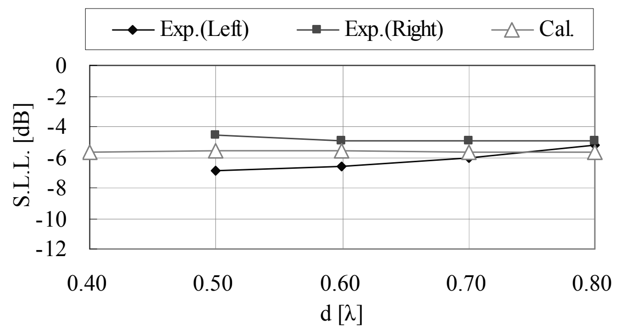



Fig.9 Change of side-lobe level in E-plane by distance d (h =0.63λ)