Proposal and Preliminary Study of a Partially Driven Array Antenna Using Transmission Line Coupling

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1. Introduction

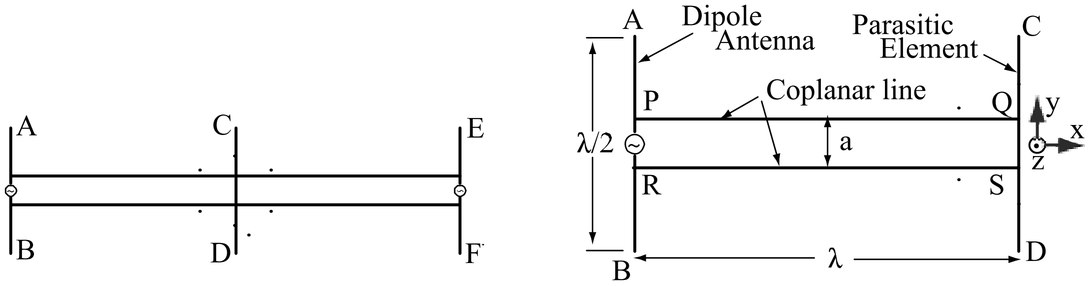
In the former partial drive technique, which contributes to the cost reduction of array antenna (AA), a part of the whole radiating elements were driven, and the rest were excited by spatial coupling[1][2]. This technique can realize the performance approximately equivalent to that of a fully driven AA. But the configuration is limited in design freedom due to spatial coupling. In that case, it is necessary to optimally determine the height and the spacing of elements. In this paper we propose a method to connect the driven and parasitic elements by using a transmission line in order to get sufficient coupling even in a printed antenna. Impedance matching can be achieved by adjusting the transmission line, as is effective to realize low profile antennas. This paper shows that a partially driven AA(PD-AA) using transmission line coupling can realize almost the same characteristics as a fully driven AA, and a meander transmission line can decrease the distance between antenna elements so that the grating lobe can be reduced.

2. Basic model of a PD-AA using transmission line coupling

Figure 1 shows the proposed basic configuration of a PD-AA with transmission coupling. The half wavelength dipoles AB and EF are driven, and CD is parasitic. Two pairs of co-planer transmission lines connect between CD and both of AB and EF, and are located in a symmetrical arrangement, and a reflective plate with infinite size is placed at a distance of $\lambda/4$ (λ: wavelength) parallel to the x-y plane.

Using the moment method, we analyzed the antenna system with a feeding voltage of 1[V]. In order to drive the whole element in phase, the transmission line connecting the point P and the point Q is required to have length of a wavelength. Changing the transmission line separation a, the currents on the driven and the parasitic elements change as shown in Fig. 2. The solid line shows the maximum current on the driven element (A-B in Fig.1), whereas the dashed line shows the maximum current on the parasitic element (C-D in Fig.1). The figure shows that the maximum currents on the driven and parasitic elements become almost equal at around a=0.2λ.

Then we simulated the characteristics of a PDAA with a=0.2λ. The magnetic field distribution in Fig.3 is generated by the electric currents on the driven and the parasitic elements, and suggests that large electric currents flow on both elements. Figure 4 shows that the effective gain is approximately similar to those of a fully driven AA, but the radiation pattern is much degraded due to the high grating lobes at $\theta = \pm 60^\circ$.



(a) Whole

(b) Left half

Fig.1 Basic configuration partially driven array antenna using transmission line coupling

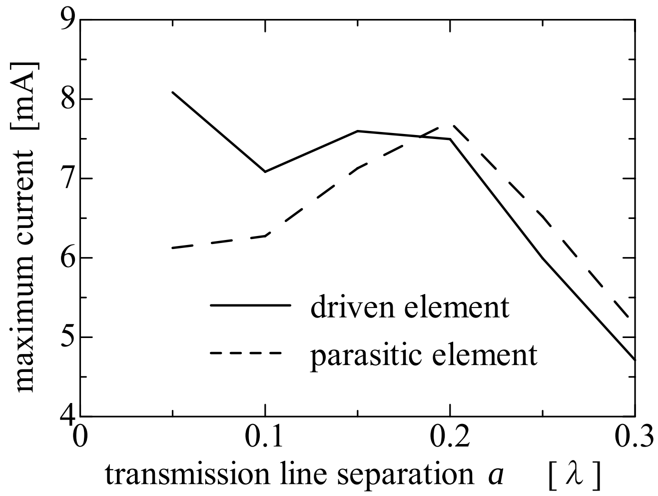


Fig.2 The transmission line separation a versus the currents on the elements

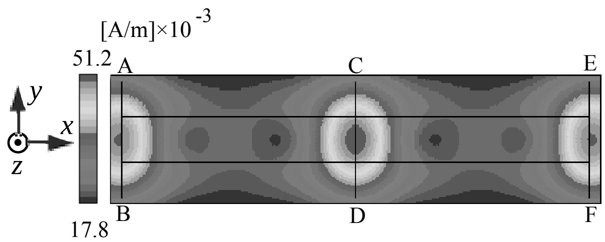


Fig.3 Magnetic field distribution in proximity of the reflecting plate

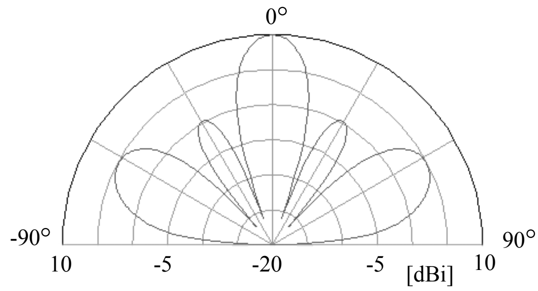


Fig.4 Radiation pattern in z-x plane

3. Improvement using meander line coupling

To suppress the grating lobes, the distance between the driven and parasitic elements should be smaller than λ/2. Figure 5 shows the proposed array antenna. The half wavelength dipole CD is connected with AB via a transmission line. The total length of the meandered line is a wavelength to keep the both elements in phase.

In the case of Fig.5, as two wires of a coplanar line curve in the same direction, we name this shape of the transmission line “odd mode”.

Figure 6 shows the current distribution on the PDAA using the odd mode line. The darker colour shows the stronger current. The currents on the both elements are strong.

Figure 7(a) shows the radiation pattern where the meandering shape is adjusted so that the length of the transmission line is close to a wavelength. The grating lobes are successfully suppressed. For the reference, the radiation pattern of a fully driven AA of Fig. 7(b) shows that this PD-AA has almost the same characteristics as the fully driven AA.

Figure 8 shows one configuration of PDAA using the even mode line. The transmission line in this case is meandered in line symmetric with respect to x-axis.

Figure 9 shows the radiation pattern of the PDAA using the mode line. The grating lobes are not successfully suppressed.

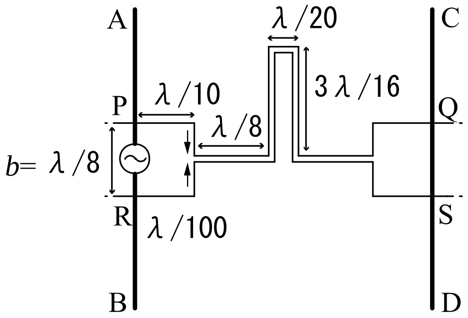
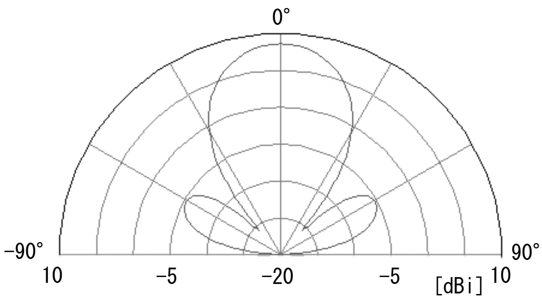
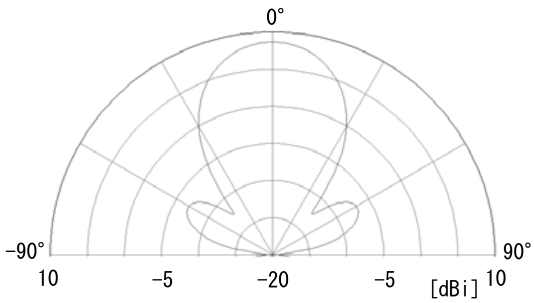


Fig.5 Configuration of a PD-AA using the odd mode meander line

Fig.6 Current distribution on the PDAA using the odd mode meander line



(a) The case of a PDAA using the odd mode meander line



(b) The case of a fully driven AA

Fig.7 The radiation patterns in z-x plane

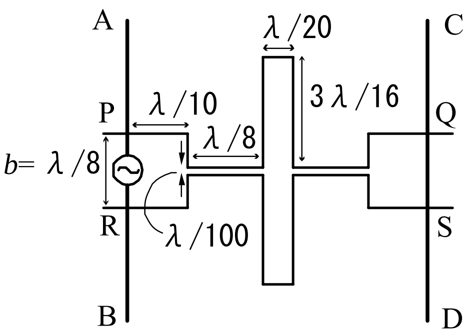


Fig.8 Configuration of a PD-AA using the even mode meander line

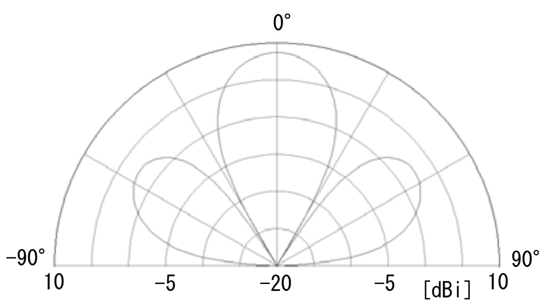


Fig.9 Radiation pattern using the even mode meander line

4. Impedance matching

It is inferred that the characteristic impedance of the meander line is determined by the diameter r_m and separation b of wires while the output impedance from the antenna element is determined by the connection positions of P, Q, R and S on the element. Also, the impedance of the antenna with the meander line of an infinite characteristic impedance should be the same as that of an isolated element or the original dipole antenna AB.

Therefore, we studied the impedance matching at the input port of the antenna in the configuration of Fig. 5 changing r_m and *b*. The simulated result is shown in Fig. 10. The return loss is below -12dB with $r_m = 0.01r_e$ and all values of *b* except 0.5λ.

Thus, it was confirmed that PD-AA gives almost equivalent impedance characteristics to a fully driven AA, and is effective in use.

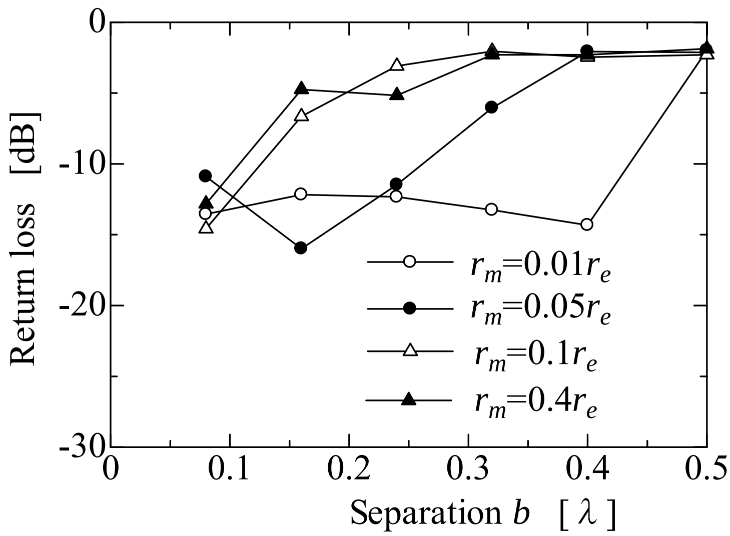


Fig.10 The transmission line separation b versus the return loss of the case of a PDAA using the odd mode meander line

5. Conclusion

We proposed a partially driven array antenna using transmission line coupling with meandered lines and analyzed using the moment method. By using a meander line, (1) we can shorten the distance between the driven and parasitic elements to suppress the grating lobes. (2) Odd mode meander line should be used for better characteristics than even mode meander line. (3) The radiation pattern and gain of PD-AA by an odd mode line are equivalent to those of a fully driven AA.

References

[1] M. Okumura, T. Imura, Y. Kamata, N. Kamo, A. Sugawara and T. Takano, "Theoretical and experimental study on a partially driven array antenna with simplified dipole elements," IET Microw. AP., Vol.2, No.7, pp.696-703, 2008.

[2] T. Imura, M. Okumura and T. Takano, "A Consideration of Arrangement of a Partially Driven Dipole Array Antenna," (in Japanese), Proc. IEICE General Conference, B-1-185, Nagoya, March 2007.