Reconfigurable Antenna by Transforming Reactively Loaded Elements to Be Electrically Invisible

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1. Introduction

Reconfigurable antennas are suitable for cognitive radio systems, which are expected in communication systems in the near future [1]. Literally reconfiguring the shape of an antenna can change its characteristics, yet it is difficult to reconfigure the physical shape electronically and at high speed. Transforming certain parts of the antenna to be electrically invisible can have the same effect as changing the shape. Here, an electrically invisible state means the radio wave is barely scattered or absorbed.

A dipole of a half-wavelength barely scatters radio wave if it is loaded with the reactance of an appropriate, positive value at the center. Scattering is diminished because the current that flows around the center becomes opposite to those on both sides and the integral of the current along the dipole becomes 0. The appropriate reactance value is almost decided by the shape of the dipole (length and width), and is about 500 Ω for a dipole of a half-wavelength [2]. That is, the electrically invisible state can be kept independently on the other antennas.

Some of the dipoles can be transformed to be electrically invisible to equivalently reconfigure their arrangement. Antenna examples with reconfigurable directivity, polarization or impedance-matched frequency are proposed.

2. Reconfigurable Directivity

Nine Yagi-Uda antennas pointed in different directions are involved with sharing the feed dipole, as shown in Fig. 1(a) [3]. Each parasitic dipole of the six-element Yagi-Uda antennas is loaded with a circuit switch for switching between a reactance port, to which a reactance appropriate for electrical invisibility is loading, and a short-circuit port as shown Fig. 1(b). No switch needs to be equipped in the RF feed circuit. The antenna characteristic was calculated by using NEC-Pro Moment Method software at a frequency of 600 MHz.

Figure 2(a) shows the radiation pattern of absolute gain when the parasitic dipoles of the Yagi-Uda *0 antenna are switched to the short-circuit ports, and the other parasitic dipoles are switched to the reactance loading ports. The radiation pattern when the reactance loading ports are exchanged to the open-circuit ports is also shown for comparison. The absolute gain is shown to be almost the same in value to that of the dipole alone; i.e., >12 dBi is achieved by switching to the reactance loading ports. Moreover, the radiation pattern of absolute gain is nearer to the pattern of the Yagi-Uda antenna alone than the pattern when the reactance loading ports are exchanged to the open-circuit ports. This confirms that the disturbance due to the mutual coupling of the other Yagi-Uda antennas is more greatly suppressed by switching to the reactance ports than open-circuit ports.

Figure 2(b) shows the radiation pattern of absolute gain when the parasitic dipoles of the Yagi-Uda antenna *0, *1, *2, *3 or *4 are switched to the short-circuit ports in turn, and the other dipoles are switched to the reactance loading ports. It is shown that the beam direction can be switched while nearly maintaining the beam gain. The input impedance is also kept to almost 10+j3 Ω. Thus, the advantage of this switching-beam array antenna is that the desired performance of a sectored beam can nearly be realized by appropriately designing the Yagi-Uda antenna unit.

3. Reconfigurable Polarization

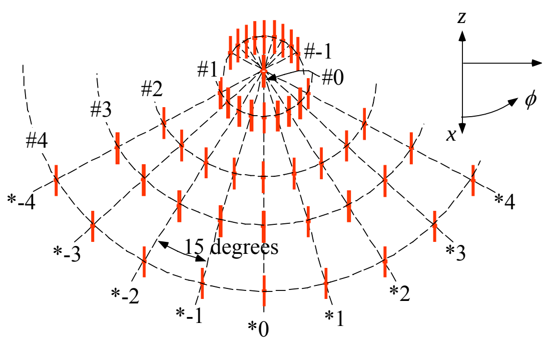
An array antenna of three dipoles, as in Fig. 3, was investigated [2]. The fed dipole is located in the vertical. The parasitic dipole near the fed one is located in the 45-degree slant angle, and loaded with a circuit switch for switching between a short-circuit port and reactance loading port. The other parasitic dipole is located in the horizontal. Figure 4 shows the current distribution on each dipole calculated by using NEC-Pro Moment Method software. The slant dipole is shown to be excited when the dipole is switched to the short-circuit port because it has a parallel component to the fed one. The horizontal dipole is also excited because it has a parallel component to the slant one. Thus, the polarization of the radiated wave has a horizontal component. On the other hand, when the switch is switched to reactance of an appropriate value of 480 Ω to be electrically invisible, the current direction on the slant dipole is reversed and the current amount diminishes, as shown in Fig. 4(b-2). As a result, the horizontal dipole orthogonal to the fed one is not excited, and the polarization remains vertical.

4. Reconfigurable Frequency

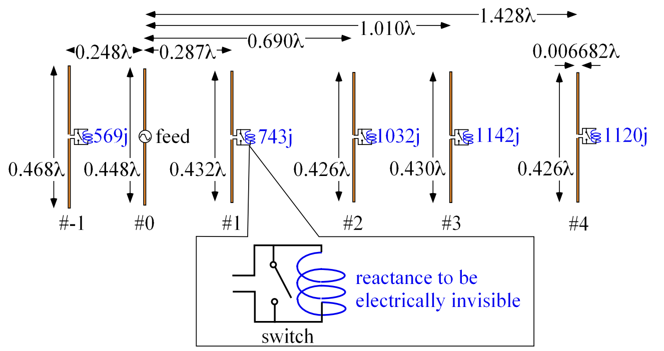
If antennas of several elements that resonate at different frequencies are arranged and some can be transformed to be electrically invisible, the impedance-matched frequency of the element antennas can be stopped at frequencies corresponding to the transformed antennas. Here, 25 wires were closely arranged, as shown in Fig. 5 [4]. The wires have different length and resonate at the frequency with a wavelength about a forth of the length. An electromagnetic coupling feed is employed to feed all wire elements by a single feed port. 25 wires and the feed probe form the structure like an inverted-F antenna. Each wire is loaded with variable reactance at the joining point to the ground plane. The electrical influence of the wires can be suppressed when the loading inductance is about 125 nH (see Fig. 6(b-2)). Thus, the reactance loading to the wires corresponding to the frequency at which the impedance matching is wanted to be band-stop are set to 125 nH and the others are set to 0 nH, i.e. short-circuited. Figure 6 shows the return loss calculated by IE3D Moment Method software. Fig. 6(a) shows that the impedance-matched frequency and band-stop frequency are nearly independently tunable by choosing the elements to set to 125 nH, whereas the levels of the two are insufficient.

5. Conclusion

By using the property of the radio wave scattering of a short wire being minimized when it is loaded with a reactance of an appropriate, positive value, the directivity, polarization or frequency is shown to be reconfigurable.

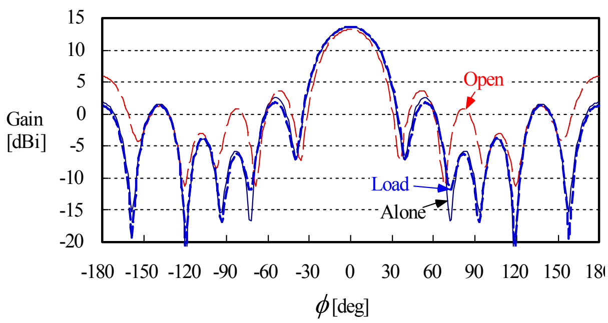


(a) Arrangement of nine Yagi-Uda antennas sharing the feed dipole.

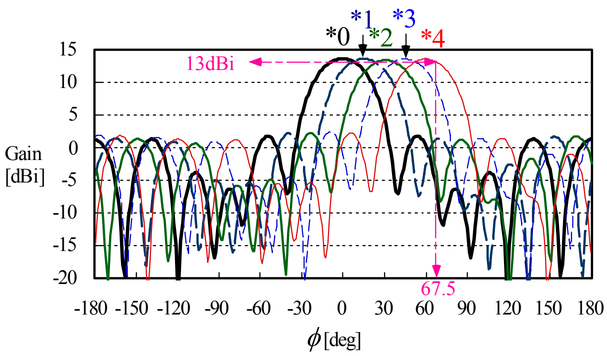


(b) Design of the Yagi-Uda antenna unit loaded with circuit switches for switching between the reactance loading ports and short-circuit ports.

Figure 1: Structure of a switched beam antenna composed of Yagi-Uda antennas.



(a) Radiation pattern of absolute gain when the dipoles of the *0 Yagi-Uda antenna switched to short-circuit ports and the others switched to the reactance-loading or open-circuit ports, and that of the Yagi-Uda antenna alone.



(b) Radiation pattern of absolute gain when the dipoles of *0, *1, *2, *3 or *4 are switched to short-circuit ports in turn and the others are switched to the reactance of appropriate values to be electrically invisible.

Figure 2: Absolute gain pattern in the H-plane of the switched beam Yagi-Uda antenna.

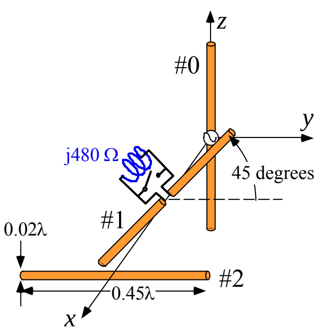
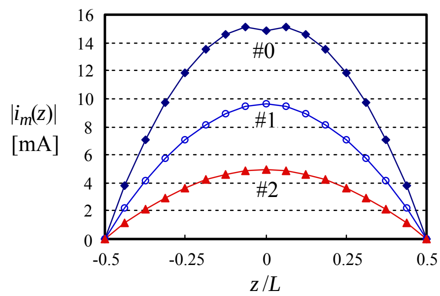
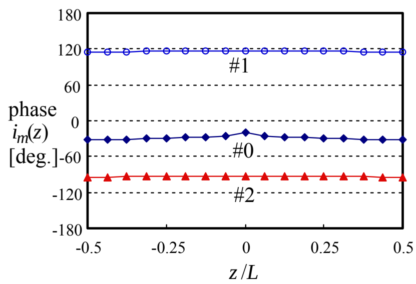


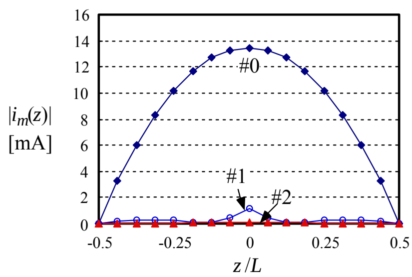
Figure3: Polarization-reconfigurable three-dipole-array.



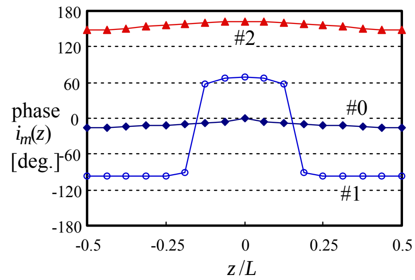
(a-1) Amplitude distribution when switched to short-circuit port.



(a-2) Phase distribution when switched to short-circuit port.



(b-1) Amplitude distribution when switched to the reactance loading port.



(b-2) Phase distribution when switched to the reactance loading port.

Figure 4: Current distribution along each dipole.

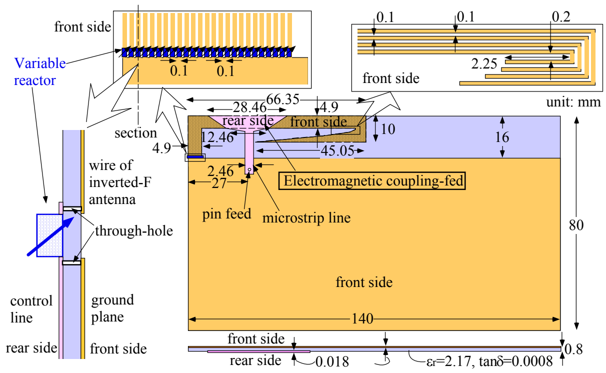
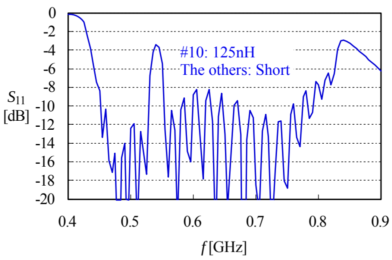
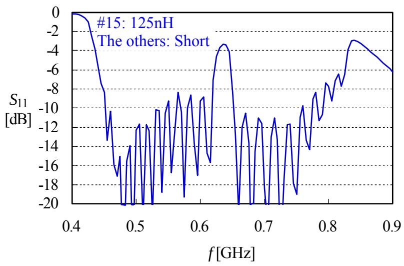


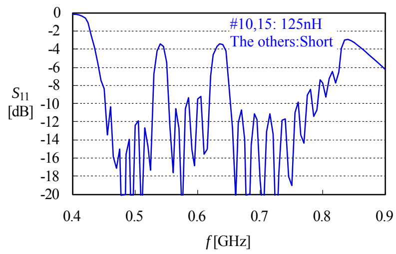
Figure 5: Structure of a tunable planar inverted-F antenna.



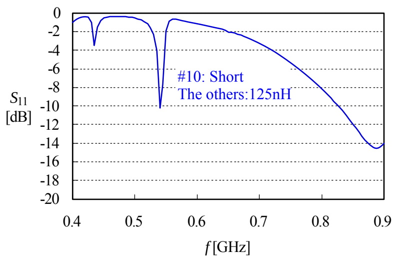
(a-1) #10 is loaded with 125 nH and the others are short-circuited.



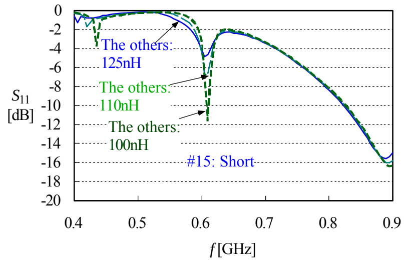
(a-2) #15 is loaded with 125 nH and the others are short-circuited.



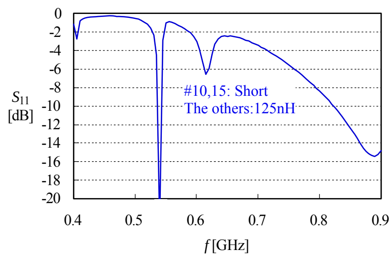
(a-3) #10 and #15 are loaded with 125 nH and the others are short-circuited.



(b-1) #10 is short circuited and the others are loaded with 125 nH.



(b-2) #15 is short circuited and the others are loaded with 100 nH, 110 nH or 125 nH.



(b-3) #10 and #15 are short circuited and the others are loaded with 125 nH.

Figure 6: Return loss of the tunable planar inverted-F antenna.

References

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Acknowledgements

This research was conducted under a research and development contract for radio resource enhancement, organized by the Ministry of Internal Affairs and Communications, Japan.