Propeller-Shaped Ultra-Wideband Planar Adaptive Antenna

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1. Introduction

We investigate adaptive antennas for ultra wideband (UWB) systems [1] working at around 3-10GHz to enhance the efficiency of frequency use and avoid serious fading caused by complicated interference in indoor environment. Because the fading happens at points where the electromagnetic-wave cancels out almost completely, the problem is often solved by changing the radiation direction roughly with a modest directivity with, e.g., a forward-back (F/B) ratio of several dB [2].

Phased array, which is a typical method for variable directivity, cannot be applied to UWB communications having widely distributed wavelength. Switching several antenna elements to various directions neither can work well since the direct coupling between the elements gets stronger when the entire antenna system needs to be miniaturized. Previously we realized a UWB adaptive antenna based on switching and stagger tuning [3]. However it was not a planar antenna. Planar antennas also lead to wearable antenna systems in combination with flexible substrate. Then we proposed an antenna (radially arrayed ginkgo antenna, RAGA) in which four tapered slot antenna (TSA) elements are set radially to weaken the direct coupling. Diode switching enables variable directivity [5]. However, reflection of the antenna $S_{11}$ is not small enough, and its side lobes are intricate and complicated.

To solve these problems in this paper, we propose a novel antenna having slot fins with curved outline and wide roots. We realize better impedance matching and lower $S_{11}$ as well as smooth side lobes.

2. Structure of the propeller-shaped antenna

Fig.1 shows the antenna (RAGA) we proposed before. Four wideband TSAs are radially arranged in such a manner that the coupling between the elements becomes weak. Each fin is connected to a power feeding part through a diode. The RF (radio frequency) power is fed to one set of fins on the top and bottom sides of the substrate. Then the antenna has variable directivity.

Fig.2 shows the structure of the new antenna we propose here. There are two main developed points to lower $S_{11}$. The first point is to employ curved fin shape. The second point is to make root part of the fin wide, as shown in Fig.3. An appropriate thickness of the root improves impedance matching. We incline each entire root at a 5.5 degree angle since our previous experiments revealed 11 degree inclination shows the best performance. We also keep sufficient effective length of the tapered-slot fin because short effective length and narrow aperture can cause lower directivity. By these artifices, the number of side lobes in the radiation pattern also decreases. We call this antenna “propeller-shaped antenna (PSA)”.

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3. Simulation results

We conducted the numerical analysis with simulation software HFSS ver.11 (Ansoft Co.). Figs. 4-6 show the results.

In Fig. 4, curves with and without crosses show the reflections $S_{11}$ of proposed PSA and conventional RAGA, respectively. In the RAGA result, $S_{11}$ is less than $-10$dB only for 7.0% of 3-10GHz frequency range. Contrarily, in the case of the PSA, it is for 69%. We realized that the reflection decreased in most frequency range compared to the RAGA. Although we still need to
improve $S_{11}$, most $S_{11}$ is near -10dB even in the range where $S_{11}$ is over -10dB. Fig.5 indicates normalized impedance characteristics of the PSA and the RAGA. Solid and dashed curves show resistance and reactance for the PSA (with crosses) and the RAGA (without crosses), respectively. In 3–10GHz, the resistance and the reactance of the RAGA varies greatly, in particular at 4–6GHz. In contrast, the variations of the PSA are comparatively modest. Then we find that we have realized better impedance matching in the PSA.

Fig.6 shows the radiation patterns of the PSA (with crosses) and the RAGA (without crosses) in the E-plane at (a)4GHz, (b)7GHz and (c)10GHz. Both antennas radiate their power in the direction of $\phi =0$, where the corresponding two diodes are on. The F/B ratios of the PSA at 4GHz, 7GHz and 10GHz are 3.9dB, 4.6dB and 3.0dB, respectively, though those of the RAGA are 8.1dB, 5.8dB and 3.2dB, respectively. We have room for improvement on the directivity. However the outlines of the radiation patterns of the PSA are improved. The radiation patterns of the RAGA have many peaks and the outlines of the side lobes are complicated. Meanwhile, those of the PSA have only a few peaks with smooth outlines. This result means that the reduction of the reflection in the PSA resulted in the decrease of direct coupling and the disappearance of the intricate side lobes caused by the interference-based spatially alternating phase in the RAGA. The simplicity of the side-lobe outlines is effective for reduction of fading in indoor multipath environment. In addition, the radiation patterns of the PSA are symmetry. Thus an evincive balun might be unnecessary in this system, and it leads to simplified circuit.
4. Conclusion
Developed shape of the fins enabled lower reflection at wide frequency band and better impedance matching. In addition, the number of intricate side lobes decreased and the outlines of the radiation patterns became simple.

References