Hyper-Wideband Four-arm Antenna

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Abstract **–An antenna, composed of low-profile four arms, is investigated. The analysis shows that bending the arms makes the VSWR value small at low frequencies. It also shows that the meandering cells introduced to each arm contribute to a decrease in the lower band-edge frequency. Thus, the investigated antenna operates across a frequency region of 2.88 GHz to 50 GHz for a VSWR = 2 criterion. The radiation pattern and gain are also investigated.**

Keywords —Low-profile, four arms, hyper- wideband antenna, base station

I. INTRODUCTION

Generally, a base station antenna is required to have an omnidirectional radiation pattern. A monopole antenna meets this requirement and has been used as the representative base station antenna. The operating bandwidth of the monopole is approximately 10%.

With progress in recent communication systems, the base station antenna is required to operate across a wide frequency range. For this, a Patch-Slot-Pin antenna has been developed, whose operation bandwidth is approximately 40% [1]. Fan-shaped [2] and planar inverted cone antennas [3] have also been developed as a wideband antenna. Note that the Patch-Slot-Pin antenna has an antenna height of approximately 0.1 wavelength at the lower band-edge frequency, and the fan-shaped and planar inverted cone antennas have an antenna height of more than one-quarter wavelength.

It is desired that the base station antenna should have small antenna height in order to be less obtrusive in the installation environment. However, in general, as the antenna height becomes smaller, the operation bandwidth becomes narrower. To overcome this bandwidth issue, a cross plate antenna has been developed [4], whose antenna height is 0.07 wavelength. This antenna has an operating bandwidth of approximately 138% for a VSWR = 2 criterion. Note that the cross plate antenna is an extended version of the body of revolution (BOR) antenna with a shorted parasitic ring (SPR) [5].

In this paper a novel antenna composed of four low-profile arms is proposed and the antenna characteristics are revealed. The VSWR bandwidth is found to be extremely wide, which cannot be found in conventional base station antennas. The lower band-edge frequency is 2.88 GHz and the upper band-edge frequency is 50 GHz.

II. DISCUSSION

A. Basis for a four-arm antenna (FAA)

Fig. 1 shows the configuration of the conventional cross plate antenna (CPA) [4], which is used for the basis for a novel four-arm antenna (FAA) in the following section B. The CPA is composed of a crossed plate printed on a dielectric substrate (relative permittivity ε_r and thickness B) and a BOR (diameter D_{BOR} and height H), where the crossed plate (length 2L and width W) is shorted to the ground plane using conducting narrow strips (width w_{pin}). The BOR is separated from the shorted crossed plate with ring slot width Δs [= $(D_{in} - D_{BOR})/2$].

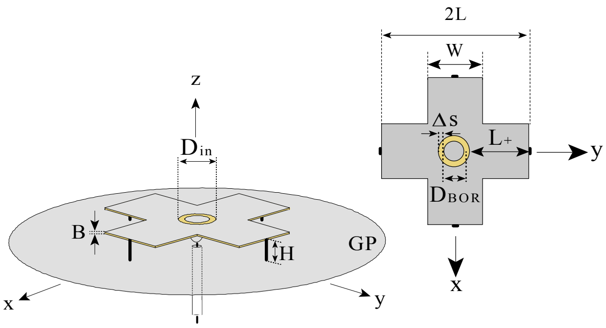

Fig. 1. Conventional cross plate antenna (CPA) [4].

Fig. 2 shows the VSWR frequency response for the CPA, where the parameters used are summarized in Table 1. The CPA has a bandwidth of 148 % for a VSWR = 2 criterion. Note that the antenna height at the lower band-edge frequency is very small: 0.075 wavelength.

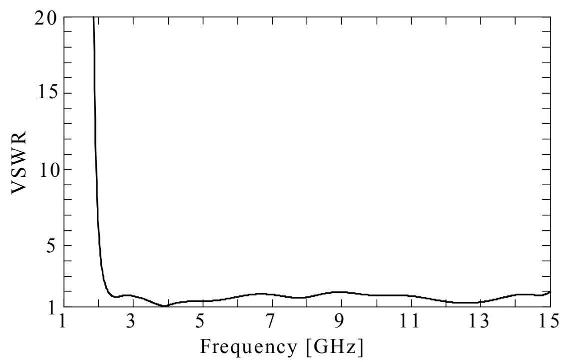

Fig. 2. VSWR for the CPA.

Table 1 Configuration parameters for CPA

Symbol	value	unit
2L	40	mm
W	15	mm
w_{pin}	1.67	mm
L_+	15	mm
ε_r	3.5	
B	0.83	mm
H	10	mm
D_{in}	10	mm
D_{BOR}	6.7	mm

B. Four-arm antenna (FAA)

Fig. 3 shows an extremity of the CPA, where the crossed plate (horizontal length 2L, width W, and height H) is replaced by four arms made of wire (horizontal length 2L, diameter 2a, and height H). Each strip pin of width w_{pin} for the CPA is also replaced by a wire of diameter 2a. Each wire is Δg away from the BOR and self-standing without a dielectric substrate. This antenna is called as the four-arm antenna in the first stage and abbreviated as FAA_0.

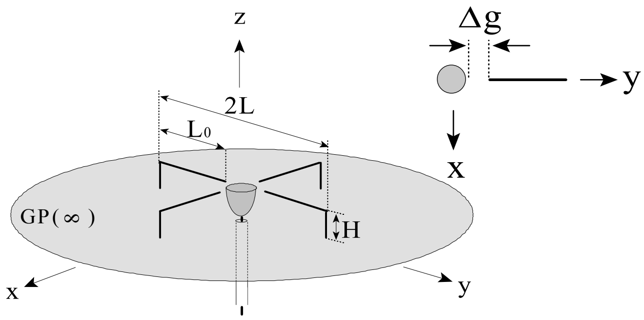

Fig. 3. Four-arm antenna in the first stage (FAA_0).

The VSWR frequency response for the FAA_0 is depicted in Fig. 4, where the following parameters are used: (2L, L_0, 2a, H, D_{BOR}, Δg) = (40 mm, 16 mm, 0.2mm, 10 mm, 6.7 mm, 0.65 mm). It is found that the FAA_0 has a small VSWR at frequencies above 4 GHz.

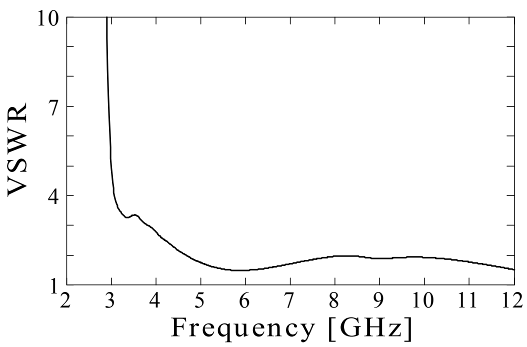

Fig. 4. Frequency response of the VSWR for the FAA_0.

Fig. 5 shows the radiation pattern in the $\theta - \phi\ (= 0^o)$ plane and in the $\theta\ (= 90^o) - \phi$ plane at 4.7 GHz (where VSWR = 2). It is found that the co-polarized component of the radiation is E_θ, exhibiting an omnidirectional characteristic around the antenna axis (z-axis).

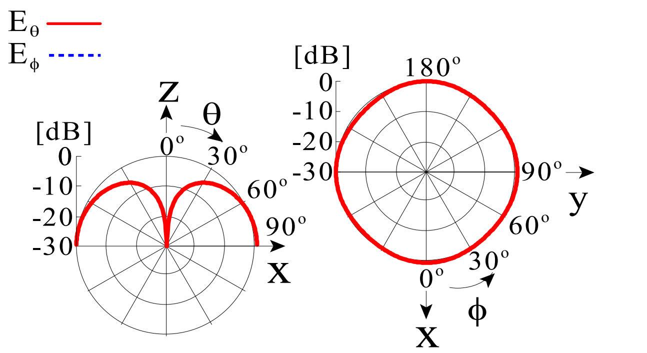

Fig. 5. Radiation pattern for the FAA_0 at 4.7 GHz. (a) In the $\theta - \phi\ (= 0^o)$ plane. (b) In the $\theta\ (= 90^o) - \phi$ plane.

In the second stage, the arm is bent, as shown in Fig. 6. The antenna is abbreviated as the FAA_{bent} to distinguish it from the FAA_0. Fig. 7 shows the VSWR for the FAA_{bent} with the bend position $L_{bent}/L_0 \equiv l_{bent}$ as a parameter. It is found that bending the arm contributes to making the VSWR small.

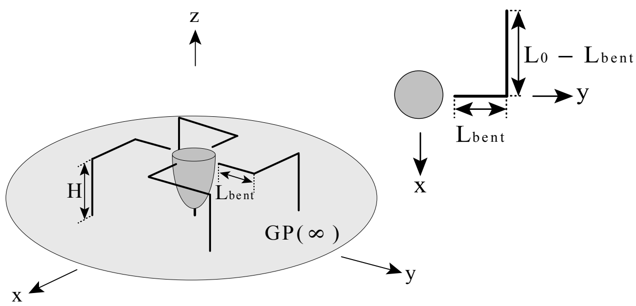

Fig. 6. FAA_{bent}, where the horizontal wires are bent.

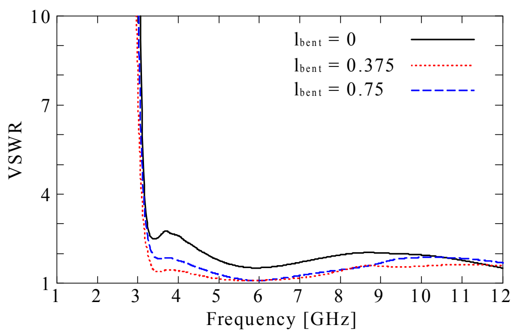

Fig. 7. Frequency response of the VSWR for the FAA_{bent} with the bend position $L_{bent}/L_0 \equiv l_{bent}$ as a parameter, where L_0 = 16 mm.

The final stage is devoted to decrease further the lower band-edge frequency $f_{L\text{-}VSWR}$. This is performed by introducing N meander-cells into each horizontal arm of the FAA_{bent}, as shown in Fig. 8, where l_{bent} is fixed at 0.375. The unit meandering cell has a total length of M+M/2+2M+M/2+M. This antenna is abbreviated as the $FAA_{meander}$.

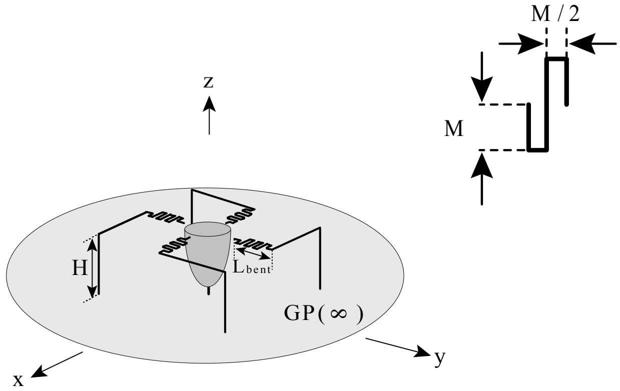

Fig. 8. $FAA_{meander}$, where meandering cells are introduced.

The increase in the number of meandering cells makes the antenna arm longer. As a result, the lower band-edge frequency $f_{L\text{-}VSWR}$ decreases. Fig. 9 shows the VSWR for N = 3 and M = 1mm. The lower band-edge frequency is decreased by approximately 300 MHz from that for FAA_{bent} (bent at l_{bent} = 0.375). The upper band-edge frequency $f_{U\text{-}VSWR}$ is 50 GHz. This VSWR bandwidth exceeds that for a UWB system.

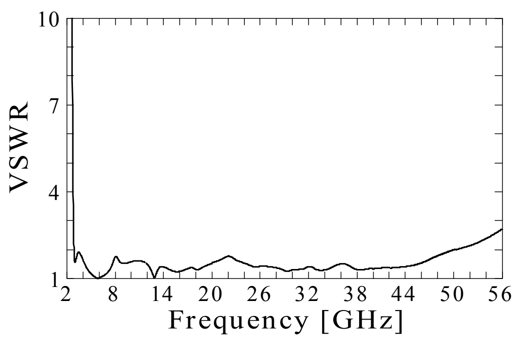

Fig. 9. Frequency response of the VSWR for the $FAA_{meander}$, where l_{bent} = 0.375, N = 3, and M = 1 mm.

The typical radiation pattern for the $FAA_{meander}$ (N = 3 and M = 1 mm) is shown in Fig. 10. Comparison of the radiation pattern for the $FAA_{meander}$ with that for the FAA_0 reveals that the meandering cells do not deteriorate the radiation pattern. The gain in the x-direction is approximately 4.3 dBi at $f_{L\text{-}VSWR}$ and 3.0 dBi at $f_{U\text{-}VSWR}$. During the presentation of this paper, the frequency response of the radiation pattern and efficiency, feed system, and applications will be discussed.

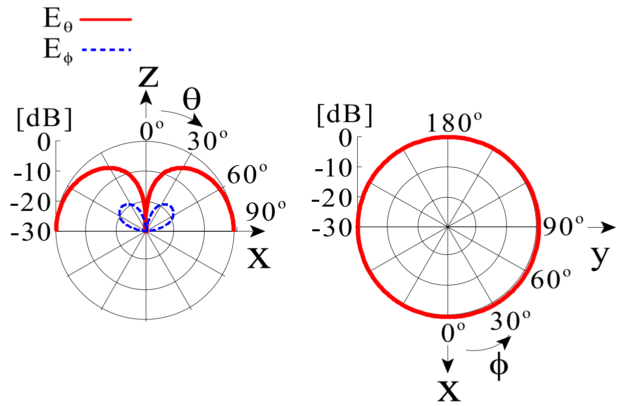

Fig. 10. Radiation pattern for the $FAA_{meander}$ at $f_{L\text{-}VSWR}$ = 2.88 GHz, where l_{bent} = 0.375, N = 3, and M = 1 mm. (a) In the x-z plane. (b) In the x-y plane.

III. CONCLUSION

An antenna composed of four arms shorted to the ground plane is analyzed, where the arms are separated from the feed BOR by a small gap. It is found that the lower band-edge frequency is decreased by the meandering cells introduced into each arm. Thus, the antenna covers a frequency range of 2.88 GHz to 50 GHz for a VSWR = 2 criterion. The vertical dimension of the antenna (antenna height) is small; 0.096 wavelength at the lower band-edge frequency. The horizontal dimension is also small; 0.192 wavelength. The other antenna characteristics (radiation pattern and gain) are also clarified.

References

[1] H. Nakano, H. Iwaoka, H. Mimaki, and J. Yamauchi, “A wideband PSP antenna radiating a linearly polarized conical beam,” 18th International Conference on Applied Electromagnetics and Communications, pp. 541-544, Dubrovnik, CROATIA, October, 2005.

[2] S. Suh, W. Stutzman, and W. Davis, “A new ultrawideband printed monopole antenna: the planar inverted cone antenna (PICA),” IEEE Trans. A P, vol. 52, no. 5, pp. 1361-1365, May 2004.

[3] H. Nakano, K. Morishita, Y. Iitsuka, H. Mimaki, T. Yoshida, and J. Yamauchi, “Fan-shaped antennas: realization of wideband characteristics and generation of stop bands,” Radio Sci., vol. 43, RS4S14, doi:10.1029/2007RS003784, 2008.

[4] H. Nakano, M. Takeuchi, and J. Yamauchi, “Cross plate antenna,” Asia-pacific conference on antennas and propagation (APCAP), pp. 1-4, Harbin, July 2014.

[5] H. Nakano, M. Takeuchi, K. Takeuchi, and J. Yamauchi, “Extremely low-profile BOR-SPR-SLOT antenna with stop bands,” IEEE Trans. AP, vol. 62, no. 6, pp. 2883-2890, June 2014.