ANTENNAS FOR MOBILE COMMUNICATIONS

H. Nakano
College of Engineering, Hosei University, Koganei, Tokyo, Japan 184-8584
nakano@k.hosei.ac.jp

ABSTRACT

Eight mobile communication antennas are presented: a composite curl/double-loop antenna, a reduced sized patch antenna, a loop antenna with a sleeve, a dual-frequency antenna, an extremely wide band antenna, a low-profile spiral antenna with a cavity, a spiral antenna array with an EBG reflector, and a curl antenna array with an EBG reflector. The radiation characteristics of these antennas are presented and discussed.

1. INTRODUCTION

This paper presents recent progress in antennas for mobile communications. Eight antennas are discussed in Subsections 2(1) - (8). The antenna in subsection 2-(1) is composed of a curl element and two loop elements for generating circularly polarized (CP) axial, conical, and tilted beams. A technique for widening the radiation beam from a patch antenna is discussed in 2-(2). The discussion for the antenna in 2-(3) centers on a technique for reducing the antenna size. The inverted LFL in 2-(4) has a card-type structure and is designed for dual-frequency operation at 2.45 GHz and 5.2 GHz. In addition, the card-type antenna in 2-(5) is investigated for obtaining a low VSWR characteristic over a frequency range of 3 GHz to 11 GHz. Methods for reducing the antenna height [1][2] are discussed in the last three subsections. The spiral in 2-(6) is backed by a cavity, whose depth (antenna height) is chosen to be small (0.07 wavelength at 3 GHz). The spiral antenna array in 2-(7) is backed by an EBG reflector, where the antenna height from the EBG reflector surface to the arrayed spirals is extremely small (0.06 wavelength). The curl antenna array in 2-(8) is also located at a height of 0.06 wavelength above the EBG surface. The CP radiation characteristics of these antennas in 2-(6), (7), and (8) are presented and discussed.

2. DISCUSSION

2-(1) A composite curl/double-loop antenna radiating CP conical, axial, and tilted beams

Fig. 1 shows the radiation patterns of a composite antenna at $f_{M\text{-}out\text{-}con}$ = 2.6 GHz, $f_{L\text{-}mid\text{-}ax}$ = 1.5 GHz, and $f_{H\text{-}in\text{-}tilt}$ = 5.8 GHz [3]. The outermost radiation element is a loop of circumference C_o, which is chosen to be approximately three wavelengths to radiate a CP *conical* beam at frequency $f_{M\text{-}out\text{-}con}$. The middle element is a loop of circumference C_m, which is chosen to be approximately one wavelength to radiate a CP *axial* beam at frequency $f_{L\text{-}mid\text{-}ax}$. The innermost radiation element is a curl for radiating a CP *tilted* beam at frequency $f_{H\text{-}in\text{-}tilt}$. Note that the rotational sense of the CP beam at $f_{M\text{-}out\text{-}con}$ is left-handed, while those at $f_{L\text{-}mid\text{-}ax}$ and $f_{H\text{-}in\text{-}tilt}$ are right-handed.

2-(2) A CP patch antenna enclosed by a folded conducting wall

A mobile communication antenna is often required to radiate a wide, circularly polarized beam. This subsection presents a “partially enclosed patch antenna” (PePA [4]) that satisfies this requirement. Fig. 2 shows the radiation pattern of the PePA, together with the radiation pattern of a corresponding open patch antenna (OPA) without a folded wall. The HPBW of the PePA in the x-z plane is 106° and the HPBW in the y-z plane is 104°. These HPBW values are approximately 40° wider than those of the corresponding OPA.

2-(3) A loop antenna on a chip dielectric material backed by a finite-size conducting plane

A compact structure is required for mobile antennas. To realize this, the square loop antenna presented here has a sleeve of width w_{slv}, where the loop is printed on a dielectric chip. Analysis shows that, as the sleeve width w_{slv} increases, the resonance frequency decreases. A resonance frequency shift of r_{shft} = 2.55 GHz/2.9 GHz = 88% is obtained, as shown in Fig.3 [5]. This means that a loop antenna reduced to 88% of the original can be realized at 2.9 GHz by scaling the antenna configuration for 2.55 GHz.

2-(4) A card-type inverted LFL antenna for dual-frequency operation

The increasing demand for mobile communications has been accelerating development of dual-frequency antennas. This subsection discusses a new dual-frequency antenna, called an inverted LFL antenna (InvLFL [6]). The InvLFL has a flat structure (card-type structure), as shown in the inset of Fig. 4, where both the top radiation elements and the ground plate lie in the same plane. The card-type structure facilitates the use of the InvLFL in PC card devices for personal computers or inside mobile phone handsets. Fig. 4 shows the frequency response of the VSWR. Note that operation at 2.45 GHz is controlled by the inverted L line and operation at 5.2 GHz is controlled by the inverted F line. The fine adjustment for dual-frequency operation is performed using a parasitic inverted L line.

2-(5) A card-type wideband antenna

With the emergence of new wireless communications systems, such as the ultra wide band (UWB) system, wideband antennas have been receiving attention [7]. This subsection presents a new card-type wideband antenna, called an elliptical ring antenna (ERA) (see the inset of Fig. 5 [8]). Analysis reveals that an appropriate choice of the ERA structural parameters realizes a low VSWR characteristic within a frequency range of 3.1 GHz to 10.6 GHz. The frequency response of the gain within the VSWR frequency range reveals that the gain in the z-direction varies between –1.9 dBi and +4.3 dBi.

2-(6) A low-profile spiral antenna backed by a cavity with absorbing material

The VSWR characteristic of a spiral antenna (SA), backed by a conducting plane, deteriorates as the antenna height (the distance between the spiral and the conducting plane) becomes smaller. This subsection describes an improvement in the VSWR for such a small antenna height. For improvement of the VSWR, absorbing material (ABM) is attached to the wall of a cavity, as shown in Fig. 6, where the antenna height h is 0.07 wavelength at a frequency of 3 GHz. Fig. 6 shows a comparison of VSWRs for SAs with and without the absorbing material [9].

2-(7) A low-profile spiral antenna array backed by an electromagnetic band gap (EBG) reflector

This subsection analyzes an SA array with an EBG reflector (see Fig. 7). It is emphasized that the antenna height above the surface of the EBG reflector is smaller (0.06 wavelength) than the antenna height for conventional SA arrays above a PEC reflector (0.25 wavelength). The spiral arms are optimized for obtaining CP wave radiation, taking into account mutual coupling among arrayed spirals. The analysis in [10] shows that a four-SA array has a frequency bandwidth of approximately 17% for a 3-dB axial ratio criterion. Within this axial ratio bandwidth, the input impedance shows a relatively constant value and the gain reaches a maximum value of 16.1 dBi.

2-(8) A low-profile curl antenna array above an EBG reflector.

Based on the results in the previous subsection 7, this subsection investigates a low-profile curl antenna array with an EBG reflector [1]. Use of a curl array element has the advantage that it can be fed without balun circuits. Fig. 8 shows the radiation pattern of a four-element array. It clearly shows that array effects narrow the CP radiation beam; the HPBW of the array is calculated to be approximately 14 degrees. (Note that the HPBW of an array element is 68 degrees.) The gain reaches a maximum value of approximately 15.4 dBi, which is approximately 6 dB higher than the gain of the array element. It is also found that the input impedance has a nearly constant value over a wide frequency range (from 5.5 GHz to 6.75 GHz) [11]. This simplifies the design of the feed circuits.

3. CONCLUSIONS

The following conclusions are obtained for eight mobile antennas. (1) A composite curl/double-loop antenna radiates CP axial, conical, and tilted beams at three different frequencies. (2) A patch with a folded conducting wall radiates a wide radiation beam. (3) The size of a loop printed on the top of a chip dielectric can be reduced by printing a conducting sleeve on the four sidewalls of the dielectric. (4) A card-type InvLFL operates in the 2.45 GHz and 5.2 GHz bands. (5) A card-type ERA realizes a low VSWR within an extremely wide frequency range. (6) The VSWR of a low-profile cavity-backed spiral is improved using absorbing material. (7) A low-profile spiral antenna array with an EBG reflector has an almost constant input impedance. (8) A low-profile curl antenna array radiates a CP wave over a wide frequency range, showing an almost constant input impedance.

ACKNOWLEDGEMENTS

The author thanks V. Shkawrytko for his kind assistance in the preparation of this manuscript.

REFERENCES

[1] F. Yang and Y. Rahmat-Samii, "A low profile circularly polarized curl antenna over electromagnetic band-gap (EBG) surface," Microwave Opt. Technol. Lett., vol 31, no. 4, pp. 264-267, Nov. 2001.

[2] J.L.Volakis, M.W. Nurnberger, and D.S. Fillipovic, "A broadband cavity-backed slot spiral antenna", IEEE Ant. Propagat. Magazine, Vol. 43, No .6, pp. 15-26, Dec. 2001.

[3] H. Nakano, Y. Ohara, S. Shimada, M. Mimaki, and J. Yamauchi, "A composite antenna radiating circularly polarized conical and axial beams", Proc. ICAP, pp.115 - 118, University of Exeter, UK, 2003.

[4] H. Nakano, S. Shimada, J. Yamauchi, and M. Miyata, "A circularly polarized patch antenna enclosed by a folded conducting wall", IEEE Topical Conf. on Wireless Communi. Tech., Honolulu, HI, [CD-ROM] s09p01, Oct. 2003.

[5] H. Nakano, T. Nakajima, M. Mimaki, and J. Yamauchi, "A loop antenna on a chip dielectric material backed by a finite-size conducting plane", IEEE Topical Conf. on Wireless Communi. Tech., Honolulu, HI, [CD-ROM] s22p01, Oct. 2003.

[6] H. Nakano, K. Morishita, Y. Sato, M. Mimaki, and J. Yamauchi, "A card-type inverted LFL antenna for dual-frequency operation", IEEE/ACES Int. Conf. on Wireless Communi. and applied Compu. Electro., Honolulu, HI, [CD-ROM] s27p03i, April 2005.

[7] S. Suh, W. L. Stutzman, and W. A. Davis, "A new ultrawideband printed monopole antenna: The planar inverted cone antenna (PICA)," IEEE Trans. Antennas and Propagation, vol. 52, no. 5, pp. 1361-1365, May 2004.

[8] H. Nakano, S. Hattori, H. Mimaki, and J. Yamauchi, "A card-type wide band antenna", Int. Symp. Antennas and Propagation (ISAP 2005), Seoul, Korea, August 2005, (submitted).

[9] Y. Okabe, J. Yamauchi, and H. Nakano, "A strip spiral antenna with absorbing layers inside a cavity", Proc. of Communi. Society Conf. of IEICE, p. B-1-107, 2001, Chofu, Japan.

[10] H. Nakano, K.Hitosugi, P. Huang, H. Mimaki, and J. Yamauchi, "Alow-profile spiral antenna array above an EBG reflector", IEEE Int. Symp. Antennas and Propagation, vol. 3A, pp. 18-21, Washington, July 2005.

[11] H. Nakano, T. Taniguchi, K. Sato, T. Maruyama, H. Mimaki, and J. Yamauchi, "A monofilar spiral antenna array above an EGB reflector", Int. Symp. Antennas and Propagation (ISAP 2005), Seoul, Korea, August 2005, (submitted).

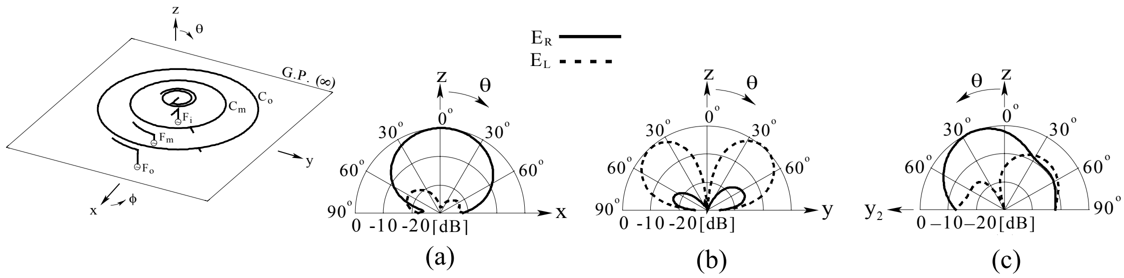

Fig. 1. Radiation patterns: (a) 1.5 GHz. (b) 2.6 GHz. (c) 5.8 GHz.

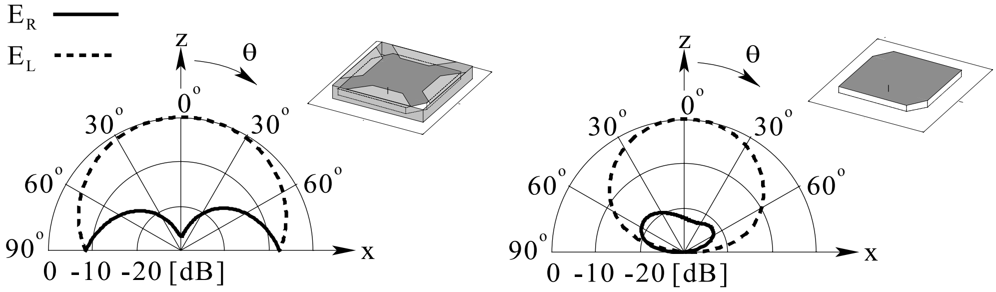

Fig. 2. Radiation patterns: (a) PePA. (b) OPA.

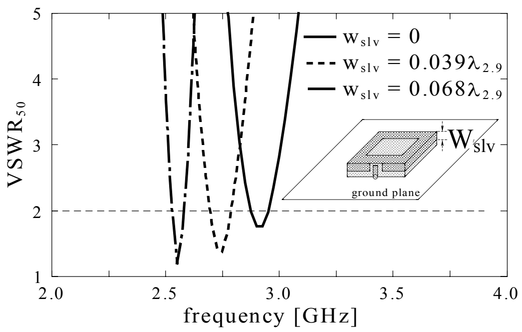

Fig. 3. VSWR for a loop on a chip dielectric material.

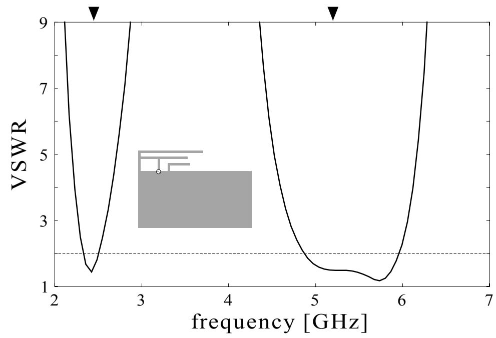

Fig. 4. VSWR of an Inv LFL.

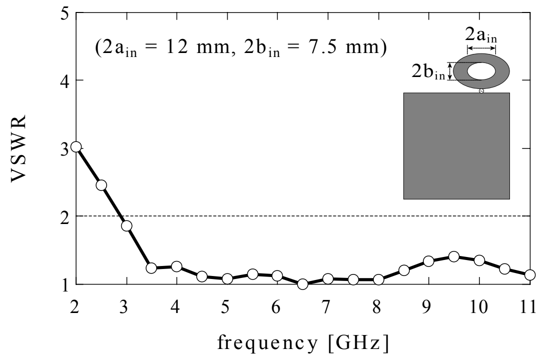

Fig. 5. VSWR of an ERA.

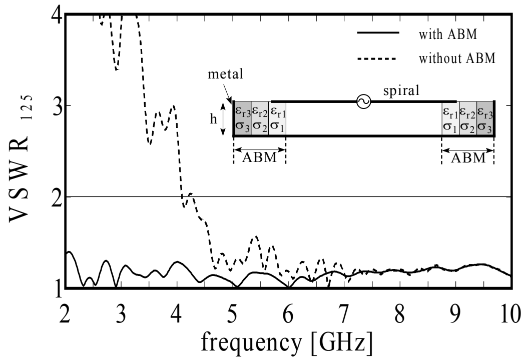

Fig. 6. VSWRs of SAs with and without absorbing material (ABM).

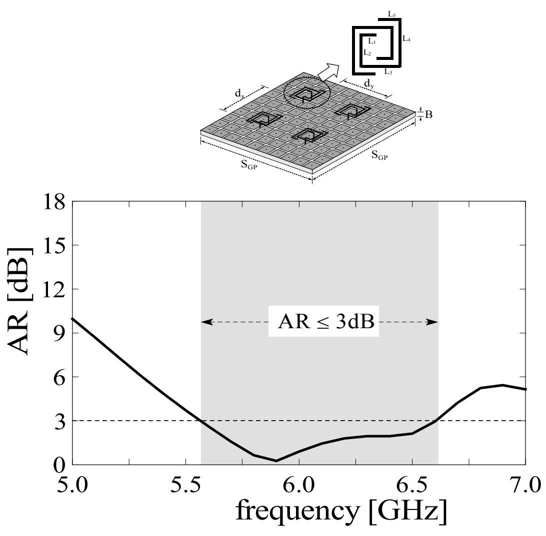

Fig. 7. Axial ratio of a low-profile spiral antenna array backed by an EBG.

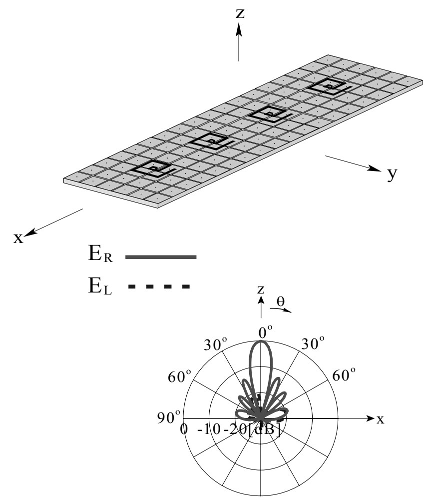

Fig. 8. Radiation pattern of a low-profile curl antenna array.