Three Principles of Designing Base-Station Antennas

Qing-Xin Chu, Yu Luo and Ding-Liang Wen
School of Electronic and Information Engineering
South China University of Technology
Guangzhou, Guangdong, China
qxchu@scut.edu.cn

***Abstract*-Three principles of designing base-station antennas are proposed: wide band impedance match, stable radiation patterns in wide frequency band and high cross polarization ratio in wide angle range.**

***Keywords*-Base-station antenna; wideband impedance match; stable radiation patterns; cross polarization ratio**

I. INTRODUCTION

Recently, different mobile communication systems have been designated with different frequency bands. In China, the 2G systems such as GSM, CDMA operate in1710-1920MHz band, the 3G systems such as WCDMA,TD-SCDMA and CDMA2000 operate in 1880-2170 MHz band and the 4G LTE systems operate in 2300-2400 MHz and 2570-2690 MHz bands. Therefore, the base-station antennas simultaneously cover 1710-2690 MHz band are necessary for modern mobile communication systems. The base-station antennas should achieve not only wideband impedance match (VSWR<1.5), but also stable 3-dB beamwidth with 65±5º for horizontal plane. For ±45º dual polarized base-station antennas, cross polarization ratio (XPD) also should be higher than 20 dB at broadside and 10 dB at ±60º.

Many methods have been proposed to broaden the impedance wideband of dipoles. Log-periodic antennas or equiangular spiral antennas can achieve wideband impedance matching, but they are bulky in their structures [1]. The patch antennas with a meandering probe [2], an L-probe [3], or an U-slot patch [4] can increase impedance bandwidth, but the radiation patterns vary substantially over the operation frequencies. In order to achieve wideband beamwidth, a wideband antenna called magnetoelectric dipole with 43.8% impedance bandwidth (SWR<1.5) was proposed [5] recently. By combining a planar electric dipole and shorted patch antenna, stable radiation pattern with 3-dB beamwidth 73±6 degree for E-plane and 76±4 degree for H-plane [6] in desired band was achieved. This work has attracted wide attentions and in depth studies [7]. Only a few studies in literature are concerned with improving the XPD within ±60º of the main lobe at the horizontal plane. In [8], the antenna has high XPD at the center frequency. In [9], the XPD of the antenna at the boresight is given. Previous studies about XPD [10]-[12] have not concentrated on how to improve XPD for ±45º dual-polarized base station antennas. In [13], XPD of a vertical-horizontal dual-polarized antenna was studied. However, XPD of a ±45º dual-polarized antenna is different from that of vertical-horizontal dual-polarized antenna, in terms of the measuring method of antennas. Two parasitic elements were added to reduce the cross-polarization of a patch antenna [14]. A 45° slant-polarized antenna was proposed in [15]. It can be seen from the measuring method that, for ±45° dual-polarized antenna, even if all the dipoles are in ideal case, it is still hard to achieved high XPD in all polar angles. Currently, engineers working in antenna companies adjust the antenna structures to improve XPD by a trial and error basis, because there are few theories for improving XPD.

In this paper, three principles of designing base-station antennas are proposed: wide band impedance matching, stable radiation patterns in wide frequency band and high cross polarization ratio in wide angle range. Several base-station antennas with good performance are design, fabricated, and measured.

II. PRINCIPLE OF WIDEBAND IMPENDANCE MATCHING

Similar to a resonator, a dipole always has many resonant modes whose frequencies are not close to each other originally. Also similar to a multi-mode filter, If the resonant modes can get close to each other, wideband impedance match could be reached as shown in Fig.1. For example, a dipole as shown in Fig.2(a) can resonate in half wavelength and one wavelength, its input impedance is shown in Fig.3. It can be found that the dipole has one resonant mode at 2.3 GHz and another resonant mode at 4.8 GHz. While the dipole is loaded a stub as shown in Fig.2(b), the two resonate modes are close to 2.3 GHz as shown in Fig.4, therefore, wideband impedance match is achieved as shown in Fig.5.

III. PRINCIPLE OF STABLE RADIATION PATTERNS

Fig.6 shows two parallel dipoles with the same phase over a big reflector. Following the image method, the two dipoles can be equivalent to the four dipoles as shown in Fig.7. The principle of broadband radiation patterns is shown in table I. As increase of frequency, the beamwidth of a dipole becomes narrow in the E-plane, while the beamwidth of an out-phase binary array (i.e. a point source and a reflector) becomes wide. So a stable beamwidth of the total radiation pattern in the E-plane is achieved. For H-plane, the beamwidth of an in-phase binary becomes narrow as increase of frequency, while the beamwidth of an out-phase binary array becomes wide. Therefore, a stable H-plane of total radiation pattern is also obtained. In a word, stable beamwidths at E- and H-planes are obtained in wide frequency band.

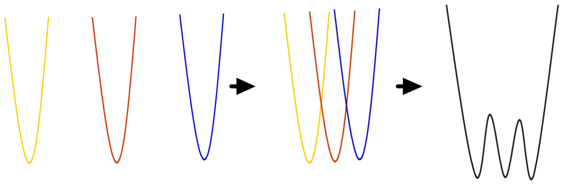


Fig.1. Principle of wideband impedance matching

(a) (b)
Fig.2. A dipole (a) not loaded a stub (b) loaded a stub

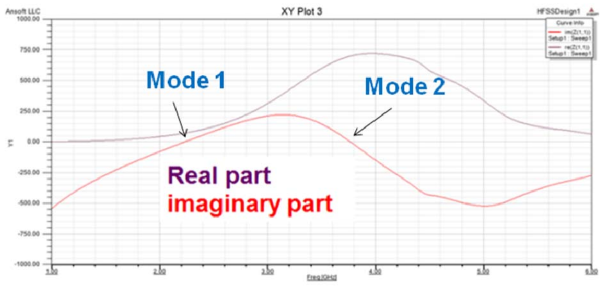


Fig.3.Input impedance of a dipole

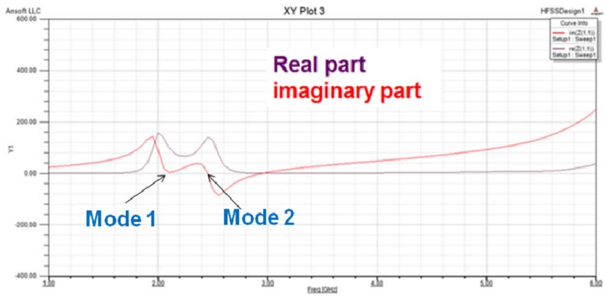


Fig.4.Input impedance of a dipole loaded a stub

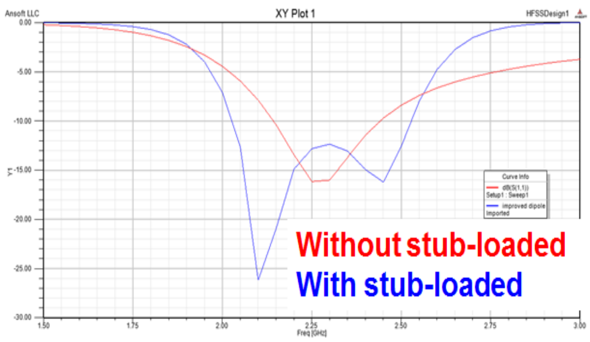


Fig.5. Refelction parameter of the dipoles

IV. Principle of High XPD in Wide Angle Range

For 4G basestation antennas, cross polarization ratio (XPD) must higher than 20 dB at broadside and 10 dB at ±60º. A simple ±45º dual polarized basestation antenna cannot satisfy the requirement. Fig.8. presents a schematic diagram of

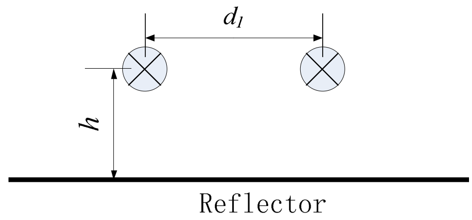


Fig.6.Two dipole with the same phase over the big reflector.

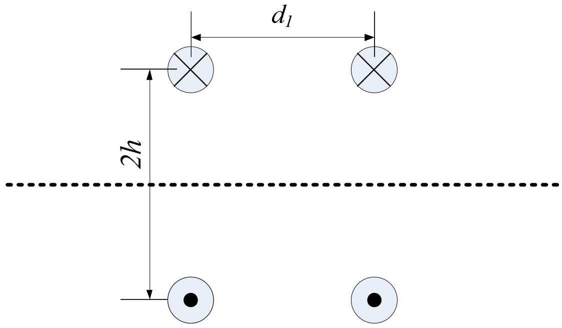
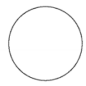
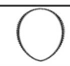
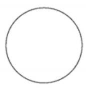
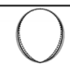


Fig.7.Analysis of Fig.6 by image method

TABLE 1. Principle of Stable Radiation Patterns

— $0.8f_0$ — f_0 - - $1.2f_0$	Radiation pattern of a dipole		Radiation pattern of an in-phase binary array		Radiation pattern of a point source and a reflector		Total radiation pattern
E-plane		×		×		=	
H-plane		×		×		=	

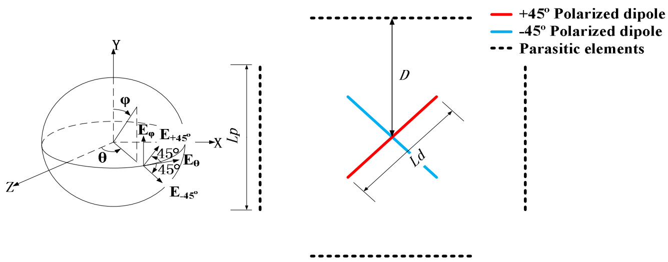
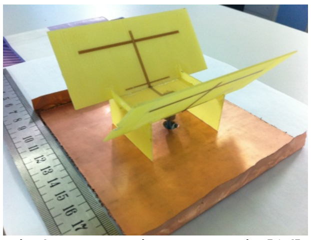


Fig.8. Schematic of the proposed ±45º dual-polarized antenna with four parasitic elements in a square contour.

TABLE I
Effect of Parasitic Elements on XPDs

	0º	+60º	-60º
Without parasitic elements	+∞	9.54	9.54
With parasitic elements	+∞	20.0	20.0

the proposed dual-polarized antenna with four parasitic elements in a square contour. Every ±45º dual-polarized antenna can be simplified approximately to a +45º polarized dipole (red thick solid line) and a -45º polarized dipole (blue thick solid line). Four parasitic elements (black dashed line) were place on the four sides of a square contour. The effects of the parasitic elements on XPD are shown in Table I. It can be seen that after the addition of parasitic element, the XPD are improved at ±60º and still large at broadside.



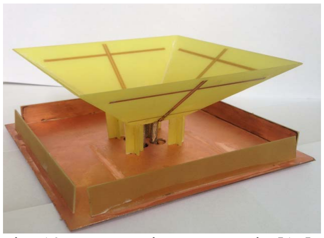
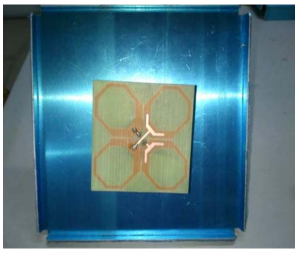


Fig.9. Bases-tation antenna in [16]. Fig. 10. Base-station antenna in [17].



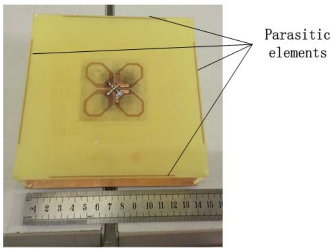


Fig.11. Base-station antenna in [18]. Fig.12. Base-station antenna in [19].

V. CONCLUSION

Three principles have been proposed to design 4G base-station antennas. According to the principles, a series of antennas with high performance have been designed, fabricated and measured as show in Fig.9-Fig. 12 [16]-[19].

REFERENCES

[1] C.A.Balanis, Antenna Theory: Analysis and Design. New York:Wiley,2005.

[2] H.-W. Lai and K.-M. Luk, "Design and study of wideband patch antenna fed by meandering probe," IEEE Trans. Antennas Propag., vol.54, no. 2, pp. 564–571, Feb. 2006.

[3] C.-L. Mak, K.-M. Luk, K.-F. Lee and Y.-L. Chow, "Experimental study of a microstrip patch antenna with an L-shaped probe," IEEE Trans. Antennas Propag.,vol. 48, no. 5, pp. 777–783, May. 2000.

[4] K.-F. Lee, K.-M. Luk, K.-F. Tong, S.-M. Shum, T. Huynh, and R.-Q.Lee, "Experimental and simulation studies of coaxially fed U-slot rectangular patch antenna," Proc. Inst. Electr. Eng.—Microw. Antennas Propag., vol. 144, no. 5, pp. 354–358, Oct. 1997.

[5] K.-M.Luk and H.Wong, "A new wideband unidirectional antenna element,"Int.J.Mcrow.Opt.Technol., vol.1,no.1,pp.2098-2101,Jul.2006.

[6] Z.-N.Chen and K.-M.Luk,Antennas for base stations in wireless communications. New York: McGraw-Hill, 2009.

[7] K.-M.Luk, B.Wu, "The magnetoelectric dipole-a wideband antenna for base stations in mobile communications,"Proceedings of the IEEE, vol.100, no.7, pp.2297-2307, Jul.2012.

[8] Z. D. Bao, Z. P. Nie and X. Z. Zong, "A Broadband Dual-Polarization Antenna Element for Wireless Communication Base station," *Antennas and Propagation (APCAP), 2012 IEEE Asia-Pacific Conference on*, pp.144-146, 2012, Singapore.

[9] M. Kaboli, M. S. Abrishamian, S. A. Mirtaheri and S. M. Aboutorab."High-Isolation XX-Polar Antenna,"*IEEE Trans. Antennas Propag.*, vol. 60, no. 9, pp. 4046–4055, Sep. 2012.

[10] T. D. Carozzi and G. Woan, "A fundamental figure of merit for radio polarimeters," *IEEE Trans. Antennas Propag.*, vol. 59, no. 6, pp. 2058-2065, Jun. 2011.

[11] S.Wijnholds,M. Ivashina, R.Maaskant, and K.Warnick, "Polarimetric with phased array antennas: Sensitivity and polarimetric performance using unpolarized sources for calibration," *IEEE Trans. Antennas Propag.*, vol. 60, no. 10, pp. 4688–4698, Oct. 2012.

[12] A. T. Sutinjo and P. J. Hall, "Intrinsic cross-polarization ratio of dual-linearly polarized Antennas for Low-Frequency Radio Astronomy," *IEEE Trans. Antennas Propag.*, vol. 61, no. 5, pp. 2852-2856, May. 2013.

[13] T. Oh, Y. G. Lim C.-B. Chae and Y. Lee, "Dual-polarization slot antenna with high cross polarization discrimination for indoor small-cell MIMO system," *IEEE Antennas Wireless Propag.Lett.*,vol.14, pp.374-377, Feb, 2015.

[14] R. Waterhouse, Printed Antennas for Wireless Communications, John Wiley & Sons, Inc., pp. 247, 2007.

[15] X. L. Quan, R. L. Li, Y. Fan and D. E. Anagnostou, "Analysis and Design of a 45° Slant-Polarized Omnidirectional Antenna," *IEEE Trans. Antennas Propag*., vol. 62, no. 1, pp.86-93, Jan. 2014.

[16] Qing-Xin Chu and Yu Luo, "A broadband unidirectional multi-dipole antenna with very stable beamwidth," *IEEE Trans. Antennas Propag.*, vol. 61, no. 5, pp. 2847-2852, May. 2013.

[17] Yu Luo and Qing-Xin Chu, "Oriental Crown-shaped differentially-fed dual-polarized multi-dipole antenna," *IEEE Trans. Antennas Propag.*, vol.PP, no.99, pp.1. (early access)

[18] Qing-Xin Chu, Din-liang Wen and Yu Luo, "A Broadband ±45° Dual-Polarized Antenna With Y-shaped Feeding Structure," *IEEE Trans. Antennas Propag.*, vol. 63, no. 2, pp. 466-473, Feb. 2015.

[19] Yu Luo, Qing-Xin Chu and Ding-Liang Wen, "A ±45º Dual-Polarized Base-station Antenna with Enhanced Cross-Polarization Discrimination via Addition of Four Parasitic Element Placed in a Square Contour," *IEEE Trans. Antennas Propag.*, major revision.