A Dual-Polarized Wideband Element Antenna for Base Station Application

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***Abstract*— This paper presents a novel wideband element antenna for base station application covering all frequency bands for existing cellular system from 1.6 to 2.8 GHz. The proposed antenna element has a stable gain range of 8 ± 0.5 dBi over frequency bands. The horizontal beamwidth is at least 60^0. The performance of this antenna element is satisfied all requirements for expected wideband base station antennas. The antenna element based on electro-magnetic dipoles consists of two double-bowtie shaped dipoles for two polarizations of $\pm 45^0$. The feeding baluns for the two dipoles have step-changed width to obtain better impedance matching, and they are simply designed for mass production. Besides, the radiators of the dipoles are double-bowtie shaped to enhance the impedance bandwidth.**

Keywords*— *Dual-polarized, base station antenna, bowtie antenna, wideband antenna, 2G/3G/4G.

I. Introduction

Due to the great development of mobile communication network, dual-polarized antennas, especially $\pm 45^0$ dual-polarized antennas, have been widely used to combat multipath fading and to increase capacity [1]. Wideband base station antennas are highly demanded to cover frequency bands of existing systems such as 2G, 3G, 4G and Wi-Fi. Furthermore, base station antennas also need to have stable radiation characteristics across the wide operating band. To obtain these requirements, using magnetic-electric (ME) dipoles is a good solution [2][3].

This paper proposes a novel wideband element antenna with stable gain and beamwidth. The element antenna is based on the ME dipole principle. However, the radiator part is double-bowtie shaped to enhance the bandwidth. The feeding balun structures are step stair shaped to get good impedance matching. Moreover, the baluns are placed outside of the dipoles so that the mass production is easy and cheap.

The paper is organized in four sections. In Section II, the principle of the proposed element antenna is explained. Section III shows simulation results to prove the performance of the proposed element antenna. Finally, the proposed element antenna is compared to other studies in Section IV, and some conclusions are also given in this section.

II. Principle and Structure of Element Antenna

A. Principle of the Element Antenna

The proposed element antenna is based on the ME dipole which consists of an electric dipole and a magnetic dipole [2][3]. The combination of these two dipoles is detailed in Fig. 1. It can be seen that the E-plane and H-plane patterns of the ME dipole are an admixture of the patterns of the electric dipole and the magnetic dipole. Thanks to the admixture, the main lobe of the ME dipole is enhanced whereas the back lobe is low. Therefore, the ME dipole has a heart-shaped patterns with a low back lobe level.

The equivalent circuit of the ME dipole is presented in Fig. 2. The magnetic dipole is represented by a parallel circuit of a resistor R_m, a capacitor C_m and an inductor L_m while the electric dipole is equivalent to a serial circuit of a resistor R_e, a capacitor C_e and an inductor L_e. From Fig. 2, the input admittance Y_{in} is calculated as the equation (1).

$$Y_{in} = Im\left\{\left(\frac{1}{R_m} + jwC_m + \frac{-j}{wL_m}\right) + \left(\frac{1}{R_e + jwL_e + \frac{-j}{wC_e}}\right)\right\}$$
$$\approx \left(wC_m - \frac{1}{wL_m}\right) - \left(wL_e - \frac{1}{wC_e}\right)\frac{1}{R_e^2} \quad (1)$$

We can see that $Im\ (Y_{in}) = 0$ if $L_mC_m = L_eC_e$ and $R_e^2 = C_e/L_m$. Thus, the electric dipole and magnetic dipole obtain resonance at the same frequency. The superposition of resonance frequencies makes the impedance bandwidth wider. This proves that the ME dipole has a wide bandwidth.

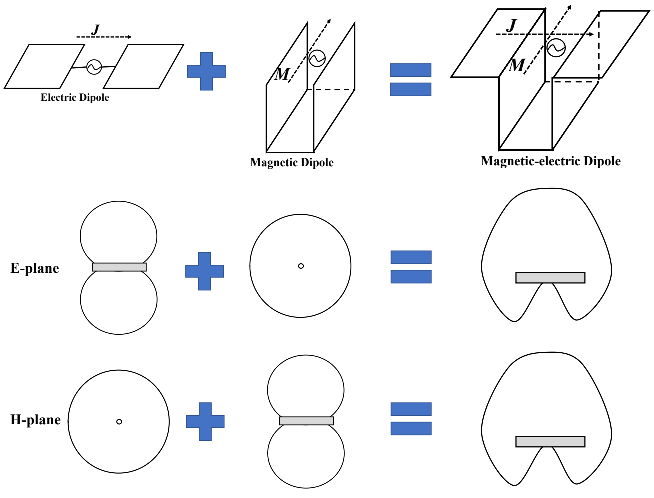

Fig. 1. E-plane and H-plane patterns of the magnetic-electric dipole antenna.

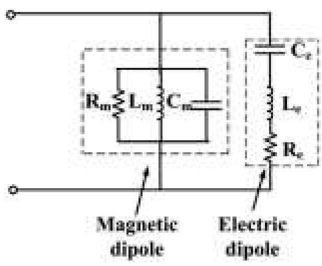

Fig. 2. The equivalent circuit of the ME dipole antenna.

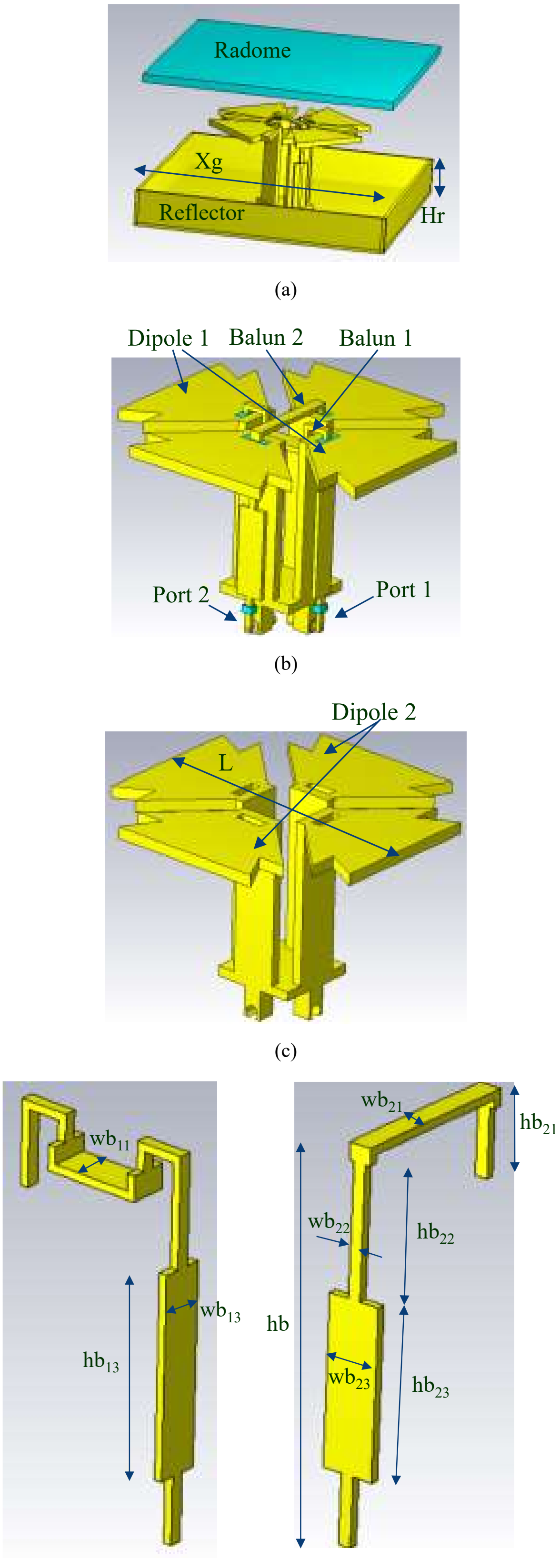

Fig. 3. Structure of the proposed element antenna: (a) 3D model with a radome and a reflector, (b) Element antenna without the radome and the reflector, (c) the two bow-tie shaped dipoles without feeding structures, (d) the balun 1 and (e) the balun 2. ($Xg = 110$; $Hr = 15.5$, $L = 62$; $hb = 45$; $wb_{11} = 4.7$; $wb_{13} = 5.2$; $h_{13} = 24$; $wb_{21} = 2.7$; $wb_{22} = 1.5$; $wb_{23} = 6.4$; $hb_{21} = 10$; $hb_{22} = 15.4$; $hb_{23} = 19.7$ (unit: mm)).

B. *Structure of the Element Antenna*

The structure of the proposed element antenna has two ME dipole with the double-bowtie shaped radiators as shown in Fig. 3. The double-bowtie shaped dipole with port 1 gives the polarization of -45^0 while the other produces the polarization of 45^0. The length *L* of the radiators is approximately equal to a half-wavelength.

The 3D overall model of the proposed element antenna with a square reflector and a square radome is shown in Fig. 3(a) while Fig. 3(b) shows the structure of the proposed element antenna without the reflector and the radome. The element antenna is fabricated by utilizing die-casting technology so that two ME double-bowtie shaped dipoles are combined into a block for easy fabrication and assembly as illustrated in Fig. 3(c). Next, Fig. 3 (d) and Fig. 3 (e) shows feeding structures (baluns) for two element antennas, respectively.

First, in the proposed element antenna, the aluminum reflector is employed to control some characteristics of the antenna such as front-to-back ratio, gain, beamwidth, isolation between ports. Next, the radome is used to get results close to the practical base station antenna which is equipped with the radome to protect it from environmental effects. The radome has dielectric constant of 3.2 and tangent loss of 0.002.

The radiator parts of the electric dipole are double-bowtie shaped. The great bandwidth enhancement can be seen in Fig. 4, where illustrates S-parameters in two cases: double-bowtie and single-bowtie. Thus, double-bowtie shaped radiators are good solution to improve the bandwidth of ME dipoles.

A review of feeding structure for ME dipoles is presented in [4]. These are some structures such as Γ shaped feed, twin L shaped differential feed, stair shaped feed, F shaped feed. Each kind of feeding structures gives different bandwidth enhancements. In this paper, we design a new feeding structure by combining advantages of the above-listed structures to achieve the target bandwidth. The width of the baluns is different at some parts as shown in Fig. 3 (d) and (e). This allows the element antenna match to 50 ohm feeding cables. Especially, the baluns are designed to go through the radiators so that they can be kept tightly and assembly easily into the dipoles, which makes the proposed element antenna endure strong wind.

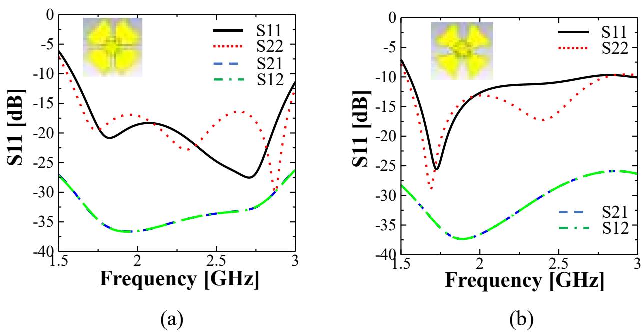

Fig.4. S-parameters: (a) The proposed element antenna with double-bowtie shape (b) The element antenna with single-bowtie shape.

III. Simulation Results

This section discusses the simulation results of the proposed element antenna. S-parameters of the element antenna are shown in Fig. 4 (a), where we can see that the S11 and S22 are smaller than -15 dB from 1.6 GHz to 2.9 GHz. Isolation between two ports is higher than 30 dB.

The effect of some key parameters as the length *L*, the height *hb* and wb_{11} and wb_{13} on S-parameters of Port 1 is presented in Figs. 5 (a)-(d), respectively. When the length L increased, the bandwidth is wider and shifted to lower frequency band. However, S11 is higher at low frequency and isolation between two ports S21 is higher at high frequency.

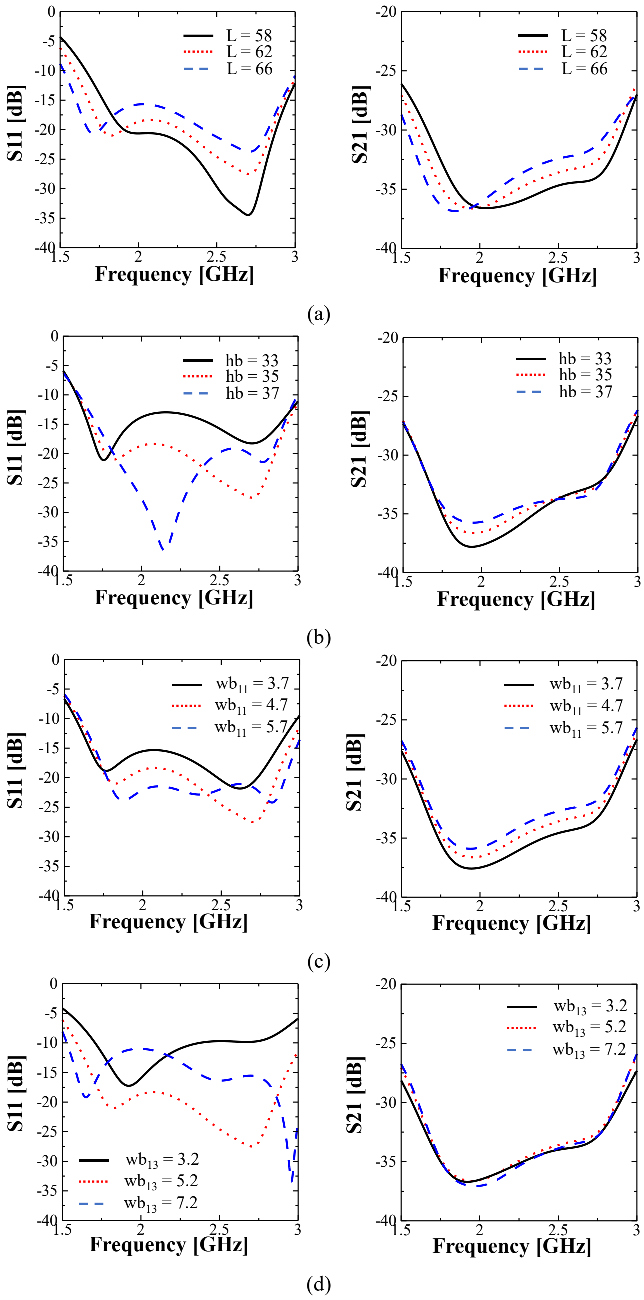

Fig.4. The effect of *L*, *hb*, wb_{11}, wb_{13} on S-parameters: (a) The effect of *L* (b) the effect of *hb* (c) the effect of wb_{11} and (d) the effect of wb_{13}.

The height *hb* only effects S21 at lower frequency band while S11 gets lower when *hb* is higher. Next, wb_{11} influences S21 over frequency band, the smaler wb_{11} is, the higher the isolation between two ports is. But, S11 gets worse. Finally, the width wb_{13} dose not effect S21 much but its effect on S11 is significant. The effect of *hb*, *L*, wb_{21}, wb_{23} on Port 2 is similar to Port 1.

Fig. 6 illustrates the radiation patterns of Port 1 at different frequencies: 1.7, 2.2, 2.6 GHz. For more details, Table 1 lists maximum gains and beamwidth of two ports at more frequencies. From Table 1, we can see that the gain increases when the frequency gets higher. This is opposite in case of the beamwidth. The beamwidth tends to decrease when the frequency increases.

In addition, the squint beam which effects the coverage of antenna [9] is smaller than 3^0. This is expected for all base station antennas.

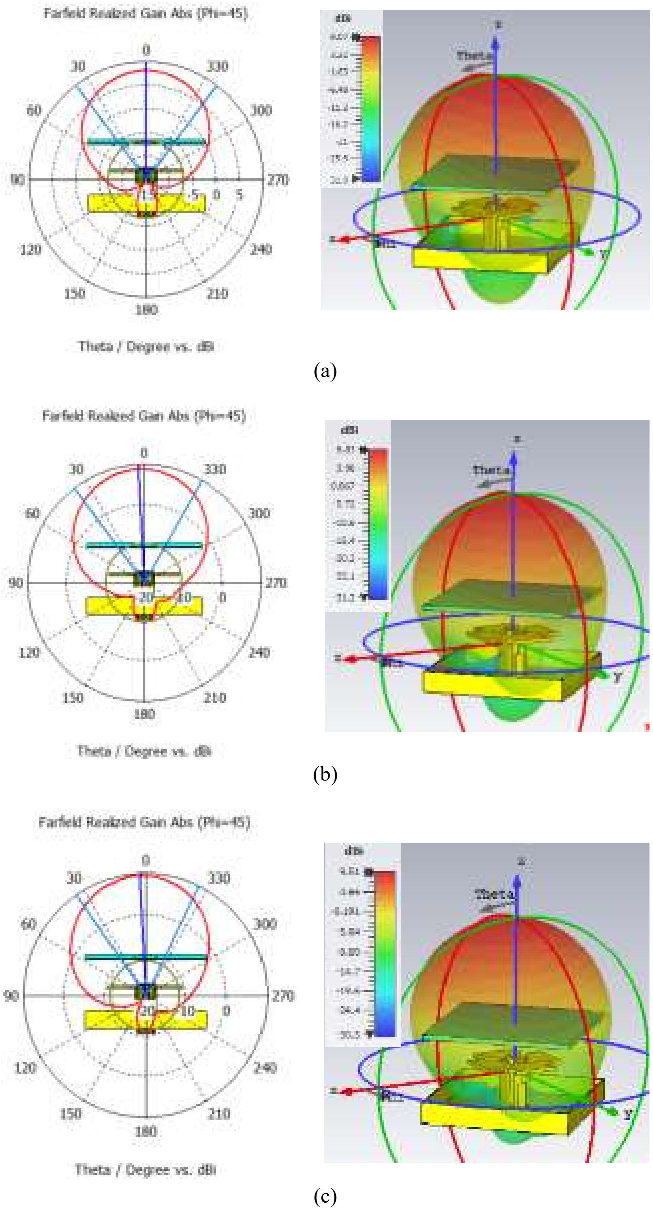

Fig. 6. 2D and 3D radiation patterns at different frequencies of Port 1: (a) 1.7 GHz (b) 2.2 GHz (c) 2.7 GHz.

TABLE I. GAIN AND BEAMWIDTH OF THE PROPOSED ELEMENT ANTENNA.

Fre. [GHz]	***Port 1***			***Port 2***		
	Gain	***Beam width***	***Squint beam***	***Gain***	***Beam width***	***Squint beam***
1.7	8.07	73.6	0	8.06	73.9	0
1.8	8.27	72.2	1	8.22	72.5	0
2.1	8.66	67.9	2	8.62	68.2	2
2.3	8.99	65.1	3	8.98	65.1	3
2.6	9.47	60.2	3	9.4	59.5	3

TABLE II. COMPARISION WITH OTHER STUDIES.

Ref.	***Gain range [dBi]***	***Bandwidth range (VSWR ≤ 1.5)***	***Size (Width × Length × Height) [mm]***	***Reflector/ Director [mm]***
[5]	9.2÷12	1.68÷3.92	57.5×57.5×27	Reflector (130×30×26)
[6]	7.6÷9.3	1.69÷2.76	60.5×60.5×34	Reflector (110×110×36)
[7]	7.7÷8.5	1.9÷2.6	109×109×1	Reflector (240×240×2)
[1]	No inform ation	1.7÷2.7	72.8×72.8	Reflector (120×120×20) and Director
[8]	8 ± 1	1.71÷2.69	41×41×37	Reflector (70×70×10) and Director
The proposed antenna	8.07÷9.51	1.6÷2.8	62×62×35	Reflector (110×110×25)

Thus, the performance of the proposed element antenna is really good for 2G/3G/4G applications. The proposed antenna covers over frequency bands of 2G, 3G and 4G systems with the stable gain and beamwidth. Specially, the squint beam which is one of the most important parameters that operators expect is satisfied.

IV. DISSCUSIONS AND CONCLUSIONS

This section gives some comparisons between the proposed element antenna with several previous researches as given in Table 2. First, the antenna using die-casting technology in [6] has wider bandwidth. However, the structure is complicated for mass production due to folded feeding structure. The proposed antenna has higher and more stable gain than the antenna in [6]. The size of the antennas in [1] and [7] is larger than that of the proposed element antenna with smaller gains. Besides, the designs in [1] and [8] need to be employed directors, this makes these designs more complicated and more high-cost while the baluns of the proposed antenna is simply designed for mass production.

Thus, the proposed element antenna has the performance competitive to the previous studies. It is highly suitable for base station application. In future work, the fabrication will be done to verify the performance of the proposed element antenna.

REFERENCES

[1] C. Ding. H. Sun, Y. J. Guo, P. Qin and Y. Yang, "Beamwidth Control of Base Station Antennas Employing Reflector and Directors," ISAP 2015.

[2] T. Limpiti, A. Chantaveerod, and W. Petchakit, "Design of a Magneto-Electric Dipole Antenna for FM Radio Broadcasting Base Station Antenna Implementation," Progress in Electromagnetics Research M, vol. 60, 75–84, 2017.

[3] C. Y. Shuai and G. M. Wang, "A Simple Ultra-Wideband Magneto-Electric Dipole Antenna with High Gain," Degruyter, Vol 72, DOI 10.1515/freq-2016-0321, 2017.

[4] Neetu, G. P. Pandey, "An Overview of Magneto-Electric Dipole Antenna Feed Design," International Journal of Advanced Engineering, Management and Science (IJAEMS), Vol 1, Issue 3, 2015.

[5] Z. Li, Y. Sun, M. Yang, Z. Wu and P. Tang, "A Broadband Dual-Polarized Magneto-Electric Dipole Antenna for 2G/3G/LTE/WiMAX Applications," Progress in Electromagnetics Research C, Vol. 73, 127–136, 2017.

[6] M. Li, K. M. Luk, "Wideband Magnetoelectric Dipole Antennas with Dual Polarization and Circular Polarization," IEEE Antennas and Propagation Magazine, Vol. 57, No. 1, 2015.

[7] L. Ge and K. M. Luk, "Linearly Polarized and Dual-Polarized Magneto-Electric Dipole Antennas with Reconfigurable Beamwidth in the H-plane" IEEE Transactions on Antennas and Propagation, VOL. 64, NO. 2, 2016.

[8] Y. Liu, H. Yi, F. W. Wang and S. X. Gong, "A Novel Miniaturized Broadband Dual-Polarized Dipole Antenna for Base Station," IEEE Antenna and Wireless Propagation Letters, VOL. 12, 2013.

[9] H. Sun, C. Ding, B. Jones and Y. J. Guo, "A Wideband Base Station Antenna Element with Stable Radiation Pattern and Reduced Beam Squint," IEEE acess, DOI: 10.1109/ACCESS.2017.2763177, 2017.