A Broadband Dual-Polarized Antenna for TD-SCDMA System

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Abstract **─** A broadband dual-polarized antenna is proposed for TD-SCDMA system. The dual-polarized antenna is combined with two perpendicularly crossed dipoles. Crossed dipoles can reduce the same frequency interference and improve the signal reception effect. The isolation of this dual-polarized antenna is greater than 25 dB for co-polarization and 28 dB for cross-polarization. The measured results demonstrate that voltage standing wave ratio (VSWR) is no more than 1.3 at the operating frequency and the antenna has an average gain of 8.3 dBi for slant polarizations. That is, our proposed antenna meets the requirements for stringent design. We use array antenna technology based on the requirements of gain and beam tilt. A 5-element dual polarized antenna array is realized by 5-way unequal power divider at 1880 - 2635 MHz. The antenna gain of the array is about 12.5 dBi for different polarization. In numerical and measured results, the specific design methods and ideas of antenna and power divider are presented. As we can see from the test results, the antenna presented in this paper is far better than the industry standard.

Index Terms **─** Array, base-station antenna, dual-polarized antenna, TD-SCDMA system.

I. INTRODUCTION

In the past 30 years, it has been witnessed a tremendous success of wireless communication in the global market. Even after decades of fast growth, the number of cellular devices is still steadily increasing, surpassing the population in some countries due to consumers' need to stay connected wirelessly. For instance, since China Mobile commercially launched TD-SCDMA 3G in 2009, statistics data reveals that there have been more than 2.3 hundred million TD-SCDMA subscribers until April 2014 [1].

One of the key components in wireless mobile communication systems is the base station antenna, which plays a critical role in converting the electromagnetic waves that propagate in free space to electric current in the base station's circuitry [2- 4]. With the development of various generations of wireless mobile communication systems [5], researchers have achieved numerous milestones for different standards of base station antennas used in many wireless communication systems including advanced mobile phone service (AMPS) system, GSM, CDMA, TD-SCDMA, WCDMA, CDMA2000, and Wimax [6-10], as well as 4G (LTE / LTE Advanced) base station antenna [11, 12]. In addition, most of related work on base station antenna design focuses on the miniaturization, broadband, dual frequency band [13, 14, 15], and smart antenna characteristics. The smart antenna technology is used to replace the conventional antenna to improve the spectrum efficiency. It has spatial filtering to the beam from all directions, which improves the reliability of the system. According to the specifications of Table 1.

Table 1: TD-SCDMA antenna specifications

Frequency	1880 - 2635 MHz
VSWR	< 1.5
Ports isolation	> 28 dB (cross polarization); > 25 dB (co polarization)
Front-to-back ratio	> 25 dB
Cross polarization ratio	> 15 dB (0 deg)
Gain	> 12.5 dBi
Angle of inclination	6 deg

II. DUAL-POLARIZED ANTENNA DESIGN

A. Antenna element design

The configurations of the proposed antenna element operating at 1880 - 2635 MHz are illustrated in Fig. 1. For a better description of the antenna element, the x-y plane is defined as the horizontal plane (H-plane) and x-z plane as the vertical plane (V-plane). Radiator arm is a square ring type structure, which is not only expand the radiation unit band width, but also greatly reduce the weight, material and cost. The brace is a quarter-wavelength Balun structure placed to make the current on two dipoles balanced and to achieve the impedance matching. Radiation arm is ± 45° dual-polarization integration, using traditional half-wave dipole form. L_1 is calculated according to the half wavelength of the center frequency point 2.2 GHz. The length of the H_3 is

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slightly smaller than a quarter wavelength of the center frequency. The rest of the size is optimized by HFSS software simulation. The specific size of the antenna can be seen in Table 2. Finally, the far-field of the antenna is measured by an outdoor test system. The system is able to measure the margin of the far field antenna pattern, phase center, gain, beam-width and so on. It also can automatically generate the test report. This system consists of a holder, an antenna rotating pedestal system, a vector network analyzer, a data-processing system, and some computers. The model of the vector network analyzer is Agilent E5017C, which is used to measure the radiation pattern of the antenna.

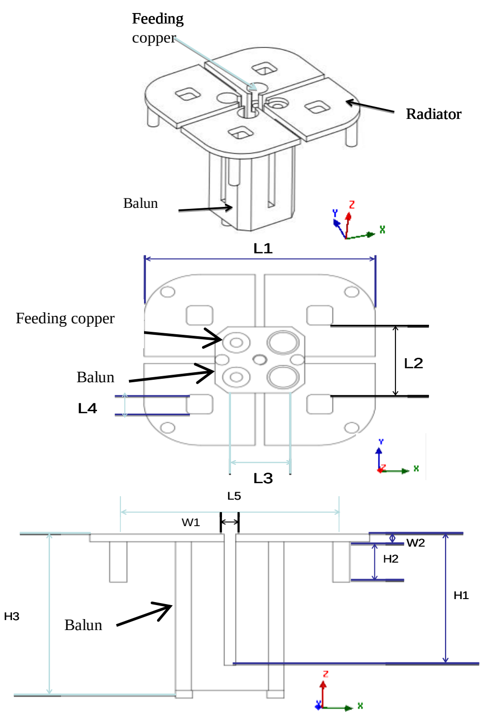


Fig. 1. Structure of the element: plan, top and side view.

Table 2: Key size of the proposed antenna (unit: *mm*)

L_1	L_2	L_3	L_4	L_5	H_1	H_2	H_3	W_1	W_2
49	20	13.5	5.5	39	26	8	31	2	1.5

The simulated VSWR and gain of one unit is given in Fig. 2. VSWR of two ports are less than 1.3 within the working frequency band and the peak gain of the antenna element is about 8.3 dBi.

B. 5-way power divider

5-element linear array is applied to enhancing the gain of the antenna to meet the requirements. Antenna has four rows of linear array since eight channels are required by TD-SCDMA. Thus, 5-way power divider is needed to meet the requirement. According to beam-forming theory, the power ratio of each element is 0.6: 0.8: 1: 0.8: 0.6. Figure 3 (a) describes the impedance calculation principle of 5-way power divider. The width of each micro-strip line can be evaluated from impedance. In the light of the required inclination angle, we can calculate the phase of each port. In Fig. 3 (b), it is shown that the specific phase calculation process.

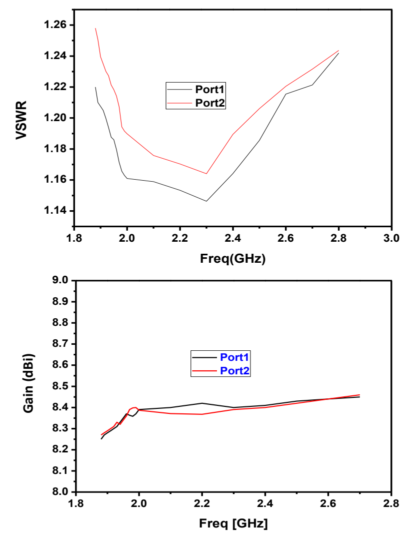


Fig. 2. Simulated results of VSWR and gain for proposed antenna element.

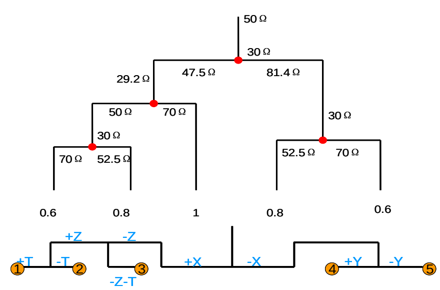


Fig. 3. Calculation principle of 5-way power divider: impedance (upper) and phase (lower).

Spacing between each unit is approximately 110 *mm* according to the 0.9 wavelength of center frequency. The ADS software is used to obtain the simulation results of the power divider. Figure 4 has shown the layout of ADS design 5-way power divider. In Fig. 5 (a), both simulation and measured data of VSWR are less than 1.12 and 1.25, respectively. The simulated and measured phase curves are shown in Fig. 5 (b), from which it can be seen that two results have good agreement. From Fig. 5 (c), we can see that the ratio of amplitude approximately as follows: 0.6: 0.8: 1: 0.8: 0.6 (S_{12}: S_{13}: S_{14}: S_{15}: S_{16}).

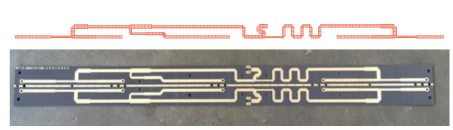


Fig. 4. Structure of power divider.

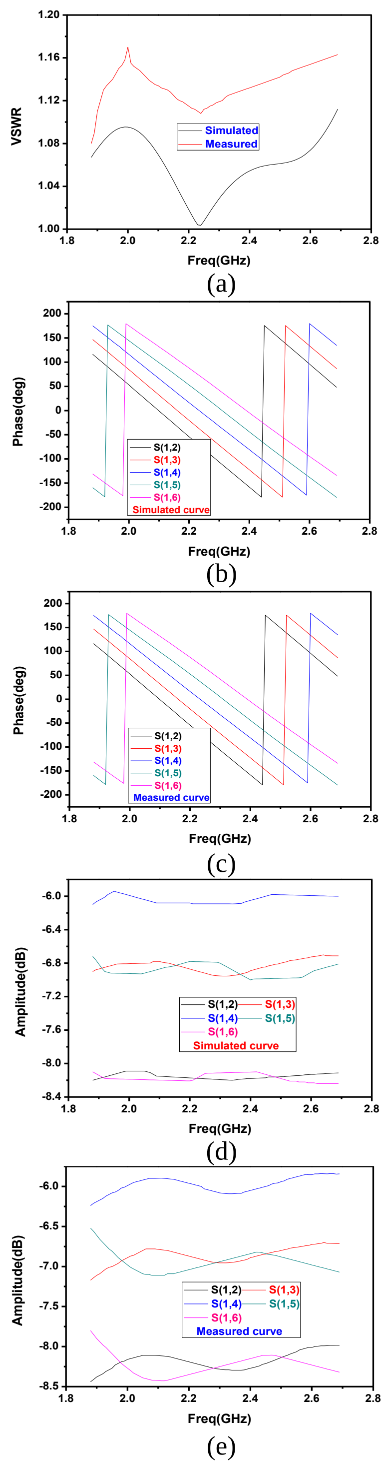


Fig. 5. Simulated and measured results of power divider: (a) VSWR; (b) simulated results of phase; (c) measured results of phase; (d) simulated results of amplitude; (e) measured results of amplitude.

C. Antenna array design

A dual-polarized antenna array with 4 × 5 elements is developed for TD-SCDMA applications which is depicted in Fig. 6. The element spacing was optimized for a maximum gain but without the appearance of grating lobes. A 5-way power divider is employed to feed the antenna array for each polarization. Flexible coaxial line is used to connect each element for each polarization to the power divider. The measured VSWR of the dual-polarized antenna array are shown in Fig. 7. The measured isolation is higher than 25 dB. The lowered isolation for the antenna array compared to the antenna element is mainly due to the coupling between two adjacent antenna elements for different polarizations. From the measurement in Fig. 8, the front-to-back ratio and axial cross polarization ratio are 28 dB and 17 dB at 1.88 GHz, 27 dB and 20 dB at 2.025 GHz, 30 dB and 22 dB at 2.635 GHz, respectively. The measured gain of antenna array are plotted in Fig. 9. The measured gain is about 13 dBi, slightly lower than the simulated result due to the losses from the power dividers and coaxial lines which were not taken into account in simulation.

Fig. 6. Prototype of array antenna.

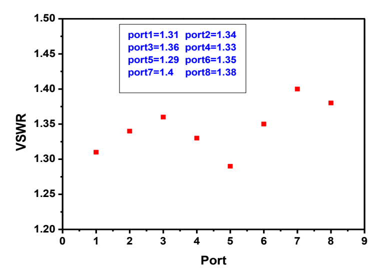
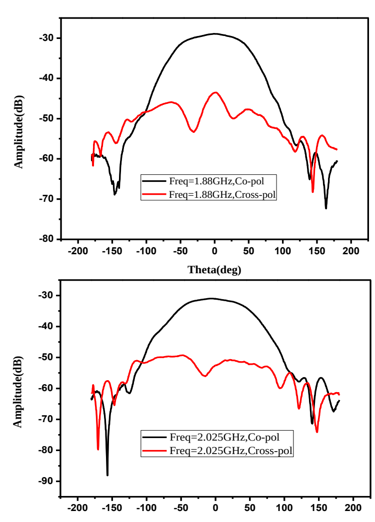


Fig. 7. Measurement of VSWR for different port.



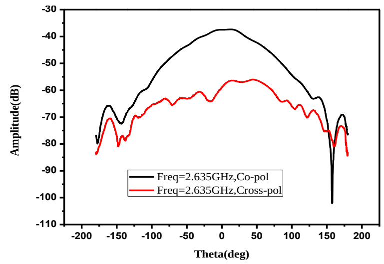


Fig. 8. Measurement for horizontal plane.

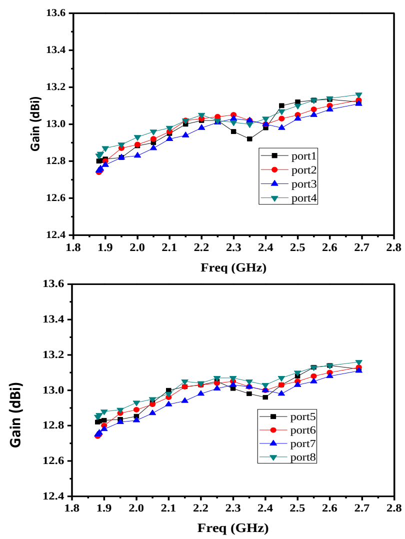


Fig. 9. Measurement of gain for different ports.

III. CONCLUSION

A broadband dual-polarized antenna is proposed for TD-SCDMA system. The dual-polarized antenna is composed of two perpendicularly crossed dipoles. The dual-polarized antenna has isolation of same polarization greater than 25 dB and isolation of different polarization greater than 28 dB. Measurements verify that this proposed antenna can meet the stringent design requirements including VSWR less than 1.3 at the operating frequency and average gain of 8.3 dBi for slant polarizations. A 5-element dual-polarized antenna array is realized by 5-way unequal power divider and the gain is about 12.5 dBi for each polarization.

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