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Simulation and Implementation of Dual-Polarization TD-SCDMA Smart Antennas

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Abstract—**In this paper, a dual-polarization TD-SCDMA smart antenna is introduced. By means of Ansoft HFSS and Microwave office, simulation results of a dual-polarization TD-SCDMA smart antenna are shown. By using simulation results, the practical antennas are made and employed in China mobile communication systems.**

***Index Term*—smart antenna; dual-polarization; TD-SCDMA; calibration network**

I. INTRODUCTION

The interdisciplinary field of smart antenna has matured gradually over the past two decades. Smart antenna is initially called adaptive antenna [1]. In recent years, it has been clear that this area of work will provide a key technological boom for the wireless communications industry. Moreover, smart antenna technology will play an important role in the rapid deployment of high data rate internet services [2]. Smart antennas can also help wireless service providers meeting the safety requirements imposed by the Federal Communications Commission and other government agencies all over the world. For example, in the US, service providers have been mandated to provide a position location accuracy of 125 metres for all wireless emergency calls at least 67% of the time. Here, smart antenna will therefore be a crucial element in locating users under a hostile multipath and rich co-channel-interference environment.

Currently, there are three international 3G wireless mobile communication standards, which are WCDMA, CDMA2000 and TD-SCDMA [3]. They all adopt smart antenna technology. In China, the TD-SCDMA systems are being deployed by China Mobile Ltd., while the other two standards are being adopted by China Telecommunications Corporation and China Unicom Ltd.

In the WCDMA and CDMA2000 standards, frequency division duplexing (FDD) is used, resulting a large difference between the uplink frequency and the downlink frequency. Thus, there is only a weak correlation between the uplink channel and the downlink channel. Considering complex wireless propagation environments in urban areas, it is very difficult to obtain ideal transmit methods in terms of uplink channel quality information and the algorithm is comparatively complex. But considering an important effect for performance improvement, smart antenna in FDD system is also being explored [4-5].

In the TD-SCDMA system, the use of the time division duplexing (TDD) scheme in air interface (i.e., identical uplink and downlink frequencies) results a strong correlation between the uplink and the downlink channels. In consequence, the downlink performance can be accurately optimized according to the performance of the uplink. Hence, among the 3G standards, TD-SCDMA is particularly suitable for adopting smart antennas.

According to the requirements of China Mobile Ltd., TD-SCDMA smart antennas should be equipped with the following characteristics: dual-polarization, wide frequency band, miniaturization and electrically adjustment. In Fig. 1, the respective frequency band allocation for TD-SCDMA system in China is depicted schematically. Thus, suitable TD-SCDMA antenna arrays should be able to operate effectively from 1.88 GHz to 2.4 GHz.

Recently the research on TD-SCDMA smart antenna has a breakthrough and dual–polarization TD-SCDMA smart antennas have been successfully developed. In this paper, the design of a dual-polarization directional smart antenna is introduced. In Section Ⅱ, the design of a dual-polarization TD-SCDMA smart antenna is described. Design of calibration network summarized in Section Ⅲ. The simulation results of the proposed antennas is presented in Section Ⅳ. In Section Ⅴ, application of broadband dual-polarization antennas in three sector cell site is introduced. The conclusion is in Section Ⅵ.

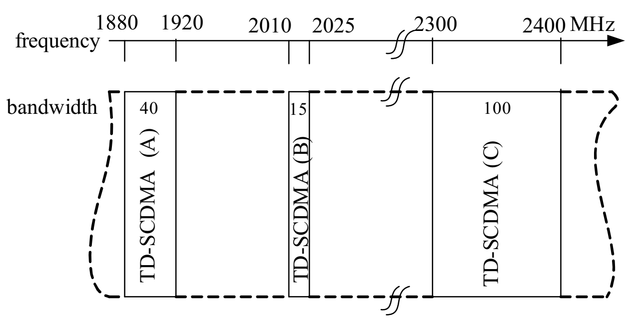

Fig. 1 TD-SCDMA frequency band allocation in China

II. THE DESIGN OF A DUAL-POLARIZATION TD-SCDMA SMART ANTENNA

The working principles of a dual-polarization smart antenna

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are similar to those of a single- polarization smart antenna [6]. The major difference is the antenna array's construction and the overall antenna performance.

A. A Broad-band dual-polarization antenna array

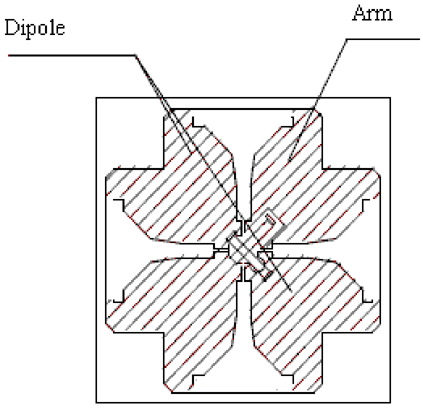

Fig.2 Half-wave dipole in dual-polarization antenna array

To improve the antenna's performance, an improved half-wave dipole has been designed (patent pending), as shown in Fig. 2.

B. *Classification of dual-polarization antennas*

A dual-polarization antenna is classified into two kinds: dual-polarization antennas with horizontal and vertical polarization; and +45°/ -45° dual -polarization antennas. Polarization with +45°/-45° is also known as cross polarization.

In a practical environment, 30 dB isolation is required between the polarized antennas. Dual -polarization antennas with horizontal and vertical polarizations are initially preferred because they can easily provide the required 30 dB isolation figure. Practical results based on the use of horizontal/vertical dual-polarization antennas are fairly positive. However, there is a weakness. Since the mobile antennas (i.e. on cars or mobile phones) mainly operate in a vertically polarized mode, the propagation efficiency is more favorable to the vertical system of a horizontal/vertical dual-polarization base station antenna than to the horizontal system. Thus the horizontal polarization is not really that suitable for transmitting purposes.

However, with +45°/-45° dual -polarization antennas, both polarizations are equivalent with respect to their propagation efficiency. The two polarizations can therefore be used with good results for transmitting and receiving signals. Furthermore, this antenna concept allows simultaneous transmission from two transmitters without the use of a transmitter combiner.

C. Layout of a dual-polarization antennas array

Dual-polarization antenna arrays can be designed to operate in narrowband and broadband systems, as shown in Fig. 3 and Fig. 4, respectively. In Fig. 3, there are four rows of antennas, with a row spacing of 75 mm. Moreover, each row array consists of nine dipoles. In Fig. 4, the four rows have a spacing of 65 mm and each row contains ten dipoles. Note that the spacings are related to $\lambda/2$, where λ denotes the wavelength.

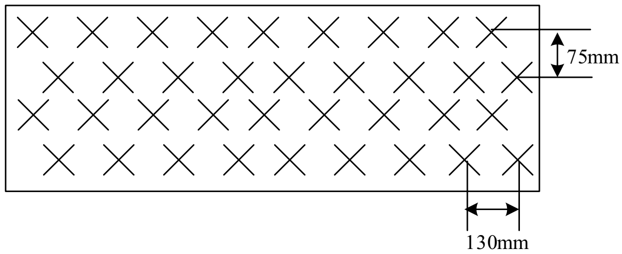

Fig. 3 A narrowband dual-polarization antennas array

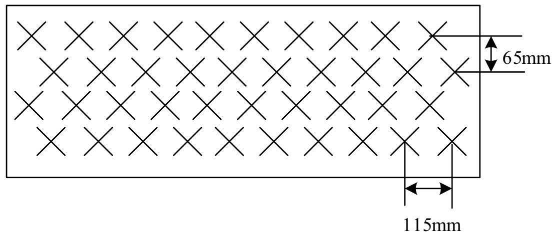

Fig. 4 A broadband dual-polarization antennas array

D. Selection of row spacing

If the row spacing of the antenna arrays is reduced, the synthesized beam will varied as follows.

Traffic beam: beam width increases, gain reduces, sideband level reduces [8] (see Fig. 5).

Broadcast beam: beam flattens, the reduction of the edge power with ±60° is lower (see Fig. 6).

Thus, reducing the row spacing is beneficial for the broadcast beam and is disadvantageous for the traffic beam. Thus, in the design of antenna arrays, we have to compromise the performance of the traffic beam and the broadcast beam.

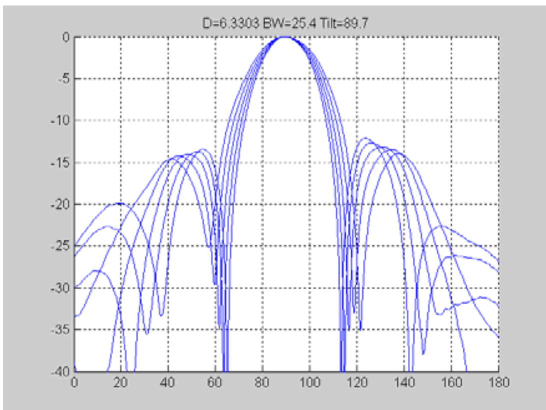

Fig. 5 Traffic beam shapes with array element spacing. From top to bottom, five broadcast beam curves corresponding to spacings of 60 mm, 65 mm, 70 mm, 75 mm and 80 mm, respectively.

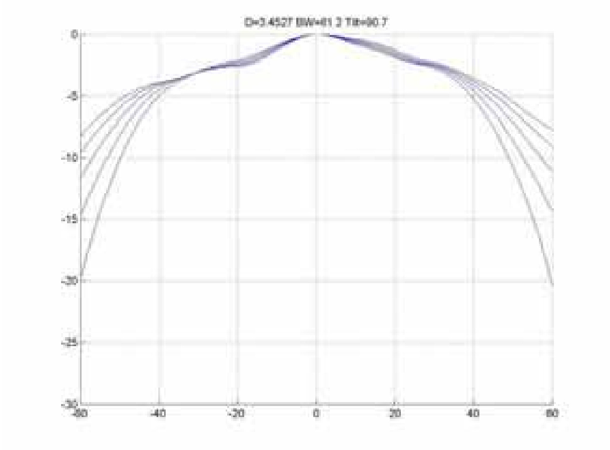

Fig. 6 Broadcast beam shapes with array element spacing. From top to bottom, five broadcast beam curves corresponding to spacings of 60 mm, 65 mm, 70 mm, 75 mm and 80 mm, respectively. The reduction of the edge power with ±60° are 8 dB, 10 dB, 11 dB, 15 dB and 20 dB, respectively.

III. THE DESIGN OF CALIBRATION NETWORK

Calibration network is necessary in TD-SCDMA smart antenna. In Fig. 7 (a) and (b), there are three layers of metal. From top to bottom, they are Copper (Port 1 to Port 2), Aluminum (second layer) and Copper (Port 3 to Port 4). This scheme is limited and only used in narrowband system. As for broadband dual -polarization, Fig. 7 cannot satisfy the directivity in the whole frequency band.

In our design, we used the patented calibration network technology [8]. The coupling degree of the calibration network is very stable, providing excellent directivity in practice. We have proposed some improvements such as adding the number of coupling holes from two to four. Based on the principle of a directive coupler, increasing the number of couplers can broad the bandwidth of the coupler. Simulation model with four coupling windows is shown in Fig. 8 and the simulation results are shown in Fig. 9.

From Fig. 9, it can be seen that the directivity is larger than 15 dB in the range of 1880 to 2400MHz. The line at the top represents the simulation results between Port 1 and Port 4 while the line at the bottom indicates the simulation results between Port 1 and Port 3.

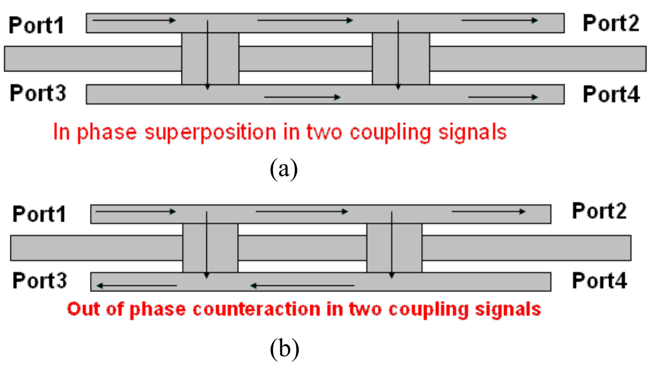

Fig. 7 Block diagram showing the operation

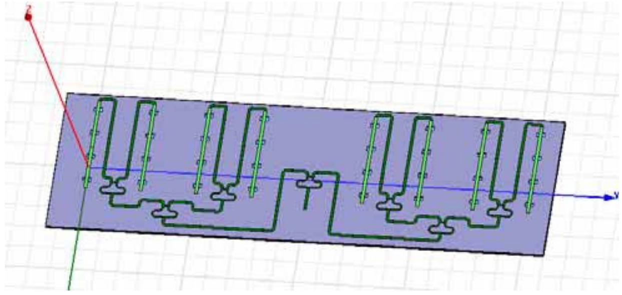

Fig. 8 The calibration network simulation model

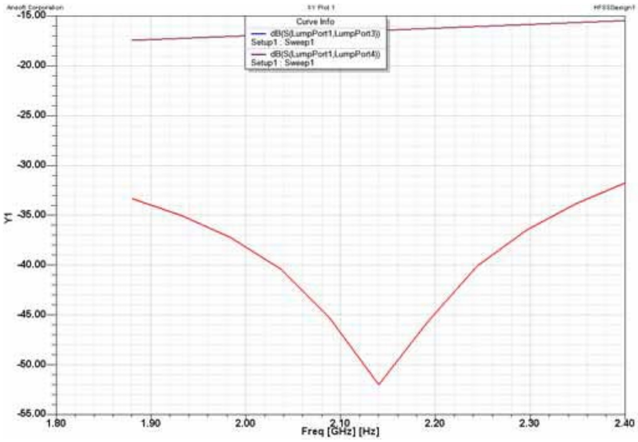

Fig. 9 Simulation results of calibration network with four coupling windows

IV. SIMULATION RESULTS OF THE PROPOSED ANTENNAS

The proposed antennas can cover three frequency bands of TD-SCDMA (i.e. A, B and C). Using the dipole in Fig. 2, we obtained the VSWR (Voltage Standing Wave Ration), isolation and cross polarization ratio performance, as shown in Fig. 10 to Fig. 12, respectively.

The advantages are as follows: the isolation is large and the cross polarization ratio is excellent. The impedance chart is shown in Fig. 10. The upper half of the diagram represents positive reactance values (inductive elements). The lower half of the diagram represents negative reactance values (capacitive elements). All the frequency band is located near the center of the circle. The nearer to the center of the circle the curve 1 is, the smaller the value of VSWR is. A perfect impedance match corresponds to a VSWR of 1:1 (In general, the VSWR of the mobile communication antenna is smaller than 1.5), but in practice, it is extremely difficult, if not impossible, to achieve it. Impedance matching means we will get maximum power transfer from source to load.

In Fig. 11, the isolation between antenna ports is shown to be larger than 30 dB. In Fig. 12, the cross polarization ratio in the axis also is greater than 28 dB and the cross polarization ratio (+60°/-60°) is larger than 10 dB. Finally, Fig. 13 depicts the exterior of a dual-polarization smart antenna designed by us.

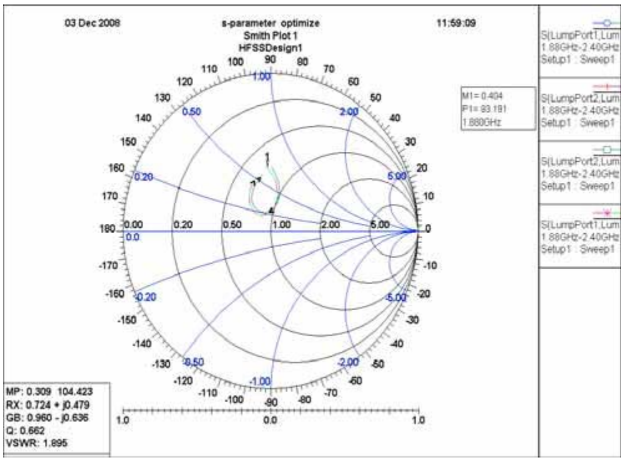

Fig. 10 Impedance chart

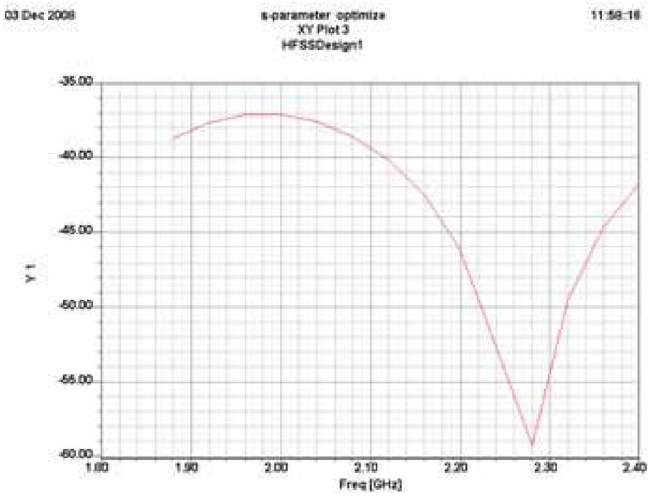

Fig. 11 Isolation

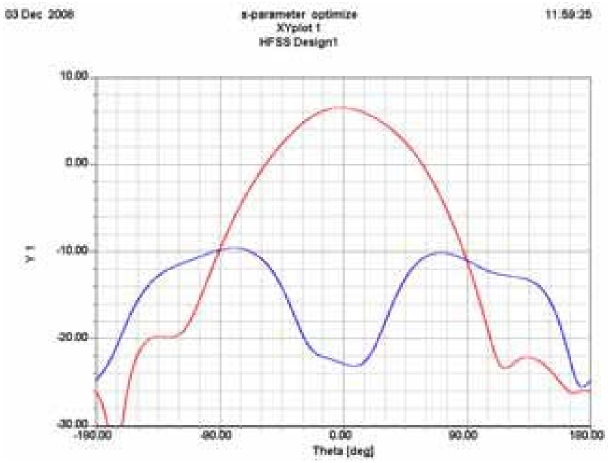

Fig. 12 Cross polarization ratio

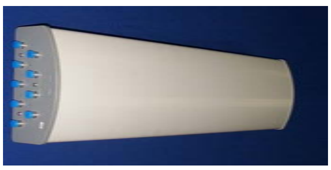

Fig. 13 A dual-polarization smart antenna

V. APPLICATION OF BROADBAND DUAL-POLARIZATION ANTENNAS IN THREE SECTOR CELL SITE

In a three-sector cell site, China Mobile Ltd. will adopt the scheme as shown in Fig. 14. In a base station, three broadband dual-polarization antenna are used in a TD-SCDMA frequency band. In future system, MIMO and smart antennas technologies will be integrated.

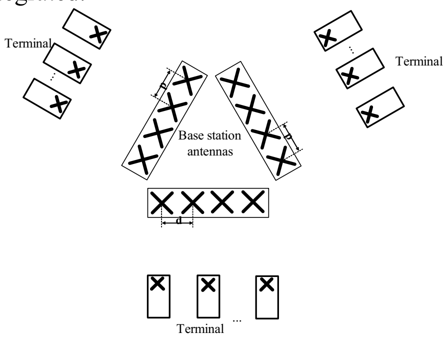

Fig. 14 Space division multiplexing of dual-polarization antennas

VI. CONCLUSION

In this paper, a dual-polarization TD-SCDMA smart antenna is studied. An appropriate array element spacing is selected and the principles of calibration network are briefly described. The simulation results of a +45°/-45° dual-polarization TD-SCDMA antenna are obtained. According to these simulation parameters, we manufacture the actual products. They will be used in the China TD-SCDMA system in the near future.

ACKNOWLEDGMENT

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