# Simulation and Implementation of A Single-Polarization Smart Antenna for TD-SCDMA System

Yejun He [1,2] , Tao Jiang [2] , Francis C.M. Lau [3]
1.College of Information Engineering, Shenzhen University, Shenzhen, P.R.China
2.Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology, Wuhan , P.R.China
3.Department of Electronic and Information Engineering ,Hong Kong Polytechnic University ,Hong Kong, China
Corresponding Author: heyejun@ieee.org

*Abstract*—**In this paper, the principle of a single-polarization smart antenna is introduced. By means of Ansoft HFSS and Microwave office, simulation results of a single-polarization smart antenna are shown. By using simulation results, the practical antenna is made and adopted in TD-SCDMA system.**

*Index Terms* ***-smart antenna; single-polarization; TD-SCDMA; radiation pattern***

## I. INTRODUCTION

Ministry of Industry and Information Technology of China (MIIT) handed out 3G licenses to China Mobile Ltd., China Telecommunications Corp., and China Unicom Ltd. on Jan 7 2009. As expected, China Mobile is to build a TD-SCDMA network, China Telecom a CDMA 2000 network, and China Unicom a WCDMA network. The operators are expected to spend tens of billions of dollars on building their new networks during the next few years.

Among the 3G standards, TD-SCDMA is only one standard in which smart antenna is used. Smart antenna is not only one key technique in TD-SCDMA but also one main difference from other 3G standards. For a TD-SCDMA system, a single-polarizatiom smart antenna has been widely employed recently. Smart antenna offers substantial benefits to the design of wireless mobile communications system such as increased antenna gain, interference rejection and diversity [1].

Smart antennas originated from the 1964 special issue, namely adaptive antennas[2]. Smart Antenna is in short for Smart Antenna System[3]. The system consists of antenna(s) and the associated digital control system. In reality, antennas are not smart but the antenna systems are. They are the smart people who know both antenna and control (and also the filter) theories to make the system intelligent or smart. Smart antenna is usually classified into two categories: omni-directional smart antenna and directional smart antenna[4].

Currently, the 2010MHz to 2025MHz frequency range (or frequency band) is used in TD-SCDMA network. The 15MHz bandwidth is relatively narrow for China with 1300 million population. In the future, it is to employ two other frequency bands of TDD in China. They are another primary TDD frequency range (1880MHz-1920MHz) and secondary TDD frequency range (2300MHz-2400MHz). If an antenna can fit the above three frequency bands or two frequency bands, antenna will not be complemented. The development direction of future smart antenna should be wide frequency band. China Mobile Ltd. has proposed the following requirements for smart antenna: dual-polarization, wide frequency band and electrically adjustable. Recently, China Mobile Ltd. has issued smart antennas bid results of the second phase in TD-SCDMA trial networks. MOBI antenna technologies (Shenzhen) Co.Ltd has obtained over 50 percent of the total shares in single-polarization smart antennas and dual-polarization smart antennas.

In this paper, the design of a single-polarization directional smart antenna is introduced. The rest of this paper is organized as follows. In Section Ⅱ, the principle of a single-polarization smart antenna is summarized. The simulation model is introduced in Section Ⅲ. The conclusion is in Section Ⅳ.

## II. PRINCIPLE OF A SINGLE-POLARIZATION SMART ANTENNA

In mobile communication systems, a single-polarization smart antenna is usually referred to as a single vertical polarization smart antenna. Experimental results show that the coverage effect of a single-polarization smart antenna is better than that of a 45° polarization smart antenna in open hills or rural areas with the mean level over 3dB-10dB. The main reason is that the antenna direction of handsets is vertical to ground while measured in a fixed place (Due to the cooperative action between shell and antenna of mobile phone, the polarization direction of mobile phone is not antenna direction but a little angle offset, which is concerned with the model of mobile phone and the hand's position on it). Therefore, the mobile phone vertical to the ground is very easy to match to the vertical polarization signal, however to rotate, this polarization matching is effective[5]. In open hills or rural areas, it is not easy for vertical polarization signal to induce polarization rotation. Consequently there are excellent coverage effect in above areas. However, for a $45^{\circ}$ polarization antenna, when the mobile user dials the number, it is easy to induce polarization mismatch or even orthogonal case. In the cities with many buildings, because the metal materials on buildings easily induce polarization rotation, there is no difference whether to employ antennas with a single-polarization or a $45^{\circ}$ polarization.

### *A. Principle of a single-polarization smart antenna*

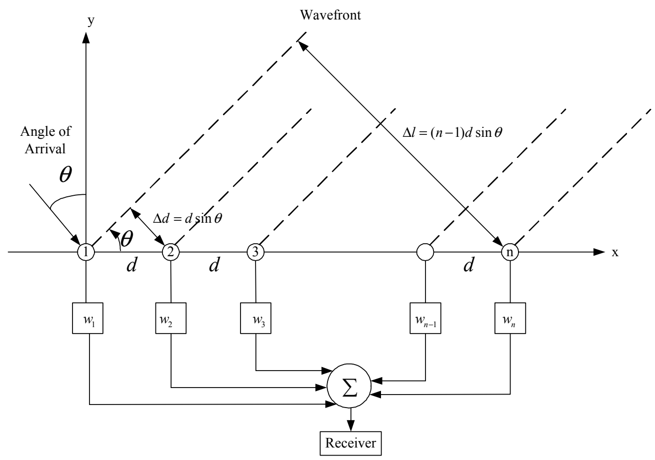


Figure 1. Smart antenna model

Although it may seem that smart antenna system is a new technology, the fundamental principles on which they are based are not new. We can explain the principle of single-polarization smart antenna using a simple example. In this example, we consider a uniform linear array (ULA) consisting of *n* identical antenna array elements as shown in Fig. 1. We assume that a signal *s(t)* is generated by a source in the far-field of the smart antenna. The impinging signal on the array is approximately a uniform plane wave. A wavefront from direction $\theta$ arrives at antenna array element 1. Then, after travelling an additional path distance $\Delta d$ , it arrives at antenna array element 2 where

$$\Delta d = d\sin\theta \tag{1}$$

With respect to array element 1, array element 2 experiences a time delay of

$$\Delta\tau = d\sin\theta / v \tag{2}$$

where *d* is the spacing between the two array elements and *v* the wave speed. That is to say, knowing *d* and measuring $\Delta\tau$ ,the angle $\theta$ of the direction of the arrival is obtained using

$$\theta = \arcsin(v\Delta\tau / d) \tag{3}$$

If *s(t)* is a narrowband signal with carrier frequency $f_c$ , then time delay $\Delta\tau$ corresponds to a phase shift of

$$\Delta\varphi = 2\pi \bullet \Delta d / \lambda = 2\pi d\sin\theta / \lambda \tag{4}$$

where $\lambda$ is the wavelength corresponding to the carrier frequency $f_c$, i.e., $\lambda = vf_c$ .Of course, if $\theta$=0, then both the time delay and phase shift between the two array elements are zero.

Assuming that all array elements are non-noisy and have identical gain in all directions, the received signal at the *n*th element is

$$u_n(t) = As(t)e^{-j(n-1)2\pi d\sin\theta/\lambda} \tag{5}$$

where *A* denotes an arbitrary gain constant. The steering vector of *N*-element ULA with spacing *d* between adjacent elements, as shown in Fig.1, is given by

$$a(\theta) = [1, e^{-j\frac{2\pi d}{\lambda}sin\theta}, e^{-j2\frac{2\pi d}{\lambda}sin\theta}, \cdots, e^{-j(N-1)\frac{2\pi d}{\lambda}sin\theta}]^T \tag{6}$$

where superscript "*T*" indicates the transpose of the matrix.

Once the steering vector for an array antenna is derived, its radiation pattern is formed by applying to each entry of the steering vector the excitation, in amplitude and phase, of the corresponding antenna element.

For clarity, the received signal at the receiver is

$$z(t) = \sum_{i=1}^{N} w_i u_i(t) = As(t)\sum_{i=1}^{N} w_i e^{-j(n-1)2\pi d\sin\theta/\lambda} \tag{7}$$

By means of adjusting the weights $\{w_n\}$ , the maximum radiation direction can aim at the desired user.

### *B. The normalized radiation pattern*

The normalized radiation pattern of an *N*-element ULA of omnidirectional elements with element spacing *d* is given in dB by

$$Y(\theta) = 10\log_{10}\left\{\frac{\left|\sum_{n=1}^{N} w_n \exp[-j(N-1)\frac{2\pi d}{\lambda}sin\theta]\right|^2}{\boldsymbol{W}^H\boldsymbol{W}}\right\} \tag{8}$$

where $\boldsymbol{W}$ is the *N*-dimensional vector consisting of the complex weights of the antenna elements.

## III. DESIGN OF A SINGLE-POLARIZATION SMART ANTENNA FOR TD-SCDMA SYSTEM

### *A. The Simulation Model*

As shown in Fig.2, the antenna is composed of eight column vertical linear array elements where each column consists of nine dipoles. According to design experience, we set two dipoles spacing to 130mm. Therefore, each column can construct one broadside array, as shown in Fig. 3. .

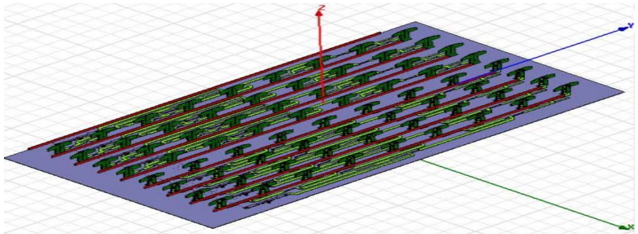

Figure 2. Combination arrays of eight column element

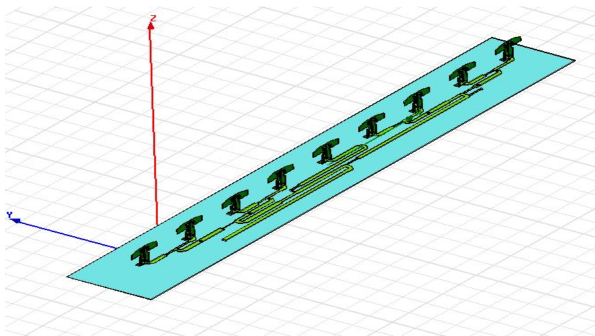

Figure 3. One column element array (nine dipoles)

*B. The Beamforming of Radiation Pattern in Elevation Plane*

*1) The object pattern*

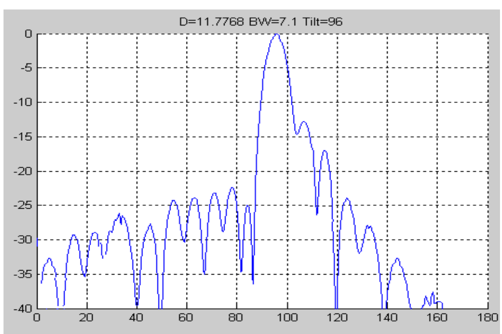


Figure 4. The object pattern

In cell mobile communication systems, as for elevation plane radiation pattern of a base station antenna, upper sidelobe suppression (USS) and lower null fill (LNF) are required. USS can reduce the interference with neighbour cells from local cell and null fill can prevent too much of the signal from overshooting the nearest part of intended coverage area. The object pattern of the whole antenna arrays is shown in Fig.4, where D denotes the directivity, BW is the beam width in degree. The reference direction of the Tilt is vertical direction.

*2) Simulation pattern*

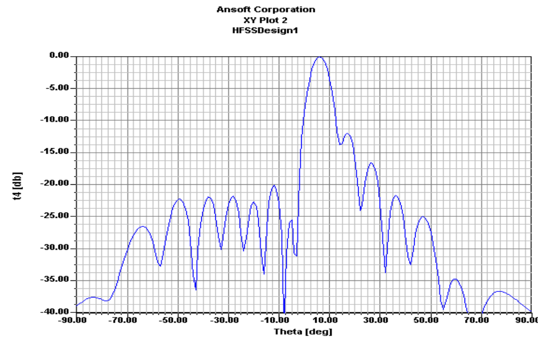


Figure 5. The simulation pattern

From the simulation pattern as shown in Fig.5, we can see that the BW of the main lobe is about 30 dB.

*3) The practical pattern measured*

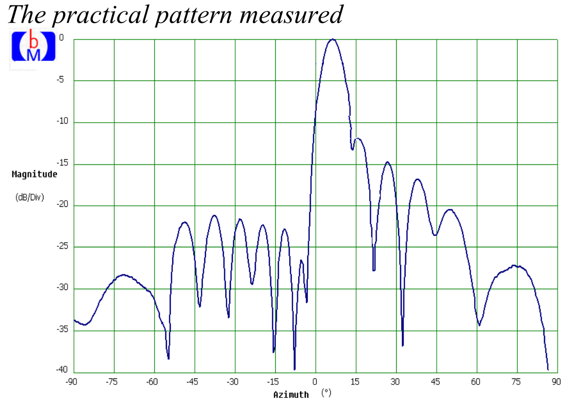


Figure 6. The practical pattern measured

We utilize the self-developed software package to plot the practical pattern as shown in Fig. 6.

Comparing the patterns as shown in Fig.4, Fig.5 and Fig. 6, it is found that the whole design, simulation and practical measurement data are very close. How to achieve excellent design requirements? The material and manufacture of cable-fed network is crucial. We select foreign-made LACM board and national F4Bm board. The dielectric constant of two kinds of materials is relatively low - 2.2. Their performance is very stable. Thus, the relative errors can be lowered at fixed absolute errors in manufacturing process of antennas. Currently, manufacturing techniques of PCB board is of high accuracy so that our products have excellent results.

*C. The Resultant Radiation Pattern and Beam Scanning in Horizontal Plane*

Beams of TD-SCDMA smart antennas include traffic beams and broadcast beams in horizontal plane. While it works in the broadcast channel, a directional smart antenna is similar to a conventional base station antenna. Coverage area of a directional smart antenna is usually $120^\circ$. Therefore, the broadcast beams with $65^\circ$ width are required to obtain the coverage in cell. When it works in the traffic channel, a directional smart antenna obtain a narrow traffic channel in order to implement directional coverage to terminals.

In TD-SCDMA system, there are two kinds of beamforming algorithms: grid of beam (GOB) algorithm[6] and eigenvalue based beamforming (EBB) algorithm. These algorithms aim to form spatial directional beams, in which the main beam (main lobe of radiation pattern) is steered toward the DOA of the desired user while nulls are created at the direction of interference. GOB algorithm is a kind of fixed beam scanning method, in which direction of beam is fixed for the fixed position's user. EBB algorithm is a kind of adaptive beamforming scheme, in which the figure of antenna radiation pattern is not fixed.

Figure 7 shows that the traffic beam with 0 degree left-tilt or right-tilt in horizontal plane is best in the various traffic beams for the resultant radiation pattern.

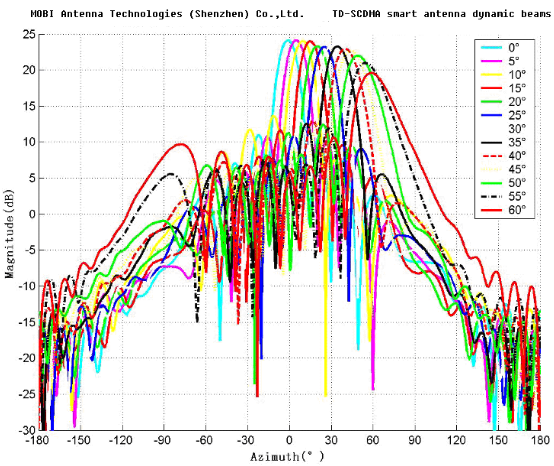


Figure 7. Beam scanning in horizontal plane

### D. The Broadcast Beam

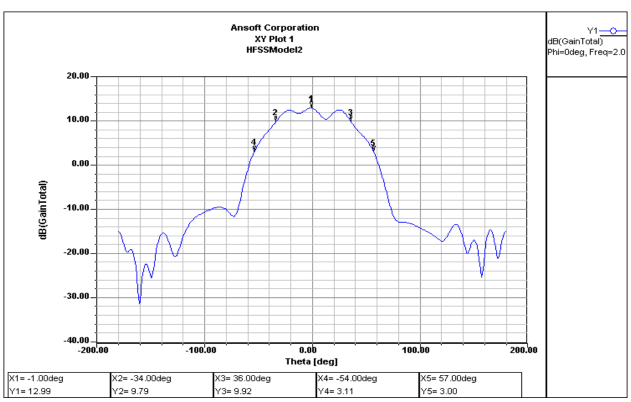


Figure 8. The broadcast beam in 2018 MHz

When the antenna is at the "sleep" stage, the antenna mainly perform a coverage. The different broadcast beams are required in various conditions, typically $65^{\circ}$ broadcast beam. In our simulation results as shown in Fig. 8, we use $65^{\circ}$ broadcast beam weight values as shown in Table 1. This antenna's gain at 0 degree is about 15dBi.

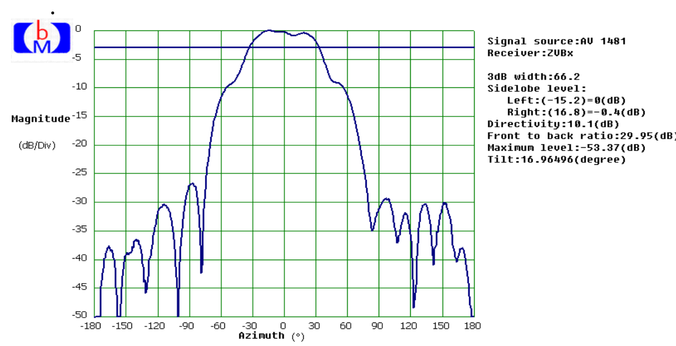


Figure 9. The practical broadcast beam

Using the weights similar to Table 1, we employ the experimental system to obtain the practical broadcast beam as shown in Fig.9. A single-polarization smart antenna's broadcast beam we made is shown in Fig. 10. This antenna is applicable to TD-SCDMA system in three-sector coverage.

Figure 10. A single-polarization smart antenna

## IV. Conclusion

In this paper, we described the principle of a single-polarization smart antenna for TD-SCDMA system. Simulation pattern and practical pattern are also given. The proposed single-polarization smart antenna includes eight column element arrays. Each column element array comprises nine dipoles. This kind of smart antenna has nine ports in total, in which the middle port is referred to as calibration port. Last year, a single-polarization smart antenna designed by us is widely used in Chinese TD-SCDMA system networks. In the near future, a single-polarization smart antenna will still exist with a dual-polarization smart antenna for a long time.

## Acknowledgment

This work was supported by 2008 Shenzhen-Hong Kong

Innovation Circle Project (No.08DF-02) and the National Natural Science Fundation of China (No.60872008). We would like to thank Xiaoqiang Hou from MOBI Antenna Technologies (Shenzhen) Co., Ltd for useful discussions and suggestions.

## REFERENCES

[1] Yejun He, Lei Huang and Xia Li (Translation). *Smart antenna engineering*. Publishing House of Electronics Industry, Beijing, 2008, August. (in Chinese).

[2] R.C. Hansen, "Special issue on active and adaptive antennas," IEEE Trans. Antennas Propagat., vol.12, no.2, pp.140-141, Mar, 1964.

[3] S.Bellofiore, C.A. Balanis, J. Foutz, and A.S. Spanias, "Smart-antenna systems for mobile communication networks:Part 1:Overview and antenna design," IEEE Antennas Propagat. Mag.,vol.44, no. 3, pp.145-154, June, 2002.

[4] http://www.computerworld.com/printthis/2003/0,4814,86668,00.html.

[5] S. Miller and J. Shapira, "Transmission Considerations for Polarization-Smart Antennas," the 51th IEEE VTC, May, 2001

[6] Savazzi, S.; Nicoli, M.; Sternad, M.; "A Comparative Analysis of Spatial Multiplexing Techniques for Outdoor MIMO-OFDM Systems with a Limited Feedback Constraint," IEEE Transactions Vehicular Technology, vol.58, no.1, 2009, pp.218 - 230 .

**Table 1.** 65° **broadcast beam weight values**

| Frequency range:1880MHz～1920MHz | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Port Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Amplitude | 0. 54 | 1 | 0. 85 | 0. 69 | 0. 69 | 0. 85 | 1 | 0. 54 |
| Phase(°) | 0 | −256 | −213 | −159 | −159 | −213 | −256 | 0 |
| Frequency range:2010MHz～2025MHz | | | | | | | | |
| Port Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Amplitude | 0. 54 | 1 | 0. 85 | 0. 69 | 0. 69 | 0. 85 | 1 | 0. 54 |
| Phase (°) | 0 | 100 | 154 | 202 | 202 | 154 | 100 | 0 |