Design and Simulation of Dipole and Cable-Fed Network of TD-SCDMA Smart Antenna[1]

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Abstract

This paper firstly proposed some considerations for cable-fed network and dipole design of TD-SCDMA smart antennas. Secondly, we constructed an eight-element linear antenna array. In this antenna array, electronic tuning downtilt angle is set as zero degree. Half-wave dipole, cable-fed network as well as fiber reinforced plastics radome are used. The proposed model is simulated by Ansoft HFSS software. Simulation results show that this dipole can obtain better bandwidth and radiation specifications. Combined-dipole antenna array is also consistent with standard of TD-SCDMA smart antenna.

1. Introduction

TD-SCDMA [1], which stands for Time Division Synchronous Code Division Multiple Access, is the Chinese specification for third generation (3G) wireless mobile services. TD-SCDMA has been another 3G technology which is adopted by ITU and by 3GPP as part of UMTS release 4, becoming in this way a global standard, which covers all radio deployment scenarios. TD-SCDMA combines an advanced TDMA/TDD system with an adaptive CDMA component operating in a synchronous mode [2]. TD-SCDMA smart antenna is also designed in China. According to the number of elements, TD-SCDMA smart antenna is classified into three groups: eight-element, six-element and four-element. In each group, there are four kinds of downtilt angle: zero degree, three degrees, six degrees and nine degrees. Recently, eight-element antenna and six-element antenna with downtilt angle of zero degree are widely used by base station manufacturers. Since eight-element antenna has two additional elements compared to six-element antenna array, the performance of eight-element antenna, which is easy to be controlled, is better than that of six-element antenna. But eight-element antenna array is more expensive than six-element antenna array. The windward area of the former is bigger than that of the latter, which results in the difficulty of installation. Thus, the intensity of antenna pedestal and poles has very high requirements. This paper proposed an eight-element antenna with downtilt angle of zero degree. Recently, most of the tested antenna is an eight-element antenna.

The rest of this paper is organized as follows. The antenna selection scenarios, including dipole, cable-fed network as well as radome, are summarized in Section 2. The simulation model is introduced in Section 3. Design of amplitude and phase of cable-fed network of TD-SCDMA smart antenna is described in Section 4. The conclusion is in Section 5.

2. Antenna array selection considerations

2.1. The consideration of dipole antenna

If the dipole type is properly selected and well designed, the antenna array can be successfully designed. The following several aspects need to be considered. Firstly, it is space and shape of dipoles.

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The spatial distance between two elements of TD-SCDMA smart antenna is seventy five centimeters, which results in narrow space of antenna array. Because the cable needs to be placed among the dipole, the space of dipole type needs to be considered. Secondly, we need notice the effect level between dipoles, also named as coupling degree. This parameter cannot be deduced by mathematic analysis. In general, It is obtained through relative measurements. In different environments and different frequencies, the coupling degree between dipoles is different [4] . Thirdly, it is dipole's implementation which needs to be integrated with other specifications. Finally, the component materials of dipoles also need to be noticed. Copper and aluminium are widely-used materials of dipole. Copper has big mass and high price, but it is easy to be welded. Aluminium's price is relatively low and its mass is light, but it needs to be plated with a layer of copper, zinc or silver as welded.

2.2. The consideration of the cable-fed network

Due to vertical planar beamforming, antenna array requires multi-dipoles. A specific amplitude and phase of signals needs to be fed into each dipole in order to get a specific beamforming. This can be done by a cable-fed network. Up to now, the cable-fed network has three classifications: a coaxial line, an air microstrip line and a printed circuit board. The coaxial line cable-fed network is composed of many coaxial lines with different impedances. Signal intensity is predefined by adjusting the impedance value of arriving at each dipole. Signal phase is implemented by designing the path length of travelling signal. Characteristic impedance of coaxial line is determined by the size and spacing of the conductors and the type of dielectric used between them. However, the shortcoming of coaxial line cable-fed network is the lack of adequent amplitude distribution due to few impedance values. Air microstrip network can perform any amplitude and phase distribution. Due to air dielectric, transmit signal attenuation of air microstrip network is small and its cost is very low. However, air microstrip network is not stable, i.e., it is easy to suffer from interference of other signals due to its open structure. In addition, air microstrip network can also interfere with other electronic devices. Printed circuit board network overcomes the shortcomings of air microstrip network, however, the cost is very high.

2.3. The radome

For the radome of antenna, there are some considerations as follows.

1) The radome's impact on antenna electric performance.
2) The radome's construction intensity.
3) The radomer's sealing characterization.
4) Material's maturing problem.
5) Material's cost.

The radome of antenna usually employs two kinds of materials which are PVC and fiber reinforced plastics. PVC is common plastics, but fiber reinforced plastics are made from plastics with fiber and minerals. Therefore, the price of fiber reinforced plastics is high. Its construction is stable and not easy to be deformed.

3. Modelling and simulation of dipole of TD-SCDMA smart antenna

3.1. Dipole and one-element antenna array design

In terms of above considerations, we design an eight-element smart antenna array. Firstly, we design an dipole. Here, a half-wave symmetrical dipole is employed. Based on 1880 to 2025MHz working frequency range, we calculate the length of half-wave symmetrical dipole.

$$\begin{aligned} \textit{Center frequency} &= \sqrt{\textit{upper bound frequency}} \\ &\times \sqrt{\textit{lower bound frequency}} \\ &= \sqrt{1880 \times 2025} \approx 1950 MHz \end{aligned} \quad (1)$$

$$\textit{Center frequency wavelength} = \frac{c}{\textit{Center frequency}} \quad (2)$$

$$= \frac{300}{1950} \approx 0.15m$$

where c represents velocity of light.

Due to shorten effect, we take the length of dipole as 74 mm, the height as 35 mm. In the meantime, we set dipole material as aluminium board with the thickness of 1.5 mm. Dipole simulation mode is shown in Fig.1.

The stimulation signal with impedance of 50 Ohms is fed into symmetrical dipole via cable-fed chip. Through magnetic field's coupling, dipole gets stimulation signals from cable-fed chip. Adjustting shape of cable-fed chip and dipole, dipole obtains better bandwidth and radiation specifications.

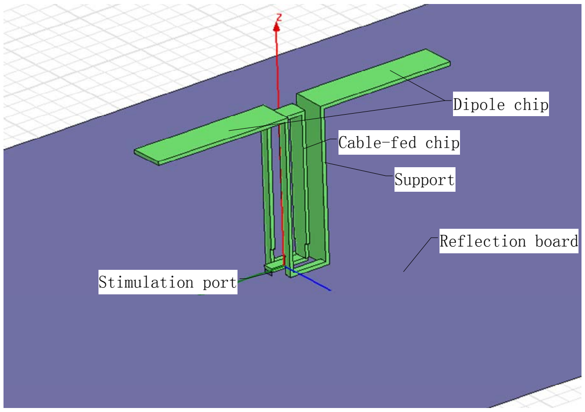

Fig.1. Dipole simulation model

This model is simulated by Ansoft HFSS software. Its simulation results are shown in Fig. 2-4.

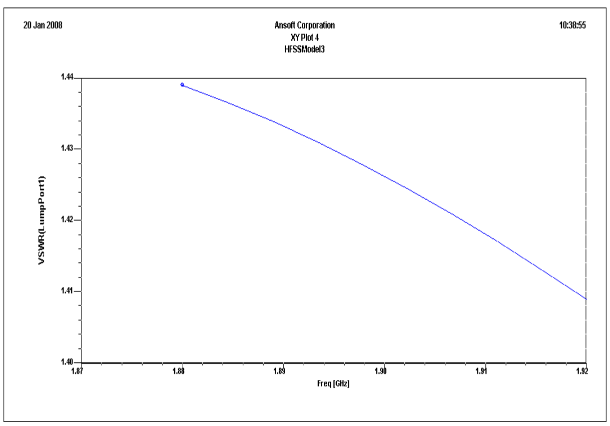

Fig.2. VSWR of dipole at 1880 ~ 1920MHz

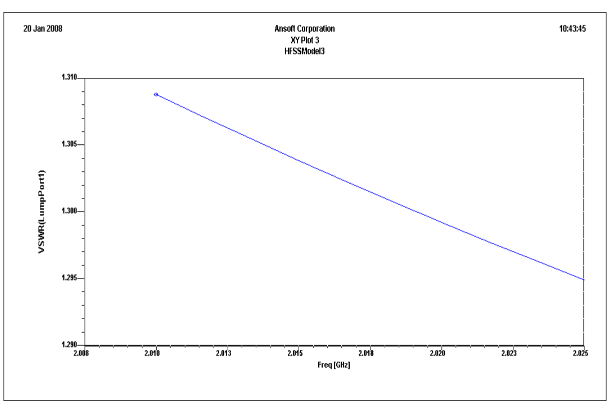

Fig.3. VSWR of dipole at 2010 ~ 2025 MHz

In Fig.2 and Fig.3, VSWR means voltage standing wave ratio which can be expressed in terms of the load and characteristic impedances. The VSWR is a figure of merit for impedance match (or mismatch). A perfect match is represented by a VSWR of 1.0:1, while a worse-case mismatch is represented by an infinite VSWR of ∞ : 1.

From Fig.2 and Fig.3, we can see that the VSWR of this dipole is lower than 1.44 in entire working frequency range. This can satisfy common antenna requirements of VSWR <1.5.

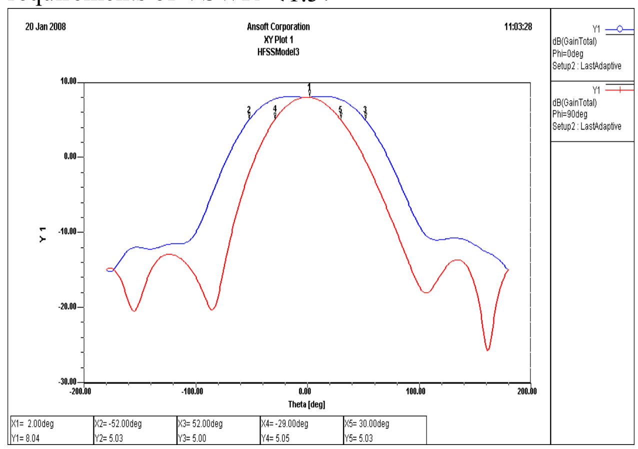

Fig.4. Gain at 2018MHz

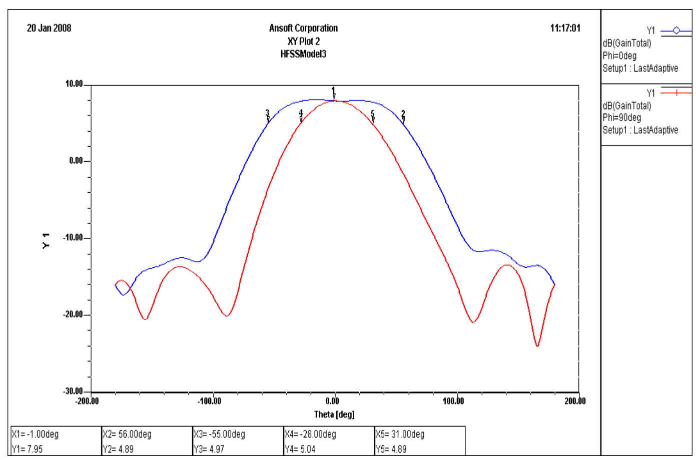

Fig.5. Gain at 1900MHz

Due to this antenna operating frequency range of 1880-1920MHz and 2010-2025MHz，it is adequate to investigate the center frequency of two frequency bands.

From Fig.4 and Fig.5, it can be seen that the gain of single dipole is 8dBi. In terms of gain superposition principle, the gain of dipole can improve 3dBi as number of dipole has doubled. Taking attenuation into consideration, nine dipoles can be lined. Thus, single column antenna with nine dipoles obtain a gain of

15dBi. One element antenna array with nine dipoles is shown in Fig.6. Based on design experience, we take spatial distance of 130 mm between two neighbour dipoles .

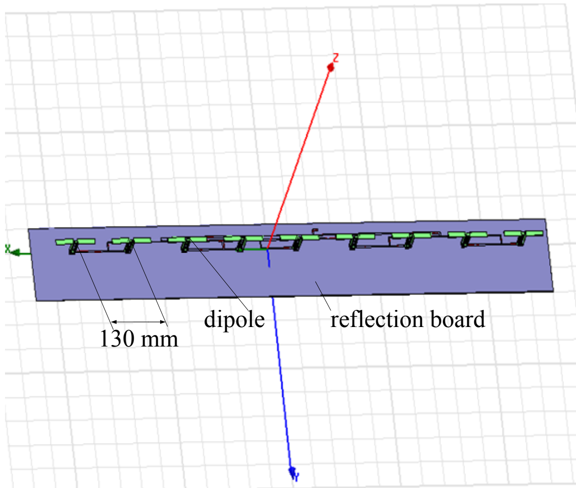

Fig.6.One element antenna array with nine dipoles

3.2. Combination of eight-element antenna array

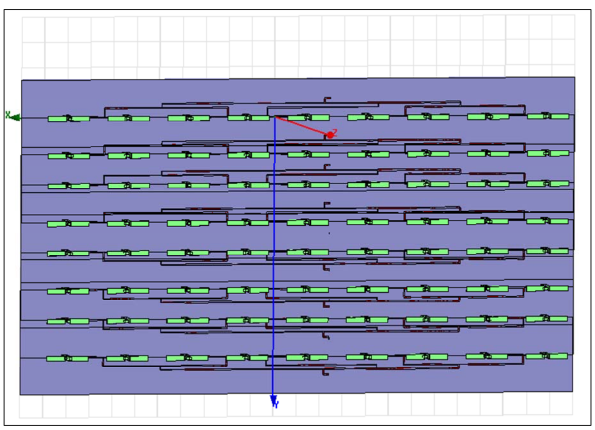

Fig.7.Combination of eight-element antenna array

In Fig. 7, combination of eight-element antenna array is given.

4. Design of amplitude and phase of cable-fed network of TD-SCDMA smart antenna

4.1. Amplitude and phase of one-element antenna array

The following is specific step to get required XOZ planar radiation pattern[3]: Firstly, we set a predined curve $f(\theta)$, where θ denotes a polar angle corresponding to a dot on a curve in XOZ plane. θ is between -90° and 90°.

$f(\theta)$ can be discretized into $f(\theta_1), f(\theta_2), f(\theta_3),..., f(\theta_{179}), f(\theta_{180})$,which are 180 line segments. $f(\theta_1)$ is a horizontal line segment between -90° and 89°. $f(\theta_2)$ is a horizontal line segment between -89° and 88°.

$\overline{E}(A,\phi,\theta)$ denotes far field radiation pattern of one element array, where A is a set of amplitude values which supply to nine dipoles, ϕ is a set of phase values which supply to nine dipoles. Similar to $f(\theta)$, $\overline{E}(A,\phi,\theta)$ can be discretized into 180 line segments:

$$\overline{E}(A,\phi,\theta_1), \overline{E}(A,\phi,\theta_2), \overline{E}(A,\phi,\theta_3),..., \overline{E}(A,\phi,\theta_{179}), \overline{E}(A,\phi,\theta_{180})$$

Let

$$\begin{aligned} D &= [f(\theta_1)-\overline{E}(A,\phi,\theta_1)]^2 + [f(\theta_2)-\overline{E}(A,\phi,\theta_2)]^2 + \cdots \\ &+ [f(\theta_{180})-\overline{E}(A,\phi,\theta_{180})]^2 \\ &= \sum_{i=1}^{180}[f(\theta_i)-\overline{E}(A,\phi,\theta_i)]^2 \end{aligned} \quad (3)$$

If arrays A and ϕ can minimize D, then A and ϕ are required amplitude values and phase values, respectively. Using Matlab programming, a set of arrays can be calculated:

$$A=\{0.5 \quad 0.5 \quad 0.5 \quad 0.7 \quad 0.7 \quad 0.8 \quad 1 \quad 0.6 \quad 0.5\} \quad (4)$$

$$\phi=\{6 \quad -10 \quad -3 \quad 6 \quad 0 \quad 18 \quad 8 \quad -7 \quad -34\} \quad (5)$$

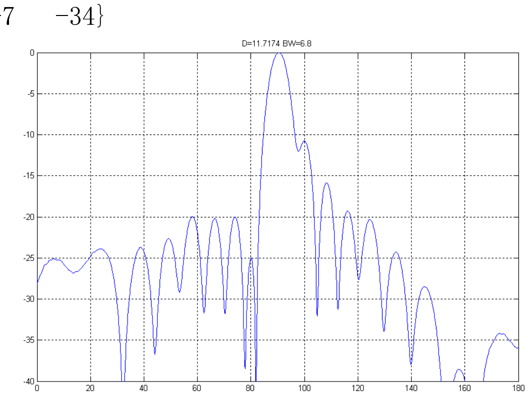

Fig.8 Radiation pattern at 1900MHz

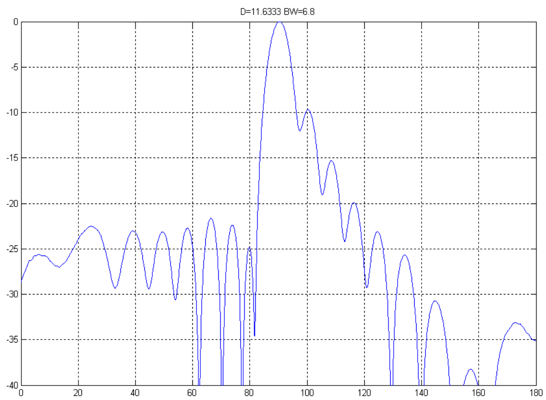

Fig.9 Radiation pattern at 2010MHz

From Fig.8 and Fig.9, it can be seen that first null beam width in upper vertical plane is -25dB which is much greater than TD-SCDMA smart antenna standard (i.e.-16dB).In addition, other sidelobe is below -20dB. The first null stuff in below vertical plane is -13dB which greater than -18 dB [5] .

4.2. Design of feed line

Microwave office software is usually used in design of feed line. Due to not considering field effects, spatial distance must be maximum between feed lines. To obtain antenna gains, we employ WANGLING PCB board with a thickness of 1 mm and a dielectric constant of 2.55.

5. Conclusion

In this paper, Dipole simulation model and combination of eight-element antenna array have been proposed to construct TD-SCDMA smart antenna. Some common design rules are also proposed. In design process of dipole, due to this antenna operating frequency range of 1880-1920MHz and 2010-2025MHz, it is adequate to investigate the center frequency of two frequency bands. In terms of specific weights of amplitude and phase of one-element antenna array, radiation pattern in XOZ plane is obtained. The proposed simulation results also conform to TD-SCDMA smart antenna standard.

6. References

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