The design of UWB Antenna for Mobile Phone and the Antenna Influence on Human Head Model

Ping Lanlan, Wu Dongsheng, Peng Jinhua, Jin Haihong, Zhang Jing

(*School of E&IE*, *Anhui JianZhu University*, *Hefei* 230601, *China*)

Abstract: In order to improve the performance of the antenna at low frequency, short circuit branch and coupling feed structure are introduced into the folded broadband single antenna in this paper, then resonant frequency is merged into the antenna using method of stagger tuning, finally, a UWB antenna is designed to work between 800MHz~2700MHz. Analysis are conducted to determine the antenna's properties. The short-circuit wire location, feeding point location and the length of folded strip are discussed in detail. The SAR is calculated by HFSS simulation software while the antenna is close to a 3D human head model. The research results show that the antenna can cover eight commonly used commercial frequency bands at present, and electromagnetic radiation of the antenna has tiny influence on the human head model.

Keywords: UWB; Mobile Phone Antenna; HFSS; Human Head; SAR

1 Introduction

With the development of mobile communication, the consumers have an increasingly demand on functions of the mobile phone, such as high rate data transmission, Bluetooth, GPS positioning, wireless network and 4G LTE. So the design of UWB antenna has a very important research significance. At present, there are nine commonly used commercial frequency bands, including GSM 850 (824-894 MHz), GSM 900 (880-960 MHz), GPS (1575MHz), DVB-H US (1670-1675MHz), DCS (1710-1880MHz), PCS (1850-1990MHz), UMTS or 3G (1920-2175MHz), Bluetooth or WLAN 802.11b/g (2400-2484MHz) and WLAN 802.11a (5150-5875 MHz)[1]. Probably all of these frequency bands will be integrated into a single mobile phone in the near future. Because of the lowest frequency of UWB antenna is determined by the size of the antenna, how would design the antenna with a sufficient bandwidth in a limited space is the bottleneck in mobile phone industry. On the other hand, with the continuous improvement of people´s health consciousness, people have paid close attention to electromagnetic radiation of mobile phone to the body, especially the influence on the head part. Therefore, the United States and many European countries developed their own SAR standards[2]. The authors designed and produced a novel UWB mobile phone antenna referring to the relevant literature[3-5]. The size of the antenna is compact and has a wide bandwidth from 800MHz to 2700MHz, with high radiation efficiency and little influence to the human body. The novel UWB antenna is suitable for small size mobile communication systems with good prospects, such as smart phones, tablet PC, etc.

2 Antenna Structure

UWB antenna can effectively avoid the resonance frequency to deviate from working frequency range due to the role of the human body. At the same time, UWB antenna can cover various frequency bands of mobile communication and save enough space for development of mobile phone functions[6-7]. At this stage, many famous companies in the mobile phone industry, such as Apple and Samsung, had started to study the application of UWB antenna in mobile phone. Figure 1 shows that the structure and size of the UWB mobile phone antenna, the unit is millimeter. The copper is printed on the FR-4 dielectric substrate that the dielectric constant is 4.4. The antenna size is 55mm * 15mm * 7.8 mm, and the ground floor size is 90mm * 55mm. Stagger tuning method[8] is used in order to broaden the bandwidth of the antenna impedance width, which means a more wide impedance bandwidth is formed by combining many different but similar resonant frequencies. However, the existing literature schemes can only cover the high or low frequency band in the mobile communication field, and the corresponding bandwidth is just enough. In this paper short-circuit wire and coupling feed structure are introduced on the base of stagger tuning, which can greatly improve the impedance bandwidth. The distance from the feed point to the end of the folded band is 43.8mm, about 1/4 wavelength of the 1.6 GHz. It improves the antenna impedance characteristics in the middle frequency band. Meanwhile, the cutting angle on the folded radiation surface makes the antenna more smooth and open, it also improves the performance of the whole frequency band.

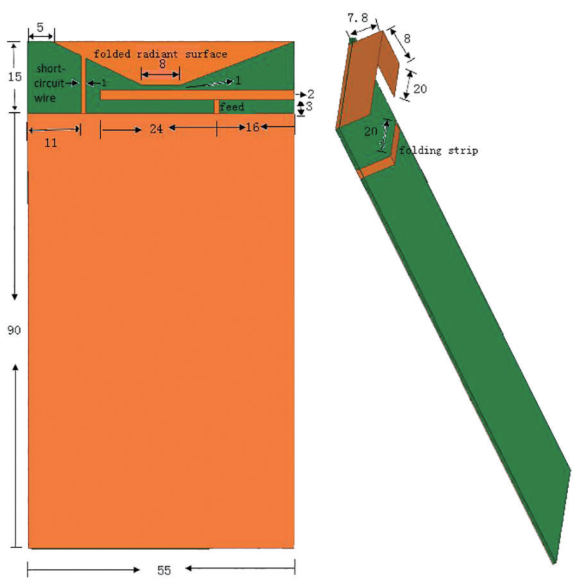

Fig. 1 The structure and size of antenna

3 Results and Analysis

The S parameters of the antenna reflect the matching between the input impedance and the feed. Generally speaking, S_{11} requires less than -10dB, but due to the complexity of the environment around the mobile devices, it can be reduced to below -6dB. Figure 2 shows that the S_{11} curve of the antenna which is obtained by the simulation after several times of optimization. From the figure, it can be seen that the antenna covers the whole frequency band of 800MHz ~ 2700MHz, and a new resonance at 1.9GHz is introduced which increases the whole impedance bandwidth. Thus, this kind of antenna can achieve a good application in 4G LTE.

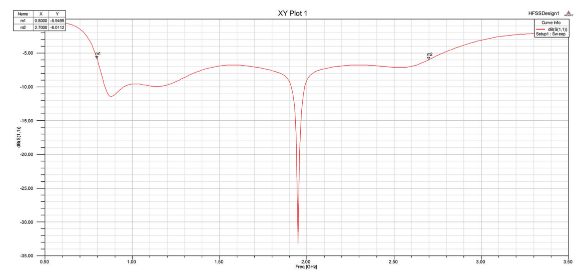

Fig. 2 S_{11} curve of the antenna

Figure 3 shows that the influence of the short-circuit wire position change on the S_{11} curve. When the distance changes from the short circuit to the edge of the antenna, the low frequency band of the S_{11} curve is obviously changed, but the change of the high frequency band is not obvious. When the distance is 9mm, the lowest frequency can reach 760MHz, and with the increase of the distance, the low-frequency stage gradually moves to the right. Thus, it can be seen that the position of the short circuit determines the lowest operating frequency of the antenna. Figure 4 shows that the effect of the feed point position change on the S_{11}. From the image, it can be seen that the change of the feed position has a great influence on the resonant frequency. Hence, the feed point location is very important, it should be selected carefully. The influence of the length of the folded strip on the S_{11} curve is given in Figure 5. It can be seen from the figure that the new resonance point of the middle frequency band is mainly affected by the length of the folded strip. The longer the length of the folded strip is, the new resonance point is shifted more to the lower frequency point. This is because the length of the folded strip corresponds to the 1/4 wavelength of the new resonant frequency. Figure 6 is the gain of the antenna, and the main radiation direction is XOZ plane. The maximum radiation gain reaches 5.2dB, and the radiation efficiency of the antenna is as high as 99.82% in free space.

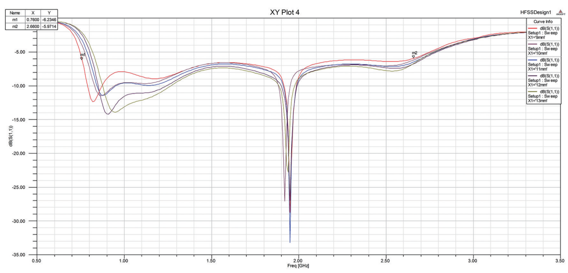

Fig. 3 S_{11} curve of the short-circuit wire position change

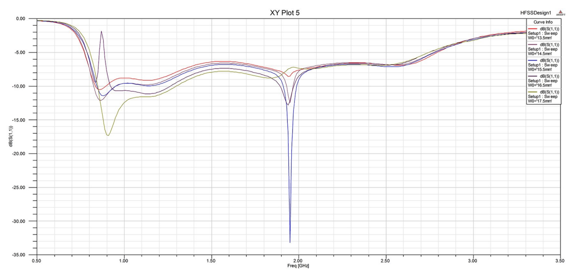

Fig. 4 S_{11} curve of the feed point change

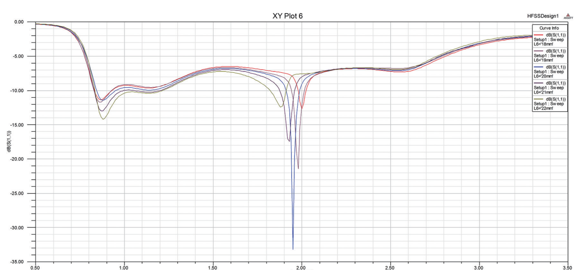

Fig. 5 S_{11} curve of the folded strip length change

The radiation patterns of the XOZ plane and XOY plane of the antenna at 1800 MHz aregiven in Figure 7 and figure 8. The radiation patterns show that the antenna has good directivity and polarization characteristics, which can meet the requirements of current intelligent mobile terminals.

In order to verify the simulation validity, a 0.3 mm-thick copper is used to produce an antenna, as shown in Figure 9, according to the optimization simulation parameters of the antenna. The measured S_{11} curve is shown in Figure 10, with -6dB as the reference, 800MHz-2600MHz as the measurement bandwidth, which is consistent with the result simulation. The simulation infers that the design of the antenna can meet the requirements of practical application.

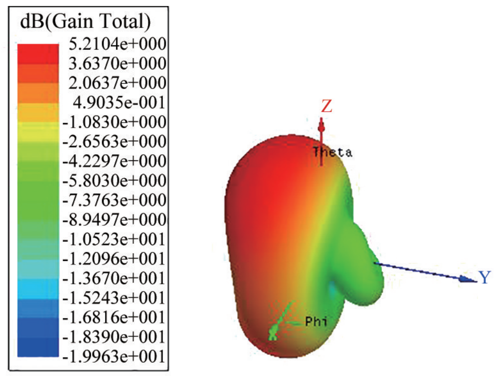

Fig. 6 The gain of the antenna

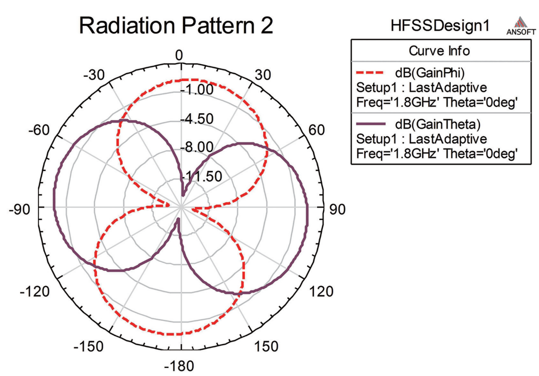

Fig. 7 XOZ plane at 1800 MHz

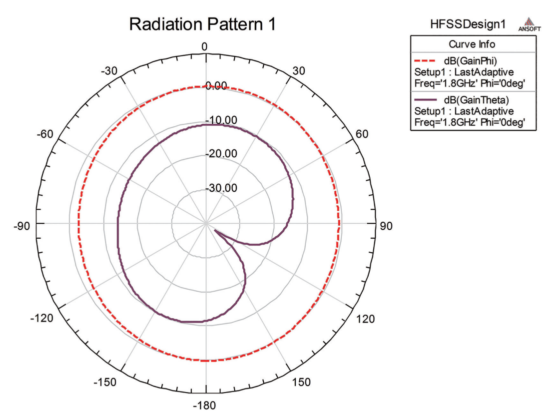

Fig. 8 XOY plane at 1800 MHz

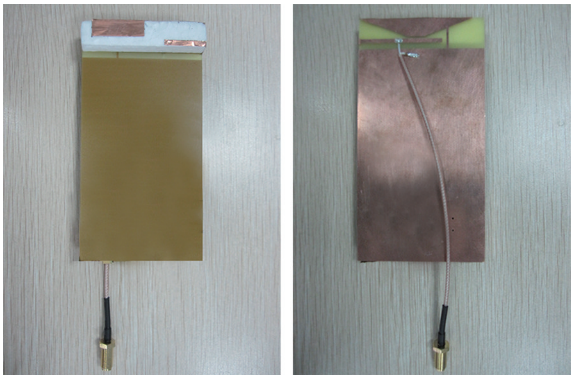

Fig. 9 (a) The front of the antenna; (b) The back of the antenna

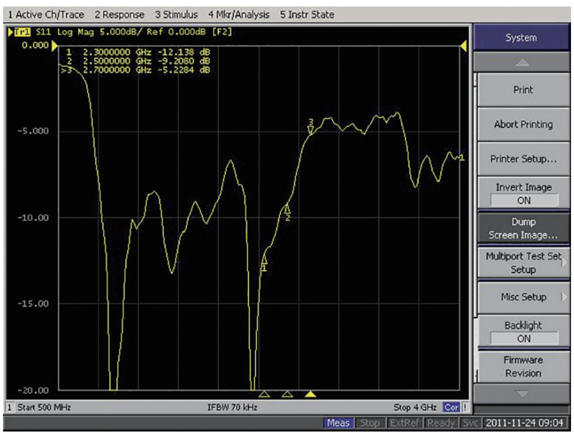

Fig. 10 The measured S_{11} curve

4 The Antenna Effect on Human Head Model

At present, while smartphones, tablets and other mobile devices bring a variety of convenience to people's life, concern regarding to the danger of electromagnetic radiation are generated. Under the action of the external electromagnetic field, the human body will produce induction electromagnetic field. Because the human body is a lossy medium, the electromagnetic field in the body will produce current, which leads to the absorption of electromagnetic energy. Commonly, SAR (Specific Absorption Rate)[9] is used to represent the biometric characterization. SAR expresses the electromagnetic radiation energy absorbed by the body tissue with the unit mass, the unit is W/Kg or mW/g.

Forhandheld devices that need to be close to the head, such as mobile phones, it is especially concerned about the electromagnetic radiation to human head during the design of antenna. In this paper, the HFSS software is used to build a 3D head model, and the mobile phone UWB antenna acts on the head. The head is a hemispherical model, which is composed of a shell and a brain tissue fluid. The relative dielectric constant of the shell is 4.6, the loss tangent is 0.01, and the radius is 111.5mm. The relative dielectric constant and loss angle tangent of the brain tissue fluid are 41.5 and 0.9, and the radius is 106.5mm. The distance between the UWB antenna and the shell is 5mm. The local SAR and the average SAR in the brain tissue fluid are simulated, shown in Figure 11. From the picture, it can be seen that the SAR is maximum near the brain tissue, the maximum local SAR reaches to 25.9 W/Kg, and the average SAR reaches to 15.8 W/Kg. With the increase of distance, the SAR value decreases rapidly and eventually reduces to 0. Figure 12 shows that the distribution of electric field in the brain tissue fluid model, and the distribution of electric field is consistent with the change of SAR. The model of the test system is relatively simple, only considered the SAR value of the brain tissue fluid model. Because the relative permittivity and conductivity of the brain tissue fluid are relatively large, the SAR values is relatively high on the surface of the head, but the values decreases rapidly in the interior. If modeling the head according to the medical anatomy, the simulated SAR values will be much smaller.

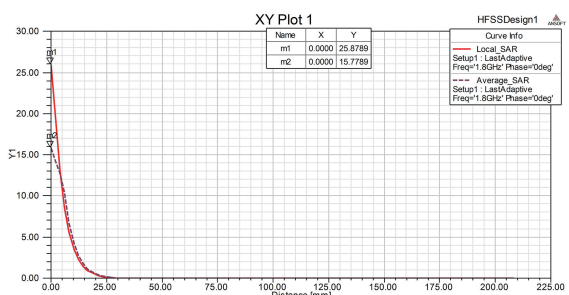

Fig. 11 The local SAR and the average SAR

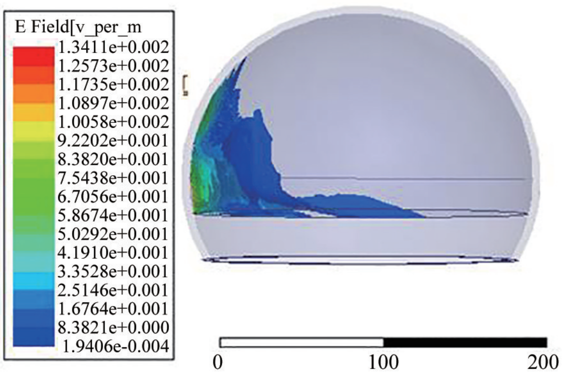

Fig. 12 The electric field in brain tissue fluid

In order to verify the influence of the antenna on human body, the authors compared the SAR value with the dipole antenna test calibration system[10], shown in Table 1. It can be seen from the table that the UWB mobile phone antenna has a smaller local SAR value and average SAR value, and the radiation efficiency is higher on the head model. This indicates that the head absorbs less electromagnetic radiation with the UWB antenna, and the harm to human body is much less, so the transmitter power of the antenna can be better utilized, saving energy consumption and improving standby time of mobile phones. Therefore, it has substantial benefits for users.

Table 1 SAR value and radiation efficiency of the antennas

parameter / antenna	the maximum local SAR	the maximum average SAR	radiation efficiency
dipole antenna	29.1	20.9	42.2%
UWB antenna	25.9	15.8	54.8%

5 Conclusion

In this paper, a UWB mobile phone antenna is designed which can cover the commercial eight frequency bands in the present communication domain, and the absolute bandwidth is up to 1.9GHz. In addition, the antenna has the advantages of small size, simple manufacture and high radiation efficiency, which are very suitable for the use of modern mobile terminal equipment. Considering the influence of electromagnetic radiation on human head, the three-dimensional head model is simulated by HFSS software, and the SAR value of the UWB antenna is also calculated. By comparing with the dipole antenna, the UWB antenna has a lower SAR value, which means less harmful to the human body.

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Authors' Biographies

Ping Lanlan received master´s degree from Nanjing University of Aeronautics and Astronautics in 2010. Now she is a lecture in Anhui JianZhu University, Her main research direction is antenna design.
E-mail: 18756096109@sina.cn.

Wu Dongsheng, is a professor in Anhui JianZhu University, His main research interests is electromagnetic field theory and antenna design.
E-mail: dongsheng_w@ahjzu.edu.cn