APPLICATION OF PHYSICAL KNOWLEDGE IN SIMULATION DESIGN HFSS SOFTWARE MICROSTRIP 5G ANTENNA

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Abstract

Nowadays, in the development trend of integrated circuits and wireless telecommunications technology, the use of antennas with small size, stable structure and high frequency selection characteristics such as microstrip antenna is an optimal solution. This paper presents some basic research results on 5G microstrip antennas operating in the 28Ghz frequency band, including theoretical calculations (based on physical methods of transmission and material selection). electromagnetic data when designing antennas), using HFSS (High Frequency Structure Simulator) software to simulate the antenna's characteristics, compare some measurement results when calculating and simulating.

Key words: Microstrip antenna, Rectangular microstrip antenna, Electrical materials for antenna design, Microstrip antenna design, Microstrip antenna design simulated by HFSS software, Microstrip antenna design at 28 GHZ band.

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1. Introduction

In recent years, information technology and data transmission have made strong technical changes, from the wired digital circuit interconnections of the 1980s, now gradually becoming information communication systems. Radio data combined with digital signal processing methods allows for longer communication distances against stronger background noise, lower transmit power and wider communication frequency range.

One of the factors to improve this information quality is the small size of the transceiver antenna system and the wide frequency range, in which the basic element being researched is a microstrip antenna[1]. The strength of the microstrip antenna compared to other common antennas is the stable structure and especially suitable for the microstrip technology currently being used to manufacture printed circuits and specialized ICs. The band is also very suitable for antenna array structure, allowing to increase gain, directivity and moreover, it is possible to combine signal processing algorithms to form smart antennas in CDMA systems. [2].

The article has limited content in investigating the characteristics of single microstrip antenna, which is structured on a dielectric plate, has low dielectric coefficient, theoretical and physical properties, and algorithms. and simulation results of characteristics and field distribution of 5G microstrip antennas operating in the 28Ghz frequency band and some designs in practice. Performance testing on actual antenna samples is measured and compared with theoretical simulation results.

2. Microstrip antenna characteristics [1]

The microstrip antenna shown in figure 1 consists of a very thin metal patch of thickness $t \ll \lambda_0$ with a wavelength in free space placed a very small distance from the ground plane ($h \ll \lambda_0$ is usually then the faceplate and the earth plane are separated by a substrate

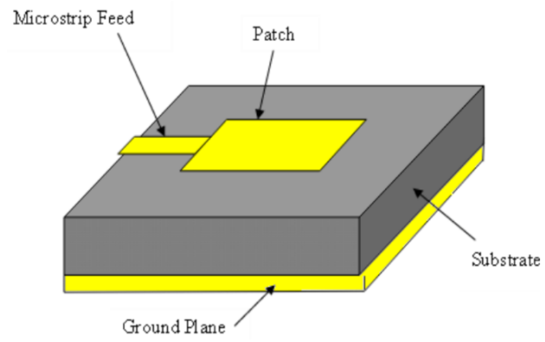


Figure 1. Microstrip antenna structure

The shape of the microstrip antenna can have many forms, including rectangular, square, round, ellipse, and donut faceplates, etc. However, the most common type is the rectangular faceplate antenna due to its ease of analysis and make. This is the same type of antenna investigated in this paper [1].

3. Electrical materials used in antenna design

Usually when designing antennas, we are often interested in choosing materials for the components that make up the antenna. By the physical knowledge learned about: electrical materials, electrical conduction, the conduction of pure and impure semiconductors. The contact of two semiconductors and its application when designing 5G microstrip antennas operating in the 28Ghz frequency band.

FR4 Epoxy is a material with a dielectric coefficient of 4.4 selected when designing 5G microstrip antennas. This material has the characteristics of continuous heat resistance of 150 degrees Celsius, instant heat resistance up to 220 degrees Celsius and high mechanical strength. Good electrical performance and flame retardant grade reach UL-94V0 application field. applications for products requiring high performance insulation.

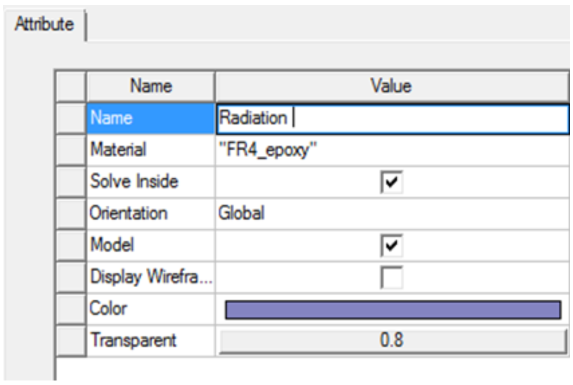


Figure 2. Material selection when designing antenna

4. The radiated field of the microstrip antenna.

There are many different methods that can be used to calculate the radiated field of microstrip antennas such as finite element method, moment method, transmission line modeling method, etc. Suitable for square and rectangular plate antennas, will be used for the following investigations [3].

Apply physical formulas when calculating the radiated field of an antenna.

The field strength vector is determined by the formula:

$$E_r = 0$$

$$E_\theta(r,\theta,\phi) = E_{\theta 0}\frac{e^{-jkr}}{r}[a_{01}\left(2\cos\left(ka\sin\theta\cos\phi\right)\right) + a_{\theta 3}\left(2\cos\left(ka\sin\theta\sin\phi\right)\right)] = \frac{e^{-jkr}}{r}F_\theta(\theta,\phi)$$

Với $a = \frac{W}{2}; a_{\theta 1} = -\cos\phi\left(\sin\frac{Y}{Y}\right)\sin\left(\frac{\sin Z}{Z}\right)$

$$E_{\theta 0} = \frac{jkhWE_0}{2\pi}; a_{\theta 3} = j\sin\phi\left(\frac{\sin X}{X}\right)\left(\frac{\sin Z}{Z}\right)$$

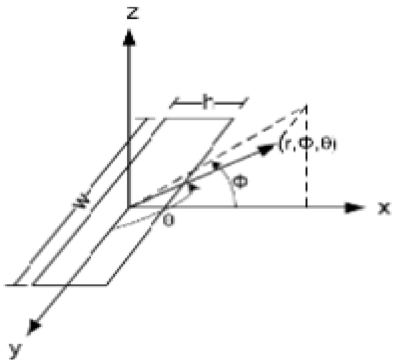


Figure 3. The coordinate system used in the antenna radiation field calculation formulas.

3. Microstrip antenna characteristics [1], [5]

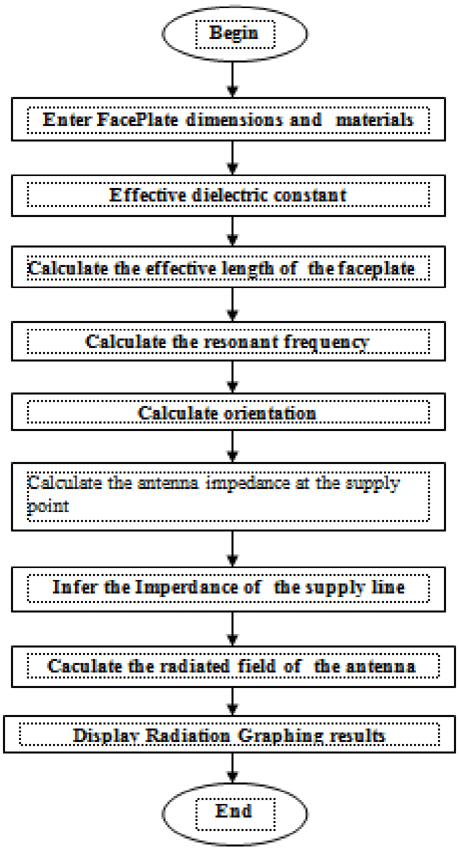
Microstrip antennas have the following advantages:

- Has volume, small size, thin thickness, easy to manufacture.
- Can be linearly polarized and circularly polarized.
- Manufacturing technology is completely suitable for high-frequency integrated circuits.
- However, besides the advantages, microstrip antennas also have some disadvantages:
- Narrow bandwidth. Some microstrip antennas have low gain.
- Large resistive loss on the supply structures of the antenna array.
- There is excess radiation from transmission lines and connections.
- Low usable energy efficiency [5].

5. Introduction to the design and simulation program

On the basis of theoretical investigation, a software algorithm has been built to solve two problems of designing and simulating microstrip antennas for two types of rectangular faceplate (for straight polarization) and square faceplate. (for circular polarization). The design problem is the process of calculating the parameters of the faceplate size, the antenna's material, the dielectric coefficient of the base layer, from the predefined characteristic requirements. The simulation problem is the reverse process from the given data about the antenna's size and material, calculating the antenna's characteristic parameters such as impedance, gain, directionality, frequency parameters. number of resonances...and plot 2D, 3D radiation. The antenna is designed using HFSS software for linearly polarized antennas (rectangular faceplate) and circularly polarized antennas (square faceplate) [6].

Algorithm flowchart of simulation program



Some simulation results:

+ Simulation 1: The microstrip antenna has a size of 0.13cm and a dielectric coefficient of 4.4 when the parameters are not optimized.

Result: 5 . irradiance graph

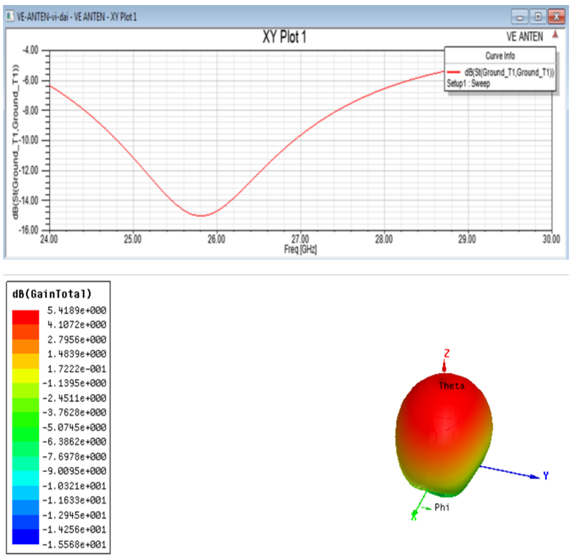


Figure 4. Radiation graph with 26Ghz resonant frequency and 5.4 dB gain when the antenna parameters are not optimized

+ Simulation 2: The microstrip antenna has a size of 0.13cm and a dielectric coefficient of 4.4 when the antenna's parameters are optimized.

Result: Graph of 6 . figure radiation

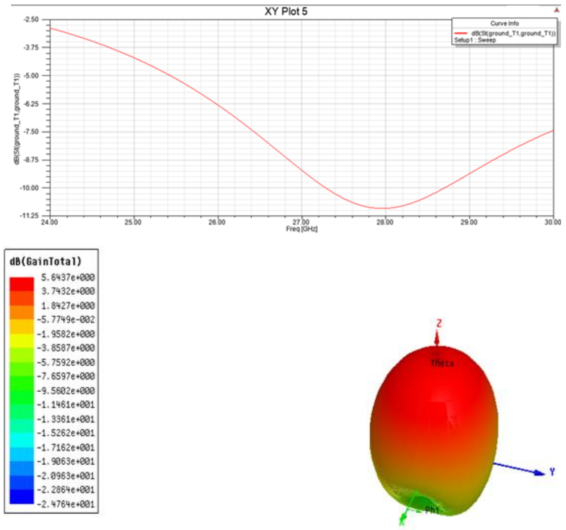


Figure 5. Radiation graph with resonant frequency 28Ghz and gain 5.4dB when optimizing antenna parameters

Simulation results of the directionality, beam of the 5G microstrip antenna operating in the 28Ghz frequency band. Energy is concentrated mainly at the top of the antenna, the lower the energy decreases. Gain factor: Gmax=5.6437dB. The simulation results are similar to the problem requirements. Gain can be increased to 6 dB if we optimize the antenna parameters in the range of 85-100m. When in practice, the 5G microstrip antenna can change parameters to match the terrain and the strongest operating range of the antenna.

5. Experimental survey.

Based on the design program of microstrip antennas using HFSS software, test designs of 5G microstrip antennas in the 28Ghz frequency band with a scan frequency from 24Ghz to 30Ghz are made.

The type of antenna has been designed:

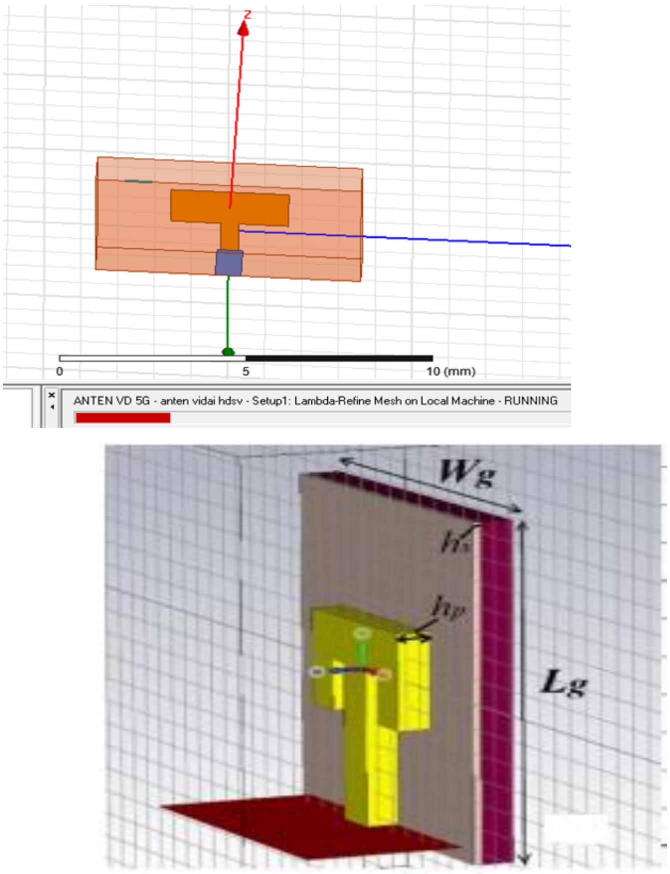
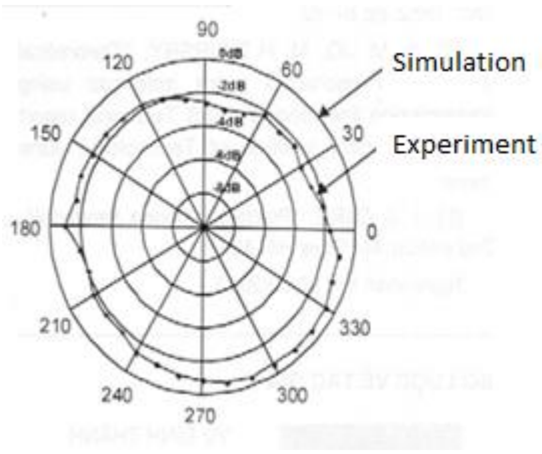


Figure 6. Sample rectangular microstrip antenna designed on HFSS software

6. Compare simulation results and experimental measurements.

Simulation and experimental results on rectangular microstrip antennas are presented in Figure 7: E-plane graph (rotation) and H-plane graph (xoz) of radiation field (theoretical).



Comment:

- The experimental results are quite consistent with the simulation results. Errors can occur from many different causes.

- Errors between simulation and experiment on the size of the faceplate, on the dielectric coefficient of the material,...[8]

- Theoretical simulation results show that there is no electromagnetic field radiation in the lower part of the earth plane, but experimental measurements show that part of the radiated field from the antenna exists below. This is due to the finite size of the antenna's ground plane and the presence of wave reflections from the surroundings in the experimental measurement [9].

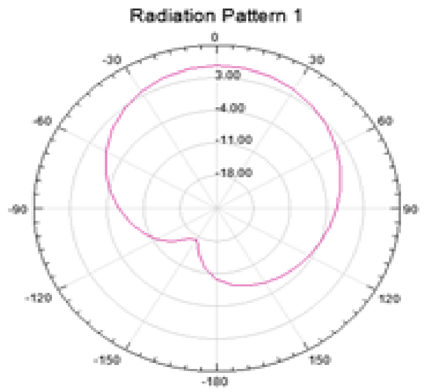


Figure 8. Experimental polarization graph

According to the graph above, we can see that the wave polarization is almost circularly polarized, but the actual gain of the linearly polarized antennas is much higher than that of the circularly polarized antennas. This is due to the presence of a hybrid 900 hybrid matrix. This causes loss and loss of multi-segment impedance matching. Moreover, in practice, the experimental design is because the type of printed circuit used is a normal printed circuit (not an ultra-high frequency printed circuit, so the loss is at high frequency, which greatly affects the hybrid matrix and therefore affects the affect the overall gain of the antenna) [10].

7. Conclusion.

The article studies the simulation of 5G microstrip antennas operating in the 28Ghz frequency band, advanced physics knowledge has been applied to optimize the parameters and solve many limitations of this type of antenna. In many new applications in the microwave frequency range at high frequencies, the smaller antenna size allows the creation of arrays of hundreds of elements in a not very large area, which increases the system gain by a factor of two. multiple times, ensuring further communication. The simulation results in the paper show that a part of the radiated field from the antenna exists below the ground plane due to the finite size of the antenna's ground plane and the presence of wave reflections from the medium. surrounding field in the experimental measurement.

The theoretical results as well as the collected data can be used to develop some further research and development directions on microstrip antennas. For example, the researches on numerical methods of analyzing the structure of ultra-high frequency circuits (moment methods, finite integration methods, etc.) allow the study of other types of microstrip antennas to be more diverse , and suitable in internet era (ND Trung, DTN Huy, T Van Thanh, NTP Thanh, NT Dung, 2021; H Van Thuc, NTP Thanh, NT Dung, DTN Huy, DTT Thao, VT Dung, 2021).

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