Antenna Modeling and Simulation Method Analysis and Research

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Abstract: Antenna is an indispensable equipment in radio communication, radio broadcasting, radio navigation, radar, remote control and other radio systems. The significance of the simulation of smart antenna system is not only to verify various technologies of smart antenna and find problems, but also to evaluate the performance of various advanced signal processing algorithms through the processing of experimental data, which can provide strong support for the smooth development of smart antenna research. In this paper, the research of antenna simulation mainly includes the definition of antenna, the development course of antenna, the achievements of antenna research and the direction of current exploration.

1. Introduction
Antenna is an indispensable part of any radio communication system. The research on antenna simulation is increasing day by day. Through the analysis of the simulation method of antenna modeling, the following research results are obtained.

2. Definition
Antennas are converters that convert guided traveling waves propagating along a transmission line into electromagnetic waves propagating through a bounded medium (usually free space), or vice versa. Antenna is a part of radio equipment used to transmit or receive electromagnetic waves. Radio communication, radio, television, radar, navigation, electronic countermeasure, remote sensing, radio astronomy and other engineering systems, all use electromagnetic waves to transmit information, all rely on the antenna to work\textsuperscript{[1-2]}. In addition, in the transmission of energy by electromagnetic waves, non-signal energy radiation also requires antennas.

3. Development History
It has been more than 100 years since the invention of the antenna. Throughout the development of antenna, it can be roughly divided into three historical stages.

Stage 1: Wire Antenna Period (late 19th century to early 1930s)
The first antenna was designed by a German physicist in 1887 to verify the electromagnetic waves predicted by the English mathematician and physicist Maxwell. The transmitting antenna is made up of two 30cm long metal rods, the ends of which are connected with two 40cm square metal plates. The electromagnetic wave is excited by spark discharge, and the receiving antenna is a ring antenna. In addition, in 1888 Hertz made a parabolic cylinder reflector antenna from zinc plates, which was fed by an oscillator placed along the focal line and operated at 455MHz. In 1901, the Italian inventor Marconi...
(1874-1937), the ocean communication is realized by using a large antenna, the transmitting antenna is 50 root prolapse fan structure composed of copper wire, coping with horizontal lines together, mounted on the horizontal line in two 150 feet high and 200 feet away from the tower, electric spark discharge transmitter connect between the antenna and the ground. This can be considered to be the first monopole antenna put into practice. The main application of early radio is long wave ocean communication, so the development of antenna is also mainly focused on the long wave band. Since 1925, medium and short wave radio broadcasting and communication began to practical applications, various medium and short wave antennas have been rapidly developed.

Stage 2: Face Antenna Period (early 1930s to late 1950s)

On the eve of World War II, the invention of microwave klystron and magnetron led to the emergence of microwave radar, which enabled the popularization of centimeter waves and made full use of the radio spectrum. During this period, parabolic antennas or other forms of reflector antennas were widely adopted. These antennas are surface antennas or aperture antennas. In addition, waveguide slot antenna, dielectric rod antenna, spiral antenna, etc. After 1940, theories about long, medium and short wave linear antennas were basically mature, and the main forms of antennas are still in use today. During the Second World War, the application of radar promoted the development of microwave antenna, especially the reflector antenna, and the rapid development of microwave relay communication, scattering communication and television broadcasting, which further developed and improved the technology of surface antenna and line antenna. During this period, the basic theory of aperture antenna was established, such as geometrical optics, aperture field method, etc., the antenna testing technology was invented, and the integrated technology of antenna array was developed.

Stage 3: Great development period (1950s to present)

In 1957, Sputnik was launched into space to mark a new era of the development of the universe, but also put forward a lot of new requirements for antennas, there are many new antennas. These new high requirements include: high gain, precision tracking, fast scanning, wide band, low sidelobe, etc. At the same time, the development of electronic computer, microelectronic technology and modern materials has provided the necessary foundation for the development of antenna theory and technology. In 1957, the United States produced a monopulse antenna for the precision tracking radar AN/FPS-16. The high-efficiency dual-mode horn feed was introduced in 1963, the corrugated horn was invented in 1966, and the high-power phased array radar AN/FPS-85 was developed in 1968. In 1972, the first practical microstrip antennas were made and began to be used as conformal antennas for rockets and missiles. In recent years, fractal antennas and other forms of miniaturized antennas have appeared.

4. Fruitful Achievement
Antenna is widely used, especially in modern science and technology.

4.1. Application of HFSS antenna simulation in EMC prediction
When designing EMC prediction software, the antenna data model can reflect the radiation characteristics of the antenna more comprehensively, which requires the antenna pattern data to be known. But in the practical work, a lot of sending and receiving device is unable to provide the direction of the antenna of the actual figure data, and using typical figure data error is too great, are introduced in order to improve the electromagnetic compatibility prediction accuracy, the article puts forward using HFSS software simulation to get the antenna pattern method, and through to the commonly used double ridged waveguide horn antenna and simulate lpda, confirmed by the simulation of antenna pattern basic and practical characteristics of the antenna.

In the prediction software of EMC between systems, the antenna model is based on the data model, and the corresponding table between the direction and the actual antenna gain is given by the equipment with the direction pattern according to the direction pattern data. Interpolation processing is carried out when necessary, while the equipment without the direction pattern is based on the typical direction pattern. For wireless communication system, antenna of receiving and transmitting equipment
need antenna pattern data. It can be seen from the implementation of the antenna model that the antenna pattern data plays a key role in the EMC interference prediction. When the device does not have a specific directional pattern, the typical directional pattern can be drawn according to the type and size of the antenna. However, the error of typical pattern data deviating from the actual pattern cannot be predicted, which will inevitably lead to too large prediction error. Therefore, this paper proposes to use HFSS (High Frequency Structure Simulator) simulation software to simulate the antenna and get the pattern data required for EMC prediction, so as to achieve the purpose of optimizing the prediction results.

4.1.1. Simulation and design of multi-band antenna based on HFSS
In today's world, the wireless communication technology industry develops rapidly, and the development and popularization of mobile data devices, especially smartphones, greatly facilitate people's life[3]. Smart phones in addition to the functions of traditional mobile phones, but also according to the user's own needs, the installation of various functions of the application software, which realizes the handheld real-time processing of personal business goals. The mobile phone itself is endowed with more and more functions at the same time, it also leads to the continuous improvement of people's requirements on the performance of mobile phones, such as higher data transmission rate, better data transmission quality and larger system capacity. These requirements all require the mobile phone antenna to have a large bandwidth and cover all the common frequency bands as far as possible; At the same time, the design of mobile phone appearance is constantly integrated with fashion and aesthetic elements, which makes the size of antenna design limited. Based on HFSS (High Frequency Structure Simulator) 3D electromagnetic damage software, this paper designs an antenna that may cover the Frequency band used in daily mobile phones. Through the simulation design and parameter optimization of the antenna model, it can be concluded that the antenna has good performance in the frequency band of 0.94GHz, 1.80GHz, 2.45GHz and 3.12 GHz, which is mainly characterized by small return loss, standing wave coefficient less than 2, and large gain. The analysis results show that the current antenna can be used as 5G mobile phone antenna.

4.1.2. Research on Antenna Experiment Course Based on HFSS Simulation Software
For antenna in the experiment teaching practice in colleges and universities to open the problem of inadequate, based on HFSS (High Frequency Structure Simulator) electromagnetic simulation software of symmetric oscillator antenna and horn antenna simulation design example, put forward using HFSS simulation software instead of antenna physical teaching experiment course reform, the antenna is obtained by simulation the return loss, voltage standing wave ratio, input impedance and pattern, to save equipment resources, enhance the teaching effect, arouse students interest[4]. The actual teaching effect of this teaching method shows that the introduction of simulation experiment plays a good role in the improvement of students' practical ability.

4.1.3. Simulation design of non-uniform bending antenna based on HFSS
Bend structure antenna has become a new hotspot in modern antenna design in terms of reducing size and improving bandwidth characteristics. Based on the HFSS software, the non-uniform bending antenna simulation design, using the HFSS (High Frequency Structure Simulator) finite element method analysis tool to study the RF characteristics of the stereo wiring on the PCB board, the Frequency domain characteristics of its broadband spectrum changes, so as to study the time domain characteristics caused by the change. The influence of the number of bent antennas on the bandwidth and central operating frequency of the antenna is discussed through the simulation design of the non-uniform bent antenna, and the influence of the change of different bent line widths on the bandwidth and central operating frequency of the antenna is discussed.
4.1.4. Wideband high gain microstrip antenna based on FSS
In order to solve the problem of narrow gain band of traditional Fabry Perot (FP) resonant antenna, a new frequency selective surface (FSS) covering structure is proposed to satisfy the resonance conditions in the wide band. Based on the principle that the reflection phase slope of the cladding layer is positive, a two-layer FSS structure with good characteristics is designed and integrated into the single-layer dielectric plate, which is used as the cladding of the microstrip antenna. A novel broadband high-gain microstrip antenna is fabricated. Simulation and measurement results show that, compared with microstrip antenna, the antenna gain can be improved in a wider band and the antenna profile can be significantly reduced by loading FSS cladding structure.

4.2. Research on Simulation System of Antenna Experimental Teaching
Visual Basic software development tool is used to design and implement the antenna experiment teaching simulation system. Firstly, the structure of the system is given, and the establishment of the antenna model, the antenna directivity diagram and the measurement of antenna input impedance are discussed. Finally, the software implementation of the system is introduced. The antenna experiment teaching simulation system realizes the measurement process of antenna directivity diagram and input impedance. The application shows that the antenna experiment teaching simulation system has the characteristics of good interactivity, practicability and lifelike.

Antenna is an important professional basic course, majoring in electronic antenna instrument used experiments, the course is expensive, however, the vast majority of colleges and universities lack enough funds to purchase the antenna experiment teaching instrument, antenna experiment easily affected by the environment at the same time, to obtain accurate measurements also need special measurement field, so to open the antenna experiment is very difficult[5]. In order to improve the quality of antenna teaching, overcome the problem of insufficient laboratory conditions, in order to truly reflect the actual antenna measurement, on the basis of completing the virtual microwave technology experiment system, this paper developed the antenna experiment teaching simulation system, and applied it to the antenna experiment teaching, and achieved good results in the experiment teaching.

4.3. Electromagnetic simulation software FDTD
Based on FDTD, a series of antenna simulation experiments are designed. Through simulation software, the antenna is modeled, and a series of antenna performance parameters, such as far-field radiation pattern, return loss, standing-wave ratio, impedance matching, etc., are calculated. The far field direction characteristics of rectangular microstrip antenna, linear array, phased array antenna and planar array antenna are calculated and analyzed, and the feasibility of antenna simulation experiment is verified in teaching, which gets good teaching effect and deepens students' understanding of antenna technology and other courses. Finite Difference Time Domain (FDTD) is a kind of professional software for numerical calculation of electromagnetic field. It uses FDTD to model and calculate the antenna, and obtains a series of performance parameters of the antenna, such as return loss, standing wave ratio, input impedance, far-field pattern, etc.

4.4. Application of Antenna Simulation in Aerospace

4.4.1. Application of FEKO in Aerospace Antenna Simulation
FEKO software as a full-wave electromagnetic analysis tool based on integral equation, the antenna system has been widely used in the analysis and design, due to its new multilevel fast multilevel core algorithm (MLFMM), will be expanded to solve the problem of antenna to maximum precision, coupled with its high frequency method and hybrid method, the method of physical optics (PO) and consistency theory of diffraction (UTD), consider a wider range of carrier on the antenna problem, the simulation results are obtained[6]. Aiming at the application of this field, first introduced the antenna types, forms, such as the background of the industry, and then introduces the FEKO in the analysis
method and characteristic of these problems, provides some examples, there are some FEKO simulation result was compared with the experimental test results, the data shows good agreement, also verified the FEKO in antenna simulation precision is good.

Because the antenna problem belongs to the radiation, in theory, the radiation field extends to infinity, and the calculation obviously can't be counting to infinity, so that the general simulation methods such as finite element method based on the maxwell differential equations need to be problem space truncation of radiation, radiation boundary conditions, but it will be to the truncation error, and need to discrete free space, this will make the analysis of the problem of unknown variables increases, which requires more computational resources. FEKO method adopted by the MoM and MLFMM are based on the numerical solution method of integral equation, itself based on green's function, firing system of equations automatically satisfy the radiation boundary conditions, this greatly simplifies the solving the problem of error accumulation, on the other hand, the integral equation method, can use the equivalence principle, only the surface of the discrete problem, according to the equivalent electric current and the equivalent magnetic current on the surface, get far field radiation pattern, equivalent to only the problem of two-dimensional discrete, reduce the number of unknown variables of the problem. Therefore, FEKO has essential advantages to solve the antenna problem. It will greatly save computational resources and enlarge the scale of solving problems.

4.4.2. Modeling and simulation of sliding beacon based on Matlab

Instrument landing system is a land-based navigation system that provides precision approach for aircraft. The system must be able to provide accurate and reliable navigation information to ensure the safe landing of aircraft. However, due to the single runway operation in Urumqi, there are many sorties and complex routes, and the flight safety pressure is great, especially after the operation with low visibility. Because the maintenance personnel cannot use the existing equipment to carry out practical operation in normal maintenance, the analysis only from the theoretical aspect will cause great troubles to the maintenance personnel, especially the training of new employees. The above problems can be improved through the modeling and simulation of the instrument landing system. Paper mainly research instrument landing system decline in beacon of modeling and simulation, first in this paper, the decline in beacon transmitter (as shown in figure 1) and the principle and simulation of the antenna, secondly discusses the working principle of the decline in beacon receiver implementation and simulation, the simulation experimental results show that the simulation in beacon giving the aircraft off course instructions correctly and guided the plane into nearly landing. In this way, navigators can fully understand the role of our equipment and how it works, better understand its working principle in maintenance work, and improve the pride of each employee in the work done [7].
4.4.3. Dynamics Modeling and Simulation of Spacecraft Winding Rib Antenna Winding Process

The winding process of the spacecraft wound rib antenna involves the coupling of large flexible deformation and large range of motion, the influence of damping factors, and the contact and collision between the wound rib and the center hub, which is an important input to obtain the development characteristics of the wound rib antenna. In this paper, the spatial absolute node coordinate method is used to model the wound rib antenna. Based on the proportional damping model, the Jacobian matrix of the damping force to the absolute coordinate array is derived. The contact collision detection model of the rigid-flexible coupling system between the wound rib and the center hub is established. Through the winding rib winding process simulation, obtained the coil winding process of dynamic response of the rib damping coefficient selection on winding speed are analyzed, the influence of the center hub contact force, the results can provide winding rib antenna dynamics analysis of the process input, and as the coil winding, in the course of the development of rib antenna test to provide the reference[8].

4.5. Antenna simulation based on ADS (Advanced Design System)

4.5.1. Simulation Design of 5.8GHz Circular Microstrip Rectifier Antenna Based on ADS

Rectifier antenna is one of the key components of wireless energy transmission. The commonly used rectangular microstrip antenna has some shortcomings, such as large area, high cost and difficult integration. According to the design theory of circular microstrip antenna and cavity model theory with feed, a new circular microstrip rectifier antenna operating at 5.8GHz is designed. Through the simulation and optimization of ADS2008 software, the receiving antenna area of the circular microstrip rectifier antenna is about 4 times smaller than that of the similar rectangular microstrip antenna, which not only greatly reduces the production cost, but also is easy to integrate and conformal, so it is more suitable to form an antenna array. The experimental results show that the energy transmission efficiency of the rectifier antenna system can reach more than 70%, which indirectly indicates the feasibility of using ADS2008 simulation to optimize the microstrip rectifier antenna[9].

4.5.2. Simulation analysis of dipole antenna performance parameters based on ADS

In order to achieve the dual performance parameters of the antenna structure analysis, this paper designs a printed dipole antenna, and studied the related theory, according to the design index of the
antenna structure, the parameters are calculated, then the Agilent ADS software company, the dipole antenna is designed for the modeling and validation of the proposed antenna performance indicators meet the design requirements. Then by changing the size of the antenna structure to simulate the performance parameters, the influence of the structure parameters of the dipole antenna on the performance of the antenna system is studied, and the corresponding conclusions are drawn. The simulation results have a certain guiding significance for the design of the dipole antenna.

4.6. Antenna simulation of missile radio fuze

The use of strong electromagnetic pulse interference or damage to electronic equipment is an effective means of electromagnetic interference developed in recent years. The strong microwave radiation forms the transient electromagnetic field, which enters the electronic equipment through various entrances (such as antenna, wire, gap). When the induced current is large, the electronic equipment can be burned, known as hard killing; When the induced current is small, it may disturb the normal work of electronic equipment, which is called soft killing. Compared with the conventional electronic jamming, the high power microwave jamming has the characteristics of high energy and wide spectrum, which can effectively jamming or damage the enemy electronic equipment under the circumstance that the working frequency band cannot be obtained. The radio fuze has a strong anti-jamming performance, but once the successful jamming can make it ineffective or early explosion, so as to achieve the purpose of disintegrating the enemy attack, so the study of the radiation effect of strong electromagnetic pulse on the radio fuze and the protection and reinforcement measures is of great significance. At present, many domestic scientific research institutions are carrying out research work in this field. In order to study the effect of electromagnetic interference on radio fuze, the S parameter of the fuze antenna needs to be obtained. The antenna model of the radio fuze is built on the simulation platform of An Soft HFSS software, and its S parameters, voltage standing wave ratio (VSWR) and three-dimensional pattern are obtained by computer simulation. The simulation results show that the center frequency and bandwidth of the antenna are in good agreement with the technical parameters of the radio fuze, which shows that the simulation results are real and reliable.

4.7. Modeling, simulation and design of three dimensional pulsed electric field sensor

With the continuous development of electronic information technology, electronic equipment is becoming more and more high sensitivity of the electromagnetic and complex electromagnetic environment of strong pulse electric field to the electronic information equipment damage or failure, for the measurement of pulse electric field is in view of the complicated electromagnetic environment electromagnetic protection study to solve one of the key problems in the first place. At present, the pulse electric field is measured by one-dimensional electric field sensor composed of monopole antenna, which has the advantages of small size, little influence on the measured electric field, simple design and so on. However, limited to the direction of the antenna, the testing results of the one-dimensional electric field sensor are greatly affected by the placement of the testing device. When it is necessary to understand all the electric field information at a point in space, different polarization directions must be tested separately. However, due to the poor repeatability of pulse electric field, multiple tests will bring large errors. To solve this problem, researchers at home and abroad focus on the design of 3D electric field sensor. Xu Yuanzhe, from the PLA University of Science and Technology, designed a parallel plate type three-dimensional pulse electric field sensor, which can realize spatial measurement of three polarization directions. However, the disadvantage is that the equipment is large in volume and the measurement bandwidth is narrow. The passive optical fiber sensor designed by D. Runde et al. from Germany based on the M-Z effect of LinbO3 can also realize the measurement of three-dimensional pulse electric field. Its advantages are small size and little influence on the measured electric field, but its disadvantages are equally obvious. Its lowest measurable field intensity is small and its cost is high. Based on the above reasons, a new three-dimensional electric field measurement sensor is designed in this paper. The sensor is composed of three small electrical antennas with mutually perpendicular tri-pyramid pyramidal surfaces, and the
external surface is presented as an orthogonal tri-pyramid device. At the same time, it can realize the measurement of pulse electric field in the whole space in cooperation with the optical fiber transmission system. Based on the theoretical modeling of the full-size three-dimensional electric field sensor, the influences of the electric field sensor on the measured electric field and the load impedance and antenna size on the test characteristics are analyzed, and the optimal design parameters of the three-dimensional electric field sensor are determined. On this basis, the probe of 3D pulsed electric field sensor is made and its main performance indexes are tested. The test results show that it has good broadband performance and the performance index of the sensor meets the design requirements\cite{12}.

4.8. Simulation and design of electromagnetic oscillator combined wideband high power microwave radiation antenna

Compared with narrowband and ultra-wideband high-power microwaves, wideband high-power microwaves have the advantages of no need of electron beam driving and guiding magnetic field, no need of vacuum working environment and high efficiency of backdoor coupling to the target, so it is more suitable for the development of compact radiation systems with high efficiency, miniaturization and practicality. Antenna, as an important part of the broadband high power microwave radiation system, has always been the focus and difficulty of related research. Broadband high power microwave radiation in the current system, the MATRIX of the system adopts the diameter of 3.7 m and a half behind impulse radiating antenna (IRA), developed by the U.S. air force research laboratory Giri in the laboratory using small broadband high power microwave source with 100 $\Omega$ axial mode helical antenna of high resistance, but its structure size is large, is not easy to the miniaturization of system; Antennas such as monopole and dipole have compact structure, but their directional pattern is omnidirectional and antenna gain is small, so it is difficult to improve the radiation factor of the radiation system. In order to satisfy the input impedance is 100 $\Omega$, center frequency is 350 MHz, bandwidth is 12%, the input power is 300 mw of broadband high power microwave radiation requirement, at the same time, the requirement of the antenna aperture dimensions is less than 0.2 m by 0.2 m as far as possible, in this paper, the electromagnetic vibrator combination antenna is studied, on the physical structure of the composite oscillator antenna and radiation characteristics of a brief introduction and analysis, simulation research the different diameter size of combination oscillator antenna, the antenna and the current loop pupil from top to bottom plate opening Angle effect on the properties of radiation, At the same time, the power capacity of the antenna is analyzed, and the radome is designed. In order to meet the requirements of compact broadband high-power microwave radiation system, a combined antenna with an aperture surface size of 20cm×20cm was designed. By using three-dimensional full-wave electromagnetic field simulation, the standing wave ratio of the antenna in the bandwidth of 0.3 ~ 1.7GHz was obtained to be less than 3, and the antenna gain in this bandwidth was greater than 2. The effects of the size of the antenna structure, the length of the current loop and the Angle of the antenna opening on the impedance bandwidth and gain of the combined electromagnetic oscillator antenna are simulated and analyzed. On this basis, a wideband signal with a peak value of 226kV is fed into the antenna. The simulation results show that the maximum radiation factor of the antenna is 150kV, the equivalent peak power is 358.8MW, and the radiation efficiency is about 70.6%. The simulation results show that the combined oscillator antenna can meet the requirements of broadband and high power microwave radiation, as well as the requirements of compact radiation system and high radiation efficiency\cite{13}.

4.9. An antenna can be used for terahertz scanning imaging

In order to overcome the shortcomings of scanning antennas used in terahertz scanning imaging technology, a rectangular waveguide antenna with narrow edges and slotted slits is designed to realize one-dimensional frequency scanning. The initial parameters such as slot distance, slot length, slot width, slot inclination and slot number are estimated by the equivalent circuit method of slot antenna design and Taylor line matrix method. Then modeling, simulation and optimization were carried out in Ansoft-HFSS software, and finally the antenna suitable for 0.101-0.111 THz bandwidth was
obtained. The simulation results show that the antenna can transmit or receive terahertz waves of different frequencies in the bandwidth at different angles along the extension direction of the waveguide, and the scanning Angle is about 6.1°. The main lobe gain at each frequency point is higher, and the main and side lobe levels are significantly different. The antenna has the advantages of compact structure, small size, light weight, low cost and fast scanning speed, which has a certain application value for terahertz scanning imaging technology[14].

4.10. A small multifrequency microstrip antenna based on a new complementary open resonant ring
Based on a new complementary open resonant ring with metamaterial properties, a small multi-band microstrip antenna is designed. Firstly, a microstrip antenna operating in the 6 GHz band is designed. Then, a new complementary open resonant ring is etched on the metal floor of the antenna. The three-dimensional electromagnetic simulation software HFSS is used to simulate the new complementary open resonant ring and the antenna loaded with complementary open resonant ring respectively, and finally a miniaturized antenna is designed. The simulation results show that, at the same resonant frequency, the size of the miniaturized antenna loaded with the new complementary open resonant ring is reduced by 25.85% compared with that of the ordinary antenna, and the resonance is generated at 6 GHz, 7.07 GHz and 7.73 GHz, which realizes the miniaturization and multifrequency of the antenna[15].

4.11. Design of W-band electrically large elliptical cylindrical reflector antenna
A W band is developed electrically large elliptic cylindrical reflector antenna, the use of geometric characteristics of elliptic double focus, through the reasonable design surface utilization ratio and efficiency of the antenna, the antenna in the near field has a narrow width of focal spot, in the far field at the same time also can have high directivity, suitable for medium and long-range requirements have higher lateral target detection radar range resolution. In order to solve the problem of heavy workload in simulation of electrically large reflector antenna, a simplified design method is proposed to improve the design efficiency of antenna. The far field radiation pattern of the antenna was measured by means of compaction field (CR) test method, and the near field focal spot width of the antenna was measured by the target detection experiment of the radar system. The good consistency between the measured data and the simulation results proves the reliability and accuracy of the whole antenna design method[16].

4.12. Phased array antenna

4.12.1. Simulation design of circular vertical phased array antenna
In order to solve the problems of short propagation distance and large attenuation in the process of ground wave propagation, a phased array is proposed to improve the ground wave radiation gain of the medium wave antenna. Through the hybrid programming of electromagnetic simulation software FEKO and MATLAB, the modeling and simulation of the 8-element medium wave circular phased array is successfully realized with 76 m vertical antenna as the unit antenna. On this basis, the circular array, orientation pattern and array gain with different radii of 25 m, 50 m, 75 m, 100 m and 125 m were modeled and simulated. The influence of different radii on the orientation pattern and gain of the 8-element medium wave vertical phased array antenna was analyzed[17].

4.12.2. Quantitative modeling and simulation of linear phased array antenna array region
In the optimization of the performance of the radar antenna, it is difficult to maintain the antenna array scientifically because of the different effects of array element failure on the performance of the antenna at different positions. To solve the above problems, a region quantization model of antenna array is proposed. First of all, the array element failure influence model is established, using the method of theoretical deduction and computer simulation respectively array element failure on antenna gain are analyzed and the sidelobe level, the influence of the effect on the performance of antenna...
array element failure is obtained rule, and puts forward the concept of quantitative antenna array area, area of quantitative model of antenna array is established. Finally, through the simulation analysis, the feasibility and effectiveness of the model are verified, which provides a theoretical basis for guiding the antenna array maintenance better[18].

4.12.3. Numerical simulation of heat dissipation characteristics of active phased array antenna
In order to reduce the modeling difficulty of thermal analysis model in numerical simulation, reduce the number of grids and save calculation cost, a method based on grid priority modeling and a multi-level grid partitioning algorithm were proposed to conduct thermal simulation analysis on the model of active phased array antenna with micro-channel liquid cooling. The multi-level mesh algorithm can be used to divide the complex antenna components into body mesh without changing the number of mesh inside the model, and the mesh quality can be improved significantly. The simulation and experimental results show that the temperature and pressure distribution of the key components of the antenna can be obtained by this analysis method. Under the condition of guaranteeing the high precision calculation, the modeling method and meshing method can improve the calculation efficiency, and have certain engineering application value[19].

4.13. Imaging modeling and simulation of spaceborne microwave radiometer under non-ideal conditions
The non-ideal factors of antenna and channel may change the received signal and direction pattern, which leads to the performance degradation of spaceborne microwave radiometer in different degrees. Considering the effects of antenna matching, channel correlation and their interaction on microwave radiometer, a microwave radiometer imaging model under non-ideal conditions is proposed. Impedance analysis method is used to study the antenna mutual coupling and matching method, and the correlation coefficient is used to analyze the channel correlation. A complete imaging model of microwave radiometer including antenna mutual coupling, antenna matching and channel correlation factors is established. The imaging results of microwave radiometer inversion under different conditions are obtained by simulation, and the simulation results are compared and analyzed. The experimental results verify the distortion of the brightness temperature inversion caused by the antenna mutual coupling and matching and the channel correlation. The performance of the microwave radiometer can be improved by selecting an appropriate antenna matching method[20].

4.14. Dynamics Modeling and Simulation of Deployment Process of Large Perimeter Truss Antenna
In order to more accurately describe the dynamic behavior in the process of large surrounding truss type antenna, the geometry precision beam element method is adopted for the surrounding truss beams and longitudinal rod and lock net flexible modeling, one-dimensional mobile media unit to drive model, combination of T type hinge, synchronization, hinge and diagonal rigid assumptions, realize the dynamic simulation of the entire antenna system. The curves of the driving force of the motor and the maximum bending stress of the longitudinal rod varying with the time of unrolling were obtained by simulation analysis. Through the analysis of the simulation curve, it is found that when the first inclined bar starts to lock, the overall driving force shows a large increase trend; Whenever there is oblique bar locking, the driving force will oscillate to a certain extent[21].

4.15. Simulation of a kind of liquid metal conical spiral antenna
In order to design a circular polarized antenna, which can replace solid metal antenna and has the characteristics of small volume, high gain, wide band and easy reconstruction, a liquid metal conical spiral antenna which is easy to adjust its shape is proposed. Taking the application in maritime satellite communication as an example, the antenna is designed and simulated by using HFSS software, and the impedance matching of the antenna is carried out by using the optimization function of the simulation software, and the good circular polarization radiation and impedance characteristics are obtained. The simulation results show that the antenna gain reaches 8.5dB in the whole INMARSAT communication
operating band (1 525 ~ 1 660.5 MHz). Axial ratio < 3 dB bandwidth reached 520 MHz. Compared with solid metal (copper) antennas of the same size and structure, the axial ratio bandwidth exceeds about 30 MHz. Therefore, the proposed liquid metal tapered spiral antenna meets the technical requirements of solid metal antenna on the premise of being easy to be reconfigurable\cite{22}.

5. The Development Direction

With the development of antenna application, antenna theory is developing constantly. The early calculation method of antenna is to assume the current distribution on the antenna according to the transmission line theory, and then calculate its radiation field from the vector potential, and calculate its radiation power from the space integral of the Poynting vector, so as to calculate the radiation resistance. Since the mid-1930s, in order to accurately calculate the current distribution and input impedance on the antenna, many people have studied the typical symmetrical dipole antenna from the point of view of boundary value problem, and proposed the integral equation method to solve the current distribution on the antenna. After 1930s, with the application of horn and parabolic antenna, various methods for analyzing aperture antenna, such as equivalence principle and electromagnetic field vector integral method, have been developed. Because the antenna problem is an electromagnetic field boundary value problem with complex boundary conditions, it is difficult to obtain a strict solution.

Since the 1970s, with the popularization of computers, various electromagnetic field numerical calculation method has come into being, such as the method of moments (MOM), finite difference time domain method (FDTD), finite element method (FEM) and the geometrical theory of diffraction (GTD), and other analysis methods, these methods become a powerful tool for analysis of all kinds of complicated problems, and have formed a commercial software. In the aspect of antenna measurement technology, the microwave antrum and near field measurement technology are developed, the test field of compact antenna and the test technology using radio power source are developed, and the automatic test system is established. The specific research process is shown in Table 1.

| Time             | Research object(antenna)                  | Research technique                                      |
|------------------|-------------------------------------------|---------------------------------------------------------|
| Starting in the mid-1930s | Double antenna                           | Integral equation method                                |
| After the 1930s  | A horn and a parabolic antenna            | Equivalence principle, vector integration of electromagnetic field |
| After the 1970s  | Various complex antennas                  | MOM, FDTD, FEM, GTD, etc                                |

6. Conclusion

Today, now the antenna has been widely used in mobile communications, radio and television, radar, navigation, satellite meteorology, remote sensing and other fields. Antenna technology has many characteristics of mature science and is still a dynamic field of technology. The main development direction is multifunctional (multi-generation), intelligent (providing information processing capacity), miniaturization, integration and high performance (broadband, high gain, low sidelobe, low cross-polarization, etc.).

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