The utility model relates to an L-band slot antenna conformal with a submarine cable

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Abstract: In order to better receive Beidou satellite signals on ships, miniaturized antennas are becoming more and more important. To solve the problem of antenna miniaturization, this paper proposes a novel back cavity slot antenna (CBSA) in conformation with submarine cable. The slot antenna works in the L-band of BDS, adopts parasitic patch structure, and uses HFSS electromagnetic simulation software for simulation and analysis. Results The maximum electric field intensity between the gaps on the surface of the antenna decreased from 854.31V/m to 681.88V/m, and the average gain of the antenna increased by 0.15dB.

Keywords: Conformal submarine cable, slot antenna, L-band

1. Introduction

In recent years, the broadband Global Area Network (BGAN) [1-3], the Global Positioning System (GPS)[4-6] and the Beidou Navigation System (BDStar)[7-9] organized by INMARSAT have become more and more widely used in various fields, and the demand for portable terminals with small size and high transmission performance is also increasing. As a common band for satellite communication and radar detection, L-band has the advantages of anti-interference and strong penetration, but when the mobile terminal is used to receive satellite signals at sea, it will be affected by a variety of complex and harsh environments and the limited space of the installation platform, so it is a wise choice to use slot antenna as a signal receiving and receiving device.

Slot antenna is an antenna formed by cutting a gap of a specific size on the conductor plate. The conductor plate can be expanded or closed, and the closing methods mainly include rectangular waveguide, circular waveguide, resonant cavity, etc. The coaxial line feeding mode can be adopted for the plane conductor plate, and the coaxial line feeding mode can be adopted for the closed conductor plate. Waveguide excitation feeding mode can also be used, and there are various ways of slotting the closed conductor plate, including transverse, longitudinal and oblique[10] .

As a special aperture antenna, slot antenna is a commonly used type of miniaturized antenna because of its strong size design adjustability and better adaptability.

Its working principle is that after blocking the surface current through the gap, the current movement trajectory of the surface changes, that is, the current periodic movement of the wide slit edge produces electromagnetic radiation effect to realize the transmission and reception of information. Since H.G. Boker proposed the concept of slot antenna in the 1940s, slot antenna has entered a leap development [11]. Literature [12]designed a wide-side longitudinal slot waveguide slot array antenna conformal with a cylindrical surface. By adding a choke slot between the waveguides, the coupling between the gaps was reduced, the influence of surface waves was suppressed, and the gain of the antenna was improved. In literature [13], a simple and efficient inverted back-cavity antenna coupling structure was proposed. The coupling was reduced by placing rectangular parasitic patch. Compared with the antenna without additional structure, the mutual coupling was reduced by 6dB in the bandwidth range of 3.2% (center frequency is 12GHz) with reflection coefficient less than -10dB, and the antenna orientation pattern was improved. The energy in the radiation direction decreases.

Based on cylindrical waveguide, a kind of slot antenna conformal with submarine cable is proposed in this paper. The waveguide wall of the cylindrical waveguide is divided into six hourglass type gaps, and the spacing between any two gaps is 60. When it floats on the sea, there is always a gap exposed to the water to receive electromagnetic waves in space. The antenna is fed by the coaxial line. The simulation results show that the design of the antenna is feasible. The antenna has the characteristics of full directivity, easy array formation, easy machining and assembly.

2. Organization of the Text

2.1 Antenna design principles:

The antenna is mainly studied from three aspects: feeding position, feeding mode and filling medium. According to the duality principle, the pattern of the slot antenna and the dual oscillator is the same, but the polarization direction of the electric field and magnetic field is different, so the position of the feed has a great influence on its radiation performance. The dual oscillator is usually fed by the center, and the feed mode of the slot antenna includes side feed, offset feed and center feed. The use of side-feed and off-feed will lead to poor coverage and uniformity distribution of antenna pattern, so the use of center feed is the preferred choice for the design of omnidirectional antenna.

The antenna is fed on the coaxial line, which is a transmission line composed of two inner and outer conductors. Between the inner and outer conductors are filled with dielectric material with dielectric constant (Ɛ) and µpermeability. The main mode of coaxial transmission is TEM[14]. Because the TEM wave field distribution in the transverse plane is the same as the static field, the static field cannot be established in the cross section of the hollow metal cylindrical waveguide (there are unequal amounts of different charges on the conductor surface, so the static state cannot exist), so the TEM wave can only be transmitted through the coaxial line.

Because the antenna is designed to be conformal with the submarine cable, its size cannot be consistent with the standard cylindrical waveguide flange, and it is smaller than the standard waveguide size, so how to achieve the predetermined radiation performance in the original frequency band in a smaller cavity becomes the biggest problem. Filling a circular waveguide with media can greatly reduce its dielectric wavelength, and the waveguide wavelength will also decrease accordingly, so it is an effective means to reduce the size of the waveguide slot array antenna[15]. In formula (1), is the cut-off wavelength of the transmission mode and represents the phase velocity; In formula (2), is the eigenvalue of the vector function of the transverse distribution to wavelength, and is the cutoff frequency; Formula (3) represents the relative dielectric constant of the medium.

$$\lambda_g = \frac{\lambda}{\sqrt{1-\left(\frac{\lambda}{\lambda_c}\right)^2}} = \frac{\upsilon_p}{f} \tag{1}$$

$$\lambda_c = \frac{2\pi}{k_c} = \frac{\upsilon}{f_c} \tag{2}$$

$$\lambda = \frac{\lambda_0}{\sqrt{\varepsilon_r}} = \frac{\upsilon}{f} \tag{3}$$

2.2 Selection of the number of antenna gaps

The number of gaps in the waveguide wall has a great influence on the receiving and transmitting performance of the antenna. In order to ensure that there are always gaps exposed to the sea surface to receive electromagnetic waves, the antenna reflection coefficient S11 and standing wave ratio VSWR corresponding to the gap number of 4, 6 and 8 (equidistant between two adjacent gaps) are analyzed respectively, and the data are compared. The results of Figures 2.4 and

2.5 show that: From Figure 2.4 it can be clearly observed that: When the frequency is 1-10GHz, the three kinds of gaps have three resonance points, among which the reflection coefficient S11 in the L-band is the smallest. When the gap number N=6, the reflection coefficient of S11 at the resonance point 1.5GHz is -33.6242dB, and the reflection coefficient in the whole L-band is less than -10dB. As can be seen from Figure 2.5, when the number of gaps N=6, the standing wave ratio at the resonance point 1.5GHz is 1.043, which is significantly lower than the other two gaps.

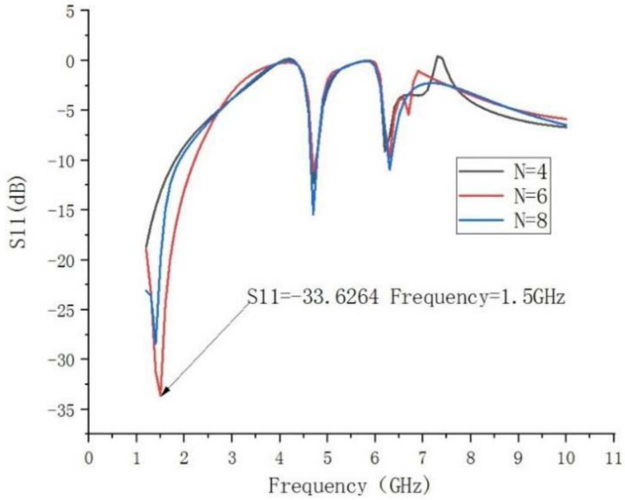


Figure 2.1 Reflection coefficient of antenna with different number of gaps

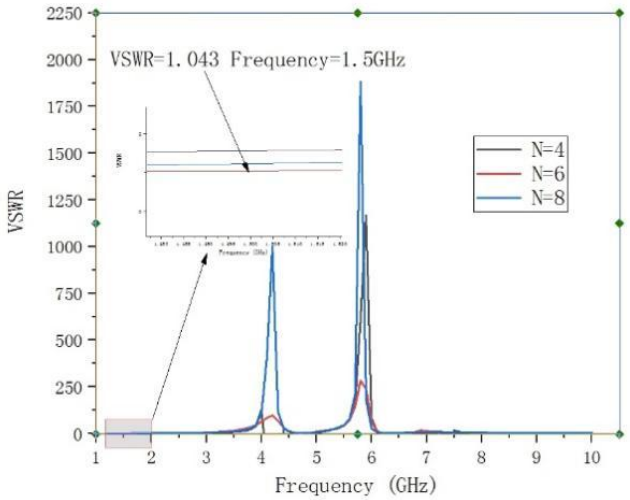


Figure 2.2 Standing wave ratio of slot antenna with different slot number

2.3 Selection of array gap structure:

For the four commonly used gap structures [16]A: rectangular gap, B: "H" shaped gap, C: "Hour-Glass" gap, D: hourglass type gap. The four shapes and their size distribution are shown in Figure 2.3:

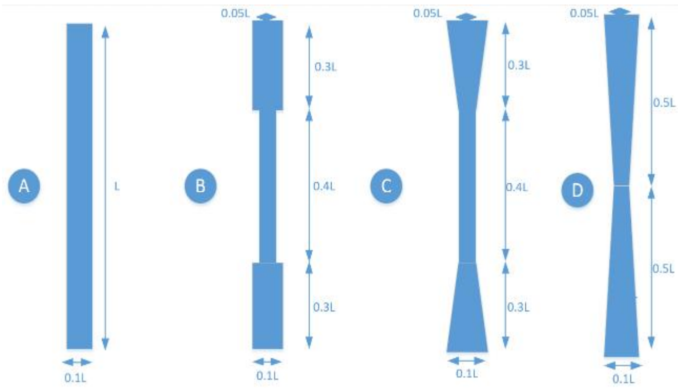


Figure2.3 Four kinds of gap structures in reference [16]

In Figure 2.3, the length of the wide slit of the four kinds of gaps is L=100mm, and the length of the narrow slit is 0.1L=10mm. The structural length ratio of the wide slit of the two kinds of gaps B and C is the same, and D is composed of two axisymmetric parts. The wall of the waveguide has six gaps, and the two adjacent gaps are separated by 60. The simulation results show that the gain of the four gap types is basically no difference. However, it can be found from Figure 2.4 that the reflection coefficient of the hourglass gap at 1.5GHz is much smaller than that of the other three gaps, and its efficiency is much higher than that of the other three gap structures. According to Figure 2.5, it can be found that the VSWR of the hourglass slot at the resonant point of 1.5GHz is much lower than that of the other three slot structures, and has good matching performance. Therefore, the hourglass slot is determined as the structure of the slot antenna.

In order to make the internal field of the gap more uniform, eliminate the uncertainty of the slot Angle and facilitate the milling machine processing, the slot Angle is processed into a semicircle.

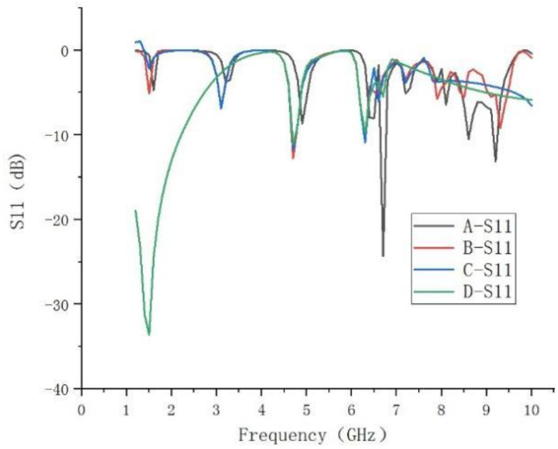


Figure 2.4 S11 reflection coefficients of the four slits

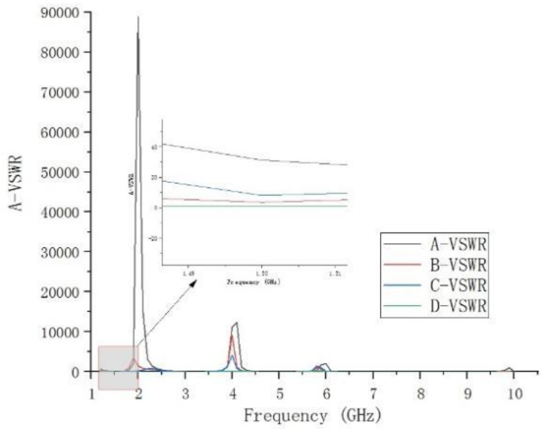


Figure 2.5 Standing wave ratio of the four slits

2.4 Antenna optimization

Each gap can be regarded as a separate dual dipole antenna, and there will be coupling between the two adjacent gaps, which will reduce the gain of the antenna and affect the transmission performance of the entire antenna system.

In order to better reduce the mutual coupling, many researchers have carried out a series of research work, such as open ring resonators (CSRRs), electrical tape gap structures (EBG) and parasitic patch band-resistance effect, generate reverse coupling current to offset the original coupling current, introduce additional resonance points to broaden the antenna bandwidth, and improve the coupling efficiency. Among the above three methods, using parasitic patch has the lowest cost and simplest structure, and there is no significant difference in reducing mutual coupling performance compared with other methods [17].

In the design of the back cavity slot conformal antenna, a patch with length rad1=9mm is conformal between every two gaps with spacing rad2=10mm. The material is alumina ceramic substrate, and the dielectric constant is 10(F/m). The antenna adopts six patches, which are equidistant from the left and right gaps. Thickness H1=0.5mm. The wall thickness of the cylindrical cavity is H0=2mm, and the diameter of the inner cavity is R0=36mm. The antenna is fed with a coaxial line, with an inner core radius of 0.5mm and a total radius of 1.15mm. The side view and main view of the antenna are shown in FIG. 2.6 and 2.7 respectively:

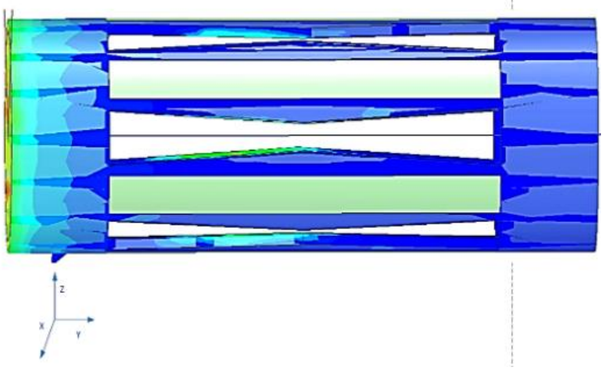


Figure 2.6 Overall side view of the antenna

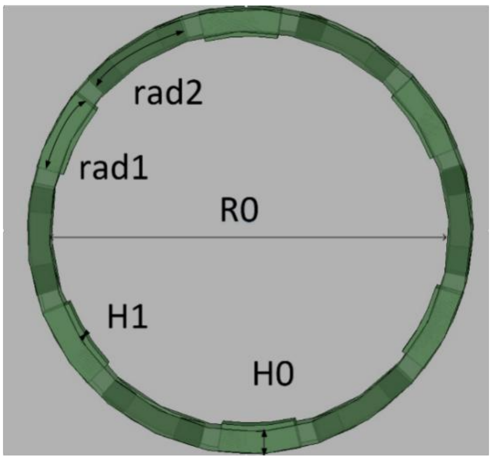
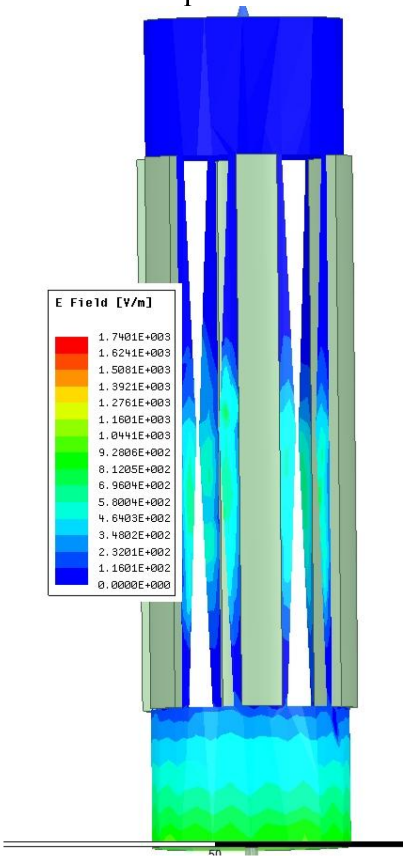


Figure 2.7 Main view of the antenna

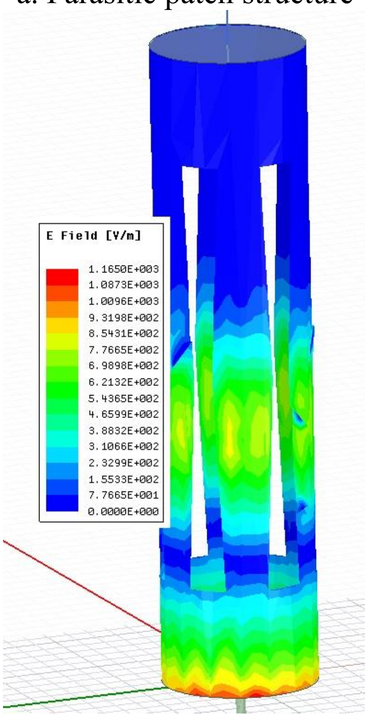
2.5 Analysis of simulation results

Simulation modeling and experiments are carried out on the designed array antenna in HFSS software. Figure 2.8 (a) shows the current diagram of the antenna surface after adding the parasitic patch. Figure 2.8 (b) shows the surface current of the antenna without any additional structure. The comparison between Figure. (a) and Figure. (b) shows that the maximum electric field intensity between the gaps decreases from 854.31V/m to 681.88V/m after the parasitic patch is added.

Figure. 2.9 shows the comparison of E-plane far-field pattern without additional structure and with parasitic patch structure; Figure. 2.10 shows the comparison of H-plane far-field pattern with or without additional structure. It can be seen from the figure that the uniformity of antenna pattern is improved after adding parasitic patch, and the total gain of adding parasitic patch increases by 0.15dB compared with the total gain of E and H planes without additional structure.



a. Parasitic patch structure



b. No additional structure

Figure 2.8 Surface current comparison of antenna with or without parasitic patch

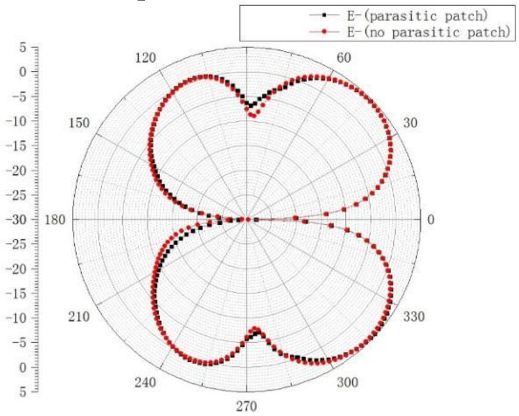


Figure. 2.9 Comparison of simulated E-plane gain of antenna with or without patch

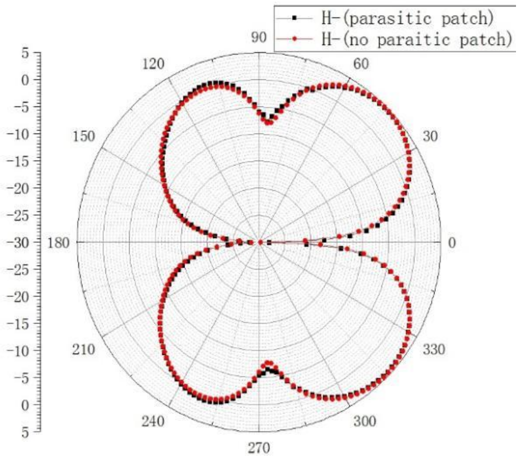


Figure. 2.10 Comparison of simulation H-plane gain diagram with or without patch antenna

3. summary

Based on the waveguide slot structure, this paper proposes a slot antenna structure that is conformed with the submarine cable. By comparing the reflection coefficient and standing wave ratio of three different slot structures and four different slot structures, and adding parasitic patches to reduce the coupling between the gaps and improve the radiation characteristics, this antenna can be used to form an antenna array and be used to receive Beidou satellite signals at sea.

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