# Simulation Analysis of Electromagnetic Shielding Effectiveness in Ventilation Window of Waveguide

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***Abstract*—This paper simulated and analyzes the case of electromagnetic field in ventilation window of waveguide for the shelter. Objective to improve the comfort of the shelter for ensure the electromagnetic shielding effectiveness. This paper introduced the electromagnetic shielding principle of cutoff waveguide plate on the basis of electromagnetic shielding principle and waveguide theory. The calculation formulas of cutoff waveguide plate shielding effectiveness calculation were showed in the paper. Research on simulation of electromagnetic in the honeycomb plate cutoff waveguide, by optimizing the waveguide aperture and length of the ventilation waveguide plate, to increase the area of the waveguide vent, but it does not reduce the shielding effectiveness. Through the simulation to meet the ventilation and electromagnetic shielding requirements of the ventilation window of waveguide.**

***Index Terms*—ventilation window of waveguide, electromagnetic shielding effectiveness, simulation.**

## I. INTRODUCTION

With the rapid development of the information technology, the electronic equipment and system are widely used more and more. The shelter is used in the field to carry out surgical treatment of mobile medical equipment. The shelter filled with high density wide spectrum of electromagnetic signals for a large number of electronic devices. The most electronic devices with electromagnetic energy conversion make the cabin electromagnetic environment is more and more complex [1]. Electronic devices inevitably open hole in the chassis, because of their own needs in ventilation and heat dissipation, the cause of electronic equipment inside the case so affected by electromagnetic interference. Also, electronic equipment seam through the hole and air vents release electromagnetic signal to the world to affecting the normal work of the other electronic equipment. In addition, the shelter need install ventilation equipment in satisfying the operation temperature, humidity and so on a series of cabin environment comfort requirements, but also emphasizes the electromagnetic shielding protection. Therefore, install ventilation window of waveguide is a kind of solutions both ventilation and electromagnetic shielding [2].

Electromagnetic shielding is use the conductive or magnetic material make the shield, the shape of shield is shell or plate [3]. The shield limit electromagnetic energy within a certain space thus suppressing electromagnetic radiation or electromagnetic interference. Electromagnetic shielding is an important component of electromagnetic compatibility technology. Principle of electromagnetic shielding is separated the shielding zone from other areas, use of shielding of electromagnetic energy of reflection, absorption and guiding role. We usually meet the radiation source is mostly alternating electromagnetic field, the electric field component and magnetic field component always exist at the same time. In lower frequency, the electromagnetic radiation ability is not strong, the electromagnetic interference occurs more in the near field, the near field of high electric field source impedance mainly component of the electric field, the near field of low electric field source impedance mainly component of the magnetic field. At higher frequencies, the electromagnetic radiation ability enhancement, far field interference occurs, the electric field and magnetic field component at this time should not be neglected [4]. Therefore, electromagnetic shielding can be divided into electric field shield, magnetic field shield and electromagnetic shielding.

The effect of electromagnetic shielding measured by shielding effectiveness[5]. Shielding effectiveness refers to the ratio of shielding before of the electric field strength E0 (or magnetic field strength H0) and after the shielding the electric field strength E (or magnetic field strength H) at the same point in space. Expressed in decibels(dB) as the unit in the project:

$$S_e = 20\lg\left|\frac{E_0}{E}\right| \tag{1}$$

$$S_h = 20\lg\left|\frac{H_0}{H}\right| \tag{2}$$

## II. ELECTROMAGNETIC SHIELDING PRINCIPLE OF WAVEGUIDE

Ventilation window of waveguide used the cutoff waveguide principle to shielding electromagnetic signal. Because the waveguide is a cutoff frequency, when the signal frequency is higher than the cutoff frequency, waveguide is conduction, when the frequency is lower than the cutoff frequency, electromagnetic wave is cutoff or attenuation and cannot transport, the frequency characteristic is similar to that of a high-pass filter [6]. Using this principle, can design relative to a particular frequency of cutoff waveguide, makes the interference signal frequency falls within the cutoff frequency, the interference signal cannot through the waveguide, which have the effect of electromagnetic shielding. Single cutoff waveguide cross section is rectangular, circular and hexagonal. Ventilation window of waveguide is made up of many cutoff waveguide lined waveguide array.

Ventilation window of cutoff waveguide cross-section form usually has the following kinds: round, square and hexagonal [7]. The spread of the square and hexagonal waveguide allows wave type less than circular waveguide, is advantageous to the isolation of electromagnetic waves. Under the condition of same insert attenuation ability, hexagonal channel area is greater than the square waveguide window. Ventilation duct often with hexagonal ventilation waveguide window. From the perspective of the processing characteristics of waveguide window, hexagonal honeycomb waveguide window of the manufacturing process is the most mature, the application of engineering is the most widely. As shown in Fig. 1.

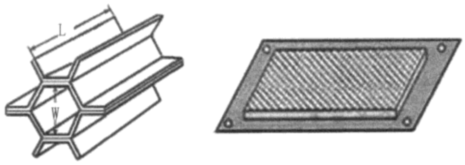


Figure 1. Hexagonal honeycomb waveguide window

The cutoff frequency is

$$f_c = \frac{15}{W} \times 10^9 Hz \tag{3}$$

The shielding effectiveness of single waveguide is

$$SE_1 = 20\lg\frac{f_c}{f} + 27.3\frac{l}{W} \tag{4}$$

Above formula, $f_c$ is the cutoff frequency, $f$ is the test frequency, $W$ is hexagonal honeycomb type of incircle diameter (cm), $l$ is the length of the waveguide, namely the thickness of the ventilation window (cm), $n$ is the ventilation window the total number of waveguide (hole).

When test frequency far greater than cutoff frequency, the shielding effectiveness of hexagon cutoff waveguide can be simplified to

$$SE_1 \approx 27.3\frac{l}{W} \tag{5}$$

For the window of waveguide, will produce electromagnetic coupling between pore, results in the decrease of shielding performance.

$$SE = SE_1 - 20\lg n \tag{6}$$

Can be seen from the above formula, the section size of waveguide decided the cutoff frequency, the depth of the waveguide to provide additional loss increase shielding effectiveness, namely depth decision shielding effectiveness. The more ventilation window of waveguide area, the greater the hole number, shielding effectiveness is lower under the condition of same thickness, so the actual use, the area of the single block ventilation window of waveguide should not be too big.

Therefore, first of all, according to the highest frequency of the interference to determine the waveguide cutoff frequency, generally take the cutoff frequency least five times the highest frequency, Secondly, according to the waveguide cutoff frequency calculating the maximum size. Finally, according to the shielding effectiveness calculation the requirement of cutoff waveguide length, generally want to make the length of the waveguide least three times the hexagonal honeycomb type of incircle diameter [8].

However, in actual use process, the ventilation window area, the greater the hole number, the more in under the condition of same thickness, shielding effectiveness is low [9]. By increasing the thickness of the ventilation window of waveguide can improve the shielding effectiveness, but increase thickness increase production costs on the one hand, on the other hand can't beyond the fixed thickness of the square. So the author, through the method of electromagnetic simulation, the ventilation duct the biggest adjust the opening size of the window, so as to make the ventilation duct the shielding effectiveness of the window and air quantity can achieve optimal.

## III. ELECTROMAGNETIC SIMULATION

Simulation is seen through the actual system model is set up and use the model of the process of the experimental study on the actual system. First of all, build the single waveguide model through the electromagnetic simulation software of FEKO [10], set the ventilation and the thickness of the waveguide window, and then in the proper range Settings the biggest opening size of the waveguide, and the proportion of the thickness of the waveguide window than 5, so that the field intensity distribution within the observation window of waveguide), and cutoff frequency is obtained. Standard ventilation window of waveguide aperture is 3.2 mm, waveguide length is 12.7 mm. And then in model 1 set a finite element modeling(FEM) is at each end of the port, a launch a receive, set the magnetic field excitation frequency between 300MHz to 18GHz, and then to carry on the grid subdivision, the size of the grid for one- twentieth of the wavelength. Subdivision graph as shown in Fig. 2.

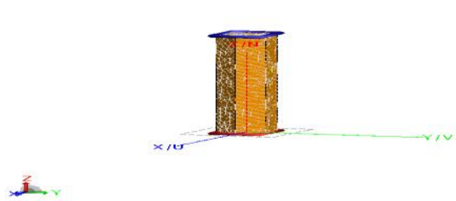
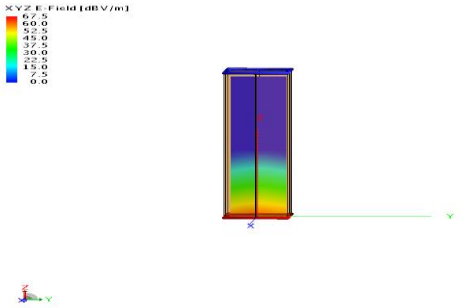
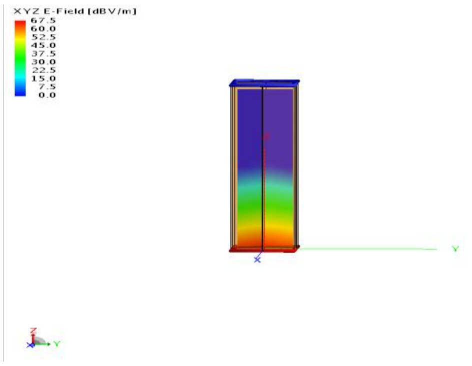


Figure. 2. Ventilation waveguide model 1

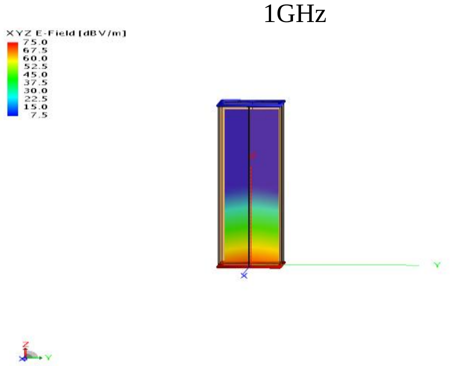
Running the program load the external incentives in mode l, get the internal electromagnetic field intensity distribution 3D effect when the external motivation of 300MHz, 1 GHz, 10 GHz and 18 GHz, as shown in Fig. 3.



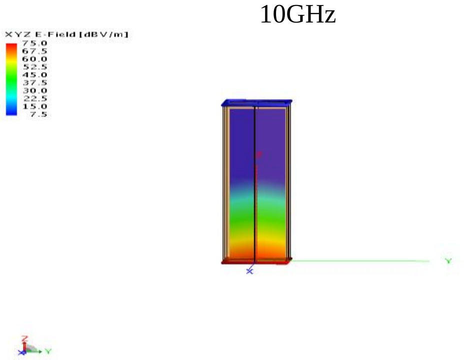

300MHz




1GHz




10GHz

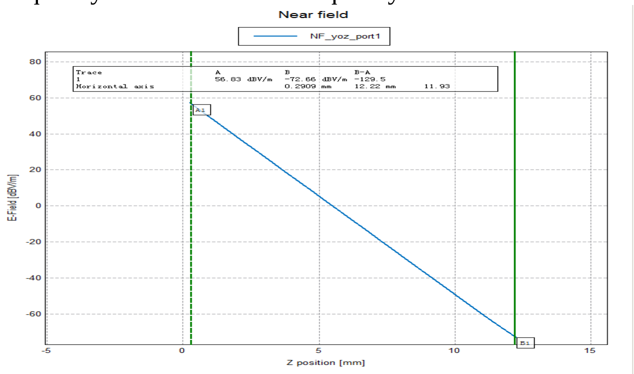



18GHz

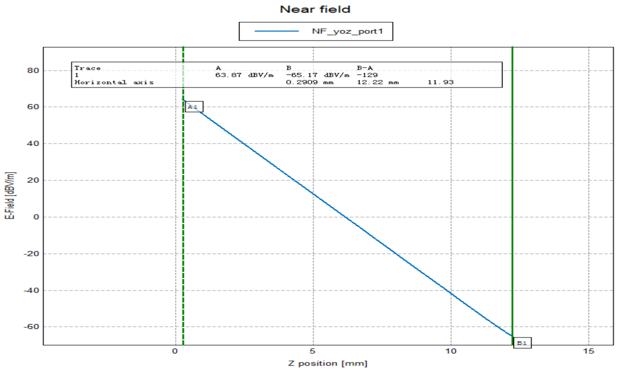
Figure. 3. Internal field intensity distribution of the 3D effect

As shown in Fig. 3, Figure in red, yellow, green, blue, dark blue color areas represent the distribution of electromagnetic field intensity from strong to weak. Fig. 4 shows the internal field intensity distribution model of a 2D effect.

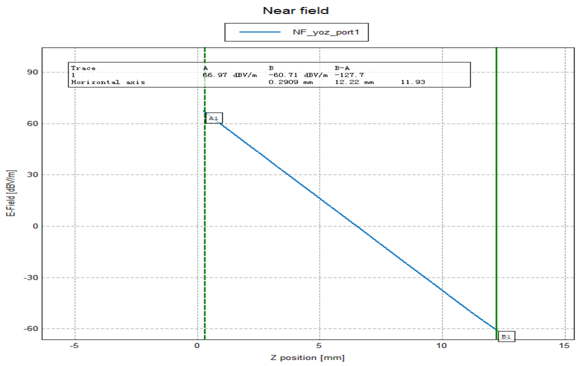
We can be seen from the Fig. 3 and Fig. 4, waveguide of electromagnetic wave shielding is higher, the least shielding effectiveness is 122dB. But this is only a single waveguide shielding effectiveness, the ventilation window of waveguide will minus the electromagnetic coupling between the hole. The area of the ventilation window of waveguide is 200mm multiplied by 200mm in the actual, the number of holes is 3200, so the attenuation of shielding effectiveness is 70.10dB. That is to say, according to the formula 6 the ventilation window of waveguide shielding effectiveness is 51.90dB, the test frequency within the cutoff frequency.



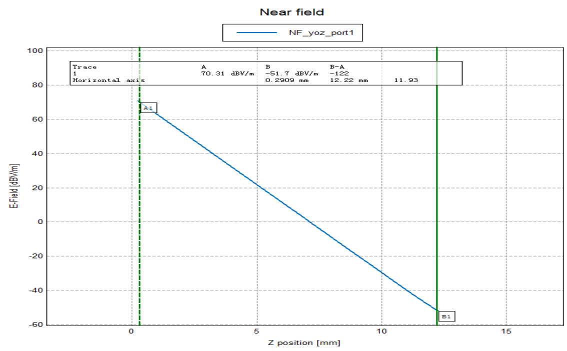

300MHz.




1GHz




10GHz




18GHz

Figure. 4. Internal field intensity distribution of 2D effect

## IV. OPTIMIZATION MODEL

GJB6109-2007 " General specification for military shelters", rules on the application of three block level can achieve the electromagnetic shielding performance [11], as shown in Table 1.

TABLE I.

APPLICATION OF ELECTROMAGNETIC SHIELDING PERFORMANCE

| Block rating | Attenuation (dB) | Frequency range (MHz) |
|---|---|---|
| I | 60 | 0.009～18000 |
| II | 60 | 0.10～10000 |
| III | 40 | 0.10～10000 |

So, the above results can meet the requirements of grade III, if you want to meet the requirements of grade I or II, and need to adjust the size of the ventilation waveguide. Next, without changing the thickness of the ventilation window of waveguide (the length of the waveguide), adjust the biggest opening size of the waveguide, we can get the second ventilation waveguide model diagram. Subdivision graph as shown in Fig. 5.

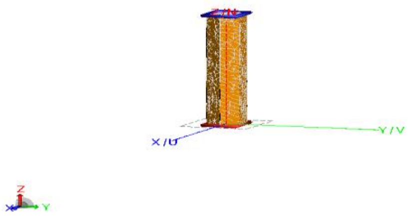
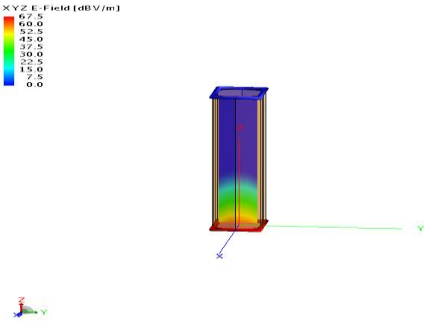
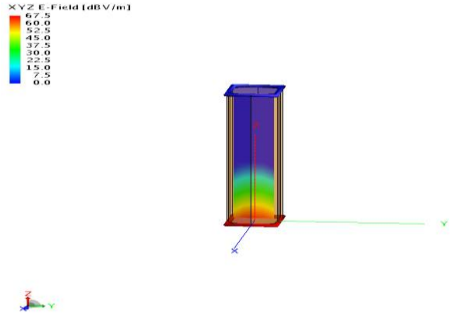


Figure. 5. Ventilation waveguide model 2

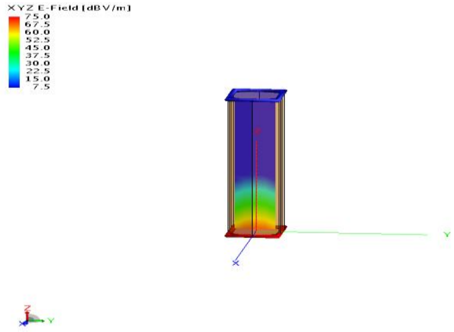
Running the program load the external incentives in mode l, get the internal electromagnetic field intensity distribution 3D effect when the external motivation of 300MHz, 1 GHz, 10 GHz and 18 GHz, as shown in Fig. 6. Fig. 7 shows the internal field intensity distribution model of a 2D effect.



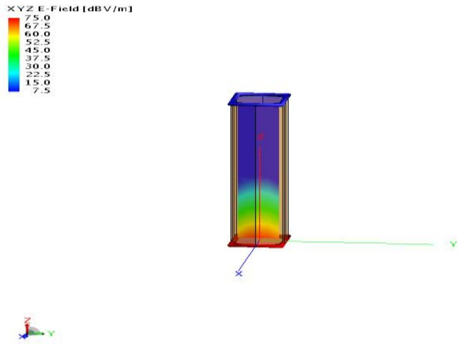
300MHz



1GHz



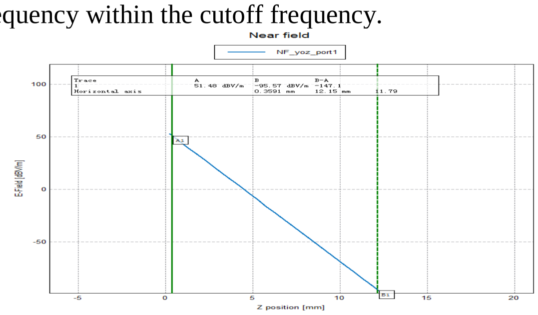
10GHz



18GHz

Figure. 6. Internal field intensity distribution of the 3D effect

We can be seen from the Fig. 6 and Fig. 7, waveguide of electromagnetic wave shielding is higher, the least shielding effectiveness is 140.8dB. But this is only a single waveguide shielding effectiveness, the ventilation window of waveguide will minus the electromagnetic coupling between the hole. The area of the ventilation window of waveguide is 200mm multiplied by 200mm in the actual, the number of holes is 4800, so the attenuation of shielding effectiveness is 73.62dB. That is to say, according to the formula 6 the ventilation window of waveguide shielding effectiveness is 67.18dB, the test frequency within the cutoff frequency.



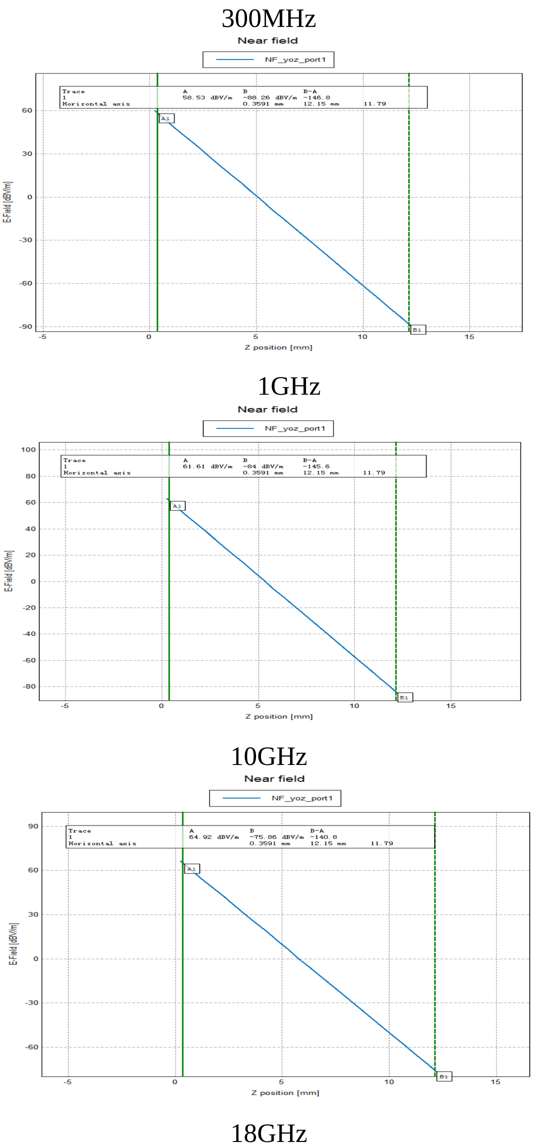



Figure. 7. Internal field intensity distribution of 2D effect

## V. EXPERIMENTAL RESULTS

In order to test the effectiveness of the electromagnetic simulation, designed a small shelter model, according to the proportion will be narrow operation application. In the microwave darkroom shielding effectiveness test of the model, its layout is shown in Fig. 8.

Shielding effectiveness of the measuring equipment have the signal source, radio frequency(RF) amplifier, transmitting antenna and receiving antenna, attenuator, electromagnetic field measurement receiver and data recorder[12].

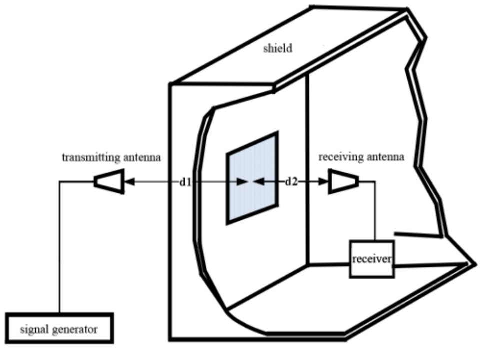



Figure. 8. Shielding effectiveness test schematic diagram

Using dipole antenna, can receive 300 MHz of direct signal A that the initial source of 92.45dB, 1.3 meters from the outer side shelter, in model the front-end orifice plate ventilation, the wind of the end plate out after orifice, the front-end orifice plate air conditioning ventilation and the front return air orifice plate air conditioning, the test data of the results are shown in Table 2.

TABLE II.

300MHZ ELECTROMAGNETIC SHIELDING EFFECTIVENESS DATA RECORDS

| Test location | Test point | The overall measurement B(dB) | Shielding effectiveness C=A-B(dB) |
|---|---|---|---|
| The front-end orifice plate ventilation | center | 3.82 | 88.63 |
| The wind of the end plate out after orifice | center | 19.90 | 72.55 |
| The front-end orifice plate air conditioning ventilation | center | 9.71 | 82.74 |
| The front return air orifice plate air conditioning | center | 4.22 | 88.23 |

Using horn antenna, can receive 1GHz of direct signal A that the initial source of 99.13dB, 1 meter from the outer side shelter, the measurement results of the same test point on the table, as shown in Table 3.

TABLE III.
1GHZ ELECTROMAGNETIC SHIELDING EFFECTIVENESS DATA RECORDS

| Test location | Test point | The overall measurement B(dB) | Shielding effectiveness C=A-B(dB) |
|---|---|---|---|
| The front-end orifice plate ventilation | center | 26.61 | 72.52 |
| The wind of the end plate out after orifice | center | 27.31 | 71.82 |
| The front-end orifice plate air conditioning ventilation | center | 19.15 | 79.98 |
| The front return air orifice plate air conditioning | center | 20.00 | 79.13 |

Using horn antenna, can receive 10GHz of direct signal A that the initial source of 93.95dB, 1 meter from the outer side shelter, the measurement results of the same test point on the table, as shown in Table 4.

TABLE IV.
10GHZ ELECTROMAGNETIC SHIELDING EFFECTIVENESS DATA RECORDS

| Test location | Test point | The overall measurement B(dB) | Shielding effectiveness C=A-B(dB) |
|---|---|---|---|
| The front-end orifice plate ventilation | center | 23.62 | 70.33 |
| The wind of the end plate out after orifice | center | 16.41 | 77.54 |
| The front-end orifice plate air conditioning ventilation | center | 20.86 | 73.09 |
| The front return air orifice plate air conditioning | center | 22.66 | 71.29 |

Using horn antenna, can receive 18GHz of direct signal A that the initial source of 75.24dB, 1 meter from the outer side shelter, the measurement results of the same test point on the table, as shown in Table 5.

TABLE V.
18GHZ ELECTROMAGNETIC SHIELDING EFFECTIVENESS DATA RECORDS

| Test location | Test point | The overall measurement B(dB) | Shielding effectiveness C=A-B(dB) |
|---|---|---|---|
| The front-end orifice plate ventilation | center | 13.05 | 67.19 |
| The wind of the end plate out after orifice | center | 13.20 | 67.04 |
| The front-end orifice plate air conditioning ventilation | center | 13.00 | 67.24 |
| The front return air orifice plate air conditioning | center | 14.02 | 67.22 |

For the electromagnetic field test, transmitting and receiving antennas must use the same structure, the connecting cable should be used in good shielding effectiveness, low insertion loss, and add to the antenna balun, to put the cable ring, keeping the receiver vertical axial cable and antenna at least 1 meter distance, can reduce the impact of cable test results produced.

The test results show that in 300MHz to 18GHz frequencies in the electromagnetic shielding effectiveness index is not lower than 67dB. Error between simulation results and experimental results is small, these errors may be the cable shielding effectiveness is not high or the receiving antenna is unstable position when used for testing, the next need to make efforts in these areas.

## VI. CONCLUSION

Ventilation window of waveguide can effectively resist waveguide under frequency electromagnetic interference, can satisfy any level according to the requirements of the electromagnetic shielding, has the wide band, good shielding effectiveness, ventilation performance is good, simple and convenient installation, stable and reliable work, etc. It used in operation shelter can have very good ventilation and heat dissipation effect and shielding effectiveness will not be affected, meet the requirements of the system of electromagnetic compatibility. When using the ventilation window of waveguide in the design must pay attention to the following two points: one is absolutely cannot make conductor through the waveguide, otherwise it will cause serious electromagnetic leakage, the other is important to ensure that waveguide relative to the frequency of the block in the cutoff state, and the cutoff frequency is much higher the frequency of the shield, more than 5 times.

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