Design and Research on the Plasma Yagi Antenna

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***Abstract*- A plasma Yagi antenna was designed based on the traditional theoretical analysis of Yagi antenna, S11 parameters and patterns were simulated by CST software. According to the simulation, we manufacture plasma Yagi antenna principle prototype and S11 parameters are measured by a vector network analyzer ,which is consistent with the simulation results .The results show that the plasma Yagi antenna has good directivity and high gain as the plasma density is high enough. The performance can be compared with the metal antenna.**

I. INTRODUCTION

The plasma antenna is an antenna that use plasma substitute metal as electromagnetic energy transfer medium. Compared to the metal antenna, the plasma antenna has a lot of outstanding advantages, such as stealth, Reconfigurability, low mutual coupling since the plasma has a unique physical properties in electromagnetic wave propagation.

The idea of plasma stealth antenna was firstly proposed by the University of Tennessee in 1996[2], many domestic and foreign research institutions also focus one the development of plasma antennas, but most of them are concentrated in the theoretical investigation [3,4], such as radiation [5] , the input impedance [6,7] , surface wave propagation [8] , the electromagnetic wave dispersion relation [9] . The structure of the plasma antenna which is used to investigate by many researchers is relatively simple [10,11] , or the fluorescent tube is looked directly as a plasma antenna[12].

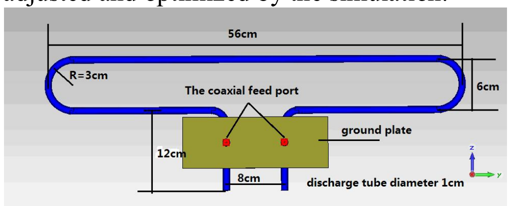
Based on the traditional Yagi antenna theory, the three-dimensional electromagnetic antenna model is created by the CST (software). Through simulation, the optimal structural parameters are obtained. Then, we manufacture plasma Yagi antenna principle prototype and measure S11 parameters with a vector network analyzer. The measured results are excellent agreement with the simulation results. The results show that the plasma Yagi antenna has good directivity and high gain as the plasma density is high enough.

II. MODEL SIMULATION OF PLASMA YAGI ANTENNA

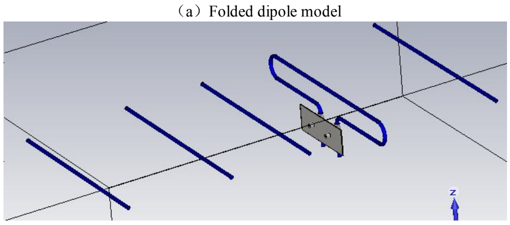
Plasma is excited by high voltage both ends of discharge tube, since if we use a half- wave dipole as active oscillator, the antenna layout will be very messy complex. Thus, we use folded dipole as active oscillator of plasma Yagi antenna. Discharge pipe at both ends of the excitation electrode are shown in Fig.1.

Figure 1 The excitation electrode of discharge tube

Folded dipole model is plotted in Fig.2 (a), the following part of parcel 5 cm long copper foil for signal coupling. The parameters of plasma Yagi antenna are set according to the metal Yagi antenna, such as size and spacing of active oscillator, director and reflector, reference parameters, which can be adjusted and optimized by the simulation.



(a) Folded dipole model



(b) Plasma Yagi antenna model

Figure 2 Folded dipole and Plasma Yagi antenna model

In the CST software, setting the plasma frequency and collision frequency can realize the desired plasma material (Drude model). During the calculation, the implementation of parallel excitation is on the two port model and two ports size is set to 1. The phase is set to be 0 ° and 180 ° and the normalized impedance is set to 50Ω.

During the calculation, the plasma collision frequency is set to be 32MHz. The antenna working frequency is changed with the plasma density as the plasma frequency is covered from 0.5~9GHz. S11 parameters is -42dB as the frequency of electromagnetic wave is 178 MHz, and the plasma frequency is 8GHz. It means that the feed-in signal only 1/10000 is reflected and the signal by feeder terminal unit are fed into the antenna array.

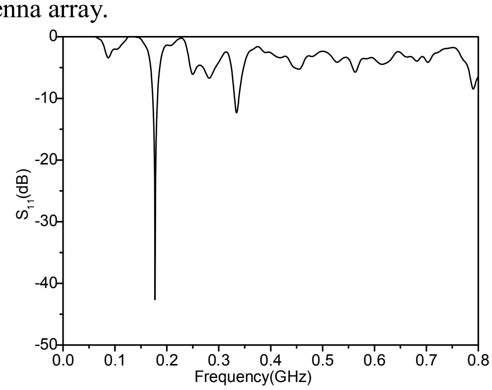
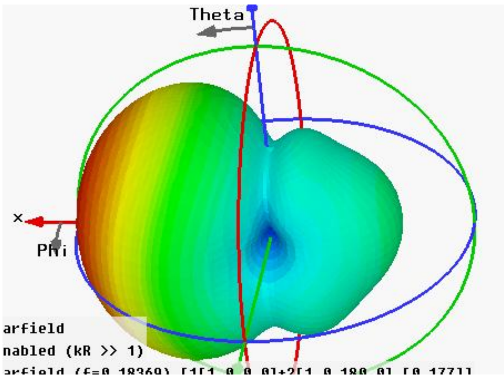
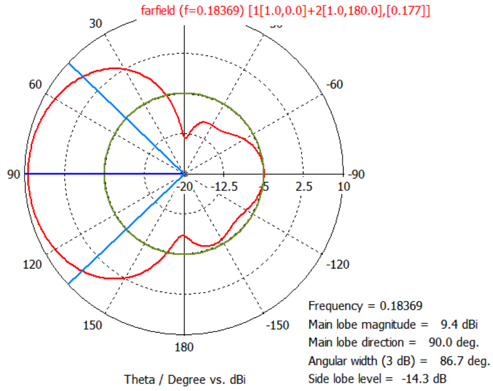


Figure 3 plasma Yagi antenna simulation of S11 parameters

The good performance of plasma Yagi directional radiation can be found in the far field monitoring region as the frequency of electromagnetic wave is 183 MHz. The peak gain of the antenna beam width is 9.4dBi, and 3dB beamwidth can be found (H surface is 86.7 ° and E surface is 62 °).



(a) Antenna radiation 3D pattern



(b) Antenna radiation H surface map

Figure 4 Radiation plasma Yagi antenna diagram

III. Fabrication and Measurement of Plasma Yagi Antenna

As shown in Fig.5, we manufactured plasma Yagi antenna folded dipole, reflector, director antenna oscillator unit, and the erection of plasma Yagi antenna measurement platform according to the Yagi antenna theory and CST simulation parameters setting, respectively. The measuring platform can be adjusted freely according to the height of Yagi antenna , each oscillator element spacing and facilitate measurements of plasma Yagi antenna, respectively.

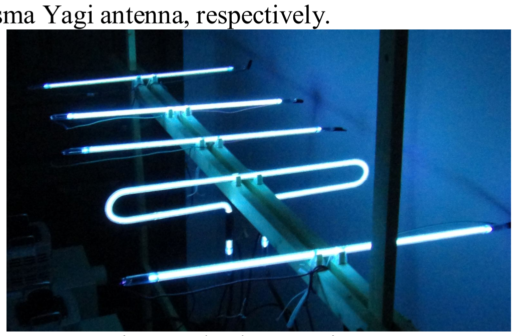


Figure 5 the plasma Yagi antenna

Capacitive coupling is widely used to couple the plasma antenna signal in antenna. One end of the glass pipe wrapped copper ring can be looked as the coaxial feed, and the copper ring and ground is connected by the coaxial line through the SMA head.

The folded dipole requires constant amplitude reversed balanced feed, but the SMA axis is not balanced feed. Thus, the balun is needed to convert the unbalanced transmission line to balance the load. The designed balun is shown in Fig.6. The 50Ω coaxial line and U part of 1/2 electrical length are not in the antenna amplitude reversed feed, but also can improve the performance in accordance with the 4:1 impedance lifting function. The 50Ω coaxial line can match the 200Ω antenna.

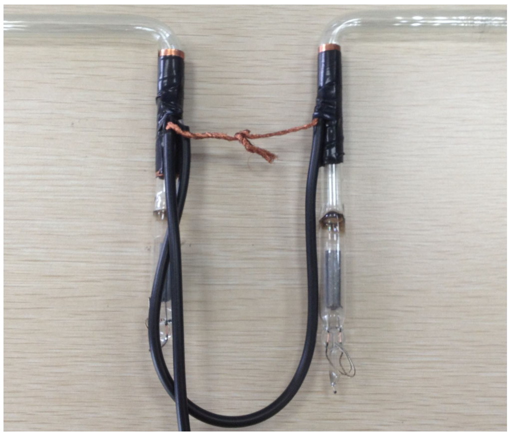


Figure 6 Plasma Yagi antenna folded dipole balun matching graph

Figure 7 Plasma Yagi antenna measurement layout

Both ends of each oscillator with CTP2000K low temperature plasma power are supplied during Plasma Yagi antenna measurement. The matched 50Ω coaxial balun is connected with the folded dipole, and the other end is connected with the AV3620 series of high performance integrated vector network analyzer. Experimental layout is shown in Fig.7.

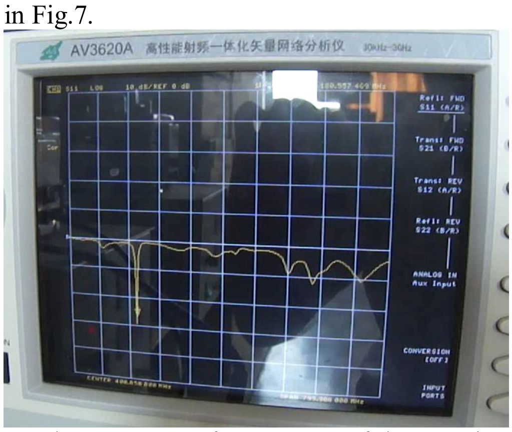


Figure 8 The measurement of S11 parameter of plasma Yagi antenna diagram

As shown in Fig.8, the obvious resonance can be found in the 180.557MHz and min S11 is -30.521dB as plasma Yagi antenna excited and adjusting the input power of each oscillator unit.

IV. Performance Analysis of Plasma Yagi Antenna

Compared CST simulation results with network analyzer measurements, the simulation result is that the S11 is -42dB at 178MHz, and the vector network measurement result is that S11 is -30.521dB at 180.557MHz as shown in Fig.9. The results show that plasma Yagi antenna has an obvious resonance at 180MHz. Therefore, the working frequency of plasma Yagi antenna can be lobtained at 180MHz .

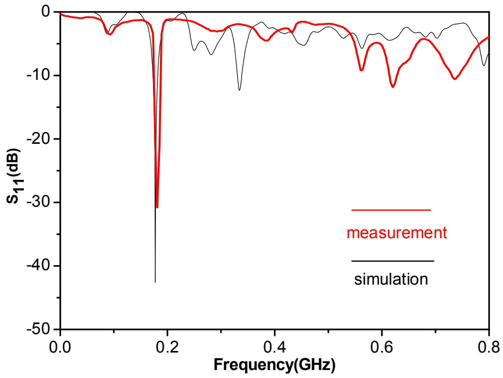


Figure 8 Comparison of simulation and measurement results

Due to the limitation of experimental conditions, the radiation pattern of plasma Yagi antenna is not measured. However, the measured S11 parameter show that the excellent agreement can be found between experimental measurement and simulation results, but the absolute value of measured S11 is smaller compared with simulation. Thus, we can infer that the gain of the plasma antenna is less than 9.4dBi as the numerical simulated by CST.

The generally Yagi antennas have the gain range 5 ~ 20dBi in free space , which compose of 2 to 31 units [13]. Directional High Gain Yagi antenna in market for sale always combine with five units, which is working at the 88 ~ 108MHz with 8dBi [14] . The designed plasma Yagi antenna are five unit and has 9.4dBi gain (measured results is less than this value). It is considerably with metal Yagi antenna gain. The result shows that the plasma antenna can be compared with the performance of the metallic antenna, as plasma density is high enough .

V. Conclusion

A plasma Yagi antenna is designed based on the theory of traditional Yagi antenna. The model of plasma Yagi antenna is created in CST, and optimization structure parameters also are obtained by the simulation. We manufacture a plasma Yagi antenna principle prototype and S11 parameters are measured with a vector network analyzer. The measured results are excellent agreement with the simulation results. The measured results also show that the plasma Yagi antenna has good directivity and high gain as the plasma density is high enough, and the performance can be compared with the metal antenna. The plasma antenna has a broader application prospects in the military field because has a lot of outstanding advantages compared to the metal antans, such as stealth, Reconfigurability, low mutual coupling and flexibility and fast control switch properties.

Acknowledgment

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