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Design a Dipole Antenna for the Time Varying Electric Field Frequency Measurement for the Future Space Mission

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***Abstract:* — The solar system and bulk of universe comprises matter which is strongly in the form of plasma. Any plasma having finite plasma density has a natural frequency of oscillations and the free energy sources present in that plasma may provide sufficient energy to the natural frequencies to propagate are termed as plasma waves. Plasma wave exist in the frequency range between Hertz to Kilohertz. Strong interactions are created between the charged particles in plasma results instabilities. To measure plasma parameters efficient antenna is required with less mass and small power consumption. The plasma wave instrument uses an electric dipole antenna to detect electric fields, and two search coil magnetic antennas to detect magnetic fields. Dipole antenna is preferred to operate in smaller frequency range to measure the local plasma wave parameters for the future space mission. Design the dipole antenna using HFSS software help to observe the frequency variation of plasma wave. The advantages of dipole antenna is that, it can be folded in to smaller dimension, shows Omni directional behavior, provide good directivity ,gain and radiation characteristics can be utilized in PWD instrument.**

***Keywords* — Electron Cyclotron Frequency, Plasma Instabilities, S parameter, Dipole Antenna**

I. INTRODUCTION

Plasma is often called the "Fourth State of Matter," the other three being solid, liquid and gas. A plasma is a distinct state of matter containing a significant number of electrically charged particles, a number sufficient to affect its electrical properties and behavior. In addition to being important in many aspects of our daily lives, plasmas are estimated to constitute more than 99 percent of the visible universe. In an ordinary gas each atom contains an equal number of positive and negative charges; the positive charges in the nucleus are surrounded by an equal number of negatively charged electrons, and each atom is electrically "neutral." A gas becomes a plasma when the addition of heat or other energy causes a significant number of atoms to release some or all of their electrons. The remaining parts of those atoms are left with a positive charge, and the detached negative electrons are free to move about. Those atoms and the resulting electrically charged gas are said to be "ionized." When enough atoms are ionized to significantly affect the electrical characteristic of gas

Monopole/dipole antenna are regularly sent on space missions to detect and measure the time-varying plasma wave electric field frequency and strength in order to extract the information of the local plasma parameters from the place of origin of these plasma waves. Plasma Wave Detectors (PWD), which comprised of a suite of instruments, is used to detect the plasma wave onboard a spacecraft. These instruments are an electric monopole / dipole antenna to detect the time varying wave electric field, a Search-coil magnetometer to measure the time varying wave magnetic field, a Langmuir probe to measure the local plasma parameters such as plasma density & temperature and a fluxgate magnetometer to measure the steady-state background magnetic field.

Due to the plasma instability various changes like electron plasma oscillation, ion cyclotron waves, whistler waves and electron burst noise will occur in the outer space and in different planets. Antenna is also designed to continue the study of dissipation processes in plasma like bow shock, soliton formation ,different substroms and radio emissions here antenna pick up all the instant changes of plasma waves in outer space and given to the ground telemetry also helpful for the future space mission. Equipment's like sensor, analyzers ,Langmuir probes and WBD instrument designed till now have various constrains such as huge mass ,large power consumption, noise interference etc. Dipole antenna is preferred as it can be folded in to smaller dimensions and also provide sufficient rigidity so that the antenna would not strike the spacecraft or the solar arrays during powered flight. Sheath independent evaluations of the plasma density profiles will be available from the analysis of the local plasma wave frequency spectrum. Earth orbiting satellite carrying plasma wave instrument commonly observe atmospheric discharges have great significance in terms of far ranging atmospheric implications'

This paper is organized as follows. Section 2 gives the theoretical discussion of antenna. Section 3 gives the methodology involves the design procedure of dipole antenna using HFSS software. Section 4 contains the results and discussion obtained and finally the section 5 contains the conclusion.

II. THEORETICAL DISCUSSIONS FOR ANTENNA.

Half wave dipole is considered as the most basic type of dipole antenna. The creation of space waves is discussed in the case of a common dipole antenna with the help of figures. Figure 1(a) shows the lines of force created between the centre-fed dipole at the end of the first quarter of the period. The charge has reached its maximum value and the waves have travelled outward a radial distance of λ/4.In figure 1(b), these lines travel a further distance of λ/4 in the next quarter i.e. λ/2 in total and the charge density on the conductors begin to diminish. This can be thought of as being accomplished by introducing opposite charges which at the end of the first half of the period have neutralized the charges on the conductors. The lines of force created by the opposite charges are three and travel a distance $\lambda/4$ during the second quarter of the first half, and they are shown dashed in Figure 1 (b). The end result is that there are three lines of force pointed upward in the first $\lambda/4$ distance and the same number of lines directed downward in the second $\lambda/4$. Since there is no net charge on the antenna, then the lines of force must have been forced to detach themselves from the conductors and to unite together to form closed loops. This is shown in Figure 1(c).

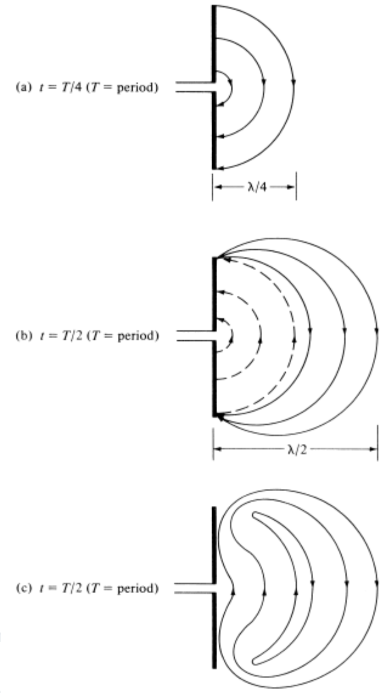

Figure 1. Formation and detachment of electric field lines for short dipole

In the remaining second half of the period, the same procedure is followed but in the opposite direction. After that, the process is repeated and continues indefinitely and electric field patterns, as shown in figure 2 are formed.

Most practical dipoles are half wave dipoles (l=λ/2) because half wave dipoles are nearly resistive load to the transmitter

$$\text{RL (dB)} = 10\, log_{10} \frac{p_i}{p_r} \qquad (1)$$

RL (dB) is the return loss , Pi is the incident power and p_r is the reflected power

Far field radiation pattern of the antenna:

$$R_{farfield}=\frac{2(D)^2}{\lambda},\ \lambda=\frac{c}{f} \qquad (2)$$

Where D is the largest dimension of the antenna

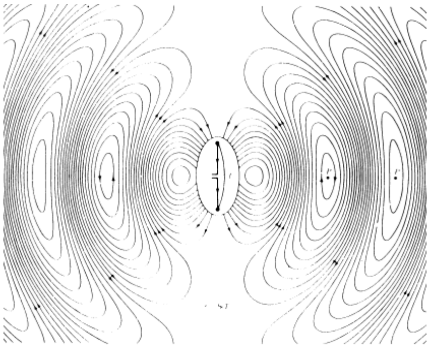

Figure 2. Electric field lines of free-space wave for a λ/2 antenna

Power radiated and radiation resistance of dipole:

$$P=\frac{\pi^2}{3c}\left(\frac{I_0 l}{\lambda}\right)^2 \quad (3)$$

Where 'l' is the length of the antenna and 'λ' is the wavelength

$$R_{radiation}=\frac{Z_0}{4\pi}cin(2\pi)\frac{Z_0}{4\pi}\int_0^{2\pi}\frac{(1-cos\boldsymbol{\theta})}{\boldsymbol{\theta}}d\boldsymbol{\theta} \quad (4)$$

Current distribution and electric field equation of half wave dipole is given by:

$$E_O=\frac{iZ_O I_O}{2\pi r}\frac{\cos(\boldsymbol{\pi}/2cos\boldsymbol{\theta})}{sin\boldsymbol{\theta}}e^{i(\omega t-kr)} \quad (5)$$

$$I_{(Z)}=I_O e^{i\omega t}cosK\text{z} \quad (6)$$

Total efficiency of an antenna is given by:

$$e_0=e_r e_c e_d \quad (7)$$

'e_0' is the total efficiency, 'e_r' is reflection (mismatch), 'e_c' and 'e_d' is conduction and dielectric efficiency

$$\Gamma=\frac{Z_{in}-Z_0}{Z_{in}+Z_0} \quad (8)$$

'Γ' is the voltage reflection coefficient at the input terminal of the antenna Z_{in} is antenna input impedance, Z_0 is the characteristics impedance of transmission line.

Voltage standing wave ratio:

$$VSWR=\frac{1+|\Gamma|}{1-|\Gamma|} \quad (9)$$

III. METHODOLOGY

To measure the time varying electric field frequency of space plasma wave and to measure the local plasma parameters, dipole antenna in hertz range is required as plasma present in the outer space is in the smaller frequency range (Hertz to Kilohertz). In planetary ionospheres, due to lower degree of ionization, the typical plasma densities are in $10^3 - 10^6$ cm^{-3} range and plasma temperature about 0.1 eV which is capable of sustaining plasma waves. To measure plasma electric field frequency, first step is to design higher frequency (GHz) antenna and measure the S parameter ,Y parameter ,Z parameter, total gain(3D polar plot), directivity and radiation pattern then reduce to the lower frequency antenna by varying the design parameter of GHz dipole antenna.

TABLE 1. Parameter values of dipole antenna in GHz

S. No	Parameter	Values
1.	Frequency	29.9211GHz
2.	Gap length	0.125mm
3.	Dipole radius(lambda/200)	0.05mm
4.	Lambda	10mm
5.	Dipole length(Resonant length-gap)/2	2.3125mm
6.	Resonant length(0.475*lambda)	4.75mm
7.	Radiation height(Gap/2+dipole length+ lambda/10)	3.375mm
8.	Radiation radius	2.55mm

TABLE 2. Parameter values of dipole antenna in MHz

S. No	Parameter	Values
1.	Frequency	900MHz
2.	Gap length	0.794mm
3.	Dipole radius(lambda/200)	1.66665mm
4.	Lambda	333.33mm
5.	Dipole length(Resonant length-gap)/2	78.7688mm
6.	Resonant length(0.475*lambda)	158.33175 mm

7.	Radiation height(Gap/2+dipole length+ lambda/10)	112.4988mm
8.	Radiation radius	83.3325mm

TABLE 3. Parameter values of dipole antenna in Hz

S. No	Parameter	Values
1.	Frequency	10,00000Hz
2.	Gap length	2570.1mm
3.	Dipole radius(lambda/200)	1500mm
4.	Lambda	3,00000mm
5.	Dipole length(Resonant length-gap)/2	69964.9mm
6.	Resonant length(0.475*lambda)	142500mm
7.	Radiation height(Gap/2+dipole length+ lambda/10)	101249.95 mm
8.	Radiation radius	75000mm

DESIGN STEPS:

1. Starting HFSS by clicking on HFSS 12.1 icon
2. Dipole creation by drawing cylinder and duplicate the structure to form 2 arms of the dipole
3. Create the lumped gap source and provide excitation using lumped port
4. Create Cylindrical air boundary is created at a distance of $\lambda/4$ and add solution setup
5. Add frequency sweep by giving Phi values 0,180,90 and the theta values -180,180,10.
6. HFSS- Analyze all
7. Create rectangular plot(‘S’,’Y’ and ‘Z’ parameters),radiation pattern,3 D polar plot.

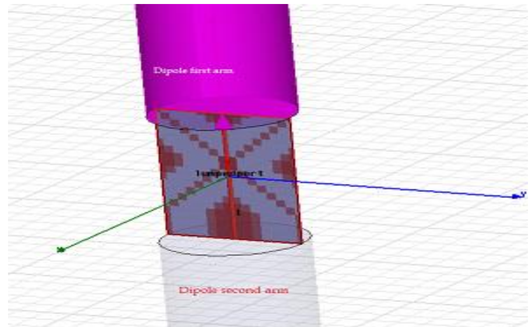

Figure 3. Dipole structure with lumped port

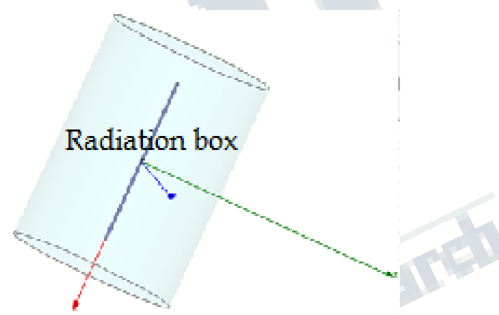

Figure 4. Radiation boundary is created around the dipole structure

IV. RESULTS AND DISCUSSIONS

In section 2, which discussed the design of dipole antenna in GHz range and plots are obtained.

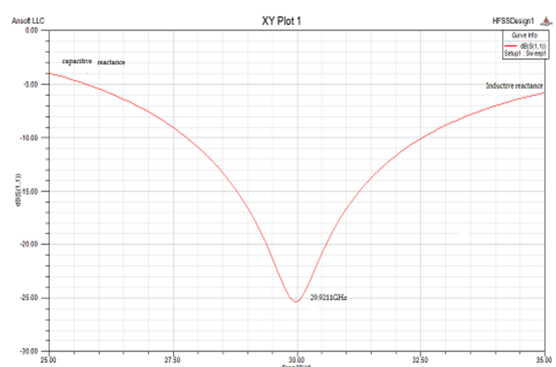

Figure 5. S parameter of the dipole antenna using port resistance 79 ohm..

The dipole antenna having return loss of -25.02dB.The dipole antenna has only a single band at 29.9 GHz. Lower cutoff frequency is 27.5GHz and upper cutoff frequency is 31.5GHz. Port resistance is taken as 79 ohm. In order to compute accurate antenna parameters, the input must be matched.

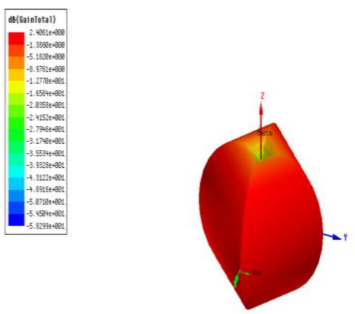

Figure 6. 3D plot of the dipole antenna.

The figure 6 shows 3D radiation pattern of dipole antenna at frequency 29.972 GHz .The maximum gain obtained is 2.4061 dB.

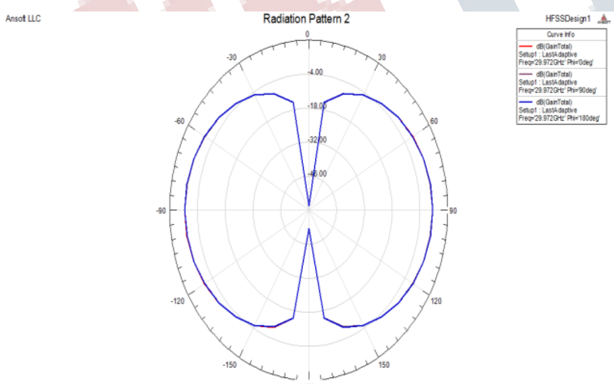

Figure 7. Radiation pattern of the dipole antenna

The result shows unidirectional radiation pattern. Main lobe direction 90 degree

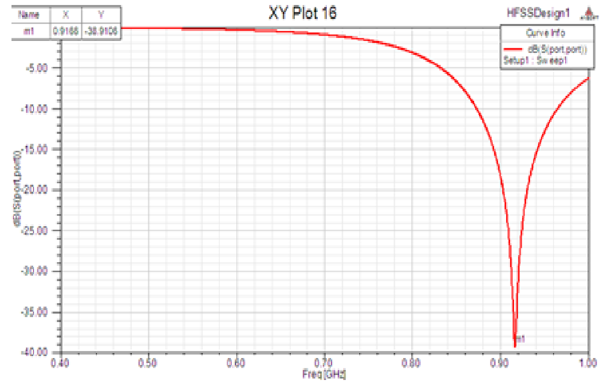

Figure 8. S parameter of the dipole antenna using port resistance 79 ohm.. (900MHz)

The dipole antenna having return loss of -39.00dB.The dipole antenna has only a single band at 900 GHz

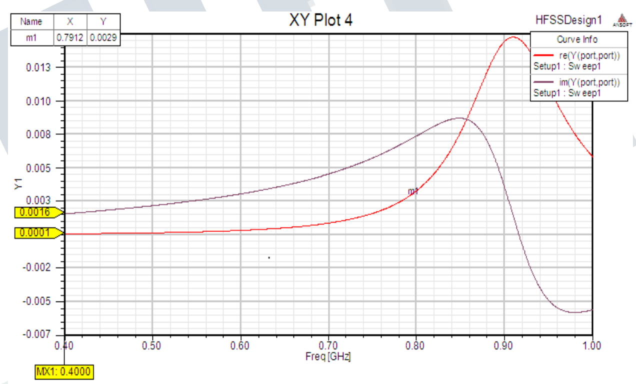

Figure 9. Y parameter of the dipole antenna (900MHz)

Fig 9 shows at the point of resonance the imaginary part crosses zero.

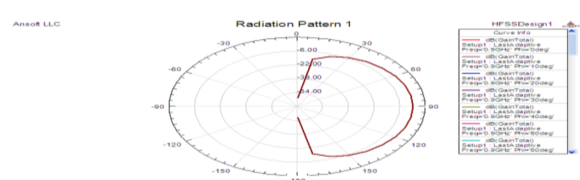

Figure 10. Radiation pattern of the dipole (900MHz)

The result shows omnidirectional radiation pattern. Main lobe direction 90 degree.

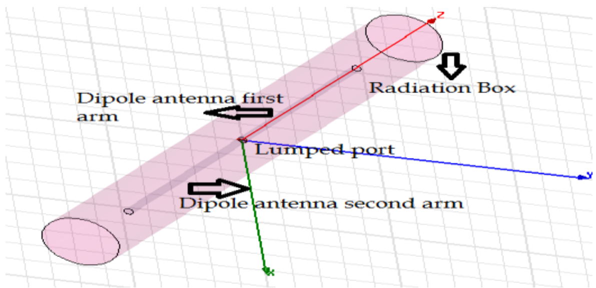

Figure 11. Dipole structure (10 lakh hertz)

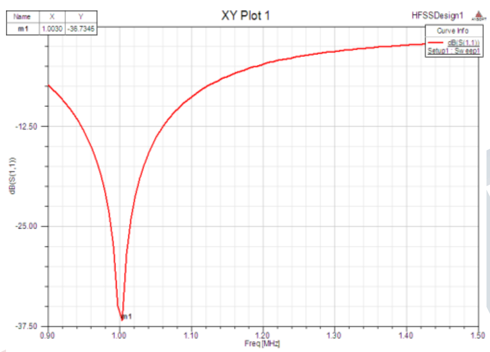

Figure 12. S parameter of the dipole antenna (10,00000 Hz).

The dipole antenna having return loss of -35.50dB and the resonant frequency is 10 lakh hertz

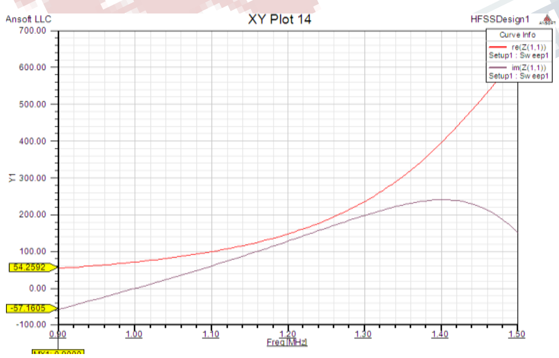

Figure 13. Z parameter of the dipole antenna (10,00000 Hz).

Fig 13 shows at the point of resonance the imaginary part crosses zero

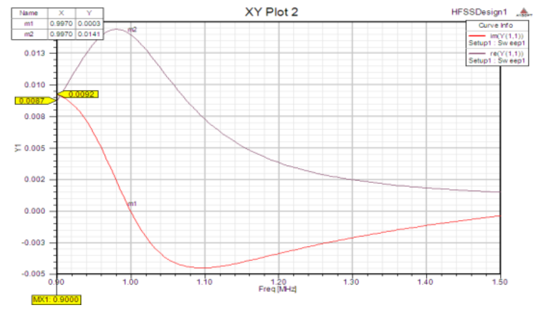

Figure 14. Y parameter of the dipole antenna (10,00000 Hz).

Fig 14 shows at the point of resonance the imaginary part crosses zero.

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V. CONCLUSION

Dipole antenna in 30 GHz,900 MHz and 10 lakh hertz that is 1000 kilohertz is designed using HFSS software. The return loss obtained smaller frequency(1000 kilohertz) is -35.50 db shows the antenna is stable .Good radiational characteristic is obtained .Omni directional behavior is obtained as major lobe is oriented along 90 degree. The peak gain obtained in smaller frequency is 1.7204 db.The radiation efficiency obtained in low frequency antenna is 0.99569.

REFERENCES

[1] Mohammed Tareq, Mazidul Islam, Razin Ahmed, F. L, "Simple Half Wave Dipole Antenna Analysis for Wireless Application," International Journal of Computer Applications (0975 – 8887).,Volume 94 – No.7,2014

[2] Truong Khang Nguyen and Ikmo Park, "Effects of Antenna Design Parameters on the Characteristics of a Terahertz Coplanar Stripline Dipole Antenna",Progress in Electromagnetics Research m., vol. 28, 129-143, 2013

[3] Amandeep Bath, Abhishek Thakur, Jitender Sharma , Prof. Basudeo Prasad,"Analyzing the Different Parameters of Dipole Antenna", IJEEE., Vol. 1,2014.

[4] Parminder Singh, Ankita Sharma, Neha Uniyal3 ,Richa Kala, "Half-Wave Dipole Antenna for GSM Applications ", International Journal of Advanced Computer Research.,Volume-2,2012 .

[5] R.P. Lepping, M.H. Acuna, L.F. Burlaga, W.M. Farrell, J.A. Slavin, K.H. Schatten, F. Mariani, N.F. Ness, F.M. Neubauer, Y.C. Whang, J.B. Byrnes, R.S. Kennon, P.V. Panetta, J. Scheifele and E.M. Worley, *"The WIND Magnetic Field Investigation"*, Space Science Reviews., Vol. 71, 207,1995.

[6] C.W. Smith, J.L. L'Heureux, N.F. Ness, M.H. Acuna, L.F. Burlaga and J. Scheifele, "*The ACE Magnetic Fields Experiment*", Space Science Reviews, Vol. 86, 613,1998.

[7] M.H. Acuna, D. Curtis, J.L. Scheifele, C.T. Russell, P. Schroeder, A. Szabo, J.G. Luhmann,*"The STEREO Magnetic Field Investigation*," Springer Science, Business Media B.V, 2008.