Estimation of transmission coefficient of a propagating electromagnetic waves through a plasma slab Using MW- MOMENT method.

Marai M. Abousetta, m.abousetta@academy.edu.ly **Hawa Ayad Hawa.Ayad@bsu.edu.ly**

Abstract

the method of moments (MoM), also known as the moment method and method of weighted residuals, is a numerical method in computational electromagnetics using on the solution of radiation and scattering problems involving conducting, dielectric, and composite objects. This study is centered on air effects on the electromagnetic (EM) wave propagation for a hypersonic vehicle passing through inhomogeneous medium (plasma slab) where it is measured the transmission coefficient of the plasma sheath by using the moment (MOM) method.

Index Terms— moments (MOM), Electromagnetic (EM), plasma slab.

I - Introduction

The results show that the motion of the plasma slab significantly affects electromagnetic propagation, and the reflection coefficient oscillates with the velocity of the plasma sheath, where during entering some object's vehicle's reentry the Earth's atmosphere, the vehicle will be surrounded by a plasma sheath which is formed by the collision of the vehicle with ambient air. Electromagnetic (EM) wave reflection and attenuation by the plasma sheath lead to interruption of communication, telemetry, and satellite navigation [1].

Numerical methods and, of equal importance, has provided a solid foundation for a thorough understanding of the techniques. Over several decades, electromagnetic scattering problems have been the subject of extensive researches. Scattering from arbitrary surfaces such as square, cylindrical, circular, spherical are commonly used as test cases in computational Electromagnetics, because analytical solutions for scattered fields can be derived for these geometries.

The low-frequency numerical method needs to discrete frequency domain Maxwell's equation, including integral equation method and differential equation method. This study mainly focuses on the study of the method of moments (MOM), which belongs to the integral equation method. As one of the most widely used methods in computational electromagnetics, the MOM only requires boundary discretization, thus avoiding dealing with absorbing boundary conditions. When applying the Rao-Wilton- Glasson (RWG) vector basis function [7], the MOM further avoids dealing with high-order singularities of the fundamental solution at origin. Therefore, the MOM is superior to the finite element method (FEM) or the radial basis function method (RBF) when calculating Rich Communication Services (RCS) [4].

II.Moment (MOM) method

In electromagnetics and antenna theory, the Method of Moments is a numerical technique used to solve electromagnetic field problems. It works by dividing a surface or volume into small segments and approximating the fields by assuming that the currents and charges are localized at these segments [1]. Electromagnetic problems of large size have existed long before the computers that could solve them. Common examples of larger problems are those of radar cross section prediction and calculation of an antenna's radiation pattern when mounted on a large structure. Many approximations have been made to the equations of radiation and scattering to make these problems tractable. Most of these treat the fields in the asymptotic or high-frequency (HF) limit and employ ray-optics and edge diffraction. When the problem is electrically large, many asymptotic methods produce results that are accurate enough on their own or can be used as a "first pass" before a more accurate though computationally demanding method is applied [5].

III. Model description

To estimate the transition coefficient, we must conceptualize the user model. geometry of three mediums starting with plasma slab assume that waves are normally incident from the left semi-infinite Medium (vacuum) into x=0, then the bound plasma slab begins from x=0 to x=a, then medium of conductor begins from x=5cm to infinity which have the following properties: electric density $is\ 10^{19}m^{-3}$, Plasma frequency=13.56M HZ collision frequency=28 GHZ, magnetic field = 1T Plasma wavelength= $800\ nm$ cm, the plasma slab thickness is 40 cm, thickness of slice 4 cm Plasma density is$ne\ =\ 1.0\ \times 10^{17}\ m^{-3}$. Hypersonic vehicle collision generates heat energy, dissociating molecules and atoms at high velocities, forming plasma sheath around vehicle, affecting EM wave propagation. We can be expressed about plasma slab by a complex frequency-dependent (relative permittivity) ε_r (ω) as follows:

$$\varepsilon_r = \frac{1-\omega^2{}_p}{\omega^2 - j\omega v_e} \qquad (1)$$

$$\omega_p = \sqrt{\frac{e^2 n_e}{\varepsilon_0 m_e}} \qquad (2)$$

Where,
ω: Frequency of cold plasma.
n_e: Electron density.
m_e: The electron mass
ω_p: Plasma frequency.

v_e : The electron collision frequency with neutral particles, where the increase of collision frequency of the plasma increases the absorbance and decreases the transmittance and reflection. At high-temperature air in the thermal equilibrium can be expressed as:

$$v_e = 3 \times 10^8 \frac{\rho}{\rho_0} T \ \ Hz \quad (3)$$

Where;

$\frac{\rho}{\rho_0}$: is the density ratio; ($\rho_0 = 1.288 \times 10^{-3}$g/$cm^3$) ,$T$: is the temperature in kelvin.

To estimate the transition coefficient, we first calculated the plasma impedance as function of the insulation constant, specify the material properties of the plasma (permittivity and conductivity), which are typically frequency-dependent due to plasma dispersion. MoM method formulating integral equations that describe the relationship between the induced currents on the plasma plate's surfaces and the incident, transmitted, and reflected electromagnetic fields and extract the transmitted field components and compute the transmission coefficient as the ratio of transmitted power to incident power, all these steps are formulated in a matlab program to obtain the required results.

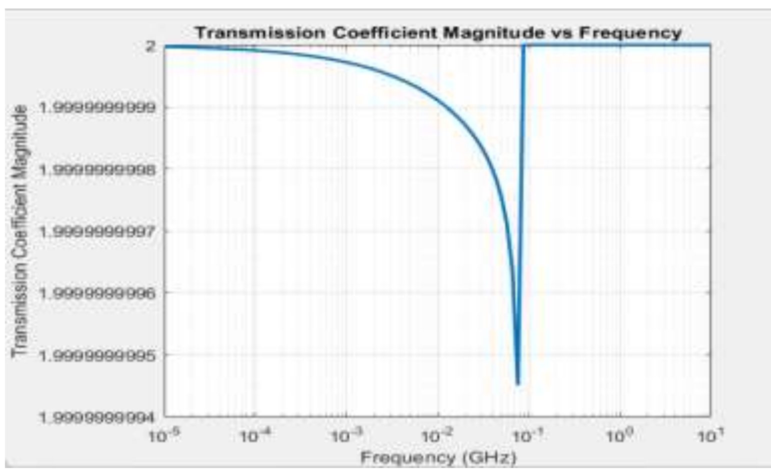

Fig. 1.Absorbed power by plasma slab computed using MOM method

IV. Results

Fig.1 shows the transmission coefficient it decreases at it reaches a particular frequency then it increases again as the frequency increases.

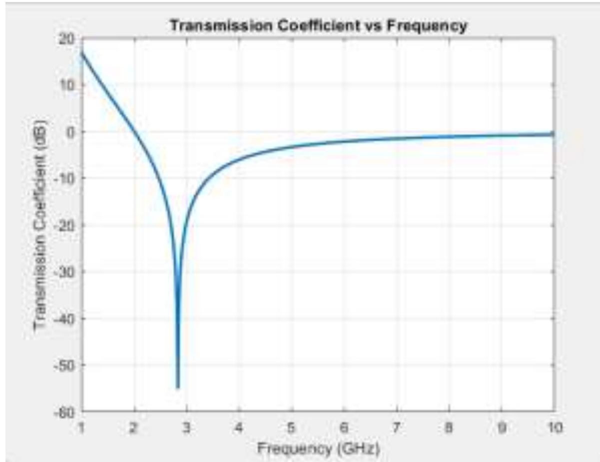

Fig.2. Transmission coefficient magnitude computed MW-MOM method.

From figure 2, which illustrates the transmission factor calculated in MW-MOM method, we note that there is a difference between the two values calculated in the same way, which necessitates the adjustment of programming to compare the results with the correct values.

V. Conclusion

The two methods are supposed to be compared and show how important the MW-MOM method and its speed in performing. We also note that the overall transmission factor is declining as the frequency increases in the plasma slap

REFRANCE

1-Effect of Plasma Sheath Velocity on Propagation of Electromagnetic Waves-
https://www.researchgate.net/publication/340154713_Effect_of_Plasma_Sheath_Velocity_on_Propagation_of_Electromagnetic_Waves
2- Fernando L. Teixeira and Weng Cho Chew, *Fellow*,
"Finite-Difference Computation of Transient
Electromagnetic Waves for Cylindrical Geometries
in Complex Media" IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 38, NO. 4, JULY 2000
3- M. Naser-Moghadasi, "A MOMENT METHOD SIMULATION OF ELECTROMAGNETIC SCATTERING FROM CONDUCTING BODIES",
Progress In Electromagnetics Research, PIER 81, 99–119, 2008.
4.You-Lin Geng, Xin-Bao Wu*, Senior Member,"* Electromagnetic Scattering by an Inhomogeneous

Plasma Anisotropic Sphere of Multilayers", IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 53, NO. 12, DECEMBER 2005.
5- Walton C. Gibson, "The Method of Moments in Electromagnetics". 2008