

Monopole Antenna Radar Cross Section Reduction with Plasma Helix

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ABSTRACT

In this paper, a new method for radar cross section reduction of a monopole antenna is proposed. In this method, a plasma helix like fluorescent bulbs is placed around the antenna element. The selected plasma parameter for this medium acts as an absorber without disturbing the antenna performance. The simulations show that radar cross section of simulated antenna is reduced in a wide frequency range. In this paper, the plasma parameter is chosen in such a way that reduces RCS at 4GHz. At this frequency, the radar cross section reduction is about 10dBsm. Due to the frequency dependent of the plasma medium, the plasma parameter must be changed for better result in the other frequencies. This change can be performed electrically without any change in the antenna structure. In this simulation, a PEC rode with 3cm diameter and 15cm height is chosen for the monopole antenna element. This monopole antenna resonates at 630 MHz. After placing the plasma helix around the antenna element, there is no significant change in the antenna performance.

1. INTRODUCTION

Radar cross section (RCS) is the measure of a target ability to reflect radar signals in the direction of the radar receiver. Radar detects targets by evaluating the strength, timing, phase shift and direction of energy returned to the detector as compared to the energy emitted from the transmitter. The RCS is related to the ratio of the reflected electromagnetic power to the incident power [1]. Radar absorbing materials are needed to suppress unwanted reflections, e.g., in compact test ranges and to minimize RCS of a target [2].

A collisional and not magnetized plasma, which has a complex dielectric constant, can be used as a good absorber for electromagnetic waves over a wide range of frequencies. This absorption leads to a reduction in the RCS over a wide frequency range [3], [4]. When an electromagnetic wave enters a weakly-ionized plasma, it is not only subjected to absorption, but also to scattering [5]. Absorption arises from loss of energy of

the wave due to energy transfer to charged particles, and subsequently to neutral particles (atoms and molecules) by elastic and inelastic collisions.

The use of plasma in different shape as an electromagnetic absorber mainly has been researched in past few years [6], [7], [8], [9].

Another way for RCS reduction of plasma antenna, is switching of the plasma state. Plasma can be switched between on and off position when needed to reduce RCS, and is switched back on again when needed to transmit and receive data [10].

In this paper unmagnetized cold plasma medium used as an absorbent for reduction of monopole antenna RCS without disturbing the monopole antenna performance.

The rest of this paper is organized as follows. First, an introduction about pervious works in this field of radar cross section is presented. Then, a Summary about plasma physics is described. Afterwards, the proposed model is introduced and finally the results

are presented and the conclusion is expressed.

2. PLASMA PHYSICS

Plasma is a collection of ionized positive ions and free moving electrons. Plasma can be generated by electron impact ionization, photo-ionization, or simply heating the gas.

Plasma medium has frequency dependent feature and it can be characterized by its parameters. Plasma frequency, ω_p and the collision frequency, V_{en} are the key plasma medium parameters. Plasma features like dielectric permittivity and conductivity related to this parameters are formulated as (1) , (2):

$$\epsilon = \epsilon_0 \left[\epsilon_\infty - \frac{\omega_p^2}{\omega(\omega - jV_{en})} \right] \quad (1)$$

$$\sigma_w = \frac{n_e e^2 V_{en}}{m(\omega^2 + V_{en}^2)} \quad (2)$$

where ϵ_∞ is the relative dielectric constant at infinite frequency, generally $\epsilon_\infty = 1$.

In this paper, the plasma is chosen as an electromagnetic energy absorber, therefore, for plasma parameters, we select $\omega_p = 50 \text{ GHz}$ and $V_{en} = 60 \text{ GHz}$. Fig. 1 shows the dielectric constant, real and imaginary parts and loss tangent of plasma medium for the above mentioned values at the frequency range of 0-10 GHz.

Another parameter that characterizes plasma medium absorption is the absorption coefficient [9]. This coefficient is related to plasma parameters like conductivity and dielectric permittivity as below:

$$\mu_w = \frac{\sigma_w}{\epsilon_0 n c} \quad (3)$$

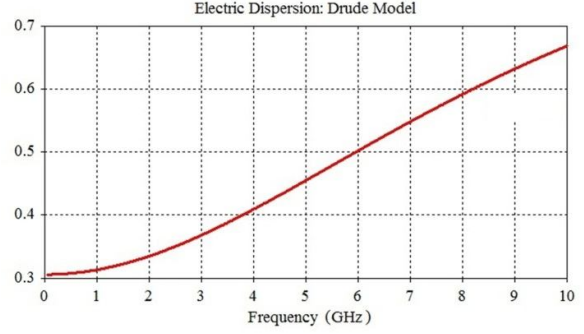
In this equation, σ_w is the conductivity of plasma medium that is calculated using (2), and n is the refractive index, as shown below:

$$n = \sqrt{\frac{1}{2} (\epsilon_w + \sqrt{\epsilon_w^2 + \frac{\sigma_w^2}{\epsilon_0^2 \omega^2}})} \quad (4)$$

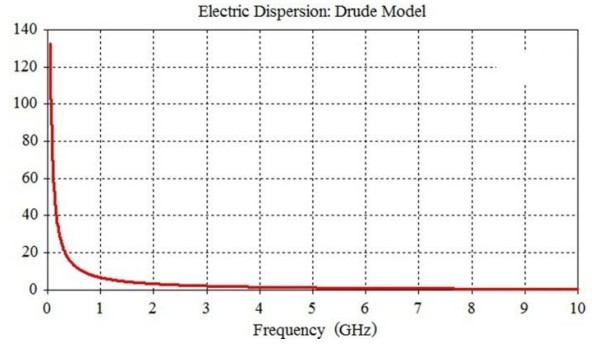
In this equation, ϵ_w is the high-frequency dielectric constant of the plasma as follow:

$$\epsilon_w = 1 - \frac{\omega_p^2}{\omega_p^2 + V_{en}^2} \quad (5)$$

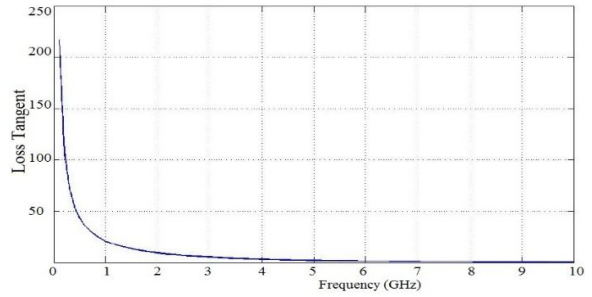
Fig. 2 shows the absorption coefficient of the selected plasma medium. As Fig. 2 illustrates, the absorption at the frequency range of 1-10 GHz is good and for the range of 2-8 GHz is comparatively much better. We expect that RCS reduction at this range is better than that for the other frequency ranges.



(a)



(b)



(c)

Figure 1: Dispersion vs. frequency a) Real part of dielectric constant, b) Imaginary part of dielectric constant, c) Plasma loss tangent.

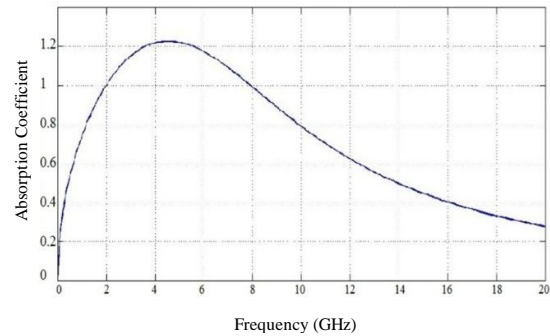


Figure 2: Absorption coefficient of the plasma.

3. SIMULATION MODEL

The simulated monopole antenna is constructed from a PEC cylinder with 3 cm diameter and 15 cm height. This cylinder is placed above a ground plane with a circular shape. A SMA port is located at the bottom of the ground plane for the antenna excitation.

The plasma medium selected in the previous section, in a helix shape like fluorescent bulbs is placed around the antenna element. The helical structure used in this simulation has 10 turns, 7 cm diameter and 15 cm height. Like fluorescent bulbs, we assumed this helix has a glass container with 0.2 mm thickness and filled with a nobel gas, that when this gas is ionized, the plasma medium can be characterized with $\omega_p = 50 \text{ GHz}$ and $V_{en} = 60 \text{ GHz}$. Fig. 3 shows the antenna structure with helix plasma medium around it. This shape is selected for plasma absorber, in order to achieve a good absorption without disturbing the antenna performance.

Antenna simulation is performed using CST Microwave Studio software.

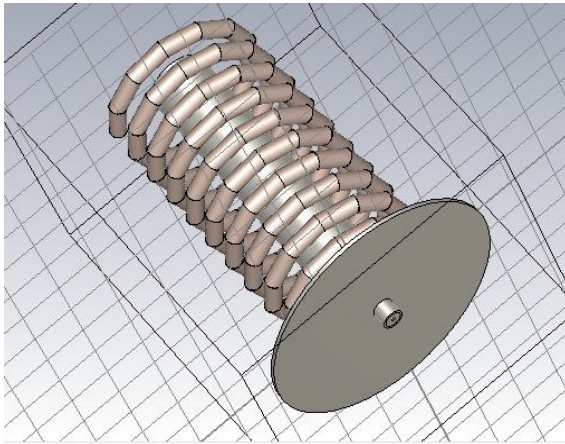


Figure 3: Simulated antenna structure.

4. RESULTS AND DISCUSSIONS

In this paper, plasma medium is used to reduce the radar cross section of the monopole antenna. Fig. 4 shows the monopole antenna return loss, with and without the plasma helix absorber.

As Fig. 4 demonstrates, the return loss of the antenna does not change significantly. Far field pattern (directivity) of the antenna is demonstrated in Fig. 5 and also the antenna efficiency shows that this plasma helix does not disturb the antenna performance significantly.

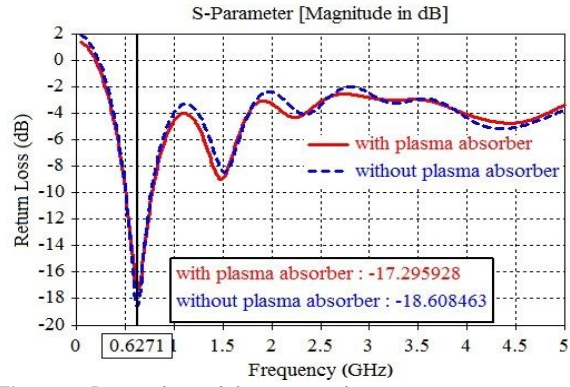
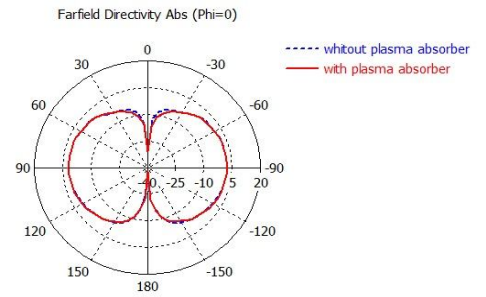
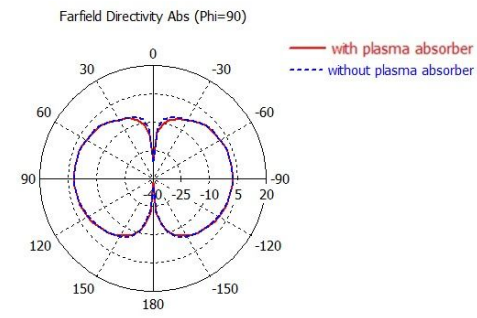


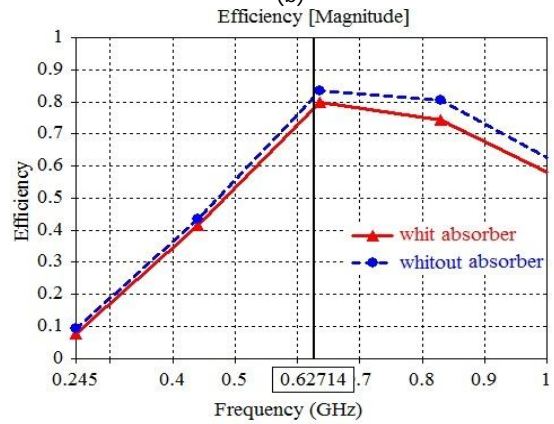
Figure 4: Return loss of the monopole antenna.



(a)



(b)



(c)

Figure 5: (a, b) Monopole antenna radiation pattern and (c) efficiency.

Fig. 6 shows the monopole antenna radar cross section at frequency range of 0.05-10 GHz in azimuth. This figure reveals that the monopole antenna RCS is reduced at this frequency range. The RCS reduction is much better at the frequency of about 4GHz. This is due to the plasma frequency dependent parameter that was shown in the previous section (Fig. 2). For better RCS reduction in the other frequencies, plasma parameter must be changed and this can be performed electrically without changing the antenna structure.

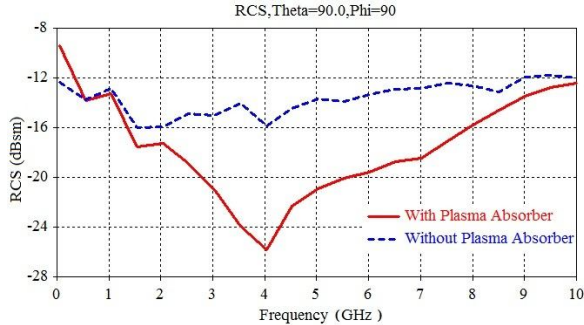


Figure 6: Radar cross section of the monopole antenna at 1-10 GHz frequency range.

From Fig. 6, it is clear that RCS reduction at 4 GHz is much better than the other frequencies. Fig. 7 shows RCS of a monopole antenna at 4 GHz with $\theta=90$.

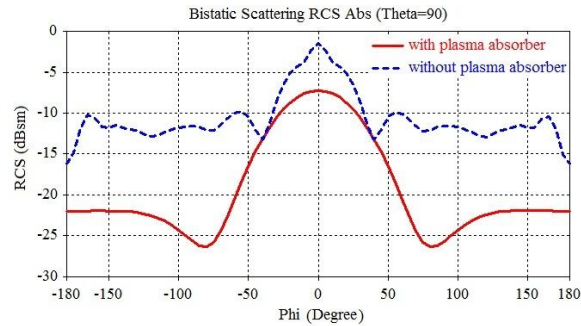


Figure 7: Radar cross section at 4 GHz.

The proposed model for RCS reduction of monopole antenna, successfully reduces the antenna RCS. This reduction is about 10 dBsm at 4 GHz. At the other frequencies, it is lower and RCS reduction nearly occurs in all directions with $\theta = 90$ degree plane.

5. CONCLUSION

In this paper, a method for RCS reduction of a monopole antenna was proposed. In this method, plasma used in a helix shape for RCS reduction of monopole antenna. Simulation reveals that RCS of a monopole antenna is reduced in a wide frequency range, namely from 1 GHz to 10 GHz. In addition, this plasma helix doesn't disturb the antenna performance. RCS reduction is about 10 dBsm at 4

GHz and for the other frequencies is comparatively lower. This method can be used for many type of monopole antenna in order to reduce the antenna RCS. In order to find higher reduction in the other frequencies, the plasma parameter can be changed electrically without any modification in antenna structure.

REFERENCES

- [1] M.I. Skolnik, *Introduction to Radar Systems*, Tata McGraw-Hill, pp. 49-64, 2001
- [2] W.H. Emerson, *Electromagnetic Wave Absorbers, Useful Tools for Engineer*, Emerson and Cumming Co. Manual, 1984.
- [3] M. Laroussi and I.R. Roth, "Numerical calculation of the reflection, absorption, and transmission of microwaves by a nonuniform plasma slab," *IEEE Trans. on Plasma Science*, vol. 21, no. 4, pp. 366-372, 1993.
- [4] B. Chaudhury and S. Chaturvedi, "Three dimensional computation of reduction in radar cross section using plasma shielding," *IEEE Trans. on Plasma Science*, vol. 33, pp. 2027-2034, 2005.
- [5] K.G. Budden, *The Propagation of Radio Waves*, Cambridge Univ. Press, pp. 470-475, 550-582, 1985.
- [6] H. Singh, A. Simy, and M.J. Rakesh, *Plasma-based Radar Cross Section Reduction*, Springer Singapore, 2016.
- [7] B. Chaudhury and C. Shashank "Radar cross section reduction using plasma blobs: 3-D finite difference time domain simulations," in *Proc. Applied Electromagnetics Conf.*, Kolkata, India, 2007.
- [8] B. Jazi, Z. Rahmani, and B. Shokri, "Reflection and absorption of electromagnetic wave propagation in an inhomogeneous dissipative magnetized plasma slab," *IEEE Transactions on Plasma Science*, vol. 41, pp. 290-295, 2013.
- [9] R. Wu, *et al.*, "RCS analysis of disk target covered with non-uniform plasma," in *Proc. IET International Radar Conf.*, Hangzhou, China, 2015.
- [10] K. Takahagi, *et al.*, "Study on radar cross section for the plasma antenna in UHF band," in *Proc. Asia-Pacific Microwave Conf.*, Japan, 2014.

BIOGRAPHIES



Mohsen Khadir received his B.Sc. degree in Electrical Engineering in 2010. He received M.Sc. degree in Communications Engineering from Tarbiat Modares University, Tehran, Iran, in 2013. His research interests include antenna design, RF amplifier and oscillator design and radar cross section reduction.



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