Use of radioactive sources in radar receiver protector

Ramezani. M.* [1], Razavi. R. [1], Hosseinzadeh. T [1]. Mir mohammad hosseini. S. A [1]
[1]Department of Physics, Faculty of Basic Sciences, Imam Hossein Comperhensive University, Tehran, Iran
* *Email: morteza_ramezani@ihu.ac.ir*

Abstract

Receiver protector protects the radar receiver while transmitting radar power. In recent years, the use of radioactive sources as an auxiliary electron source in the receiver protector has led to the generation of a regular breakdown voltage and is one way to prevent damage to the receiver. In this paper, a mixture of cobalt source (as a radioactive source) and helium gas are used to produce a radioactive ignitron. The MCNPX code is used to calculate the deposition energies in the receiver chamber. Then, the electrical potential energy caused by ionization of radioactive source in different activities is determined with CST software at a working frequency of 12 GHz.

Keywords: Radioactive ignitron, Receiver protector, Breakdown voltage.

Introduction

In the typical use of radars, the radar transmission power is 10^6 W, while the maximum possible power for a radar receiver is about a few watts [1]. Obviously, some kind of protective insulation is needed between the transmitter and the receiver to protect the radar receiver [2]. Radar receiver protector generally protects the receiver from damage during the transmission of radar power. Radar receiver protectors are generally not ideal limiters, in some cases there is a leak to the receiver. Typical receiver protectors have many disadvantages, including:

1- Decreased sensitivity of the receiver due to noise.
2- Requiring a high voltage source about 1000 volts.
3- The relatively short lifespan which is between 500 and 1000 hours due to the erosion of the electrodes.

To overcome the above disadvantages, Recently, radioactive sources have been used as an auxiliary electronic source in the receiver protector and have replaced the direct source. Radioactive sources as an auxiliary electron source reduce the breakdown voltage of the receiver protector against destructive waves.

In this paper, we used the actual dimensions of an x-band receiver protector and a cobalt and helium gas source to generate an auxiliary electron source to create a reliable and safe breakdown voltage at 12 GHz.

Theoretical method

The geometry used in the simulation was considered as a rectangular cubic chamber with dimensions of 10.16 mm, 22.86 mm and 50 mm. The transfer of beta particles and the energy deposition in the chamber was simulated using the MCNPX code. Equation (1) is used to calculate the rate of electron production in the chamber [3]:

$$q = \frac{5N_\alpha}{2\pi}\int_0^{50}\int_0^{22.8}\frac{n(z)dxdy}{z^2} \qquad (1)$$

Where, Z is the distance along the height of the chamber, n(z) is the number of ion-pair produced versus the height of the chamber and Nα is the number of decays per second.Then, in the ionized gas environment, the plasma frequency (the rapid and continuous movement of electrons back and forth in the plasma environment called the plasma frequency, or in other words the plasma response to an external electric field) and the collision frequency(the duration of the collision, the electron with the particles in the plasma is called the collision frequency. In the collision frequency, the collision of the electron with the neutral atom is considered) are calculated using equations (2) and (3) [4].

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

where n_e is the equilibrium density of electrons, e is electron charge, m_e is electron mass and ε_0 is the electrical permeability.

$$\gamma_c = 8.3 \times 10^5 \pi a_{He}^2 \sqrt{T} n_e \qquad (3)$$

a_{He} is the radius of the helium molecule and T is the temperature.

Results and discussion

The electron density, plasma frequency and collision frequency vs different activities in the ionized gas environment are shown in Figures (1), (2) and (3) respectively.

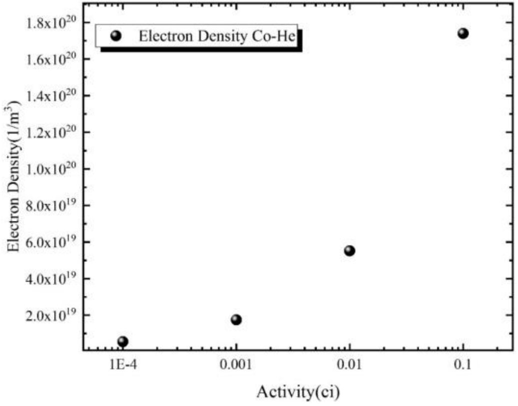

Figure 1. The electron density of the chamber is studied in different activities.

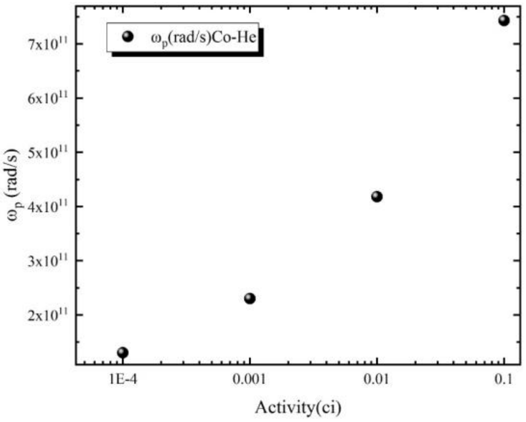

Figure 2. The plasma frequency of gas and source mixtures studied in different activities.

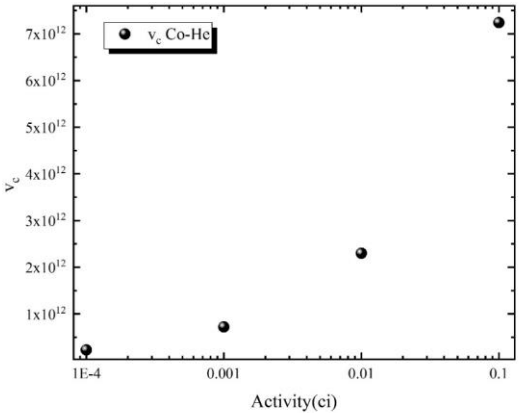

Figure 3. The collision frequency of gas and source mixtures studied in different activities.

As can be seen from figures 1 to 3, when the activity of the source increases, the electron density, plasma frequency and collision frequency in the mixed source environment and the gas, increase. In the following, we use CST software to define the mixture of source and gas (ionized material). Using the plasma frequency and collision frequency values calculated in Figures (2) and (3), we simulate the ionized environment (plasma), which is shown in Figure (4).

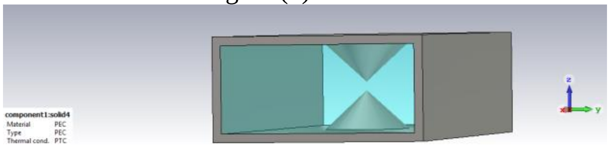

Figure 4. Simulation of ionized chamber and environment with CST software.

Since we know that the receiver protector has the role of a waveguide, we considered the standard input port, which includes an impedance of 50 ohm and frequency of 12 GHz for this ionized environment (the cobalt source and the helium gas). Then, we obtained the amount of electric field in the area between the two cones in the receiver shield, and after that this procedure was repeated for the pure helium gas to extract the electric field. In figures (5) and (6) the obtained values of the electric field are shown.

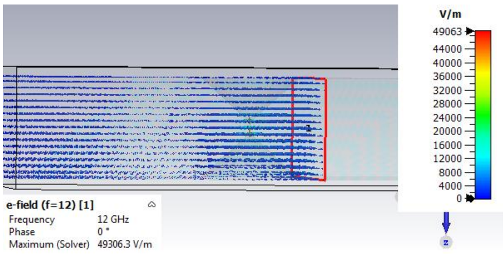

Figure 5. Electric field obtained for pure helium gas.

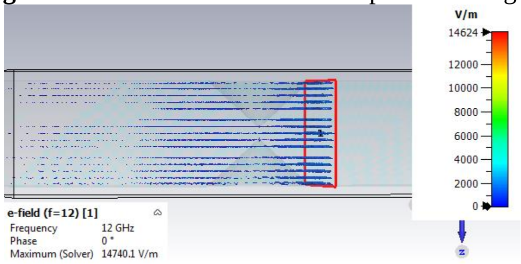

Figure 6. Electric field obtained for For mixed gas (cobalt source+ helium gas).

The difference between the two electric fields may be due to the electric field of the radioisotope source added to the helium gas as can be seen in Eq. (4):

$$E_{nuclear} = E_{pour} - E_{com} \quad (4)$$

$E_{nuclear}$ is the electron auxiliary field, E_{pour} is the electric field of helium gas and E_{com} is the electric field of helium gas and cobalt source. Figure 7 shows the auxiliary electron field extracted from Equation 4.

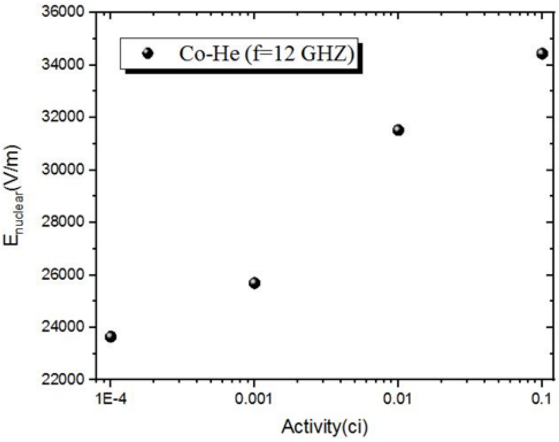

Figure 7. Nuclear electric field (auxiliary) obtained for mixed gas (cobalt + helium) at a frequency of 12 GHz.

According to the figure, it can be concluded that with increasing the activity of the cobalt source, the amount of auxiliary electron field increases, which can create a reliable and safe breakdown voltage for the receiver protector. On the other hand, increasing the amount of auxiliary electron field reduces the breakdown voltage in the receiver protector and reduces the damage that may occur in the receiver protector.

References

[1] R. Lake. et al. U.S. Patent No. 3, 781. 719, (1973).
[2] A. Cook. et al. Appl. Phys. Lett. 97, 011504 (2010).
[3] H. August, IAEA, VIENNA, (1966).
[4] M. Dehghan, et al. Advanced Defence sci & technol, (2019).