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Optimization of Operating Parameters of Plasma Antenna

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In this work, the operating parameters of the plasma antenna are optimized using a kinetic model based on Particle in Cell-Monte Carlo Collisions (PIC-MCC) method. This optimization study is performed via the investigation of variations in the operating parameters of the plasma antenna, i. e., its dimensions, background gas pressure, and the applied voltage frequency and their consequent effects on the plasma frequency, kinetic energy of electrons and plasma current density of plasma antenna. While the antenna performance is improved at higher tube lengths and applied frequencies, it is optimized at a particular tube radius. Moreover, higher background pressures have increasing effects on the plasma antenna operation. Based on this parametric study, the optimum operating parameters of the plasma antenna are established.

1 Introduction

Plasma discharge characteristics of the plasma antenna such as density or conductivity can be controlled by varying of its operating parameters such as working pressure, dimensions of its dielectric tube, plasma antenna length, and so on [1]. This ability enhances the electrical and mechanical manipulating capability of plasma antenna which is called re-configurability. Plasma frequency is proportional to the square root of electron density for a metal antenna ($n_e \sim 10^{18} - 10^{28}$ m^{-3}, for various metals) and is fixed in the X-ray region. While the plasma frequency of a plasma antenna ($n_e \sim 10^6 - 10^{18}$ m^{-3}) can be varied in the radio-frequency (RF) or even in the microwave region which is based on the variations in electron density inside the plasma antenna. Thus, the stealth capability of a plasma antenna in the electronic warfare can be improved [1].

Surface wave plasma discharge tube uses the propagation of surface waves along plasma and dielectric tube interface to produce and sustain the plasma discharge [2]. Generally, these plasmas are long quiescent, stable and reproducible. Considering the nonlinear effects which are specific to the bounded plasma discharges, the appearance of the plasma surface solitary wave on the interface between the plasma column and the bounding dielectric medium was studied by L. Stenflo [3]. On the basis of energy balance equations, Y.M. Aliev [4] obtained the axial distribution of the produced electron density by the ionizing surface waves. Moreover, using appropriate launching structures such as the Surfatron [5], these waves can be excited very efficiently. A review on the properties of the sustained plasma columns based on azimuthally symmetric surface waves is given by Moisan et al. [6]. Chaker et al. [7] studied experimentally the microwave and RF surface wave sustained discharges as plasma sources and varied the background gas pressure from 1 to 30 mTorr. They observed that, the higher electron densities occur at higher gas pressures. Moreover, they examined their system for four different frequencies, i. e., 27, 50, 100 and 200 MHz and the increasing effects of the higher RF generator frequencies on the plasma density was reported.

Initially, the surface wave produced plasmas were used in the plasma antenna by Borg et al. [8]. They showed that the surface wave plasmas produce very low noise and can be used to produce plasma in a plasma antenna. The Surfatron surrounds only a small portion of the discharge vessel and antenna is feed from one end, so stealth capability of the plasma antenna is improved because of the reduction in the metal elements.

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Kumar et al. excited a 0.3 m long plasma column by a surface wave, which acts as a plasma antenna [9]. They examined the antenna characteristics of such assembly and showed that, when the number of antenna elements is varied from 4 to 10, the directivity of such antenna increases from 2.9 to 4.1 [9]. Moreover, they observed that, the variations in the operating parameters such as working pressure (0.03 - 0.30 mbar), applied voltage frequency (3 - 10 MHz), applied input power (10 - 100 W), radius of the plasma antenna glass tube (1.5 - 2.5 cm) and length of the plasma column (5 - 30 cm) causes the transformation of the plasma column of the plasma antenna into a finite number of cylindrical stationary striations [10]. Moreover, in another experimental study by Kumar et al. [11], the current and conductivity distributions, electric field, power patterns, directivity and efficiency of the plasma antenna were examined. An equivalent metallic copper antenna was built up and its antenna parameters are compared with that of the plasma antenna. The plasma current on the surface of the plasma antenna at various background gas pressures and different axial positions was experimentally measured.

Rayner et al. examined theoretically and experimentally the excitation of a plasma antenna using an argon surface wave plasma discharge operating at 500 MHz with RF power levels up to 120 W and gas pressures from 0.0225 to 0.375 Torr [12]. Their results show that, at higher applied powers, the length of the plasma antenna increases and plasma density decreases linearly from the wave launcher to the end of the plasma antenna [12].

The plasma antenna parameters with two different background gases, i. e., Neon and Argon at the pressure of 1 Torr were studied by Bonde et al. [13].The return loss and the radiation pattern of these two plasma antennas were discussed. They observed that, in the frequency ranges around the optimum frequency, both gases yield the return loss below -15 dB. In another work, using different number of turns of coil as coupling sleeve, Halili et al. [14] analyzed the performance of a monopole plasma antenna. Their plasma antennas were fabricated with three different background gases i. e., neon, argon and xenon with the pressures as 0.5 Torr, 5 Torr and 15 Torr, respectively [14].

Chao et al. adopted a cylindrical-coordinate Finite Difference Time Domain (FDTD) algorithm to model a plasma antenna with the length of 0.4 m [15]. They computed the input impedance and radiation efficiency of plasma antenna in the frequency ranges from 75 MHz to 400 MHz. Their numerical results show the simultaneous variations in the characteristics of plasma antenna with plasma frequency (or the square root of plasma density) and collision frequency [15]. Moreover, Ye et al. obtained the system equations according to the rule of the disturbing current, which was excited by the surface waves on the interface between plasma column and the dielectric tube [16].

Despite of much theoretical and experimental efforts to understand the electrical and physical characteristics of plasma antenna, a detailed kinetic and microscopic description of its operational properties is still absent. Thus, in this paper, using a two dimensional kinetic model based on Particle in Cell-Monte Carlo Collisions (PIC-MCC) simulation technique, the effects of varying of the operating parameters, i. e., plasma antenna dimensions, background gas pressure and the applied voltage frequency on the plasma frequency, kinetic energy of electrons and plasma current density are studied. The optimum operating parameters of the plasma antenna are established based on this parametric study.

2 Simulation model

In this work, using a 2D PIC-MCC simulation method, an optimization study is performed on the operating parameters of the plasma antenna, i. e., plasma antenna dimensions, background gas pressure and the applied voltage frequency. The considered discharge mechanism for the plasma antenna is the surface wave discharge getting excited by a common RF generator at low pressure gases [2, 5, 6, 17, 18]. The surface wave movement on the dielectric tube of the plasma antenna and along its gaseous media results in the formation of the striations inside the plasma antenna [10].

PIC-MCC simulation method is able to estimate the basic features of the low pressure gaseous discharge media such as plasma antenna that cannot be simulated with the other simulation methods such as fluid models. These features are mostly including the nonlocal plasma kinetic effects, Ohmic heating, and striation formation inside the plasma antenna [19, 20, 21]. On the other hand, the differential cross sections for collisions, that are essential in the plasma antenna, can be easily implemented in the PIC-MCC simulation schemes. This method provides the evolution of different features of plasma antenna, as it works in RF range. While the PIC-MCC simulation method can overcome many limitations of the other methods, it is computationally expensive and typically limited to the simple geometries with few gas species, such as plasma antenna. However, the obtained results can also be used to find optimum of the operating conditions or propose novel designs for performance improvements [22, 23].

The PIC-MCC simulation method takes the advantage of the collective behaviour of various charged particles in the plasma discharges to describe the behaviour of different species based on the modelling of a reduced number of computer particles (or super-particles) [24, 25, 26, 27]. Generally, one super-particle per 10^5 to 10^7 real particles is chosen in the existing reported literatures. In spite of this much of reduction in the number of particles, Birdsall showed that the plasma physics are retained by this method for plasma simulation [28]. As mentioned above, the trajectory of these super-particles is tracked by solving the fundamental equations, i. e., Newton-Lorentz coupled with Maxwell equations. Moreover, as no assumption has been made on their velocity distribution, the kinetic behaviour of each species is modelled via a very little approximation. In this method, the simulations are performed for electrons and ions of plasma and the background neutrals are assumed to have an uniform spatial distribution. Finally, the boundary conditions are imposed by the external circuits and can be self-consistently considered based on the solution of the obtained equation from the Kirchhoff Circuit Law (KCL) simultaneously with Maxwell equations [29].

In cylindrical coordinates, the possible modes of propagation of surface waves are defined by their field intensity dependence upon the azimuthal angle φ. This field intensity in the case of uniform media varies as $\exp(\mathrm{i}m\varphi)$ for traveling waves, where m is the integer defining the mode of propagation [17]. Here the plasma antenna is considered a dielectric tube in cylindrical coordinates and z-axis coincides with its axis. The m = 0 mode for surface wave produced plasma is considered and there is azimuthal symmetry in the plasma antenna. Thus, (z, r) coordinates will describe the problem sufficiently.

As shown in Figure 1, the plasma antenna is considered as a dielectric tube that is evacuated by conventional rotary or diffusion pumps and filled by argon gas. A surface wave launcher such as Surfatron [5] is mounted at one end of the tube and excites the traveling surface waves to produce and sustain the plasma discharge. The power generator works in RF range along with an impedance matching network [9]. Because of cylindrical symmetry, the z-axis is considered along dielectric tube axis and r-axis is along its radius. The origin of coordinate system is placed at one end of the tube on the center of the surface wave launcher.

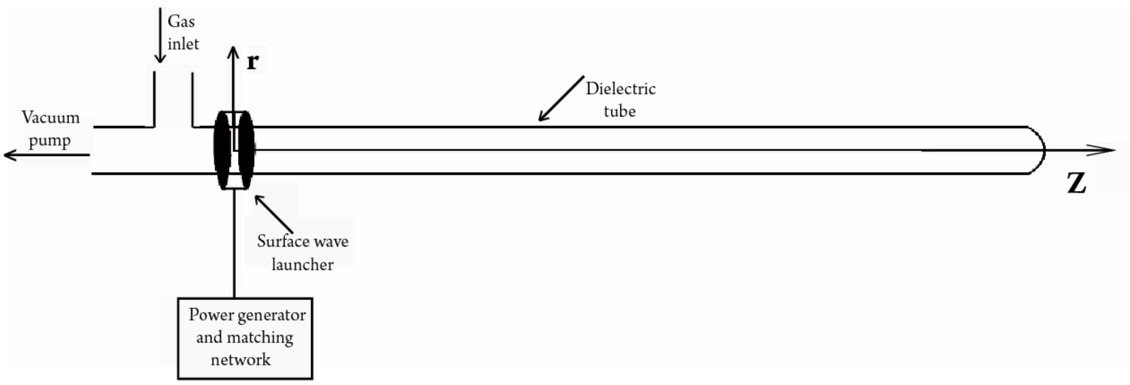


Fig. 1 Schematic diagram of plasma antenna and simulation coordinates.

Because of the nature of surface wave produced plasmas, ionizations of second and higher order argon atoms are ignorable and only two charged species (electrons and argon ions (Ar^+)) are taken into account. The excitation of surface wave on the surface of tube occurs from one end of plasma antenna (z = 0) by a surface wave launcher and damps as it propagates along the column. This wave transfers some of its energy to the plasma at each point. This damping of the electromagnetic wave along the sidelong surface of the tube is considered to obtain the boundary conditions for plasma antenna in the simulation scheme.

In PIC-MCC simulation method, particles are defined in a continuum position and velocity space. Field values are defined at discrete locations in space. Particle and field values are advanced sequentially in time, starting from initial conditions. The particle equations of motion are solved at every time step, using field values interpolated from the discrete grid to particle locations. The force on every particle is computed by interpolation of the field values from the grid position to the given particle positions. The position and velocities of each particle is next updated based on the solution of the classical equation of motion [24]. Next, particle boundary conditions are applied. For modeling collisions, the Monte Carlo collision (MCC) scheme is applied [25, 30]. Source terms for the field equations are accumulated from the particle locations to the grid locations. The field values are then advanced by one time-step, and the time loop starts again (Figure 2) [19, 24, 25, 28, 30].

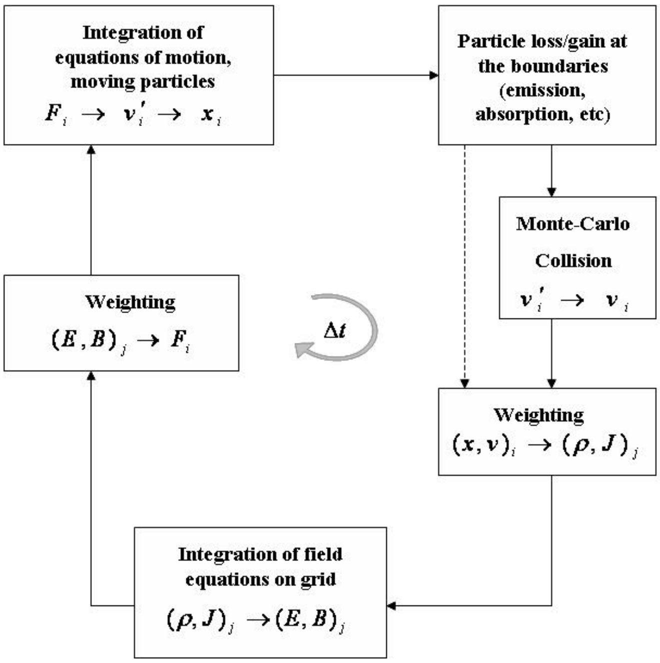


Fig. 2 Schematic diagram of plasma antenna and simulation coordinates.

In the PIC-MCC simulation scheme, each super-particle, representative of one or a much larger number of real particles, is designated in continuum space by its position and velocity. Initially, a Maxwellian distribution is assumed for electrons and ions. Further, the particles are uniformly distributed in the plasma antenna. Particle boundary conditions such as absorption and emission are used to account for the relation between the plasma discharge current in the plasma tube and the current in the external circuit. When an electron or ion passes from the discharge into an end wall, it adds to the wall charge and is deleted from the list of active particles. Additionally, secondary emissions occur when a charged particle impacts the wall of the tube causing ejection of electrons from the surface [25]. The gas within the antenna tube is taken to be argon at low pressures, i. e., 0.005 - 0.050 Torr [9].

The potentials and fields inside the plasma antenna are obtained using Poisson's equation:

$$\nabla \cdot \varepsilon_0 \nabla \Phi(x,t) = \rho(x,t) \tag{1}$$

The potential (Φ) can be separated as follows [24, 31]:

$$\Phi = \Phi_P + \sum_{Boundaries} \Phi_L \tag{2}$$

where Φ_P and Φ_L represent the Poisson and Laplacian parts of electrical poential (Φ). Therefore, the field may be described by the combination of the following equations:

$$\nabla \cdot \varepsilon_0 \nabla \Phi_P = -\rho \tag{3}$$

$$\nabla \cdot \varepsilon_0 \nabla \Phi_{Li} = 0 \tag{4}$$

The boundary condition for equation (3) is $\Phi = 0$ on all boundaries as the Poisson field is solely due to charge in the medium. For each boundary with a Dirichlet condition, equation (4) is solved for $\Phi_i = 0$ on the equipotential surface, and $\Phi = 0$ elsewhere which gives us $\Phi_{Li} = 0$ (the potential due to the i^{th} Laplacian field). Φ_L is obtained by the superposition of all the Laplacian fields. Neumann boundary conditions are included through $\Phi_P = 0$. This method neglects charges induced by a driven electrode on other boundaries which are connected to an external circuit. It is also possible to solve the field Poisson equation with boundaries and circuits [25]. In this work, an X11- based Object Oriented Particle In Cell (XOOPIC) code [32] is used which is based on PIC-MCC simulation scheme. This C^{++} program is designed to simulate the behaviour of charged particles in a two dimensional geometry. This code is an electromagnetic program and solves Maxwell's Equations on a mesh to self-consistently advance the particles in time [32]. In the two dimensional (cylindrical coordinates (r, z)) simulations, for stability and accuracy of calculations, the Courant-Levy stability criterion on the time step is given by [24].

$$\Delta t \leq \frac{1}{c}\left(\frac{1}{(\Delta z)^2}+\frac{1}{(\Delta r)^2}\right)^{-1/2} \tag{5}$$

Thus, choosing the simulation parameters such as time step (Δt) and cell sizes (Δz andΔr) has an important role in the high accuracy and stability of simulation [33]. The velocity and energy of particles should be considered in choosing of the simulation time steps and it has to be lower than the required time for a particle to pass through a cell. The time step (Δt) is inversely proportional to the plasma frequency. Usually, there must be [25]

$$\omega_{pe} \cdot \Delta t \leq 1.62 \tag{6}$$

where, ω_{pe} is the plasma frequency and, generally, is defined as follows [34]:

$$\omega_{pe} = \left(\frac{4\pi n_e}{m_e}\right)^{1/2} \tag{7}$$

where, n_e is the electron density per cubic centimetre and m_e is the electron mass. On the other hand, the mesh spacing in each direction h, should be a fraction f, of the Debye length, i. e.,

$$h = f\lambda_D = f\left(\frac{\varepsilon_0 T_e}{e n_e}\right)^{1/2} \approx 7000 f\left(\frac{T_e}{n_e}\right)^{1/2} \tag{8}$$

where, T_e (eV) is the electron temperature, and f is usually chosen to be about 0.5 [25]. Generally, in the common plasma antennas operating based on the surface wave discharges, the electron temperature (or the kinetic energy of electrons) is in the order of 1-5 eV [18].

3 Simulation results

In this section, using the above explained 2D PIC-MCC simulation model and based on a parametric study, the operating parameters of a plasma antenna are established. This parametric study is performed based on varying of the length and radius of the plasma antenna, the pressure of argon gas within the plasma antenna and RF generator frequency on the kinetic energy of electrons, plasma current density and plasma frequency. Unless otherwise mentioned, the simulations are performed with the chosen parameters presented in table 1. It must be noted that the plasma frequency is proportional to square root of electron density and is obtained from the following relation:

$$\omega_p = 2\pi f_p \tag{9}$$

where

$$f_p \approx 10^4\sqrt{n_e} \tag{10}$$

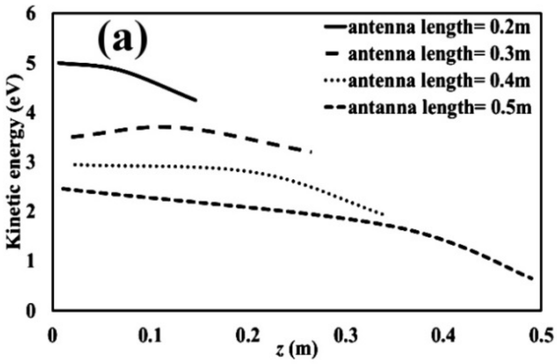
and n_e is electron density per cubic centimeters [34]. Thus, the effect of operating parameters on the plasma frequency is similar to the electron density. Increase in the electron density results in the higher plasma frequencies and consequently, the operating frequency band of plasma antenna will be improved. Plasma current density magnitude is obtained according to $J = \sum_j e n_{ej} V_{dj}$, where V_{dj} is drift velocity of each electron and summation is over all of the plasma electrons [34]. Effects of ions current density are ignored because of their low drift velocity in comparison with the plasma electrons.

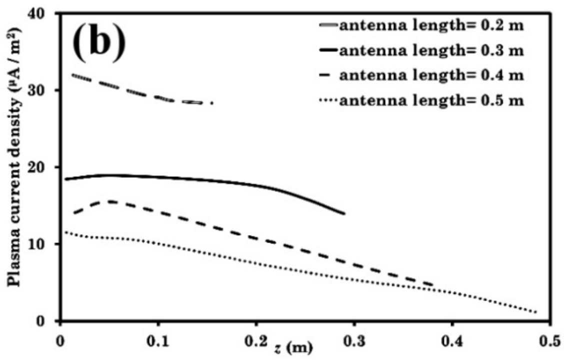
Table 1 Simulation Parameters

Number of cells in length (z) direction	100
Number of cells in radius (r) direction	5
Number of simulation cycles	10^7
Time step (Δt)	8.2×10^{-12}s
Length	30 cm
Diameter	3 cm
Number of physical particles to computer particles (np2c)	10^7
Pressure	0.02 mbar
Gas	Ar (Argon)
RF generator frequency	200 MHz
Geometry	0 (Cylindrical geometry)
Dielectric tube relative permittivity	5 for glass

3.1 Effects of the plasma antenna length

Here, to obtain the optimal length for plasma antenna, the length of plasma antenna is varied from 0.15 to 0.5 m, while the other parameters are taken from table 1. As the length of the plasma antenna increases, for a given pressure, the residence time for electrons to ionize the neutral particles inside the plasma antenna is higher. Each electron suffers a larger number of ionizing collisions as it travels from the position of applied surface wave to the plasma antenna end; as a result, the production of charged particles inside the plasma antenna is higher at higher plasma tube lengths. Moreover, at higher lengths, due to increasing of the tube volume, the number of background argon atoms and consequently, the number of electrons is increased.





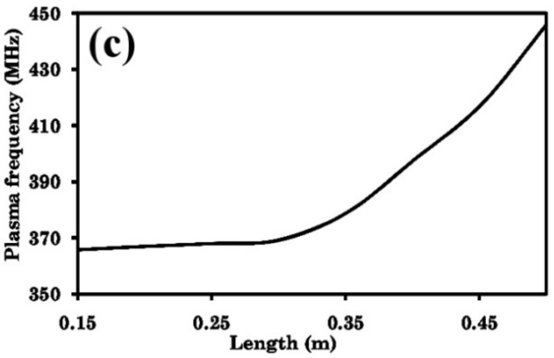


Fig. 3 (a) Variations in the kinetic energy of electrons versus axial distances from the surface wave launcher for different lengths of plasma antenna: 0.2 m (black line), 0.3 m (long dashed line), 0.4 m (dotted line) and 0.5 m (dashed line), (b) Variations of the plasma current density versus axial distances from the surface wave launcher for different lengths of plasma antenna: 0.2 m (dash-dotted line), 0.3 m (black line), 0.4 m (dashed line) and 0.5 m (dotted line), (c) Variations in the plasma frequency versus plasma antenna length.

As shown in Figures 3a) and 3c), a reduction in the kinetic energy of electrons and an increase in plasma frequency (density) is observed at higher plasma antenna lengths. It causes increase in the plasma frequency and improved operating frequency band of the plasma antenna. It must be mentioned that, to obtain plasma frequency, the average value of the total electron density in the entire of plasma medium is used. As shown in Figure 3b), variations in the length of plasma antenna have interesting effects on the plasma current density. As the RF generator input power is kept constant, despite of increase in the plasma current density at higher lengths, owing to the reduction in the applied electric field and its consequent effects on drift velocity of plasma charged particles, the plasma current density decreases at higher lengths. Finally, as observed in Figures 3a) and 3b), at higher axial positions from the surface wave launcher, the plasma current density and kinetic energy are reduced. This is owing to the reduction in the plasma density and drift velocity of electrons at higher axial positions which is a direct result of axially damping of the surface wave power. The observed damping of the wave power or its corresponding electric field and its effects on the plasma density is one of the fundamental specifications of surface wave plasma discharges [6, 10, 35]. Furthermore, an axial decrease in the plasma current is reported by Kumar et al. [11].

3.2 Effects of Plasma antenna radius

To achieve the optimized radius for plasma antenna, the radius of plasma antenna is varied from 0.005 to 0.03 m, while the applied voltage along tube side wall is held constant. The kinetic energy of electrons has a maximum value that occurs at r_0 = 0.01 m. At higher values of the antenna radius, the electric field along the radius, at constant applied voltages, reduces. Thus, it causes a reduction in the kinetic energy of electrons. Ionization and production of new charged particles, therefore, reduces, as seen in the peak values of kinetic energy of electrons in Figure 4a). On the other hand, at the lower values of the radius, due to the quickly absorption of charged particles by the tube walls, the average value of kinetic energy would be reduced. It may be noted that the lower values of the tube radius lead not only to reduction of the kinetic energy, but also, as shown in the Figure 4c), causes an increment in the operating frequency band of the plasma antenna. Moreover, the effect of tube radius on the plasma current density is interesting. As seen in Figure 4b), the plasma current density is maximized at r_0 = 0.01 m, where the kinetic energy of plasma electrons inside the plasma antenna is optimized (Figure 4a)).

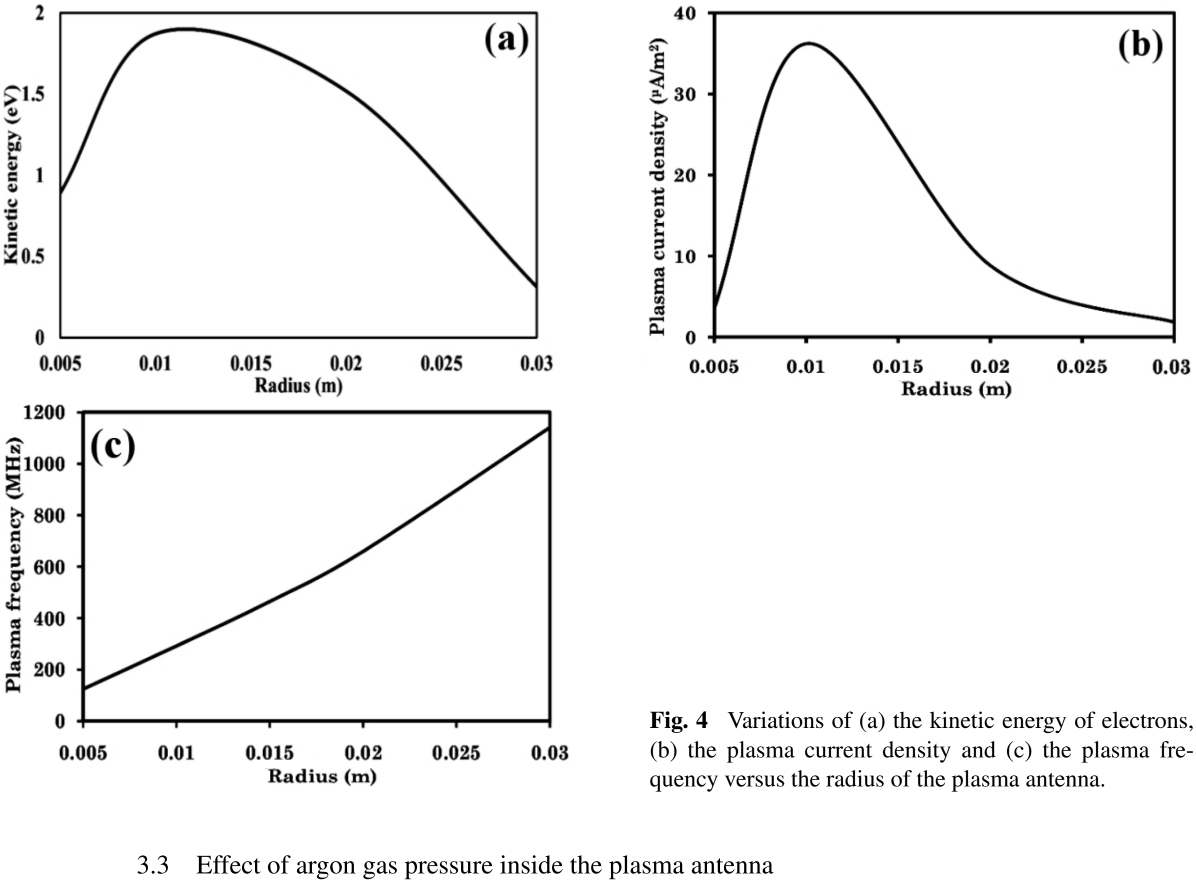
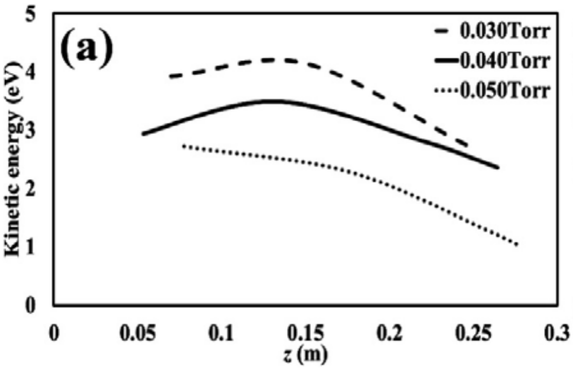
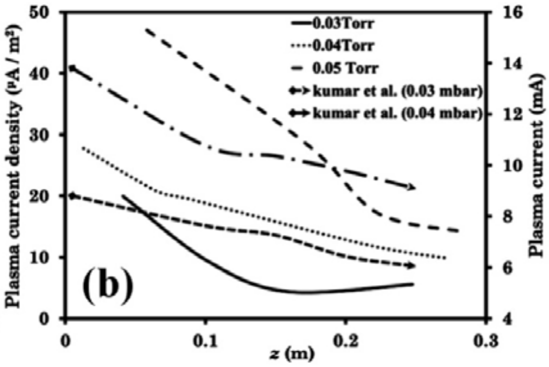


Fig. 4 Variations of (a) the kinetic energy of electrons, (b) the plasma current density and (c) the plasma frequency versus the radius of the plasma antenna.

3.3 Effect of argon gas pressure inside the plasma antenna

The effect of gas pressure on the nature of plasma discharge in the plasma antenna is studied in this section. The gas pressure varies from 0.005 to 0.050 Torr, while other parameters are kept constant (table 1). Increasing of the background gas pressure raises the number of ionizing collisions. This results in increasing of the charged species inside plasma tube. Thus, owing to the induced electric field by space charges, the electric field and consequently, the acceleration of charged particles will be reduced. This will affect the kinetic energy of electrons. This behavior is clear in the Figure 5a) for plasma antenna. However, increase in background pressure results in increased charged particles inside plasma antenna due to the increased ionization, acceleration and finally (as shown in the Figure 5c)), according to equations (9) and (10), it will increase the plasma frequency. As seen in Figure 5b), increase in the background gas pressure inside the plasma antenna and its consequent effects on the increasing of the plasma density results in the higher plasma current densities. The experimental findings by Kumar et al. for plasma current of the plasma antenna are depicted on the secondary (right) vertical axis in figure 5b) [11]. Moreover, in an experimental study by Chaker et al. [7] on the microwave and RF surface wave sustained discharges, the occurrence of higher electron densities was observed at higher gas pressures at same axial positions [7].





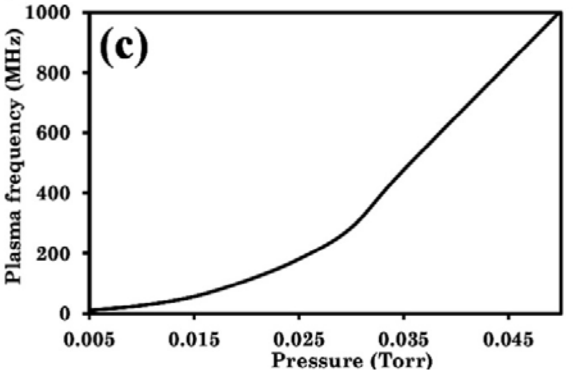


Fig. 5 (a) Variations in the kinetic energy of electrons versus axial distances from the surface wave launcher for different argon gas pressure values: 0.03 Torr (dashed line), 0.04 Torr (black line) and 0.05 Torr (dotted line). (b) Variations of the plasma current density versus axial distances from the surface wave launcher for different argon gas pressure values: 0.03 Torr (black line), 0.04 Torr (dotted line) and 0.05 Torr (dashed line); moreover, the experimental findings by Kumar et al. [11] are depicted on secondary (right) vertical axis. (c) Variations in the plasma frequency versus the pressure of argon gas.

3.4 RF generator frequency

The formation of the charged particles inside plasma antenna is strongly influenced by the applied voltage frequency. Thus, the effects of the applied voltage frequency on the plasma discharge characteristics in the plasma antenna are studied, here. The simulations are performed for the simulation parameters presented in table 1, with the applied voltage frequency varying from 3 to 200 MHz.

Operation of plasma antenna is often at a low pressure i.e., from 1 to a few mTorr and at a high frequency i.e., from 3 to 200 MHz. At the applied voltage frequency about 25 MHz, as seen in Figure 6c), the plasma frequency is minimized. At higher applied voltage frequencies, owing to the quick variations in applied electric field, due to faster electron impact with the background argon gas in the plasma antenna, the ionization rate increases. Moreover, there is a direct relationship between pressure and applied voltage frequency in the plasma discharge medium [36]. Increase in RF generator frequency results in the higher pressures inside the plasma antenna. Thus, this phenomenon produces more charged species in the medium. However, the creation of higher number charged particles in plasma antenna will reduce their acceleration and consequently, the average value of the kinetic energy of the charged particles (Figure 6a)) will decrease. Moreover, there is a little increase in the operating plasma frequency band which might be due to lower charged particles density. Finally, the dependency of the plasma current density on applied voltage frequency is presented in Figure 6b). As shown, increase in applied voltage frequency causes the higher plasma current densities. Moreover, on increasing the applied frequency, the RF wave energy is increased and higher ionization and particles drift velocity is obtained. Finally, similar to the presented results for variation plasma antenna length in figures 3a) and 3b), the reduction in the plasma current density and kinetic energy is clear. The experimental findings by Chaker et al. [7], show the increasing effects of the higher RF generator frequencies on the plasma density at the same axial positions.

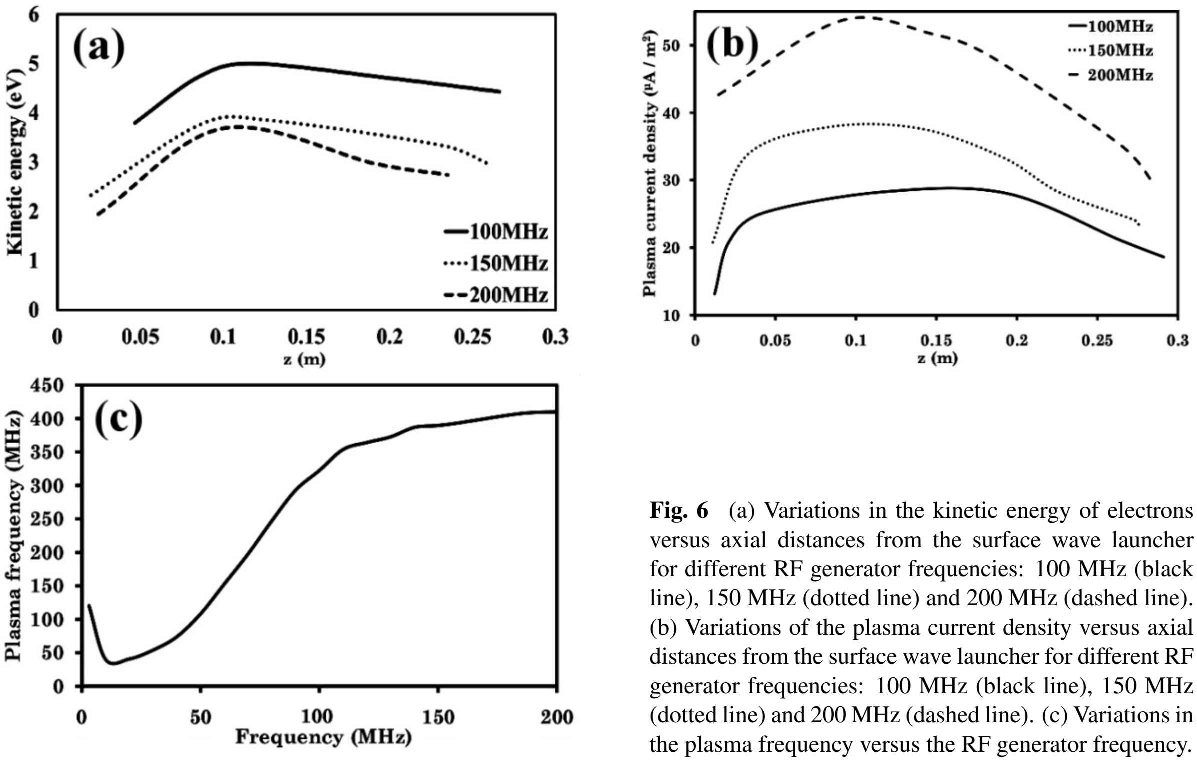


Fig. 6 (a) Variations in the kinetic energy of electrons versus axial distances from the surface wave launcher for different RF generator frequencies: 100 MHz (black line), 150 MHz (dotted line) and 200 MHz (dashed line). (b) Variations of the plasma current density versus axial distances from the surface wave launcher for different RF generator frequencies: 100 MHz (black line), 150 MHz (dotted line) and 200 MHz (dashed line). (c) Variations in the plasma frequency versus the RF generator frequency.

4 Discussions

Using a 2D3V fully kinetic PIC-MCC model, the operating parameters of a plasma antenna are optimized. It has been found that, this microscopic model of the discharge is suitable for investigation of the influence of some central parameters in the plasma antenna. The model is found to suitably simulate the discharge within the plasma antenna, and give valuable insight about the influence of four central parameters on the plasma response. It is observed that, while increase in tube length and working RF generator frequency improves the antenna performance, there exists an optimum value for tube radius which maximizes performance. Furthermore, increased value of background pressure is seen to be important for high efficiency of plasma antenna operation. Finally, the results of parametric study and the established operating parameters are listed in table 2.

Table 2 Established Operating Parameters

Operating parameter	Plasma antenna length	Plasma antenna radius	Argon gas pressure inside the plasma antenna	Rf generator frequency
Optimized value	0.50 m	0.01 m	0.050 Torr	200 MHz

5 Conclusions

In this work, a plasma antenna that is sustained by surface waves is simulated through a 2D PIC/MCC model. Based on a parametric study, the operating parameters of the plasma antenna through their effects on the plasma frequency, kinetic energy of electrons and plasma current density of plasma antenna are optimized. It was seen that, increase in the length of plasma antenna results in the lower kinetic energy and higher plasma frequency as the most important characteristic parameters of the plasma antenna. It was observed that, the plasma antenna performance is optimized at a specific tube radius (r_0 = 0.01 m). On the other hand, the improving effects of higher tube lengths, applied frequencies and background gas pressures on the antenna performance were shown.

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