THE RESEARCH OF ANTENNAS ON THE COLD PLASMA

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Abstract

The results of researches internal and external characteristics of loop and rod antennas on the basis of cold plasma gas discharge are presented. The rows of advantages of such antennas above the metallic ones have been pointed.

Keywords: Cold plasma; loop plasma antenna; rod plasma antenna; radiation pattern; standing wave ratio on voltage; antenna gain; antenna efficiency.

1. INTRODUCTION

From the beginning of past century and to nowadays a number of works on research of cooperation of electromagnetic waves with plasma and on creation of plasma antennas (PA) is published [1-3]. However, not yet fully studied or not published the information about the results of researches of such characteristics of PA as input impedance, standing wave ratio on voltage (VSWR) on the input of PA, radiation pattern (RP), efficiency and other parameters of PA.

Microwave properties of two varieties of PA from cold plasma are considered in this paper: loop asymmetrical PA of standing wave (LPA) and the rod running wave cylindrical rectilinear PA (RPA).

2. INITIAL DESCRIPTIONS OF COLD PLASMA

The frequency range of researches of PA was chosen less than plasma frequency of electrons f_e, values of which in accordance with [1] calculated and represented in a table

Table. The plasma frequencies of electrons f_e depending on effective concentration (N_e) in plasma of the charged particles

N_e, cm^{-3}	$5 \cdot 10^{12}$	10^{13}	10^{14}	$5 \cdot 10^{14}$	10^{15}
f_e, GHz	20	28	89	200	280

The conductivity of cold plasma in presence the electromagnetic field and the relative permittivity was determined also on by ordinary correlations from [1].

3. THE LOOP PLASMA ANTENNA

Let us explore characteristics the LPA of published in 2001 in Russian [4] and American society of physicists in 2007 [5]. In the software environment *FEKO* (version 5.4) LPA was modelled and explored as the fig. 1.

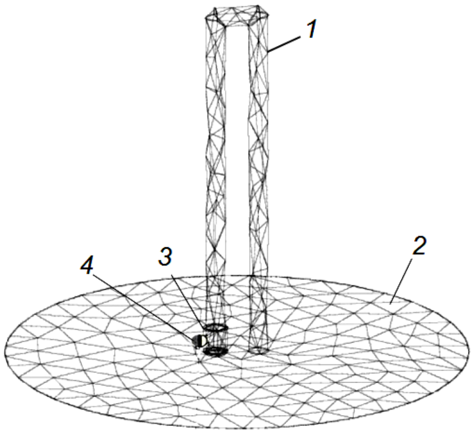

Fig. 1. Computer model of LPA: *1*- the plasma rod; *2*- the metallic conducting disk; *3*- the port of excitation point; *4*- the metallic ring (holder) for excitation of plasma loop.

The calculations of the LPA parameters are executed in a frequency range of $f = 45 - 450\, MHz$. For this frequency band graphic dependence of cold plasma conductivity (with the temperature of electronic components of plasma $T_e = 10^4\ ^0K$) which have been got from formulas [1] are presented on fig.2.

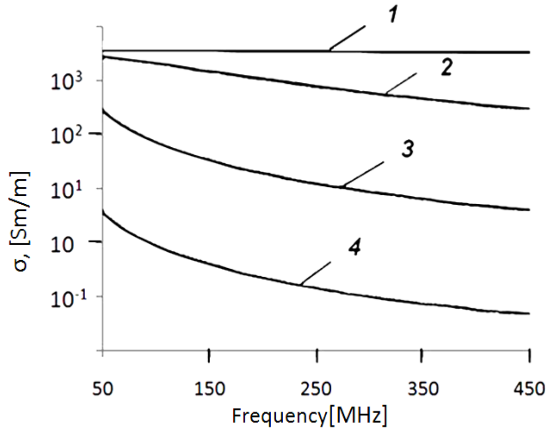

Fig. 2. The graphics of cold plasma conductivity versus frequency: *1*- the effective concentration of the charged particles in plasma Ne=10^{15} sm^{-3}; *2*- Ne=10^{14} sm^{-3}; *3*- Ne=10^{13} sm^{-3}; *4*- Ne=10^{12} sm^{-3}.

Results of the computer calculations VSWR on the input of the LPA excitation point in a band $f = 45 - 450\ MHz$ for ordinary concentration of the charged particles in plasma of Ne=10^{13} sm^{-3} at the proper values σ =*var* (fig.2) and at the change ε in limits from $-2 \cdot 10^6 \ldots -3{,}97 \cdot 10^4$ in accordance with [1] are represented on the fig. 3 (curve *1*). Here for the comparison the dependence calculation of VSWR loop asymmetrical antenna of a similar configuration from ideal metal is presented (curve *2*). As is obvious from comparison of dependences *1* and *2*, frequency range of antenna possessing properties of cold plasma wider, than for antenna of a similar configuration made of perfect electric conductor. Such result was expected, taking into account the known publications about wideband properties of ordinary emitters from a metal with small conductivity.

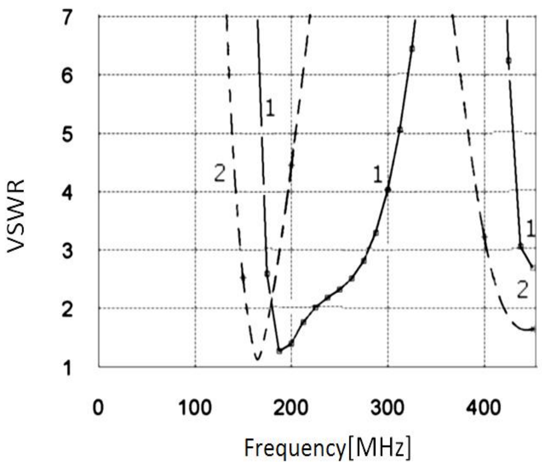

Fig. 3. The VSWR graphics in a frequency band: 1 – at frequency dispersion of conductivity σ =var (fig.2) and ε_r =var [1]; 2- for the ideal metal of that configuration.

Results of the RP calculations of examined LPA in that software environment *FEKO* on three frequencies of the examined band represented on fig.4.

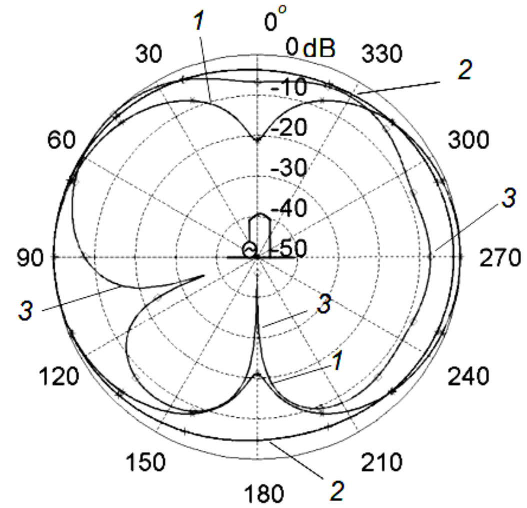

Fig. 4. The radiation pattern of the LPA at σ =*var* (fig. 2) and ε_r = *var* [1]: *1*- 45MHz; *2*- 150MHz; *3-450*MHz. *(*0dB=0dBi).

As is obvious from fig. 4 character RP is isotropic and small depending on the change of frequency, however there is a dip in RP on higher frequencies of range, that does not influence on the isotropic properties LPA.

Taking into account what is going on polemic in scientific community to estimation of dielectric permeability of cold plasma [6, and others], we executed the LPA researches at more extended values of ε_r. Thus conductivity of PA σ in the explored frequency range was determined as well as higher on formulas from [1], and ε_r = const by optimization on the criterion of minimum of the having a special purpose function VSWR (ε_r) in the set frequency range, that by comparison of two frequency dependences VSWR (experimental and calculation) (fig.5):

$$\min \mathrm{VSWR}(\varepsilon_r)\ ,\quad \varepsilon_r \in (-\infty < \varepsilon_r < \infty).$$

On fig.5 the experimental and calculation frequency dependences LPA VSWR are shown with σ =*var* (fig.2), which correspond to the closeness of the charged particles in LPA $N_e \approx N_i = 10^{13} cm^{-3}$ and ε_r, got optimization. As is obvious from the graphics at some values ε_r, for example, ε_r =500 LPA provides more wide frequency band, than for the case of considered on fig.3 for ε_r =*var* [1]. The RP for the second case (fig.5) have the same isotropic properties, as RP, resulted on fig.4.

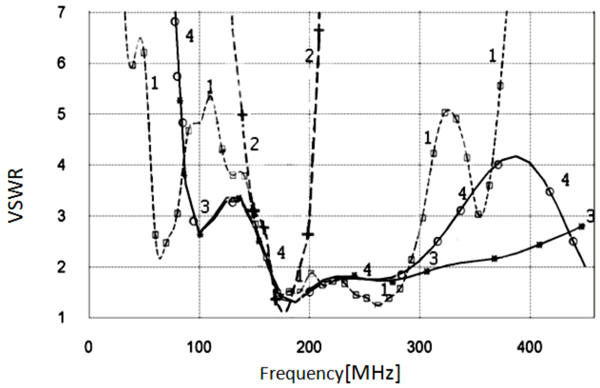

Fig. 5. The *VSWR* graphics in a frequency band: *1* is the experimental graphic for LPA fig.1; *2* is the experimental graphic for loop antenna of a similar configuration (fig.1) from an aluminum tube; *3* is the calculation graphic for a LPA of fig.1 for ε_r =1; *4* is the calculation graphic for a LPA of fig.1 for ε_r =500, (σ =var, fig.2).

4. THE ROD PLASMA ANTENNA

The examined rod plasma antenna RPA is a cylindrical circular rod with diameter *0.7λ* and long 7λ, excited from the end by a electromagnetic wave with frequency of 6,3 GHz. Calculation the RP RPA progressive wave in the software environment *FEKO* resulted on fig.6.

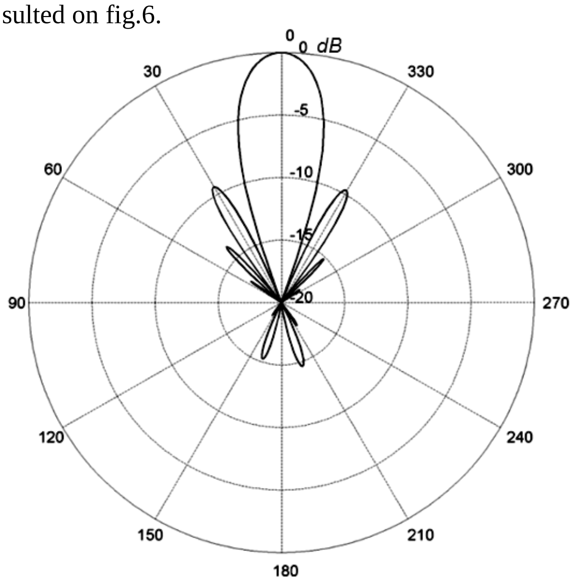

Fig. 6. The radiation pattern of the RPA in the scale gain factor for a case of $\sigma = 2{,}1*10^{-4}\, Sm/m$, [1]; ε_r =5, (0dB=6dBi).

It is obvious from fig. 6 that the RP form corresponds to progressive wave antennas, however amplification ratio of RPA in the main lobe direction is probably low and does not exceed 6dBi. It is cause in relation to low efficiency of the considered antenna which not exceeds 18%. If to set for the RPA calculation σ and ε_r (negative value) in complete accordance with formulas [1], we get unreal and difficult physically explainable results.

CONCLUSIONS

1) It is found out at the LPA researches, that on the level of VSWR ≤ 2 they had a frequency band more than 50 %, that LPA is wideband antenna. The LPA efficiency has frequency dispersion as at constant so at the dispersion values of ε_r. At the classic values σ and classic negative ε_r of plasma [1] on frequencies of near to resonances the LPA efficiency grows to 100 %. At the constant positive ε_r the efficiency LPA does not exceed 70 %.

2) At researches the RPA a diameter 0.7λ and long 7λ, an directivity is got more 11dBi, however on results calculations the RPA efficiency does not exceed 18 % and consequently gain factor is 6 dBi. Consequently, it is necessary to continue the search of the real and optimum variants RPA.

ACKNOWLEDGMENTS

Authors of paper thankful to company EMSS and command of technical support for the given possibility of studying and use of software product *FEKO*. In connection with absence of sponsor other support, which our “Research Laboratory” needs in, we cannot extend the volume of theoretical and experimental researches of plasma antennas and plasma generators on the basis of clean gases and gases mixtures, including using the THz band of electromagnetic waves.

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