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# Experimental and numerical studies of the plasmonic resonance of a low-pressure hemispherical plasma discharge in the upper VHF band

A. Laffont, R. Pascaud, T. Callegari, L. Liard, O. Pascal, and J.-P. Adam

**Abstract**— This paper aims to present investigations of the plasmonic resonance of a hemispherical plasma discharge in the high VHF band. First, this plasmonic resonance is experimentally studied by illuminating the plasma discharge with an incident plane wave and by measuring its response using a coaxial probe located directly inside the plasma. In order to validate the experimental results, a numerical study is then proposed by coupling plasma and electromagnetic simulations.

## I. INTRODUCTION

Plasmonic resonance is a physical phenomenon that can occur in conductive objects that are electrically small when subjected to electromagnetic excitation [1]. For instance, if the electrically small object is spherical, its plasmonic resonance is obtained when its permittivity is close to  $-2$ . First studied in the late 1960s for the radio frequency domain [2], interest in this plasmonic resonance has been revived more recently for the development of electrically small antennas. In the VHF band, the resonance condition may be obtained using cold plasmas out of thermodynamic equilibrium [3].

In a previous study, the characterization of the plasmonic resonance of a low-pressure hemispherical plasma discharge was experimentally investigated using two coaxial probes placed symmetrically at a distance of 40 mm of the plasma discharge [4]. Although the plasmonic resonant phenomenon of the plasma discharge was observed, its identification resulted from the plasma-induced perturbation of the transmission coefficient between the two monopoles and not from a direct measurement of the plasmonic resonance.

In this paper, we study this plasmonic resonance by illuminating the plasma with an incident plane wave, and by measuring its response using a coaxial probe located directly inside the plasma. Such measurements have been performed using a gigahertz transverse electromagnetic (GTEM) cell. These results are then compared with numerical studies coupling plasma and electromagnetic simulations.

## II. CHARACTERIZATION IN THE GTEM CELL

A GTEM cell is a strip line expanding pyramidally for guiding an electromagnetic wave similar to a TEM wave. The

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hemispherical glass shell containing the plasma discharge is positioned in the GTEM cell as shown in Fig. 1a. It has a radius of 10.7 cm, i.e.  $\lambda/9$  at 300 MHz. The plasma is made of neon gas with 1% xenon and controlled to obtain the plasmonic resonance at our frequencies of interest. A coaxial probe is inserted into the plasma to measure the intensity of the plasmonic resonance. This can typically be done by considering the transmission coefficient between the input of the GTEM cell and the coaxial probe positioned inside the plasma. The measurement results show a significant increase in transmission compared to the case without plasma, namely more than 20 dB between 200 and 320 MHz. These values underline that the resonance phenomenon is clearly identified.

## III. PLASMA AND ELECTROMAGNETIC SIMULATIONS

These results are finally compared with a numerical study in which the plasma is simulated in-house software as shown in Fig 1b. The simulated plasma properties are then used to create an electromagnetic model for which the plasmonic resonance can be assessed by considering its radar cross-section when illuminated by a plane wave. This study allows to qualitatively retrieve the measured plasmonic resonance phenomenon of the hemispherical plasma discharge in the upper VHF band and understand its properties and characteristics, a necessary step in the design of electrically small plasma-based antenna systems.

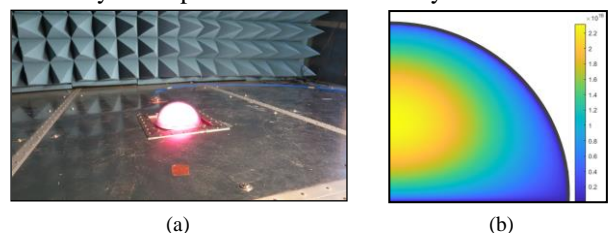


Fig 1: (a) Plasma in the GTEM cell – (b) Simulated electron density.

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