*36th EPS Conference on Plasma Phys. Sofia, June 29 - July 3, 2009 ECA Vol.**33E**, P-2.131 (2009)*

STUDY OF THE PLASMA RF IMPEDANCE VARIATIONS USING AN AMPLITUDE MODULATED RF SOURCE

O. S. Stoican

INFLPR, Bucharest-Magurele, Romania, stoican@infim.ro

Abstract: An experimental setup aimed to study variation of the plasma rf impedance is described. The operating principle is based on the measurement of the level variation of rf field due to the interaction with plasma volume. Such studies are important in order to investigate the variation of the plasma properties for various experimental conditions.

Experimental setup: The simplified block diagram of the system is shown in Fig.1. The rf chain contains a rf source (rf signal generator) and a receiver (rf wideband amplifier followed by a demodulator), capacitive coupled using a split metallic cylinder (diameter=65mm, length=20mm) surrounding the discharge tube. The demodulator stage permits to detect either the variation of the incident rf signal amplitude or the low frequency plasma impedance variations. One of the metallic sections (S_1) is used to apply the rf signal to the plasma, while the other (S_2) is used to collect the rf signal traveling through the plasma.

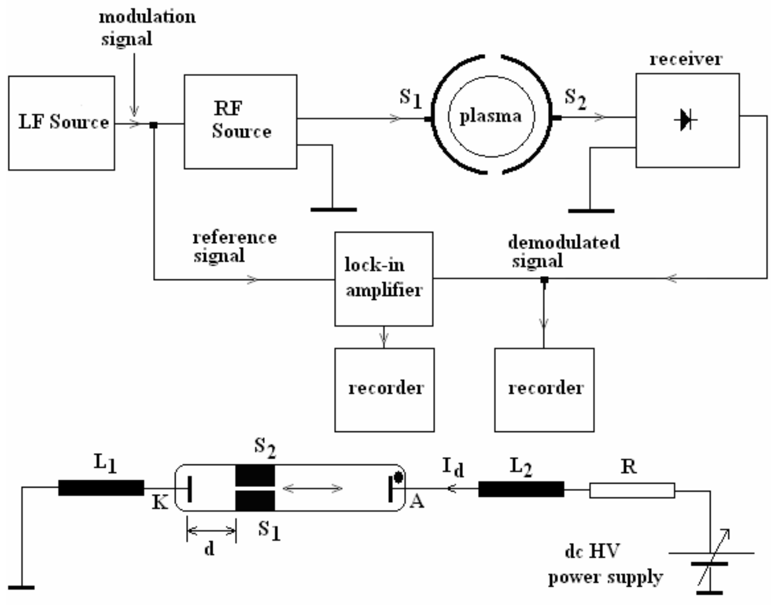

Fig. 1 Block diagram of the experimental setup

The split cylinder can be translated along the discharge tube allowing the study of the rf absorption variation as a function of the discharge region. In order to increase sensitivity and to improve the signal to noise ratio the voltage provided by the rf generator can be amplitude modulated. Thus, the synchronous detection technique can be used in order to avoid the spurious signals owing to the plasma fluctuations. All measured data are acquired and processed automatically by a computer.

The above described system has been tested using a dc electrical discharge as a plasma source. The discharge tube consists of a Pyrex glass tube, 65 mm in diameter, having two disk planar electrodes made of aluminium, which are separated by 400 mm. The two electrodes are connected to a HV dc power supply (Spellman SL150) by means of a ballast resistor R=60kΩ.

Measurements: Amplitude of the demodulated rf signal as a function of the rf source frequency at different discharge currents and gas pressures has been recorded. A typical record is shown in Fig. 2. The presence of several rf absorption dips can be observed. The magnitude of the absorption dips depends on the discharge current as it can be seen in Fig. 3.

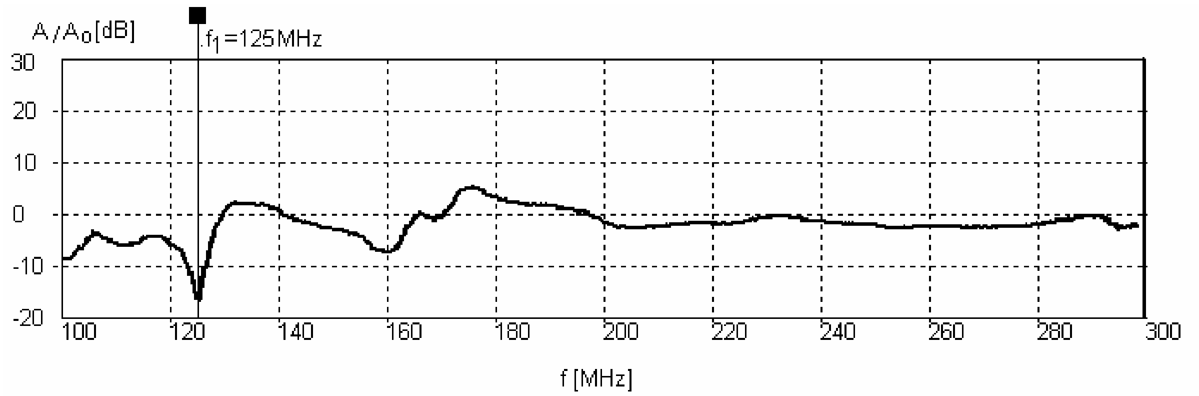

Fig. 2 Relative amplitude variation of the demodulated rf signal as a function of the rf source frequency in the range of 100 – 300MHz (A_0–amplitude of the demodulated signal in absence of the discharge). Experimental conditions: pressure p=10^{-2} mbar, discharge current I_d =3.46mA, distance split cylinder-cathode d=170 mm.

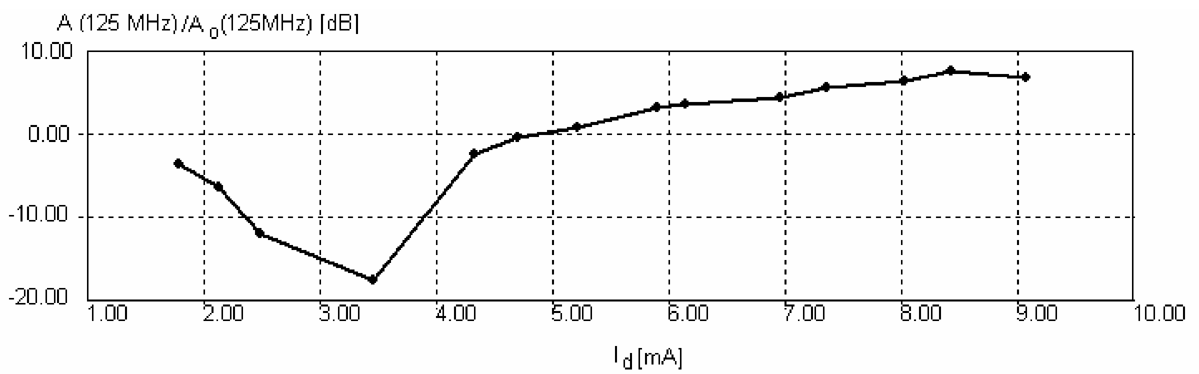

Fig.3 The magnitude of the rf absorption dip at frequency f_1= 125MHz as a function of the discharge current. Experimental conditions: pressure p=10^{-2} mbar, distance split cylinder-cathode d=170 mm.

Extensive measurements revealed that the magnitude and the frequency of the absorption dips also depend on the gas pressure and the position of the split cylinder with respect of the electrodes.

Equivalent electrical circuit: A simplified rf equivalent electrical circuit is presented in Fig.4. Due to the ionized gas existing within split cylinder, depending on its rf characteristics, a fraction of rf current flows through the discharge tube dc electrical supply circuit. The element Z_p is the impedance of the plasma volume existing within the split cylinder while the element Z_d represents the equivalent impedance corresponding to leakage rf current through the dc electrical supply circuit. The elements R_g and R_i are the internal resistance of the rf source and the input resistance of the receiver. A modified rf equivalent electrical circuit can be considered by inserting two rf choke coils L_1, L_2, into the discharge tube electric supply circuit. In this case the impedance Z_d may be neglected. The elements C_0 and C_w represent the equivalent capacitance of the split cylinder and the equivalent capacitance of the system split capacitor armature-outer plasma column surface, respectively [1]. In the absence of plasma the elements C_w, Z_p and Z_d do not exist.

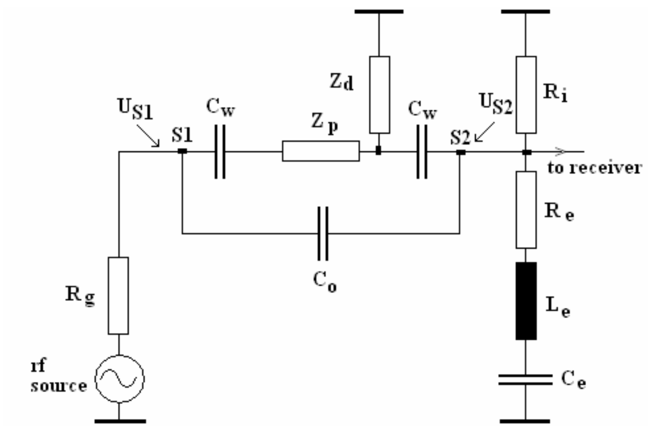

Fig. 4 Simplified rf equivalent electrical circuit of the experimental system

In the case of the absorption dip marked in Fig. 2, measurements indicate that its frequency $f_1 \cong 125$MHz remains approximately constant in the investigated discharge current range (1-10mA). It can be assumed that, under such experimental conditions, the impedance Z_p has only a resistive component and the resonant absorption is due to the external circuit [2]. According to the above considerations, the elements L_e, C_e and R_e, with $4\pi^2 L_e C_e f_1^2 \cong 1$, are included in the equivalent circuit. The discharge plasma acts as a resistance inserted between the two capacitors C_w of the system split capacitor armature-outer plasma column surface.

The model is able to explain qualitatively the experimental data. The variation of the ratio U_{S2}/U_{S1} as a function of the rf source frequency for equivalent circuit, obtained theoretically, is shown in Fig. 5.

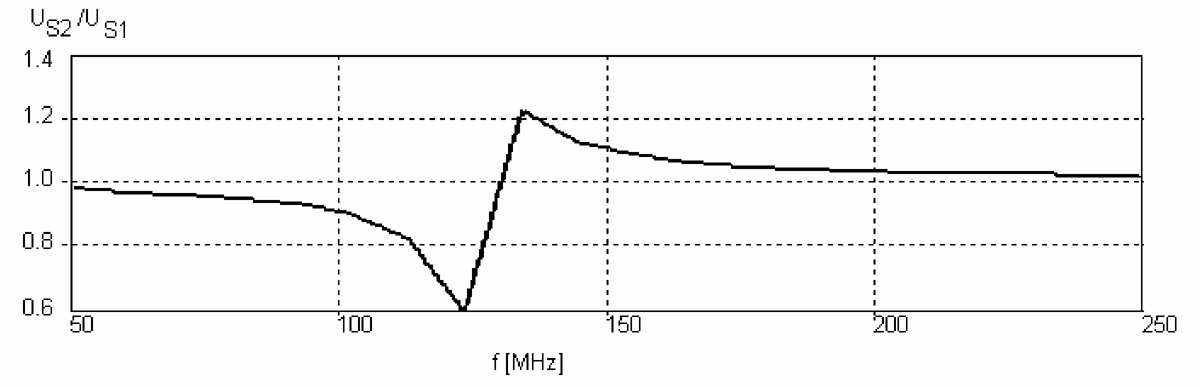

Fig. 5 Variation of the ratio U_{S2}/U_{S1} as a function of the frequency in the range of 50 – 250 MHz for the equivalent circuit presented in Fig. 4. The impedance Z_p was assumed to be purely resistive ($|Z_p|\cong R_p$). Components L_e and C_e have been selected so that $(2\pi L_e^{1/2}C_e^{1/2})^{-1}$=125MHz. The curve is similar to that obtained experimentally in Fig. 2. Theoretical result.

The variation of the ratio U_{S2}/U_{S1} as a function of the dimensionless parameter $X=X_w/R_p=(2\pi fC_wR_p)^{-1}$, where X_w is the capacitive reactance of the capacitor C_w, obtained theoretically, is shown in Fig. 6. The resistance R_p is related to the electron density so that variation of the parameter X simulates variation of the discharge current. In the absence of the plasma: $R_p\to\infty$ and $X\to 0$.

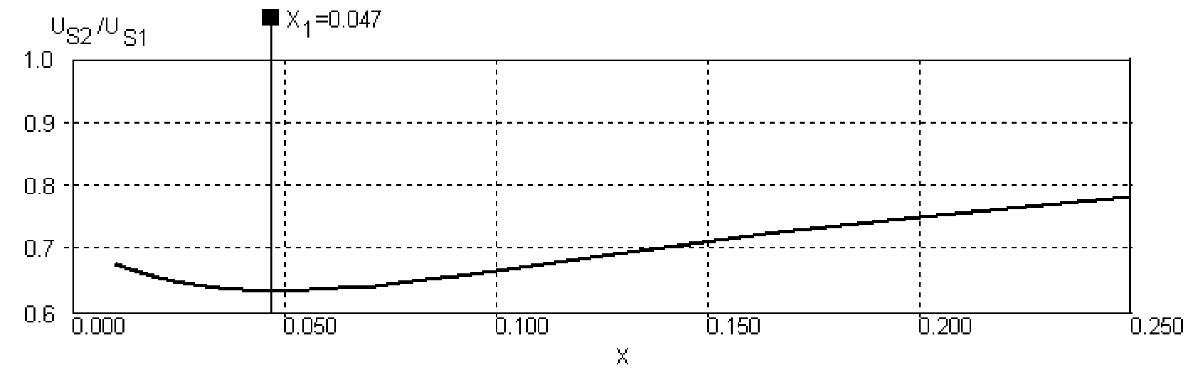

Fig.6 Variation of the ratio U_{S2}/U_{S1} as a function of the parameter $X=X_w/R_p=(2\pi fC_wR_p)^{-1}$. There is a minimum corresponding to $R_p=21.27X_w$. The curve is similar to that obtained experimentally in Fig. 3. Theoretical result.

[1] O. S. Stoican**,** *Gate dip oscillator circuit used for plasma diagnosis,* 19th ESCAMPIG, July 15-19, 2008, Granada, Spain, Programe, p.33 (P2-09).

[2]- N. Gherbanovschi, O. Stoican, *Roum. Reports in Physics*, **54**, 1-5, pp. 265-267 (2002)