

Radiofrequency Conductivity of Gas-Discharge Plasmas in the Microwave Region

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November 10, 1947

IN connection with a specific application, we have been investigating the conductivity of gas discharges in the microwave region. The problem involves the transmission of low power, very high frequency signals through a coaxial transmission line containing part of a gas-discharge tube as a dielectric gap in the center conductor.¹ The length of this gap is so determined that the radiofrequency signal normally is attenuated at least 40 decibels when the discharge is off.

The conditions established with respect to the signal level are: (1) that the radiofrequency energy be insufficient to accelerate electrons produced in the discharge to inelastic collision levels, and (2) the mean free path of electrons in the discharge be large compared to the amplitude of possible electronic oscillations in the radiofrequency field. Simple theoretical considerations lead, in the steady state, (1) to the use of non-electronegative gases, and particularly to the heavier rare gases such as argon, neon, krypton, or appropriate mixtures of them, and (2) to pressures such that the electronic mean free time be of the order of the period of the incident waves.²

The most significant results are presented here. The data shown below are for measurements made with signals of 2000 megacycles per second and power levels below about 1 milliwatt. For these conditions, pressure below 10 millimeters of mercury of the gases cited above gave best results in accordance with the tentative theory. Some typical characteristics of radiofrequency signal attenuation as a function of discharge direct current are shown in Fig. 1. The discharge tubes were so constructed relative to the coaxial line that discharge plasma fills the region of the dielectric gap. For relatively low current discharges, with either normal glow or arc conditions, the attenuation of the incident signal increases beyond the attenuation of the gap in the absence of a discharge. With further increases in discharge current, the attenuation is seen to fall sharply to a low value. This rapidly rising characteristic is suggestive of a resonance phenomenon. This appears to be related to the high frequency electronic plasmoidal oscillations.^{3,4} The frequencies of such oscillations are given by $\nu = (Ne^2/\pi m)^{1/2}$, where N is the electron density in the discharge plasma, e , and m are the electronic charge and mass, respectively. Hence, in a discharge plasma one might expect a continuous spectrum of oscillation frequencies limited at the high frequency side by the value of ν corresponding to the maximum electron density. The maximum electron densities deduced from the discharge direct currents at conditions of minimum attenuation of radiofrequency signal (order of 3 decibels) were found to correspond to values of N which, when inserted in the above equation, yield a value of ν approximating the frequency of the radiofrequency signal. It appears that for conditions of maximum conductivity of a radiofrequency signal of frequency ν , an oscillation close to that frequency would exist in the conducting plasma

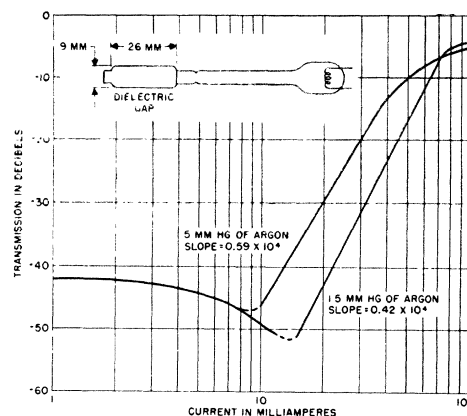


FIG. 1. Typical characteristics of radiofrequency signal attenuation as a function of discharge direct current.

even in the absence of the radiofrequency signal. This led us to investigate the radiofrequency oscillations produced in a direct current gas discharge in the absence of any external radiofrequency fields.

The results of this investigation indicate that such high frequency oscillations do exist in the discharge and have increasing amplitudes with increasing direct currents. In addition to these high frequency oscillations, we observed low frequency oscillations similar to those previously reported.^{5,6} These oscillations are classified here, along with random oscillations, as noise. For conditions of minimum attenuation, this noise power was found to be of the order 2×10^{-19} watts/cycle at 2000 megacycles per second.

It may be indicated that this method may be used in the study of the properties of the gas discharge plasma. In particular, information concerning electron densities, electronic mean-free path, and in the disintegrating plasma, the electron distribution functions may be obtained.

¹ D. E. Kerr, S. C. Brown, and W. P. Kern, *Bull. Am. Phys. Soc.* **22**, 28 (1947).

² H. Margenau, *Phys. Rev.* **69**, 608 (1946).

³ L. Tonks and I. Langmuir, *Phys. Rev.* **33**, 195 (1929).

⁴ I. Langmuir, *Proc. Nat. Acad. Sci.* **14**, 627 (1928).

⁵ J. D. Cobine and C. J. Gallagher, *J. Franklin Inst.* **243**, 41 (1947) and the references included therein.

⁶ B. Granovsky and L. Bykhovskaya, *J. Phys. U.S.S.R.* **X**, 351 (1946).

The Radiations from 2.70-Day Au¹⁹⁸

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November 21, 1947

THE radiations from 2.70-day Au¹⁹⁸ have been investigated with photographic and counter recording spectrometers of 10-cm radius. Sources were prepared by irradiating gold foil in the Clinton pile. Kurie plots, made from sources of various thicknesses, all indicate that the maximum energy of the continuous spectrum is 0.970