EFFECTS OF A MAGNETIC FIELD ON THE NOISE IN HOT-CATHODE GAS DISCHARGE TUBES

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ABSTRACT

The noise in hot-cathode gas discharge tube is, in general, affected by a magnetic field transverse to the axis of the tube. It was pointed out in our previous paper[1)] that there were two types of noise in argon-mercury tubes which were considered to originate from different mechanism, and in this paper it will be shown that there is some remarkable difference in the effect of a magnetic field between these two types of noise.

I. Introduction

In our previous paper it was shown that at what part of ionized gas and by what mechanism the radio-frequency noise in gas discharge tubes was produced. A magnetic field transverse to the normal flow of current will give us a more available means to investigate the origin and the mechanism of noise production because of its advantages of variable field strength and no restriction of applying position.

A gas discharge tube noise generator, despite of its high noise level, has a disadvantage that its noise level depends intensely on the frequency because of undesirable spurious oscillations and some other instabilities. However, it has been recognized that these defects could be removed by applying transverse magnetic field, though nothing definite has been found regarding in what manner this should be accomplished.[2)]

The results obtained indicate that there are two different types of noise in argon-mercury tubes, and one of them has a property quite similar to that of argon tubes. There is a limited frequency range over which the magnetic field is effective, and this limiting frequency is considered to be associated with the mean collision frequency, then with gas pressure.

2. Experimental Procedure

All tubes used in our experiment are of the same size, 26 cm length and 2 cm diameter, and have an oxide coated cathode, heated by an external source until the discharge started. Two tubes are used in most cases, one of them is filled with argon gas (1 mm Hg) and mercury vapour, and the other contains argon gas only (1 mm Hg) (Hereafter, they will be written as 1 AH for the former and as 1 A for the latter.). Some other tubes containing argon at higher pressure are used in the supplementary observations. The magnet, the flux density was varied up to 3200 gauss, has a pair of pole pieces of radius 1.6 cm. The noise voltages are measured by an electric-field intensity meter having a bandwidth of about 10 kc, and are represented in db above 1 $\mu V/(kc)^{1/2}$.

3. Experimental Results

The AH tube has two types of noise, one of them, written as the type I, can be observed under any discharge condition and is proportional to $f^{-3\sim-4.5}$ in the frequency range below about 0.7 Mc, and the other, written as the Type II, is seen at frequencies above 0.7 Mc depending on the discharge conditions near the cathode. The Type I noise is seen to have the same origin with that of the A tubes. There are some evidences[1] that the plasma plays an important role for the generation of the Type I noise and the cathode fall for the Type II. The effect of the magnetic field on these two types of noise will now be described.

3.1. The Effects of the Magnetic Field applied to the Discharge Plasma

In Figs. 1 and 2, obtained for the 1 AH tube and the 1 A tube respectively the dotted lines show the noise level when a magnetic field is applied to the middle of the plasma. The two dotted curves at 0.1 Mc and 0.6 Mc in Fig. 1, showing the Type I noise for AH tube, decrease somewhat at first and then increase exponentially until a saturation is reached with increasing magnetic field. The lower the measuring frequency, the less the rate of increase and the less the intensity of the magnetic field where the saturation level is reached.

On the contrary, the Type II noise for AH tubes, represented by the lowest dotted curve of 5 Mc in Fig. 1, shows little variation with magnetic field. From the above, the generation of the Type I for AH tubes proves to be attributed

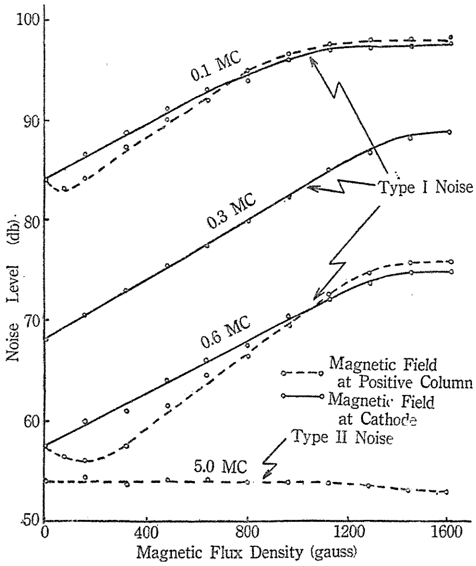

FIG. 1. Effect of magnetic field on noise for 1 AH tube.
(discharge current = 200 mA)

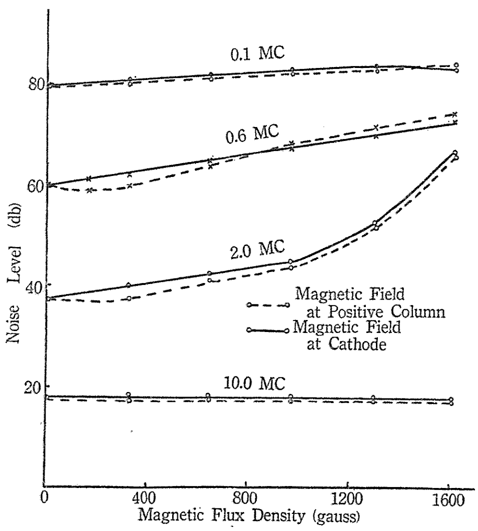

FIG. 2. Effect of magnetic field on noise for 1 A tube.
(discharge current = 200 mA)

mainly to the discharge plasma while the Type II has nothing to do with it. Our previous conclusion[1] may be emphasized by the results of Fig. 2 because the effect of a magnetic field on the noise of A tube is similar to that of the Type I for AH tube.

3. 2. The Effects of the Magnetic Field applied to the Cathode Fall

The Type I noise for 1 AH tube and the noise of 1 A tube are indicated with the solid lines in Figs. 1 and 2 respectively in contrast with the results of 3.1. It seems curious that the variation of the noise level with magnetic field in this case is similar to that of the former case (3.1). However, this will be probable provided that the magnetic field act not only near by the cathode but also to a part of cathode fall where many ions exist. Actually it was shown in our previous paper, that the Type I noise of lower level can exist in the cathode fall. Consequently, the same variation with magnetic field as in the case of 3.1 could be expected.

On the other hand, the Type II noise for AH tube exhibits complicated variations, typical examples of them are indicated in Fig. 3. In the frequency range from 1 to 2 Mc, the noise level shows one minimum, but above 3 Mc one maximum and two minima are observed. The values of the magnetic field intensity corresponding to these maxima and minima increase with frequency and the noise voltages corresponding to them decrease exponentially with magnetic field. That the Type II noise for AH tube is generated mainly near the cathode by some mechanism different from that of the Type I is also verified from these results.

3.3. The Effect of Magnetic Field on the Noise Characteristics at Various Discharge Current and Gas Pressure

Generally speaking, if the magnetic field is sufficiently intense, as indicated

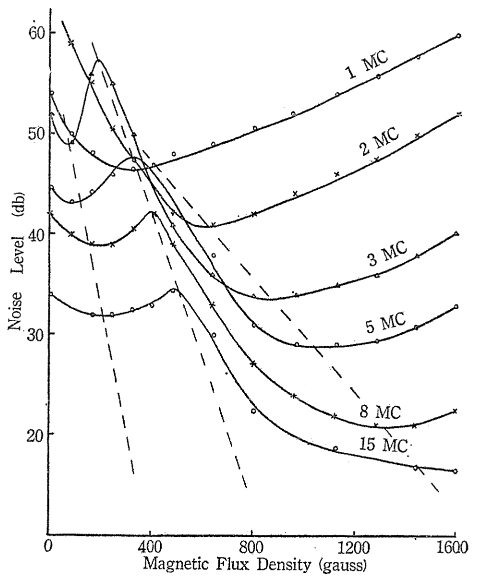

FIG. 3. Effect of magnetic field applied at cathode fall on Type II noise for 1 AH tube. (discharge current=200 mA)

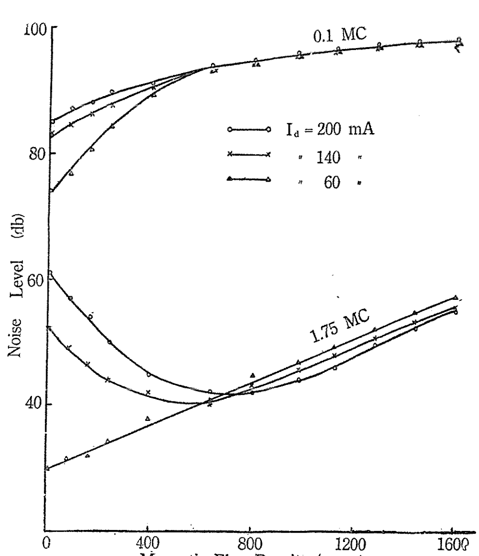

FIG. 4. Variation of noise characteristic with discharge current. (1 AH tube, magnetic field applied to cathode)

in Fig. 4, the noise level is little dependent on discharge current, but rather inversely related to it compared with the case of low magnetic field. At lower magnetic field the noise levels show appreciable difference by the discharge current, but at higher magnetic field a contraction of these noise levels may be seen regardless of the discharge current.

The effect of magnetic field on the noise characteristics at various gas pressure is generally very severe. Whilst the effect of the magnetic field is remarkable in 1 A tube, it reduces so much in 5 A tube that any effect cannot be appreciable. This is full of suggestions as to the source of the magnetic field effect.

3.4. Broadening of Noise Bandwidth and Limits of Magnetic Field Effect

The bandwidth of constant noise in A tubes, especially at low pressure, may be extended appreciablly by applying a magnetic field. Typical examples are indicated in Fig. 5.

However, AH tubes are not necessarily able to do this, since the effect of a magnetic field on the Type II noise is much complicated (see Fig. 3). But by using an impractically intense magnetic field, the flattening of the noise spectrum will be possible to some extent.

From Fig. 5 the more distinct information as to the limit of magnetic field effect is acquired. The lower and upper limiting frequencies in 1 A tube seem to be about 0.1 and 10 Mc respectively.

4. Discussion

The effect of a magnetic field on the noise of the gas discharge tubes was first studied by Cobine and Gallagher.[2] Although our results coincide with them in several points, there are some important discrepancies, for example, the noise level is affected by the magnetic field applied to the discharge plasms, and is little affected by the discharge current under the application of an intense magnetic field (if the magnetic field should give some change in plasma ion oscillation as shown by Cobine and Gallagher, the noise would be affected by current *i.e.* ion density, considerably).

To interprete these discrepancies, we shall now consider a gyrating motion of ions by a magnetic field. The angular frequency of gyration is represented by

$$\omega_g(=2\pi f_g)=\frac{eB}{Mc}, \qquad (1)$$

where e, M, c and B denote ionic charge, mass, light velocity and magnetic flux density (gauss) respectively. We find $f_g=0.12$ Mc for argon ion at $B=3200$ Gauss.

On the other hand, providing 1 mm Hg argon pressure and 300°K ion temperature, the mean ion collision frequency f_c is about 2.3 Mc for argon ion and about 1.0 Mc for mercury ion. Therefore the probability that an ion may gyrate for a few cycle without any collision seems very small.

It appears that this is a reason why the effect of the magnetic field could not be seen below 0.1 Mc and any discrete oscillation could not exist in the noise spectra of Fig. 5.

Moreover, it may safely be said by our calculation[1] that if $f_g \ll f_c$, the noise spectrum will be flatten up to a frequency near f_c. However, our results in this

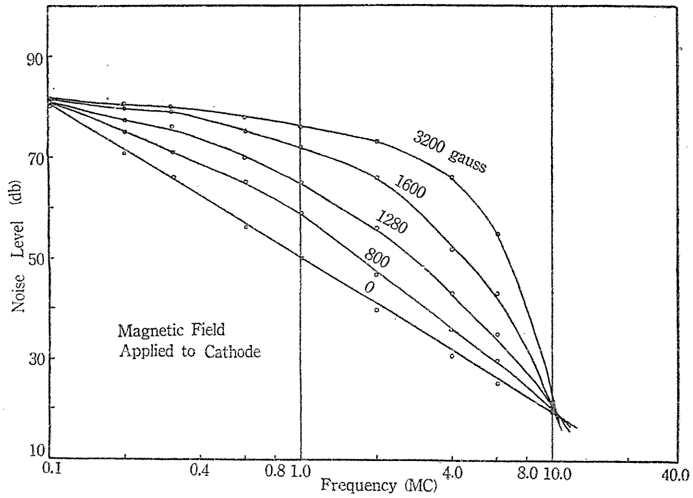

FIG. 5. Noise spectra of 1 A tube for various values of magnetic flux density. (discharge current = 200 mA)

paper cannot all be explained by the ion gyration. As to these we are required much more further researches.

5. Acknowledgement

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