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A NEW METHOD OF ESTIMATING PREOSCILLATION NOISE IN A PULSED OSCILLATOR (MAGNETRON)

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Abstract

Starting-time jitter in pulsed magnetrons is an effect often observed. It is thought to be caused principally by a corresponding initial r-f amplitude jitter resulting from preoscillation noise. Measurements of the time jitter have been extrapolated to compute the amplitude variations and subsequently the rms preoscillation noise. Values 100 decibels above that expected from a temperature-limited diode carrying the same current have been found for the QK-61 magnetron.

A NEW METHOD OF ESTIMATING PREOSCILLATION NOISE IN A PULSED OSCILLATOR (MAGNETRON)

The usual measurement of magnetron preoscillation noise is a static one. In such a measurement the plate voltage is raised to a point where the "build-up Q" is just less than infinite. This voltage is just below the oscillation threshold, and hence r-f output is noise generated by the incoherent space charge. The power is determined by means of a calibrated receiver. In terms of magnetron starting, the significance of this measurement is not quite clear, for conditions of the experiment are certainly not duplicated during starting, particularly if we use a voltage pulse whose rise time is short compared to the build-up time of the r-f voltage. In fact, it is difficult to define the noise at all in this case, since it is narrow-band in character and, over the short time interval at the beginning of the r-f rise, will appear to have a sinusoidal time dependence. Hence the boundary between this "sinusoidal" noise and the coherent oscillations is an indefinite one. Nonetheless, the rms noise may be measured in this case. It has been found experimentally that the starting time will vary quite appreciably from pulse-to-pulse. These fluctuations may be ascribed to similar fluctuations in initial amplitude, A_o. By assuming that A_o has a Rayleigh distribution and that the build-up commences exponentially, a given starting-time distribution may be used to compute the rms noise. Consider Fig. 1 which shows the r-f build-up of a magnetron and the accompanying fluctuations. It is known that the initial portion of such curves closely follow a rising exponential (1). The limits of this behavior are denoted as the voltages V and V_{on} in the figure. The inverse time-constant of the rise may be found experimentally by considering any of the curves such as the one shown dotted

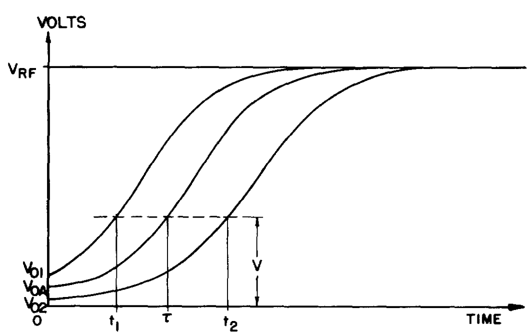

Fig. 1 R-f build-up of a magnetron and the accompanying fluctuations.

$$\frac{V}{V_{oA}} = e^{K\tau}$$

or

$$K = \frac{1}{\tau} \ln\left(\frac{V}{V_{oA}}\right) \quad . \qquad (1)$$

Usually, our observations are made by means of a square-law detector; hence we should rewrite Eq. 1 as

$$K = \frac{1}{2\tau} \ln\left(\frac{V}{V_{oA}}\right)^2 \quad . \qquad (2)$$

The observed limits of the time fluctuations are t_1 and t_2, hence

$$Kt_1 = \frac{t_1}{2\tau} \ln\left(\frac{V}{V_{oA}}\right)^2 = \ln\left(\frac{V}{V_{o1}}\right)$$

$$Kt_2 = \frac{t_2}{2\tau} \ln\left(\frac{V}{V_{oA}}\right)^2 = \ln\left(\frac{V}{V_{o2}}\right)$$

and then

$$\frac{V}{V_{o1}} = \left[\left(\frac{V}{V_{oA}}\right)^2\right]^{t_1/2\tau} \quad ; \quad \frac{V}{V_{o2}} = \left[\left(\frac{V}{V_{oA}}\right)^2\right]^{t_2/2\tau} \quad . \tag{3}$$

A Rayleigh distribution may be assumed for the noise envelope, which determines the values V_{o1} and V_{o2}. This distribution may be written

$$P(V_o)dV_o = \frac{2V_o}{\overline{V_o^2}} e^{-V_o^2/\overline{V^2}} dV_o = 2xe^{-x^2} dx \tag{4}$$

where $x = V_o/\sqrt{\overline{V_o^2}}$. If Eq. 4 is integrated between the limits 0 and x, values for x_1 and x_2, corresponding respectively to V_{o1} and V_{o2} from Eq. 3 may be found. This computation must involve the total number of pulses observed in finding t_1 and t_2, for this number determines the probability

$$P(0,x) = \int_0^x P(x)\, dx = 1 - e^{-x^2} \quad . \tag{5}$$

In order to determine the absolute power level of the noise, it is necessary to establish the level of the voltage V. If the magnetron is operating into line of impedance Z_o with a peak output P_o, then

$$V_{RF} = (2P_oZ_o)^{1/2}$$

and

$$V = A_R V_{RF} = A_R (2P_oZ_o)^{1/2} \tag{6}$$

where A_R is a constant which may be determined from observation. Now we may write from Eqs. 6 and 3

$$V_{o1} - V_{o2} = A_R\sqrt{2P_oZ_o} \left\{\left[\left(\frac{V_{oA}}{V}\right)^2\right]^{t_1/2\tau} - \left[\left(\frac{V_{oA}}{V}\right)^2\right]^{t_2/2\tau}\right\} \tag{7}$$

but from the known values of x_1 and x_2,

$$V_{o1} - V_{o2} = \sqrt{\overline{V_o^2}}\, (x_1 - x_2) \tag{8}$$

so combining Eqs. 7 and 8, we arrive at

$$P_N = \frac{\overline{V_o^2}}{2Z_o} = \frac{A_R^2 P_o}{(x_1 - x_2)^2} \left\{\left[\left(\frac{V_{oA}}{V}\right)^2\right]^{t_1/2\tau} - \left[\left(\frac{V_{oA}}{V}\right)^2\right]^{t_2/2\tau}\right\}^2 \quad . \tag{9}$$

It is evident that a measurement of noise power on the basis just presented will necessarily be only approximate, for the quantities V, $x_1 - x_2$, and the zero time reference are not precisely specified. These uncertainties are the result of our definitions, as we have merely indicated some rather indefinite criteria to aid in determining the values. Fortunately, however, P_N as calculated from Eq. 9 is not a critical function of these quantities. Provided, then, that we evaluate Eq. 9 judiciously, it should yield a good estimate of the preoscillation noise.

Experimental observations have been carried out on a QK-61 magnetron operating into a matched, 50-ohm load and modulated by a fast rise time, hard tube pulser. By using the 5.25 inch per microsecond sweep available on the Model P-5 Synchroscope, and a crystal detector followed by a 10 megacycle video amplifier, the following values have been observed:

$$A_R^2 = \frac{1}{4}$$

$$P_o = 50 \text{ watts (Peak Power)}$$

$$(V_{oA}/V)^2 = \frac{1}{10}$$

$$\tau = 0.025\ \mu\text{sec}$$

$$t_1 = 0.020\ \mu\text{sec}$$

$$t_2 = 0.0675\ \mu\text{sec} \quad .$$

The values for t_1 and t_2 are averages taken from several observation periods each of one minute duration. The pulse repetition rate was 400 per second, hence 2400 pulses occurred during each period. We may, then, evaluate x_1 and x_2 by rewriting Eq. 5 as

$$x = \left\{ \ln \left[\frac{1}{1 - P(0,x)} \right] \right\}^{1/2} \tag{10}$$

and $P(0,x_1) = 2399/2400$; $P(0,x_2) = 1/2400$. We find $x_1 = 2.82$, and $x_2 = 0.02$, so $x_1 - x_2 = 2.80$ and $P_N = 216$ milliwatts. This figure is about 100 db above that which one would expect from a temperature-limited diode carrying the same current ($\backsim$100 milliamperes) and about 20 db greater than that found by static measurements on the QK-61. Such a large value may probably be attributed to the low magnetic field (1400 gauss) used with this magnetron and the larger plate voltage (1050 volts) present during the transient as opposed to the static measurement.

Reference

(1) G. B. Collins: Microwave Magnetrons, Radiation Laboratory Series, pp. 372-6 (McGraw-Hill Book Co., New York, 1948).