Int Conf. on Microwave tubes, 1962

Spurious phenomena in "M" type tubes

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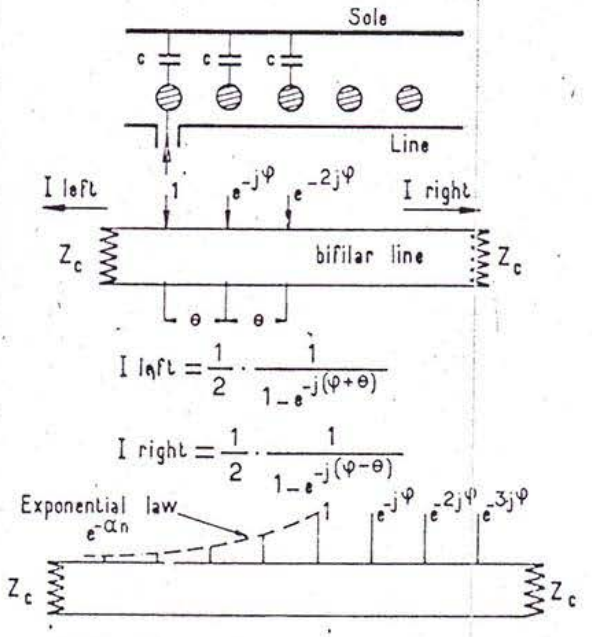
Most if not all spurious phenomena taking place in 'M' type tubes: parasitic oscillations, frequency jumps in 'M' type carcinotrons, excess noise, seem to originate from two sources:

- The excess noise created in the gun region.
- The modulation of the beam in the gun region by the r.f. field radiated from the delay structure, mainly at the ends of it.

However, the strong effect of the direction of the magnetic field on the holes of the 'M' type carcinotron is not yet clearly understood.



DIFFERENCE IN RADIATED POWER

$$R = 10 \log \frac{1+e^{-2\alpha} - 2e^{-\alpha} \cos(\varphi+\theta)}{\left(1-e^{-\alpha}\right)^2}$$

	$\varphi+\theta=\pi$	$\varphi+\theta=\frac{\pi}{2}$	0
$\alpha=2$	R = 2.2 dB	1.3	0
$\alpha=1$	6.7	4.5	0
$\alpha=0.5$	12	9.3	0

Fig. 1

Fast mode excitation from a delay line.

Let us consider at first a pure circuit problem: the radiation of power at the ends of a delay structure. We consider a latter line with its simple equivalent circuit: a low pass filter.

In Fig. 1 one sees the circular cross section of the bars; under the bars is the ground piece and above them the sole; a fast mode may propagate between the sole and the line according to a classical TEM mode.

Let us suppose that the first finger is attacked

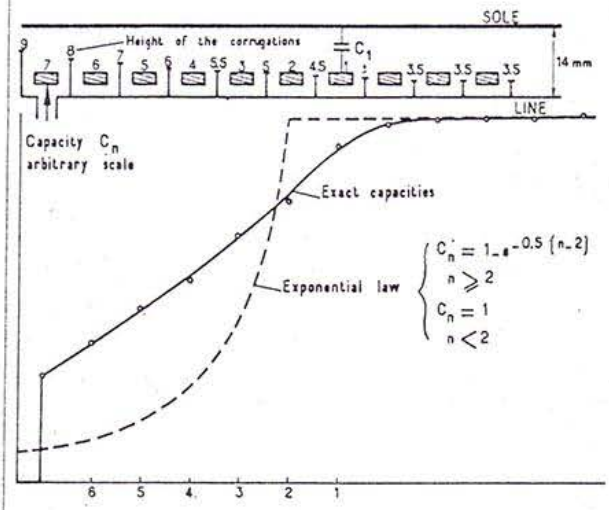


Fig. 2

Capacities between a barline and a sole

by an r.f. source, one shall have on the bars a set of voltages V, $Ve^{-j\varphi}$ and so on. Through the capacity C between each bar and the sole they correspond to injected currents on the bifilar line I, $e^{-j\varphi}$ and so on. We suppose that this corresponds to a constant current source, so that the total current is given by the sum of a geometrical series; the total current flowing to the left is nearly equal to the total current flowing to the right if the delay ratio φ/θ is very much greater than unity.

Now, let us suppose that the injected current increases at first according to an exponential law and then become constant. The total current and consequently the radiated power may be greatly reduced according to the table of Fig. 1. For instance an improvement of 9,3 dB may be obtained at the middle of the band, if $\alpha = 0.5$. The exponential law has been chosen for simplicity of calculation but it is not the best shape.

In Fig. 2 one sees a practical line in which a

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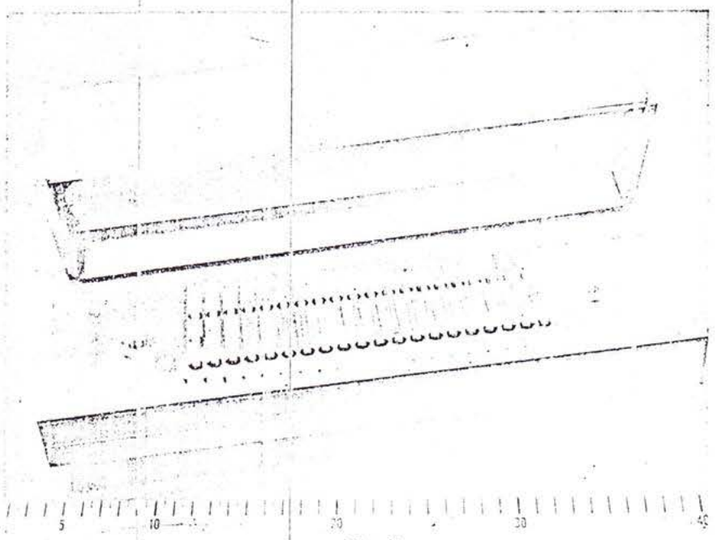

Fig. 3
Photograph of a tapered ladder line

progressive coupling is ensured by corrugations of decreasing heights. The full line corresponds to the exact capacities measured with an electrolytic tank, and the dotted line an exponential approximation.

Fig. 3 shows the experimental line; the corrugations are of constant height at the right and of progressive height at the left. The experimental results are shown in Fig. 4; the experimental method consists in matching the delay structure in a progressive manner; the sole constitutes with the delay line a ridged waveguide which is matbhed by door knob transitions to bolometers at each end. P_r is the ratio of the input power to the power radiated at the right.

One sees that an improvement of 20 dB is obtained with the corrugations. The comparison with the theory is done in Fig. 5. The dotted lines correspond to the experimental data with and without tapered ends: the full lines corresponding to the computation with the exact capacities are in agreement with the experimental data; the exponential law appears to be pessimistic. The two upper dotted curves correspond to the maximum errors of measurement; they are due to the radiation of the attenuation of the delay line which is actually too much rapid.

A simpler means to appreciate the radiated power is to shortcircuit the delay line by an image plane after some calls and to measure the VSWR at the input; it is shown in Fig. 6; one has observed that the minimum VSWR, that is the maximum of radiated power, occurs when a maximum of voltage corresponds to the first finger, which is in agreement with the proposed theory.

In conclusion it is possible to decrease the radiated power by 10 to 20 dB with tapered ends. Fig. 7 is an example of a tapered ladder line of circular shape. Fig. 8 is a tapered ladder line operating on the first harmonic in a carcinotron.

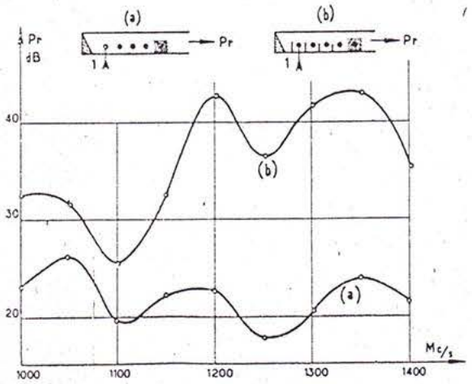

Fig. 4
Fast mode excitation versus the frequency

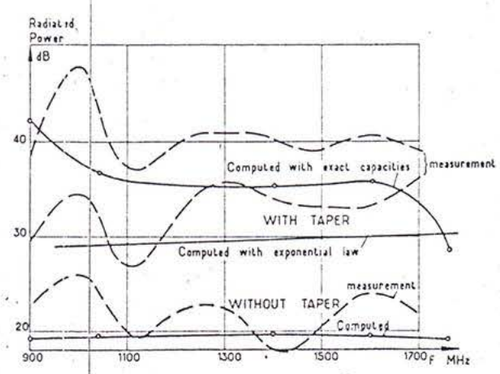

Fig. 5
Fast mode excitation versus the frequency

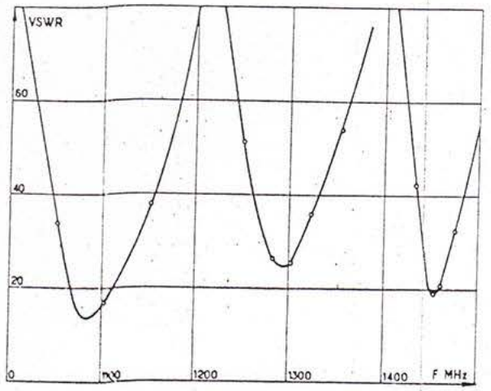

Fig. 6
VSWR of a short-circuited delay structure

other means to decrease the radiated power is to lower the impedance of the sole to line transmission or to create a stopband in this propagation. The radiation may originate only from the ends of the delay line but also from any mechanical irregularities of it and also from the bunched beam when it reaches the collector.

Let us now consider the commonly used short gun represented in Fig. 9. Experiments have been done on such a gun with large dimensions, the size of the cathode being 1 cm - 10 cm. The magnetic field is rather low, about 30 oersted.

It is well known that such a gun gives an excess noise only when it is space charge limited: this is shown again in Fig. 10, the noise voltage being plotted versus the cathode temperature for a constant collector current.

The noise signal may be observed on the collector on a wide band oscilloscope (Fig. 11). With a slow sweep (lower curve) the signal seems to be completely erratic; but, with a fast sweep (upper figure) a fundamental frequency appears which is in this case 100 Mc/s The noise, near

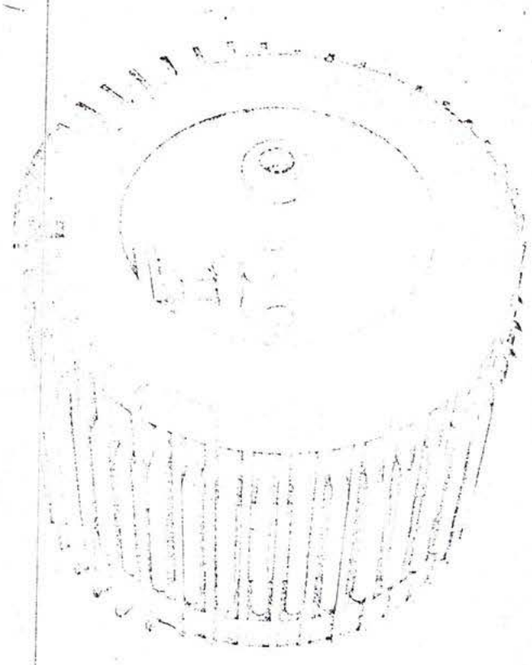

Fig. 7
Photograph of a tapered circular line

the gun appears to be a kind of oscillation strongly modulated by noise; however, after a long drift space it tends to approach a true white noise; in this case, the noise began to decrease slowly above a frequency $f \sim v/D$, v being the velocity of the electrons and D the sole-line distance.

The central curve corresponds to a moderate sweep velocity; one sees a periodic modulation which is perhaps connected to the transit time

Fig. 8
Photograph of a tapered ladder line for the operation on the backward space harmonic

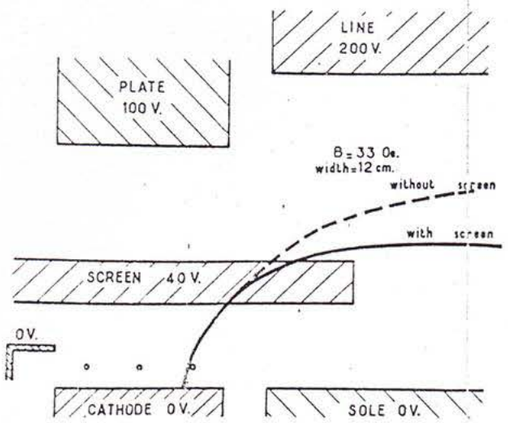

Fig. 9
Trajectories in an 'M' type gun with and without a grid

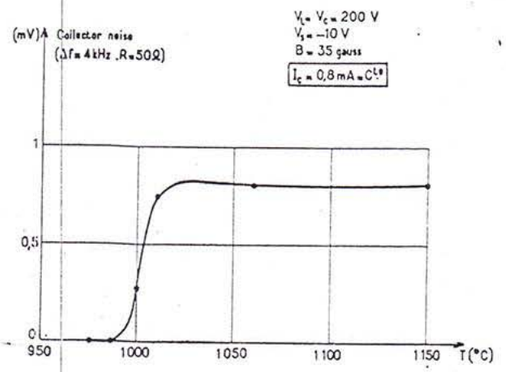

Fig. 10
Noise in the beam versus the cathode temperature

between the gun and the collector; the collector current flows back to the plate lead and induces a voltage between the plate and the cathode since the plate and the cathode are never short-circuited for the frequencies of interest. The spectrum of the noise is shown in Fig. 12 without

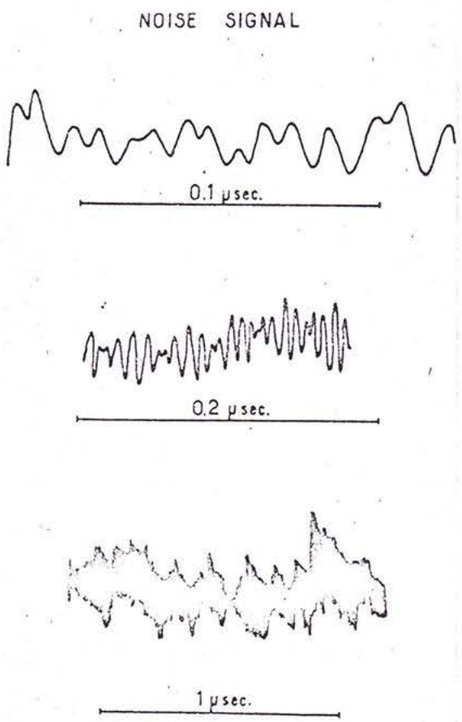

Fig. 11
Oscillograms of the noise signal

and with an r.f. shortcircuit between the plate and the cathode.

The spectrum is smooth with a short circuit but exhibits periodic variations without short circuit. The decoupling due to the short circuit is indicated by the upper curve.

Another important phenomenon is the drastic reduction in noise resulting from a positive screen grid in front of the cathode; such guns are shown in Fig. 13 and 14. Fig. 15 shows the currents on the electrodes and the noise modulation N versus the magnetic field; there is no excess noise for $B/B_c < 1,4$. A comparison is done with a classical gun in Fig. 16, curve 1; the gridded guns correspond to the curves 2 and 3.

From these experiments it may be thought that the excess noise appears in the gun when the space charge field cancels the external electric field around a region of the cathode surface. The effect of the grid, at least for moderate magnetic fields is to ensure a uniform d.c. field around the cathode; this is also obtained

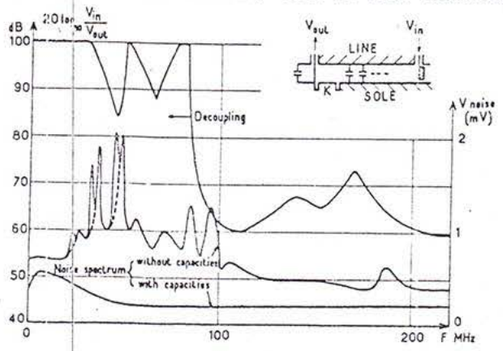

Fig. 12
Noise spectrum with and without a shortcircuit between the cathode and the plate

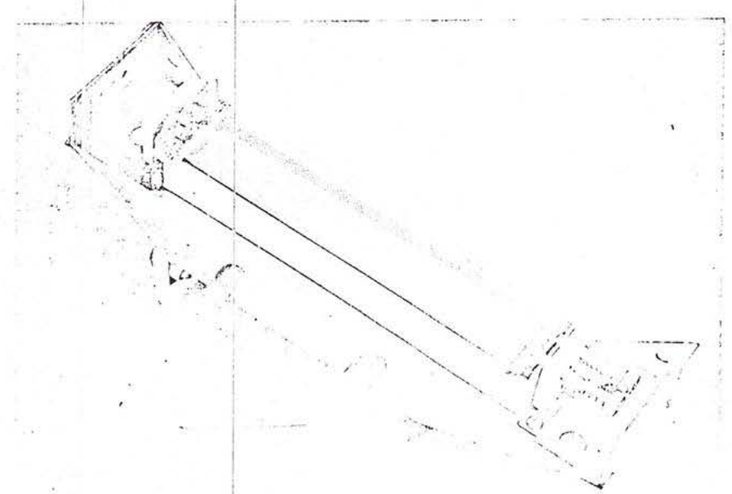

Fig. 13
Photograph of a gridded cathode

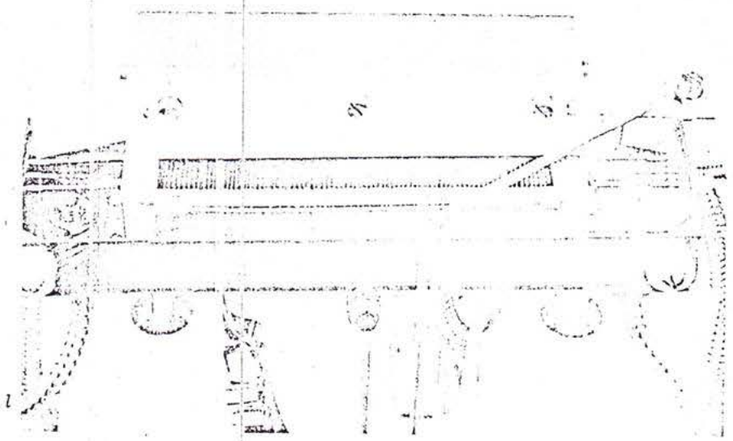

Fig. 14
Photograph of a gridded optical system

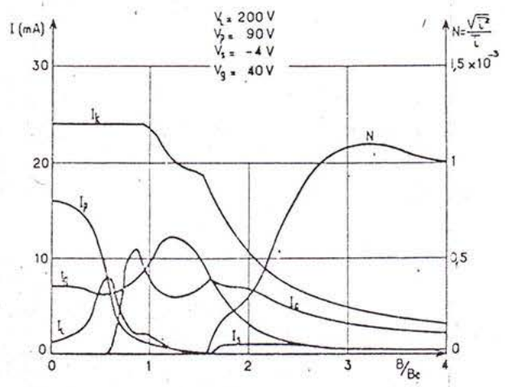

Fig. 15
Noise and currents versus the magnetic field

if the cathode is temperature limited or if the width of the cathode in the direction of the electron velocity is small compared to the height of the cycloid, since in these cases the space charge field is too small to cancel the external field.

The noise due to the gun appears in pulsed TFOM like a white noise at about 30 dB below the signal on the spectrum analyser.

In 'M' type carcinotrons the excess noise involves a noisy signal at the frequency of oscillation below the starting current as it has been shown by B. Glance and B. Epsztein. Besides, the noise may cause a low efficiency when the coupling impedance of the line is very low. The frequency jumps observed generally in 'M' type carcinotrons may be explained by the effect of the r.f. field radiated from the delay line on the beam in the gun region; this effect exists even if the cathode is temperature limited, but it is stronger, and much more holes are

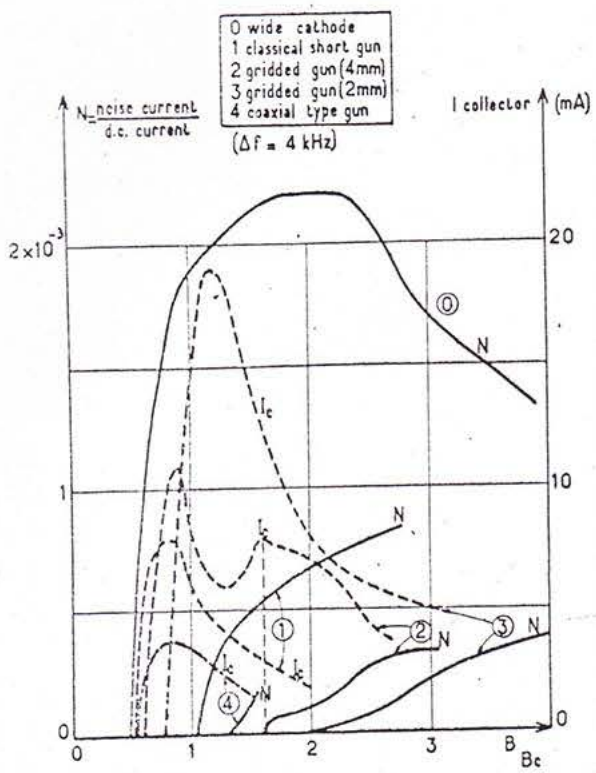

Fig.16

Noise and collector currents versus the magnetic field for gridded guns and coaxial type guns

observed when the cathode is space charge limited and when the excess noise is present. The effect of an r.f. voltage on the beam modulation, the cathode being temperature limited has been computed. From this calculation a condition is found for the discontinuities which shows that the longer the gun, the more likely are the discontinuities to appear a point well checked by experience. Holes may appear, from this theory,

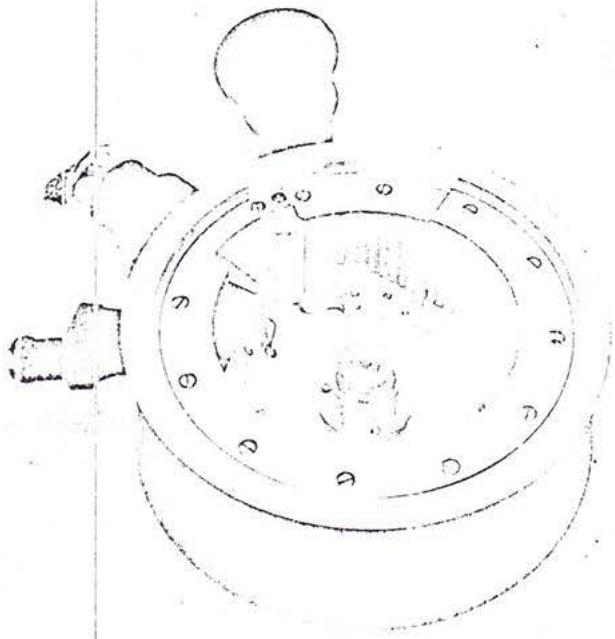

Fig.17

'M' type carcinotron with a tapered interdigital line

in practical tubes, if some resonances exist with Q factors of some 100.

Even in the case when no discontinuities are present, a phenomenon similar to frequency pulling should happen, sometimes positive and sometimes negative, depending on the plate voltage.

An 'M' type carcinotron is shown in Fig.17 using a taper to reduce the fast mode radiation; this tube exhibits no discontinuities if the magnetic field is constant all along the interaction space.

These studies have been supported by the U.S. Signal Corps, the British C.V.D., and Raytheon.