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The Measurement of Microphonic Effects in Vacuum Tubes

Adapted from an article by R. Bird M.Sc. D.I.C.
that appeared in Electronic Engineering, Nov. 1951.

UP TO THE PRESENT, the reduction of microphonic output from vacuum tubes has been very much regarded as a matter of trial and error. With equipments becoming ever more sophisticated, the need for greater vibration resistance in many tube types presses urgently.

Consequently, more-accurate methods of microphonic detection and measurement are necessary as an aid to better tube design.

One purely qualitative method of investigation has been to connect a tube in question as the first stage of an audio power amplifier connected to a loudspeaker, and then to give the tube a "standard" blow with a small hammer, the resultant volume, pitch, and quality of the sound heard from the loudspeaker providing some idea of the merit of the tube. Although fairly crude, this method has the virtue of simplicity and is still in use where large quantities of tubes must be quickly evaluated. Several other equally quick but crude measurement techniques exist, but these will not be expanded upon, as the purpose of this paper is to outline more sophisticated, quantitative investigative methods.

An attempt has been made by previous workers to determine the absolute microphonic performance of a tube by relating its electrical output to the frequency and intensity of a sound field in which it is placed. A schematic diagram of the required apparatus is shown in Fig. 1. The tube to be tested is set up to function as a voltage amplifier, but with its grid coupled to its cathode. It is then placed near the center of an anechoic chamber, with a measuring microphone in close proximity to the tube. A full-range loudspeaker is placed nearby. The electrical measurement equipment and the operator are situated outside the chamber.

The sound pressure from the loudspeaker thus acts as a wide-range "vibrator" of the tube under test. As the force of the vibrations must be kept as nearly constant as possible with changing frequency, the sound pressure in the immediate vicinity of the tube is monitored by the measuring microphone. Its output is fed back to the sweep oscillator, which contains a special regulating circuit that raises or lowers the drive level to the speaker as required.

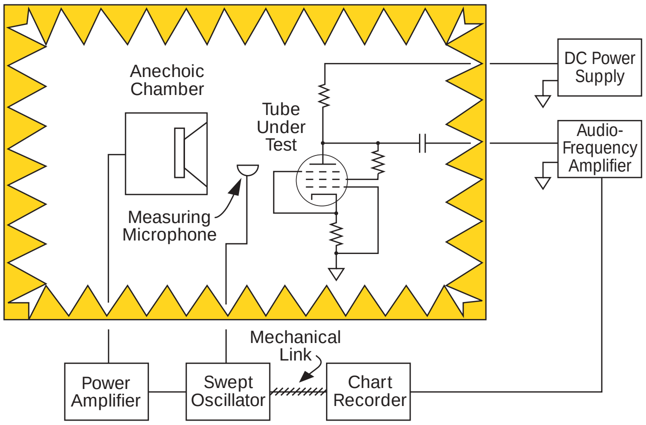

FIG. 1. An apparatus for measuring a tube's microphonic output.

The chart recorder and sweep oscillator are mechanically linked in such a way that the frequency calibration lines on the driven paper of the recorder, as they appear under the stylus of the recorder pen, coincide with the output frequency of the swept oscillator.

The tube may then be simply tested for microphonic output by starting the recorder, which drives the swept oscillator to produce an output of slowly increasing frequency. As the tube's output in the test circuit is solely a function of the mechanical vibration to which it is thereby subjected, it is a simple matter to plot this output with the recorder. Knowing the voltage gain of the circuit in which the tube has been placed, and knowing the output voltage induced by the mechanical excitation caused by the swept but essentially constant-amplitude sound pressure provided by the speaker/microphone/-feedback circuit combination, simple arithmetic will

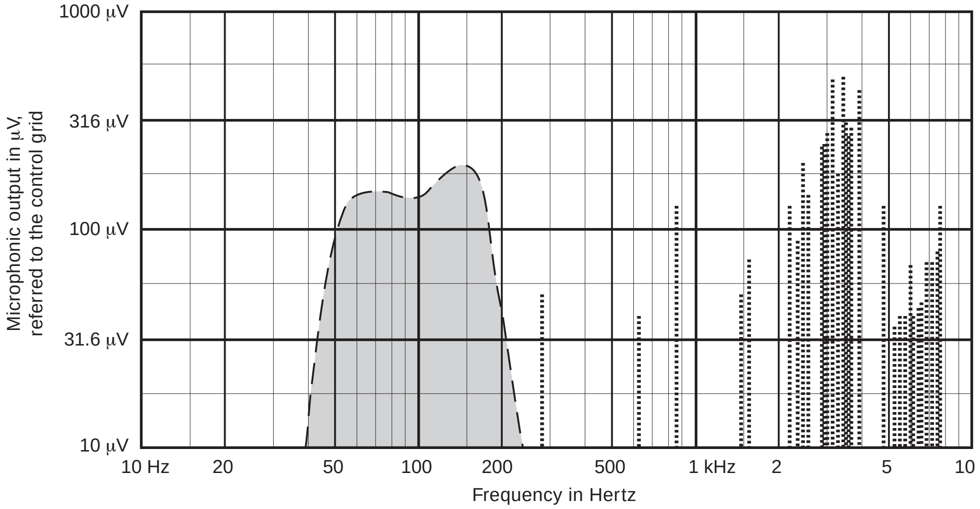

FIG. 2. Microphonic output from a high-gain miniature pentode. Note that the mechanically induced output voltages from the tube equate to equivalent electrical input voltages on the order of those produced by modern moving-coil phono cartridges through the mid-band. This is a “worst-case” laboratory situation in terms of the mechanical excitation applied; but typical listening-situation-induced vibration can easily produce stimulae only 30 to 50dB down from those in the test situation. This means that the microphonic signal can be, in the case of a 200µV output moving-coil cartridge, as little as 35 to 55dB down through the mid-range frequencies from 1kHz to 5kHz.

yield the equivalent electrical input voltage to the grid which, in normal operation, would yield the output voltage achieved by the mechanical vibration of the tube.

A typical pentode response diagram is shown in Fig 2. Each of the vertical lines corresponds to an electrical output resulting from the excitation of a mechanical resonance in some part of the tube’s structure. Nearly all of these resonances are of very high Q, being excited over a band of only a few cycles. The broad grey-shaded area represents the band of frequencies which will stimulate the resonant characteristic of the cathode.

While data on the frequency and severity of the various resonances is essential, it provides only part of the information required to remedy the problem. It remains to determine which of the various elements has been stimulated to resonance. As it is not usually possible to actually see far enough into the tube because of the plate, various internal shields, the getter patch, and/or beam forming electrodes obstructing the view, visual methods are of little practical value.

Mathematical methods are fraught with enormous difficulty due to the often complex shapes and indeterminate mechanical properties of the structures involved.

Grid-wire resonances may be investigated by a rather expedient means as follows:

The grid structure, consisting of the two side-rods and the grid wire helix, is cemented to a small coil of wire such as used in a conventional moving-coil tweeter. The coil is replaced in the field of the permanent magnet in which it would normally reside if driving a speaker element and is driven by a variable frequency oscillator/ power amplifier combination. The grid wires are viewed under a microscope, and as the resonant frequency of a turn of grid wire is reached, it springs into vigorous vibration and becomes blurred. The spread of resonances in the control grid wires of the pentode of Fig. 2 is shown in Fig. 3.

While this method is useful for determining resonances in a grid structure, it provides few clues as to how the various elements within a multi-element tube might interact.

It has been suggested by Dr. E.G. James of the G.E.C. Laboratories that the capacitance change produced between a vibrating electrode and its neighbors might be used as a means of detecting these motions in a manner analogous to the way in which a capacitor microphone converts sound pressure to electrical energy.

A highly sensitive capacitance bridge operating at a measurement frequency of 1MHz. was found to be well suited to this technique, being able to resolve changes in capacitance of 0.00003pF! The same acoustical excitation system as shown in Fig. 1 is employed. With the leads from the bridge to the test apparatus properly shielded and tied down to prevent, as far as possible, their natural resonant modes from producing false data, the system is first run

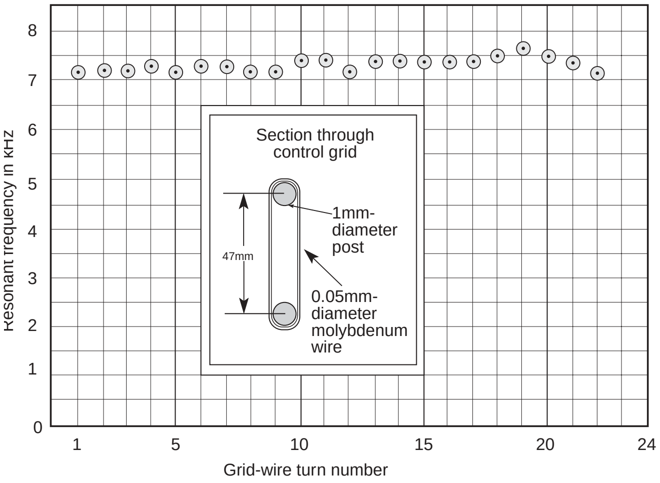

Fig. 3. Resonant frequency of individual control-grid wires of a miniature pentode.

without a tube in situ to be sure that the output from lead vibration, if any, is known and recorded. Fig. 4 shows the amplitude and frequency of many resonant modes within the pentode discussed in this paper.

The most troublesome resonant modes are those of the cathode in the vicinity of 100Hz. Vibrations above this frequency may be prevented, in large measure, from reaching the tube by the use of a special resiliently mounted socket. The difficulty with the cathode is that it may not be rigidly held at both ends but must be free at one end at least in order to be able to expand when heated by the filament. Failure to provide for this expansion will result in the cathode bowing to one side and possibly fouling the control grid.

The variation in microphonic performance between tubes of the same type, even though produced consecutively on one assembly line, may be as large as that between different types. To get a fair picture of the performance of a particular type, a large number of samples must be tested. It should then be possible to define the troublesome frequency ranges and attempt to isolate the offending structure(s) by microscopic or capacitance-bridge methods. Failing this, trial and error is a last resort.

Thus the design of a low-microphonic tube is a long and arduous process, and research continues to produce truly non-microphonic types.

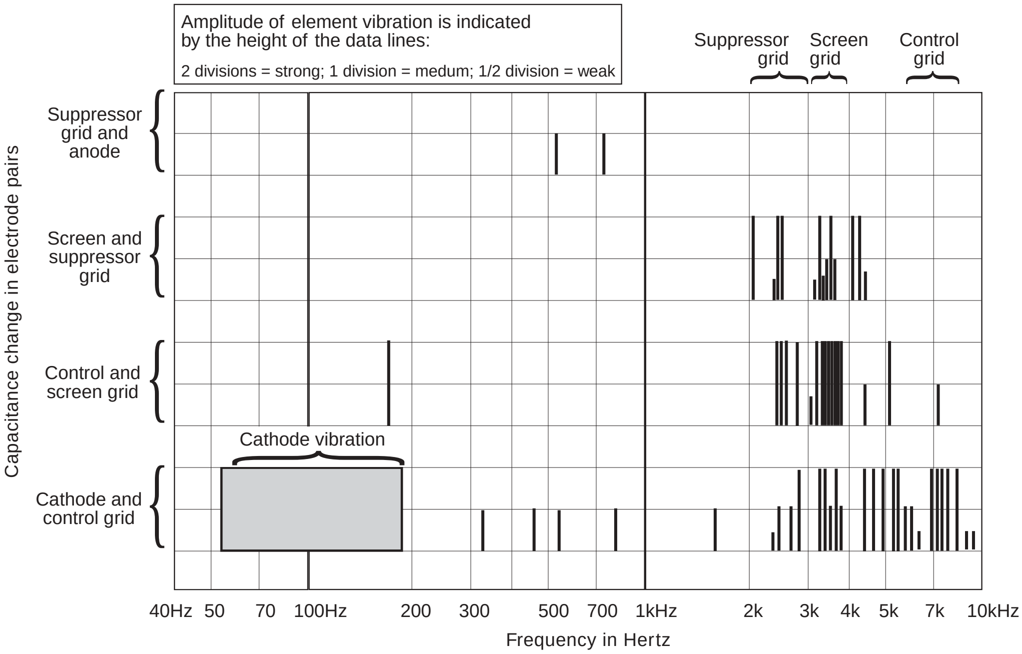

Fig. 4. Variation with frequency of capacitance between adjacent electrodes in a miniature pentode.