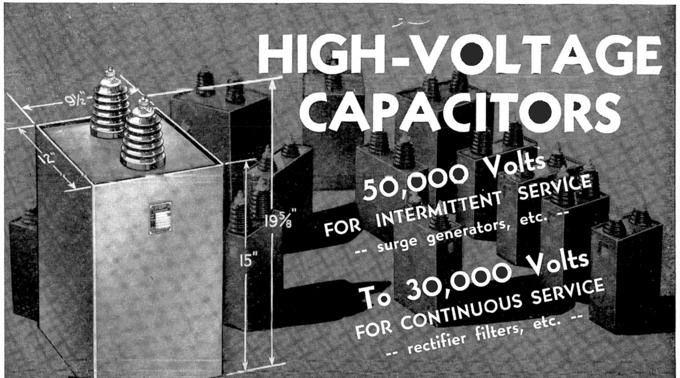

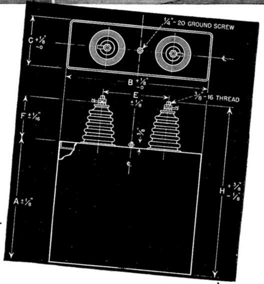

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H. F. Frequency Measurements

PART III

By the Engineering Department, Aerovox Corporation

THE Q of the conventional tuned circuit falls off rapidly at the extremely high frequencies, impairing both stability and efficiency of oscillator circuits in which it is employed. In order to alleviate this effect, it has become standard practice to employ tank circuits of radically different design, to obtain higher Q values. These higher-efficiency tank circuits take the shape of parallel-line or concentric pipe systems.

Line-Controlled Oscillator. The parallel-line tuned circuit is basically identical with the Lecher frame, already described as a wavelength measuring device. This will be indicated later in the description of the Barkhausen-Kurz and Gill-Morrell oscillators. Another line-controlled oscillator circuit, a variation of the ultraudion, is shown in Figure 1.

In this circuit, the grid and plate lines are each one-quarter wavelength long at the operating frequency. Linear tank circuits of this description obviously are practical only at the extremely high frequencies, since a quarter-wave line need be only a few inches long at those frequencies. The ability of the linear tank to perform as a resonant circuit is based upon well-known properties of the quarter-wave line. That is, standing waves will exist along such a line, when excited, extending (as shown in Figure 2) from a point of zero current at the open end to a point of maximum current at the shorted end. These points correspond respectively to those of high and low impedance. By employing a balanced line in the oscillator (that is, with grid connected to one line and plate to the other), the current and voltage components of the standing wave will be out of phase and radiation from the lines, and attendant losses, will be reduced or eliminated. In the oscillator circuit (Figure 1), wavelength (frequency) may be changed by shifting the position of the shorting bar, thus increasing or decreasing the effective length of the line.

Tube filament leads possess a small amount of inductance which becomes more troublesome in the circuit as the oscillator frequency is increased. Since at very high frequencies, the electrical length of filament leads, both inside and outside of the tube, approaches an appreciable fraction of a wavelength, standing wave effects will be present along these leads. The net result will be to introduce various degrees of phase shift between the active filament and the point to which its return connection is made. This applies equally to cathodes in the indirectly-heated-type tube. The filament or cathode lines must accordingly be increased in electrical length to restore the phase angle to its proper value at the return point. For this purpose, the coils, L_1 and L_2 are introduced in series with the filament leads. Loading effects, due to the tube grid-plate capacitance and to the capacitance of any capacitor connected

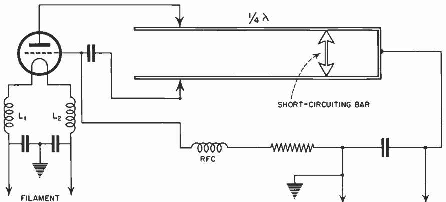


FIG. 1

in parallel with the lines, act to shorten the electrical length of the line. However, this effect may be compensated by cutting the line initially to a length somewhat longer than the actual computed quarter wavelength, locating the exact operating wavelength by means of the shorting bar.

The characteristic impedance of a two-wire quarter-wave line, such as employed in the line-controlled oscillator is stated as:

$$(1)\qquad Z_o = 276.3\ \log_{10}(S/r)$$

Where Z_o is impedance (ohms),
S is distance between centers of lines,
r is radius of line conductor.

S and r may be measured either in inches or centimeters, provided the same unit of measurement is used in both cases.

Tube loading effect may be reduced somewhat by tapping the plate and grid connections down the line, as indicated in Figure 1, best results being obtained when the taps are close to the shorting bar.

Barkhausen-Kurz Oscillator. In this type of oscillator (See Figure 3), also attributed to Gill and Morrell, oscillation is produced by rotation of electrons within tiny orbits within the vacuum tube.

Tubes having cylindrical, coaxial elements are the most satisfactory for operation in the B-K oscillator circuit. The circuit is arranged as shown in Figure 3-A. Unlike conventional triode circuits, the grid of the B-K oscillator tube is maintained at a high positive potential with respect to filament, while the plate electrode receives a negative voltage. This plate voltage is considerably less than the grid voltage, and in some applications is even *zero.*

The behavior of electrons within the triode is illustrated in Figure 3-B. Electrons leaving the filament are attracted by the highly-positive grid. Some of these electrons travel at such high velocities that they speed through the grid mesh toward the plate. The plate, being of negative potential, repels the approaching electrons, which turn about and travel back through the grid structure. They may be drawn again through the grid mesh and travel once more toward the plate for a repetition of the action.

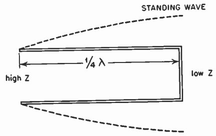


FIG. 2

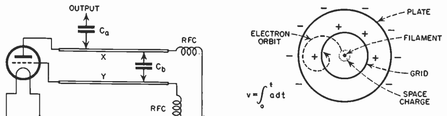
Oscillations by virtue of electron movement back and forth within the tube, are thus set up. The frequency of such oscillations depends upon the velocity at which the electrons move about their orbits and the length of the latter. Obviously, the orbit length will be reduced, and the highest attainable frequency increased, as the tube interelectrode spacing decreases. Highest frequencies are accordingly reached in tubes having small electrode spacing.

B-K oscillations are purely of the electron-orbit type and their frequencies are independent of external circuit constants. The magnitude of positive grid voltage acts with electrode spacing to determine the velocity of oscillating electrons. Barkhausen has stated the relationship between these factors and wavelength in the following approximate equation:

$$(2)\qquad \text{Wavelength} = 1000\,d\Big/\sqrt{E_g}\ \text{centimeters}$$

Where d = separation of grid and plate (cms.)
E = D.C. grid voltage when plate and filament are both at zero potential.

In the true Gill-Morrell oscillator, alternating voltages induced in the oscillation circuit, as the parallel lines X and Y in Figure 3-A, are superimposed upon the direct grid and plate voltages. The moving electrons within the interelectrode space are accordingly subjected to an alternating, rather than steady field. The frequency then becomes almost entirely independent of the plate and grid voltages and may be determined by the external circuit constants. The bridging capacitor, C_b, may thus be moved along the parallel-wire system, X-Y, to obtain a continuous variation of oscillation frequency. An alternative arrangement might indicate a variable capacitor at C_b. Signal voltage is coupled out of the oscillator circuit through the coupling capacitor, C_a, which is small in value.



a = acceleration of electron in filament-grid space (assuming uniform filament-grid field).

v = velocity of electron at time t after it starts movement toward grid from point farthest from grid.

d = filament–grid spacing.

-A-

-B-

FIG. 3

Typical operating conditions for a cathode-type triode with cylindrical electrodes (such as types '27 or '56) are: plate voltage —2 to —5, grid voltage 67.5. The r. f. chokes are difficult to specify with regard to inductance, their final values depending to some extent upon particular tubes employed and layout of components, as well as upon oscillation frequency. Generally they will be composed of a few turns of No. 30 to No. 36 insulated wire space-wound at a small diameter and preferably air-supported.

The parallel conductors may be wires or rods. However, they must be stiff or taut and rigidly supported by high-quality insulating posts. The capacitance of C_a and C_b must be small, the actual values being governed by the highest frequency at which the oscillator may be operated. Either air-type capacitors or high-Q mica units may be employed at C_a and C_b, although the former type will be preferable.

Tunable - Pipe Oscillator. General Radio Co. has produced a tunable concentric-line oscillator which is totally shielded and covers the range 150-600 Mc. (200-50 cm. wavelength). The basic construction of this instrument is shown in Figure 4. The active elements of the coaxial resonant circuit are the outer cylinder, A, and the inner screw, B. The traveling shorting disc, C which acts to vary the length of the line is moved along the interior of the chamber by rotating the screw conductor by means of dial D. Contact is made to the inner wall of the outer cylinder and to one line of the filament by means of metal brush blades, E-E-E, arranged in groups about the circumference of the traveling disc.

The tube, a Western Electric 316-A, is enclosed within the outer cylinder together with all other components which are a part of the actual oscillating circuit. A coaxial output jack is provided at the tube housing to accommodate a properly-terminated line. The output impedance of this oscillator is of the order of 75 ohms.

The active portion of the concentric line is that portion included between the triode tube and the shorting disc, C. The outer cylinder is grounded for shielding and since it is also the point for B-plus connection to the plate power supply, the latter must be so constructed that the positive terminal may be grounded with safety.

Lumped-Constant Oscillator. At the extremely high frequencies the effective Q of the resonant circuit may be increased materially by a combined process of eliminating radiation and minimizing circuit resistance. This is accomplished in the "pot" oscillator of Peterson by building the inductance and capacitance into a single unit which is of the nature of a coaxial system. A type of pot oscillator is shown in Figure 5.

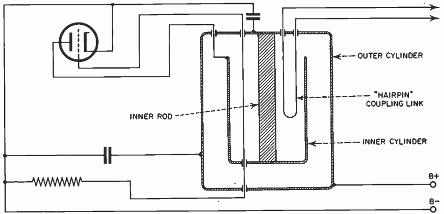


FIG. 5

The capacitor consists of the two concentric cylinders, while the inductance is the internal rod. It is seen that the inductance and capacitance are connected in parallel by this arrangement. This circuit does not comprise a concentric line when it has been designed properly. The inductance and capacitance are lumped when the length of the system is one-tenth wavelength or less. When this length is increased beyond this figure, however, the circuit takes on the properties of a concentric line instead, and the reduced circuit resistance afforded by the large-area conductors is sacrificed.

Figure 5 employs a tickler feedback circuit, although several circuits, including the ultraudion are possible with the pot arrangement. The resonant frequency is governed by the length and diameter of the inner rod and by the length and diameter of the two cylinders. This type of oscillator is most adaptable to single-frequency generation; for example, in setting up a standard spot frequency and its harmonics. Continuous variation of frequency over a small range may be accomplished by means of a small external variable capacitor connected in parallel with the resonant circuit. However, such a unit will tend to destroy the lumped-constant characteristics of the oscillator.

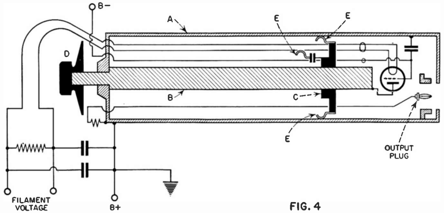


FIG. 4