Excerpt from Chapter 9 of

F-M Simplified

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A New Tube. The Armstrong phase-shift method and the Crosby reactance-tube system of producing F-M have both been known for some time. Recently, however, an entirely new system

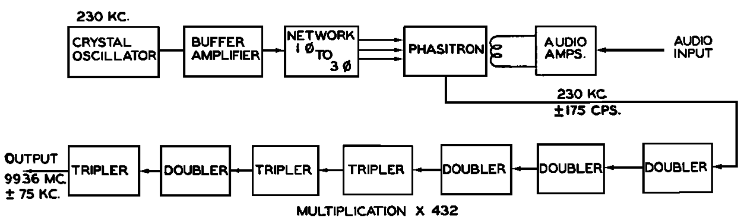

FIG. 10.18. A block diagram of the exciter unit of an F-M transmitter utilizing the Phasitron.

for producing F -M has been devised by Dr. Robert Adler and utilized commercially by the General Electric Company. This newer system employs a specially designed tube, which produces the preliminary F-M. The tube is known as the "Phasitron," and is the modulator unit for the transmitter.

A block diagram of the exciter unit, which includes all the circuits except the power amplifiers, is shown in Fig. 10.18.

The stability of the carrier is dependent upon the 230-kc crystal oscillator. In this respect, the circuit resembles the Armstrong unit. Indeed, the resemblance between the two extends even farther because this system also utilizes phase shifting to obtain equivalent F-M. However, the difference lies in the fact that all of the phase shifting due to modulation occurs within one tube, the Phasitron, whereas in the Armstrong system several tubes are required to accomplish the same purpose.

The entire transmitter is designed around the Phasitron. An internal view of the Phasitron is shown in Fig. 10.19A, with a labeled drawing in Fig. 10.19B. Although specific reference is made in what follows to the labeled schematic drawing, the reader will be able to gain a clearer idea of the entire functioning of the tube if he makes a continual cross-reference between both diagrams of Fig. 10.19. For every part labeled in Fig. 10.19B, stop and locate that part on the tube shown in Fig. 10.19A.

The tube is designed so that electrons emitted from the cathode reach the positive plates or anodes 1

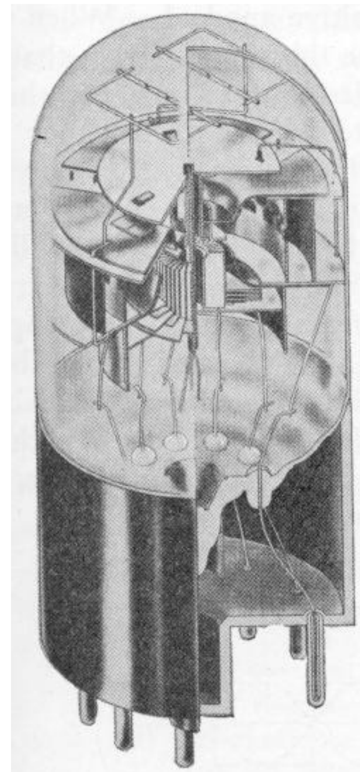

FIG 10.19*A*. Internal view of Phasitron.

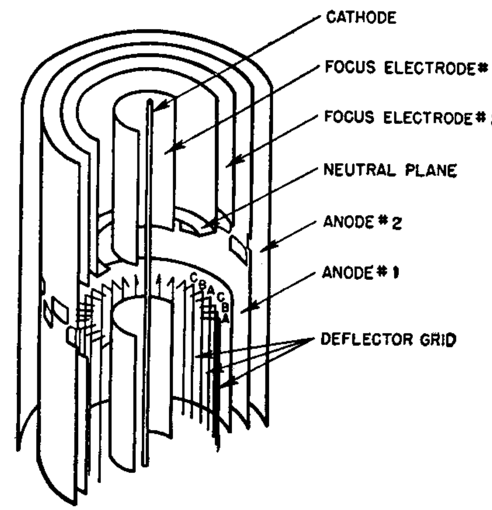

FIG. 10.19*B*. A labeled schematic drawing of the internal segment of the Phasitron.

and 2 in one definite plane. At all other points the electrons are prevented from reaching these anodes by shields. From Fig. 10.19A, we see that the only exposed section of the cathode is at the center. Above and below the center, two shields prevent any emitted electrons from reaching either anode 1 or 2.

Since the cathode at the center section emits electrons in all directions, or 360°, the emitted electrons will assume the appearance of a circular disk. The formation of this electron disk is shown in

Fig. 10.20. In order to keep the electron disk very thin, especially at the edges, two focusing electrodes are inserted. The focus electrodes 1 and 2 are shown in Fig. 10.19 B.

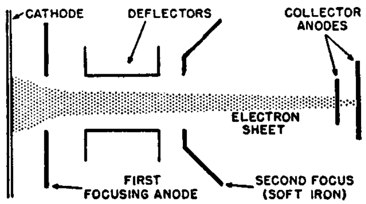

Fig. 10.20. The electron-optical arrangement in the tube for producing an electron disk.

The electron disk extends out from the cathode until it reaches the positive anode 1. When we examine this plate, we see that it has holes punched in it, each hole separated from its neighbor as shown in Fig. 10.21. The dividing line between the upper and lower holes represents the line where the edge of the electron disk impinges on anode 1. If the edge of the electron disk impinges directly on this line, no electrons will be in the plane of the punched holes and be able to reach anode 2, which is located directly behind anode 1. Except for these holes in anode 1, no other direct path is available for the electrons to reach anode 2. This, of course, is purposely done, and fits in with the action of the tube.

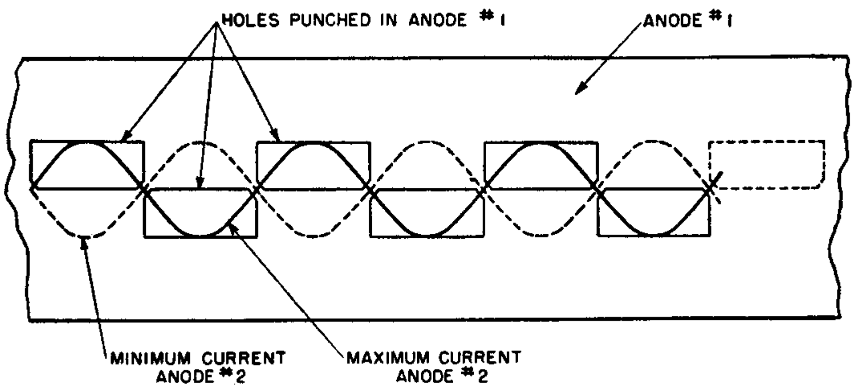

Fig. 10.21. The placement of the holes punched in anode 1.

A specially constructed set of grid wires are situated below the level of the electron disk. The grid wires are near the outer edge of the circular electron disk, just before the electrons reach anode 1. However, because the grid wires are below the electron disk, any voltage on the grid wires will only act to do one of two things: either pull the edge of the electron disk down with a positive charge or else repel the edge of the electron disk up with a negative charge.

Thus, if we connected all the grid wires together and placed an alternating voltage on them, the edge of the electron disk would rise and fall vertically (flip up and down) as the voltage changed. But whether they rose or fell, they would reach either anode 1, or, if they passed through its holes, anode 2.

The foregoing would result if all the grid wires were tied together. Actually they are not. There are 36 distinct grid wires. For the sake of explanation, every three wires have been labeled *A*,

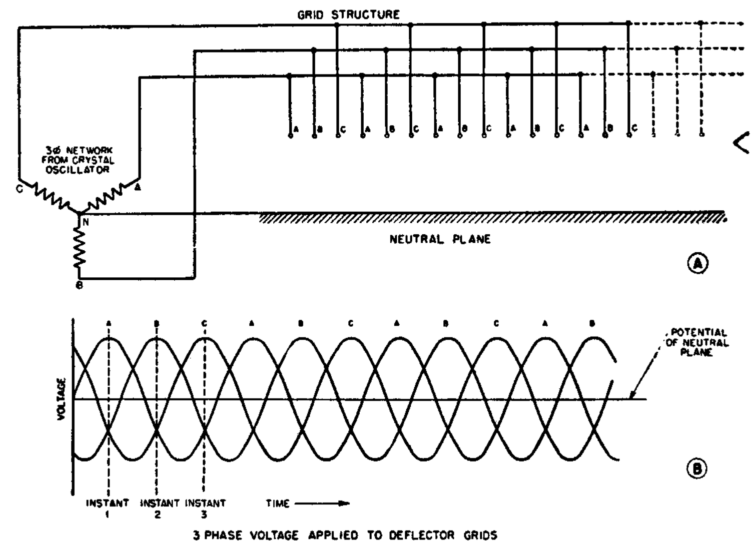

Fig. 10.22. (*A*) The application of the three-phase voltage to the grid structure. (*B*) The voltage variation of each set of grids.

B, and *C*, successively, until all of the 36 wires have been lettered. In construction, all the wires marked *A* are connected together electrically, as are all the *B* wires and all the *C* wires. We obtain, in this manner, a repetition in potential for every third wire, and every third wire will possess the same polarity. In the overall view, there are three sets of grid wires, each set containing 12 grid leads.

The grid wires are arranged in this manner in order that a three-phase voltage may be fed to them, one phase to group *A*, one to group *B*, and the third phase to group *C*. Fig. 10.18 indicates that the three-phase voltage is obtained from the crystal oscillator branch. The crystal oscillator generates a single-phase voltage, which when amplified is converted to three-phase by an appropriate network. The three-phase voltage is then applied to the three sets of grids (Fig. 10.22A). Each phase is shown applied to a separate group of grids, with the common terminal of the three-phase system attached to the electrode marked "neutral plane." This electrode is directly above the group of grid wires. Any voltage between the neutral plane and the set of grid wires will act directly on the electron disk passing between these two elements.

To represent the alternating three-phase voltage, Fig. 10.22B is helpful. Each phase is shown separately, with its variations from instant to instant. The response of the edge of the electron disk to these changing grid voltages will depend upon the voltage polarity on the different sets of grid wires at any instant with respect to the neutral plane electrode.

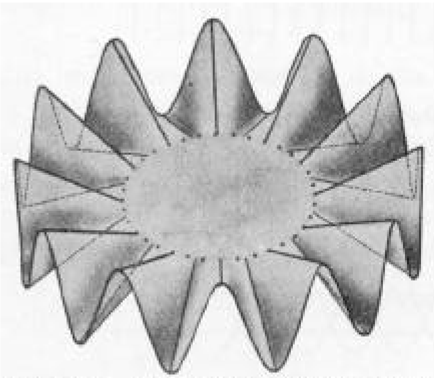

FIG. 10.23. The ruffled appearance of the edge of the electron disk.

At instant 1, Fig. 10.22B, the voltage at all the *A* wires is at its maximum positive value, while the voltages at the *B* and *C* set of grid wires are equally negative. Hence, above each *A* wire, the electron disk is attracted downwards while above each *B* and *C* wire, the edge of the electron disk is repelled upwards. The resultant shape of the disk edge possesses a ruffled appearance as shown in Fig. 10.23.

Since the grid voltage is always changing, at instant 2 we find that all the *B* wires are at their maximum positive value, while all the *A* and *C* wires are negative. Now those sections of the edge of the disk that were attracted downward previously to all the *A* wires will have gradually shifted around until they are attracted to the *B* wires. Extending the same line of reasoning, it is readily seen that at instant 3, the edges above the *B* wires will shift to the *C* wires. After this, the sequence occurs over again, with *A*, *B*, and *C* following in order as outlined.

If we were standing inside the tube, perched above one grid wire, it would appear to us as though the electron disk was rotating rapidly, with the ruffled edges of the disk rising and falling in step with the rise and fall of the controlling crystal-oscillator frequency. Since there are 12 sets of 3 wires each, we would find 12 maxima and 12 minima in the ruffled edges of the electron disk. This is evident from Fig. 10.23.

The effect of the variation in the position of the edges of the disk is to vary the amount of current that reaches anode 2, situated directly behind the hole openings in anode 1. Anode 1 has 24 holes punched in it. Twelve are above the plane of the electron disk and 12 below. Suppose that at the instant when all the A grid wires are positive, the ruffled edge assumes such a position that all the electrons pass through the anode 1 openings. This condition is indicated by the heavy, dark line in Fig. 10.21. At this instant of time, anode 2 is receiving its maximum current. But, as the ruffled edges of the disk rotate, anode 2 gets less and less current because less and less electrons reach the openings of anode 1. The second anode receives its least amount of current, which is practically zero, when the ruffled edges of the disk assume the position indicated by the dotted lines in Fig. 10.21. At this moment the electrons, at all points, are striking the solid sections of anode 1. Between the maximum and minimum amounts of current flow to anode 2 is one-half cycle. Thus, the current flowing to anode 2 varies sinusoidally at a frequency determined by the crystal oscillator.

It is now possible to see one reason for employing the three-phase voltage. Without it, we would not have any ruffled edges on the electron disk, and we could not produce the sinusoidal current variation arriving at anode 2.

Modulating the Phasitron. The above represents the basic operation of the circuit with no modulation. The output from GL-2H21, the Phasitron tube, would merely consist of the 230-kc frequency due to the crystal oscillator.

Before we consider the modulation, let us note the effect of a magnetic field on the rotating ruffled edge of the electrol1 disk. The electron disk is horizontal in position, starting at the central cathode and extending to the anodes. Suppose we wind a coil about the tube, as shown in Fig. 10.24. Then its magnetic field will extend vertically, or up and down. Hence, the electron disk and the applied magnetic field are at right angles to each other.

It can be proven, both mathematically and experimentally, that when an electron travels at right angles to a magnetic field (as it is obviously doing here) the electron will be deflected at right angles to both the direction of the magnetic field and its direction of travel. Within the Phasitron the electrons originally travel directly from cathode to anode l or 2. This is shown by the arrow in Fig. 10.25. Upon the application of a vertical magnetic field, the beam begins to shift at right angles to its former direction. The shift is in the

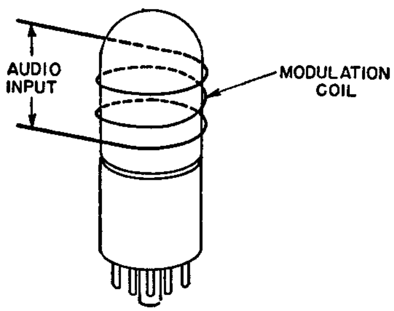

FIG. 10.24. Modulating the Phasitron tube.

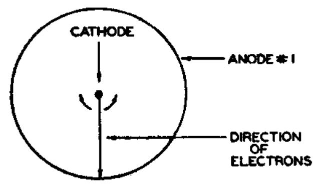

FIG. 10.25. Illustrating the effect of the modulation coil on the electron disk within the Phasitron tube.

direction of one of the two smaller arrows in Fig. 10.25. (Two arrows are shown, depending upon whether the magnetic flux is up or down.) These small arrows, it can be seen, are at right angles to the path of travel of the electrons and to the direction of the magnetic lines of force. How far the electrons shift either to the right or left of their original position depends upon the strength of the applied magnetic field. For a strong field, a large shift occurs; for a small field, a small shift.

Now let us modulate the current flowing through the coil by the audio voltages. The audio current will alternate in direction from instant to instant. In response to this periodic change in direction, the shifting of the electron disk will also be periodically to the right or left. Thus, superimposed on the regular rotation of the electron

disk due to the three-phase voltage will be this alternate shifting back and forth. Here is exactly the same type of action that occurred in the vector diagram used originally to explain phase modulation. The effect, then, of the modulation coil wound about the tube is to produce, through the fluctuating magnetic field set up by the audio currents, a back-and-forth shifting of the rotating electron disk. Due to the shifting of the electron disk, the current reaching anode 2 will likewise vary. Since the shifting of the disk represents a phase modulation wave, the current received by anode 2 will also be phase-modulated. And from phase modulation we can obtain equivalent frequency modulation. The modulation coil is connected to a push-pull voltage amplifier tube. This, in turn, obtains its input from a 6SL7 audio amplifier. The frequency modulation produced as a result of the foregoing action is, at its maximum, equal to ±175 cycles. By means of 4 doublers and 3 triplers, it becomes possible to raise the ±175 cycles to ±75 kc. This represents a multiplication of 432 ($2 \times 2 \times 2 \times 2 \times 3 \times 3 \times 3 = 432$). At the same time, of course, the crystal oscillator frequency is also increased 432 times, from 230kc to 99.36mc. For any other frequency between 88-108mc, the crystal oscillator frequency would change accordingly. To find the crystal frequency needed, merely take the assigned frequency of the carrier and divide this by 432.