May 31, 1955 B. WARRINER, IV 2,709,786

MAGNETRON AUTOMATIC FREQUENCY CONTROL

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Fig. 1

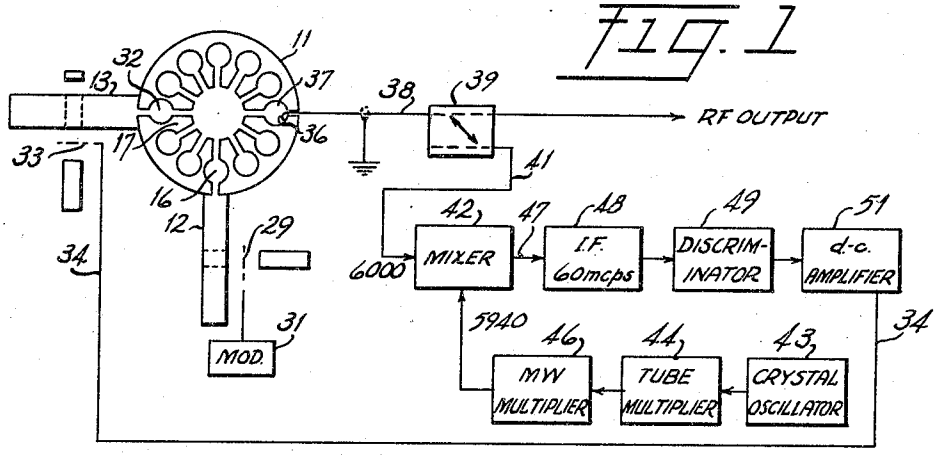


Fig. 2

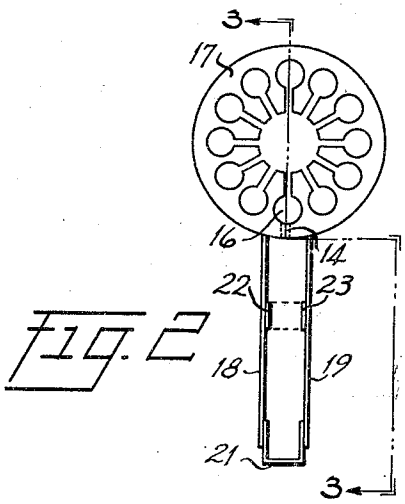


Fig. 3

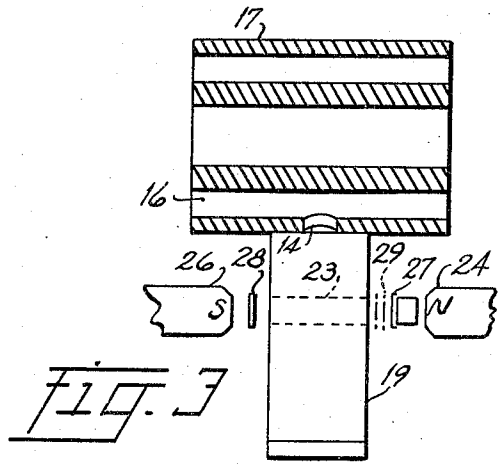
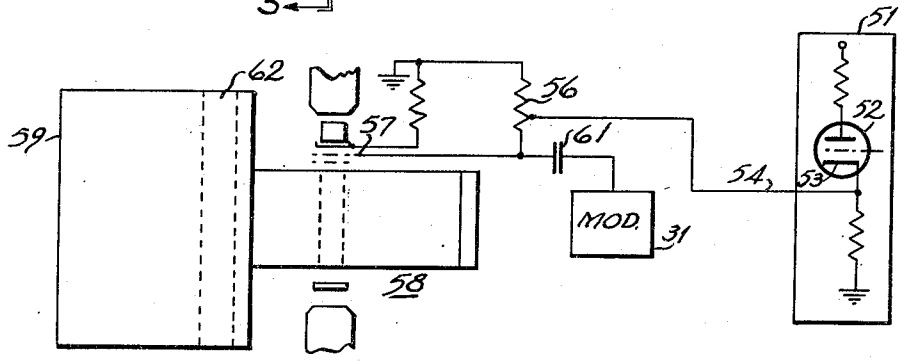


Fig. 4



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MAGNETRON AUTOMATIC FREQUENCY CONTROL

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3 Claims. (Cl. 332—5)

This invention pertains to the automatic frequency control of a magnetron and more specifically to the automatic central frequency control of a modulated magnetron, both the modulation and the control of central frequency being accomplished by the use of one or more spiral beams of electrons.

This invention is particularly applicable to multicavity magnetrons, and includes the employment of a microwave parallel plate resonant structure coupled to one cavity of such a magnetron. This resonant structure is combined with an electron gun and a magnetic field to produce a spiral beam of electrons capable of modifying the impedance of the parallel plate structure and therefore the resonant frequency of the magnetron cavity to which it is coupled, such modification of the frequency of one cavity also modifying the magnetron output frequency. When the resonant structure is combined with an automatic frequency control chain operated by the magnetron output, the median frequency of the magnetron output can be controlled. In addition, frequency modulation about this controlled median frequency can be effected by use of another similar spiral electron beam generator or by modulation of the same spiral beam.

One object of this invention is to control automatically and electronically the frequency of oscillation of a frequency-modulated or amplitude-modulated magnetron.

Another object is to control automatically the mean frequency of oscillation of a magnetron by the interaction therewith of a spiral beam of electrons generated in an external parallel plate resonant structure.

Another object is to control automatically the mean frequency of oscillation of a magnetron by use of a spiral electron beam generated in an external structure, combined with frequency modulation of the magnetron in the same external structure.

Further understanding of this invention may be secured from the detailed description and accompanying drawings, in which:

Figure 1 is a schematic circuit diagram illustrating one embodiment of the invention.

Figure 2 depicts a top view of a magnetron anode coupled to a parallel plate resonant structure.

Figure 3 is a side view of the device of Fig. 2 partly cross-sectioned on the line 3—3.

Figure 4 is a circuit diagram illustrating the manner by which both modulation and frequency control may be effected in a single parallel plate resonant structure.

Referring now to Fig. 1, a 12-cavity magnetron **11** is designed to generate a central frequency of, say 6000 mc. p. s. The magnetron is frequency modulated about the central frequency of 6000 mc. p. s. and this central frequency is automatically controlled to eliminate fortuitous variations and drift. Both types of control employ a spiral electron beam resonant structure, the two structures being indicated at **12** and **13**.

This type of structure is well known in the microwave art and may be briefly described as follows. In Figs. 2 and 3 a single structure of this type is connected by

means of an iris opening **14** to one cavity **16** of a multicavity magnetron having an anode block **17**. The iris opening **14** may be closed by an airtight covering transparent to electromagnetic fields, permitting the interior of the magnetron to be evacuated. The resonant structure consists basically of two parallel plates **18** and **19** short-circuited at both ends, at one end the plates being effectively connected by the metallic anode **17** and at the other end connected by an adjustable tuning plunger **21**. The distance between the two closed ends is made equal to one-half wavelength corresponding to the 6000 mc. p. s. frequency. The plates are therefore resonant at this frequency, having voltage nulls at the ends and a voltage maximum at center. A small block is fastened to the center of each plate at **22** and **23** to decrease the distance between plates and concentrate the electric field at that point. A uniform magnetic field is applied to the space between the blocks **22** and **23** in a direction transverse the parallel plates, as is indicated in Fig. 3 by the schematically represented north and south magnetic pole pieces **24** and **26**. An electron gun for producing electrons from a cathode **27** cooperates with an anode **28** positively charged relative to the cathode to pass a stream of electrons through the space between blocks **22** and **23**, transversely thereto and in the same direction as the magnetic field. The entire structure including the parallel plates, the electron gun, and the anode is enclosed in an airtight envelope to permit evacuation. However, in the drawings this envelope is omitted for greater clarity.

The electron gun cathode stream is under the control of a control grid **29**, by means of which the impedance of the parallel plate structure is controlled and in turn the frequency of oscillation of the magnetron.

The path of the electron stream between cathode and anode is spiral in form, and by appropriate adjustment of the component magnitudes and electrical and magnetic parameters can be made to draw energy from the oscillating resonant structure and give energy up to it at different parts of the cycle, the adjustment being such that this action occurs in quadrature to the oscillations within the magnetron cavity. The resonant structure therefore affects the magnetron as a purely reactive load, having no resistive component. That is, the structure acts on the magnetron in a manner so as to affect only its frequency, and not its output amplitude.

By changing the electromagnetic parameters the oscillations of the resonant structure may be placed in phase with those of the magnetron, in which case the operation of the resonant structure places a purely resistive load upon the magnetron and therefore affects its output voltage without affecting its output frequency. In this instance as in that previously discussed, the control grid **29** acts as the controlling instrumentality.

The resonant structure of Figs. 2 and 3 and structure **12** of Fig. 1 thus can be employed either to frequency modulate or to amplitude modulate the output of the magnetron **11**. In either case the rectangle **31**, Fig. 1, represents conventional modulating equipment for applying a modulating voltage to the control grid **29** of the parallel plate structure **12**.

The parallel plate structure **13** is similar to the structure **12** previously described, and therefore a description thereof is unnecessary. The structure **13** connected by means of an iris opening to another cavity **32** of the magnetron, and its control grid **33** is under the control of an automatic frequency control feedback connection **34**.

The output energy is abstracted from magnetron **11** by means of any suitable conventional coupling such as the loop **36** inserted in a magnetron cavity **37**. The loop is suitably connected to a microwave guide **38**, which

may be either of the coaxial or the hollow type. A directional coupler 39 is inserted in the output connection 38 to abstract a small amount of microwave energy for the purpose of sensing frequency. The directional coupler output, nominally having a central frequency of 6000 mc. p. s., is applied through a waveguide 41 to a microwave mixer 42. This mixer is of the conventional type consisting of a silicon crystal rectifier with two wave guide input terminals and one intermediate frequency output terminal.

One wave guide input terminal is connected to the wave guide 41 while the other wave guide input terminal is connected to the output of a crystal oscillator multiplier chain. The oscillator 43 comprises a quartz crystal cut to oscillate at a frequency of 46.66 mc. p. s. Its output is multiplied in frequency by means of "lighthouse" tubes 44 or similar tubes suitable for high frequency amplification to a frequency of 840 mc. p. s. The multiplier 46 employs velocity-variation on other suitable multiplier tubes, for example klystron tubes, to arrive at a final frequency of 5940 mc. p. s. The output signal at this frequency is applied to the mixer 42 and the difference between 5940 and 6000, or 60 mc. p. s., is derived by the mixer 42 and applied from its output terminal through conductor 47 to an intermediate frequency amplifier 48. This amplifier is conventional, and is broadband enough to be receptive to whatever difference frequency is likely to be emitted due to the uncorrected frequency error of the magnetron. Its output is applied to a discriminator 49 tuned to 60 mc. p. s. The discriminator may be of any of the conventional types, the output being a direct voltage having a sense and magnitude dependent upon the frequency aberration at the input thereof. The discriminator output is amplified in a conventional direct-coupled amplifier 51. The direct-current amplifier output is connected through conductor 34 to the control grid 33 associated with the parallel plate resonant structure 13. The parallel plate resonator 13 controlled by the direct current potential applied to the grid 33 operates in the manner previously described, in this instance its effect on the magnetron 11 producing only a reactive change which modifies the magnetron output central frequency without producing any amplitude modulation, the sense of the change being in such direction as to reduce the error signal applied through conductor 34. In order that the automatic frequency control be sensitive to changes in the central frequency and not to the modulation frequency the automatic frequency control feedback loop is provided with sufficient time delay to integrate the error signal sufficiently to make this distinction.

It is possible to combine the functions of the resonant structures 12 and 13 in a single resonant structure. One manner in which this may be accomplished is illustrated in Fig. 4. The final stage of the direct-coupled amplifier 51 comprises a cathode follower tube 52, from the cathode 53 of which a connection 54 is made through resistor 56 to the control grid 57 of a resonant structure 58 similar in all respects to the resonant structure of Fig. 3. The control grid 57 is thus biased by a direct voltage controlled by the amplifier 51 and through this bias controls the central frequency of the magnetron 59. The control grid 57 is also connected through condenser 61 to a modulator 31 similar in all respects to the like-numbered modulator of Fig. 1, so that the resonant frequency of the cavity 62 of the magnetron 59 is frequency modulated, in turn frequency modulating the magnetron power output in the manner previously described.

What is claimed is:

1. A magnetron automatic frequency control comprising, a multicavity magnetron, a resonant structure containing parallel plates having a length equal to one-half wavelength of the desired magnetron central frequency, a pair of opposed bosses in the centers of said parallel plates whereby the space embraced between the centers of the plates is constricted, an electron gun including a cathode, a focusing electrode and an anode positioned to pass an electron stream transversely of said resonant structure through said constricted space, a pair of magnet poles positioned to produce a magnetic field transversely of said parallel plates through said constricted space, a wave guide circuit connection between said parallel-plate resonant structure and one cavity of said magnetron, a control grid associated with said electron gun to control the current of said electron stream and thereby to control the frequency of oscillation of the microwave field in said connected cavity, the amplitude of oscillation not being affected, a modulator, an alternating current connection between said modulator and said control grid for frequency modulation of said magnetron, an output wave guide coupled to another cavity of said magnetron, a discriminator feedback loop energized from said output wave guide, and a direct-current connection between said discriminator feedback loop and said control grid in such sense as to cause the direct-current output of said discriminator to neutralize changes in the central frequency of the magnetron output energy, thereby maintaining constant central frequency thereof.

2. A magnetron frequency control comprising, a multicavity magnetron, a grid controlled resonant structure coupled to one cavity of said magnetron, an output wave guide coupled to another cavity of said magnetron, a modulator, an alternating current circuit interconnecting said modulator and the control grid of said resonant structure, a discriminator energized by the signal in said output wave guide, and a direct current circuit interconnecting the output of said discriminator and the control grid of said resonant structure.

3. A magnetron automatic frequency control comprising, a multicavity magnetron, resonant means including a control grid positioned to control a spiral electron stream, said resonant means being coupled to one cavity of said magnetron, an output wave guide coupled to another cavity of said magnetron, a discriminator feedback circuit including time delay means energized by the signal energy in said output wave guide, a direct current circuit interconnecting the output of said discriminator circuit and said control grid, a modulator, and an alternating circuit interconnecting the output of said modulator and said control grid.

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