

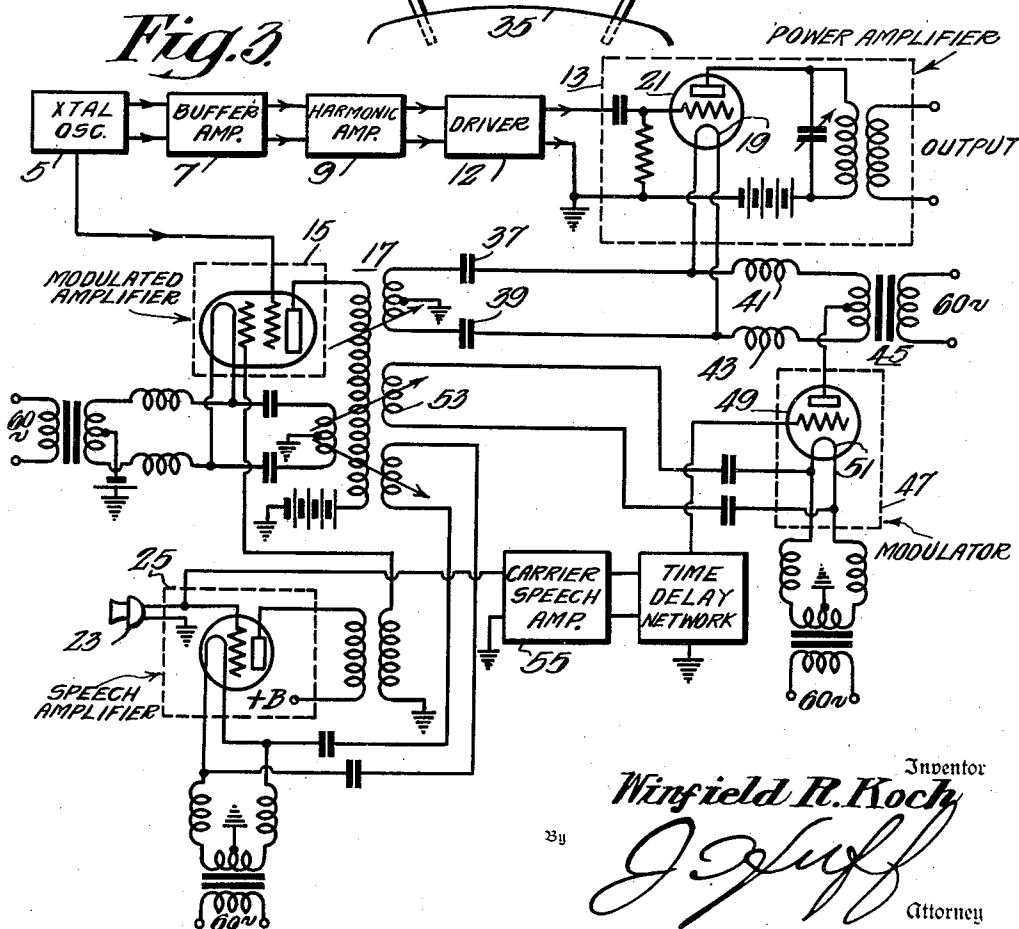
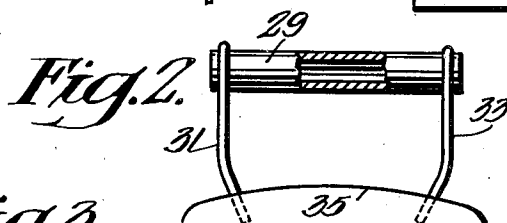
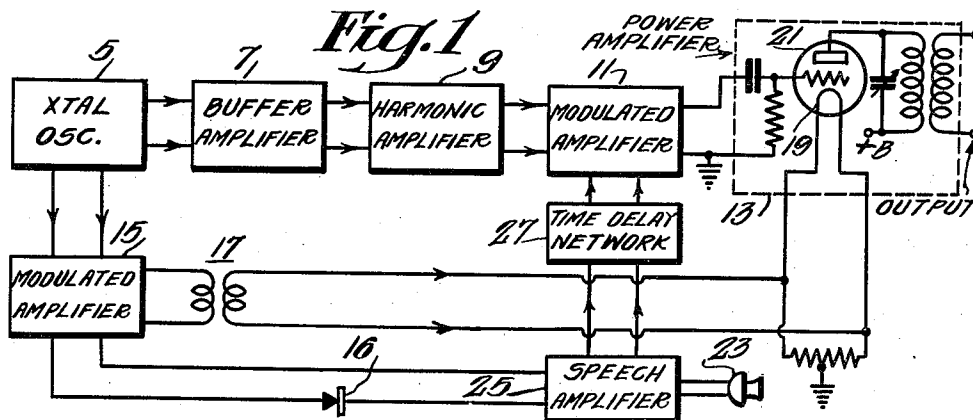
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FILAMENT SUPPLY SYSTEM

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FILAMENT SUPPLY SYSTEM

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This invention relates to filament supply systems and has for its principal object the provision of a method and means for improving the efficiency of operation of high power radio frequency amplifier tubes by varying the filament excitation in accordance with the modulating voltage.

The filaments of power tubes are ordinarily run at a temperature sufficient to provide the necessary electron emission during peak modulation. In ultra high power tubes the current consumption required to so energize the filament or cathode is an appreciable portion of the operating cost of the transmitter. In addition, it is known that the useful life of the tube is limited to a large extent by the life of the cathode, and that the cathode life may be increased substantially by reducing its average temperature.

In accordance with the present invention, the filaments of high power tubes are energized with a current, preferably a radio frequency current, modulated in accordance with the modulation voltage. Radio frequency excitation alone may be utilized, or in conjunction with a direct or low frequency alternating current excitation which is sufficient to maintain the filaments at a low normal temperature, for example, sufficient to provide satisfactory operation at carrier output or during periods of slight modulation.

In addition to the saving in power during standby periods, or during periods of low modulation, a substantial increase in the life of the tube is produced which of itself is an important factor. This is due principally to the decreased average emission of the filament, but also due to the more uniform current distribution of the filament which is inherent in alternating frequency operation of the filament as distinguished from direct current operation. It is known that when direct current is used, the filament tends to burn out at one end because of the non-uniform electron emission. Another advantage of radio frequency excitation of the filament is that troubles from 60 cycle hum are greatly reduced, or completely eliminated. Further objects of this invention therefore include the provision of an improved filament supply for high power tubes; the provision of means for increasing the operating efficiency of high power transmitters; and the provision of means for increasing the life of high power amplifier tubes while at the same time decreasing difficulties due to commutator ripple and hum which frequently arise from the use of conventional filament excitation systems.

This invention will be better understood from the following description when considered in connection with the accompanying drawing in which Figure 1 is a schematic diagram of a modulated transmitter in accordance with this

invention, partly in block diagram; Figure 2 is a view of a tubular filament; and Figure 3 is a schematic diagram of a preferred form of invention, also partly in block diagram. Similar reference numerals refer to similar elements through the several figures of the drawing.

In Fig. 1, the output of a conventional crystal oscillator 5 is coupled to a buffer amplifier 7 which is, in turn, coupled through a harmonic amplifier 9 and a modulated amplifier 11 to a power amplifier 13. The oscillator 5 also supplies energy to a modulated amplifier 15 the radio frequency output of which is applied through a transformer 17 to the filament 19 of the output tube 21 of the power amplifier 13. A microphone 23 is connected to a conventional speech amplifier 25, the output of which is applied to the modulated amplifier 15 through a rectifier 16 and also through a time delay network 27 to the modulated amplifier 11.

While I have shown a power amplifier tube 21 having a filamentary cathode, it is to be understood that an indirectly heated cathode may also be utilized. Preferably, however, the filament takes the form of a tubular element of the type illustrated in Fig. 2. For example, the filament may comprise a tubular member 29 mounted at both ends by suitable supporting means 31 and 33 in the glass press 35. The filament is not necessarily hollow, as illustrated, although I have found that its temperature responds more rapidly to changes in excitation if a hollow member is used.

By using radio frequency currents to energize the filament I am able to take advantage of a phenomena which is well known to those skilled in the art as a "skin effect." This effect is that radio frequency currents tend to travel near the surface of a conductor, and consequently radio frequency excitation tends to heat the outer surface of the filament more rapidly than the interior of the filament. For example, the "skin thickness" constant of copper at one megacycle is approximately .006 centimeter. This means that a radio frequency current of one megacycle flowing through a copper conductor will flow substantially through the conductor to a depth of only .006 centimeter from the outer surface. The skin thickness constant increases inversely as the square root of the frequency.

It is appreciated that a filament has a certain amount of thermal inertia, that is, the mass of the filament tends to heat slowly upon the application of a current. A conventional filament energized by direct or low frequency alternating current, would, therefore, respond too slowly to a varying current controlled by the modulation voltage to have any appreciable effect increasing the cathode emission during peaks in the modulating voltage. However, by employing radio fre-

quency currents, and possibly a hollow filament, the thermal inertia is sufficiently reduced to make practical the increase of emission in response to changes in the modulating voltage since the temperature of only a small portion of the mass of the filament is affected.

Upon the application of sound waves to the microphone 23 a modulating voltage is applied to the modulated amplifier 15, the effect of which is to increase the normal output of the amplifier above the minimum value necessary to maintain the filament 19 at, say, an incandescent state. The rectifier 16 is included in the circuit between the microphone and the modulated amplifier 15, in order to remove the negative half of the modulation voltage. The increased output of the amplifier increases the filament emission an amount sufficient to increase the available electrons so as to increase the current capacity of the power amplifier tube 21. At the same time, or at a slightly subsequent time when the time delay network is used, the modulating voltage is applied to the modulated amplifier 11 to increase the potential of the power amplifier grid and upwardly modulate the carrier current in the conventional manner. By including a time delay network 27 in the circuit between the speech amplifier 25 and the modulated amplifier 11 a short period of time is provided in which the cathode may reach peak excitation so that the tube will be ready to carry its maximum current by the time its excitation from the modulated amplifier 11 is applied.

In Fig. 1 the entire filament excitation is provided by the radio frequency current derived from the modulated amplifier 15. In accordance with a preferred embodiment of my invention, however, conventional excitation methods are employed to supply a minimum current to maintain the filament at a temperature sufficient to operate the tube during periods of low modulation corresponding to the carrier output condition. Such a system is illustrated in Fig. 3 to which reference is now made.

The essential elements of the transmitter from the crystal oscillator 5 to the power amplifier 13 are the same as those described in connection with Fig. 1. The modulated amplifier 15 is supplied with radio frequency energy from the oscillator 5, as before, and its output is coupled through a transformer 17 to the filament 19 of the power amplifier tube 21. In this case, however, blocking condensers 37 and 39 are connected in this circuit and the filament is also energized by a parallel connection, through a pair of radio frequency choke coils 41 and 43 by a transformer 45 connected to the 60 cycle power line. In this case, the standby or low modulation filament excitation current is supplied at maximum efficiency to the filament from the conventional power line. During modulation peaks, however, the excitation is increased by a superimposed radio frequency current derived from the modulated amplifier 15. Since the minimum excitation is determined independently of the amplitude of the radio frequency energy, a rectifier is not required in the modulation control circuit.

Radio frequency excitation is applicable not only to the power amplifier tube, but also to other tubes of the transmitter, although it will be appreciated that the greatest saving will be obtained where the system is used in high power tubes in which the filament current is consider-

able. Thus in a high level modulation system of the type illustrated in Fig. 3 radio frequency energizing currents, alone, or in combination with low frequency or direct current excitation, may be applied to the high level modulator 47. In the case illustrated, the anode-cathode path of the modulator tube 49 is connected in the ground return of the cathode of the power amplifier tube 21, the impedance of the tube thus constituting a biasing resistor for the output amplifier. The filament 51 of the modulator tube is coupled to a winding 53 of the radio frequency output transformer 17, this circuit also including isolating capacitors. The grid of the modulator tube 49 is coupled to a carrier speech amplifier 55 through a time delay network 27.

Radio frequency excitation of the filament may also be applied to low power tubes to provide a regenerative feedback circuit which increases the operating speed of the system. Thus the filament of the modulated amplifier 15 is coupled to the output transformer 17 as is the filament of the speech amplifier 25. As a result, a modulating voltage which tends to increase the excitation of the power amplifier and modulator filaments likewise increases the excitation of the modulated amplifier 15 and the speech amplifier 25. As a result, the radio frequency output of the modulated amplifier 15 tends to build up more rapidly in response to an increase of the modulating voltage than it would in the absence of the feedback. Tube saturation, however, prevents the system from going into oscillation by reason of the regenerative feedback coupling through the filament.

The frequency of the radio frequency current used to energize the filaments of the tubes is preferably a different frequency from that amplified by the output tube. In the case illustrated, for example, this is accomplished by including a harmonic amplifier between the oscillator and the output. Thus the filament excitation frequency is a sub-harmonic of the output frequency. The filament excitation frequency should not, however, be selected at random since beat frequencies would then be produced in the output tube. I have thus described a system for substantially reducing the power required to energize the filaments of high power radio frequency amplifier tubes by reducing the excitation during standby periods or periods of low modulation. In addition, the system increases the life of the tubes and reduces hum and commutator ripple in the system.

I claim as my invention:

1. In a modulated transmitter including a thermionic discharge device having a cathode electrode, the method of operation which includes producing radio frequency currents in said device, modulating said currents, utilizing other radio frequency currents to energize the cathode of said device, and varying the amplitude of said other currents as a function of said modulations to produce a substantial variation in the energization of said cathode corresponding to said modulations.

2. In a modulated transmitter including a discharge device having a cathode and a grid electrode, the method of operation which includes the steps of applying first heating currents to said cathode, superimposing radio frequency heating currents on said cathode, applying a modulating voltage to said grid, and varying the amplitude of said radio frequency heating currents in accordance with said modulating voltage to produce

a substantial change in the heating of said cathode corresponding to said modulating voltage.

3. In a system including a thermionic discharge device having a hot cathode electrode, the method of operation which includes utilizing said device to produce modulated radio frequency signals, generating radio frequency currents bearing a fixed harmonic relation to the carrier frequency of said signals, applying said currents to said cathode to produce a resultant heating thereof, and varying the amplitude of said currents as a function of said modulations to produce a substantial variation in the electron emission from said cathode corresponding to said modulations.

4. In a system including a thermionic discharge device for amplifying modulated radio frequency signals, said device having input and output circuits and a thermionic cathode electrode, the method of operation which includes the steps of applying modulated radio frequency signals to said input circuit, applying first heating currents to said cathode, generating other radio frequency currents bearing a fixed harmonic relation to the carrier frequency of said modulated radio frequency signals, superimposing said radio frequency currents on said cathode to increase substantially the excitation thereof, and varying the amplitude of said radio frequency currents in accordance with the modulations of said signals to produce a resultant variation in the excitation of said cathode.

5. In a system including a thermionic discharge device for amplifying modulated radio frequency signals, said device having a cathode electrode, the method of operation which includes the steps of heating substantially only the outer surface of said cathode to energize said cathode, and varying the intensity of said heating in accordance with the modulations of said signals.

6. In a system including a thermionic discharge device for amplifying modulated radio frequency signals, said device having an input circuit and a thermionic cathode electrode, the method of operation which includes the steps of applying modulated radio frequency signals to said input circuit, applying a first heating current to said cathode to produce only sufficient electrons for normal signal levels, generating a second heating current for said cathode, the frequency of said second heating current being such that substantially all of said current flows along the surface of said cathode, and varying the intensity of said second heating current to increase the electron emission of said cathode during upward modulations of said signals above said normal signal levels.

7. In a transmitter comprising a power amplifier output tube, a modulator tube, means for applying a radio frequency voltage to said output tube, and means for applying a modulating voltage to said modulator tube, said tubes having thermionic cathode electrodes, the method of operation which includes the steps of applying first heating currents of constant average amplitude to energize said cathode electrodes, generating other currents of radio frequency, applying said other radio frequency currents to the cathode electrode of at least one of said tubes to increase the heating thereof, and

controlling the amplitude of said other radio frequency current in accordance with said modulating voltage to thereby substantially increase the heating of said cathode during periods of maximum modulation.

8. A modulated transmitter comprising the combination of an output amplifier tube having a thermionic cathode, means for applying modulated radio frequency currents to said amplifier, means for generating other radio frequency currents, means for applying said other currents to said cathode to produce electron emission, and means for varying the amplitude of said other currents in accordance with said modulations to provide a substantial corresponding variation in the electron emission from said cathode.

9. In a modulated transmitter, the combination of an amplifier tube for radio frequency currents, said tube having a thermionic cathode, means for applying first heating currents to said cathode, efficient radio frequency transfer means for applying auxiliary radio frequency currents to said cathode to increase the excitation of substantially only the outer surface of said cathode, and means for varying the amplitude of said auxiliary currents and said radio frequency currents in accordance with modulating signals.

10. In a modulated transmitter, the combination of an amplifier tube having a thermionic cathode, means for applying signal-modulated radio frequency currents to the input circuits of said tube, first means for energizing said cathode to produce an electron emission just sufficient to produce normal output in the absence of modulation, and means including a source of radio frequency current modulated by the same signal for increasing the cathode excitation during periods of upward modulation to increase the electron emission of said cathode and to produce peak output during said periods.

11. In a modulated transmitter including an amplifier having input and output circuits and an electron-emissive cathode electrode, the method of operation which includes applying modulated radio frequency input currents to said input circuit, deriving modulated radio frequency output currents from said output circuit, and applying other similarly modulated and amplified radio frequency currents to said cathode electrode, the amplitude of said other radio frequency currents being sufficient to produce a substantial variation of the cathode to vary its electron-emission in accordance with the modulations of said radio frequency output current.

12. In a modulated transmitter including a discharge device having a cathode and grid electrode, the method of operation which includes the steps of applying modulated radio frequency currents to said grid electrode, applying first heating currents to said cathode, superimposing radio frequency heating currents on said cathode, varying the amplitude of said radio frequency heating currents in accordance with the modulation envelope of said radio frequency currents, and adjusting the amplitude of said first heating currents to limit the electron emission of said cathode to a value sufficient only to carry output currents of carrier level.

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