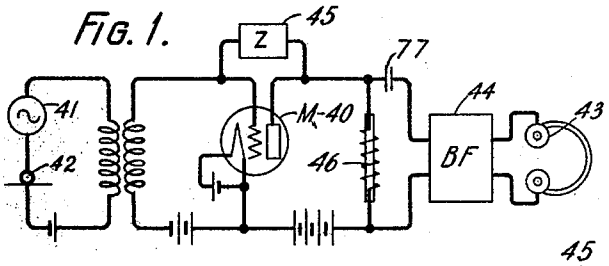
March 10, 1931. J. F. FARRINGTON 1,795,484

WAVE SUPPRESSION CIRCUIT

Original Filed July 31, 1923

FIG. 1.



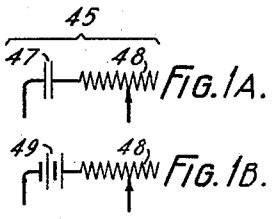


FIG. 1A.

FIG. 1B.

FIG. 2.

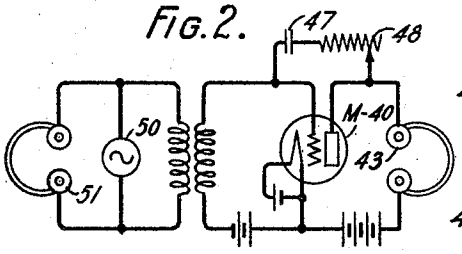


FIG. 3.

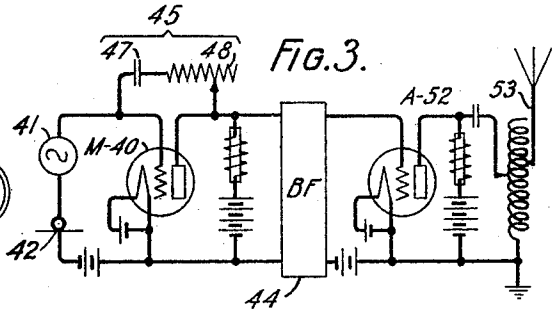
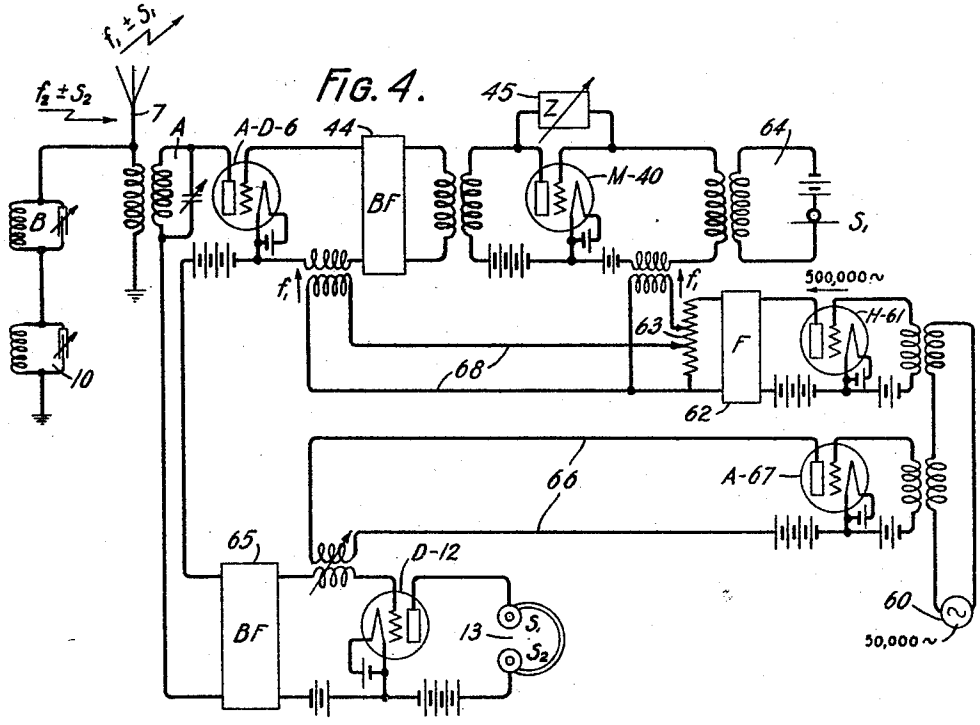


FIG. 4.



INVENTOR
JOHN F. FARRINGTON
BY W. Griggs
ATTORNEY

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UNITED STATES PATENT OFFICE

JOHN F. FARRINGTON, OF FLUSHING, NEW YORK, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

WAVE-SUPPRESSION CIRCUIT

Original application filed July 31, 1923, Serial No. 654,823. Patent No. 1,724,917, dated August 20, 1929. Divided and this application filed June 13, 1927. Serial No. 198,444.

This invention relates to wave suppression circuits, particularly in the form of wave modulating systems employing electric space discharge devices as modulators.

The invention provides a modulating device in which all unmodulated waves of a range of frequencies impressed on the device can be suppressed to any desired degree, without necessitating employment of a plurality of discharge paths in the device.

This application is a division of application Serial No. 654,823, filed July 31, 1923, which eventuated into Patent 1,724,917, granted August 20, 1929.

In the specific embodiments of the invention shown in the drawings by way of example, the modulating device is a three-electrode electric space discharge tube, with a resistance connecting its control electrode or grid to its anode, the resistance having such magnitude as to transmit to the cathode-anode circuit a current adequate to balance out, or neutralize, or counteract to any desired degree, all currents of the impressed wave frequencies which are transmitted through the device. Thus the waves impressed on the modulator input circuit can be excluded from the modulator output circuit, and the waves in the otuput circuit restricted to modulated waves or products of the modulating or distorting action of the device due to the curvature of its input voltage-output current characteristic.

Fig. 1 is a circuit diagram for facilitating explanation of the principle of operation of a single tube carrier suppression modulating system;

Figs. 1A and 1B indicate specific arrangements of impedance elements which may be employed in the circuit, Fig. 1;

Fig. 2 represents an arrangement whereby the completeness of carrier suppression may be estimated and the circuit accurately adjusted to increase the completeness of the carrier suppression;

Fig. 3 shows a simple transmission system employing a single tube carrier suppression modulator; and

Fig. 4 is a circuit diagram illustrating the utilization of a circuit, such as that shown in Fig. 3, in a partial carrier suppression difference frequency duplex telephone system.

In Fig. 1, the input circuit of a modulating tube M—40 is supplied with carrier waves from a source 41 and signaling waves from a source 42. The plate-filament circuit of the tube M—40 is connected to a receiving instrument 43 through a filter 44. An impedance network 45 is connected between the grid and the plate of the tube M—40. The usual batteries and the choke coil 46, together with a stopping condenser 77 are employed in the circuit as indicated. In a circuit such as illustrated in Fig. 1, it is possible to suppress from the output circuit current of the carrier frequency supplied by source 41 and current of the signaling frequency supplied by source 42. The physical principles on which the operation of the present circuit are, in a broad sense, based, are explained in the description of Fig. 1 of U. S. patent to Nichols 1,558,909, October 27, 1925. In the patent it is shown that a three-element electric discharge device may be considered a virtual source, adapted to impress on its output circuit an electromotive force similar to that impressed on its grid but opposite in phase; or, from another point of view, as a means for transmitting an impressed electromotive force wave through a circuit of impedance R_o (the plate-filament impedance) with an amplification μ and a reversal of phase. It is a function of the network, connected between the grid and plate, to transmit to the same points in the output circuit an electromotive force equal and opposite to the electromotive force from the virtual source. In order to transmit through the network 45 an electromotive force which will be equal to that transmitted through the device, the impedance of the network must satisfy the relation

$$Z = \frac{R_o}{\mu}.$$

Since impedance R_o is substantially a pure resistance, the impedance Z must be effectively a pure resistance, as it is in the Nichols system. In this system the network com-

prises a pure resistance and a plurality of reactive elements which are tuned to the frequency at which the balance is to be effected. The present invention constitutes an improved Nichols arrangement to the extent of balancing out all the electromotive force waves impressed on the grid-filament circuit, by providing a network whose impedance is substantially a pure resistance for all of these frequencies. It therefore provides a system in which a single tube can be used to accomplish substantially the same results as could otherwise be accomplished by the use of a push-pull arrangement of two tubes as illustrated, for example, by U. S. patent to Hartley, 1,419,562, June 13, 1922.

The above relation holds only for frequencies applied to the input circuit and not to those frequencies which result from the curvature of the tube characteristic, and which appear in the output circuit. Among the components of the output current are the sum and difference frequencies resulting from intermodulation of the waves impressed on the input circuit and also harmonics of the impressed waves. With the value of impedance 45 corresponding to the above mentioned condition, if the voltage amplitude of waves of carrier frequency f from source 41 impressed on the grid circuit is represented by e_1, and if the source 42 is a source of signaling frequency s which applies to the tube M—40 a voltage of amplitude e_2, the output voltage of frequency $2f$ will be

$$A\mu^2\frac{e_1^2}{2}$$

and of

$$2s,\ A\mu^2\frac{e_2^2}{2}$$

and of the frequencies $f+s$ and $f-s$, $A\mu^2 e_1 e_2$, where A is a constant depending on the tube. In order that the amplitude of the output voltage of frequency $2s$ (or other multiples of the signaling frequency) may be small as compared with the amplitude of the output voltages of frequencies $f+s$ or $f-s$, the value of e_1 should be large as compared to e_2. The double frequency $2f$ will lie outside the range of $f-s$ or $f+s$ and can be suppressed by the filter circuit 44.

Inasmuch as the impedance 45 should satisfy the equation

$$Z=\frac{R_o}{\mu}$$

for the frequencies f and s, it may approximate a pure resistance.

Fig. 1*a* discloses one arrangement in which a large condenser 47 and a variable resistance 48 are connected between the grid and the plate of the tube M—40. The function of the condenser 47 is not related to that of the resistance 48 and is necessary only to insure, when the combination is used in a practical vacuum tube circuit, that the plate-filament potential is not communicated to the grid. If its capacity is of large enough value, this result may be secured without sensibly affecting the value or character of the impedance of the combination as a whole. In Fig. 1*b*, the variable resistance 48 is placed in series with a source of electromotive force 49 so adjusted as to balance the plate-filament battery of the tube M—40. The source 49 has its positive terminal connected to the plate.

The suppressing effect of such an arrangement as illustrated in Fig. 1 may be verified experimentally for audible frequencies by an arrangement such as that of Fig. 2. A source 50 supplies waves of any frequency for which the circuit is to be tested. This current is supplied to the tube input circuit through the transformer as shown and the telephone receiver 43 is connected to the output circuit. The receiver 51 is directly connected to the source 50. By listening at receivers 43 and 51 simultaneously and adjusting the resistance 48, the particular value of the resistance may be found for which the only tone heard in the receiver 43 corresponds to a harmonic or multiple frequency of the tone heard in receiver 51. When speech currents are supplied from source 50, the condition for balance is not so exactly defined as with a single tone because the double frequency of speech in general constitutes intelligible sounds. For speech frequencies, therefore, the actual adjustment is made at that point at which the operator concludes that the sound produced by receiver 43 consists principally of harmonic frequencies.

A simple transmission circuit involving a single tube carrier suppression modulator is shown in Fig. 3. Source 41 supplies waves of carrier frequency and source 42 waves of signaling frequency to the modulating tube M—40. These elements are shown as serially included in the input circuit, which should be taken to indicate diagrammatically any known method of supplying waves of these frequencies to the input circuit by means of inductive, capacitative, or resistance couplings arranged in series or parallel. The network 45 consists of the large condenser 47 and adjustable resistance 48. As mentioned above, the amplitude of the desired modulated components may be made large as compared to the amplitude of the harmonics of the audible signaling frequencies by making the carrier wave voltage large with respect to the signaling wave voltage. This results in a relatively large amplitude harmonic of the carrier wave frequency, which may be suppressed by the low pass or band pass filter 44, which suppresses multiple frequencies of the carrier wave source and may also suppress multiple frequencies of the signal wave source. If desired, the filter 44 may have its cut-off limit at such a point as to sup-

press one side band of the modulated wave. The cut-off may also be such that the filter accomplishes additional suppression of the carrier wave. The currents transferred through the filter 44 are amplified by any suitable amplifying system, such as the amplifier A—52, and radiated from antenna 53 or otherwise transmitted or utilized as may be desired.

Fig. 4 represents a duplex system employing a single tube carrier suppression modulator such as is described in connection with Fig. 1. In this circuit the modulator is adjusted so that the unmodulated component of carrier frequency current is not entirely suppressed for a reason which will be hereinafter stated.

In Fig. 4 the source 60 supplies waves of some convenient base frequency, for example 50,000 cycles per second. A harmonic generator H—61 is connected to the source 60 and produces waves of a suitable multiple frequency, for example, 500,000 cycles per second, which are selected by any suitable selective network 62. A proper voltage of this frequency may be taken off from the potentiometer 63 and applied to the input circuit of the modulator M—40. Signaling waves to be transmitted are supplied from the microphone circuit 64 to the input circuit of the modulator M—40, which is so adjusted as to almost but not quite suppress the unmodulated carrier frequency. The resulting modulated waves are transmitted through a filter 44 to eliminate multiple carrier frequencies, amplified by the amplifier A—D—6 and impressed upon the antenna 7 by means of the coupling coil in the tuned circuit A. The tuned circuit B is tuned to the outgoing carrier frequency and the network 10 serves to tune the antenna for the incoming carrier frequency. If desired, a circuit connection 68 may be employed to impress upon the input circuit of the amplifier A—D—6 an adjustable small component of the outgoing carrier wave frequency. For this purpose the connection 68 is provided with an adjustable tap upon the potentiometer 63. There are thus radiated from the antenna 7 modulated carrier waves of the frequencies $f_1 \pm s_1$, where f_1 represents 500,000 cycles and s_1 the signal to be transmitted. A component of the unmodulated carrier frequency may be included in the radiated energy and may be regulated to any desired amount. Let it be assumed that incoming carrier waves of similar nature having the frequencies of $f_2 \pm s_2$, where f_2 represents 550,000 cycles, are being received. The incoming waves combine in the plate-filament circuit of the amplifier A—D—6 with the similar outgoing carrier waves and owing to the detecting action of the tube, difference frequency waves result. These difference frequency waves comprise in general side bands of frequencies $(f_2 - f_1) \pm s_1$ or $(f_2 - f_1) \pm s_2$ or either of them depending on which station is transmitting at the instant in question or a combination of them if both stations are attempting to transmit simultaneously, these side bands being based upon an intermediate carrier wave of frequency $f_2 - f_1$, which however is not present as such. These waves are selected from other interfering waves by a suitable band pass filter 65. The circuit 66, including an amplifying tube A—67, is loosely coupled to the input circuit of the detector D—12 to supply thereto waves having the frequency $f_2 - f_1$ of the intermediate frequency unmodulated carrier component. These waves are combined with the side band waves transferred through the filter 65 and the action of the detector D—12 similarly as in the usual case is such as to reproduce therefrom the speech currents represented in said side bands, which side bands are based on the combining intermediate carrier frequency. During transmission the outgoing signal will be heard as side tone in receiver 13 and during reception the incoming signal will be heard. A desired amount of the unmodulated outgoing carrier wave having frequency f_1 as determined by the adjustment of the suppressing means 45 and the circuit 68 may be transmitted. It is assumed in the above that the type of receiving circuit at the distant station is such that only a very slight amount of unmodulated carrier wave should be received, as would be the case, for example, if it were desired to prevent an interceptor from reproducing the signal by simple detection. By elaboration of circuit and especially by means of some type of double detection receiving system, the desired receiver may receive such a wave and reproduce the signal from it. The receiving circuit of Fig. 4 is not dependent in any way on the amount of unmodulated carrier wave outgoing or incoming, since a separate local source, namely, circuit 66 is used to supply the intermediate frequency carrier wave for the second stage of detection.

What is claimed is:

1. In a modulating system, a thermionic modulator having an anode, cathode, and grid, an input circuit connected to said grid and cathode, and an output circuit connected to said anode and cathode, a source of waves of carrier and modulating frequency in said input circuit, a circuit comprising substantially only resistance connected between said input and output circuits, said resistance being so electrically dimensioned relatively to the anode-cathode impedance of said modulator as to prevent the flow of unmodulated waves without regard to their number or to their frequencies through said output circuit, and means connected to said output circuit for freely transferring modulated waves and suppressing waves of frequencies which are

multiples of the frequency of the carrier wave source.

2. In a modulating system, an electron discharge device functioning as a madulator and having an anode, a cathode, and a grid, an input circuit connected to said grid and cathode, an output circuit connected to said cathode and anode, a source of carrier waves of relatively large amplitude and a source of modulating waves of relatively small amplitude connected to said input circuit, and an impedance element comprising only one type of impedance connected between said input and output circuits and adapted to prevent the flow of unmodulated waves through said output circuit.

3. In a modulating system, an electronic modulator having an anode, a cathode and a grid, an input circuit connected to said grid and cathode, an output circuit connected to said anode and cathode, a source of waves of carrier frequency of relatively large amplitude and a source of waves of modulating frequency of relatively small amplitude connected to said input circuit, and an impedance network connected between said grid and anode having an impedance for waves of all frequencies including the modulating and carrier frequencies equal to the internal impedance of the electronic modulator divided by the amplification constant of the modulator.

4. In combination, a network and two circuits connected thereto, a space discharge device included in said network having anode, cathode, and discharge control elements, and a resistance element included in said network, so associated with said elements and of such constant value over a substantial frequency range as alone to prevent said network from transmitting waves of any frequency in said range from one of said circuits to the other.

5. A system comprising two circuits and a network connecting said circuits, a space discharge device included in said network, having anode, cathode, and discharge control elements, and a current path included in said network, connecting said anode and control elements and having an impedance element comprising only one type of impedance of such value for all frequencies of a substantial frequency range as to prevent said network from transmitting waves of any frequency in said range from one of said circuits to the other with greater transmission efficiency than any desired predetermined efficiency.

6. Means responsive to electric waves covering a band of frequencies for generating electric waves covering another frequency band, an output circuit for said means, means for supplying the first mentioned waves to said first mentioned means, and a circuit comprising substantially only resistance connected between said supply means and said output circuit and so electrically dimensioned relatively to the impedance of said output circuit as to prevent any of the first mentioned waves from appearing across said output circuit.

7. Means responsive to waves of different frequencies including a band of frequencies for generating waves of other frequencies, an output circuit connected to said means for utilizing certain of the latter waves, means to supply the first mentioned waves to said first mentioned means, and a circuit comprising substantially only resistance connected between said supply means and said output circuit and so electrically dimensioned relatively to the impedance of said output circuit as to prevent waves of any of the first mentioned frequencies from flowing in said output circuit.

In witness whereof, I hereunto subscribe my name this 8th day of June, A. D. 1927.

JOHN F. FARRINGTON.