Jan. 8, 1946.

E. S. PURINGTON

2,392,693

FREQUENCY DISCRIMINATOR

Filed May 27, 1942

4 Sheets-Sheet 1

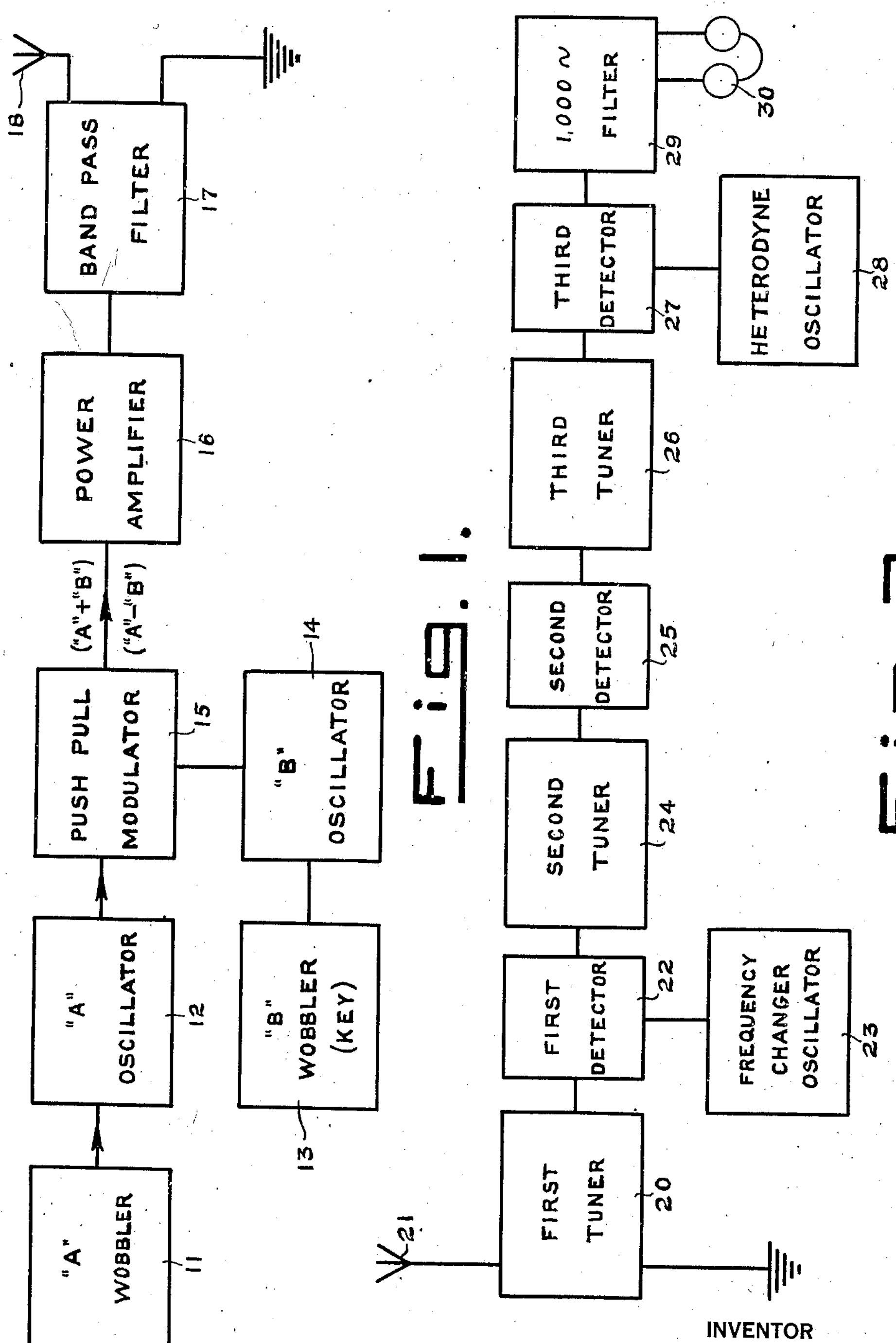

Fig. 1.

Fig. 2.

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4 Sheets-Sheet 2

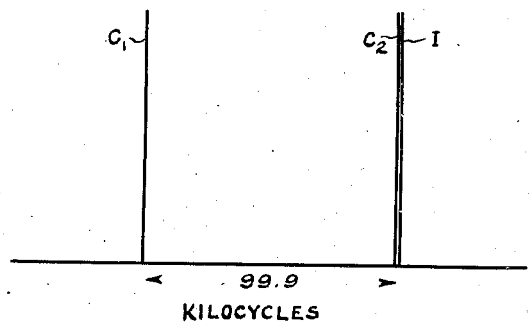

Fig. 3.

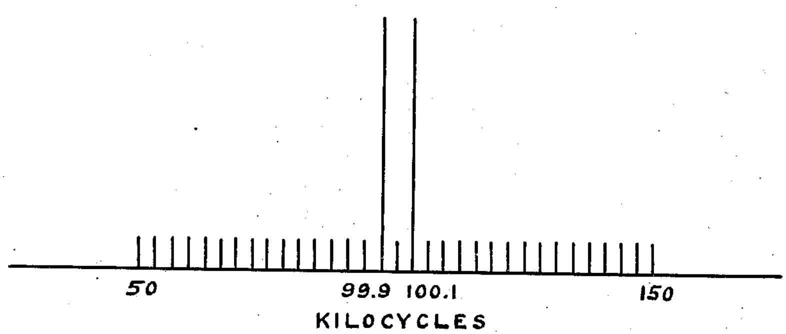

Fig. 4.

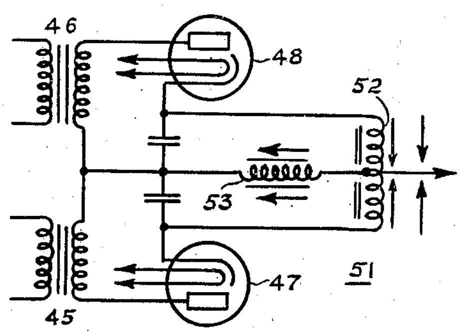

Fig. 6.

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FREQUENCY DISCRIMINATOR

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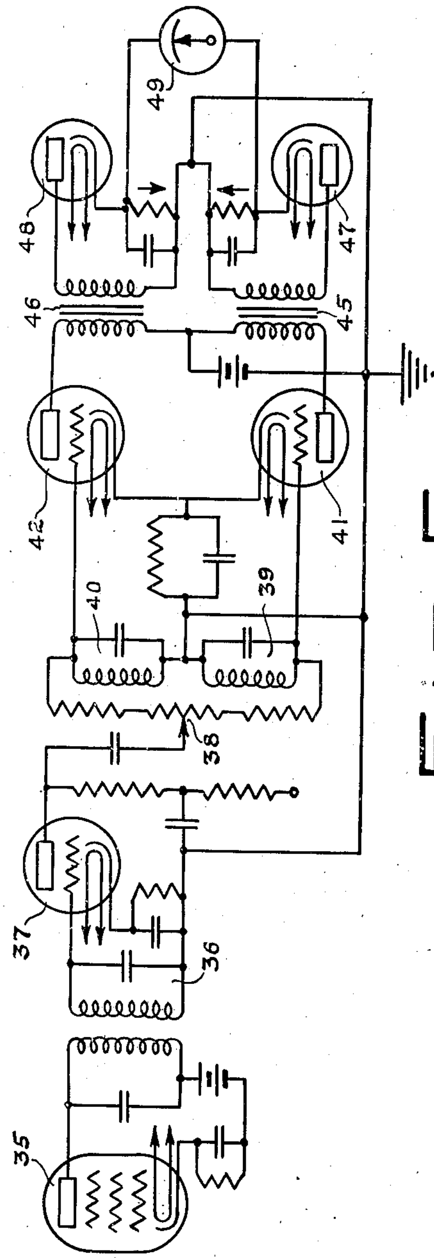

Fig. 5.

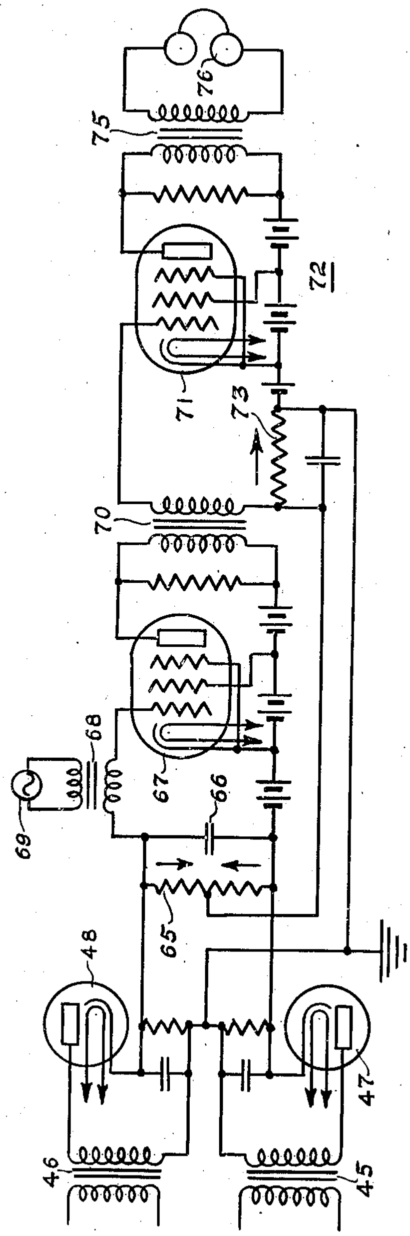

Fig. 8.

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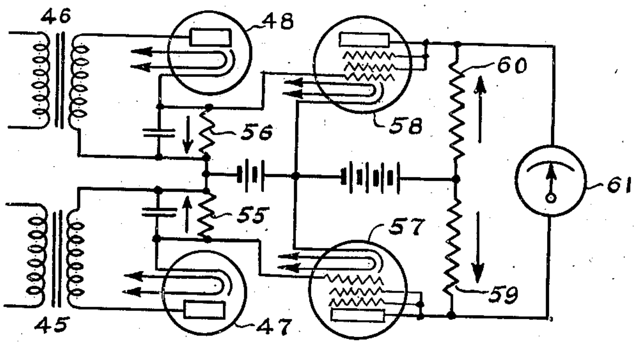


Fig. 7.

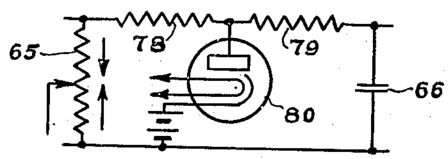


Fig. 9.

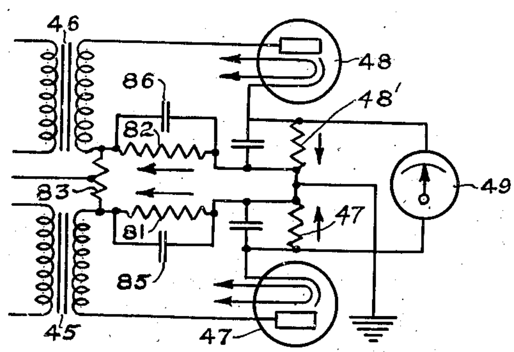
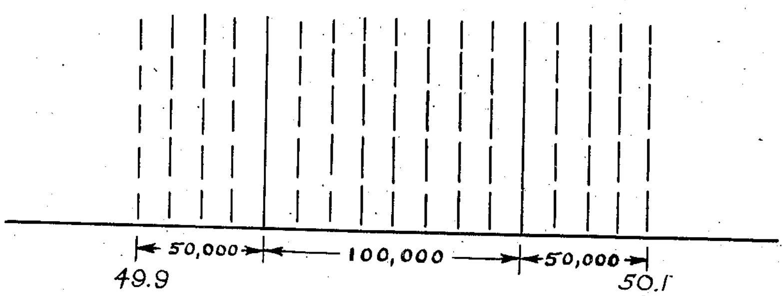


Fig. 10.



MEGACYCLES

Fig. 11.

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Patented Jan. 8, 1946 2,392,693

UNITED STATES PATENT OFFICE

2,392,693

FREQUENCY DISCRIMINATOR

Ellison S. Purington, Gloucester, Mass., assignor, by mesne assignments, to Radio Corporation of America, New York, N. Y., a corporation of Delaware

Application May 27, 1942, Serial No. 444,630

4 Claims. (Cl. 250—8)

This invention relates to radio receiving systems, and more particularly to a system for reducing interference in radio reception.

The invention further relates to receivers for receiving signals of the type produced by the transmitter of the special system of radio telegraphic communication disclosed in U. S. Patent No. 1,690,719 granted to E. L. Chaffee and E. S. Purington on November 6, 1928. The essential features of that transmission system are:

1. Creation of two or more continuous wave equivalents, usually by a direct or push-pull modulation process, involving an A oscillator, and a lower but superaudible frequency oscillator; the difference between the frequencies of the continuous waves being designated the B frequency.

2. Artificially frequency modulating the A oscillator, and consequently "wobbling" all of the continuous wave equivalents, the frequencies of which depend upon the A oscillator.

3. Changing the difference or B frequency for purposes of signalling.

When the high frequency energy is properly received and detected it will produce received currents of the B frequency which can be sharply tuned to, the degree of sharpness possible being determined by the key speed of the signal being sent. The B frequency energy then operates a current detector, such as a heterodyne system, to make the conveyed signals intelligible.

The second process of artificial wobble, or frequency modulation, primarily provides for a high degree of selectivity and reduction of fading. This frequency modulation is entirely artificial and has nothing to do with the signal frequency. Its purpose is to spread the radiated energy over a wide band so that stray disturbances are reduced and intentional interferences from continuous wave transmitters, spark and other I. C. W. transmitters can produce interference for only a part of the time. In this way a diversified transmission is produced and since the rate of frequency modulation is chosen low, but with several excursions of modulation for a single dot or dash, any selective fading effects are averaged out very effectively. By the use of a suitable wobbler pattern and other features the system becomes private against reception by the usual types of receivers.

The third process of changing the spacing between the continuous wave equivalents without causing them to appear and disappear is primarily for maintenance of privacy. This is, also, a frequency modulation process at the signal rate usually applied to the B oscillator, and it is, therefore, possible to apply the well known principles of frequency modulation signalling in the receivers for such transmission systems. The present invention shows the details of one specific application, namely, the "back to back" detector disclosed in U. S. Patent No. 1,776,065 granted to E. L. Chaffee on September 16, 1930.

The present invention, also, consists in certain new and original features of construction and combinations of parts hereinafter set forth and claimed. Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, the mode of its operation and the manner of its organization, may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which:

Figure 1 shows a schematic diagram of a transmitter used in connection with this invention,

Figure 2 illustrates schematically a receiver constructed in accordance with this invention,

Figure 3 illustrates the continuous wave radiations as received by the receiver shown in Figure 2,

Figure 4 illustrates the output of the second detector of the receiver shown in Figure 2,

Figure 5 depicts an audio frequency discriminator used following the third detector of the receiving system of Figure 2,

Figure 6 shows a modified form of part of the circuit illustrated in Figure 5,

Figure 7 shows a modification of the circuit of Figure 6,

Figure 8 illustrates an expander type compensator used as a modified form of part of the circuit shown in Figure 5,

Figure 9 illustrates the use of a limiter on the direct current output of the compensator of Fig. 8,

Figure 10 shows a method of securing automatic volume control in accordance with total energy, as applied to the circuit of Fig. 5,

Figure 11 illustrates the transmitted spectrum of the transmitter illustrated in Figure 1.

Like reference characters denote similar circuit elements parts in the several figures of the drawings. In the following description and in the claims parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring to the accompanying drawings, and more particularly to Figure 1, a transmitter is shown which may be used to produce the desired radiations. This transmitter may be constructed in accordance with the teachings of the aforesaid U. S. Patent No. 1,690,719. The transmitter is schematically shown as comprising an A wobbler 11, an A oscillator 12, a B wobbler 13, a B oscillator 14, a push-pull modulator 15, a power amplifier 16 and a band pass filter 17 which is provided with an antenna 18.

The A wobbler 11 varies the frequency of the oscillations generated by the A oscillator 12, which may nominally be 50 megacycles, from 49.95 to 50.05 megacycles. The variation is preferably a "saw tooth" frequency modulation pattern to distribute the energy fairly uniformly throughout the band. The B oscillator 14, which may nominally generate oscillations of 50 kilocycles, is provided with a modulating signal by a key arrangement, or B wobbler 13, for changing the oscillator frequency between the values 49.95 and 50.05 kilocycles. The B oscillator is thus frequency modulated between these limits with a "square wave" signalling pattern.

It may, also, be said that the B oscillator generates two amplitude modulated waves, one of 49.95 kilocycles, dot and dash amplitude modulated, and the other of 50.05 kilocycles, also dot and dash amplitude modulated, with the modulation 180 degrees out of phase. In either case similar currents will occur in the receiver and the principles of frequency modulation signal reception may be applied to supplement the principles of wideband artificial frequency modulation in producing high grade selectivity.

The A and B oscillators 12 and 14 jointly feed the outputs thereof into the push pull modulator 15 so that two continuous wave equivalents are produced of frequencies equal to the sum and the difference of the instantaneous values of the A and B oscillator frequencies. This energy may then be passed through a power amplifier 16 and a following suitable radio frequency band pass filter 17 to create the transmission spectrum indicated in Figure 11; the resultant energy is radiated from the antenna 18.

This radiation is seen, from Fig. 11, to cover a total band width of 200,000 cycles centered at 50 megacycles, the energy being substantially uniformly distributed throughout the band. Half of the total band width is due to the difference of the two continuous wave equivalent frequencies, namely twice the instantaneous frequency of the B oscillator. The remainder of the total band width is due to the artificial variation of the frequency of the A oscillator. If the transmitted spectrum is directly, or after frequency conversion, impressed upon an amplitude modulation detector, currents corresponding to twice the frequency modulated B oscillator will be produced by the heterodyning action of one of the continuous wave equivalents upon the other.

A receiver for receiving transmitted energy of this type is shown diagrammatically in Figure 2, and the receiver is constructed in accordance with the teachings of U. S. Patents Nos. 1,522,882 and 1,681,293 granted to John Hays Hammond, Jr. on January 13, 1925 and August 21, 1928 respectively. Such a receiver may comprise a first tuner 20 connected to an antenna 21, a first detector 22 which is connected to a frequency changer oscillator 23; a second tuner 24; a second detector 25; a third tuner 26; third detector 27, the latter being connected to a heterodyne oscillator 28. The output of detector 27 is fed to a 1000 cycle filter 29, the output circuit of which is connected to a reproducer, such as a pair of head phones 30.

In this receiver system the first tuner 20, first detector 22, frequency changer oscillator 23, second tuner 24 and second detector 25 function to produce a current of a frequency equal to the instantaneous difference of the two continuous wave equivalents, namely 99.9 or 100.1 kilocycles. Such currents are sharply tuned by the third tuner 26 to discriminate against all differences between disturbing continuous wave equivalents which are outside this range. The heterodyne oscillator 28 and third detector 27 constitute a current detector for producing audio tones, such as for example, 800 cycles at one end of the key modulation of the B oscillator with the key up and 1000 cycles at the other end with the key down. For further reducing the amount of interference that other transmitters can produce a special type of circuit utilizing both the 800 and 1000 cycle currents is provided. A brief analysis of the nature of such disturbances is given below.

Suppose, for example, that in the transmitter depicted in Figure 1 the A wobbler 11 was inoperative and that the A oscillator is exactly 50 megacycles, then with the key down the continuous wave radiations would be 49,950,050 and 50,049,950 cycles, as indicated at C_1 and C_2 respectively in Figure 3, thereby producing a detected output of 99.9 kilocycles. With the key up slightly different radiations would be produced yielding 100.1 kilocycle detected output. If these radiations were observed, and a standard continuous wave transmitter caused to radiate, an interfering frequency of 50,049,950 cycles would be produced as indicated at I exactly matching one of the transmitted radiations with the key down.

Under these conditions the third tuner 26 and third detector 27 would be actuated not only by the conjoint action of C_1 and C_2, but, also, by the conjoint action of C_1 and I, so that communication would be disrupted if, for example, I is about 6 decibels below C_2 in strength. If, however, the A wobbler 11 is operative so that C_1 and C_2 are varied by about 50,000 cycles from mean, then the beat note between C_1 and C_2 remains 99.9 kilocycles as before, independent of the state of wobble, while the beat note due to C_1 and I is frequency modulated between the approximate limits of 50,000 and 150,000 cycles. Under these conditions the third tuner 26 with a band width of the order of 400 cycles is efficiently actuated by the desired signal, but very ineffectually interfered with by the frequency modulated signal resulting from the heterodyning of C_1 and I.

The output of the second detector 25 is illustrated in Figure 4 and shows the signal energy either C_1 (99.9 kilocycles with the key down) or C_2 (100.1 kilocycles with the key up) and the interference I covering the wide band frequency modulated energy range from 50 to 150 kilocycles. If, for example, C_2 and I are equal and the desired signal in the output of the second detector 25 is 1 microwatt, then the interfering signal is 1/100 of a microwatt per kilocycle of band width. Hence, with a band width of 400 cycles, sufficiently broad for the desired signal, the interference is only 0.4 of one percent as strong in the third tuner 26 as it would be if the A wobbler were inoperative. Since the signal is independent of the wobble, the action of the wobbler reduces the interference with respect to the signal by about 24 decibels.

Further reduction of interference may be accomplished by taking advantage of the fact that the third tuner 26 is energized with constant amplitude signals regardless of whether the key is up or down, and could be provided with a limiter device for improving the ratio of signal to interference, or it could be provided with back to back detection. The present invention covers the case with the energy converted down to a lower frequency, for example to the audio band, by use of a suitable heterodyne detector, making the audio signal either 800 or 1000 cycles depending upon the position of the key.

A typical audio frequency discriminator is depicted in Figure 5. In this figure the heterodyne detector tube of the third detector **27** of Figure 2 is indicated at **35**. The plate circuit of the tube **35** feeds, through a coupled circuit network **36** designed for maximum transmission at 800 and at 1000 cycles, an amplifier tube **37**. The plate circuit of the tube **37** is connected by a potentiometer **38** to two filter circuits **39** and **40**. The latter are tuned to 800 and 1000 cycles respectively, and are each connected to the respective input electrodes of two tubes **41** and **42**. The output circuits of the tubes **41** and **42** are coupled by two transformers **45** and **46** to two rectifiers **47** and **48**. A center point galvanometer **49** may be connected between the cathodes of the rectifier tubes **47** and **48**. The galvanometer **49** may be replaced by a relay or other device to control a sound type indicator, such as the head phones **30** of Figure 2.

The output of the heterodyne detector **35**, carrying the 800 and 1000 cycle currents and the disturbance, feeds through the coupled circuit **36** and is amplified by the tube **37**. The output energy from the tube **37** passes through the potentiometer **38**, and is split up by the two filter circuits **39** and **40** so that the input grid of the tube **41** will be energized at a maximum with 800 cycle energy and the grid of the tube **42** will be energized at a maximum with 1000 cycle energy. The tube **41** will, therefore, be most strongly energized with the key up, and the tube **42** will be most strongly energized with the key down.

The circuit may be so adjusted by the potentiometer **38** that the band width of transmission from the plate of the tube **35** to the tube **41** is the same as to the tube **42**, so that equal signals of 800 and 1000 cycles are produced. Figure 4 indicates that during a period of several cycles of wobble of the A oscillator substantially as much interference or stray energy will be impressed upon the grid of the tube **41** as upon the grid of the tube **42**, regardless of the position of the key. The 800 cycle circuit **39** will be energized to a greater extent with the key up, and the 1000 cycle circuit **40** will be energized to a greater extent with the key down.

Which circuit is energized to the greater extent and, therefore, whether the key is up or down, may be determined by the use of the rectifiers **47** and **48**. In this system the amplified energy from the tube **41** drives the rectifier **47** through the transformer **45**, and the amplified energy from the tube **42** drives the rectifier **48** through the transformer **46**. A comparison of the rectified outputs may be made by the center point galvanometer **49**, which is connected between the cathodes of the rectifiers **47** and **48**. The load resistors of the rectifiers are shown arranged in series between the cathodes of the rectifiers; the junction of the series resistor is grounded. The galvanometer **49** may, if desired, be replaced by a relay to control a sound type indicator. By balancing the system carefully so that the rectifiers **47** and **48** produce similar effects considerable improvement in selectivity over a tuned circuit can be obtained.

The sensitivity of the indication, however, is not independent of the presence or absence of the interference, as it decreases with the increase of interference. This is apparent from the following analysis in which E_r represents the random energy, which, although not of the same wave form, is equally impressed upon the two rectifiers **47** and **48** when averaged over one or two cycles of the A wobble. E_u is the energy operating the rectifier **47** when the key is up, and E_d is the energy operating the rectifier **48** when the key is down. The signal energy $E_s=E_d-E_u$.

With the key up or down the numerical magnitude of the difference of the potentials V of the cathodes of the rectifiers **47** and **48** is:

$$V=K\left\{\sqrt{E_s+E_r}-\sqrt{E_r}\right\}=K\sqrt{E_s}\left\{\sqrt{1+\frac{E_r}{E_s}}-\sqrt{\frac{E_r}{E_s}}\right\} \quad (1)$$

in which K is a constant of the system.

If

$$X=\frac{E_r}{E_s}$$

is the ratio of the stray energy to the signal energy, then the relative sensitivity R given by:

$$R=\frac{V}{K}\sqrt{E_s}=[\sqrt{1+X}-\sqrt{X}] \quad (2)$$

The following table indicates the change of relative sensitivity as the ratio of interference to signal is increased:

$X=\frac{E_r}{E_s}$	0	1	3	5	10
R	1	.41	.27	.21	.15

When the interference in the 1000 cycle circuit reaches about 20 percent of the signal on an energy basis the circuit of Figure 2 becomes unsatisfactory. One method of compensating for loss of sensitivity for the desired signal as the ratio of interference to signal increases is shown in Figure 6. This method determines the effect in accordance with the sum of the rectified currents as well as their difference.

In Figure 6 the secondaries of the transformers **45** and **46** are connected to the opposed rectifiers **47** and **48** in a manner similar to that shown in Figure 5. The output circuits of the rectifiers **47** and **48** are connected to a dynamometer type relay **51** which is provided with a rotor coil **52** and a stator coil **53**.

The rectified currents from the output circuits of the rectifiers **47** and **48** in Fig. 6 will pass through the rotor winding **52** in opposite directions, and through the stator winding **53** in the same direction, as indicated by the arrows adjacent the respective windings. Thus, the current flowing through the rotor winding **52** is proportional to the difference of the two rectified currents, and the current through the stator winding **53** is proportional to the sum of the two rectified currents. The torque of the dynamometer **51** is proportional to the product of the magnetizing effects of the currents in the rotor winding **52** and the stator winding **53**.

The magnetizing effect for the rotor winding **52** will be:

$$M_r=K_2\sqrt{E_s}[\sqrt{1+X}-\sqrt{X}] \quad (3)$$

and for the stator winding **53**:

$$M_s=K_1\sqrt{E_s}[\sqrt{1+X}+\sqrt{X}] \quad (4)$$

The torque T, which is proportional to the product of the magnetizing effects, is:

$$T=CM_rM_s=CK_1K_2E_s \quad (5)$$

and is, therefore, independent of the interference, as the increased magnetization due to one winding compensates for the diminished magnetization due to the other winding.

In Figure 7 is shown another method of compensation by the use of direct current amplifying circuits using tubes with a special grid structure for which the plate current is a suitably increasing function of the grid voltage. Tubes of the 6K7 type, with screen and suppressor connected to the plate, have approximately the proper characteristics. In Figure 7 the secondaries of the transformers 45 and 46 are connected to the respective rectifiers 47 and 48. The output circuits of the latter include series-related resistors 55 and 56, which in turn are connected to the input grids of two direct current amplifying tubes 57 and 58. The latter may be of the special grid structure type previously referred to. The input grid of tube 58 is connected to the cathode end of load resistor 56, while the grid of tube 57 is connected to the cathode end of resistor 55. The junction of resistors 56 and 55 is connected to the negative terminal of the grid bias source of tubes 58—57. The output circuits of the tubes 57 and 58 are connected to a resistance network 59—60. The latter is bridged by an indicating device 61, such as a center point galvanometer.

The rectified output current of the rectifier tubes 47 and 48, in Fig. 7, flows through the resistors 55 and 56 causing a potential difference to be built up across these resistors which is proportional to the current passing through them. This potential is impressed upon the grids of the tubes 57 and 58, and controls the plate current as an increasing function of the grid voltage. The plate current of the tubes 57 and 58 passes through the resistance network 59—60 in the direction of the arrows towards the respective plates of the tubes, and causes a potential difference to be built up across these resistors proportional to the current flowing them. The galvanometer 61 indicates the potential difference across the resistance network 59—60, and, therefore, the relative strength of the signals in the 800 and 1000 cycles channels, thus indicating whether the key is up or down. In this system the interference raises the average of the grid voltages of the two tubes 57 and 58 so that smaller difference of the rectified current due to the interference produces substantially a fixed amount of change of plate current in the resistors 59 and 60. This does not affect the indication of the galvanometer 61.

Figure 8 shows an expander type compensator used in connection with the circuits shown in Figure 5. In this system the secondaries of the transformers 45 and 46 are connected to the rectifiers 47 and 48. Between the cathodes of the rectifiers is bridged a resistor 65 shunted by a condenser 66. The resistor 65 is in shunt across the opposed diode resistors. The input electrodes of a tube 67 are connected across the resistor 65. The grid circuit of tube 67 includes the secondary of a transformer 68, the primary of which is connected to a tone source 69. The latter may be an alternator generating audio frequency current.

The output electrodes of the tube 67 are connected through a transformer 70 to the input circuit of tube 71 which forms a part of an expander type amplifier 72. Connected in the grid return path of the tube 67 is a resistor 73, one end of which is connected to the midpoint of the resistor 65, and the other end is grounded. The resistor 73 is, also, included in the grid circuit of tube 71. The output circuit of the tube 71 is connected through a transformer 75 to a pair of headphones 76.

In the operation of the system shown in Figure 8, the rectified currents from the rectifiers 47 and 48 flow through the resistor 65 in the direction of the arrows towards the grounded midpoint of resistor 65. The difference of the currents in the resistor 65 is impressed upon the grid of the tube 67, and controls the transmission of the tone energy from the tone source 69. The sum of the two currents through resistor 65 flows through the resistor 73 in the direction of the arrow towards the cathode of tube 71 thereby causing a potential difference to be built up across this resistor which is proportional to the current therethrough. This potential controls the gain of the amplifier 72, which is, therefore, controlled by the sum of two rectified currents from the rectifiers 47 and 48.

Thus, when the key is up and there is more energy passing through the transformer 45 from the 800 cycle circuit than there is through the transformer 46 from the 1000 cycle circuit, more current will pass through the lower half of the resistor 65 than through the upper half. This will cause a decrease in the gain of the amplifier 67 so that very little of the tonal current from the tone source 69 will be transmitted to the head phones 76. On the other hand when the key is down more current will pass through the upper half of the resistor 65 thus increasing the gain of the amplifier 67, which will increase the transmission of the tonal current to the headphones 76 thereby giving an audible signal.

The change of rectified currents is modified by the presence of interference in both channels when the signal changes from the 800 to the 1000 cycle channel. The production of tone by the keying tube 67 diminishes as the interference increases, but the amplification by the expander tube 71 increases thereby maintaining a substantially constant tonal output independent of the interference.

In Figure 9 is shown a limiting device which may be inserted in the grid circuit of the tube 67 shown in Figure 8. In this modified form of the invention two resistors 78 and 79 are connected in the grid circuit of the tube 67, and a rectifier tube 80 is connected to the junction of these two resistors. In the operation of the circuit shown in Figure 9, the tube 80 acts to limit the potential applied to the grid of the tube 67 to a definite predetermined value. Hence, when no interference is present, and a high potential is produced across the resistor 65, the potential on the grid of the tube 67 will be held to a definite limit. As the interference increases the potential across the resistor 65 will decrease. As long as it remains higher than the predetermined value the potential on the grid of the tube 67 will remain unchanged, thus making the output of the keying tube 67 more independent of the interference value.

As it is not practicable to use automatic volume control upon previous circuits from the final tonal output of the system, any automatic volume control action should preferably be determined by the total energy, as, for example, by the rectifier of the 800 and 1000 cycle tones as shown in Figure 10. The rectifier circuits depicted in this figure are similar to those shown in Figure 5, with the exception of the addition of the resistor network comprising three resistors 81, 82 and 83. The resistors 81 and 82 are shunted respectively by condensers 85 and 86. The resistors 48′ and 47′ are connected in series between the diode cathodes, each resistor being properly bypassed. The junction of the two resistors 48′ and 47′ is grounded. The resistors 82 and 81 are respectively in series with resistors 48′ and 47′ in the respective space current paths of diodes 48 and 47. The resistor 83 is common to both resistors 82 and 81, and is connected between the anode ends thereof.

In the operation of the automatic volume control arrangement shown in Figure 10, the rectified currents from the respective cathodes of rectifiers 47 and 48 flow to respective anodes through the resistors 81 and 82 in the direction of the arrows thereby causing negative potentials to be built up at the resistor 83 which are proportional to the rectified currents. The negative potential of the midpoint of the resistor 83 is used as the automatic volume control bias in a manner well known in the art which need not be more fully described herein. It is sufficient to point out that such bias is applied over the lead from the midpoint of resistor 83 to prior amplifiers of the system.

While the invention herein is illustratively practiced with respect to improvement in the previous mentioned patents, it is not intended to be in any way limited to any particular transmission system. For example, it may well be applied to continuous wave transmission systems with the wave not keyed off and on, but with the wave shifted between two somewhat different values, or to any frequency modulation system falling within the scope of the appended claims.

Although only a few of the various forms in which this invention may be embodied have been shown herein, it is to be understood that the invention is not limited to any specific construction but might be embodied in various forms without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. A frequency modulation transmission channel provided with an indicator, a receiver including frequency modulation detecting means comprising a pair of rectifiers and a differential output, and means interposed between the rectifiers and indicator to make the indication substantially independent of interfering disturbances upon both rectifiers, said means including a first device controlled in accordance with the difference of the outputs of the rectifiers, means to vary the operation of the first device at a periodic rate, and a second device responsive to the first device and controlled in accordance with the sum of outputs of the rectifiers.

2. A frequency modulation transmission channel provided with an indicator, a receiver including frequency modulation detecting means comprising a pair of rectifiers and a differential output, and means interposed between the rectifiers and indicator to make the indication substantially independent of interfering disturbances upon both rectifiers, said means including a first device controlled in accordance with the difference of the outputs of the rectifiers, and a second device controlled in accordance with the sum of outputs of the rectifiers, said first device being a keying circuit, and the second device being a variable gain amplifier for the output of the keying circuit.

3. In a signalling system wherein there is transmitted to a receiver waves composed of the sum and difference frequencies of a high frequency wave and a lower frequency wave whose frequency has been varied to either side of the lower frequency, means receiving the transmitted frequencies and deriving therefrom signals corresponding to said signalling variations, a frequency-variation responsive device having an input network to which said derived signals are applied, and means actuated by the responsive device for indicating solely said derived signals.

4. In a signalling system wherein there is transmitted to a receiver waves composed of the sum and difference frequencies of a high frequency wave subjected to a saw tooth frequency sweep and a lower frequency wave whose frequency has been varied at an audio rate to either side of the lower frequency, means receiving the transmitted frequencies and deriving therefrom audio signals corresponding to said signalling variations, a frequency-variation responsive device having an input network to which said derived signals are applied, and means actuated by the responsive device for indicating solely said derived signals.

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