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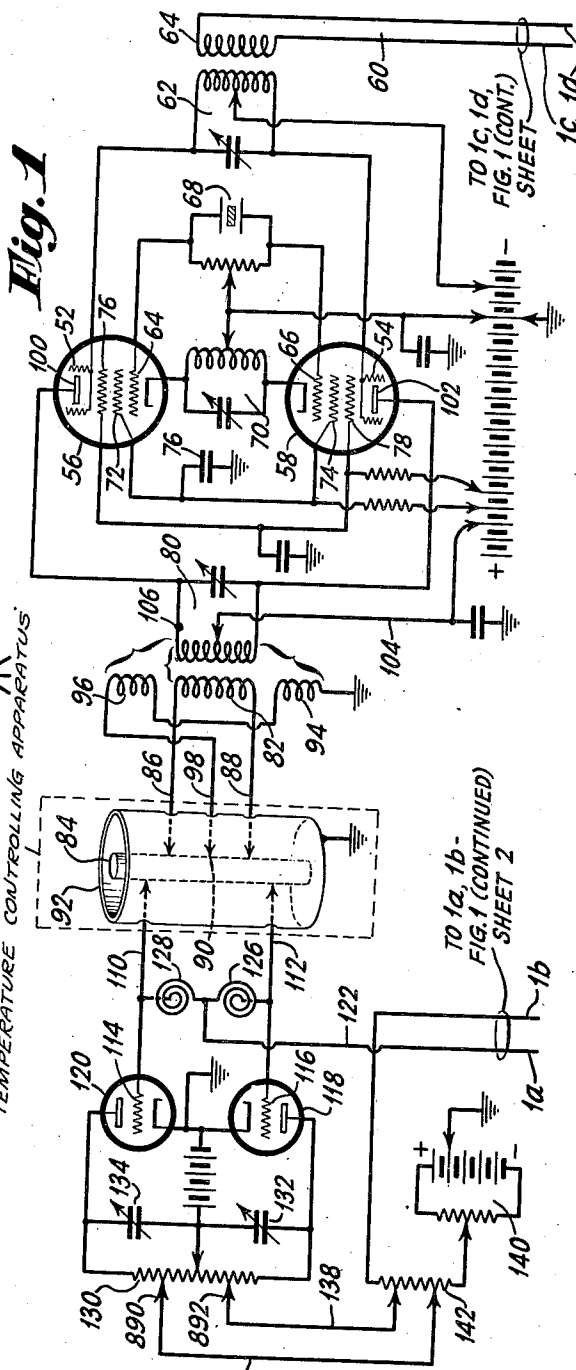
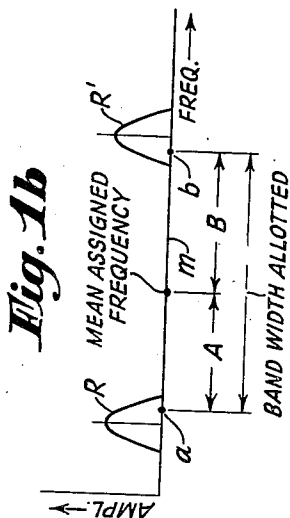
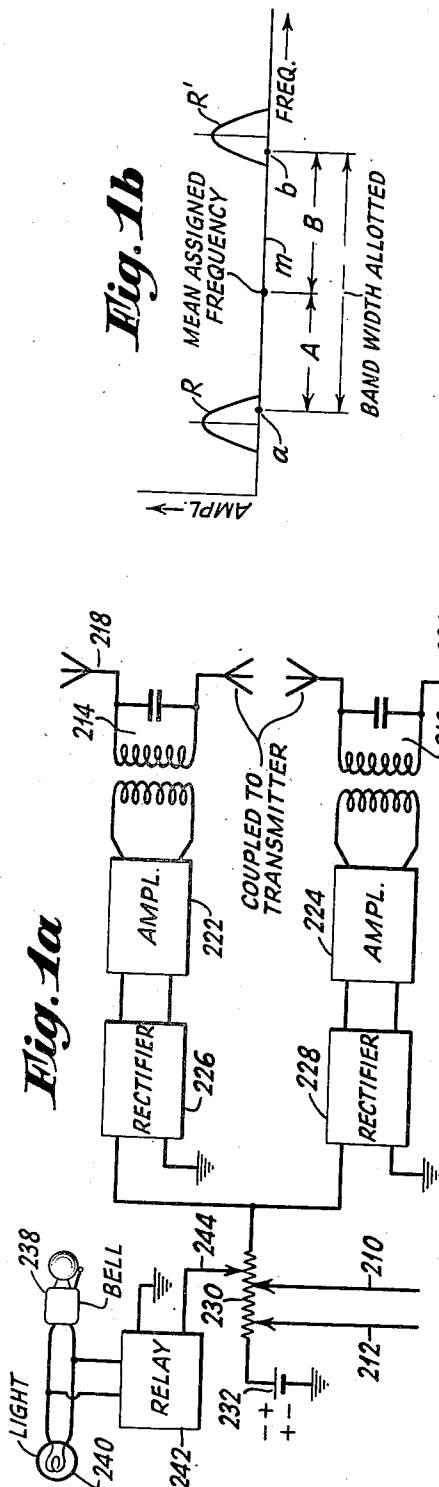
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2,296,962

FREQUENCY MODULATION

Filed Dec. 22, 1939

6 Sheets-Sheet 1



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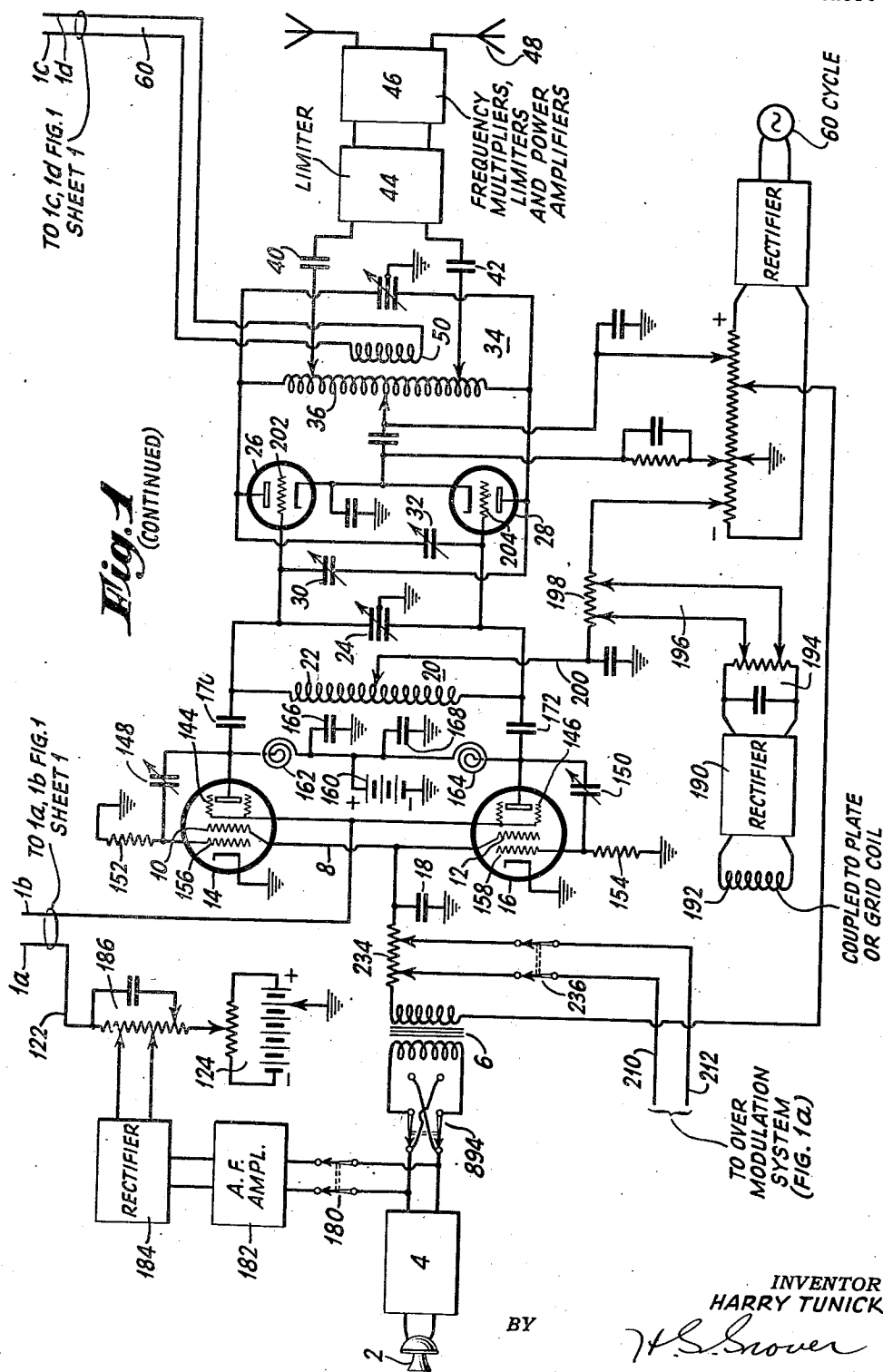
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FREQUENCY MODULATION

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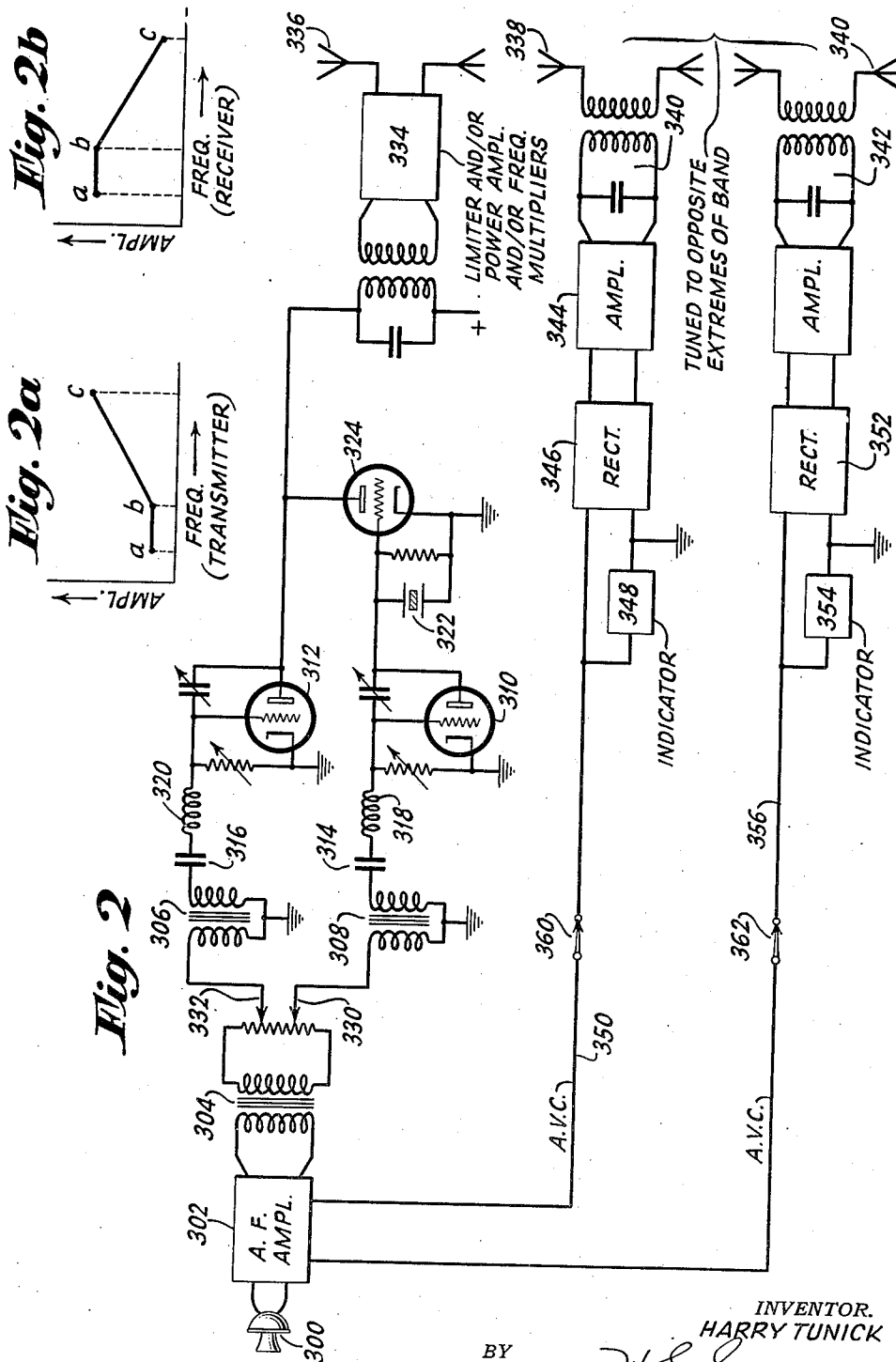
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FREQUENCY MODULATION

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6 Sheets-Sheet 3



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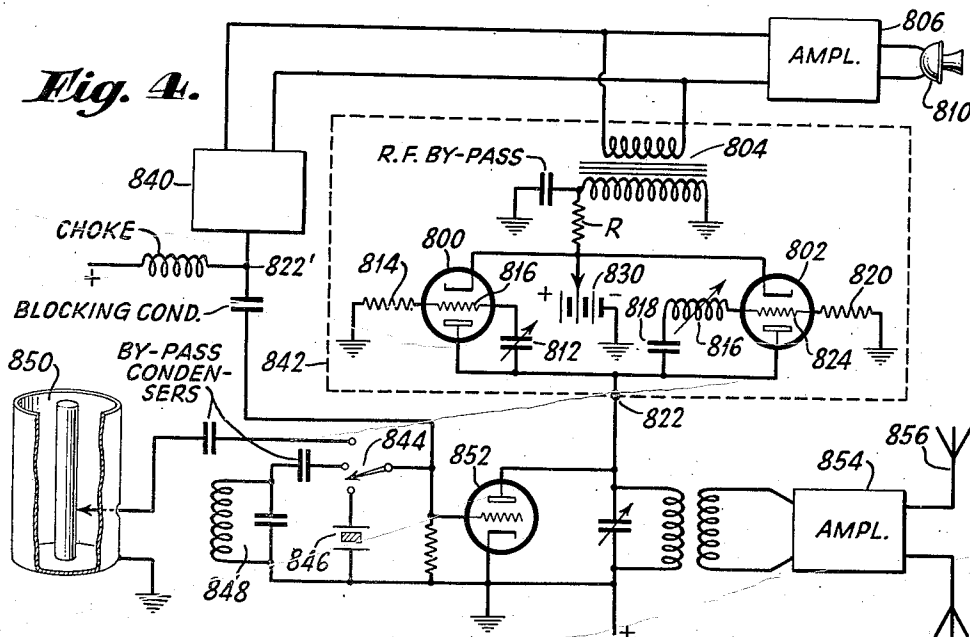
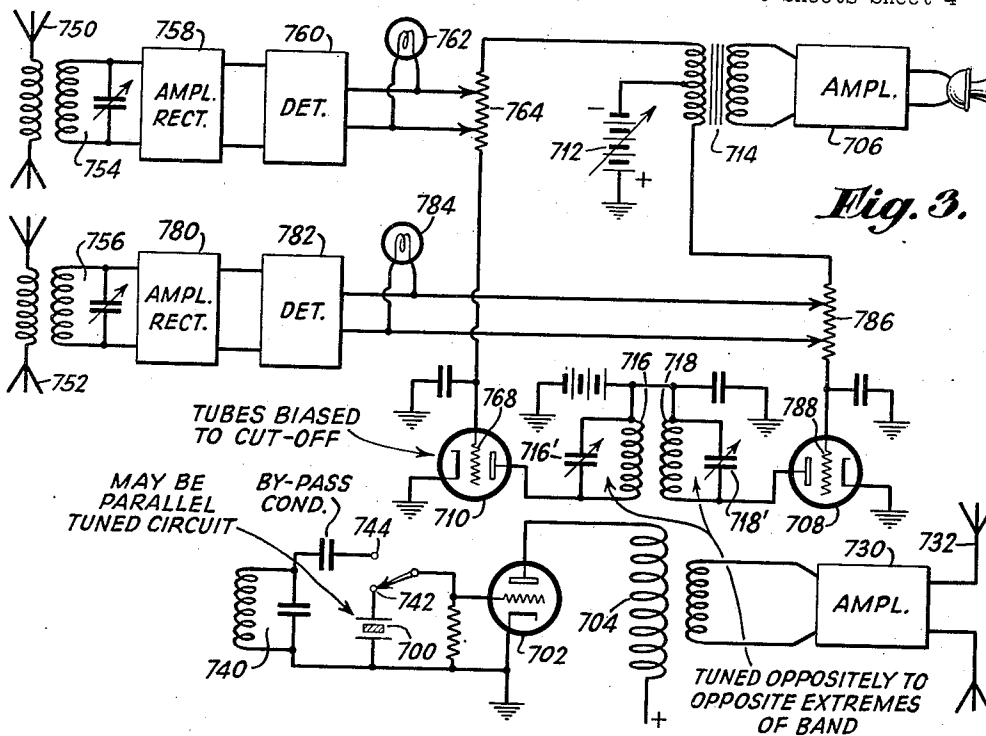
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FREQUENCY MODULATION

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Sept. 29, 1942.

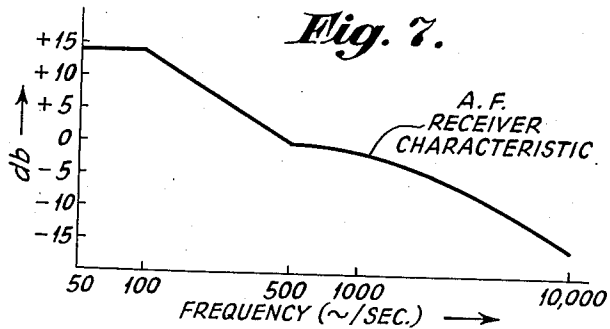
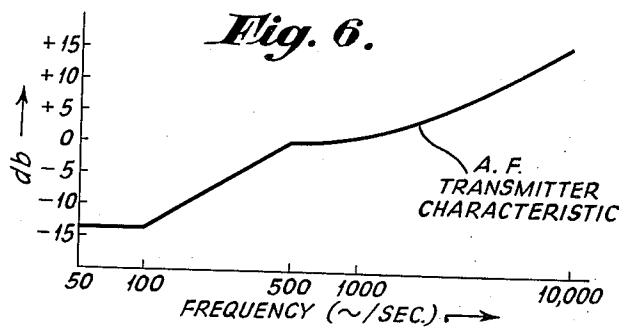
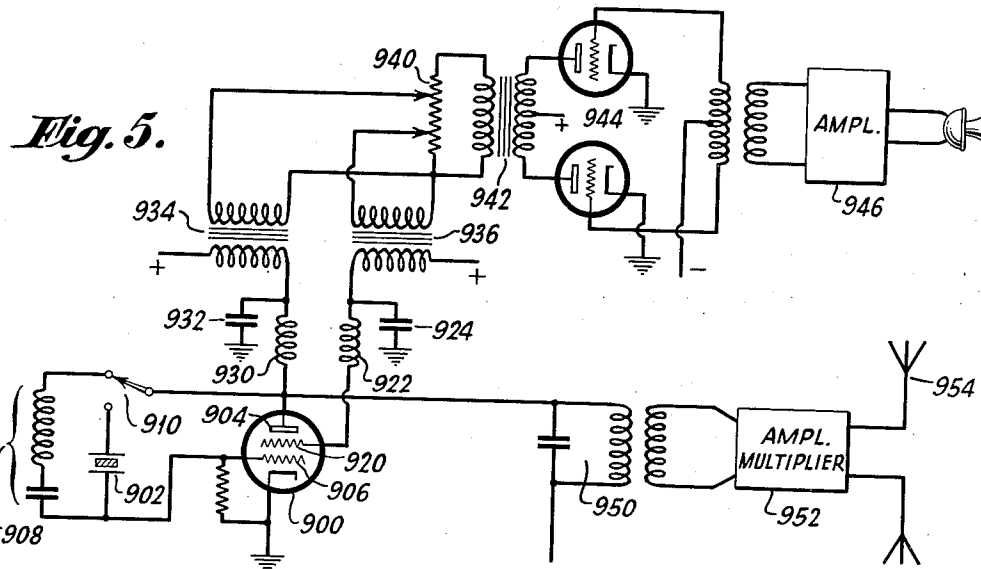
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FREQUENCY MODULATION

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6 Sheets-Sheet 5



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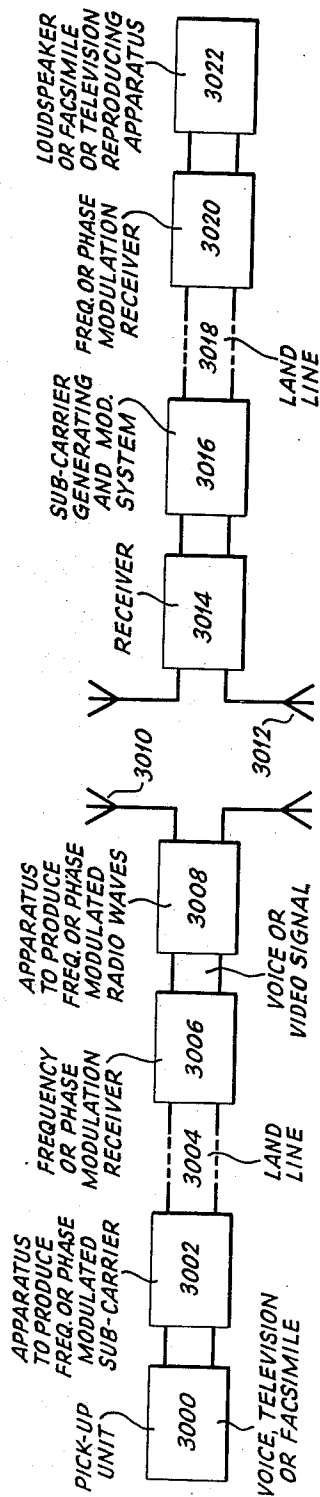
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FREQUENCY MODULATION

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Fig. 8.



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UNITED STATES PATENT OFFICE

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FREQUENCY MODULATION

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Application December 22, 1939, Serial No. 310,495

20 Claims. (Cl. 250-6)

The inventions described herein relate to frequency modulation systems and apparatus.

A few of the objects of my inventions are to provide improved automatic frequency controlling circuits for frequency modulation transmitters; to provide over-modulation indicating and controlling means for frequency modulation transmitters; and to provide improved apparatus for effecting frequency modulation.

In the drawings:

Figure 1 is a wiring diagram of a frequency modulation transmitter having a circuit for automatically bringing the transmitter back to its mean assigned frequency. Means are provided whereby this automatic correction is operative only upon cessation of the modulating signal. Other features also are present.

Figure 1A is a wiring diagram of an over-modulation indicating and correcting system which may be applied to the transmitter of Figure 1.

Figure 1B is explanatory of Figure 1A.

Figure 2 is another form of frequency modulation transmitter.

Figures 2a and 2b are curves used in the explanation of the device of Figure 2.

Figures 3, 4 and 5 are wiring diagrams of other frequency modulation radio transmitters.

Figures 6 and 7 are characteristic curves of amplifiers which may be used in conjunction with transmitters described herein and receivers for receiving the transmissions from the transmitters.

Figure 8 is a block diagram of a frequency and phase modulation signaling system.

In Figure 1, the signal pick-up device 2 feeds signal amplifier 4. The pick-up device 2 may be a voice microphone or a television or facsimile pick-up unit. If light signals are picked up, amplifier 4 would be a video amplifier. The amplified signal from amplifier 4 is fed through transformer 6 and lead 8 to the screen grids 10, 12 of reactance tubes 14, 16. In case video signals are transmitted, radio frequency by-pass condenser 18 should be made smaller so as not to by-pass the highest video frequencies from amplifier 4 or, if desired, 18 may be omitted.

The reactance tubes 14, 16 act to change the tuning of the grid circuit 20, comprising coil 22 and condenser 24, an amount proportional to the amplitude of the signal fed through transformer 6 and at a rate or frequency identical to the frequency of the signal fed through transformer 6. As a consequence, the push-pull connected oscillator tubes 26, 28 regeneratively cross coupled by condensers 30, 32, produce frequency

modulated high frequency oscillations in the tank or plate circuit 34 comprising inductance coil 36 and condenser 38. The frequency modulated oscillations are fed through condensers 40, 42 to a power amplifier and/or limiter 44 and then to additional power amplifiers and/or limiters and/or frequency multipliers 46 and radiated by antenna 48.

To prevent drift in the mean frequency of the push-pull oscillator 26, 28 a coil 50 is coupled to either the plate tank coil 36 as shown or, if desired, it may be coupled to the grid coil 22. The oscillator energy picked up at coil 50 is fed to the suppressor grids 52, 54 of tubes 56, 58 through leads 60, coupling coil 64 and tuned circuit 62. Between the grids 64, 66 of tubes 56, 58 there is connected a piezo-electric crystal 68 oscillating at some suitable frequency higher or lower than the mean frequency of oscillation of push-pull oscillator generator 26, 28. Tuned circuit 70 connected between the cathodes of tubes 56, 58 is tuned to the crystal frequency or to some harmonic thereof. The screen grids 72, 74 are grounded for radio frequency currents by the action of by-passing condenser 76 and serve as the anodes for the oscillating system formed by the crystal 68, tuned circuit 70 and the cathodes of tubes 56, 58. Electrodes 76, 78 serve to screen the crystal controlled oscillating system from the suppressor grids and plates of tubes 56, 58. All of the electrodes of tubes 56, 58 are suitably polarized or biased as shown. The beat frequency oscillations resulting from inter-action of crystal controlled oscillations and those from the transmitter generator fed through coupling coil 64 are resonated in the tunable plate circuit 80. This beat frequency is preferably of a lower frequency than either the crystal frequency or the mean frequency of oscillator tubes 26, 28, although if desired it may be higher than either the crystal frequency or the frequency of oscillation generator 26, 28.

Beat frequency energy is fed in push-pull or phase opposition through coil 82 magnetically coupled to the coil of tuned circuit 80. Coil 82 excites the resonant line 84 through leads 86, 88 coupled thereto and symmetrically spaced about the midpoint 90. Resonant line 84 is one half wave length long at the beat frequency; that is, at the desired mean or resonant frequency of circuit 80. Resonant line 84 may be temperature controlled and should be shielded by the grounded metallic concentric shield 92.

Coils 94, 96 are symmetrically coupled to either coil 82 or to the coil of circuit 80 or to

both. Coils 94, 96 are arranged so that the electromotive forces induced therein are additive and these electromotive forces are fed in push-push to the midpoint 90 of resonant line 84. If desired, coils 96, 94 may be omitted and lead 98 connected through a bypassing condenser to point 106 of tuned circuit 80. Leads 110, 112 are symmetrically variably tapped, as shown, to the resonant line 84 and excite the grids 114, 116 of the detectors 118, 120. The grids of detectors 118, 120 are biased through lead 122 and potentiometer 124, suitable chokes 126, 128 being provided to prevent high frequency currents from passing into lead 122. A resistance 130 is connected between the plates of detector tubes 118, 120 and shunted across each portion of resistor 130 are time constant condensers 132, 134.

By virtue of the foregoing arrangement, should the frequency of oscillation generator tubes 26, 28 drift from its mean assigned value for any reason, the rectified current output of tubes 118 or 120 will be larger depending upon the relative drift in frequency of oscillation generator tubes 26, 28. This change in frequency produces a voltage drop across leads 136, 138 which is added to or subtracted from the voltage from potentiometer 140 fed through resistance 142 to the suppressor grids 144, 146 of reactance tubes 14, 16. Reactance tubes 14 and 16 are drawing lagging or leading currents depending upon the adjustments of condensers 148, 150 and resistors 152, 154. In other words, by virtue of condenser 148 and resistance 152 the voltage impressed upon grid 156 of tube 14 is such as to make that tube draw either a leading or lagging current with respect to the current in the grid circuit 20. So also for reactance tube 16, the condenser 150 and resistor 154 cause grid 158 to be subjected to such a voltage as to cause tube 16 to draw either a lagging or leading current. The voltage impressed upon the suppressor grids 144, 146 through leads 136, 138 and resistor 142 is made to be in such a direction as to correct for departures in frequency of oscillation generator 26, 28 from its mean assigned frequency and to bring it back to that mean assigned frequency for which the voltage difference across leads 136, 138 as derived from resistor 130 is zero or negligible.

The plates of the reactance tubes 14, 16 may be supplied with potential from any suitable source such as 160 feeding the plates through choke coils 162, 164. Bypassing condensers 166, 168 may be provided if desired. Also, blocking condensers 170, 172 are used to connect the plates of the reactance tubes to the grid circuit 20.

Frequency modulation of the oscillations produced by tubes 26, 28 is accomplished by impressing signal voltages through transformer 6 and lead 8 upon grids 10, 12, thereby effectively varying the amount of leading or lagging current drawn by the reactance tubes in accordance with the amplitudes of the signal voltages and at a frequency identical to the signal frequency. Obviously, changing the amount of lagging or leading current drawn by the reactance tubes 14, 16 effectively changes the tuning of the grid circuit 20 and thereby changes the frequency of the tube system 26, 28.

If desired, another pair of reactance tubes may be connected similarly to the plate circuit 34 of the push-pull oscillation generator, in which case the suppressor and screen grids would be connected in parallel to the suppressor and screen grids of tubes 14 and 16. Phase displaced voltages on the grids of these additional reactance

tubes could be taken in a similar fashion from the plate circuit 34 as was done from the grid circuit 20 and, of course, the cathodes or filaments of these additional tubes would be grounded. This modification, in which another pair of reactance tubes is connected to the plate circuit 34, is illustrated in Figure 1C.

As shown in Figure 1C, the suppressor grids R144 and R146 of the plate circuit reactance tubes R14, R16 are connected in parallel and to the suppressor grids 144, 146 of reactance tubes 14 and 16. Similarly, screen grids R10, R12 are connected in parallel and to the screen grids 10, 12 of the grid circuit reactance tubes 14, 16. Phase displaced voltages are taken from the plate circuit 34 and fed to the control grids R156 and R158 by means of condensers R148, R150 and resistors R152, R154.

In order that the frequency controlling system may not serve to oppose the frequency modulation produced by the signal, part of the signal voltage may be fed through switch 130, signal amplifier 182 and rectifier 184, whose rectified voltage is impressed across the resistance condenser time constant circuit 186. Arrangements should be made as regards the amplifying power of the amplifier 182 and voltage developed by rectifier 184 so that in the presence of the lowest value of signal desired to be transmitted the voltage impressed by rectifier 184 in series with the voltage from potentiometer 124 is such as to bias detector tubes 120, 118 to cut off. In this way, when the device 2 picks up signals to be transmitted, the frequency controlling circuits are rendered inoperative. Obviously, the system of Figure 1 may be operated without this auxiliary control by opening switch 180, in which event automatic frequency control of the system will take place at all times. With switch 180 closed, frequency correction takes place only in the absence of signal at point 2.

Since frequency modulation of the oscillation generators 26, 28 may entail a certain amount of amplitude modulation, limiters 44 are provided. As an alternative or as an additional means for reducing this incidental amplitude modulation, rectifier 190 is provided. The input coil 192 for rectifier 190 may be coupled to either the grid coil 22 or to the plate coil 36. The rectified voltage which will vary in accordance with amplitude changes in the oscillation generator is fed from time constant circuit 194 and leads 196 to resistor 198 in series with the grid biasing lead 200 connected through coil 22 to the grids 202, 204 of the push pull connected tubes 26, 28. Leads 196 should be so connected that the voltage inserted in series with the grid biasing lead 200 from the fast a. v. c circuit 194 is in such a direction as to wipe out amplitude changes in the oscillation generating circuits to which coil 192 may be coupled. If desired, of course, coil 192 may be coupled to an output circuit of either limiter 44 or an output circuit or input circuit of circuits 46 should circuits 44 or 46 imperfectly eliminate undesired amplitude variations.

Leads 210, 212 of Figure 1 are identical to leads 210, 212 of Figure 1A which illustrates an over-modulation system for a frequency modulation transmitter. Assuming, as shown in Figure 1B, that the frequency channel allocated to a frequency modulation transmitter is represented by the frequency range between points A and B, then tuned circuits 214, 216 connected to the coupling antennas 218, 220 are tuned so as to have resonant points R, R' respectively at or

slightly beyond the frequencies A and B. As a consequence, should the transmitter frequency be shifted an amount greater than the deviations A and B away from the mean assigned frequency M of Figure 1B, current will be induced in the amplifiers 222, 224 in turn coupled to rectifiers 226, 228. The rectifiers are connected so as to feed current through resistor 230 in series with the polarizing battery or source 232. In the presence of over-modulation, leads 210, 212 are so connected as to inject a voltage in resistor 234 (Fig. 1) in series with the signal lead 8 in such a direction as to cut down the amount of frequency swing of the oscillation generating system. This auxiliary control may be eliminated, if desired, by opening switch 236. In the alternative, or in addition to this auxiliary control, a bell 238 and a light 240 may be actuated through relay 242 connected through lead 244 to resistance 230 of Figure 1A.

In the transmitter of Figure 2, microphone 300 feeds an audio frequency amplifier 302 whose characteristic is as shown in Figure 2A. That is, amplifier 302 should have a flat characteristic along the range A to B of about 10 to 500 or 10 to 1000 cycles. From points B to C the characteristic should rise preferably linearly. B to C represents the remainder of the audio frequency range which may be as desired from 500 or 1000 to 5000, 7500 or 10,000 or more cycles. When such an amplifier is used at the transmitter, the frequency modulation audio frequency amplifier at the receiver should have a complementary characteristic, namely, flat along the frequency range from A to B and then drop off from the frequency range B to C, as shown in Figure 2B.

The output of audio frequency amplifier 302 is fed through transformer 304 and additional transformers 306, 308 to the grids of reactance tubes 310, 312. Audio frequency by-passing condensers 314, 316 are provided as are also radio frequency chokes 318, 320. Depending upon the adjustments of reactance tubes 310, 312 the crystal 322 is effectively shunted by variable capacity or inductance represented by tube 310 and the plate circuit of the crystal controlled oscillation generator tube 324 is also shunted by a variable inductor or capacity represented by reactance tube 312. Both tubes 310, 312 should be adjusted so as to add similar reactances, namely, capacitive or inductive, to the grid and plate circuits of crystal controlled generator 324.

If desired, of course, the crystal may be replaced by a tuned circuit or a quarter wave resonant line. The audio frequency voltages applied to the reactance tubes 310, 312 may be adjusted by virtue of taps 330, 332 on the potentiometer shunting the secondary of transformer 304. The output of the oscillation generator may be fed through a limiter and/or power amplifier and/or frequency multiplier 334 whose output as radiated by the antenna 336.

As before, over modulation pickup antennae or coils 338, 340 are provided, antenna 338 feeding into a circuit 342 tuned to or slightly beyond one extreme frequency of the channel assigned to the transmitter of Figure 2. Similarly, tuned circuit 342 is tuned to or slightly beyond the other extreme frequency of the channel assigned to the transmitter. Circuit 340 energizes amplifier 344, in turn connected to rectifier 346.

When the swing exceeds the channel allotted to the transmitter, an indication is produced in indicator 348 and to automatically prevent this

condition from persisting, an automatic volume control lead 350 is provided. Lead 350 may be connected to one of the audio stages of amplifier 302 to cut down its gain when output is produced in rectifier 346. Similarly, when the transmitter goes beyond its extreme allotted frequency in the other direction, rectifier 352 becomes active to produce an indication in the bell or lamp indicator 354 and also inject a gain reducing voltage in the automatic volume controlling lead 356 leading to the same or another amplifier stage in audio frequency amplifier 302. If desired, the system may be operated without the automatic volume controlling feature, in which case switch 360 and/or switch 362 may be opened.

Incidentally, in connection with Figure 1, the condenser of tuned circuit 80 may be omitted and, if desired, may be replaced by a resistance to broaden the pass band of energy fed into coil 82.

In Figure 3 I have illustrated another improved frequency modulation transmitter. The crystal 700 controls the frequency of oscillation of the crystal controlled oscillator tube 702 which is provided with an inductive output circuit or coil 704 which may be shunted, if desired, by a tuning condenser. In the absence of signal from the signal amplifier 706, tubes 708, 710 are biased to cut off by voltage source 712. Tubes 708 and 710 are made alternately conducting with audio frequencies transferred through transformer 714. Coil 716 is so wound as to increase the inductance reflected into coil 704 with current flow through tube 710 and coil 718 is so wound and polarized as to decrease by reflection the effective amount of inductance in coil 704. Consequently, the frequency of oscillation of oscillation generator tube 702 is varied in accordance with signals from amplifier 706. The output of the oscillator is fed to power amplifiers and/or limiters and/or frequency multipliers 730 and then radiated over antenna 732. The crystal may, of course, be replaced by a parallel tuned circuit 740 by throwing switch 742 to its upper position 744.

Preferably, by adjusting the volume of signal fed to the various transformers described herein and by suitable adjustment and choice of the frequency multipliers, I prefer to radiate a wave whose frequency is equal to, for the loudest signals, any integer up to one hundred times the highest modulating frequency plus the highest modulating frequency. Thus, if we assume the highest modulating frequency to be 5000 cycles and the integer to be, for example, five, then the radiated carrier frequency deviation should be five times 5000 plus 5000 or 30,000 cycles, making the total band width used by the transmitter 60,000 cycles. For the case where the integer is, for example, 100, the deviation is 500,000 plus 5,000 under the above rule, thereby making the total band width employed 1,010,000 cycles.

It is interesting to note that the amplitude time characteristic of a signal, such as speech signals, is not symmetrical about the time axis. In other words, the positive half cycles of the speech signal may be on the average greater than the negative half cycles. Consequently, when frequency modulating with speech waves, the transmitter may go beyond one extreme of its assigned channel and not beyond the other. As one way of remedying this situation, I have provided in connection with the transmitter of

Figure 3 two pick-up antennae 750, 752 coupled to the radiating antenna 732. Antenna 750 feeds tuned circuit 754, tuned to or below the lowest frequency of the frequency channel assigned to the transmitter 702, 730, 732 and tuned circuit 756 is tuned to or above the highest frequency of the channel assigned to the transmitter of Figure 3. Tuned circuit 754 feeds amplifier rectifier 758 and detector 760. The detected output, when the frequency of the transmitter goes beyond the lower limit of the assigned channel, causes indication in an indicator 762 and also impresses a voltage across resistor 764 in series with the grid 768 of a tube 710. The voltage impressed in resistor 764 is in such a direction as to cut down current flow through tube 710 and, hence, reduce the effective inductance reflected into coil 704 by coil 716. That is, assuming coil 716 with increasing current therethrough causes an effective increase in inductance of coil 704, over-modulation in one direction as detected by the action of coil 754 will manifest itself through the voltage drop in resistance 764 to reduce the frequency swing in that direction in which over-modulation is being produced.

Coil 718 acts effectively to reduce the effective inductance of coil 704 and hence increases the frequency of oscillation of tube 702 with increasing current flow through coil 718. When the radiated wave from antenna 732 goes above its upper assigned frequency current will be produced in tuned circuit 752 and the current in this circuit will be amplified by amplifier 780 and rectified by rectifier 782. This rectified current produces an indication in the indicator 784 and also produces a voltage drop across resistor 786 in series with the grid 788 of tube 708. This voltage drop should be arranged in such a way as to reduce the current flow through tube 708 and hence through the action of coil 718 upon coil 704 bring the frequency of oscillation of tube 702 within its assigned channel.

Incidentally, it is to be noted that the unsymmetrical characteristic of the amplitude time characteristic of speech waves may cause the automatic frequency controlling system of Figure 1 to drag the oscillator over a period of time to one side of its mean assigned frequency especially when the system of Figure 1 is operated with switch 180 open. To correct for this, taps 890, 892 of Figure 1 may be unsymmetrically tapped about the midpoint of resistor 130 until the unsymmetrical characteristic of the modulation introduced at point 2 is compensated. To facilitate this adjustment, bearing in mind the unsymmetrical characteristic of speech waves, a reversing switch 894 (Figure 1) may be provided for reversing the polarity of the signal fed into lead 8 through transformer 6.

In the transmitter of Figure 4, reactance tubes 800, 802 are made more conductive by the action of transformer 804 associated with the cathodes of reactance tubes 800, 802. Transformer 804 is energized by signal amplifier 806 in turn connected, if desired, to a microphone 810. Condenser 812 and resistor 814 are adjusted so as to energize the grid 816 with a relatively leading voltage. Condenser 818, coil 816 and resistance 820 are adjusted so as to impress a relatively lagging voltage with respect to the voltage at point 822 upon the grid 824 of tube 802. The cathodes of the reactance tubes are connected to a source of potential 830 such that both tubes draw a mean current in the absence of signal from amplifier 806. The apparatus within box 75

840 is identical to that within the dotted rectangle 842. By the action of switch 844 either the crystal 846, parallel tuned circuit 848 or resonant line 850 is connected in the grid circuit of the high frequency oscillation generator 852. The output of the generator 852 is fed through power amplifier and/or limiter and/or frequency multiplier to antenna 856.

Obviously, both reactance tubes 800, 802 may be adjusted so that they both draw leading currents or both draw lagging currents. Preferably, coil 816 is omitted and condensers 812, 818 are made identical in size so that both reactance tubes 800, 802 act alike.

In the transmitter of Figure 5 the oscillator tube 900 may have either crystal 902 connected between the plate 904 and grid 906 or, as shown, the series tuned circuit 908 is connected by means of switch 910 between the plate 904 and grid 906. The screen grid 920 is supplied with voltage through radio frequency choke 922 and by-pass condenser 924. The plate 904 is supplied with plus voltage through choke 930 bypassed by by-passing condenser 932. Transformers 934 and 936 insert alternating signal voltages in the plate and screen voltage leads. These signal voltages are derived from potentiometer 940 connected to the secondary of transformer 942 whose primary is connected across the plates of push-pull amplifier 944 energized from audio or signaling amplifier 946. Since like voltage changes applied to the screen 920 and plate 904 produce opposite effects on the frequency of oscillation of tube 900 transformers 936 and 934 are so polarized as to oppositely swing the screen 920 and plate 904 in voltage in accordance with signal voltages derived from amplifier 946. The output circuit 950 of the oscillator 900 is fed to the limiter 952 which may be a power amplifier and/or frequency multiplier and in turn 952 energizes the antenna 954.

If desired, the audio frequency amplifier at the transmitter, such as the amplifier 4 of Figure 1 or the amplifier 302 of Figure 2 or the amplifier 706 of Figure 3, may have a characteristic such as shown in Figure 6, in which case the receiving audio frequency amplifier should have an amplitude frequency characteristic such as shown in Figure 7. In the transmitter amplifier characteristic of Figure 6, the gain is flat from about 50 to 100 cycles, rises linearly from about 100 to 500 cycles and then rises according to the sloping characteristic shown from 500 cycles on. The receiving characteristic of Figure 7 is complementary to that of Figure 6 and is flat from 50 to 100 cycles, decreases the gain linearly from 100 to about 500 cycles and then slopes off in gain as shown from 500 cycles up.

Clearly, many of the features of my present invention are applicable to phase modulation systems. For example, the over-modulation indicating system may be used exactly as shown for a phase modulation transmitter. Also, all of the frequency modulation transmitters described herein may be caused to produce phase modulated waves by adding an additional correcting circuit in the audio stages of the transmitter which serves to increase the audio amplifier output with audio frequency, as described in Peterson Patent No. 2,070,681.

In the system of Figure 8 the pick up unit 3000, which may be a voice, television or facsimile pick up unit, frequency or phase modulates a sub-carrier generated by apparatus within rectangle 3002. This frequency or phase modulated

sub-carrier is fed over land lines 3004 to a suitable frequency or phase modulation receiver 3006 which reproduces currents of modulation frequency similar to those fed from 3000 into the sub-carrier system 3002. The output of frequency or phase modulation receiver 3006 is then used to frequency or phase modulate the radio transmitter 3008 whose output is in turn radiated by radiator 3010.

The transmitted frequency modulated waves are received on the receiving antenna 3012 and translated by the frequency or phase modulated receiver 3014 into the modulation frequency waves corresponding to those at the output of apparatus 3000 at the transmitter. These de-modulated waves of modulation frequency are used to frequency or phase modulate a sub-carrier wave in the apparatus represented by 3016. This frequency or phase modulated sub-carrier is then fed over land line 3018 to a distant receiving point at which a frequency or phase modulation receiver 3020 is located. The receiver 3020 de-modulates the frequency or phase modulated sub-carrier and feeds the de-modulated waves into a loudspeaker facsimile recorder or television reproducing apparatus 3022.

The foregoing system has among its advantages the fact that the pick-up unit 3000 may be remotely located from the transmitting antenna 3010 and that the de-modulating receiver 3006 may be used both for monitoring as well as for modulating the radio transmitter 3008. Similarly, the receiving arrangement is advantageous since the receiving antenna 3012 may be located in the suburbs of a city and the reproducing apparatus 3022 may be located within a city, in which event the urban noises generated in urban areas are kept from affecting the output of 3022.

Any of the transmitters or receivers heretofore specifically described may, of course, be used in the system of Figure 8, as will be apparent to those skilled in the art.

In connection with Figure 3, as shown on the drawing, the coils 716, 718 are preferably shielded and uncoupled from each other although individually coupled to the coil 704. Also, coils 716, 718 are preferably tuned by condensers 716' and 718' to opposite extremes of the frequency band transmitted by oscillation generator 702. From another point of view it may be said that these off tuned circuits 716', 716 and 718', 718 serve to swing the resonant frequency of the oscillation generator plate circuit 704 through and about its mean frequency in accordance with the modulation fed through transformer 714.

In connection with Figure 5, the relative voltages applied to the plate 904 and screen grid 920 may be adjusted as shown by the taps on resistor 940 and/or by adjusting transformers 934, 936.

Instead of manually reversing the polarity of the signal modulation input for the transmitting system shown, for example, in Figure 1 the polarity thereof may be automatically reversed by systems such as shown by J. L. Hathaway in his U. S. Patents 2,158,820 and 2,158,821.

In the claims which follow, the term "angular velocity modulation" shall be understood to include frequency modulation or phase modulation or hybrid modulations such as produced by pre-distorting or pre-emphasizing circuits at the transmitter.

Having thus described my invention, what I claim is:

1. In combination, an oscillation generator, a source of signals, means for angular velocity

modulating oscillations from said generator with signal waves from said source, means automatically frequency controlling said oscillation generator to correct for departures from its mean assigned frequency, and means, responsive to signals to be transmitted, for disabling or rendering inoperative said automatic frequency correcting means.

2. Apparatus as claimed in claim 1, characterized by the fact that means are provided responsive to signaling waves for rendering said automatic frequency controlling means inoperative in the presence of signals and operative in the absence of signals.

3. An angular velocity modulation over-modulation system comprising a circuit tuned to or beyond an extreme frequency of the frequency channel to which an angular velocity modulation transmitter has been assigned, said tuned circuit being coupled to said transmitter so that usable current flows in said circuit only when said transmitter produces waves of frequencies exceeding the channel assigned to said transmitter, means for rectifying the current produced in said tuned circuit, and means for indicating presence of said rectified current, said apparatus being characterized by the fact that means are provided responsive to said rectified current for reducing the frequency swing of the transmitter so that it does not produce angular velocity modulated oscillations of a frequency extending beyond the frequency to which said circuit is tuned.

4. An angular velocity modulation over-modulation system comprising a circuit tuned to or beyond an extreme frequency of the frequency channel to which an angular velocity modulation transmitter has been assigned, said tuned circuit being coupled to said transmitter so that useful current flows in said circuit only when said transmitter produces waves of frequencies exceeding the channel assigned to said transmitter, means for rectifying the current produced in said tuned circuit, said apparatus being characterized by the fact that means are provided responsive to said rectified current for reducing the frequency swing of the transmitter so that it does not produce angular velocity modulated oscillations of a frequency extending beyond the frequency to which said circuit is tuned.

5. In an angular velocity modulation system, an angular velocity modulated transmitter, a pair of tuned circuits tuned to or beyond extreme frequencies of an assigned frequency modulation channel, means for rectifying currents produced in said tuned circuits, and means for utilizing the rectified currents to reduce the frequency swing of said transmitter so as to confine the angular velocity modulated waves produced thereby within said assigned or allocated frequency channel.

6. In a frequency modulation system, an oscillation generator, means for frequency modulating oscillations from said generator in accordance with unsymmetrical waves from a source of modulating waves, and means for preventing unsymmetrical action upon said oscillation generator due to the unsymmetrical nature of the waves from said source, said apparatus being characterized by the fact that said oscillation generator is provided with automatic frequency controlling means, and being further characterized by the fact that said automatic frequency controlling means is adjusted in such a way as to compensate for the unsymmetrical nature of voice waves used to produce the frequency modulated oscillations.

tions in such manner that the frequency controlling system brings the oscillation generator back to its mean assigned frequency rather than on the average to a different frequency which might be the case due to the normal action of the unsymmetrical voice waves.

7. In a system wherein the wave length rather than the amplitude of oscillations is modulated, a source of oscillations to be modulated, a reactance tube connected to said source, said reactance tube having a multiplicity of electrodes, means subjecting one pair of said electrodes to phase displaced oscillations from said source, means subjecting another pair of electrodes of said reactance tube to signaling current waves, and means for subjecting still another pair of electrodes of said reactance tube to automatic frequency controlling voltages derived from said source of oscillations, and characterized further by the fact that a pair of electrodes of said reactance tube is provided with and subjected to over modulation control voltages.

8. In combination, a source of complex signal modulating waves, an amplifier to amplify said waves, an oscillation generator, a reactance tube circuit coupling said amplifier and generator whereby the waves derived from said generator are angular velocity modulated in accordance with waves from said source, a pair of frequency discriminator circuits, a pair of rectifiers connected to said discriminator circuits, said discriminator circuits being energized by modulated waves derived from the generator and being adjusted so that said rectifiers produce substantial rectified voltages when said generator is over-modulated, and means connecting said rectifiers to said reactance tube circuit in such a way as to produce a modulation to oppose the signal modulation only when over-modulation occurs.

9. Apparatus as claimed in the preceding claim, characterized by the fact that the rectifiers are connected to the signal amplifier to reduce the gain thereof when over-modulation occurs.

10. Apparatus as claimed in claim 8, characterized by the fact that the rectifiers are connected to the reactance tube circuits to reduce the amount of angular velocity modulation when over-modulation occurs.

11. In combination, a generator of carrier waves, a source of control waves, means to angular velocity modulate carrier waves from said generator with waves from said source, and means responsive to the modulated waves for reducing the degree of angular velocity modulation thereof only when the degree of modulation exceeds pre-determined limits.

12. In combination, a generator of carrier waves, a source of modulating waves, means to angular velocity modulate waves derived from said carrier generator with waves from said modulating wave source, and means responsive only to over-modulated waves for reducing the amount of over-modulation.

13. In combination, an oscillation generator, a reactance tube circuit for varying the frequency of said generator, means to vary the conductivity of said reactance tube circuit at signal frequency to thereby vary the frequency of oscillations generated, automatic frequency control means connected to said reactance tube circuit for maintaining said generator in operation substantially at a pre-determined frequency in the absence of signal frequency waves, and means connected to said reactance tube circuit and responsive to

over-modulation of said generator to reduce the over-modulation thereof.

14. In combination, a generator of carrier waves, circuits for transmitting waves derived from the generator, a source of variable control voltage, circuits arranged to frequency modulate waves derived from said generator in accordance with said variable control voltages, a frequency controlling circuit arrangement for frequency stabilizing said generator; a rectifying system, operative to produce rectified current only when the frequency modulated waves swing beyond desired frequency limits, to produce a voltage representative of the excessive frequency swing, and apparatus utilizing the rectified voltage so produced to reduce the amount of frequency modulation produced by said control voltage.

15. In combination, a generator of waves, apparatus connected to said generator to frequency modulate waves generated thereby, a first discriminator-detector system for automatically frequency controlling said generator to maintain said generator operating at a substantially constant mean frequency, and a second discriminator-detector system responsive to over-modulation of said generator for reducing said over-modulation.

16. In a system for controlling the maximum deviation of frequency modulated oscillations irrespective of changes in the average intensity of said signals, means for producing rectified current only when the deviations of the modulated oscillations exceed a selected frequency, the intensity of said rectified current being proportional to the extent by which the frequency of said modulated oscillations exceeds said selected frequency, and means excited by the rectified current produced for changing the mean frequency of said oscillations as a function of said rectified current, said last-mentioned means being operative only when said maximum deviation is exceeded.

17. The method of controlling the peak deviations of oscillations modulated in frequency by voltages the average value of which may vary slowly which includes the steps of producing, only from undesired, excessive frequency deviations, additional voltage the value of which is a function of the extent which the peak deviation of said modulated oscillations exceed a selected value during modulation, and changing the mean frequency of said oscillations in accordance with said additional voltage.

18. In a frequency modulator including an oscillation generator, a reactance tube modulator coupled thereto and means for controlling the impedance of said reactance tube by signals, means for deriving from said modulated oscillations a potential solely from peak swings thereof which go beyond a selected frequency, and means for additionally controlling the impedance of said reactance tube in accordance with said derived potential.

19. In combination, a generator of carrier waves, a source of control voltages, means to frequency modulate carrier waves from said generator in accordance with voltages from said source, a frequency to amplitude converting circuit, a rectifier coupled thereto, means for feeding frequency modulated waves to said converting circuit and thence to said rectifier, and a circuit coupling the output of said rectifier to said generator, said converting circuit and rectifier operating to reduce the degree of frequency

modulation of the carrier waves only when the degree of modulation exceeds predetermined limits.

20. In combination, a generator of carrier waves, a source of modulating waves, means to frequency modulate waves derived from said generator with waves from said modulating wave source, a frequency to amplitude converting and

5 detecting system responsive only to over-modulated waves for producing detected current only when over-modulation occurs, and a circuit utilizing said detected currents for reducing the degree of frequency modulation of said carrier waves when over-modulation occurs.

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