July 26, 1949. C. W. EARP 2,476,964
RECEIVING SYSTEM FOR FREQUENCY OR PULSE
MODULATED ELECTROMAGNETIC WAVES
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FIG. 1.

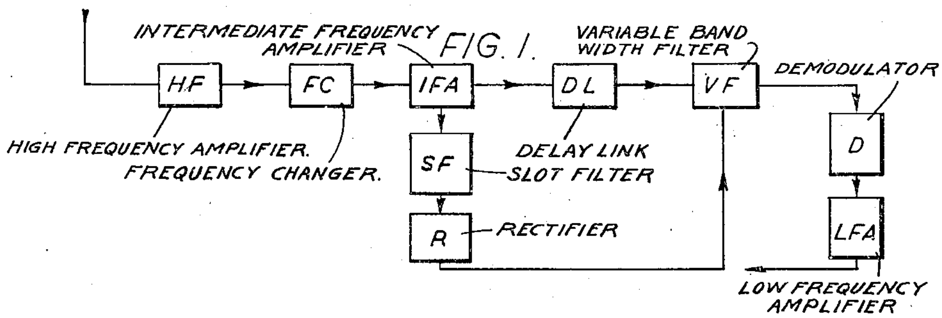

FIG. 2.

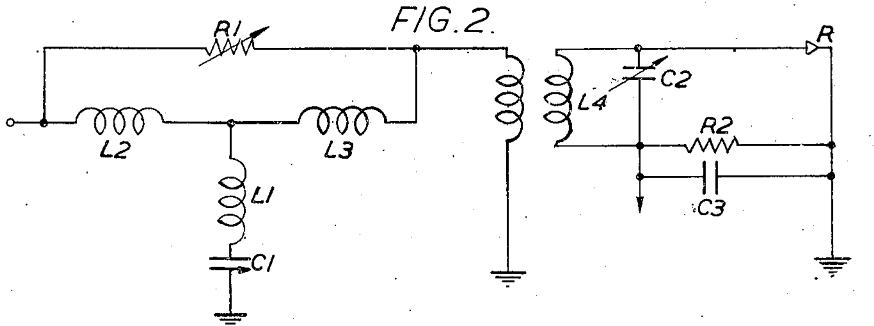

FIG. 3

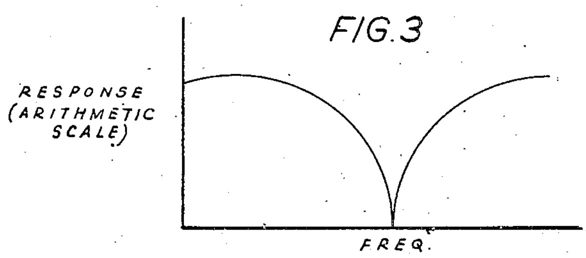

FIG. 4.

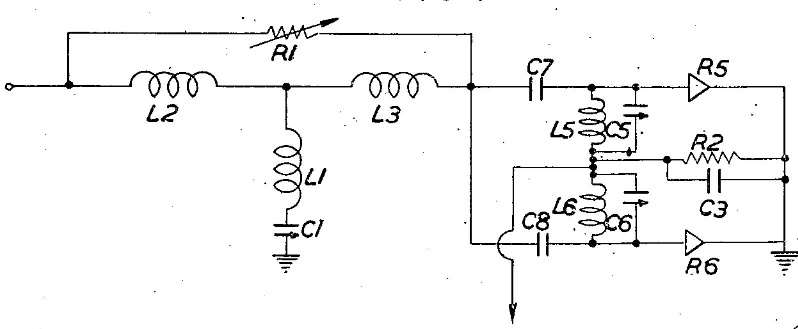

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FIG. 5.

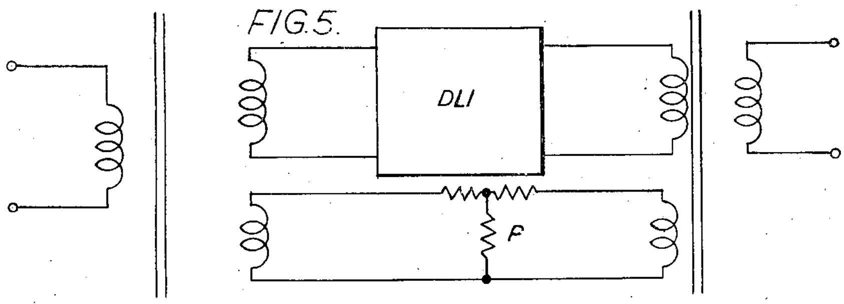


FIG. 6.

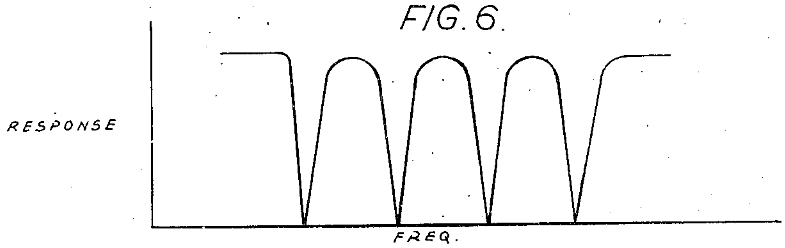


FIG. 7.

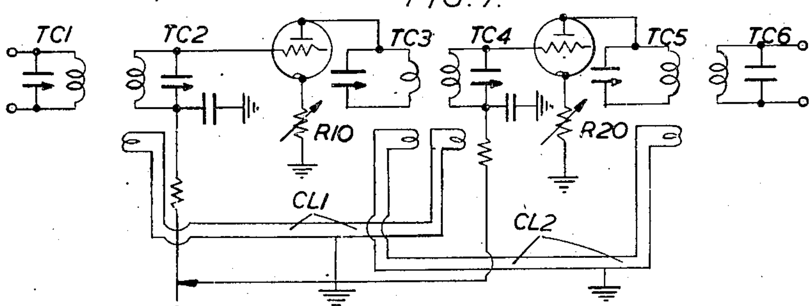
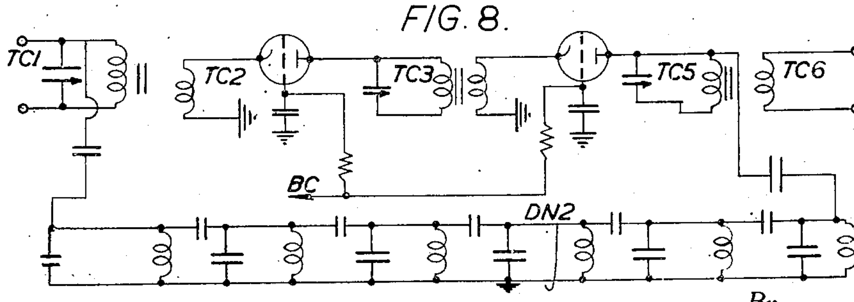


FIG. 8.



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2,476,964

RECEIVING SYSTEM FOR FREQUENCY OR PULSE MODULATED ELECTROMAGNETIC WAVES

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7 Claims. (Cl. 250—20)

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The present invention relates to a method of and arrangements for the reception of electromagnetic waves modulated in such manner as to vary the transmission frequency band width with depth of modulation. The invention relates particularly, though not specifically, to a method of and arrangements for the reception of frequency modulated electromagnetic waves or a train of modulated electrical pulses.

It is the object of this invention to provide in arrangements of the type specified a high signal to noise ratio for both high and low levels of modulation. The theoretical possibility of such arrangements is evident from the fact that over a wide range of modulation of such transmissions, the sideband content is substantially constant, so that signal to noise ratio should not vary over this range of modulation.

The advantages of arrangements as provided by the present invention are most apparent where it is desired to transmit an intelligence wave which varies in amplitude between wide limits. For example, in order to transmit orchestral music, a signal to noise ratio 80 db. for peaks of modulation must normally be obtained in order that a reasonably good signal to noise ratio can be obtained during the troughs of modulation. In the arrangements to be described, the signal to noise ratio can be maintained at say, 30 db. in the troughs of modulation, while not requiring the high power of transmission associated with a peak signal to noise ratio of 80 db.

The principle of this invention lies in the following. The frequency band-width occupied, and the resultant noise power which must be received, varies according to the amount of modulation. The receiver band-width is, therefore automatically adjusted according to the band-width occupied by the transmission.

In the case of a frequency modulated wave, the transmission frequency spectrum occupies a frequency band which expands and contracts according to the amount of modulation.

In the case of pulse trains in which for zero modulation the repetition frequency is constant at "f" per second, the unmodulated transmission can be considered as a spectrum of carrier waves which are spaced at equal intervals of f cycles per second over the frequency band. Modulation of such a pulse train produces modulation of these carrier waves, and causes the transmission to occupy a large number of separate frequency bands, all of which expand and contract according to the amount of modulation.

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For example, if the pulse train is time modulated, that is, the time interval between pulses is varied or modulated, or in other words, the repetition frequency f, or the pulse group-phase is modulated, the total transmission is a multiple frequency modulated transmission. Similarly, a modulation of the high frequency phase of successive pulses causes phase modulation of all the separate carrier waves which constitute the pulse train. The expression "depth of modulation" used in the appended claims is intended to mean the amount of shift of the carrier frequency for frequency modulation and the amount of change in the repetition frequency or the phase shift for pulse modulation.

The ideal receiver for the case of a frequency modulated transmission will have a single pass-band which expands and contracts with transmitter modulation depth.

The ideal receiver for pulse modulation systems will have a plurality of pass-bands, each of which expands and contracts according to the depth of modulation. This latter receiver may be provided with a comb-like filter i. e. a filter having a comb-shaped response frequency characteristic, in which the "response teeth" have a variable thickness or band-width. Such filters are more fully described hereinafter.

According to the most general aspect of the present invention, the method of reception of electromagnetic waves modulated in such manner as to vary the transmission frequency band-width with depth of modulation comprises varying automatically the receiver operating band-width according to the depth of modulation of the received waves.

Arrangements for carrying out the method of reception according to the invention comprise means for producing a voltage proportional to the depth of modulation in the received waves and for applying said voltage to control automatically the operating frequency band-width of the receiver. In a practical arrangement, a variable band-width filter is provided and takes the form of an amplifier with negative and positive feedback paths.

The invention will be better understood after reading the following description given in conjunction with the accompanying drawings which show diagrammatically the circuit arrangements of one practical embodiment of the invention.

In the drawings;

Figure 1 is a block schematic diagram of the general receiving arrangement embodying the invention.

Figure 2 shows diagrammatically a slot filter and rectifier arrangement suitable for incorporating in the arrangement shown in Fig. 1 for receiving frequency modulated waves.

Figure 3 is a frequency-response characteristic curve of the filter of Fig. 2.

Figure 4 shows a modified arrangement of the filter shown in Fig. 2.

Figure 5 shows diagrammatically a slot filter suitable for incorporation in the arrangement shown in Figure 1 for receiving trains of modulated electrical pulses and

Figure 6 shows the frequency-response characteristic curve of the filter shown in Figure 5.

Figures 7 and 8 show diagrammatically circuit arrangements for variable frequency band filters suitable for incorporation in the arrangements shown in Figure 1 and for the reception of frequency modulated waves and trains of modulated pulses respectively.

Figure 1 shows a block schematic diagram of a suitable receiver for carrying out the invention. In this diagram, only the more essential parts are shown, in order to show the application of the invention to both frequency modulated and time modulated pulse systems. In the case of frequency modulation the usual limiter stage would, of course, be added before the demodulator. Similarly, a modulated pulse system receiver might include "trigger" circuits for noise elimination.

After optional high frequency amplification in H. F. and frequency changing in FC, the signal is amplified in IFA. Here, the signal is fed into two paths. In the first path, the signal passes via a "delay link" DL, or path of appreciable transit time. This delay link DL may be comprised of a number of tuned circuits coupled together to form a band pass filter.

From DL, the signal passes through the variable band-width filter VF. This variable filter may have a single, or multiple response bands as hereinafter more fully described, which are variable in width. After filtering, the signal is demodulated by known means in D, which may, for example, be a frequency discriminator. This demodulator yields the low frequency modulating wave, which may be raised to the required level in the amplifier LFA.

The second path of the signal from IFA is to the "slot filter" SF. This is a filter which passes little or no signal when the latter is unmodulated, but which gives a response rising with the amount of modulation. Suitable "slot filters" are described hereinafter.

The wave which passes through the slot filter is rectified and detected in rectifier R yielding a direct current which is zero for no modulation, but which rises in level according to the amount of modulation. This direct current is used to control the band-width of the variable filter VF. For small depths of modulation the band-width of VF is small, but when a negative bias is applied to it by rectifier R, the pass band expands, or the pass bands expand to accommodate the prevailing modulation.

Suitable slot filters

Figure 2 shows the schematic diagram of a slot filter and rectifier circuit suitable for use as SF and R in Figure 1. In this filter, the "bridged-T" network comprised of $C_1L_1L_2L_3$ and R_1 is arranged to give infinite rejection of the received carrier wave. Sidebands are approximately tuned in L_4C_2 to yield an overall filter characteristic approximately as shown in Fig. 3. Rectifier R produces a D. C. voltage across R_2 which voltage is approximately proportional to the frequency deviation of the received signal.

Fig. 4 shows a modified arrangement which gives a better overall characteristic. In this, two tuned circuits L_5C_5 and L_6C_6 are used, one tuned to slightly higher than carrier frequency, and one slightly lower and feeding separate rectifiers R_5R_6 which in turn feed a common load resistor R_2. The tuned circuits are fed from the bridged-T network via condensers C_7C_8. The voltage produced across R_2 is then applied to control the variable filter VF (Fig. 1).

Figure 5 shows a multi-slot or comb-like filter circuit especially suitable for the case of a pulse transmission. In this, the signal is passed equally through two parallel paths, one path including a delay link DL1 of delay equal to the pulse repetition period, and the other including an aperiodic pad P which gives an attenuation equal to that of the delay link DL1. The multiple slot filter has a response frequency characteristic as shown in Figure 6, rejecting all frequencies which appear in the unmodulated pulse transmission. Whilst a delay network is shown in one path, it will be understood that a differential delay equal to the pulse repetition period between the two paths should be obtained in practice. The output of the filter shown in Figure 5 is fed to a rectifying unit as in Figure 2 or 4.

Suitable variable-bandwidth filters VF

Figure 7 shows the schematic diagram of a filter which provides a single passband controllable by means of grid-bias to valves comprised in the filter. This filter is in principle an amplifier designed to pass the maximum band which may be occupied by the signal, with the following additions:

1. The amplifier is provided with a large amount of aperiodic reverse feedback, by means of cathode resistances R_{10} and R_{20}.

2. The amplifier is provided with selective positive feedback by the coupling links CL1 and CL2 between TC4 to TC2 and TC5 to TC3 respectively.

Grid bias control for the valves is supplied from the output of R (Figure 1) as described and indicated at BC in Figure 7.

For small values of grid-bias, the amounts of positive and negative feedback are adjusted, by adjusting R_{10} and R_{20}, to give a single but stable narrow response band. Application of bias, of course, removes feedback causing the filter-amplifier to give a broader response up to the maximum bandwidth as determined by the tuned circuits TC1—TC6 without feedback.

Figure 8 shows one form of variable filter especially suitable for a pulse transmission. This variable filter is essentially a broad-band amplifier in which a considerable amount of aperiodic reverse feedback is applied, plus a further feedback loop containing a delay network DN2. Owing to the rotation of phase with frequency in the delay network DN2, this feedback loop provides a feedback which alternates from positive to negative a number of times over the pass-band of the amplifier. When the valves of the amplifier are working at minimum grid-bias and maximum gain, the overall response characteristic is a spectrum of very narrow pass-bands equally spaced at frequency intervals equal to the repetition frequency of the pulse train to be received.

Under the control of bias obtained from R (Figure 1) and applied to BC, which cuts down valve gain and hence removes feedback, the filter-amplifier pass bands may be expanded until, if required, no gaps are left in the overall response curve.

In the filter amplifier of Figure 8, the reverse feedback is applied separately on each stage of the amplifier by using "inverted" amplifiers; that is, grids are grounded, and inputs are applied to the cathode. The delay network DN2 is comprised of a number of tuned circuits coupled together to provide a broad pass-band, and a transit time or delay equal to the pulse repetition period.

What is claimed is:

1. Receiving apparatus for the reception of frequency modulated electromagnetic waves and having a single variable frequency bandpass control comprising an amplifier having positive and negative feedback paths in each stage, means for producing a voltage responsive to the depth of modulation of the received waves, and means to apply said voltage to vary automatically the amount of the negative feedback in said amplifier.

2. Receiving apparatus, as claimed in claim 1, wherein said reversed feedback is obtained by means of a resistance in the cathode grid circuit of each stage, and said voltage is applied to vary the grid bias of said stages.

3. Receiving apparatus for the reception of trains of modulated electrical pulses comprising an amplifier having a negative feedback path in each stage and a feedback path connecting the output to the input of the amplifier, said stages operating as inverted amplifier stages, with the control grids thereof earthed and the inputs applied to the cathodes, but with the control bias voltage applied to said grids, and said feedback path connecting the output to the input of the amplifier providing a broad passband of frequencies and having a delay equal to the repetition period of the received pulses, and means for producing a voltage responsive to the depth of modulation of the received pulses, said voltage being applied to vary automatically the amount of the negative feedback in said amplifier.

4. Receiving apparatus for reception of frequency modulated waves comprising an amplifier having a variable width band pass characteristic, means to vary the band width of said amplifier, means for producing a voltage responsive to the depth of frequency modulation of the received waves comprising a slot filter and rectifier, said slot filter comprising a bridged-T network arranged to reject the unmodulated carrier frequency, a further network to which the output of said network is fed, said further network being tuned approximately to the side bands of the received waves, the output of said further network being fed to said rectifier, a resistance in the output of said rectifier across which a control voltage is obtained, and means to apply said control voltage to vary the band width of said amplifier.

5. Receiving apparatus, as claimed in claim 4, wherein said bridged-T network feeds into two tuned circuits, one tuned slightly above and the other slightly below the unmodulated carrier frequency, said tuned circuits feeding respective rectifiers, the outputs of which are fed to a common resistance from which the desired control voltage is obtained.

6. Receiving apparatus for the reception of time modulated electrical pulses comprising a variable width band pass filter, means for producing an intermediate frequency voltage responsive to the depth of modulation, means for applying said voltage to said filter to vary the width of its band pass characteristic to control the frequency band width of the receiver, wherein said means for producing a voltage responsive to the depth of modulation of the received pulses comprises a slot filter of the comb-type having multiple response frequency bands and a rectifier, said slot filter comprising two electrical paths in parallel, having a differential delay equal to the unmodulated pulse repetition frequency and having equal attenuations, means for feeding the outputs of said paths to said rectifier, and a resistance across which the desired control voltage is obtained and into which the rectifier feeds.

7. Receiving apparatus for the reception of electromagnetic radio frequency waves modulated in such manner as to vary the transmitted frequency band width comprising means for producing an intermediate frequency voltage varying according to depth of frequency modulation, means for converting the intermediate frequency voltage into audio frequency voltage, a filter between said means for producing and means for converting, and means for applying part of the intermediate frequency voltage to control the frequency band width of said filter, the last mentioned means comprises a second filter connected between the means for converting and said filter.

CHARLES WILLIAM EARP.

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