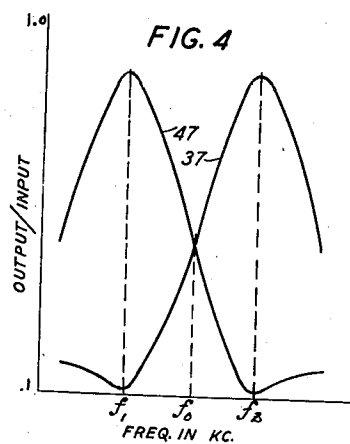
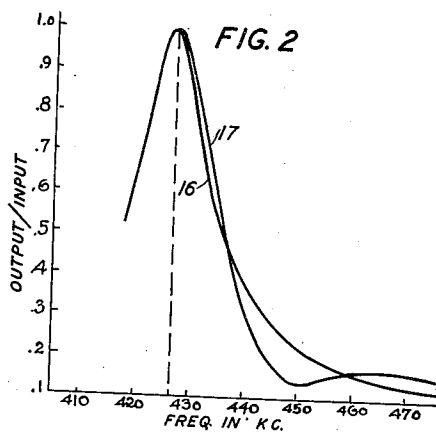
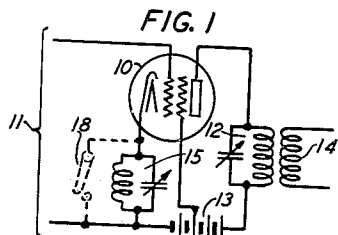


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FREQUENCY MODULATION RECEIVER

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FREQUENCY MODULATION RECEIVER

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This invention relates to receivers for frequency modulation systems and particularly to demodulation and conversion circuits therefor.

An object of the present invention is to provide efficient, accurate and undistorted detection of frequency modulated waves.

In one method of detecting or demodulating frequency modulated waves to obtain the modulating signal waves, the frequency modulations are first converted to amplitude modulations from which the signal may be obtained by rectification or the like. This conversion process may be accomplished by impressing the frequency modulated waves on a so-called "slope circuit," that is, a circuit having an impedance which varies with frequency. For the efficient, accurate and undistorted operation of said circuits several characteristics are necessary. Among these are the following: First, the impedance at one limit of the frequency swing should be low and substantially zero to provide for efficient conversion; second, the variation of impedance must be substantially linear throughout the complete range of frequency variation to give an accurate reproduction of the modulation; third, the impedance of the circuit should fall off rapidly beyond the other limit of the frequency variation so that harmonic effects will be discriminated against.

Two types of circuit which have been found very useful as slope circuits for such purpose are the series and shunt resonant circuits. When such circuits are used in an amplifier the gain thereof will vary with frequency in accordance with the impedance characteristic of the circuit. Of these two types both have certain advantages and disadvantages. Thus, the series resonant circuit will in general be found to have a linear characteristic over a wider frequency range than the shunt of antiresonant type. On the other hand, in its practical forms, this circuit has a comparatively low impedance in the range of best linearity so that it cannot advantageously be used with vacuum tube amplifiers. Also the impedance tends to increase beyond the upper limit so that harmonics are accentuated rather than discriminated against. Shunt resonant circuits on the other hand have comparatively high impedance in the range of good linearity which makes them readily adapted for use with vacuum tube amplifiers. In addition the increase in impedance is abruptly interrupted at or near the resonant point so that they afford good discrimination against harmonics. However, the range of linearity is com-

paratively limited and particularly departures from linearity occur in the region of low impedance, where it is desirable that the circuit be worked for one limit of the frequency swing in order that the resultant amplitude variations will represent full modulation and efficient conversion be attained.

A further object of the present invention is to overcome this disadvantage of shunt resonant circuits in their use for conversion in frequency modulation receivers.

In accordance with a feature of this invention there is provided for converting frequency modulation to amplitude modulation, a circuit including an amplifier, a shunt resonant circuit tuned to a frequency at or near one limit of the frequency swing of the frequency modulations and a negative feedback path for the amplifier having such an impedance characteristic that the linearity of the over-all characteristic of the circuit is increased and the impedance thereof made low in the region of the other frequency limit. More specifically the negative feedback path comprises a second shunt resonant circuit connected in a portion of the cathode path common to both the grid and plate circuits and tuned to a frequency at or near the limit of the frequency swing, opposite to the limit at which the first circuit is resonant.

These and other objects and features of the invention may be more readily understood by reference to the following description of the drawing in which:

Fig. 1 is a schematic circuit diagram of a conversion circuit of the present invention;

Fig. 2 is a graph illustrating the operation of the circuit of Fig. 1;

Fig. 3 is a schematic circuit diagram of a frequency modulation radio receiver embodying the invention; and

Fig. 4 is a graph illustrating the operation of the circuit of Fig. 3.

Fig. 1 shows one embodiment of the invention in a conversion or slope circuit for frequency modulated waves. This circuit comprises a vacuum tube 10. The input frequency modulated waves are supplied to the grid circuit of this tube at the input terminals 11. The plate circuit includes a shunt resonant circuit 12 connected in series with the plate battery 13 between the anode and cathode. The output amplitude modulated waves are taken off the secondary winding 14 coupled to the inductance of the circuit 12. In the cathode path of the tube there is connected a second shunt circuit 15. This circuit

15 is common to both the plate and grid circuits and therefore provides a negative feedback path.

The operation of this circuit can be readily understood by reference to Fig. 2 which is a graph of the frequency-gain characteristic of the circuit. Curve 16 shows the characteristic with only the resonant circuit 12 operative, the circuit 15 being short-circuited by means of a switch 18.

An examination of this curve (16) will show that the portion of the frequency range over which the gain variation is linear is relatively limited and particularly that at the range of lower gains the departures from linearity are very marked.

Curve 17 shows the characteristics of the complete circuit (switch 18 open). The over-all characteristics as shown by curve 17 will be observed to give a gain variation with frequency which is much more linear than that of curve 16 and further that it goes to a very low value of gain within the range of substantially linear variation.

In the circuit on which the data for the curves of Fig. 2 were taken the circuit 12 was tuned to 427 kilocycles employing an inductive coil of 500 microhenries and a condenser of 260 micro-microfarads, the value for the Q of the circuit or the ratio of reactance to resistance being 110 and the circuit 15 was tuned to 450 kilocycles employing an inductance coil of 13 microhenries and a condenser of .0104 microfarad, the value of Q being 52.

These circuit constants and the resultant characteristics are given as one typical example of what may be accomplished with the circuit of this invention. As will clearly appear to one skilled in the art, the various circuit constants both as to their absolute and relative values may be varied to meet the design requirements in any particular application of the invention.

Fig. 3 shows schematically a frequency modulation radio receiver of the push-pull type employing the conversion circuit of this invention. In this circuit the frequency modulated waves received in the antenna 21 are supplied to the input of a first detector 22 to which are also supplied oscillations from a beating oscillator 23. The intermediate frequency output of the detector 22 is supplied to an intermediate frequency amplifier 24 for selective amplification and then to an amplitude limiter 25. The foregoing portion of the receiver is of course conventional in its arrangement and is therefore shown in block schematic.

The output of the limiter 25 is supplied to a push-pull or balanced conversion circuit 26 each half of which employs a conversion circuit of the type shown in Fig. 1.

As is well understood in the art the operation of a push-pull converter and detector for frequency modulated waves is achieved by the use of two slope circuits one having an impedance or gain characteristic which decreases with frequency in the range of the frequency swing and the other having the reverse slope, that is, a gain or impedance increasing with frequency. The two curves should cross at the mean or carrier frequency. When the outputs of such circuits are combined in phase opposition the resultant will be zero for inputs of the main carrier frequency. However, since the envelopes of the modified waves from the two conversion circuits vary in opposite senses and the combination is produced

in phase opposition the resultant components will be additive at other frequencies.

One converter path comprises a vacuum tube amplifier 30 having a shunt resonant circuit 32 connected in its plate circuit and a second shunt resonant circuit 35 connected in the cathode path common to both the plate and grid circuits. A resistor-condenser circuit 39 is also connected in this cathode path for providing a grid biasing voltage.

The other converter path is similarly arranged including the amplifier tube 40, the shunt resonant circuits 42 and 45 and the biasing network 49. Plate current and screen grid bias for both tubes 30 and 40 are supplied from the battery 27.

The output of the two paths are taken off through the secondary coils 34 and 44 coupled to the inductance elements of the respective resonant circuits 32 and 42. These outputs are supplied to the respective diode detectors 33 and 43 and the resultant signal voltages developed across the load resistors 38 and 48 are combined in phase opposition in the signal output circuit 28.

Fig. 4 is a graph showing the operating characteristics of the two converter paths comprised by the amplifiers 30 and 40 and their respective circuits. In this figure, frequency is plotted against the ratio of output to input, that is, gain. f_0 is the frequency of the intermediate frequency carrier and f_1 and f_2 the limits of the frequency swing. The curve 37 shows the characteristic of the amplifier 30 and the curve 47 that of amplifier 40. To obtain such characteristics the circuit 32 is tuned to the frequency f_2 and circuit 35 is tuned to the frequency f_1 . Similar circuits 42 and 45 are tuned to the frequencies f_1 and f_2 , respectively.

What is claimed is:

1. A converter circuit for a receiver of frequency modulated waves comprising an amplifier having input and output circuits, a tuned circuit in one of said circuits, and a feedback path for said amplifier having such an impedance characteristic as to cooperate with the impedance characteristic of said tuned circuit to produce an overall gain for said amplifier that varies linearly with frequency from substantially zero to a high gain across the range of the frequency swing of said frequency modulated wave.

2. A converter circuit according to claim 1 in which the feedback path includes a second tuned circuit resonant at a frequency different from the resonant frequency of the first tuned circuit.

3. A converter circuit for a receiver of frequency modulated waves comprising an amplifier having input and output circuits and a third circuit common to said input and output circuits, a first tuned circuit connected in said output circuit, and a second tuned circuit connected in the common circuit, the resonant frequencies of said tuned circuits being of the order of the respective limiting frequencies of the frequency swing of said frequency modulated wave whereby the over-all characteristic of said amplifier is linearly proportional to frequency over the range of said frequency swing.

4. A converter circuit for a receiver of frequency modulated waves comprising an amplifier having input and output circuits and a third circuit common to said input and output circuits, a shunt type resonant circuit included in said output circuit and tuned to a frequency of the

order of one limiting frequency of the frequency swing of the modulated wave, and a second shunt type resonant circuit included in said third circuit and tuned to a frequency of the order of the other limiting frequency of said frequency swing.

5. A receiver for frequency modulated waves comprising two amplifiers each having an input circuit, an output circuit and a third circuit common to said input and output circuits, a shunt type resonant circuit included in the output circuit of one of said amplifiers, and tuned to a frequency of the order of one limiting frequency of the frequency swing of said modulated waves, a second shunt type resonant circuit included in the said third circuit of said one of said amplifiers and tuned to a frequency of the order of the second limiting frequency of said frequency

swing, a third shunt type resonant circuit included in the output circuit of the other of said amplifiers and tuned to a frequency of the order of said second frequency limit, a fourth shunt type resonant circuit included in the said third circuit of said other amplifier and tuned to a frequency of the order of said one limiting frequency, means for supplying the received frequency modulated waves to the input circuits of said amplifiers in parallel, and means for combining in phase opposition the outputs from said amplifiers.

6. A radio receiver according to claim 5 in which the last-mentioned means comprises means for rectifying the outputs from each of said amplifiers and combining the rectified components in phase opposition.

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