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RADIO REPEATER

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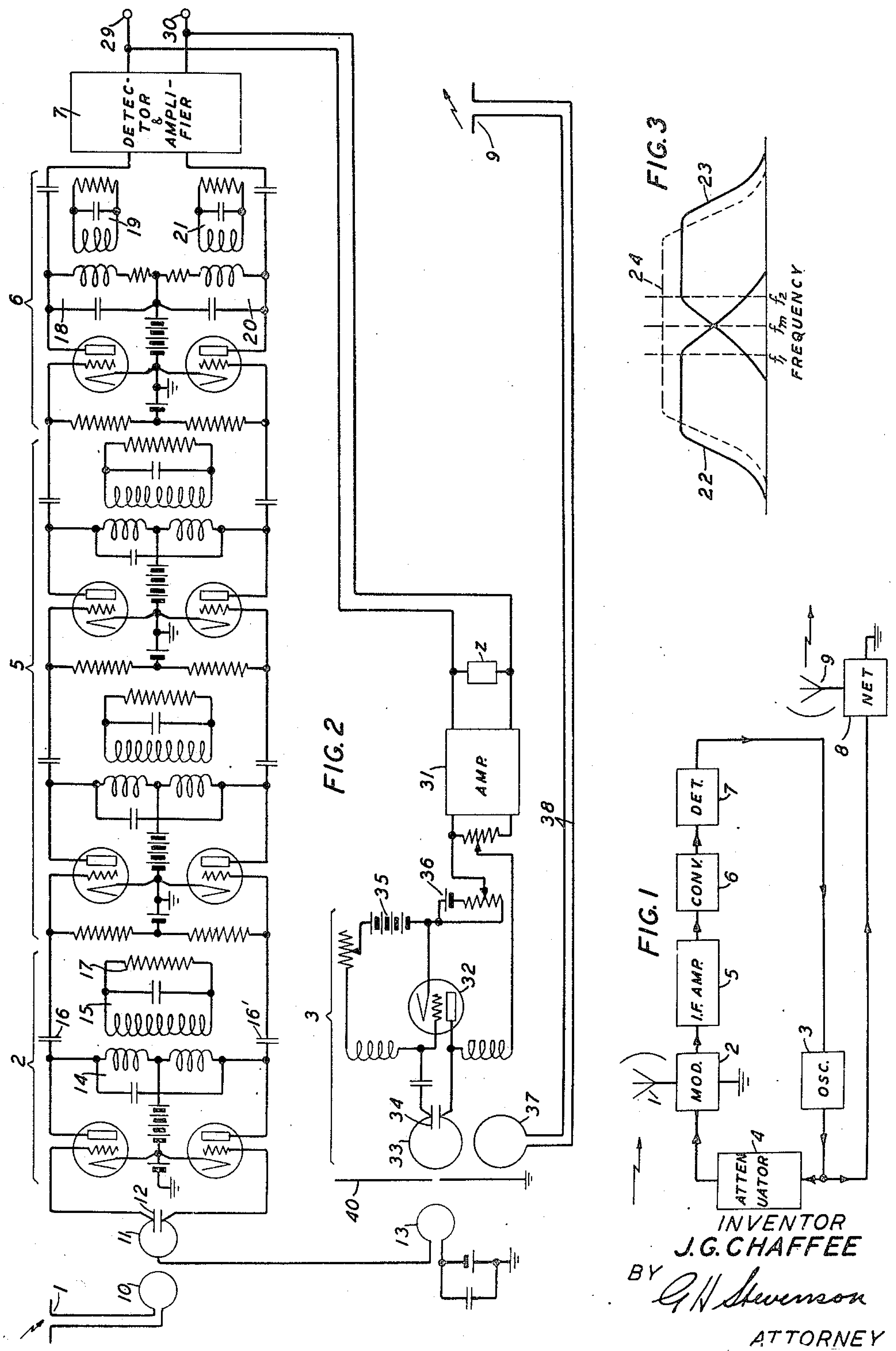

INVENTOR
J. G. CHAFFEE
BY G. H. Stevenson
ATTORNEY

UNITED STATES PATENT OFFICE

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RADIO REPEATER

Joseph G. Chaffee, Hackensack, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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4 Claims. (Cl. 250—15)

This invention relates to radio telephone repeaters and more particularly to repeaters for frequency modulated waves of ultra-high frequencies.

An object of the invention is the reduction of signal distortion and noise producing disturbances in repeaters for frequency modulated waves. Another object is to facilitate the energy amplification of signal modulated carriers in ultra-high frequency repeaters.

At frequencies greater than 100 megacycles per second the present limitation of vacuum tube constructions make it difficult to secure any substantial amount of amplification and large power output without recourse to the use of a very large number of amplifier stages. Furthermore, the noise and signal distortion generated in the multiplicity of stages and coupling networks results in a serious deterioration of the signal transmission. This is particularly true in the case of frequency modulated waves.

In accordance with the invention, the amplification of the received energy is effected at a greatly reduced frequency and the amplified low frequency energy is transformed to frequency modulated high frequency energy at a level sufficiently high for retransmission without further amplification. An important feature of the invention is the use of reverse feedback in the system for the purpose of decreasing noise and signal distortion.

The nature and the operation of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing, of which:

Fig. 1 is a functional schematic of a repeater in accordance with the invention;

Fig. 2 shows the detailed circuit arrangements of the repeater in Fig. 1; and

Fig. 3 is illustrative of certain characteristics of the repeater system.

The principal features of a radio repeater embodying the invention are illustrated by the block schematic of Fig. 1 which shows the basic elements of the system and their interconnections. Frequency modulated waves received upon an antenna 1 are transmitted to a heterodyne modulator 2, to which is also coupled a local oscillator 3 through an attenuating device 4. Currents of the difference frequency are selected from the output of detector 2 and are amplified in an intermediate frequency amplifier 5. The amplified currents are then impressed upon converter circuit 6, which may comprise two filters with crossed linear characteristics, whereby amplitude modulation is provided corresponding to the frequency modulations of the received wave. Signal frequency currents are detected from the amplitude modulated waves by means of detector 7 which may include filtering means for removing the high frequency pulsations.

The detected signal currents are applied to the local oscillator 3 to modulate the frequency of the currents generated therein. This oscillator may be of the Barkhausen type, in which case frequency modulation is readily effected by superimposing the signal oscillations upon the anode voltage of the oscillator vacuum tube. The oscillator is designed and constructed to provide sufficient output power for retransmission of the signal and for this purpose its output circuit is connected through a suitable coupling network 8 to a transmitting antenna 9. Antennae 1 and 9 are preferably directive in opposite directions to avoid external feedback coupling. Their directive character is indicated by the reflectors shown associated therewith.

The action of the feedback around the receiving portion of the receiver is to hold the mean frequency of the local oscillator to a steady value differing from that of the incoming waves by an amount determined by the crossed characteristics of the filters in converter 6 and also to reduce the frequency swing of the intermediate frequency currents to an extent dependent upon the strength of the feedback. The output frequency of oscillator 3 and the frequency swing of its modulation are therefore both slightly different from those of the incoming waves, but with fairly strong feedback the change in the extent of the frequency modulation is not material.

At the same time the feedback operates to effect a substantial reduction of noise disturbances and signal distortion originating in the receiving circuit so that the retransmitted wave is substantially free from signal deterioration from these causes.

In the above respects the receiving portion of the repeater is similar to the receiver for frequency modulated waves described in my U. S. Patent 2,075,503, issued March 30, 1937, wherein the action of the feedback circuit in reducing the frequency modulation and diminishing the effects of distortion and noise producing disturbances are explained. It is contemplated that the received waves may have a maximum modulation swing of the order of plus or minus 100,000 cycles per second and that sufficient feedback may be employed to reduce the modulation swing of the intermediate frequency currents to about 10,000 cycles or less per second.

The circuit configuration of the repeater shown schematically in Fig. 1 is illustrated in greater detail in Fig 2. The receiving antenna 1, which is shown as a simple dipole, is connected through a high frequency line to a coil 10 which in turn is coupled to a tuned circuit in the input of modulator 2 comprising coil 11 and condenser 12. A tap at the midpoint of coil 11 connects to a pick-up loop 13 coupled to the output of the local oscillator 3. Modulator 2 comprises two triodes arranged as a duplex demodulator, the received waves being impressed on the grids of the two tubes in series and the heterodyne oscillations upon the two grids in parallel. The output of the modulator is coupled to the input of intermediate frequency amplifier 5 through a band selective network comprising series blocking condensers 16, 16′ and a composite shunt impedance comprising coupled tuned circuits 14 and 15 and resistance 17. The two tuned circuits are each tuned to be anti-resonant at the intermediate frequency and are coupled sufficiently closely to provide a band-pass selective characteristic for transmission to resistance 17. By proper adjustment of the value of resistance 17, the impedance that the combination presents to the detector output terminals can be made large and uniform in the desired transmission band and low outside the band. The selective shunt impedance provides band selective transmission from the detector to the input of intermediate frequency amplifier similar in character to that provided by a double tuned transformer coupling. It has the advantage over the transformer coupling that the phase shift produced is smaller and is limited to a maximum of plus or minus 90 degrees. The capacities of blocking condensers 16 and 16′ are large enough so that their impedances are negligibly small at all frequencies of interest. Other forms of band selective shunt impedances may be used, for example, the impedance provided by a mid-shunt terminated band-pass filter with a suitable resistance connected to its remote terminals.

The intermediate frequency amplifier 5 comprises two push-pull amplifier stages each having a selective output circuit similar to that of the modulator. The modulation converter 6 consists of a push-pull amplifier stage provided with selective output circuits by means of which the amplitude modulation is introduced. The desired conversion characteristic is provided by the composite shunt impedances 18, 19 and 20, 21. These circuits have band selective characteristics but are so proportioned that the frequency range of the transmitted currents lies on the upper cut-off region of circuit 18, 19 and on the lower cut-off region of circuit 20, 21. By means of the resistances included in each secondary circuit, the slopes of the two cut-off characteristics are made linear over the frequency range of the modulation of the intermediate frequency currents. The two impedances are also proportioned so that their respective cut-off characteristics cross at the normal intermediate frequency and at the midpoints of their linear ranges.

The selective characteristics of the converter and of the intermediate frequency amplifier are indicated by the curves of Fig. 3 wherein curve 22 represents the response characteristic of circuit 18, 19, curve 23 the response characteristic of circuit 20, 21, and dotted line 24 the response of the intermediate frequency amplifier. The mean frequency of the modulated wave is designated f_m and lies at the crossing point of curves 22 and 23. The modulation swing covers the range from f_1 to f_2 corresponding to the linear cut-off ranges of the two circuits. The band width of the intermediate frequency amplifier response is considerably greater than the frequency range of the modulation. This feature and the use of band selective converter circuits have been found to assist in the diminution of the effective phase shift in the complete feedback loop.

Detector 7 may be of any type suitable for detecting signals from amplitude modulated waves, but its circuits should be such as to provide for the detection and transmission of signal currents of all frequencies down to and including zero frequency. The circuit shown in my above-noted U. S. Patent 2,075,503 is suitable for this purpose. The provision for detecting and feeding back current variations down to zero frequency permits the automatic control and stabilization of the mean intermediate frequency by the action of the feedback. A signal amplifier may also be included, if desired, as part of detector 7. This also should provide for the transmission of zero frequency currents for frequency stabilization.

From the output terminals 29 and 30 of the signal detector a feedback path extends to a direct current and signal amplifier 31 and thence through an adjustable potentiometer to the anode circuit of the vacuum tube in oscillators 3. A monitoring circuit may be connected to terminals 29 and 30, if desired.

Oscillator 3 is of the Barkhausen type. It comprises a triode vacuum tube 32, to the grid and plate of which is connected an oscillating circuit consisting of an inductance 33 and a capacity 34. The grid of the vacuum tube has impressed on it a high positive direct current voltage from battery 35 and the anode is polarized to a much lower voltage by battery 36 and an adjustable potentiometer associated therewith. Choke coils and blocking condensers confine the high frequency currents and the bias voltages to their proper paths. The signal output of amplifier 31 is superimposed upon the normal bias of the oscillator anode and, in accordance with the well-known properties of the Barkhausen type of oscillator, produces proportional variations of the oscillator frequency. The oscillator coil 33 is coupled to a secondary coil 37 through which the output energy of the oscillator is transmitted to line 38 and outgoing antenna 9.

Another type of oscillator which is well suited to the purposes of the invention, and which has the advantage of giving an output wave substantially free from amplitude modulation, is disclosed in the copending patent application of O. E. DeLange, Serial No. 195,501, filed March 12, 1938.

Since oscillator 3 generates oscillations of large power, it is necessary to provide a large attenuation in the coupling to the input of demodulator 2. In the figure, an apertured shield 40 is shown located between the oscillator coil and the pick-up coil 13. The extent of the shielding and the size of the aperture may be arranged to provide an adequate amount of coupling. Other well-known types of attenuator may, of course, be used, for example resistance or capacity attenuation may be included in the line between coil 13 and coil 11.

A shunt impedance Z of general configuration is shown connected in the signal portion of the feedback path at the input of signal amplifier 31. The purpose of this impedance is to control the cut-off characteristic of the feedback circuit so that an optimum amount of feedback consistent with stability against singing of the system may be used. Shaping of the cut-off characteristic may also be effected by means of the coupling circuits in amplifier 31. The principles underlying the control of the cut-off characteristic and the design of suitable impedance networks for effecting the desired control are explained in the copending application of H. W. Bode, Serial No. 149,565, filed June 22, 1937, Patent No. 2,123,178 to which reference is made.

The various vacuum tubes in the circuit of Fig. 2 are shown as triodes. It will be understood, however, that other types of tubes, such as screen-grid tetrodes and pentodes, may also be used and that other modifications of the circuit may be made without departing from the invention as defined by the appended claims.

What is claimed is:

1. The method of repeating a wave modulated in frequency in accordance with signals which comprises modulating the received wave with a heterodyne wave, selecting a frequency modulated component from the resulting wave, deriving currents representing the signal from said selected wave, modulating the frequency of said heterodyne wave in accordance with said signal currents in such sense as to reduce the frequency variation of said selected component, and transmitting a portion of said modulated heterodyne wave.

2. A repeater for frequency modulated waves comprising a source of heterodyne waves, modulating means for combining received frequency modulated waves with waves from said source, means for deriving signal currents from the resultant wave produced by said combining means, means for modulating the frequency of said heterodyne wave source in accordance with said derived signal currents and an output circuit coupled to said heterodyne source for retransmitting said frequency modulated heterodyne waves.

3. A radio repeater for frequency modulated waves comprising a transmitting antenna, an oscillation generator coupled thereto, a receiving antenna, a receiver coupled thereto, said receiver comprising a heterodyne demodulator, an intermediate frequency circuit selective to currents of the difference of the frequencies of the received wave and the heterodyne wave, a conversion circuit for producing amplitude modulation of the intermediate frequency currents in accordance with the frequency modulations thereof, and a signal detector, a circuit for impressing the signal voltages from said detector upon said oscillation generator to modulate the frequency thereof and a circuit coupling said heterodyne demodulator and said oscillator for supplying frequency modulated heterodyne waves.

4. In a radio repeater for frequency modulated waves comprising a transmitting oscillator coupled to a transmitting antenna and a heterodyne receiver coupled to a receiving antenna, the method of operation which comprises beating received frequency modulated waves with oscillations from said generator, selecting currents of the difference frequency, producing amplitude modulations of the difference frequency currents, detecting currents of the modulation frequencies from the amplitude modulated currents, and modulating the frequency of the oscillations from said generator in accordance with the detected currents in such sense as to reduce the frequency modulation of the selected intermediate frequency currents.

JOSEPH G. CHAFFEE.