

April 7, 1942.

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2,279,177

SUPERHETERODYNE RECEIVING SYSTEM

Filed June 26, 1940

2 Sheets-Sheet 1

FIG. 1.

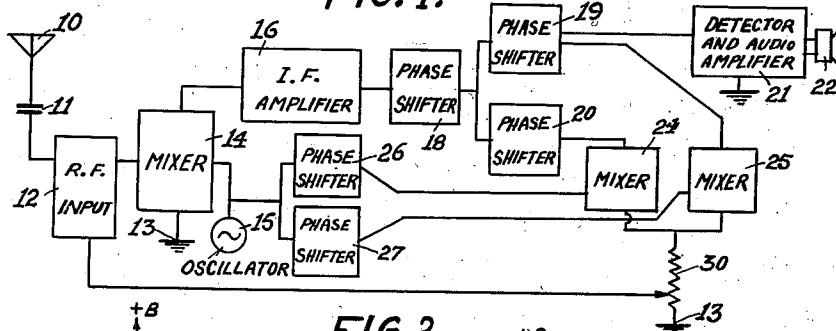


FIG. 2.

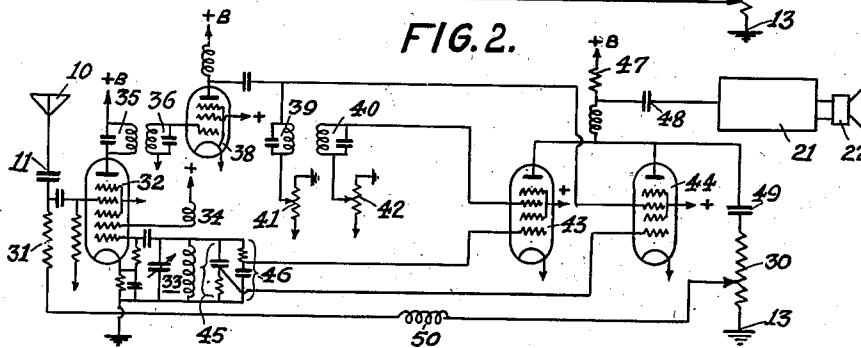


FIG. 3.

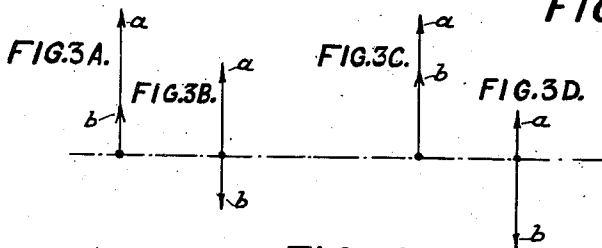
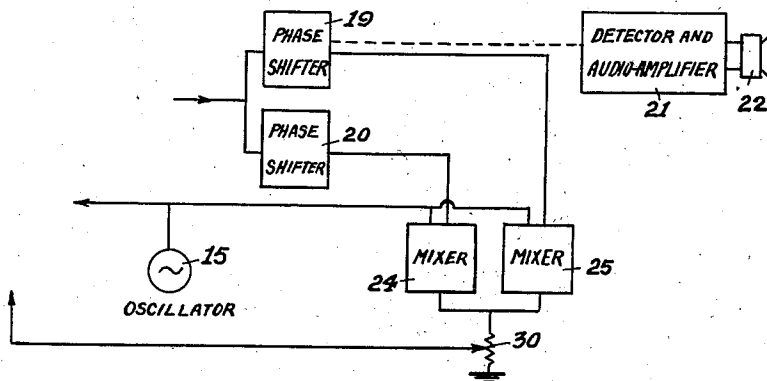


FIG. 4.



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2 Sheets-Sheet 2

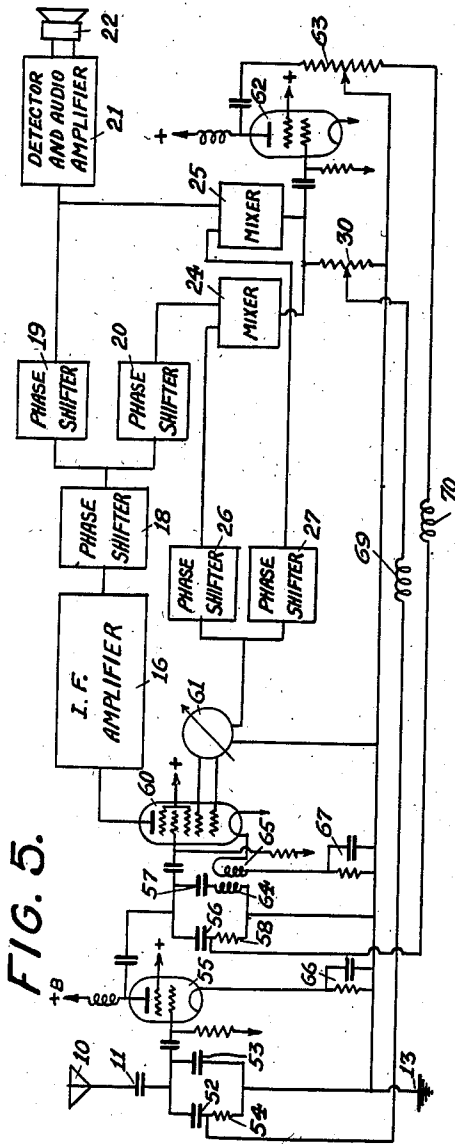


FIG. 5.

FIG. 6A.

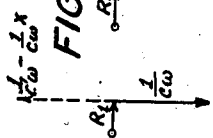
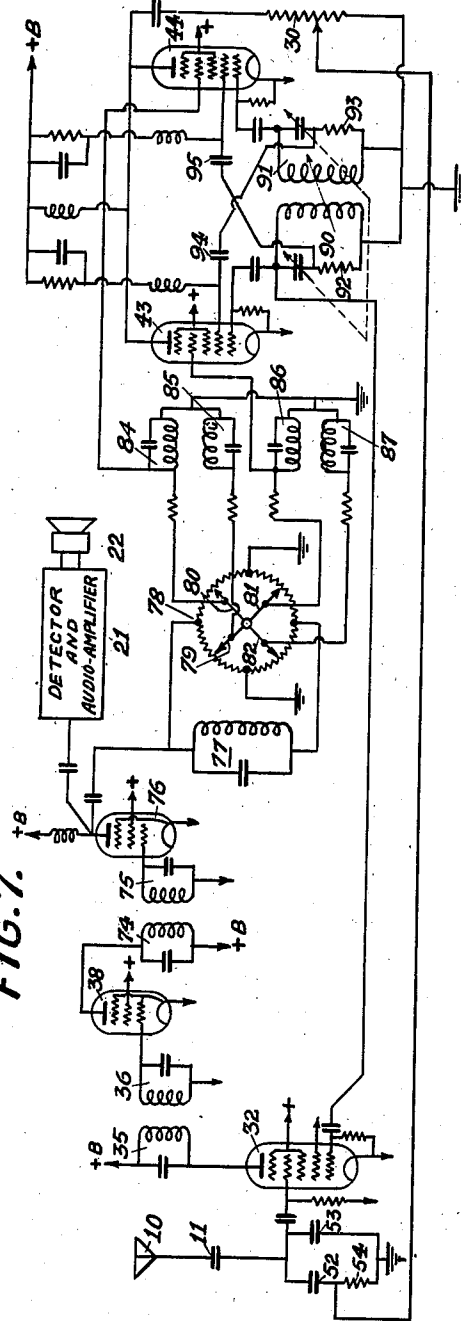


FIG. 6B.

FIG. 7.



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SUPERHETERODYNE RECEIVING SYSTEM

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Application June 26, 1940, Serial No. 342,508
In Germany December 4, 1939

12 Claims. (Cl. 250—20)

The present invention relates to electric amplifiers and a method of operating the same, more particularly amplifiers of the superheterodyne type as used in radio receivers and the like, wherein an incoming signal wave is combined with a locally generated oscillation to produce an intermediate or beat frequency signal of fixed frequency impressed upon an intermediate frequency amplifier designed for efficiently and selectively amplifying the intermediate frequency signal.

An object of the invention is the provision of a system for and method of eliminating the so-called image frequency interference inherent in superheterodyne amplifiers of the type aforementioned.

Another object is the provision of an image frequency rejecting system in a superheterodyne radio receiver which is substantially equally effective for all frequencies within a given operating range for which the receiver has been designed.

A further object is the provision of an image frequency rejecting system for superheterodyne receivers which is equally and automatically effective over the entire operating frequency range of the receiver thereby making it possible to completely dispense with a radio frequency amplifier preceding the first detector frequency changer stage of the receiver or to considerably limit the number of pre-selection stages.

Another object is the provision of a superheterodyne receiver in which an R. F. amplifier is dispensed with and the selectivity of the receiver is afforded solely by the characteristics of the intermediate frequency amplifier.

Another object is to provide a superheterodyne receiver characterized by high selectivity to eliminate the image frequency interference by automatic tuning of the incoming high frequency signal simultaneously with the adjustment of the local oscillating frequency.

Another object is the provision of a superheterodyne receiver of high selectivity including suppression of the image frequency and tunable solely by adjusting the local oscillating signal.

The above and further objects and aspects of the invention will become more apparent from the following detailed description taken with reference to the accompanying drawings forming part of the specification and wherein:

Figure 1 is a block diagram illustrating a basic receiving system embodying the principle of the invention.

Figure 2 is a circuit diagram of a receiver of the type according to Figure 1.

Figures 3A to 3B are vector diagrams illustrative of the function of the invention.

Figure 4 is a partial block diagram illustrating

ing a modification of a superheterodyne receiver shown in the preceding figures.

Figure 5 is a circuit diagram partly in block diagram form showing an embodiment of the invention to effect automatic tuning of the R. F. input signal in a superheterodyne receiver.

Figures 6A and 6B are vector diagrams illustrative of the function of Figure 5, and

Figure 7 is a circuit diagram similar to Figure 5 embodying features of improvement in accordance with the invention.

Like reference characters identify like parts throughout the different views of the drawings.

With the aforementioned objects in view, the invention contemplates the provision of means for producing potentials of both signal and image frequency from a portion of the intermediate frequency energy of the receiver and feeding back these potentials to a point of the high frequency (R. F.) input circuit preceding the first detector or mixer stage of the receiver. Further means are provided and the feedback circuit is so designed and adjusted that the signal and image frequency feedback potentials react upon the respective input signal potentials in such a manner as to relatively weaken or completely eliminate the image frequency substantially without selective amplification preceding the first mixer or frequency changer required in the case of superheterodyne receivers known in the prior art.

According to one modification, the feedback potentials at signal and image frequency, respectively, are rendered unequal and fed back in negative phase relation to react upon the respective input signals in such a manner that the inverse feed back for the image frequency is a multiple of the feedback for the signal frequency, resulting in a substantial attenuation or complete suppression of the image frequency. Alternatively the arrangement and adjustment of the system may be such that a positive feedback results for the signal frequency and a negative feedback for the image frequency which in turn will result in a substantial attenuation or complete suppression of the image frequency interference.

According to another modification of the invention, the phase of the feedback potentials is adjusted in such a manner as to cause a substantial reactive component to be superimposed upon the signal input frequency resulting in an automatic tuning effect for the signal frequency in the input circuit and consequent attenuation of the image frequency in substantially the same manner as if one or more selective high frequency amplifying stages were provided preceding the first detector or frequency changer stage in a standard superheterodyne receiver.

As is well known, if an incoming frequency wave having a frequency w in radians per sec-

ond is combined with a locally produced signal having a frequency w_2 by means of a modulator or mixer of known type, an intermediate or beat frequency signal is obtained having a frequency w_1 equal to the difference between the incoming and local oscillations; i. e. $w_1 = w_2 - w$. If a further signal having a frequency w_3 equal to $w_2 + w_1$ is simultaneously received it will mix with the heterodyne frequency w_2 and produce the same intermediate frequency thereby causing interference with the desired signal.

According to known methods this interfering signal also known as image frequency due to its location relative to the signal frequency, like an object relative to its image upon opposite sides of the local frequency, is attenuated before it reaches the first detector or mixer stage in the receiver. In order to sufficiently attenuate an image frequency signal, two or more pre-selector stages are usually required involving the use of at least two tuned circuits with the attendant difficulties of ganging and tracking the circuits and making it further desirable to choose an intermediate frequency as high as possible. The latter requirement has the disadvantage of greatly reducing the selectivity of the circuit.

By the present invention the above disadvantage is substantially overcome and elimination of the image frequency interference is insured in a most efficient and simple manner without substantially impairing the efficiency and selectivity and other desirable characteristics of the receiver. In particular it is possible by the employment of the invention to provide substantially aperiodic or automatically tuned input circuits and to use a low intermediate frequency thereby in turn increasing the selectivity and greatly simplifying both the design and operation of a superheterodyne receiver.

Referring to the drawings, Figure 1, item 10 represents an antenna coupled to the high potential side of an input circuit 12 through a condenser 11, the low potential side of the circuit 12 being connected to ground 13, in the example shown through a variable portion of a feedback impedance 30 to be described later. The input circuit 12 may consist of a simple impedance such as an induction coil, resistance, a tuned circuit, or an R. F. amplifier comprising one or more aperiodic or tuned stages as will become apparent from the following. The input signals are impressed upon a frequency changer or mixer 14 and combined in the latter with a local oscillation generated by an oscillator 15 to produce an intermediate frequency signal impressed upon an intermediate frequency amplifier 16 for selective amplification in a manner well known in the art. The output signal of the intermediate frequency amplifier is impressed upon a phase shifting device 18 of suitable type and construction and serves to energize a pair of auxiliary frequency changing or mixer devices 24 and 25 by way of further phase shifting arrangements 19 and 20, respectively. An audio frequency amplifier 21 which may include a second detector is suitably connected to the system such as the output of the intermediate frequency amplifier by way of the phase shifting devices 18 and 19. The audio frequency amplifier may serve to energize a suitable translating device such as a loud speaker 22 in the example shown. Alternatively, the audio amplifier may be energized by the combined output of the mixing devices 24 and 25 as shown in Figure 2 in which case a special second detector may be dispensed with. The

mixing devices 24 and 25 are furthermore excited by potentials derived from the local oscillator 15 by way of further phase shifting devices 26 and 27, respectively. The combined output of the mixing devices 24 and 25 is applied to an impedance such as an ohmic resistance 30 serving to produce a feedback potential impressed upon the input circuit 12.

Assuming that the intermediate frequency components applied to the mixing devices 24 and 25 are in phase quadrature by suitably adjusting the phase shifting arrangements 19 and 20 and that furthermore the phases of the local oscillating potentials applied to the mixing devices 24 and 25 are likewise in quadrature by suitably adjusting the phase shifting devices 26 and 27, then the individual outputs of the mixing devices may be expressed mathematically as follows:

1st mixer:

$$K_1 A \sin w_1 t \cdot H \cos w_2 t = -\frac{K_1 A H}{2} \sin (w_2 - w_1) t + \frac{K_1 A H}{2} \sin (w_2 + w_1) t \quad (I)$$

2nd mixer:

$$K_2 A \cos w_1 t \cdot H \sin w_2 t = +\frac{K_2 A H}{2} \sin (w_2 - w_1) t + \frac{K_2 A H}{2} \sin (w_2 + w_1) t \quad (II)$$

For the sake of simplicity, it has been assumed that the modulation in the devices 24 and 25 is substantially linear.

By adding the outputs of the devices 24 and 25, the formula for the feedback potential produced by the impedance 30 will be as follows:

$$F_{b1} = \frac{A H}{2} (K_2 - K_1) \sin (w_2 - w_1) t + \frac{A H}{2} (K_2 + K_1) \sin (w_2 + w_1) t \quad (III)$$

Furthermore by subtracting the outputs of the devices 24 and 25, the formula for the feedback potential will be as follows:

$$F_{b2} = \frac{A H}{2} (K_2 + K_1) \sin (w_2 - w_1) t + \frac{A H}{2} (K_1 - K_2) \sin (w_2 + w_1) t \quad (IV)$$

In the above equation w_1 represents the intermediate frequency in radians per second, w_2 is the local oscillating frequency, A and H are the amplitudes of the intermediate frequency and local oscillating signals, K_1 and K_2 are coefficients depending upon the conversion efficiency of the modulators 24 and 25, respectively, and various other factors and constants of the circuit.

As is understood, under the above circumstances $w_2 - w_1$ represents the desired signal frequency w , and $w_2 + w_1$ represents the image frequency. Thus if the intermediate frequency w_1 is equal to 100 kc. and the local oscillating frequency w_2 is equal to 1000 kc., then the desired signal frequency will be equal to 1000-100=900 kc. and the image frequency will be equal to 1000+100=1100 kc.

If now the relationship for $w_2 + w_1$ (image frequency) is chosen by proper design and adjustment of the circuits in such a manner that the feedback from the impedance 30 to the input circuit 12 is negative, then the image frequency

will be substantially attenuated (see vectors *a*, *b*, Figure 3). In this case the feedback for the desired signal $w_2 - w_1$ may also be negative but to a much lesser degree than the feedback for the image frequency (see Figure 3B) in case that K_2 is larger than K_1 . Alternatively, the feedback for the desired signal may be positive if K_2 is smaller than K_1 (Figure 3D). The feedback for the image frequency may in both cases be negative and alike (Figures 3A and 3C).

A major advantage of an arrangement described hereinabove is the fact that the high frequency input circuit may be substantially aperiodic. A further advantage is the fact that the positive feedback for the desired signal may be adjusted substantially independently of the negative feedback for the image frequency signal. Still a further advantage is due to the fact that the entire tuning process can be effected by adjusting the local oscillating frequency thereby dispensing with the difficulties of tracking and ganging several tuned circuits as employed in superheterodyne receivers at present known in the art.

Referring to Figure 2, there is shown a complete circuit diagram for a system according to Figure 1. In the example illustrated the antenna 10 is connected to the high potential side of an input resistance 31 by way of coupling condenser 11, the low potential side of the resistance 31 being connected to a variable tap of the feedback resistance 30 in the common output circuit of the frequency changer or mixer valves 43 and 44. The high frequency potential developed by the resistance 31 is impressed upon the signal input grid of an electronic frequency changer or mixer valve 32 of the pentagrid or similar type well known in the art by way of a suitable coupling arrangement such as a grid condenser and grid leak resistance as shown. The first and second grids of the valve 32 next to the cathode are connected in a known manner to a suitable oscillating circuit comprising in the example shown a tunable tank circuit 33 coupled to the first grid and cathode and arranged in feedback relation with the circuit of the second positively biased grid through a feedback coil 34 in such a manner as to maintain sustained oscillations in the circuit 33 determined by its tuning adjustment such as a variable condenser in a manner well understood. As is understood, a separate oscillator may be employed and potential at oscillating frequency applied to the first grid of tube 32 in a manner well understood by those skilled in the art. The intermediate frequency signal produced by combination of the input signals with the local oscillation is transmitted to the input of an intermediate frequency amplifier valve 38 by way of a band pass coupling circuit comprising a tuned primary 35 and secondary 36 resonant to the intermediate frequency. The amplifier 38 may be of any known type and comprise several amplifying stages fixedly tuned to the intermediate frequency as is understood. The amplified intermediate frequency signals are impressed upon a band pass filter comprising a tuned primary 39 and tuned secondary 40 on the one hand and to the signal input grid of a further electronic mixer valve 44. The input grid of an additional mixer valve 43 is energized from the output of the band pass filter 39—40 which in the example shown serves as a phase shifting device to effect a quadrature phase shift of the intermediate frequency signal applied to the valve 43. The low frequency sides of the circuits 39

and 40 are connected to variable taps 41 and 42 on the cathode resistors for the valves 43 and 44, respectively.

As is well known, in a tuned band pass filter of the type 39—40 the primary and secondary potentials are in phase quadrature if the circuits are tuned to exact resonance with the impressed frequency and as a result the signal input grids of the mixer valves 43 and 44 will be excited by intermediate frequency potentials in phase quadrature in compliance with Formulae I and II. Similarly, the oscillating grids of the mixers 43 and 44 are excited by quadrature potentials derived from the local oscillator circuit 33 by way of a pair of phase shift circuits 45 and 46, respectively, each comprising a condenser in series with a resistance. The combined output of the valves 43 and 44 is applied by way of coupling impedance 47 and coupling condenser 48 to the audio frequency amplifier 21 thus making it possible to dispense with a second detector. A portion of the combined output is further applied to the feedback impedance 30 by way of coupling condenser 49. Instead of combining intermediate frequency signals at phase quadrature with quadrature local oscillations, any other phase relation between the signals may be employed in such a manner as to cause a substantial attenuation of the image frequency.

In Figure 4 there is shown an arrangement of this type wherein the local oscillating potentials applied to the mixing devices 24 and 25 are in phase while the intermediate frequency signals are in phase quadrature as in the case of Figure 1 and Figure 2. With this modification the outputs of the mixers 24 and 25 are expressed by the following formulae:

1st mixer:

$$K_1 A \sin w_1 t \cdot H \cos w_2 t = -\frac{K_1 A H}{2} \sin (w_2 - w_1) t + \frac{K_1 A H}{2} \sin (w_2 + w_1) t \quad (V)$$

2nd mixer:

$$K_2 A \sin w_1 t \cdot H \sin w_2 t = +\frac{K_2 A H}{2} \cos (w_2 - w_1) t + \frac{K_2 A H}{2} \cos (w_2 + w_1) t \quad (VI)$$

By adding or subtracting these outputs it is found that the desired signal $w_2 - w_1$ will be phase shifted with respect to the image signal $w_2 + w_1$ by 90° . Thus, if the phase of the feedback potential for the desired signal is adjusted so as to result in positive reaction or regeneration the phase of the feedback signal for the image frequency will contain a reactive component, resulting in a substantial attenuation of the image frequency interference.

The employment of a reactive feedback component impressed upon the high frequency input circuit of the receiver if properly chosen or adjusted may serve to effect an automatic tuning for the signal frequency and consequent attenuation of the image frequency in accordance with a further feature of the invention as illustrated in Figure 5. In the latter the input circuit coupled to the antenna comprises a pair of condensers 52 and 53 connected in parallel with at least one of the condensers, in the example shown condenser 52, having a resistance 54 connected in series therewith. This input circuit 52—54 serves to energize the input circuit of a

high frequency amplifying valve 55. The output circuit of the latter is connected to the signal input grid of a mixer valve 60 similar to the valve 32 in Figure 2 by way of a similar coupling network comprising a pair of condensers 56 and 57 in parallel with the condenser 56 having a resistance 58 connected in series therewith. The output of the mixer valve 60 provided with a local oscillator 61 is impressed upon the intermediate frequency amplifier 16 and mixing devices 24 and 25 in substantially the same manner as shown in Figures 1 and 2. The feedback potential from the resistance 30 is applied to the junction between condenser 52 and resistance 54 of the high frequency input circuit.

The potential impressed upon the grid of the high frequency amplifying valve 55 is equal to the voltage drop

$$\frac{i}{wC}$$

developed by the condenser 53, wherein i is the current flowing in the circuit 52—54, C represents the capacity of the condenser 53, and w is the frequency in radians per second of the incoming signal. The feedback potential derived from the resistance 30 will be proportional to

$$\frac{i}{wC^x}$$

wherein x is a factor including all the conversion and amplifying coefficients, provided the conversion and amplification of the entire system is substantially linear.

If the design and adjustment of the input circuit is such that

$$\frac{i}{wC} - \frac{i}{wC'} - \frac{i}{wC^x}$$

wherein C' represents the capacity of the condenser 52, then the current i in the circuit 52—54 may be expressed by the following formula:

$$i = \frac{E \sin wt}{\sqrt{R^2 + \left(\frac{1}{wC} + \frac{1}{wC'} - \frac{1}{wC^x} \right)^2}} \quad (VII)$$

and if

$$\frac{1}{wC} - \frac{1}{wC'} - \frac{1}{wC^x} = 0$$

then the current assumes a value as follows:

$$i = \frac{E \sin wt}{R} \quad (VIII)$$

wherein E is the potential of the signal impressed by the antenna and R is the value of resistance 54. Consequently the potential developed across condenser 53 and impressed upon the grid of amplifier 55 will be as follows:

$$p = \frac{E \sin wt}{R} \cdot \frac{1}{wC} \quad (IX)$$

As is understood, the condensers 52 and 53 may be replaced by inductances of suitable value.

From the foregoing (Formula IX), it is seen that the circuit 52—54 behaves exactly like a tuned circuit as far as the desired signal is concerned. All the signals on adjacent frequencies will be attenuated on account of the fact that the factor x becomes rapidly zero due to the selective property of the intermediate frequency amplifier. The vector diagram for the desired signal is shown in Figure 6a and for the image frequency signal in Figure 6b; that is, in other words the image frequency signal will be substantially out of tune and attenuated corre-

spondingly. If the local oscillator is now re-tuned such as by adjusting the variable condenser with the conversion constants of all the frequency changing valves and the oscillating potentials remaining constant, the circuit 52—54 will be automatically tuned to the desired new signal frequency $w_2 - w_1$. In this manner a high frequency amplifier which may comprise one or more stages may be provided preceding the first detector or mixer stage in a similar manner to that in known superheterodyne receivers but with the substantial advantage that the amplifier contains fixed coupling elements only tuned purely electrically and automatically by the adjustment of the local oscillating frequency. Thereby the problem of ganging and simultaneous control of a plurality of tuned circuits is completely eliminated.

If more than one frequency amplifying stage is employed, provision should be made that the feedback potentials for each stage are of proper amplitude. Thus in the example shown in Figure 5 the feedback potentials applied to the second stage is amplified by an amount equal to the amplification of the valve 55. For this purpose an additional amplifier 62 is provided coupled to the combined output of the mixer devices 24 and 25 and having a separate feedback resistance 63 in its output circuit. A variable tap of this feedback resistance is connected to the junction between condenser 56 and resistance 58 of the signal input circuit for a second high frequency amplifier stage or the mixer 60 in the example illustrated. As is understood the input circuit may normally be either aperiodic as described and tuned to the signal frequency by the reactive feedback component, or the circuit may be tuned by a tuning reactance of different kind such as an induction coil so as to be off resonance normally and brought to exact resonance by reactive regeneration in the manner described.

The circuit according to Figure 5 is adjusted as follows; in the first place the phase of the intermediate frequency signal is adjusted by means of the phase shifting device 18 and/or the proper design of the intermediate frequency amplifier 16 in such a manner that the feedback potential for the signal frequency will be reactive. Then the circuit 56—58 is properly tuned by adjusting the tap on the potentiometer 63 and subsequently the circuit 52—54 is likewise tuned by adjusting the tap on the resistance 30. After this has been done the receiver is ready for operation and may be tuned to a desired transmitting station solely by controlling the local oscillating frequency, whereby the input circuits of the high frequency stages and the mixer are automatically tuned to the respective signal frequencies throughout the entire operating range of the receiver. Items 66 and 67 are biasing networks in the cathode leads of the tubes 55 and 60, respectively, to provide proper grid-operating bias in accordance with standard practice.

The reactive feedback in an arrangement according to Figure 5 is substantially independent of frequency due to the employment of ohmic resistances 30, 63, 54, and 58. Since the circuits 52—54 and 56—58 are equivalent to tuned circuits comprising capacitative and inductive reactances, they may be regenerated to further increase the selectivity such as by the provision of mutually coupled inductance coils 64 and 65 the former being included in the circuit 56—58 and the latter being inserted in the cathode return lead of

valve 60. However, experiments have proven that the tuning of the circuits 52—54, and 56—58 is so sharp that regeneration would be required only in exceptional cases. The resistances 54 and 58 should be relatively small (500 ohms or less) which makes it necessary to increase the amplification of the intermediate frequency amplifier compared with an equivalent receiver of standard design.

It can be shown that in a superheterodyne system described hereinabove the automatic tuning of the R. F. section is substantially insensitive to the higher harmonics of the local oscillating frequency. When an aperiodic input circuit without automatic tuning is used, components having a frequency $n(w_2 \pm w_1)$ would be present in the audio output of the receiver. By employing a system according to the invention with automatic tuning of the R. F. amplifier, the second, third, and fourth harmonic of the local oscillation will either produce no reactive component for the signal components of like frequencies or such components will be inversely phased with respect to the corresponding signal components. In the case of the fifth harmonic of the local oscillation, the latter will be in exact tune with the same harmonic of the desired signal. In order to eliminate any difficulties arising therefrom, a suitable low pass filter may be provided between the antenna and the input circuit, or choke coils 50, Figure 2, and 69 and 70, Figure 5, may be inserted in the feedback circuits attenuating or suppressing the fifth harmonic component and other disturbing frequencies of the feedback potentials. In most cases the latter is so small that special attenuating or suppression means may be dispensed with.

As is understood from the foregoing, the automatic tuning adjustment of an R. F. input circuit in a superheterodyne receiver as shown in Figure 5 not only serves to eliminate the effect of any image frequency which may be received simultaneously with the desired signal but will reduce any other interfering signal affecting the receiver thereby improving the general selectivity characteristic of the receiver. Furthermore it will be evident that the reconstruction of a reactive R. F. signal component from energy derived from the intermediate frequency amplifier to be fed back upon an R. F. signal input circuit for affecting automatic tuning, may be accomplished by means different from the specific circuits shown and obvious to those skilled in the art.

It is furthermore within the scope of the invention to produce feedback energy for the desired signal only impressed upon the R. F. input circuit in inverse phase relation or in other words to provide negative feedback for the entire receiver comprising both R. F. and I. F. sections to eliminate distortion and other defects. While it is known to provide separate inverse feedback in the I. R. and A. F. sections, this would not result in elimination of distortion created in the first detector and frequency changer. By an arrangement of the type mentioned inverse feedback potential is impressed from the output of the I. F. amplifier to the input of the first detector or mixer stage preceding this amplifier, thus taking into consideration the distortions produced in the mixer stage which usually is the major source of the total distortion in a superheterodyne amplifier.

From the foregoing it will be understood that in order to maintain exact tuning over the entire operating range of the receiver, the local os-

cillating potentials applied to the auxiliary frequency changers 24 and 25 should be maintained in exact phase quadrature or vary according to a definite law or relation. The phase shifting circuits 45 and 46 as shown in Figure 2 are adapted to produce an exact quadrature phase shift but have the disadvantage that the amplitudes of the potentials are dependent upon frequency.

In order to avoid this deficiency, a special local twin oscillator may be provided preferably associated with the auxiliary mixer valves 43 and 44 as shown in Figure 7. In the latter the oscillator comprises two inductively coupled resonant circuits 90 and 91 having variable tuning condensers connected or ganged for simultaneous control and having ohmic resistances (about 10 to 500 ohms) 92 and 93 connected in series with the tuning condensers. The circuits 90 and 91 are coupled to the oscillating grids of the mixer valves 43 and 44, while feedback potentials are applied from the anode grid of one valve to the junction between the ohmic resistance and tuning condenser of the oscillating circuit connected to the other valve by way of coupling condensers 94 and 95, respectively in the manner shown in the drawing. Provided that the valves 43 and 44 have substantially equal characteristics and that the circuit elements; i. e., condensers, inductances, resistances, etc., of both circuits are exactly equal or matched, then the oscillating potentials in the two circuits will be equal and in exact quadrature phase relation over the entire tuning range, i. e., substantially independently of the tuning adjustment. A twin oscillating circuit of this type presents the further advantage of producing a smaller amount of harmonics than a single local oscillator, provided both circuits are suitably de-tuned for the same operating frequency. In this case the resultant frequency will be in the center between the tuning frequencies of the circuits and the local oscillating frequency may be caused to follow a certain law with regard to the common output oscillation. Thus for instance if the circuits are adjusted in such a manner that for zero setting of the tuning condensers the difference between the tuning frequencies of the circuits is a maximum and that by adjustment of the tuning condensers to maximum capacity the circuits are tuned exactly alike, then the amplitude of the local oscillation at zero setting of the condensers will be lower than the amplitude at maximum condenser setting. As is understood a reverse relation may be obtained by designing the circuits so that their frequencies differ more as the wave length increases.

One of the circuits, in the example circuit 90, may serve to energize the grid of the first mixer 32 of the receiver. This will result in an additional load on the circuit 90 and in order to compensate for this effect the resistance 92 is advantageously designed to have a lower value than the resistance 93.

The receiver according to Figure 7 is substantially similar to Figures 2 and 5 except for the provision of a special (twin) oscillator for the purpose as described. Moreover, in the example shown, two intermediate frequency amplifying stages are provided, the first stage being comprised of an amplifier valve 38 and input coupling (band-pass) network 35—36, and the second stage being comprised of a similar amplifier 76 and input coupling (band-pass) network 74—75.

In order to insure an exact and constant quadrature relation between the intermediate

signal potentials impressed upon the signal input grids of the mixer valves 43 and 44, there is further provided in Figure 7 an adjustable phase shifting arrangement connected to the output circuit 77 of the valve 76. This phase shift arrangement, in the example shown, is of the type as described in my copending patent application Serial No. 320,725, filed February 24, 1940, entitled "Electric phase control system," and comprises a resistance bridge system 78 having four resistance arms arranged in circular formation with one pair of diagonal points or apices of the bridge circuit connected to the input circuit 77 and the remaining apices connected to ground or any other zero potential point of the system. The bridge is provided with four adjustable contacts 79, 80, 81, 82 spaced at relatively fixed angles of 90° from each other and arranged for common rotation by the aid of a suitable adjusting member (not shown). Contacts 79 and 80 are connected to the high potential sides of a pair of inductively coupled resonant circuits 84 and 85 tuned to the intermediate frequency and contacts 81 and 82 are connected to the high potential sides of a further pair of resonant circuits 86 and 87 also tuned to the intermediate frequency, the low potential sides of the resonant circuits 84 to 87 being grounded. The high potential side of circuit 84 is connected to the input grid of mixer valve 44 and the high potential side of resonant circuit 86 is connected to the input grid of the mixer valve 43. By an arrangement of this type the potentials impressed upon the signal grids of the valves 43 and 44 will be exactly in phase quadrature and can be shifted by rotating the contacts 79 to 82 with respect to the phase of the input signal in the circuit 77 to adjust the feedback potential impressed from the resistance 30 to the input circuit 52—54 to its proper phase to effect automatic tuning of the input circuit in the manner described.

Experiments have shown that by means of a circuit according to Figures 5 and 7, extreme selectivity is obtainable and in order to prevent a cutting of the extreme side bands the intermediate frequency amplifier should be designed to have a proper band pass characteristic as well as a substantial constant phase characteristic in order to prevent selective tuning effects for definite component frequencies of the signal being amplified liable to cause distortions and other defects. Filters with characteristics of this nature are described for instance in British Patent 474,382. In this case the input circuit of the receiver and the receiver as a whole will have an ideal band pass characteristic with the same band width being maintained over the entire tuning range. A receiver as shown in Figure 7 by proper design and adjustment will have the efficiency of a superheterodyne receiver with three R. F. stages and adjustable band with for each frequency and six intermediate frequency stages; i. e., requiring at least four ganged condensers compared with a single tuned condenser and a substantially limited number of R. F. and I. F. stages provided in Figure 7.

It will be evident from the foregoing that the invention is not limited to the specific circuits and arrangements of parts as well as steps shown and described herein for illustration, but that the principle and novel thought underlying the invention are susceptible of numerous variations and modifications coming within the broader scope and spirit of the invention as defined by the ensuing claims. The specification and draw-

ings are accordingly to be regarded in an illustrative rather than in a limiting sense.

I claim:

1. In a superheterodyne receiver subject to image frequency interference, an input circuit for receiving radio frequency signals, a local oscillator, first frequency changing means energized from said input circuit and said local oscillator for producing intermediate frequency signals, means to produce a pair of fractional intermediate frequency signal energies having a quadrature phase relation with respect to each other, further means to produce a pair of fractional local oscillating energies having also a quadrature phase relation with respect to each other, additional frequency changing means for combining each of said fractional intermediate frequency energies with either of the fractional oscillating energies to produce resultant energies at signal and image frequency, and means for combining and feeding back said resultant energies upon said input circuit.

2. In a superheterodyne receiver subject to image frequency interference, an input circuit for receiving radio frequency signals, a local oscillator, first frequency changing means energized from said input circuit and said local oscillator for producing intermediate frequency signals, means to produce a pair of fractional intermediate frequency signal energies having a quadrature phase relation with respect to each other, further means to produce a pair of fractional local oscillating energies also having a quadrature phase relation with respect to each other, additional frequency changing means for combining each of said fractional intermediate frequency energies with either of the fractional oscillating energies to produce resultant energies at signal and image frequency, and means for combining and feeding back said resultant energies upon said input circuit, the relative amplitude and phase of the energies fed back being such as to cause a degeneration of the image frequency and regeneration of the signal frequency in said input circuit.

3. In a superheterodyne receiver subject to image frequency interference, an input circuit for receiving radio frequency signals, a local oscillator, first frequency changing means energized from said input circuit and said local oscillator for producing intermediate frequency signals, means to produce a pair of fractional intermediate frequency signal energies having a quadrature phase relation with respect to each other, further means to produce a pair of fractional local oscillating energies also having a quadrature phase relation with respect to each other, additional frequency changing means for combining each of said fractional intermediate frequency energies with either of the fractional oscillating energies to produce resultant energies at signal and image frequency, means for combining and feeding back said resultant energies upon said input circuit, and phase shifting means to cause a reactive feedback potential at signal frequency being impressed upon the input circuit to automatically maintain said input circuit in tune with the signal frequency by controlling the local oscillating frequency.

4. In the art of receiving radio signals, the steps of receiving radio frequency input signals, beating the received signals with local generated oscillations to produce intermediate frequency signals, producing a first pair of energies from said intermediate frequency signals having a

quadrature phase relation with respect to each other, producing a second pair of energies from said locally generated oscillations also having a quadrature phase relation with respect to each other, beating each of said first pair of energies with either of said second pair of energies to produce a pair of resultant energies, and combining and feeding back said resultant energies upon said input signals in such relative phase and amplitude relation as to cause substantial attenuation of interfering signals having a frequency differing from the signal frequency.

5. In the art of receiving radio signals, the steps of receiving radio frequency input signals, beating the received signals with locally generated oscillations to produce intermediate frequency signals, producing a first pair of energies from said intermediate frequency signals having a quadrature phase relation with respect to each other, producing a second pair of energies from said locally generated oscillations also having a quadrature phase relation with respect to each other, beating each of said first pair of energies with either of said second pair of energies to produce a pair of resultant energies, and combining and feeding back said resultant energies upon said input signals in such phase and amplitude relation as to effect a regeneration of the desired signals and a degeneration of interfering signals having a frequency differing from the signal frequency.

6. In the art of receiving radio signals, the steps of receiving radio frequency input signals, beating the received signals with locally generated oscillations to produce intermediate frequency signals, producing a first pair of energies from said intermediate signals having a quadrature phase relation with respect to each other, producing a second pair of energies from said locally generated oscillations also having a quadrature phase relation with respect to each other, beating each of said first pair of energies with either of said second pair of energies to produce a pair of resultant energies, combining the resultant energies, and phase shifting and feeding back the combined energy upon said input signals to cause a reactive component at signal frequency to be superimposed upon said input signals.

7. In a superheterodyne receiver, an input circuit for receiving radio frequency signals, a local oscillator, first frequency changing means energized from said input circuit and local oscillator to produce intermediate frequency signals, means for producing a pair of fractional intermediate frequency energies, further means for producing a pair of fractional local oscillating energies, at least one pair of said fractional energies being in phase quadrature relation with respect to each other, additional frequency changing means for combining each of the fractional intermediate frequency energies with either of the fractional local oscillating energies to obtain resultant energies, and means for combining and feeding back said resultant energies upon said input circuit, the relative phase and amplitude of the energies fed back being such as to effect attenuation of interfering signals having a frequency differing from the signal frequency.

8. In a superheterodyne receiver, an input circuit for receiving radio frequency signals, a local oscillator, first frequency changing means energized from said input circuit and local oscillator

to produce intermediate frequency signals, means for producing a pair of fractional intermediate frequency energies, further means for producing a pair of fractional local oscillating energies, at least one pair of said fractional energies being in phase quadrature relation with respect to each other, additional frequency changing means for combining each of the fractional intermediate frequency energies with either of the fractional local oscillating energies to obtain resultant energies, and means for combining and feeding back said resultant energies upon said input circuit, and means to cause a reactive feedback potential at signal frequency to be developed in said input circuit.

9. In a superheterodyne receiver, an input circuit for receiving radio signals, a local oscillator, first frequency changing means energized from said input circuit and said local oscillator to produce intermediate frequency signals, means for producing fractional intermediate frequency and local oscillating energies, additional frequency changing means energized by said fractional energies to produce resultant energy at signal frequency, means for feeding back said resultant energy upon said input circuit, and means to develop a reactive potential feedback at signal frequency in said input circuit.

10. In a superheterodyne receiver, an input circuit for receiving radio frequency signals comprising resistance and reactance elements of one kind only, a local oscillator, first frequency changing means energized from said input circuit and said local oscillator to produce intermediate frequency signals, means to produce fractional intermediate frequency and local oscillating energies, additional frequency changing means energized by said fractional energies to produce resultant energy at signal frequency, means for feeding back said resultant energy upon said input circuit, and phase shifting means to develop a reactive feedback potential at signal frequency in said input circuit.

11. In a superheterodyne receiver, an input circuit for receiving high frequency signals, a local oscillator, first frequency converting means energized from said input circuit and said local oscillator to produce intermediate frequency signals, means for producing fractional intermediate frequency and local oscillating energies, additional frequency converting means energized by said fractional energies to produce resultant energy, and means for feeding back said resultant energy upon said input circuit.

12. In a superheterodyne receiver, an input circuit for receiving high frequency signals, a local oscillator, first frequency converting means energized from said input circuit and said local oscillator to produce intermediate frequency signals, means for producing fractional intermediate frequency and local oscillating energies, additional frequency converting means energized by said fractional energies to produce resultant energy including a component at signal frequency, means for feeding back resultant energy upon said input circuit, and further means to cause at least part of the feedback potential at signal frequency developed in said input circuit to be in phase quadrature with the input signal currents.

JOZEF PLEBANSKI.

CERTIFICATE OF CORRECTION.

April 7, 1942.

Patent No. 2,279,177.

JOZEF PLEBANSKI.

It is hereby certified that the above numbered patent was erroneously issued to the inventor, said PLEBANSKI, whereas said patent should have been issued to --Radio Patents Corporation, a corporation of New York-- as assignee of the entire interest therein, as shown by the record of assignments in this office; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 21st day of July, A. D. 1942.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.