

June 16, 1936.

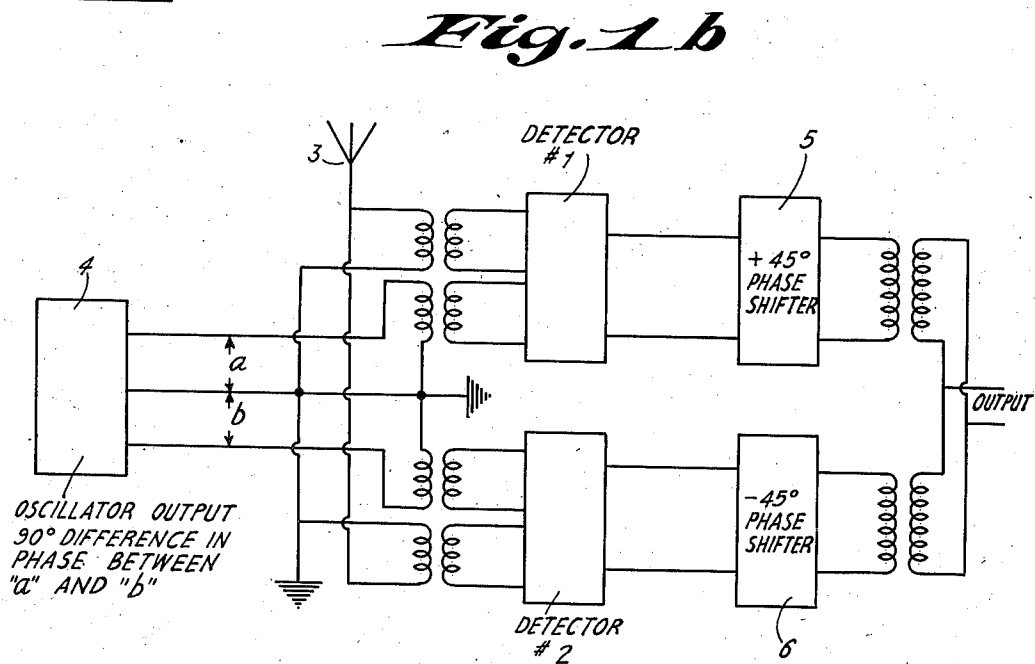
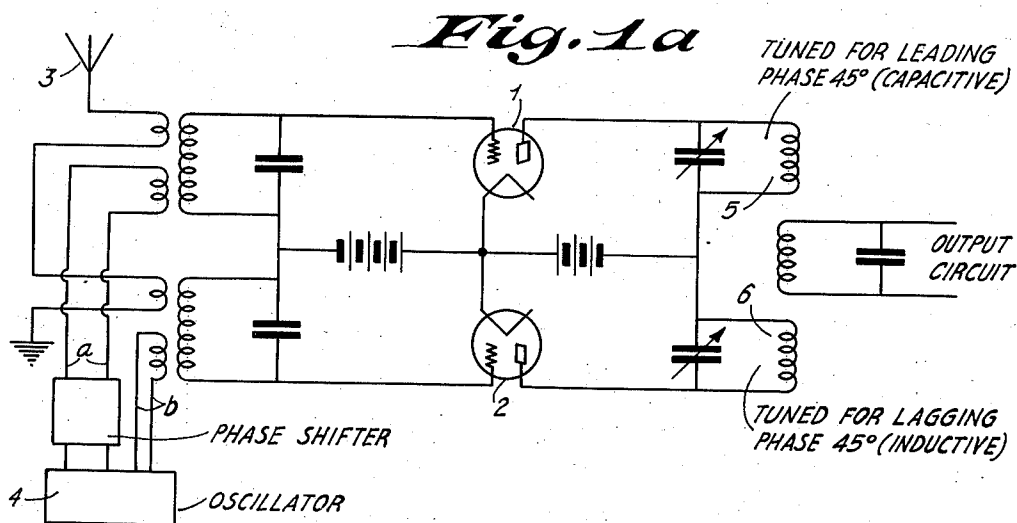
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2,044,745

RECEIVING CIRCUITS

Filed Aug. 1, 1933

10 Sheets-Sheet 1



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10 Sheets-Sheet 2

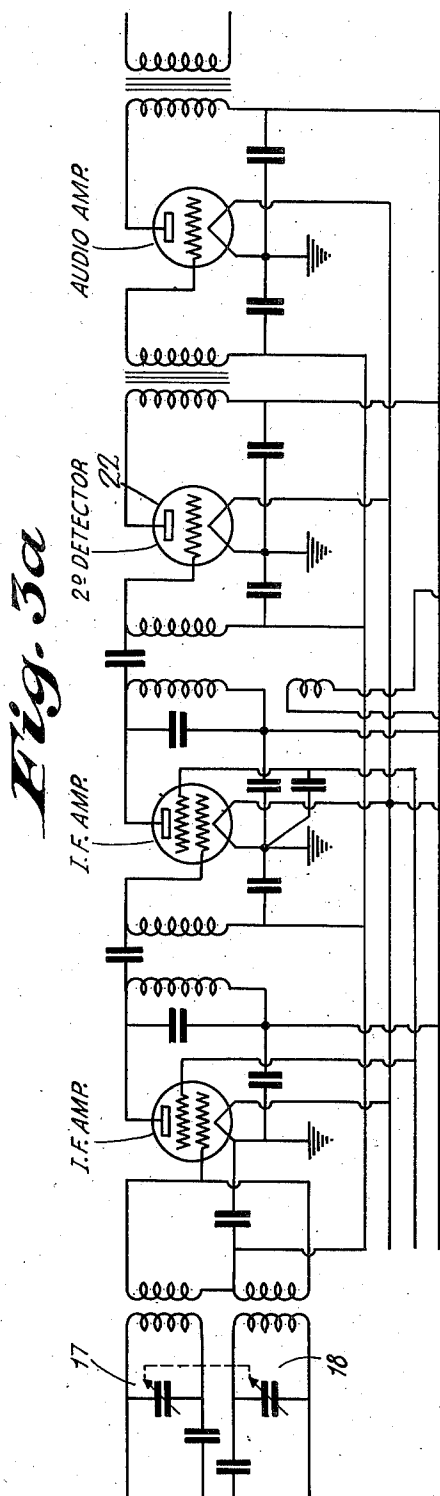


Fig. 2e
SECOND OR LOW
FREQUENCY BEATING
OSCILLATOR USED FOR
RECEPTION OF C.W.
TELEGRAPH SIGNALS

Fig. 2a

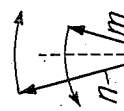


Fig. 2b



Fig. 2d



Fig. 2c

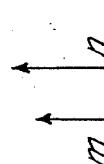
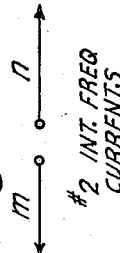


Fig. 2f



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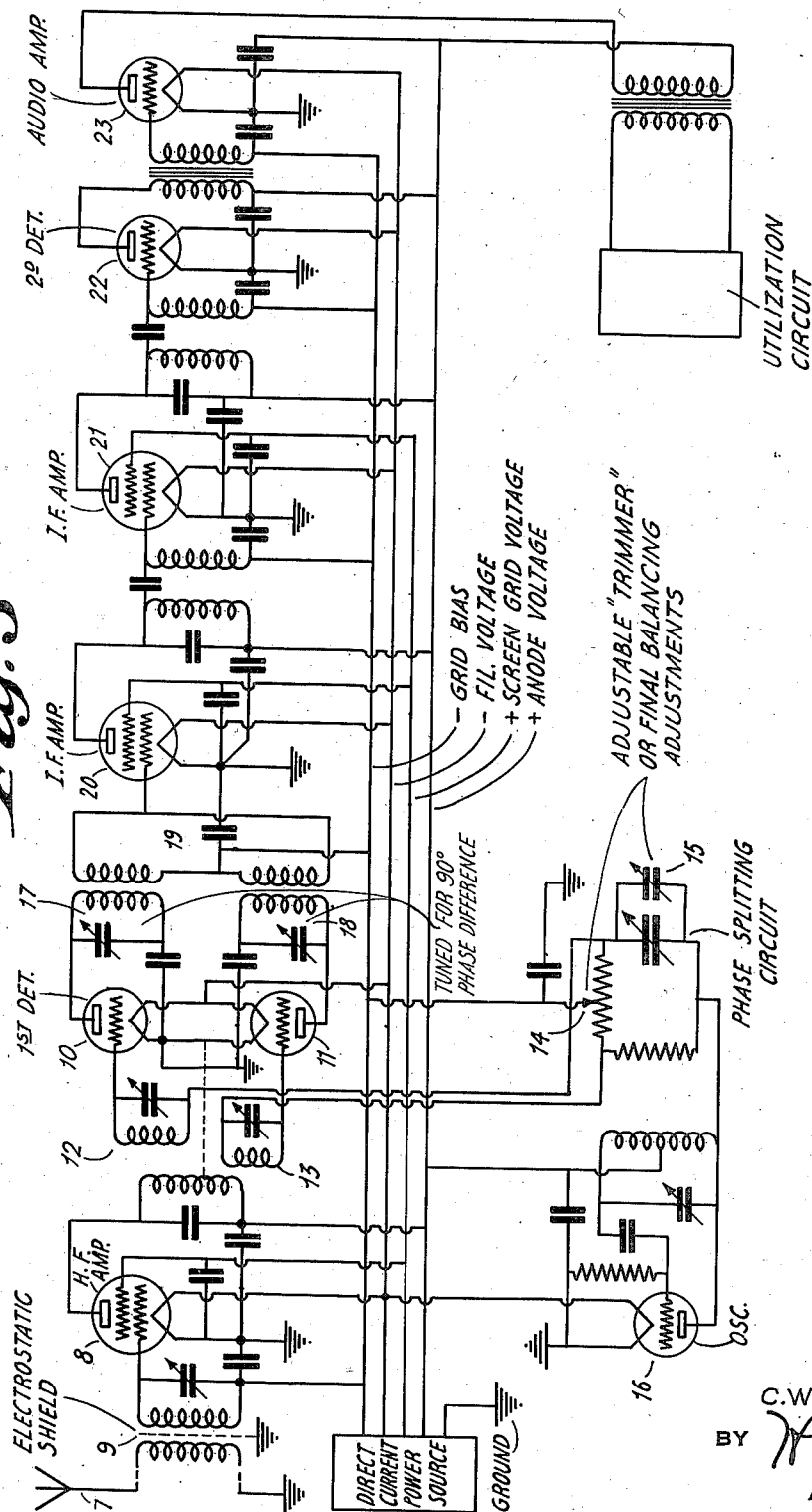
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Fig. 3



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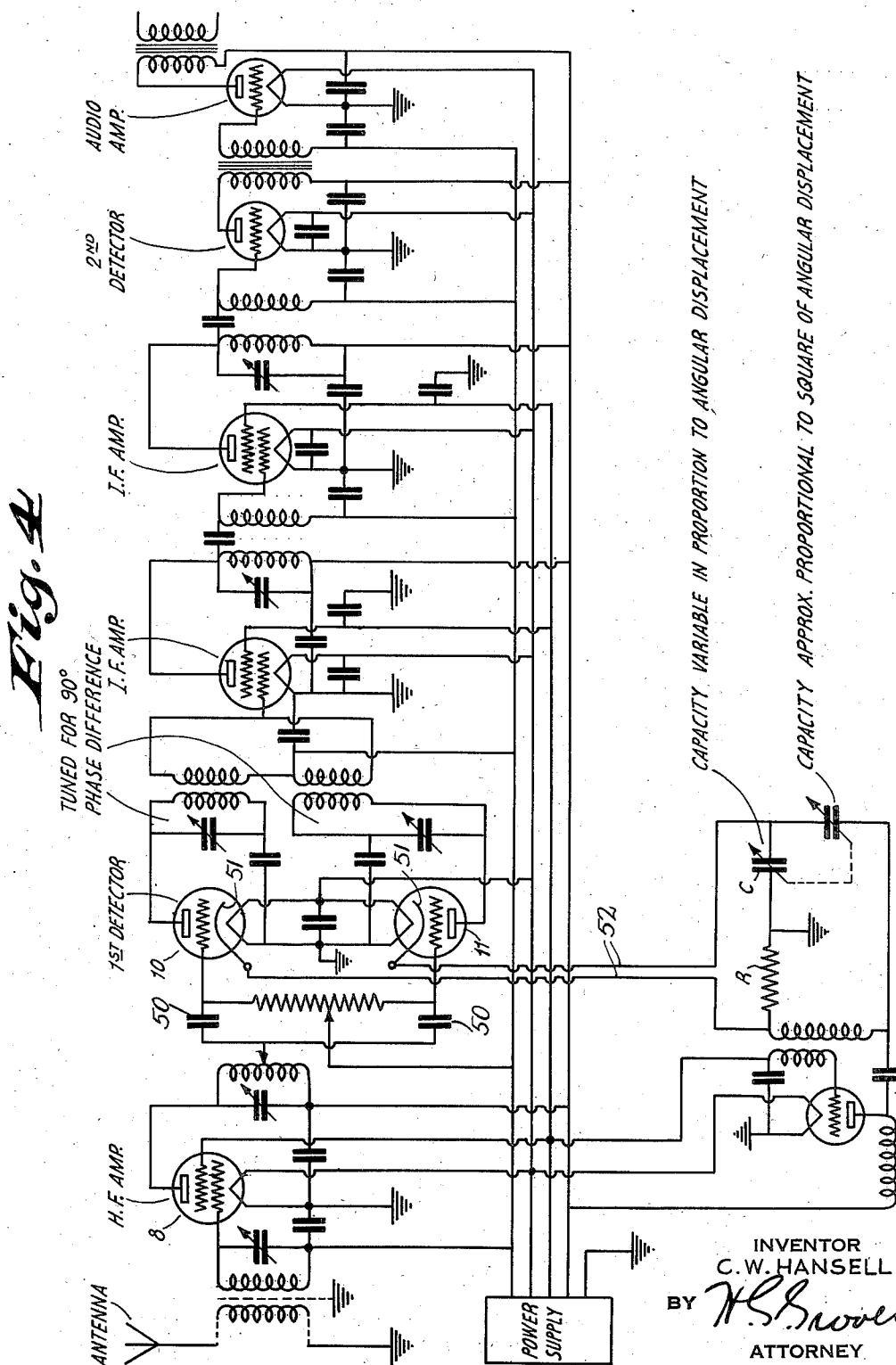
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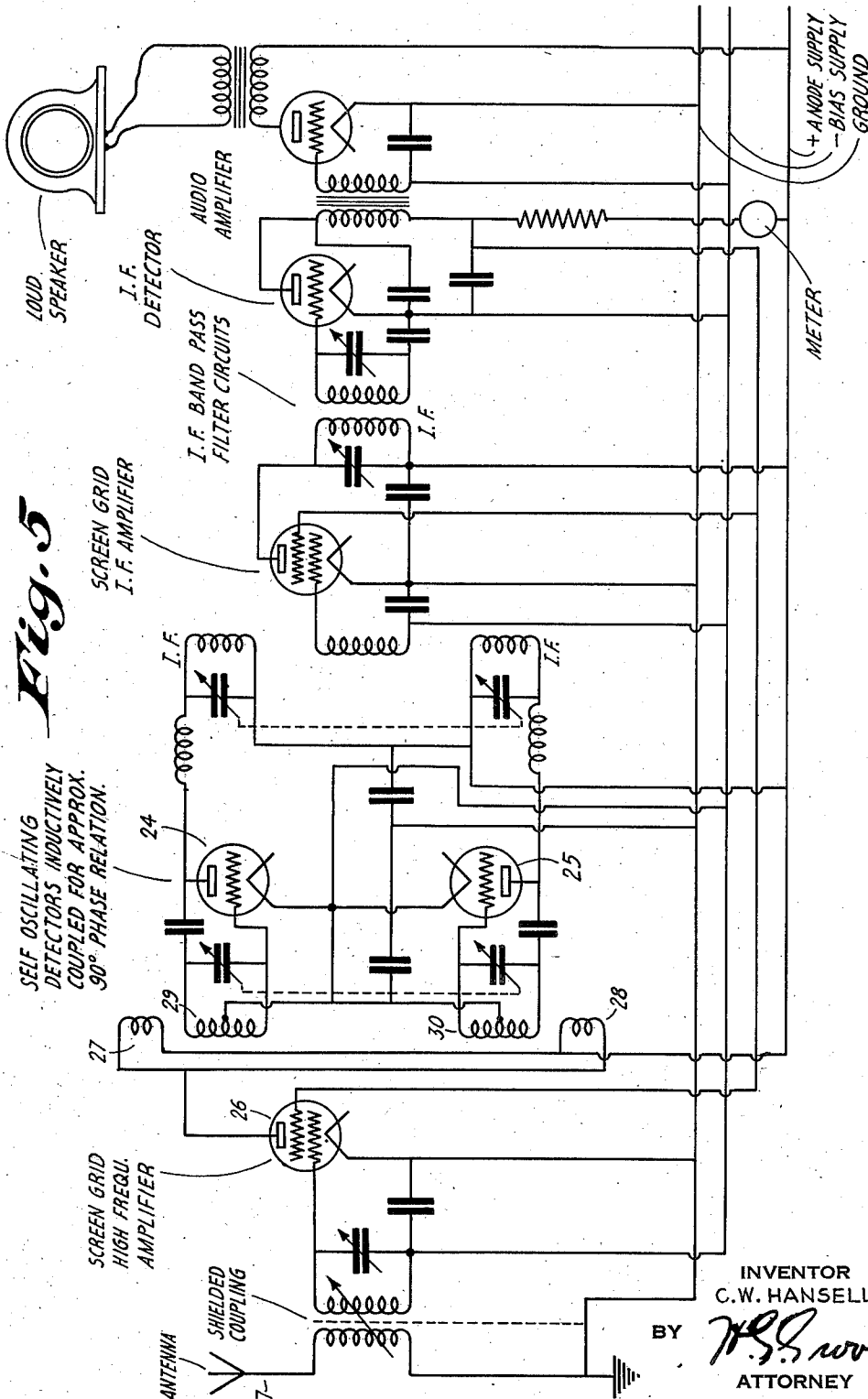
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10 Sheets-Sheet 5



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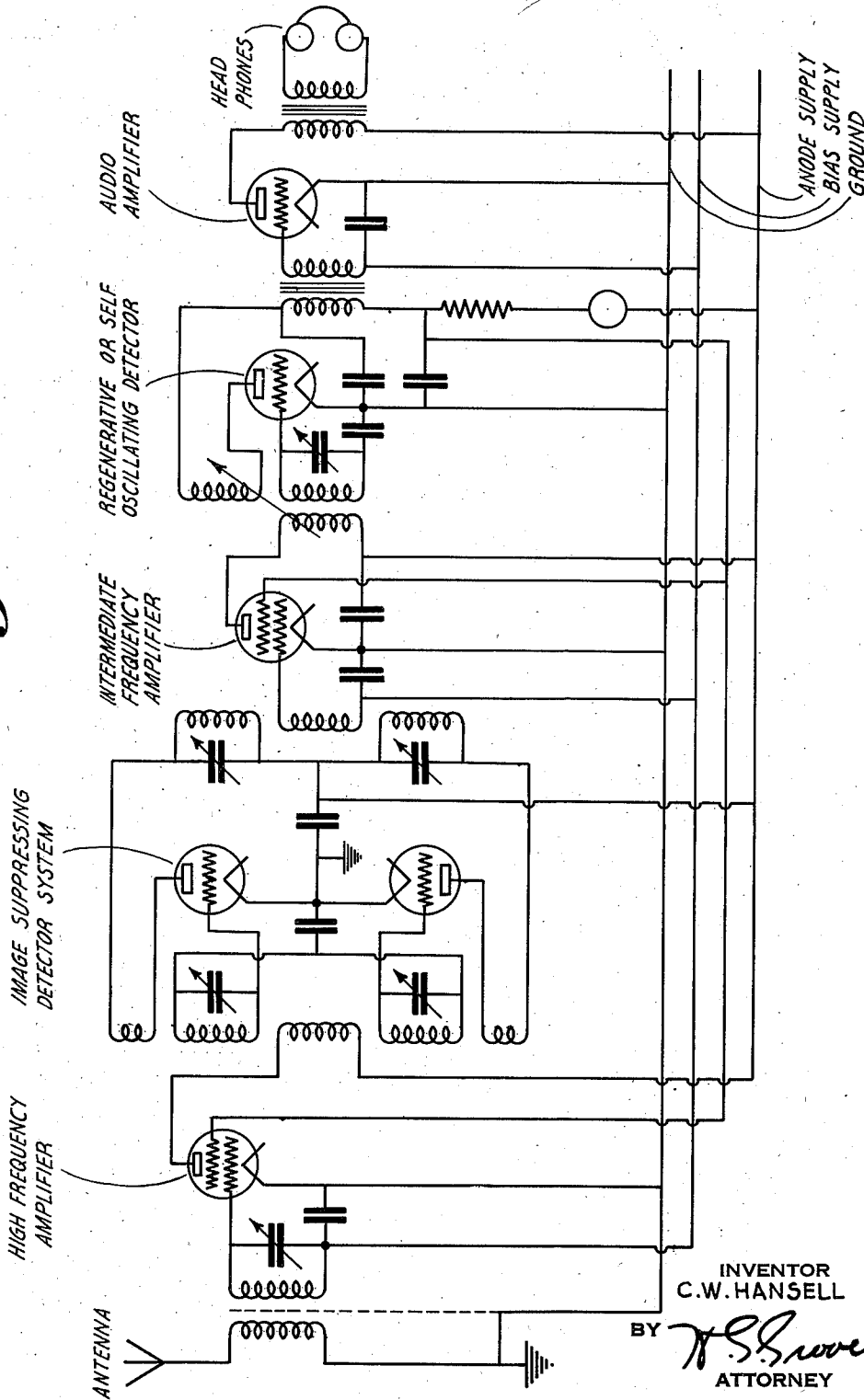
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10 Sheets-Sheet 6

Fig. 6



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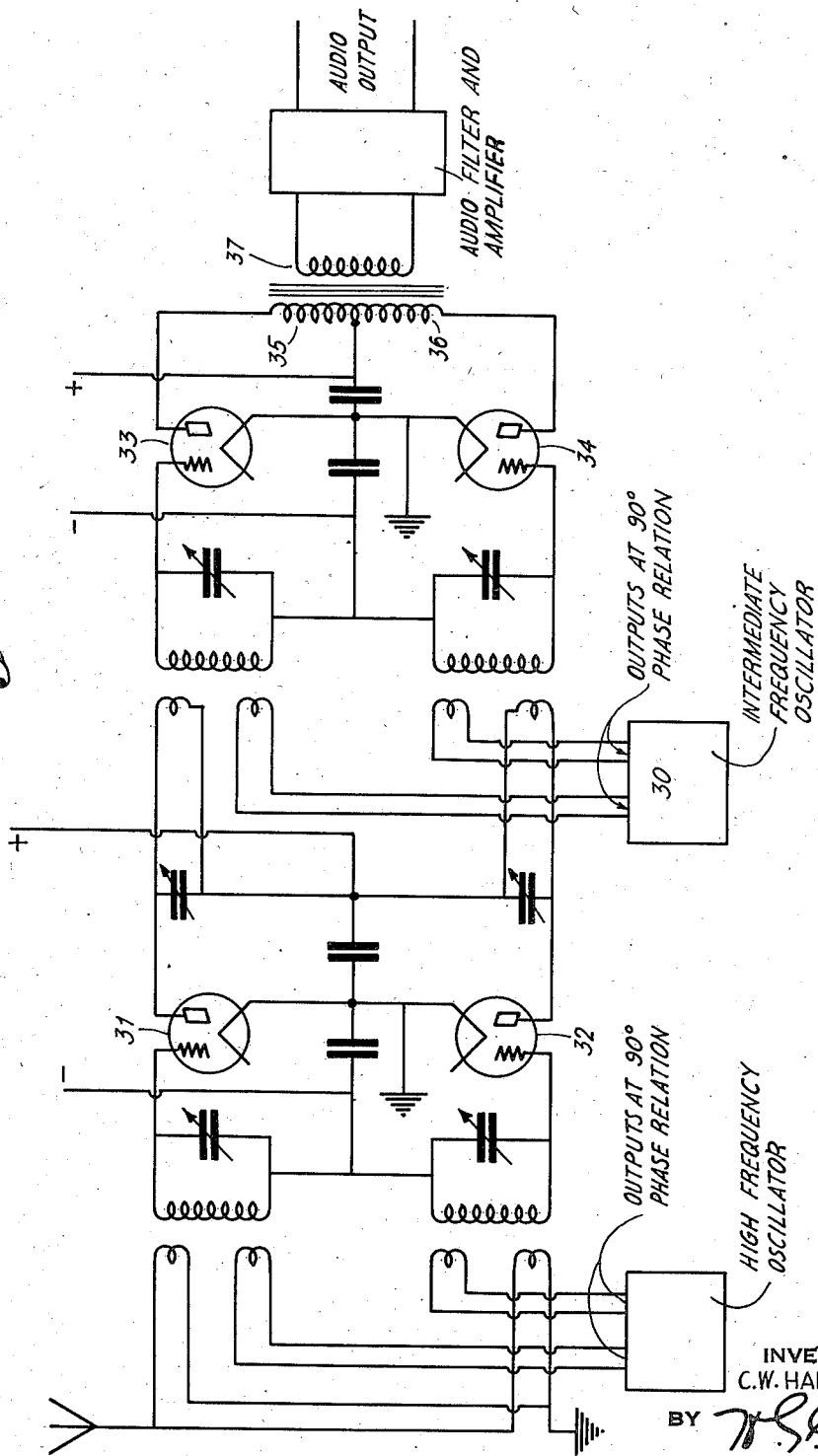
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Fig. 7



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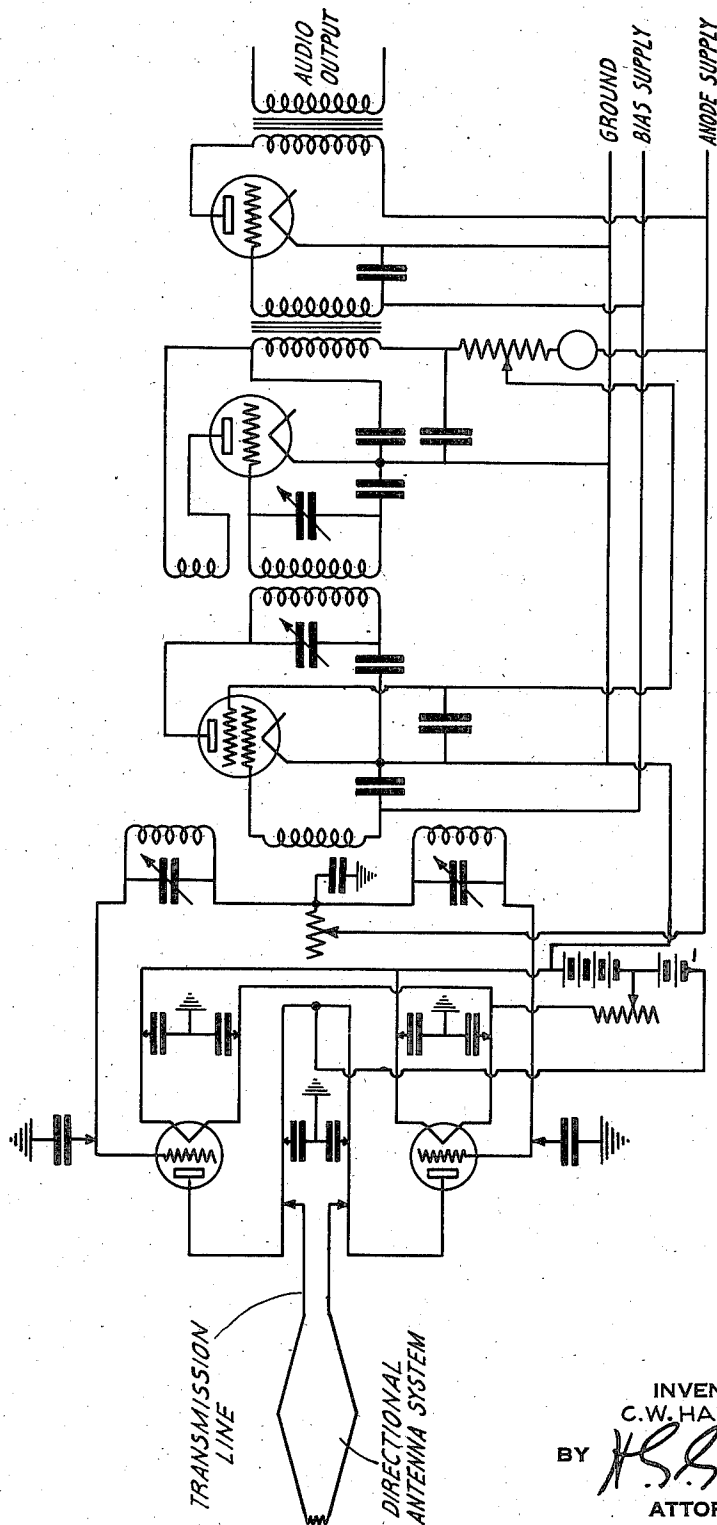
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10 Sheets-Sheet 8

Fig. 8

COUPLING BETWEEN THE OSCILLATOR VARIABLE BY MOVING
RELATIVE POSITIONS OF WIRE LINE TUNING SYSTEMS OR
BY MOVING OTHER ELEMENTS NEAR THE OSCILLATORS.



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Fig. 9.

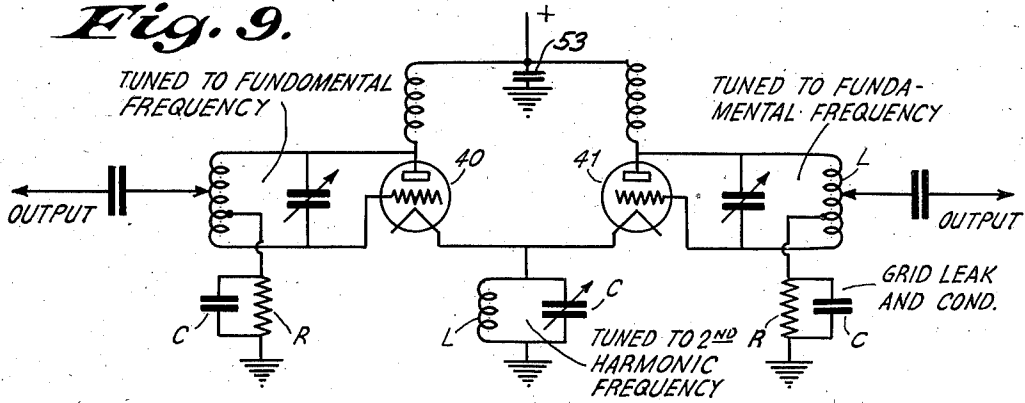


Fig. 10

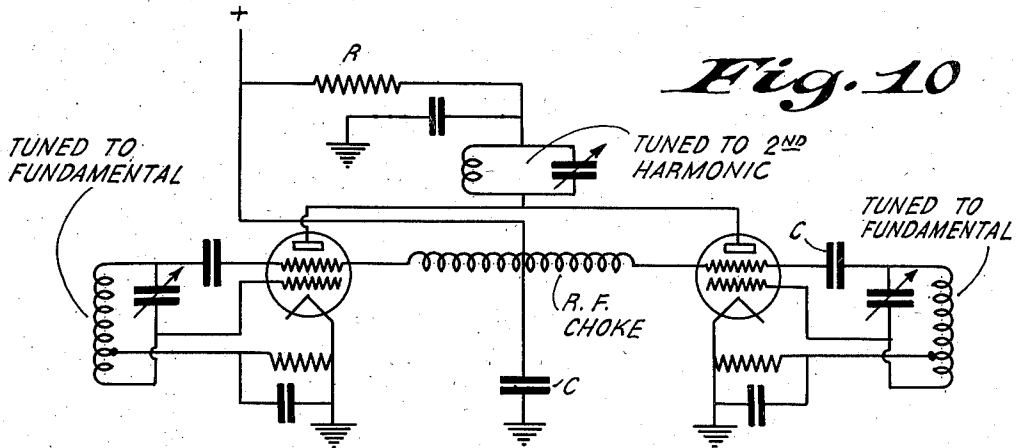
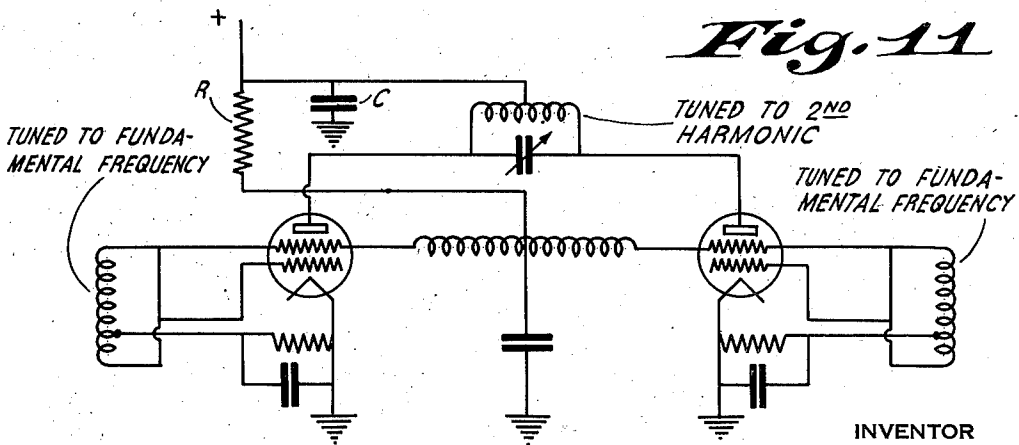


Fig. 11



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10 Sheets-Sheet 10

I.F. FREE FROM IMAGE SIGNALS

TUNED 45°
LEADING FOR I.F.

HIGH
FREQ.
COUPLING
COIL

TUNED
TO HIGH
FREQ.

TUNED TO 2ND HARMONIC OF
HIGH OSCILLATION FREQUENCY

HIGH FREQUENCY INPUT

Fig. 12

TUNED 45° PHASE
LAGGING FOR I.F.

HIGH
FREQ.
COUPLING
COIL

TUNED
TO HIGH
FREQ.

Fig. 13

TUNED 45°
LEADING FOR I.F.

TUNED TO
HIGH FREQ.

HIGH FREQ.
INPUT

COUPLED

TUNED TO 2ND
HARMONIC OF
HIGH FREQ.

I.F. OUTPUT

TUNED 45°
LAGGING FOR I.F.

TUNED TO
HIGH FREQ.

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UNITED STATES PATENT OFFICE

2,044,745

RECEIVING CIRCUITS

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Application August 1, 1933, Serial No. 683,115

20 Claims. (Cl. 250—20)

This invention relates to superheterodyne radio receiving circuits and, more particularly, to a method of and apparatus for suppressing image signals in such circuits.

One common and serious defect in high frequency superheterodyne receivers which are designed and constructed to give good frequency selectivity in the band around a desired signal is the failure of such receivers to suppress the "image" band of frequencies symmetrically spaced on the opposite side of the beating oscillator frequency from the desired signal. Thus, for tuning adjustment, the receiver is known to admit two bands of frequencies separated by twice the frequency of the intermediate frequency circuits. For example, if such a receiver were designed and adjusted to use a frequency of 20 million cycles per second from the first beating oscillator and to have an intermediate frequency pass band around one million cycles, then it would receive frequencies picked up by the receiver in bands around 19 million and 21 million cycles per second. This has been found to be a very undesirable arrangement because of the probability of interference between signals in the two bands and the increase in noise engendered.

One of the reasons for designing a receiver with such an undesirable characteristic is the desire to reduce the cost of construction. If the receiver were designed to use a higher intermediate frequency and there were provided sufficient high frequency selectivity in circuits ahead of the first detector, the image band passed through the first detector might be effectively suppressed. However, when very high frequencies are being received, the intermediate frequency after the first detector might have to be made so high that the selectivity of the intermediate frequency circuits would not be sufficient to prevent image signals appearing in the circuits after the second detector. Then it would be necessary to provide a third detector with associated circuits and the receiver would have to be made much more complex and expensive.

The present invention overcomes the above-mentioned difficulty and provides a highly efficient and simple method of suppressing image signals; and this is effected, generally, by causing the output currents from two detectors used to receive the same signal to balance out substantially for frequencies on one side of the beating oscillator frequency and to add together wholly or in part for frequencies on the other side of the beating oscillator frequency. More specifically, it has been found that if the output

from a source of constant radio frequency is supplied to two separate detector circuits with a difference in the phase of the current in one detector input circuit with respect to the other by, say, 90 degrees, and a radio signal frequency also applied to both detectors in like phase, there will be obtained in the outputs of the separate detectors currents corresponding to beats between the radio frequency energies. Under these conditions there will be obtained from the two detectors outputs corresponding to the beat frequency between the oscillator and the signal frequency, and the beat frequency outputs of the two detectors will have a phase relation corresponding to the difference in phase between the two radio frequency currents fed into the detectors from the oscillator. In such case the polarity of the beat frequency output from a heterodyne detector reverses as the frequency of one of the beating currents is moved above or below the frequency of the other beating current. Also, if the same pair of currents are used to cause beats in two separate detectors under similar conditions, i. e., they are applied to the detectors with a shift in relative phase, then the two detector outputs will have a difference in phase equivalent to a polyphase power system. Then if one beating frequency were applied above or below zero beat with the other there will be produced a reversal in polarity and in direction of rotation of the polyphase detector output currents. This reversal in polarity and direction of rotation makes it possible, according to the present invention, to propose a receiver in which the outputs from two detectors used to receive the same signal can be made to substantially balance out for frequencies on one side of the beating oscillator frequency and to add together wholly or in part for frequencies on the other side of the beating oscillator frequency. There is thus obtained a heterodyne detector system which has little or no output for frequencies below that of the beating oscillator and full output for frequencies above the beating oscillator, or vice versa.

The invention is more adequately described in connection with the accompanying drawings wherein Figures 1a and 1b show, merely for purposes of illustration, different ways of obtaining detector outputs according to the principles of the present invention; Figures 2a to 2f show vector diagrams which represent the different detector voltages and currents in the detector circuits when effected in accordance with the present invention; and Figures 3 to 8 inclusive illustrate, by way of example only, various image sup-

pressing receiver arrangements embodying the principles of the present invention. Figures 9 to 13 inclusive show various circuit schemes whereby oscillators may be made to give a 90 degrees phase relation over a wide band of frequencies.

Referring to Figures 1a and 1b, there are shown simple diagrams of the image suppressing heterodyne detector system of the present invention wherein two detectors 1 and 2 are supplied with high frequency energy from any source of received energy, such as an antenna 3 and also from a local beating oscillator 4. The energies supplied to the detectors 1 and 2 from local beating oscillator 4 are applied to the detectors with a difference in phase of preferably 90 degrees. A phase shift apparatus has been indicated in Figure 1a. In actual practice, it is probable that the two output circuits, designated a and b, from the oscillator will be tuned and that the phase shift will be obtained by simply adjusting one above and one below the output frequency so that one carries current of leading phase and the other carries lagging current with respect to the oscillator output voltage. Since the frequency will be constant, it is entirely practical to depend upon the tuning of the circuits to produce the phase shift. Of course, if preferred, some other form of phase shifting device, as indicated, which may comprise a radio goniometer or artificial transmission line, may be used to shift the phase. The oscillator may be variable in frequency or it may comprise a crystal unit such as is known to be capable of supplying extremely constant frequencies through the use of a piezoelectric crystal. It will be apparent, of course, from the foregoing that, if desired, the phase of the received energy may be applied 90 degrees differently in phase to the detectors 1 and 2 instead of a difference in phase of the currents from the outputs of the oscillator 4.

The beats between the received signal energies and the local oscillator give outputs from the two detectors 1 and 2 which differ in phase by 90 degrees. The output from detector 1 can be made 90 degrees leading in phase with respect to output from detector 2 for received energizes below the frequency of the local oscillator. Then, for received energy frequencies above that of the local oscillator the output of detector 1 will lag that of detector 2 by 90 degrees. Now, if there are employed circuits, such as 5 and 6, after the detectors which cause an additional 90 degrees phase shift between the two detector outputs either the higher or lower received frequency output components from the detectors can be made to add while the other components are suppressed. Then, if the detector outputs are equal in amplitude there is received one band of frequencies above or below the local oscillator frequency while there is suppressed the image band below or above the local oscillator frequency.

An analysis of the principle upon which the present invention is based follows, for which the vector diagrams of the currents and voltages are shown in Figures 2a to 2f inclusive. These figures are believed to be self-explanatory. Let the high frequency incoming signal=

$$\text{Re}[He^{i\omega h t}(1+Kh \cos \omega a t)]=Ahe^{i\omega h t}$$

Let the low frequency incoming signal=

$$\text{Re}[Le^{i\omega l t}(1+Kl \cos \omega b t)]=Ale^{i\omega l t}$$

where ωa and ωb are audio frequencies, Kh and Kl the modulation factors, etc.

ωh =high frequency, ωl =low frequency.

Let ωi =intermediate frequency and ωo =oscillator frequency.

Let Ao =amplitude of oscillator and assume very large compared to Al and Ah of incoming waves, that is: $Al \ll Ao$ and $Ah \ll Ao$ call

$$\frac{Ah}{Ao} = m \text{ and } \frac{Al}{Ao} = n$$

Then $m \ll 1$ and $n \ll 1$

This is the normal condition in a superheterodyne receiver.

Now $\omega o = \omega i + \omega h = \omega l - \omega i$

Assume phase of ωo on #2 first detector shifted by 90° leading #1. Then we have impressed on the two first detectors:

$$\text{On \#1 } Ao e^{i\omega o t} + Ah e^{i\omega h t} + Al e^{i\omega l t} =$$

$$Ao e^{i\omega o t} [1 + m e^{i(\omega h - \omega o)t} + n e^{i(\omega l - \omega o)t}]$$

$$\text{On \#2 } Ao e^{j(\omega o t + \frac{\pi}{2})} + Ah e^{i\omega h t} +$$

$$Al e^{i\omega l t} = Ao e^{j(\omega o t + \frac{\pi}{2})} \left[1 + \right.$$

$$\left. m e^{j(\omega h t - \omega o t - \frac{\pi}{2})} + n e^{j(\omega l t - \omega o t - \frac{\pi}{2})} \right]$$

$$\text{or: On \#1 } Ao e^{i\omega o t} [1 + m e^{i\omega i t} + n e^{-i\omega i t}]$$

$$\text{On \#2 } Ao e^{j(\omega o t + \frac{\pi}{2})} \left[1 + \right.$$

$$\left. m e^{j(\omega l t - \frac{\pi}{2})} + n e^{-j(\omega l t + \frac{\pi}{2})} \right]$$

The rectified component is given by the absolute value of the following complex expressions:

Then rectified current from #1=

$$Ao \left[1 + m e^{i\omega i t} + n e^{-j(\omega i t + \frac{\pi}{2})} \right] \cong$$

$$Ao [1 + m \cos \omega i t + n \cos \omega i t]$$

Then rectified current from #2=

$$Ao \left[1 + m e^{j(\omega l t - \frac{\pi}{2})} + n e^{-j(\omega l t + \frac{\pi}{2})} \right] \cong$$

$$Ao [1 + m \sin \omega i t - n \sin \omega i t]$$

because $m \ll 1$ and $n \ll 1$

The inter-frequency currents are then

$$\#1 \ Ao [m \cos \omega i t + n \cos \omega i t]$$

$$\#2 \ Ao [m \sin \omega i t - n \sin \omega i t]$$

Call the second detectors a and b connected in circuits from 1 and 2.

Now assuming that the phase of #2 current is shifted by 90° (leading) with respect to #1, The voltages impressed on detectors a and b are then proportional to:

$$(a) \ m \cos \omega i t + n \cos \omega i t$$

$$(b) \ m \cos \omega i t - n \cos \omega i t$$

The rectified currents are then:

$$(a) \ m + n$$

$$(b) \ m - n$$

Therefore depending upon connections one may eliminate either m or n . If n is eliminated there is left

$$2m = 2[1 + Kh \cos \omega a t]$$

or the audio modulation of the higher incoming radio frequency.

With this type of detector it is possible to beat

directly down to audio frequencies or down to relatively low intermediate frequencies without trouble due to interference between signals on opposite sides of the local or receiver oscillator frequency. In marine receivers for reception of continuous waves one might, for example, wish to beat directly down to 1000 cycles. This could be done by taking the outputs from the two detectors 1 and 2 through phase splitting circuits 5 and 6 designed to give substantially perfect cancellation of waves 1000 cycles below the receiver oscillator frequency and perfect addition of waves 1000 cycles above. If the pass band for the audio frequency circuits were made 500 cycles wide then the suppression of waves plus and minus 250 cycles from the perfectly suppressed wave would still be fairly good. Also by adjusting the relative amplitudes and phases of currents in detector inputs or outputs or both, any particular interfering wave might be almost perfectly balanced out without much change in the strength of reception for the desired wave. If the audio selectivity is made greater, or the output frequency is made higher, keeping the same selectivity, the need for and difficulties in balancing any particular undesired frequency become less. In practice, it is possible to beat directly down to audio frequencies in a very cheap mobile receiver, but it is preferred for high class receivers to beat down to an intermediate frequency and use a second detector in order to more perfectly balance out all image reception. Where an intermediate frequency is used, the final band passed by the receiver may be small as compared to the intermediate frequency and almost perfect balancing can be obtained for the whole image frequency band. In some cases, it may be desirable to utilize circuits for holding constant amplitudes and relative phase differences over large percentage bands of frequencies.

Figure 3 illustrates a schematic diagram of a complete super-heterodyne receiver for telephone reception using the image signal balancing arrangement. In this diagram, energy is received over an antenna 7 which is coupled to a high frequency amplifier 8 through an electrostatic shield 9 in a well known manner. The output from amplifier 8 is applied to the two tubes 10 and 11 of the first heterodyne detector.

In addition, there is provided an oscillator 16, the output of which is applied to a phase splitting circuit designed preferably to give a shift of about 90 degrees between the two inputs 12 and 13 to the two tubes 10 and 11, respectively, of the first detector. This phase splitting circuit is supplied with trimmer or vernier adjustments 14 and 15 for exactly balancing undesired image frequencies.

The tuned circuits of the high frequency amplifier 8, oscillator 16 and detector input circuits are assumed to be variable, but uncontrolled by one mechanism. Plug-in coils or circuits may be employed to adapt the high frequency circuits to any one of several desired bands of frequencies. The high frequency circuits assigned to marine service, for example, are divided up into rather small percentage bands so that it should be entirely practical to provide wave change from one band to another by means of switches or plug-in circuit elements and have these elements adjusted for balancing out image signals in their respective bands.

The currents from the two detector tubes 10 and 11 are shown applied to their individual output circuits 17 and 18, respectively, which are

tuned to frequencies above and below the desired intermediate beat frequency from the first detector system. The detuning of these circuits should be such as to cause a shift in relative phase of currents set up in them equal to the phase shift provided by the phase splitting circuit in the output of the oscillator. In this case the phase shift will be 90 degrees. As a result, the detector outputs corresponding to one band of high frequencies will oppose one another and those due to the other band will add in the common output circuit 19 which is coupled to both detector output circuits 17 and 18.

Output circuit 19 carrying a desired band is shown applied to an intermediate frequency amplifier having two stages 20 and 21, the circuits of which provide selectivity around the desired signal to any desired degree. The intermediate frequency amplifier is shown followed by a second detector 22 and an audio amplifier 23. The circuits illustrated in Figure 3, as so far described, are suitable for reception of telephone signals, but may be made suitable for continuous wave telegraph signals by providing a locally generated beating frequency input, as shown in Figure 3A, to the second detector 22. By providing means to turn the second beating oscillator on and off the receiver may be quickly adapted to either modulated phone or continuous wave telegraph reception. In connection with this figure, it should be noted that, if desired, the capacity of the condensers of the circuits 17 and 18, as indicated by the dash connecting line, may vary oppositely as their common shaft or control is turned in one direction. Other ways are, of course, known of constructing differently variable condensers.

The intermediate frequency circuits may be fixed and do not require changes or tuning to tune the receiver from one desired signal frequency to another. However, if desired, a differential condenser or other adjustment may be provided for the two detector output circuits to provide more exact adjustment for balancing undesired image signals.

Figure 4 illustrates a modification of Figure 3 wherein the output circuit for the first amplifier 8 is coupled directly to the grids of detectors 10 and 11 through blocking condensers 50 in order to eliminate the two tuned input circuits for the detector tubes. In this case, if indirectly heated vacuum tube cathodes such as shown at 51 are used the phase split local oscillator energy may be applied to the cathodes through the leads 52 instead of the grids. A simplification of this sort is a great aid in providing unicontrol tuning.

In this figure there is also shown an arrangement for simplifying the phase splitting circuits of the oscillator to the detectors, and this is accomplished by passing the oscillator circuit radio frequency current, or a portion of it, through a resistance and condenser in series, as shown. The voltage drop across the resistance and condenser will always be 90 degrees different in phase. If the condenser in series with the resistance is designed to change its capacity in proportion with its angular adjustment and the main tuning condenser provides a linear variation of frequency with angular adjustment both condensers may be mounted on one shaft and the voltages from the phase splitting condenser and resistance held substantially equal over the whole range of tuning adjustment. In this latter circuit the impedance of the phase splitting condenser and resistance

will be small compared with the impedance of the main resistance and coil of the oscillator circuit.

Figure 5 is a further modification and illustrates a receiver arrangement for high frequency telephone signals which eliminates the first beating oscillator by making the circuits of the first detector self-oscillating to hold the two tube circuits on the same frequency and at the proper phase angle by suitably controlled coupling between them. In this circuit two detector tube circuits 24 and 25 are held at 90 degrees phase relation by means of reactive coupling between them which is provided by a small amount of inductive or capacitive mutual reactance. In practice, a small amount of mutual inductance would be preferable because the percentage of mutual inductance would remain constant even though the frequency of oscillation be varied over a large range by means of unicontrol variable condensers.

Referring in more detail to this figure, there is shown an antenna 7 coupled to a screen grid high frequency amplifier 26. Amplifier 26 serves to prevent energy from the oscillators in the receiver from reaching the antenna and being radiated in a manner to produce interference in other receivers. A capacity neutralized amplifier might be used although it is preferred to employ the screen grid tube amplifier, with appropriate shielding, as shown.

The output of screen grid high frequency amplifier 26 is coupled to both of the two high frequency detectors 24 and 25 through coils 27, 28, 29 and 30. The mutual inductance introduced through these coils not only couples the output of the amplifier 26 to the two detector tubes 24 and 25, but may also provide all or part of the inductive coupling between the two oscillating detector circuits. By virtue of this inductance coupling between the two oscillators, which are assumed to be electrically identical or similar, they are held in synchronism with a constant phase difference of substantially 90 degrees when correct adjustments have been made. Consequently, beats between the two detector oscillations and amplified energies from the antenna 7 result in detector output beat frequency energies substantially 90 degrees different in phase.

The tuned circuits of the high frequency amplifier 26 and self-oscillating detectors 24, 25 may be electrically similar and all tuned by three similar condensers on the same rotatable shaft or, at any rate, mechanically operated by a single tuning arm. If desired, plug-in coils may be used in some cases to adapt the receiver to reception in different bands.

The oscillating detector tubes as shown in this particular diagram are assumed to have grid bias and regeneration such that the strength of oscillations is held to something on the order of half maximum amplitude and the amplitude left quite sensitive to small amounts of helping or opposing energy fed in from the amplifier. At the same time the anode current is made sensitive to the amplitude of oscillation and all these factors contribute to making the detectors very sensitive.

The intermediate frequency outputs from the two detectors are shown applied to two tuned circuits. These circuits are similar except that one is tuned above and one below the middle of the intermediate frequency pass band by such an amount as to cause opposite shifts of 45 degrees in the currents set up in the circuits. If

desired, the tuned circuits might be replaced by reactance-resistance phase splitting circuits, artificial lines, radio goniometers or any other known phase shifting devices.

The tuned detector output circuits shown in the diagram are equipped with condensers which may be varied differentially for controlling the relative phase shifts in the currents in order to obtain most perfect cancellation of any particularly strong interfering image signal.

The two circuits are shown coupled to the input of an intermediate frequency amplifier. The relative coupling to the two circuits should be differentially variable for exactly balancing the amplitudes of any undesired image signals. If preferred, means may be provided for varying the detector sensitivities, instead, by varying the electrode potentials, regeneration, circuit losses, etc.

The output circuit of the intermediate frequency amplifier is shown coupled to a second detector through a coupled circuit band pass filter. The output of the second detector is amplified and passed to the loudspeaker or any other suitable utilization device.

To obtain automatic volume control there is shown a resistor in series with the anode supply to the final detector. The voltage drop in this resistor varies in accordance with the strength of average input to the detector. The changing voltage tends to decrease the detector sensitivity for increasing input and also varies the screen grid voltage on the amplifier tubes in a direction to decrease their amplification.

Although, in the diagram there has been shown only one source of voltage for each of the grid bias, screen grid and anode potentials it will be understood that, in practice, different voltages may be used on electrodes of different tubes.

To illustrate one way in which the receiver may be utilized we might assume that the signals from a telephone transmitter operating on a carrier frequency of 40,000,000 cycles per second is to be received. If this is a high quality transmitter its carrier may carry modulating frequencies from about 25 to 7500 cycles.

In the first detector we may employ an oscillating frequency of 39,600,000 cycles which will produce an intermediate frequency carrier of 400,000 cycles. The image band which we wish to eliminate is one having a midband at 39,200,000 cycles, which is only about one part in 50,000 removed from the desired band so that it is not appreciably reduced by the selectivity of the circuits ahead of the first detector.

Assuming all adjustments are correct we may balance the 400,000 cycle image energy almost perfectly to zero in the input to the intermediate frequency amplifier. The intermediate frequency circuits eliminate energies of frequency more than plus or minus 7500 cycles removed from the 400,000 cycles. Energies which are 7500 cycles removed will not balance quite perfectly because they are nearly 2% removed from the balanced frequency. The amount of unbalance in this case will amount to possibly as much as 2 to 2.5 degrees in angle and 2.5% to 3% in amplitude which may produce an unbalanced amplitude of undesired image energy as much as 2% of the sum of the desired detector outputs. In the case assumed, the maximum interfering effect from any part of the image band will then be about 2% of normal amplitude, 0.04% of normal power or 25 decibels reduced. Assuming that the desired carrier is reasonably strong the chief result of unbalance image energy would be to

produce audio noise of maximum intensity at 7500 cycles, but which would decrease very rapidly at lower audio frequencies.

Another circuit similar to that of Figure 5 wherein two detector tubes are used with the ordinary type of regeneration or oscillation may be employed for marine or similar equipment. Such an arrangement is shown in Figure 6, wherein the high frequency waves are beat down to relatively low intermediate frequencies and the second detector made regenerative for phone and modulated wave reception or self-oscillating for reception of continuous waves. By careful attention to obtaining maximum sensitivity in the self-oscillating detectors there is thus obtained an extremely simple and inexpensive receiver which has substantially the same performance characteristics as the more elaborate super-heterodyne receivers.

Figure 7 shows an image band suppressing receiver system wherein no phase shifting is required between currents in the intermediate frequency output circuits. Instead, the output currents from the second pair of detectors 33 and 34 are phase shifted due to the use of 90 degree phase relative inputs from the intermediate frequency oscillator 30. In this system, image band signals from the first detectors 31 and 32 are balanced out. Preferably, a low intermediate frequency is used. High frequency and intermediate frequency amplifiers and many other refinements may be added, if desired. Reversing relative polarities of the primary windings 35 and 36 of the audio transformer 37 allows selection of the band either above or below the high frequency oscillator.

Figure 8 shows an arrangement for ultra high frequency reception wherein the two first detector tubes are adjusted and used as Barkhausen oscillators locked in step with a difference in phase between the oscillations. The Barkhausen effect may be used, if desired, only for regeneration to obtain increased high frequency sensitivity and selectivity.

Figure 9 shows a scheme for holding the oscillators in synchronism with a phase relation of substantially 90 degrees, regardless of variations in their frequency. This arrangement gives the oscillators a fixed 90 degrees phase relation over any range of frequencies by coupling the two oscillators 40 and 41 in such manner that their second harmonics are always held substantially 180 degrees out of phase. In this way their fundamental frequencies, of necessity, are always half this phase difference or at 90 degrees.

Second harmonic coupling is obtained in Figure 9 by inserting a common circuit, tuned approximately to the second harmonic frequency, between the cathodes of the two tubes 40 and 41 and ground, or the negative side of the anode circuit power supply system. Preferably, the coupling between the oscillators at the fundamental frequency is a minimum, though some coupling is permitted. The effect of the circuit shown tuned to the second harmonic (or any other even harmonic, if desired) is to insert a strong degenerative effect at the second harmonic frequency into each oscillator circuit taken alone. In other words, it tends strongly to reduce the strength of oscillation in each oscillator. However, when both oscillators are active they balance out second harmonic currents in the circuit tuned to the harmonic and thus each permits the other to oscillate full strength, without second harmonic degeneration. This full strength os-

cillating condition will be assumed automatically by the two oscillators 40 and 41 and, consequently, their second harmonics are held at 180 degrees phase relation, which corresponds to 90 degrees phase relation from the fundamental.

It is preferred in the circuit arrangement just described that all variable condensers shown be controlled by one shaft or knob.

It will be noted that the accuracy of phase control between the two oscillators is only slightly dependent upon the tuning of the second harmonic circuit, it only being necessary that the circuit develop considerable harmonic frequency impedance. As a result, the system has no critical adjustments and is quite practical to construct and operate. Obviously, other detailed circuit arrangements may be used instead; for example, the harmonic frequency tuned circuit may be inserted in series with the positive or anode end of the power supply circuit instead of in the negative or cathode end. Also, any other known type of oscillator circuit may be used.

If the oscillators 40 and 41 are used directly as detectors, the high frequency input may be coupled to them and intermediate frequency circuits inserted in series with the anode supply leads.

An alternative to the arrangement of Figure 9 may be set up with two relaxation oscillators or frequency dividers having their frequency controlled by a double frequency oscillator, output from which would be applied to the frequency dividers 180 degrees out of phase. If tripping tube or glow tube, condenser, resistance frequency dividers are used the resistance can be uncontrolled with the oscillator condenser to hold correct relative adjustments over a large range of frequencies.

Figures 10 to 13 utilize auxiliary electrodes for second harmonic synchronization of oscillators at the 90 degree phase relation.

Figure 10 shows two oscillator circuits in which the screen grids of four electrode tubes are used as anodes. In the circuit the plates of the tubes are connected in parallel and then placed in series with a circuit tuned to the second harmonic of the oscillator frequency. In order that the second harmonic circuit may lock the oscillators in step at 90 degree phase relation it is necessary for the second harmonic circuit to cause a reduction in oscillator power except when the second harmonics are 180 degrees out of phase. In other words, the building up of oscillations in the second harmonic circuit must reduce the current flow to the screen grids. Since the second harmonic circuit, when oscillating, reduces the anode voltage, simultaneously with reduction in screen grid voltage from the fundamental frequency oscillation we must have conditions which cause a reduction in screen grid circuit with reduction in anode voltage. We may obtain this condition by making the anode D. C. voltage positive, but much less than the screen grid D. C. voltage so that, due to "dynatron" effect a considerable portion of the screen grid current is furnished by secondary emission from the plate. Then oscillation at second harmonic frequency, in the second harmonic circuit, reduces the anode voltage at the times when electron currents are flowing in the tube and so reduces the current to the screen grid. In this case maximum power is produced in the fundamental frequency circuits when the second harmonic currents to the plates are 180 degrees out of phase so that no second harmonic current is built up in the second harmonic tuned circuit. The oscillators automati-

cally adjust themselves to this maximum oscillation condition, if the circuits are correctly adjusted, and so the fundamental frequency oscillations are held at 90 degree phase relation.

5 Figure 11 shows another circuit in which the plates are maintained at a considerably higher D. C. potential than in Figure 1 so that secondary emission currents returning from anodes to screen grids is prevented. In this case the anode potentials tend to draw the electrons through and away from the screen grids in a way to greatly reduce the screen grid current and the strength of oscillations at fundamental frequency.

10 The second harmonic circuit in this case is connected between the plates in push-pull fashion. Now if second harmonic oscillations are set up in the circuit, when electron currents flow, the plate potentials are reduced and allow a greater flow of current to the screen grids. Then the stronger the second harmonic currents become the greater will be the power developed at the fundamental frequency in each oscillator. The second harmonic currents normally will be maximum when they are 180 degrees out of phase on the two plates. Therefore, the system normally holds the second harmonics at 180 degrees and the fundamental frequency oscillations at 90 degrees phase relation.

15 Figure 12 shows schematically a diagram of a system in which two high frequency oscillators are held in synchronism at 90 degrees phase relation by means of a second harmonic tuned circuit connected in series with the paralleled connections to the screen grids of two four electrode tubes. In this case, unless the oscillators hold the second harmonics at 180 degrees phase relation, oscillations are set up in the second harmonic tuned circuit which exert a strong degenerative effect, a condition which the tube circuits automatically avoid.

20 In this same figure there is shown an input coupling for a high frequency to be detected. There is also shown the intermediate beat frequency output circuits arranged to provide 90 degrees relative phase shift in the two intermediate frequency outputs. Coupled to these two circuits is an intermediate frequency output circuit after which may include amplifiers, detectors, loudspeakers, recorders, etc., the operation of which will have been made relatively free from image band interference.

25 Figure 13 shows schematically a self-oscillating detector system using five electrode tubes. It will be noted that there is also shown a high frequency input to the first pair of grids from the cathode. The input grids are shielded by the next set of grids which are tuned for the second harmonic of the self-oscillation frequency and are effectively grounded back to the cathodes for the fundamental frequency. Of course, appropriate circuit shielding would be used in addition.

30 The third pair of grids and the anodes are used to produce the high frequency self-oscillations held 90 degrees different in phase due to locking by the second harmonic developed in the circuit to the second pair of grids.

35 The final output is obtained from two oppositely detuned circuits, tuned on either side of the beat frequency between the local oscillations and the incoming signal which is to be received.

40 It will be apparent that many modifications may be made in the circuits above described without departing from the present invention. For example, in the oscillator circuits shown, various trimmer adjustments may be provided for bal-

ancing exactly the undesired image frequency energies. The trimmers for adjustment of phase may operate on the tuning of the high frequency oscillating circuits differentially or upon the tuning of the two intermediate frequency output circuits differentially. Relative amplitudes may be adjusted accurately by differential variation of high frequency input or intermediate frequency output couplings or by differential adjustments of vacuum tube electrode potentials.

45 In practice, since the intermediate frequency circuits may always operate in a fixed or relatively fixed frequency band they do not require adjustments in operation other than perhaps some trimmer adjustments of phase and amplitude for exactly balancing image band interference. The high frequency circuits, including the second harmonic circuit should preferably be controlled by a single tuning dial.

50 The circuits of Figures 10, 12 and 13, and others like them where a single ended, or unbalanced second harmonic circuit is used which requires no transformer action, may very well operate well enough for many practical purposes by inserting a resistance in place of the tuned circuit. In cases where this can be done the tuning system will be simplified through the elimination of one variably tuned circuit.

55 Obviously, the image suppressing detector systems may be combined with nearly all the known circuit elements and features necessary to produce an economical and efficient receiving system for any useful purpose. For example, the detector may be combined with reflex circuits in which a single tube may simultaneously perform several different and distinct functions.

60 It is to be distinctly understood that the present invention is not limited to radio reception, but may be utilized in carrier telegraph, telephone, or other communication systems over wires, beams of light, sound waves, or any other form of radiation or guided wave energy transfer, signaling or control system.

I claim:

1. The method of suppressing the effects of undesired bands of frequencies which includes receiving signal energies, generating local energies, beating the undesired energies with locally generated energies of like frequency but of different relative phases so as to produce beat frequency energies of different phases, then shifting the relative phases and combining the beat frequency energies in such a manner that they substantially balance out.

2. The method of receiving desired bands of frequencies which includes receiving energies including the desired bands, generating local energies, beating the desired energies with the locally generated energies of like frequency but different relative phases so as to produce beat frequency energies of different phases, then shifting the relative phases and combining the beat frequency energies in such a manner that they add together wholly or in part.

3. The method of suppressing the effects of undesired bands of frequencies but utilizing desired bands of frequencies which includes generating energies of like frequency but different phases, beating both with the locally generated energies of like frequency but different phases so as to produce beat frequency energies in such a manner that the undesired energies are substantially balanced out while the desired energies add together wholly or in part.

4. The method of suppressing image band re-

ception in a super-heterodyne receiver having two detectors which includes supplying the two detectors with radio frequency energies of like frequencies but different phases, to produce beat frequency energies of different relative phases, then shifting the relative phases and combining the detector output energies so that image frequency band energies are substantially balanced out while the desired frequency band energies are added together wholly or in part.

5. In a signal receiver comprising two detectors whose input circuits are arranged to receive the signal energy simultaneously, the method of operation which comprises combining in said detectors signal energy and locally generated energy, one of which has a difference in phase in said input circuits of substantially 90 degrees, obtaining from said detectors energy having substantially an additional 90 degrees phase shift, and combining energies obtained from both of said detectors whereby there is effectively suppressed an image band of frequencies differing by a predetermined amount from the frequency of the locally generated frequency.

6. In a super-heterodyne receiver comprising a signal collecting circuit coupled to two detectors having separate input and output circuits and whose input circuits are arranged to receive the signal energy simultaneously, the method of operation for obtaining image signal suppression which comprises generating local oscillatory energy of substantially constant frequency, supplying one of said energies to said detectors with a difference in phase of substantially 90 degrees, combining said signal energy and locally generated oscillatory energy in each of said detectors, obtaining in said detector output circuits substantially an additional 90 degrees phase shift between the energies in said output circuits, and combining the energies in both of said output circuits whereby energies of frequencies above said local oscillator frequency substantially add and energy below said oscillator frequency substantially balance each other.

7. In combination in a receiver, a first detector and a second detector, each having input and output circuits, a source of signal energy and a source of locally generated oscillations both sources being coupled simultaneously to said input circuits, means coupling said sources to said input circuits designed to shift the relative phases of the energies from said sources on said respective input circuits by substantially 90 degrees, means in said detector output circuits for shifting the phase of the output energies 90 degrees with respect to each other, and a utilization circuit coupled to said last means.

8. In combination, in a super-heterodyne radio receiver, a first detector and a second detector each having input and output circuits, a source of signal energy coupled to both input circuits of said detectors, and a local beating oscillator also coupled to both input circuits, means for shifting the phase of the currents from said oscillator to one of said input circuits substantially 90 degrees with respect to currents from said oscillator delivered to said other input circuit, tuned circuits in the output circuits of said first and second detectors for causing a 90 degrees shift in phase in the outputs of said detectors, and a tuned intermediate frequency circuit coupled to both said detector output circuits.

9. In combination, in a super-heterodyne receiver, a first detector and a second detector, each having input and output circuits, an antenna coupled to both input circuits of said de-

tectors, and a local beating oscillator so coupled as to supply leading currents to one of said detector input circuits and lagging currents substantially 90 degrees out of phase with said leading currents to the other of said detector input circuits, phase shifting means in each of said output circuits for providing substantially 45 degrees leading phase in one of said outputs and 45 degrees lagging phase in the other of said outputs, and a tuned utilization circuit coupled to both of said output circuits.

10. In combination, in a super-heterodyne receiver, a first detector and a second detector, each having input and output circuits, an antenna coupled to both input circuits of said detectors, and a local beating oscillator so coupled as to supply leading currents to one of said detector input circuits and lagging currents which are substantially 90 degrees out of phase with said leading currents to the other of said detector input circuits, phase shifting means in each of said output circuits for providing substantially a 90 degrees phase shift between said two detector outputs, said detectors being arranged to provide output energies which are substantially equal in amplitude, and a utilization circuit coupled to both of said output circuits.

11. In combination, in a super-heterodyne radio receiver, a first detector and a second detector, each having input and output circuits, an antenna, a high frequency amplifier arranged to receive signal energy from said antenna coupled to both input circuits of said detectors, circuit means for causing the flow of local oscillatory energy in both input circuits of said detectors with a phase difference of substantially 90 degrees, and phase shifters in the output circuits of said detectors for effecting an additional 90 degrees phase shift between the two detector outputs, and a utilization circuit coupled to both of said detector output circuits.

12. In combination, in a super-heterodyne radio receiver, a first detector and a second detector each having input and output circuits, an antenna, a screen grid radio frequency amplifier coupled to said antenna through a transformer and arranged to receive signal energy from said antenna and to supply said signal energy to both input circuits of said detector, shielding means between the windings of said transformer, circuit means for causing the flow of local oscillatory energy in both input circuits of said detectors with a difference in phase of substantially 90 degrees, phase shifters in the output circuits of said detectors for effecting an additional 90 degrees phase shift between the two detector outputs, an intermediate frequency amplifier coupled to both detector output circuits, a third detector, and a band pass filter between said intermediate frequency amplifier and said last detector, an audio frequency amplifier coupled to said last detector, and a translation device in circuit with said audio frequency amplifier.

13. In combination, in a receiver, a first oscillator detector and a second oscillator detector having input circuits inductively coupled to each other for effecting an approximate 90 degrees phase relationship between the oscillatory energy in said input circuits, means for supplying signal energy to said input circuits, output circuits for said detectors, phase shifting means for obtaining an additional 90 degrees phase shift between the two detector outputs, and a utilization circuit coupled to both of said output circuits.

14. In combination, in a receiver, a first oscillator detector and a second oscillator detector having input circuits inductively coupled to each other for effecting an approximate 90 degrees phase relationship between the oscillatory energy in said input circuits, means for supplying signal energy to said input circuits, output circuits for said detectors, individual tunable phase shifters in each output circuit for obtaining an additional 90 degrees phase shift between the two detector outputs, unicontrol means for said tunable phase shifters, and a utilization circuit coupled to both of said output circuits.

15. In combination, in a receiver, a first oscillator detector and a second oscillator detector, having input circuits inductively coupled to each other for effecting an approximate 90 degrees phase relationship between the oscillatory energy in said input circuits, unicontrol tuning means in said input circuits, means for supplying signal energy to said input circuits, output circuits for said detectors, individual tunable phase shifters in each of said output circuits for obtaining an additional 90 degrees phase shift between the two detector outputs, and unicontrol means arranged to control said individual tunable phase shifters differentially, and a utilization circuit coupled to both said output circuits.

16. An image signal suppressing receiver system including two self-oscillating electron discharge tube detectors and controllable means coupling said detectors so arranged as to maintain their oscillations at the same frequency but different in phase by substantially 90°.

17. In a superheterodyne receiver, the combination of a first detector and a second detector, each having input and output circuits, a source of high frequency signal energy, means coupling said source to the input circuits of said detectors, adjustable means for tuning said input circuits to the signal frequency, a local oscillator having an output circuit including a phase splitting circuit provided with a vernier control means for regu-

lating the current in said output circuit, connections between said detector input circuits and spaced apart points of said phase splitting circuit, means for tuning one of said detector output circuits to a frequency higher than the frequency difference between the signal and oscillator frequencies, means for tuning the other detector output circuit to a frequency lower than said frequency difference and a utilization circuit coupled to both said detector output circuits.

18. The combination defined in the preceding claim in which said vernier control means comprises a variable condenser in series with an adjustable resistor.

19. In a superheterodyne receiver, the combination of a first detector and a second detector each having input and output circuits, variable condensers connected to said input circuits to tune them to the same resonant signal frequency, unicontrol operating means for adjusting said condensers, a local beating oscillator coupled to said input circuits to supply potentials thereto which differ in phase in said respective input circuits by substantially 90 degrees, adjustable means in the output circuits of said detectors for causing a phase shift of substantially 90 degrees in the said output circuits and a utilization circuit coupled to each of said output circuits.

20. In a superheterodyne receiver, the combination of a first detector and a second detector, each comprising an electron discharge tube having a cathode, control grid and plate, means for impressing signal voltages on said control grids which are in phase, a local oscillator having an output circuit so arranged that the phase difference between two points thereof is substantially 90°, a connection between each of said points and the respective cathodes of said tubes, circuits connecting said cathodes and plates including means for causing a phase shift of more than 45° in said circuits and a common output circuit coupled to said last named circuits.

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