July 2, 1940. G. GUANELLA 2,206,695

MEANS FOR RECEIVING HIGH FREQUENCY SIGNALS

Filed May 17, 1938 4 Sheets-Sheet 1

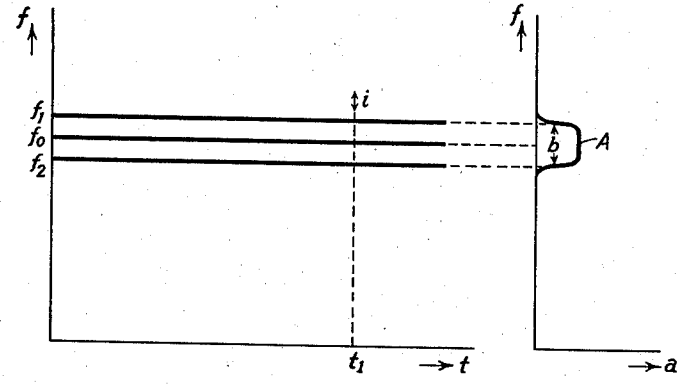


Fig: 1

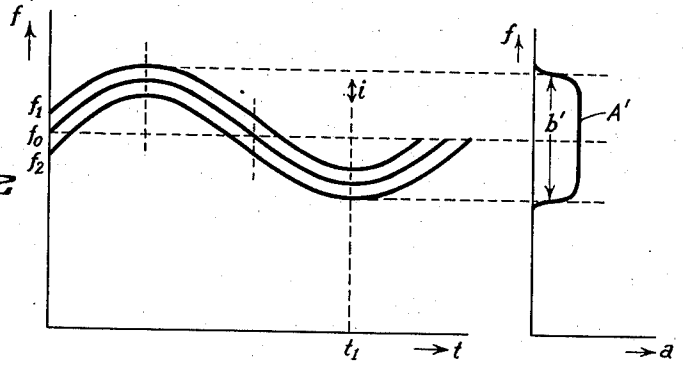


Fig: 2

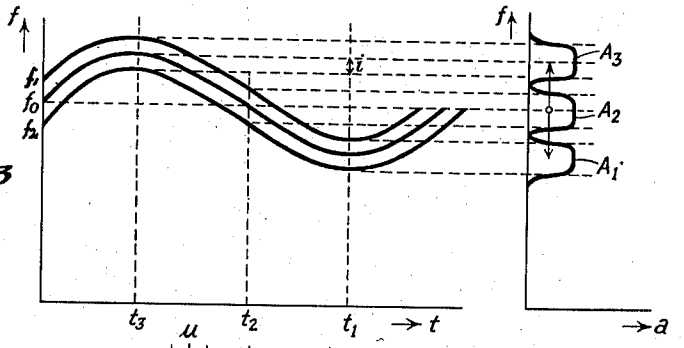


Fig: 3

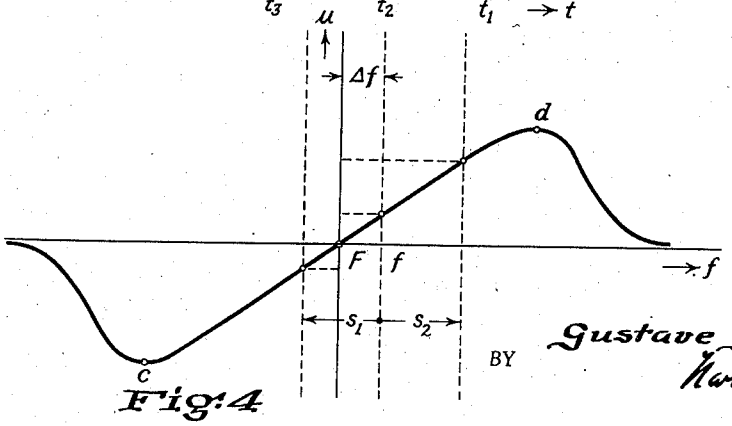


Fig: 4

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MEANS FOR RECEIVING HIGH FREQUENCY SIGNALS

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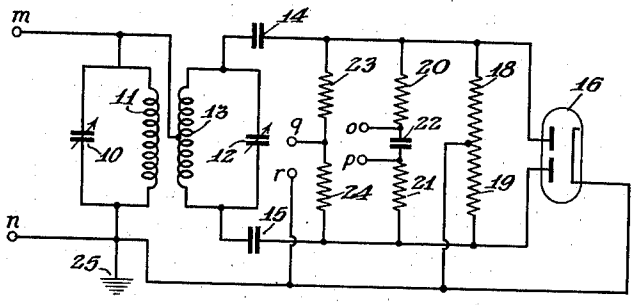


Fig: 5

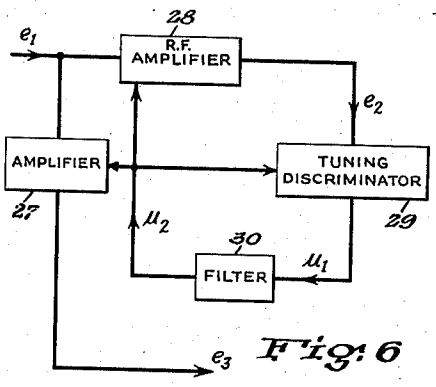


Fig: 6

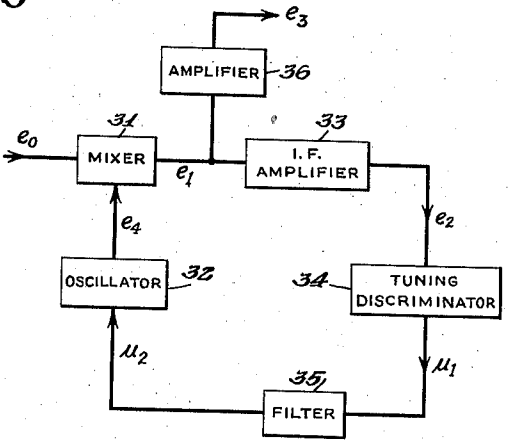


Fig: 7

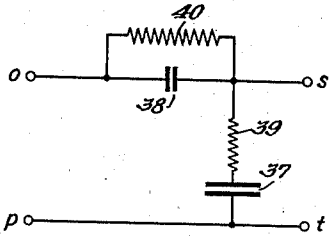


Fig: 8

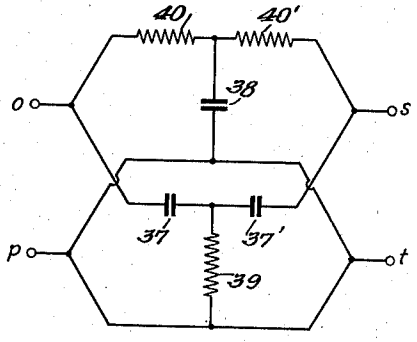


Fig: 9

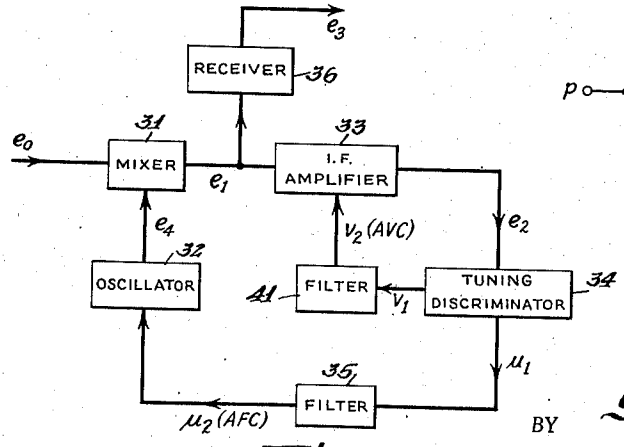


Fig: 10

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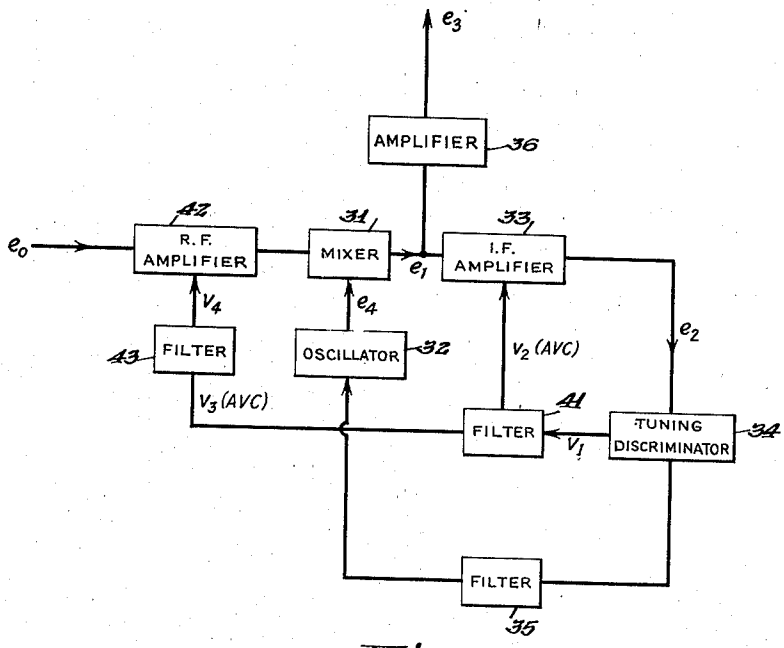


Fig. 11.

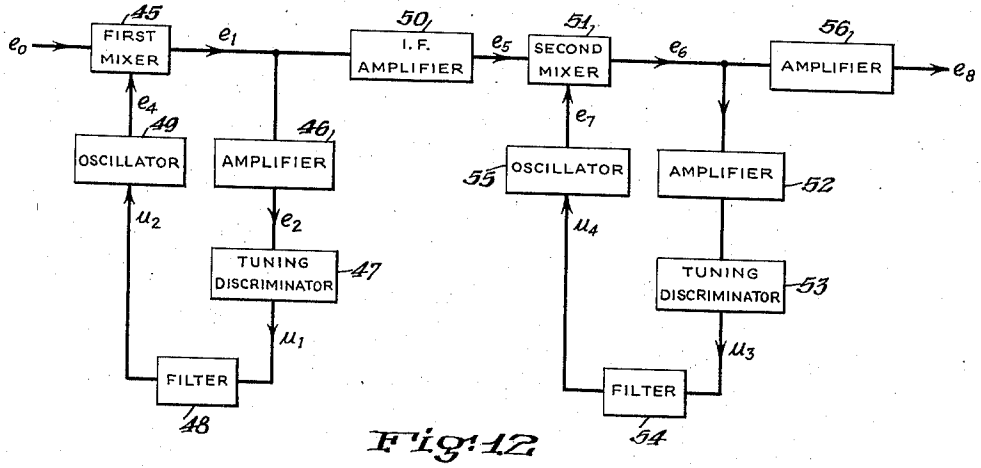


Fig. 12.

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MEANS FOR RECEIVING HIGH FREQUENCY SIGNALS

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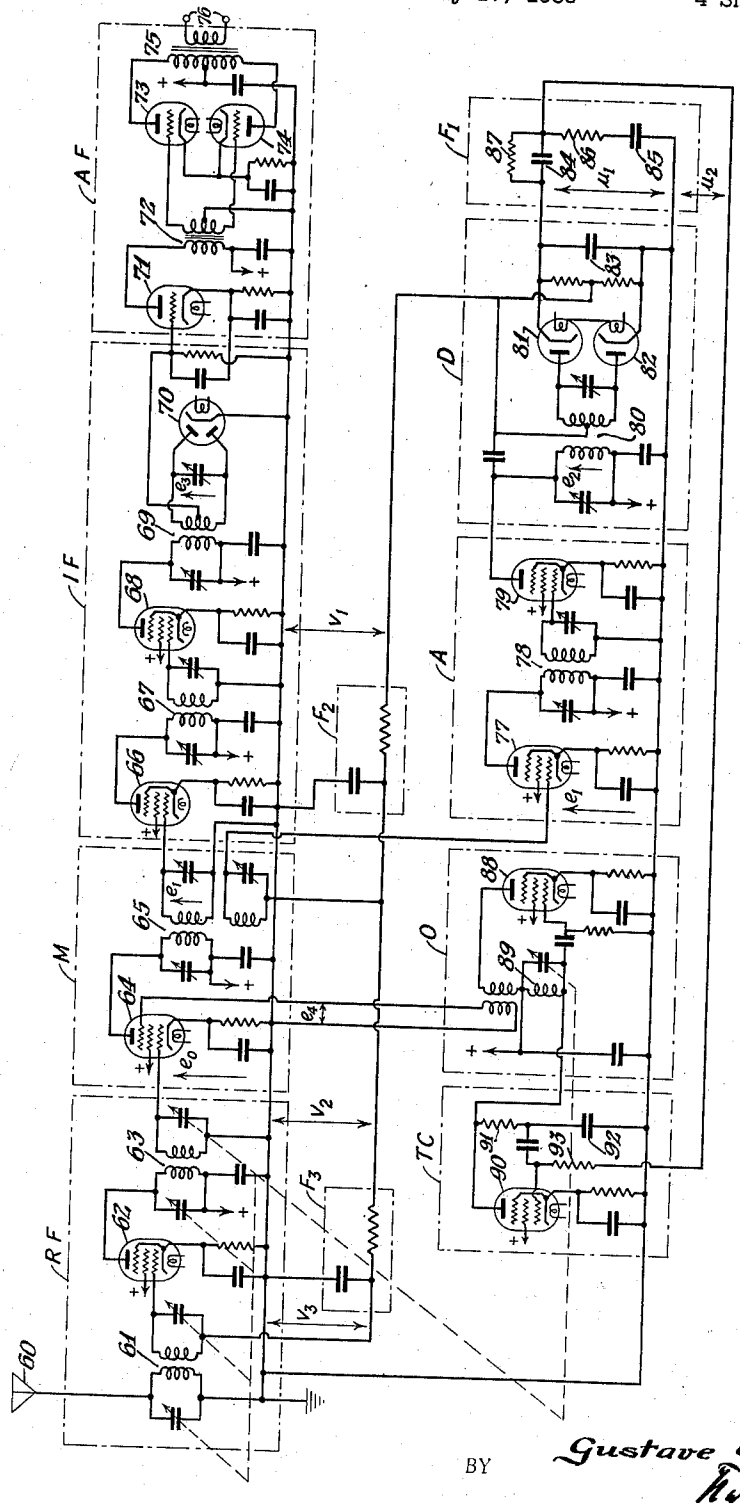


Fig. 4

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Patented July 2, 1940

2,206,695

UNITED STATES PATENT OFFICE

2,206,695

MEANS FOR RECEIVING HIGH FREQUENCY SIGNALS

Gustave Guanella, Zurich, Switzerland, assignor to Radio Patents Corporation, New York, N. Y., a corporation of New York

Application May 17, 1938, Serial No. 208,366
In Switzerland July 10, 1937

8 Claims. (Cl. 250—20)

The present invention relates to means for receiving high frequency signals, more particularly to the reception of modulated signals having a carrier or unmodulated component subject to rapid fluctuations of both regular and irregular character and due to various causes and origins.

As is well known, in modulating the amplitude of a high frequency carrier wave it is impossible in most cases to avoid a simultaneous frequency or phase modulation manifested by fluctuations of the carrier frequency in the rhythm of the low frequency or modulating signal to be transmitted. These fluctuations in general amount to only a small fraction of the average carrier frequency. However, the range of the resultant frequency band transmitted may be considerably increased beyond the range determined by the low frequency modulation. As a result, a selective receiver having a considerably extended response or receiving band width is required for the reception of such oscillations, since in case of a limited response characteristic of the receiver an undesired, non-linear conversion of the frequency modulation into an amplitude modulation will occur making reception in most cases impossible.

Aside from this fact, it is generally required in a receiver employing band-pass filters with subsequent rectification that the carrier frequency at any time coincides with the medium or central response frequency of the filter or receiving circuits to avoid asymmetrical phase rotation in the side bands liable to lead to non-linear distortion during rectification. For these reasons, great difficulties are experienced in receiving amplitude modulated oscillations subject to carrier frequency fluctuations.

In case of receiving short waves, selective circuits can be easily constructed having the necessary extended band width comprising both the modulation side bands and the carrier frequency fluctuation range since in this case the resultant band is still small compared with the carrier frequencies employed. However, it is understood that due to the extended receiving band width or resonance characteristics disturbances and interference of various origins having frequency components falling within the extended transmitting range of the selective circuits are received in an undesirable manner together with the signal frequencies.

When employing superheterodyne reception, additional difficulties are encountered in case of a fluctuating carrier frequency due to the extended frequency range and in view of the fact that the frequency range is no longer small compared with the intermediate frequency employed in receivers of this type. For this reason, the employment of superheterodyne reception for short waves has been difficult in most cases and entirely unfeasible and impractical in the case of ultra short waves. Thus, the special advantages of frequency transformation and subsequent amplification employed in the superheterodyne type of reception cannot be utilized for the reception of ultra short waves, the straight amplification of which, as is known, is also accompanied by substantial difficulties.

Accordingly, it is an object of the present invention to substantially overcome the difficulties experienced in receiving amplitude or otherwise modulated carrier signals the carrier frequency of which is subject to rapid fluctuations of the order of the modulating frequencies to be transmitted due to additional frequency or phase modulation or to other causes.

Another object is to provide a receiving system for modulated carrier signals subject to rapid fluctuations of the carrier frequency using selective receiving means having a band width or response which is equal to or only slightly exceeds the range of the modulation side bands of the signals to be received.

Another object is to provide a system and a method for receiving a high frequency carrier wave modulated according to a signal wave to be transmitted and being subject to periodic fluctuations of the carrier frequency according to the instantaneous values of said signal wave, enabling the employment of sharply selective circuit means having frequency response characteristics not substantially exceeding the side band or modulation range occasioned by the non-fluctuating carrier wave modulated in accordance with said signal wave.

A more specific object is to provide a system and a method for receiving a high frequency carrier wave having an amplitude modulated according to a signal wave to be transmitted and being subject to periodic fluctuations of the carrier frequency according to the instantaneous values of said signal wave, enabling the employment of a sharply tuned band-pass receiver having a response characteristic (band width) not substantially exceeding the side band range occasioned by the amplitude modulation of the constant non-fluctuating carrier in accordance with said signal wave.

A further object is the provision of a receiv-

ing system and a method especially suited for short and ultra short wave signals.

The above difficulties in receiving a modulated carrier wave subject to fluctuations of the carrier frequency due to additional frequency and/or phase modulation, are substantially overcome by the novel method and system proposed by the invention. By the new method it is possible to employ selective circuits or networks having a band width or response characteristic which comprise or exceed only slightly the frequency range occasioned by the low frequency modulation or signal side band range and by which a superheterodyne reception is enabled for the shortest wave lengths at present used in practice.

As is known, an amplitude, frequency or phase modulated carrier wave may be resolved into a greater or lesser number of components of different frequency corresponding to the low frequency or signal wave which in their entirety may be substituted by a single frequency of variable amplitude or frequency.

Further objects and novel aspects of the invention will become more apparent from the following detailed description of practical embodiments thereof taken with reference to the accompanying drawings forming part of this specification and wherein:

Figures 1 to 4 represent diagrams explanatory of the function and operation of the invention,

Figure 5 shows by way of example a discriminating circuit suitable for use in a receiving system of the type according to the invention,

Figure 6 shows in block diagram form an inventive receiving system embodied in a straight or radio frequency (RF) amplifier,

Figure 7 shows a modified receiving system embodied in a superheterodyne receiver,

Figures 8 and 9 show partial circuit arrangements to be employed in the previous circuits to improve the operation thereof,

Figures 10 and 11 show modified receiving systems of the type shown in Figures 6 and 7, respectively, with features of improvement embodied therein to improve the operation,

Figure 12 shows a receiving system according to the invention employed in a multiple superheterodyne receiver,

Figure 13 is a complete circuit diagram for a superheterodyne receiver suited for short wave and ultra-short wave reception constructed according to the invention.

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

With the above objects in view, the present invention contemplates the generation of a tuning control potential varying according to the amount of instantaneous detuning of a receiver relative to the instantaneous frequency of a received carrier frequency wave. This tuning control potential serves to control the tuning adjustment of the receiver in such a manner as to maintain the detuning at each instant within a sufficiently small limit independently of rapid fluctuations of the carrier frequency of the received signals such as fluctuations due to additional frequency modulation in case of an amplitude modulated signal according to a low frequency or modulating signal wave being transmitted which may be within the audible range.

Exact analysis has shown that the instantaneous frequency of an oscillatory circuit having variable parameters such as variable inductance or capacitance elements actually corresponds to the resonance frequency which may be computed in a known manner from the instantaneous values of the parameters (see A. Erdelyi: "On the free oscillations in condenser circuits with periodically fluctuating capacitance," Annalen der Physik, 5th series, vol. 19, page 604). Also, the "mean damping" is found to correspond to the damping of an equivalent circuit with fixed parameters. However, in case of periodically fluctuating parameters corresponding amplitude variations occur in general which in the present case are of secondary importance in view of the fact that the frequency fluctuations are slight in comparison to the average value of the carrier or tuning frequency. In the practically rare cases where this is not the case, the above amplitude fluctuations may be eliminated by a rapidly acting control arrangement of the type of the known automatic volume control (AVC) systems commonly used in radio receivers. Such amplitude fluctuations may also be avoided by simultaneously varying both the inductance and capacitance of the oscillatory circuit in equal amounts.

Investigation has further shown that in case of periodically varying tuning parameters, certain natural frequencies may build up excessive amplitudes and cause oscillations within certain unstable operating regions. This phenomena occurs only if the frequency of the tuning variations differs substantially from the average tuning (carrier) frequency of the oscillatory circuit and they may be eliminated by providing sufficient damping in the circuits.

Since the tuning of the receiver according to the present invention is regulated so as to constantly follow the instantaneous frequency of the received carrier wave, it will be referred to hereafter as "synchronized tuning" for the purpose of this specification. In this respect, that is in the instantaneous control of the tuning which follows the most rapid variations of the received frequency, the invention differs fundamentally from the known methods and arrangements for automatic tuning or frequency control (AFC) which act to effect a subsequent correction of receiver tuning after an initially incorrect adjustment to the received carrier wave or as a result of a relatively slow carrier frequency change known as drift. In accordance with this special purpose and function, a rapid action in the known arrangements for automatic tuning is not desirable nor required, the usual time constants being of the order of one second. In contrast thereto, time constants of the order of one thousandth of a second are required to eliminate the effect of rapid fluctuations at a rate of the order of the component frequencies of the modulating signal wave being transmitted such as in case of additional frequency modulation to secure a synchronized tuning in accordance with the objects and function to be obtained by the present invention.

Referring to the diagrams according to Figures 1 to 3 of the drawings wherein are plotted frequencies as a function of time, f_0 represents the carrier frequency and f_1 and f_2 the upper and lower modulation side frequencies of an amplitude modulated high frequency carrier wave. In the case of Figure 1, the carrier frequency f_0 is assumed to be constant, that is there is no additional frequency modulation or fluctuation and accordingly the side band frequencies f_1 and f_2 also have a constant value. Signals of this type may be received by means of a selective circuit having a response characteristic A with a band width b corresponding to the modulation fre-

quency or side band range of the signals as shown by the diagram in Figure 1 representing signal response a as a function of the frequency f. An interfering signal comprising a frequency range indicated by the arrow i and occurring at a time t_1 is completely eliminated by the action of the selective circuit as is readily understood.

If, on the other hand, the carrier frequency for one reason or another (such as due to an additional frequency modulation as explained hereinbefore) is subject to rapid fluctuations, conditions are changed as represented in Figure 2. In the latter, it is assumed that the carrier f_0 and with it the side band frequencies f_1 and f_2 fluctuate rapidly according to a sinusoidal variation. A reception of signals of this type with normal means is possible only if the resonance characteristic A' of the receiver has a band width b' encompassing both the modulation frequency range and the range of the carrier fluctuations such as shown in the illustration. In this case, the interfering frequencies i fall within the response range of the receiver and accordingly will be received together with the desired signals.

Referring to Figure 3 which illustrates the operation of a receiver proposed by the invention, the tuning of the receiver is varied in synchronism with the carrier frequency f_0 such as indicated by the band filter curves A_1, A_2, A_3, corresponding to instants t_1, t_2 and t_3, respectively, during the fluctuating cycle. In this case, the disturbing frequencies i are no longer received together with the signal frequency due to the instantaneous location of the resonance characteristic A_1 outside the disturbing signal range i at the instant t_1.

For the generation of a tuning responsive control potential, apparatus is required having a characteristic as shown by the diagram according to Figure 4 wherein u represents the tuning responsive potential as a function of signal frequency f. There is thus required a tuning control potential u varying in dependence upon the instantaneous differential Δf between the received instantaneous frequency f and the natural or resonant frequency F of the receiver which control potential at each instant varies both according to the sense and amount of detuning Δf. The received high frequency f which in the example illustrated is somewhat above the tuning frequency F will cause the generation of a corresponding positive control potential adapted to effect the necessary instantaneous tuning control within the required short time period. If the received frequency f is below the tuning frequency F, a similar control potential but of opposite polarity will be generated. If the received signals comprise the side bands s_1, s_2 due to modulation in accordance with a signal wave, the same control potential should be produced, that is the control potential should not be dependent upon the instantaneous condition of the amplitude modulation. This is the case if the characteristic according to Figure 4 is substantially a straight line within the operating range comprised by the carrier and side frequencies. Thus, an approximate linear portion of the curve is required between the points c and d, i. e. within a range comprising the greatest deviations to be expected between the received frequencies and the instantaneous tuning frequency of the receiving circuit. Beyond these points, a rapid descent of the curve to the zero line is desirable in order to prevent the generation of a control potential by disturbing frequencies liable to interfere with the tuning control operation.

For the generation of a control potential of the type according to Figure 4 a system of known type used for automatic frequency control (AFC) for radio receivers properly modified may be employed for the purpose of this invention.

An arrangement of this type is shown by way of example in Figure 5. According to the latter, the fluctuating high frequency potential is impressed via terminals m and n upon a primary resonant circuit comprising a capacity 10 shunted by an inductance 11. This circuit is inductively coupled with a secondary resonant circuit comprising a capacity 12 and inductance 13 thereby forming what is generally known as a band-pass filter or network. In a circuit of this type if tuned to the average or carrier frequency, the voltage across the secondary has a mutual phase relative to the voltage across the primary which varies between 0 and 180° as the frequency of the impressed potential varies relative to the natural or tuning frequency of the network. By connecting the primary circuit to the electrical center of the secondary such as to the center tap of the inductance 13 as shown, the sum and difference of both primary and secondary potentials are formed which sum and difference potentials are separately rectified such as by the aid of a double diode rectifier 16, thereby producing a tuning control potential at terminals o—p varying in dependence upon the sense and amount of detuning of the network relative to the impressed signal frequency. The condensers 14 and 15 are provided to block the tuning control potential from the resonant circuits while numerals 18 and 19 represent leakage resistances, 20 and 21 are smoothing resistances, and 22 is a smoothing condenser for eliminating the high frequency ripples or fluctuations in the control potential. In order to ensure a rapid and instantaneous variation of the control potential corresponding to rapid frequency fluctuations, the time constant of the combination 18—14—19—15 and of (20+21)—22 should have a sufficiently low value. In addition to the tuning control potential, a further potential varying according to the carrier amplitude or signal strength may be derived from the junction point of a pair of resistances 23 and 24 placed across the output circuit and one side of the input circuit, terminals q—r. This amplitude responsive control potential may serve for automatic volume control or for a special amplitude control described hereinafter. As is understood, any other known frequency discriminator circuit arrangement having properly designed circuit constants to suit the special requirements of the invention may be employed for the purpose described.

In order to control a parameter or element determining the tuning of an oscillatory circuit such as an inductance or capacitance element in dependence upon the tuning control potential various methods suggested in connection with arrangements for automatic frequency control (AFC) in radio receivers may be employed in practicing the present invention. Thus, an electron valve may be employed as a variable reactance element forming part of an oscillatory or resonant circuit whereby the reactance of such valve is controlled by adjusting a suitable biasing potential. Alternatively, an iron cored inductance coil forming a tuning element in an oscillatory or resonant circuit may be provided with an aux-

iliary pre-magnetization winding energized by the tuning control potential.

Referring to Figure 6, there is shown in block diagram form a basic receiving circuit of the type according to the invention. Numeral **28** represents a tuned radio frequency (RF) amplifier upon which is impressed an input potential wave e_1 having a fluctuating carrier frequency and amplified to a value e_2. The amplified potential e_2 is applied to a tuning discriminator **29** which may be of the type according to Figure 5 or of any other suitable construction known. In this manner, a tuning control potential u_1 is generated by the discriminator which varies both in polarity and magnitude according to the sense and in proportion to the amount of detuning of the receiver relative to the frequency of the impressed signal potential e_2. If desired, this control potential u_1 may be smoothened by means of a filter **30** which latter should be permeable for the low (fluctuating) frequency variations of the control potential. The thus obtained control potential u_2 which fluctuates in accordance with the modulating signal wave or any other carrier frequency variation of e_1 or e_2 is utilized to control the tuned circuits in the receiver radio frequency amplifier **27** which amplifier has a narrow band width characteristic varied according to the control potential u_2 and producing an output signal e_3. The tuned circuits of the RF amplifier **28**, tuning discriminator **29** and receiver amplifier **27** are preferably ganged so as to simultaneously tune these circuits. The control potential u_2 may also if desired be used to control the tuned circuits in both the amplifier **28** and the discriminator **29** in such a manner that the amount of detuning relative to the instantaneous carrier frequency and in turn the regulating potential u_2 are maintained within a predetermined minimum range. The potential e_3 may be rectified and is substantially free from interfering signals whose frequency is outside the instantaneous band-pass or response range of the tuned amplifier **27**. In the case of straight high frequency amplification, it has been found desirable to control the tuning of the RF amplifier **28** and the discriminator **29** simultaneously with the tuning of the amplifier **27** as shown and described. In the latter case it is also possible to omit the receiver amplifier **27** and to use the output signal e_2 of the amplifier **28** for detection and translation of the low frequency signals to be received.

Referring to Figure 7, there is shown a similar receiving system embodied in a superheterodyne receiver. In this modification the input potential e_0 having a fluctuating carrier frequency is impressed upon a mixer **31** of any known type and construction and combined therein with a potential of an auxiliary frequency e_4 produced by a local oscillator **32** in a manner well known. The difference (or sum) frequency e_1 obtained in this manner is applied to an intermediate frequency (I.F.) amplifier **33** and the amplified intermediate frequency signal e_2 impressed upon the tuning discriminator **34**. The latter is fixedly tuned to the invariant frequency of the selective or band filter circuits of the I.F. amplifier **33**. Thus, the tuning and control potential u_1 produced by the discriminator **34** varies in accordance with the instantaneous deviation of the intermediate carrier frequency from the fixed intermediate tuning frequency of the amplifier **33**. This potential (u_1) may be smoothened through a filter **35** and the filtered potential (u_2) is applied to the oscillator **32** to regulate the oscillator frequency in such a manner that the deviation of intermediate frequency e_1 or e_2 obtained by the action of the mixer **31** always remains within a desired predetermined limit range. The intermediate frequency signals may be further amplified such as by a separate amplifier **36** and rectified to operate an output or translating device such as a loud-speaker in a manner well known. If required, any existing radio frequency (RF) pre-selector circuits may be controlled by the same tuning control potential, otherwise the pre-selecting circuits should be designed with a sufficiently wide response band width.

In the design of the control and discriminator circuits, certain requirements have to be complied with in an effort to avoid self-excitation and hunting effects within the regulating system and to ensure a sufficiently rapid and instantaneous regulation for the fastest fluctuations to be expected of the received carrier frequency.

This can also be expressed by the requirement that the phase difference between all periodic frequency variations to be expected and the tuning variations caused by the corresponding variations of the tuning control potential should always remain smaller than 180°.

This behavior and the tendency to produce hunting in case of frequency changes can be best understood by considering a single sudden frequency change. In this connection, there is to be considered in the first place the so-called regulating factor R by which is understood the quotient between a predetermined deviation of the received carrier frequency and the tuning variation caused by a tuning control potential produced as a result of such deviation. Furthermore, there is to be considered the so-called transit period t_1 and the transition time t_2 within the regulating cycle. By t_1 there is understood the time which has elapsed after a sudden frequency change until the initiation of the tuning regulation and by t_2 there is understood the duration of the regulating action corresponding to a definite sudden or permanent detuning in the frequency control arrangements **29** or **34** according to Figures 6 and 7, respectively. It is advisable to assume a linear relationship of the tuning variation as a function of time which coincides with the steep portion of the actual characteristic curve, whereby t_2 is defined as the time period within this linear increase to the instant when a constant final value is reached. With these assumptions made the condition for the stability may be represented with sufficient approximation by the following mathematical expression

$$R > \frac{t_1}{t_1 + t_2} \qquad (I)$$

In choosing the several constants, the following is to be considered. The regulating factor R is characteristic of the reduction of the amount of detuning by the regulating action. This factor is determined substantially by the sensitivity of the tuning discriminator arrangements **29** or **34**, Figures 6 or 7, respectively, the amplification and the tuning variation corresponding to a definite tuning control potential. An initial degree of detuning V is reduced by the regulating action to a value

$$V\left(\frac{R}{1+R}\right) \qquad (II)$$

The transit time t_1 is determined primarily by the time constant of the amplifier for a definite high frequency signal and depends to a substantial extent upon the band width or response characteristic of the selective circuits (band-pass filters). This transit time is characteristic for the most rapid frequency variations for which a tuning control may still be expected. In the interest of an effective tuning regulation with rapid frequency fluctuations it is further desirable that the transition time t_2 should be as short as possible, which transition time is determined mainly by the time constant of the discriminator **29** or **34** and the smoothing filter **30** or **35**, Figures 6 and 7, respectively.

Since in most cases the band width of the selective circuits in the amplifiers **28** and **33**, Figures 6 and 7, respectively, should be considerably larger than the minimum band width determined by the low frequency modulation in order to obtain small transit periods as pointed out above, it is advisable to provide special amplifiers designed with a narrow band width for the normal demodulation and translation of the high frequency or intermediate frequency signals, in order to prevent reception or disturbing frequencies to the greatest possible extent. These special amplifiers are shown at **27** and **36** in Figures 6 and 7, respectively, connected ahead of the RF or IF amplifiers, respectively, and supply an output signal e_3 to be demodulated and further amplified for operating an output or translating device. The amplifier **36** differs from the amplifier **27** however in that the narrow band width is constant at one frequency therefore requiring no tuning control whereas the amplifier **27** being of the RF tuned type having a narrow band width characteristic necessitates the tuning frequency to vary according to the tuning control potential so as to be receptive to the varying received carrier frequency.

In the known arrangement for automatic frequency control (AFC) used in radio receivers, the tuning control potential is smoothened to a considerable extent, the time constants required being of the order of one second. In the case of a fast acting tuning control according to the invention which instantaneously follows the rapid frequency changes of a received carrier frequency wave, time constants which are by several thousandths smaller are required in general, i. e. the transition period should be of the order of the period of the fastest frequency fluctuation to be expected.

The following is to be considered, according to a further feature of the invention. In case of large frequency variations of a received carrier signal it may happen that the regulating action is interrupted or disturbed by a momentary cessation of this frequency or by a short impulse caused by a disturbing frequency. In this case, the automatic receiver tuning may cease to function and remain at a fixed value whereby reception will in general be interrupted until a wave with a similar instantaneous frequency is received and synchronized tuning restored. This may be caused by a separate transmitter of higher or lower carrier frequency. This instability or "jumping" upon other frequencies is eliminated according to a further feature of the invention by an arrangement whereby the tuning of the receiver after each interruption is automatically returned to the proper value of the high frequency carrier wave being received in such a manner that synchronized tuning is restored within a short period and the interruption is scarcely noticeable. This can be accomplished by a suitable design of the transmission circuits for the regulating potential such as the filters **30** and **35**, Figures 6 and 7, respectively. Suitable transmission networks for this purpose are shown in Figures 8 and 9.

According to Figure 8, the input terminals *o—p* are connected to the discriminator circuits **29** or **34**, Figures 6 and 7, respectively, and a tuning control potential applied from the output terminals *s—t* to the resonant circuit such as the tank circuit in the oscillator of a superheterodyne receiver to be controlled. The condenser **38** serves to transmit the rapidly varying tuning control potential corresponding to a frequency or phase modulation of the received oscillations without appreciable attenuation and time lag due to the fact that the by-passing of these frequencies through the large resistance **39** is negligible. The condenser **37** having a capacitance substantially higher than the capacitance of the condenser **38**, on the other hand, is charged through resistance **39** and a further still higher resistance **40** with a potential corresponding to the average value of the tuning control potential. If the regulating action has been interrupted by a disturbance of any kind, the instantaneous charge of the small capacity **38** is discharged in a short period through the resistance **40** in such a manner that the potential of the condenser **37** appears at the terminals *s—t*, that is a control potential corresponding to the average frequency of the oscillations being received. In this manner, the synchronization with the received high frequency oscillations is restored within a short period. Thus, by the action of the resistance **40** and condenser **37** a highly steadied or smoothened control potential is produced for effecting a slow acting automatic frequency control while through the action of the condenser **38** there is produced a rapidly varying control potential for effecting "synchronized tuning" in accordance with rapid tuning variations caused by additional frequency or phase modulation or to other causes.

Referring to Figure 9 there is shown an alternative circuit for producing both slow and rapid tuning control potentials. In this case the control potentials for the slow automatic frequency control are passed through the circuits **40**, **38** and **40'**, **38** while the rapid control potentials for automatic synchronization are passed through the circuits **37**, **39** and **37'**, **39**. It may be advantageous to provide suitable limiting devices in the transmission path for the synchronizing potentials in order to suppress excessively high frequencies in the control potential which may be caused by disturbing phenomena and which are not desired in the tuning regulation. Furthermore, the slow and rapid regulations may be separated in the case of superheterodyne reception employing a double heterodyning method whereby one local oscillator is utilized to effect the slow acting (AFC) control while the other oscillator serves for effecting the fast acting control or synchronization.

Difficulties may be experienced in carrying out a synchronized tuning control due to the fact that the received high frequency oscillations are amplitude modulated. As a result, the tuning control potential fluctuates according to the modulating frequency, whereby for very low instantaneous amplitudes of the received oscillations, the tuning regulation may become temporarily in-

effective. This phenomena results in undesirable fluctuations of the tuning at low frequency equivalent to an additional frequency modulation of the received oscillation. This drawback may be remedied by maintaining the high frequency or intermediate frequency signal amplitudes at a constant value prior to their application to the discriminator (29 or 34, Figures 6 and 7, respectively) by means of a fast acting automatic amplitude control arrangement. Such a fast amplitude control serving to equalize the low frequency variations of the amplified high frequency signals is shown in Figure 10 which otherwise corresponds to Figure 7. In the latter, the control potential varying in accordance with the amplitude or signal strength is derived from the discriminator circuit 34 or from a special circuit arrangement provided for this purpose. When using a discriminator of the type according to Figure 5, this amplitude responsive potential v_1 may be derived from points q—r as described previously. After the higher disturbing frequencies have been eliminated by a filter 41, the control potential v_2 is used to control the gain of the amplifier 33. In general, the amplitude or volume control arrangement may be similar to the systems extensively used in radic circuits with the exception that the time constants have to be designed to be substantially lower than the time constants used in the conventional circuits for comparatively slow variations, i. e. of the order of $\frac{1}{1000}$ and less of the time constants required in the conventional AVC systems. Such a fast acting volume control may be combined with a normal volume control arrangement such as shown in Figure 11. In the latter, the filter 41 is designed in such a manner as to be permeable for the higher frequencies v_2 of the volume control potential v_1 serving to instantaneously control the gain of the amplifier 33 and to limit the low frequency amplitude modulation at the output of the amplifier to a minimum. The mean or average value v_3 of the AVC potential v_1 on the other hand is transmitted through a filter 43 having a time constant corresponding to the conventional AVC circuits and applied to a gain control element of an RF amplifier 42 in a known manner. In this case, the intermediate frequency e_2 cannot be employed after amplification in 33 for deriving the low frequency signals due to the fact that the low frequency amplitude modulation is compensated in this amplifier 33 by the potential v_2. The limiting of the amplitude e_2 to a constant value may also be effected by means of elements having an operating characteristic with a sharp bend such as a saturation characteristic.

The principal circuits according to Figures 6, 7, 10 and 11 merely constitute examples for carrying out the invention whereby all unnecessary auxiliary devices have been omitted as being superfluous for an understanding of the invention.

The novel fast acting tuning control is specially suited for use in receiving circuits for ultra short waves employing multiple heterodyning whereby the tuning control may be applied to one or several of the auxiliary oscillators. A possible arrangement of this type is illustrated in Figure 12. In the latter, the incoming high frequency signal e_0 is impressed upon a first mixer 45 and combined with an auxiliary frequency e_4 produced by a first oscillator 49. The intermediate frequency e_1 is impressed upon an amplifier 46 having a wide response or band width such as an aperiodic amplifier, whereby the signals are amplified to a sufficient level for operating the discriminator 47. The tuning control potential u_1 produced by the latter is passed through a smoothing device or filter 48 and serves to control the frequency of the local oscillations generated by the oscillator 49 in a manner described hereinbefore. The amplifier 46 has to be designed with a sufficiently wide band width due to the large and rapid variations of the received high frequency oscillations and therefore a low time constant of this amplifier is required. The fluctuations of the first intermediate frequency are considerably reduced due to this arrangement so that the first IF amplifier 50 may be designed with a correspondingly smaller band width which however still exceeds the frequency range determined by the amplitude modulation of the received oscillations. As a result, disturbing frequencies which are at a great distance from the received instantaneous frequency will produce intermediate frequencies which are transmitted through the amplifier 46 and will result in a corresponding error in the synchronized tuning control of the first oscillator. This tuning error however is equalized by a similar synchronized control of the second local oscillator 55. The disturbing frequencies are without importance and are eliminated to a substantial extent by the comparatively narrow frequency range or band width of the IF amplifier 50. The remaining frequency fluctuations especially those produced by interfering signals in the first intermediate frequency section are eliminated to a substantial extent after additional superheterodyning of e_5 in a second mixer 51 with the local frequency e_7 produced by the oscillator 55. The second intermediate frequency signal e_6 is amplified by an amplifier 52 and applied to a tune discriminator 53 to produce a tuning control potential u_3 smoothened by a filter 54 (u_4) and applied to the oscillator 55 in a manner substantially similar as previously described. In this manner frequency fluctuations of the second intermediate frequency are reduced to a minimum and as a result thereof the amplifier 56 may be designed with a relatively narrow band width thus substantially eliminating the remaining disturbing frequencies in the final oscillations (e_8). If desired, heterodyning to a further still lower frequency may be employed before final demodulation of the signals to further improve the results obtained by the invention.

Referring to Figure 13, there is shown a complete circuit diagram for a superheterodyne receiver embodying the improvements according to the present invention and especially suited for short and ultra short waves, although not limited thereto.

Modulated high frequency signals such as amplitude modulated signals which are frequency modulated in accordance with the low frequency or modulating signal wave to be transmitted in addition to amplitude modulation and which may be further subject to relatively slow carrier frequency fluctuations due to fading and other causes, are intercepted by an antenna 60 of any suitable design and impressed through a tuned input transformer 61 upon the grid of an electron valve 62 of suitable construction forming a radio frequency amplifier marked RF in the drawings. The amplified high frequency signal potentials e_0 are applied through a tuned output coupling transformer 63 to one of the control grids of an electronic mixer or frequency

converter valve 64 of known type forming a frequency changer stage designated M in the drawing. The oscillating signal potential e_4 of different frequency is supplied by a local oscillator O and impressed upon a separate control grid of the valve 64, preferably separated from the first control grid by a positively biased screen in the manner well known whereby intermediate or beat frequency signals e_1 are obtained in the secondary of a tuned coupling transformer 65 inserted in the anode or output circuit of the valve 64. The intermediate frequency signals e_1 are amplified in a known manner by means of an intermediate frequency transformer IF comprising in the example illustrated a pair of electron valve amplifiers 66 and 68 coupled in cascade through an interstage transformer 67 fixedly tuned to the intermediate frequency. The amplified intermediate frequency signals e_3 are applied to a detector circuit or demodulator such as a double diode detector 70 in the example shown through a further tuned transformer 69. The demodulated or low frequency signal currents which may be audio, video or any other signal current variations are further amplified by means of an audio frequency amplifier AF comprising in the example shown an input or driver stage 71 coupled to a push-pull output stage 73—74 through an audio frequency transformer 72. The amplified audio signals supplied from the secondary terminals 76 of the push-pull output transformer 75 may serve to operate a suitable translating device such as a loud speaker in a manner well understood.

So far the system corresponds to the conventional superheterodyne receiver now being in general use. There is further provided in accordance with the present invention an arrangement to eliminate the effect of periodic relatively rapid variations of the carrier frequency such as caused by a frequency modulation in addition to an existing amplitude modulation according to a low frequency or signalling wave being transmitted, as well as of relatively slow more or less irregular fluctuations of the carrier frequency due to fading, temperature influence and other causes. For this purpose a portion of the intermediate frequency signal energy produced by the mixer M and derived from a separate tuned secondary winding of the transformer 65 is applied to an auxiliary intermediate frequency amplifier A comprising a pair of electron valves 77 and 79 coupled in cascade by a tuned interstage transformer 78. The output potential e_2 of the amplifier A is utilized to generate a tuning control potential u_1 by means of a discriminating circuit arrangement D of substantially the same type as shown in Figure 5. The latter comprises a phase rotating transformer 80 and a pair of diode rectifiers 81 and 82 arranged in such a manner that the vectorial sum and difference of the primary and secondary potentials of the transformer 80 appears at the diodes 81 and 82, respectively, in a manner described hereinbefore. Thus, the differential u_1 between the rectified potentials occurring at the opposite terminals of the condenser 83 is a measure for the detuning of the transformer 80 relative to the intermediate signal frequency of the receiver. This detuning is maintained at a sufficiently small limit by an automatic adjustment of the local oscillator frequency e_4 by the aid of a control or tuning corrector device TC. For this purpose it is necessary that rapid variations of the control potentials u_1 are not suppressed or weakened to an appreciable extent by an excessive smoothing or filtering action. The high frequency components of the control potential u_1 are suppressed by the by-passing condenser 83. The periodic low frequency fluctuations of the control potential are transmitted through the series condenser 84 of a filter F_1 corresponding substantially to the arrangement shown and described in connection with Figure 8. A by-passing of the low frequency fluctuations through the condenser 85 is avoided by the provision of resistance 86. The time constant of the combination 84—86 is chosen sufficiently high so that the lowest audio frequency components according to which the received oscillations are frequency modulated are transmitted without substantial attenuation. Accordingly this time constant should be of the order of from $\frac{1}{100}$ to $\frac{1}{10}$ of a second. In order to restore the controlling action automatically in case of a sudden disturbance or interruption the further condenser 85 is provided being charged to the average value u_1 through resistances 87 and 86 as described in detail hereinabove. Since the average value of this control potential changes only slightly in accordance with the relatively slow average variations of the received high frequency oscillations such as due to fading, temperature or other influences the time constant of condenser 85 in conjunction with resistances 87 and 86 may be chosen of very high value such as of the order of 10 seconds. In this manner the charge of condenser 85 is not varied by instantaneous disturbances whereby the average control potential u_2 corresponds to the average amount of detuning, thereby maintaining the automatic tuning synchronizing action at or about the average value of the received signal frequency. In other words, the filter F_1 acts to suppress the inaudible low components of the control potential u_1, the received signal oscillations usually not being frequency modulated in accordance with these inaudible low frequencies. On the other hand, the filter transmits the direct current component serving for effecting automatic tuning upon the average value of the received signal frequency as well as the audible low frequency components serving for effecting rapid automatic or synchronized tuning in the rhythm of a frequency modulation of the received signal oscillations.

The tuning adjustment of the oscillator O may be effected in any suitable manner such as by the employment of an electron valve representing a variable reactance regulated by the tune control potential u_2 as a biasing potential.

In the example illustrated the oscillator valve 88 has an oscillatory or tank circuit 89 connected between its grid and cathode and coupled with the anode circuit to generate sustained local oscillations in a manner well known. There is further connected across the tank circuit 89 an electron valve 90 serving as a variable tuning reactance and a series combination comprising an ohmic resistance 91 and a condenser 92. The junction between the latter is connected to the control grid of the valve 90 whereby the latter is controlled by quadrature potentials derived from the tank circuit 89 thereby producing quadrature current variations in the output of the valve 90. The latter are impressed upon the tank circuit of the oscillator thereby varying the apparent reactance and with it the oscillator frequency. The reactance of the valve 90 is adjusted in accordance with the control potential u_2 ap-

plied to the control grid of the valve 90 through a series resistance 93.

According to a further feature there is derived from the discriminating circuit D a control potential v_1 varying according to the amplitude of the intermediate frequency signals. In the example illustrated this potential is derived from the output of a single rectifier (82) of the discriminator system, while the frequency or tuning control potential u_1 is derived from the outputs of both rectifiers 81 and 82 in the manner described hereinbefore. The amplitude responsive potential v_1 is freed from high frequency components by a filter F_2 designed to pass the audible or low frequencies. The thus obtained output potential v_2 of the filter F_2 which varies in accordance with the low or modulating frequency signal wave is impressed through the secondary of the coupling transformer or band-pass filter 65 upon the input grid of the auxiliary intermediate frequency amplifier A, whereby the amplitude variations or modulation of the amplified intermediate frequency potentials e_2 impressed upon the discriminator D are substantially suppressed, and the rapid automatic frequency control or synchronized tuning is independent of the degree of amplitude modulation of the signals received. The amplitude responsive potential v_2 is applied to a further filter F_3 to suppress the audible or low frequencies thereby obtaining a control potential v_3 at the output of the filter F_3 varying in accordance with relatively slow fluctuations of the carrier amplitude of the received signals such as caused by fading, effects of temperature, drift, etc. This potential v_3 which corresponds to the conventional arrangements for automatic volume control (AVC) is applied to the grid of the RF amplifier 62 to effect a normal automatic volume control. In accordance with the different functions of the potentials v_2 and v_3 the time constant of the filter F_2 should be of the order of $\frac{1}{10,000}$ to $\frac{1}{1000}$ of a second and the time constant of F_3 of the order of from one to about $\frac{1}{10}$ of a second.

The method hereinabove described for effecting synchronized tuning is well suited for receiving an amplitude modulated high frequency wave subject to additional frequency and/or phase modulation in accordance with variations of a low frequency or signal wave to be transmitted or of other disturbing frequencies, such as fluctuations of the operating potentials and the like.

According to a further embodiment, the invention may be employed for secret sending by varying the carrier frequency of an amplitude modulated wave according to a special schedule at low frequency whereby a reception with ordinary receiving means is rendered impossible. In this case, the synchronized tuning results in a continuous following of the receiver tuning corresponding to the frequency variations thereby enabling a ready reception of signals of this type.

By the action of the automatic rapid or synchronized tuning, the variations of the intermediate frequency signals e_1 are reduced to a minimum. Therefore, the transformers or band filters of the intermediate frequency amplifier IF may be designed with a corresponding narrow band width. On the other hand, it is obvious that the band filter of the pre-amplifier RF must be designed to encompass the entire range of frequency fluctuation and modulation band width of the received signal wave. The latter can be easily accomplished in practice due to the fact that a greater band width can be easily obtained in case of high frequencies with normal coupling arrangements and damping values. As has been pointed out, the transmitting range of the transformers or band filters in the auxiliary intermediate amplifier A should be designed in such a manner as to avoid undesired building up of oscillations or phase rotation dependent on frequency and liable to impair the function of the rapid or synchronized tuning regulation of the entire receiver.

It will be evident from the above that the invention is not limited to the specific exemplifications and circuits as well as methods disclosed herein for illustration, but that the novel concept and underlying principle disclosed are subject to numerous variations and modifications coming within the broader scope and spirit of the invention as defined in the appended claims.

The specification and drawings are accordingly to be regarded in an illustrative rather than in a limiting sense.

I claim:

1. A receiver system adapted to receive a high frequency carrier having its amplitudes modulated at signal frequencies within a predetermined frequency range, said carrier fluctuating in frequency at the rate of said signal frequencies, comprising a high frequency receiver channel tuned to a predetermined frequency and having a band pass of a width substantially that of said signal frequency range, frequency discriminating means responsive to said fluctuations and control means energized by said discriminating means to convert said fluctuating carrier to a second carrier the frequency of which is substantially constant and substantially equal to the predetermined frequency of said receiver channel, the time constant of said discriminating and control means being at the most of the order of $\frac{1}{1000}$ of a second, whereby said carrier fluctuations are substantially instantaneously compensated.

2. A receiver system adapted to receive a high frequency carrier having its amplitudes modulated at signal frequencies within a predetermined frequency range, said carrier fluctuating at the rate of said signal frequencies, comprising an input channel having a frequency response range substantially broader than and embracing said signal frequency range and two outputs, frequency discriminating means responsive to said fluctuations and control means energized by said discriminating means to convert said fluctuating carrier into a second carrier the frequency of which is substantially constant, said discriminating means associated with one of said outputs, the time constant of said discriminating and control means being at the most of the order of $\frac{1}{1000}$ of a second, whereby said carrier fluctuations are substantially instantaneously compensated, and a high frequency amplifying channel associated with the other of said outputs and substantially tuned to said second carrier frequency, said amplifying channel having a band pass of a width substantially that of said signal frequency range.

3. A superheterodyne receiver system adapted to receive a high frequency carrier having its amplitudes modulated at signal frequency within a predetermined frequency range, said carrier fluctuating in frequency at the rate of said signal frequencies, comprising an input channel having a frequency response range substantially broader than and embracing said signal frequency range and including a mixer having two outputs, a

source of local oscillations associated with said mixer so as to produce a second carrier of intermediate frequency in said mixer, frequency discriminating means responsive to said fluctuations and associated with an output of said mixer so as to derive carrier energy of intermediate frequency therefrom, said discriminating means adapted to develop voltages representative of magnitude and sense of said fluctuations, the time constant of said discriminating means being at the most of the order of 1/1000 of a second so that said voltages are developed substantially instantaneously, control means energized by said discriminating means for applying said voltages to said source of local oscillations so as to cause instantaneous fluctuations of the latter in such sense that a substantially constant intermediate frequency results in said mixer, and a high frequency channel fixedly tuned to said constant intermediate frequency and having a band pass width substantially that of said signal frequency range, said latter channel associated with another output of said mixer.

4. In a receiver system as described in claim 3, means associated with said discriminating means for developing a voltage representative of the amplitude of said second carrier, amplifying means associated with and preceding said discriminating means, said amplifying means including a gain control element, and means for applying said voltage to said control element in a manner so as to counteract variations in said amplitude.

5. In a receiver system as described in claim 2, means associated with said discriminating means for developing a potential representative of the amplitude of said fluctuating carrier, and means responsive to said potential to counteract amplitude variations in the carrier applied to said discriminating means.

6. In a receiver as claimed in claim 1, current limiting means for substantially suppressing amplitude variations in the carrier applied to said discriminating means.

7. A receiver system adapted to receive a high frequency carrier having its amplitudes modulated at signal frequencies within a predetermined frequency range, said carrier fluctuating in frequency rapidly at the rate of said signal frequencies and slowly below said rate, comprising a high frequency receiver channel tuned to a predetermined frequency and having a band pass of a width substantially that of said signal frequency range, frequency discriminating means responsive to all said fluctuations and control means energized by said discriminating means to convert said fluctuating carrier into a second carrier the frequency of which is substantially constant and substantially equal to the predetermined frequency of said receiver channel, the output of said discriminating means comprising a compound filter network, one part of said network having a time constant at the most of the order of 1/1000 of a second, whereby said rapid fluctuations of said fluctuating carrier are substantially instantaneously compensated, another part of said network having a considerably larger time constant, whereby said slow fluctuations of said fluctuating carrier are substantially compensated.

8. A receiver system adapted to receive a high frequency carrier having its amplitudes modulated at signal frequencies within a predetermined frequency range, said carrier fluctuating in frequency rapidly at the rate of said signal frequencies and slowly below said rate, comprising a high frequency receiver channel tuned to a predetermined frequency and having a band pass of a width substantially that of said signal frequency range, frequency discriminating means comprising means responsive to said rapid fluctuations and means responsive to said slow fluctuations, said rapidly and slowly responsive means arranged to convert said fluctuating carrier into a second carrier the frequency of which is substantially constant and substantially equal to the predetermined frequency of said receiver channel, the time constant of said rapidly responsive means being at the most of the order of 1/1000 of a second, whereby said rapid fluctuations of said fluctuating carrier are substantially instantaneously compensated, said slowly responsive means having a considerably larger time constant, whereby said slow fluctuations of said fluctuating carrier are substantially compensated.

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