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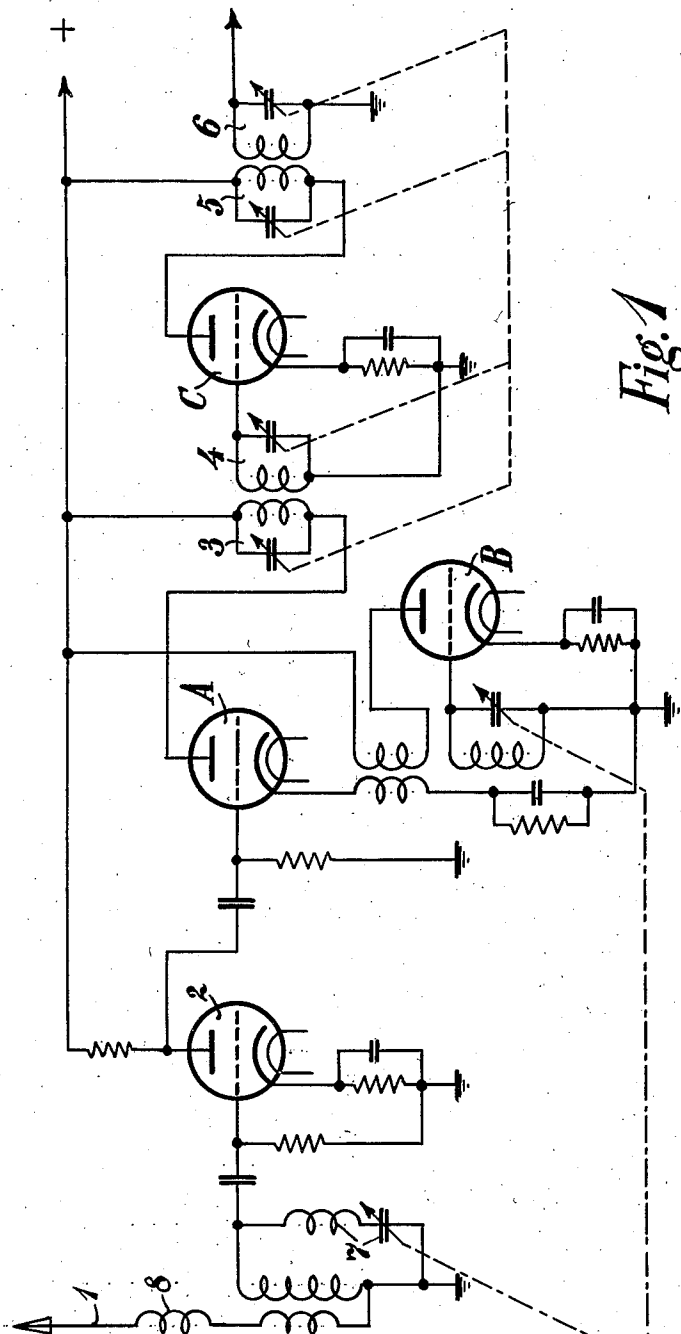
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METHOD OF AND MEANS FOR REDUCING DISTURBANCES IN WIRELESS RECEPTION

Filed July 2, 1938

2 Sheets-Sheet 1



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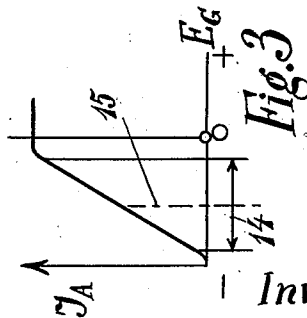
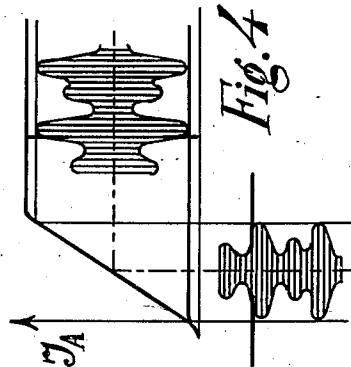
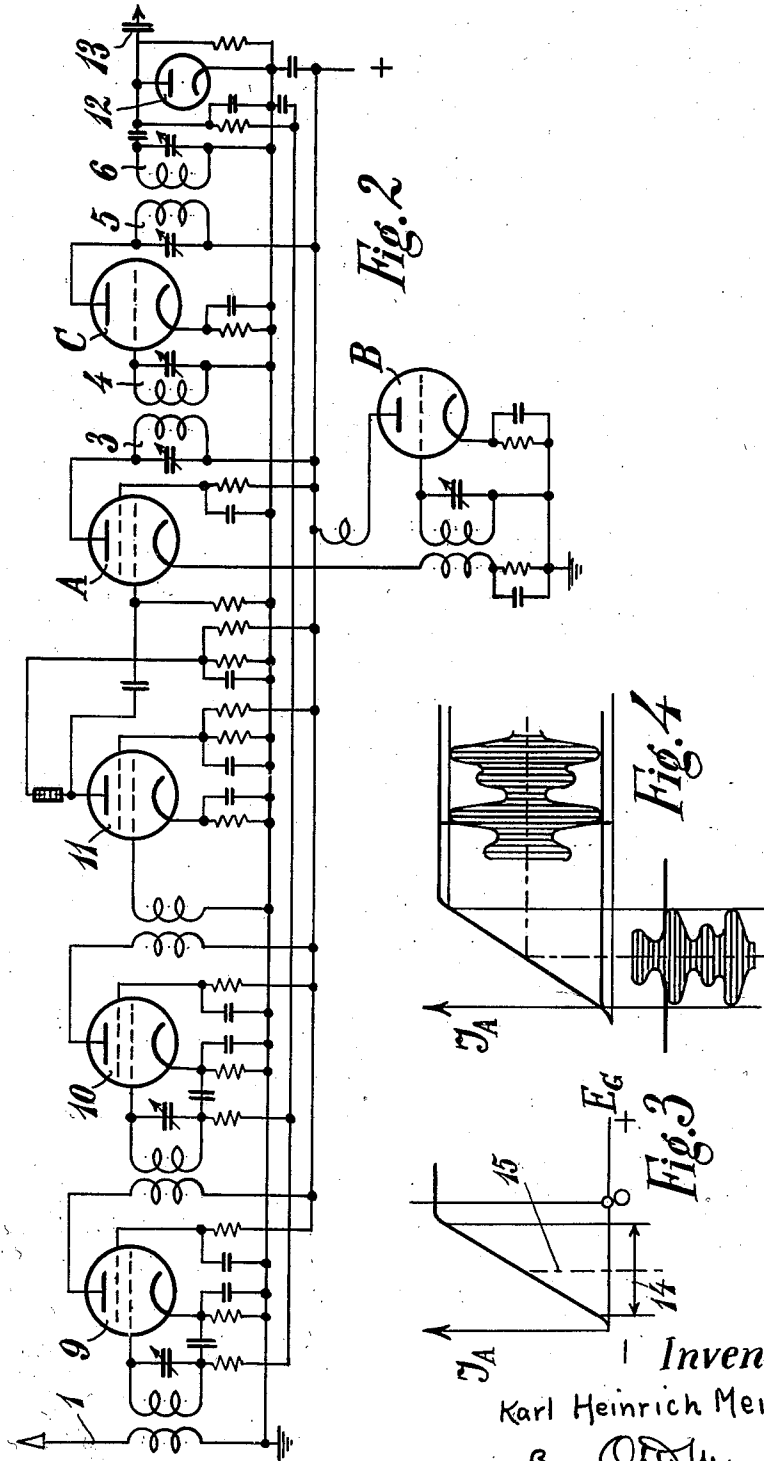
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UNITED STATES PATENT OFFICE

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METHOD OF AND MEANS FOR REDUCING
DISTURBANCES IN WIRELESS RECEP-
TION

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Application July 2, 1938, Serial No. 217,164
In Switzerland July 8, 1937

9 Claims. (Cl. 250—20)

Electric phenomena in the atmosphere such for example as arise through the collapse of electric fields in space produce in high frequency receiving systems which they strike forced oscillations which will be referred to in general as disturbances in reception. In linear systems, that is to say systems whose effective capacities, inductances and resistances are independent of the magnitudes of the fields acting upon them and are not varied by outside influences during the reception of a high frequency wave, these electric field collapses constantly give rise to natural oscillations. The appearance of these natural oscillations is, particularly in a resonant circuit, easily explainable. In such a circuit which contains inductance and capacity a voltage pulse acting suddenly and lasting a short time charges the capacity of the resonant circuit. The discharge of this capacity takes place in an oscillatory manner through the inductance connected thereto and during such an interval of time as is necessary for the losses which occur in the circuit to reduce to zero the electrical energy supplied. The play of energy when the resistance is vanishingly small is of a particularly simple form. Here the transfer of energy is limited to a continuous swing of energy between the condenser and the coil.

When such a resonant circuit is coupled to four terminal networks, such for example as band filters, these circuits affect one another reciprocally, owing to the mutual coupling, in such a way that the current in one of the circuits excites a current in the other. With forced oscillations impressed by the primary circuit upon the secondary circuit, for example by means of an alternator, only the oscillations of the exciting circuit predominate in the two circuits, but there can however appear, in turn, two frequencies, the so-called resonance frequencies. If on the other hand the exciting circuit supplies free, damped oscillations, there are built up in each of the two circuits two oscillations of different frequencies, the so-called coupling frequencies or coupling oscillations, which exist simultaneously together and accord with the resonance frequencies.

Since, because of this fact, the coupling frequencies set up by free, damped oscillations require the longer to decay the smaller the losses of these circuits are, or the larger their capacity for storing electric energy is, the susceptibility of the receiving apparatus to disturbances conditioned by the properties of the tuning circuits must decrease the more, the smaller the values of capacities and inductances of the resonant circuit are.

Since with decreasing capacity and inductance the capacity for storing electric energy of these resonant circuits decreases, consequently the sus-

ceptibility to atmospheric disturbances of a receiving set increases with increasing wave length, because in this case the capacity and inductance must also increase in order to be in resonance for these wave lengths, but this, on the other hand, is equivalent to a longer decay time of the excited coupling oscillations.

The method, according to the present invention, of reducing the susceptibility to atmospheric disturbances consists in this, that the frequencies to be received are by superposition transposed into frequencies at which the resonance and selectivity elements, such for example as four terminal networks or chain conductors, which are necessary for the selective choice of the transposed received frequencies, are tuned to a resonance frequency for which the capacity for storing electric energy is so small and the coupling for damped oscillations is so loose that the relationship between the damped and undamped oscillations assumes values at which the portion of the damped oscillations, that is to say disturbance voltages, can be regarded as negligible.

The apparatus for carrying out the method accordingly has a modulator circuit with which is associated a local high frequency generator, the whole of the reception spectrum from the antenna being fed to this modulator, so as to be transposed to a higher frequency, tuning means for the selective choice of a frequency band being associated with the anode circuit of the modulator stage. According to the invention, the electric constants of the inductances and capacities of these tuning means are so dimensioned that the capacity of these circuits to store electric energy and also the coupling for damped oscillations is so small that the residual disturbance energy at the end of the four terminal network as the result of a disturbance is insufficient to maintain the coupling oscillations evoked by the reciprocal action of the tuning circuits through the disturbance.

Receiving apparatus with a reception wave transposed to a constant intermediate frequency by superposition is already known in itself and is quite generally termed a superheterodyne receiver. In these known forms of construction it is a matter of obtaining both stable high frequency amplification and also a sufficient sharpness of separation. The value of this intermediate frequency is in the main determined by the consideration that it should be in a wave length region in which no disturbances are possible from transmitters working on the same intermediate frequency wave.

Whilst, on account of the reduction of the capacity for storing electrical energy of this four terminal network, the quantity of energy necessary for the maintenance of coupling oscillations also falls, there also stands out still more clearly

the differential behaviour of undamped and damped oscillations with increasing resonant frequency of this four terminal network. The effect of this is that with increasing resonant frequency the coupling between the two resonant circuits of the four terminal network for damped oscillations becomes continually looser when the pass band width for undamped oscillations remains constant. This will be more fully explained by an example:

There will be taken as a basis for consideration a band filter consisting of two oscillatory circuits, formed by parallel connection of coil and condenser, which are coupled together. The apparent impedance of such a resonant circuit passes as a function of frequency through a resonance maximum and on both sides falls away the more steeply, the smaller the ohmic losses in the oscillatory circuit are. If such a circuit is connected to a current source having a high internal resistance, the voltage arising in the oscillatory circuit varies as a function of the frequency just as the apparent impedance itself according to the resonance curve. As absolute band width b there is usually meant the distance between the two frequencies at which the amplification has fallen from the resonance maximum V_0 to $V_0/\sqrt{2}$. In addition there is the simple relation that the relative band width b/f_0 is connected with the coil damping $d=R/\omega L$ by the simple relation $b/f_0=d$. That is to say the absolute band width is only dependent upon the ratio R/L . For any given band width, therefore, this ratio will remain constant, independent of the resonant frequency. If now two such resonant circuits are coupled to form a four terminal network, the degree of coupling must be so chosen that once again a predetermined band-width results therefrom. This is the case if the degree of coupling is so chosen that the coupling factor k is so related to the quality of the circuit r that $kr=1$. The quality of the circuit r is dependent upon frequency and is given by the expression $r=\omega L/R$. In what follows there will be calculated the disturbance energy transmitted through the coupling to the second resonant circuit of the four terminal network for two different resonant frequencies. The two resonant frequencies are 100 kc. and 10 mc. The band width is the same for both cases, namely $1=k.r$. For an assumed disturbance energy

$$N = \frac{1}{2} e^2 C = \frac{1}{2} I^2 L$$

the same in both cases, which excites damped natural oscillations in the first tuned circuit of the four terminal network, the energy transmitted to the second oscillatory circuit of the four terminal network in the first case (that is with a resonant frequency of 100 kc.) amounts to $N'=N.k$. The constant L/R amounts to 10^{-4} . Consequently the coupling

$$k = \frac{1}{\omega L/R} = \frac{1}{\omega 10^{-4}} = \frac{1}{6.28 \cdot 10^5 \cdot 10^{-4}} = 0.16 \cdot 10^{-1} = 1.6\%$$

and in the second case

$$\frac{1}{6.28 \cdot 10^7 \cdot 10^{-4}} = 0.16 \cdot 10^{-3} = 0.016\%$$

This example shows that by tuning the four terminal network to the higher resonant frequency, only 1% of the disturbance energy acts upon the second resonant circuit of the four terminal network, if it be assumed that, in the example of the tuning of the four terminal network to the lower resonant frequency, the disturbance

energy reaching the second oscillatory circuit amounts to 100%.

It will also be shown by a further numerical example how the ratio of useful to disturbance voltage varies with increasing resonant frequency through the differential behaviour of such four terminal networks. In order to be able to make use of simplified assumptions, in this example the coupling frequencies arising through the reaction of the second circuit upon the first circuit of the four terminal network will be neglected. As a basis for the example, therefore, there will be taken two intermediate frequency stages of a receiving apparatus tuned to different frequencies 100 kc. and 10 mc., these intermediate frequency stages being such that in the anode circuit of the first intermediate frequency stage there is a band filter, the secondary side of which forms the grid circuit of a second tube which also itself has a band filter in its anode circuit. In order to form the ratio of useful to disturbance voltage, the voltages prevailing in the secondary circuit of the second filter will be determined.

As already explained, the voltage in a four terminal network for undamped oscillations varies as a function of the frequency just as the apparent impedance itself according to the resonance curve, assuming that the amplifier tube connected to the four terminal network has a high internal impedance.

If, on the other hand, the first resonant circuit of such a four terminal network yields free undamped oscillations, in this case such a four terminal network can be regarded as a resonance transformer of which the transformation ratio of the primary to the secondary depends both upon the numbers of turns and also in particular upon the coupling, that is to say looser coupling is equivalent to smaller transformation ratio.

It can therefore be assumed directly that the voltage on the secondary side of the four terminal network has the same relation to the primary voltage as the relation of the coupling of the two circuits together.

In order to make this example still clearer, it will be assumed that the overall amplification of the apparatus considered is unity.

In receiving from a transmitter, the disturbance voltage should have a maximum of 5% of the useful voltage. The voltage available from the transmitter and acting on the grid of the first intermediate frequency stage amounts to 1 millivolt and the disturbance voltage 20 volts. The maximum permissible disturbance voltage of 5% is naturally the relation for piano passages in the transmission, as otherwise, since the dynamic variations of a transmission amount to about 1:100 during soft passages the disturbance voltage would be as great as the useful voltage. The disturbance voltage can therefore be regarded as negligible if it amounts to 5% of the useful voltage during soft passages in the transmission. As has already been stated above, the coupling of the two resonant circuits of a four terminal network for disturbance energy amounts to 1.6% at a resonant frequency of 100 kc. and 0.016% at a resonant frequency of 10 mc.

As assumed, the useful voltage is 1 millivolt with a fully modulated transmitter and the disturbance voltage 20 volts. The disturbance voltage must therefore have a maximum value of 0.0005 millivolt, that is to say 0.5×10^{-6} volts. Since the coupling at 100 Kc is 1.6% there is still

present in the first four terminal network a disturbance voltage of

$$\frac{1.6 \cdot 20}{100} = 0.32 \text{ volt}$$

and in the second four terminal network

$$\frac{0.32 \cdot 1.6}{100} = 0.00512 \text{ volt} = 5.12 \text{ millivolts}$$

At 10 Mc the disturbance voltage at the first filter is

$$\frac{0.016 \cdot 20}{100} = 0.0032 \text{ volt}$$

and at the output of the second band filter is

$$\frac{0.0032 \cdot 0.016}{100} = 0.00000512 \text{ volt}$$

or 0.5×10^{-6} volts.

Whilst by superposition to 100 Kc the disturbance voltage amounts to 5.12 millivolts, on the other hand the maximum permissible disturbance voltage has been found to be $0.5 \cdot 10^{-6}$ volts, so that in this case, since the useful voltage at piano passages amounts to 10μ volts, the disturbance voltage is 512 times greater than the useful voltage, whilst by superposition to 10 Mc the maximum permissible disturbance voltage (that is 1% of 10μ volts) is not exceeded.

As follows from the above numerical example, the ratio of useful to disturbance voltage continues to improve with increasing resonant frequency of the four terminal network. This is both because the storage capacity of this circuit continually decreases with increasing resonant frequency and also because of the circumstance that at the higher frequencies the coupling of the resonant circuits of the four terminal network for damped oscillations continually becomes looser. Whilst the inter-relation between coupling and frequency has already been explained, the storage capacity of this circuit will now be discussed shortly. A voltage pulse arising from a disturbance will charge the capacity of the first resonant circuit of the four terminal network. This charge represents a store of energy which renders possible the maintenance of damped natural oscillations of the resonant circuit. These natural oscillations will decay the quicker, the larger the loss resistance of the circuit, or the smaller this store of energy is.

Since it is naturally not possible to alter the ratio R/L , unless the absolute band width is also altered, this store of energy can only be reduced by reducing the circuit constants L and C . This, however, has as a result that the resonant frequency of these circuits becomes continually higher as L and C become smaller. In order, however, with circuits which are tuned to such a high frequency, to be able to carry out a selective choice of frequencies of the order of the 10th power smaller than the resonant frequency of the tuning circuits, the whole of the reception spectrum from the antenna, which if desired can be first amplified in one or more stages, is fed to a modulator circuit, and by means of this modulator circuit, with which is associated a local high frequency generator, is transposed to this high frequency.

If, therefore, with a disturbance-free wireless receiver according to an embodiment of the invention, it is desired not to exceed a certain ratio of disturbance to useful voltage, it is necessary either to increase the transposed frequency, generally called the intermediate frequency, in such

a way that the storage capacity of the four terminal network used becomes still smaller, and as a result the coupling for damped oscillations becomes still looser, or else the number of four terminal networks, for a given wave length of the transposed frequency, is increased to such an extent that once more the desired relation between useful and disturbance voltage is obtained.

In general the useful field strength available from the transmitter can be taken as 1 millivolt/m, whilst with atmospheric conditions powerfully disturbed electrically, disturbance voltages up to several hundred volts may arise. The maximum permissible disturbance voltage of 1-5% of the useful voltage represents the relation which the disturbance voltage should bear to the useful voltage. The maximum permissible disturbance voltage of 1-5% is naturally the relation for piano passages in the transmission, as otherwise, since the dynamic variations of a transmission amount to about 1 : 100, during soft passages the disturbance voltage would be as great as the useful voltage. The disturbance voltage can therefore only be regarded as negligible if, during soft passages in the transmission, it does not exceed at the most a value of a few percent of the useful voltage.

Now that the relation of useful and disturbance voltage has been made clear by the above explanations, the effects of the steps according to the invention will be set out once more in a condensed form.

1. Reduction of the energy storage capacity of the resonant circuits employed and following from this a smaller disturbance energy from a voltage impulse. ($\frac{1}{2}e^2.C = \frac{1}{2}I^2L$ becomes smaller with increasing transposition frequency).

2. Looser coupling for damped oscillations at higher transposition frequency, with the result: more rapid decay of the coupling oscillations.

3. For a certain desired relation between useful and disturbance voltage there is therefore required for each transposition frequency a minimum number of four terminal networks, or in other words: For a given transposition frequency, as high as possible, a minimum number of four terminal networks is necessary in order to bring the relation between damped and undamped oscillations or the relation between disturbance and useful voltage to a determined value.

The transposition according to the invention will be further explained by a numerical example:

The frequency of the transmitter to be received is 500 kc., the frequency of the oscillator 10,000 kc. Consequently the resulting transposition frequency is 9500 kc. If now the circuits for this transposition frequency are tuned to 9500 kc., this transposition frequency will contain only modulated high frequency signals which are initiated by the transmitter of 500 kc. to be received. In this way it is possible, since the resonant circuits connected after the modulator are adjustable for any desired frequencies, to carry out the selective choice of reception frequencies with resonant circuits whose decay time for impulsive oscillations is vanishingly small.

When the receiver according to the invention is constructed, the resulting transposition frequency is directly amplified further and demodulated in known manner, in order to render the transmission audible after passing the low frequency stage. If, however, it is a case of furnishing an already existing set with a device according to the invention, this can be carried out

in a previous auxiliary device in such a way that the waves are transposed back to the original reception wave by a modulator with the aid of the local oscillator. A numerical example may make this clearer:

The reception frequency is again 500 kc., whilst the oscillator frequency is again 10,000 kc. One would therefore have after the first modulator a transposition frequency of 9500 kc. The second modulator tube receives again the oscillator frequency of 10,000 kc. so that the transposition frequency leaving this second modulator is again 500 kc. In order that the individual voltage pulses arising from atmospheric disturbances and whose impulse duration is of the order of milliseconds shall not excite the normal receiver connected after the device to natural oscillation, the output of this auxiliary device may be provided with an amplitude filter which only passes voltages up to a certain maximum value. Since this amplitude filter is not the subject of the present invention, further description thereof can be dispensed with.

The invention is illustrated in the drawings by means of two embodiments.

Figure 1 shows the circuit for the first embodiment.

Figure 2 shows the circuit for the second embodiment.

Figure 3 is a graph showing the characteristics of an amplifying part thereof; and

Figure 4 is a diagram illustrating the mode of operation of this embodiment.

In the drawings, there is represented in Fig. 1 a constructional example of the device according to the invention, in which a reception range of from 200 to 2000 m. will be assumed. All the radiated frequencies, including also those of the broadcast band from 150 to 1500 kc., act together on the antenna 1 and are fed to the mixing stage A after passing the aperiodic high frequency amplifying stage 2. This stage therefore makes no selection from the combined frequency band; it is unselective. To the mixing stage is coupled the oscillator B the frequency of which is 20,000 kc. To the mixing stage is further coupled the first transposition amplifier C which filters out the desired frequency, to which the resonant circuits 3, 4, 5 and 6 are tuned, from the frequency mixture resulting from the mixing. These resonant circuits are adjustable, for the given frequency band and the oscillator frequency of 20,000, within the frequency interval from 18,500 to 19,850 kc. The tuning to the desired transmitter can be considerably simplified by using, after the mixing stage, a fixed intermediate frequency and by varying the oscillator frequency. With a fixed intermediate frequency of for example 20,000 kc., the oscillator frequency must be varied between 20,150 and 21,500 kc. for selecting incoming frequencies from 150 to 1500 kc. The latter procedure has the advantage that, for the selective choice of transmitter, only a single variable condenser is required, whilst the condensers of the intermediate frequency circuits can be left at a fixed value. In order that no disturbances should be originated through image frequencies it is desirable to employ in the antenna circuit a filter network 8 which allows all frequencies up to about 2000 kc. to pass and then exhibits a sharp increase of attenuation for higher frequencies. Still preferable is the provision of a voltage resonance member 7 which presents a short circuit to the image frequencies, that is to say frequencies which lie about double the transposi-

tion frequency above the reception frequencies (that would be the band $150 + 2.20,000 = 40,150$ kc. to $1500 + 2.20,000 = 41,500$ kc. for the assumed fixed transposition frequency of 20,000 kc.). The tuning of the variable condenser of the voltage resonant circuit advantageously follows directly with the tuning of the oscillator condenser.

If it should be required that, with the constructional form of the receiving apparatus above described with reference to Fig. 1, all the damped oscillations acting thereon should disappear from the transmission, owing to the differential behaviour of the four terminal network for damped and undamped oscillations, it is necessary, with increasing ratio of the damped to the undamped oscillations, to increase both the transposed transmission frequency and the number of four terminal networks.

If one reckons with a ratio of magnitude of 10^6 to 1 for the difference between damped and undamped oscillations, as happens with local storms at the reception point, it is seen at once that it is only possible by an extremely high transposition frequency on the one hand and also by a very large number of four terminal networks on the other hand to remove the undamped transmission frequencies from the damped oscillations superimposed thereon.

This disadvantage can, according to a further embodiment of the invention be removed by reducing or cutting down the amplitudes of the damped oscillations, by means of an amplitude filter, to the value of the maximum amplitudes of the modulated transmitter. In this way there can act on the receiving apparatus only disturbance amplitudes whose values no longer extend beyond the transmitter amplitudes. Thus the ratio of disturbance to useful amplitudes will be definitely limited in an upward direction for all sources of disturbance.

An example of such an arrangement is shown in the drawings in Figs. 2-4.

Fig. 2 shows the high frequency part of the receiver,

Fig. 3 the characteristic of an amplifier tube connected as an amplitude filter, and

Fig. 4 a diagram illustrating the mode of operation of the arrangement.

The receiver has an antenna 1 as pick-up device, and also the two amplifying and selecting stages 9, 10. It further has the amplitude filter 11 and the modulator A which receives from the local generator B the frequencies necessary for transposition with the transmission frequency. In the anode circuit of the modulator A is arranged the four terminal network consisting of the oscillatory circuits 3, 4. To this four terminal network is connected the amplifier tube C of the intermediate frequency stage, which in turn on its anode side has a four terminal network 5, 6. The secondary side of this four terminal network is connected to the rectifying diode 12. This diode delivers the demodulated high frequency through the condenser 13 to the low frequency stage of the receiver and also at the same time to the grid circuits of the amplifier and control tubes 9, 10, a control voltage whereby the amplification is varied according to the magnitude of this control voltage. This control voltage has for its object to maintain the maximum amplitudes which reach the amplitude filter 11 of the same magnitude for all frequencies to be received. These control devices are known and have for their object in the present invention not so much the compensation of fading which may arise but much more a compensation of the different trans-

mission field strengths arriving. For this reason the time constant of this control device, in contradistinction to the so-called fading control, is made long, that is to say at least of the order of 1 second.

The high frequency leaving the amplifier stage 10, which through the selecting members is already tuned to a given transmitter, reaches the amplitude filter 11. This amplitude filter is constructed from a screen-grid tube which receives a maximum anode voltage of only 6 volts whilst the screening grid requires 35-40 volts. Under these voltage conditions there is obtained a characteristic J_A (E_G) which substantially corresponds to the characteristic of Fig. 3, that is to say, the emission of the tube commences abruptly, and, excepting for a small bend at the beginning, then rises completely proportionally to the grid voltage and shortly before reaching zero grid voltage changes slowly into a line of constant current even at very highly positive grid voltages. This amplitude filter is in the circuit biased by a negative bias to the mid point of the grid control region. This grid control region, which is indicated by the reference 14 of Fig. 3, receives the grid bias represented by the dotted line 15. The anode resistance of the amplitude filter is somewhat critical and should not exceed the value of 5000 ohms.

The mode of operation of this amplitude filter is seen from the diagram of Fig. 3. The transmission amplitude arriving is so adjusted that with 100% modulation of the transmitter, the maximum transmission amplitude just swings the grid of this amplitude filter over the grid control region. If now disturbance peaks are superimposed upon the transmission, these peaks are cut off by the amplitude filter to such an extent that in the theoretically most favourable case, that is with 100% transmitter modulation, the disturbance voltage is only just as large as the useful voltage.

In any case the relationship is in general less favourable since when the transmitter is not fully modulated the amplitudes of the disturbance voltages are always greater than the amplitudes of the useful voltages. The relationship will have the value 100:1 at 1% modulation of the transmitter. Through this amplitude filter, therefore, since the maximum dynamic variation in a transmission amounts to about 1:100, the relationship between disturbance and useful voltage, in the most unfavourable case will amount to 100:1, that is to say this relationship will be definitely limited in an upward direction by the amplitude filter.

For the rest, reference should be made to the description of the example of Fig. 1 with regard to the further mode of operation of this receiving arrangement.

I claim:

1. Apparatus for reducing disturbances in wireless receivers comprising an input circuit for receiving energy from an antenna, a modulator circuit including a tube having an anode circuit, a local high frequency oscillation generator coupled to said modulator, means for feeding from said input circuit to said modulator frequencies received by said antenna, said modulator being adapted to transpose said received frequencies to a higher frequency level, and tuning means coupled to said anode circuit for the selective amplification of the transposed frequencies, said tuning means for the selective amplification comprising inductances and capacities of such magnitudes

that the capacity of said tuning means for storing electrical energy and the coupling between the circuits of said tuning means for damped oscillations is so low that the residual disturbance energy at the output of said tuning means, arising from a disturbance, is insufficient to maintain the coupling oscillations initiated by the disturbance through the reciprocal action of the circuits of said tuning means.

2. Apparatus for reducing disturbances in wireless receivers comprising an input circuit for receiving energy from an antenna, a modulator circuit including a tube having an anode circuit, a local high frequency oscillation generator coupled to said modulator, means for feeding from said input circuit to said modulator frequencies in a wide frequency spectrum received by said antenna, said modulator being adapted to transpose said spectrum to a higher frequency level, and tuning means coupled to said anode circuit for the selection from the transposed spectrum of a desired frequency band, said tuning means comprising inductances and capacities of such magnitudes that the capacity of said tuning means for storing electrical energy and the coupling between the circuits of said tuning means for damped oscillations is so low that the residual disturbance energy at the output of said tuning means, arising from a disturbance, is insufficient to maintain the coupling oscillations initiated by the disturbance through the reciprocal action of the circuits of said tuning means.

3. Apparatus according to claim 2, and comprising in said input circuit a voltage resonance member, having a tuning condenser operable directly with the condenser of said oscillation generator, for the purpose of suppressing image frequencies.

4. Apparatus according to claim 2, wherein for the purpose of permitting selection of the desired transmitter frequency, the resonant circuit in the anode circuit of the modulator is tunable.

5. Apparatus according to claim 2, wherein for the purpose of permitting selection of the desired transmitter frequency, there is provided a control member for varying the frequency of said oscillation generator, the resonant members in said modulator circuit being tuned to a fixed resonant frequency.

6. Apparatus according to claim 1 comprising, at a suitable point in the receiving arrangement, an amplitude filter which is incapable of passing voltages which are greater than the control grid range of this filter, so that the ratio of disturbance to useful amplitudes is limited in an upward direction for all disturbing frequencies which may become active upon the receiving apparatus.

7. Apparatus according to claim 1 comprising, at a suitable point in the receiving arrangement, an amplitude filter which is incapable of passing voltages which are greater than the control range of this filter, so that the ratio of disturbance to useful amplitudes is limited in an upward direction for all disturbing frequencies which may become active upon the receiving apparatus, said amplitude filter comprising an electron amplifier tube having an anode and at least two grid electrodes, one of said grid electrodes being arranged as control grid and another as screening grid, and means being provided for supplying voltages to said anode and grid electrodes, the voltage applied to said anode being at most one

half of the voltage applied to said screening grid and the bias voltage applied to said control grid being such that an incoming signal is adapted to swing the voltage of said control grid over substantially the whole of the straight portion of its characteristic. 5

8. Apparatus according to claim 1, including an amplitude filter between said receiving circuit and modulator circuit for reducing the damped disturbing oscillations to the value of the maximum amplitudes of the transmitter station being received. 10

9. Apparatus according to claim 1, including a thermionic amplitude filter between said receiving circuit and modulator circuit for reducing the damped disturbing oscillations to the value of the maximum amplitudes of the transmitter station, and control means having a large time constant for said amplitude filter whereby the grid of the amplitude filter, with 100% modulation of the transmitter, operates along substantially the straight portion of the grid characteristic thereof.

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