

Sept. 17, 1946.

M. ZIEGLER

2,407,863

RECEPTION OF FREQUENCY MODULATED WAVES

Filed April 12, 1943

Fig. 1.

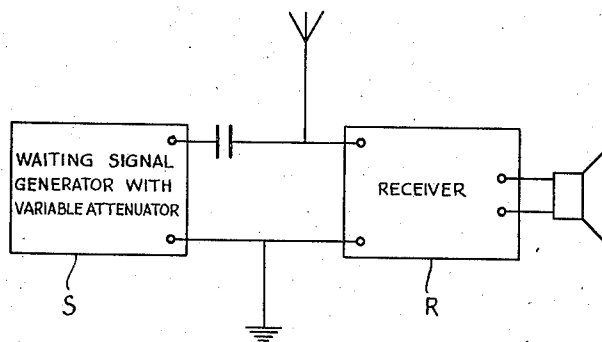
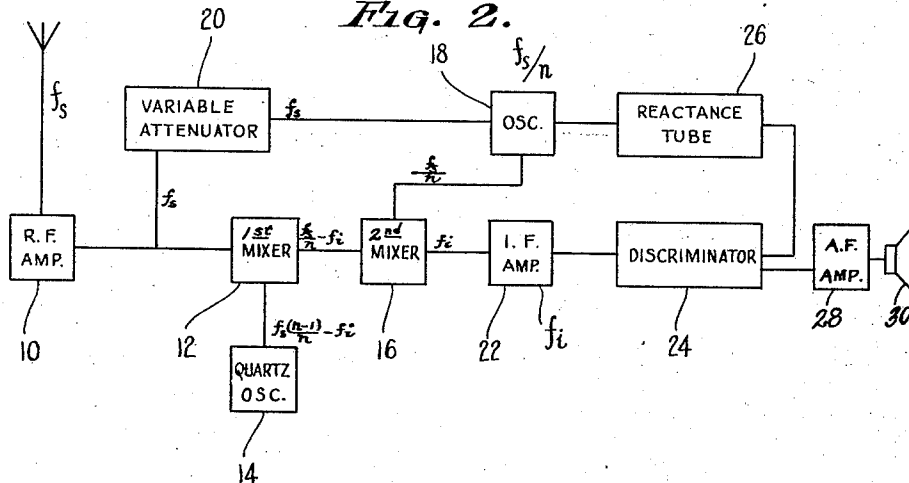


Fig. 2.



MARC ZIEGLER.
INVENTOR.

BY

Edw. J. Hansen

ATTORNEY

UNITED STATES PATENT OFFICE

2,407,863

RECEPTION OF FREQUENCY MODULATED WAVES

Marc Ziegler, Buenos Aires, Argentina, assignor
to Hartford National Bank and Trust Company,
Hartford, Conn., as trustee

Application April 12, 1943, Serial No. 482,785

4 Claims. (Cl. 250—20)

1

The present invention is concerned with the reception of frequency modulated waves and more particularly with the maintenance in properly tuned condition of frequency modulated receivers, and with the prevention of the reception of unwanted signals.

In the practice of reception of radio signals at fixed frequency, as for example frequency modulation communication receivers and also amplitude modulation communication receivers, which have to stay tuned to the frequency of the signal to be received under all circumstances, without the necessity of any readjustment, two different types of designs have been proposed and are being used.

In the first category, the correct frequency adjustment is guaranteed only by the stability of the selective circuits used and therefore, in the places where the circuit frequency has an important influence on the correct adjustment of the receiver, the common L. C. circuit has been replaced by a quartz crystal. Typical representatives of frequency modulation receivers using this system usually contain two crystal oscillators, one at higher frequency for the first frequency changer stage and a second one at a lower frequency for the second frequency changer stage. In that way, a constancy of the frequency adjustment is obtained which is just equal to that of the crystal used.

A real drawback of this system, however, is that the frequency of the crystals cannot be changed during operation. Therefore, the frequency precision required for these crystals, especially the crystal of higher frequency is rather high in order to insure that a receiver of that type is really adjusted within narrow limits to the fixed frequency of the transmission to be received.

In frequency modulated reception especially accurate tuning is very important; first, because generally the comparative immunity of frequency modulation reception from impulsive interference is dependent on that accurate tuning and secondly because a slight detuning of the receiver may lead to unacceptable distortion owing to the fact that at maximum frequency excursion the instantaneous frequency may run beyond the linear part of the discriminator characteristic. The precision required in frequency modulated communication practice at 40 mc. when it is demanded that the intermediate frequency be correct to within 0.5 kc. is not less than 1.25×10^{-5} which is a requirement making the crystal rather expensive. For the same reason, the temperature coefficient of the crystal must be very low.

2

As a matter of fact, in communication practice, temperature variations as large as 60° C. may be commonly expected, so that the same requirement of intermediate frequency stability would lead to the excessive requirement of 2×10^{-7} per degree C. when no thermostatic arrangement is used.

All these drawbacks are not present for the designs of the second category in which the desired frequency adjustment is obtained by automatic frequency control commanded by the incoming signal. For example, reference may be made to my copending United States Patent applications Serial No. 464,380 filed November 3, 1942 and Serial No. 478,705, filed March 10, 1943 where a method of automatic frequency stabilization is described together with its application to the reception of frequency modulated waves. The automatic frequency control action can be made very effective, and can correct with great accuracy all possible deviations of the tuning of the receiver. It has been explained in said first application, that the deviations of a local oscillator from a desired frequency can be made practically as small as desired and the intermediate frequency signal in a frequency modulation receiver of that type will easily be maintained within a few hundred cycles equal to the correct frequency, even when the frequency of the local oscillator shifts away a frequency value which is hundreds of times as large, as for instance 100 kc.

In that case no crystal is necessary, which is an important advantage, but the drawbacks of crystal control receivers of the first category are replaced in common receivers of the automatic frequency control type by another inconvenience. The effective frequency control, of course holds only as long as the desired signal is present, and in the absence of this signal the frequency adjustment which is no longer controlled, may shift outside the range of regulation, so that the automatic frequency control cannot operate when the signal comes in. In the absence of the desired signal, the automatic frequency control may moreover be made operative by another undesired signal, the receiver then adjusting itself to that undesired signal. In both cases, the desired conditions can only be restored by manual readjustments, but these are of considerable inconvenience in many practical instances and therefore unacceptable in the specification of a communication receiver.

I now have found that this drawback of the receivers of the automatic frequency control type which are much superior in all other respects,

can be compensated by superposing on the desired signal, in some part of the receiver, a local signal of equal frequency that will still be there when the desired signal disappears and will take care of keeping the automatic frequency control arrangement in condition for adjusting the receiver correctly to the desired signal when the latter comes in again. The possible frequency differences between the emission to be received and the local signal are readily kept well within the range of regulation. This local superposition or substitution signal may be called "waiting signal."

It is obvious that the amplitude value of the waiting signal must be substantially smaller than the voltage developed at the place of injection by the transmission signal during the reception so as not to interfere with the desired signal during its reception.

It is very commonly required in the specification of a communication received that the receiver shall be made insensitive to all signals below a certain level. In order to fulfill this requirement, all kinds of complicated silencer or squelch arrangements have been designed for cutting down the amplification of some part of the receiver so long as the incoming signal has not reached a certain minimum value. This minimum value generally is adjustable in order to make the receiver adaptable to different conditions of reception. The advantage of such a silencer or squelch arrangement is that, when the desired signal is not present, noises from other and less strong signals, static interferences and internal spontaneous fluctuations are not reproduced and the receiver is completely quiet.

I have now found that a very convenient squelch action can be provided by the above mentioned waiting signal. As a matter of fact, this waiting signal can be made adjustable to any value so that any squelch level may be obtained.

With my invention, I therefore solve two problems at the same time: First, that of improving the security of operating conditions of a frequency modulated receiver of the automatic frequency control type and second that of providing a very simple and very effective squelch device.

I have also found that it is not unavoidably necessary to obtain the waiting and squelch signal from a special local oscillator, which would mean a complication of the design, but that it can be derived from one of the existing local oscillators of the receiver.

This and other details and features of my invention will be made clear in the description of the figures, wherein

Fig. 1 represents a block diagram of a frequency modulation receiver of the automatic frequency control type with a separate crystal oscillator providing the waiting and squelch signal required.

Fig. 2 represents schematically a basic embodiment of a receiver wherein an adjustable waiting and squelch signal is obtained from a local quartz crystal oscillator of the receiver.

In Figure 1, S is a well shielded signal generator of frequency substantially equal to that of the signal to be received, and of a constancy better than that of the local oscillators used in the receiver R, as for example a crystal oscillator.

This generator provides at the input of the receiver a signal of smaller amplitude than the signal to be received but large enough to make the receiver operate correctly and adjust itself

automatically on the frequency of the injected signal. Hence, the correct adjustment is guaranteed also in the absence of the signal to be received during a waiting time of any length by the injected signal, which I have therefore called "waiting signal."

When the desired signal comes in, the receiver is already adjusted on the right frequency so that no manual tuning operation is necessary. In the case of frequency modulated reception, the presence of the waiting signal does not cause any significant disturbance as long as its amplitude is smaller than the amplitude of the signal at the place of injection. This desirable effect is characteristic of frequency modulation receivers and has been explained by H. Roder in the publication "Electronics" (May, 1937, vol. 10, No. 5, pages 22 to 25 inclusive, 60, 62 and 64). As pointed out therein, a frequency modulation receiver is only responsive to the stronger of two signals. Furthermore, when the amplitude of the weaker of the two signals is less than one-half the amplitude of the stronger signal, the disturbing phase shift produced (and hence the disturbing equivalent frequency modulation produced) is never more than about one-two hundredths ($\frac{1}{200}$) of the legitimate phase shift equivalent to the permissible degree of frequency modulation of the signal. Such a small disturbance cannot produce a significant interference effect. In the case of an amplitude modulated receiver, the waiting signal will produce with the desired signal a beat frequency signal which may be audible and therefore unacceptable. The only solution in that case would be to switch off the waiting signal generated as soon as necessary.

The above mentioned property of the frequency modulated receiver can be made use of for obtaining an adjustable silencer by providing the signal oscillator of Fig. 1, with a convenient adjustable attenuator. As a matter of fact if we inject a non-modulated signal of, for example, 50 microvolts in the antenna, the receiver will respond only to signals larger than said value and if no signals are present larger than 25 microvolts, the receiver will be perfectly quiet. If used for that purpose, the injected signal may therefore be called a squelch signal, as it replaces the squelch arrangements known in the art.

This holds for any level above the normal lower working limits of the receiver which generally, for frequency modulated communication receivers wherein a silencer is needed, is very low, that is lower than 1 microvolt.

As a matter of fact, the waiting and squelch signal does not need to be injected in the antenna of the receiver but at any point before the mixer. The value of the signal injected then, of course, must be increased adequately.

The disadvantage of an arrangement such as that of Fig. 1 is that it requires in addition to a normal receiver a complete oscillator plus attenuator which makes the feature a rather expensive one. In Fig. 2 however, the effects described have been fully obtained without the addition of a separate oscillator. The waiting signal is provided by one of the local oscillators normally present in the receiver, the frequency of said local oscillator being kept automatically at the correct value by stabilization from the other local oscillator which itself is quartz stabilized.

This receiver has therefore all the stability of a receiver with a local crystal oscillator and the consequent guarantee of receiving the communi-

5

cation when it comes in, and all the automatic adjustability to the incoming signal of a classical receiver of the automatic frequency control type with consequent advantages with regard to selectivity and absence of distortion.

In the example given in Fig. 2 the signal frequency is f_s . After one stage of radio frequency amplification 10 the first mixer 12 is passed through, which operates with a quartz oscillator 14 of frequency

$$f_s \left(\frac{n-1}{n} \right) - f_i$$

to obtain a first intermediate frequency

$$\frac{f_s}{n} + f_i$$

The second mixer 16 operates with an oscillator 18 at frequency

$$\frac{f_s}{n}$$

so as to get a second intermediate frequency f_i . The waiting and squelch signal is obtained as the n^{th} harmonic of the second local oscillator 18. This harmonic, as is well known, always exists in practice, in the anode circuit of the oscillator tube and may be obtained without further equipment. The intensity of the harmonic wave is adjustable by means of the attenuator 20. The second intermediate frequency wave is amplified by the intermediate frequency amplifier 22 and applied to the discriminator 24 which in turn controls the reactance tube 26 and energizes an audio frequency amplifier 28 and a loudspeaker 30 in known manner. The discriminator is adjusted so as to give a control voltage which is zero in value when the frequency applied at its input is equal to the nominal intermediate frequency f_i . The frequency of the second local oscillator 18 is automatically controlled by means of the reactance tube 26 on the grid of which the output of the discriminator is applied.

It will readily be understood that the oscillator 18 will be adjusted automatically at such a frequency that the output of the discriminator will be as nearly possible zero, that is when the intermediate frequency is as nearly as possible equal to the predetermined value f_i for which the discriminator is adjusted, so that the controlled oscillator frequency will be practically

$$\frac{f_s}{n}$$

and its n^{th} harmonic will have substantially the frequency of the signal to be received. The waiting and squelch signal therefore works simply as described above for Fig. 1.

For n any value may be chosen larger than 2 and smaller than a higher limit determined by practical considerations. For lower values of n (3 or 4) a good signal-to-image relation is obtained; for higher values of n a better amplification of the first mixer stage may be expected as the first intermediate frequency is lower but the signal-to-image relation is poorer and it may become difficult to obtain enough squelch signal amplitude of the desired frequency. For a signal frequency of 40 mc. the value of $n=4$ seems to be convenient.

It must be observed that a very careful shielding of the second local oscillator 18 is necessary in order to reduce the waiting signal picked up directly by the antenna or other parts of the receiver down to the lowest limit of reception.

6

This may present some difficulties, but these difficulties can be solved conveniently by using the existing technique of standard signal generators and the like.

Evidently, many other arrangements can be readily devised by those skilled in the art, to give the same results on the same principles. The circuit indicated is not to be considered as limitative since the choice of the circuit may depend on particular circumstances which do not effect in any way the fundamental nature of the invention.

It must also be understood that the present invention may be applied either to frequency modulated receivers of classical types or to those incorporating automatic frequency stabilization using frequency counters, especially inductance type frequency counters, or those using excursion shrinkage and the like, as described in my co-pending United States patent applications Serial Nos. 464,380, filed November 3, 1943, 477,990 filed March 3, 1943, 478,705 filed March 10, 1943 and 451,186, filed July 16, 1942.

I claim:

1. A superheterodyne receiver for frequency modulated waves comprising an input channel for receiving a signal wave, a first mixer stage coupled to said channel to receive said signal wave therefrom, a wave source coupled to said mixer stage for producing a first intermediate frequency wave, a second mixer stage coupled to said first mixer stage, a controllable frequency oscillator generating a fundamental frequency wave coupled to the said second mixer stage for producing an intermediate frequency wave having a predetermined frequency value, an intermediate frequency amplifier coupled to the said second mixer stage, a frequency-responsive detector coupled to the intermediate frequency amplifier for producing a control voltage proportional to the average deviation of the said second intermediate frequency wave from the said predetermined value, means responsive to the said control voltage for varying the frequency of the oscillator in a sense to reduce the deviation of said second intermediate frequency wave from the predetermined value to substantially zero, means to inject into said first mixer a wave having a frequency which is substantially equal to frequency of the wave applied from the input channel and which bears a harmonic relationship to the frequency of the said fundamental wave to produce in the intermediate frequency amplifier an intermediate frequency wave substantially the same frequency as the frequency of the intermediate frequency wave and at the output of the detector a control voltage substantially equal to the control voltage derived from said second intermediate frequency wave resulting from the signal wave, and means to vary the intensity of the said injected wave.

2. A superheterodyne receiver for frequency modulated waves comprising an input channel for a signal wave, a first mixer stage coupled to the input channel to receive said signal wave therefrom, a wave source coupled to said mixer stage for producing a frequency modulated intermediate frequency wave, a second mixer stage coupled to said first mixer stage, a controllable frequency oscillator generating a fundamental frequency wave coupled to the said second mixer stage for producing a frequency modulated intermediate frequency wave having a predetermined frequency value, an intermediate frequency amplifier coupled to the said second mixer stage, a

7

frequency-responsive detector coupled to the intermediate frequency amplifier for producing a control voltage proportional to the average deviation of the said second intermediate frequency wave from the said predetermined value, means responsive to the said control voltage for varying the frequency of the oscillator in a sense to reduce the average deviation of the said intermediate frequency wave from the predetermined value to substantially zero, means to inject into said first mixer a wave having a frequency which is substantially equal to the frequency of the wave applied from the input channel and which bears a harmonic relationship to the frequency of the said fundamental wave to produce in the intermediate frequency amplifier an intermediate frequency wave having a frequency substantially the same as the frequency of the said second frequency modulated intermediate frequency wave and at the output of the detector a control voltage substantially equal to the control voltage derived from the said second frequency modulated intermediate frequency wave, and means to adjust the intensity of the said injected wave to thereby adjust the intensity of the said third intermediate frequency wave to an intensity greater than a predetermined value and less than the intensity of the said second frequency modulated intermediate frequency wave.

3. A superheterodyne receiver for frequency modulated waves comprising an input channel for a frequency modulated signal wave, a first mixer stage coupled to the input channel to receive said signal wave therefrom, a wave source coupled to said mixer for producing a frequency modulated intermediate frequency wave, a second mixer stage coupled to said first mixer stage, a controllable frequency oscillator generating a fundamental wave and harmonics thereof coupled to the said second mixer stage for producing a frequency modulated intermediate frequency wave having a predetermined intermediate frequency value, an intermediate frequency amplifier coupled to the said second mixer stage, a frequency-responsive detector coupled to the intermediate frequency amplifier for producing a control voltage proportional to the average deviation of the said second intermediate frequency wave from the said predetermined value, means responsive to the said control voltage for varying the fundamental and harmonic frequencies of the oscillator in a sense to reduce the average deviation of the said second intermediate frequency wave from the predetermined value to substantially zero, means to inject a harmonic wave from the oscillator into the said first mixer to produce in the intermediate frequency amplifier an intermediate frequency wave having a frequency substantially same as the frequency of the said second frequency modulated intermediate frequency wave and at the output of the detector a

8

control voltage substantially equal to the control voltage derived from the said second frequency modulated intermediate frequency wave, and means to vary the intensity of the said injected wave to thereby adjust the intensity of the said third intermediate frequency wave to a value greater than a predetermined value and less than the intensity of the said second frequency modulated intermediate frequency wave.

4. A superheterodyne receiver for frequency modulated waves comprising an input channel for a frequency-modulated signal wave, a first mixer stage coupled to the input channel to receive said signal wave therefrom, a stable frequency oscillator coupled to the mixer stage, the frequency of the oscillator being equal to

$$f_s \frac{(n-1)}{n} - f_i$$

where f_s is the central frequency of the signal wave received, n is any number greater than 2 and f_i is a predetermined intermediate frequency, a second mixer stage coupled to said first mixer stage, a controllable frequency oscillator generating a fundamental wave nominally equal to the frequency of the received signal wave divided by n and harmonics of said fundamental frequency coupled to said second mixer stage for producing an intermediate frequency wave having a frequency nominally equal to f_i , an intermediate frequency amplifier coupled to said second mixer, a frequency-responsive detector coupled to the intermediate frequency amplifier for producing a control voltage proportional to the deviation of the intermediate frequency wave from the value f_i , means responsive to the said control voltage for varying the fundamental and harmonic frequencies of the controllable oscillator in a sense to reduce the average deviation of the said second intermediate frequency wave from the value f_i to substantially zero, means to inject a harmonic of said controllable oscillator substantially equal to the frequency f_s into the first of said mixers to produce in the intermediate frequency amplifier an intermediate frequency wave having a frequency substantially the same as the frequency of the said second intermediate frequency wave derived from the signal wave and at the output of the detector a control voltage substantially equal to the control voltage derived from the said second intermediate frequency wave resulting from the signal wave, and means to vary the intensity of the injected harmonic wave to thereby adjust the intensity of the said third intermediate frequency wave resulting from the harmonic wave to a value greater than a predetermined value and less than the intensity of the said second intermediate frequency wave resulting from the signal wave.

MARC ZIEGLER.