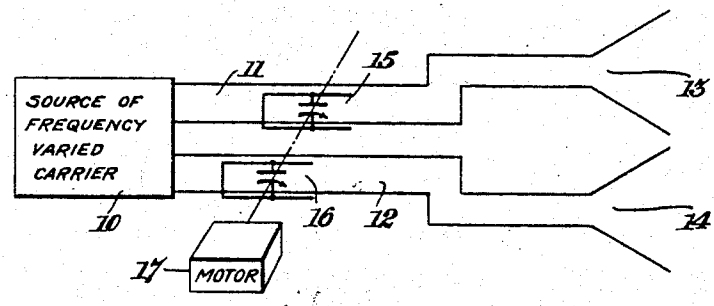
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RADIO RECEIVER

Filed May 21, 1942

Fig:1.



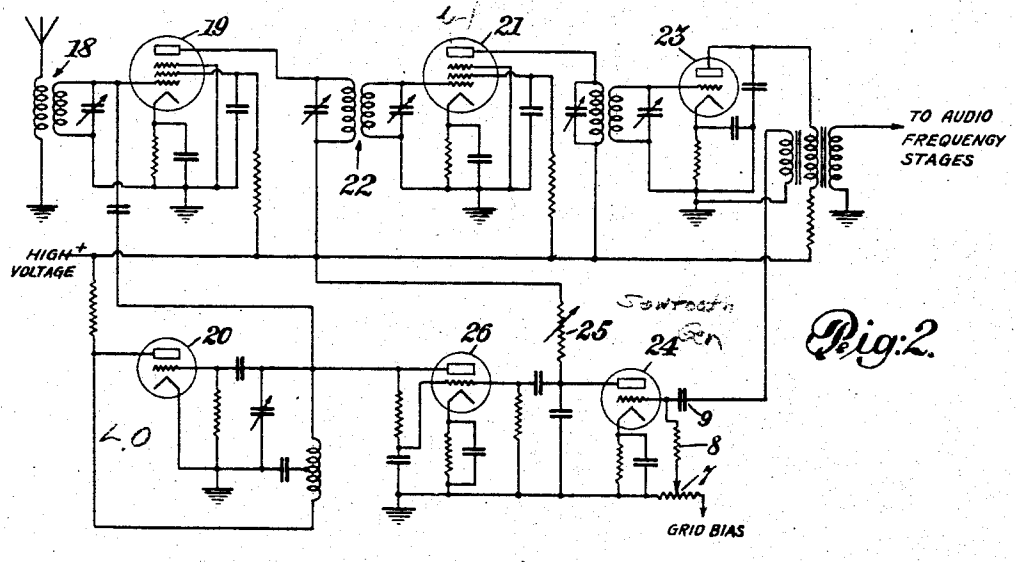


Fig:2.

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RADIO RECEIVER

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Application May 21, 1942, Serial No. 443,894

6 Claims. (Cl. 250—20)

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This invention relates to frequency modulated systems and in particular to such systems wherein a carrier frequency is modulated by intelligence in any well-known manner and in addition is regularly wobbled or swept over a certain range of frequencies. Systems of this kind which are particularly adaptable to aerial navigation problems have been proposed in U. S. Patent 2,241,897 to A. Alford.

It is an object of this invention to provide improved means for receiving and detecting signals transmitted by systems of the above indicated nature.

Another object is to provide means for improving the signal-to-noise ratio in receivers for such systems.

A further object is to provide a receiver responsive to a wobbled carrier frequency substantially to the exclusion of other fixed-frequency carriers even if the latter are in the frequency range of such wobbling.

A still further object is to provide a receiver responsive to a wobbled carrier frequency substantially to the exclusion of reflected or refracted carrier energy arriving over an indirect path so as to have an abnormal delay.

A more specific object is to render a receiver substantially continuously responsive to such a wobbling carrier, said receiver being at any instant responsive to a smaller band of frequencies than comprehended by said wobbling.

Other objects and various further features of novelty and invention will hereinafter be pointed out or will become apparent to those skilled in the art from a reading of the following specification in connection with the drawings included herewith. In said drawings—

Fig. 1 schematically illustrates a method of transmitting intelligence on a frequency-wobbled carrier; and

Fig. 2 is a schematic circuit diagram of a portion of a receiver responsive, in accordance with the invention, to energy transmitted by the circuit of Fig. 1.

As indicated, frequency-wobbled carrier systems have particular utility in the aerial navigation field wherein it is of importance to define radio courses with relatively high precision. A simple apparatus for defining such a course is shown in Fig. 1 where a common source 10 of frequency-varied or wobbled carrier is simultaneously supplied into two transmission lines 11, 12 for ultimate radiation by two antenna systems 13, 14, respectively. In order to define a course from which deviation will be readily detectable, each side thereof must be characterized differently. Accordingly, modulation means 15, 16 are included with each of lines 11 and 12. In the form shown, these comprise variable shunt capacities varying synchronously and in accordance with different signals as controlled by rotation of motor 17. The circuit described is thus effective to radiate from antenna 13, a signal which is amplitude modulated in accordance with the characteristics of modulator 15 on a wobbled carrier and from antenna 14, a signal which is amplitude modulated in accordance with the characteristics of modulator 16 on the same wobbled carrier.

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As also described in the above patent, at shorter carrier wavelengths the danger of reflection from nearby objects increases. Such objects produce deleterious effects in the uniformity and clarity of the course pattern it is desired to define. As indicated in the above-mentioned patent, varying the carrier frequency by periodically wobbling the same does not eliminate reflections from nearby objects. Its effect, however, is periodically to change the interference patterns produced by such reflections so that on an average the correct course is radiated. If the airplane or other unit equipped with receiving apparatus includes means responsive to substantially the entire frequency band as produced by such wobbling, it is clear that on an average, a receiver will be responsive only to the correct course signals, for the changes therein due to changes in the reflecting characteristics of objects near the transmitter are so fast as not to be detectable.

Inherent in the operation of such receivers is the disadvantage that they are always open to receive an unnecessarily large band of frequencies. They are thus always responsive to relatively large amount of noise or other disturbances as compared with the strength of the signal ultimately detected, and operation is therefore relatively inefficient.

In accordance with the invention, this undesirable feature is very substantially eliminated by providing means at the receiver whereby the latter is rendered responsive substantially only to energy of a given frequency; this given frequency of receptiveness being constantly varied so as to be equal to the instantaneous frequency of the wobbled carrier, whereby a relatively narrow band receiver may be employed and signal-to-noise ratio is improved. A preferred arrangement for accomplishing this result is shown in Fig. 2. In accordance with this preferred arrangement, the radio-frequency receiver circuit

is responsive to a wide band of frequencies including all those represented by the wobbling, and a single substantially constant intermediate frequency is produced by mixing with the received radio frequencies sweeping oscillations produced by a local oscillator controlled to vary its frequency in accordance with the wobbling pattern. Since the intermediate frequency is substantially constant, that and subsequent stages may be responsive to a relatively narrow band of frequencies, thus excluding substantially all noise occurring at frequencies other than the instantaneous carrier frequency.

In accordance with the embodiment of Fig. 2, the swinging local oscillator is kept in step by means of a circuit including a detector, generating pulses in response to deviation of the intermediate frequency from the relatively narrow band of frequencies to which the intermediate frequency stage is responsive. For present purposes, it is assumed that the frequency wobble is in accordance with a saw-tooth pattern. These pulses accordingly are made to synchronize a saw-tooth generator or other means for generating a wave form substantially in accordance with the expected wobble. The signal produced by the saw-tooth generator controls the circuit producing reactance varying in accordance with an applied signal and this reactance is made to change the tuned condition of the swinging oscillator.

More specifically the circuit of Fig. 2 comprises a radio frequency receiving circuit 18, which, as above indicated, is responsive to a relatively wide band of frequencies including all those covered by the wobbled carrier. Frequencies thus detected are fed to a converter stage 19 to which local oscillations supplied by an oscillator including tube 20 are also fed. The result of received frequencies and local oscillations is to produce in the output of tube 19 an intermediate frequency. This intermediate frequency is relayed to intermediate frequency amplifier 21 through a coupling circuit 22 passing a relatively narrow band of frequencies.

It is clear that this intermediate frequency coupling circuit 22 will be effective to pass substantially only one predetermined intermediate frequency. Accordingly, any abrupt deviations of the intermediate frequency from this predetermined frequency will be noticeable by a decided drop in signal magnitude in the output of 23. At the instant when the incoming signal stops its linear rise in frequency and abruptly starts down in frequency (and while the oscillator 20 is still continuing its linear upward sweep in frequency) a sudden variance from the expected intermediate frequency will occur. As indicated, this steep wall is employed to trigger or synchronize a saw-tooth generating circuit including a hot cathode gas-filled triode 24 of the so-called grid-glow type to start a fresh saw-tooth for each such wall. For this purpose a triggering impulse is derived from a so-called differentiating network including a series capacitance 9 and shunt resistor 8. This saw-tooth generating circuit is preferably so designed as to produce a wave substantially of the form of the frequency wobble and having its natural or free recurrence frequency slightly less than that of the wobble, for reasons that will hereafter become apparent. If desired, the slope and height of the saw-tooth wave may be changed as desired as by varying a resistance 25 supplying high voltage to the anode of tube 24 or potentiometer controlling the grid

bias. The saw-tooth voltage produced by the circuit of tube 24 is next fed to a control tube 26 having a circuit similar to that commonly used in automatic frequency control systems for producing in its output circuit changes in effective reactance corresponding in magnitude to the applied signal.

Tube 26 and its circuit are thus effective to produce in its output a reactance changing in magnitude in accordance with the applied saw-tooth wave. This varying reactance, as above indicated, is used variably to tune the oscillating circuit of tube 20 whereby local oscillations varying in accordance with the saw-tooth pattern are produced.

As mentioned, the form of saw-tooth variations is so designed as to vary substantially in accordance with the wobbled carrier. In this manner, the varying local oscillations supplied to converter 19 are normally oppropriate for mixture with the received signals so as to produce a substantially constant intermediate frequency. For each swing of the wobbled carrier, however, it will be noted that, at the end thereof when a change from linearity or other regular pattern commences, the local oscillator will be producing a frequency which when mixed with the wobbled carrier will produce an intermediate frequency slightly different from the desired substantially constant one. Almost instantaneously this difference will become characterized by a sudden departure from the normal intermediate frequency. The effect of this sudden departure from normality will be a very sudden drop in detected signal as produced in the output of tube 23. This sudden change is effective immediately to start a new saw-tooth wave in generator 24. The new saw-tooth wave makes a corresponding change in effective reactance in the output of tube 26 with a corresponding change in the local oscillating frequency. When the latter frequency is mixed with received wobbled carrier, the substantially constant and desired intermediate frequency will again be produced.

The circuit just described in connection with Fig. 2, thus effects an almost instantaneous correction in the local oscillating frequency with the resultant derivation of this substantially constant intermediate frequency. The narrow band portion of the receiver is accordingly maintained in a state tuned to receive signals characterizing the wobbled carrier substantially all the time. The intelligence or other modulation on the wobbled carrier as produced by modulators 15 and 16 may subsequently be isolated into separate channels for identification in accordance with well-known circuit principles. These audio-frequency stages may be coupled to the output of detector 23, as has been generally indicated by appropriate labeling of the drawing.

The circuit of Fig. 2 has the particular advantage that it will follow the wobbled carrier substantially independent of other carrier frequencies (which latter may be constant or wobbled in accordance with other patterns). This feature is an outcome of the fact that saw-tooth generator 24 may be designed normally to operate to produce a saw-tooth varying substantially in accordance with the wobble. Since the normal period of saw-teeth produced by this generator is preferably slightly greater than that of the wobble in frequencies to be received, the intermediate frequency will deviate from the desired value momentarily once for each cycle of the wobble. In this manner, saw-tooth generator 24 is syn-

chronized once every cycle of wobble. It will therefore take a very strong jamming signal characterized by a regular periodic saw-tooth wobble substantially the same as that to be received to pull the receiver of Fig. 2 out of step with the signals to be received, as will be clear.

It has been indicated above that the invention is particularly adaptable to such frequency wobbled systems as shown in Fig. 1 wherein there is amplitude modulation of the wobbled carrier. Clearly, however, the invention is broader than this limitation, for there are many additional forms of modulation and other systems, in conjunction with which the invention will be useful. For example, a receiver in accordance with the invention may be employed in not only in so-called "course beacons" and "localizers" employing frequency-wobbled carriers for defining direction horizontally, but also in so-called "instrument landing" systems employing similar wobbled carriers for defining glide paths.

When a receiver according to my invention is used to follow a frequency wobbled transmitter, one remarkable result is that only signals arriving directly or by the shortest path can be heard. The reason for this is that signals arriving with a substantial delay (e. g., signals arriving after one or more reflections) will have at any instant the same frequency which the directly transmitted signals had a short time earlier. If the rate of change of frequency is fast enough and if the effective band width of the receiver at any instant is narrow enough, the receiver will strongly discriminate against reflected signals arriving a very short time after the direct signal. Thus, if the saw-tooth wobble is such as to vary the carrier by ten megacycles in 1/10,000 of a second, and if the instantaneous band width of the receiver is ± 1000 cycles per second from center, then the receiver will exclude signals delayed as little as 10^{-8} seconds, (or will at least attenuate them as compared to the direct wave). This would mean that a reflected wave whose path length was only three meters longer than the direct path could be excluded (or at least attenuated). Thus, false courses due to reflected waves may be eliminated (or reduced) by this excluding (or attenuating) action of the receiver as well as being averaged out by the inherent averaging out action of the frequency wobble.

Although the invention has been described in connection with a wobbling of carrier in accordance with a saw-tooth form, it is clear that other types of variation may be used. Whatever the mode of periodic variation represented by the periodic wobble, the same type of wave may clearly be locally generated at the receiving apparatus to control the tuned state of the latter. Since the wobble is recurrent periodically, it is always possible to derive from the detected signals a synchronizing signal which will keep the locally generated wave-form (corresponding to frequency variation of the wobbled frequencies) substantially in step with the wobble.

Although I have described my invention in detail in particular connection with the preferred forms illustrated, it is to be understood that many modifications, additions, and omissions may be made fully within its scope, as defined by the appended claims.

What is claimed is:

1. The method of detecting a frequency-wobbled carrier wave, wobbled in a predetermined recurrent pattern which method comprises receiving substantially the entire band of said frequency wobbled wave, generating a control wave having variable characteristics corresponding substantially to the frequency wobbling of the received wave, generating a local oscillation, varying said oscillator in frequency under control of said control wave, mixing said locally generated oscillation with said carrier whereby a substantially constant intermediate frequency is obtained, and correcting any deviation of said control wave from correspondence with said frequency wobbled wave in response to departure of said intermediate frequency from its substantially constant frequency value.

2. Apparatus for detecting a frequency-wobbled carrier wave comprising receiver means responsive to substantially the entire band of said wobbled frequencies, local oscillators means, frequency converter means for producing intermediate frequencies responsive to the frequencies of said band and to output from said oscillator means, tuned circuit means responsive to a narrow band of frequencies including said intermediate frequencies, means detecting the output from said tuned circuit means, means generating a signal varying substantially in accordance with said wobbled frequencies in response to output from said detector means, oscillator control means for controlling the frequency of said local oscillator means to vary its frequency substantially in correspondence with the frequencies of said frequency wobbled carrier, and means responsive to said signal for connecting any deviation of said oscillator control means.

3. Apparatus for detecting a frequency-wobbled carrier frequency comprising receiver means responsive to substantially the entire band of said wobbled frequencies, local oscillator means varying in frequency over a range substantially of the same extent as the received carrier frequencies, converter means responsive to said band and to output from said oscillator means whereby intermediate frequencies are produced, means producing a signal in response to deviation of said intermediate frequencies from a given frequency and means included in said local oscillator means for changing the variation in the oscillation frequency thereof in response to said signal whereby a substantially constant intermediate frequency is produced.

4. Apparatus for detecting energy including a frequency-wobbled carrier frequency comprising receiver means responsive to substantially the entire band of said wobbled frequencies, local oscillator means, means for periodically varying the frequency of said oscillator means in substantially the pattern of said wobbled frequencies, converter means responsive to said band and to output from said oscillator means whereby a substantially constant intermediate frequency is produced, and means responsive to a substantial departure of said intermediate frequency from its substantially constant value for deriving a synchronizing signal, and means correcting the frequency variation of said oscillator means in response to said synchronizing signal.

5. In a system for detecting a carrier wave frequency-wobbled in a predetermined periodic pattern, local generating means producing, substantially in synchronism with the received carrier, a wave independent of the wobbled carrier wave and substantially of the form and periodic pattern of the carrier, means deriving a signal indicative of the departure of said locally generated wave from synchronism with said carrier

wave, and means responsive to said derived signal to correct said departure.

6. A receiver for receiving and detecting a carrier wave, wobbled in frequency over a recurring cycle, comprising a receiver means responsive to the entire band of said wobbled frequencies, a local oscillator, a control wave generator for producing a control voltage varying substantially proportionally with the variable frequency cycle, means for applying said control wave to said local oscillator to proportionately control the frequency of said local oscillator, mixer means for mixing the output of said local oscillator and said received waves to produce a substantially constant intermediate frequency, means for deriving a control pulse in response to departure of said intermediate frequency from said substantially constant value, and means for correcting said control wave generator in response to said control pulse.

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