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RADIO RECEIVER

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This invention relates to signaling systems such as radio telephone and telegraph systems and particularly to radio systems in which a single frequency oscillation such as a carrier is utilized.

An object of the invention is to eliminate or reduce the effect of noise on the operation of such systems.

In radio telephone systems, certain types of control equipment are operated by the received carrier wave. One example is the so-called Codan (carrier-operated-device anti-noise) in which the received carrier wave is utilized for rendering operative a normally blocked radio receiver. In such systems, it is necessary to provide high selectivity of the carrier wave to prevent false operation by noise currents. However, the received wave may vary in frequency because of transmitter variations, fading or the like, consequently the selective circuits must accommodate a band wide enough to take care of such variations. As a result noise currents will also be admitted so that noise cannot be completely discriminated against by frequency selectivity.

The effect of frequency variations can be reduced to permit the use of higher selectivity by the use of automatic tuning systems or the equivalent. One type of system for accomplishing this purpose is that disclosed and claimed in United States Patent 2,093,871 to Levin of September 21, 1937.

This type of system makes use of a multiple modulation process. The intermediate frequency output of the first detector of the superheterodyne radio receiver is fed to a first modulator in which it is combined with the output of a fixed frequency oscillator. One modulation product (sum or difference) is selected in the output of this modulator and supplied to a second modulator. The original intermediate frequency is also supplied to this second modulator. One of the resultant products of this second modulator will be an oscillation of frequency equal to the frequency of the oscillations from the fixed frequency oscillator used in the first modulation process. This oscillation may be selected in a narrow filter since it is of fixed frequency depending only upon the stability of the fixed frequency oscillator used with the first modulator. Where only a single frequency oscillation representing the carrier is desired for some control operation, the filter band may be made extremely narrow. As a result it would appear that the effect of all noise currents except

those of the exact frequency of the received carrier would be eliminated. However, it has been found that in the absence of a received carrier, there occurs false operation which is not explainable upon the basis of noise currents of the carrier frequency.

Applicant has demonstrated that this effect is due to the band of noise currents passed by the earlier selective circuits of the system. Thus, the first modulation process will produce the same frequency translation of the noise currents in the intermediate frequency band as that produced on the carrier. The side-band output of this modulator will therefore contain an oscillation corresponding to the carrier surrounded by noise currents corresponding in relative frequencies and phase to those in the intermediate frequency band fed to the modulator. The filter used for selecting the desired side-band output cannot be too highly selective as the frequency of the desired modulation product representing the carrier will vary in absolute value in the same way as the frequency of the received wave. If the filter is somewhat narrower than the first intermediate frequency filter, some of the noise components may be removed. However, those within the pass-band will remain.

The corresponding noise components in the two branches supplied to the second modulator will, of course, be separated by a frequency corresponding to the frequency of the oscillation supplied to the first modulator. Intermodulation of each pair of corresponding noise currents will therefore produce a modulation product of that frequency. These resultant currents will tend to add together vectorially in phase so that in the absence of some special precaution, the noise currents will produce a pseudo-carrier of the same frequency as that produced by the action of the two carrier waves. Because its frequency is the same as that of the carrier, this pseudo-carrier cannot be eliminated by the narrow filter connected to the output of the second modulator. The result is that even in the absence of a received carrier, the noise currents will produce a current of the same frequency and consequently the same effect as the received carrier.

In accordance with a feature of the present invention, the effect of noise just discussed is eliminated by the introduction of a differential phase shift or time delay between the currents fed to the second modulator over the two paths. By a proper control of the phase of the noise currents from these two paths, the component

modulation products can be made to add in such phases that their effect is not cumulative.

More specifically, the object of the present invention is accomplished by providing such a phase shift for each noise component in one band of oscillations fed to the second modulator that the component modulation products representing the combination of corresponding noise components of the two bands will not add in like phase. To accomplish this there must be produced a phase shift in one of the bands which varies across the band as distinguished from a phase shift which is the same for all frequencies in the band. Assuming that the noise currents in the frequency band are of equal amplitude, the vector addition of the modulation components will result in zero for a phase shift in one branch differing from that in the other by 2π , 4π , etc. radians over the band. This corresponds to a difference in transmission delay of the two branches of

$$\frac{1}{F'} - \frac{2}{F}$$

etc., seconds, where F is a band width in cycles per second.

The features of this invention as just described result in the elimination of the pseudo-carrier. However, this current does not take the place of the original noise but appears in addition thereto. Further, the second modulation process may also produce noise currents of frequencies close to that of the carrier by the intermodulation of noise currents in the two branches differing by nearly the carrier frequency. Such pairs of currents are, of course, of random phase and cannot be made more random by phase control.

These and other features and aspects of the invention may be more readily understood by reference to the following detailed description in connection with the drawing in which:

Fig. 1 is a block schematic circuit showing the invention;

Fig. 2 is a single line, block schematic circuit of a radio receiver employing the invention in a codan circuit thereof; and

Fig. 3 is a graph illustrating the operation of the invention.

Referring to Fig. 1, there is shown a source of oscillations 5 which may in the case of a radio receiver, be either the received oscillations or the intermediate frequency. The frequency of the output of the source of the oscillator 5 is represented as $f_1 \pm \Delta$ where f_1 is the nominal frequency and Δ is the frequency variation.

The oscillations from the source 5 are fed to two paths 6 and 7. In the path 7 the oscillations are transmitted through a delay network 8 to one input of a modulator 9. Oscillations of frequency f_2 from a constant frequency oscillator 10 are also supplied to the modulator 9. A filter 11 is connected to the output of the modulator 9. This filter is designed to select one of the sidebands of the modulation process to the exclusion of other frequencies. There will therefore appear in the output of the filter 11 only frequencies $(f_1 \pm \Delta) + f_2$ or $(f_1 \pm \Delta) - f_2$, depending on whether the upper or lower side-band produced by this modulator 9 is employed. The side-band selected by the filter 11 is supplied to a second modulator 12 along with the original oscillations from the oscillator 5 supplied over the path 6. One of the side-bands produced by the modulator 12 will be an oscillation of frequency f_2 which may be selected in the filter 13. It will be observed that while the variations (Δ) in the

received or intermediate frequency represented by the source 5 appear in both of the paths 6 and 7, the output of the second modulator 12 contains a component of fixed frequency f_2 without such variations. This is due to the double modulation process in which the variations cancel out.

The filter 11 must be capable of taking care of the frequency variations (Δ) in the oscillations from the source 5 and consequently must have a band width 2Δ . As a result there will appear in the output of the filter 11, not only the oscillation representing the incoming signal $(f_1 \pm \Delta)$ but also noise currents lying within the 2Δ frequency band. These noise currents represent the original noise currents accompanying the received signal. The effect of the modulation process in the modulator 9 is to produce the same frequency translation of the noise currents as is produced on the signal wave. Each component of the noise currents in the output of filter 11 therefore corresponds to a similar noise current in the circuit branch 6 and the corresponding components in the two branches are separated in frequency by the frequency f_2 .

One effect of the modulation process in the modulator 12 is to produce for each pair of corresponding noise currents of the two branches a modulation component of frequency f_2 . If there were no difference in the phase characteristics of the two branches 6 and 7, these resultant components would add vectorially so as to produce a cumulative output of frequency f_2 of substantial magnitude even when the individual noise currents which go to produce it are comparatively small. With such a system, therefore, there may appear in the output of the filter 13 due to random noise currents, a current of frequency f_2 , even in the absence of current of frequency f_1 from the source 5. (This pseudo-carrier and the components which go to make it up do not take the place of the noise currents but appear additionally thereto.) As has been previously discussed, this pseudo-carrier may be eliminated or reduced to an immaterial value by a proper control of the relative phase constants of the two branches 6 and 7. This is a function of the delay network 8 in the circuit of Fig. 1.

While the network 8 is herein shown as an individual circuit element connected in the input to the modulator 9, it should be understood not only that the particular point of its connection in the branch 7 is immaterial, but also that it need not be a separate circuit element as its function may be incorporated in other circuit elements such as the filter 11. The only requirement is that the over-all phase constant of the circuit 7 differs from that of the circuit 6 in the required manner. This, of course, could also be produced by the addition of a network of the proper phase constant in the circuit 6 instead of that branch being the direct connection shown.

However, it will be found that, in general, the desired effect can be most economically produced by a control of the phase characteristic of the branch 7. The inherent nature of the system requires the use of a filter 11 in this branch, and the usual type of network employed for such filters has a phase characteristic of the type required so that it may be used to produce part or all of the required differential phase shift. On the other hand in the branch 6 there is no particular need for any network which might produce a delay action in the

As has been stated the required differential phase shift between the branches 6 and 7 is such that the components of pseudo-carrier in the output of the modulator 12 will not add vectorially to produce a cumulative effect. The particular requirement for the differential phase constant for this purpose can be most readily understood by consideration of the condition in which the noise energy is uniformly distributed throughout the band, i. e., equal amplitude noise currents. It also appears that this is a fair assumption for the average condition of noise.

Under such conditions and with no difference in phase constants between the two branches, the components of the pseudo-carrier would tend to add in phase and produce the maximum resultant. On the other hand if the relative phase constants of the two branches are such that there is produced a progressive phase shift across the band (2Δ) such that the phase of the component on one extreme of the band differs from that on the other 2π radians (or other even multiple π radians) it is obvious that the resultant vector summation will be zero. The effect of various differential progressive phase shifts are shown graphically in Fig. 3. In that diagram the ordinates represent the vector sum of the pseudo-carrier components in the output of modulator 12 and the abscissae represent differential progressive phase shifts or delay across the frequency band $F=2\Delta$.

Clearly the effect of curving the resultant vector addition of the pseudo-carrier components is achieved only by a phase shift which is progressively greater across the frequency band of one branch than of the other. Uniform phase shifts of the entire band which may be different in the two branches do not disturb the in-phase vector addition.

Fig. 2 is a schematic circuit diagram of a radio telephone receiver of the superheterodyne type employing the present invention in a codan circuit. As is well understood in the art, codan circuits are used for reducing the noise in radio receivers when no signal is being received. Such circuits are particularly desirable with radio receivers employing automatic volume control as with such receivers the gain will be so increased during periods in which no signal is received that the received noise will be highly amplified so as to produce undue disturbances in the output. In general the radio receiver is arranged to be blocked in the absence of a received carrier and the codan circuit responds to a received carrier to render the radio receiver operative. Obviously the codan must distinguish between noise and carrier which introduces various problems particularly for use at short waves where the received carrier may vary considerably in frequency as well as amplitude.

In the circuit of Fig. 2, the radio signals received in the antenna 21 are selected in the tuned circuits 22 and 24 connected to the input and output, respectively, of a radio frequency amplifier 23. After this selection and amplifying process the radio waves are supplied to the input of the first detector 25 where they are combined with oscillations from a beating oscillator 26 to produce the intermediate frequency oscillations. The intermediate frequency output of the first detector 25 is selected in the intermediate frequency filter 27 amplified by the intermediate frequency amplifier 28. Additional stages may be employed as is well known in the art although

only a single stage is shown herein for the purpose of simplicity.

The output of the intermediate frequency amplifier is branched off in several branches. Two paths, namely 36 and 37, go to the codan circuit as will be described in detail hereinafter. Another path goes to the second or signal detector 29 in which the audio frequencies are detected and supplied through an audio frequency amplifier 30 to the audio frequency circuit 31. This circuit is normally blocked by the short-circuiting contacts 32 but is rendered operative in response to a received carrier wave by the operation of the codan circuit as will be described.

An additional branch of the intermediate frequency circuit goes to an automatic volume control rectifier 33, the output of which is supplied to the radio frequency amplifier 23, first detector 25 and intermediate frequency amplifier 28 to control the gain of those stages as is well understood in the art.

The codan circuit, for the purpose of taking care of frequency variations in the received carrier, employs a circuit of the type shown in Fig. 1 embodying the features of the present invention. Thus the output of the intermediate frequency amplifier 28 is fed through the intermediate frequency filter 38 and circuit 37 to a modulator 39 in which the intermediate frequency is combined with constant frequency oscillations from an oscillator 40. The output of the modulator 39 includes two band-pass filters 41 and 44 in which one of the side-bands of the modulation process is selected. Thus, the intermediate frequency may be 455 kilocycles, the oscillator 40 may produce oscillations of 300 kilocycles, and the filters 41 and 44 may be designed to select the upper side-band of 755 kilocycles. Of course, any variations in the frequency of the carrier wave received in the antenna 21 will be reflected in variations in the intermediate frequency carrier of 455 kilocycles and consequently in variations in the nominal 755 kilocycle output of the modulator 39. As a result the filters 41 and 44 must have pass-bands wide enough to accommodate such frequency variations.

Included in the output path of the modulator 39 in addition to the filters 41 and 44 is an amplifier 45. After selection and amplification by the filters 41 and 44 and the amplifier 45, the 755 kilocycle side-band of the modulator 39 is supplied to the modulator 42. The 455 kilocycle intermediate frequency output of the amplifier 28 is also supplied to this modulator 42 through the circuit 36. One of the side-band products produced by the modulator 42 will be a frequency of 300 kilocycles. This product is selected by the filter 43 which is of the well-known crystal bridge type which may be designed to have a very narrow pass-band.

It will be noted in the codan circuit as so far described that the circuit 36 from the intermediate frequency amplifier to the modulator 42 is a direct connection containing no network producing a phase shift, in this sense being similar to the circuit 6 of Fig. 1. Similarly the circuit 37 between the intermediate frequency amplifier 28 and the modulator 42 contains three networks, namely, the intermediate frequency filter 38 and the 755 kilocycle filters 41 and 44. Each of these networks is a single section filter and produces a phase shift which varies progressively by about π radians across its pass-band. The three filters in tandem insure a total phase shift of something more than 2π radians. The

filters correspond to elements 8 and 11 in Fig. 1 and can be designed to produce any desired phase shift or delay. The differential phase characteristic of the two paths to the modulator 42 can thus be so controlled that the pseudo-carrier components in the output of the modulator 42 add to zero.

As has been pointed out above, these pseudo-carrier components do not replace the noise currents in the output of the modulator 42, but appear in addition thereto. The modulator output may also include products produced by the intermodulation of pairs of noise currents differing by nearly the frequency of the carrier. While the filter 43 may be made highly selective, there will usually be a certain narrow band of noise currents which it will pass in addition to the 300 kilocycle carrier. In order to compensate for such noise currents, there is provided a second path from the modulator 42 which includes a band elimination filter 51 also of the crystal bridge type. This filter will not pass the 300 kilocycle carrier but only noise currents on each side thereof.

In order to make the codan operate when the carrier exceeds the noise by a fixed amount, the small amount of noise which comes through with the 300 kilocycle carrier is separated from it by the band elimination filter 51. Such noise currents are rectified in the rectifier 46 and supplied to a biasing winding 50 of the codan relay 48. The 300 kilocycle carrier output of the filter 43 is similarly rectified in the rectifier 49 and supplied to the operating winding 47 of the codan relay 48.

When no carrier is being received, the relay 48 is held operated in one direction (as shown) by the rectified noise output supplied to the winding 50. In this position the radio receiver output is disabled by the relay contacts 32 which short-circuit the audio output circuit 31. When a carrier is received, the energy of the 300 kilocycle carrier in the output of the filter 43 produces an opposing effect through the winding 47 and causes the operation of the relay 48 in the opposite direction. This opens the short-circuit on the line 31 at the relay contacts 32, to complete the audio frequency output path of the receiver and render the circuit operative.

While the invention has been illustrated herein as specifically applied to the codan circuit of a radio telephone receiver, it is clear that it is not so limited but may be applied to other systems for example ICW radio telegraph receivers, test circuits, and the like.

What is claimed is:

1. In a system for receiving signals subjected to noise, two signal paths, one of said paths including a modulator for combining the received signals with oscillations of constant frequency, a second modulator for combining the outputs of said two paths, means in the output of said second modulator for selecting oscillations of said constant frequency, and means for providing such a difference in transmission delay through said two paths that the noise currents in the output of said first modulator do not combine with corresponding noise currents in the other path to produce a cumulative output from the second modulator of said constant frequency.

2. In a system for receiving radio signals subjected to noise, two signal paths, one of said paths including a modulator for combining the received signals with oscillations of constant frequency to produce modulation products of frequency

equal to the sum and difference of the frequencies of the signal oscillations and the constant frequency oscillations and means in the output of said modulator for selecting one of said modulation products, a second modulator for combining the signal currents in the other of said two paths with the modulation products selected by the afore-mentioned means, means in the output of said second modulator for selecting oscillations of said constant frequency to the substantial exclusion of oscillations of other frequencies, and means for providing such a difference in transmission delay through said two paths that the component modulation products produced by the combination of corresponding noise currents in the output of the first-mentioned selecting means and in said other path add with such phase relationship as to produce substantially zero output from the second modulator of said constant frequency.

3. In a system for receiving signals subject to noise, two signal paths, one of said paths including a modulator for combining the received signals with oscillations of constant frequency and filter means having a pass-band including the frequency of one of the side-bands of said modulation process and high attenuation for frequencies of the modulating oscillations connected to the output of said modulator, a second modulator for combining the output of said filter means and the signal oscillations in the other of said two paths, means in the output of said second modulator for selecting oscillations of the frequency of said constant frequency oscillations and substantially excluding oscillations of other frequencies, and means in one of said paths for producing such a varying phase shift throughout the frequency range passed by said filter means that the total phase shift in said path differs from that in the other path by a factor of the order of 2π radians across said frequency range.

4. In a system for receiving signals subject to noise and varying in frequency throughout a range of F cycles per second, two signal paths, one of said paths including a modulator for combining the received signals with oscillations of constant frequency and filter means having a pass-band of F cycles per second for selecting one of the side-bands of the modulation process to the exclusion of the modulating frequencies and connected to the output of said modulator, a second modulator for combining the output of said filter means with the output of the other of said two paths, means in the output of said second modulator for selecting oscillations of the frequency of said constant frequency oscillations to the substantial exclusion of oscillations of other frequencies, and means for providing a total transmission delay in one of said paths differing from the total transmission delay of the other of said paths by the order of

$$\frac{1}{F}$$

seconds.

5. In a system for receiving signals subject to noise, two signal paths, one of said paths including a modulator for combining the received signals with oscillations of a constant frequency and filter means having a pass-band of F cycles per second for selecting one of the side-bands of said modulation process to the exclusion of frequencies of the modulating oscillations and connected to the output of said modulator, a second modulator for combining the output of

said filter means with the signal output of the other of said two paths, means in the output of said second modulator for selecting oscillations of the frequency of said constant frequency oscillations to the substantial exclusion of oscillations of other frequencies, and means for providing a total transmission delay in one of said paths which differs from the total transmission delay of the other of said paths by substantially an integral multiple of

$$\frac{1}{F}$$

seconds.

6. In a system for receiving signals subject to noise and varying in frequency, two signal paths, one of said paths including a modulator for combining the received signals with oscillations of constant frequency and filter means connected to the output of said modulator and having a pass-band substantially equal in width to the frequency variations of the received signal for selecting one side-band of the modulation process to the exclusion of the modulating oscillations, a second modulator for combining the output of said filter means with signal oscillations in the other of said two paths, and means in one of said paths for producing such a varying phase shift through the output frequency range passed by said filter means that the total phase shift in said path differs from that in the other of said paths by a factor of the order of 2π radians across said frequency range.

7. A radio receiver comprising means for combining the received radio signals with local oscillations to produce intermediate frequency signals, two paths for said intermediate frequency signals, a source of constant frequency oscillations, a modulator for combining the intermediate frequency signals in one of said two paths with the constant frequency oscillations from said source, filter means for passing oscillations of a narrow band of frequencies including one side-band of said modulation process and connected to the output of said modulator, a second modulator for combining the output of said filter means with the intermediate frequency signal output of the other of said two paths, a second filter means connected to the output of said second modulator for selecting oscillations of the frequency of said constant frequency oscillations to the substantial exclusion of oscillations of other frequencies, and means for producing in conjunction with said first filter means such a progressive phase shift over the band of frequencies passed by said first filter means that the vector sum of the modulation components of said constant frequency produced in said second modulator by the interaction of the noise currents in said band of frequencies and the corresponding noise currents in the intermediate frequency signal band from said other of said two paths is small in comparison with the algebraic sum of said components.

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