May 1, 1945. R. C. MATHES 2,375,126

DIVERSITY RADIO RECEIVER

Filed May 8, 1943

FIG. 1

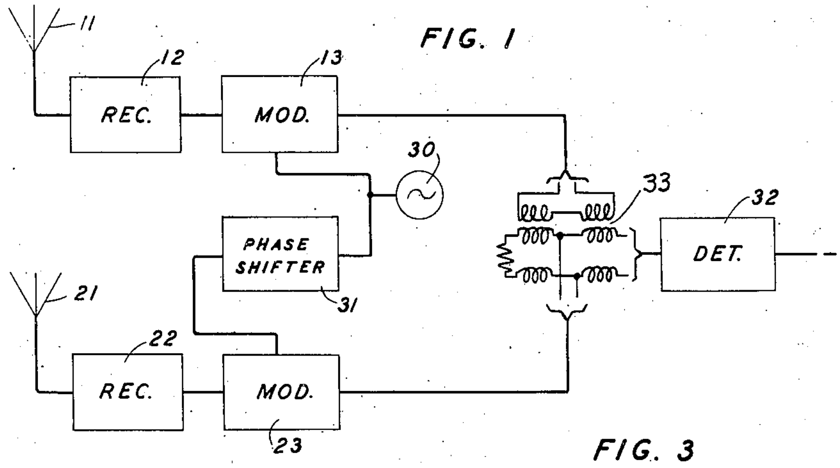


FIG. 2

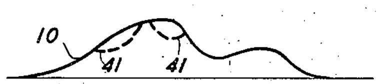


FIG. 2A

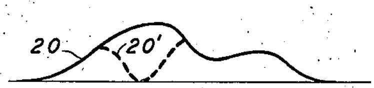


FIG. 3

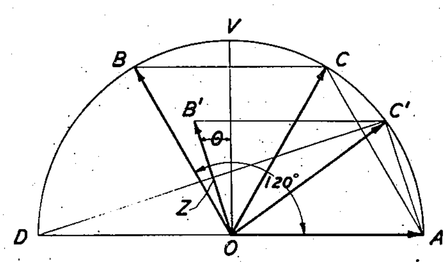
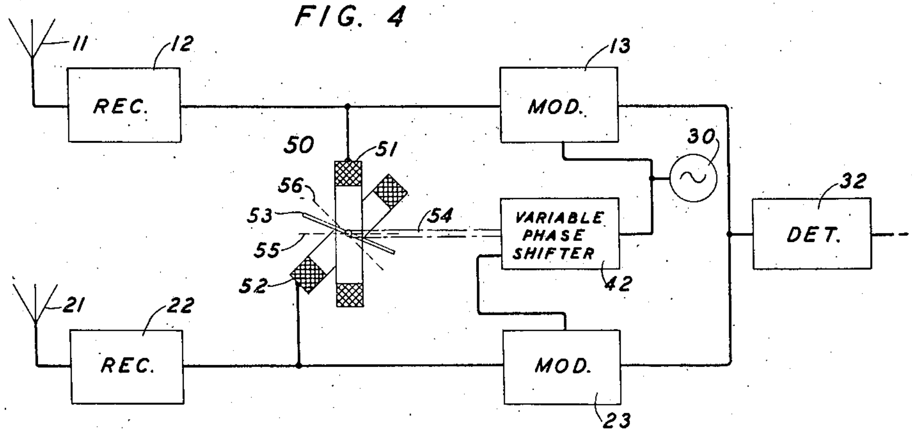


FIG. 4



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DIVERSITY RADIO RECEIVER

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Application May 8, 1943, Serial No. 486,239

6 Claims. (Cl. 250—20)

This invention relates to radio receiving systems of the diversity type and particularly to diversity systems for the reception of telegraph or similar signals of low frequency or slowly varying type, such as telautograph, facsimile or the like.

An object of the invention is to overcome the effects of fading and particularly to avoid the effects of large reductions in signal amplitude due to fading.

One general method that is used for overcoming the effects of fading in radio communication is in the use of diversity systems. The operation of such systems is based on the fact that radio waves of even slightly different frequencies, or radio waves from the same transmitter that arrive at a receiver by different paths are subjected to different fading conditions. The first type of system is known as a frequency diversity system. The second type may be a space diversity system, an angle diversity system or the like, depending upon what method is used for selecting the waves arriving over the different paths. In all systems the beneficial effects are achieved by combining the individual signals or by continuously selecting between them.

A further object of the invention is to provide an improved method of combining the signals in a diversity receiving system.

In a specific preferred embodiment of this invention the detected telegraph or similar signals from two diversity channels are caused to modulate carrier supplies from a single carrier source with one carrier supply shifted in phase by 120 degrees with respect to the other. The outputs of the two modulators are combined and detected. With this system the resultant signal will be equal to the two received signals as long as they are both of the same amplitude and will closely approximate the larger of the two received signals when they differ in amplitude.

The invention will be more fully understood by reference to the following detailed description in connection with the drawing in which:

Fig. 1 is a block schematic circuit diagram of one embodiment of the invention;

Figs. 2 and 2A are explanatory diagrams representing time versus signal amplitude;

Fig. 3 is an explanatory vector diagram; and

Fig. 4 is a block schematic circuit diagram of a second embodiment of the invention.

Fig. 1 shows, for the purposes of illustrating the invention, a radio receiving system for receiving a signal that has been transmitted as modulations of two radio carriers of slightly different frequencies. One such modulated signal is received by the antenna **11** and amplified and detected in the receiver **12**. Similarly, the second signal is received, amplified and detected by antenna **21** and receiver **22**.

The two detected signals are combined in the respective modulators **13** and **23** with local carriers from a common oscillator **30**. The carrier oscillations supplied to one of the modulators (**23**) is shifted in phase by 120 degrees by being transmitted through the phase shifter **31**. The outputs of the two modulators are combined and supplied to a detector **32** preferably of the rectifier type from which the required signal is obtained.

The outputs of the two modulators **13** and **23** which are preferably of the balanced type are combined through the hybrid coil **33** to avoid any possibility of interaction.

The operation of the system of Fig. 1 can probably be best understood with the aid of the diagrams of Figs. 2 and 3. It should also be borne in mind that the effectiveness of a diversity system is based on the fact that, in general, the fading will only adversely affect the signal shape of only one of the diversity channels at any particular time.

When no fading is present the signal received over the two channels will have exactly the same shape as indicated by the full line curves **10** and **20** of Figs. 2 and 2A. Let us now suppose that fading conditions are such that the signal received in the receiver **11—12** is not disturbed while the same signal as received over channel **21—22** is distorted as indicated by the dashed curve **20'**.

The effect of combining these two signals (**10** and **20'**) by means of the circuit of Fig. 1 may be determined by reference to the vector diagram of Fig. 3. In this diagram the vector OA represents the signal output from modulator **13** and the vector OB represents the signal output from the modulator **23** when the received signals are of the same amplitude, the phase difference being due to the action of the phase shifter **31** on the supplied carrier. In such a case the amplitude of the resultant (OC) of the combination will be equal to each of the originals (OA and OC). If the vector OB is reduced to zero, the amplitude of the resultant signal is unchanged, being equal to OA. For intermediate values of OB the end of the resultant vector OC will lie along the chord AC. The maximum deviation of amplitude of the resultant will be when OB is one half OA and will amount to about 13 per cent, which would be negligible for telegraph signals and could be tolerated in most other types of code systems.

Bearing in mind these facts we see that the signal resulting from the combination of signal represented by the curve **10** and the signal with the large fade represented by the curve **20'** will look like the signal of curve **10** with the two small fades represented by the dotted curves **41** in relation to the curve **10**.

While in the above explanation it has been assumed that fading conditions have affected the signal received at the antenna 21 and not that received at the antenna 11, it will be observed that the same effects are produced under conditions in which the signal received at the antenna 11 fades and not that received at antenna 21.

While the invention has been described with reference to Fig. 1 as applied to a frequency diversity system, it is equally applicable to space, angle or similar diversity systems where the two received signals are modulations of the same carrier frequency.

Fig. 4 shows a modification of the system of Fig. 1 in which there is embodied a further refinement for eliminating the residual reaction of fading, inherent in the former.

The system of this figure is in general similar to that of Fig. 1 and similar circuit elements have been given the same reference numerals. It differs from that of Fig. 1 in the use of a variable phase shifter 42 in place of the fixed phase shifter 31 and the addition of a ratio control device 50 connected through a shaft 54 to the variable phase shifter 42.

The ratio control device 50 comprises two magnetic coils 51 and 52 mounted at an angle with respect to each other and a magnetic armature 53 fixed to the shaft 54. The signal input to the modulator 13 is also fed to the coil 51 and the signal input to modulator 23 is fed to coil 52. If there is no signal received in antenna 21 (amplitude of B signal is zero) the armature 53 will take the position indicated by the dashed line 55. Similarly, if no signal is received in the antenna 11 the armature 53 will assume the position indicated by the dotted line 56. When the two signals are of equal strength the armature 53 will assume the intermediate position in which it is shown. For intermediate values of relative signal strengths the armature 53 will take corresponding positions between the limits 55 and 56.

The variable phase shifter is arranged so that when the armature 53 is in this intermediate position it produces a phase shift of 120 degrees. As the armature 53 moves to other positions it operates through the shaft 54 to vary the phase shift so as to maintain the amplitude of the resultant combined signal equal to the amplitude of the larger signal. This action may be understood by reference to the vector diagram of Fig. 3 as will now be explained.

As was pointed out above in connection with the system of Fig. 1, when the two signals (OA and OB) are equal and are combined with a phase difference of 120 degrees the resultant $OC=OA=OB$. Now, assuming that the signal received in the antenna 21 is less than the signal OA (received in antenna 11) and equal to OB′ the problem is to determine the angle AOB′ at which the signals must be combined to make the resultant $OC'=OA$.

Let R= length of vector OA, and XR=length of vector OB'.

The chord $AC'=OB'=XR$.

The angle AC′D is 90 degrees.

Accordingly DC′ is perpendicular to OB′, OB′ being parallel to AC′.

Since OC′B′ is an isoceles triangle,

$$OZ=ZB'=\frac{XR}{2}$$

$OC'D+B'OC'=90$ degrees and $OB'C'=B'OC'$

Accordingly $B'OV=OC'D=\theta$.

Then,

$$\sin\theta=\frac{XR}{2R}=\frac{X}{2}$$

And angle $B'OA=90$ degrees+arc sine $X/2$.

When $X=1$, $B'OA=120$ degrees, and

When $X=0$, $B'OA=90$ degrees.

It can, therefore, be seen that the phase shift produced by the phase shifter 42 should vary from 120 degrees when the two signals are equal to each other, to 90 degrees when one signal is reduced to zero. For intermediate values of relative signal strengths the phase shift should be 90 degrees plus the arc whose sine is X/2, where X is the fraction that one signal is of the other.

What is claimed is:

1. In a radio receiving system, two diversity branches, a source of local carrier oscillations, a modulator for modulating oscillations from said source with signals from each of said branches, a phase shifter included in the circuit from said oscillator to one of said modulators so that the oscillations supplied thereto are 120 degrees out of phase with the oscillations supplied to the other of said modulators at least when the signals from said branches are substantially of the same amplitude, and means for combining the outputs of said modulators.

2. In a radio receiving system, two diversity branches, a source of local carrier oscillations, a modulator for modulating oscillations from said source with signals from each of said branches, a phase shifter included in the circuit from said oscillator to one of said modulators so that the oscillations supplied thereto are of the order of 90 to 120 degrees out of phase with the oscillations supplied to the other of said modulators, and means for combining the outputs of said modulators.

3. In a radio receiving system, two diversity branches, a source of local carrier oscillations, a modulator for modulating oscillations from said source with signals from each of said branches, means for producing a fixed phase shift of 120 degrees between the oscillations supplied to one of said modulators and the oscillations supplied to the other of said modulators, and means for combining the outputs of said modulators.

4. In a radio receiving system, two diversity branches, a source of local carrier oscillations, a modulator for modulating oscillations from said source by signals from each of said branches, a variable phase shifter included in the path from said source to one of said modulators, means for combining the outputs of said modulators, and means for controlling the phase shift produced by said phase shifter in accordance with the relative amplitudes of the signals in said branches.

5. A system in accordance with claim 4 in which the last-mentioned means produces a phase shift of 120 degrees when said signals are of equal amplitude.

6. A radio receiving system in accordance with claim 4 in which said last-mentioned means produces a phase shift that varies between 120 degrees when the signals in said branches are of equal amplitude and 90 degrees when the amplitude of one of said signals is substantially zero.

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