

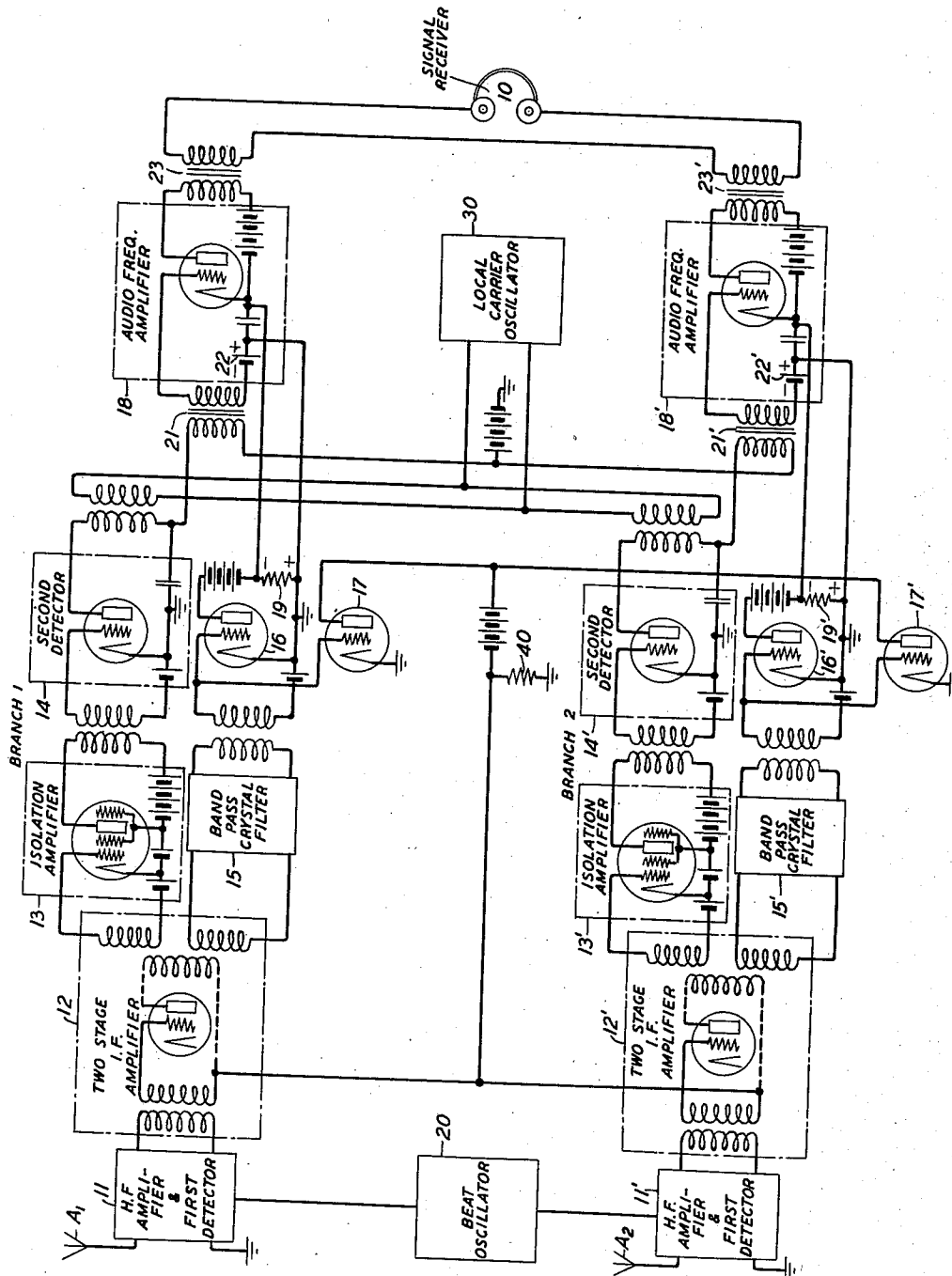
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A. A. OSWALD

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SINGLE SIDE BAND DIVERSITY RADIO RECEIVING SYSTEM

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INVENTOR
BY A. A. OSWALD
George C. Ford
ATTORNEY

UNITED STATES PATENT OFFICE

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SINGLE SIDE BAND DIVERSITY RADIO RECEIVING SYSTEM

Arthur A. Oswald, Maplewood, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

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This invention relates to radio communication systems, and more particularly to methods and means for reducing fading effects and maintaining a favorable signal-to-noise ratio in a diversity reception system. The present application relates to a specific modification of the invention disclosed and claimed in the copending application Serial No. 291,481, filed August 23, 1939, of F. A. Polkinghorn, assigned to the same assignee to which the present application is assigned.

In a diversity system the same transmitted signal is simultaneously received over a plurality of paths through space from the signal source at the transmitting station. The amplitude of received signal over the various paths usually varies as between the different paths with changes in the condition of the space transmission medium, so that as the amplitude of the signal received over one path increases, that over another or other of the paths may diminish. These amplitude variations are generally at random and are continually taking place.

It is customary in certain types of diversity systems either to provide means for automatically switching the signal receiving apparatus at the receiving station so as to keep it connected with the path over which the signal of the greatest amplitude at any particular time is arriving, or, alternatively, to permit the signal receiving apparatus at all times to be connected with all of the paths and to automatically control the energy contributions to the signal receiver by the various paths in proportion to the varying amplitudes of the signals being received over them. It is toward diversity operation of the latter sort that the present invention is particularly directed.

In the double side band type of radio transmission the carrier upon which the side bands are based is usually transmitted with the side bands at sufficient amplitude to provide for the proper demodulation of the side bands in the final detector at the receiving station. When general fading takes place, the carrier fades with the side bands; and as the noise introduced at the receiving station input of the fading path is transmitted to the receiving apparatus as a modulation of the carrier frequency, the same fading of the carrier and its side bands which reduces the signal amplitude also reduces the noise amplitude.

In the single side band type of radio transmission it has been the practice either to eliminate the carrier entirely, or to transmit it at a much reduced energy level. When no carrier is transmitted, a suitable demodulating carrier of the proper frequency is generated and supplied at the

receiving station. When carrier is transmitted at a reduced energy level, it is customary either to utilize it at the receiving station to control the frequency of a local oscillator that supplies the frequency for final demodulation, or, after reconditioning and amplifying at the receiving station, to utilize it at the proper frequency directly to effect the demodulation of the signal side bands. In either case the locally generated demodulating frequency, or the demodulating frequency controlled by the original carrier, or the reconditioned and amplified original carrier itself at the proper frequency for demodulation has in some cases been supplied to the final detectors at a fixed amplitude that does not vary with the variation of carrier amplitude that may take place as a result of the presence or absence of fading over the space path.

Such practice is not favorable to the best operation of a diversity system in which the plurality of paths over which the signal is received are at all times connected with the signal receiving apparatus at the receiving station. This is because the fading over any path which diminishes the amplitude of the signal does not diminish the amplitude of the noise that enters the receiving system by way of the receiver input of that path. The constant amplitude of the locally supplied carrier, or of the reconditioned received carrier, causes the relative noise output of that path to remain constant even though the signal contributed by the path has faded. Therefore all of the paths contribute noise to the common signal receiving apparatus, while only those of them in which fading has not occurred contribute signal at a favorable signal-to-noise ratio. The result is that, in the absence of some corrective measure, the over-all signal-to-noise ratio of such a system is adversely affected.

In the diversity system of the present invention this effect is overcome by the employment of a method and means for controlling the amplitudes of the signal and accompanying noise passing by way of each of the diversity branches to the common signal receiver in accordance with the amplitude of a selected portion of the energy received from the transmitting station over the corresponding space path. Specifically, in the preferred embodiment, when the signal and selected controlling portion, which may for example be the accompanying carrier or an accompanying pilot frequency, of any path fade, the gain in the signal and noise transmitting portions of the corresponding diversity branch is caused likewise to be diminished. Thus, the output of any one or

more of the diversity branches upon which the signal is fading is reduced in accordance with the amount of fading, and a more favorable overall signal-to-noise ratio is maintained in the common signal receiver into which all of the branches feed.

The manner in which this result is accomplished will be explained by reference to the accompanying drawing which represents schematically a single side-band diversity receiving system consisting, as illustrated, of two radio reception branches, each arranged to receive radio signals arriving from the same signal source over different space paths, convert the signals to audio frequencies and transmit them to a common signal receiving device.

For the sake of simplicity, communication of the radio receiving apparatus with the different space paths is represented as being by way of the antennas A1 and A2, which may be of any suitable type. These antennas feed over radio reception branches 1 and 2, respectively, to the common signal receiver 10. Only two antennas with their associated radio receivers are shown, but it will be understood that any greater number, usually three in a space diversity system, may be used. The elements included in each radio reception branch are of identically the same type as those included in the other branch; and corresponding elements are designated by the same reference numbers, excepting that a prime is affixed to the designating numerals of the second branch. The description of the arrangement and operation of the elements in one branch may therefore be understood to apply to the operation and arrangement of the elements in the other branch.

The energy received by the antenna passes to high frequency amplifier and first detector elements 11. In the first detector the received energy is modulated by a high frequency wave supplied by the beat oscillator 20 and the desired products of modulation are amplified in a two-stage intermediate frequency amplifier 12. The above-mentioned elements may be regarded as constituting the radio receiver of the reception branch. The intermediate frequency amplifier 12 operates into a branched circuit, one branch of which includes an isolation amplifier 13 and a second detector 14, and the other branch of which selects a narrow frequency band including the carrier that passes through the band-pass crystal filter 15 to a rectifying device which in the present instance consists of the two detectors 16 and 17.

To the output of the second detector 14 there is supplied a local carrier frequency from the local carrier oscillator 30, and the audio frequency products of modulation of the local carrier and the signal intermediate frequencies feed into the input of audio frequency amplifier 18 by way of transformer 21. The degree of amplification of the audio frequencies in amplifier 18 is controlled by the potential across the resistance 19 included in the output circuit of the detector 16, this potential being applied in opposition to the normal biasing potential in the input circuit of the amplifier 18. The amplified audio frequencies of branch 1, together with those of branch 2, are then inductively communicated by way of transformers 23 and 23', respectively, to a circuit in which they are combined, further amplified if desired, and passed to the common signal receiver 10.

The detector tubes 17 and 17' of branch 1 and

branch 2, respectively, control the potential drop across the common resistance 30, and the variable potential thus developed is applied to the amplifiers 12 and 12' of branch 1 and branch 2, respectively, to give the usual diversity common automatic volume control to the system.

In the operation of the system it is assumed that the distant station is transmitting a radio frequency carrier of relatively small amplitude, and a single side band resulting from the modulation of the carrier frequency with the signal frequency. The radio receiver elements 11 and 11' of the two radio reception branches 1 and 2 are tuned to select the carrier and its side band, and the beat oscillator 20 is so adjusted as to produce, by modulation with the incoming wave, an intermediate frequency wave of the desired frequency, for instance, 400 kilocycles. A portion of this amplified intermediate frequency, as has been described, passes into the branch circuit including the band-pass crystal filter 15. This filter may be designed to pass a frequency band the width of which is sufficient to accommodate the carrier at its intermediate frequency value with such frequency variation as may occur on either side of this value as a result of imperfect frequency stability in the carrier oscillator at the transmitting station and in the beat oscillator 20 at the receiving station. For a moderate degree of frequency instability in these oscillators the band passed by the filter 15 may be 200 cycles wide, or narrower to the extent that the oscillator stability warrants. After passing through filter 15 the narrow band including the carrier at its intermediate frequency value passes to the input circuits of detectors 16 and 17.

In the output of detector 16 there is produced a direct current the amplitude of which varies with the variations in the amplitude of the carrier received over the corresponding branch. Any fading of the carrier and its associated side band at the receiving antenna of the corresponding branch results in a reduction in current flowing through the resistance 19 in the output circuit of detector 16 and a corresponding potential reduction across the resistance.

The bias in the input circuit of the audio frequency amplifier tube 18 is determined by the potential of the biasing battery 22 and the potential drop across the resistance 19. This bias is so adjusted that with no carrier input to detector 16, amplifier 18 substantially suppresses transmission to the common signal circuit. With a normal carrier input to detector 16 the increased potential across resistance 19, in opposition to the potential of biasing battery 22, decreases the negative bias in the input circuit of audio frequency amplifier 18 to produce normal gain in the transmission of the signal of this branch to the signal receiver. Thus, when the fading over any path is such as to produce an unfavorable signal-to-noise ratio, the gain in the corresponding branch of the system is automatically reduced in proportion to the reduction of the radio frequency input to the corresponding antenna, and the contribution of that branch to the common signal receiver circuit is proportionately diminished or substantially suppressed.

As indicated in the drawing, the amplifier 13 in the signal sub-branch of each of the branches 1 and 2 is of the screen grid type for preventing the local carrier oscillations which are fed into the plate circuit of the second detector 14 from

feeding back through the channel and appearing in the other detector circuits.

The diversity common automatic volume control which is secured by employing the voltage drop across the resistance 40 common to the plate circuits of the detectors 17 and 17' to control the grid bias of the amplifiers of several branches simultaneously and equally, is well known in the art and needs no specific description. It ensures that the radio frequency outputs of the respective receivers of the several branches shall have the same relative signal strengths as the radio frequency inputs to the receivers.

If it be assumed that, from a condition of equality, the radio frequency energy received upon antenna A1 and transmitted through radio reception branch 1 increases, while that received upon antenna A2 and transmitted through radio reception branch 2 diminishes, the common automatic volume control effected by detectors 17 and 17' and the individual transmission gain control effected by detectors 16 and 16' will operate in such a way as to tend to magnify the contribution of branch 1 which has the more favorable signal-to-noise ratio and to reduce the contribution of branch 2 which has the less favorable signal-to-noise ratio. The increasing negative bias on the amplifier tubes of both branches resulting from the increasing radio frequency input from antenna A1 stabilizes the volume contribution of branch 1 at a predetermined value and reduces the relative contribution of branch 2 in which the signal is fading. At the same time detector 16 of branch 1 operates to reduce the negative bias in the input circuit of audio frequency amplifier 18 to permit a proportionately greater signal transmission through this branch to the common signal receiver; while detector 16' of branch 2, responding to the diminishing energy input received from antenna A2, reduces the opposing bias developed in resistance 19', thus increasing the negative bias in the input circuit of amplifier 18' to diminish the audio frequency output in accordance with the reduction in radio frequency energy received over the corresponding branch. The result is that the signal received in the common signal receiver 10 is principally that received over the path of the diversity system which has the most favorable signal-to-noise ratio, while the noise that would otherwise enter the common receiver over the path or paths of reduced signal energy is diminished or completely suppressed by the device which reduces the gain of the transmission path in accordance with the reduction in the received radio frequency energy. In a properly proportioned system in accordance with the present invention the signal volume delivered to signal receiver 10 is held substantially constant.

The interposition of a rectified-carrier-operated gain controlling device, such as the audio frequency amplifier 18, in the path which the signals and noise must traverse to reach the common signal receiver 10, further serves the useful function of excluding from the common signal circuit modulation products due to the intermodulation of noise components with each other, which intermodulation may take place even in the absence of the locally applied modulating carrier frequency. Whatever the nature of the noise and signal demodulation in the second detector may be, the transmission of the signal and noise components through that part of the

signal sub-branch that includes the second detector and audio frequency amplifier is controlled in amplitude in accordance with the amplitude of the rectified energy received from the transmitting station.

If it should be desired to effect a greater degree of frequency stability, this may be done in the manner disclosed in Patent 2,041,855 to R. S. Ohl, issued May 26, 1936. That is, the filtered carrier received from the transmitting station may be reconditioned and then used for obtaining automatic frequency control of the beating oscillator 20 and synchronization of the local carrier oscillator 30. Or, if desired, in accordance with the disclosure of the Ohl patent, the filtered carrier after being reconditioned and amplified may constitute the source of locally applied carrier oscillations in place of the local carrier oscillator 30. As disclosed in the Ohl patent, the reconditioned carrier is supplied for demodulation at substantially constant amplitude regardless of fading in transmission, and therefore, if applied in the present system in substitution of the carrier oscillations generated locally by oscillator 30, the system is susceptible of and requires the same automatic gain control in accordance with the amplitude of the rectified received carrier energy of the corresponding branch that is utilized in the present invention.

The specific disclosure herein is that of a diversity system in which the same signal is simultaneously received over a plurality of paths by way of separate antennas. It will be understood that the invention is also applicable to an angle diversity system in which the same signal is simultaneously received at different vertical angles by way of a single array of spaced antenna units, and is demodulated at each angle by reconditioned carrier arriving at that angle, or by locally generated carrier synchronized by the received carrier of the corresponding path.

It will also be understood that the transmission gain control of each reception branch in accordance with the amplitude of the rectified energy received from the transmitting station over that branch may, within the scope of the invention, be alternatively applied at other points in the signal conveying portion of the sub-branch, as at the input of the isolation amplifier 13.

In the foregoing the energy received over each branch and selected and rectified to control the signal transmission gain of that branch, has been specifically described as that of the transmitted carrier frequency. It will be understood that in systems where the carrier is entirely suppressed and a pilot frequency is transmitted in its place, as a side-band of the suppressed carrier, this pilot frequency may be selected and rectified and used to control the signal gain of the corresponding branch in the same manner as has been described for the carrier.

What is claimed is:

1. In a diversity radio receiving system, a plurality of radio receivers arranged to receive radio signals from the same signal source by different paths, means for selecting and rectifying a portion of the energy received from the transmitting station by each receiver, means for combining the rectified currents, means for controlling the amplification of all the receivers in accordance with the combined rectified currents so that the radio frequency outputs of the respective receivers have the same relative signal strengths as the inputs thereto, a signal detector for each receiver, said detectors having their inputs connected to the

radio frequency outputs of the respective receivers, means for supplying carrier oscillations to said detectors, an amplifier for each receiver connected in the signal conveying circuit of the corresponding detector, an audio frequency circuit common to said amplifiers and signal detectors of all of said receivers, and means responsive to said individual rectified currents for so controlling the amplification of the respective amplifiers and detectors as to maintain the audio signal contribution of each receiver to said common circuit proportional to the respective received radio signal strengths.

2. In a reduced carrier diversity radio receiving system comprising a plurality of radio reception branches each including a radio receiver and each connected with a common signal receiver, means operatively coupled to each branch for selecting and rectifying a portion of the signal carrier, means under the control of the combined rectified carrier currents of all the branches for similarly controlling the amplification of the radio receivers of all of the branches so that the radio frequency outputs of the respective receivers have the same relative signal strengths as the inputs thereto, a signal detector for each branch, a substantially constant amplitude source of carrier oscillations at the receiving station connected to the detector inputs of the various branches, an amplifier for each branch included in the signal conveying circuit of the corresponding detector, and means responsive to the amplitude variations of the rectified carrier current of each branch for controlling the gain of said amplifier of the corresponding branch.

3. In a diversity radio receiving system comprising a plurality of radio reception branches each including a radio receiver and each connected with a common signal receiver, means operatively coupled to each branch for selecting and rectifying a portion of the energy received from the transmitting station by each receiver, means under the control of the combined rectified currents of all the branches for similarly controlling the amplification of the radio receivers of all of the branches so that the radio frequency outputs of the respective receivers having the same relative signal strengths as the inputs thereto, a signal detector for each branch, a substantially constant amplitude source of carrier oscillations at the receiving station connected to the detector inputs of the various branches, an amplifier for each branch included in the signal conveying circuit of the corresponding detector, and means responsive to the amplitude variations of the rectified carrier current of each branch for controlling the gain of that portion of the corresponding branch which includes said signal detector and said amplifier.

4. In a single side band diversity radio receiving

system comprising a plurality of radio reception branches each connected with a common signal receiver, means operatively coupled to each branch for selecting and rectifying a portion of the energy received from the transmitting station by way of the corresponding branch, a signal detector for each branch, a substantially constant amplitude source of carrier oscillations connected to the detectors of the various branches, an audio frequency amplifier for each branch included between the detector output of the corresponding branch and said common signal receiver, and means responsive to the amplitude variations of the rectified energy of each branch for controlling the gain of said audio frequency amplifier of the corresponding branch.

5. In a diversity radio receiving system comprising a plurality of radio reception branches connected with a common signal receiver and each including a radio receiver, means operatively coupled to each branch for selecting and rectifying a portion of the energy received from the transmitting station by way of the corresponding branch, means operated by the combined rectified energy derived from all of the branches for similarly controlling the amplification of the radio receivers of all of the branches so that the radio frequency outputs of the respective receivers have the same relative signal strengths as the inputs thereto, a signal detector for each branch, a substantially constant amplitude source of carrier oscillations at the receiving station connected to the detectors of the various branches, an audio frequency amplifier for each branch included in the signal detector output of the corresponding branch, and means responsive to the amplitude variations of the rectified current of each branch for controlling the gain of said audio frequency amplifier of the corresponding branch.

6. The method of maintaining a favorable signal-to-noise ratio in a diversity radio receiving system utilizing means for receiving in different radio reception branches the radio signals arriving from the same signal source over different space paths, applying equal amplification to the energy received in each branch, separately selecting and rectifying a portion of the energy received over each branch, and separately demodulating the signal energy component of each branch by carrier oscillations supplied from a substantially constant amplitude local source, which consists in separately amplifying the demodulated signal energy of each branch, utilizing the rectified portion of the energy of each branch to control in accordance with its own amplitude the degree of amplification of the demodulated signal component of the corresponding branch, and combining and utilizing the demodulated signal components of all the branches.

ARTHUR A. OSWALD.