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RECEIVER FOR SINGLE SIDE BAND
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This invention relates to radio systems and more particularly to receivers for systems in which only one side band is transmitted with the carrier for a given signal communication, thus permitting the frequency range normally occupied by the other side band to be utilized for the transmission of a single side band of another signal communication.

As is well known, when a signal communication is modulated on a carrier, two side bands are produced, one lying above and one lying below the carrier. Each of these side bands contains frequency components from which the original signal may be reproduced. Ordinarily, in the operation of reception, both side bands beat with the carrier to reproduce the original signal.

However, the original signal may be reproduced by beating but one of the side bands with the carrier. This is taken advantage of in the so-called single side band system to enable the system to transmit two separate signal communications upon the same carrier frequency. In modulating one signal communication upon the carrier, the lower side band is suppressed, and similarly, in modulating the other signal communication upon the carrier, the upper side band is suppressed. The two remaining side bands, one representing the one signal communication and the other representing the other signal communication, are then transmitted along with the carrier frequency.

The purpose of the present invention is to provide a receiver which will permit of proper reception of such received signals so that the two individual signal communications may be separated from each other and properly demodulated without interference one with the other. It is also the purpose of the invention to provide a receiving arrangement which will receive and demodulate the signals efficiently, with a minimum of apparatus and in the most economical manner.

Further details of the invention will be clear from the following description when read in connection with the accompanying drawing in which Figure 1 shows one type of receiver adapted for single side band reception, while Fig. 2 shows a preferred form of receiver, in which the amount and cost of apparatus have been reduced to a minimum without loss of efficiency.

In the drawing, the various parts of the apparatus are shown in the form of squares or blocks with suitable labels, because all of the various parts, such as attenuation networks, amplifiers,

filters, modulators, demodulators, etc., are well known in the art. The invention, of course, resides in the manner in which these various elements are put together and associated with each other in order to accomplish the desired result.

In Fig. 1 there is shown an antenna AT connected through an attenuation network AN of a well-known type and through a high frequency amplifier HFA to a first demodulator D₁. The demodulator D₁ functions to step down the received signal bands to an intermediate stage in the frequency spectrum, and for this purpose is supplied with a beating frequency generated by the oscillator O₁. The beating oscillator O₁ may be any known type of vacuum tube oscillator and need not be herein described. However, inasmuch as the system herein considered will ordinarily be operated at very high frequencies, it is desirable to have the frequency generated by the oscillator O₁ rigorously controlled by means of an automatic governing arrangement. This tends to stabilize the frequency in a manner which will be described later.

The beating action of the demodulator D₁ results in producing a new carrier with associated side bands stepped down in the frequency spectrum by an amount equal to the difference between the original carrier frequency and the beating frequency generated by the oscillator O₁. It also produces a correspondingly higher carrier and associated side bands, which will be stepped up in the frequency spectrum by an amount equal to the difference between the received carrier and the frequency generated by the oscillator O₁. As it is desired to utilize only the lower carrier and its associated side bands, an appropriate intermediate frequency filter IFF is connected with the output circuit of the demodulator D₁.

This filter is so designed that it will select the stepped down carrier frequency and its associated side bands, excluding the stepped up carrier and its associated side bands and also excluding the original carrier. The frequencies thus selected will then be impressed upon the intermediate frequency amplifier IFA₁. The filter IFF may be of any known type of band filter, and need not necessarily be a crystal filter, as there will be a wide separation between the wanted and unwanted frequencies appearing in the output circuit of the demodulator D₁. In many instances, the ordinary electrical filter made up of coils and condensers will suffice for this purpose.

As the filter IFF may be either a crystal filter or an ordinary electrical filter, it is indicated by a rectangle formed of thin single lines. The convention used in the drawing portrays a crystal filter in the form of a rectangle having heavy lines, while an ordinary electrical filter is shown as a rectangle having thin parallel lines to form its sides.

In order the better to understand the invention and the functioning of the apparatus, it will be well to consider at this point the functioning of the apparatus for a particular frequency allocation.

In considering the frequencies involved, the convention employed in the drawing shows side bands as rectangles lying horizontally one above the other with the corresponding carrier frequency shown as a horizontal line in between. The horizontal bracket appearing above the side band rectangles indicates the portions of the apparatus in which the illustrated frequencies appear. Thus, the received carrier and associated side bands are indicated below the horizontal bracket which embraces the antenna AT, the attenuating network AN and the high frequency amplifier HFA.

If we assume that the original signal communication involved frequencies in the range from about 100 cycles to 6500 cycles, and the carrier frequency ultimately transmitted is f , there will be emitted at the sending station, after suitable modulation and translation, a carrier frequency f , and an upper side band corresponding to one signal communication extending from $f+100$ cycles to $f+6500$ cycles. There will also be a lower side band corresponding to another signal communication extending from $f-100$ cycles to $f-6500$ cycles.

The vertical arrow pointing upward at the left of the upper band (designated "B channel band" and shown just below the amplifier HFA in Fig. 1), indicates that in this band the frequencies are in the same order (although much higher in the frequency spectrum) as the original band representing the signal communication. In other words, the lowest frequency in the upper band designated as the B channel band corresponds to the lowest frequency in the original band, and the highest frequency in the B channel band likewise corresponds to the highest frequency of the original band. The lower band sent out from the transmitter, however, has the order of its frequencies reversed because the band corresponding to that frequency communication was modulated on the same carrier frequency as the other band and the lower resultant side band was selected. As is well known, in the lower side band resulting from a modulating operation the frequencies are reversed with respect to the modulating signal band. This is indicated by the arrow pointing downward at the left of the A channel band.

Let us now suppose that the beating frequency generated by oscillator O_1 is $f-2900$ kc. The demodulated action results in the production of sum and difference frequencies. As only the latter will be selected, it will be unnecessary to consider the former.

Taking up the difference frequencies, we find that when the beating frequency $f-2900$ kc. is subtracted from the upper frequency $f+6500$ cycles of the B channel band, the resultant frequency in the B_1 channel band becomes 2906.5 kc. This is the upper frequency of the B_1 channel band. Similarly, by subtracting the beating

frequency from the lower frequency $f+100$ cycles of the B channel band, we obtain as the lower frequency for the B_1 channel band 2900.1 kc. The order of these frequencies in the spectrum, it will be noted, is the same as in the B channel band, and therefore, the arrow ahead of the B_1 channel band points upward.

The difference between the original carrier f and the beating frequency $f-2900$ kc. is of course 2900 kc., and this becomes the intermediate frequency carrier. Similarly, if we make the necessary subtractions for the upper and lower frequencies of the A channel band, we obtain 2899.9 kc. and 2893.5 kc. as the respective upper and lower frequencies of the A_1 channel band. Here again the order of the frequencies in the A_1 channel band are the same as in the A channel band and the arrow to the left of the rectangle points downwardly, indicating that the order of the frequencies is still reversed with respect to the frequencies in the original signal communication band at the transmitter.

As indicated by the bracket above the B_1 and A_1 channel bands, these bands and the corresponding carrier will exist in that portion of the circuit between the first demodulator D_1 and the second demodulator D_2 . This portion of the circuit includes the intermediate frequency filter IFF and the intermediate frequency amplifier IFA₁. The filter IFF merely selects between widely separated frequencies such as the frequency 2906.5 kc. of the band B_1 and the frequency $f-6500$ cycles which is the lowest received frequency. Hence, an ordinary electrical filter made up of condensers and coils will serve the purpose.

The second demodulator D_2 may be of any well known type and is similar in principle to the first demodulator D_1 . Its function is to step down the intermediate frequency carrier and the B_1 and A_1 channel bands to a still lower position in the frequency spectrum. For this purpose, it is supplied with a beating frequency generated by the oscillator O_2 and, if desired, this beating frequency may be amplified by an amplifier A_2 of some well known type. In the case illustrated, the second beating frequency is 3000 kc. This is 100 kilocycles higher than the intermediate carrier frequency, which it will be remembered was 2900 kc. Since the beating frequency is in this instance higher than the modulating frequency, instead of being lower as in the case of the demodulator D_1 , the difference frequencies which are to be utilized in the output of the demodulator D_2 will be reversed in order with respect to the intermediate frequency bands as will appear later.

For example, considering first the B_1 channel band, if we subtract the upper frequency 2906.5 kc. of said band from the beating frequency of 3000 kc., the resultant frequency will be 93.5 kc., which constitutes the lower frequency of the B_2 channel band. The frequency 2900.1 kc. of the B_1 channel band likewise becomes 99.9 kc. and constitutes the upper frequency of the B_2 channel band. Similarly, the intermediate carrier frequency of 2900 kc. becomes 100 kc. The upper frequency 2899.9 kc. of the A_1 channel band becomes 100.1 kc., and the frequency 2893.5 kc. of the A_1 band becomes 106.5 kc., the lower and the upper frequencies, respectively, of the A_2 channel band.

It will thus be seen that all of the frequencies in the group, including the A_2 and B_2 channel bands are reversed in their order although low-

ered in position in the frequency spectrum. Consequently, the arrows to the left of the rectangles representing the A_2 and B_2 channel bands are reversed with respect to those of the A_1 and B_1 channel bands. These arrows indicate that the frequencies in the A_2 channel band are now in the same frequency order as in the original signal communication band corresponding to A_2 , whereas the frequencies in the B_2 channel band are in reverse order with respect to the frequencies in the original signal communication band corresponding thereto.

The next step is to separate the carrier frequency thus stepped down from the correspondingly stepped down A_2 and B_2 channel bands. For this purpose, the output of the second demodulator D_2 is connected to three channels, A, B and C. The A branch includes second intermediate frequency amplifiers AA_2 and AA_2' and AA_2'' for amplifying the selected side band, and a filter AF_2 for selecting the desired side band, which in this case is the A_2 channel band extending from 100.1 kc. to 106.5 kc. This is represented by the rectangle beneath the horizontal bracket spanning the four pieces of apparatus above referred to and appearing in the A branch.

Similarly, the B branch includes second intermediate amplifiers BA_2 , BA_2' and BA_2'' for amplifying the selected band, and a filter BF_2 for selecting the desired band. As shown by the horizontal rectangle associated with the bracket beneath these four pieces of apparatus, the band selected will be the B channel band extending from 93.5 kc. to 99.9 kc.

Finally, we have in the C branch three intermediate carrier amplifiers CA , CA' and CA'' as well as a filter CF for amplifying and selecting the intermediate carrier frequency 100 kc. The lower frequency of the A_2 channel band is only 100 cycles above the intermediate carrier of 100 kc. and since the latter is only 100 cycles above the upper frequency 99.9 kc. of the B_2 channel band, the selectivity on a percentage basis is very small. It is therefore necessary to employ crystal filters AF_2 , CF and BF_2 in the branches A, C and B, respectively, in order to obtain a sharply selective discrimination. This, of course, adds somewhat to the expense of the apparatus, because a crystal filter is higher in cost than the ordinary electrical filter. If crystal filters were not here employed, it would ordinarily be necessary to step down the bands still further in the frequency spectrum before the final detecting operation, in order to obtain such relative separation between the frequencies nearest to each other as will enable them to be selected by ordinary electrical filters. This, of course, would involve a considerable increase in the cost of the apparatus.

In order to effect the final demodulating or detecting operation a final demodulator AFD is included in the A branch and a final demodulator BFD is included in the B branch, so that the A_2 channel type band and the B_2 channel band will be respectively applied to the input circuits of these demodulators. The final intermediate carrier frequency of 100 kc., which was selected in the C branch, is then applied to the demodulators AFD and BFD through carrier amplifiers CA_a and CA_b . This carrier frequency being lower than the selected A_2 channel band in the A branch, beats therewith, in the demodulator AFD , and produces a difference frequency band extending from 100 cycles to 6500 cycles, as shown by the rectangle beneath the bracket underlying voice

channel amplifier AA_v and the voice frequency filter AF_v . The frequencies in this final voice band are in the same order in the spectrum as those in the A_2 channel band, so that the arrow ahead of the rectangle points upwardly. In other words, this final band has the same frequencies and in the same order as the original signal communication band, which modulated the carrier at the sending station.

In the case of branch B, the final carrier of 100 kc. is higher than any of the frequencies in the B_2 channel band. Consequently, the difference frequencies selected in the output circuit of the final demodulator BFD by the filter BF_v , and amplified by the amplifier BA_v , will be in reverse order with respect to the frequencies in the B_2 channel band. As the frequencies in the B_2 channel were reversed with respect to the frequencies of the original signal communication band, the resultant B voice band has frequencies corresponding to and in the same order as those in the original modulating voice band.

In order to stabilize the frequencies generated by the beating oscillator O_1 a portion of the nominal 100 kc. carrier frequency selected in the branch A is applied through amplifiers CA to carrier modulators CM . A 100 kc. reference frequency, which may be supplied preferably by a crystal oscillator or other highly stabilized frequency source, is also supplied by the reference oscillator O . This reference frequency is applied through phase shifters PS and amplifiers RA to the carrier modulators CM . The carrier modulators CM are of a well known type and so arranged that if the frequency from the branch C is equal to the 100 kc. frequency from the oscillator O and is in the proper phase relationship, no alternating current appears in the output circuit of the modulators.

If, however, the frequency of the current from the branch C differs slightly from that of the current from oscillator O , an output current corresponding to the difference frequency is supplied from the output circuit of the carrier modulator CM to the control motor CC of known type. The control motor is therefore rotated slightly, and correspondingly changes the effect of a condenser or other electrical element controlling the frequency of the beating oscillator O_1 . This changes the frequency generated by said oscillator O_1 so that the frequency appearing in the branch C will be equal to that of the current supplied by the reference oscillator O and the alternating component applied to the motor again becomes zero causing it to cease rotation.

As has already been pointed out, the three principal filters AF_2 , CF and BF_2 in the branches A, C and B respectively, should be of the crystal type, because of the high degree of selectivity required. In order to reduce the number of crystal filters, the circuit of Fig. 2 may be used. This circuit is identical with that of Fig. 1 as respects the arrangements, connections and characters of the pieces of apparatus shown outside the dotted rectangle labeled "Medium audio frequency apparatus." The apparatus outside this rectangle in Fig. 2 also operates in a manner identical with that shown in Fig. 1. Certain changes are made, however, in the medium and audio frequency apparatus, as will now appear.

The output of the second demodulator D_2 , instead of dividing immediately into three branches A, B and C, as in Fig. 1, is first passed through a second intermediate frequency amplifier IFA_2 ,

so that the A_2 channel band, the 100 kc. carrier and the B_2 channel band frequencies may be amplified. The output of this amplifier IFA_2 is then divided into three branches, A, B and C, for effecting the selecting operations as between the two side bands and the carrier.

The carrier is selected into the branch C by means of crystal filter CF which is connected to an amplifier CA for amplifying the selected carrier. The crystal filter is so sharply selective that it picks out but a very narrow band of frequencies centering on the 100 kc. carrier. This carrier is then applied to a third intermediate frequency carrier modulator CM' , which is also supplied with a 10 kc. frequency from the oscillator O.' This produces sum and difference frequencies of 110 kc. and 90 kc. These two frequencies (as well as the 100 kc. carrier and the 10 kc. frequency) are sufficiently separated so that the 110 kc. frequency may be selected by an ordinary electrical filter CF_a . Similarly, the difference frequency of 90 kc. may be selected by the ordinary electrical filter CF_b . The selected frequencies 110 kc. and 90 kc., respectively, are applied to the third channel demodulators AD_3 and BD_3 in the branches A and B, respectively.

The input circuits of these two third demodulators receive from the output of the amplifier IFA_2 all of the frequencies involved in the A_2 channel band, the B_2 channel band and the carrier frequency of 100 kc. lying between them. All of these frequencies beat with the 110 kc. frequency supplied to the demodulator AD_3 to produce difference frequencies corresponding to each of the frequencies appearing in the output of the amplifier IFA_2 . As the beating carrier in this instance is higher than any of the frequencies appearing in the A_2 and B_2 bands the resultant frequencies in the output of the demodulator AD_3 will be reversed in their order. As we are only concerned with the frequencies corresponding to the 100 kc. carrier and the A_2 channel band, however, we will disregard the effect of the frequencies in the B_2 channel band.

Considering now the difference frequencies produced in the output of the demodulator AD_3 , the carrier frequency of 10 kc. corresponds to the carrier frequency of 100 kc. in the output of the demodulator D_2 . Similarly, the upper frequency 9.9 kc. of the A_3 channel band corresponds to the frequency of 100.1 kc. in the A_2 channel band, and the lower frequency 3.5 kc. corresponds to the frequency 106.5 kc. of band A_2 . Thus, it will be seen that the frequencies in the A_3 channel band have been reversed in their order in the frequency spectrum with respect to those in the A_2 channel band. Hence, the arrow to the left of the rectangle representing the A_3 channel band points downward.

This particular channel band and the associated 10 kc. carrier frequency can be selected from the frequencies corresponding to the B_2 channel band appearing in the output of the demodulator AD_3 , and from the sum frequencies resulting from modulating operation of AD_3 , by means of an ordinary low-pass filter of the electrical type shown at AF_3 . The selected frequencies are then applied through the third intermediate frequency amplifier AA_3 to the final channel demodulator AFD . In this modulator the carrier frequency of 10 kc. beats with the A_3 channel band frequencies to produce a final voice band involving frequencies from 100 cycles to 6500 cycles. This band is amplified by the voice

amplifier AA_v and selected from any other frequencies in the output of the final demodulator AFD by means of a voice frequency filter AF_v .

It will be noticed that the 100 cycle frequency of the A voice band corresponds to the 9.9 kc. frequency in the A_3 channel band and that the 6500 cycle frequency in the A voice band likewise corresponds to the 3.5 kc. frequency in the A_3 channel band. Thus, it will be seen that the frequencies in the final voice band are inverted in order with respect to those in the A_3 channel band. Therefore the arrow to the left of the A voice band points upward, indicating that the A voice band frequencies are in the same order in the spectrum as the corresponding frequencies in the original signal communication band at the transmitter.

In a similar manner the A_2 and B_2 channel bands, as well as the 100 kc. carrier, are applied to the third demodulator BD_3 in the branch B. Also the difference frequency of 90 kc. is selected from the output of the carrier modulator CM' by means of a carrier filter CF_b and applied to the demodulator BD_3 . The beating action between this frequency and the input frequencies applied to the demodulator BD_3 results in the production of difference frequencies ranging from 3.5 kc. to 16.5 kc. The electrical filter BF_3 selects from these the B_3 channel band extending from 3.5 kc. to 9.9 kc. and also the 10 kc. carrier. The selected frequencies are in turn amplified by the amplifier BA_3 and applied to the final demodulator BFD . This converts the frequencies to the voice range extending from 100 cycles to 6500 cycles, this band being amplified and selected by the voice frequency amplifier BA_v and by the voice frequency BF_v . The final demodulating step, of course, reversed the order of the frequencies in the B voice band with respect to those in the B_3 channel band so that the voice band contains the same frequencies in the same order as the original signal communication.

It will be noted that the beating frequencies of 110 kc. and 90 kc., respectively, applied to the third demodulators AD_3 and BD_3 , respectively, are so chosen as to bring the A_3 channel band selected in the A branch and the B_3 channel band selected in the B branch into the same frequency range. It is, of course, not necessary that these two bands be brought into the same identical range, the primary consideration being that the bands be stepped low enough in the frequency spectrum to permit of selection by an ordinary electrical filter instead of a crystal filter. However, bringing these bands into the same range has the advantage that the filters AF_3 and BF_3 , which are employed for selective purposes, may be of identical design.

It will be evident from the inspection of the arrangement of the medium and audio frequency apparatus in Fig. 2 that only one crystal filter is used, this being the filter designated CF. Since this filter has to make a very sharp selection between the 100 kc. carrier frequency and the A_2 and B_2 channel bands, it is necessary that this filter have a narrow, sharply defined band such as may be provided by a crystal filter. At no other point in the medium and audio frequency apparatus is a selection so close as this required. For example, the filters CF_a and CF_b employed to select between the 110 kc. beating frequency, the 90 kc. beating frequency, and the 100 kc. carrier frequency appearing in the output of the modulator CM' , are only required to select between rather widely separated frequencies.

Therefore, these two filters may be of ordinary electrical type employing condensers and inductance coils.

The same is true of the filters AF₃ and BF₃. These filters are only required to select the 10 kc. carrier and the channel band lying just below it from the band lying just above the 10 kc. carrier in each path. The nearest frequency of the band lying above in each case is 10.1 kc. In other words, the filter only has to discriminate between two frequencies of the order of 10,000 cycles, differing from each other by 100 cycles, so that the percentage selection is as great as one per cent. This can readily be handled by an ordinary electrical type of filter.

Contrasting this with the situation in Fig. 1, where the crystal filters AF₂, CF and BF₂ have to select between three frequencies of the order of 100,000 cycles, differing from each other by only 100 cycles, it will be evident that the requirements for the filters are much more severe in this case. The percentage of selection here is only one-tenth of a per cent as compared with one per cent in Fig. 2. It is, therefore, necessary that all three filters AF₂, CF and BF₂ be crystal filters.

While this invention has been disclosed in certain specific arrangements which are deemed desirable, it will be obvious that the general principles herein set forth may be embodied in many other organizations, widely different from those illustrated, without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. In a transmission system in which only one side band is transmitted for any given signal communication and side bands corresponding to two independent signal communications are transmitted one on either side of a common carrier, the method of reception which consists in stepping down both signal bands to an intermediate point in the frequency spectrum where it is possible to select the carrier from the two side bands, applying both bands to each of two demodulating paths, shifting both bands in each of said paths so that the one signal band in the one path will lie in the same frequency range in that path that the other signal band occupies in the other path, selecting the bands in each path lying in the same range, and finally demodulating the selected band in each path to its normal signal range.

2. In a transmission system in which only one side band is transmitted for any given signal communication and side bands corresponding to two independent signal communications are transmitted one on either side of a common carrier, the method of reception which consists in stepping down both signal bands to an intermediate point in the frequency spectrum where it is possible to select the carrier from the two side bands, applying both bands to each of two demodulating paths, shifting both bands down in the frequency range in each of said paths to a point where the upper band in one path occupies the same frequency position as the lower band in the other path, selecting the bands occupying the same frequency position in the two paths, and finally demodulating the selected band in each path to its normal signal range.

3. In a transmission system in which only one side band is transmitted for any given signal communication and side bands corresponding to two independent signal communications are transmitted one on either side of a common car-

rier, the method of reception which consists in stepping down both signal bands to an intermediate point in the frequency spectrum where it is possible to select the carrier from the two side bands, applying both bands to each of two demodulating paths, beating both bands in each of said paths with beating frequencies so related that a resultant band corresponding to each of the two different signal communication bands will occupy the same frequency position in each of said paths, selecting the bands occupying the same frequency position in the two paths, and finally demodulating the selected band in each path to its normal signal range.

4. In a transmission system in which only one side band is transmitted for any given signal communication and side bands corresponding to two independent signal communications are transmitted one on either side of a common carrier, the method of reception which consists in stepping down both signal bands to an intermediate point in the frequency spectrum where it is possible to select the carrier from the two side bands, applying both bands to each of two demodulating paths, beating both bands in one path with a frequency lying near but above the upper band in one path, beating both bands in the other path with a frequency lying near but below the lower band in the other path, selecting in the first path the band corresponding to one signal communication, selecting in the second path the band corresponding to the other signal communication, and finally demodulating the selected band in each path to its normal signal range.

5. In a transmission system in which only one side band is transmitted for any given signal communication and side bands corresponding to two independent signal communications are transmitted one on either side of a common carrier, the method of reception which consists in stepping down both signal bands to an intermediate point in the frequency spectrum where it is possible to select the carrier from the two side bands, applying both bands to each of two demodulating paths, selecting from between said bands the carrier corresponding to the point in the frequency spectrum to which the bands have been shifted, converting the selected carrier to two beating frequencies lying near but one above and one below the two signal bands, beating both bands in one path with one of said converted beating frequencies, beating both bands in the other path with the other beating frequency, selecting in the first path the resultant band corresponding to one signal communication, selecting in the other path the resultant band corresponding to the other signal communication, and finally demodulating the selected band in each path to its normal signal range.

6. In a transmission system in which only one side band is transmitted for any given signal communication and side bands corresponding to two independent signal communications are transmitted one on either side of a common carrier, the method of reception which consists in stepping down both signal bands and the common carrier to an intermediate point in the frequency spectrum where it is possible to select the carrier from the two side bands, applying both bands to each of two demodulating paths, selecting from between said bands carrier corresponding to the point in the frequency spectrum to which the bands have been shifted, converting the selected carrier to two beating frequencies

lying one above and one below the two signal bands and so related thereto that when the one beating frequency beats with the one band and the other beating frequency beats with the other band, both bands will be shifted to the same position in the frequency spectrum, beating both bands in one path with one of said converted

beating frequencies, beating both bands in the other path with the other beating frequency, selecting in the two paths the bands lying in the same position in the frequency spectrum, and finally demodulating the selected band in each path to its normal signal range.

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