

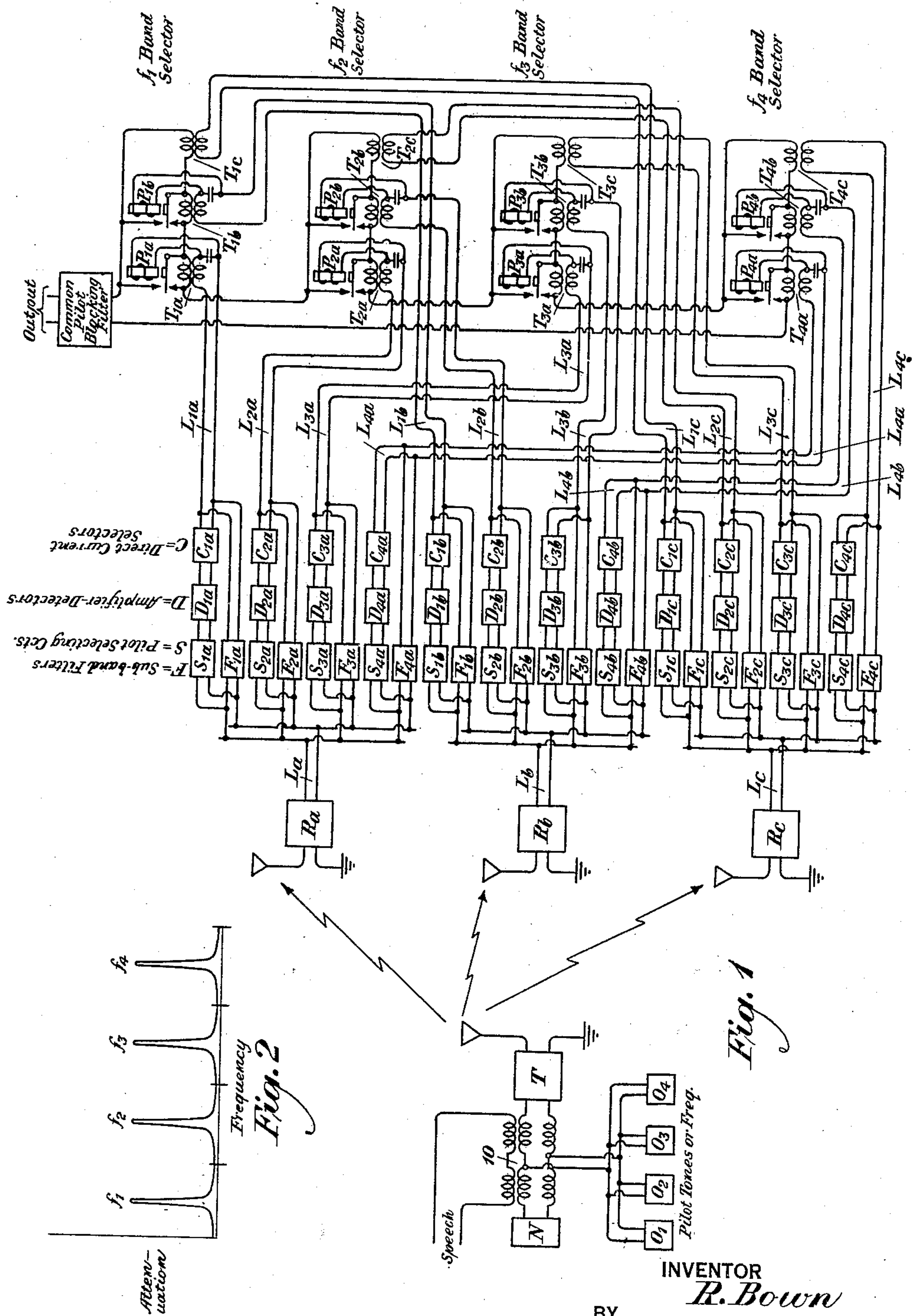
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AUTOMATIC SELECTION OF RECEIVING CHANNELS

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## AUTOMATIC SELECTION OF RECEIVING CHANNELS

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This invention relates to methods and means for limiting the extent which any received signal may vary in intensity.

One source of signal variation is that due to changes in the strength of the signal as received from the signal medium. In the case of radio reception such variations are generally known as fading. Fading is particularly severe when receiving short wave lengths, and the method generally employed for maintaining a more or less constant demodulated signal has been to provide an automatic gain control or regulator. This method of regulation has certain limitations, however, and becomes inadequate, for example, when the signal drops below the limiting noise level. The present invention has as one of its objects the provision of a system which will be free from these limitations and may be used either independently or supplementary to automatic gain regulation for maintaining a constant output level at all times.

The invention is based on the fact that, if a number of receiving stations properly located and sufficiently far apart are used to pick up a transmitted signal, the signal does not fade similarly at each of the receiving stations. Observations made on various wave lengths have shown that the receiving antennae need only be separated from each other by a distance of the order of a wave length or so in order to get this effect. The possibility of the signal fading out equally at all of the receiving stations at the same time is therefore reduced with increase in the number of receiving stations.

It has been heretofore proposed to use more than one receiver to pick up the radio signal and to choose for use the receiver giving the best results. In the past this was accomplished by cutting over manually from a receiver giving a signal of low volume to another which at the moment was giving a signal of larger volume, and again switching back to the first receiver or some other receiver

as the signal again became low in volume. Obviously, such a method of operation was limited to cases where the changes in the signal occurred slowly enough to permit the operator to select the best receiver or receiver output.

Where the signal intensity changes quite rapidly, as is often the case with short wave reception, a system capable at all times of rapidly cutting in the best of the available received signals is desirable. It is therefore proposed to use a number of receiving stations, properly located, and to continuously and automatically select the receiver or output of the receiver giving a useful signal, minimizing in this way the effect of rapid changes in the amplitude of the received current and reducing the possibility of the signal entirely fading out.

While it would be desirable to have the selecting apparatus so arranged as to always select the receiver having the largest signal output, excellent reception will always be obtained if the selected receiver has an output above a predetermined minimum. In accordance with the present invention, the selecting apparatus is arranged to select exclusively the first receiver whose output exceeds the predetermined minimum value, thereby permitting of the use of a very simple form of selecting circuit.

Where a particular receiver is so selected due to the fact that its output as a whole is of sufficient volume to cause the operation of the selecting relay, it not infrequently happens that some parts of the voice band from a particular receiver will be very low in volume, due to so-called selective fading. It is, therefore, desirable that for such parts of the received signal reception take place from some other receiver. Accordingly, the voice band is divided up into several sub-bands at each receiver by suitable filtering arrangements, and the selecting mechanism is so operated that reception for each sub-band is derived



from a receiver whose output as to that sub-band exceeds a predetermined minimum. In order to simplify the selecting operations, pilot frequencies corresponding to each sub-band are transmitted from the transmitting station, and these pilot frequencies are used to operate the selecting devices.

The invention may be more fully understood from the following description when read in connection with the accompanying drawing, Figure 1 of which illustrates a circuit arrangement embodying the principles of the invention, and Fig. 2 of which is a curve illustrating the operation of a selecting filter which may be employed in connection with the invention.

Referring to Fig. 1 of the drawing, T designates a radio transmitter of some known type capable of translating speech currents into radio waves for transmission through the ether. Preferably, transmitter T is of a type in which the so-called carrier component and one of the so-called side band components are suppressed so that the entire energy capacity of the radio transmitter may be used for the transmission of signaling energy in the form of the transmitted side band. In order to impress the speech energy upon the radio transmitter, the speech circuit is connected to the transmitter through a hybrid coil 10.

Inasmuch as the present invention involves the separation of the voice band into a plurality of sub-bands at the receiver and the selection of a receiver giving the signal of desired amplitude for each sub-band, provision is made at the transmitter to modulate the carrier wave in accordance with pilot frequencies, one corresponding to each sub-band. Accordingly, four pilot generators  $O_1$ ,  $O_2$ ,  $O_3$  and  $O_4$  are connected to the midpoints of the hybrid coil 10 and the transmitter T is balanced by means of a network N so that while the pilot frequencies are impressed upon the transmitter T, they are prevented from reacting in the speech circuit through the hybrid coil 10. Each pilot frequency should be so located with respect to one of the sub-bands to which it corresponds as to be either at the margin of the sub-band or within the sub-band so that it will be subjected to substantially the same transmission conditions as the sub-band to which it corresponds. Consequently, the side band transmitted through the air will include the four speech sub-bands together with radio frequencies corresponding to the several pilot frequencies, and each of the pilot radio frequencies will be subjected to substantially the same transmission conditions as regards fading, etc., as the side band frequencies corresponding to the speech sub-bands.

At the receiving station a plurality of similar receivers  $R_a$ ,  $R_b$  and  $R_c$  are provided. Each of these receivers is arranged to receive at the same wave length and each receiver may

be of any type well known in the art, but where the carrier component is suppressed at the transmitter, the receiver will be provided with local sources of energy to supply the carrier wave which beats with the received side band to produce the detected voice waves and impress them upon the output circuits  $L_a$ ,  $L_b$  and  $L_c$ . As a result of the beating action, audio frequency waves will also be produced in the circuits  $L_a$ ,  $L_b$  and  $L_c$  corresponding to each of the pilot frequencies generated at the transmitter. The amplitude of these pilot frequency waves will be determined by the amplitude of the locally supplied carrier and the amplitudes of those frequencies of the received side band which correspond to the original pilot frequencies. As the locally supplied carriers will have substantially the same amplitude at each of the receivers, and as this amplitude will be entirely independent of fading or other transmission effects, the pilot frequencies in the circuits  $L_a$ ,  $L_b$  and  $L_c$  will have amplitudes determined by the fading effects of the corresponding radio frequencies as received at the several receivers.

Now it is well known that where radio waves are subjected to fading, the effects are entirely different at different receivers in the same area even though the receivers are separated only by distances of the order of a wave length or so. Also, a phenomenon known as selective fading has been observed as a result of which certain parts of the detected voice band will be subjected to fading effects, while other parts of the voice band will either not be subjected to fading or will not fade to the same extent. As regards the output of a particular receiver, the detected pilot frequencies will be subjected to the same fading as the voice sub-bands within which they lie. Consequently, any speech sub-band with its corresponding pilot frequency may be supplied to the output circuit of one receiver with one amplitude and to the outputs of other receivers with greater or lesser amplitude. The receiving circuit is, therefore, so organized that as respects each sub-band that sub-band will be supplied to the final receiving circuit from a receiver in whose output the sub-band appears with an amplitude above a predetermined minimum. In order to control the selection between sub-bands from different receivers, the amplitudes of the pilot frequencies corresponding to the different sub-bands determine the operation of the selecting devices, and as these pilot frequencies are received constantly, the selection as respects each of the sub-bands takes place independently of whether or not voice signals are actually being transmitted and received. The selecting arrangement is of such character that in the final output of the receiving system the several sub-bands may not all be received from the same receiver but may be received from



one or more receivers depending upon the effects of selective fading.

In order that the selecting operations may take place, the output circuit of each receiver, such as  $R_a$ , for example, is supplied to a plurality of individual circuits corresponding to each sub-band such as  $L_{1a}$ ,  $L_{2a}$ ,  $L_{3a}$  and  $L_{4a}$ . Band filters such as  $F_{1a}$ ,  $F_{2a}$ ,  $F_{3a}$  and  $F_{4a}$  are included in the several branches to select in each branch a different sub-band of the detected voice band appearing in the output circuit of the receiver. These filters may be of any known character such, for example, as filters of the well-known Campbell type. The circuits such as  $L_{1a}$ ,  $L_{2a}$ , etc., may be connected to the common output circuit  $L$  through transformers  $T_{1a}$ ,  $T_{2a}$ ,  $T_{3a}$  and  $T_{4a}$ .

In a similar manner, the output of receiver  $R_b$  is divided into four branches,  $L_{1b}$ ,  $L_{2b}$ , etc., and these branches may be associated with the common output circuit  $L$  through transformers  $T_{1b}$ ,  $T_{2b}$ ,  $T_{3b}$ , etc. Each of these branches also includes sub-band selecting filters such as  $F_{1b}$ ,  $F_{2b}$ , etc.

So, also, the output of the receiver  $R_c$  is divided into a plurality of sub-band circuits  $L_{1c}$ ,  $L_{2c}$ , etc., through sub-band filters  $F_{1c}$ ,  $F_{2c}$ , etc., and these sub-band circuits may be connected to the common output circuit  $L$  through transformers such as  $T_{1c}$ ,  $T_{2c}$ ,  $T_{3c}$ , etc.

Where the pilot frequencies are located at the edge of the corresponding sub-band the pilot frequencies may be suppressed from the various sub-band circuits, such as  $L_{1a}$ ,  $L_{2a}$ , etc., by means of the sub-band filters such as  $F_{1a}$ ,  $F_{2a}$ , etc. If, however, the pilot frequencies are not completely suppressed by this means, or if the pilot frequencies are so located as to fall well within the corresponding sub-band, they may be finally prevented from being transmitted to the hearer by including in the common circuit  $L$  a suppression filter of known type so arranged as to sharply suppress the unwanted pilot frequencies while permitting the free transmission of the frequencies within the voice band other than the pilot frequencies. Such a filter should have a characteristic somewhat as represented by the curve of Fig. 2, in which  $f_1$ ,  $f_2$ ,  $f_3$  and  $f_4$  represent the pilot frequencies which, in the case assumed for purposes of illustration, are located substantially centrally of each sub-band. As filters having such characteristics are well known in the art, no description thereof is deemed necessary.

As has already been stated, the function of the pilot frequency, which as it appears in the output of each receiver corresponds in amplitude to its associated voice sub-band, is to control the selection of the sub-band from the output of a receiver in which the sub-band appears with an amplitude exceeding a predetermined minimum limit. In order to accomplish this result, the pilot frequencies

are selected from the branch circuits, such as  $L_{1a}$ ,  $L_{2a}$ , etc., ahead of the band selecting filters  $F_{1a}$ ,  $F_{2a}$ , etc., by means of sharply selective circuits such, for example, as tuned circuits, conventionally indicated at  $S_{1a}$ ,  $S_{2a}$ ,  $S_{3a}$  and  $S_{4a}$  in the case of the receiver  $R_a$ . Similar pilot selecting circuits are provided for each of the other receivers. The selected pilot frequencies are impressed upon amplifier-detector units such as  $D_{1a}$ ,  $D_{2a}$ , etc., associated with each of the individual sub-band circuits. These amplifier-detector arrangements are indicated conventionally and may be of any known type such, for example, as those used in connection with echo suppressors. The function of the amplifier-rectifiers is to amplify the selected pilot frequencies and produce therefrom direct current components having amplitudes determined by the amplitude of each pilot frequency appearing in the output of each receiver. The direct current components thus developed will correspond in amplitude to the amplitude of the sub-bands appearing in the outputs of the several receivers. In order to transmit over the various sub-band circuits, such as  $L_{1a}$ ,  $L_{2a}$ , etc., only the direct current components resulting from the pilot frequencies, while suppressing the pilot frequencies therefrom, selecting circuits such as suppression filters  $C_{1a}$ ,  $C_{2a}$ ,  $C_{3a}$ , etc., are connected upon the output sides of the amplifier-detectors. These selecting devices may be of any known type in the art and should be designed so as to permit the passage of direct currents and perhaps currents of very low frequencies while suppressing the higher frequency currents corresponding to the pilot frequencies.

The direct currents thus generated and selected are transmitted over the circuits such as  $L_{1a}$ ,  $L_{2a}$ ,  $L_{3a}$ , etc., together with the selected voice sub-bands. The direct current components pass through the windings of selecting relays  $P_{1a}$ ,  $P_{2a}$ , etc., one corresponding to each of the four sub-bands of the receiver  $R_a$ , and through the windings of relays  $P_{1b}$ ,  $P_{2b}$ , etc., corresponding to each of the four sub-bands in the output of receiver  $R_b$ , and so on for other receivers, if desired. In the case illustrated, selecting relays are not provided for the several sub-bands of the receiver  $R_c$ , which acts as a stand-by receiver and which is always connected to the common output when no other receiver is connected thereto. The direct currents generated in connection with the four sub-band circuits of the receiver  $R_c$ , therefore, in this instance serve no useful purpose, and the apparatus for producing such direct currents might be omitted but is here illustrated in order to indicate how the apparatus would be arranged if additional receivers were to be provided beyond the receiver  $R_c$ . The sub-band frequencies transmitted along with the direct current components above referred to pass into the com-



mon circuit L through transformers such as  $T_{1a}$ ,  $T_{1b}$ ,  $T_{2b}$ , etc. (provided their secondaries are not short-circuited) without passing through the windings of the selecting relays.

5 The selecting relays are arranged in groups, those corresponding to the same sub-band in the different receivers being grouped together, for the purpose of selecting the receiver from which that particular sub-band is to be derived. For example, the relays  $P_{1a}$ ,  $P_{2b}$  (and  $P_{3b}$ , if provided) are all arranged in a group, these relays being operated by the direct current components from the several receivers corresponding to the pilot frequency  $f_1$ . The arrangement is such that the first operated relay from the left in each group determines the receiver from which the sub-band corresponding to the pilot frequency  $f_1$ , for example, is to be derived. In order to accomplish this result, the armature of each relay has its contacts so arranged that when the relay is non-energized the transformers, such as  $T_{1a}$ ,  $T_{1b}$ , etc., are short-circuited by the back contacts of the selecting relays. Therefore, if all of the relays are released, the sub-band corresponding to the pilot frequency  $f_1$  will be derived from the receiver  $R_c$  through the transformer  $T_{1c}$ . If, however, one of the relays as, for example, relay  $P_{1b}$  is operated, the short-circuit is removed from the secondary of its transformer  $T_{1b}$  and all transformers to the right are short-circuited over the front contact of said relay and all transformers to the left are short-circuited over the back contacts of the non-operated relays. The result is that as respects the sub-band corresponding to pilot frequency  $f_1$ , the output of the receiver  $R_b$  is exclusively connected to the circuit L.

40 In order to more fully understand the selecting operation, let us assume a concrete case in which the sub-band corresponding to pilot frequency  $f_1$  appears with an amplitude above the predetermined minimum in the outputs of all three receivers, the sub-band corresponding to pilot frequency  $f_2$  appears with an amplitude above the minimum in the outputs of the receivers  $R_b$  and  $R_c$ , the sub-band corresponding to the pilot frequency  $f_3$  appears with an amplitude above the minimum in the outputs of receivers  $R_a$  and  $R_c$ , while the sub-band corresponding to the pilot frequency  $f_4$  appears with an amplitude above the minimum in the output of receiver  $R_c$  only. In each of these cases the pilot frequencies corresponding to the several sub-bands will appear in the outputs of the several receivers with amplitudes proportional to those of the sub-bands to which they correspond. Therefore, in the case of the first sub-band having the pilot frequency  $f_1$ , this pilot frequency will appear in the outputs of all three receivers with an amplitude above a predetermined minimum which is necessary to provide the direct current component for oper-

ating the selecting relays. (It will be understood, of course, that the relays will be so designed as to have a margin of operation determined by the minimum signal component which it is desired to receive.) Under the conditions just described, the direct currents will be produced from the pilot frequency  $f_1$  in the outputs of each of the three receivers which are of sufficient amplitude to operate all of the selecting relays of the  $f_1$  group. Consequently, both relays  $P_{1a}$  and  $P_{1b}$  will be operated, with the result that the secondary of the transformer  $T_{1a}$  will have its short-circuit opened, while the transformers  $T_{1b}$  and  $T_{1c}$  will be short-circuited over the front contact of relay  $P_{1a}$ , even though the short-circuit normally existing about the winding of transformer  $T_{1b}$  is removed. Consequently, as regards the sub-band corresponding to the pilot frequency  $f_1$ , this sub-band is derived exclusively from the output of the receiver  $R_a$  over the circuit  $L_{1a}$ .

In the assumed case, the pilot frequency  $f_2$  will appear in the outputs of receivers  $R_b$  and  $R_c$  with sufficient amplitude so that the corresponding direct current components will operate relay  $P_{2b}$  over the branch  $L_{2b}$  without causing the operation of relay  $P_{2a}$ . The secondary of transformer  $T_{2a}$ , therefore, remains short-circuited and the transformer  $T_{2c}$  is short-circuited over the front contact of relay  $P_{2b}$  which, by removing the short-circuit normally existing across the secondary of the transformer  $T_{2b}$ , causes the sub-band corresponding to pilot frequency  $f_2$  to be derived over the circuit  $L_{2b}$  from the receiver  $R_b$  exclusively.

Similarly, in the case of the sub-band corresponding to frequency  $f_3$ , the pilot frequency  $f_3$  will appear in the output circuits of the receivers  $R_a$  and  $R_c$  with amplitudes above the minimum necessary to produce direct currents capable of operating the selecting relays  $P_{3a}$  (there being no relay corresponding to the receiver  $R_c$  for this sub-band). The relay  $P_{3a}$  upon being operated, removes the short-circuit from the secondary of transformer  $T_{3a}$  and at its front contact short-circuits transformers  $T_{3b}$  and  $T_{3c}$  so that the third side band is supplied to the common receiving circuit L over the branch circuit  $L_{3a}$  from receiver  $R_a$  exclusively.

Finally, as respects the fourth sub-band which is received with an amplitude above the predetermined minimum in the output of the receiver  $R_c$ , only the pilot frequency  $f_4$  will appear in the output of the receiver  $R_c$  with sufficient amplitude to operate a selecting relay of the  $f_4$  group, if such relay is provided. In the case illustrated, no such relay is provided, and as the frequency  $f_4$  appears in the output circuits of receivers  $R_a$  and  $R_b$  with insufficient amplitude to cause the operation of selecting relays  $P_{4a}$  and  $P_{4b}$ , the fourth sub-band will be supplied to the



common circuit L from the output of receiver  $R_c$  over the branch  $L_{4c}$  and through the transformer  $T_{4c}$ . Incidentally, it might be noted at this point that the fourth sub-band would be supplied through the transformer  $T_{4c}$ , even if no one of these receivers supplied this sub-band with an amplitude above the required minimum. The receiver  $R_c$  functions, as regards this sub-band in the instance assumed, as a stand-by receiver.

To summarize for the assumed case, the first and third sub-bands are derived exclusively from the receiver  $R_a$ , the second sub-band from the receiver  $R_b$  and the fourth sub-band exclusively from the receiver  $R_c$ . Obviously, various other combinations would arise depending upon the selective fading conditions affecting the several sub-bands.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a signaling system subject to variable transmission conditions, a plurality of receivers each receiving the same signal band and so related to each other that the received signal bands and component parts thereof vary differently at the several receivers with variations in transmission conditions, means to separate the received bands at each receiver into sub-bands, a receiving circuit, and means to combine in said receiving circuit sub-bands each selected from a receiver whose output of that sub-band exceeds a predetermined minimum.

2. In a signaling system subject to variable transmission conditions, a plurality of receivers each receiving the same signal band and so related to each other that the received signal bands and component parts thereof vary differently at the several receivers with variations in transmission conditions, means to separate the received bands at each receiver into sub-bands, a receiving circuit, means to select as to each sub-band the receiver whose output of that sub-band exceeds a predetermined minimum, and means to combine in said receiving circuit the selected sub-bands from the selected receivers.

3. In a signaling system subject to variable transmission conditions, a plurality of receivers each receiving the same signal band and so related to each other that the received signal bands and component parts thereof vary differently at the several receivers with variations in transmission conditions, means to separate the received bands at each receiver into sub-bands, a receiving circuit, separate connections to said receiving circuit adapted to be established for the transmission of each separate sub-band from each receiver, and means to establish an exclusive connection for

each sub-band to a receiver whose output of that sub-band exceeds a predetermined minimum.

4. In a signaling system subject to variable transmission conditions, a plurality of receivers each receiving the same signal band and so related to each other that the received signal bands and component parts thereof vary differently at the several receivers with variations in transmission conditions, means to separate the received bands at each receiver into sub-bands, a receiving circuit, separate connections to said receiving circuit adapted to be established for the transmission of each separate sub-band from each receiver, and means to complete one of said connections to a receiver for each sub-band to the exclusion of other connections for the same sub-band.

5. In a signaling system subject to variable transmission conditions, a plurality of receivers each receiving the same signal band and so related to each other that the received signal bands and component parts thereof vary differently at the several receivers with variations in transmission conditions, means to separate the received bands at each receiver into sub-bands, a receiving circuit, separate connections to said receiving circuit adapted to be established for the transmission of each separate sub-band from each receiver, and means to complete for each sub-band a connection to a receiver whose output of that sub-band exceeds a predetermined minimum, said completed connection for each sub-band being exclusive of connections to other receivers for the same sub-band.

6. In a signaling system subject to variable conditions, a plurality of receivers each receiving the same signal band and so related to each other that the received signal bands and component parts thereof vary differently at the several receivers with variations in transmission conditions, means to separate the received bands at each receiver into sub-bands, a receiving circuit, means to transmit a pilot frequency corresponding to each sub-band from a transmitting station, separate connections to said receiving circuit adapted to be established for the transmission of each separate sub-band for each receiver, and means controlled by the pilot frequency for each sub-band to complete one of said connections to a receiver for each sub-band.

7. In a signaling system subject to variable transmission conditions, a plurality of receivers each receiving the same signal band and so related to each other that the received signal bands and component parts thereof vary differently at the several receivers with variations in transmission conditions, means to separate the received bands at each receiver into sub-bands, a receiving circuit, means to transmit a pilot frequency corresponding to each sub-band from a transmitting station, separate connections to said receiving circuit



adapted to be established for the transmission  
of each separate sub-band for each receiver,  
and means controlled by the pilot frequency  
for each sub-band to complete a connection  
5 for each sub-band to a receiver whose output  
of such sub-band exceeds a predetermined  
minimum.

In testimony whereof, I have signed my  
name to this specification this 7th day of De-  
10 cember, 1928.

RALPH BOWN.

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