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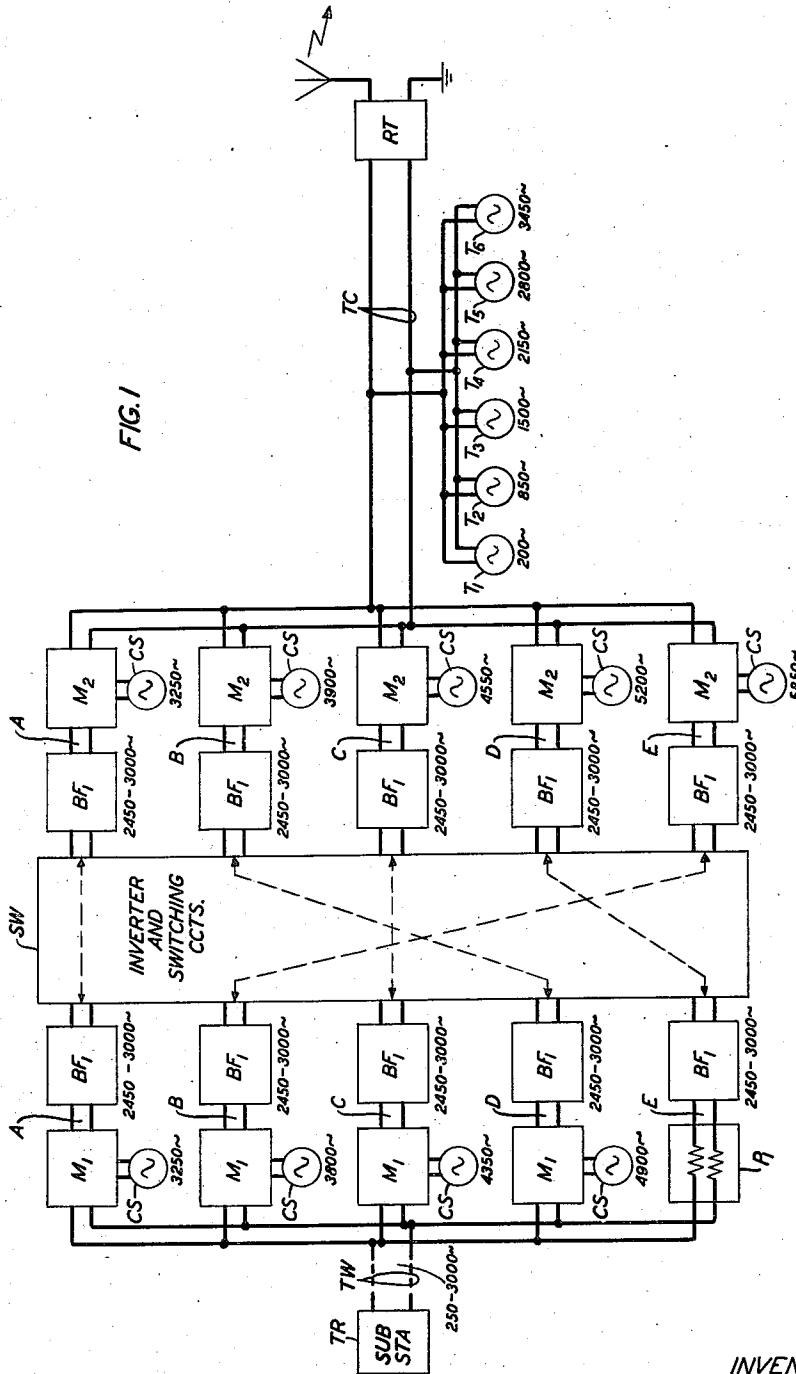
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2,407,259

TRANSMISSION CONTROL IN SIGNALING SYSTEMS

Filed July 9, 1941

6 Sheets-Sheet 1



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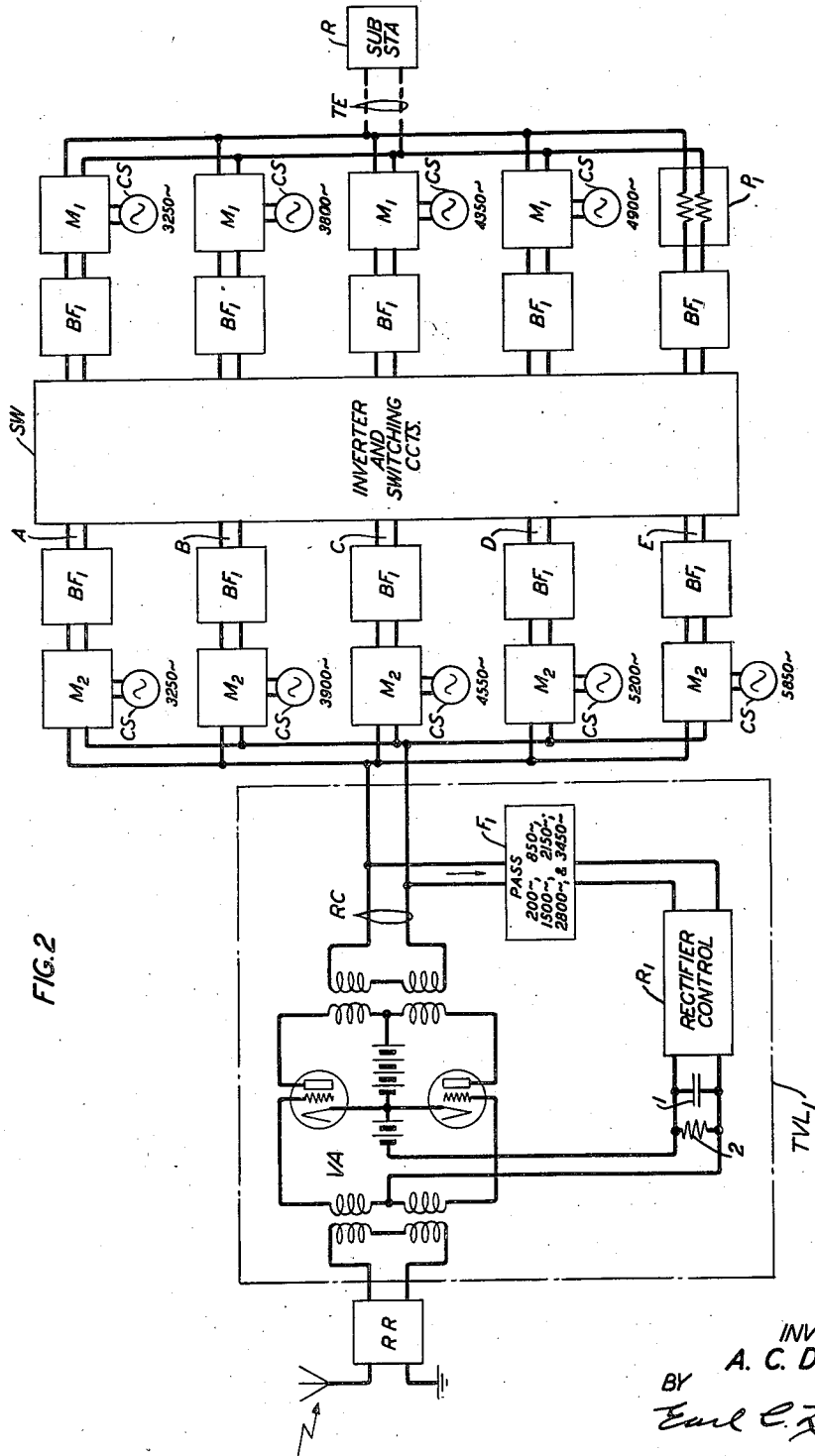
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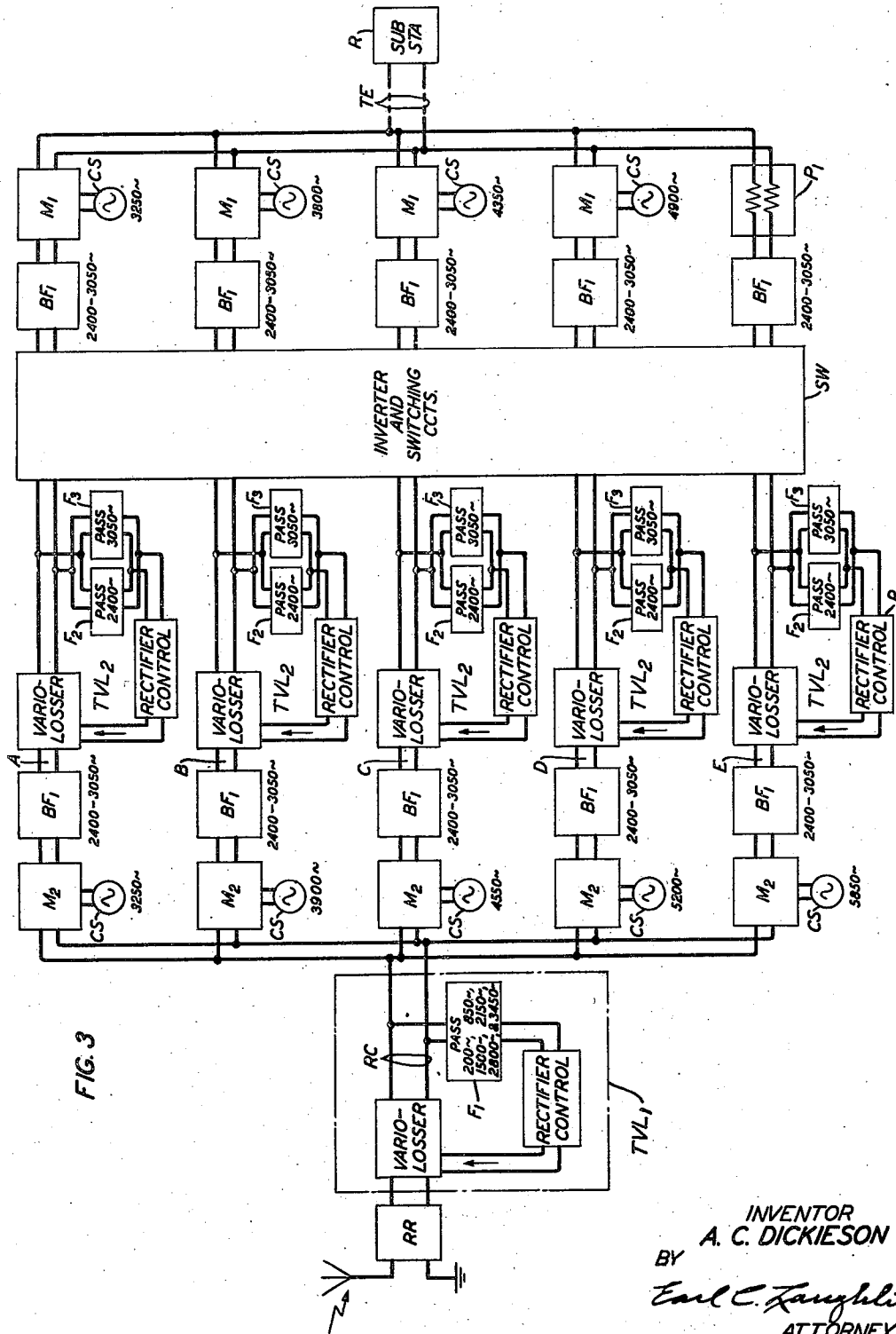
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6 Sheets-Sheet 3



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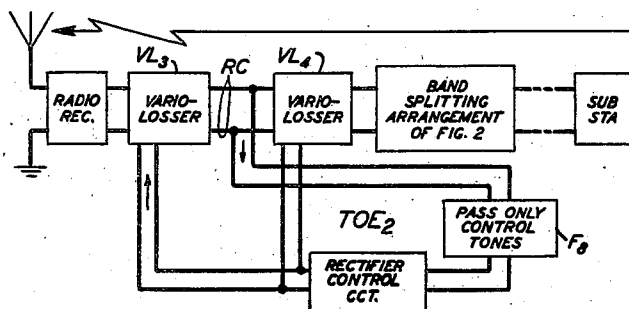
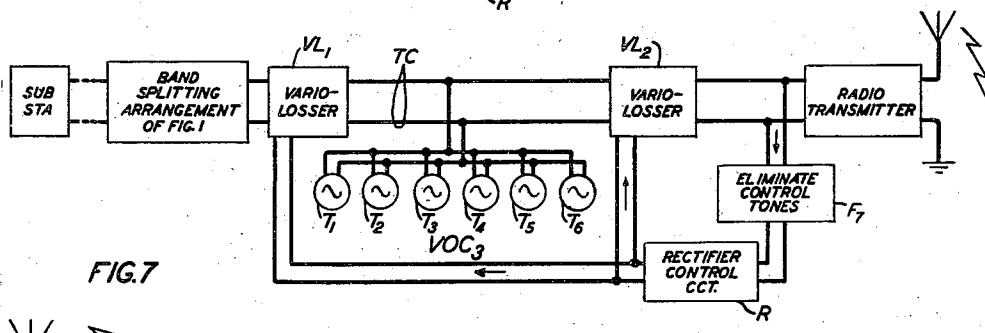
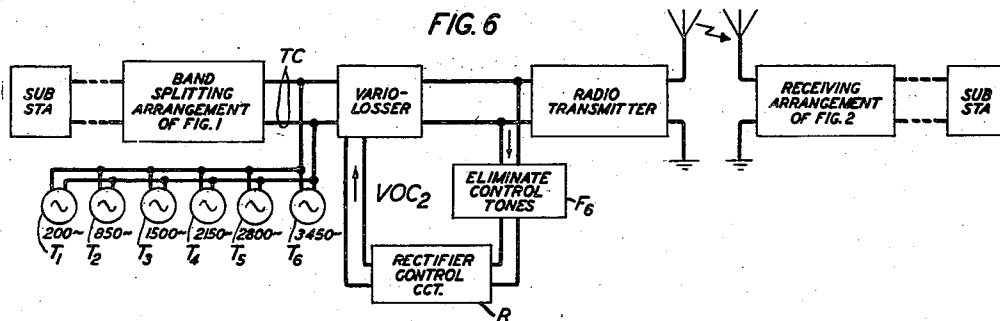
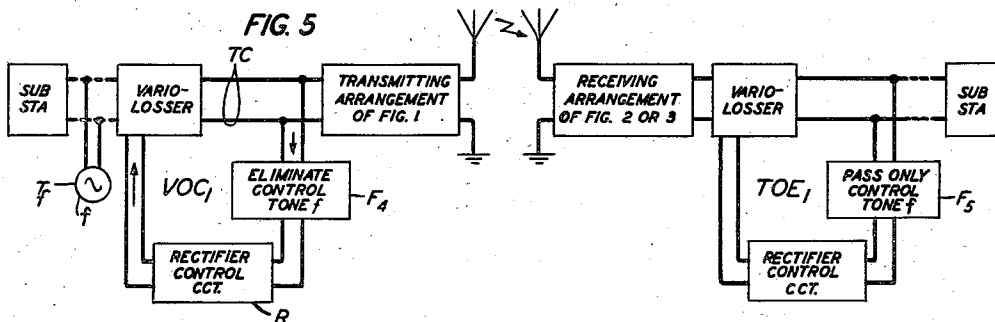
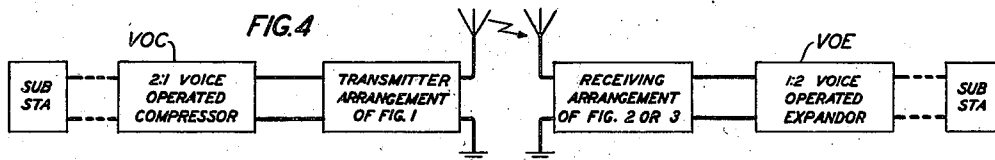
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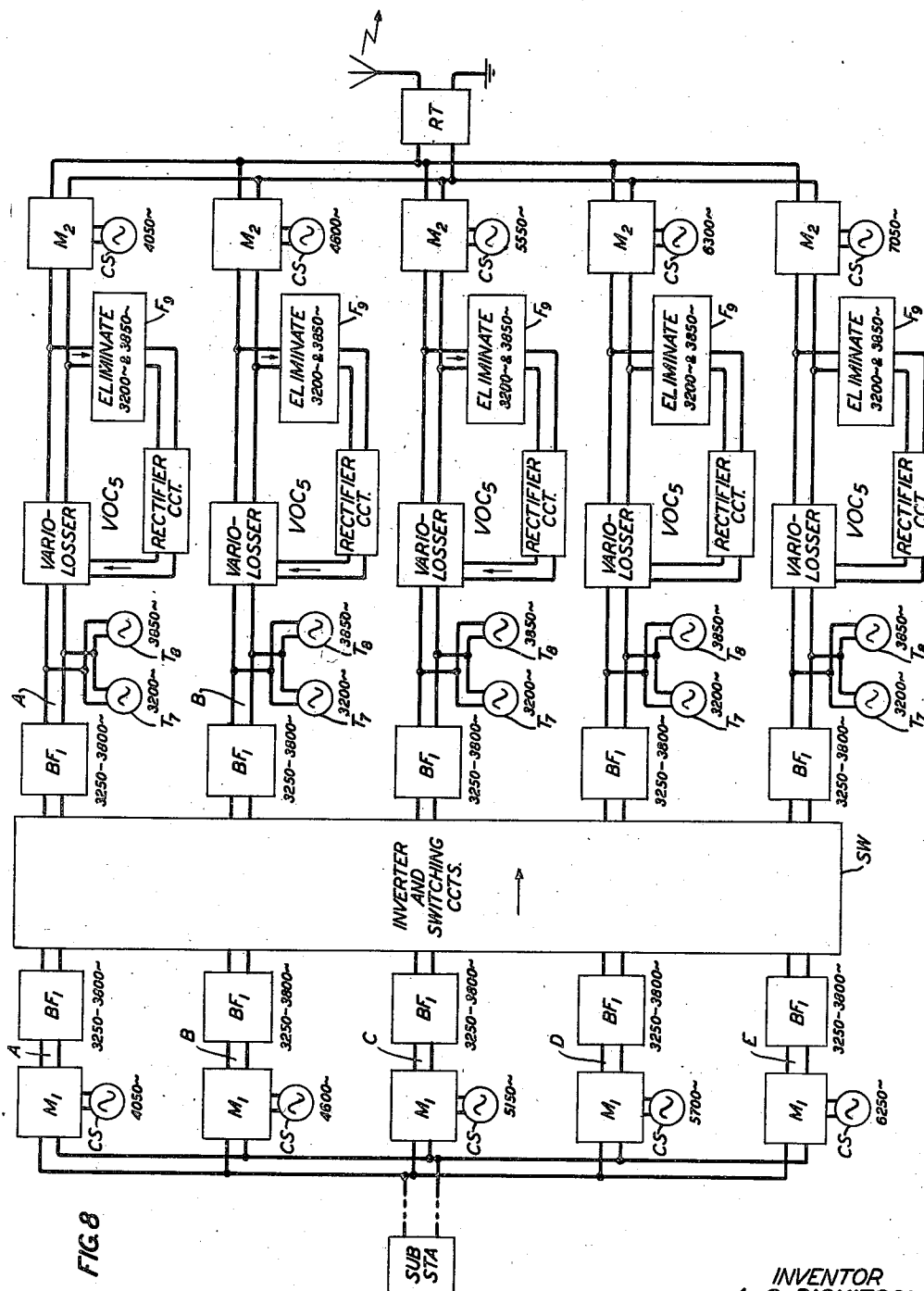
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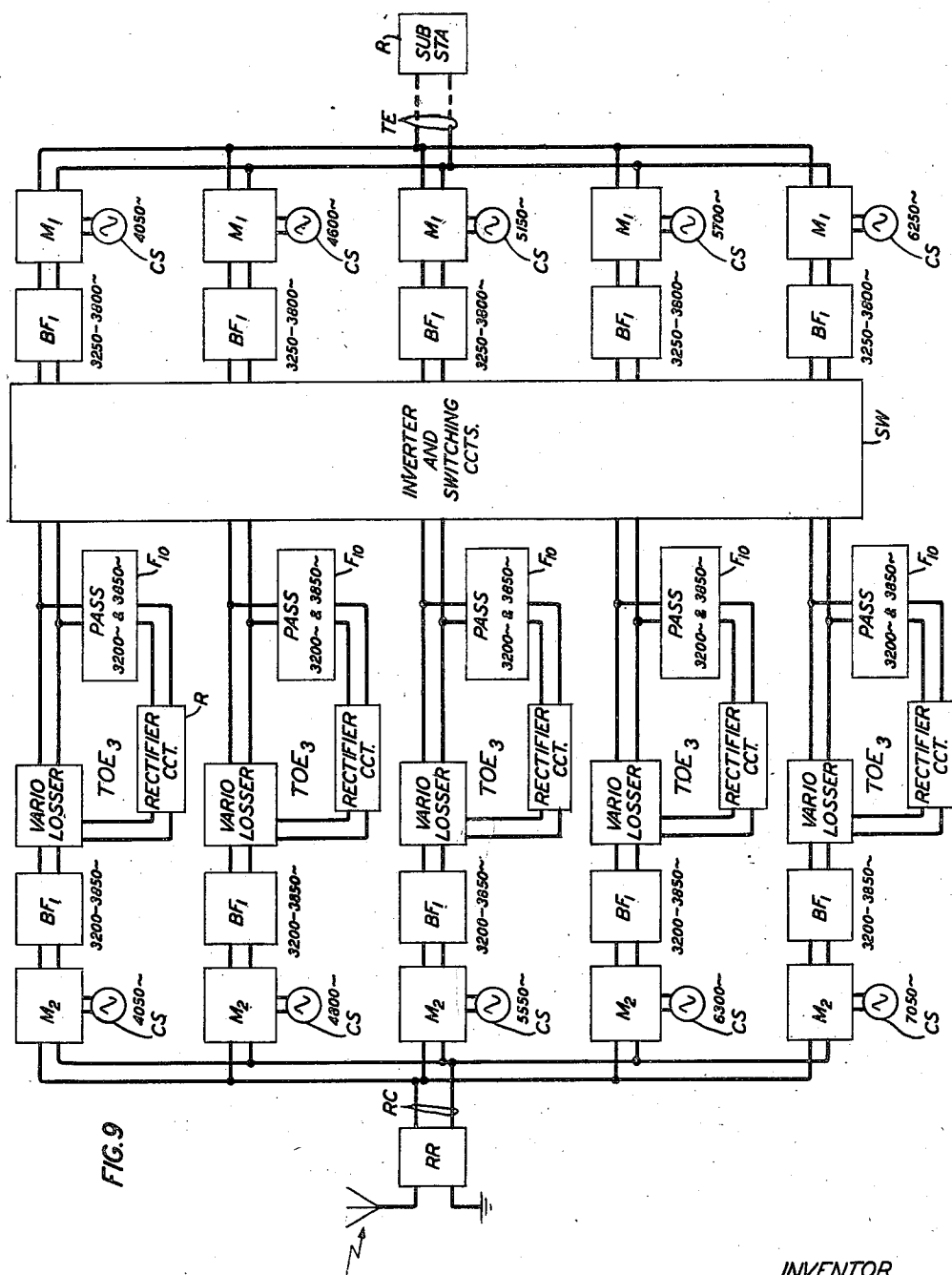
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TRANSMISSION CONTROL IN SIGNALING SYSTEMS

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UNITED STATES PATENT OFFICE

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TRANSMISSION CONTROL IN SIGNALING
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This invention relates to transmission control in a telephone or other signaling system, particularly in a two-way signal transmission system employing a variable or noisy transmission medium, such as the radio link in a two-way radio telephone system.

On long radio telephone systems, because of the large cost of transmitter output power, it is economically necessary to load the transmitter fully on all calls. This required the use of a transmitting gain-control device, either manually or automatically operated, which has led to "constant volume" operation with the supplemental use of vodas (volume-operated device anti-singing) switching circuits and echo suppressors to insure signal transmission in only one direction at a time, with prevention of singing and suppression of echoes.

To increase the ability of the receiving vodas branch at the receiving end of such a system to operate properly in the presence of variable noise or static received from the signal transmission medium, and to reduce the effect of noise on the listener, so-called compandors came into use. A compandor consists of a signal-controlled device, called a compressor, at the transmitting end of the system, which operates to raise the level of signals of lower amplitude before transmitting them to the transmission medium, above that of the noise or static to be encountered in that medium, while reducing the higher amplitude signals to a level which will not overload the transmission apparatus, such as the amplifying vacuum tubes in the system; and of a similar signal-controlled device, called an expander, at the receiving end of the system operating in reverse manner to restore the received signals to the relative amplitudes that they had at the transmitting end of the system. It was found that such compandors provided improved operation on long wave circuits, but were not entirely satisfactory in the case of short wave radio circuits because of the effects of fading, that is, occasional variations in the strength of received signals due to changes in the radio link. Any change in the loss of the radio link, usually caused by fading, which is not compensated by the carrier-operated gain control device employed in the radio receiver for compensating for variations in received carrier signal strength, will be effectively amplified by the expander device at the receiving end of the system. This fading is both flat and selective with frequency.

It has been noted in connection with wire line circuits that the cutting off of transmission in

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one direction during conversation, as accomplished by an echo suppressor device, causes a considerable increase in repetition rate. The observed average number of repetitions per unit of time has been found to be a useful index of telephone circuit performances, a lower rate in general indicating a better circuit. Also, a circuit in which a vodas device is employed at each terminal with consequent transmission lock-outs under some conditions of operation, caused by the simultaneous operation of the two devices by the signals for opposite directions both originating within the time interval equal to the one-way transmission time over the circuit between the two devices, has a higher repetition rate than one with echo suppressors only. Aside from the question of the additional expense involved in the use of such devices, it would be desirable to remove them from a system, since doing so would eliminate a circuit degradation in the only way possible.

The ordinary constant net loss circuit has two disadvantages. First, the transmitter is loaded fully only for the loudest talker. Second, if the desired net loss is low, then it becomes important to hold down variations in the loss of the radio link to prevent singing, which is difficult to accomplish with fading conditions. If variable gain is added in the transmitting circuit to keep the transmitter loaded up, it becomes necessary to add an equivalent amount of loss somewhere in the four-wire loop to prevent singing. The most advantageous place to do this is at the far end of the circuit, that is, in the receiving side. If the signal currents of all talkers are brought to the same amplitude level at the transmitter, then clearly the transmitted voice current itself cannot be used as an indicator of the amount of gain or loss to be added in the receiving circuit.

The single-side-band radio telephone circuits, especially, are known to be subject to considerable volume variations due to flat and selective fading. Receiving vodads (volume-operated gain-adjusting devices) have been used with such systems to regulate on a volume basis. The concept of volume, however, involves a time interval of several seconds. Most vodads designed to regulate volume are inherently rather too slow to take care of many types of fading. If a fast operating device is employed, it tends to wipe out the inflections of speech, with some penalty to calls not subject to such fading. The receiving vogad device, moreover, cannot readily distinguish whether a received speech syllable has suffered amplitude change in the radio link, since it

has no information from the far end of the system as to the original amplitudes. By sending over the system one or more pilot tones the input amplitudes of which are held constant, information as to the fading conditions in the radio link can be readily transmitted to the receiving terminal and utilized there to properly adjust transmission apparatus to compensate for such conditions. By this means the problem can be divorced from volume considerations and made a pilot channel project involving flat and selective regulation.

Another requirement complicating the operation of such systems which has become of considerable importance in recent years, particularly in the case of transoceanic radio telephone systems, is that the transmitted message be made as unintelligible as possible to an unauthorized listener. This has led to the use of various types of so-called secrecy or privacy devices for distorting the signals before sending them over the signal transmission medium, and for restoring them to their original intelligible form at a receiving station.

An object of the invention is to control signal transmission over such a two-way signal transmission system in an efficient and economical manner.

A more specific object is to control signal transmission over a two-way radio telephone system in such manner as to improve the signal-to-noise ratio, reduce the effects of flat and selective fading, provide privacy and reduce singing and echo difficulties without the use of vodas switching devices or echo suppressors.

These objects are attained in accordance with the invention by the use of particular combinations of band splitting and spreading devices, tone and signal-controlled compressors and expanders, and tone-controlled variable loss devices at the terminals of the signal transmission system.

The various objects and features of the invention will be understood from the following detailed description when read in conjunction with the accompanying drawings in which Figs. 1 to 9 show diagrammatically various embodiments of the invention applied to the transmitting and receiving circuits at the terminals of a two-way radio telephone system.

The block diagram of Fig. 1 of the drawings shows the transmitting side of each terminal of a two-way radio telephone system embodying one form of the invention. It includes a band-splitting device, similar to the band-splitting privacy device of my Patent 2,132,205, issued October 4, 1938, modified to provide a slight spreading of the produced distorted subbands so as to allow room for insertion of a plurality of tones or pilot frequencies spaced throughout the band to be transmitted over the transmission medium along with the distorted signal subbands.

The band-splitting and spreading device as shown in Fig. 1 comprises five branches or channels, respectively identified by the characters A, B, C, D and E, having their inputs connected in parallel to a transmission circuit TW leading to the transmitter circuit TR of a telephone subscriber's station, and having their outputs connected in parallel to the transmitting circuit TC leading to a radio transmitter RT. Each of the branches or channels A, B, C and D includes in order, reading from left to right, a modulator M₁, a band-pass filter BF₁, a second band-pass filter BF₂ and a second modulator M₂. The fifth

branch or channel E includes in order, reading from left to right, an attenuation pad P₁ providing an attenuation loss in that channel equivalent to that produced in each of the other branches A to D by the modulator M₁, a band-pass filter BF₁, a second band-pass filter BF₂ and a modulator M₂.

Each of the filters BF₁ in the five channels A to E are identical band-pass filters transmitting the frequency band 2450-3000 cycles per second. Each of the modulators M₁ in the channels A to D and the modulators M₂ in the channels A to E are preferably of the known double-balanced copper-oxide type such as illustrated in the aforementioned patent. The carrier sources CS associated with the modulators M₁ in the channels A to D supply waves of constant frequency, 3250 cycles, 3800 cycles, 4350 cycles and 4900 cycles respectively, and the carrier sources CS associated with the modulator M₂ in the channels A to D and E respectively, supply waves of constant frequency; 3250, 3900, 4550, 5200 and 5850 cycles respectively. All of the carrier frequencies of the sources CS may be supplied by a tone generator of the inductor type as in the system of my aforementioned patent.

Also associated with each channel A to E at a point between the two band filters BF₁ is a switching circuit, indicated by a box labeled SW, the function of which is to connect the output of the first filter BF₁ in each channel to a second filter BF₂ in the same or any other channel directly or through an inverter, in order to scramble up the frequency bands selected by the preceding filters in the several channels in accordance with any one of a number of secret combinations, with or without inversion of frequency in the individual bands, in the manner described in my aforementioned patent.

Connected in parallel across the transmitting circuit TC between the outputs of the modulators M₂ in the channels A to E and the radio transmitter RT are the six constant frequency tone or pilot sources, T₁ to T₆ respectively, supplying waves of the frequencies 200, 850, 1500, 2150, 2800 and 3450 cycles, of fixed input amplitudes.

The transmitting terminal of Fig. 1 operates as follows:

Let it be assumed that speech waves having a frequency band of 250-3000 cycles are received over the circuit TW from a telephone subscriber, and are impressed on the inputs of the five channels A to E, the five channels dividing these waves into five equal energy portions each comprising all frequencies in the original voice frequency band, 250-3000 cycles.

The band of speech frequencies in channel E will be transmitted through the attenuation pad P₁ to the first filter BF₁ in that channel. The band of speech frequencies in the channel A will modulate in the modulator M₁ with the modulating frequency of 3250 cycles from the associated carrier source CS to produce combination waves the lower side-band of which will comprise the band of frequency components 3000-250 cycles of which the band filter BF₁ will select those in the range 3000-2450 cycles, which represent the frequency components from 250-800 cycles in the original speech band. Similarly, the bands of speech frequencies in the channels B to D will modulate in the modulators M₁ with the modulating frequencies of 3800, 4350 and 4900 cycles, respectively, supplied from the associated carrier sources CS to produce combination waves the lower side-bands of which are 3550-800

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cycles, 4100-1100 cycles and 4650-1900 cycles respectively. In each case, the band filter BF₁ passes the band 2450-3000 cycles. Thus the 2750-cycle range of the original speech band is divided into five 550-cycle portions, each of which has been shifted to occupy the common frequency range 2450-3000 cycles.

The selected subbands in the outputs of the first band filters BF₁ in the channels A to E are then interchanged by the switching circuits SW between the several channels in the manner described in my aforementioned patent and the rearranged frequency subbands are selected by the second set of band filters BF₂ in the respective channels in the output of that switching device. The selected waves are then impressed on the inputs of the second group of modulators M₂ to modulate therein with the carrier frequencies supplied by the associated carrier sources CS of the frequencies 3250 cycles, 3900 cycles, 4550 cycles and 5850 cycles respectively, to translate the five transposed subbands downward to adjacent positions in the frequency spectrum except for a separation of 100 cycles between the several subbands. The resulting waves in the output of the modulators M₂ are combined in the transmitting circuit TC with the six pilot tones of frequencies 200, 850, 1500, 2150 and 2800 and 3450 cycles from the tone sources T₁ to T₆, the frequencies of the six tones falling in the spaces between the separated distorted speech subbands due to the suitable selection of the carriers associated with the second group of modulators M₂. The combined waves are transmitted over the circuit TC to the radio transmitter RT which will radiate them to the receiving station of the system over the intervening radio link.

Fig. 2 shows one type of radio receiving terminal in accordance with the invention which could be used with the transmitting terminal of Fig. 1 at each station of a radio telephone system. As indicated, it comprises a common receiving circuit RC connected to the radio receiver RR, including the tone-operated vario-losser TVL₁, and a five-channel band-splitting and spreading arrangement identical with that used in the transmitting terminal of Fig. 1 as indicated by the use of similar identification characters for identifying the individual elements, but having the elements in these channels connected in reverse order, that is, the output of the receiving circuit RC feeding in parallel directly into the inputs of the modulators M₂ in the five channels A to E and the outputs of the modulators M₁ in the channels A to D, and of the attenuation pad P₁ in channel E, feeding in parallel to a common circuit TE leading to the receiving circuit R of the subscriber's station.

The tone-operated vario-losser TVL₁ may be of any desired type, for example, of the type illustrated comprising a vario-amplifier VA consisting of two three-electrode amplifying vacuum tubes connected in push-pull in the circuit RC, with a control condenser 1 shunted by a resistance 2 in the common portion of the control-grid cathode circuits of the tubes; and a backward-acting control circuit comprising in order a filter F₁ followed by a control rectifier R₁ which preferably is of the "trigger" type, the output of which is connected across the condenser 1 and parallel resistance 2 in the control grid-cathode circuits of the vario-amplifier tubes.

The combined distorted speech and tone waves received over the radio link from the transmitting terminal (Fig. 1) of one station are picked

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up and detected by the radio receiver RR of the receiving terminal (Fig. 2) of another station and pass to the vario-amplifier VA of vario-losser TVL₁, which will amplify them in accordance with its setting. The setting of VA is controlled by the tone waves of frequencies 200, 950, 1500, 2150, 2800 and 3450 cycles in the combined waves, which are selected by the filter F₁ in the backward-acting control circuit of TVL₁ and are rectified by the rectifier R₁. The rectified waves apply a charge to the condenser 1 which is proportional to the summation of the amplitudes of the tone frequencies passed by F₁ causing the control grid bias of the vario-amplifier tubes and thus the gain or loss of the receiving circuit RC to compensate for the effect of loss variations in the radio link on the transmitted signal waves; and to insert loss in the receiving circuit equivalent to the amount of gain inserted in the transmitting circuit at the other station to keep the radio transmitter loaded up to maintain the net loss constant to prevent singing, if the system is to be operated as a constant net loss system. The device TVL₁ acts as a flat loss regulator, the setting of which, because of the use of six tones, is not unduly influenced by the fading of one or more of the tones, thus producing better compensation than the usual carrier-controlled automatic volume control device. The signal waves passing from the output of the vario-amplifier VA to the following band-splitting and spreading device will, therefore, have substantially the same amplitude level as the original signal waves at the transmitting station.

The waves so controlled pass from the output of TVL₁ to the band-splitting and spreading arrangement in which they go through modulating and filtering and switching operations which are the reverse of those produced by the similar arrangement at the transmitting station, so as to restore the signals to the original frequency relations they had at the transmitting station, the restored signals being transmitted over the circuit TE to the receiver R of the listening subscriber. To accomplish this, the switching circuit SW in the band-splitting and spreading arrangement of the receiving terminal of Fig. 2 will have to be synchronized with the corresponding switching circuit SW of the transmitting terminal (Fig. 1) at the distant station controlling the setting up of the secret combinations, so that the former will set up the same combinations as set at the other station, and will operate in the manner which is the reverse of the latter so as to unscramble the secret combinations.

The alternative receiving terminal of Fig. 3 adapted for operation with a transmitting terminal of the type shown in Fig. 1 differs from that of Fig. 2 merely in the addition of an identical tone-operated vario-losser TVL₂ in each of the band-splitting channels A to E, the latter differing from the tone-operated vario-losser TVL₁ in the common receiving circuit RC, merely in that the backward-acting control of each employs in its input in place of the filter F₁, two parallel filters or selective circuits F₂ and F₃ passing the frequencies 2400 and 3050 cycles respectively, corresponding to the two tones immediately adjacent, one on each side of the transmitted distorted signal band, appearing as the difference products of modulation between the tones from the distant station and the carrier frequencies supplied to the modulators M₂. Thus 200 cycles from the radio receiver would modulate with 3250 cycles in the A band modu-

lator M_2 to give 3050 cycles, 800 cycles would give 2400 cycles, etc. The band filters BF_1 following these modulators pass the wider band 2400-3050 cycles. Thus the vario-lossers TVL_2 would be controlled by the summation of the amplitudes of the two tones adjacent to the band being controlled, giving a variable equalizer for selective fading, continuously adjusting. Such an equalizer could be used on any radio channel, whether operated constant volume or constant net loss.

Another alternative receiving arrangement which could be used with the transmitting terminal of the type shown in Fig. 1 would be the same as shown in Fig. 3 with the elimination of the tone-operated vario-losser TVL_1 in the common receiving channel RC, in which case the range of adjustment of the vario-lossers in the band-splitting channels would be made great enough to take care of flat as well as selective fading.

These three receiving arrangements have a common purpose, i. e., to compensate for the variations in transmission of the radio link. The tones from the transmitting end are sent at constant amplitude, independent of talker volume, and any change in tone amplitude at the receiving end and consequently the loss adjustments of the vario-lossers are related to radio circuit variations. For this reason, these three arrangements could be used on a circuit whether operated on a constant volume or constant net loss basis; they result in holding the circuit loss from the point where the tones are applied ahead of the transmitter to the output of the vario-lossers at a constant value.

One of the difficulties associated with adding tones on top of the speech already present in the system is cross-modulation in the radio transmitter. In a system employing the transmitting arrangement of Fig. 1 and the receiving arrangement of Fig. 2 or 3, the radio link would be stabilized in loss so that a 2:1 voice-operated compandor comprising a 2:1 voice-operated compressor VOC at the transmitting end in front of the band-splitting and spreading arrangement and a 1:2 voice-operated expander VOE in the output of the band-splitting and spreading arrangement at the receiving terminal, could be added, as indicated diagrammatically in Fig. 4. The voice-operated compressor and expander used may be of any of the well-known types, for example, such as disclosed in Norwine Patent 2,164,344, issued July 4, 1937, or in Doba Patent 2,018,489, issued October 22, 1936. This would give some 20 decibel cross-talk reduction as well as an improvement from the standpoint of reduction in the effects of radio noise. A higher ratio compandor would give more improvement with some added difficulty in design and, of course, more expansion of residual variations in loss of the radio link.

Another alternative system is illustrated diagrammatically in Fig. 5. It employs the transmitter arrangement of Fig. 1 including the band-splitting and spreading arrangement and the multitone transmitting arrangement, an added tone source T_1 generating a constant amplitude wave of some frequency f different from that of the other tones for which frequency space would be provided by suitable spreading of the subbands in the transmitting arrangement, connected across the common circuit TC at a point in front of the transmitting arrangement, and an intermediate voice-operated compressor VOC

having a filter F_4 for eliminating the tone frequency f , in the input of its rectifier control circuit, and operating with this a receiving terminal including the receiving arrangement of Fig. 2 or 3 followed by a volume range expander TOE_1 transmitting both the restored voice waves and the received tone, controlled by a backward-acting rectifier control circuit having in its input a filter F_5 passing only the frequency f , so as to be operated only by the added control tone of frequency f transmitted from the transmitting station, in such a way as to keep the tone output of TOE_1 constant. This interlocks the compressor and expander, perhaps making possible the use of a higher ratio compressor and reducing the difficulty of designing the expander. If a 5:1 compandor comprising a voice-operated 5:1 compressor at the transmitting station and a reciprocal 1:5 voice or tone-operated expander at the receiving station in accordance with the arrangement of Fig. 4, or Fig. 5 revised, then the transmitter could be loaded as fully as by a transmitting vogad. This latter combination could be used for a constant net loss circuit, without requiring the addition of vodas switching circuits to prevent singing, as the loss through the compressor, radio circuit and expander can be kept constant.

Fig. 6 shows diagrammatically an alternative system similar to those discussed above in connection with Figs. 4 and 5 except that the functions of compandor and flat regulator are combined. This system includes at the transmitting terminal a band-splitting and spreading arrangement followed by an arrangement for adding six control tones within the frequency space left by the spreading of the distorted signal subbands, such as is illustrated in Fig. 1. The distorted subbands and six tones combined in TC are transmitted through a voice-operated volume range compressor VOC_2 including a filter F_6 in its backward-acting rectifier control circuit for eliminating the control tones, so that the loss of the compressor is controlled by speech energy only. In this system, the receiving arrangement is like that illustrated in Fig. 2 in which the vario-losser in the common receiving path in front of the restoring band-splitting and spreading arrangement is controlled by the sum of the received six tones, with speech excluded from the vario-losser control circuit, this receiving arrangement being provided with sufficient range to care for fading also. In such a system, selective fading of one tone would not cause undue expansion. If the applied compressor has a 2:1 ratio, this arrangement could be applied to present constant volume radio telephone circuits. It could, of course, be used in a constant net loss circuit, but if only a 2:1 compressor is used without auxiliary transmitting gain adjustment, the transmitter is not as fully loaded by weak talkers as is desirable.

Another possible alternative arrangement is to use a higher ratio (say 5:1) compandor with constant net loss operation. The higher the ratio, the lower the amplitude of the interlocking tones when the compressor is putting in loss. For a 5:1 ratio, it might be necessary, as illustrated in Fig. 7 to send the speech signals distorted by a band-splitting and spreading arrangement like that of Fig. 1, through a voice-operated compressor VOC_3 employing two equivalent vario-losser pads VL_1 and VL_2 in tandem in the transmitting circuit TC controlled in parallel by the rectified speech energy of the same backward-

acting rectifier control circuit, and to send the six tones generated by the sources T_1 to T_6 through the second vario-losser pad VL_2 controlled by the same rectified speech energy, so that the transmitted tones vary over half the range in decibels that the loss in the voice band undergoes. By this means, the tone amplitudes will not fall so low in the radio transmission path, facilitating the separation of the tones from static and radio noises at the receiving end, and preventing these noises from interfering with the loss adjustments. In the compressor VOC_3 , the tones are excluded from the control circuit by the filter F_7 . At the receiving terminal of Fig. 7, both the received tone and distorted speech signal pass from the radio receiver through a tone expander TOE_2 comprising two equivalent vario-lossers VL_3 and VL_4 in tandem in the receiving circuit RC , controlled in parallel by a backward-acting rectifier control circuit the input of which is taken off from the receiving circuit RC at a point between the two vario-losser pads, and which by a filter F_8 in its input is made selective to the received control tones only, to keep the tone output constant and restore the 5:1 range to the voice signals. The resulting waves are then transmitted through a band-splitting and spreading arrangement like that at the transmitting terminal but operating in reverse manner, such as shown in the receiving terminal of Fig. 2, to restore the received speech waves to the relative signal frequency relations they had at the transmitting terminal.

Alternative arrangements of the system of Figs. 6 and 7 would employ at the receiving terminal in addition to the flat expander in the common circuit, expanders in the individual sub-band channels, controlled separately by the sum of the two tones immediately adjacent to the particular signal band transmitted, one on each side, similar to the arrangements employed in the individual channels of the receiving terminal of Fig. 3. In this case, the common expander would follow the compressor and would also correct for the flat loss variations in the radio path, and the individual expanders would correct for selective fading.

It will be seen, then, that by using high ratio (5:1) compressors, the transmitter is loaded substantially as well as by ordinary gain adjustment methods, and by interlocking the compressors and expanders by tones the possibility of singing is obviated without recourse to vodases or echo suppressors. So therefore, the loss of the entire circuit can be held to a constant low value, and by combining two such one-way paths with well-known hybrid coil circuits, an equivalent two-way circuit of constant net loss can be achieved having all of the noise reduction advantages of so-called constant volume operation with none of the resultant disadvantages due to lock-out and clipping.

The arrangements described above employing a compressor common to all subbands have the disadvantage that gain is introduced in the expander at all frequencies when the speech energy may be mainly in one subband. A system having a transmitting terminal such as illustrated in Fig. 8 and a receiving terminal such as illustrated in Fig. 9 will not have these disadvantages.

The radio transmitting terminal of Fig. 8 differs from that of Fig. 1 in the following particulars. A modulator M_1 is employed in the input of each channel including channel E. Carrier

frequencies of 4050, 4600, 5150, 5700 and 6250 cycles are respectively applied by the carrier sources CS to the modulators M_1 in the channels A to E, to modulate respectively with the five energy portions of the voice signaling band supplied to the inputs of the respective modulators to respectively different higher positions in the voice frequency spectrum with a frequency sub-band, 3250 to 3800 cycles, in common, which is selected by the two band filters BF_1 in the output of the modulator M_1 in each channel. Carrier frequencies of 4050, 4800, 5550, 6300 and 7050 cycles are respectively applied to the modulators M_2 in the output portions of the corresponding channels to modulate with the distorted voice subbands passed by the second band filter BF_1 in the channel, to shift these subbands to adjacent lower positions in the frequency spectrum, spread sufficiently to allow room for the insertion of ten different pilot tone frequencies, one on each side of each of the adjacent subbands. The constant amplitude pilot frequencies 3200 and 3850 cycles are applied to each channel from the tone sources T_7 and T_8 , two of which are connected in parallel across each channel in the output of the second band filter BF_1 as indicated. An individual voice-operated volume range compressor, identified as VOC_5 , is connected in each channel A to E between the point of connection of tone sources T_7 and T_8 thereto and the input of the modulator M_2 in the channel, each compressor containing in the input of its rectifier control circuit a filter F_9 designed to suppress the frequencies 3200 and 3850 cycles corresponding to those of the tone sources connected to the channel while passing other voice frequencies.

The receiving terminal of Fig. 9 includes a five-channel band-splitting and spreading arrangement like the arrangement of Fig. 8 but with the elements in each channel connected in reverse order as in the receiving terminal of Fig. 2, operating to take the distorted signals received from the transmitting terminal of a distant station, corresponding to Fig. 8, picked up in and detected by the radio receiver RR , and to produce the required modulating, filtering and switching operations to restore them to the frequency relations which they had at the transmitting terminal prior to their distortion. Each channel A to E of the band-splitting and spreading arrangement of Fig. 9 includes between its two band filters BF_1 , the first of which selects the frequency band 3200 to 3850 cycles, and the second of which selects the band 3250 to 3800 cycles, an individual volume range expander TOE_3 , which, because of the connection of a suitable filter F_{10} in the input of its backward-acting rectifier control circuit, adapted only to pass the frequencies corresponding to the two tone frequencies 3200 and 3850 cycles applied to the corresponding channels at the distant transmitting terminal (like Fig. 8) is controlled only by the rectified tones of those frequencies in accordance with the variations encountered by those particular tones in transmission over the radio link, so as to produce an expansion in the received signals which is equal to the compression supplied by the compressor in the corresponding channel at the transmitting terminal. Thus by using a separate compressor and expander for each subband, gain is added only in the subbands carrying speech. This will give added improvement in signal-to-noise ratio, and some reduction of the "hush-hush" effect. It is apparent that in this arrangement the twin vario-

losser arrangements of Fig. 7 could be used, so that the amplitudes of the control tones would vary only half as much as the amplitudes of speech.

If in the system of Figs. 8 and 9 the carrier frequencies are so selected as to spread the subbands by the width of one subband, and if the frequency allocations are staggered in the two channels (upper and lower radio side-band), then this arrangement will provide the added advantage, that the third order modulation products involving upper side-band and carrier fall in blank spaces in the lower side-band, and vice versa.

In the systems as described above, the employment of several tones always present in the radio link makes other uses possible. For example, the tones may be used for transmitting telegraph signals when speech is not present. If the circuit is set up to carry a plurality of tones for the above-described purposes, one or two more may be added for telegraph purposes, or for combination switching in the privacy system.

It will be noted that a crack of radio noise falling in the frequency space occupied by one of the control tones will usually tend to increase the circuit loss rather than to decrease it; this will tend to reduce singing difficulties in constant net loss circuits.

Various other modifications of the circuits illustrated and described which are within the spirit and scope of the invention will be apparent to persons skilled in the art.

What is claimed is:

1. A signal wave transmission system comprising a transmitting station and a receiving station connected by a variable transmission medium, said transmitting station including means to transform a signal wave comprising a band of frequency components into a plurality of different frequency subbands the frequencies of which respectively represent the component frequencies in different frequency ranges within said band of signal frequencies, said subbands being slightly separated from each other in the frequency spectrum and means to combine and transmit to said medium said subbands along with a plurality of fixed input amplitude tone waves of different frequencies spaced between those of said subbands, said receiving station including means controlled by the tone waves received over said medium from the transmitting station for inserting in the path of the received signal waves a loss varying in accordance with the summation of the amplitudes of the received tone waves to compensate for the effect of variations in said medium on the transmitted signal waves, means to separate the signal subbands in the compensated wave, and means for producing transformations in said subbands which are the reverse of those at the transmitting station to reproduce the original signal wave.

2. A signal wave transmission system comprising stations connected by a variable wave transmission medium, at least one of said stations including means for dividing a wave of a band of frequency components representing signals into a plurality of equal energy portions each containing said band of components, frequency shifting and filtering means operating to transform said energy portions into an equal number of frequency subbands the frequencies of which respectively represent the component frequencies in different frequency ranges within the original signal frequency band, said subbands respectively

occupying a different separated position in the frequency spectrum, and means to combine and transmit to said medium said subbands along with a plurality of fixed input amplitude tones of frequencies spaced between those of said subbands, the other of said stations including means to insert into the path of the received waves a loss which varies in accordance with the summation of the amplitudes of the received tones only to compensate for the effect of variations in said medium on the transmitted signal waves, means to divide the compensated signal wave into the same number of equal energy portions as the original signal wave was divided at the transmitting station, and frequency shifting and filtering means operating on the divided energy portions in a manner which is the reverse of that at the transmitting station to reproduce the original signal wave.

3. A signal transmission system comprising stations connected by a variable signal transmission medium, each of said stations comprising a transmitting and a receiving circuit, said transmitting circuit including means for dividing a wave of a band of signal frequency components representing a message into a plurality of equal energy portions, each comprising said band of frequencies, modulating means for shifting the frequency of the band in the several energy portions so that each shifted band occupies a different position in the frequency spectrum with a certain frequency range in common to all the shifted bands, filtering means for selecting from each of the shifted bands a subband within said common frequency range, other modulating means for shifting the selected subbands to different, slightly separated adjacent positions in the frequency spectrum, a plurality of sources generating fixed input amplitude tone waves of different frequencies lying between those of the separated signal frequency subbands and means for superposing and transmitting to said medium said separated frequency subbands and tone waves from said sources, said receiving circuit comprising means for receiving and detecting the signals and tones transmitted from the other station, means controlled by the received tones for inserting in the path of the detected waves a loss varying in accordance with the summation of the amplitudes of the received tones to compensate for the effects of variations of said transmission medium on the transmitted signal waves, and means to reproduce the original signal wave from the compensated wave.

4. The system of claim 3, in which the last-mentioned means comprises means for dividing the compensated wave into the same number of equal energy portions as produced in the original signal wave in the transmitting circuit of the other station, each including the same band of frequencies, and modulating, filtering and combining means corresponding to those used in the transmitting circuit of the other station but operating in reverse manner on the divided energy portions to produce a wave having the same frequency relations as the original signal wave at the transmitting station.

5. The combination of claim 2, in which said system is a two-way radio signal transmission system, said variable transmission medium is the radio link therein, said other station includes means controlled by the received tone waves for inserting a loss into each of the individual paths of the several divided signal energy portions, which is proportional to the summation of the amplitudes of two tones of frequencies adjacent

to the band being controlled, one on each side, appearing in said paths as products of modulation in the frequency shifting operation therein due to the applied tones received from the transmitting station, to compensate for the effects on the transmitted signal wave of selective fading conditions in said radio link, the loss inserted in the path of the received signal wave prior to its division, controlled by said received tones operating to compensate for flat fading variations in said radio link.

6. The system of claim 2, in which said transmitting station includes a signal-operated compressor for compressing the volume range of the combined signal subbands and said plurality of fixed amplitude tones before transmitting them to said medium.

7. The system of claim 2, in which said transmitting station includes a signal-operated compressor operating to produce a given amount of compression in the volume range of the shifted frequency signal portions, and for producing compression of said fixed input amplitude tones to half the volume range in decibels of the compressed signal waves, before transmitting them to said medium, and said receiving station includes a tone-operated expander for expanding the volume range of the received signal wave prior to dividing it into equal energy portions, in the same ratio in which it was compressed at the transmitting station.

8. A signal wave transmitting system comprising a transmitting station and a receiving station connected by a variable radio link, said transmitting station comprising a plurality of transmitting channels each supplied with the band of frequencies of the signal wave to be transmitted, modulating and filtering means in said transmitting channels for transforming the supplied signal frequency band into an equal number of narrow bands the frequencies of which respectively represent the frequencies in different frequency ranges in said signal frequency band, said narrow bands respectively occupying a different separated position in the frequency spectrum, and means to transmit said narrow bands together with a plurality of constant input amplitude tone of frequencies spaced between those of the separated narrow bands to said medium for transmission thereover, said receiving station comprising means for detecting the signal and tone waves received over said medium, the same number of receiving channels as there are transmitting channels at the transmitting station, each supplied with the detected waves, modulating and filtering means in each of said receiving channels for respectively producing transformations in the supplied distorted signal waves which are the reverse of those produced in the corresponding transmitting channel at the transmitting station on the original signal wave, to reproduce the frequencies in a respectively different frequency range of the original signal wave, means for inserting a loss in each of said receiving channels which is proportional to the sum of the amplitudes of two tones of frequencies adjacent to the applied distorted signal band, one on each side, appearing in the channel as modulation products of the modulating operation in that channel, to compensate for variable conditions in said transmission medium, and means for superposing the resulting compensated signal bands on a common circuit to reproduce the original signal wave.

9. A signal wave transmission system compris-

ing a transmitting station and a receiving station connected by a variable transmission medium, said transmitting station including a plurality of transmitting channels each supplied with the frequency band of the signal wave to be transmitted, the channels including modulating and filtering means for transforming the supplied band into the same member of relatively narrow bands of the same width but of different frequencies, slightly separated from each other in the frequency spectrum, the frequencies in the respective narrow bands representing the frequencies in different frequency ranges within the original signal frequency band, individual signal controlled wave compressors in said transmitting channels for respectively compressing the volume range of different ones of the narrow bands produced in said channels, and means for superposing in a common circuit and transmitting to said medium the compressed narrow signal bands along with a plurality of tone waves of different frequencies spaced between those of said separated narrow bands, said receiving station comprising means for detecting the receiving narrow frequency bands and tone waves, the same number of receiving channels as there are transmitting channels at the transmitting station, each supplied with the detected signal and tone waves, other modulating and filtering means in each of said receiving channels for respectively producing transformations in the supplied signal waves which are the reverse of those produced in the original signal band in the corresponding transmitting channel of the transmitting station, to respectively reproduce the frequencies in a different subband within the original signal frequency band, an individual tone controlled expander in each receiving channel for respectively expanding the volume range of the signal waves transmitted thereover to restore the original amplitude relations in the reproduced original signal subband, and means for superposing all of the expanded signal subbands in a common circuit to reproduce the original signal wave.

10. The system of claim 9, in which the transformation of the original signal band in the transmitting channels of the transmitting station to produce said separated narrow frequency bands, includes a preliminary modulating step to shift the frequency of the original signal band in each of said transmitting channels so that each shifted band occupies a different position in the frequency spectrum with a certain frequency range in common to all the shifted bands, and a filtering step to select from each shifted band the same frequency band within said certain range, followed by a second modulation step, said plurality of tone waves of different frequencies spaced between those of said separated narrow bands, transmitted to said medium, being modulation products produced by applying to each of the transmitting channels in front of the modulating means for said second step, two constant amplitude input tones of frequencies, which are the same for each channel, adjacent said same frequency band, one on each side thereof, selected in said filtering step, said individual expanders in the receiving channel at the receiving station being controlled by the summation of the amplitudes of two tone waves of frequencies corresponding to those of said two tones, appearing as modulation products in each of said receiving channels and selected therefrom.

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