Sept. 12, 1939. R. S. CARUTHERS 2,172,832

CARRIER CURRENT TRANSMISSION SYSTEM

Filed Sept. 28, 1938

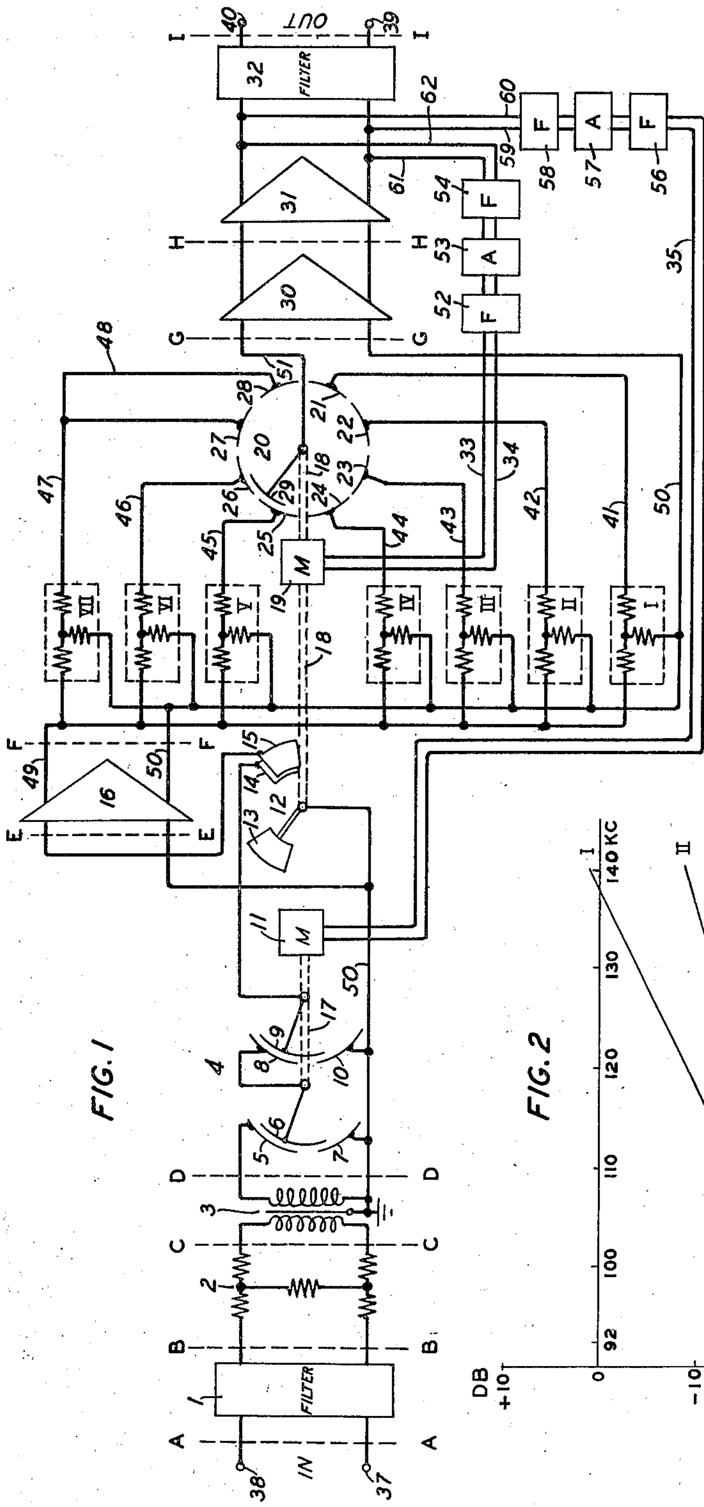

FIG. 1

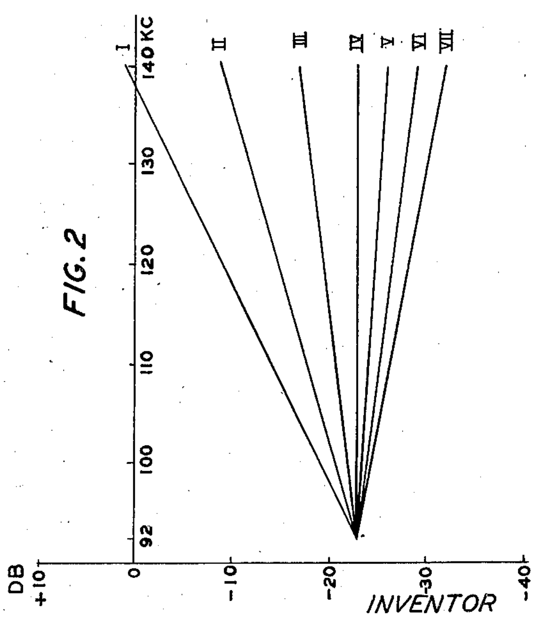

FIG. 2

FIG. 3

TABLE OF TRANSMISSION LEVELS

	A-A	B-B	C-C	D-D	E-E	F-F	G-G	H-H	I-I	
1	-4	-11	-21	+1	-46	-25	-48	-44	0	92 KC
	-5	-12	-22	0	-47	-26	-57	-53	0	140KC
2	-28	-35	-45	-23	-46	-25	-48	-44	0	92KC
	-35	-42	-52	-30	-53	-32	-57	-53	0	140KC
3	-40	-47	-57	-35	-46	-25	-48	-44	0	92KC
	-5	-12	-22	0	-11	+10	-22	-18	+35	140KC
4	-40	-47	-57	-35	-81	-60	-83	-79	-35	92KC
	-5	-12	-22	0	-46	-25	-57	-53	0	140KC

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Patented Sept. 12, 1939

2,172,832

UNITED STATES PATENT OFFICE

2,172,832

CARRIER CURRENT TRANSMISSION SYSTEM

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Application September 28, 1938, Serial No. 232,095

10 Claims. (Cl. 178—44)

This invention relates to carrier current transmission systems and more particularly to the regulation of such systems especially those involving a considerable number of telephone transmissions. At carrier frequencies the line losses and the variations in these losses with weather are considerably greater than at voice frequencies, and in general these effects increase as the frequency of the carrier is increased. When, therefore, a carrier system includes a considerable number of separate transmissions and thus a considerable frequency spread, and when, moreover, such a system includes an open-wire transmission line which is subject to rain, snow and sleet conditions, as well as change in temperature, it becomes necessary to make rather elaborate provisions, for the maintenance of the desired transmission levels at all frequencies.

It is an object of this invention to provide means whereby the whole carrier transmission may be automatically maintained at a predetermined level.

A further object is to provide means for automatically compensating for frequency discriminative variations in attenuation under abnormal weather conditions.

An additional object is to provide a means by which under abnormal frequency discriminative attenuation on a wide band carrier transmission amplifier overload is prevented.

Another object is to provide an amplifier in which the high frequency gain may be regulated without change in the low frequency gain.

When a considerable number of carrier transmissions are to be transmitted over a transmission line, as for example, an open-wire telephone or telegraph line, so that the frequencies transmitted cover an extensive range, it is a usual practice to provide automatic regulations so that the received transmission levels will remain substantially constant in spite of variations in circuit attenuation. Such variations will result from temperature changes and more particularly in the case of open-wire lines will be brought about by exposure to such other weather conditions as fog, rain, snow and sleet. These variations in attenuation may be classified as (1) those in which the average attenuation over the whole transmitted band of frequencies is changed and (2) those in which the attenuation change is discriminative as to transmitted frequency. In general, it may be said that a given change in weather conditions will produce a greater change in line attenuation for the upper frequencies than for lower ones.

A good method for compensating for these two classes of attenuation change has been found to be the provision of two separate compensators, (1) a "flat" compensator which effects an amplification change which is flat or non-discriminative with respect to frequency and (2) a "twist" or "slope" compensator which may be designed to effect greater amplification changes at the upper than at the lower frequencies or it may be designed to effect greater changes at the lower than at the upper frequencies. Such compensators may be associated with one or more of the amplifiers or repeaters which form a part of the transmission system and may be automatically operated by means of pilot transmissions. Thus a pilot transmission at a frequency at the lower edge of the transmitted band may be sent over the circuit, picked off at a convenient point or points, rectified and the rectified current employed to operate a motor geared or otherwise coupled to the appropriate compensator which may be a potentiometer, an attenuator or other means for changing gain in equal amounts at all frequencies. A convenient arrangement involves picking off the pilot transmission at the output of an amplifier and using the rectified-current-supplied motor-driven compensator to effect a change in the gain and thus the output level of that amplifier at the frequency of the pilot transmission until a specified level is reached. The flat compensator is then properly set.

In like manner, a second pilot transmission at a frequency at the upper edge of the transmitted band may be employed to set the slope or twist compensator. This general method employing two pilots is disclosed in patent to K. C. Black 2,019,594, November 5, 1935, and another use of flat and twist or slope compensators is disclosed in F. A. Brooks Patent 2,075,975, April 6, 1937. My invention incorporates various improvements in the regulation of board band carrier transmission systems, including means whereby the setting for each pilot transmission is substantially independent of the adjustment of the other, also means for the prevention of amplifier overload in the case of abnormal line attenuations, and various features inter-related thereto. For a more complete understanding of these matters, reference is made to the detailed description taken together with the drawing in which:

Fig. 1 shows a schematic diagram of a regulating repeater circuit according to the invention;

Fig. 2 illustrates the attenuation frequency characteristics of the networks which may be employed in a slope regulator, and

Fig. 3 is a table in which are tabulated figures illustrative of the method of functioning of the circuit of Fig. 1.

Before proceeding with a detailed description, it should be noted that Fig. 1 shows a one-way repeater circuit for insertion in a multiplex line at an intermediate repeater point, and that this repeater comprises an amplifier of three sections in tandem, viz., 16, 30 and 31 connected between the directional filters 1 and 32 with gain control means partly ahead of the amplifier and partly between sections 16 and 30.

Fig. 1 may be considered to represent diagrammatically a means of practicing the invention by the employment of a special repeater designed particularly to provide regulation to compensate for severe weather conditions. Its input terminals 37, 38 are connected to a receiving directive filter 1. This filter for purposes of illustration may be assumed to pass a band of frequencies including a lower limiting frequency of 92 kilocycles and an upper limiting frequency of 140 kilocycles.

The receiving directive filter 1 may be assumed to pass the band 92 kilocycles to 140 kilocycles with a uniform attenuation of 7 decibels and substantially prevent the passage of all other frequencies. The output of filter 1 is connected to 10-decibel pad 2 which provides a constant impedance for the termination of filter 1 and transformer 3. Thus transformer 3 which may have an impedance of 125:20,000, presents a comparatively high impedance substantially independent of frequency against which the double potentiometer 4 may function. An impedance ratio of 125:20,000 represents a voltage step-up of approximately 22 decibels.

The potentiometer 4 consists of two three-plate condensers in tandem, the combination arranged to function in the manner of a single three-plate condenser as used and discussed in the patents to Anderson et al. 2,106,336, January 25, 1938, and C. R. Eckberg, 2,115,141, April 26, 1938. The first condenser comprises fixed plates 5, 7 and movable plate 6 and is so designed that the sum of the capacity between plates 5 and 6 and the capacity between plates 7 and 6 is a constant for any position of the movable plate 6. The second condenser comprises fixed plates 8, 10 and movable plate 9 and is so designed that the sum of the capacity between plates 8 and 9 and the capacity between plates 10 and 9 has a constant value for any position of movable plate 9. Each condenser performs as a potentiometer having an infinite number of steps and by the tandem connection shown, structural advantages accrue such as small capacity values combined with rugged construction.

It may be observed that since the line voltage, incoming through filter 1 and pad 2 and stepped up through transformer 3, appears, looking to the left at D—D, as across a substantially pure resistance, the condenser 4, which preferably should have an impedance which is large in comparison with said resistance, functions as a potentiometer which is substantially flat with frequency when operating into the grid circuit of amplifier 16. The condenser type potentiometer is operated through the drive shaft 17 by the pilot motor control 11, and in a preferred embodiment may cause attenuation of minimum 6 decibels, maximum 47 decibels.

In series with the condenser potentiometer 4 and the grid circuit of amplifier 16 is the condenser 12 comprising the fixed plates 14, 15 and the movable plate 13. Condenser 12 is operated by pilot motor control 19 through drive shaft 18 which is extended to operate multiplate condenser 20. In the shown position, movable plate 13 of condenser 12 is out of mesh with stationary plates 14 and 15 and the direct capacity between plates 14 and 15 is of such a value as to constitute negligible loss in the connection between condenser potentiometer 4 and the grid circuit of amplifier 16 in view of the high impedance of the said grid circuit. When, however, movable plate 13 is operated so as to mesh between stationary plates 14 and 15, it functions to shield plate 14 from plate 15 thereby reducing the direct capacity between them and at the same time introducing a direct capacity to ground through lead 50 from each stationary plate respectively. Thus, for that portion of the motion of movable plate 13 in which it is meshed to a greater or less degree between stationary plates 14 and 15, condenser 12 constitutes a variable network of Π section as disclosed in E. B. Payne Patent 2,075,957, April 6, 1937, and is there demonstrated under the conditions shown to constitute a flat attenuator, that is, free from frequency discrimination.

The condenser 20 is a multielectrode or multiplate condenser, which may have a large number of stationary plates or electrodes. In the shown embodiment there are eight stationary plates, 21, 22, 23, 24, 25, 26, 27, 28 and a single movable electrode 29. The fixed plates are shown as arcs of a circle concentric with the circle of which the movable plate 29 is an arc. In practice, these plates would take the form of one or more circular sectors as is common in variable air condensers. If desired, either the fixed plates or the movable plates, or both, may be specially shaped in order to produce a desired relation between angular movement of the movable plate and change in electrostatic capacity. In case condenser 20 is constructed with eight fixed plates, each plate would occupy approximately 45 degrees of arc and the movable plate 29 would also preferably in this case span approximately 45 degrees of arc.

It should be noted that the coupling between condensers 12 and 20 by means of drive shaft 18 is so phased that movable plate 13 of condenser 12 is in a position of maximum coupling or full mesh with stationary plates 14, 15 for that position of shaft 18 which brings movable plate 29 of condenser 20 into maximum coupling or full mesh with stationary plate 28, and thus, if the condenser 20 has eight fixed electrodes as shown, the plates 13, 14, 15 of condenser 12 will preferably each span approximately 45 degrees of arc.

The output of amplifier 16 which may be designed to have a fixed gain of 21 decibels is shown connected by leads 49, 50 to networks I to VII in parallel. These networks may be T sections as shown but will ordinarily contain a plurality of both reactive and non-reactive components, and thus the attenuation through them will vary with frequency.

The series of networks shown are assumed to be so designed as to have equal attenuation for the lowest frequency of the band to be transmitted, for example, 92 kilocycles and to have an attenuation which departs increasingly from the low frequency or 92 kilocycles attenuation as the frequency is increased up to the highest band frequency, for example 140 kilocycles. Moreover, the series of networks is so designed with respect to each other that the amount of said departure at a given frequency changes progressively from network to network throughout the series. This condition is illustrated by the curves of Fig. 2, in which, whereas all networks are shown to have an attenuation of 23 decibels at 92 kilocycles, network I has at 140 kilocycles an attenuation of −1 decibel, network II +10 decibels, network III +18 decibels, network IV +24 decibels, network V +27 decibels, network VI +30 decibels and network VII +33 decibels. The curves of Fig. 2 are plotted in terms of the algebraic change in transmission level at the various frequencies in passing through the respective networks.

The outputs of the several networks I to VII are connected to the stationary electrodes 21 to 27, respectively, of the multielectrode condenser 20, and thus the condenser 20 functions as a combined coupler and potentiometer such that any characteristic of frequency discrimination between that represented by network I and that represented by network VII may be inserted by an appropriate setting of the movable electrode 29. This general method for obtaining intermediate characteristics was disclosed in Eckberg, supra, as applied to a single network and as extended to two or more networks in R. W. Chesnut Patent 2,049,195, July 23, 1936.

It is apparent that the combination of the networks I to VII with the condenser 20, the movable electrode of which is connected by lead 51 to the grid circuit of amplifier 30, constitutes a twist or slope compensator which, properly motivated, is capable of inserting a regulatory effect of any required characteristic between that of curve I and that of curve VII of Fig. 2.

The amplifier 30 is fundamentally a part of the slope compensator circuit, is inserted to provide a high impedance termination to the multielectrode condenser coupler 20, and may have a net gain of 4 decibels.

Amplifier 31 contributes the main amplification of the repeater. It may be of the feedback type disclosed in H. S. Black Patent 2,102,671, December 21, 1937, having a frequency discriminative element in its feedback or β circuit (not shown). Thus it may produce a gain of 44 decibels at 92 kilocycles and 53 decibels at 140 kilocycles.

The transmitting directive filter 32 may be designed to pass the band 92 kilocycles to 140 kilocycles and may be assumed to have negligible attenuation throughout the band.

It is assumed that 92-kilocycle and 140-kilocycle pilots are picked off the circuit at the output of the amplifier 31. The 92-kilocycle wave is carried by leads 59, 60 to 92-kilocycle selective filter 58, thence to amplifier-rectifier 57 and smoothing filter 56 and so by leads 35, 36 to pilot motor control 11. Similarly the 140-kilocycle wave is carried by leads 61, 62 to 140-kilocycle selective filter 54, thence to amplifier-rectifier 53 and smoothing filter 52 and so by leads 33, 34 to pilot motor control 19. For the sake of simplicity the details of the various selective, amplifying and rectifying circuits and the details of the motor drive have been omitted, since the general practice of pilot control is old and well known to those skilled in the art, capable of accomplishment in various ways, and no novelty in the means of securing pilot operation of control devices is claimed in this invention.

The operation of a regulating repeater according to the invention as employed for the compensation of variations in weather conditions on an open-wire line carrying a broad band of carrier transmission in accordance with a preferred embodiment as shown in simplified diagram in Fig. 1 may be clarified by a consideration of its operation under a number of assumed typical line and weather conditions.

For the purposes of illustration it is assumed that the line in question is equipped with a plurality of repeaters spaced at appropriate intervals throughout its length, that one or more of said repeaters may be specifically designed to compensate for severe variations in weather conditions, of which special repeaters, the repeater of Fig. 1, may be assumed to be illustrative, and that the general theory of operation of the system is based on the proposition that the output transmission level at a repeater point shall have been adjusted through, or by reason of, the repeater equipment, to a predetermined value, said value being identical for all frequencies. This state of transmission levels may, under practical conditions, not be precisely achieved in every case but, it may be assumed to be an intrinsic basis of repeater design. Thus, by way of illustration, it may be assumed that under ideal conditions, repeater output will be at zero level at all frequencies and hence repeater input level at each frequency will represent the attenuation produced at the particular frequency by the section of line following the last preceding repeater.

The general procedure of compensation to be described comprises adjusting potentiometer 4 under the control of the 92-kilocycle pilot to give the proper output level at the 92-kilocycle frequency and regulating the interstage compensator between stages 16 and 30 to give the proper slope over the 92 to 140-kilocycle band under the control of the 140-kilocycle pilot.

Referring to the table of Fig. 3, row 1 may be assumed to present a typical state of the repeater when used on a short dry line, that is, on a line on which the distance to the next preceding repeater is comparatively short, the line being for that distance assumed to be surrounded by an atmosphere of low relative humidity. Thus, let input level at A—A be at 92 kilocycles, −4 decibels and at 140 kilocycles, −5 decibels. Having passed through receiving selective filter 1, these levels are reduced at B—B to −11 decibels and −12 decibels, respectively, are by the pad 2 reduced at C—C to −21 decibels and −22 decibels, respectively, and by reason of the voltage step-up of the transformer 3 appear at D—D at levels of +1 decibel and zero respectively. This is a high level for the input to condenser potentiometer 4 and the low frequency 92-kilocycle pilot actuates the pilot motor control 11 to cut in a flat loss of 47 decibels, the greatest loss of which potentiometer 4 is capable. No loss is assumed to have been introduced by condenser 12 and thus the level at E—E becomes −46 decibels at 92 kilocycles and −47 decibels at 140 kilocycles, which is reduced by amplifier 16 to values at F—F of −25 decibels and −26 decibels. In passing through the slope compensator comprising the networks I to VII and the multielectrode coupler 20, the level at 92 kilocycles is reduced by the minimum attenuation of the slope compensator, i. e., 23 decibels to a level of −48 decibels at G—G whereas the 140-kilocycle pilot causes the operation of pilot motor control 19 to position movable electrode 29 at a point intermediate between full coupling with fixed electrode 26 and full coupling with fixed electrode 27 so that an attenuation of 31 decibels at 140 kilocycles is introduced thus bringing the 140 kilocycles level at G—G to −57 decibels. The amplifier **30** introduces a flat gain of 4 decibels thus raising the level at H—H to −44 decibels at 92 kilocycles and −53 decibels at 140 kilocycles, and in sequence the feedback amplifier **31**, adding its gain of 44 decibels at 92 kilocycles and 53 decibels at 140 kilocycles brings the repeater output at I—I to zero level for all frequencies since, as noted above, the transmitting selective filter **32** is assumed to introduce no loss.

Row **2** of the table of Fig. 3 illustrates the adjustments which might be found in the repeater of Fig. 1 when used in sequence to a long wet section of line. In this case the incoming levels might be −28 decibels at 92 kilocycles and −35 decibels at 140 kilocycles which are reduced to −23 decibels and −30 decibels at D—D the input to the flat compensator. This compensator introduces a flat loss of 23 decibels which, combined with the 21-decibels gain due to amplifier **16**, results in levels at F—F the input to the slope compensator of −25 decibels at 92 kilocycles and −32 decibels at 140 kilocycles. The slope compensator introduces only 2 decibels slope loss over its fixed flat attenuation of 23 decibels. Thus the loss at 140 kilocycles is only 2 decibels more than at 92 kilocycles and the levels at G—G are −48 decibels at 92 kilocycles and −57 decibels at 140 kilocycles which the amplifiers **30** and **31** bring down to zero level as before. In this case, the pilot motor control actuated by the 140-kilocycle pilot positions the movable plate **29** of multiplate condenser **20** at a position overlapping both fixed plates **24** and **25**.

Consideration of the operation of the repeater self-adjusting compensators as outlined above, emphasizes a major advantage of my invention. In devices of the sort as used heretofore, the slope or twist compensator introduced not only a variable high frequency adjustment but a variable low frequency adjustment as well. Any change in the compensation for high frequency loss was accompanied inherently by a change in the low frequency compensation which thus would ordinarily require a readjustment of the slope compensator, and so on. This condition arose from the fact that the networks producing slope attenuation were all in series, and the final result was the sum of the component results of the individual networks.

Now I have discovered that it is possible to design a series of networks each one of which is capable by itself of displaying the desired characteristics of a portion of the required operating range, and of having such electrical proportions that when all the networks are connected in parallel a flat and invariable loss over the whole frequency range results, to which may be added the frequency discrimination attenuation of the particular network. Thus I am able to obviate the cut-and-try method of adjustment and to adjust the flat gain once and for all by means of the flat compensator so that the 140-kilocycles control of the slope compensator adjusts only slope and has no effect upon the 92-kilocycles gain. Thus my invention affords improved stability and reduced maintenance.

A further important advantage of my invention lies in its provision for the prevention of overload as will be apparent from a consideration of rows **3** and **4** of the table of Fig. 3. It is assumed in this case that by reason of abnormal conditions in the line and equipment preceding the repeater under consideration, the input level at the low frequencies, as for example at 92 kilocycles, has been greatly reduced. Thus the level at A—A may be −40 decibels at 92 kilocycles and −5 decibels at 140 kilocycles. Considering row **3** which illustrates what would happen if condenser **12** were not included, the flat compensator introduces an 11-decibel loss and the level at F—F becomes −25 decibels at 92 kilocycles and +10 decibels at 140 kilocycles. It will be noted that the level at F—F is the same as for rows **1** and **2** at 92 kilocycles but is much higher at 140 kilocycles. The slope compensator is therefore operated to insert maximum loss, namely, 33 decibels which corresponds to complete coupling between movable electrode **29** and fixed electrode **27** which, however, only reduces the 140-kilocycle level to −22 decibels at G—G and this level plus the amplification of amplifiers **30** and **31** would become an output of +35 decibels. Amplifier **31** would ordinarily be unable to handle the power represented by this level and overload would result. It is to obviate a condition of this sort that I have devised the variable condenser network **12** operated by the high frequency pilot. The operation of this network is shown by the tabulation of row **4** of the table of Fig. 3. Assume, as before, that the 92-kilocycle pilot acting through pilot control motor **11** will cut down the flat level to the point where zero level at 92 kilocycles is produced at the output. The output level of the flat attenuator is thus −46 at 92 kilocycles and −11 at 140 kilocycles. Because of the high level of the 140 kilocycles the pilot control motor **19** will continue to operate beyond complete coupling between movable plate **29** and fixed plate **27** and will couple movable plate **29** with fixed plate **28** and at the same time mesh movable plate **13** between fixed plates **14** and **15** of condenser network **12**. This motion will continue as long as the output level of the 140-kilocycle pilot is above zero level. Since the network **12** is a flat network, its operation is to reduce the 92-kilocycle pilot as well as the 140-kilocycle pilot and hence as it increases attenuation, flat regulator **4** will decrease attenuation in the effort to maintain the output level of the 92-kilocycle pilot at zero level. At the completion of this process the 140-kilocycle pilot is reduced to a zero level output, the regulator **4** has been adjusted to minimum loss, namely, 6 decibels, and the network **12** has inserted a loss of 40 decibels, making a total flat loss between D—D and E—E of 46 decibels. Thus the level at E—E is −81 decibels at 92 kilocycles and −46 decibels at 140 kilocycles. The amplifier **16** brings these levels up to −60 decibels and −25 decibels at F—F. Since in order to bring the 140-kilocycle pilot to zero level at the repeater output, the movable plate **29** of coupler **20** has been positioned substantially opposite fixed plate **28**, which, however, is coupled to plate **27**, there is introduced between F—F and G—G the loss of network VII which is 23 decibels at 92 kilocycles and 32 decibels at 140 kilocycles, so that the level at G—G becomes −83 decibels at 92 kilocycles and −57 decibels at 140 kilocycles and hence adding the gain of amplifiers **30** and **31** the output level at 92 kilocycles is −35 decibels and at 140 kilocycles, zero or normal level. Thus overload of the amplifier is prevented and subsequent repeaters and line sections with their normally greater attenuation at the upper than at the lower frequencies will function to progressively correct the discrepancy between the high and low frequency levels.

I have thus traced step by step the operation of a specific embodiment of my invention employing for that purpose a particular association of apparatus and particular numerical values. This arrangement, however, is not to be considered to circumscribe or limit the said invention, it being understood that various modifications and divergences may be incorporated. In particular, it is to be noted that whereas in the illustrative embodiment I have shown the high frequency pilot in control of equalization or slope and the low frequency pilot functioning to control flat gain, this arrangement may be reversed and the upper pilot used to control flat gain, the lower pilot to control slope. In this case I would ordinarily design the network characteristics to have a negative rather than a positive divergence so that the several characteristics would be shown fanning out to the left instead of to the right as in Fig. 2.

Not only may the functions of the upper and lower pilots be interchanged as between regulation of flat gain and slope equalization but these functions under some circumstances may with advantage be divided between them and thus each pilot may control the insertion of a network (or a fraction thereof) by which both flat gain and slope are simultaneously affected. Since both pilots will, in general, function simultaneously and any operation by one pilot may induce resultant operation by the other, care must be exercised that an unstable arrangement is not produced.

I have found that for stability either pilot producing a given change at one pilot frequency must, if it is itself of that frequency, produce a lesser corresponding change at the other pilot frequency than would be produced by the other pilot under the same conditions. As an example, a decibel change at the lower pilot frequency caused by the lower pilot must be accompanied by a lesser change at the upper pilot frequency than would accompany a decibel change at the lower pilot frequency caused by the upper pilot, and similarly a decibel change at the upper pilot frequency caused by the lower pilot must be accompanied by a greater change at the lower pilot frequency than would accompany a decibel change at the upper pilot frequency caused by the upper pilot.

These and other modifications may be made without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. A transmission regulating system, comprising a first regulator, adapted to produce increments of transmission level change in identical amounts at all frequencies, and adapted to be operated in response to a first pilot frequency, a second regulator adapted to produce increments of transmission level change in amounts which are a function of the frequency of transmission and adapted to be operated in response to a second pilot frequency, and an emergency regulator adapted to produce increments of transmission level change in identical amounts at all frequencies under the independent control of said second pilot frequency.

2. A transmission regulating system for a carrier wave transmission line transmitting carrier transmission over a wide band of frequencies, comprising a first pilot frequency at the lower edge of said band, a second pilot frequency at the upper edge of said band, means for the control of transmission level over said line in small increments of equal amount at all frequencies throughout the said band actuated by said first pilot frequency, independent means for the control of transmission level over said line in small increments but said increments a predetermined function of frequency actuated by said second pilot frequency, and emergency means actuated by said independent means adapted to provide additional control in increments of equal amount at all frequencies throughout said band.

3. A transmission regulating system for a carrier wave transmission line transmitting a wide band of frequencies, comprising an amplifier, a first means adapted to regulate the gain of said amplifier to compensate for average variations in line attenuation, a second means adapted to regulate the gain of said amplifier to compensate for frequency discriminative variations in line attenuations, and auxiliary means actuated only by said second means adapted to prevent overloading of said amplifier in the presence of abnormal frequency discriminative variations in line attenuations.

4. A transmission regulating system for a carrier wave transmission line transmitting a wide band of frequencies, comprising an amplifier, a first means adapted to regulate the gain of said amplifier in a manner to compensate for average variations in line attenuations comprising a first attenuator controlled by a pilot wave at a frequency having comparatively low line attenuation, a second means adapted to regulate the gain of said amplifier in a manner to compensate for frequency discriminative variations in line attenuation comprising a second attenuator controlled by a pilot wave at a frequency having comparatively high line attenuation and auxiliary means controlled exclusively by said second means adapted to supersede the control of said second attenuator to prevent amplifier overload.

5. The method of regulating amplification over a line transmitting a broad band of frequencies which consists in transmitting a first pilot wave at a frequency at one edge of the band, transmitting a second pilot wave at a frequency at the other edge of the band, adjusting the average line gain on the basis of the received level of said first pilot adjusting the line gain differentially as to frequency on the basis of the received level of said second pilot, and preventing overload by additional flat regulation on the basis of the resulting level of said second pilot after said adjusting of average line gain on the basis of the received level of said first pilot.

6. The method of compensating for changes in attenuation varying with frequency over a line transmitting a broad band of frequencies which consists in transmitting over said line a first pilot wave at a frequency of low change in attenuation, transmitting over said line a second pilot wave at a frequency of high change in attenuation, providing an excess of line amplification and reducing the average amplification to hold the received level of said first pilot to a predetermined value, changing the ratio of low frequency amplification to high frequency amplification to hold said second pilot to a predetermined level and providing an additional flat gain reduction by said second pilot to prevent high frequency overload.

7. In combination, a series of networks having attenuations which are substantially a linear function of frequency over a given frequency range, having identical attenuations at the lowest fre-

quency of said range and having progressively greater change in attenuation with increase of frequency from network to network throughout the series, the inputs of said networks connected in parallel, and means for supplying thereto waves of the said range, the outputs of said networks respectively connected in the order of the series to stationary plates of a variable air condenser which comprises a series of equally spaced stationary plates without substantial mutual capacity from one plate to another, and a movable plate adapted to be set from full electrostatic coupling with one stationary plate to any division of coupling between two adjacent plates, an amplifier and means for making electrical connection from said movable plate to the input of said amplifier, in series in the input circuit of said amplifier an adjustable flat attenuator having stationary and movable elements so related that for the greater part of the range of movement of said movable element the attenuation is substantially small and constant while for a small part of said range the attenuation increases rapidly, a fixed mechanical connection between the movable element of said flat attenuator and the movable plate of said air condenser tying the motion of one to the motion of the other and said fixed connection so assembled as to maintain a desired sequence relation between the respective positions of said movable plate and said movable element whereby the gain-frequency characteristic of said amplifier is regulated without substantial change in flat gain for normal amplifier inputs but whereby flat attenuation is cut in circuit to prevent overload of said amplifier.

8. The combination of claim 7 in which said adjustable flat attenuator comprises a T-network having capacity elements.

9. The combination of claim 7 in which said adjustable flat attenuator comprises an air condenser having two fixed plates and one movable plate.

10. The combination of claim 7 in which said movable plate is driven by a motor and operating power therefor is supplied by a pilot wave within the said frequency range and selectively drawn from the output of said amplifier.

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