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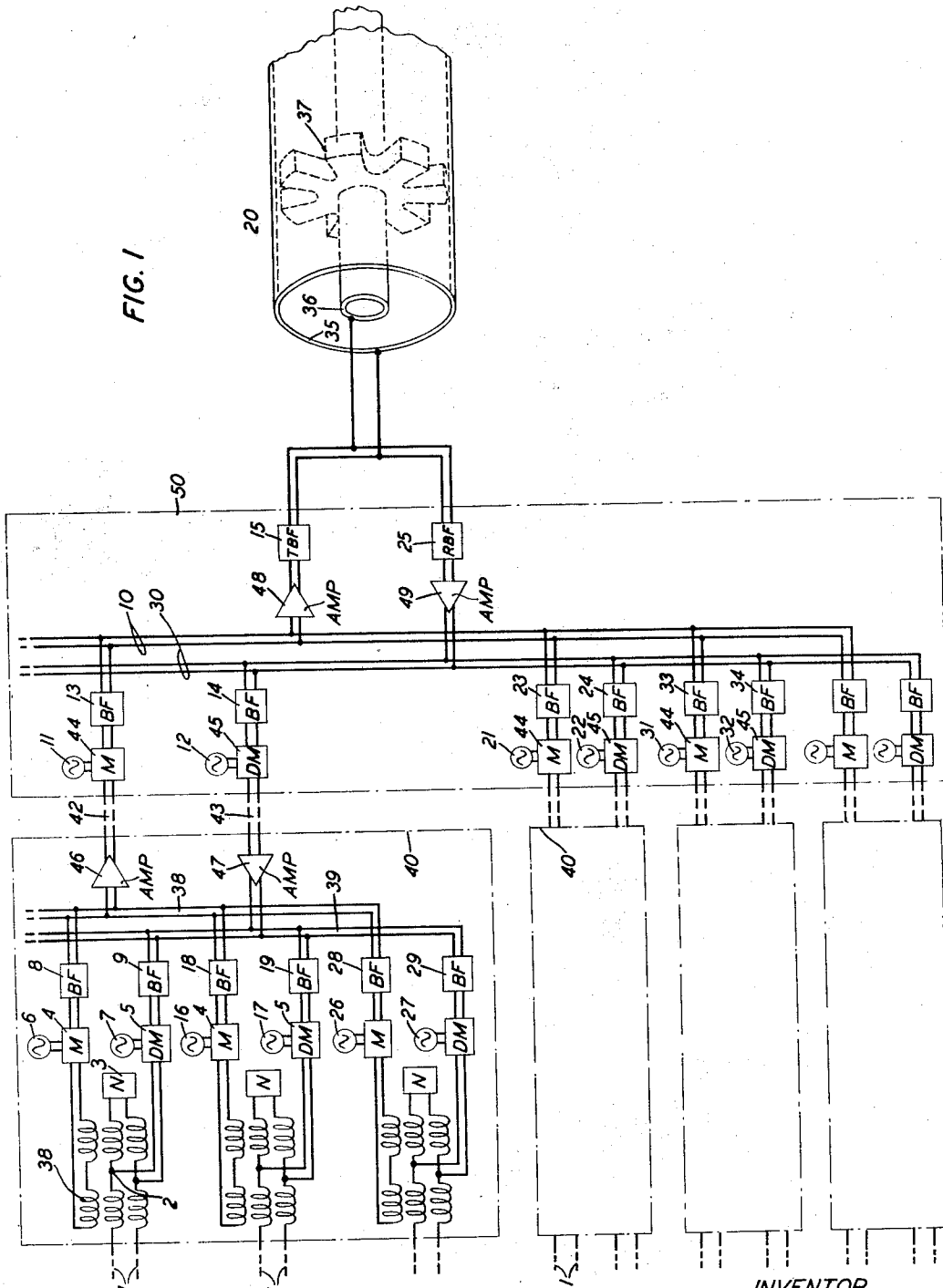
M. E. STRIEBY

1,941,116

COMMUNICATION SYSTEM

Filed May 21, 1931

2 Sheets-Sheet 1



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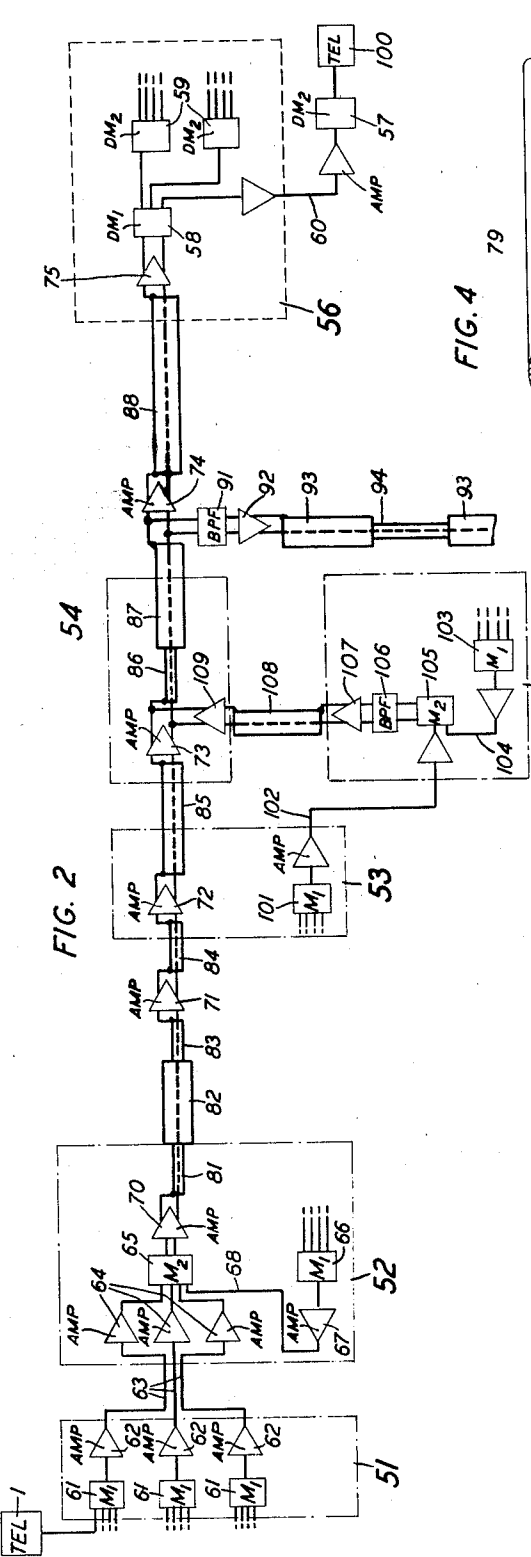
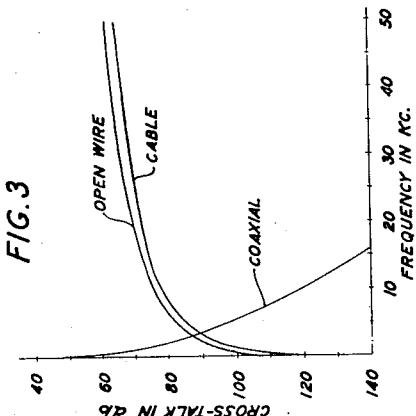
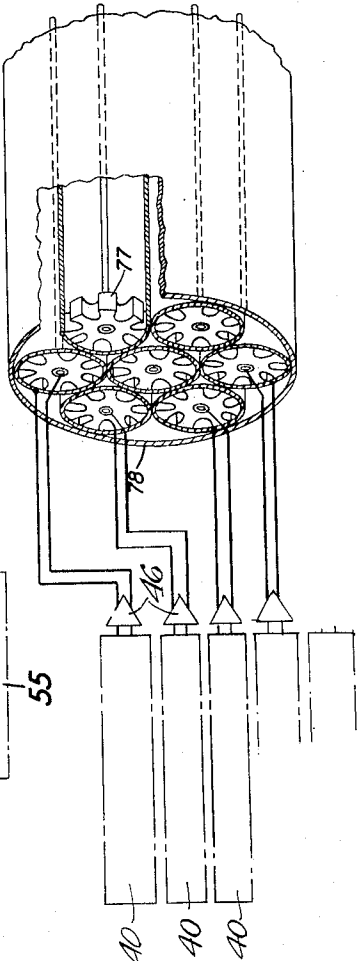


FIG. 4



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UNITED STATES PATENT OFFICE

1,941,116

COMMUNICATION SYSTEM

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Application May 21, 1931. Serial No. 538,919

15 Claims. (Cl. 178-44)

The present invention relates to an electrical system for the transmission of intelligence and more particularly to a system employing carrier waves.

5 It is an object of this invention to increase the flexibility and efficiency of a carrier wave transmission system, to extend the signaling frequency range, and to reduce the amount and cost of apparatus required.

10 A system in accordance with applicant's invention is adapted to the transmission of signaling waves extending over a much wider range of frequencies than it has heretofore been the practice to employ. It is especially adapted to utilize
15 to the fullest extent the characteristics of a transmission line in which one conductor, essentially in the form of a hollow cylinder, serves as the return path for an inner conductor concentric therewith and separated therefrom by a suitable dielectric. Patent No. 1,781,124 issued to
20 H. R. Nein on November 11, 1930 discloses a suitable type of line. Such a transmission line is capable of carrying with moderate attenuation waves having frequencies of the order of megacycles per second.

25 Applicant's system preferably makes use of carrier waves on which signals are impressed by successive processes of modulation. A plurality of signals are first impressed on a corresponding
30 number of carrier waves and applied to a transmission line in a manner well known in the art. At a succeeding point in the system these modulated waves are applied as a group to a second carrier wave of higher frequency. Other groups
35 of modulated waves arriving at the same point over other transmission lines may similarly be applied to the same or to individual carrier waves. The resulting wide band of carrier wave signals that may be obtained by this process is then
40 applied to a second transmission line, preferably one of the coaxial conductor type. Two-way transmission may be obtained, as heretofore, either by using different frequency ranges for the two directions or by using separate conductor
45 pairs.

The attenuation per unit length of a coaxial conductor transmission line varies approximately as the square root of the frequency and inversely as the inner diameter of the outer conductor.
50 These factors, together with the distance between the repeaters, which are inserted at intervals in the transmission line, and the permissible attenuation between repeaters, are closely yet flexibly related to each other. Taking advantage
55 of this flexibility, the size of the conductors may be reduced where the distance between repeaters is less than a given standard, increased where it is greater, and varied according to the maximum frequency to be transmitted.

In a country-wide network embodying applicant's system, widely different problems of construction and various traffic requirements may be met. The invention contemplates as one feature
65 the use of different sized coaxial conductors to meet these different requirements. If a large number of circuits are required through open country, a heavy, coaxial-type conductor two or three inches in external diameter may be the best solution. If physical conditions, such as city
70 streets or other difficult terrain, make the use of a large, rigid conductor impracticable, it may be more economical to use one or more coaxial conductor pairs of small diameters, enclosed perhaps in a lead sheath to form a flexible cable
75 such as shown in an application of H. W. Dudley bearing Serial No. 487,153, filed October 8, 1930. As noted above, the small conductors will transmit the entire frequency spectrum used with the large conductor, although much larger attenuation will be encountered and closer spacing
80 of repeaters will be required. Under some conditions it may be best to use several small coaxial conductor circuits in a cable each of which transmits only a part of the frequency spectrum. This would require that the frequency range be
85 broken up by suitable apparatus at the terminal of the large conductor, so that the transmission over the small conductors becomes essentially a carrier-on-cable system.

As a concrete illustration, suppose it were desired to bring into an urban district such as New York a thousand-channel system. A coaxial pair with a 3¼-inch pipe as the outer conductor would
90 serve in the rural districts to transmit the four and a half million cycle band of frequencies that this might require. In the metropolitan area, however, considerable difficulty would be met in attempting to run a large, inflexible conductor through the underground network of lines, pipes
95 and other construction to be found beneath many city streets. A flexible coaxial pair of one-half inch diameter within a lead sheath would be much more practicable. This would transmit the entire frequency band, attenuating the highest frequency approximately six decibels per mile. Such a conductor could be used to reach the first repeater station out of New York, which could be at a distance of about eight miles, far enough that the expense of installing a large pipe line
100 under the Hudson River and under the densely populated districts could be avoided. If it appeared more economical the 3¼-inch pipe line could be terminated at some suburban point, apparatus provided to reduce the four and a half
105 million cycle band to thirty-three separate bands each with a maximum frequency of about 140 kilocycles, and a cable containing thirty-three coaxial pairs of quarter-inch diameter run from there to New York. A multi-conductor cable of
120

suitable type is disclosed in the Dudley application, supra.

In many cases, as where a city off the route of the large conductor transmission line is to be connected into the system, the number of channels required for the branch line would not be sufficient to warrant the installation of a large conductor and its attendant modulating and demodulating equipment. Such a situation might be met by using a multi-conductor cable as just described. Again, it might be preferable to enclose one or more coaxial pairs in a cable containing also a number of voice frequency pairs.

A common situation for which a coaxial conductor transmission system is especially adapted arises from the fact that existing repeater stations are not equally spaced. With systems used heretofore this condition resulted in the attenuation between repeaters being less than or greater than the standard value found to be most satisfactory for the system. The coaxial conductor line, however, can be proportioned so that the desired attenuation will obtain in every repeater section.

Another characteristic of the coaxial conductor transmission line particularly adapts it to use in applicant's system. As disclosed in U. S. Patent No. 1,841,473 which issued to E. I. Green on January 19, 1932, the characteristic impedance of extended sections of a coaxial conductor line is determined by the ratio of the diameters of the two conductors. Hence, two lines of different diameters may be joined together directly without occasioning a serious impedance irregularity, (which would result in undesirable reflection phenomena), provided the same ratio of diameters is maintained.

It is an object of this invention to adapt the conductors of a coaxial conductor transmission line to the irregular spacing of the repeaters therein.

A further and more particular object of the invention is to obtain an optimum proportioning of the conductors comprising a repeater section in which certain lengths of said conductors are of predetermined diameter.

The inherent immunity of a coaxial conductor circuit from external interference is another consideration that enters into the design of applicant's preferred embodiment of his invention. The level of signals transmitted over such a conductor may be permitted to fall to an unusually low value, so low in fact that the molecular disturbances arising in the vacuum tubes and other repeater elements and thermal agitation in the conductor, become the limiting factors in many cases. Because of the concentric disposition of the conductors with respect to each other, the electrostatic and magnetic fields created by signals on the line are closely confined to the annular space between the conductors, and more especially so at the higher frequencies. Both of the foregoing characteristics tend to make cross-talk between adjacent coaxial pairs small.

Other objects and features of applicant's invention will appear from a consideration of the following description of a specific embodiment of the invention. In the drawings:

Fig. 1 shows in schematic form the terminal apparatus and circuits employed in an embodiment of applicant's invention;

Fig. 2 shows diagrammatically a telephone transmission system embodying applicant's invention;

Fig. 3 shows the relative susceptibility of sev-

eral types of transmission lines to cross-talk; and Fig. 4 shows in detail an element of the systems of Figs. 1 and 2.

Referring now to Fig. 1, there is shown schematically the general layout of a terminal station. This figure shows the manner in which successive modulation and demodulation are made use of for the purpose of effecting two-way translation of signals between a common coaxial conductor line 20 and a multiplicity of ordinary telephone lines 1. The group of apparatus designated 40 includes a plurality of "channel" modulators 4 for transferring the telephone signals from lines 1 to positions in the intermediate frequency band of modulated waves applied to conductors 42. It also includes a plurality of "channel" demodulators 5 for reducing the intermediate frequency bands of modulated waves incoming over conductors 43 to their original low frequencies for application to the telephone lines 1. At 50 is shown a group of apparatus for transferring the plurality of bands of singly modulated waves supplied by the several groups 40 to their respective positions in a still higher and broader band of waves applied to line 20. A modulator 44 is therein provided for each of the groups 40. Likewise a plurality of "group" demodulators 45 are included, each of which effects the preliminary stage of demodulation of a portion of the band of waves arriving over line 20. The output of each of these demodulators is applied to its associated apparatus 40 for further demodulation and eventual application to telephone lines 1.

The channel modulating and demodulating circuits 40 may be of the types used in ordinary carrier wave transmission practice. For purposes of illustration, three telephone frequency channels are shown in each group; a great many more would be employed in actual practice. Each of the telephone lines 1 is provided with a hybrid coil 2 which separates the outgoing and incoming telephone signal waves; the networks 3 balance the lines. Signals entering the hybrid coil 2 from the subscriber's telephone circuit pass through the output windings 38 of the hybrid coil to a modulator 4. The latter is preferably of the type in which the carrier wave is suppressed, as in that described in U. S. Patent 1,343,306, issued June 15, 1920, to J. R. Carson. In each channel one side band is suppressed by the respective succeeding band pass filters 8, 18, 28. The signal bands issuing from these several filters are applied to the collecting bus 38, pass through amplifier 46 and conductors 42 to the second stage or group modulator in apparatus 50. The frequency of the carrier waves which are produced by the several high frequency generators 6, 16, 26 and applied to modulators 4, may differ from each other by a little more than the width of the signal band to be transmitted. The separation necessary will depend on the type of filter used. G. A. Campbell Patent 1,227,113, May 22, 1917 discloses a suitable type. The frequency of the uppermost band produced by the modulators 4 may be of the order of five hundred thousand cycles per second, that of the lowest fifty thousand. These figures are purely arbitrary, however, and may be varied in accordance with the number of channels to be provided, the number and characteristics of the lines available, and other factors.

The receiving apparatus of each group 40 includes a plurality of band pass filters 9, 19, 29 connected to the distributing bus 39 for separat-

ing the carrier wave channels comprising the band of signals applied to the bus from amplifier 47 and conductors 43. Following each of these band pass filters in circuit is a demodulator 5, to which is connected the individual high frequency generators 7, 17, 27. The demodulators and the high frequency generators may be of the type disclosed in the Carson patent, supra, or of any other suitable types. The frequency of the carrier wave supplied to each demodulator by its associated high frequency generator is such that final demodulation of the applied waves is obtained. The resulting audio frequency signals pass to the input windings of hybrid coils 2 and thence to the subscriber's lines 1.

The group modulating and demodulating circuits shown at 50 are similar to the channel circuits 40 except that here a multiplicity of groups of carrier wave channels are transferred by a second modulation process to positions in a still wider band of modulated waves and, conversely, a wide band of received modulated waves is separated into a multiplicity of groups each of which is then reduced by demodulation to the frequency range of the single modulation carrier system. As shown in Fig. 1, two-way transmission over a single pair of conductors 20 may be used. Different frequency ranges are employed to effect the separation of the signals passing in opposite directions. If a frequency of the order of five million cycles per second is selected as the highest frequency, the transmitting band pass filter 15 might pass a band extending from three thousand to five thousand kilocycles per second and the receiving band pass filter 25 a band of from five hundred to twenty-five hundred kilocycles per second. Where two or more transmission lines are available between points it is preferred to use separate lines for each direction of transmission.

Signals from the channel apparatus in each group 40 are applied to respective modulators 44. From high frequency generators 11, 21, 31, etc., carrier waves are supplied, the frequencies of which lie in the range of from three thousand to five thousand kilocycles per second and differ from each other by the order of the group band width. The doubly modulated waves then pass through band filters 13, 23, 33, etc., respectively, to collecting bus 10. They are then passed as a band through a common amplifier 48 of suitable design and the transmitting band pass filter 15 to transmission line 20.

Signals arriving over the transmission line 20 are separated from these outgoing waves by a receiving band pass filter 25. They are then passed through amplifier 49 and applied to the distributing bus 30. Filters 14, 24, 34, etc., divide the received band of signals into a number of groups of channels. Each group of waves is then applied to an individual demodulator 45, connected to respective sources of carrier waves 12, 22, 32, etc. The frequency of the carrier waves generated are adjusted to reduce the several groups of channels acted on to the range for which the channel circuits 40 are adapted. They will therefore lie between five hundred and twenty-five hundred kilocycles per second in the specific embodiment described.

Terminal stations at other points in the system to which conductor 20 is connected may be designed in accordance with the principles underlying the design of the terminal station illustrated and described herein. Although channel equipment 40 and group equipment 50 may be

in close proximity, as at a terminal station, it is within the scope of applicant's invention to place them at widely separated points, a carrier wave transmission line of suitable design being used to connect them. Furthermore, apparatus similar to that of the terminal stations may be connected to the conductor 20 at intermediate points for connection with other points in the system.

The transmission line 20 shown in Fig. 1 comprises an outer cylindrical shell 35, preferably of copper, and an inner one 36, also preferably of copper, maintained in concentric relation therewith by means of insulating spacers 37. The latter are of some suitable dielectric material of small loss angle and low dielectric constant, so that minimum leakage between the conductors will be introduced. In some situations, as for example, where it is desired to connect a number of groups of first stage modulators to distant second stage modulators, it may be found advantageous to utilize a multi-conductor cable such as shown at 79, in Fig. 4. This cable comprises a number of coaxial conductors arranged in a group within a lead sheath 78. The individual coaxial conductors are designed on the same basis as conductor 20 of Fig. 1. The central conductor of each pair may be either tubular, or solid. Insulating spacers 77 of porcelain, hard rubber, glass or other suitable material are provided at intervals along the central conductor. A multi-conductor cable of this type is described in greater detail in the patent application of H. W. Dudley, supra.

The coaxial conductor type of line, as mentioned hereinbefore, has certain characteristics which may be taken advantage of in accordance with applicant's invention. The relation between attenuation and frequency of a coaxial conductor line at high frequencies is given roughly by the following equation:

$$\alpha = \frac{R}{2} \times \sqrt{\frac{C}{L}} + \frac{G}{2} \times \sqrt{\frac{L}{C}} \quad (1)$$

where R, G, C and L are the resistance, shunt conductance, capacity and inductance, respectively, per unit length. The factors R, C and L may be shown to be given by the following approximate formulæ, G being assumed equal to zero:

$$R = k_0 \cdot \sqrt{f} \cdot \left(\frac{1}{b} + \frac{1}{c} \right) \quad (2)$$

$$L = k_1 \cdot \log_e \frac{c}{b} \quad (3)$$

$$C = \frac{k_2}{\log_e \frac{c}{b}} \quad (4)$$

where b is the outer diameter of the inner conductor, c is the inner diameter of the outer conductor, f is the frequency, assumed for purposes of calculation to be the highest frequency of the band to be transmitted, and k_0 , k_1 and k_2 are numerical constants. The attenuation may therefore be expressed in terms of diameter and frequency as follows:

$$\alpha = \frac{k_3 \cdot \sqrt{f} \cdot \left(\frac{1}{b} + \frac{1}{c} \right)}{\log_e \frac{c}{b}} \quad (5)$$

or, since the ratio of c to b is preferably maintained constant,

$$\alpha = \frac{k_4}{c} \sqrt{f} \quad (6)$$

In other words, the attenuation per unit length of line is proportional to the square root of the frequency and inversely proportional to the diameters of the conductors. Within the range of frequencies employed by applicant the size of conductor may therefore be reduced where desired without occasioning much more than a proportional change in the attenuation.

Another characteristic of coaxial conductors may also be utilized to advantage. The characteristic impedance of such a line is given by the approximate expression.

$$Z = \sqrt{\frac{L}{C}}$$

Both L and C, Equations (3) and (4) respectively indicate, are functions only of the ratio of the diameters of inner and outer conductors. The expression for the characteristic impedance may be reduced to

$$Z = \frac{k_5}{\log \frac{c}{b}} \quad (7)$$

a function only of diameter ratio. A more detailed and precise analysis is contained in U. S. Patent No. 1,841,473, which was granted to E. I. Green on January 19, 1932. As disclosed therein this characteristic enables changes to be made in the diameter of a coaxial line without occasioning reflection phenomena provided the same ratio of inner diameter to outer diameter is maintained.

In Fig. 2 is shown schematically the layout of an extended system suitable for interconnecting distant centers of population and intermediate distribution points. Coaxial conductor pairs of different respective diameters are shown connected in tandem so as to produce an attenuation of the required amount between repeaters and at the same time to accommodate the physical structure of the conductor to the various kinds of terrain that may be encountered.

At 51 is indicated an urban district at one terminal of the system. The telephone subscriber's set 1 is representative of the thousands that may be associated with the telephone central offices of the district. A suburban area is indicated at 52; here a number of ordinary carrier channels from the urban district and a representative one from the surrounding district are shown connected to a second stage modulator for application to a single coaxial conductor line. A tributary line enters at the distant point 54 to join areas 53 and 55 to the system. The first of these areas 53, it may be assumed, does not require a sufficient number of channels to warrant the installation of group modulating equipment; it is therefore connected to the more populous area 55 where the necessary modulating facilities are already available. At a subsequent point on the line a number of high frequency channels are diverted over conductor 93 for transmission to other cities. In the terminal area 56 is located a first stage demodulating apparatus 58. Several channels are subsequently fully demodulated at this point. Other channels may be transmitted as a carrier system to be finally demodulated at 57 and eventually connected into an ordinary telephone exchange system 100.

For the sake of simplicity a unidirectional system has been illustrated. It will be obvious, however, that a parallel return system may be provided or that if desired the frequency range may be divided in order to permit transmission in the two directions, as shown in Fig. 1. In the latter

case two-way repeaters, well known in the art, may be used.

Referring now to the details of Fig. 2, there is shown in the urban district 51 a number of first stage modulators 61, preferably of the type shown in Fig. 1, arranged for connection with the telephone system of that district. After signals are here impressed on carrier waves they pass through respective output amplifiers 62 to transmission lines 63 which conduct them to the input amplifiers 64 in the suburban district 52. Separate cables may be used for lines 63 or a multi-conductor cable such as shown in Fig. 4 may be employed. The telephone exchanges of the area 52 are connected to the first stage modulator 66. The modulated carrier waves from the latter, together with those arriving over lines 63, are applied to the second stage modulator 65, which is preferably of the type shown in Fig. 1. The resulting wide band of signal waves is then passed through amplifier 70 and applied to a pair of coaxial conductors 81.

Between amplifier 70 and the first amplifier or repeater 71 there is indicated a change in the diameter of the conductors. The first section, 81, is of small diameter. It may be comprised of a small flexible lead covered pair of conductors adapted for installation in the conduits of the local telephone system. At the outskirts of the area, where little difficulty would be encountered in laying a rigid conductor of large diameter, the section 81 is connected to another pair of coaxial conductors such, for example, as shown at 20 in Fig. 1. While the diameters of the outer conductors may change from a fraction of an inch in section 81 to several inches in section 82, the same ratio of inner diameter of outer conductor to outer diameter of central conductor is preferably maintained. With a given diameter of outer conductor a minimum of attenuation may be obtained when this ratio is approximately 3.6. The optimum figure varies, however, with the maximum frequency transmitted and with the absolute diameters of the conductors, as shown in an application of J. M. West bearing Serial No. 538,647, filed May 20, 1931. Similarly, when approaching repeaters 71 it may be found desirable to use a section 83 of reduced diameter.

The immunity of coaxial conductors from variations in atmospheric conditions and from interference from stray electrical fields may be used to good advantage in accordance with applicant's invention. The shunt conductance of open wire lines varies between wide limits as atmospheric conditions change the effectiveness of the insulation between conductors. As a result the apparatus associated with the repeaters for limiting the input signal level and for controlling the gain of the repeater must be operative over a correspondingly wide range and the full effectiveness of the repeater can be realized only under optimum conditions. The noise level in an open wire line due to atmospheric disturbances is also considerable, and, more important from the standpoint of operating efficiency, an otherwise unnecessarily high ratio of signal level to noise level must be maintained. Fig. 3, comparing the cross-talk in open wire circuits, ordinary cable circuits, and coaxial conductor circuits, shows how effectively the coaxial conductor circuit is shielded from interference. Cross-talk in the case of the first two increases steadily with rise of frequency; in the coaxial conductor it decreases and even at fifteen thousand cycles per second is too small to require consideration.

It is of less importance than the noise inherent in the amplifying elements of the repeaters and the resistance noise in the conductors.

With the lower level to which signals may be attenuated thus determined by a relatively fixed noise level instead of by the widely variable one met in open wire systems, it is possible to utilize nearly the full gain of the repeaters at all times. The conductors themselves can be so proportioned that signals are attenuated between repeaters to this limit, the necessity for attenuating pads being in many cases eliminated and the requirements of the gain controlling apparatus greatly reduced.

As stated hereinbefore repeaters may be installed in a coaxial conductor line at intervals of perhaps fifty miles. It would be desirable for the sake of uniformity, and therefore economy, that each repeater section be identical with every other one in length, diameter, attenuation, etc., the apparatus in each being operated at its greatest capacity. Another consideration enters, however, viz., that it is more desirable that the repeaters be located at existing telephone repeater offices within cities and towns, where expert attention is available and where the repeater may be associated or combined with local modulators and demodulators and similar apparatus. Between certain points, as 72 and 73 of Fig. 2 standard repeater spacing, of perhaps fifty miles, may be obtained. At another point there may be no telephone repeater station at the fifty mile point and it may be necessary that the repeater 72, for example, be only thirty miles from the preceding one 71. Again it may be necessary to transmit eighty miles between repeater points, as in section 88 between repeater 74 and repeater 75. This unequal spacing of repeater stations would, if a uniform conductor were used, tend to cause wide differences in the level of signals arriving at the several repeaters.

These differences in level may be corrected in accordance with the usual practice by inserting attenuating pads, as at a point just preceding the repeater 72 at the terminal of the short repeater section 84, to reduce to a standard input level the signals applied to the amplifier. In the long repeater section 88 a standard repeater of greater power may be used at 74. In both cases an automatic gain control may be used in conjunction with each repeater, with or without the attenuator pad mentioned, to maintain the input to each repeater at a suitable level. The use of attenuating pads, which has been the practice in the case of open wire lines, is from one view-point a waste of energy, from another it means that the transmission efficiency of the line is greater than necessary, that a greater line attenuation could be tolerated.

In accordance with applicant's preferred embodiment of his invention the proportions of concentric conductors are varied to compensate for the dissimilarities in repeater sections. Equation (6) shows that for a given ratio between the inner diameter of the outer conductor and the outer diameter of the central conductor the attenuation of a coaxial line varies inversely as the size of the outer conductor. Given any two points between which a predetermined attenuation is permitted, a coaxial conductor of such diameter can be selected that it will introduce just the required attenuation. Between repeater points, for example, there is an optimum value for the total attenuation determined chiefly by the cost and power output of the repeaters.

Fifty-five decibels was found to approximate the optimum in one instance. Elimination of attenuating pads is not the only advantage resulting from a proportioning of the conductors to the permissible attenuation between the points they connect. The economy of conducting material effected by reducing the diameters where a higher rate of attenuation can be tolerated is of much more significance. This will be appreciated when it is realized that the conductor accounts for approximately three-quarters of the cost of the system.

It has been seen that the diameter of the conductors may be changed at will provided the same diameter ratio is maintained. One section 86 of the conductor between repeater points 73 and 74, for example, may be of limited diameter, the following section 87 of large diameter. Even in this circumstance the diameter of conductor 87 may be so selected that the total allowable attenuation between repeaters 73 and 74 is just obtained. Similarly, the conductor 82 need be no larger than is required to make the total attenuation in sections 81, 82 and 83, just equal to the allowable amount. For the thirty mile repeater section 84 mentioned above, the diameter of the outer conductor might be reduced from perhaps three inches, the size used in the standard fifty mile section 85, to three-fifths of this value or approximately two inches. The central conductor is reduced in proportion. Similarly, in the eighty mile section an outer conductor of about five inches diameter instead of the standard three inch might be used.

While the length of the repeater section is an important factor in determining the diameter of the conductors, the frequency range transmitted is no less so. Attenuation, Equation (6) shows, varies approximately with the square root of the frequency; for this reason it is the attenuation of the highest frequency transmitted that is controlling. Where the uppermost frequency bands are removed from the main channel, as by the branch line 93, the following section 88 may be designed with respect to the new uppermost frequency. The relation between the several factors involved as determined for a particular system is shown in tabular form below. In the first column is represented the inner diameter of the outer conductor in inches; in the second, the number of miles between repeaters; in the third, the maximum frequency to be transmitted, in kilocycles per second; and in the fourth, the number of one-way channels provided.

Diameter of outer conductor	Repeater spacing	Maximum frequency	Number of channels
3 in.	100 mi.	1100 kc/s	250
3 in.	50 mi.	4500 kc/s	900
2 in.	100 mi.	450 kc/s	110
2 in.	50 mi.	1700 kc/s	340
2 in.	25 mi.	7300 kc/s	1450
1 in.	50 mi.	600 kc/s	120
1 in.	25 mi.	2000 kc/s	400
$\frac{3}{4}$ in.	25 mi.	500 kc/s	120
$\frac{1}{2}$ in.	25 mi.	140 kc/s	30

Immediately following repeater 73 in circuit there is shown a tributary transmission line 108. The latter introduces signals from the second stage modulator 105, which in turn is fed by a local first stage modulator 103 and a similar modulator 101 located in the nearby area 53. The signals thus conveyed to the main line occupy a frequency band above the highest frequency signals transmitted by amplifier 73 or a band which

has been left vacant for them, or which has previously been diverted. Band pass filter 106 is designed to pass only these channels. From the main line there branches off, just before the next
 5 repeater station 74 is reached, a line 93. The band pass filter 91 prevents all except the selected channels from entering this branch. At 94 in the branch line is represented a short section of small diameter such as might be used at a river
 10 crossing or under the streets of a town in the path of the transmission line.

Returning now to the main line, there is shown at the terminal of the long section 88 an amplifier 75 and a first stage demodulator 58. Several
 15 groups of channels may immediately thereafter be fully demodulated in apparatus 59 and the resulting telephone frequency channels connected into the local exchange system. Another group may be transmitted at carrier frequencies
 20 over line 60 to the distantly located demodulator 57, for eventual connection with the telephone exchange 100.

The particular values of dimensions and frequencies set forth herein are only for the purposes of illustration. The principles underlying
 25 the proportioning of the conductors may be applied to coaxial conductor systems generally with little restriction as to the diameters, frequency, repeater spacing and the particular type of line used, whether it be a single coaxial pair, a multi-
 30 conductor cable or equivalents thereof, within the scope of the appended claims.

What is claimed is:

1. In a signaling system, a transmission line
 35 comprising a central conducting path and an outer cylindrical return conducting path coaxial therewith and insulated therefrom, amplifiers at irregular intervals in said line, the attenuation between successive amplifiers being the same and
 40 comprised substantially only of the attenuation of said transmission line.

2. In a communication system, a transmission line divided into a plurality of sections having
 45 different rates of attenuation, each of said sections comprising a central conducting path and a cylindrical return conducting path coaxial therewith, and amplifiers at a plurality of points in said line, the length of said sections and the
 50 rates of attenuation therein being such that the line attenuation between successive amplifier points at the maximum frequency to be transmitted therebetween is the same throughout said line.

3. In a communication system adapted to transmit a wide band of frequencies, a line comprised
 55 of a central conductor and an outer cylindrical conductor coaxial therewith and insulated therefrom, and a plurality of repeaters in said line, said line being divided into a plurality of sections having different diameters of conductors,
 60 the diameters of said conductors in said sections being such that for the maximum signaling frequency the total attenuation between each of said repeaters is the same and comprised substantially only of the attenuation of said line.

4. In a system for the communication of intelligence, a transmission line, a plurality of repeaters
 70 at unequal intervals therein, said line comprising an inner conductor and an outer cylindrical return conductor coaxial therewith and insulated therefrom, the rate of attenuation of the signals of highest frequency transmitted between said
 75 repeaters varying inversely with the distance between said repeaters.

5. A system in accordance with claim 4 in which

the diameters of said conductors between said repeaters are directly proportional to the distances between said repeaters and the square root of the maximum frequency to be transmitted.

6. In a system adapted to transmit signaling
 80 waves of a wide range of frequencies extending to at least one hundred thousand cycles per second, a transmission line comprising a pair of conductors spaced in coaxial relation to each other and separated by an insulating dielectric,
 85 and a plurality of repeaters at irregular intervals in said line, the diameters of conductors between successive repeaters being so proportioned with respect to the maximum frequency to be transmitted and to the distance between said
 90 repeaters that said signaling waves are reduced to a level determined chiefly by the noise level in said system.

7. A combination as defined in claim 6 in which
 95 said reduction of signal level is caused substantially by the attenuation of said conductors alone.

8. In a communication system, a transmission line comprising a central conducting path and
 100 an outer tubular return conducting path concentric therewith and separated therefrom by a dielectric which is chiefly gaseous, a plurality of amplifiers at predetermined irregular intervals in said line, said outer path having between said
 105 successive ones of said amplifiers sections of unequal diameters, the diameters and lengths of said sections being so mutually proportioned that signals are reduced between successive amplifiers by the attenuation of said conductors alone to
 110 a level determined chiefly by the level of molecular noise.

9. In a communication system, a transmission line comprising a central conducting path and an
 115 outer tubular return conducting path concentric therewith and separated therefrom by a dielectric which is chiefly gaseous, a plurality of amplifiers at intervals therein, the diameter of said outer path varying in sections between certain
 120 of said amplifiers; the lengths and diameters of said sections being so related to each other that signals are attenuated in the same degree between successive ones of said amplifiers substantially by the attenuation of said transmission line alone.

10. In a communication system, a transmission
 125 line, a plurality of amplifiers at irregular intervals therein, said amplifiers being operative over a restricted range of input signal amplitudes, the attenuation constant of said line being different in different sections between said
 130 amplifiers and so proportioned to the lengths of said sections and the output levels of said amplifiers that between said amplifiers, signals are reduced substantially by the attenuation of said line alone to a level within said operative range of said
 135 amplifiers.

11. A communication system having therein a
 140 transmission line comprising a plurality of sections of concentric conductor cable adapted to transmit with small attenuation frequencies of at least one hundred thousand cycles per second, a plurality of repeaters at intervals in said line,
 145 the attenuation constants of said sections being unequal and so proportioned with respect to each other and the lengths of said sections between successive repeaters that substantially the total signal attenuation between said repeaters occurs in said line and is the same throughout said system.

12. A carrier wave transmission system comprising in combination at a terminal thereof, a

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plurality of telephone exchanges, a central station, means at each of said exchanges for translating speech frequency signals to and from respective positions in a band of carrier frequencies, means comprising transmission lines individual to said exchanges for conducting signals in said carrier frequency band between said respective exchanges and said central station, means at said central station for translating said carrier frequency bands to and from respective positions in a wider band of carrier frequencies, and a transmission line for conducting said wider band of carrier frequencies between said central station and remote terminals.

13. A carrier wave transmission system comprising in combination at a terminal thereof, a plurality of telephone exchanges, a central station, a coaxial conductor transmission line connecting each of said exchanges with said central station, means at each of said exchanges for translating signals in a multiplicity of speech frequency channels to respective positions in a wide band of carrier frequencies, means to apply said signals to said respective transmission lines, means at said central station for translating said bands of carrier frequency signals to respective positions in a band of frequencies of the order of megacycles in width, a coaxial conductor transmission line for conveying said last mentioned band of signals to remote distributing points, and means at said terminal of said system for correspondingly, inversely operating on signals received over said last mentioned transmission line.

14. In a carrier wave transmission system, a plurality of groups of signal wave channels, a

transmission line associated with each of said groups, means to impress the signal waves of each of said groups on carrier waves of different frequencies for transmission over said lines, another transmission line, means in each of said first mentioned lines to impress the waves therein on a carrier wave of higher frequency for transmission over said last mentioned line, demodulating means to receive the doubly modulated signal waves from said last mentioned line, means at an intermediate point of said second mentioned transmission line to divert a band of waves transmitted thereover, and demodulating means to restore the signal waves impressed on said band of diverted waves to their original frequencies.

15. In a carrier wave transmission system, a plurality of groups of signal wave channels, a transmission line associated with each of said groups, means to impress the signal waves of each of said groups on carrier waves of different frequencies for transmission over said lines, another transmission line, means in each of said first mentioned lines to impress the waves therein on a carrier wave of higher frequency for transmission over said last mentioned line, demodulating means to receive the doubly modulated signal waves from said last mentioned line, means at an intermediate point on said second mentioned transmission line to select a band of waves transmitted thereover, a second transmission line, means to partially demodulate said band of waves and to apply them to said second line, and means to demodulate finally the waves transmitted by said second line.

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