Sept. 12, 1939.

A. D. BLUMLEIN

2,172,354

MULTIPLEX SIGNALING SYSTEM

Filed Nov. 6, 1936

3 Sheets-Sheet 1

Fig. 1

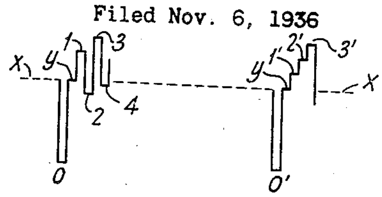


Fig. 2

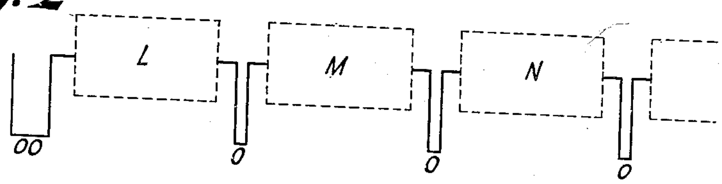


Fig. 3

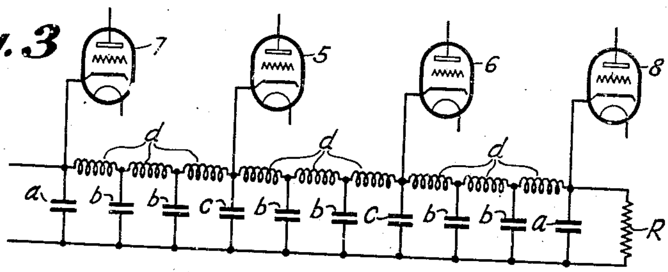


Fig. 4

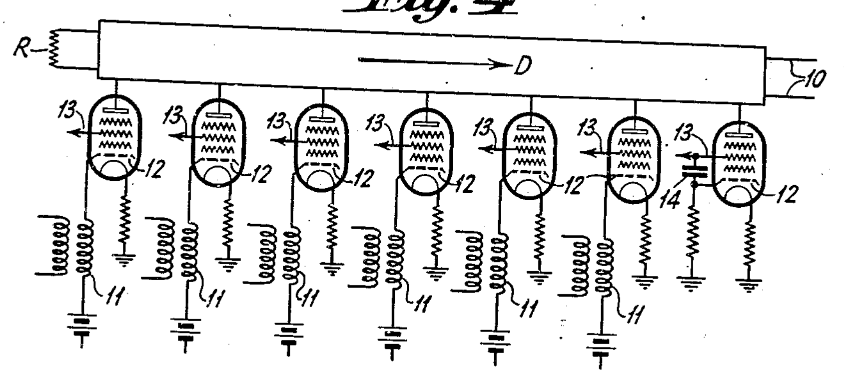
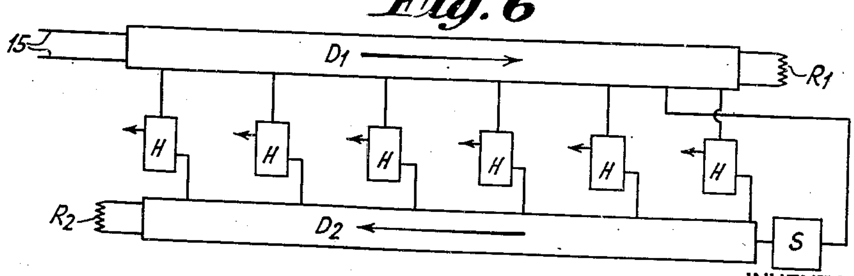


Fig. 6



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Sept. 12, 1939. A. D. BLUMLEIN 2,172,354

MULTIPLEX SIGNALING SYSTEM

Filed Nov. 6, 1936 3 Sheets-Sheet 2

Fig. 5

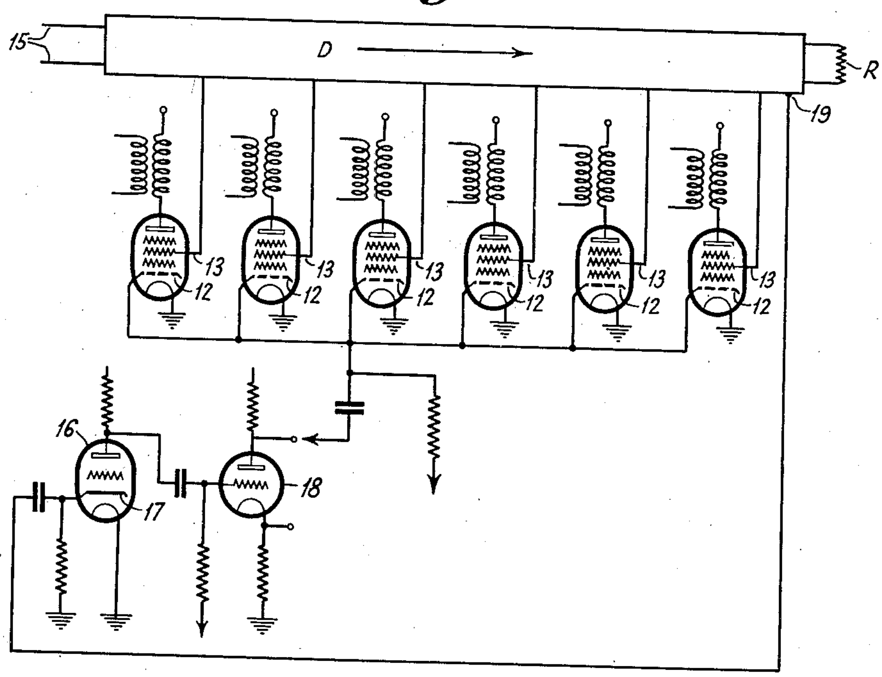
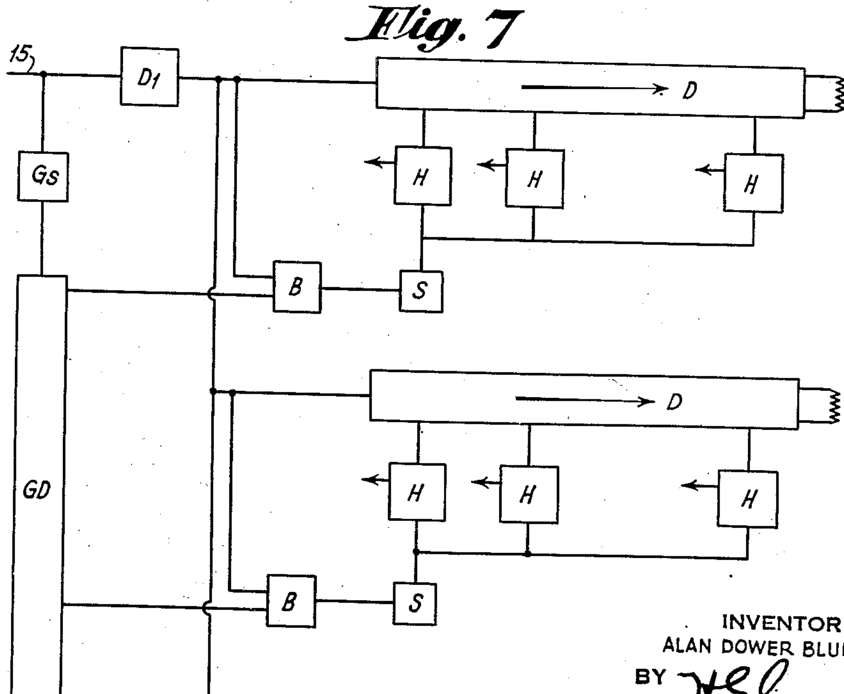


Fig. 7



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Filed Nov. 6, 1936

3 Sheets-Sheet 3

Fig. 8

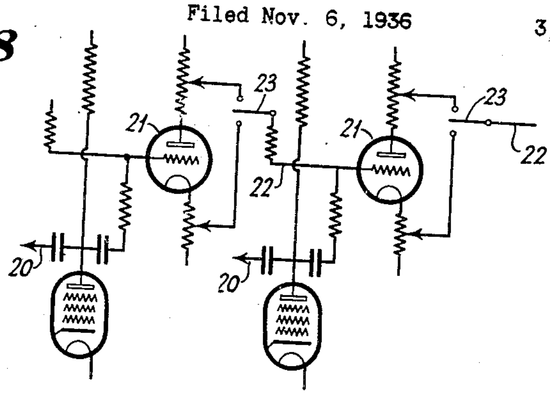


Fig. 9

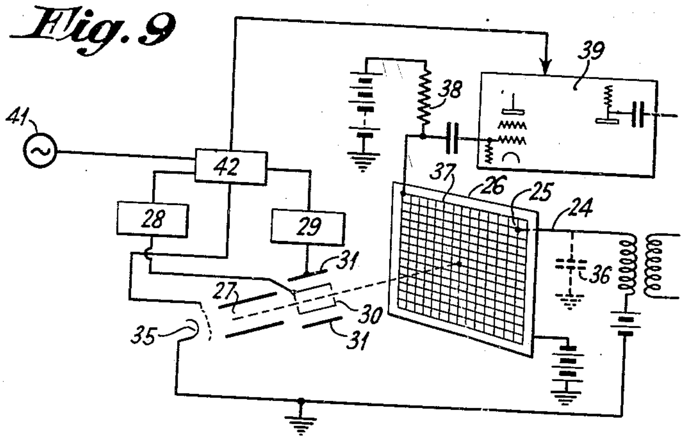


Fig. 10

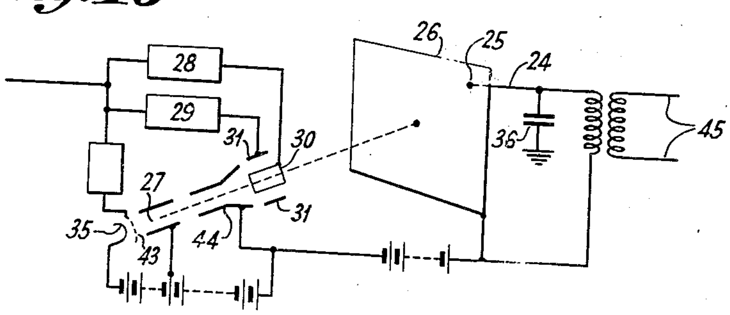
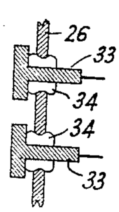


Fig. 11



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UNITED STATES PATENT OFFICE

2,172,354

MULTIPLEX SIGNALING SYSTEM

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Application November 6, 1936, Serial No. 109,456
In Great Britain November 14, 1935

11 Claims. (Cl. 178—51)

The present invention relates to multiplex signaling systems.

Multiplex systems are known in which a plurality of telegraph channels are obtained through a single circuit. The circuit may be a land-line or a radio link for example. In the systems it is usual to employ mechanical distributors to connect the circuit in turn to each telegraph instrument at the transmitting and receiving point simultaneously. The whole cycle of connection of the line to all the receiving instruments on the circuit must occupy a time less than the time occupied by one signal dot.

The present invention deals with systems in which telephone frequency circuits may be connected in multiplex manner through a circuit such as a radio link or high frequency cable intended to cover a wide range of frequencies.

In such systems, on account of the comparatively wide band of frequencies required for each channel, mechanical distributors are unsuitable.

It is an object of the present invention to provide improved distributors capable of high speed operation.

According to the present invention, there is provided a system of multiplex telephony or telegraphy, said system comprising means for feeding signals from a plurality of channels through a single circuit, the arrangement being such that, in operation, there is transmitted through said circuit a train of elementary signals interspersed with synchronizing signals having an amplitude outside the amplitude range of said train of signals, each elementary signal being representative of the signal in one of said channels, and means being provided for utilizing said synchronizing signals to control switching devices for connecting said channels in turn to said circuit.

The wave transmitted through the circuit may comprise a plurality of groups of signals, each group comprising a plurality of trains of elementary signals, and each elementary signal being representative of the signal in one of the channels. Each train then comprises the signals from a set of channels and successive trains comprise the signals from different sets of channels. Each group of signals includes an elementary signal from every channel; the trains within a group are separated from one another by synchronizing signals and the groups are separated from one another by further synchronizing signals of different duration or different amplitude, or of both different duration and different amplitude from the synchronizing signals separating the trains within a group.

In one arrangement, according to the invention, the switching means comprise a plurality of relays which may be thermionic in character, the relays being adapted for connecting the channels, in turn, to the line and being arranged to be operated successively by means of controlling signals derived from delay networks.

In another arrangement according to the invention, the switching means comprise a cathode ray tube in which an electron beam is caused to scan a screen having a number of targets associated with the incoming or outgoing channels, the tube thereby serving as a distributor. Further, according to the invention there are provided means for feeding a part of the signal from one channel into a succeeding channel at the receiving end of the circuit for the purpose of neutralizing or reducing cross talk which may be introduced due to distortion of signal wave form.

In order that the invention may be more clearly understood, and readily carried into effect, several embodiments thereof will now be described with reference to the drawings wherein:

Fig. 1 shows the wave form of a multiplex signal which is obtained in one arrangement according to the invention;

Fig. 2 illustrates the wave form of a multiplex signal which is obtained in another arrangement according to the invention;

Fig. 3 shows one way in which thermionic valves may be controlled in a multiplex distributor;

Figs. 4 and 5 shows distributor circuits for use at the sending and receiving ends, respectively, of a multiplex link;

Figs. 6 and 7 illustrate modifications of Fig. 5;

Fig. 8 shows a circuit for reducing or neutralizing cross-talk between channels;

Figs. 9 and 10 show arrangements employing cathode ray tubes at the sending end and receiving end, respectively; and

Fig. 11 shows a construction of signal plate suitable for use in the tubes of Figs. 9 and 10.

It is assumed that it is desired to transmit signals from a plurality of channels (telegraph, telephone or other signaling channels) through a single circuit which may comprise a radio link or a cable capable of handling signals covering a wide range of frequencies. The circuit is associated at its two ends with distributors which are adapted to operate synchronously to connect the transmitting and receiving channels successively to the circuit. Thus, if there are n channels, the distributors first connect the first channel to the circuit for a short period of time, thus allowing a signal to pass in this channel; the distributors then switch over to the second channel to allow a signal to pass in the second channel and then to the third, fourth, etc., up to the nth channel. The distributors then switch back to the first channel and the process is repeated continuously. The frequency at which the distributors make complete cycles must be at least as high as the minimum frequency which causes no deleterious effect on the signals being transmitted. Thus, if the channels are telegraphic, the frequency at which the distributors complete a cycle of change must be greater than the reciprocal of the time occupied by one signal dot.

Fig. 1 shows the wave form of a signal in the single connecting circuit in a system according to the invention. The wave comprises a series of uniformly spaced synchronizing pulses of which two are indicated by the references O and O' in the figure. The zero line of the signals is shown by the line x, x. The signal from the first channel is indicated at **1**, that from the second channel at **2**, that from the third channel at **3**, and so on for the remaining channels. After the synchronizing signal O', the channels are again connected in turn to the circuit and the portions of the composite signal due to the signals in the first, second and third channels are indicated at **1'**, **2'** and **3'**, respectively. It will be seen that, during the interval between the corresponding points in these consecutive cycles of the distributors, the signal value in channel **1** has become less positive, that in channel **2** has changed from a negative value to a positive value, whilst that in channel **3** has remained unchanged. By employing suitable circuits to separate the pulses of say channel **1** at the receiving end, and rectifying these pulses, they may be caused to produce a signal of a wave-form substantially corresponding to the wave-form of the signal in channel **1** at the sending end. Similarly for the other channels. If the synchronizing pulses occur at a frequency of 10,000 per second, then signals embracing frequencies up to nearly 5,000 cycles per second can be transmitted through the circuit on each channel.

If it is assumed that the multiplex signal of Fig. 1 can be transmitted with sufficient sharpness through a circuit capable of handling a frequency range extending to one-half the number of pulses transmitted per second (the number of pulses per second is equal to the product of the frequency of the synchronizing pulses and the number of channels), then a frequency range of 5,000 n cycles per second will be required for n channels each requiring the transmission of frequencies up to 5,000 cycles per second. It will be seen that this is exactly equal to the minimum frequency range required by a multiple carrier signaling system radiating n single side-band modulated carriers, each having a side-band width of 5,000 cycles per second, it being assumed that the channels are close packed and are separated by infinitely sharp filters at the receiving end. In practice the multiplex signal requires a greater frequency band than that mentioned above but a corresponding multiple carrier system also requires a range greater than the theoretical minimum value mentioned above.

In the multiplex system considered above, the synchronizing pulses O, O' are employed for maintaining synchronism between the distributors at the two ends of the connecting circuit. Such an arrangement is quite satisfactory provided that the number of channels is not too great, for example, not greater than 20. If the number of channels (n) is much greater than 20, then errors may be introduced in dividing the intervals between successive synchronizing pulses into n equal periods. These errors will not, in general, be of equal magnitude and in the same sense at the two ends, and the result may be incorrect connections to the channels. For example, it might happen that when the 31st channel was connected to the circuit at the transmitting end, the 30th channel was connected to the circuit at the receiving end. Even if the error is insufficient to cause a signal pulse to be wholly fed to an incorrect channel, the error may be sufficient for a part of a pulse to be fed to an incorrect channel.

If a large number of channels is to be employed, for example 200, the signals are preferably divided up as shown in Fig. 2. In this figure, rectangles, L, M, N are employed to denote trains of signals. The train L contains signals from channels **1**, **2**, **3** . . . p, the train M contains signals from channels $p+1$, $p+2$, $p+3$ . . . $2p$, and so on. Thus if there are q trains each deriving signals from different channels, a number of channels equal to the product $p.q.$ may be represented in the composite signal. After the end of the qth train, a repetition of the sequence begins. The trains L, M, N are separated from one another by synchronizing pulses O similar to those of Fig. 1. A sequence of q trains of signals which will be termed a group of signals is separated from the succeeding group by a group synchronizing signal which differs from train synchronizing signals O. Thus, the group synchronizing signal OO shown before train L differs from train synchronizing signals O in that the group signal has a longer duration than the train signal.

When the group signals are employed to operate a primary distributor and the train signals are used to operate a secondary distributor, it is possible to connect 400 channels in rotation without dividing any interval between synchronizing signals into more than 20 parts. Thus, if a group comprises 10 trains ($q=10$), each train representing 20 channels ($p=20$), then the 199th channel is selected by counting from group synchronizing signal OO up to the 9th train and then counting up to the 19th signal in this train. If it is desired to transmit telephony involving frequencies up to about 5,000 cycles per second, then the group synchronizing signals must have a frequency of 10,000 per second; in the example considered in which there are 10 trains per group, the train synchronizing frequency is 100,000 per second.

It will be observed that the group synchronizing signal OO functions for group L as a train synchronizing signal. If desired, a train synchronizing signal of normal form may be inserted between the signal OO and the beginning of the group L. In another arrangement, either the leading or trailing edge of signal OO is timed to take the place of a train synchronizing signal. In yet another arrangement, the group synchronizing signal OO is broken into parts in the manner known for frame sychronizing signals in television systems, one of these parts being used as a train synchronizing signal. It will be seen that the group synchronizing signals OO and the train synchronizing signals O bear a close resemblance to the frame and line synchronizing signals used in many televisions systems.

For multiplex telephony by the method just discussed, group and train frequencies are much higher than the frame and line frequencies commonly used in television systems. However, by using synchronizing frequencies comparable with those employed in television, it is possible to realize high speed multiplex telegraphy. By employing somewhat lower synchronizing frequencies, multiplex telegraphy over a circuit with a band width of the same order as that of ordinary telephone circuits may be obtained. Such a multiplex system may be used for remote control purposes whereby each channel controls the operation of a device such as a switch or a rheostat. Again, the system may be used for remote metering where the impulses are proportional to the readings of current, power or other measurable quantity in various circuits.

It will be seen that for the successful handling of signals such as are shown in Figs. 1 and 2, it is necessary for the transmission circuit to have a uniform frequency reponse over the required range and also to be substantially free from phase distortion. The requirements of the transmission circuit are therefore the same for the above purpose as for a television link. If low frequency components are not transmitted (these components may not be fed to the transmission circuit, or may be lost either in the transmission circuit or at the receiving end thereof) they may be reestablished at or before the distributor at the receiving end with reference to the peaks of the synchronizing signals or with reference to some other recurrent fixed amplitude (for example the zero period shown at *y* in Fig. 1) in a manner well known in television systems and generally referred to as "D. C. re-insertion".

The possibility of reinsertion of D. C. allows low frequency components to be neglected at the receiving end so that noise due to induction from power circuits etc., can be lessened in its effects. This is particularly the case where a very high synchronizing frequency is employed such as that described for the transmission of 10 trains of signals with a group frequency of 10,000 per sec. employing a train synchronizing frequency of 100,000 per sec. Such a signal may be transmitted over a concentric single core cable and the low frequency. subject to induction, may be neglected, since the lower frequencies and the D. C. may be reinserted with reference to a signal occurring 100,000 times per sec. At the higher frequencies, the concentric cable is not subject to induction owing to the thickness of its sheath.

Fig. 3 shows a circuit in which a number of valves is operated in turn from a delay network. The delay network consists of series inductances *d* and shunt condensers *a*, *b*, *c*, and is terminated by a resistance R. The condensers *c* are equal to the condenser *b*, less an allowance for the input capacity of the valves **5**, **6**. The condensers *a* are equal to half *b*, less an allowance for the input capacity of the valves 7, 8. The ratio of the inductances *d* to the full size condensers *b* is made equal to R^2. The cut-off frequency of the filter so obtained is made well above the highest working frequency, so that phase errors and mismatching as cut-off frequency is approached do not prejudice its operation. Other forms of filters may be employed such as those having resistances shunted across the inductances to minimize phase or reflection errors, and similarly a more accurate termination than a plain resistance may be employed.

At the sending end the control grids of valves **5**, **6**, **7**, **8** are coupled to the separate channels and the anodes of these valves are connected in parallel and coupled to the single transmission circuit. When the arrangement of Fig. 3 is used at the receiving end, the grids of the valves are connected in parallel and fed with the multiplex signal from the transmission circuit and the anodes are coupled to the separate channels. The grids are normally biased beyond anode current cut-off but a suitable negative pulse on the cathode of a valve renders it conductive for a period equal to the length of the pulse.

If a pulse is fed in at the left hand end of the filter, it will operate each valve in turn, and if the duration of the pulse is approximately the time delay between successive valves, each valve will be switched on in turn and will be switched off as the succeeding valve is switched on. A series of valves, such as shown in Fig. 3, can therefore be used for passing signals to a transmission circuit or accepting them from a tranmission circuit, the relative timing of the switching to the various channels being obtained from the delay network.

Fig. 4 shows an assemblage of hexŏde valves adapted to pass signals from six telephone channels and a synchronizing pulse in succession to a line **10**. The screen connections and source of heating current and bias potential are not shown. Any suitable type of feed well known in the art may be employed to obtain the feed currents and biases for these valves or for other valves shown in other figures.

The telephone channels are brought in to transformers **11** which apply telephone frequency potentials to the inner control grids **12** of the hexode valves. These valves have high resistances in their cathode circuits, so that the average current of each valve is about the same. The outer control grids **13** of the valves are biased negatively so that no signals pass to the line, and the anodes are connected to the line **10** through a delay of network D. This network is not shown in detail but is represented by a box terminated by a resistance R. The other end of the delay network is connected to the line **10** leading to the receiver or to a radio transmitter through any desired amplification or matching means.

For transmitting a signal of the type shown in Fig. 1, having a repetition frequency of 10,000 per second, the total delay from the point of connection of the first valve to the point of connection of the last valve is made just less than $1/_{10,000}$ second. Once every $1/_{10,000}$ second the pulse generator (not shown) applies a positive pulse to the outer control grid of all hexodes simultaneously. The extreme right hand hexode is not connected to a telephone channel, but has its inner grid connected through a condenser **14** to the outer grid so as to produce a large pulse of current in the line which represents the synchronizing pulse O. Simultaneously, the other hexodes apply pulses to the delay network representative of the voltage at that instant in the telephone circuits, since the available current which can be passed to the anode by the outer control grid, depends on the potential of the inner control grid. These signals arrive simultaneously at the various tapping points along the delay network. They there divide, half of each signal flowing left to the terminating resistance R, and the other half flowing right to the line. Since the delays of the various valves to the line are different, the signals will arrive in succession at the line and produce a waveform, as shown in Fig. 1, having, however, only six channels. The signals flowing to the left to resistance R will not be reflected (assuming the correct termination) and will therefore not reach the line.

It will be realized that in Fig. 4 the signals have been applied to the delay network and the synchronizing pulse has been applied simultaneously to all valves, whereas in the description given of Fig. 3, the synchronizing pulse was applied to the delay network so as to make each valve operate in turn. In the arrangement of Fig. 4, the capacity of the various anodes can form part of the network, but the drive for the control signal must be sufficiently powerful to charge the outer control grids of all valves simultaneously. In the arrangement of Fig. 4 the synchronizing signal is transmitted ahead of the group of signals with which it is synchronized. By placing the synchronizing valve at the other end of the delay network, it can be arranged that the synchronizing signal follows the group with which it is generated. With a reasonably steady pulsing frequency, the two arrangements are indistinguishable. For a slightly irregular pulsing frequency, the receiver can be made to operate with either arrangement.

Fig. 5 shows a receiving system for the signals generated in Fig. 4. A delay network D is connected at the left to the incoming line 15 and is terminated on the right by resistance R. As before, six hexode valves are connected to this delay network. In this case the outer control grids 13 go to the network. A tapping is taken from the right hand end of the delay network to the control grid of a valve 16, which is arranged to operate as a self-biasing separator valve. It is arranged that the synchronizing signal appears in the positive sense on the grid 17 of this valve so that it passes current at each synchronizing signal, but as is more fully explained in British Patent No. 422,906, self-biases itself to be insulating for all other signal amplitudes. The output of this valve is taken to a further amplifier valve 18 which has sufficient output to charge the inner control grids 12 of all six hexodes in the required period. As an alternative, the coupling condenser between the two valves may be made very small, so that the synchronizing signal is converted to a sharp negative followed by a sharp positive pulse on the grid of the valve 18. Either the negative pulse or the positive pulse may be utilized by taking the connection of the hexode grids 12 from the anode or cathode of valve 18. This or similar means may be employed to change the synchronizing pulse into a suitable pulse for actuating the hexodes. The correct timing of the pulse actuating the hexodes may be obtained by altering the position of tapping 19 along the delay network D. For example, if there is delay in passing the signals through valves 16 and 18, or if the tail end of the synchronizing pulse is used to operate the hexodes, the tapping 19 may be moved along the delay network towards the left as far as is required to give the correct timing.

The various hexodes receive appropriate pulses from the line, depending on the position of their tapping points. Every time the synchronizing signal operates valves 16 and 18, the hexodes become conductive and pass a signal to the anode circuits in accordance with the signals coming along the line. The anode current therefore consists of pulses recurring 10,000 times a second, carrying the telephone currents as a modulation. If desired, a filter may be put between the anodes and the telephone circuits to eliminate the pulsating carrier.

As shown in Fig. 5, the synchronizing signal used to operate the receiving train of valves is the synchronizing signal preceding the group of impulses. By moving the tapping 19 to the other end of the delay network, the synchronizing pulse following the group of impulses may be employed.

It will be noted that provision is made for using a sharp or short synchronizing signal to operate the receiving hexodes. It may be advantageous to use a shorter pulse on receiving hexodes than is used on transmitting hexodes, so that the middle portion of the elementary signal only is used at the receiver. Such an arrangement gives less liability to cross-talk due to slight mis-timing. Alternatively, short signals may be used at the transmitter so as to leave a slight dead gap between the signals of successive elementary channels. In actual practice for economic reasons, the signals will never be as rectangular and sharp, as shown in the drawings, but will consist of pulses beginning and substantially ending within the time period defined by the square pulses shown in the drawings.

Fig. 6 shows a block diagram of a six-channel receiving unit for receiving signals of the type transmitted by the circuit of Fig. 4, but employing delay networks in both the line and pulsing leads to the valves. The relays which may be hexode valves and are designated as rectangles H, have their outer control grids connected to a delay network D1 in the line circuit. The delay of this network is not as great as that of the network D of Fig. 5, and may, for example, be of the order of $\frac{1}{20,000}$ of a second. The synchronizing pulses are collected from a tapping 19, as shown before, a little way back along the network, to allow for time delay in the separating mechanism S. The actuating pulses from the separating mechanism (which may be similar to valves 16 and 18 in Fig. 5) are passed along another delay network D2 (terminated by a resistance R2) which has a delay equal to the difference between the total delay required and the delay in D1. The pulse is passed along this second delay network in the opposite direction and it will be seen that the signals are separated by the relay valves H, as though the total delay had been put either totally in the line, or totally in the pulsing circuit. This arrangement has the advantage that the valve capacities are included as part of the shunt condensers in the delay network, which calls for less energy from the separating mechanism S to actuate the six hexodes than is required in the arrangement of Fig. 5. Such a reduction in power is of considerable advantage in the case of a system employing a greater number, for example 20 hexodes. Similarly, the delay network D_1 in the line circuit prevents the sum of the grid capacities of the hexodes being bridged directly across the line circuit.

Fig. 7 shows a block diagram of a system for receiving a wave of the type shown in Fig. 2. There are shown at S, separators for synchronizing pulses. These separators employ the trailing edge of the synchronizing pulse to operate the relay valves H. The signals from the line 15 are passed to a number of delay networks D having a delay equal to the time period of one train of signals. The signals from the line 15 are also passed through a group pulse separator GS. This separates the group pulse (pulse OO in Fig. 2) and passes a group pulse down the group delay network GD. This has a total delay equal to the total period of a group and has tappings along its length at time intervals equal to the time between successive trains. This network need not have as good a frequency characteristic as the delay networks in the separate trains, as it requires only to pass a pulse of a width slightly shorter than the time of one train. The pulse so obtained is caused to operate on blocking valves B, which are put in the leads to the synchronizing separators of each train. The pulse from GD allows the blocking valve B to pass a synchronizing pulse to S which then operates the relays of the appropriate train. The next synchronizing pulse, however, does not pass to that separator because of the blocking valve B, but passes to the next synchronizing separator, since the group pulse has by this time unlocked the appropriate blocking valve. By this means the separate trains of signals are separated from one another and fed to the appropriate channels. The network DI between the line and the train separators is put in to provide the necessary delay to allow time for the operation of the group separator GS.

In Fig. 7 the synchronizing signals are shown applied to all valves simultaneously. Delay networks can obviously be put in the pulsing leads for relays H, after the manner of Fig. 6. Similarly, the synchronizing pulses are shown taken off at the left hand end of the delay networks D. They may, if preferred, be tapped off from the right hand end. With reasonably accurate train and group frequencies, the end of the delay networks from which the synchronizing pulses are taken is not of primary importance.

A similar arrangement can be used at the transmitter, the synchronizing signals being provided by a suitable pulse generator and being made to operate, in turn, on train delay networks. In the case of a transmitter, the right hand end of the lines shown in Fig. 7 pass to the outgoing line and the terminations are transposed to the left. Similarly, provision is made for mixing the synchronizing signals with the impulses on the line to produce a wave of the type shown in Fig. 2.

Fig. 8 shows schematically a method of correcting cross-talk due to bad pulse shaping. If the channel does not pass very high frequencies, the pulse representing the signal for any one elementary channel persists in the time allocated for the next channel, or even in a bad case into the next channel but one. Such persistence may take the form of a gradual decay of the pulse, which adds a signal in the same sense to the following channel. Alternatively, the persistence may consist of an overshoot in the opposite direction, which adds an opposite signal to the succeeding channel.

Fig. 8 also shows the anode connection for two hexodes arranged as in Fig. 5, except that the outputs are taken away through capacitative connections **20**. To points **20** are coupled triodes **21**. Triodes **21** serve to amplify the signals for the purpose of providing cross-talk correction. The amplifying triodes have resistance potentiometers in both anode and cathode circuits and cross-connecting leads **22** pass to the succeeding stage and may then be connected across either the cathode or anode potentiometers of the valves **21**. These connections feed current into the output of the succeeding stage and can be set to neutralize the cross-talk therein by suitable positioning of the switches **23** and adjustment of the appropriate potentiometer. It will be noted that cross-talk is to a small extent fed on to the next stage but one, so that assuming a logarithmic decay or a logarithmic decaying series of overshoots, cross-talk correction can be achieved for a large number of stages. As an alternative, a small telephone frequency coupling may be made between the anode of one valve and the grid of the next, which corrects cross-talk satisfactorily enough for most purposes. The cross-talk correction circuits need not pass dot frequencies from the line, but should be flat for the telephone frequency range.

Figs. 9 and 10 show arrangements for sending and receiving signals of the type shown in Fig. 2 by means of cathode ray tubes. The evacuated glass envelope is not shown in either Fig. 9 or Fig. 10. In both figures the lead **24** is connected to a target **25** on the signal plate **26** which is scanned by a beam of electrons produced by a gum assembly **27**. This beam is caused to scan the signal plate **26** by means of two saw tooth oscillation generators **28**, **29**, the outputs of which are applied to electrostatic deflecting plates **30**, **31**. In the case of both tubes, the target **25** is one of a number of targets arranged in rows on the plate **26**. These targets may be constructed as shown in Fig. 11, where a metal plate **26**, which may be the envelope of a cathode ray tube, has holes in it through which are pushed metal plugs **33** insulated from the signal plate **26** and held gas-tight by glass beads **34**. The formation of such a plate requires glass with a coefficient of expansion similar to that of the metal employed. In a transmitting tube shown in Fig. 9, a wire mesh screen **37** is interposed between the gun **27** and the signal plate **26** containing the targets, which screen is held positive with respect to the gun cathode **35**. The signal plate **26** is held slightly negative with reference to the gun cathode **35** and the mean potential of the target is held slightly positive with respect to the gun cathode **35**. When the beam is directed at a given target, a fraction of the electrons are turned back from the target to the grid mesh-work in front of it. This fraction turned back depends on the potential of the target, which during the moment of scanning is that of the telephone channel which is connected to the target in question.

A small condenser **36** is shown as representing the capacity to earth of the target **25**, which should be large enough to hold its potential steady during the instant of scanning. The currents to the screen **37** are passed through a resistance **38**, the voltage across which is amplified at **39** and passed to the cable or radio link by a lead **40**. The scanning pulses are generated by an oscillator **41** and pulse generator **42** as for television, blackout being provided to turn the cathode ray beam off during return strokes. Synchronizing pulses are also generated and mixed in with the line signals. The wave-form obtained is similar to that shown in Fig. 2 if an area is scanned, or as shown in Fig. 1 if only one line of targets is scanned. In the latter case only line scanning is provided and one set of deflecting plates may be dispensed with.

As an alternative to taking the signals from the screen **37**, they may be obtained from the metal plate **26**, the signals being fed from the elements through capacities between elements and this plate, which capacities may be the inevitable capacities formed in the construction; the telephone frequency currents being fed to the elements through a high resistance. In both the case where the signals are taken from grid **37** or plate **26**, the synchronizing signals may be produced simply by shutting the beam off, since a limiting signal in one direction is produced by such switching of the beam.

Fig. 10 shows a circuit for use at the receiving end, a signal plate similar to that at the transmitter being used, except that the grid in front of the targets is omitted. The line signals coming in are passed to saw-tooth oscillation generators 28, 29 which produce saw-tooth synchronizing signals as in a television receiver. Amplified line signals are passed to the control electrode 43 of the cathode ray gun which modulates the beam in accordance with the line signals. The beam impinges on to the target which is held positive with respect to the second anode 44 to prevent the flow of secondary emission current. The current in the target is therefore proportional to the beam current, and a direct coupling is taken from the target to the telephone circuit 45, with the interposition, if necessary, of a filter to smooth out the pulses. As before, for waves of the form shown in Fig. 2, a complete area is scanned; for those of the form of Fig. 1, only a line is scanned. In both the transmitting and receiving tubes the scanning accuracy requires to be better than one part in the number of elements in a train or a number of trains in a group.

The cathode ray transmitting and receiving apparatus may be used interchangeably with a delay network type as shown in the earlier drawings; thus a cathode ray transmitting tube may be used with a delay network receiver and vice versa.

The transmission of signals here described requires a transmission link suitable for facsimile or television signals, in that substantially no phase distortion is tolerable within the working frequency range. On the other hand, curvature distortion due to amplifying tubes, etc., does not give cross-talk in the channels as in a multiple carried transmission system.

It will be understood that the scope of the invention is not limited to the arrangements shown in the drawings, and that these are by way of illustration only. Thus, for example, in circuits employing a row of valves as in Fig. 4, it is not essential that hexode valves should be used. Instead of such valves, rectifiers may be employed, the signal pulses being applied to the line as shown in Fig. 4 through rectifiers so arranged that only the peak of the pulse rises to sufficient voltage to pass through the rectifiers. Secondary windings of the telephone transformers are shunted by suitable small condensers and are connected in series with the source of the pulses and each rectifier, so that the E. M. F. from the telephone circuit affects the amplitude of the pulse passed through the rectifier. The rectifiers employed may be of the copper oxide or contact type, and the number of valves may in this way be considerably reduced.

Again, bridge circuits of known type, including contact rectifiers, may be used, the signal amplitude modulating the pulse amplitude passed through the bridge circuit. Tests have shown that it is possible to transmit a telephone frequency range which extends up to half the cycle frequency. Thus if a pulse representing the message of one particular channel is sent 7,000 times per second, then frequencies up to 3,500 can be transmitted on this channel. Any attempt to transmit higher frequencies than 3,500 leads to the production of unwanted difference frequencies. If such frequencies exist in the telephone channel, it is necessary to insert a simple filter to cut out frequencies above half the pulsing frequency.

The systems here described are very suitable for operation over cables which are built to constant attenuation and velocity.

What is claimed is:

1. The combination with a system of multiplex signaling in which, at the transmitter, signals are fed from a plurality of channels through a signal circuit and in which a train of elementary signals is transmitted through that circuit and having means for interspersing said elementary signals with synchronizing signals having an amplitude range outside the amplitude range of said elementary signals, each elementary signal being representative of the signal in one of said channels, of switching means at said transmitter responsive to said synchronizing signals for connecting each of said channels in turn to said signal circuit.

2. A system according to claim 1, in which a plurality of groups of signals is transmitted through a single circuit, each group comprising a plurality of trains of elementary signals representative of signals in separate channels, the trains within a group being separated from one another by synchronizing signals, there being provided means for separating the groups from each other by further synchronizing signals of different duration from the synchronizing signals separating the trains within a group.

3. A system according to claim 1 in which a plurality of groups of signals is transmitted through a single circuit, each group comprising a plurality of trains of elementary signals representative of signals in separate channels, the trains within a group being separated from one another by synchronizing signals, there being provided means for separating the groups from each other by further synchronizing signals of different amplitude from the synchronizing signals separating the signal trains within a group.

4. A system for multiplex signaling in which a plurality of groups of signals is transmitted through a single circuit, each group comprising a plurality of trains of elementary signals representative of signals in separate channels, means for separating the trains within a group from one another by synchronizing signals having an amplitude range outside the amplitude range of said elementary signals, and means for separating the groups from each other by further synchronizing signals of different amplitude from the synchronizing signals separating the signal trains within a group.

5. A system for multiplex signaling in which a plurality of groups of signals is transmitted through a single circuit, each group comprising a plurality of trains of elementary signals representative of signals in separate channels, means for separating the trains within a group from one another by synchronizing signals having an amplitude range outside the amplitude range of said elementary signals, and means for separating the groups from each other by further synchronizing signals of both different duration and amplitude from the synchronizing signals separating the signal trains within a group.

6. A system for multiplex signaling in which a plurality of groups of signals is transmitted through a single circuit, each group comprising a plurality of trains of elementary signals representative of signals in separate channels, means for separating the trains within a group from one

another by synchronizing signals having an amplitude range outside the amplitude range of said elementary signals, and means for separating the groups from each other by further synchronizing signals of different duration from the synchronizing signals separating the trains within a group.

7. The combination with a system of multiplex signaling in which, at the transmitter, signals are fed from a plurality of channels through a signal circuit and in which a train of elementary signals is transmitted through that circuit, and having means for interspersing said elementary signals with synchronizing signals having an amplitude range outside the amplitude range of said elementary signals, each elementary signal being representative of the signal in one of said channels, of switching means at said transmitter in the form of a plurality of relays responsive to said synchronizing signals for connecting each of said channels in turn to said signal circuit.

8. A system in accordance with claim 7, including a delay network between said signal circuit and said relays.

9. A system in accordance with claim 7, characterized in this that a delay network is provided for influencing the timing of said synchronizing means.

10. The combination with a system of multiplex signaling in which, at the transmitter, signals are fed from a plurality of channels through a signal circuit and in which a train of elementary signals is transmitted through that circuit, and having means for interspersing said elementary signals with synchronizing signals having an amplitude range outside the amplitude range of said elementary signals, each elementary signal being representative of the signal in one of said channels, of switching means at said transmitter responsive to said synchronizing signals for connecting each of said channels in turn to said signal circuit, said switching means including a cathode ray tube serving as a signal distributor.

11. The combination with a system of multiplex signaling in which, at the transmitter, signals are fed from a plurality of channels through a signal circuit and in which a train of elementary signals is transmitted through that circuit, and having means for interspersing said elementary signals with synchronizing signals having an amplitude range outside the amplitude range of said elementary signals, each elementary signal being representative of the signal in one of said channels, of switching means responsive to said synchronizing signals for connecting each of said channels in turn to said signal circuit, said switching means including a cathode ray tube serving as a signal distributor, said cathode ray tube having a screen and a plurality of targets behind said screen, said targets being associated with signal channels.

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