

Feb. 16, 1943.

A. D. BLUMLEIN

2,311,021

MULTIPLEX RECEIVING SYSTEM

Original Filed Nov. 6, 1936

Fig. 3.

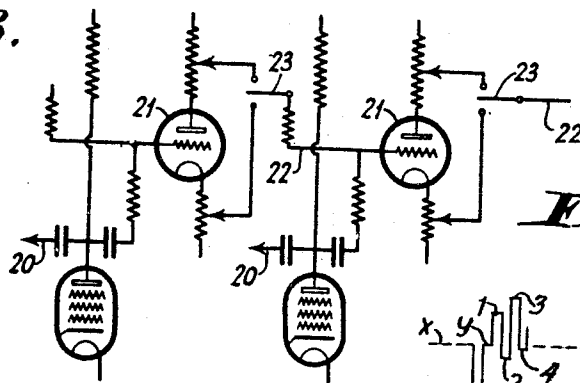


Fig. 1.

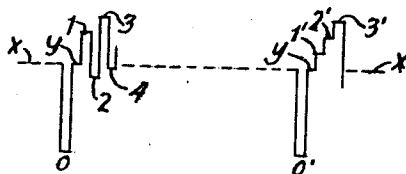


Fig. 4.

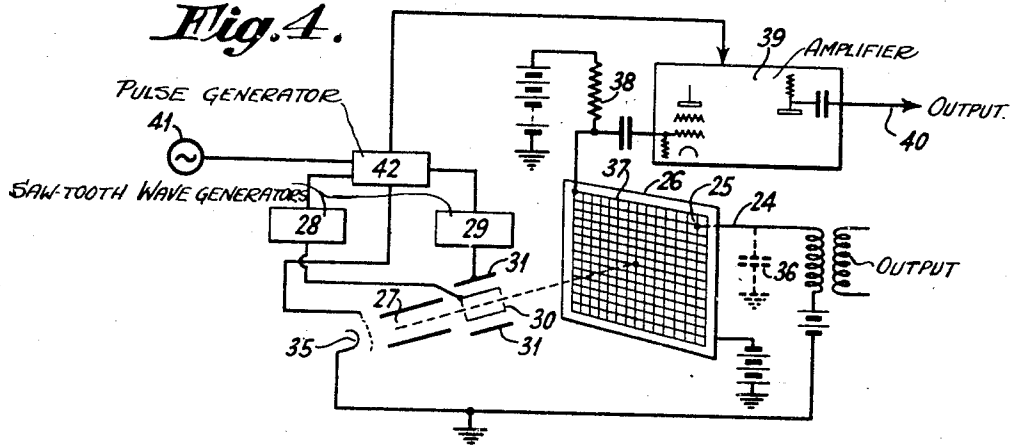


Fig. 5.

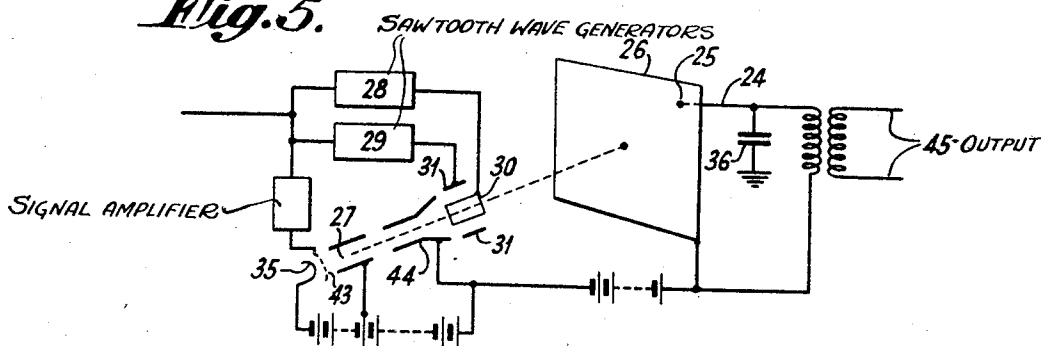


Fig. 6.

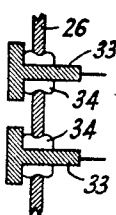
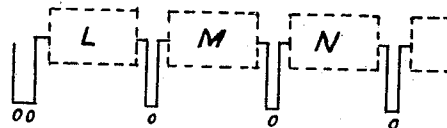


Fig. 2.



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2,311,021

MULTIPLEX RECEIVING SYSTEM

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Original application November 6, 1936, Serial No. 109,456. Divided and this application July 19, 1939, Serial No. 285,276. In Great Britain November 14, 1935

4 Claims. (Cl. 179—15)

The present invention relates to multiplex signalling systems, and more particularly to receiving apparatus as used in such systems. This application is a division of my application Serial No. 109,456, filed November 6, 1936.

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. In these 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 a 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 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 serves 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 present 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 drawing wherein:

Figure 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 a circuit for reducing or neutralizing cross-talk between channels;

Figs. 4 and 5 show arrangements employing cathode ray tubes at the sending end and receiving end, respectively; and

Fig. 6 shows a construction of signal plate suitable for use in the tubes of Figs. 4 and 5.

It is assumed that it is desired to transmit signals from a plurality of channels (telegraph, telephone or other signalling 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 n th 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 0 and 0' 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 0', 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 signalling 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 0, 0' 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 q th train, a repetition of the sequence begins. The trains L, M, N are separated from one another by synchronizing pulses 0 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 0. Thus, the group synchronizing signal 00 shown before train L differs from train synchronizing signals 0 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 00 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 00 functions for group L as a train synchronizing signal. If desired, a train synchronizing signal of normal form may be inserted between the signal 00 and the beginning of the group L. In another arrangement, either the leading or trailing edge of signal 00 is timed to take the place of a train synchronizing signal. In yet another arrangement, the group synchronizing signal 00 is broken into parts in the manner known for frame synchronizing signals in television systems, one of these parts being used as a train synchronizing signal. It will be seen that the group synchronizing signals 00 and the train synchronizing signals 0 bear a close resemblance to the frame and line synchronizing signals used in many television 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 response 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. Sometimes the low frequency components are not transmitted. That is to say, they are fed to the transmission circuit, or they may be lost either in the transmission circuit or at the receiving end. It is possible, however, to re-establish the low frequency components 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, subjected 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 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. 3 also shows the anode connection for two hexodes arranged as in Fig. 5 of my Patent 2,172,354 (of which the instant application is a division) except that the outputs are taken away through capacitive 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. 4 and 5 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. 4 or Fig. 5. 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 gun 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. 6, 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. 4, 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 inherent 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 pro-

duced simply by shutting the beam off, since a limiting signal in one direction is produced by such switching of the beam.

Fig. 5 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 velocity must be maintained accurate to within one part in the number of elements in a train or the 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 produce cross-talk in the channels as in a multiple carrier transmission system.

It will be understood that the scope of the invention is not limited to the arrangements shown in the drawing, and that these are by way of illustration only.

It will be understood by those skilled in the art that bridge circuits of known type, including contact rectifiers, may be used, the signal amplitude modulating the pulse amplitude being 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. In a multiplex system which is receptive of a succession of trains of elementary signals, each elementary signal being appropriate to a different channel, and there being a group of channels appropriate to each train, said elementary signals being restricted to a predetermined amplitude range and being interspersed with synchronizing signals the amplitude of which exceeds

said range, a plurality of receiving circuits each appropriate to a different multiplex channel, a channel distributor comprising a cathode ray tube having a mosaic of target electrodes each connected to an appropriate one of said receiving circuits, means responsive to said synchronizing signals when they possess one given characteristic for causing said channel distributor to switch successive elementary signals into different ones of said receiving circuits in turn, and means responsive to said synchronizing signals when they possess another characteristic for causing said channel distributor to switch successive trains of elementary signals into different groups of said receiving circuits which are respectively appropriate to different ones of said groups of channels.

2. In a multiplex system in which a plurality of groups of signals is received through a single circuit, each group comprising a plurality of trains of elemental signals, separate signals being respectively appropriate to different channels, said signals being restricted to a predetermined amplitude range, the trains within a group being separated from one another by synchronizing signals of one characteristic, and successive groups of trains being separated from one another by synchronizing signals of a different characteristic, the synchronizing signals of both characteristics being of an amplitude outside said predetermined amplitude range, a plurality of receiving circuits each appropriate to a different multiplex channel, a continuously operable channel distributor for switching successive elemental signals cyclically into different ones of said receiving circuits, means responsive to the first said synchronizing signals for correcting the phase of said distributor with respect to each said train of signals, and means responsive to the second said synchronizing signals for correcting the phase of said distributor with respect to each said group of signal trains.

3. In a system for receiving multiplex signals which have been transmitted in groups through a single circuit each group comprising a plurality of trains of elementary signals representative of signals in separate channels, means for amplifying said signals to within a predetermined amplitude range, a cathode ray tube distributor having a mosaic of target electrodes by which said signals after amplification are successively allocated to separate receiving channels, phase correcting means for said distributor, the last said means being responsive to synchronizing signals of two types wherein those of one type are of different duration and amplitude from those of the other type and all synchronizing signals are amplitudinally distinguishable from said elementary signals, means responsive to synchronizing signals of the first type for operating the phase correcting means so as to maintain suitable separation between said trains of signals, and means responsive to synchronizing signals of the second type for operating the phase correcting means so as to maintain suitable separation between the groups of signals.

4. A multiplex receiving system comprising means for selecting and amplifying to within a predetermined amplitude range elementary intelligence-bearing signals, means for selecting synchronizing signals which have been interspersed between successive trains of the first said signals, means for selecting synchronizing signals which have been interspersed between successive groups of said trains, deflecting cir-

cuits operable from said synchronizing signal-selective means, and a cathode ray tube distributor for assigning successive elementary signals to different receiving channels, said distributor having the following components, to wit, a mosaic of target electrodes constituting different output terminals for the respective receiving

channels, line scanning means operable by one of said deflecting circuits at the frequency of said train-interspersed synchronizing signals, and frame scanning means operable by the other of said deflecting circuits at the frequency of said group-interspersed synchronizing signals.

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