Nov. 30, 1948. D. D. GRIEG 2,454,792

PULSE MULTIPLEX COMMUNICATION SYSTEM

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Fig. 1.

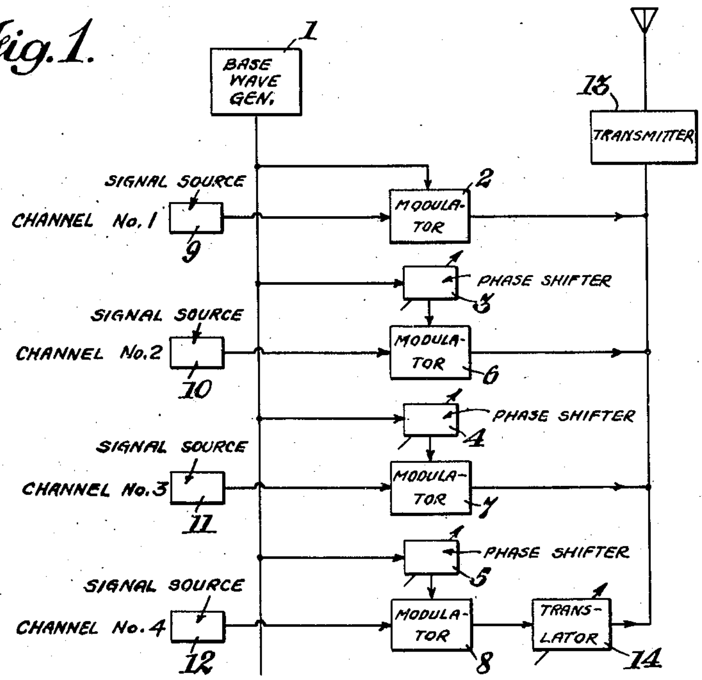

Fig. 2.

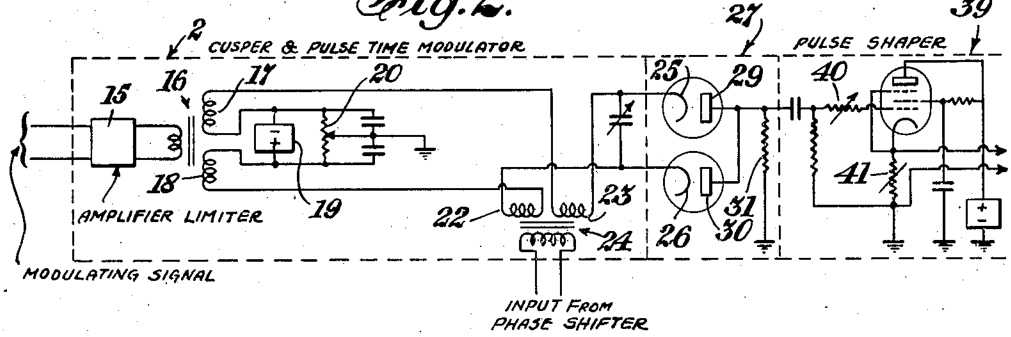

Fig. 3.

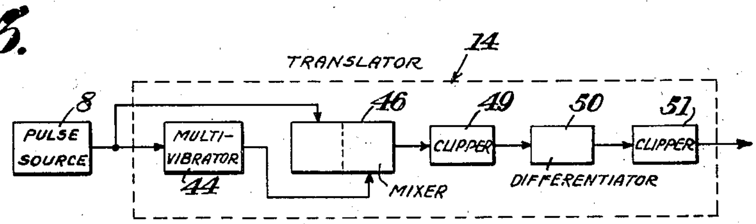

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Fig. 4.

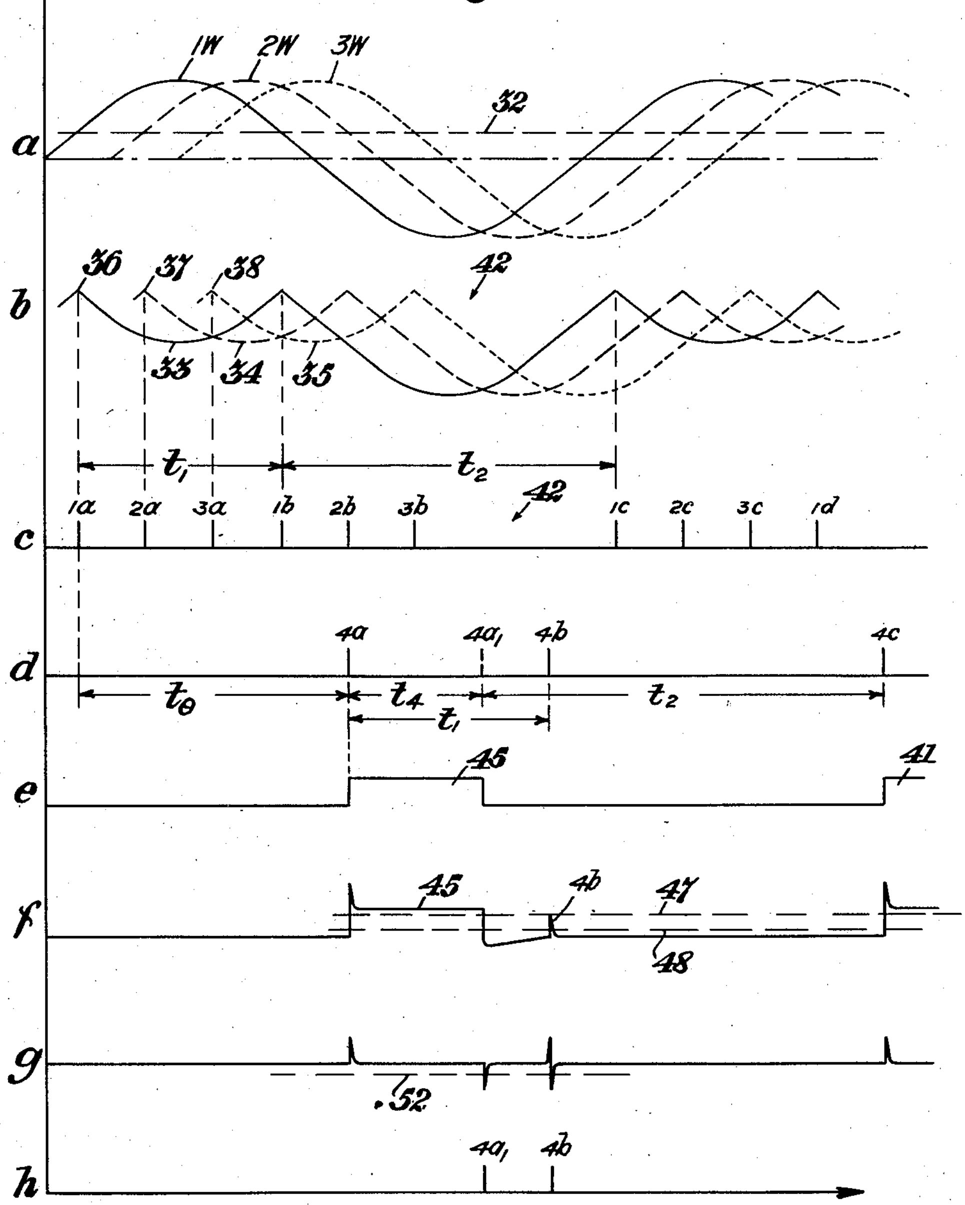

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Fig. 5.

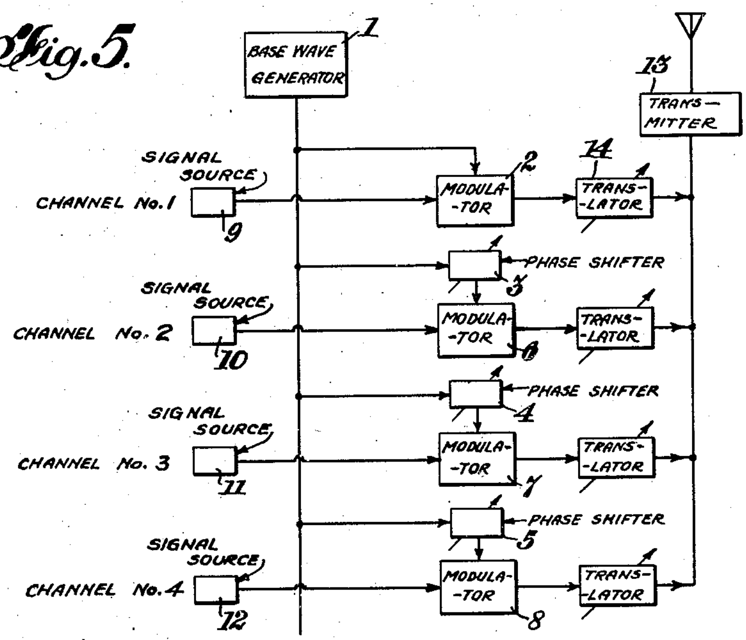

Fig. 6.

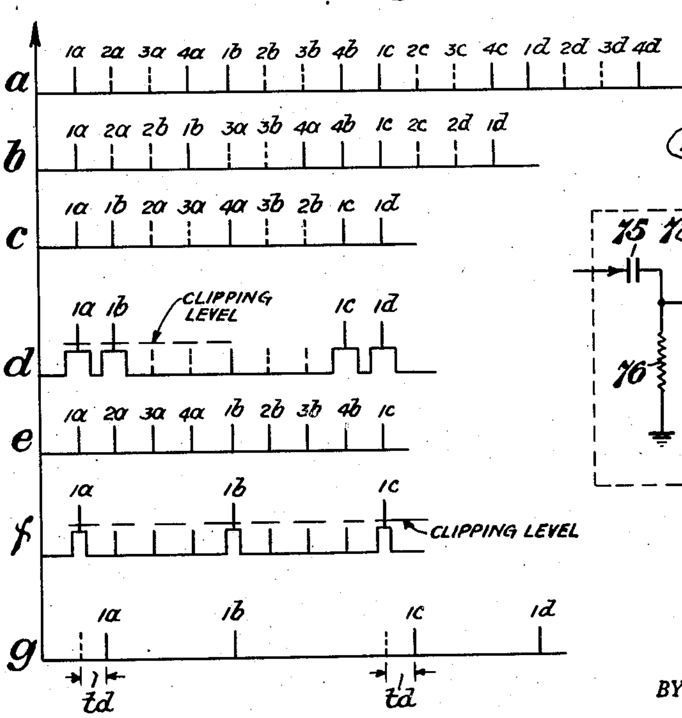

Fig. 8.

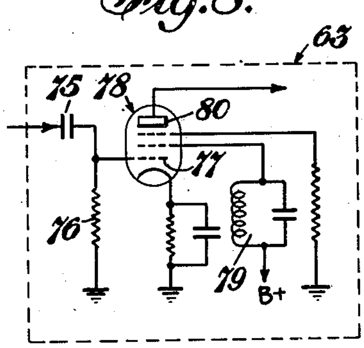

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Fig. 9.

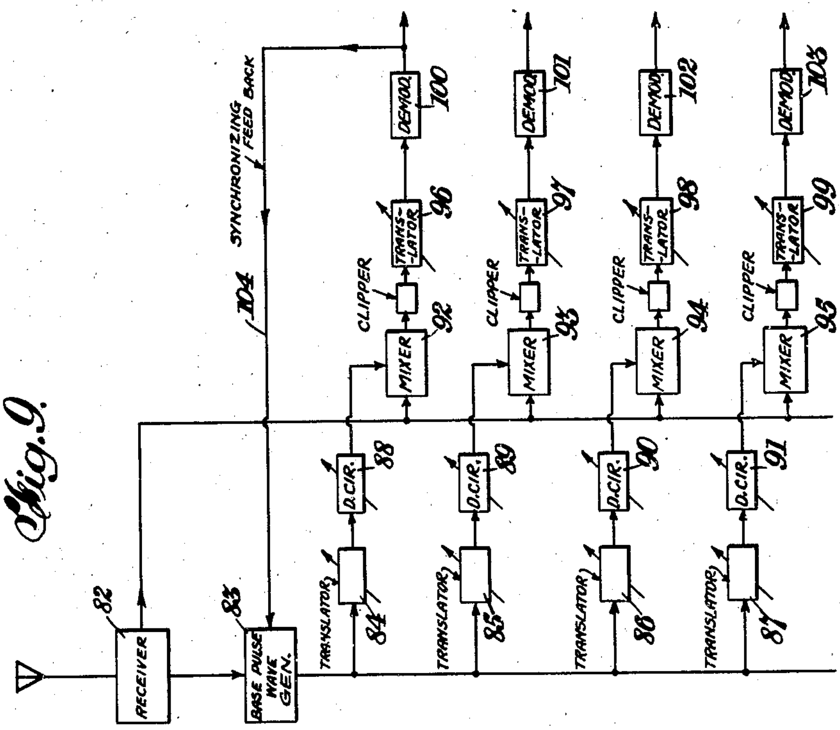
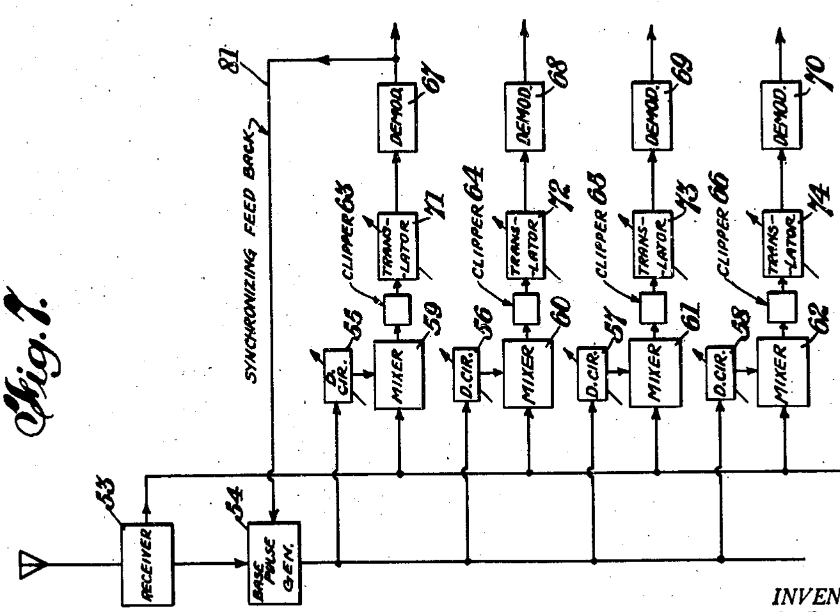


Fig. 7.



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UNITED STATES PATENT OFFICE

2,454,792

PULSE MULTIPLEX COMMUNICATION SYSTEM

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Application August 19, 1944, Serial No. 550,184

17 Claims. (Cl. 179—15)

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This invention relates to communication systems and more particularly to multi-channel signal communication systems and methods employing a plurality of pulse trains for transmitting and selectively receiving various intelligence.

In intelligence conveying systems and more particularly in pulse communication systems, intelligence may be transmitted by trains of short impulses modulated in accordance with signal voltages. According to these systems the modulation may be by displacement in time or with respect to other pulse characteristics.

In the time displacement modulation of pulses, as in one instance disclosed in the copending application of E. M. Deloraine and J. L. Fearing, Serial Number 506,802, filed October 19, 1943, now Patent No. 2,429,613, dated October 28, 1947, entitled "Transmission systems," describing a multichannel signalling system, the pulses for each channel may be paired off, the time interval between these pulses being smaller than the time interval between succeeding pairs of pulses. The different trains of channel pulses are differently timed so that when they are fed to a common transmission link, they are interleaved together with a given time spacing between succeeding pulses. At regular intervals the train of pulses is interrupted to form groups of pulses usable for synchronization at the receiving end. At the receiving terminal means are provided to segregate the respective channels from the incoming transmitted pulse trains. The pulses of a segregated channel are then applied to a relatively simple demodulator for reproduction of the intelligence conveyed by such channel.

In other instances, the pulses of the various channels are interleaved by means of quite regular sequential timing, necessitating more involved demodulating means at the receiving terminal as compared to the simple demodulator employed for irregularly timed pulse trains.

In order to render the facilities of multiplex systems of this type more fully available, it is frequently desirable to be able to shift, translate the spacing or offset the different channel pulses with respect to one another and along the time axis, either to fill in unused spaces between groups of pulses or pulse pairs, or for the purpose of varying the relative timing position of the channels. The latter may be of advantage, for instance, when trying to preserve the privacy of communication, i. e. to avoid undesired detection of any given one or a plurality of channels, or where rearrangement of the spacing of the channels from a regular to an irregular one is desirable.

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An irregular spacing is advantageous in that it makes it possible for a relatively simplified demodulator to be used at the receiving end, as will appear hereinafter.

The translation from regular to irregular spacing, of course, may be also had at the receiving terminal, as in many systems it is preferable to transmit uniformly spaced pulses.

In accordance with my invention, one or more circuits, for translating the position of pulses which may be of the type disclosed in my copending application Serial Number 522,139, entitled "Translator system," filed February 12, 1944, may be provided, as required, at the transmitter, as well as at the receiving terminal. A pulse position translating circuit may be provided for each or any of the channels to be used, as desired, at the transmission end, while at the receiving terminal, I provide pulse position translating circuits for varying the relative time position of the channel pulses themselves, or as a means for obtaining a channel segregating deblocking signal from a locally produced pulse train.

Accordingly, it is an object of my invention to provide a multi-channel pulse type communicating system and method wherein the spacing of the pulses of the various channels with respect to one another and of the pulses of a single channel may be varied at will.

It is also an object of my invention to provide a multi-channel communicating system, wherein pulse position translating means are provided both at the transmitting and the receiving end.

The above and other objects and features of the invention will become more apparent upon consideration of the particular description thereof made with reference to the accompanying drawings, in which:

Fig. 1 is a block diagram of the transmitting terminal of a multi-channel communicating system incorporating pulse position translating circuits in accordance with the invention;

Fig. 2 is a cusper type modulator circuit for one of the channels of Fig. 1;

Fig. 3 is a typical pulse position translator circuit shown in block form;

Fig. 4 is a series of graphs illustrating the operation of the cusper modulator circuit of Fig. 2, the type of pulse train obtainable from the circuit of Fig. 1, and the operation of the translator circuit of Fig. 3;

Fig. 5 is a block diagram of another form of transmitting terminal in accordance with the invention;

Fig. 6 shows a number of graphs indicating miscellaneous pulse train relationships as obtained from the circuit of Fig. 2 and correlated to the receiving circuits of Figs. 7 and 9;

Fig. 7 is a block diagram of the receiving terminal of a multi-channel signalling system having means for translating the position of the pulses of each of the channels;

Fig. 8 is a schematic diagram of a demodulator circuit for translating the time modulated pulses into amplitude modulations;

Fig. 9 is a modification of the receiving terminal of Fig. 7.

Turning first to Fig. 1, the reference character 1 designates a control generator for producing a basewave which may have any desired frequency. Energy from the source 1 is applied directly to a modulator 2 and over phase shifters 3, 4 and 5 to time modulators 6, 7 and 8, respectively, representing the circuits of the four channels illustrated in the figure. Separate signal sources 9, 10, 11 and 12 apply modulating signals to the modulators 2, 6, 7 and 8 to provide, for instance, time modulated pulse trains for a transmitter 13 in accordance with the signals. A pulse position translator 14 is provided in channel 4 to shift the modulated pulses of the modulator 8, as desired.

The modulators 2, 6, 7 and 8 may be of any one of several forms whereby a basic train of pulses, as obtained from the wave produced at the generator 1, may be time modulated according to the signal from the signal sources 9, 10, 11 and 12. However, to illustrate the utility of a pulse position translator in connection with a specific example, a modulator will be described hereinafter, as disclosed in the copending application Serial Number 506,802 by E. M. Deloraine and J. L. Fearing, filed October 19, 1943, and as shown in detail in Fig. 2. The modulator of Fig. 2, as will appear presently, is a so-called biased "push-pull" type of modulator. There are available a number of other suitable "push-pull" types of modulators, for example the cusper types disclosed in the copending joint application of E. Labin and D. D. Grieg, Serial Number 455,897, filed August 24, 1942, now Patent No. 2,416,329, dated Feb. 25, 1947, or the gate clipping type disclosed in a second joint application of E. Labin and D. D. Grieg, Serial Number 455,899, also filed August 24, 1942, now Patent No. 2,387,969, granted October 30, 1945.

In the modulator circuit of Fig. 2, the modulating signal wave from the signal source 9 is applied to an amplitude limiter 15. The output of the amplitude limiter 15 feeds the primary of a transformer 16 between the two windings 17 and 18 of which is connected a direct current, biasing source of potential 19 having in shunt therewith a potentiometer 20. In series with each of the two secondary windings 17 and 18 is connected one of the two secondary windings 22 and 23 of an input transformer 24 adapted to receive the base wave energy 1W, graph *a* Fig. 4, from generator 1, either directly as in channel 1 or through a phase shifter as in channels 2, 3, and 4 such as shown for three channels in the graph *a* of Fig. 4. Each of the secondary windings 22 and 23 of the transformer 24 is connected with one of the cathodes 25 and 26 of a full wave rectifier 27. The anodese 29 and 30 of the rectifier 27 are connected together through an output resistance 31 to ground.

The operation of the cusper of Fig. 2, as disclosed in the application Serial Number 506,802 referred to hereinabove, will be briefly recapitulated in the present instance. Any of the time control waves 1W, 2W or 3W shown in graph *a*, differing in phase from each other by the action of the phase shifters in each of the channels, is applied to the transformer 24. The potentiometer 20 controls the biasing of the secondaries which may be at the level 32 (graph *a*). The full wave rectification of the waves as obtained at the load resistor 31, thus occurs with reference to said level 32, as the axis of rectification, thereby producing cusper output waves 33, 34 and 35 having cusps 36, 37 and 38, etc., graph *b*. These cusps are paired off in time, the interval t_1 between the cusps of each pair being smaller than the interval t_2 between succeeding pairs of cusps of the same channel. The relationship of the two intervals represented by t_1 and t_2 is determined in part by the selected bias on the cusper as well as by the number of channels to be contained in one period of the time controlled wave, such as represented by 1W. The shape of the pulses delivered by the modulator is determined by a pulse shaper circuit 39 into which the output of the cusper circuit 2 is fed. The adjustment of a control grid resistor 40 and a cathode resistor 41 determines the width of the resulting output pulses as well as their relative flatness. By inspection of graphs *b* and *c* (Fig. 4), the pulses corresponding to the various cusps will be recognized, as for instance pulse 1*a* which is the resultant of the cusp 36. In view of the small and large wave portions on opposite sides of the axis 32, the pulses of the three channels form groups of six pulses leaving an interval 42 therebetween. As disclosed in application Serial Number 506,802 previously mentioned, this interval may be used for monitoring or synchronizing purposes at the corresponding receiving station. In this instance, however, the insertion or sandwiching in of an additional channel for signalling or monitoring purposes is proposed, as illustrated in connection with channel 4 of Fig. 1. For this reason the pulse position translator circuit 14 in channel 4 (Fig. 1) has been provided.

The pulse position translator circuit may be of the type disclosed in the copending application Serial Number 522,139 mentioned hereinabove, and as shown in block form in Fig. 3. The pulse position translator receives a series of pulses from a source such as the modulator 8 in channel 4 of Fig. 1. This pulse train is comprised of pulses which are paired off as in graph *c*, and are referred to in graph *d* of Fig. 4 as 4*a* and 4*b*, showing their relationship with respect to the pulse trains of channels 1, 2, and 3, t_o indicating the shift in phase due to the phase shifter 5. Pulse 4*b* is first positioned in time interval 42 as finally required, and pulse 4*a* is then shifted toward 4*b* by means of the translator circuit 14 by a time interval t_4 to a position 4*a*1, which places pulses 4*a* and 4*b* into the interval 42 graph *c*, Fig. 4, as desired. The operative effect of the translator circuit depends on a delay t_4 given the leading pulse 4*a* by means of a multivibrator circuit 44 (Fig. 3) which is energized by the leading pulse 4*a* to produce a frequency dividing pulse 45 (graph *e*, Fig. 4). The width of pulses 45 may be adjusted by suitably varying the proper parameters of the circuit 44 and thereby controlling the amount of delay effected thereby. From the multivibrator or delay device 44 the pulses 45 are passed on to a mixer circuit 46, wherein the combination of pulses 4*a* and 4*b* and of the pulses 45 produces a waveform such as shown in graph *f* (Fig. 4). This waveform is then clipped at levels

47 and 48 in a clipper circuit 49 and differentiated in a circuit 50, the result of which is shown in graph g (Fig. 4). These pulses are then clipped again and amplified in a circuit 51 at a level 52, producing a series of pulses 4a1 and 4b, in accordance with graph h of Fig. 4 which are now offset in such a manner as to fall within the interval 42 (graph c, Fig. 4). Any desired translation in the position of the pulses may thus be achieved in the manner just described.

Another possibility for translating the position of pulses at the transmitter end of a signalling system is illustrated in Fig. 5, wherein each of the four signalling channels is provided with a pulse position translator 14, otherwise being generally similar to the circuit of Fig. 1. However, in this instance, the individual modulators 2, 6, 7 and 8 are not biased as in the case of Fig. 1 and in fact are totally unbiased except for the periods when modulating voltages are applied. This will result in regularly spaced pulses being supplied from the modulators of the type indicated in graph a, Fig. 6. By the proper adjustment of the phase shifters and modulators in each of the channels of Fig. 5, another grouping of the trains of pulses as shown in graph b, Fig. 6, may be obtained, if desired. Another possible result obtainable by manipulation of the circuit of Fig. 5 is shown in the pulse train of graph c, Fig. 6. Other variations are possible as required.

Fig. 7 illustrates in block form a receiving circuit for receiving regularly spaced incoming pulses, such as shown in graph e, Fig. 6. Here, the pulse trains, coming in regular sequences, are received in a receiver 53, and are from there fed to a base pulse generator 54, where they are effective in exciting a basic pulse undulation having a repetition frequency directly proportional to that of the incoming regularly spaced pulses of one of the channels. The base pulse wave, thus obtained, is applied in turn to each of delay circuits 55, 56, 57 and 58 where the base pulse is given a suitably timed delay in phase, to be used as a channel deblocking and segregating signal in the mixer circuits 59, 60, 61 and 62, to which the incoming pulse trains from the receiver 53 have been applied simultaneously. The resultant of the mixer circuit 59 is shown in graph f of Fig. 6, corresponding to the pulse trains of graph a (Fig. 6). These output pulses are then clipped in clipper circuits 63 through 66, the respective channels thus becoming separated. In order to make it possible, as brought out hereinabove, for simplified time displacement demodulators 67 through 70 to be used, pulse position translators 71 through 74 are provided in each of the channels preceding the demodulators.

A simple form of such a demodulator is shown in Fig. 8. The pulses are applied over coupling elements 75 and 76 to an input grid 77 of a demodulating tube 78. These pulses serve to shock excite a circuit 79 tuned to a harmonic of the cadence frequency of the input pulses. This wave generated in circuit 79 is combined with the pulses applied at the grid 77 in controlling the output of the anode electrode 80, raising in effect the pulses to different amplitude levels in accordance with the time displacement modulation. The demodulator shown by way of example is not a part of this application and so its operation is not explained in detail. For a complete understanding of the operation of this demodulator circuit, reference is had to my copending application 459,959 of September 28, 1943, now Patent No. 2,416,306, granted February 25, 1947, entitled

"Demodulator." These demodulated pulses are then passed on to an audio reproducer or other suitable type of amplitude modulation responsive equipment. Without going into the details of the operation of the demodulator of Fig. 8, it will suffice at this time to point out that the circuit, which is quite simple, will operate best when the time modulated pulses applied to its control grid are irregularly spaced or offset rather than being spaced regularly as shown in graph f, Fig. 6. By proper adjustment of the corresponding pulse position translator circuit, every other pulse of the pulse train shown may be displaced or offset to form a train of paired-off pulses as illustrated in graph g, Fig. 6, the amount of time displacement being indicated by t_d. The displacement is attained in a manner as has been described in connection with Figs. 3 and 4.

A synchronizing feed back connection 81, Fig. 7, is provided from the output of the demodulator 67 to the base pulse wave generator 54 serving to keep the generator from drifting out of synchronism with the cadence frequence of the incoming pulses.

Should the incoming pulses be of the displaced type shown for instance in graphs b and c of Fig. 6, it becomes necessary to translate in position or offset the deblocking signal pulse in order to segregate the individual channels. The circuit for doing this is shown in block form in Fig. 9. The incoming pulse trains applied to a receiver 82 are effective in exciting a base pulse wave generator 83, as explained in connection with Fig. 7, to produce a base pulse wave. The base pulse wave generator may be, for instance, the type known as a "blocking oscillator," the principles of which are well-known and will not be described in further detail. The base pulse wave, thus obtained, is applied over the respective pulse position translators 84 to 87, where in each case it obtains a suitable translation in the base pulses corresponding to the offset of the pulses of the respective channel. To the translated base pulse of each channel is then given, if necessary, a proper shift in phase or timing by means of the delay devices 88 to 91 to effect a complete synchronization of the basic pulses with the desired channel pulses. The basic pulses, now positioned to properly segregate the respective channels, are then applied to mixers 92 through 95, there serving to deblock for instance channel 1, in the manner shown in graph d, Fig. 6, from the pulse trains of graph c, Fig. 6, the deblocked pulses then being clipped at a level just above the deblocking pulses, as in graph d. The pulses for the various channels obtained in this manner may still be regularly spaced as far as the ultimate demodulator is concerned, and the receiver of Fig. 9 is therefore provided with additional translating devices 96 through 99 in the four channels in order to be able to translate the individual channel pulses obtained by deblocking into a desired offset relation for demodulation. The demodulators 100 through 103 may be similar to those discussed in connection with the receiver shown in Fig. 7. A synchronizing feed back connection 104 from the output side of the demodulator 100 to the base pulse wave generator 83 is provided, similarly to that shown in Fig. 7.

It is apparent from the above description that I have provided a communicating system of extreme flexibility wherein the relative offset of the pulses of the various channels is quite independent at either terminal of the system from that of the other terminal.

It is to be distinctly understood that the embodiments of my invention specifically described herein are given by way of example only and are not to be regarded as limitations on the scope of my invention, as set forth in the objects thereof and in the accompanying claims.

I claim:

1. A multi-channel communicating system comprising means for producing for each of a plurality of channels a separate pulse train time modulated in accordance with a corresponding signal, means to time differently the pulses of the different channels to interleave the different pulse trains together as a single train of pulses, pulse position translating means in at least one of said channels, means for transmitting said interleaved train of pulses over a common transmitting medium; pulse receiving means having a plurality of receiving channels; a plurality of channel pulse train segregating means, one for each of said receiving channels; pulse position translating means in at least one of said receiving channels, and demodulating means in each of said channels.

2. A pulse communicating system comprising means for producing a train of pulses modulated in accordance with a signal, means to translate the position of said pulses, means to transmit said pulses, means to receive said pulses, means to translate the position of said received pulses associated with said receiving means, and means for demodulating said pulses.

3. A multiplex signalling system comprising means for producing a train of pulses for each of a plurality of channels, means biasing the operation of said pulse producing means to pair off the pulses, the pulses of each pair, when unmodulated, having a time interval therebetween different from the time interval between the succeeding pairs of pulses of the same channel, means to time differently the pulses of different channels means for applying the trains of pulses to a transmission medium common to all channels, whereby the pulses are interleaved together and, because of the paired-off relation of the pulses, form distinct groups of pulses with a given time interval between the groups; means for producing at least one pulse channel additional to the above named channels, means to translate the position of the pulses of said additional channel, whereby the pulses thereof may be sandwiched into the time intervals between said groups of pulses.

4. A multiplex signalling system comprising means for producing a train of pulses for each of a plurality of channels the pulse trains and channels being related in time in accordance with a base wave and modulated in accordance with a corresponding signal, means for transmission of said pulses, common to all channels, means for receiving the output of said common means, means responsive to said output for deriving a control wave corresponding to said base wave channel-segregating means responsive to said control wave forming a plurality of receiving channels corresponding to the transmitted channels, means in each of said receiving channels to translate the relative spacing of the pulses of such channel, means to demodulate said translated pulses in each channel, means for feeding back demodulation energy to the means deriving said control wave.

5. A multiplex signalling system in accordance with claim 4, wherein said channel segregating means includes base pulse energy generating means, timing means for said base pulse energy, and pulse mixing and clipping means in each of said channels.

6. A multiplex signalling system in accordance with claim 4, wherein said channel segregating means includes base pulse energy generating means, and channel pulse train deblocking means comprising base pulse position translating means, timing means for said base pulse energy, and pulse mixing and clipping means in the circuit of each of said receiving channels.

7. A multi-channel receiving system comprising means for receiving a plurality of series of pulses interleaved to form a single pulse train, means to produce base energy pulses controlled by said receiving means; means for segregating the individual channels from said pulse train including base pulse position translating means, means for delaying in phase said base pulses, means for mixing said received pulse train and said base pulses delayed in phase, and clipping means for acting on the output of said mixing means, whereby the segregation of a series of pulses of a given channel is obtained; means for translating the relative position of the segregated pulses of said given channel; and means to demodulate the pulses of said given channel.

8. A method of multiplex communication over a plurality of channels, comprising producing a train of pulses for each channel displaced in time with respect to one another, modulating each of said trains of pulses in correspondence with a signal, translating in position the pulses of at least one channel, interleaving together said channel pulse trains for transmission over a common transmitting medium, receiving said interleaved pulse trains over a common receiving medium, and segregating said channel pulse trains for demodulation.

9. A method of multiplex communication over a plurality of channels, comprising producing a train of pulses for each channel the pulses and channels being related in time in accordance with a base wave, each channel modulated in accordance with corresponding signals and displaced in time one from the other, transmitting said trains of pulses over a common transmitting medium, receiving said trains of pulses, deriving from said received pulses a control wave corresponding to said base wave segregating said pulse trains in accordance with said control wave into individual channel trains, translating into different relative position the pulses of said individual channel pulse trains, demodulating said offset pulse trains and controlling the segregating means by demodulation energy.

10. A method of multiplex communication over a plurality of channels, comprising producing a train of pulses for each channel, the pulses of each channel being paired-off, with the pulses of each pair having a time interval therebetween different from the time interval between succeeding pairs of pulses of the same channel; modulating the pulses of each train in accordance with a signal; timing the trains of pulses, whereby the pulses of all the trains except at least one are interleaved together for transmission purposes and, because of the paired-off relation of the pulses, form distinct groups of pulses with a given time interval between the groups; translating into offset time position the pulses of said one of said trains to fit into the intervals between said groups of pulses; transmitting said interleaved trains of pulses over said common medium; and at a receiving point, receiving said interleaved trains of

pulses segregating in accordance with individual channels said interleaved trains of pulses; and demodulating each of said segregated trains of pulses.

11. A method of multiplex communication over a plurality of channels having a transmission medium common to all the channels, comprising producing a train of pulses for each channel, applying the trains of pulses to said common medium for transmission with the timing of transmission different for each train, whereby the pulses of the different trains are interleaved together in said common medium, translating into offset position as desired the pulses of the individual channel trains with respect to the other channel trains, whereby a desired relative offset relation among the pulses of the channel trains is achieved; and at a receiving point, receiving said interleaved pulse trains over a common medium, segregating said pulse trains in accordance with individual channels, and demodulating the segregated pulse trains of said individual channels.

12. A method of multiplex communication over a plurality of channels, comprising producing a train of pulses for each channel, modulating the pulse train for each channel in accordance with a signal, applying said trains of pulses to a common medium for transmission with the timing of transmission different for each train, whereby the pulses of the different trains are interleaved together in said common medium, receiving said interleaved pulse trains over a common medium, utilizing said received interleaved pulse trains for producing basic energy pulses, applying said basic pulses to each of a plurality of channels with the timing thereof different for each channel, using said differently timed basic pulses in each channel to segregate by deblocking and clipping the corresponding channel pulse train from the received pulse trains, translating in position the deblocked pulses in each channel to effect a pairing-off of the pulses in each train, and demodulating the paired-off pulses of each channel.

13. In a method of multiplex signalling of a plurality of channels in accordance with claim 12, the step of synchronizing said basic energy pulses by means of the train of demodulated pulses of one of said channels.

14. A method of multiplex communication over a plurality of channels, comprising producing a train of pulses for each channel, modulating the train for each channel in accordance with a signal, indiscriminately interleaving together said pulse trains of said channels, applying said interleaved trains of pulses to a common medium for transmission with the timing of transmission different for each train; receiving said interleaved pulse trains over a common medium, utilizing said received pulse trains for generating basic energy pulses, dividing said basic pulses into a plurality of series of pulses corresponding to said plurality of channels, translating in position as required each series of basic pulses and varying the relative phasing thereof for alignment in time with a train of channel pulses, deblocking with said plurality of basic pulse series the respective corresponding channel pulse trains; clipping each delocked pulse train to obtain individual channel pulse trains, translating into offset position said segregated pulses; and demodulating the offset pulses.

15. In a method of multiplex signalling of a plurality of channels in accordance with claim 14, the step of synchronizing said basic energy pulses by means of the train of demodulated pulses of one of said channels.

16. A multichannel communicating system comprising means including a base wave generator for producing and interleaving in time displacement series of pulses each series modulated by the signal of its respective channel, means for interpolating in intervals between pulses of said series, the series of pulses modulated by the signal of an additional channel including devices under control of said base wave for determining the interval and further means responsive to a pulse of the series to be interpolated to cause translation of pulses of the last mentioned series to conform to the interval.

17. A multichannel system according to claim 16 in which the said intervals are those occurring between sequences of pulses one from each channel.

DONALD D. GRIEG.

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