

Oct. 28, 1947.

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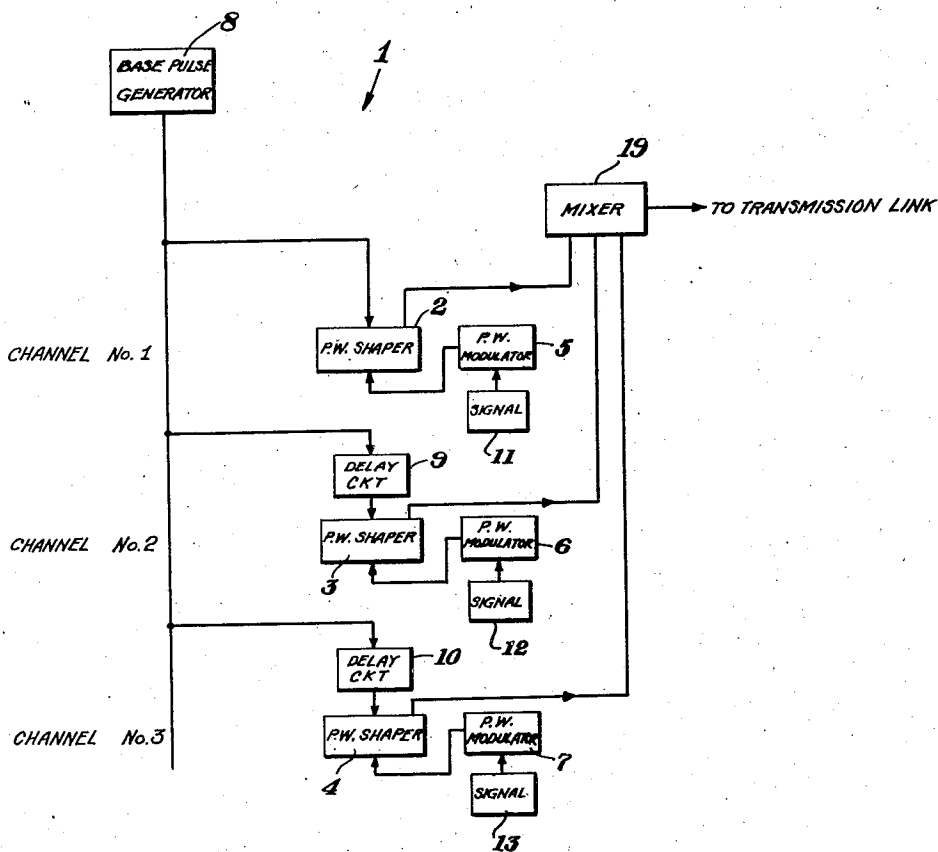
2,429,616

PULSE WIDTH MULTICHANNEL SYSTEM

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Fig. 1.



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Fig. 2.

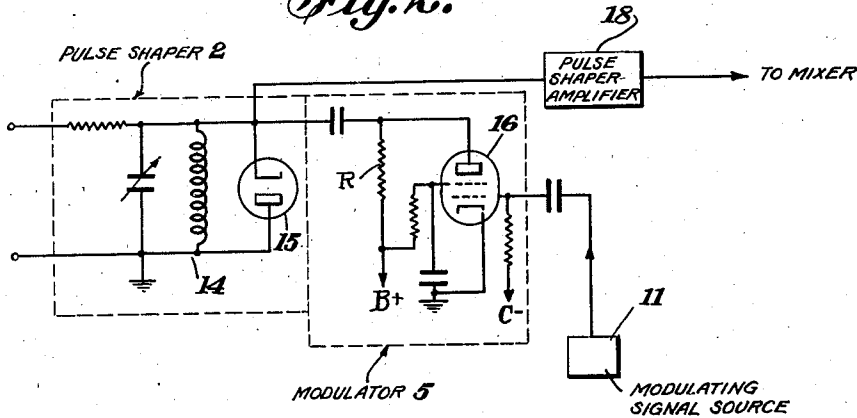


Fig. 3.

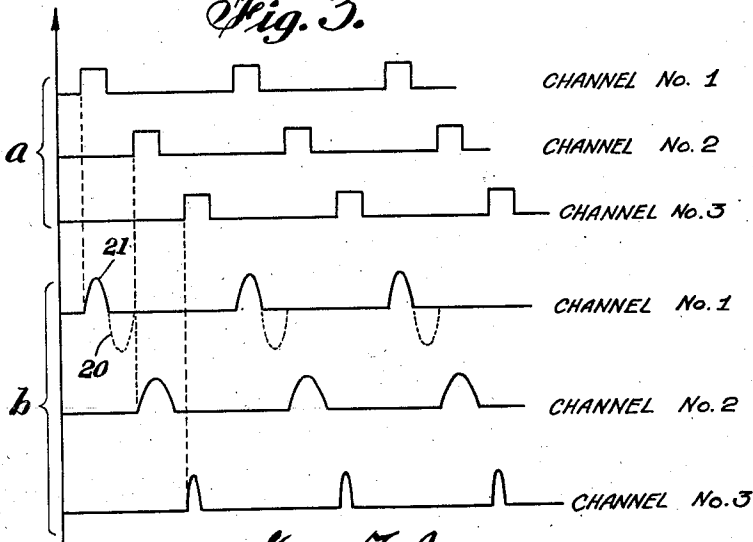
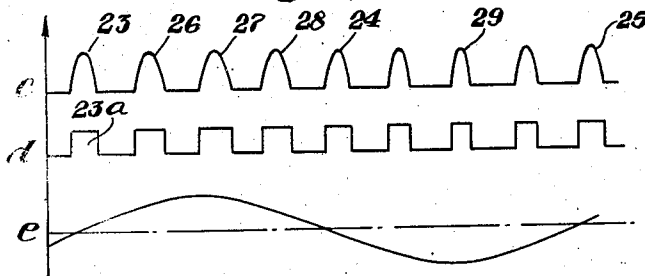


Fig. 3A.



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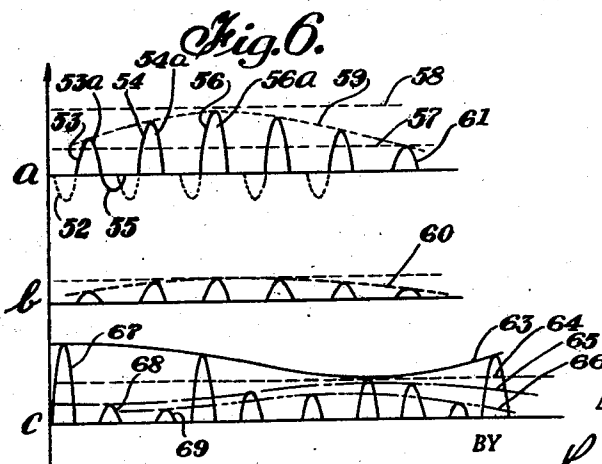
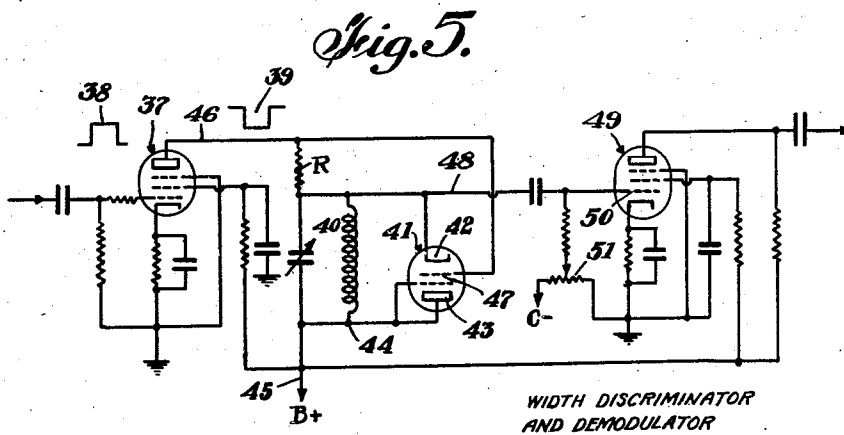
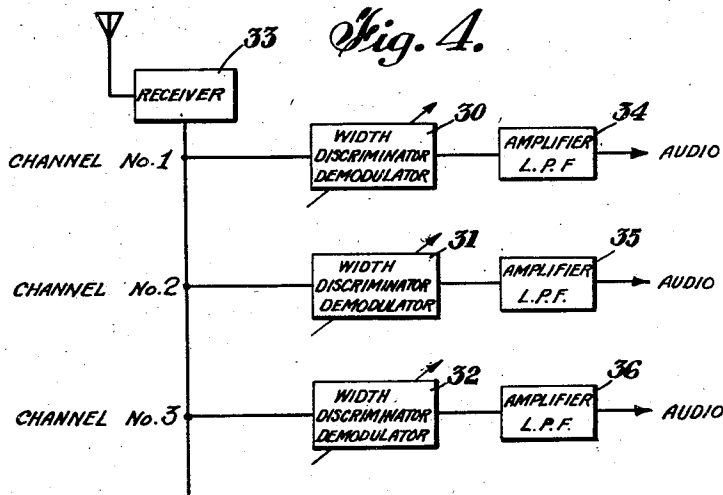
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PULSE WIDTH MULTICHANNEL SYSTEM

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3 Sheets-Sheet 3



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PULSE WIDTH MULTICHANNEL SYSTEM

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Application July 29, 1944, Serial No. 547,125

12 Claims. (Cl. 179—15)

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This invention relates to communication systems and more particularly to multi-channel transmission or broadcasting and selective reception of transmitted channels.

One of the objects of this invention is to provide a method and means for multi-channel communication or broadcasting over a common transmitting medium such as a transmission line or a given carrier frequency wave, as the case may be, the different channels carrying their respective intelligence by means of pulse trains and the pulses of each channel being distinguished by different identifying or characteristic widths.

Another object of the invention is to provide a method and means for multi-channel communication wherein the pulses of each channel, having a characteristic average width, are made to carry signal intelligence by modulation in width of the individual pulses.

Another object of this invention is to provide a method and means for communication wherein the intelligence is carried by pulses having a characteristic width which is modulated in accordance with the instantaneous value of the intelligence.

Another object of the invention is to provide a method and means at receiving points for selectively detecting any one or more of a plurality of signal channels transmitted in time spaced relation over a common transmission medium with respect to the characterizing width of the pulses of the various channels. An additional object of the invention is to provide a communication system of the character hereinabove referred to, wherein at the receiving point after segregation of the individual channels according to their characteristic pulse width, a reproduction of the original signal intelligence is obtained in amplitude modulated form from pulses conveying the intelligence in the modulation of their widths.

In accordance with my invention, a plurality of communicating channels are provided and are each represented by a series of pulses, the average width of which for each channel has been given a characteristic value different from the identifying pulse width of other channels. The several series of pulses are time controlled so that the pulses of the different channels interleave together to form a single train of pulses for transmission purposes over a common transmission medium to one or more receiving points. At each receiving point there are one or more channel selectors adapted to segregate according to the characteristic average pulse width one or more channels. The characterizing pulse width for

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each channel is further modulated over a portion thereof by a modulating signal which it is desired to transmit. The limiting factor in connection with modulation of the width of the pulses of the various channels which are to be transmitted in a common consecutive pulse train, is the consideration that the maximum or minimum modulated pulse width of a given channel should be of such a value as not to overlap or be equal to the value in width of the modulated pulses of another channel substantially adjacent in time thereto so as to make detection or selection according to average pulse width feasible. This consideration applies before and during demodulation, as will appear hereinafter.

At the receiving point, I may provide, as will be explained in detail hereinbelow, a pulse width selector circuit which may also serve as a pulse width demodulator.

The above and other objects and features of the invention will become more apparent upon consideration of the following detailed description to be read in connection with the accompanying drawings, in which:

Fig. 1 is a block diagram of the transmitter of a multi-channel communication system in accordance with my invention;

Fig. 2 is a schematic circuit diagram of the pulse shaper and pulse width modulator of the circuit of Fig. 1;

Fig. 3 are graphical illustrations of the operation of the transmitter of Fig. 1;

Fig. 3A illustrates the modulation in width of a series of pulses in accordance with a signal;

Fig. 4 is a block diagram of a receiver for a communication system according to my invention;

Fig. 5 shows a circuit in schematic form of a pulse width discriminator and demodulator of the receiver of Fig. 4; and

Fig. 6 illustrates graphically the demodulating action of the circuit of Fig. 5.

Referring now to Fig. 1, a transmitter 1 is shown provided with a plurality of transmitting channels, three of which are shown. The three channels include pulse width shaper circuits 2, 3 and 4, and pulse width modulators 5, 6 and 7 respectively. The timing of the pulses for the three channels is controlled by a base pulse generator 8 which is connected directly to the unit 2 and through delay circuits 9 and 10 to the pulse width shapers 3 and 4, respectively. The sources of modulating signals for each of the channels are indicated at 11, 12 and 13.

The production of pulse trains for each of the

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channels which are distinguished by a characteristic average pulse width, and which are modulated with respect to this average pulse width in accordance with a modulating signal, may be attained by means of various circuits. One such circuit is illustrated in Fig. 2.

Suitably shaped pulses of the type shown in curve *a* of Fig. 3, for channel 1 for example, are applied to an adjustable resonant circuit 14 across which is connected a rectifier tube 15 whose purpose is to limit the undulations resulting from shock-excitation of the circuit 14 to the first, or primary undulation of one polarity. The separate circuits for the several channels may be tuned to different frequencies thus producing undulations of different widths for the different channels. In effective shunt with the resonant circuit 14 is a reactance tube 16 whose control grid in turn, is in part energized from a modulating voltage source 11. As is well-known in the art the reactance tube 16 presents an additional impedance across the tuned circuit 14, the variation in value of which changes the tuning of the circuit 16 within certain predetermined limits. In the embodiment shown the reactance tube presents a resistance varying in accordance with the modulating voltage, which in series with the condenser in the ground lead is across the tuned circuit which causes the resonant frequency thereof to vary in a like manner in accordance with known laws. Undulations which are modulated in width are thus obtained as in curve *c*, and are preferably passed through a shaper and amplifier 18 which may also serve as a peak riding clipper for removing any amplitude variations resulting from the modulating process for the purpose of reshaping the undulations into a rectangular pulse form of the type illustrated in curve *d*, Fig. 3A. The output of the respective pulse shaper amplifier in each channel is then fed into a combining or mixing circuit 19, Fig. 1, from where the pulses of the three channels are transmitted over a cable or radio frequency communication link interleaved in the form of a single train of pulses.

In Fig. 3, curve *a* represents the three series of equally spaced, equal width rectangular pulses of the type produced by the pulse source 8 and applied to the resonant circuit 14 of the shapers 2, 3 and 4, respectively. The three pulse series are shown displaced in phase due to the action of the delay circuits 9 and 10 in channels 2 and 3, the original pulse train, as obtained from generator 8, being shown for channel 1. It should be noted that the widths of these initiating pulses are greater than the maximum pulse width ultimately produced during the modulation process. On being applied to the tuned circuit 14, the leading edges of the pulses of the several channels, curves *a*, will shock-excite in the circuits 14, oscillatory undulations as illustrated in curve *b*, (Fig. 3). As the resonant circuits are tuned to a different wavelength in each channel, the oscillatory undulations are given different characteristic average widths as brought out in connection with the three channels in curve *b*. This average pulse width is assumed to coincide with a zero modulating voltage. Any modulation therefore, in the tuning of the circuit as effected by the reactance tube 16 will vary between limits as determined by positive and the maximum negative points on the modulating voltage curve, such as shown in curve *e* (Fig. 3A).

The rectifier tube 15 eliminates any negative undulations so that only the desired positive pulses are obtained. Thus the rectifier will elim-

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inate negative undulations corresponding to that indicated at 20, following positive undulations as at 21 (curve *b*, Fig. 3). A representative width modulated train of undulations is indicated in curve *c*, Fig. 3A, shown at a different time scale than the curves of Fig. 3. It will be noted for example, that the undulations 23, 24, 25 are all of equal width since they represent undulations of the shock-exciting circuit which take place when the modulated voltage controlling the reactance tube 16 is at zero value. As the modulating voltage increases in accordance with curve *e*, however, the tuning of the shock-excited circuit 14 varies so that the first undulations produced will be of slightly greater width, for example, as at 26, which is wider than undulation 23, but less wide than undulation 27, occurring at a point corresponding to the peak positive value of the modulating voltage wave, and which has the largest width accordingly. Conversely, as the modulating voltage decreases the undulations decrease in width as, for example, 28. As the modulating voltage curve changes to an increasing negative value the pulses become increasingly narrower so that at 29 an undulation having a minimum width is shown corresponding to a maximum negative signal voltage value. Finally, as the signal voltage becomes zero again, an average width undulation is obtained, illustrated by 25. The undulations of curve *c* are made to pass through the shaper and amplifier 18, wherein they are given the shape of a rectangular type of pulse, as in curve *d*, having an average width 23*a* which is modulated in accordance with the modulating signal voltage.

A simple pulse width modulating system is here provided which will furnish pulses of substantially equal amplitude modulated in width according to the intelligence from a significant average pulse width for each channel. Other circuits may be used for this purpose in accordance with specific requirements.

At the receiving point, a receiver 33 (Fig. 4) used with radio transmission supplies each of the channels 1, 2 and 3 separated by circuits corresponding to the channels at the transmitter with the transmitted train of pulses comprising all the channels. Each separate circuit is comprised of an adjustable width discriminator and demodulator circuit 30, 31 and 32, to each of which is applied the interleaved multi-channel pulse train as transmitted. Each of the width discriminator and demodulator circuits, as will be described in connection with Fig. 5, segregates from the incoming interleaved multi-channel pulse train a corresponding series of pulses in accordance with the average pulse width to which it has been adjusted. These circuits also demodulate the pulses of the segregated series for a given channel into a train of corresponding undulations which vary in their amplitudes as the width of the corresponding pulses and according to the instantaneous values of the original modulating signal. From these amplitude modulated undulations an audio type of signal envelope is obtained by elimination of the high frequency pulse components by the application of the series of resulting undulations through amplifier and low-pass filter circuits 34, 35, 36, in each of the three channels respectively. The audio type envelope corresponding to the original signal may then be used in any audio type reproducer, as a loud speaker or other like apparatus, as desired.

The pulse width discriminator and demodulator circuits 30, 31 and 32 may be of the type

shown in Fig. 5 and described in greater detail in the copending application, Serial Number 487,072, filed May 15, 1943, by E. Labin and Donald D. Grieg. The circuit includes a limit clipping stage 37 as an input coupler, which limits all input pulses to substantially the same amplitude and also inverts the input pulses from a positive polarity, as indicated at 38, to a negative polarity as at 39. Output pulse energy from the stage 37 is then applied through a resistor R to a shock-excited L-C circuit 40 which is tuned to a frequency having a period proportionate to the maximum modulated width of the pulses of a given channel. Connected across the tunable circuit 40 is a vacuum tube 41, the cathode 42 of which is connected to the input side of the circuit 40, while the anode 43 is connected to the opposite side 44 of the resonant circuit. This side 44 is also connected to a source of anode potential 45. The pulse energy, as shown at 39, from the anode connection 46, is supplied to the grid 47 of the tube 41 so as to block the conduction between the cathode 42 and the anode 43 while pulse energy is being applied to the circuit 40. The undulations produced in the circuit 40 in response to the pulse energy coming over the anode connection 46, are taken off through a connection 48 for application to a threshold clipping and amplifier stage 49. The bias on the grid 50 is controlled by adjustment of a resistor 51.

As the interleaved multi-channel pulse train is applied to the circuit 40 which has been tuned to a given frequency or wavelength corresponding to a desired incoming pulse width, the leading edges of the incoming pulses applied at negative polarity will produce by a shock-excitation an initial negative undulation as at 52 (curve *a*, Fig. 6) normally followed by positive undulations similar to 53, 54, etc., in the form of a damped wave. When the circuit 40 is tuned to a frequency, the period of which is exactly twice that of a given desired pulse width, the trailing edge of a pulse having the desired width occurs where the initiated oscillatory energy crosses the zero axis from undulation 52 to undulation 53. Since the trailing edge of the desired pulse shock excites the circuit in the same direction at this point, a positive undulation produced thereby in the circuit 40 will add algebraically to the undulation originally caused by the leading edge of the pulse to produce undulation 53. The next succeeding pairs of undulations produced by the leading and trailing edges of a pulse having the desired width would normally tend to produce a negative undulation 55 which would continue as a damped wave. The damping tube 41, however, eliminates these trailing oscillations so that they do not interfere with the undulations produced by subsequent pulses applied to the circuit 40. A pulse having a width which is less than the desired one will not produce maximum undulations as great as, for instance, the undulation 56, which corresponds to the tuning adjustment for a desired pulse width in the instance illustrated in curve *a*, Fig. 6. The reason for this is readily apparent, because the shock excitations produced by the leading and trailing edge of the pulses of lesser width than the desired one are in part opposed to one another. The effect of the high Q of the circuit and the manner of tuning is such as to produce a similar effect, that is, undulations that are smaller than those due to pulses having a desired width for pulses having a larger than the desired width. In the case of the pulses having a larger than the desired width,

the algebraic summation of the undulations caused by the leading and trailing edges thereof is also less than in the case of the undulations produced in response to pulses having the desired width.

A threshold clipping and amplifying stage 49 is adjusted to clip at a level 57, thereby obtaining and amplifying the crest portions 53a, 54a, 56a, etc. of the undulations 53, 54, 56 in curve *a*, Fig. 6. The clipping level 57 is placed at such a setting so as to render obtainable crest portions of all undulations extending into the range between level 57 and an upper level 58 corresponding to the maximum amplitude undulation 56. As indicated this range takes into account the full deviation from zero modulation of pulse width due to variation in amplitude of the original signal for the positive portion of the signal, undulation 61 being representative of zero undulation. The range in amplitude of the undulations indicated in curve *a*, Fig. 6, may, of course, be extended as required by the dynamic amplitude variation of the signal to be communicated. Curve *b* of Fig. 6 indicates the amplitude range setting and undulation responses for the pulse train of another channel having an average unmodulated pulse width different from that shown in curve *a*, the principle, however, being the same in each case.

Graph *c* of Fig. 6 illustrates further the previously described action by indicating the three channel series of pulses 67, 68, 69 simultaneously received by a single width demodulator. In the illustration a demodulator has been tuned to accept the channel pulses indicated by 67. It will be noted that the modulation envelope 63 is a maximum for this pulse series. The clipping level 64 is adjusted so as to remove the minor envelope variations 65, 66 of the adjacent channels 68 and 69. Corresponding to the width tuning of the next channel demodulator, for example, pulse series 68, the envelope 65 will be at a maximum and the remaining minor envelope variations will be removed. In this latter example, the envelopes of graph *c* will be essentially the same but of course with pulses 67 and 68 reversed as to their amplitude relationship.

The trains of undulations, thus obtained, for each channel from the respective width discriminator circuit, are then applied to the amplifier and low pass filter circuits 34, 35 and 36, shown in Fig. 4, wherein the high frequency components represented by the undulation crests are eliminated and audio type envelopes 59 and 60 are finally obtained corresponding to the signal transmitted over the corresponding channels.

While I have described above the principles of my invention in certain specific embodiments, especially in connection with the transmitter and width discriminator receiver circuits, it is to be clearly understood that this description of the invention is made only by way of example, and not as a limitation on the scope thereof as set forth in the objects and in the accompanying claims.

I claim:

1. In a method of multi-channel communication, the steps comprising producing a series of pulses for all the channels, timing differently the pulses of the different channels, shaping the pulses of the respective channels with a different given base width, modulating in width said pulses according to instantaneous signal values of an intelligence, and translating said series of pulses over a transmitting medium; and, at a re-

ceiving terminal segregating the pulses having the different given base width into different channels corresponding thereto, translating the width modulated pulses into corresponding amplitude modulated undulations and producing from said modulated undulation an audio type signal corresponding to the original intelligence.

2. A multi-channel communication system comprising means for producing a series of pulses for all channels, means for timing differently the pulses of different channels, means for shaping the pulses with a characteristic given width for the respective channels, means for modulating in width said pulses according to the instantaneous values of a signal intelligence, and means for transmitting said series of pulses over a transmitting medium; and, means at a receiving point responsive to the pulses having substantially said characteristic width to produce corresponding undulations in their respective channels and means to translate the undulations from said last-named means into audio type intelligence.

3. A method of multi-channel communication, comprising producing a separate series of pulses for each of a plurality of channels, shaping the pulses of each channel with a given identifying width different from the identifying width of other channels, timing differently the pulses of the different channels to interleave the different series of pulses together as a single train of pulses for transmission over a common transmitting medium, modulating in width the pulses of each channel according to instantaneous signal values of an intelligence, and transmitting said train of pulses over said transmitting medium; and, at a receiving point, rendering distinct in said train these pulses having the identifying width of a given channel, by translating them into corresponding undulations having amplitudes within a distinguishing amplitude range, according to the width modulation thereof, and producing from said undulations within said range an audio type signal corresponding to the original intelligence.

4. A method of selectively receiving a given channel of communication from a multi-channel train of pulses wherein the pulses of the channels have a width characteristic different for each channel and are modulated with respect to their width within a given range in accordance with the instantaneous values of signal intelligence, comprising rendering distinct in said train of channel pulses these pulses having the characteristic width range of a given channel, and translating the distinguished width modulated pulses into corresponding amplitude modulated undulations.

5. A method of selectively receiving a given channel of communication according to claim 4, wherein the pulses of a given channel with respect to other channels which are adjacent in time are given a range of width variations which for minimum modulation in pulse width result in an amplitude larger than the amplitude resulting from the maximum width of any adjacent channel, and clipping said larger amplitude undulations at a level at least above that of the undulations due to any adjacent channel.

6. A method for selectively receiving from a plurality of pulses forming a pulse train these pulses constituting a given channel of communication conveying signal intelligence wherein the pulses have a characteristic width which is varied within a given width range in accordance with

the instantaneous values of signal intelligence, the steps comprising rendering distinct in said pulse train the pulses of said given channel according to their pulse width range, segregating said distinguished width modulated pulses into corresponding undulations of equal width the amplitudes of which vary as the corresponding pulse width values, and producing from these amplitude modulated undulations an audio type signal corresponding to the original intelligence.

7. A method for selectively receiving from a plurality of pulses forming a pulse train those pulses constituting a given channel of communication conveying signal intelligence wherein the pulses have a characteristic width which is varied within a given width range in accordance with the instantaneous values of signal intelligence, the steps comprising rendering distinct in said pulse train those pulses having a given pulse width range by translating them into corresponding undulations having amplitudes within a distinguishing amplitude range according to the width modulation thereof, and producing from said undulations within said range an audio type signal corresponding to the original intelligence.

8. A multi-channel communication system comprising separate means for producing a series of pulses for each of a plurality of channels, means for shaping the pulses with a given width characteristic for each channel, means controlling the separate pulse producing means to time differently the pulses of the different channels to interleave the different series together as a single train of pulses, means for modulating in width the pulses of each channel according to the instantaneous values of a signal intelligence, and means for transmitting said train of pulses over a common transmitting medium; and, means, at a receiving point, for rendering distinct in said train those pulses having the characteristic width for a given channel, and means to translate said distinguished pulses of each channel into audio type intelligence.

9. A multi-channel transmission system comprising separate means for producing a series of pulses for each of a plurality of channels, means for shaping the pulses with a given width characteristic for each channel, means controlling the separate pulse producing means to time differently the pulses of the different channels to interleave the different series together as a single train of pulses, means for modulating in width the pulses of each channel according to the instantaneous values of a signal intelligence, and means for transmitting said train of pulses over a common transmitting medium.

10. A multi-channel transmitting system in accordance with claim 9, wherein said means for shaping the pulses includes a tuned circuit, and the means for modulating the width of the pulses include a circuit element forming a part of said tuned circuit having an impedance adapted to be varied by signal intelligence.

11. A system for selectively receiving a given channel of communication from a multi-channel train of pulses wherein the pulses of the channels have a width characteristic different for each channel and are modulated with respect to their width within a given range in accordance with the instantaneous values of signal intelligence, comprising means responsive to those pulses having a characteristic width range for a given channel for producing undulations, and means for translating the undulations of said last named

means into intelligence corresponding to the original signal.

12. A system for selectively receiving a given channel in accordance with claim 11, wherein said responsive means and said means for translating include a circuit tuned to a frequency having a period corresponding to the maximum modulated pulse width for each channel.

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