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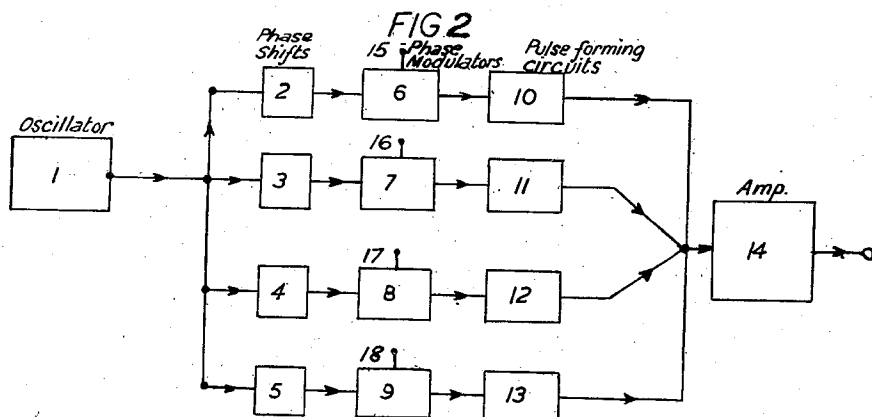
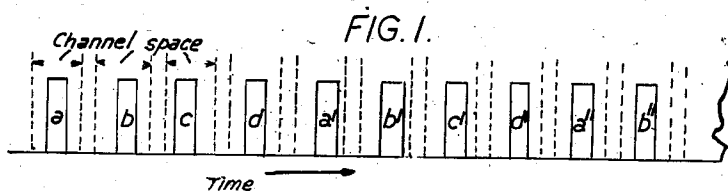
P. K. CHATTERJEA ET AL

2,447,233

PULSE TIME MODULATION MULTIPLEX RECEIVER

Filed March 15, 1944

7 Sheets-Sheet 1



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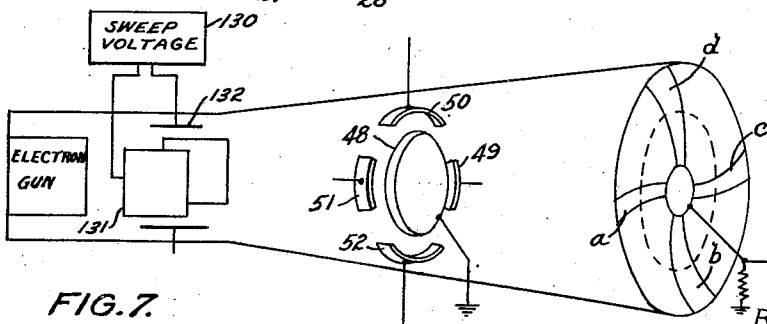
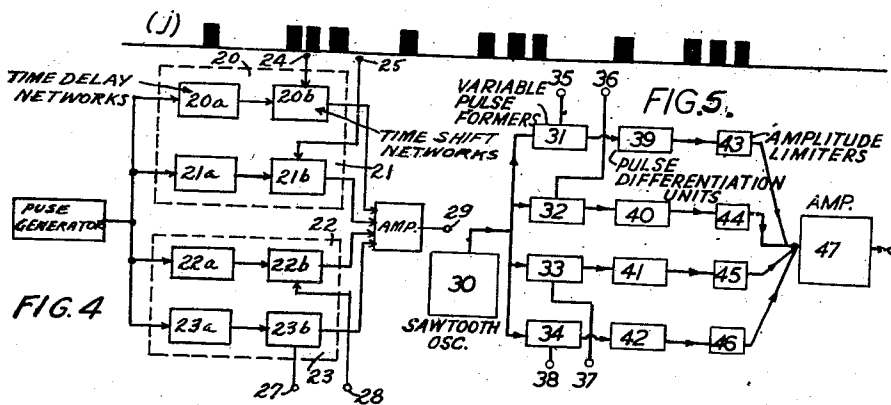
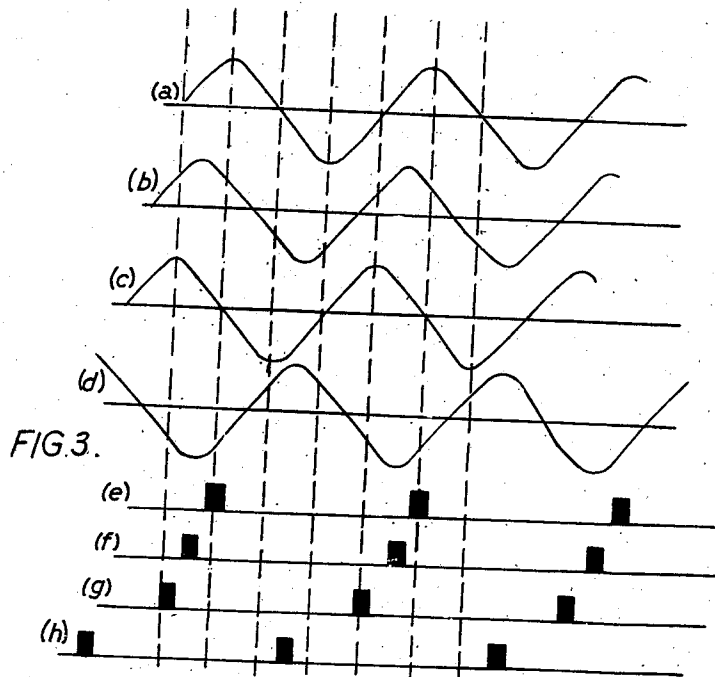
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PULSE TIME MODULATION MULTIPLEX RECEIVER

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7 Sheets-Sheet 2



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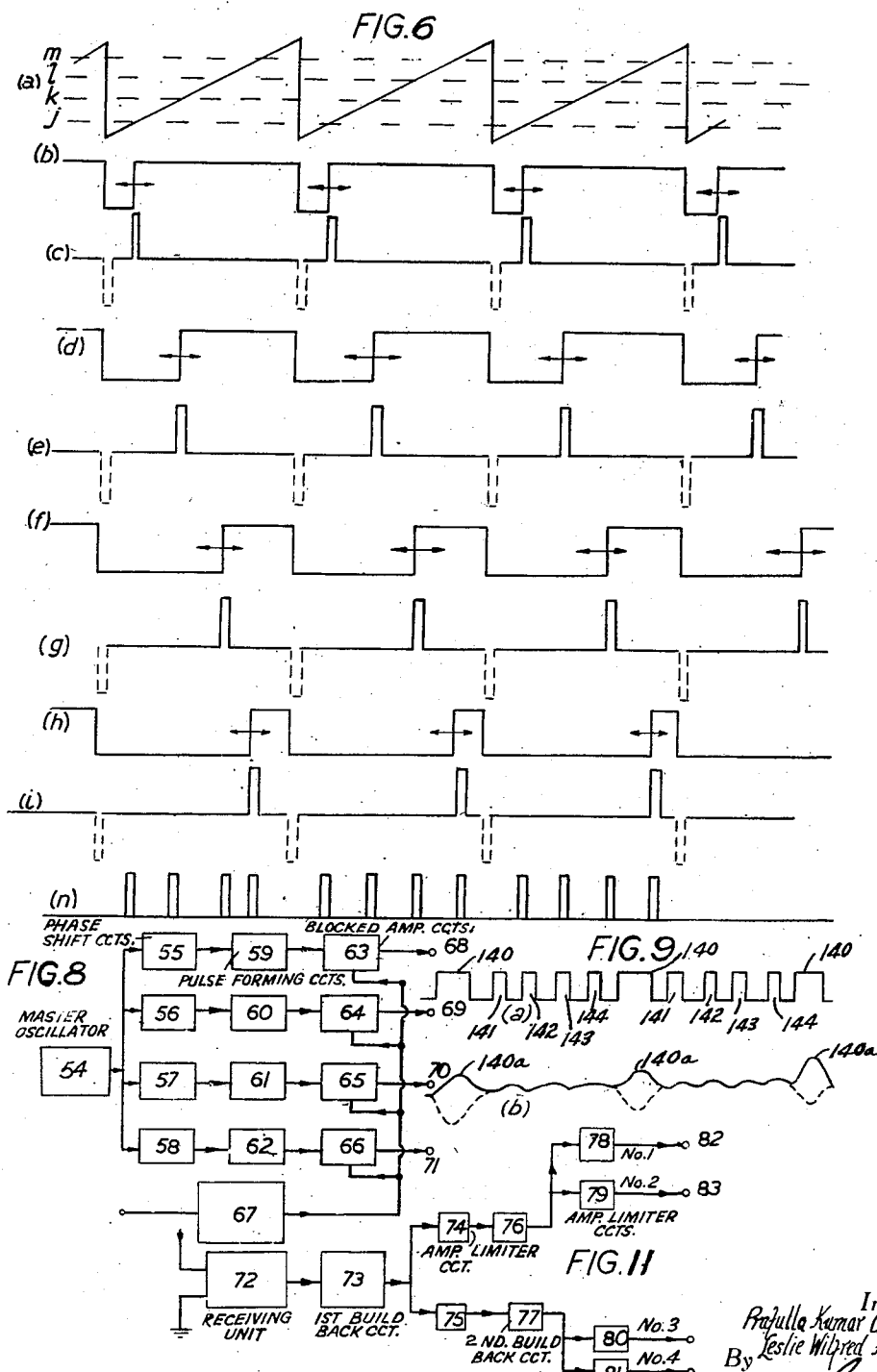
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PULSE TIME MODULATION MULTIPLEX RECEIVER

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7 Sheets-Sheet 3



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PULSE TIME MODULATION MULTIPLEX RECEIVER

Filed March 15, 1944

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FIG. 10.

FIG. 15

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graph LR
    96[RECEIVER 96] --> 105[PULSE EXTRACTOR 105]
    105 --> 106[CORRECTING UNITS 106]
    106 --> PI[PULSE INSERTER]
    PI --> 98[1ST DIVISION 98]
    PI --> 100[2ND DIVISION 100]
    98 --> 99[1ST DIVISION 99]
    98 --> 101[2ND DIVISION 101]
    99 --> 102[2ND DIVISION 102]
    99 --> 103[2ND DIVISION 103]
    100 --> 104[PILOT FREQ. SELECTION FILTER 104]
    104 --> A[CHANNEL 1 A]
    101 --> B[CHANNEL 2 B]
    102 --> C[CHANNEL 3 C]
    103 --> D[CHANNEL 4 D]
    103 --> 105
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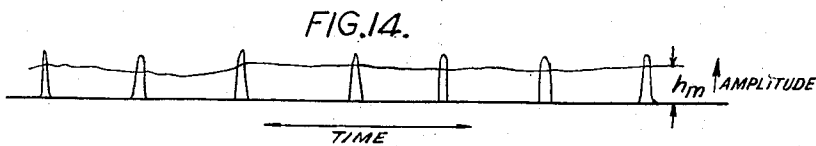
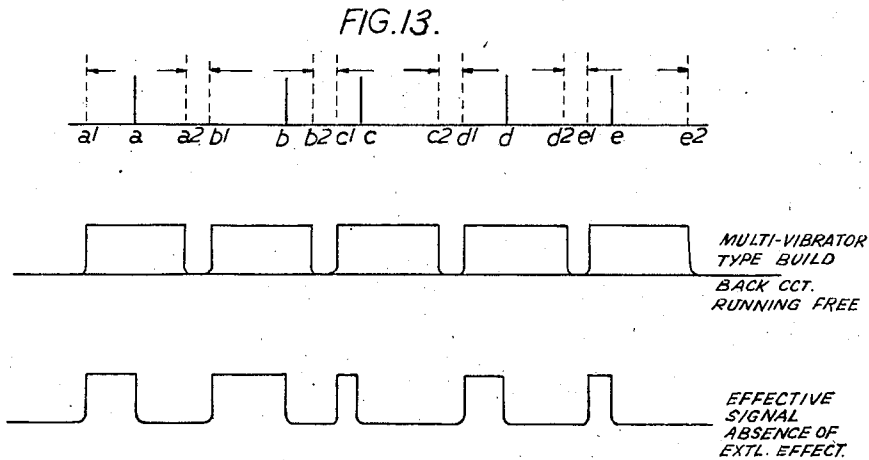
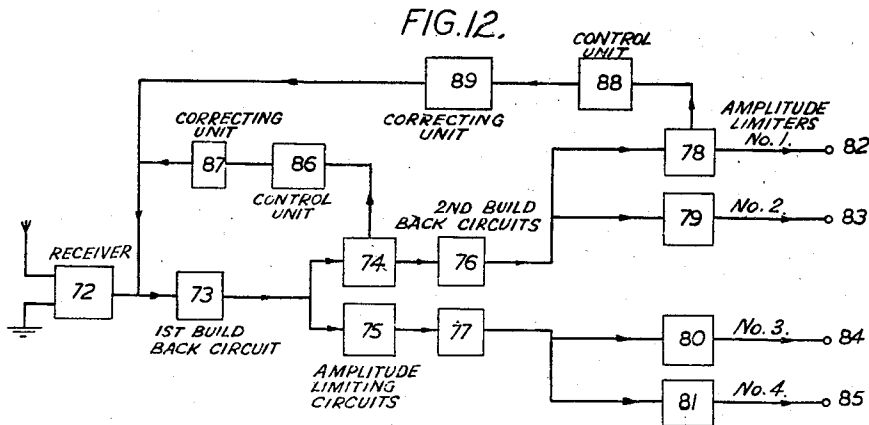
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PULSE TIME MODULATION MULTIPLEX RECEIVER

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7 Sheets-Sheet 5



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FIG.16.

CHANNEL TERMINAL	- A B C D A B C D
CORRECT SEQUENCE	- 1 2 3 4 → 1 2 3 4
WITH INTERFERENCE PULSE	- 1 INT. 2 3 → 4 1 2 3
WITH PULSE MISSING	- 1 3 4 1 → 2 3 4 1

FIG.17

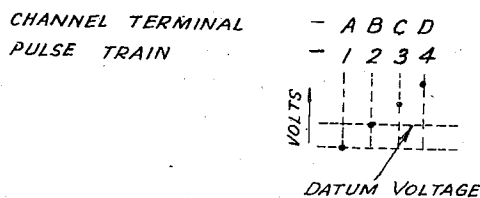


FIG.18.

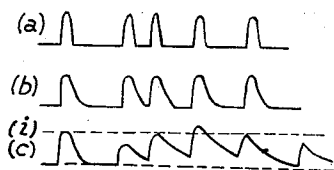
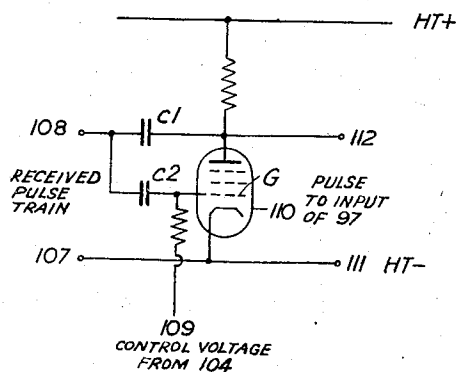


FIG 19.



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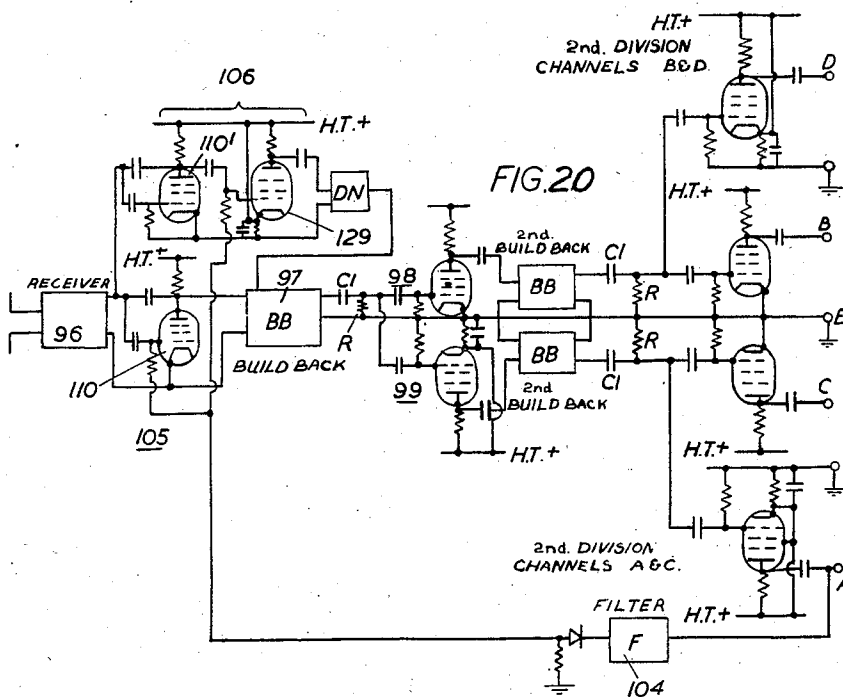
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PULSE TIME MODULATION MULTIPLEX RECEIVER

Filed March 15, 1944

7 Sheets-Sheet 7



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UNITED STATES PATENT OFFICE

2,447,233

PULSE TIME MODULATION MULTIPLEX
RECEIVER

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Application March 15, 1944, Serial No. 526,566
In Great Britain April 7, 1943

10 Claims. (Cl. 179-15)

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The present invention relates to multiplex signal high frequency transmission systems of the kind utilising electrical pulses.

It is now well known that signal waves bearing intelligence can be transmitted by means of a train of electrical pulses occurring at equal time intervals and whose durations are varied in accordance with the instantaneous amplitude of the signal. Such pulses are herein referred to as duration modulated pulses. In a modification of this system of signal wave transmission, short electrical pulses of constant duration are transmitted to mark the leading and trailing edges of duration modulation pulses, and when either the leading or trailing edge occurs at equal intervals of time, only the pulse marking the edges of the duration modulated pulses which occur at varying intervals of time need be transmitted. This type of transmission is sometimes referred to as a single pulse or time modulated pulse transmission or pulsed phase modulation, the pulses of constant short duration occurring at varying intervals of time in accordance with the instantaneous amplitude of the signal wave to be transmitted.

When both the fixed and moving marking pulses of a duration modulated system are transmitted, the system is referred to as a double pulse system. In the single pulse system, the fixed pulse may be reinserted at the receiver and the solid pulses or duration modulated pulses obtained from the fixed and movable pairs of pulses for example by means of known build back circuits which serve to reproduce the original rectangular duration modulated pulses. If in the single pulse system the pulse duration is only a small fraction of the time interval between the occurrence of successive pulses, and if the variation of this time interval taken up for a maximum time or phase modulation of the pulses is also small, then other trains of similar pulses may be transmitted having the same pulse repetition frequency, but whose pulses occur in the intervals between the pulses of another train. Thus each pulse train may bear time or phase modulation of its respective signal wave and a multiplex channel transmission system is provided. It is the object of this invention to provide practical arrangements whereby such a system may be put into practice.

In systems of this type four main operations are essential. Firstly, producing the trains of unmodulated or unphased pulses, one train for each channel, the pulses of each train for each channel, the pulses of each train being correctly

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timed or phased to occur with respect to the pulses of other trains of the system, and modulating the pulses of each channel with the respective signal wave. Secondly combining all the channels into one transmission. Thirdly, at the receiving end of the system directing the pulses of a channel to respective receiving apparatus. Fourthly, obtaining the signal waves from the train of pulses in the respective channel.

It will be understood that more than one of these operations may be performed by the same equipment; that the pulses may be transmitted by line, wave guide or radio, and may comprise direct current pulses or trains of waves of higher frequency than the pulse repetition frequency.

Apparatus for carrying out these operations in practice will now be described, reference being made to the accompanying drawings.

In the drawings:

Fig. 1 is an explanatory diagram relating to an arrangement for producing time-phased pulses;

Fig. 2 shows in block schematic a circuit arrangement of a multi-channel pulse signalling system;

Fig. 3 is an explanatory diagram used in connection with Fig. 2;

Fig. 4 shows in block schematic another circuit arrangement of a multi-channel pulse signalling system;

Fig. 5 shows in block schematic a further circuit arrangement of a multi-channel pulse signalling system;

Fig. 6 is an explanatory diagram used in connection with Fig. 5;

Fig. 7 shows diagrammatically a cathode ray tube arrangement for producing time-phased modulated pulses in a plurality of channels;

Fig. 8 shows in block schematic form circuit arrangements of a receiving equipment;

Fig. 9 shows explanatory curves used in the description of Fig. 8;

Fig. 10 shows explanatory curves used in the explanation of the operation of the receiving circuit shown in block schematic form in

Fig. 11 shows a block schematic of a modified receiver circuit;

Fig. 12 shows in block schematic form the receiving circuit of Fig. 11 incorporating corrective devices in accordance with features of the invention;

Figs. 13 and 14 show various curves used in the description;

Fig. 15 shows in block schematic form receiv-

ing arrangements incorporating further corrective devices;

Figs. 16 and 17 are explanatory data;

Fig. 18 shows curves used in the explanation of the operation of the corrective devices used in Fig. 15;

Fig. 19 is a circuit arrangement of the unit 105 of Fig. 15;

Fig. 20 shows a circuit arrangement of the systems shown in Fig. 15.

From one aspect, a system of the type specified comprises a series or train of short constant duration pulses, every "nth" pulse of which is time or phase modulated in accordance with a desired signal wave, there being "n" different channels. From another aspect, a system of the type specified comprises a plurality of pulse generating devices of the same pulse repetition frequency, one for each channel, and which are properly time-phased with respect to each other so that the generated pulses of one device or channel occur during the intervals between the generated pulses of the other devices or channels, the duration of the pulses and the intervals between successive pulses of the combined channels leaving sufficient time between successive occurrences of pulses in the combined channel train to allow for time modulation of the pulses.

The pulses of a plurality of channels are shown in Fig. 1 of the drawings. By way of example, four channels are illustrated. Channel 1 consists of pulses a, a^1, a^{11} , etc. Channel 2 consists of pulses b, b^1, b^{11} , etc., and so on for channels c and d which are representative of channels 3 and 4 respectively. Each pulse is liable to occur at any position within the time interval indicated by its adjacent dotted lines, depending on the amplitude of the modulating signal.

Arrangements for producing a time-phased pulse train for one channel will now be described.

Firstly, a train of pulses are duration modulated according to known technique, and differentiated for example by passing through a high pass filter to produce pulses of short constant duration of opposite signs respectively at the instants of the leading and trailing edges of the duration modulated pulses.

There are many ways of phase modulating a pulse train, and similarly there is also a variety of methods which may be employed for combining individually modulated pulse trains, and/or the producing of pulse trains having the correct unmodulated relationship prior to their being modulated by their respective modulating signals. A basic circuit arrangement is shown schematically in Fig. 2 where 1 represents a sinusoidal oscillator of the pulse repetition frequency of each channel. Its output is fed to units 2, 3, 4 and 5, which phase the sinusoidal wave the correct amount in each channel corresponding to the unmodulated relative pulse phases of the different channels as shown at a, b, c and d Fig. 3. Units 6, 7, 8 and 9 are further phasing circuits in which the degree of phasing is controlled by the applied signal voltage applied at terminals 15, 16, 17 and 18, respectively, according to known practice such as is employed in frequency modulation systems. If desired, these two stages 2-6, 3-7, 4-8 or 5-9, may conveniently be combined. Units 10, 11, 12 and 13 are pulse forming circuits for example biased amplifiers and amplitude limiters which convert the applied phased sinusoidal waveforms into short duration pulses, which pulses from all the channels are fed to a common amplifier so as to form the required single pulse

train in amplifier or other unit 14. This whole operation is further illustrated by Fig. 3 where a represents the output of 1, Fig. 2. It is usual though not necessary to allow this to provide one of the channels so that here no phase displacement is given by 2, Fig. 2. Phase displacements given by units 3, 4 and 5, Fig. 2, provide outputs as shown at b, c and d , Fig. 3, respectively.

Neglecting for the moment the variable phase shifting produced by the modulation, signal units 10, 11, 12 and 13 produce pulses as shown at e, f, g and h , Fig. 3, which on combining at unit 14, Fig. 2, produces the pulse train j , Fig. 3, which may then be employed to modulate a carrier wave transmitter according to known practice.

Another basic arrangement for producing the phased pulse trains is shown in Fig. 4 where 19 is any pulse generator and 20, 21, 22 and 23 are time delay networks which may each be divided into two sections 20a, 20b, 21a, 21b, 22a, 22b, 23a and 23b, respectively, if desired, parts 20A, etc., giving the requisite fixed delay so as to phase the pulses of each channel appropriately and parts 20B, etc., providing a small variable delay, controlled by the modulating signal which would be applied at terminals 24, 25, 26 and 27 respectively. Such variable time delay device may, for example, comprise an artificial line network having an electron discharge device arranged so that by means of its reactance variation, known as the "Miller effect," the inductance or capacity of the net work can be varied to modify the delay produced by the line network. The "Miller effect" is controlled in known manner by the signal voltages. This circuit may be of any well known form as is used in ordinary phase modulation circuits, it being only necessary to substitute a pulse train for the usual sine wave input of such phasing units. A suitable circuit for this purpose is illustrated in U. S. Patent No. 2,259,392, granted October 14, 1941. Then these pulse trains would be combined at amplifier 28 and the resulting pulse train obtained at terminal 29 used for modulating a transmitter.

A third basic arrangement for producing the phased pulse trains is illustrated by Fig. 5 where 30 is a sawtooth generator or generator of any waveform from which it is possible to produce a variable width pulse. This is then fed into pulse former units 31, 32, 33 and 34 respectively each containing an amplifier, and these amplifiers are each biased or otherwise adjusted so as to pass varying portions of the wave form and thus to produce progressively longer duration pulses from channel to channel (see Fig. 6). By applying also a modifying voltage determined by the channel modulation signal to terminals 35, 36, 37 and 38 respectively, operating for example on the amplifier control grids, these various width pulses may be duration modulated and then after differentiation by units 39, 40, 41 and 42 which comprise, for example, high pass filters and amplitude limiting by units 43, 44, 45 and 46 respectively, to eliminate one of the differential pulses, the differential pulses due to the moving edges of the duration modulated pulses are obtained and are the required phased pulse trains which may be combined together in amplifier unit 47 prior to being used to modulate a transmitter. If the initial waveform is a sawtooth the resulting pulses will have one fixed edge the differential pulses resulting from which are eliminated, and one variable edge, but in the case of, say, a sinewave both edges will vary. However, this

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makes no difference as by amplitude limiting the desired differential pulse train may be obtained.

Referring to Fig. 6, *a* represents the waveform generated by 30, Fig. 5, and dotted lines *j*, *k*, *l* and *m* represent the cut-off voltages of units 31, 32, 33 and 34 respectively so producing after amplification and amplitude limitation pulse trains shown correspondingly at *b*, *d*, *f* and *h*, Fig. 6. Application of a modulating voltage will cause these pulses to be individually duration modulated, the leading edge being the variable so that it is from this edge that the required phased pulse can be obtained by differentiation as shown at *c*, *e*, *g* and *i* respectively.

The pulse derived from the fixed trailing edge (shown dotted) is removed by the limiting circuits. On combination at 47, Fig. 5, the required pulse train *n*, Fig. 6 is obtained.

A further method of producing phased pulse trains in accordance with our invention which may be employed makes use of an impulse tube in which a circular scan is employed, and a set of deflector plates and target bars are provided for each channel. Such an arrangement is shown diagrammatically in Fig. 7 where the deflector plate assembly consists of say a common plate 43 and for example four plates 49, 50, 51 and 52 between each of which and the common plate 43 are applied the corresponding channel modulation signals. The target may consist of one structure providing the correctly placed bars on which are produced the required phased pulses which are obtained at say terminal 53, from the end of resistance *R*. The target bars *a*, *b*, *c*, *d* are connected at one end to a common terminal plate *e* which in turn is connected to earth potential through resistance *R*.

The beam is caused to rotate at the pulse repetition frequency by known means, for example, two voltages from a source 130 at the correct frequency in quadrature phase applied between perpendicularly related pairs of deflecting plates 131, 132. A deflection circuit for such rotation of the beam is shown and described on page 217 of "Ultra High Frequency Techniques" by Brainerd, Koehler, Reich, and Woodruff. The unmodulated trace of the beam is shown at *f* in Fig. 7, and when the modulating potentials are applied to the electrodes 43-49, 43-50, 43-51 and 43-52, the radial deflection of the beam is varied thus varying the times at which it strikes the bars *a*, *b*, *c* and *d* and produces corresponding time-phased pulses in the resistance *R*.

In these multichannel systems it is preferable to provide means to synchronize the receiver for proper channel selection so that manual adjustment is not necessary. To this end we provide that one of the channels may carry a distinctive synchronizing characteristic. Such a characteristic may constitute a particular difference in pulse duration or width as shown by the wide pulses 140 of Fig. 9, the normal narrow channel pulses being shown at 141, 142, 143 and 144. Such a characteristic may be imparted for example in one of the pulse-forming circuits such as circuit 10 of Fig. 2. Shaping pulses in this manner to secure a desired width or duration is well known in the art and does not need specific illustration. It is commonly used for the purpose of securing television synchronizing pulses for example. Alternatively, a known frequency may be applied to the particular synchronizing channel.

Turning now to the receiving side of the system of communication according to the invention, there are various methods whereby the pulses

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forming the independent communication channels may be separated out at the receiver. One method consists in employing a master oscillator from which by phasing circuits, pulse trains relatively phased to correspond to the various channels may be obtained. These pulses may then be used to control a circuit so that the received signal is only accepted during the period at which the corresponding channel pulses arrive. Such a system is shown in Fig. 8 where 54 is the master oscillator of frequency corresponding to the pulse repetition frequency of each channel.

55, 56, 57 and 58 are the phase shift circuits and 59, 60, 61 and 62 the pulse forming circuits respectively which may be of forms as hereinbefore described in connection with the transmitter. The pulses so formed are given a duration corresponding to the maximum modulation excursion of the corresponding channel pulses and are used to unbias, or otherwise control blocked amplifier circuits 63, 64, 65 and 66 so that they only pass a signal pulse during the period of the controlling pulse duration. The inputs to these blocked amplifier units are obtained from the receiving unit 67 which if the transmission medium is a radio link will consist of the H. F. amplifying and rectification systems, according to standard practice so that its output will then be similar to the pulse train used for modulating the transmitter. The signals obtained at terminals 68, 69, 70 and 71 will therefore be pulse trains forming individual channels which may then be demodulated as described hereinafter.

A modification of this arrangement for receiving and separating the individual channel pulse trains consists of means for synchronising the master oscillator 54 with its counterpart at the transmitter and one channel may be employed for this purpose, by transmitting one channel pulse train without time modulation but with other distinctive characteristics. Then at the receiver, a frequency selecting circuit is used of the types which may result in either the generation of solid pulse or sawtooth waveform of either the required frequency or a multiple of it from which may be obtained the required master frequency for either direct use or for synchronising. Where a large number of channels are employed it is possible to obtain the fundamental frequency of the transmitted pulse train and divide this down for obtaining the required master frequency obtaining only a negligible degree of cross talk. Having once obtained the channel pulse repetition frequency any of the systems described for the transmitter equipment may be employed to obtain the required pulses at the receiver for unblocking the respective receiving channels as described hereinbefore.

Where a relaxation oscillator or additive circuit is employed comprising a capacity charged by the received pulse train to a voltage which triggers off a discharge circuit for producing a waveform with the channel pulse repetition frequency ease of synchronisation may be increased by giving to the unmodulated pulse train of the synchronising channel a duration slightly greater than the other channels, then on rectification of the received total pulse train comprising all the channels, a peak voltage may be obtained for use as a synchronising pulse or an additional boost voltage in the case of the additive circuit. Such a system is commonly used for separation of television synchronizing pulses, for example, see U. S. Patent No. 2,207,775. Referring to Fig. 9, curve *a* represents the transmitted pulse train

and *b* the rectified mean voltage. It will be seen that pulses 140B corresponding to transmitted pulses 140 may be easily segregated by amplitude clipping to provide the synchronizing waves.

The same effect can of course be obtained by omitting one channel, a negative dip being obtained as shown dotted at *b*, Fig. 9, which may be used as the synchronising pulse.

An entirely different method of reception makes use of the double pulse build back circuit principle and may be termed "Progressive selection method." A build back circuit is a multi-vibrator type circuit which has a free oscillation period at least as great as the greatest pulse separation and has double stability, or in other words, two conditions of rest, and is arranged to remain in either condition of rest until acted upon by a pulse, whereupon it shifts to the other condition of rest in which condition it remains until acted upon by a pulse of the same polarity as the previous pulse, whereupon it shifts back again to its first condition of rest. The method using such a circuit consists in passing the received pulse train obtained from the receiving unit after rectification of the H. F. carrier signal, through a buildback circuit with the result that alternate pairs of pulses form a longer duration pulse, the leading edge being formed by one pulse and the trailing edge by the next, the position of these edges being dependent upon the positions of the corresponding pulses. On passing this newly formed pulse through a differentiating circuit a positive and a negative pulse will be obtained from the respective edges and these may readily be separated by passing through a limiter stage. This therefore, has the result of separating the received pulse train into two separate trains. A further division of these two trains may now be carried out until eventually pulse trains corresponding to individual channel pulse trains are obtained. The operation of this arrangement may be readily seen by referring to Fig. 10 where *e* represents a received pulse train containing for example four channels, namely *a*, *b*, *c* and *d*, channel *a* consisting of pulse *a*, *a*¹, *a*¹¹, etc., channel *b* of pulses *b*, *b*¹, *b*¹¹, et etc.

On feeding this pulse train *e* to a build back circuit the pulse train shown at *f* is obtained which on passing through a differentiating circuit, for example a high pass filter, produces pulse train *g* consisting of alternate positive and negative pulses from which by passing through correctly adjusted limiting circuits may be obtained pulse trains *h* and *i*. On repeating these operations with build-back and differentiating circuits utilising the pulse train shown at *h*, pulse train *j* is obtained and thence pulse trains *k*, *l* and *m* from which it will be seen that pulse train *l* consists of the pulses forming channel *a* only i. e. *a*, *a*¹, *a*¹¹, etc. and pulse train *m* consists of channel *c* pulses only namely *c*, *c*¹, etc. A similar operation carried out utilising pulse train *i* would result in the separation of pulses of channels *b* and *d*.

The great advantage of this system of reception is that no synchronising mechanism need be employed at the receiver but the number of channels required in this system must be 2^n where *n* can have any integral value between 1 and infinity. A schematic circuit arrangement for such a system is shown in Fig. 11 in which 72 represents the receiving unit from which the multi-channel pulse train is obtained. 73 represents the first build back circuit and differentiation circuit followed by limiter circuits 74 and 75 respectively ad-

justed to pass only one of the differentiated pulses from the output of 73. Each of these then feeds into the second build back and differentiation circuits 76 and 77 respectively, from which the two further pulse trains forming the required channel pulse trains are obtained via amplitude limiter circuits 78, 79, 80 and 81 at terminals 82, 83, 84 and 85 respectively. Whilst an aerial pick-up has been shown in Fig. 11 it will be understood the pulses may be received over a transmission line.

More specific circuit details will be disclosed hereinafter in connection with Fig. 20.

The demodulation of the individual channel pulse trains may be performed by the employment of a circuit as described in the specification of United States application No. 374,660, issued Patent No. 2,406,790, September 3, 1946, or by any other known pulse demodulation circuit such as a low pass filter. The circuit disclosed in said application is a differentiating detector circuit having a three element discharge tube provided with a grid leak and condenser input circuit. The whole system may be made to include all the advantages inherent in pulse systems of transmission such as improved signal to noise ratio and economical power consumption. With the synchronised systems of reception each channel is made unresponsive to any unwanted signal such as noise interference except during the period at which the wanted pulse may occur. In the case of the progressive selection method, by operating all amplifiers in the pulse circuits from anode current cut off to overload or saturation value, unwanted signals are in this case also eliminated except for the period occupied by the pulse edge as with all pulse systems of transmission.

In its basic form the progressive selection system just described is liable to produce unwanted results if the received signal is not entirely free, especially where radio links are employed, from external influence such as interference or fading etc. or intentional jamming by inserting extra pulses to change the recurrence frequency.

Under such circumstances it is possible that any individual channel signal may appear at different selecting circuits in a random fashion.

The following are the methods and arrangements according to features of this invention by which such occurrences may be prevented—it will be realised that these methods will also secure the correct starting operation or selection, in proper rotation, of the channels of the communication system.

In describing the following methods it will be assumed that such details as limiting, differentiating and other such items will be inserted where necessary, as will be understood by those versed in the art. The description will first be of the principles of methods which may be used. These can be enumerated as follows:

(a) Correction of functioning may be obtained by the use of build back circuits of the multi-vibrator type wherein their "free" or natural running frequency periods correspond to maximum permissible time modulation of the received pulse train in the manner shown in Fig. 13 in which *a*, *b*, *c*, etc., represent the pulses, *a*¹, *a*², *b*¹, *b*², *c*¹, *c*², etc., the respective limits of time modulation. The second curve in this figure shows the pulses when the multivibrator circuit is running free at the pulse repetition frequency of each channel multiplied by the number of channels, the pulses having the maximum durations. The third curve shows the pulses in the multivibrator out-

put circuit when controlled by signal pulses, there being no external effect to upset the proper and correct reception. To ensure correct occurrence at equally spaced intervals of time, the leading edges of the pulses would be synchronised to a local master oscillator, which would in turn be synchronised with the average repetition frequency of the incoming pulses. Trigger pulses from the master oscillator may be suitably phased in a known manner and used to operate the multi-vibrator circuit in one sense to produce the leading edges of the pulses shown in the third curve of Fig. 13, while the incoming signal pulses are used to operate the multi-vibrator in the other sense to produce the trailing edges of the pulses.

(b) By converting the time interval of the interference into an amplitude transient which latter may then be used to provide the required correction. For example, referring to Fig. 14, a train of sharp signal pulses would produce in a circuit a mean D. C. level of height h_m which in the absence of external effects will be constant but when any external interference arrives the value of h_m will vary and this variation may be used to provide the required correction, as by utilizing the value h_m to control the blocking of the receiver so that the interference pulse will block the receiver and prevent the response of the build back circuit at that instant.

(c) A distinguishing feature may be given to one channel pulse train such as a pilot frequency modulation f_c which may occupy the same channel as a signal or may occupy a channel itself. Alternatively one channel pulse train may consist of pulses of a duration different from the pulses in the remaining channels. Other methods not so satisfactory consist in giving the pulses in one channel a different amplitude or a differently shaped edge from the pulses of other channels.

Use is then made of this distinguishing feature or channel characteristic at the sections of the system where pulse trains are separated by providing an additional unit capable of indicating whether the special pulse train is in its correct path of the equipment. The output from this unit may then be arranged to provide the necessary correction such as to insert or eliminate a pulse from the incoming signal, or modify the operation of a build back circuit to produce the equivalent effect.

For the case of a pilot frequency this unit will consist of a pulse demodulation circuit incorporating a filter capable of selecting the control frequency f_c , and for the case of a different pulse width or duration, a demodulation circuit giving a D. C. output voltage at a constant level for correct operation, and a variation for incorrect operation. This D. C. output may be applied directly or by means of a bridge circuit arrangement balanced at the voltage of correct operation to provide the requisite correcting control.

A control unit must be incorporated at the output of each pulse separating stage, i. e. 74, 75 (Fig. 11), i. e. at the output of the differentiating and limiting stages, in order to ensure correct channel selection on starting up the receiver, or if an interfering signal lasts for a large number of received pulses, or alternatively if the receiver signal fades badly.

It will be appreciated that although it is only necessary to employ one channel for control purposes, more than one may be used for providing greater scope for detail design considerations.

Referring again to Fig. 10 and to Fig. 12 in which parts are given like reference to corresponding parts in Fig. 11, let it be assumed that pulse train a has a distinguishing feature, such as a modulation frequency f_c . Now the first stage of selection occurs after pulse train g has been obtained and results in two separate pulse trains h and i the former containing pulses a and c and the latter b and d . If the circuits for accepting a and c , i. e. 74 in Fig. 12, do so in fact, the control unit 86, Fig. 12, then extracts from the a and c pulse train the component of frequency f_c which is applied to prevent correcting unit 87, Fig. 12, from functioning. If the pulse train fed to 74, Fig. 12, consists of pulses b and d then no f_c is obtained and unit 87, Fig. 12, applies, as explained fully hereinafter, the necessary correction to 73, Fig. 12, for example by inverting the pulse train f , Fig. 10, or by inserting a pulse in the received pulse train.

It will be seen that the pulse train accepted by 74 as correct may be a, c, a, c , etc., or c, a, c, a , etc., only one of which will provide the correct signals at outputs 82 and 83 etc., Fig. 12, hence the same control operation must be repeated by units 88 and 89, Fig. 12, which provide a signal capable of causing the output from unit 73 to be advanced or retarded two signal pulse periods, by the insertion or elimination of two received pulses. By causing circuit 89 to control the first build back unit 73 and not the later ones such as 76 it is possible to ensure that the correct signal is obtained at the output terminals 82, 83, 84 and 85 respectively, by the use of only one pilot frequency.

(d) By providing a distinctive modulation for each channel so that at the receiver means may be provided for converting this modulation into a voltage to be used for controlling correction circuits if a channel other than the correct one appears at a selected channel terminal equipment. The type of correction provided depends on the cause and duration of received signal interruption. For simplicity correction will be described for overcoming interference appertaining to the received signal and not to circuits at a later stage of the receiving equipment, which if deemed necessary could be a duplication of parts of these arrangements. This method has many advantages over the more straight forward methods referred to under (c) and typifies a type of synchronising method for multichannel systems employing a modulating component as opposed to a special pulse characteristic at channel pulse repetition frequency.

A schematic diagram of such an arrangement is shown in Fig. 15 and in more detail in Fig. 20. The parts in Fig. 20 which correspond to the blocks in Fig. 15 are given the same references as the blocks. As there are known build back circuits represented at BB available which will operate with positive or negative pulses, it is assumed that the appropriate ones are used, otherwise additional phase reversal devices will be necessary. The units comprising capacity C_1 and resistance R together form a pulse differentiation circuit. DN is a delay network and F a filter or other arrangement for producing a D. C. control voltage from the characteristic of the channel, for example, the pilot frequency. The block 96 represents the first stages of a receiver giving an output similar to the train of phased pulses used for modulating the transmitter. These are then passed through correcting unit 106 to the first build back and differentiation circuit 97 after

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which the first division takes place at units 98 and 99 and the process is repeated giving two further divisions at units 100 and 101 from 98 and 102 and 103 from 99. This process may be continued further, but by way of example, a four channel system will be described herein, as shown in Fig. 15. Units 104, 105 and 106 are the circuits provided for maintaining correct channel selection.

For the case where a pilot frequency is used outside the required signal frequency band, the pilot frequency wave may have a different amplitude or frequency for each channel. In the latter case the filter for separating out the pilot frequency may be such as to provide at the output thereof different amplitudes for different input frequencies received. In one case, such a filter would be connected to the output of one channel and be provided with a rectifier circuit for producing a D. C. voltage which has a predetermined value when the correct signal is received and would vary when the wrong signal is received by that channel. The variation in voltage may then be used to provide the correction to the incoming pulse train so that the pulses fed to the channel having the filter provide the said predetermined datum voltage which exerts no control or variation in the operation of the correcting unit. This pilot frequency selection filter is indicated in Fig. 15 by 104 the output from which is fed to the two correcting units 105 and 106. Unit 105 is capable of extracting pulses from the received pulse train and unit 106 provides means for inserting pulses in the received pulse train. Such units will be described more in detail in connection with Fig. 19.

The necessity for providing two such types of correction units 105, 106 is in order to prevent continuous over correction which is a possibility when employing control voltages whose variations are slow compared to the pulse repetition frequency. Fig. 16 indicates in the third row down the effect of the introduction of a short interfering signal (INT), or in the fourth row down the loss of a pulse (the second pulse) due to fading and it will be seen that these occurrences are equivalent to altering the channel selection sequence.

For example, let it be assumed that unit 104 Fig. 15 is connected to channel terminal B and that pulse train 2 provides in the output of unit 104 a voltage equal to the predetermined or datum voltage, and then as shown in Fig. 17, the voltage produced at terminal B by the channel 1 train of pulses will be less and voltage produced by pulse trains of channels 3 and 4 greater respectively than the voltage produced by the pulse train of channel 2. If an interference pulse is received pulse train 1 may be received at channel B and then output voltage of unit 104, Fig. 15, will be reduced from that produced by the correct train 2. From a study of Fig. 17 it can be seen that a pulse missed will cause an increased voltage output while 2 pulses missed will cause a greater output voltage of 104, a condition which, as will be seen hereinafter will cause a quicker correction and is especially useful where more than four channels are employed. The effect of a long period of noise, or fading may leave the system in any condition, but if circumstances are such as to require it there will immediately be produced in the filter output the necessary correcting voltage.

Units 105 and 106 may consist of a variable

impedance shown as an electron discharge tube 110, Fig. 19, whose control grid G is provided with bias voltage from unit 104 applied at terminal 109. The received pulse train is applied between terminals 107 and 108 to the anode and control grid via capacities C1 and C2 respectively.

The operation of unit 105, the pulse extractor unit, Fig. 15, can best be explained in conjunction with Fig. 18 and Fig. 19. (a) Fig. 18 represents the input pulse train to 105, Fig. 15, at terminals 107 and 108, Fig. 19, obtained from receiver 96, Fig. 15. Under normal conditions the output voltage of unit 104, Fig. 15, which is fed to 109, Fig. 19, to control the impedance of the tube is such as to cause the output of 105, Fig. 15, obtained at terminals 111 and 112, Fig. 22, to be as shown at (b) Fig. 18.

On the occasion of an additional interference pulse being received it will be seen that channel pulse train No. 1 will be received at B (see Fig. 16) so that the voltage output of 104, Fig. 15, will be reduced which will cause the impedance of 110, Fig. 19, to increase. The tube 110, Fig. 19, is initially biased beyond positive cut-off, i. e. beyond saturation point so that the resulting increased negative bias voltage on valve 110, Fig. 19, will cause this valve to feed an out of phase pulse to terminals 112 and 111, and the succeeding output pulses from unit 105 will tend to decrease in amplitude. However, as the impedance of valve 110, Fig. 19, increases, so does the time of the trailing edges of output pulses also increase. These successive pulses will still operate unit 97, Fig. 15, until an extra large spacing between pulses occurs when unit 97, Fig. 15, will not be operated, owing to the fact that the succeeding pulse occurring after the extra large spacing occurs after the preceding pulse has terminated and the amplitude of the said succeeding pulse is not sufficient by itself to operate the build back circuit 97.

Due to the variable spacing which occurs between the pulses and the consequent reduction in voltage at a relatively slow rate compared to the mean pulse repetition frequency, pulses will only be eliminated as just described after the longest intervals which are liable to occur between pulses. The chances, however, of pulse elimination will increase until the requisite number of pulses have been eliminated and the control voltage from 104 is increased to its normal value.

Unit 106 of Fig. 15 provides means for inserting an additional pulse or pulses into the received train of pulses and consists of a similar circuit to that of Fig. 19, or an impedance may be used in place of valve 110 so as to produce at the terminals 111, 112, a varying amplitude pulse train which is fed to an amplifier 129 (Fig. 20) that is normally biased beyond out off. Its grid bias is, however, controlled by the output voltage of 104, Fig. 15, so that in the event of this output becoming positive due to missing pulses in the received pulse train, the amplifier's bias is reduced and a maximum amplitude pulse, obtained from the second of two pulses occurring close together, is amplified and passed through a delay circuit DN (Fig. 20) from which it is fed to the first build back circuit 97. A nominal delay should be used in DN, and if the first pulse coincides with another pulse, the operation will be repeated. The frequency of this operation will be increased as the control voltage increases. In curve c, Fig. 18, the dotted line (i) shows the cut off bias to

which the amplifier 129, Fig. 20 drops as the output from 104 increases and the continuous line shows the varying amplitude pulses in the output of 110. It will be seen in this illustrative case that only one pulse passes to amplifier 129.

The random action of this addition and subtraction of pulses by units 106 and 105 respectively provides time for the control voltage to be restored to normal and so eliminates the possibility of excessive over-correction. Although a low frequency control signal must inherently tend to be relatively slow in operation, by correct adjustment of the circuit time constants involved, it is possible to obtain very rapid action with the arrangement described as use is made of the first initial change only.

The advantages of employing a distinctive feature of the channel modulations as compared with the employment of additional pulses for synchronisation are a reduction of the overall band width of transmission with a saving in radiated energy, and also it would most probably permit of an increase in the maximum permissible modulation per channel.

A further point applicable to the system herein described is that it is possible to adjust unit 105, Figs. 15 and 20, so that pulses of a shorter duration than the correct pulses will not be passed through it with sufficient amplitude to operate the first build back circuit.

All that is necessary to convert a phased pulse system as hereinbefore described, into a double pulse system is the provision at the receiving end of the fixed marking pulses which may readily be accomplished by any of the following methods.

Firstly, to the master oscillator of the channel pulse frequency, obtained by any of the previously described methods may be added further phasing circuits for generating the fixed marking pulses.

Secondly, in the system requiring a pulse for controlling "pass" circuits, this pulse should be increased in duration and phased so as to permit both the received phased pulses and the inserted fixed pulses to be passed. The fixed pulses are obtained by multiplication from the master oscillator i. e. if four channels are required, then the fourth harmonic is generated and the corresponding pulses obtained therefrom applied simultaneously to each channel circuit, one pulse of every four being accepted by each channel in turn.

Whilst an antenna has been shown, the pulses may, it will be understood, be received over a transmission line.

Another method, employing the progressive selection principle has one channel unmodulated and then the pulses in this channel are either phased by time delay networks or by extracting a wave of channel pulse repetition frequency and obtaining from it pulses which are properly phased by phasing circuits for the respective channels.

This principle could, of course, be employed with any system of phased pulses.

In the case where a large number of channels are required, and a frequency multiplication stage is employed, it may be found an advantage to sub-divide the channels into groups.

It will be understood that the methods and arrangements described hereinbefore for directing the pulses to their respective channels at the receiver may also equally well be employed in a multiplex system utilising duration modulated pulses in place of the time modulated or phased pulses, with the exception of the progressive selec-

tion system which involves differentiation circuits. The signals may be obtained in each channel from the duration modulated pulses in known manner.

What is claimed is:

1. In a multichannel electrical signalling system utilizing the transmission of electrical pulses, each channel comprising a train of time-phase modulated pulses, time-phased with respect to the pulses of other channels, means for directing the pulse trains of the channels to respective receiving apparatus including progressive selection means for deriving from the received total pulse train of all the channels a particular channel pulse train comprising a first stage including build back circuit means for deriving from consecutive pairs of received pulses further pulses of durations equal to the time intervals between the received pulses of the respective pairs, means for differentiating said further pulses, means for eliminating pulses of one sign from the pulses resulting from the differentiation means, and further stages including build back circuit means for obtaining in like manner from consecutive pairs of the selected differentiated pulse train of the preceding stage further pulse trains which comprise pulses of a single channel only, and means in each receiving apparatus for deriving as an amplitude modulated wave from the time-phase modulation of the train of pulses receive the intelligence carried thereby.

2. In a multichannel electrical signalling system as claimed in claim 1, progressive selection means wherein said means for deriving from the received total pulse train or from a train of resulting differentiated pulses comprises a build back circuit arrangement for producing pulses whose durations are equal to the time intervals between the pulses of the respective pairs of pulses.

3. Progressive selection means as claimed in claim 1 further comprising correcting means for ensuring correct channel selection of pulses from the received pulse train.

4. Progressive selection means as claimed in claim 1 further comprising correcting means incorporated at the output of each pulse separating stage for ensuring correct channel selection of pulses from the received pulse train.

5. Progressive selection means as claimed in claim 1 further comprising correcting means incorporated at the output of each pulse separating stage for ensuring correct channel selection of pulses from the received pulse train, said means being designed to insert a pulse or to eliminate a pulse from the received pulse train at the input to a pulse build back circuit means.

6. In a multi-channel electrical signalling system utilizing the transmission of electrical pulses, each channel comprising a train of time-phase modulated pulses, time-phased with respect to the pulses of other channels, receiving apparatus comprising means for directing the pulse trains of the channels to respective channel receiving circuits including progressive selection means for deriving from the received total pulse train of all the channels a particular channel pulse train comprising a first stage including build back circuit means for deriving from consecutive pairs of received pulses further pulses of durations equal to the time intervals between the received pulses of the respective pairs, means for differentiating said further pulses, means for eliminating pulses of one sign from the pulses resulting from the differentiation means, further stages

including build back circuit means for obtaining in like manner from consecutive pairs of the selected differentiated pulse train of the preceding stage further pulse trains which comprise pulses of a single channel only, and correcting means incorporated at the output of each pulse separating stage for ensuring correct channel selection of pulses from the received pulse train, said correcting means comprising a control unit and a correcting unit, said control unit being responsive to a characteristic of the received pulses and said correcting unit comprising means for inserting a pulse in the received pulse train and means for eliminating a pulse in the received pulse train under the control of said control unit, and means in each channel receiving circuit for deriving as an amplitude modulated wave from the time-phase modulation of the train of pulses received the intelligence carried thereby.

7. Progressive selection means as claimed in claim 6 wherein said control unit comprises means for giving a variable output voltage depending upon the variability of predetermined characteristic of the pulses in a channel.

8. Progressive selection means as claimed in claim 6 wherein said means for eliminating a pulse from the received pulse train comprises a variable impedance, means for varying said impedance under the control of said control unit, means for applying the received pulses to the input terminals of said impedance, and means for applying the output pulses to the build back circuit means.

9. Progressive selection means as claimed in claim 6 wherein said means for inserting a pulse into the received pulse train comprises an impedance, means for applying the received pulses to the input terminals of said impedance, an amplifier, means for varying the gain of said amplifier under the control of said control unit, means for feeding the output from said impedance to said amplifier, and means for feeding the output of said amplifier through a delay network of appropriate delay constant to the build back circuit means.

10. Progressive selection means as claimed in claim 6 wherein the means for eliminating a pulse from the received pulse train comprises a var-

iable impedance electron discharge tube, and wherein is provided means for varying the impedance of said tube under the control of said control unit, means for applying the received pulses of the input terminals of said tube, and means for applying the pulses from the output of said tube to the build back circuit means.

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