April 14, 1953 E. S. PURINGTON 2,635,228

REMOTE SELECTIVE CONTROL SYSTEM

Filed June 2, 1948 3 Sheets-Sheet 1

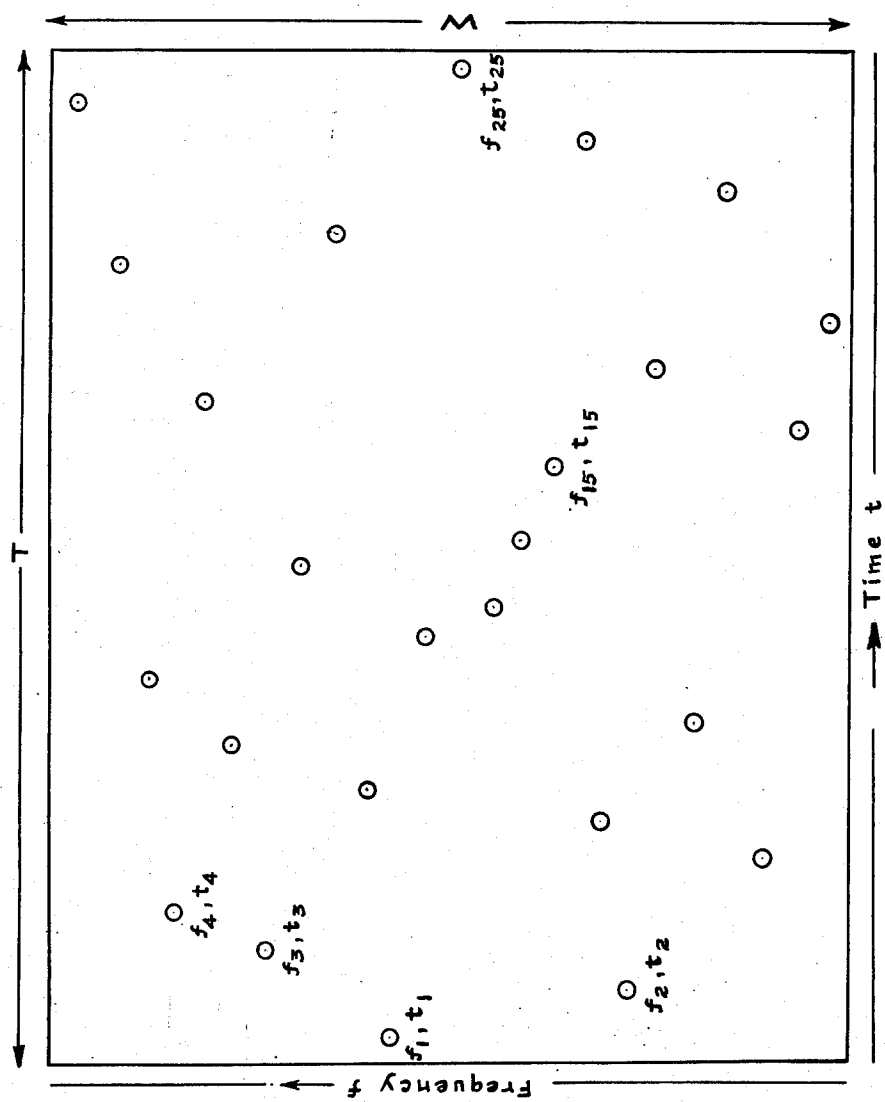


Fig. 1.

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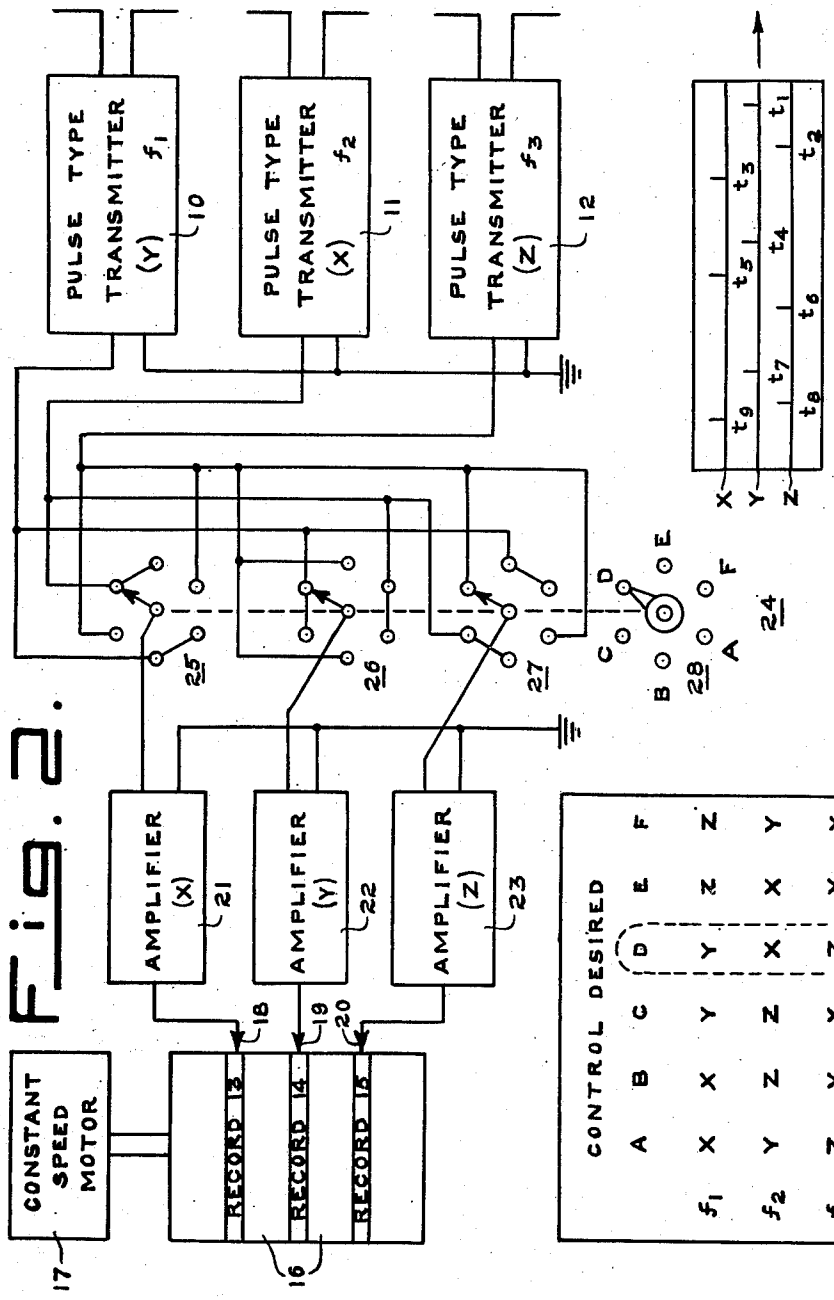


Fig. 2.

Fig. 3.

CONTROL DESIRED	f_1	f_2	f_3
A	X	Y	Z
B	X	Z	Y
C	Y	Z	X
D	Y	X	Z
E	Z	X	Y
F	Z	Y	X

Fig. 4.

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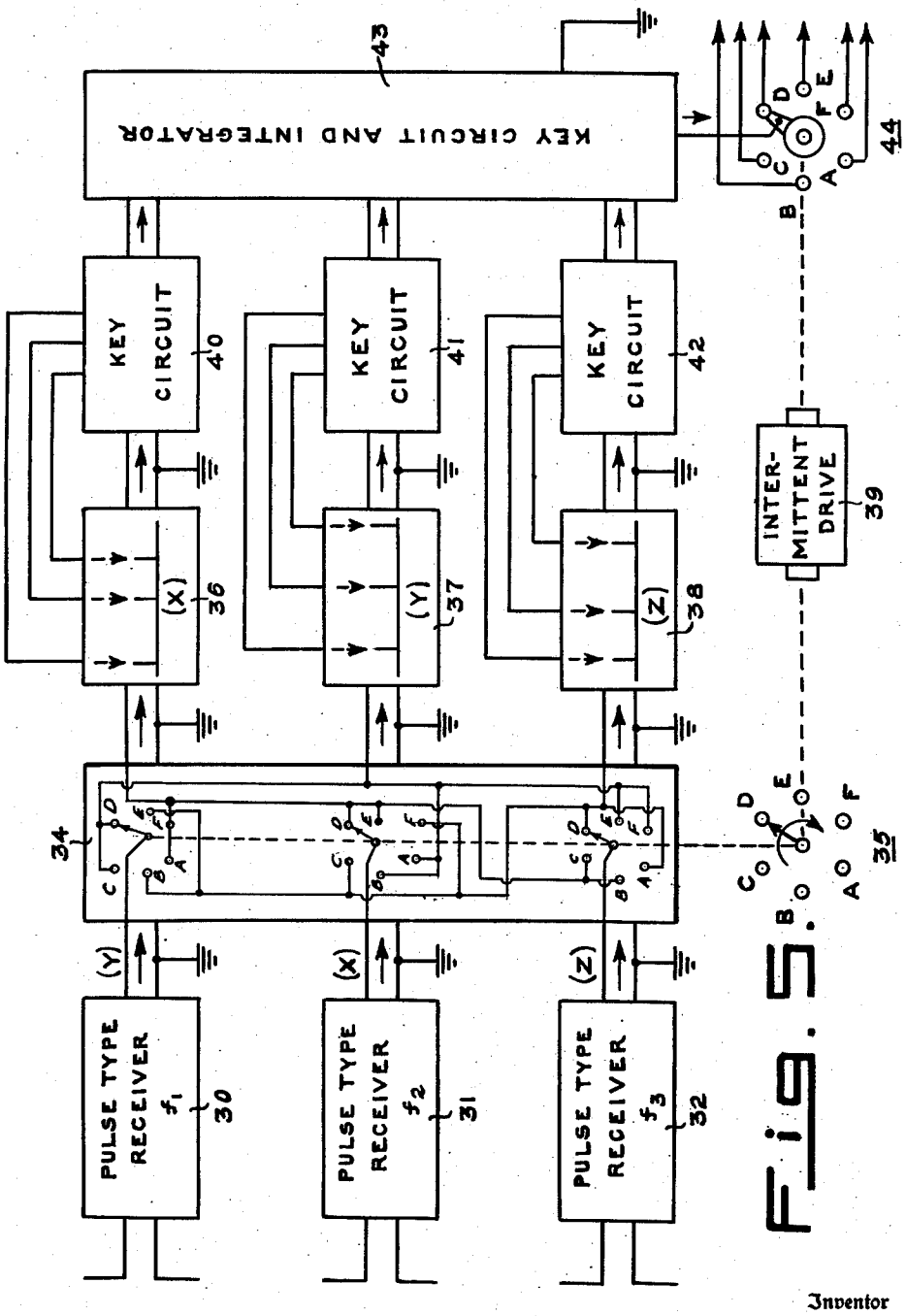


Fig. 5.

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REMOTE SELECTIVE CONTROL SYSTEM

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Application June 2, 1948, Serial No. 30,593

2 Claims. (Cl. 340—167)

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This invention relates to an improved method of control by pulses of radiant energy, using pulses diversely transmitted both as to time and as to radiant energy frequency.

One of the objects is to provide a super-secure type of radio control for guided missiles and the like where considerable complexity is justifiable to provide security both against unauthorized control and against undesired interference upon control. The need for such security systems has been long recognized and is now of very great importance.

While in the commercial communication art, an objective is maximum amount of signals of a given quality with a minimum of time, band width and power, the problem of radio control is security of transmission of each signal within an allowable time limit and within the prescribed wave band or bands, and with a permissible amount of power. The radar type pulse method provides the advantage of a very high peak power which is a highly desirable feature of security systems if correctly utilized. For example systems which involve tuning to the fundamental pulse repetitive rate at the receiver without first capitalizing upon the entire pulse pattern is not a correct method, as it discards the very abundant harmonics of the fundamental which are thus transmitted and received, without making any use of them.

In a previously issued Patent U. S. 2,424,900, I have shown an example of one method of using radar type pulses in control work, involving two trains of recurrent pulses, transmitted with a time separation but brought into time coincidence at the receiver by delay methods. The present invention is an improvement on the previous systems with a distinction that the radiations are randomly distributed in time and in frequency. While the transmitted pattern may be recurrent, the distribution is such as to conceal the recurrent nature and also to render the system not responsive to interferences by recurrent signal trains.

The nature of the invention will be better understood by referring to the following description, taken in connection with the accompanying drawings in which specific embodiments have been shown for purposes of illustration.

In the drawings:

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Fig. 1 is a diagram illustrating the diversity in time and frequency distribution of the transmitted pulses constituting a control signal;

Fig. 2 is a diagrammatic view showing a transmitter system providing six independent control operations;

Figs. 3 and 4 are charts illustrating the operation of the transmitter of Fig. 2; and

Fig. 5 is a schematic diagram showing the corresponding receiver system co-operating with the transmitter of Fig. 2 to provide for the reception and interpretation of the transmitted signals.

In Fig. 1, the radiated pulse pattern is depicted on a frequency versus time plane, with ordinates of the respective circular dots representing the carrier frequencies on which pulses are sent, and abscissas of the dots representing the times at which the pulses are sent. The total time allowed for the transmission of a complete pattern is T, and the total band width for the transmission is W. It will be understood that the pattern may be transmitted recurrently so that a large number of patterns of duration T may be sent for a given control. Moreover it will be understood that there may be places in the total band of width W where signals may not be sent. The allocation of bands, and of time for a control operation will depend upon the transmission requirements and is not involved in the present invention. In the illustrative pattern, the carrier frequencies are designated f_1 to f_{25}; the times at which the pulses are sent are designated t_1 to t_{25}. Thus the circle marked f_{15}, t_{15} has coordinates telling both the carrier frequency and the time associated with the fifteenth pulse of the twenty-five pulse pattern. Although the pulses need not be of the same pattern as to pulse width in a time sense, or pulse strength in a peak voltage sense, the simple case where the individual pulses are of like nature is here especially considered. It will also be understood that there is no significance as to the shape of the pulse indication, since of course only the time and frequency centers can be truly depicted. The circular dots merely represent the instants of time that the system could be disturbed by continuously radiated waves of a given frequency, thereby altering the wave form at the receiver detector where the transmitted pulse forms are to be demodulated and utilized.

There are a number of ways that a pulse pattern as here depicted may be sent and utilized. In general this pattern is describable as pulsed frequency modulation, in that it can be produced by an FM type transmitter in which successive pulses are produced when the transmitter has different frequency values. Basically the arrangement is shown in U. S. Patent 1,420,257 to John Hays Hammond, Jr., also covering a system of electric wave signalling comprising unitary transmission means propagating electrical vibrations successively varying in frequency, and a receiving station including a plurality of elements successively energized in response to said successively varying vibrations and a device responding to said transmission means only as the result of the successive energization of a plurality of said elements. Another way of producing electrical vibrations successively varying in frequency is to utilize as many independent radar type transmitters as there are pulse frequencies. The control of the time-frequency pulse pattern can be in any number of ways; as for example by use of punched cards similar to Fig. 1; or by use of pulses recorded on a plurality of record tracks; or by use of a single pulse and a plurality of delay lines or other so called memory systems for applying the delayed pulses to various transmitters at appropriate times.

The advantages of the present invention as to resistance to undesired control and to interference upon desired control is briefly (1) that pulse type radiations will be required to make any impression upon the system because of the high peak powers of the radiated pulses; (2) that the system is not capable of ready analysis, since it corresponds to successive bursts of monochromatic light which will give the impression of a single broad pulse of white light in many wave analyzers; (3) that the operation of the desired control can be made to be on a statistical basis, with for example execution of the control upon undisturbed reception of sixty percent of the required pulse signals; (4) that the separations of time and frequency are so great that any random pulse pattern applied will occasionally produce a pulse of proper time and frequency value, but will not cause disturbances in either more than 60 percent of the required locations to exercise control, or on more than 40 percent of the required locations to cause disturbance upon control duly exercised by the remaining 60 percent of the properly energized locations. It will be understood that although I show for illustration twenty-five pulses with different time and frequency ordinates, this is purely for illustration. For any given applications, the optimum number will depend upon circumstances, but will certainly be somewhere between a minimum of one pulse, corresponding to a single radar transmission, and an infinite number of pulses corresponding to a true "white light" pattern, both limits corresponding to very insecure systems.

Fig. 2 shows schematically a transmitter for six independent control operations by use of a plurality of pulses sent on three radar type transmitters. This is less general than indicated in Fig. 1, and is a special case in that the frequency coordinates and time coordinates of all pulses are not independent, since for example f_4 may be identical with f_7. In the illustration, the time coordinates are all different, and nine pulses are shown for purposes of simplicity. The frequency coordinates correspond to transmitter carrier frequencies f_1, f_2 and f_3 of three radar type amplitude modulated transmitters.

In the transmitter Fig. 2, the three pulse transmitters for transmitting amplitude modulated pulses of carrier f_1, f_2, f_3 are designated 10, 11 and 12 respectively. The times at which these are pulsed is determined by three pulse records, designated 13, 14, 15 on a rotating member 16 driven by a constant speed motor or other source 17. These recordings may be magnetic, photographic or any desired type, and are provided with suitable pickups 18 to 20 and pulse amplifiers 21 to 23. The timing of the pulse trains designated x, y, and z in the amplifiers 21 to 23 is illustrated in Fig. 3, with pulses occurring at times t_3, t_5, t_9 for train x; at times t_1, t_4, t_7 for train y; at times t_2, t_6, t_8 for train z. These pulse trains may be recurrent with a repetition rate determined by the speed of the constant speed motor 17. In place of a mechanical system with a recorded set of pulse trains, the pulses in amplifiers 21 to 23 can be set up in other ways, for example by use of a pulse oscillator forming a repetitive train, from each pulse of which the nine pulses may be derived for the three trains by use of time delay circuits. Interposed between the amplifiers 21 to 23 and the pulse type transmitters 10 to 12 is a multiple multisection switch 24 with six positions designated A to F in accordance with six independent control operations which may be desired. The three sections 25 to 27 have the rotary blades connected to the outputs of amplifiers 21 to 23, while the fixed contacts are connected to the inputs of the transmitters 10 to 12, in such a fashion that the three amplifiers can be connected to the three transmitters in any of the six possible manners. The various connections of the different records x, y, z, to the transmitters f_1, f_2, f_3, for the six control operations A to E is given in tabular form in Fig. 4, in lieu of a detailed description of the connections from the fixed contacts to the transmitters. Thus for operation D as depicted, pulse train x operates through channel f_2; train y operates through channel f_1 and train z operates through channel f_3. The switch section 28 may be for operational purposes by which for example the desired control operation may be selected by rotating the blades of all switch sections, and the handle then depressed to establish contact and cause a sufficient number of repetitive trains to be sent out on the three transmitters. For operation D, the pulse coordinates of Fig. 1 would involve combinations of frequency coordinates f_1 to f_3 and time coordinates t_1 to t_9, with nine pulses in the entire frequency modulated repetitive pulse pattern. For other operations the pulse coordination would be different combinations. Thus the pulses for operation A for example although in the same T and W region of the time-frequency diagram, will not operate a mechanism responsive to the pulses for operation D, because they cannot overlap those for operation D on the diagram. The requirements of multiple operation, of course, renders the system more vulnerable because the complete time-frequency diagram would involve a total of fifty-four distinct regions where the system must be responsive, but this is true of any multiple control system. The present arrangement, with a large amount of space between pulses both on a time and a frequency basis, will provide a high degree of security even with multiple operation.

The receiver arrangement, Fig. 5, is of the signal seeking type, in which the connections are

made in sequence to make the system responsive to the various control combinations, and to distribute the resulting control signal to the proper outlet work circuit if a control operation is being requested by the transmitter. Three receivers 30, 31, 32 responsive to pulses of carrier frequencies f_1, f_2, f_3 are provided, connected into a switching arrangement 34, with index 35, by which the outputs of the receivers are connected to the inputs of three delay circuits 36, 37, 38, in any of the six possible combinations. The internal connection of this switch 34 which is similar to switch 24 of Fig. 2, are such for example that when the system is set for reception of operation D, the outputs of the receivers are connected to the delay lines as indicated. The delay lines 36 to 38 have fixed taps correlated with the pulse patterns of the records 13 to 15 so that when the pulse trains x, y, and z are impressed on the lines 36, 37, 38, respectively, there will be a pulse at each tap of delay line 36 simultaneously with the presence of a pulse at each tap of delay lines 37 and 38. Thus the delay lines serve to produce nine simultaneous pulse effects although the times of arrival were all different. The switch 34 is driven by an intermittent drive 39 in such a manner that the switch is on a given position for several periods of repetition of the pulse pattern, before it moves to the next position. Thus when the switch moves to position E, with the transmitter calling for operation D, the receiver 31 with train x will be connected to delay line 36, just as for the position shown; but receiver 30 receiving train y will be connected to delay line 38, while receiver 32 receiving train z will be connected to delay line 37. Therefore although the pulses of train x come to a delay line which the pulses match, there is a mismatch between the lines and the pulses for the other trains y and z. Thus there will be simultaneous arrival at the taps of the delay line 36 for the three pulses of train x, but not for the other delay lines.

The taps on the delay lines 36, 37, 38 are connected to coincidental key circuits 40, 41, 42 so arranged that a pulse output from this device occurs when the inputs are all simultaneously pulsed, but there will be no output if only one or two of the inputs are simultaneously pulsed. While any key circuit of suitable form may be used, reference is made to that of my copending application, Serial No. 557,983, now abandoned, which shows a key circuit involving two triodes with plates and cathodes in parallel and a common feed resistor. For three pulses, an added tube may be used, and adjustments made such that the succeeding clipper circuit operates to produce a single pulse only when all three grids are pulsed sufficiently negative to drive the combined plates sufficiently positive.

For the system set momentarily at D and actuated by a control signal with characteristics for operation D, there will therefore be a pulse at the output of all key circuits 40, 41, 42, all at the same time. When the system is set for a control operation other than that for which it is set, a pulse will appear at the output of only one of the three key circuits.

The outputs of the individual key circuits 40 to 42 are connected to the input of a key circuit and integrator 43, which may be of construction similar to that of the above copending application Serial No. 557,983, now abandoned, but adapted for three coincidental inputs on three triodes instead of two. It may further, if desired, include an amplifier circuit tuned to the repetition rate, so that several cycles of pulsing with the nine pulses per cycle are required to build up the signal. Thus for example, with twenty repetitive cycles required to produce a useful load signal, and nine pulses required for each cycle, a total of 180 individual pulses in a suitable pattern are necessary to produce the required control.

The output of the key circuit 43 is connected to the moving blade of a distributor 44 which is driven from the drive 39 in step with the switch index 35. The contacts of the distributor circuit are connected to work circuits for the various operations A to E, in such a manner that when the circuit produces an output due to a match of the switch position with the incoming signal, the output will actuate the desired work circuit.

It will be understood that in place of a signal seeking arrangement as shown in Fig. 5, the switch may be dispensed with, and arrangements made for reception of any of the six control signals and connection to the appropriate work circuit. This would involve for example, eighteen delay lines, eighteen key circuits, and six key circuits and integrators. Furthermore it will be understood that in place of delay lines, other methods of bringing the pulses into coincidence may be used, as for example by magnetic recording of the signals, subsequent pickups at different points along the record, all followed by a wiping circuit. Also it will be understood that the system may be built on a statistical basis, by providing for example that the key circuits will respond to produce an output pulse on operation of any two of the three inputs so that interferences of the same general nature as the signal will neither operate nor interfere with operation even when there is a considerable amount of overlap of pulses at the proper frequencies. It will be especially noted that using tuning to the rate of repetition, an extra safeguard is provided, since interfering signals which might occasionally cause output pulses from the key circuit will not be properly timed to build up the final work signal. It will be understood that additional devices of a general nature for the purposes of increasing security may be applied to the present system.

Although only a few of the various forms in which this invention may be embodied have been shown herein, it is to be understood that the invention is not limited to any specific construction but might be embodied in various forms without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. A remote selective control system comprising means for transmitting repetitive patterns of pulses each pattern comprising a plurality of concurrent groups of short pulses, the pulses of each group having a single carrier frequency different from the carrier frequency of the other groups, the time separation between the individual pulses in each of the groups being selectable for each group, a plurality of receiving means each tuned to a different one of the said carrier frequencies, individual coincidence means connected to each receiving means and operative to produce a pulse in response to the selectable time separation of the pulses, and further coincidence means responsive to reception of simultaneous pulses from the individual coincidence means for producing a control pulse.

2. The system claimed in claim 1, further comprising selectable switching means connecting the individual coincidence means to the different receiving means in different selectable combinations, and further switching means actuated with said selectable switching means to connect said further coincidence means to a different output connection for each selected combination.

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