Nov. 29, 1949 E. LABIN ET AL 2,489,297

ELECTRONIC PULSE FILTERING SYSTEM

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Fig. 1.

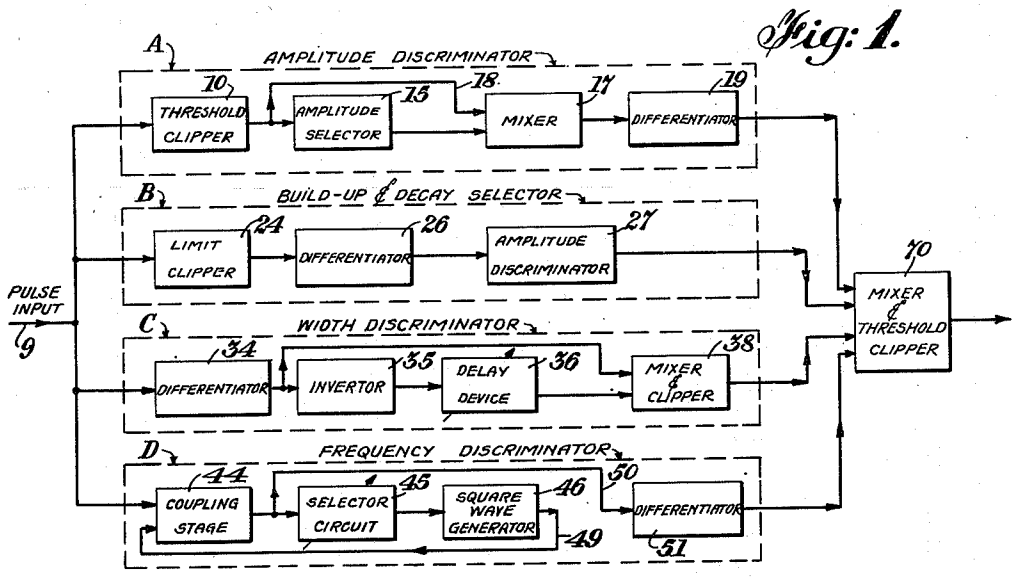
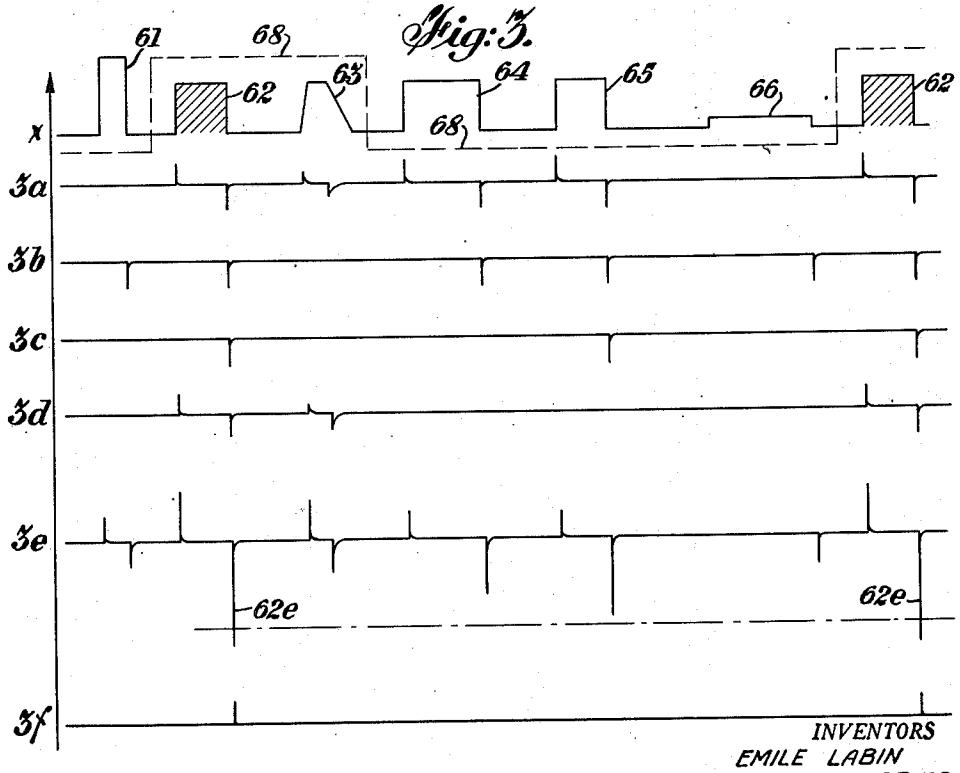


Fig. 3.



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Fig. 2A.

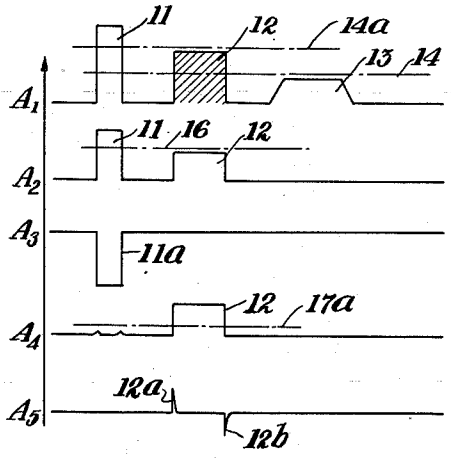


Fig. 2B.

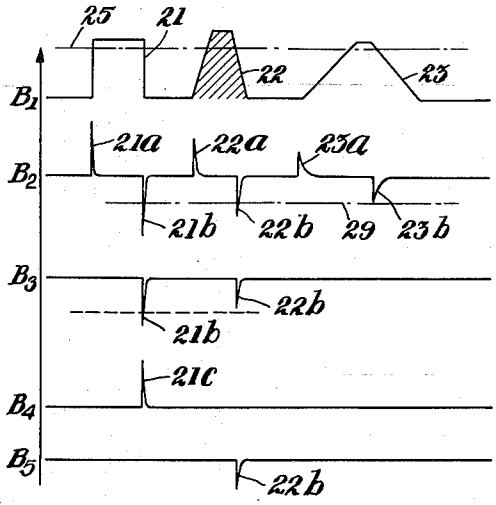


Fig. 2C.

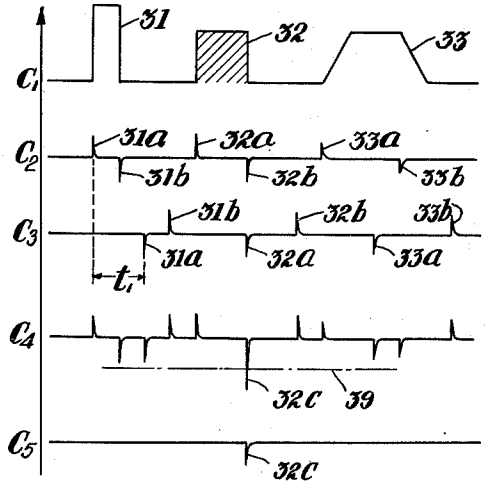
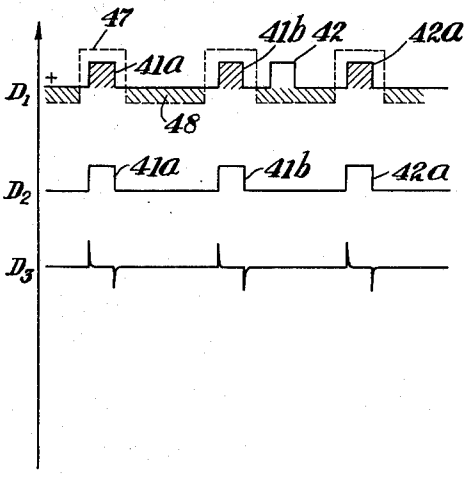


Fig. 2D.

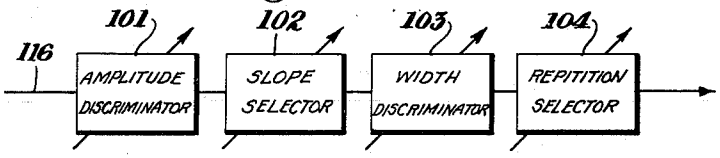


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Fig. 4.



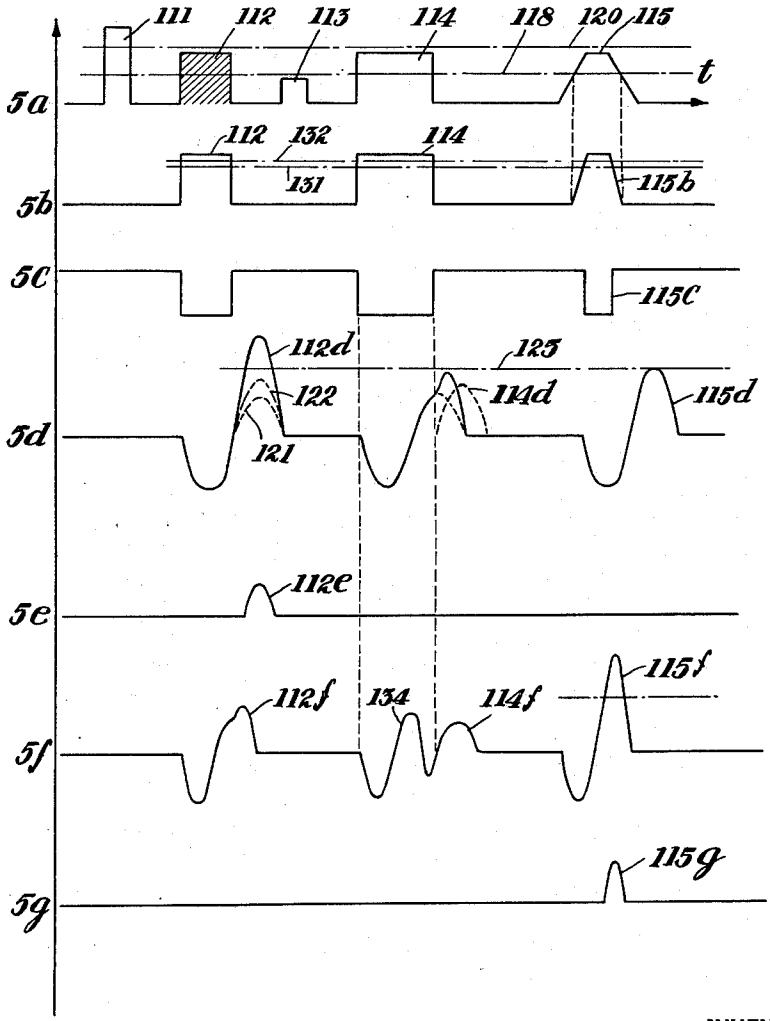


Fig. 5.

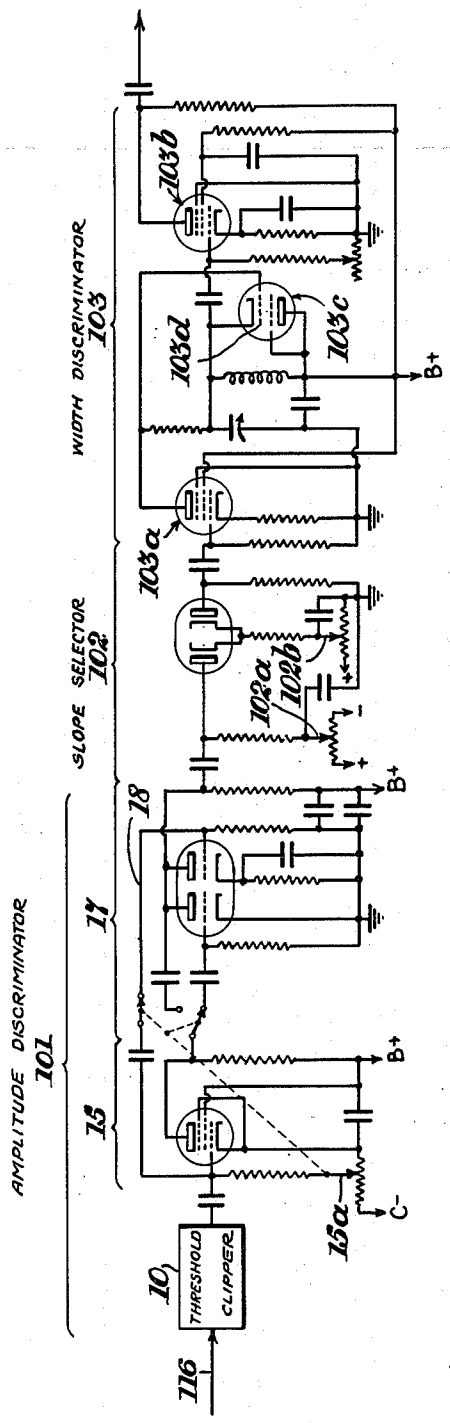
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Fig. 6.



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UNITED STATES PATENT OFFICE

2,489,297

ELECTRONIC PULSE FILTERING SYSTEM

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Application May 24, 1943, Serial No. 488,180

16 Claims. (Cl. 250—27)

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This invention relates to communication systems utilizing trains of pulses for conveyance of intelligence and more particularly to a selective filtering system therefor.

In the case of pulse communication, either radio or telegraphy, where the pulses are time modulated for transmission of intelligence, interference pulses or pulses of other communicating channels present will cause interference and jamming for the usual receiver. In the case of radio communication an enemy may, for example, attempt to jam the communication by utilizing a similar pulse transmission. This imposes on the same carrier unwanted pulses of one or more shapes. Then again, additional pulses differing in character such as amplitude, width, the slopes of leading and trailing edges and/or pulse repetition rate may be added to the train of pulses as separate channels of communication or merely to confuse the enemy and render it difficult for him to determine which of the pulses of the wave carries the intelligence which he wants to jam.

It is one of the objects of our invention to provide a method and means to eliminate from a train of pulses those pulses which differ in one or more shape characteristics from a given pulse shape.

Another object of our invention is to provide a selective pulse filtering system capable of eliminating those pulses differing in amplitude, width, slope (build-up and decay characteristics of leading and trailing edges) and/or the repetition rate from wanted pulses of a given shape and given repetition rate.

Assuming, for example, that a train of pulses is made up of pulses differing in shape characteristics such as amplitude, width and slope and also in repetition rates, a pulse filtering system in accordance with our invention is capable of selecting those pulses of a given pulse shape and given repetition rate from the train of pulses and to eliminate all other pulse shapes and pulses of said given pulse shape occurring outside of the given repetition rate. In one embodiment of the invention energy of the train of pulses is subjected separately in parallel circuits to a plurality of filtering operations and the resultant thereof mixed and clipped, while in another embodiment the train of pulses is subjected in succession to a series of filtering operations. Each of the filtering operations operate on a different shape characteristic or repetition rate to assist in the elimination of those pulses differing from a given pulse shape or in given repetition rate. One of the filtering operations, for example,

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eliminates those pulses differing in amplitude with respect to a given amplitude characteristic, a second filtering operation eliminates those pulses differing in slope from a given slope characteristic, a third operation eliminates those pulses differing in width from a given width characteristic and a fourth operation eliminates odd pulses not included in a given pulse repetition rate. The unwanted pulses, of course, may differ in one, two or three shape characteristics or only in pulse repetition rate from a wanted pulse and its repetition rate. Regardless of these differences our system operates to effectively eliminate the unwanted pulses.

For a further understanding of the invention, reference may be had to the following detailed description to be read in connection with the accompanying drawings, in which:

Fig. 1 is a block diagram of one embodiment of our invention;

Figs. 2A, 2B, 2C and 2D are graphical illustrations representing the filtering operation of the parts of the system illustrated in Fig. 1;

Fig. 3 is a graphical illustration representing the end result of the combined filtering operation of the parts of Fig. 1;

Fig. 4 is a block diagram of a second embodiment of our invention;

Fig. 5 is a graphical illustration of the operating steps of the system of Fig. 4; and

Fig. 6 is a schematic diagram of the amplitude discriminator, slope selector and width discriminator of Fig. 4.

Referring to Fig. 1, the filtering system therein shown is divided into four branches A, B, C and D connected together in parallel. Each of these branches performs a different filtering operation. The branch A discriminates in amplitude between the pulses applied thereto, branch B discriminates as to differences in slope, that is, differences in the build-up and decay character of the leading and trailing edges of the pulses, branch C discriminates as to differences in width, and branch D discriminates according to a given pulse repetition rate.

Referring to the branch A of Fig. 1 and to Fig. 2A, assume that a train of pulses I_1, I_2 and I_3 such as shown in curve A_1 is applied to the branch. Pulse I_2 is a desired pulse of a given amplitude, while pulse I_1 is of greater amplitude and pulse I_3 is of less amplitude. The amplitude discriminating means of this branch may comprise any suitable amplitude discriminating means, such for example as disclosed in the copending applications of D. D. Grieg Serial No.

561,553, filed November 2, 1944, now United States Patent No. 2,434,921, issued January 27, 1948, and Serial No. 487,071 filed May 15, 1943, now United States Patent No. 2,419,548, issued April 29, 1947, or the system disclosed in U. S. Patent No. 2,406,882. For purposes of illustration, however, we choose to show the amplitude discriminator disclosed by Grieg in application Serial No. 487,071, the circuit details of which are shown in Fig. 6.

When the pulses of curve A_1 are applied to the branch A through input 9, the pulses are first subjected to a threshold clipping action by the clipper 10 whereby the smaller pulse 13 is eliminated by the threshold clipping level 14. If the larger pulse 11 were desired, the clipper would then be biased to clip at level 14*a*.

The output of the threshold clipper 10 retains the pulses 11 and 12 as shown by curve A_2. These pulses are applied to an amplitude selector 15, Figs. 1 and 6, adjustable at 15*a* to threshold clip the pulses at a level 16 thereby clipping the upper portion of the larger pulse 11. This clipped portion is amplified and inverted as shown by curve A_3 as pulse 11*a*. The output of the amplitude selector 15 is applied to a mixer 17, Fig. 6, together with the output of threshold clipper 10 which is supplied to the mixer 17 through connection 18. The pulse energy 11*a* thus cancels pulse 11 leaving the wanted pulse 12 as indicated by curve A_4.

The output of the mixer 17, if desired, may be applied to a differentiator 19, Fig. 1, thereby translating the pulse 12 into positive and negative pulses 12*a* and 12*b* corresponding respectively to the leading and trailing edges of the pulse. The mixer 17 may be biased to provide a threshold clipping operation at a level 17*a* to remove noise fluctuations and other disturbances such as might occur due to the cancelling operation of the larger pulses. As is clear in Fig. 2A, the amplitude discrimination takes place regardless of the shape or width of the pulses.

Referring to branch B of Fig. 1 and Fig. 2B, let it be assumed that a train of pulses 21, 22 and 23 such as indicated by curve B_1 is applied to the input of the branch B. Pulse 22 is the wanted pulse and it has given build-up and decay slopes, while pulse 21 has a width corresponding to the base of pulse 22, its leading and trailing edges are steeper than those of pulse 22. Pulse 23 has the leading and trailing edges of greater slope and the base thereof is wider than the base of pulse 22.

The pulses 21, 22 and 23 are applied to a limit clipper 24 to limit the amplitude of the pulses as indicated by the clipping level 25. The output of the clipper 24 is applied to a differentiator 26 whereby positive and negative pulses are produced corresponding respectively to the leading and trailing edges of each of the pulses. These differentiation pulses, as shown by curve B_2, are of amplitudes corresponding to the steepness of the corresponding edges of the pulses 21, 22 and 23. Thus, the pulses 21*a* and 21*b* are of greater amplitude than the pulses 22*a* and 22*b*, and the latter are of greater amplitude than the pulses 23*a* and 23*b*. In order to discriminate between these pulses of different amplitude, the output of the differentiator 26 is applied to an amplitude discriminator 27 which may be identical with the amplitude discriminator of branch A (see circuit parts 15 and 17 of Fig. 6). It follows, therefore, that by proper clipping of the pulses 21*a* or 21*b*, as the case may be, a pulse output is obtained corresponding to the larger pulse 21.

Since it be desirable, however, to obtain a pulse corresponding to the wanted pulse 22 and to eliminate those corresponding to pulses 21 or 23, a clipping operation will be performed at level 29 corresponding to the clipping level 14 in Fig. 2A. This results in carrying forward the pulses according to curve B_3. By clipping and inverting the peak of the greater pulse 21*b* as indicated by the pulse 21*c* (curve B_4) and mixing it with the pulses of curve B_3, the pulse 21*b* will be eliminated leaving pulse 22*b* (curve B_5) which corresponds to the trailing edge of the pulse 22. If desired, the clipping operation may be made on pulses 21*a* and 22*a* thereby resulting in an output pulse corresponding to the leading edge of the pulse 22.

Referring to Fig. 2C and branch C of Fig. 1, let it be assumed that the width discriminator of branch C receives a train of pulses illustrated by curve C_1. This curve is shown provided with pulses 31, 32 and 33 in which pulse 32 is the wanted pulse of a given width. Pulse 31 is of less width than pulse 32 while pulse 33 is of greater width. Pulse 31 is also shown of greater amplitude than pulse 32 while pulse 33 also differs in the slope of the leading and trailing edges thereof.

The width discriminator may be any suitable width filtering circuit and preferably is of the character disclosed in the copending application of E. Labin, Serial No. 467,509 filed December 1, 1942, now United States Patent No. 2,418,127, issued April 1, 1947. The pulses of curve C_1 are applied to a differentiator 34 thereby translating the pulses 31, 32 and 33 into positive and negative pulses illustrated by curve C_2. The pulses produced by the differentiation of input pulses 31 and 32 are of the same amplitude since the build-up and decay slopes of these input pulses are the same. The pulses 33*a* and 33*b* of input pulse 33, however, are of less amplitude. It follows that a clipping operation could be used to eliminate the pulses 33*a* and 33*b* similarly as in the case of the pulses illustrated in Fig. 2B. This, however, would leave pulses 31*a*, 31*b* and pulses 32*a*, 32*b* without any other difference except the timing therebetween.

According to the method selected for purposes of illustration, width discrimination is made by applying the output of the differentiator 34 to an invertor 35 and then through a delay device 36 which is adjusted to retard the pulses an amount t_1 corresponding to the width of the wanted pulse 32. This inversion and retardation effect is illustrated by curve C_3. The pulse output of the delay device 36 (curve C_3) together with the pulse output of the differentiator 34 (curve C_2) are applied to a mixer and clipper stage 38. Curve C_4 illustrates the mixed relationship of the pulses. It will be noted that in this mixing operation only those pulses 32*a* and 32*b* are in alignment and therefore are the only pulses of the two curves that add together as indicated at 32*c*. The stage 38 is preferably biased to clip the pulses at a level 39, thereby selecting pulse 32*c* and eliminating all the other pulses. It therefore follows that by this method all pulses differing in width from a given pulse shape are eliminated and a new pulse 32*c* is produced corresponding to the trailing edge of the pulse of given width.

If an output pulse corresponding to the lead-

ing edge of the wanted pulse is desired, this may be accomplished by inverting the pulses of curve C_2 and mixing same with pulses according to curve C_2 delayed a period equal to the period of the wanted pulse. This will result in a large pulse corresponding to the leading edge of the wanted pulse and by clipping all other pulses can be eliminated.

Referring now to Fig. 2D and branch D of Fig. 1, let it be assumed that the pulses 41*a*, 41*b*, 42 and 42*a* of curve D are applied to the input of branch D. The pulses 41*a*, 41*b* and 42*a* are the wanted pulses and they are shown to occur at a given repetition rate. The blocking feature of the branch D is of special utility for eliminating other pulses of shape identical to the wanted pulses, which occur at a repetition rate differing from the repetition rate of the wanted pulses. The method followed in carrying out this blocking operation may be in accordance with known method or those disclosed in the copending application of H. G. Busignies Serial No. 380,186, filed February 24, 1941, now United States Patent No. 2,423,082 issued July 1, 1947, and U. S. Patent No. 2,406,019. The pulses of curve D_1 are first applied to the coupling stage 44. The output of the coupling stage 44 is applied to a selector circuit 45. The selector circuit is tuned to a period corresponding to the repetition rate of the wanted pulses so as to produce a suitable harmonic. By suitable adjustment, the selector means 45 and the square wave generator 46 may be caused to produce from this harmonic a blocking potential occurring only when no wanted pulses are due for reception. This blocking potential is illustrated by the potential line 47. When the blocking potential drops below the zero axis of curve D_1, as indicated at 48, a negative blocking potential is produced at the output of the square wave generator which is applied by connection 49 to the coupling stage 44. This blocking potential will thereby eliminate pulses such as the pulse 42 occurring between the wanted pulses. The wanted pulses thus passed by the coupling stage 44 are applied over connection 50 to a differentiator 51 by which the pulses are translated into positive and negative pulses shown by curve D_3.

In Fig. 3, curve *x*, we have shown an input train of pulses which, let it be assumed, is applied at the input 3 to the filtering system of Fig. 1. The pulses of this train are selected of various shape characteristics to illustrate the filtering function of the several branches of the filtering system. The train comprises pulses 61, 62, 63, 64, 65 and 66. Assume that pulse 62 is the wanted pulse having a given amplitude, given build-up and decay characteristics and a given width. The pulse 61 differs both in amplitude and width from the wanted pulse 62. Pulse 63 differs in build-up and decay slopes from pulse 62 and pulse 64 differs therefrom in width. The pulse 65 is identical to the shape of pulse 62 but is outside of a given repetition rate of pulse 62. Pulse 66 differs from pulse 62 in that it is of smaller amplitude and of greater width.

Curve 3*a* represents the output of the branch A after the pulses are filtered according to amplitude (see Fig. 2A). Curve 3*b* represents the output of the branch B after the pulses have been filtered according to the buildup and decay slope characteristics of the wanted pulse 62 (Fig. 2B). It will be seen that only those pulses having the corresponding slopes remain at the output of the branch B. Curve 3*c* represents the output of branch C in accordance with the width discrimination (see Fig. 2C). Curve 3*c*, therefore, has pulses corresponding only to the input pulses of a width equal to the width of pulse 62. Curve 3*d* represents the output of branch D in accordance with the given repetition rate of pulse 62 (see Fig. 2D). This blocking effect is indicated by the blocking potential 68 and it will be seen that pulse 65 is thereby eliminated. This blocking feature may be adjusted to eliminate the other pulses 61, 63, 64 and 66 in branch D, although not necessarily so.

Curve 3*e* represents the output of the several branches as they appear in mixed relation in the mixer and threshold clipper 70. It will be seen from the alignment of pulsations of curves 3*a*, 3*b*, 3*c* and 3*d* that the pulsations corresponding to the trailing edge of wanted pulses 62 are greater in number than for any of the pulsations corresponding to the unwanted pulses. The threshold clipping function of the mixer 70 may therefore be adjusted to clip only the largest pulsations which in this case are pulses 62*e*. The final output is represented by curve 3*f*.

It is thus clear that according to this embodiment of our invention all pulses differing in shape characteristics as well as repetition rate from a given pulse shape and a given repetition rate are eliminated thereby reducing interference to only pulses or disturbances that are in superposition of a wanted pulse. Since this superpositioning of interfering pulses is infrequent such interference may be disregarded or at least easily overcome by repeating signals.

In the embodiment shown in Fig. 1, the several shape discriminating stages are arranged in parallel and the outputs thereof are combined and clipped to obtain the wanted signal increments. In Figs. 4, 5 and 6, a second embodiment is illustrated in which the several pulse discriminating stages are arranged in tandem. The consecutive stages of this system comprise an amplitude discriminator 101, a slope selector 102, a width discriminator 103 and a repetition rate selector 104. Each of these stages is adjustable so that a pulse of given shape, that is of given amplitude, given slope characteristics, given width and the repetition rate of which is known may be selected. For a discussion of the application of the pulse amplitude, slope and width discriminating features of this embodiment as an interference limiter in radio receivers reference may be had to our copending application Serial No. 488,182, filed May 24, 1943, now United States Patent No. 2,434,937, issued January 27, 1948.

Let it be assumed, for example, that a train of pulses 111, 112, 113, 114 and 115 such as shown by curve 5*a* of Fig. 5 is applied to the input 116 of the amplitude discriminator 101. Also assume that pulse 112 is the given pulse shape of the wanted pulses. The amplitude discriminator is preferably selected of the character disclosed in branch A of Fig. 1. According to the clipping features of the discriminator of branch A, the pulses are first clipped at a level 118 to eliminate the smaller pulses such as pulse 113 and second, at a level 120 to clip the larger pulses for inversion and mixing whereby the larger pulses such as pulse 111 are eliminated. Curve 5*b*, therefore, represents the output of the amplitude discriminator 101 after the larger and smaller pulses 111 and 113 of curve 5*a* are eliminated. It will be noted that by this amplitude discrimination, pulse 115 has been re-shaped increasing

the steepness of the edges thereof as indicated at 115b.

The slope selecting stage 102 may be of any known gate clipping character capable of clipping the pulses between two selected levels. For illustration purposes we show in Fig. 6 a clipper gate of this character which is also disclosed in our copending application Serial No. 488,182. Assuming that pulse 112 has the given slope characteristics, the stage 102 will be adjusted at 102a and 102b to slice the pulses between limits such as indicated by lines 131 and 132 where pulse 115b, for example, differs in width from pulse 112.

The width discriminator 103 is of the adjustable L-C damped circuit character disclosed in our copending application Serial No. 488,182. As described in detail in our aforesaid copending application, the width discriminator first inverts and amplifies at 103a the pulse energy to provide negative pulses as shown by curve 5c. It will be noted that by slicing pulse 115b and amplifying, a pulse 115c substantially rectangular in shape is produced. These negative pulses are then applied to the L-C circuit to produce undulations according to curve 5d. Where the L-C circuit is tuned to a period twice the time interval between the leading and trailing edges of pulse 112, the shock excitation caused by the leading and trailing edges will produce oscillations 121 and 122 which are in step and therefore produce a maximum undulation 112d. The pulses 114 and 115, however, are of larger and smaller periods respectively than the period of this tuning adjustment. The larger period of pulse 114 produces oscillations which are out of step and therefore form an undulation 114d which is of amplitude less than the amplitude of undulations 112d. The period of pulse shape 115b being smaller than the period of pulse 112 also produces an undulation 115d which is of smaller amplitude. By suitably clipping at a level 125 by clipper tube 103b, a pulsation 112e is obtained corresponding to the wanted pulse 112. The damper tube 103c is maintained inoperative by the input pulse energy applied to the control grid 103d. After the duration of the input pulse energy the tube 103c is permitted to conduct when oscillations in the L-C circuit swing to negative polarity thereby damping out the oscillatory energy following undulations 112d, 114d and 115d as indicated in curve 5d.

Should it be desired to obtain a pulsation corresponding to the pulse 115 and to eliminate the other pulses of the curve 5a, the slope selecting stage 102 will be adjusted substantially as above to gate clip the pulses of curve 5b between limits 131 and 132. By width discrimination of the resulting pulse shapes of curve 5c with the L-C circuit for stage 103 tuned at a period which is twice the period of pulse 115c, a series of undulations 112f, 114f and 115f different from the corresponding undulations of curve 5d is produced. It will be observed that the undulation 115f is of greater amplitude than the undulations 112f and 114f. By a clipping operation the pulsation 115g may be segregated from the other undulations.

The additional undulation 134 adjacent undulation 114f is the oscillation produced by the leading edge of the pulse.

The repetition rate selector stage 104 is shown in tandem relation with respect to the shape discriminator stages of Fig. 4 and may be used to eliminate pulses identical in shape with the wanted pulse where they occur outside of the given repetition rate of the wanted pulse. Since this is illustrated graphically in Figs. 2D and 3, a further illustration and description of the function thereof is believed unnecessary.

It will be observed that the width discriminator feature of Fig. 4 is considerably different from the width discriminator C of Fig. 1. Should it be desirable, the width selector 103 may be substituted for the width discriminator C. Should the substitution be made, it will be necessary, however, to provide a delay device for the output from branches A and B so as to retard the pulse output of these branches an amount corresponding to the retardation of the undulations produced by the width discriminator in response to the input pulses. The repetition rate discriminator could, in that case, be used in series with the mixer stage 70 similarly as in the series arrangement of Fig. 4.

While we have shown and described the principles of our invention in connection with specific embodiments, we recognize that various changes and modifications may be made therein without departing from the invention. For example, any two or more of the discriminating stages may be used together in the manner illustrated where a lesser number of shape characteristics are involved and where pulse repetition rate is not an important factor. It will be understood, therefore, that these embodiments are given by way of example only and not as limiting the objects of our invention and the appended claims.

We claim:

1. A method of selectively filtering a train of pulses to eliminate those pulses differing in shape characteristics from a given pulse shape comprising subjecting energy of the train of pulses independently to a plurality of filtering operations, each of said filtering operations being such as to eliminate those pulses differing in one of said characteristics from said given pulse shape, mixing the remaining pulses from each of the filtering operations whereby the pulse energy passed by the filtering operations is greater for pulses of the given pulse shape than for pulses of other shapes, and clipping the greater pulse energy thus obtained thereby eliminating the energy corresponding to those pulses differing from said given pulse shape.

2. The method defined in claim 1 wherein said given pulse shape has given amplitude and slope characteristics, and the filtering operations are such as to eliminate those pulses differing in at least a selected one of said characteristics.

3. The method defined in claim 1 wherein said given pulse shape has given amplitude and width characteristics, and the filtering operations are such as to eliminate those pulses differing in at least a selected one of said given characteristics.

4. The method defined in claim 1 wherein the given pulse shape has a given base width characteristic and the edges thereof have given slope characteristics, and the filtering operations are such as to eliminate those pulses differing in at least a selected one of these characteristics.

5. The method defined in claim 1 wherein the given pulse shape has given amplitude, width and slope characteristics, and the filtering operations are such as to eliminate those pulses differing from said given pulse shape in at least a selected one of said characteristics.

6. A system for selectively filtering a train of pulses to eliminate those pulses differing in shape characteristics from a given pulse shape comprising a plurality of pulses filtering means,

means connecting said filtering means in parallel so that each operates independently on input energy of the train of pulses, each of said filtering means being such as to eliminate those pulses differing in one of said characteristics from said given pulse shape, a mixer, means to supply the output of said filtering means to said mixer, whereby pulse energy corresponding to the characteristics of said given pulse shape passed by the filtering operations of said filtering means combine, the pulses corresponding in all of the given shape characteristics producing a combined energy greater than those pulses differing from one or more of the given shape characteristics, and means for clipping the greater pulse energy thus obtained thereby eliminating the energy corresponding to those pulses differing from said given pulse shape.

7. The system defined in claim 6 wherein the filtering means comprise an amplitude discriminator stage, a slope discriminator stage and a width discriminator stage.

8. The system defined in claim 6 in combination with a pulse repetition rate discriminator arranged to eliminate pulses identical in shape with said given pulse shape but occurring outside of a given repetition rate.

9. The system defined in claim 6 wherein there are at least two filtering means, one of said filtering means being arranged to eliminate those pulses differing from the amplitude characteristic of said given pulse shape and the other of said filtering means being arranged to eliminate those pulses differing from the width characteristic of said given pulse shape.

10. The system defined in claim 6 wherein there are at least two filtering means, one of said filtering means being arranged to eliminate those pulses differing from the amplitude characteristic of said given pulse shape and the other of said filtering means being arranged to eliminate those pulses differing from the slope characteristic of said given pulse shape.

11. The system defined in claim 6 wherein there are at least two filtering means, one of said filtering means being arranged to eliminate those pulses differing from the slope characteristic of said given pulse shape and the other of said filtering means being arranged to eliminate those pulses differing from the width characteristic of said given pulse shape.

12. The system defined in claim 6 wherein the filtering means comprise an amplitude discriminator means, a slope discriminator means, a width discriminator means and a pulse repetition discriminator means.

13. A system for selectively filtering a train of pulses to eliminate those pulses differing from one or more of the given amplitude, given slope and given width characteristics of a given pulse shape, comprising filter means to pass energy of those pulses having said given amplitude characteristic, filter means to pass energy of those pulses having said given slope characteristic, filter means to pass energy of those pulses having said given width characteristic, and means to combine the operations of the several filter means to produce a final unitary sequence of output pulses having a timing according to those pulses of said train having said various given shape characteristics.

14. The system defined in claim 13 wherein the means for combining the operations of the several filtering means includes means for connecting said filter means in tandem relation whereby certain of said filter means operate on the pulse energy output of other of said filter means.

15. The system defined in claim 13 wherein the means for combining the operation of the several filter means includes means for connecting said filter means in parallel circuit relation for separate operation on the pulses of said train and means for combining the output of the several filter means for producing therefrom said final output pulses.

16. The system defined in claim 13 in combination with a pulse repetition rate discriminator for eliminating pulses of said given pulse shape occurring outside of a given repetition rate.

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