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PULSE CORRECTING CIRCUIT

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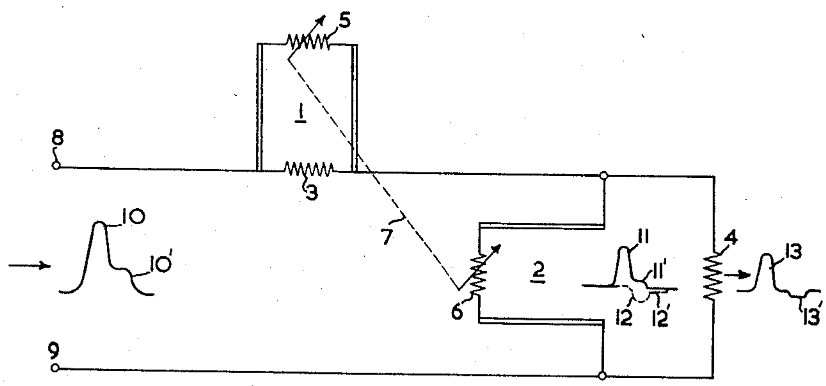

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PULSE CORRECTING CIRCUIT

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This invention relates to a pulse correcting circuit for improving the pulse shape of short pulses, more particularly pulses having a duration of 0.05 μsec. and less, which are used for example in radar apparatus.

Experience has shown that, when such pulses are used, the trailing edges of the pulses can be distorted by the introduction of pulse tails, for example, owing to deviations from a transmission characteristic required for faithful transmission. The duration of these tails can be several times that of the pulses while their amplitude is a fraction, for example ⅓, of the pulse amplitude.

This phenomenon is troublesome for various uses, for example in radar apparatus, the tails of the echo pulses reducing the distance discrimination and adversely affecting the image display on the screen.

It is an object of the invention to provide a simple pulse correcting circuit which enables the pulse tails to be materially reduced.

According to the invention the pulse corrector circuit is constituted by a four-terminal network comprising the series combination of two line sections of equal characteristic impedance and equal electric length, said line sections being terminated at the input side by their characteristic impedances and at their remote ends by finite resistances the product of which is equal to the square of the characteristic impedances of the line sections, the output voltage being taken from the terminating resistance of one of the line sections.

It should be noted that, in order to double the duration of pulses, it is already known to use a four terminal network comprising the series combination of two line sections of equal characteristic impedance and equal characteristic length, which are terminated at their input side by their characteristic impedances. However, in this known circuit arrangement, one of the line sections is open and the other is short-circuited, the characteristic impedance of the open line section constituting the output resistance of the network.

In order that the invention may readily be carried into effect, one embodiment will now be described, by way of example, with reference to the accompanying drawing.

The single figure of the drawing shows the circuit arrangement of a pulse correcting circuit in accordance with the invention, which comprises the series combination of two line sections 1 and 2 of equal characteristic impedance R_0 and equal electrical length L, which are terminated, at their input sides, by resistors 3, 4, the values of which are equal to that of the characteristic impedance R_0. At their remote ends, the line sections 1, 2 are closed by finite resistors 5, 6, the product of which is equal to the square of the characteristic impedance R_0, the resistor 4 associated with the line section 2 constituting the output resistance of the circuit. In the embodiment shown, the resistors 5, 6 at the remote ends are adjustable and are provided with adjusting members coupled to a common adjusting shaft 7, the product of these resistors 5, 6 being equal to the square of the characteristic impedance R_0 irrespective of their adjustment by means of the adjusting shaft 7. Thus, if the value of the resistor 6 associated with the line section 2 is R, the value of the resistor 5 associated with the line section 1 is given by

$$\frac{R_0^2}{R}$$

To set out more clearly the operation of this circuit arrangement, it is assumed that there is supplied to input terminals 8, 9 a current pulse the variation of the amplitude of which with time is given by $f_1(t)$.

Upon the occurrence of this current pulse $f_1(t)$, the latter is distributed in equal parts to the resistors 3, 4 and the line sections 1, 2 the pulsatory current supplied to the line sections 1, 2 propagating along these lines sections 1, 2 and after reflection at the resistors 5, 6 being returned to the resistors 3, 4 after a period of time equal to the speed of propagation α of an electrical disturbance in said line sections 1, 2 per unit of length (propagation constant) multiplied by twice the electric length L of these line sections 1, 2.

It can be proved mathematically that at the output resistor 4 of the arrangement, a current appears which is given by the formula:

$$f_2(t)=\tfrac{1}{2}[f_1(t)+a.f_1(t-2\alpha L)] \qquad \text{(I)}$$

where a is the reflection factor at the resistor 6, which is given by

$$a=\frac{R-R_0}{R+R_0} \qquad \text{(II)}$$

Hence, there appears at the output resistor 4 a non-delayed pulse and a pulse delayed by a period of time 2αL, the shape of both pulses being equal to that of the input pulse while the amplitude of the delayed pulse is a fraction a of the non-delayed pulse. The polarity and the amplitude of the delayed pulse can be suitably adjusted by adjustment of the resistor 6 at the remote end of the line section 2.

The reflection factor at the resistor 5 of the line section 1 is given by:

$$\frac{\frac{R_0^2}{R}-R_0}{\frac{R_0^2}{R}+R_0}=\frac{R_0-R}{R_0+R}=-a \qquad \text{(III)}$$

so that at the resistor 3 of the line section 1 there appears a current:

$$f_2'(t)=\tfrac{1}{2}[f_1(t)-a.f_1(t-2\alpha L)] \qquad \text{(IV)}$$

From the Formulas I and IV it follows that the pulses at resistors 3 and 4, which are delayed by a time interval 2αL, are equal in shape and amplitude but opposite in polarity, so that during the occurrence of these delayed pulses the current supply circuit does not pass current. Consequently the shape of the delayed pulses is not modified by the current supply circuit.

When a pulse 10 of the shape shown in the figure having a duration τ of, say, 0.01 μsec. and a pulse tail 10′ of equal duration τ, is supplied to input terminals 8, 9, with an electric length of the line sections such that the delay period of the line sections 1 and 2 is equal to ½ of the duration of the input pulse, i.e. ½τ, and suitable adjustment of the resistor 5, 6 there is obtained at the output resistor 4 an output pulse, the pulse tail of which is appreciably reduced. The term "delay period" of the line sections is to be understood to mean here the product of the propagation constant α and the electric length L of the line sections.

As has been explained hereinbefore, there are produced at the output resistor 4 a non-delayed pulse 11, 11′ and a pulse 12, 12′ delayed by the time interval τ, adjustment of the resistor 6 enabling this delayed pulse 12, 12' to be made equal in amplitude and opposite in polarity to the pulse tail 11' of the non-delayed pulse. Together these pulses 11, 11' and 12, 12' provide an output pulse 13 having a pulse tail 13' the amplitude of which is appreciably reduced, as is shown in the figure.

In order to maintain the correct pulse shape, the impedance Z_i of the pulse correcting circuit between the terminals 8, 9 should act as an ohmic resistance for the essential components represented in the frequency spectrum of a pulse.

This condition is satisfied by the circuit arrangement shown comprising the series combination of networks 1, 3, 5 and 2, 4, 6, for the reactive components of the impedances of networks 1, 3, 5 and 2, 4, 6 compensate one another, as will be proved mathematically hereinafter.

The impedance Z_i between the input terminals 8, 9 is equal to the sum of the impedances of the networks 1, 3, 5 and 2, 4, 6, the network 2, 4, 6 comprising the parallel combination of the resistor 4, which is equal in value to the characteristic impedance R_0, and of the impedance Z of the line section 2 which is closed at the remote end by the resistor 6, the network 1, 3, 5 comprising the parallel combination of the resistor 3 of value R_0 and the impedance Z' of the line section 1 closed at the remote end by the resistor 5.

Consequently, the input impedance Z_i between the input terminals 8, 9 is:

$$Z_i=\frac{R_0Z}{R_0+Z}+\frac{R_0Z'}{R_0+Z'} \qquad \text{(V)}$$

The impedance Z of the line section 2 which is closed at its remote end by the resistor 6 of value R can be written:

$$Z=\frac{R+jR_0\tan\alpha L}{1+j\frac{R}{R_0}\tan\alpha L} \qquad \text{(VI)}$$

and the impedance Z' of the line section 1 closed at its remote end by the resistor

$$\frac{R_0^2}{R}$$

$$Z'=\frac{\frac{R_0^2}{R}+jR_0\tan\alpha L}{1+j\frac{R_0}{R}\tan\alpha L} \qquad \text{(VII)}$$

As has been mentioned hereinbefore, in these formulas α is the propagation constant and L the electric length of the line sections 1 and 2.

After substitution of the Formulas VI and VII in Formula V and elaboration it is found that the impedance Z_i between the terminals 8, 9 is equal to the characteristic impedance R_0 of the line sections 1 and 2:

$$Z_i=R_0 \qquad \text{(VIII)}$$

Between the input terminals 8, 9 there is a constant ohmic input impedance Z_1, which is maintained on variation of the resistors 5, 6 connected at the remote ends of the line sections, 1, 2, provided that between these resistors 5, 6 the relationship is maintained that the product of these resistors 5, 6 is equal to the square of the characteristic impedance R_0 of the line sections 1, 2. Thus, the pulse shape is not modified on variation of the resistors 5, 6, by means of the mechanical coupling 7.

A further important advantage of the constant input impedance consists in that a plurality of arrangements of the kind described can be connected in cascade without these arrangements influencing one another. Such an arrangement can be used to advantage for the correction of pulse tails having a duration which is several times that of the pulses. The electric lengths of the line sections in successive component arrangements are preferably chosen so that the delay periods αL of these line sections are substantially equal to successive multiples of one half of the duration of the pulses supplied to the input terminals.

What is claimed is:

1. A pulse correcting circuit for correcting the amplitude of a pulse tail following a pulse, comprising a pair of input terminals, two transmission line sections of equal electrical length and equal characteristic impedance and each having an input end and an output end, impedance means respectively connected across the input ends of said transmission line sections and each having a value of impedance equal to said characteristic impedance, means connecting the input ends of said transmission line sections in series between said input terminals, first and second resistors respectively connected across the output ends of said transmission line sections, the product of the resistance values of said first and second resistors being equal to the square of said characteristic impedance, and a pair of output terminals connected across the input end of one of said transmission line sections.

2. A circuit as claimed in claim 1, in which the electrical length of each of said transmission line sections has a value to cause the time delay in each line section to be substantially equal to one-half of the duration of said pulse.

3. A pulse correcting circuit for correcting the amplitude of a pulse tail following a pulse, comprising a pair of input terminals, two transmission line sections of equal electrical length and equal characteristic impedance and each having an input end and an output end, impedance means respectively connected across the input ends of said transmission line sections and each having a value of impedance equal to said characteristic impedance, means connecting the input ends of said transmission line sections in series between sad input terminals, first and second variable resistors respectively connected across the output ends of said transmission line sections, means connected to vary said variable resistors simultaneously in a manner such that the product of their resistance values is always equal to the square of said characteristic impedance, and a pair of output terminals connected across the input end of one of said transmission line sections.

4. A pulse correcting circuit for correcting the amplitude of a pulse tail following a pulse comprising a plurality of networks connected in sequence and each having a pair of input terminals and a pair of output terminals, the input terminals of each succeeding network being connected to the output terminals of the preceding network, each of said networks comprising two transmission line sections of equal electrical length and equal characteristic impedance and each having an input end and an output end, impedance means respectively connected across the input ends of said transmission line sections and each having a value of impedance equal to said characteristic impedance, means connecting the input ends of said transmission line sections in series between said input terminals, first and second resistors respectively connected across the output ends of said transmission line sections, the product of the resistance values of said first and second resistors being equal to the square of said characteristic impedance, the input end of one of said transmission line sections being connected across said output terminals, the electrical lengths of said transmission line sections in the successive networks having values to cause the time delays therein to be substantially equal to successive multiples of one-half of the duration of said pulses.

5. A pulse correcting circuit for correcting the amplitude of a pulse tail comprising a pair of input terminals, two equal transmission line sections each having an input end and an output end, means terminating said input ends in the characteristic impedance of said lines and

means serially connecting said input ends between said input terminals, means connected to terminate the output end of each of said transmission line sections with a finite resistance, said finite resistances being relatively proportioned to provide equal and opposite reflection factors at the output ends of said two transmission lines, and a pair of output terminals connected across the input end of the one of said transmission lines having a negative reflection factor.

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