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DISTORTION CORRECTING FOR TRANSMISSION LINES

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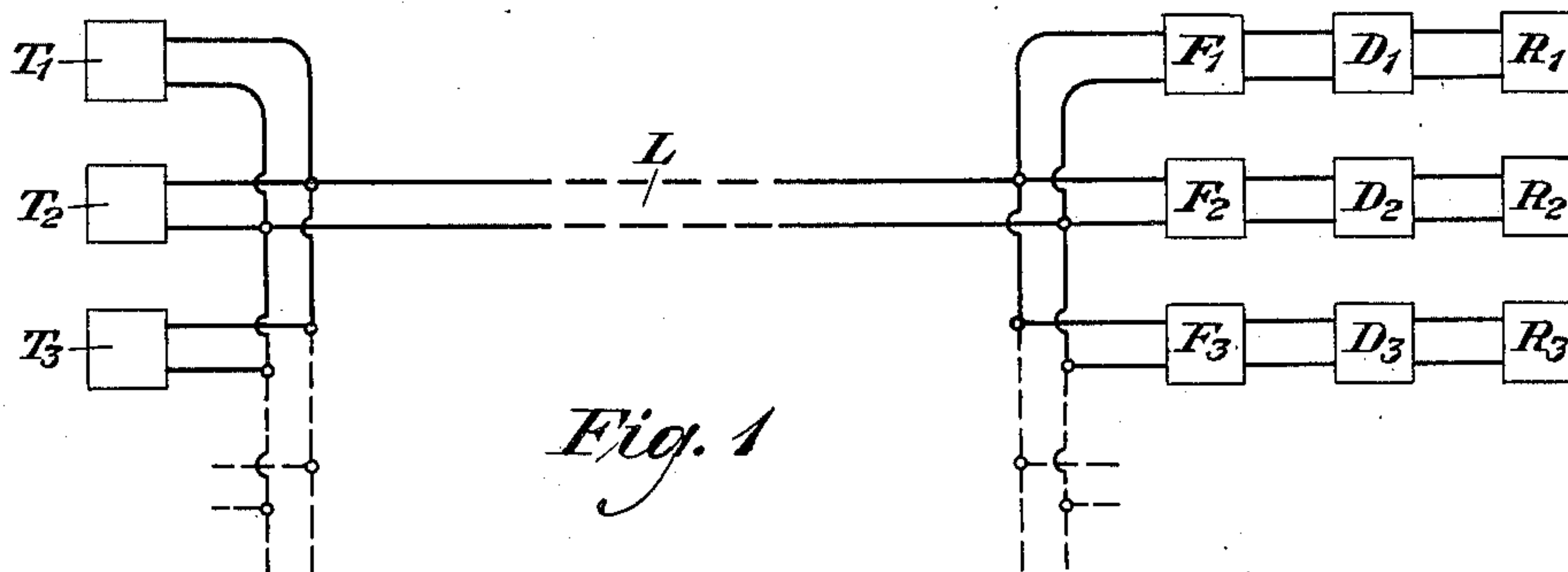


Fig. 1

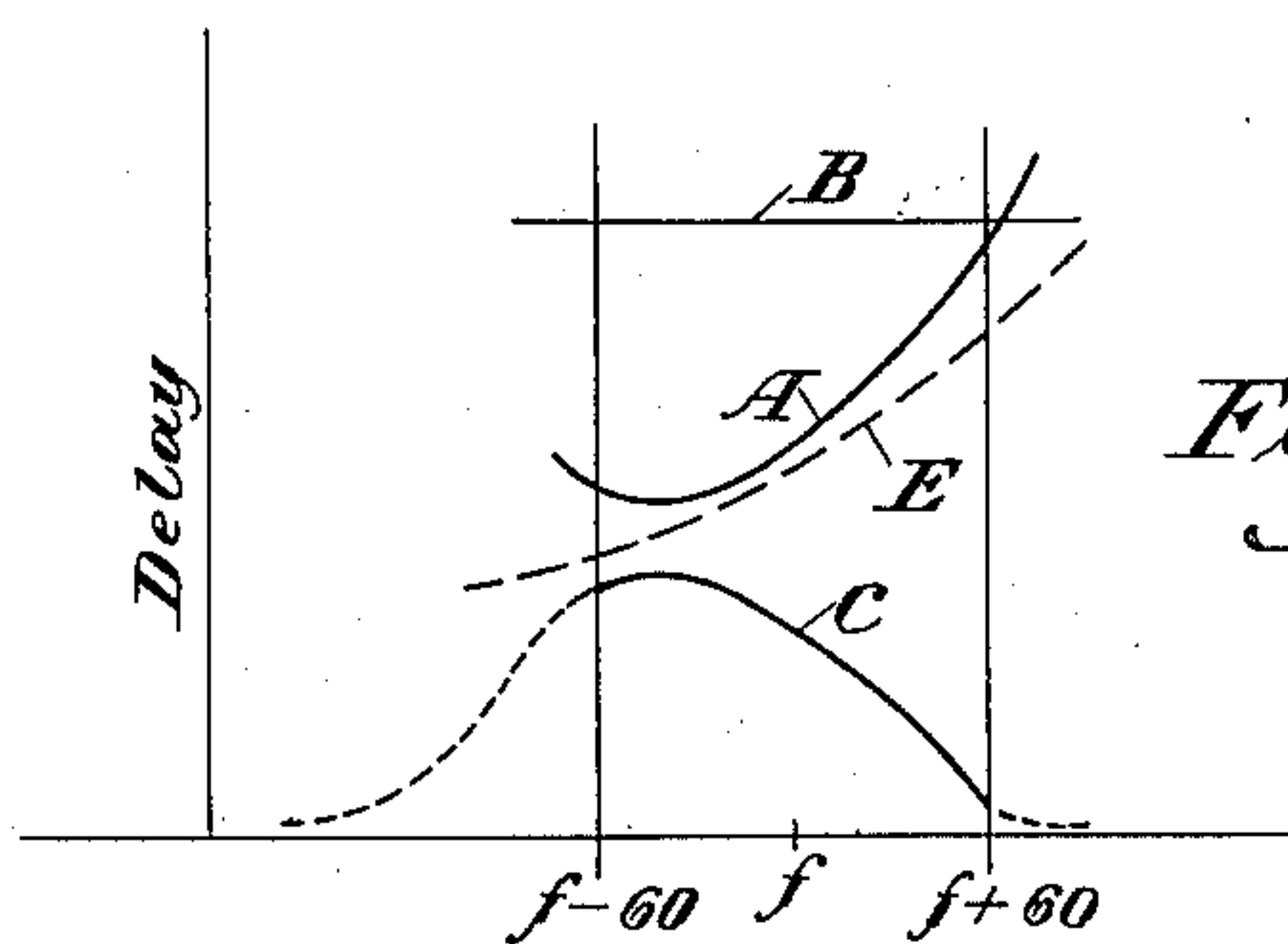


Fig. 2

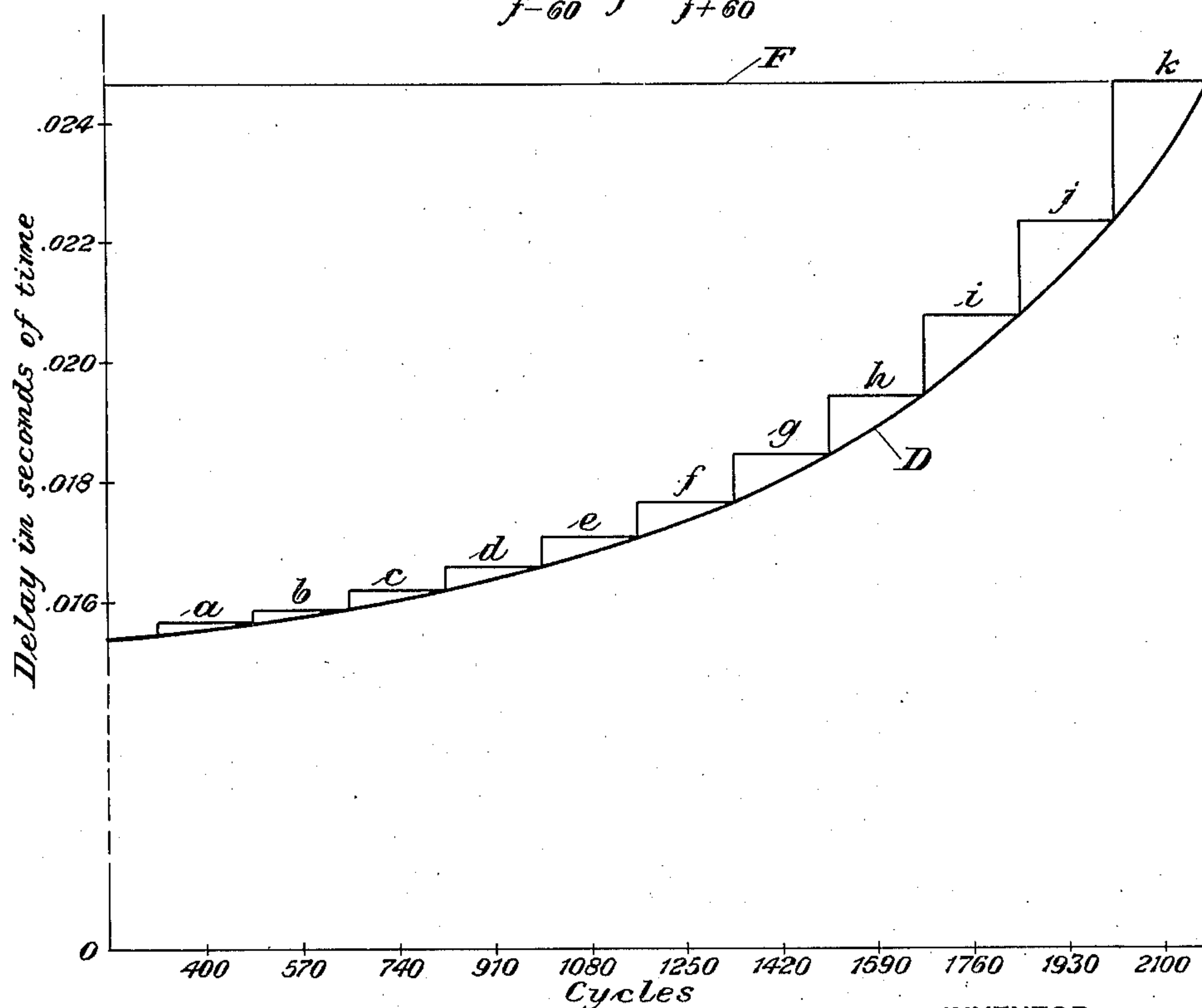


Fig. 3

INVENTOR  
H. Nyquist  
BY *gr 708*  
ATTORNEY



## UNITED STATES PATENT OFFICE

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## DISTORTION CORRECTING FOR TRANSMISSION LINES

Harry Nyquist, Millburn, N. J., assignor to  
American Telephone and Telegraph Company,  
a corporation of New York

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5 Claims. (Cl. 178—44)

This invention relates to the correction of distortion in transmission lines, and more particularly to a method and means for correcting for the differences in time of transmission and in the attenuation of the components of a complex wave, such as an electrical signal wave over a transmission line.

One of the purposes of this invention is to give a method of delay correction for certain types of signaling, such as telegraphic signaling, by which the cost of such delay correction will be much reduced. Another purpose is to reduce the work of calculation ordinarily required in designing the necessary delay networks. Still another purpose is to provide only so much delay as is necessary to obtain sufficient equalization, thus yielding an economy in the number of elements which must be brought together for the desired end.

In transmission lines such as are used for signaling purposes, the velocity of transmission and the attenuation depend on the frequency, and as a result the various components making up the initial wave are changed in magnitude and phase, resulting in a substantial distortion which becomes greater as the length of the line is increased.

Various attempts have been made to correct for this distortion, this being commonly accomplished by the introduction of electrical networks of such character as to introduce additional delay and attenuation in those portions of the frequency spectrum in which they are located, and by suitable design of the electrical networks it is possible to give a transmission line a practically uniform characteristic throughout that portion of the frequency spectrum of interest. Such correction networks are illustrated in my Patents 1,735,052, November 12, 1929, and 1,770,422, July 15, 1930.

For long lines the cost of a sufficiently large number of sections to introduce the delay necessary for equalizing throughout a wide frequency band may be excessive, nor is such equalizing necessary for certain kinds of signaling. Thus, when a given line is to be used for several signaling channels of different frequency bands, I would point out that it is only needful to introduce a separate and much more moderate phase correcting network in each channel instead of a single phase corrector correcting for the entire line characteristic. Such separate phase correcting networks may be placed wherever one desires in portions of the system where the channels are separate, but the most natural place would be to introduce them at the receiving ends

following the filter of each channel. By a signaling channel is meant that portion of the signaling capacity or frequency range of a signaling medium, such as a pair of wires, which is required for transmitting a given message.

The invention will be better understood by reference to the following specification and the accompanying drawing in which Figure 1 represents schematically a transmission line adapted for signaling on a plurality of channels: Fig. 2 shows a delay characteristic curve of a transmission line in a certain portion of its frequency spectrum, along with the modifications which it is desired to introduce in this characteristic; and Fig. 3 gives the delay characteristic curve for such a line over a much wider frequency band and shows the corrections which should be applied to different portions of that frequency band.

In order to explain the invention and to illustrate how the reduction in the number of electrical networks may be accomplished, let us consider a voice frequency carrier telegraph system operating on a transmission line such as shown at L in Fig. 1, with a plurality of channels over a range of frequencies from about 350 cycles to about 2350 cycles. If such a line is used in connection with carrier telegraph communication, for which kind of signaling this invention is especially applicable, we may assume, for illustrative purposes, that the frequency spectrum is divided into twelve channels with a carrier frequency spacing of 170 cycles, each channel having a width of approximately 120 cycles. The need for assuming a substantial width for the signaling channel, such as 120 cycles, is due to the fact that the carrier frequency will be modulated by the keying device at a certain frequency which might be in the neighborhood of 10 or 20 cycles per second. Corresponding side band frequencies will thus appear. Such keying, however, will break the carrier at the transmitting end into sections which are substantially square topped and it is desirable that this characteristic should carry through the transmission line fairly well. In order to do this it is desirable that not only the frequencies corresponding to the rate of keying but certain higher components should also be retained and these frequencies also appear as side bands on the carrier. A common experience in this type of signaling is that satisfactory results are obtained with a band width of about 120 cycles and a carrier spacing of about 170 cycles. When operating in such a case over long cable circuits the higher frequency channels are subject to excessive distortion due to the delay of the line hav-



ing a steep slope at those frequencies, as shown in the curve D of Fig. 3. To correct the line delay in the usual manner would require much apparatus, the amount being proportional to the area  
 5 between the curve D and the final delay curve over the entire frequency range, which may be indicated by the line F of Fig. 3. This is clearly set forth in my patents to which reference has already been made, and special attention is called  
 10 to Patent 1,735,052 where it is pointed out on page 2, line 30 et seq. that there would be required eight sections of type A, six sections of type B and one section of type C networks, these  
 15 networks being types fully described in that patent and being the number of each necessary to practically equalize a loaded line of the kind and length described in that specification throughout the frequency range of about 400 to 2100. The design of such a correcting network  
 20 would involve laborious calculations, as it requires much work to obtain a final delay curve flat over a wide range of frequencies. Also, the amount of apparatus required to make up these various sections of delay networks is very considerable. This invention discloses how it is unnecessary to introduce so much delay as this in  
 25 the event that the whole signaling spectrum is divided into a number of signaling channels, for in that case it becomes unnecessary to introduce a considerable amount of constant delay at the  
 30 lower frequencies.

Referring more specifically to Fig. 3, the curve D gives the delay characteristic for a typical line of the kind described in my Patent 1,735,052, this  
 35 being a No. 19 gauge medium heavy loaded cable circuit 154 miles long with a repeater at the middle and at the receiving end. Assuming that, starting with a frequency of 400 cycles as the mid frequency of one channel, there come succeeding  
 40 channels spaced one after the other by 170 cycles, it is then evident that all that is necessary is to introduce into each channel an amount of delay just sufficient to give a flat or substantially flat characteristic over the width of that channel.  
 45 In any one channel, then, the amount of apparatus necessary to produce the required delay is proportional to the area between the curve D and the horizontal line shown as corresponding to any one channel. Thus, referring to Fig. 2, the  
 50 mid frequency of any one channel may be represented by  $f$ , and the transmission characteristic of the channel over the region from  $f-60$  to  $f+60$  may be represented by the curve A. It is desired that a delay shall be introduced in this channel  
 55 which will give a flat characteristic, as shown by the line B. In order to accomplish this it will be necessary to introduce a delay network the characteristic of which is given by the curve C, this curve being of such value that curve A plus curve  
 60 C gives the curve B. A network having a characteristic with a slope like that shown in curve C is easy to find since no restrictions are given as to the shape of the curve outside the limits  $f \pm 60$ .

From the curve of Fig. 3 it is apparent that some  
 65 of the channels, such as  $a$  and  $b$ , may not need any phase correction for medium lengths of line, for at the low frequencies the characteristic of such a line as described is quite flat in itself. At the higher frequencies, however, it may be need-  
 70 ed badly due to the fact that the curve D becomes steeper as one goes to higher frequencies.

Referring to Fig. 1, it is understood that  $T_1$ ,  $T_2$ ,  $T_3$  etc. represent the individual transmitting stations and as such include the necessary filters to  
 75 isolate the one channel from the other. Also, in

connection with the receiving channels  $R_1$ ,  $R_2$ ,  $R_3$ , etc., it is to be understood that there must be introduced the corresponding filters  $F_1$ ,  $F_2$ ,  $F_3$ , etc. In general, it will be understood that the  
 80 delay networks  $D_1$ ,  $D_2$ ,  $D_3$ , etc. may be introduced wherever desired in the transmission circuit so long as they are introduced at some place where the signaling channels are separated. In general, however, I find it most convenient to have these  
 85 delay networks introduced after the filters  $F_1$ ,  $F_2$ ,  $F_3$ , etc., and an added refinement in carrying out this invention is to make these delays compensate not only for the line characteristic but also for the delay in the sending and receiving filters. Such  
 90 refinement is exceedingly difficult to bring about in case a single correcting network for the entire line is used, but becomes an added and significant feature in connection with my invention for the reason that the delay of the filters for any one  
 95 channel can be quite readily calculated. It is this refinement which accounts for the particular form of the curve A shown in Fig. 2. This delay characteristic is made up of two parts, namely, that due to the transmission line itself given by the dotted curve E of Fig. 2, and that due to the  
 100 terminal apparatus, the two together giving the delay characteristic of curve A.

From the above description it will be apparent that where a large number or even all of the channels have separate phase equalizers after  
 105 their receiving filters, the total amount of phase correcting apparatus will be much less than the amount needed to equalize the entire line characteristic in the ordinary manner. In any given case the gain can be shown by adding up the  
 110 area under each of the delay curves of the individual channel correctors and comparing this total area with the area needed to equalize the delay curve in the ordinary manner. By reference to Fig. 3 it is seen that for a line such as we  
 115 have assumed, this reduction in necessary apparatus is very large.

What is claimed is:

1. In a signaling system comprising a plurality of channels on one transmission line each for a  
 120 separate message, means at one point in the line for keeping the message channels separate, and a separate delay correcting network for each such channel, the correction for each channel being substantially that required to equalize for its band  
 125 width.

2. In a carrier current signaling system comprising a plurality of channels on one transmission line each for a separate message, means at  
 130 the receiving end of the line for separating the message channels, and a separate delay correcting network for each such channel, the correction for each channel being substantially that required to equalize for its band width.

3. In a carrier current signaling system comprising a plurality of channels on one transmission line each for a separate message, a separate  
 135 circuit at one point in the line for each channel, means in each such circuit to exclude all but the frequency band of its channel, and a delay correcting network for each such circuit, the correction in each circuit being substantially that required to equalize for its band width.

4. In a signaling system comprising a plurality of channels on one transmission line each for a  
 145 separate message, the method of compensating for delay which consists in separating the channels at some point in the circuit and introducing in each channel so separated a delay of an amount and a character to substantially equalize  
 150



the delay over the band width of that channel.

5 5. In a carrier current signaling system comprising a plurality of channels on one transmission line each for a separate message for which delay equalization is necessary, the method of keeping effective delay compensation to a minimum which consists in separating the channels

at some point in the circuit and introducing in each channel so separated an amount of delay compensation which shall not exceed that required to equalize the delay over the band width of that channel.

HARRY NYQUIST.

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