Dec. 12, 1939. L. HOCHGRAF 2,183,140

CROSS-TALK MEASURING AND CORRECTING APPARATUS

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FIG. 1

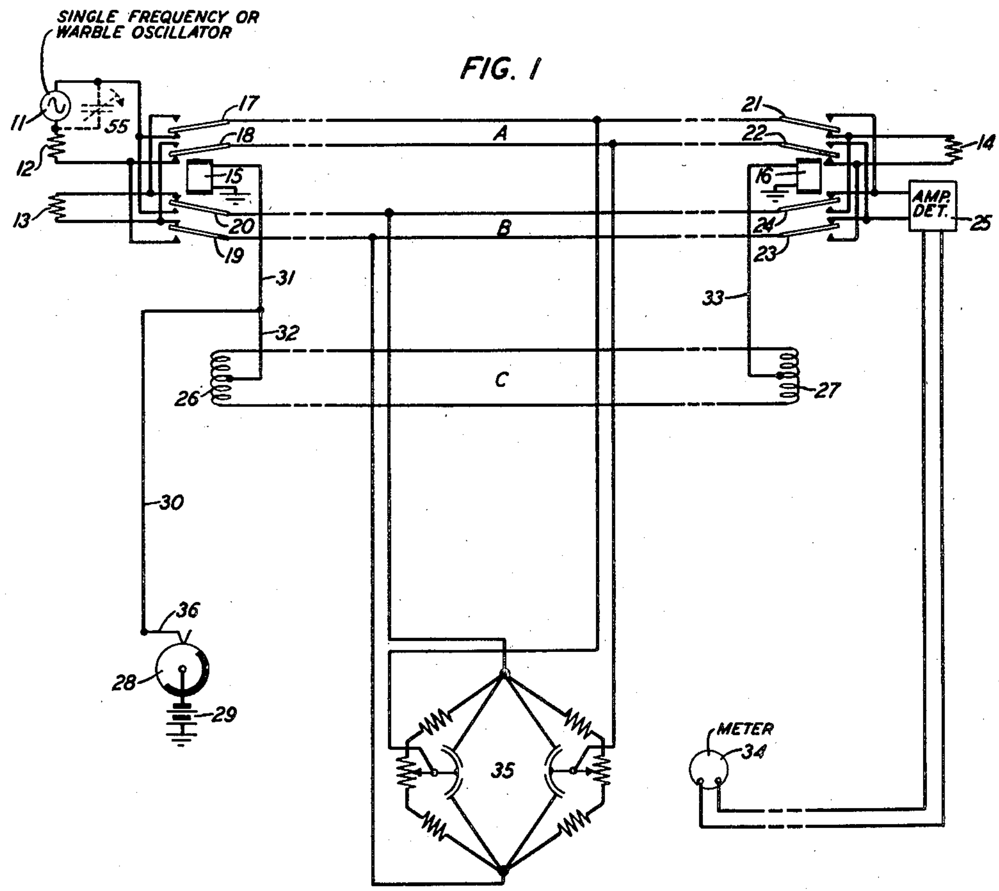
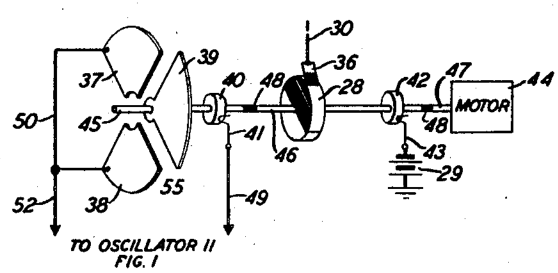


FIG. 2



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CROSS-TALK MEASURING AND CORRECTING APPARATUS

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This invention relates to cross-induction between transmission lines and particularly to means for the ready evaluation and correction of such cross-induction or cross-talk.

Such evaluation and correction of cross-talk has particular importance between telephone cable pairs used for carrier current transmission. However, it has considerable significance in connection with many other transmission systems.

An object of this invention is to provide means for the easy and rapid determination of the nature and magnitude of the corrective means required for the correction or elimination of cross-talk between two pairs of transmission lines.

Another object is to provide means for the rapid and easy determination of the average cross-talk between two pairs of transmission lines as first one and then the other of the two pairs of lines is made the disturbing line.

Another object of this invention is to provide means whereby the evaluation of the cross-talk between two pairs of transmission lines is made semi-automatic thus requiring a minimum expenditure of time and effort on the part of the operator.

Another object is to provide means for the ready determination of the average cross-talk between two pairs of transmission lines when transmitting any simple or complex wave and also when transmitting a warble tone.

Another object is to provide means for the rapid adjustment of an adjustable network adapted to correct cross-talk between two pairs of lines.

In making cross-talk measurements on telephone lines, one ordinarily distinguishes between near-end cross-talk and far-end cross-talk. Near-end cross-talk measurements are ordinarily made by connecting an oscillator to one pair of wires or line called the disturbing line and some form of detector to the other line called the disturbed line, the oscillator and the detector being located at the same end of the line. In far-end cross-talk measurements, the oscillator is located at one end of the line and the detector at the other end, that is, they may be separated by several hundred miles. My invention is particularly useful in providing means to facilitate the determination and correction of far-end cross-talk. This correction is ordinarily achieved by the addition or insertion of resistive or reactive circuit elements after the manner, for example, disclosed in the patent of A. G. Chapman, 1,863,651, issued June 21, 1932, or the patent of M. A. Weaver, 2,080,217, issued May 11, 1937.

The value of far-end cross-talk between two pairs A and B where pair A is the disturbing circuit, is usually somewhat different from the value where pair B is the disturber even though the pairs A and B have substantially the same attenuation and characteristics. These two values are called the AB and BA cross-talks respectively.

A two-way compromise balancing network may be used to balance the average of these two cross-talk values. Compromise balancing can be carried out as follows:

1. Measure the AB cross-talk
2. Measure the BA cross-talk
3. Compute the average of these two values
4. Adjust the balancing network to balance this average giving equal AB and BA residuals.

While this method is fairly satisfactory for balancing at a single frequency, it is a rather slow process. For that reason it is not satisfactory if balancing is to be done at a number of frequencies or over a band of frequencies. The disclosure of my invention presents a satisfactory method for facilitating compromise balancing whether of a single frequency, multi-frequency or band frequency type. As a specific example of practice according to my invention, I provide at one end of the lead or cable section of which the two lines or pairs form a part, an oscillator or other source of testing current, at the other end an amplifier-detector; at some third point which may well be the center but might be any other point between the two line terminals, a line balancing device known as an admittance unbalance bridge is connected. A slow-acting or integrating meter which may be a milliammeter is located at this third point and wired through to the output of the amplifier-detector. A measurement or setting may be made by connecting the oscillator to one pair, the amplifier-detector to the other pair and adjusting the admittance unbalance bridge until the milliammeter reading is a minimum. The bridge reading then indicates the dimensions of the balancing network required to reduce the cross-talk to its minimum value.

I may also provide means for rapidly switching the oscillator and the amplifier-detector back and forth between the two pairs, taking care to so synchronize the switching that the oscillator and amplifier-detector are always on alternate pairs. Under this condition the reading of the meter attached to the output of the amplifier-detector will indicate the AB and the BA cross-talk alternately and if the switching is rapid enough or the action of the meter properly damped the average of the AB and the BA cross-talk will be indicated. When the admittance unbalance bridge is so set as to reduce this average meter reading to a minimum the dimensions of the compromise balancing network will be indicated by the bridge readings.

It will be understood that this disclosure has relation to a specific example of my invention and that the scope of the invention is not limited by it but is defined in the appended claims.

Referring to the drawing:

Fig. 1 is a diagram presenting in schematic form an arrangement according to the invention for determining the far-end cross-talk between two lines and for determining at the same time the dimensions of the balancing network required to reduce the cross-talk between said two lines to a minimum value; and

Fig. 2 is a schematic drawing illustrating a method of synchronizing the commutator for operating the electromagnetic switches, with the air condenser in the warble tone oscillator.

Fig. 1 shows two lines A and B subject to cross-talk the one with the other. At one end of these lines an oscillator 11 is connected through the blades 17 and 18 of the electromagnetic switch 15 to the line A and a line terminating network 13 is connected through the blades 19 and 20 of the electromagnetic switch 15 to the line B. These connections may be said to be at the "far end" of the line. At the other or "near end" of the line, a terminating network 14 is connected through the blades 21 and 22 of the electromagnetic switch 16 to line A and an amplifier-detector 25 is connected through blades 23 and 24 of electromagnetic switch 16 to line B. At some suitable and convenient intermediate point a balancing device which may be an admittance unbalance bridge 35 is connected between lines A and B. Also at this intermediate point is provided a meter 34 which is wired to the amplifier-detector 25 and by its readings indicates the amount of current picked up by the amplifier-detector. The condition shown is that in which the electromagnetic switches 15 and 16 are energized or operated and the apparatus is in the position to measure the AB cross-talk, that is, the cross-talk from line A to line B. If the switches 15 and 16 are deenergized then terminating network 13 is connected through blades 17 and 18 to line A and oscillator 11 is connected through blades 19 and 20 to line B at the far end. At the near-end terminating network 14 is connected through blades 23 and 24 to line B and amplifier-detector 25 is connected through blades 21 and 22 to line A. Under this condition the apparatus is in the arrangement to measure the cross-talk between line B and line A, that is, the BA cross-talk. In order that the equipment may be switched synchronously or simultaneously from the AB position to the BA position and, further, in order that this switching may be accomplished at any desired speed, there is provided a commutator 28 through which a grounded battery 29 provides operating current for switches 15 and 16. The operating current for switch 15 may be traced from ground to battery 29, commutator 28, brush 36, lead 30 and lead 31 to the electromagnetic switch 15 and thence to ground. The operating current for switch 16 flows from ground to battery 29, commutator 28, brush 36, lead 30, lead 32, thence through phantom coil 26 on spare line C to the near end phantom coil 27, lead 33 and the winding of the electromagnetic switch 16 and thence to ground.

In Fig. 2 a motor 44 drives a shaft having live portions 47, 46 and 45 and insulating portions 48. Mounted on the live portion 46 of this shaft is the commutator 28 and on the live portion 45 an air condenser 55 having two fixed plates 37 and 38 and a movable plate 39. This air condenser 55 is connected into the tuning circuit of oscillator 11 as indicated by dotted lines in Fig. 1 in case a warble tone is required for testing. A warble tone is a tone whose frequency varies cyclically through a predetermined frequency range. It may be produced for example from a vacuum tube oscillator having a motor driven air condenser in its tuning circuit as described for example in Arnold et al. Patent 1,573,367 issued February 16, 1926.

When the condenser 55 is in the position shown in Fig. 2, the capacity between the fixed plates 37 and 38 and the movable plate 39 is at a minimum and consequently the frequency of the oscillator is at its maximum. When the shaft has been rotated through 90 degrees from the position shown in Fig. 2 the capacity between the fixed plates and the movable plate is at its maximum and the frequency of the oscillator at its minimum or lowest frequency. It will be apparent, therefore, from the fixed relation between the commutator and the air condenser that the oscillator will pass through a complete frequency cycle for each position of the switches 15 and 16 of Fig. 1.

The use of the admittance unbalance bridge at 35, Fig. 1, as an instrument for the determination of the measure of cross-talk, or conversely for the determination of the dimensions of the compensatory or balancing network required to compensate against cross-talk is well known. Discussions of its use are to be found, for example, in the patent to Chapman 1,863,651 issued June 21, 1932.

In the determination of the balancing network in accordance with my invention, the oscillator 11 of Fig. 1 is adjusted to give the desired testing current. This may be a warble tone in which case the oscillator frequency will be set at some suitable frequency by means of its tuning adjustment, usually by adjusting the value of the capacity in the frequency determining circuit of the oscillator, and the auxiliary condenser 55 connected in parallel with this oscillator tuning condenser. When the shaft 45 is rotated the frequency of the oscillator will vary through a cycle. By properly proportioning the relation between the oscillator tuning condenser and the auxiliary condenser 55, the desired allocation and width of band may be produced.

Having set the oscillator 11 to deliver the desired testing current, the motor 44 may be energized causing (*a*) the commutator to revolve thus alternately energizing and deenergizing the switches 15 and 16 by means of the battery 29, and (*b*) varying the capacity of the condenser 55, thus synchronously causing the frequency of the oscillator to pass through its cycle or band of frequencies twice for each revolution of the drive shafts 45, 46, 47, 48 and thus impressing the complete cycle of frequency alternately on line A and line B. If the oscillator is set up to deliver a single frequency only, then the condenser 55 will not be connected into the oscillator tube circuit and the single frequency will be impressed for the period of one-half revolution of the motor shafts 45, 46, 47, 48 alternately on line A and line B.

While these adjustments and connections are being made at the far end of the line, the amplifier-detector at the near end will have been energized and its output connected through to the meter 34 located beside the admittance unbalance bridge 35. Assuming that the bridge is set initially for zero compensation, that is, so that there would be no indicated cross-talk if the lines were perfectly compensated, then, with the bridge in this condition, the meter 34 should indicate the AB cross-talk and the BA cross-talk alternately as the commutator 28 is revolved and the switches 15 and 16 are alternately energized and deenergized. In practice, I cause the commutator to make several revolutions per second and I employ a meter 34 having a moving system so damped or of such a natural period that at the speed of commutation from the AB condition to the BA condition and alternately back and forth the needle of the meter does not flicker up and down but assumes a substantially steady fixed position representative for the average between AB cross-talk and BA cross-talk. Having the far-end and near-end apparatus operating properly as described, I now adjust the admittance unbalance bridge 35 to the position giving zero or minimum reading at meter 34 and from the setting of the several arms of the bridge 35 for this condition I am able to read off the dimensions of the compromise network to compensate for the existing cross-talk after the manner disclosed in Chapman Patent 1,863,651.

In place of the calibrated admittance unbalance bridge, I may employ an adjustable network which when adjusted for minimum cross-talk according to the above procedure may remain as a permanent line balancing and cross-talk preventing network.

It will be apparent that ordinarily at least three operators will be required in making cross-talk corrections according to my invention, namely, an operator at the far end, an operator at the near end, and a third to operate the admittance unbalance bridge. However, the same number of operators have ordinarily been required in the determination of far-end cross-talk and compromise networks under the conditions previously employed, whereas when my invention is used the time required for making the determination is greatly reduced.

Although my invention has been disclosed in terms of a particular embodiment, it must not be considered limited by these terms but rather by the following claims.

What is claimed is:

1. In combination, a pair of circuits, a source of oscillations, a measuring device and means for continuously switching said source between said circuits in alternation with said measuring device so that said source and said measuring device are each constantly connected to one of said pair of circuits but not simultaneously to the same circuit.

2. In combination, a pair of adjacent signaling circuits, a source of waves of a test frequency, cross-talk measuring means, a first switching means operating to connect said source in rapid succession alternately to each of said circuits at adjacent points so as to transmit pulses of said test frequency successively over said circuits, a second switching means operating in synchronism with said first switching means to connect said measuring means alternately to said circuits and in alternation with said first switching means so that it will receive the cross-talk pulse due to each pulse of test frequency transmitted over said circuits, the rate of switching being such that the measuring means will indicate the average value of cross-talk between said circuits.

3. In combination, a pair of signaling circuits adjacent and parallel to each other; a source of alternating current; cross-talk detecting means; a first switching means for connecting the circuits in rapid rotation to said source; a second switching means for connecting the circuits in rapid rotation to said detecting means, means for so synchronizing said first and second switching means that said source and said detecting means are at no time connected to the same circuit, and balancing means for balancing out cross-talk between said circuits.

4. In a system for making measurements of cross-induction between two lines or pairs of conductors subject to cross-induction either one into the other, means at the far end for producing a testing current of any desired characteristic, means at the near end for measuring any small fraction of said testing current which may be received there, means for connecting said source of testing current alternately to first one and then the other of said two lines, coacting means for simultaneously connecting the said measuring means to the alternates of said two lines, and means at a third point between said near end and said far end for measuring the cross-talk between said two lines.

5. In a system for making measurements of cross-talk betwen two lines or pairs of conductors subject to cross-talk either one into the other, means at one terminal of said two lines for producing a source of testing current, suitable current detecting means at the other terminal of said two lines, means for simultaneously switching said testing current source to one of said lines and said current detecting means to the other of said lines, mean associated with said switching means for rapidly interchanging the connections of said testing current source and said current detecting means respectively between said two lines, balancing means connected between said two pairs of lines adapted to reduce the cross-talk between said two lines, and suitable means associated with said current detecting means for indicating a minimum current.

6. A system according to claim 5 in which the balancing means connected between said two pairs of lines consists of a calibrated admittance unbalance bridge such that its readings indicate the dimensions of a balancing network equivalent to the bridge in cross-talk reduction.

7. A system according to claim 5 in which said balancing means consists of a calibrated admittance unbalance bridge with which is associated a damped electric meter operated from said current detecting means and adapted to indicate the average cross-talk between the two lines.

8. A system for effecting cross-talk reduction between two lines comprising means for producing a suitable source of testing current first on the one or A line and then on the other or B line, means for detecting alternately the current induced in the B line by the testing current in the A line, and then the current induced in the A line by the testing current in the B line, means for rapidly switching the testing current from line A to line B to line A, and so forth, means for simultaneously switching the current detect-

ing means from line B to line A to line B, and so forth, minimum current indicating means associated with said current detecting means adapted to give a steady reading averaging the current into the said detecting means during the said switching, and means associated with said lines adapted to reduce said steady reading to a minimum.

9. In combination, a pair of transmission lines A and B running between two terminals or reference points in the same pole line or in the same cable, at the far end of said line means for producing suitable testing current, a line terminating network suitable for terminating either line A or line B at the far end, and a remotely controlled two-position switch which in its operated position may connect said means for producing testing current to line A and said terminating network to line B and in its non-operated position may correspondingly connect said means for producing testing current to line B and said terminating network to line A; at the near end of said line a line terminating network suitable for terminating either line A or line B at the near end, current detecting means suitable for detecting suitably small amounts of the species of current used in testing, and a remotely controlled two-position switch which correspondingly to the far end switch may in its operated position connect said near end terminating network to line A and said current detecting means to line B, and in its non-operated position may connect said current detecting means to line A and said near end terminating network to line B; at a third point on said line an admittance unbalance bridge connected between said lines, and a suitable device connected through from the said current detecting means and capable of indicating the magnitude of the current picked up by the said current detecting means, and particularly to precise minimum of said current; and a motor-driven commutator for periodically operating and releasing said remotely controlled switches at any desired rate.

10. The combination of claim 9 in which the source of testing current consists of a vacuum tube oscillator, the frequency of which is variable over a predetermined band by means of a variable air condenser in the frequency determining circuit of the said oscillator, the said air condenser being so coupled with the means for operating the remotely controlled switches that the operation of the switches is synchronized with the change in frequency of the oscillator and identical wave trains are sent out on lines A and B alternately.

11. In combination, two transmission lines A and B subject to cross-talk either one with the other, means including a damped indicating meter for rapidly determining and balancing out the AB cross-talk and the BA cross-talk, and means for determining the compromise network for maximum freedom from both AB and BA cross-talk.

12. A cross-talk measuring and balancing set comprising a set of line terminating networks, a vacuum tube oscillator equipped to produce single frequency or warble tone output, an amplifier-detector with damped indicating meter, switches for simultaneously switching between oscillator and network at the one end of the line and between network and detector amplifier at the other end of the line, an admittance unbalance bridge, and a combined commutator and condenser drive for operating the switches and the warble tone oscillator in synchronism.

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