

June 7, 1932.

O. H. COOLIDGE

1,861,524

SYSTEM FOR NEUTRALIZING CROSSTALK BETWEEN SIGNALING CIRCUITS

Filed Jan. 6, 1931

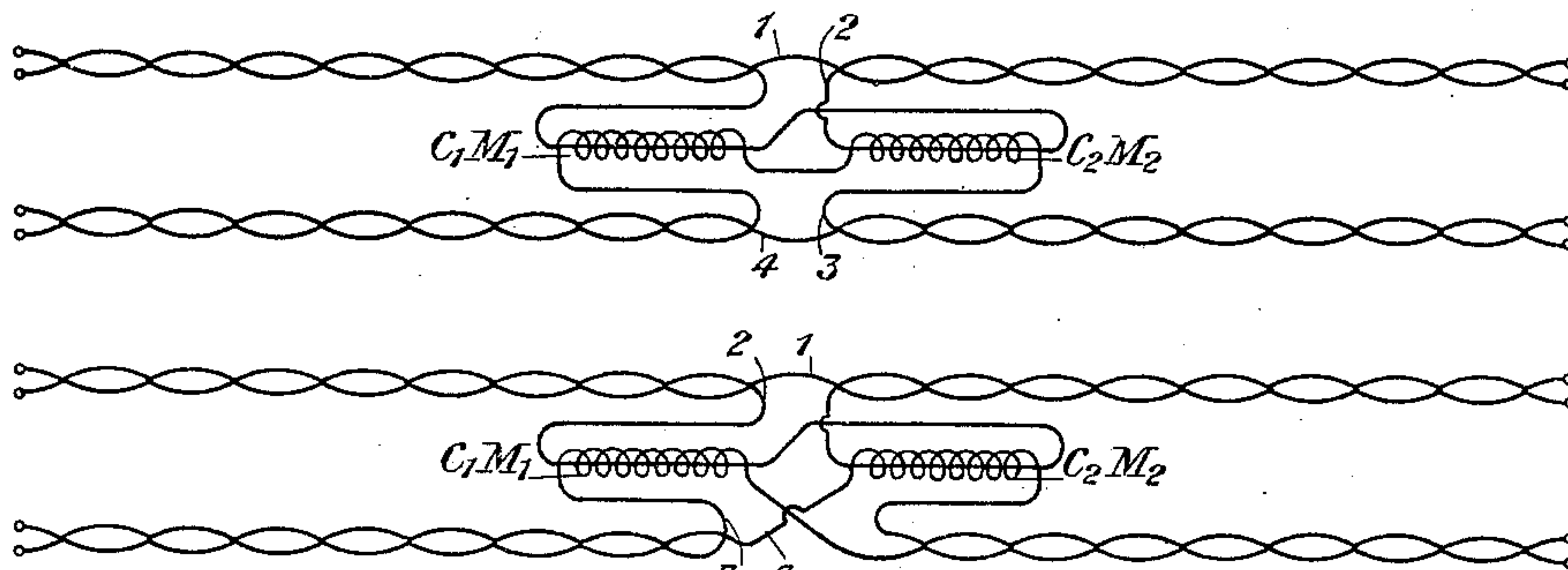


Fig. 1

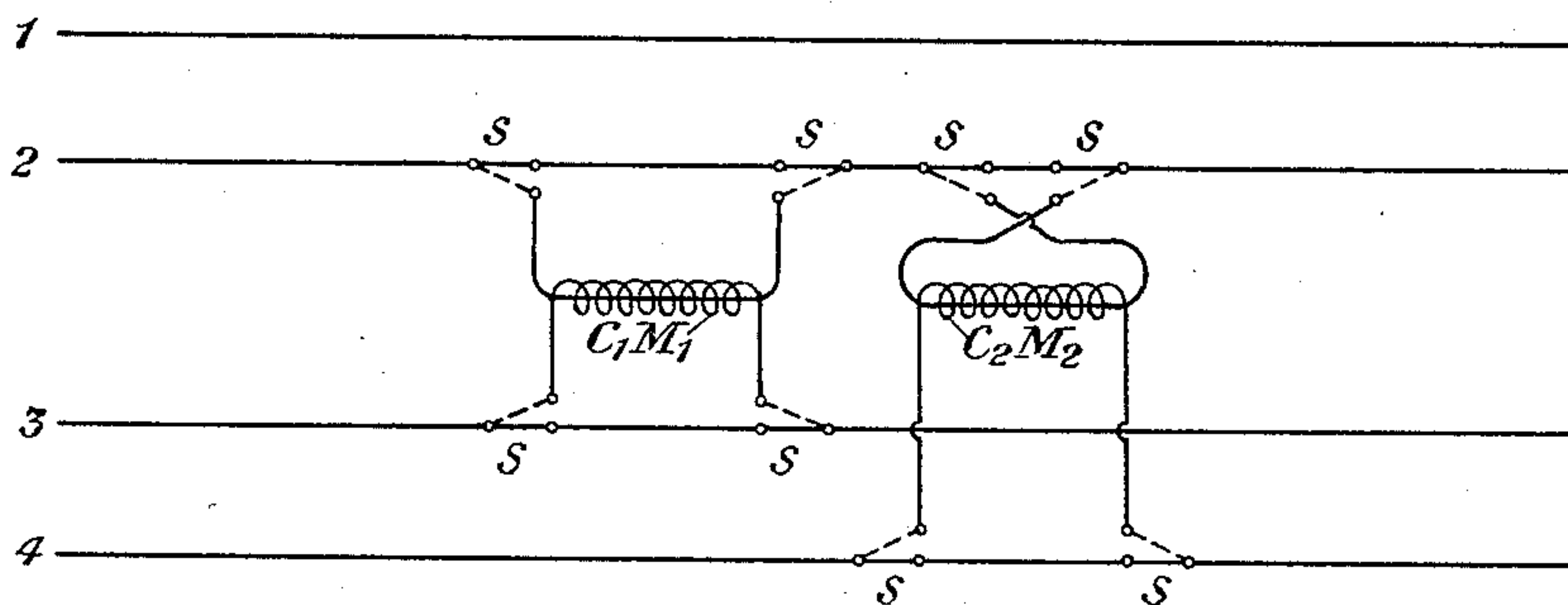


Fig. 2

INVENTOR
O. H. Coolidge
BY *g r 70 a*
ATTORNEY

UNITED STATES PATENT OFFICE

OLIVER H. COOLIDGE, OF BEDFORD HILLS, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

SYSTEM FOR NEUTRALIZING CROSSTALK BETWEEN SIGNALING CIRCUITS

Application filed January 6, 1931. Serial No. 506,964.

An object of my invention is to provide a practice for compensating between conductor pairs so as to eliminate crosstalk between them. Another object of my invention is to effect such compensation entirely by the use of twisted pair. Still another object is to use twisted pair in a precise way to balance the mutual inductance and capacity between two transmission lines. These objects and other objects of my invention will become apparent on consideration of a limited number of specific examples of practice according to the invention which I will disclose in the following specification. It will be understood that this disclosure relates principally to these particular examples of the invention, and that the scope of the invention will be indicated in the appended claims.

Referring to the drawing, Figure 1 is a diagram showing several cable pair circuits belonging to one cable and neutralized for crosstalk according to my invention; and Fig. 2 is a detail diagram showing how the compensation may be introduced between two circuits.

When several signaling circuits extend side by side as in a cable or in the form of open wire lines on poles, there may be some mutual effects of capacity and inductance between them that will occasion crosstalk. In the cable the pairs are twisted to compensate such effects in great degree, and in the open wire lines transposition is practiced to the same end. Nevertheless, there are likely to be some accidental dissymmetries even after careful twisting or transposition that will occasion some degree of crosstalk.

My invention is applicable for open wire lines as well as for cable pairs, but I will present the case of compensation for cable pairs by way of example.

Fig. 1 shows diagrammatically four cable pairs extending together in the same cable sheath. There may be a large number of such pairs, of which the four shown are only a few, and they may extend together in the same cable sheath a distance of, say, 25 miles between consecutive repeater stations along a long cable transmission line. At a place about half-way between the ends of this cable

section, that is, $12\frac{1}{2}$ miles from either end, one or both conductors of each of two pairs between which there is crosstalk may be interrupted and compensating elements introduced to annul the crosstalk. In connection with Fig. 2, I will now explain the principle involved in making the corrections that are shown in Fig. 1.

A quantity of compensating twisted pair consisting of an indefinite length of two insulated wires wrapped or twisted compactly together in the form of a compact helix. This twisted pair has a certain capacity c per unit length and a certain mutual inductance m per unit length, with a definite ratio between them so that $c = km$.

Before correction is made, the conductors 1, 2, 3 and 4 extend continuously as indicated in Fig. 2. By tests made upon them in this condition, it is ascertained that the capacity between conductors 1 and 4 exceeds that between 2 and 3 by the quantity C ; also, that the mutual inductance between conductors 1 and 4 exceeds the mutual inductance between 2 and 3 by the value M . Hence, to compensate, it is desired to introduce capacity C between conductors 2 and 3 and mutual inductance M between conductors 2 and 3. This result will be effected by introducing two distinct lengths of compensating twisted pair in the manner shown in Fig. 2, and shifting the eight switches s to the dotted line positions. Let the lengths of these two sections of compensating twisted pair be such that their capacity values are, respectively, c_1 and c_2 ; accordingly, their inductance values will be according to the equation $c_1 = km_1$ and $c_2 = km_2$, respectively.

Since the element c_1m_1 is between conductors 2 and 3, whereas c_2m_2 is between conductors 2 and 4, the net capacity between conductors 2 and 3 due to the introduction of both elements c_1m_1 and c_2m_2 is given by the equation

$$c_1 - c_2 = C.$$

Comparing the connections of the element c_2m_2 with the connections of c_1m_1 , it will be seen that the axial conductor of c_2m_2 is reversed and the helical conductor of c_2m_2 is

connected in the opposite side of the line, thus amounting to two reversals. Therefore, the inductance effects of the two introduced units c_1m_1 and c_2m_2 will be added, so that

$$m_1 + m_2 = M,$$

whence

$$c_1 + c_2 = kM.$$

From the foregoing two equations for $c_1 - c_2$ and $c_1 + c_2$, it is readily deduced that

$$c_1 = (C + kM)/2 \text{ and} \\ c_2 = (-C + kM)/2.$$

Knowing the values of C , M and k , the foregoing equations give the values of c_1 and c_2 , and accordingly, the proper length of compensating twisted pair units can be cut off and introduced as shown in Fig. 2.

In the last foregoing equation, if C should exceed kM , this would place a negative value on c_2 . It would take care of this merely to connect the right-hand unit c_2 between the wires 2 and 3 instead of between 2 and 4, keeping the reversed connection in the wire 2 as shown in Fig. 2. In Fig. 1, the connections of the lower pair of units are as shown in Fig. 2, but the connection of the upper pair of units are as just mentioned for a case when C is greater than kM .

It will be seen that according to my improved system for neutralizing crosstalk, the procedure is simply first to ascertain the uncompensated capacity and mutual inductance between the conductors of the two pairs to be balanced. From these data a simple calculation shows the proper lengths to be given to two units of compensating twisted pair. These two units are cut off at the proper lengths. Also, the simple computation just mentioned shows how they are to be connected in the conductors of the two pairs, and the two units are connected accordingly. The method is not a cut-and-dry method and therefore it is not inconvenient to interrupt two circuit conductors and reconnect them to the terminals of the units of compensating twisted pair, because this can be done once for all.

I claim:

1. In combination, two conductor pairs between which compensation is to be effected for crosstalk and two lengths of twisted pair with the two conductors of each twisted pair interposed in conductors of the respective pairs to be balanced.

2. In combination, two conductor pairs between which compensation is to be effected for crosstalk and two units each comprising capacity and mutual inductance in the same proportion, said units each having two pairs of terminals connected in respective conductors of said pairs, and said units being adjusted so that net effective compensating capacity and inductance are introduced be-

tween the pairs to compensate for said crosstalk.

3. In combination, two conductor pairs between which compensation is to be effected for crosstalk and two adjustable units each having two pairs of terminals and having a constant ratio of capacity and mutual inductance at all adjustments, said units having their terminals connected in respective conductors of said pairs and adjusted to establish the proper net effective compensating capacity and mutual inductance between the pairs.

4. In combination, two conductor pairs between which compensation is to be effected for crosstalk and two lengths of twisted pair conductor, one conductor of each length of twisted pair being connected in series in a conductor of a respective pair to be compensated the lengths of said twisted pair conductors being adjusted to give the proper net effective capacity and mutual inductance between the conductor pairs between which compensation is to be effected.

5. In combination, two line conductor pairs between which compensation is to be effected for crosstalk and two lengths of twisted pair each having four terminals, certain of the conductors of said line conductor pairs being interrupted and their ends at the interruption being connected to the terminals of the twisted pairs, the connections for one twisted pair being reversed relatively to the corresponding connections for the other twisted pair, and the lengths of the twisted pairs being adjusted to compensate the cross-capacity and inductance between the given line conductor pairs.

6. In combination, two line conductor pairs between which compensation is to be effected for crosstalk and two adjustable four-terminal units of distributed capacity and mutual inductance in a constant ratio at all adjustments, certain of the conductors of said line conductor pairs being interrupted and their ends at the interruption being connected to the terminals of said units, and said units being adjusted to compensate the cross-capacity and inductance between the given conductor pairs.

7. In combination, two conductor pairs 1—2 and 3—4 with the cross-capacity C between 1 and 4 in excess of that between 2 and 3, and with the mutual inductance M between 1 and 4 in excess of that between 2 and 3, and two twisted pair units one conductor of one such unit being interposed in conductor 2, the other conductor of the same unit being interposed in conductor 3, one conductor of the other twisted pair unit being interposed in conductor 2 and the remaining conductor of the last-mentioned unit being reversely interposed in one conductor of pair 3—4.

8. The method of balancing two line conductor pairs for cross-talk which consists in

interposing two short lengths of twisted pair
conductor, one end of each twisted pair con-
ductor in a respective line conductor and
poling the connections and adjusting the
5 length of each twisted pair to neutralize both
cross-capacity and mutual inductance be-
tween the two line pairs.

In testimony whereof, I have signed my
name to this specification this fifth day of
10 January, 1931.

OLIVER H. COOLIDGE.

15

20

25

30

35

40

45

50

55

60

65