O. B. BLACKWELL & G. A. ANDEREGG.
METHOD OF REDUCING TELEPHONIC DISTURBANCES.
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1,064,433.

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Fig. 1.

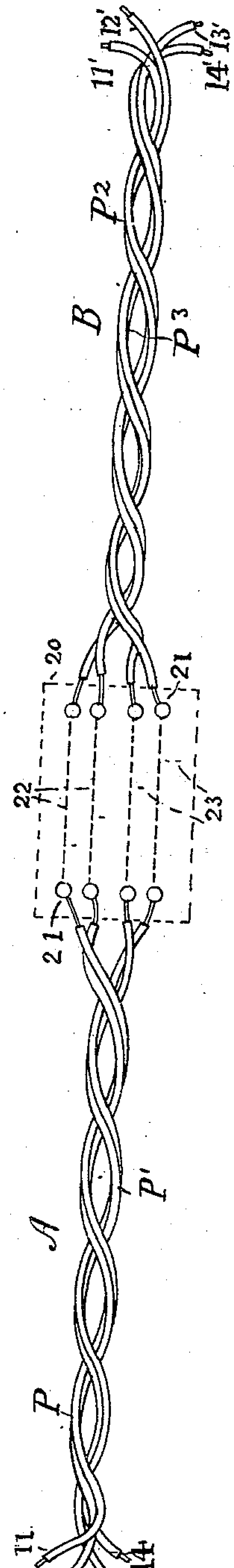
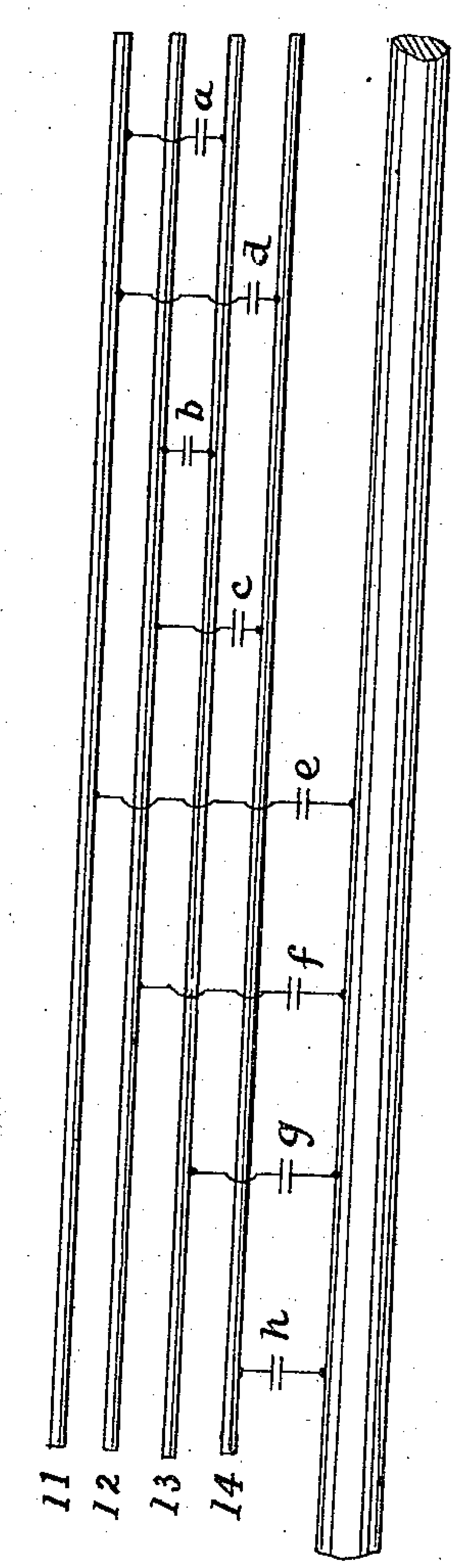


Fig. 2.



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METHOD OF REDUCING TELEPHONIC DISTURBANCES.

1,064,433. Specification of Letters Patent. **Patented June 10, 1913.**

Application filed April 11, 1912. Serial No. 690,158.

To all whom it may concern:

Be it known that we, OTTO B. BLACKWELL and GUSTAVUS A. ANDEREGG, residing at Maplewood and Oak Park, in the counties of Essex and Cook and States of New Jersey and Illinois, respectively, have invented certain Improvements in Methods of Reducing Telephonic Disturbances, of which the following is a specification.

In telephone circuits made up of closely associated conductors, as in the case of twisted pairs included in a cable, there is liable to occur a disturbance commonly termed "cross-talk", this being chiefly caused by inequalities in the capacities of the conductors of one pair with relation to those of another pair. This is especially troublesome in phantom circuits, in which there may be cross-talk between the phantom and both of its sides or physical circuits and also between said side circuits. This invention contemplates a method of nullifying or reducing such disturbances by effecting a more perfect balance of the capacities.

In the accompanying drawings, in which the same characters of reference are applied to like parts in all figures, Figure 1 illustrates successive sections of a four-conductor component or "quad" of a cable, these sections being connected through a testing apparatus indicated conventionally, and Fig. 2 is a diagram disclosing the distribution of capacities between the elements of a phantom circuit contained in a cable.

Our invention will be explained in its application to a quad or portion of a cable adapted for use in forming a phantom circuit, the four conductors of which are twisted in pairs and these pairs being twisted together, each two-conductor pair furnishing a physical circuit, while these circuits taken with the conductors of each in parallel give a third pair of conductive elements constituting the phantom circuit. In Fig. 1 of the drawings are illustrated two successive sections A and B of the quad as they might terminate at a cable manhole, section A containing the physical pair P comprising the conductors 11 and 12 and the physical pair P′ having conductors 13 and 14, these together forming the phantom pair 11—12, 13—14; the section B has corresponding pairs P^2, with the conductors 11′—12′, and P^3, with the conductors 13′, 14′, together with the phantom pair 11′—12′, 13′—14′.

The relation of the capacities which may cause cross-talk in the quad A is illustrated diagrammatically in Fig. 2, in which the capacities between the conductors themselves appear as condenser a, b, c, d; while the capacities of the respective conductors to ground, or to the sheath and other conductors of the cable, are illustrated as condensers e, f, g, h. If these capacities were equal or distributed so as to balance one another, there would be no transfer of potential and no cross-talk from these sources, but the capacities of a commercial cable are not uniform and mutual disturbances result. These disturbances may be shown to be approximately proportional to

$$(a+c)-(b+d),$$

as between the side circuits;

$$2(a-b-c+d)+(e-f),$$

between the phantom and the side circuit P; and

$$2(a+b-c-d)+(g-h)$$

between the phantom and the side circuit P′. The same expressions with the characters primed may be employed to show the unbalances in the other section B. The total unbalance of the two sections when joined will be the algebraic sum of the individual unbalances. Now if when the conductors of the sections are spliced they are connected 11 to 11′, 12 to 12′, 13 to 13′ and 14 to 14′, the unbalance between the sides of both sections will be

$$(a+a'+c+c')-(b+b'+d+d')=y+y';$$

y and y' being the respective unbalances in the sections A and B. If the connections of the pairs P and P^2 were transposed, the pairs P′ and P^3 remaining as before, the unbalance will be

$$(a+b'+c+d')-(a'+b+c'+d)=y-y'.$$

The pairs P′, P^3 may also be transposed, or both pairs together, but the same totals $y+y'$ or $y-y'$ will be produced. It therefore appears that by properly choosing the conductors which are connected, according to the amounts and relative direction of unbalance, a minimum cross-talk will result.

In the same way the total unbalance of the phantom to either side is the algebraic sum of the unbalances of the sections, and this may be adjusted by connecting the sections in accordance with the respective capacity values. By joining the pair in one section to one or the other of the pairs in the succeeding section the magnitude of the unbalances brought together may be controlled, and whether these add or subtract may be determined by the connection of the respective conductors of one pair to one or the other of the conductors of the pair chosen in the other section.

Three sources of cross-talk have been considered—the side to side unbalance and that of the phantom to each of the sides. However, if the correction is made for any two of these, the possible combinations for adjusting the unbalance will be exhausted, and the third must be left uncorrected as far as the two particular sections are concerned. But the remaining unbalance may be provided for in joining succeeding sections.

The determination of the capacities may be by any usual or desired method and employing any convenient apparatus; the details of the measuring operations will therefore not be described. We may tentatively connect the conductor groups of successive sections in various combinations through a measuring apparatus as conventionally indicated by the dotted square 20 in Fig. 1, the ends of the sections being secured to terminals 21 and joined by conductors 22 within the apparatus, these conductors being provided with taps 23 leading to the measuring devices (not shown). We then determine the capacity unbalances for the total length of both sections. The conductors upon the completion of the test are disconnected from the measuring apparatus and permanently spliced to give a minimum capacity unbalance and consequently the least cross-talk, all the elements of the phantom being considered. Or the unbalances for all the conductor groups in the sections may be separately measured and recorded, and the preferable connections chosen from these results.

As an example of results which might be found in practice, assume the groups of conductors to be first connected directly 11 to 11′, 12 to 12′, 13 to 13′ and 14 to 14′, and the capacity relation between the phantom P, P^2 and P′, P^3 to its side P, P^2 measured and there found to be an unbalance of twenty micro-microfarads. The connection of the side circuit P, P^2 is then transposed, so that it is connected 11, 12′ and 12, 11′, and an unbalance of forty micro-microfarads obtained. The relation of the phantom to the other side P′, P^3 is then tested, the companion pair P, P^2 being restored to its first or direct connection, since this gave the better balance, and the side now under test directly connected—13, 13′, and 14, 14′; an unbalance of three hundred and thirty micro-microfarads results.

Upon transposing the side P′, P^3, so that it is connected 13, 14′ and 14, 13′, there is an unbalance of thirty micro-microfarads. With the pairs as thus joined—the first P, P^2 direct and the second P′, P^3 transposed the capacity relation between the side circuits is tested and ninety micro-microfarads obtained. The pair P, P^2 is then transposed—11, 12′ and 12, 11′ giving an unbalance of ten micro-microfarads. The sections are permanently spliced in accordance with this connection. The unbalance between the side circuits could have been brought to the same value by transposing the second side—13, 14′ and 14, 13′, but this would have given a greater unbalance of three hundred and thirty micro-microfarads between this side and the phantom. The final transposition of the first pair P, P^2 obviously increased the unbalance of this side of the phantom, but to a less extent than it decreased the unbalance between the sides.

We claim:

1. The method of reducing disturbances between groups of adjacent conductors which consists in determining the differences in capacities of the conductors of one group with relation to those of another, and then so combining the capacities of the groups that they tend to balance.

2. The method of balancing successive groups of conductors, between the conductors of each of which groups are inequalities in the capacities, which consists in determining such inequalities and then so joining the conductors in successive groups that said inequalities tend to neutralize one another.

3. The method of balancing successive groups of conductors which consists in connecting the groups to one another in various combinations, measuring the capacities between the conductors as thus joined, and permanently connecting the conductors to give the preferred relation between the capacities.

4. The method of balancing a phantom circuit, between the elements of successive sections of which there are inequalities in capacity, which consists in determining the inequality of capacity between the side cir-

cuits of the phantom and between the side circuits and the phantom, and then so joining such elements in the successive sections as to produce a minimum total unbalance.

5. The method of reducing disturbances between adjacent conductors arranged in successive groups which consists in determining the differences in capacities of the conductors of one group with relation to those of another group of the series, and then so combining the capacities of the successive groups that they tend to balance.

In testimony whereof, I have signed my name to this specification in the presence of two subscribing witnesses, this 14th day of March, 1912.

OTTO B. BLACKWELL.

Witnesses:

ROBERT S. SUTLIFFE,

FRANK POWELL.

In testimony whereof, I have signed my name to this specification in the presence of two subscribing witnesses, this 5th day of April, 1912.

GUSTAVUS A. ANDEREGG.

Witnesses:

ROY C. JONES,

EVANS L. SHUFF.