(No Model.) 2 Sheets—Sheet 1.

S. W. HOLMAN.

TELEPHONE CABLE.

No. 491,109. Patented Feb. 7, 1893.

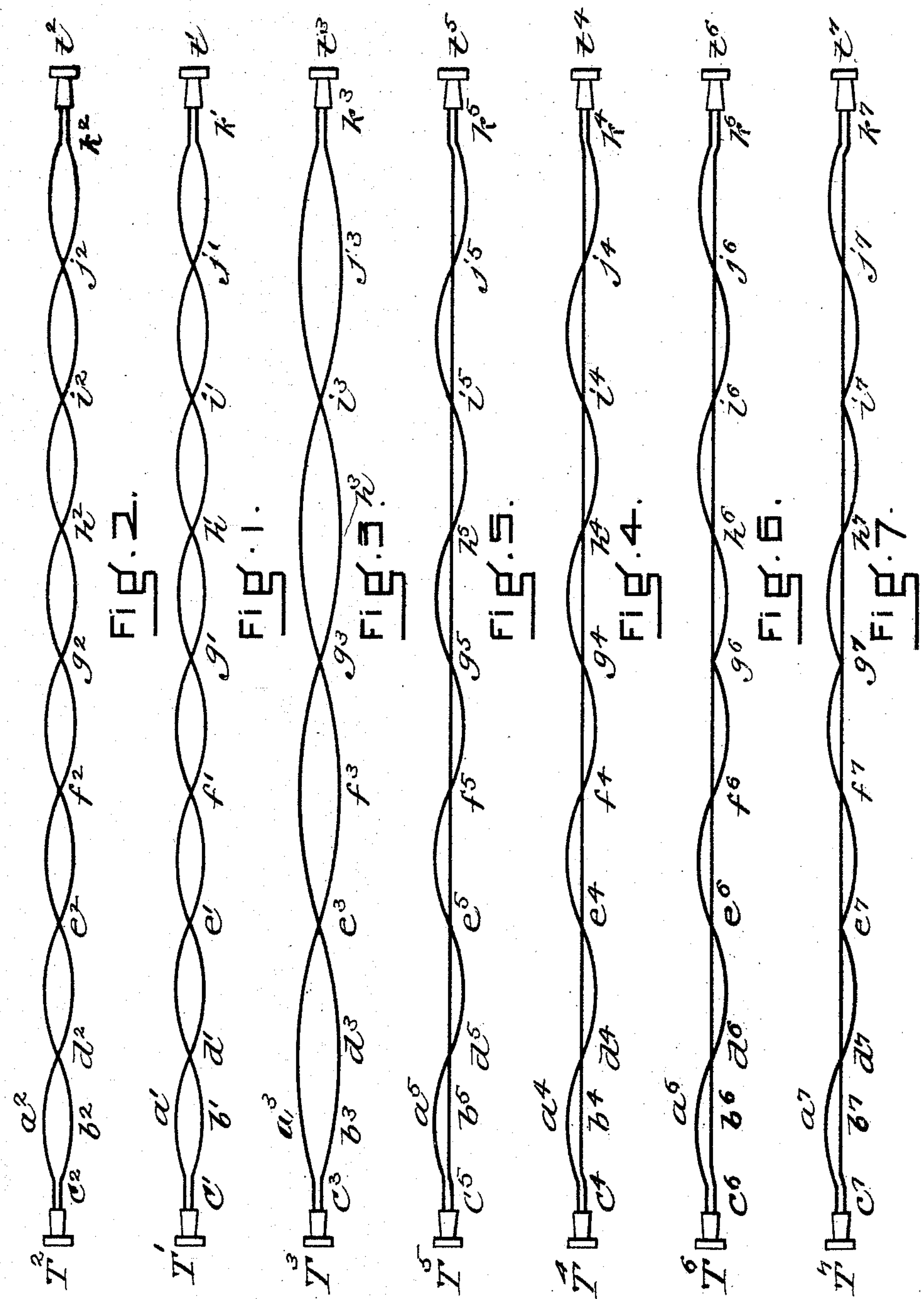

Fig. 2. Fig. 1. Fig. 3. Fig. 5. Fig. 4. Fig. 6. Fig. 7.

WITNESSES

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A. G. Burrow.

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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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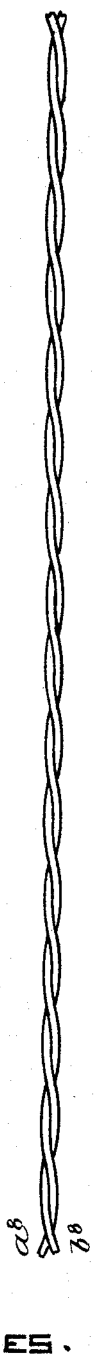

Fig. 8.

Fig. 9.

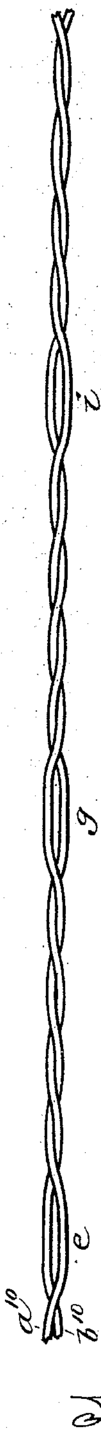

Fig. 10.

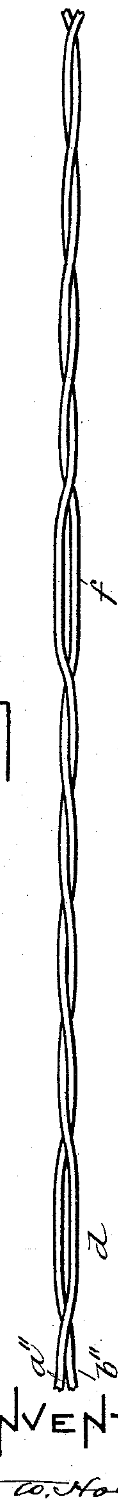

Fig. 11.

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UNITED STATES PATENT OFFICE.

SILAS W. HOLMAN, OF BOSTON, MASSACHUSETTS.

TELEPHONE-CABLE.

SPECIFICATION forming part of Letters Patent No. 491,109, dated February 7, 1893.

Application filed November 5, 1892. Serial No. 451,022. (No model.)

To all whom it may concern:

Be it known that I, SILAS W. HOLMAN, a citizen of the United States, residing at Boston, in the county of Suffolk and Commonwealth of Massachusetts, have invented a new and useful Improvement in Electric Telephone-Cables, of which the following description is a specification.

My invention relates to cables composed of twisted pairs of electric conductors, for telephone metallic circuits, and its object is to prevent inductive disturbance or cross-talk between neighboring circuits.

It consists in varying either the pitch or direction of the twist, or both, according to the methods hereinafter described.

The accompanying diagrams will be found convenient in describing the benefits of my invention. They are plane projections of twisted metallic circuits, Figure 1, being a plane projection of two insulated wires each evenly twisted about the other in the direction of the hands of a watch and with a twist of uniform pitch. Fig. 2, is in all respects like Fig. 1. Fig. 3, is twisted like Fig. 1, except that the pitch of the twist is twice as great, *i. e.*, each wire twists about the other, one half as many times in the same length of circuit. Fig. 4, is a plane projection of two insulated wires in which one is straight and the other is wound spirally about it, in the direction of the hands of a watch, the pitch of the twist being uniform throughout its length. Fig. 5, is like Fig. 4. Fig. 6, is like Fig. 4, excepting that the direction of twist is reversed at point g^6, so that between g^6 and k^6 the direction is opposite to that of the hands of a watch. Fig. 7, shows three such reversals, *i. e.*, at e^7, g^7 and i^7. Figs. 8, 9, 10 and 11 show the manner of twisting the wires in perspective.

I find two causes of inductive cross-talk in cables as now constructed. One, due to the fact that the two conductors are frequently unevenly twisted about each other so that one is comparatively straight, while the other is in a spiral about it. The other, due to the unbalanced parallelism that exists between two evenly and uniformly twisted pairs.

It will be convenient to consider the second difficulty first.

In Figs. 1 and 2, are represented two circuits as ordinarily arranged in a cable, the twist being of uniform pitch, care having been taken that each wire of a pair is evenly twisted about the other, this being the construction adopted in the best cables hitherto constructed. It will be seen, however, that owing to the fact that a' is more nearly parallel to a^2 than to b^2, and further, that b' is more nearly parallel to b^2 than to a', a current in the circuit T′, t', will induce a current in the circuit T^2, t^2. This I propose to avoid by substituting for circuit T^2, t^2, a circuit T^3, t^3, in which the pitch of the twist differs from that of T′, t'. In the case shown the pitch of twist in T^3, t^3, is double that of T′, t'. An inspection, now, of circuits in Figs. 1 and 3 will show that although a' is more nearly parallel to a^3 for the distance c', d', it is more nearly parallel to b^3 for the distance d', e', and moreover, although b' is more nearly parallel to b^3 for the distance c', d', it is more nearly parallel to a' for the distance d', e', so that the parallelism becomes balanced and T′, t' has no inductive effect on T^3, t^3.

The other cause of inductive cross-talk, that due to the uneven twisting of the two wires of a pair, is illustrated in Figs. 4 and 5, which represent two circuits as ordinarily arranged in a cable, the twist being of uniform pitch; but care not having been taken to twist each wire of a pair evenly about the other. For clearer illustration the case has been so exaggerated, that in each pair one wire is straight and its mate is in spirals about it. An examination of circuits, Figs. 4 and 5, will show that, inasmuch as b^4 is parallel to b^5, both being straight, while a^4 is parallel to a^5, both being spiral, in the same direction, a current in T^4, t^4, will set up a current in T^5, t^5. This I propose to avoid by substituting for circuit T^5, t^5, a circuit T^6, t^6, which is similar to T^4, t^4, excepting that at the middle point g^6, the direction of the spiral is reversed, so that while the action of a^4 and a^6 tends to produce a current in one direction, in the portion of the circuit c^6, g^6, it tends to produce an equal and opposite current in the portion of the circuit g^6, k^6.

Induction, due to uneven twisting of the two wires of each of two circuits as illustrated in Figs. 6 and 7, both of which have reversals in the twist of the wires, but at unequal intervals, is eliminated, as will be seen on inspection of them, where a^6 between c^6 and g^6, acts upon a^7, between the points c^7 and e^7, to produce a current in one direction, and between e^7 and g^7, to produce a current in the opposite direction; the two currents neutralizing each other. Similarly a^6 between g^6 and k^6, has no injurious resultant action on a^7, between g^7 and k^7. In general, cross-talk due to this cause may be avoided by the use of pairs of conductors, in a part or all of which pairs, the direction of twist is periodically reversed, and which are so arranged that the sections of different twist of each pair are of a different length from those in any adjacent pair.

As a concrete illustration: suppose I have a cable of seven metallic circuits, I may twist circuit No. 1 once in four inches and reverse the direction of the twist every one hundred turns. Circuit No. 2 I may twist once every four and one-fourth inches and reverse the twist every one hundred turns. Circuit No. 3, once every four and one-half inches and reverse the twist every one hundred turns and so on increasing the length of the turn in each circuit one-fourth of an inch.

In practice it is not necessary to have as many different pitches of twist as there are circuits in the cable, since only adjacent or neighboring circuits are likely to affect one another inductively, and I find in practice that, in a one hundred pair cable or a five hundred pair cable only about twenty different pitches of twist need be employed.

It is evident that if sufficient care were taken in the construction of cables so that the two wires of each pair twisted with perfect evenness about one another, the cause of cross-talk, due to uneven twisting would be removed and it would then be necessary only to vary the pitch of the twist in different pairs so as to overcome the cross-talk due to unbalanced parallelism as heretofore described: but in the manufacture of such cables, perfect uniformity of twist is impracticable, and therefore both the variation in pitch and reversal of twist will be found desirable.

In Figs. 8, 9, 10 and 11, I have endeavored to illustrate concretely the manner of twisting the wires by my improved method, but the plane projections in the preceding figures will give a better understanding of the benefits of the invention. In Figs. 8 and 9 the wires a^8, b^8, and a^9, b^9, of the two pairs are twisted in the same direction throughout with different pitches. In Figs. 10 and 11, the wires a^{10}, b^{10}, of one pair are twisted with a different pitch from the wires a^{11}, b^{11}, of the other pair and the twist of the pair a^{10}, b^{10}, is reversed at regular intervals, e, g, i, which are shorter than the intervals between the reversals of twist in the pair a^{11}, b^{11}, at d, f.

I claim,

1. A cable composed of two or more twisted pairs of electric conductors, each pair having a twist of different pitch from that of any adjacent pair, for the purpose specified.

2. A cable composed of two or more twisted pairs of electric conductors, in a part or all of which pairs the direction of the twist is periodically reversed, and in which such sections of twist in each pair differ in length from those in any adjacent pair.

3. A cable composed of two or more twisted pairs of metallic circuit electric conductors, each pair having a twist of different pitch from any adjacent pair and each pair having the direction of its twist reversed at regular intervals, which intervals in each, differ in length from those in any adjacent pair, for the purpose substantially as described.

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Witnesses:

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