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METHOD OF AND MEANS FOR CORRECTING LOADING SECTION IRREGULARITIES IN TRANSMISSION LINES.

APPLICATION FILED SEPT. 13, 1916.

1,219,760. Patented Mar. 20, 1917.

Fig. 1

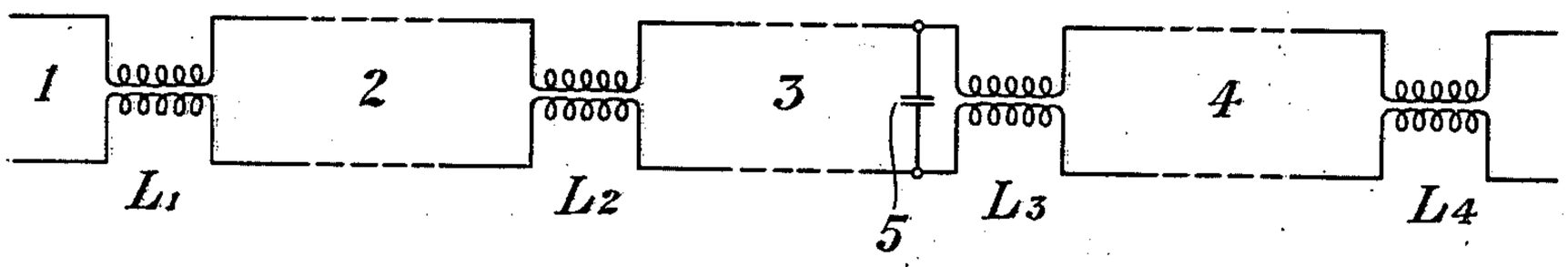


Fig. 2

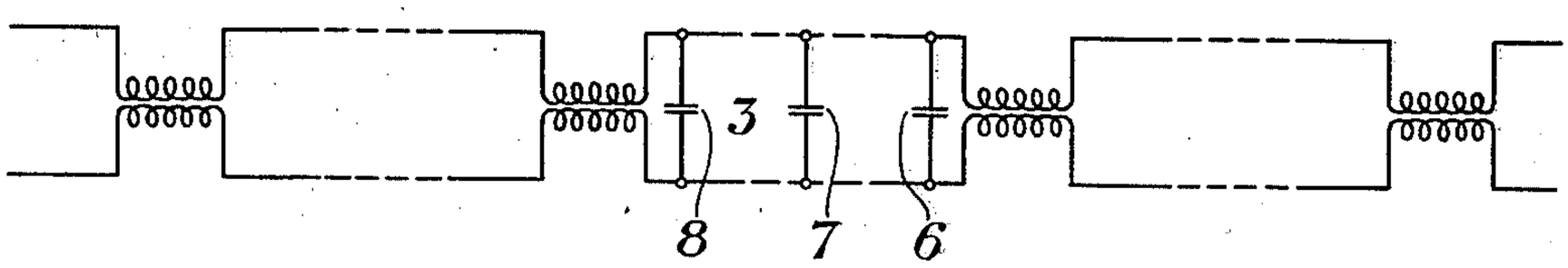
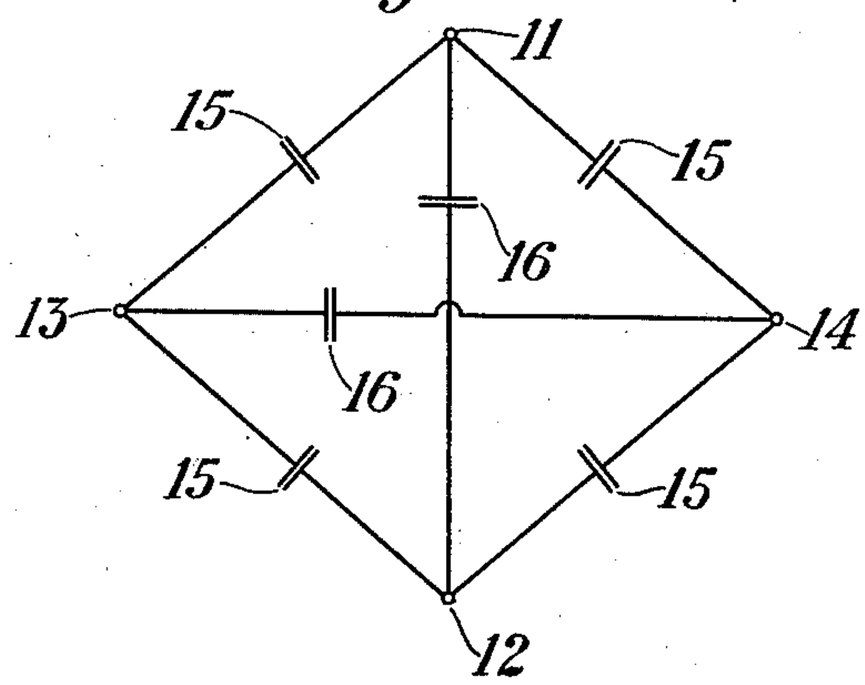


Fig. 3



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UNITED STATES PATENT OFFICE.

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METHOD OF AND MEANS FOR CORRECTING LOADING-SECTION IRREGULARITIES IN TRANSMISSION-LINES.

1,219,760. Specification of Letters Patent. Patented Mar. 20, 1917.

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To all whom it may concern:

Be it known that we, JOHN MILLS and RAY S. HOYT, residing at Wyoming and Brooklyn, respectively, in the counties of Essex and Kings and States of New Jersey and New York, have invented certain Improvements in Methods of and Means for Correcting Loading-Section Irregularities in Transmission-Lines, of which the following is a specification.

This invention relates to loaded lines for the transmission of telephonic currents and more particularly it relates to means for equalizing the loading sections and for correcting transmission irregularities therein due to differences in loading sections. Its object is to provide means whereby loading sections, whose characteristics are different, shall be rendered electrically similar, in other words to provide means for rendering the loading uniform.

It is well known to those acquainted with the art that irregularities in loaded lines are highly objectionable and very considerably reduce the advantages accruing from the employment of loading coils. Irregularities not only increase the attenuation and give rise to reflectional losses but also render it very difficult to balance the line impedance with artificial lines in two-way repeater circuits, thereby limiting the amount of amplification possible without repeater "singing".

Loading irregularities may be of two kinds: first, irregularities of the loading coils and second, irregularities of the line. It is the latter type of irregularity whose correction is the object of the present invention. Line irregularities may be due to differences in the actual length of loading sections; that is the distance between consecutive loading coils, or may be due to different distributed line constants in the conductors of the different sections.

Practical conditions often make it very difficult to construct a loaded line system having the required uniformity of loading necessary for the best repeater operation and the correction of irregularities by actual physical reconstruction may be very expensive. It is therefore desirable to provide means for rendering the loading sections electrically uniform and equal without having recourse to physical reconstruction of the line or relocation of the loading coils.

We have discovered that to secure uniformity of loading sections it is not necessary, as heretofore supposed, that the loading sections be of the same physical length and have the same distributed line constants. We have further discovered that if the total electrostatic capacity of the loading sections be made equal by the introduction of condensers between the conductors of sections having a defect of capacity, the line will behave electrically like a uniform line and that all the advantages consequent upon uniformity of loading sectional length, which heretofore was secured only by careful physical construction of the line, may be realized by the introduction of said condensers.

In practice the loading sections are electrically short, and the distributed inductance of each line sectiou is small compared with the inductance of a loading coil, so that line irregularities appear in practice as differences in the line capacity per loading section. If therefore, the capacities of the different loading sections are made equal, the line will behave electrically like a uniformly loaded line although the various sections may differ widely in physical length and distributed constants. In the present invention electrical uniformity of loading is provided by inserting condensers in the irregular sections so proportioned with reference to the capacity of the normal section and the irregular section, that the resultant capacity of the irregular section is equal to that of the normal section.

This invention is best understood by reference to the accompanying drawings in which Figure 1 is a diagram of a loaded transmission line with the equalizing means of this invention inserted in an irregular section; Fig. 2 is a diagram of a loaded transmission line with a plurality of equal-

izing means inserted in an irregular section; and Fig. 3 is a diagram of a cross section of a four wire phantom system which shows the method of connecting the equalizing condensers in an irregular section of a phantom system.

Referring to Fig. 1, a transmission line is shown consisting of loading sections, 1, 2, 3, 4, . . . the adjacent sections being connected by load coils L_1, L_2, L_3, L_4 . . . For purposes of illustration it will be assumed that the measured capacities of sections 1, 2, 4 . . . are all equal to C which may be taken as the normal capacity per loading section of the line. Assume, however, that the capacity, measured or computed, of section 3 is C′ where C′ is less than C. Then, in accordance with this invention, a condenser 5 is connected between the two conductors of section 3, the capacity of said condenser being C—C′, that is the capacity of said condenser is equal to the defect in capacity of the section in which it is connected.

It will be understood that the equalizing condenser may be profitably inserted to increase the capacity of an irregular section whether the defect of capacity in the irregular section is due to a short loading section or to a defect in the distributed line capacity of said irregular section. Since the capacity of condenser 5 is necessarily positive it will be seen that the equalizing or building out condenser may only be employed when there is a defect rather than an excess of capacity in the irregular section. When there are a large number of irregular sections in the line it may, therefore, be desirable to select that of largest capacity as the normal section and insert equalizing condensers in all the other sections.

If the irregularities are due to a few long sections, that is sections having an excess of distributed capacity, said long sections may be converted into short sections by the insertion of additional loading coils, and the consequent defect of capacity corrected by condensers as explained above. It will therefore be seen that the means disclosed for correcting irregularities in loading sections is not limited in its application to irregularities due to a defect of capacity in one or more sections but may be extended to the correction of irregularities due to an excess of capacity in one or more sections.

In Fig. 1 a single equalizing condenser is illustrated. It is, of course, well understood that a single condenser does not exactly represent the effect of the distributed capacity of a line section. If very high precision is required, therefore, a plurality of condensers may be inserted in the irregular section, as shown in Fig. 2.

Referring to Fig. 2, the arrangement there shown does not differ from that shown in Fig. 1, except that in the arrangement of Fig. 2 a plurality of equalizing condensers is inserted in section 3. In said figure, three condensers 6, 7 and 8 are shown, condensers 6 and 8 being preferably inserted near the ends of section 3, while condenser 7 is preferably inserted near the middle of section 3. The aggregate capacity of said three condensers should be approximately equal to the defect in capacity of section 3.

In Figs. 1 and 2 the equalizing condensers are shown as inserted in a loaded transmission line consisting of two parallel conductors. In phantom loaded systems wherein four parallel wires serve as the conductors for two "side" circuits and a "phantom" circuit a more complicated system of equalizing condensers is necessary. In such a system it is necessary that provision be made for inserting equalizing capacities in the side circuits and the phantom circuits without causing interference or cross-talk. Fig. 3 is a diagram illustrating the mode of inserting equalizing condensers in a phantom system.

Referring to Fig. 3, 11, 12, 13 and 14 are the cross sections of the four wires forming the conductors of a phantom loaded system, said cross section being assumed as taken in an irregular loading section in which there is a defect of capacity both as regards the side circuits and the phantom circuit. Conductors 11 and 12 constitute the two conductors of one side circuit and in parallel one side of the phantom circuit; similarly conductors 13 and 14 constitute the two conductors of the other side circuit and in parallel the other side of the phantom circuit. Condensers 15, 15, 15, 15 are connected between conductors 11 and 13, 11 and 14, 12 and 13, and 12 and 14, said condensers being preferably similar and equal. Between conductors 11 and 12 is connected a condenser 16; similarly between conductors 13 and 14 is connected a similar and equal condenser 16. As regards the phantom circuit, conductors 11 and 12 are in parallel, constituting one side while conductors 13 and 14 are in parallel constituting the other side of the phantom circuit. The capacity as regards the phantom circuit due to the inserted condensers is clearly seen to be 4 C_a where C_a is the capacity of each condenser 15. As regards each side circuit it will be readily seen that the capacity between the conductors 11 and 12 or between the conductors 13 and 14 is C_a+C_b where C_b is the capacity of each condenser 16. Let C_p be the capacity between the sides of the phantom circuit of the normal section and C_p' for the irregular section. Similarly let C_s be the capacity between the conductors of the side circuit of the normal section and C_s' for the irregular

section. Then, the values of the equalizing capacities are determined by

$$4C_a = C_p - C_p'$$

$$C_a + C_b = C_s - C_s'$$

Solving for C_a and C_b

$$C_a = \tfrac{1}{4}(C_p - C_p') \quad (1)$$

$$C_b = (C_s - C_s') - \tfrac{1}{4}(C_p - C_p') \quad (2)$$

By aid of equations (1) and (2) the proper values of C_a and C_b may be computed in terms of the capacities of sides and phantom circuits of the regular and irregular loading sections.

The corrective means of this invention is disclosed and illustrated as specifically embodied in condensers connected in irregular sections. In general said condensers are sufficient to realize a high degree of uniformity in loading sections, since, as heretofore stated, the effects of line inductance and resistance are small. If, however, a very high degree of uniformity is required, inductance and resistance may be inserted in irregular sections to render said irregular sections more nearly electrically equivalent to the normal section without departing from the spirit and scope of this invention. Furthermore, while the proportioning of the corrective capacities, as hereinbefore given, is approximately correct, they may be proportioned more exactly, when particularly high precision is required, so as to compensate somewhat for the ignoration of the distributed line inductance. It will thus be understood that the invention is not limited to the particular proportioning of capacities given in this specification. This invention will thus be seen to be broadly directed to correcting loading section irregularities in both two wire transmission lines and four wire phantom transmission lines and to rendering an irregularly loaded line the electrical equivalent of a uniformly loaded line.

What is claimed is:

1. The method of correcting irregularities in loading sections of periodically loaded transmission lines which consists in inserting in irregular sections corrective impedances of such value as to render the irregular section electrically equivalent to the normal section.

2. The method of correcting irregularities in loading sections of periodically loaded transmission lines which consists in connecting across irregular sections corrective impedances of such value as to render the resultant capacity of the irregular section equal to that of the normal section.

3. The combination of a transmission line, loading coils dividing said line into sections and means connected across said line for correcting irregularities of loading sections said means consisting of impedance elements having such values that the line is electrically equivalent to a uniformly loaded line.

4. The combination of a transmission line, loading coils dividing said line into sections and means connected across said line for correcting irregularities of loading sections said means consisting of condensers having such capacities that the line is electrically equivalent to a uniformly loaded line.

5. The combination of a transmission line, loading coils dividing said line into sections and means connected across said line for correcting irregularities of loading sections said means consisting of condensers having such capacities that the resultant capacities of the loading sections are equalized.

6. The combination of a phantom transmission line, loading coils dividing said line into sections and means connected with said line for correcting irregularities of loading sections, said means consisting of impedance elements having such values that the line is electrically equivalent as regards both phantom and side circuits, to a uniformly loaded line.

7. The combination of a phantom transmission line, comprising four conductors, loading coils dividing said line into sections, and means connected between each two conductors for correcting irregularities of loading sections, said means consisting of condensers having such capacities that the line is electrically equivalent as regards both phantom and side circuits, to a uniformly loaded line.

In testimony whereof, we have signed our names to this specification in the presence of a subscribing witness, this sixth day of September 1916.

JOHN MILLS.
RAY S. HOYT.

Witness:
JOHN R. CARSON.