Feb. 24, 1948. E. L. GINZTON 2,436,427

IMPEDANCE TRANSFORMER

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Fig. 1.

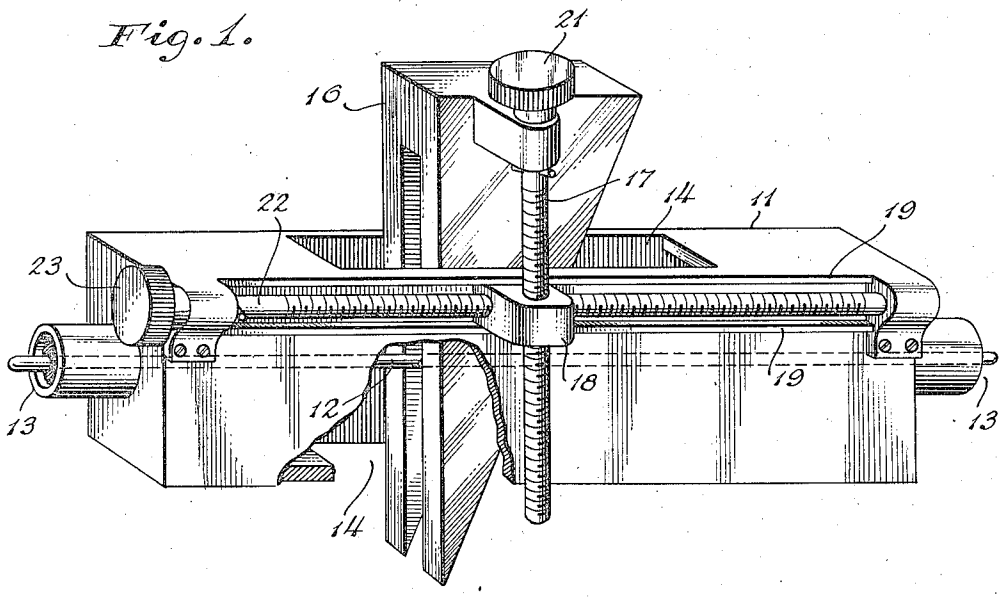
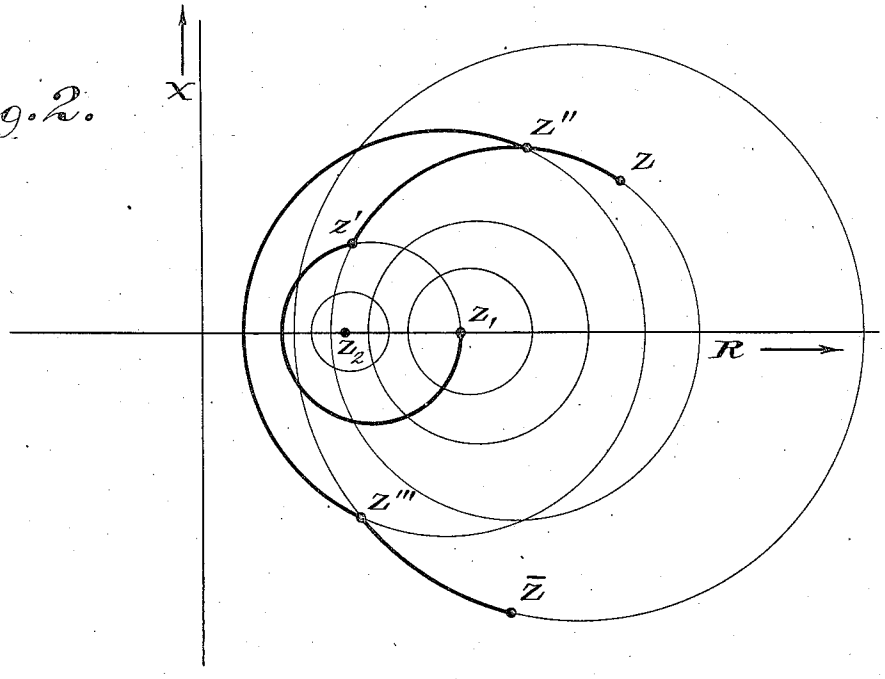


Fig. 2.



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IMPEDANCE TRANSFORMER

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23 Claims. (Cl. 178—44)

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The present invention relates to the art including impedance matching and transforming devices especially adapted for use in systems utilizing high frequency electromagnetic energy. In transferring energy from one high frequency device to another, it is well known that the impedances of the source and load must be properly matched in order to avoid the production of standing waves with attendant losses and decreases in the efficiency and power-carrying capacity of the energy-transmitting system.

The present invention is directed toward the provision of an improved impedance transforming device which is adapted to efficiently couple and match one impedance element with a second impedance element, or to transform a given impedance value into a desired value, with a minimum of adjustment and a maximum facility and efficiency. Many types of impedance matching and transforming devices are known, such as those shown in copending application Serial No. 448,992, filed June 29, 1942, in the names of William W. Hansen et al. However, all such devices require the use of sliding metallic joints in order to permit adjustment of the device for transforming an impedance value impressed at one end of the device to another value at the other end. Such sliding metallic joints introduce considerable complexity of construction, and increase losses due to the finite resistance of such joints.

According to the present invention, an impedance transformer is provided in which all sliding metallic joints in the path of the high frequency energy flow are entirely omitted and an easily fabricated device is produced. This is done in the present case by providing a movable section of dielectric which acts to change the impedance characteristics of the device suitable for matching or transforming impedances, without the necessity for sliding metallic joints.

Accordingly, it is an object of the present invention to provide an improved impedance transformer for transforming one impedance value to another value.

It is another object of the present invention to provide an improved impedance transformer of fixed length suitable for rigid connection in a high frequency system.

It is still another object of the present invention to provide an improved impedance transformer having no sliding metallic conducting joints.

It is a further object of the present invention to provide an improved impedance transformer

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utilizing a movable dielectric mass for adjusting the characteristics thereof.

It is still another object of the present invention to vary the characteristics of a transmission line by an adjustable dielectric member.

Further objects and advantages of the present invention will become apparent from the specification, taken in connection with the accompanying drawing wherein one embodiment of the invention is illustrated and in which

Fig. 1 shows a partially cut-away perspective view of the impedance matching and/or transforming device of the present invention, and

Fig. 2 shows an impedance diagram useful in explaining the operation of the invention of Fig. 1.

The present invention provides an impedance transformer generally of the coaxial transmission line type (although other types of transmission lines may be used), which may be rigidly connected in any coaxial transmission line system. The main body of the device is provided by a housing 11 which is shown as being of square cross-section, although it is to be understood that any other cross-section adapted to function in the manner to be described, may be used. This casing 11 is provided with a central conductor 12 preferably concentrically and symmetrically disposed therewithin. The casing 11 and conductor 12 provide a type of coaxial transmission line having a predetermined characteristic impedance with the usual air dielectric material. This characteristic impedance may be chosen to have a standard value, which may be the same as that of the concentric line used in other portions of the system.

Connected at either end of this transmission line 11, 12 is a coupling device or terminal 13 comprising any usual or conventional cylindrical coaxial transmission line terminal. Preferably the inner conductor 12 extends into and forms an integral part of these terminals 13, and the relative dimensions of casing 11, conductor 12, and terminals 13 are chosen to make the characteristic impedance of the terminal sections 13 equal to that of the main portion of the device comprising casing 11 and conductor 12. This condition is not necessary, however, since the impedance transformer itself can compensate for any lack of matching between the terminal sections and the main body of the device. Also, if desired, a smooth transition section may be connected between the terminals 13 and the main body 11 to provide a minimum of impedance discontinuity at the ends of the device. However,

these are refinements which are not necessary to the functioning of the device, although desirable.

As is clearly shown in Fig. 1, the housing 11 is provided with a pair of openings 14 at opposite sides thereof into which is inserted a movable dielectric mass or member 16. Dielectric mass 16 may be composed of any suitable dielectric material having a dielectric constant appreciably different from that of air, and is preferably chosen to have a high efficiency and low power loss at the high frequencies to be utilized. A suitable material for this dielectric is polystyrene.

As shown in the drawing, dielectric mass 16 is adapted to be moved transversely of the housing 11 by means of a suitable screw 17 threaded into a member 18 which is prevented from transverse motion by means of guide flanges 19. Accordingly, rotation of knob 21 will produce a transverse displacement of dielectric mass 16. Dielectric mass 16 is also adapted to be moved axially of the device by means of a knob 23 and a screw 22 which is also threaded into member 18. Accordingly, by rotation of knob 23, dielectric mass 16 is axially displaced along the device, guided by flanges 19. Dielectric mass 16 may be formed in a number of different shapes but is preferably chosen to have a wedge-shape, such as shown in the figure, straddling the inner conductor 12 of the device.

It will be seen that in this manner rotation of knob 21 will insert an adjustable length of dielectric between inner conductor 12 and the outer housing 11. As is well known, a change in dielectric material in a coaxial transmission line produces a change in the characteristic impedance of the line. Adjustment of knob 21 therefore will produce a section of coaxial transmission line at the center of the device, having adjustable length and with a characteristic impedance differing from that of the rest of the line. At the same time, adjustment of knob 23 will displace the relative position of this different-characteristic-impedance coaxial line section along the device. Thus knob 21 adjusts the axial extent of the dielectric, or the distance separating the left air-filled line section from the right air-filled line section, while knob 23 adjusts the position of the dielectric, and thus increases one of the air-filled end section while decreasing the other equally. These two adjustments, as will be seen, provide all the adjustments necessary to transform an impedance value impressed at one end of the device to another value at the other end.

Although dielectric mass 16 is shown in the form of a right triangular wedge, many other forms can be utilized, the only necessary condition being that the axially-extending dimension of the dielectric mass is variable along the transverse direction so that varying lengths of dielectric can be effectively inserted into the device by rotation of knob 21. Another shape for dielectric member 16 which is well adapted for use is an isoceles triangular shape having its axis of symmetry perpendicular to the central conductor 12.

Referring to Fig. 2, there is shown an impedance diagram whose coordinate axes represent, respectively, resistance and reactance. On this diagram, the point Z_1 represents the characteristic impedance of the coaxial line 11, 12 when the dielectric mass 16 is entirely withdrawn, and point Z_2 represents the characteristic impedance of the coaxial line at the position of dielectric mass 16 when the dielectric mass 16 is inserted. In view of the fact that the dielectric constant of dielectric mass 16 is greater than that of air, it will be seen that the characteristic impedance value Z_2 must be less than Z_1.

If now an impedance element of arbitrary impedance value is connected to one end, say the left end, of the device, it may be required to match this impedance value or transform it to the characteristic impedance Z_1 of the line section 11, 12. This situation may arise, for example, where the entire apparatus to the right of the device of the present invention is already suitably matched in impedance to that of line 11, 12.

Let the arbitrary impedance element have an impedance value represented by the point Z, and let it be connected to the left end of the device of Fig. 1. Generally, this impedance value will have both resistive and reactive components, as shown by the illustrated position of Z. As the position of dielectric mass 16 is moved axially of the device by means of knob 23, the impedance value at the left edge of dielectric mass 16, seen looking toward the arbitrary impedance element of impedance value Z, will vary with motion of the dielectric mass 16 along an arc of the circle of the diagram passing through point Z. This circle is formed as one of the bipolar coordinate circles having the point Z_1 as the pole thereof. A more complete discussion of the use of such bipolar coordinate circles is given in the above-mentioned U. S. application Serial No. 448,992, and in the book "Microwave Transmission" by J. C. Slater, at pages 29–40. Briefly, it may be stated that for each half wavelength of transmission line of characteristic impedance Z_1 inserted between the arbitrary impedance Z and the point of observation, the transformed impedance value at the point of observation will make one rotation about the circle passing through the impedance value Z. For less than a half wavelength of line thus inserted, the impedance value will be transformed by an amount corresponding to a smaller arc of this circle. Accordingly, by making the opening 14 in casing 11 at least one-half wavelength long, the transformed impedance value at the leading edge of the dielectric mass 16 can be made to assume any value on the circle passing through point Z.

The transformed impedance value at the right end of dielectric mass 16 will be displaced from the first transformed impedance value along an arc of a similar bipolar coordinate circle having the point Z_2 as the pole thereof, the amount of such displacement depending on the axial length of dielectric mass 16 interposed between conductors 11 and 12. A number of such bipolar coordinate circles are shown in the drawing for each of the two poles Z_1 and Z_2. By adjusting the axial position of the dielectric mass 16, therefore, the impedance value at the left edge of dielectric mass 16 can be transformed to a value Z' which lies on the bipolar coordinate circle $Z'Z_1$ having pole Z_2. Therefore, by adjusting the knob 21 to adjust the effective length of the transmission line section having the dielectric therein, the impedance value Z' at the left edge of the dielectric mass 16 can be transformed into the impedance value Z_1, as is required. Since this impedance value at the right edge of the dielectric mass 16 is the same as the characteristic impedance Z_1 of the line 11, 12 and of the terminal 13 (under the condition where the terminal has the same characteristic impedance as the main line section 11, 12) it will be seen that the arbitrary impedance value Z has been suitably transformed into the value Z_1 at the right hand of the device, and if the sys-

tem to the right of the impedance transformer is properly matched to the impedance value Z_1, the entire system will thereby be matched. In this way, by two simple adjustments the required impedance transformation is obtained.

If the system to the right of the device is not properly matched, then the dielectric mass 16 must be adjusted to a position such that the transformed impedance value at the right edge of the dielectric mass 16 is given a value such that the additional length of transmission line 11, 12 and the length of transmission line formed by terminal 13 transforms this impedance value into the required impedance value $\overline{Z}$ at the right of terminal 13 which matches the system to the right. Thus, by suitably adjusting the axial position of dielectric mass 16, the impedance value Z impressed to the left terminal of the device could be transformed into an impedance value Z'' at the left edge of the dielectric mass 16. This impedance value Z'' is then transformed to an impedance value Z''' at the right edge of the dielectric mass 16 by adjusting screw 21, and the further section of concentric line 11, 12 to the right of dielectric mass 16 will then transform this impedance value Z''' into the required impedance value $\overline{Z}$. Thus the impedance value Z is transformed into another impedance value $\overline{Z}$.

Although the above description has stated that the leading edge or left edge of dielectric mass 16 was perpendicular to the axial dimension of the device, it is to be noted that this need not be made strictly thus. Rather, the dielectric mass may be made isosceles triangular or may be made to have any desired contour, without changing the qualitative correctness of the explanation given above. A change in the contour will merely change the relationship between an angular displacement of knob 21 and its effect upon impedance matching. By suitable choice of this contour, optimum facility in adjustment may be derived.

Also, the impedance element of value Z to be transformed need not be connected to the left end of the device, as assumed above for purposes of illustration, but may be connected at either end. Accordingly, I have shown an improved form of impedance transformer which does not need any sliding metallic contacts and which is adapted to easily and simply transform one impedance value into a second impedance value.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An impedance matching transformer comprising a section of coaxial transmission line adapted to be connected between the circuits to be matched in impedance, a dielectric mass of contour variable in a direction along the axis of said line and adapted to be inserted between inner and outer conductors of said line, means for adjusting said dielectric mass transversely with respect to said line section whereby an adjustable length of said dielectric mass appears between said conductors, and means for adjusting the position of said dielectric mass along said line section, whereby said circuits may be matched in impedance by adjusting the longitudinal and transverse positions of said dielectric mass.

2. An impedance matching transformer comprising a section of coaxial transmission line adapted to be connected between two circuits to be matched in impedance, means for inserting an adjustable length of dielectric material between the inner and outer conductors of said line, and means for adjusting the position of a predetermined length of said dielectric material along said line whereby said circuits may be matched in impedance by adjusting the inserted length and position of said dielectric material.

3. An impedance matching transformer comprising a section of transmission line having an impedance element of arbitrary impedance value connected at one end thereof, and means for producing an arbitrary desired impedance value measured at the other end of said section, said last-named means comprising means for inserting an adjustable length of dielectric material in said line section, and means for adjusting the position of a predetermined length of said dielectric material along said line section, whereby said desired impedance value may be obtained by adjusting the inserted length and position of said dielectric material.

4. An impedance matching transformer comprising a section of transmission line adapted to have a circuit element of arbitrary impedance value connected at one end thereof, and means for producing an arbitrary desired impedance value measured at the other end of said section, said last-named means comprising a dielectric mass of contour variable in a direction along said line section, and means for inserting said mass in said line section intermediate the ends thereof and for adjusting the transverse position of said mass with respect to said line section, whereby the length of dielectric mass between said conductors may be adjusted to produce said desired impedance value.

5. An impedance matching transformer comprising a section of hollow-conductor transmission line having a predetermined characteristic impedance when containing only air and adapted to have an element of arbitrary impedance value connected at one end thereof, and means for producing an arbitrary desired impedance value measured at the other end of said section, said last-named means comprising a dielectric mass having a varying dimension parallel to said line section whereby the axial extent of the portion of line, whose characteristic impedance is affected by the dielectric mass, is a function of said varying dimension, said varying dimension extending for a substantial portion of the axial extent of said dielectric mass, said dielectric mass being positioned intermediate the ends of said hollow conductor transmission line with a preselected value of said dimension interposed within said transmission line, and means for adjusting the position of said dielectric mass along said section, whereby said desired impedance may be produced.

6. An impedance transformer comprising a section of hollow-conductor transmission line having a predetermined characteristic impedance, said transmission line section being adapted to be connected at one end to a device having a first impedance value and at the other end to a device having a second impedance value, a dielectric mass in said line section and intermediate said devices, said dielectric mass having a variable dimension parallel to said line

section whereby the axial extent of the portion of line section, whose characteristic impedance is affected by the dielectric mass, is a function of said varying dimension, said varying dimension extending for a substantial portion of the axial extent of said dielectric mass, and means for adjusting the position of said dielectric mass with respect to the conductors of said line to match said two impedance values connected to the ends of said line section.

7. An impedance matching transformer comprising a transmission line section of a first characteristic impedance adapted to be connected between a pair of devices having impedances to be matched, means for modifying a portion of said section to form thereof a transmission line portion having a different characteristic impedance from said first characteristic impedance, means for adjusting the length of said portion, and means for adjusting the position of said portion along said section, whereby said two impedances may be matched by adjustment of said adjusting means.

8. An impedance transformer comprising a first air-filled transmission line section having a predetermined characteristic impedance, a second air-filled transmission line section having the same characteristic impedance as said first line section, a third line section intermediate said first and second sections and having dielectric means therein defining the axial extremes of said third line section, said dielectric means being adjustable to vary the separation of said axial extremes and thereby varying the axial length of said third line section, said dielectric means being also axially adjustable for altering the axial position of said third line section relative to said first and second sections.

9. An impedance transformer comprising a transmission line having a hollow conductor, dielectric means intermediate the ends thereof and having a pair of boundary surfaces separated along the axis of said conductor, at least parts of said surfaces being within said hollow conductor, said dielectric means being adjustable to vary the axial separation of the boundary surfaces within said hollow conductor and also being adjustable to simultaneously move the boundary surfaces within said hollow conductor axially of said line and in the same direction, whereby by adjustment of the separation and position of the boundary surfaces within said hollow conductor an impedance value presented at one end of said line may be transformed to an arbitrary desired value at the other end.

10. An impedance transformer comprising a transmission line section having at both ends a predetermined characteristic impedance, dielectric means for modifying a portion of said section to form a transmission line portion intermediate said ends having a different characteristic impedance, and means for adjusting the position of said portion within said section, whereby a device of given impedance value connected to one end of said section may produce a desired impedance value at the other end of said section.

11. An impedance transformer comprising a transmission line section having a predetermined characteristic impedance, dielectric means for modifying a portion of said section to form a transmission line portion having a different characteristic impedance, and means for adjusting the length of said portion, whereby an arbitrary impedance value appearing at one end of said first section may be transformed to a desired impedance value at the other end of said first section.

12. An impedance transformer comprising a section of transmission line of predetermined characteristic impedance interposed in cascade relation along further sections of transmission line of different characteristic impedance, means for adjusting the length of said first-named section, and means for adjusting the positioning of said first-named section with respect to said further sections, whereby an arbitrary impedance value appearing at one end of said further sections may be transformed to a desired impedance value at the other end of said further sections.

13. An impedance matching transformer for coupling a source of high-frequency energy to a load, comprising a transmission line having two conductors, means for connecting said line at one end to said source, means for connecting said line at the other end to said load, means for inserting an adjustable length of dielectric material between the conductors of said line, and means for adjusting the position of a predetermined length of said dielectric material along said line, whereby said source and said load are efficiently matched.

14. An impedance matching transformer for coupling an alternating-current source to a load, comprising a transmission line section having two conductors adapted to be connected between said source and said load, a dielectric mass of contour variable in a direction along said line section, means for inserting said mass between the conductors of said line intermediate said source and said load and for adjusting the transverse position of said mass with respect to said line section, whereby the length of said dielectric mass between said conductors may be adjusted to match said source and said load.

15. An impedance matching transformer for termination by a load of a finite impedance value adapted to be supplied from a source having a second impedance value, comprising a section of transmission line having two conductors, means for connecting said line at one end to said load, means for connecting said line at the other end to said source, a dielectric mass of adjustable effective electrical length positioned between the conductors of said line section intermediate said load and said source, and means for adjusting the position of a predetermined value of the effective electrical length of said dielectric mass along said section, whereby said impedance values may be matched by said adjustment.

16. Apparatus for presenting a predetermined input impedance value when terminated by a load of finite impedance value, comprising a section of transmission line having two conductors, means for connecting said conductors at one end to said load, a dielectric mass between said conductors, and means for adjusting the length and position of said dielectric mass between said conductors to vary said input impedance value.

17. An impedance transformer for presenting a predetermined input impedance value to an alternating current source when terminated in a load of finite impedance value, comprising a section of transmission line having two conductors, means for connecting said transmission line section at one end to said load, and a dielectric mass of adjustable electrical length variably positioned between said conductors intermediate the ends of said line for adjusting the input im-

pedance value of said line by adjustment of the electrical length and position of said mass.

18. An impedance transformer for presenting a predetermined input impedance value to an alternating current source when terminated in a load of finite impedance value, comprising a transmission device of a fixed overall length including three cascade-connected variable length transmission line sections, wherein a first of said sections for connection to said load has a first characteristic impedance, the second of said sections connected to said first section has a second characteristic impedance, and the third of said sections connected to said second section and providing the input terminal of said device has a characteristic impedance equal to said first characteristic impedance.

19. High frequency apparatus comprising a transmission line section having coaxial outer and inner conductors, said outer conductor having an opening formed in the sidewall thereof, a low-conductive element, and means for adjustably inserting said element through said opening into the transmission line section, said means providing adjustment of at least a portion of said element transversely of said line for a distance greater than that separating said conductors.

20. High frequency apparatus comprising a transmission line having coaxial and spaced inner and outer conductors and having a predetermined characteristic impedance, said outer conductor having an opening therein, an element in said opening and adapted to change said predetermined characteristic impedance upon insertion between said conductors, and means coupled to said element for providing adjustment of at least a portion of said element through the region adjacent said inner conductor and for a distance longer than the distance between said conductors.

21. High frequency energy transmission apparatus comprising a section of coaxial transmission line including an axially slotted outer conductive member and a coaxial inner conductive member, and a dielectric body of variable axial contour adjustably supported within said slot for transverse movement with respect to said inner and outer conductive members.

22. High frequency energy transmission apparatus comprising a section of coaxial transmission line including an outer conductive member and an inner conductive member, said outer member being axially slotted over a predetermined portion thereof, a dielectric body of variable axial contour, and means adjustably supporting said dielectric body within said slot for transverse and axial movement with respect to said inner and outer conductive members.

23. High frequency energy transmisison apparatus comprising a section of coaxial transmission line including an axially-slotted outer conductive member and a coaxial inner conductive member, a wedge-shaped dielectric body having a continuously variable dimension parallel to the axis of said coaxial line section and a recess extending perpendicularly to said axis for receiving the inner conductive member when said dielectric body is inserted within said transmission line section, and means adjustably supporting said dielectric body within said transmission line section for transverse and axial movement with respect to said inner and outer conductive members, whereby a predetermined desired axial length of dielectric body may be selectively positioned relative to the ends of said line section in accordance with adjustment of said supporting means.

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