

March 2, 1948.

F. J. BINGLEY

2,437,067

ADJUSTING MEANS FOR TRANSMISSION LINES

Filed Nov. 17, 1943

2 Sheets-Sheet 1

FIG. 1

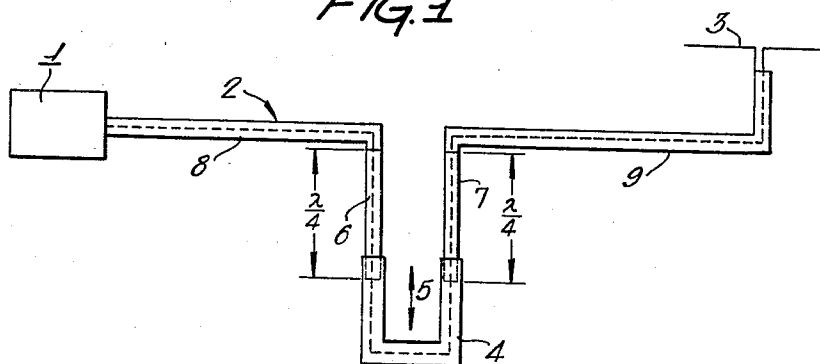


FIG. 2.

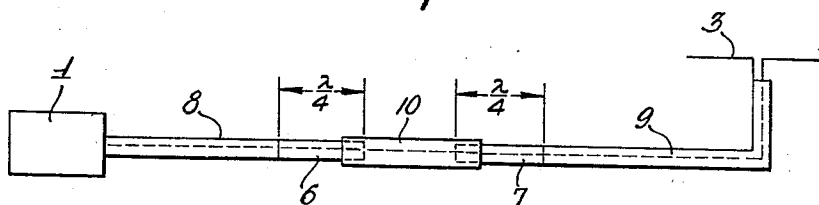
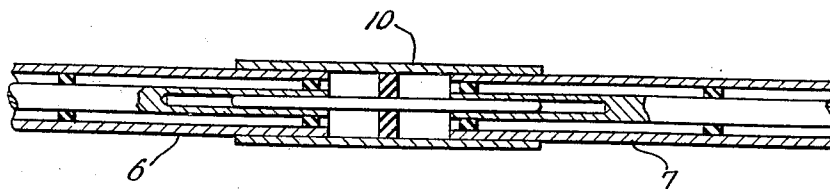


FIG. 5.



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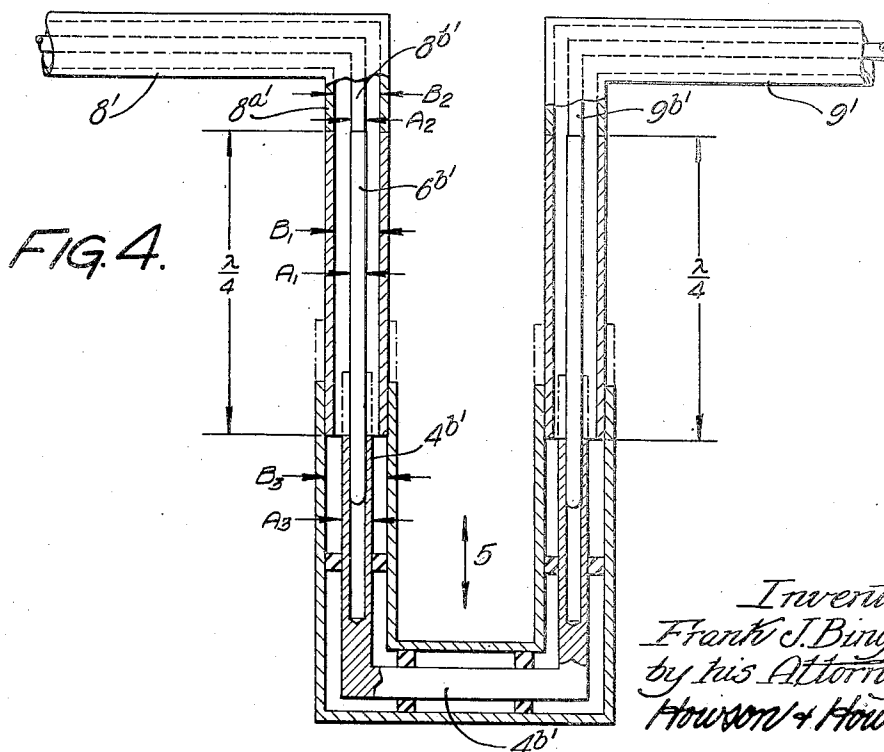
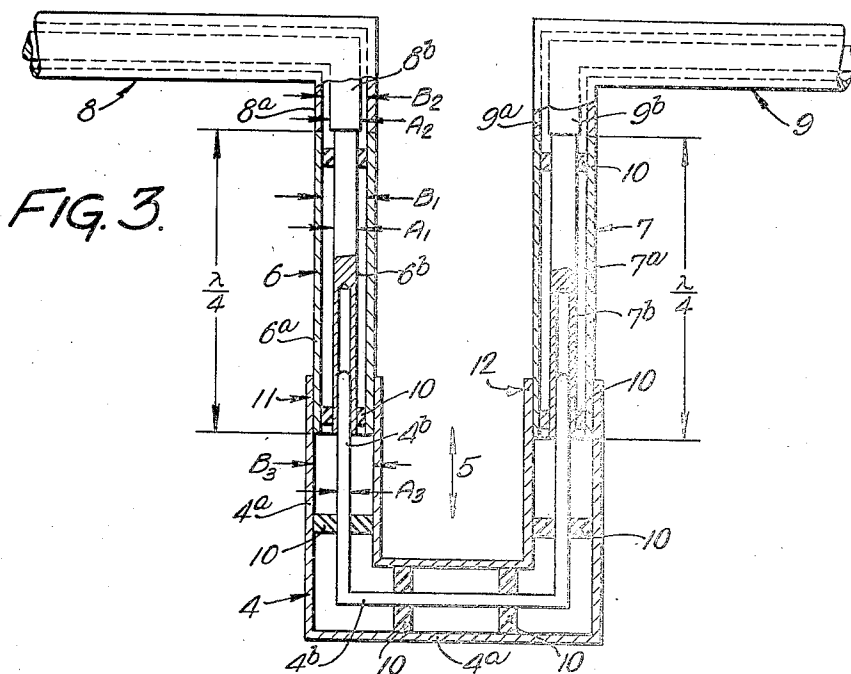
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2 Sheets-Sheet 2



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ADJUSTING MEANS FOR TRANSMISSION
LINES

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6 Claims. (Cl. 178-44)

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This invention relates to co-axial transmission lines and has to do with the problem of maintaining matched impedances while providing for line-length adjustments.

In ultra high frequency transmitting installations—particularly television—it is common practice to employ a co-axial transmission line for interconnecting the transmitter per se with the radiating antenna; and for certain electrical reasons, which need not be explained here, it is expedient to insert in such a line means by which its electrical length can be adjusted. One such means which is highly convenient comprises a U-shaped portion of co-axial cable known as a "trombone," because of its similarity, in appearance, to the slideable tube in the musical instrument of that name.

Interconnecting two sections of co-axial line through the medium of a trombone affords the essential lengthwise adjustability; but, as practiced heretofore has resulted in objectionable impedance mismatches—which it is the primary object of this invention to avoid. That is to say, it is the primary object to provide convenient and effective means whereby the length of a co-axial line can be adjusted without introducing an impedance mismatch.

It is a subordinate object to devise a trombone type line-length adjustment which introduces no impedance mismatch.

It is well known that two transmission line sections having different characteristic impedances can be coupled without mismatching by interposing between the adjoining ends a quarter-wave-length coupling section whose characteristic impedance is equal to the geometric mean of the characteristic impedances of the line sections to be coupled. That is to say, the coupled line sections will be matched if

$$Z_1 = \sqrt{Z_2 Z_3} \quad (1)$$

where Z_1 is the characteristic impedance of the quarter-wave-length coupling section and Z_2 and Z_3 are, respectively, the characteristic impedances of the two line sections to be coupled.

One of the major aspects of the present invention resides in the concept that a trombone section can be made to match, as to characteristic impedances, each of two line sections, and can be made to maintain the impedance match throughout all adjustments, by interposing between each leg of the trombone and its respectively associated line section a quarter-wave section having a characteristic impedance which is equal to the geometric mean of the characteristic

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impedances of the trombone and the connected line sections.

Another important aspect of this invention is a novel telescopic joint which serves to avoid the creation of a superfluous and detrimental intermediate characteristic impedance between the trombone, or other adjusting section, and the adjoining quarter-wave sections—which latter impedance would function to destroy or impair the impedance match which is intended to be achieved.

While a trombone is generally the most desirable form of line-length adjusting means for carrying out this invention, it will be pointed out that, where circumstances permit, there can be employed, instead, a straight section capable of performing the same function as the trombone.

In the drawings which accompany this specification

Fig. 1 is a schematic diagram of a television transmitting system, showing a co-axial transmission line with an adjusting "trombone" in accordance with this invention;

Fig. 2 is a schematic diagram of an alternative arrangement showing a straight telescopic adjusting section which can be employed in place of the trombone;

Fig. 3 shows details of construction of the trombone;

Fig. 4 shows, for comparison, a trombone construction not in conformity with the invention; and

Fig. 5 is a detail of the straight telescopic section of Fig. 2.

In Fig. 1, the rectangle 1 may be taken to represent a television transmitter the output of which is connected through a co-axial transmission line 2 to a dipole antenna 3. To provide for adjustments of the length of the transmission line there is inserted therein a trombone section 4 which is slidably movable, as indicated by the double-headed arrow 5. It is old practice to make use of a trombone section for varying line length; but in the past this practice has resulted in the introduction of impedance mismatches between the interconnected line sections—the mismatch in each case being due to the fact that the characteristic impedance of the trombone was not identical with that of the interconnected line sections, and the further fact that the trombone could not be made to operate as a matching section because it could not be a quarter-wave-length long, or odd multiple thereof, in more than one position of adjustment.

My invention consists, in part, in the provision

of two quarter-wave sections 6 and 7 interconnecting the two ends of the trombone with the two line sections 8 and 9—each quarter-wave section having a characteristic impedance equal to the geometric mean of the characteristic impedances of the sections which it interconnects. Thus, the characteristic impedance of quarter-wave section 6 must be equal to the geometric mean of the characteristic impedances of trombone 4 and line section 8. This is expressed mathematically by the previously stated Formula 1.

The arrangement of Fig. 1 makes it possible to adjust line length without disturbing either the transmitter 1 or antenna 3, and is generally preferred for that reason. But where it is not inconvenient to move the transmitter or antenna there may be employed, instead of the trombone, a straight adjusting section 10, as shown in Fig. 2. The arrangement of Fig. 2 is in all other respects identical with that of Fig. 1.

In Fig. 3 there is illustrated in detail the construction of that portion of the line which includes trombone 4 and quarter-wave sections 6 and 7, together with fragments of line sections 8 and 9.

Each section of the line, including the trombone section and the quarter-wave sections, as well as main sections 8 and 9, is a co-axial cable comprising an outer tubular conductor and an axial conductor which is centralized with the outer tubular conductor by means of suitable insulators. Line section 8 is composed of an outer tubular conductor 8a and an axial conductor 8b, both of circular cross-section. Quarter-wave section 6 is composed of an outer tubular conductor 6a and an axial conductor 6b, likewise of circular cross-section. Line section 9 is composed of similar conductors 9a and 9b; and quarter-wave section 7 of corresponding conductors 7a, 7b. Trombone 4 comprises an outer tubular conductor 4a and an axial conductor 4b, each of circular cross-section.

The axial conductors are centralized and supported by means of insulating discs 10.

The length of each quarter-wave section can be either one quarter-wave length (at the transmitted frequency) or any odd multiple thereof.

An important feature of this invention, which makes it easy to maintain the essential impedance match between the trombone and the two main line sections 8 and 9 resides in the arrangement of the telescopic joints 11 and 12, which afford slidable interconnection between the trombone and the quarter-wave sections; and in order to make clear the significance, from an electrical standpoint, of the particular arrangement of joint shown, it will be expedient to discuss briefly the mathematics involved in the determination of characteristic impedance of co-axial conductors, and to restate in dimensional terms the previously given equation for matching impedances.

The formula for computing the characteristic impedance of a co-axial cable comprising a circular outer tube and a circular axial conductor is

$$Z = 138 \log_{10} \frac{B}{A} \quad (2)$$

wherein Z is the characteristic impedance to be determined; B is the inside diameter of the tube; and A is the outside diameter of the axial conductor.

Substituting in the general Formula 1 expressions according to the form of the right hand

side of Equation 2, there is obtained an equation expressing the dimensional properties which must obtain between each quarter-wave section and the line sections which it interconnects in order to realize an impedance match.

Thus:

$$138 \log_{10} \frac{B_1}{A_1} = \sqrt{\left(138 \log_{10} \frac{B_2}{A_2}\right) \left(138 \log_{10} \frac{B_3}{A_3}\right)} \quad (3)$$

The dimensional quantities A_1, A_2, A_3, B_1, B_2 and B_3 are indicated in Fig. 3. The left side of Equation 3 defines the characteristic impedance of each quarter-wave section while the two factors under the radical on the right side define, respectively, the characteristic impedances of sections 8 and 4, or sections 9 and 4—as the case may be.

It will be seen that the only variables entering into determination of the characteristic impedance of a co-axial cable are the diameters B and A and the ratio

$$\frac{B}{A}$$

and that the length of the line is irrelevant. The actual dimensions A and B are immaterial, except insofar as they affect the

$$\frac{B}{A}$$

ratio.

It follows from the above that if the telescopic joints each presented a short intervening portion of line having a characteristic impedance of its own—differing from that of the quarter-wave sections and differing from that of the trombone—the impedance match between the trombone and main line sections brought about by the quarter-wave sections would be destroyed; and, of course, the impedance match between the main line sections would also be destroyed incidentally. In the structure of Fig. 3 the telescopic joints do not possess any characteristic impedance which differs from the characteristic impedance of the respective quarter-wave sections. This is true because, irrespective of the position of adjustment of the trombone, the

$$\frac{B}{A}$$

ratio within each telescoped portion remains constant, and always equal to that of one of the two connected sections—in this case the quarter-wave section.

In order to achieve that condition certain requirements must be met. These requirements are (1) the conductors of each of the two inter-telescoped sections must be external and internal, respectively, in relation to the corresponding conductors of the other section, and (2) the external axial conductor must be co-terminous with the internal tubular conductor. Applying this rule, it will be seen that section 6 (Fig. 3) is composed of a tubular member 6a constituting the internal tubular member of joint 11, while the companion member 6b constitutes the external axial member of the joint. The other half of joint 11 is composed of an external tubular member 4a and an internal axial member 4b. This satisfies the first requirement of the rule. The second requirement of the rule is satisfied by the fact that the lower end of conductor 6b is co-terminous with the lower end of conductor 6a. That is to say, they terminate in the same lateral plane. If they did not so terminate there would be introduced a section of intermediate character-

istic impedance which would impair the impedance match.

With the view to further clarification of this important point, there is shown in Fig. 4 a trombone structure which is the full equivalent, mechanically, of Fig. 3, but quite different electrically in that it does not satisfy the requirements of the above-stated rule and, therefore, will not maintain an impedance match when the trombone is moved in either direction from the one precise setting in which it is shown in full lines.

The only constructional difference between Fig. 3 and Fig. 4 is that in Fig. 4 the relationship of the axial conductors 4b' and 6b' is reversed as compared to the corresponding conductors of Fig. 3. Axial conductors 8b' and 9b' are shown smaller than corresponding conductors 8b and 9b in order to conform to the essentialities for obtainment of an impedance match with the trombone in the position of adjustment wherein it is shown in full lines. In that position and no other the characteristic impedance of the trombone of Fig. 4 is matched to those of the main line sections 8' and 9'; and that is true because when the trombone is moved to any other position such, for example, as that indicated by the dot-dash lines, there is introduced at each joint a new intermediate characteristic impedance which arises from the presence of a new

$$\frac{B}{A}$$

ratio. This ratio, with the trombone moved upwardly, would be

$$\frac{B_1}{A_2}$$

and with the trombone moved downwardly it would be

$$\frac{B_2}{A_1}$$

Any arrangement utilizing the trombone section, or its equivalent, in combination with the two quarter-wave sections, to achieve a constant impedance match is within the contemplation of this invention; but the arrangement illustrated in Fig. 3 embodying the novel telescopic joints therein shown represents the preferred practice.

Details of construction of the adjusting arrangement of Fig. 2 are shown in Fig. 5, and it will be observed that this is electrically identical with Fig. 3.

Obviously, the legs of the trombone can be made of any convenient length; and the length of adjusting section 10 can likewise, be anything desired.

I claim:

1. In a co-axial transmission line, two quarter-wave-length co-axial matching sections, and a U-shaped co-axial trombone section interconnecting said quarter-wave-length sections and adjustably movable with respect thereto, there being a telescopic sliding joint formed between one end of said trombone section and one end of one of said quarter-wave-length sections, and a second telescopic sliding joint formed between the other end of said trombone section and one end of the other quarter-wave-length section, one half of each said joint comprising an internal axial conductive member and an external tubular conductive member surrounding and concentric with said axial conductive member, the other half of each said joint comprising an external axial conductive member and an internal tubular conductive member surrounding

and concentric with said external axial conductive member, said tubular conductive members of each joint being slidably telescoped together, said axial conductive members of each joint being slidably telescoped together, said external axial conductive member being co-terminous with said internal tubular conductive member.

2. In a co-axial transmission line, two co-axial impedance-matching sections each having an electrical length equal to an odd number of quarter-wave lengths, and a U-shaped co-axial trombone section interconnecting said matching sections and adjustably movable with respect thereto, there being a telescopic sliding joint formed between one end of said trombone section and one end of one of said matching sections, and a second telescopic sliding joint formed between the other end of said trombone section and one end of the other matching section, one half of each said joint comprising an internal axial conductive member and an external tubular conductive member surrounding and concentric with said axial conductive member, the other half of each said joint comprising an external axial conductive member and an internal tubular conductive member surrounding and concentric with said external axial conductive member, said tubular conductive members of each joint being slidably telescoped together, said axial conductive members of each joint being slidably telescoped together, said external axial conductive member being co-terminous with said internal tubular conductive member.

3. A co-axial transmission line comprising two main sections, an adjustable movable section for varying the length of the line, and two coupling sections, all of said sections being connected in series, said coupling sections each having an electrical length equal to an odd number of quarter-wave lengths, and each interposed lengthwise between and interconnecting one of said main sections and one end of said adjusting section, each of said coupling sections having a characteristic impedance equal to the geometric mean of the characteristic impedances of the said sections to which it is immediately connected.

4. A co-axial transmission line comprising two main sections, an adjustable movable section for varying the length of the line, and two coupling sections, all of said sections being connected in series, said coupling sections each having an electrical length equal to a quarter-wave length, and each interposed lengthwise between and interconnecting one of said main sections and one end of said adjusting section, each of said coupling sections having a characteristic impedance equal to the geometric mean of the characteristic impedances of the said sections to which it is immediately connected.

5. A co-axial transmission line comprising two main sections, an adjustably movable U-shaped trombone section for varying the length of the line, and two coupling sections, all of said sections being connected in series, said coupling sections each having an electrical length equal to an odd number of quarter-wave lengths, and each interposed lengthwise between and interconnecting one of said main sections and one end of said trombone section, each of said coupling sections having a characteristic impedance equal to the geometric mean of the characteristic impedances of the said sections to which it is immediately connected.

6. A co-axial transmission line comprising two main sections, an adjustably movably U-shaped

trombone section for varying the length of the line, and two coupling sections, all of said sections being connected in series, said coupling sections each having an electrical length equal to a quarter-wave length, and each interposed lengthwise between and interconnecting one of said main sections and one end of said trombone section, each of said coupling sections having a characteristic impedance equal to the geometric mean of the characteristic impedances of the said sections to which it is immediately connected.

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