

June 5, 1956

MING S. WONG

2,749,522

CIRCULAR LINE STRETCHER

Filed March 24, 1952

4 Sheets-Sheet 1

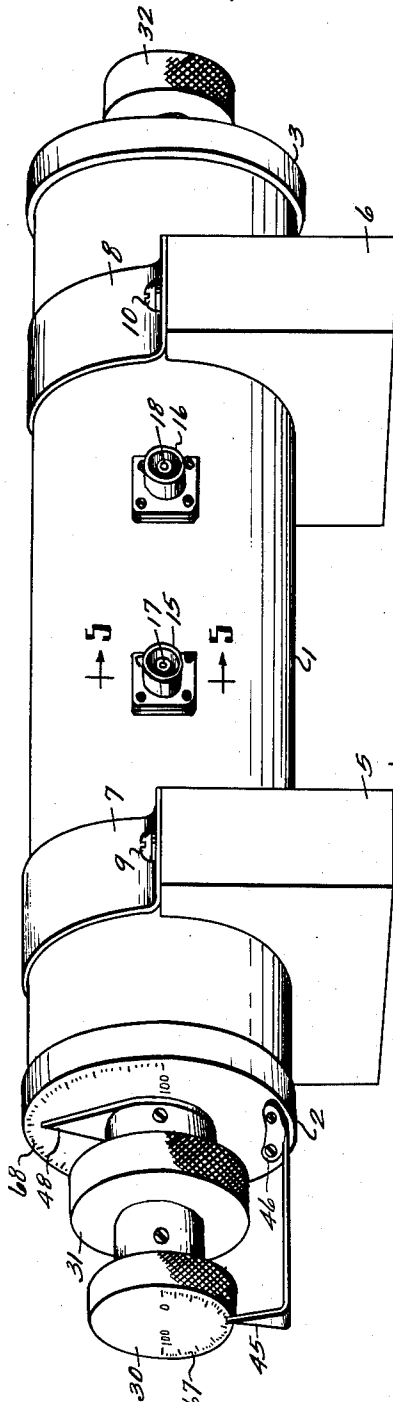


Fig. 1

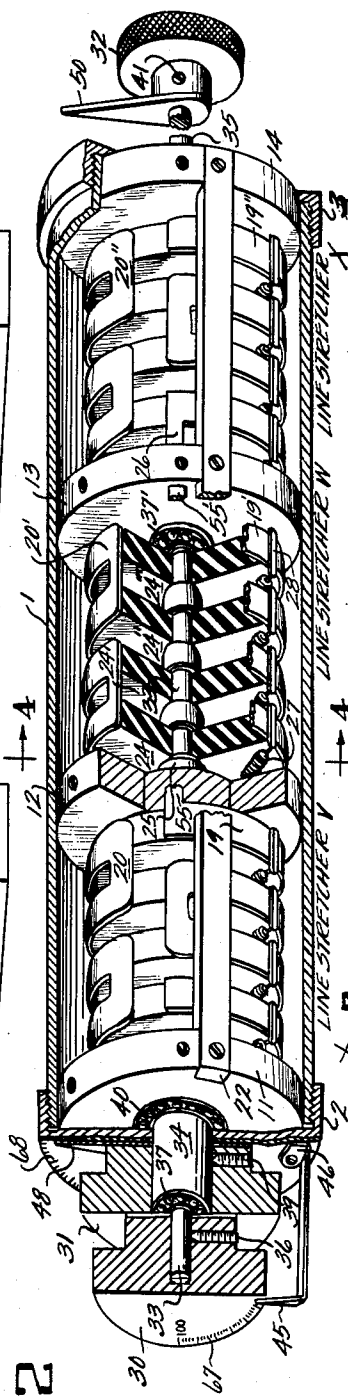


Fig. 2

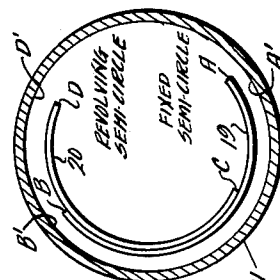


Fig. 3

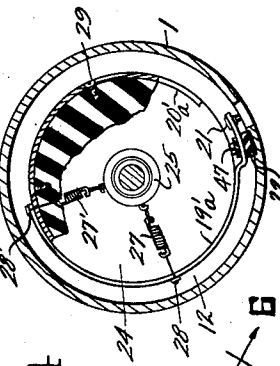
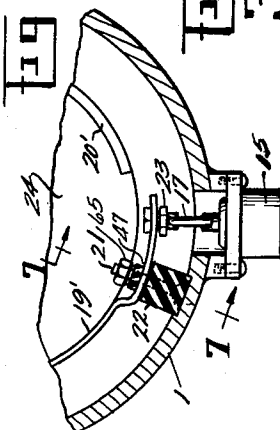


Fig. 5

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Fig 6

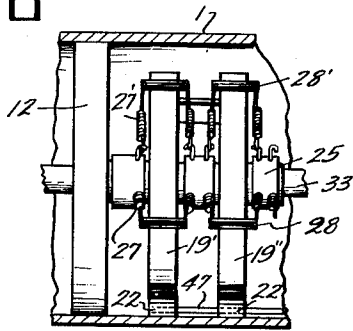


Fig 7

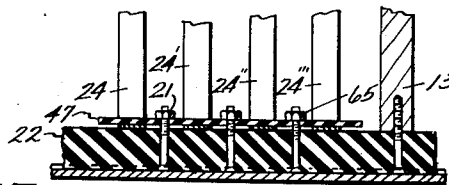


Fig 12

Fig 8

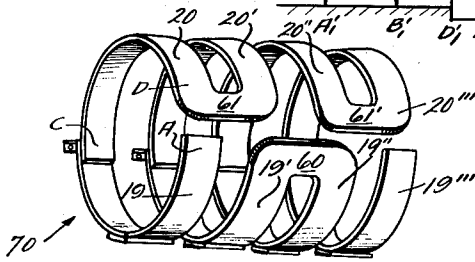


Fig 11

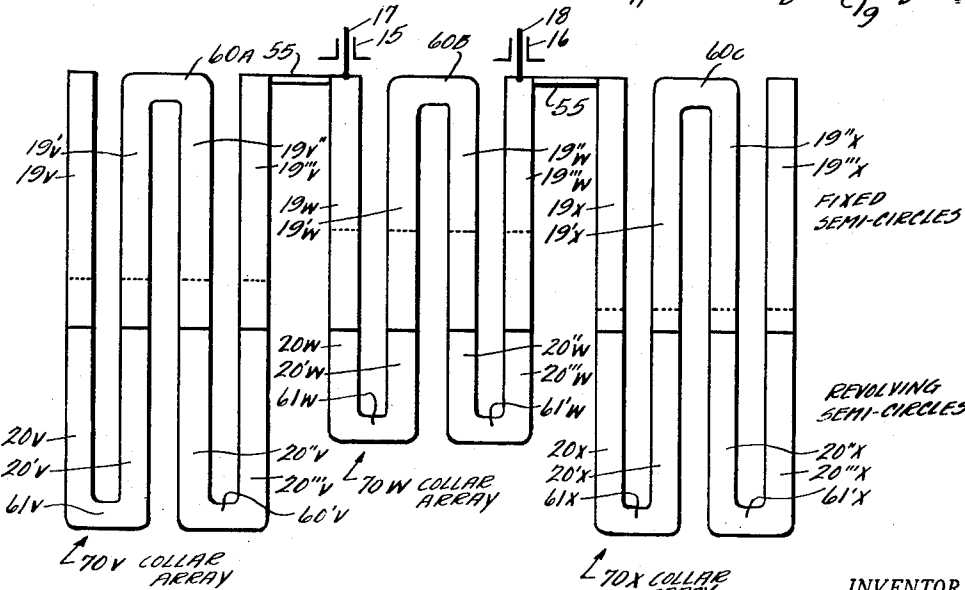
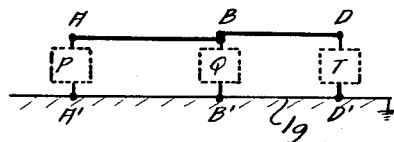


Fig 9

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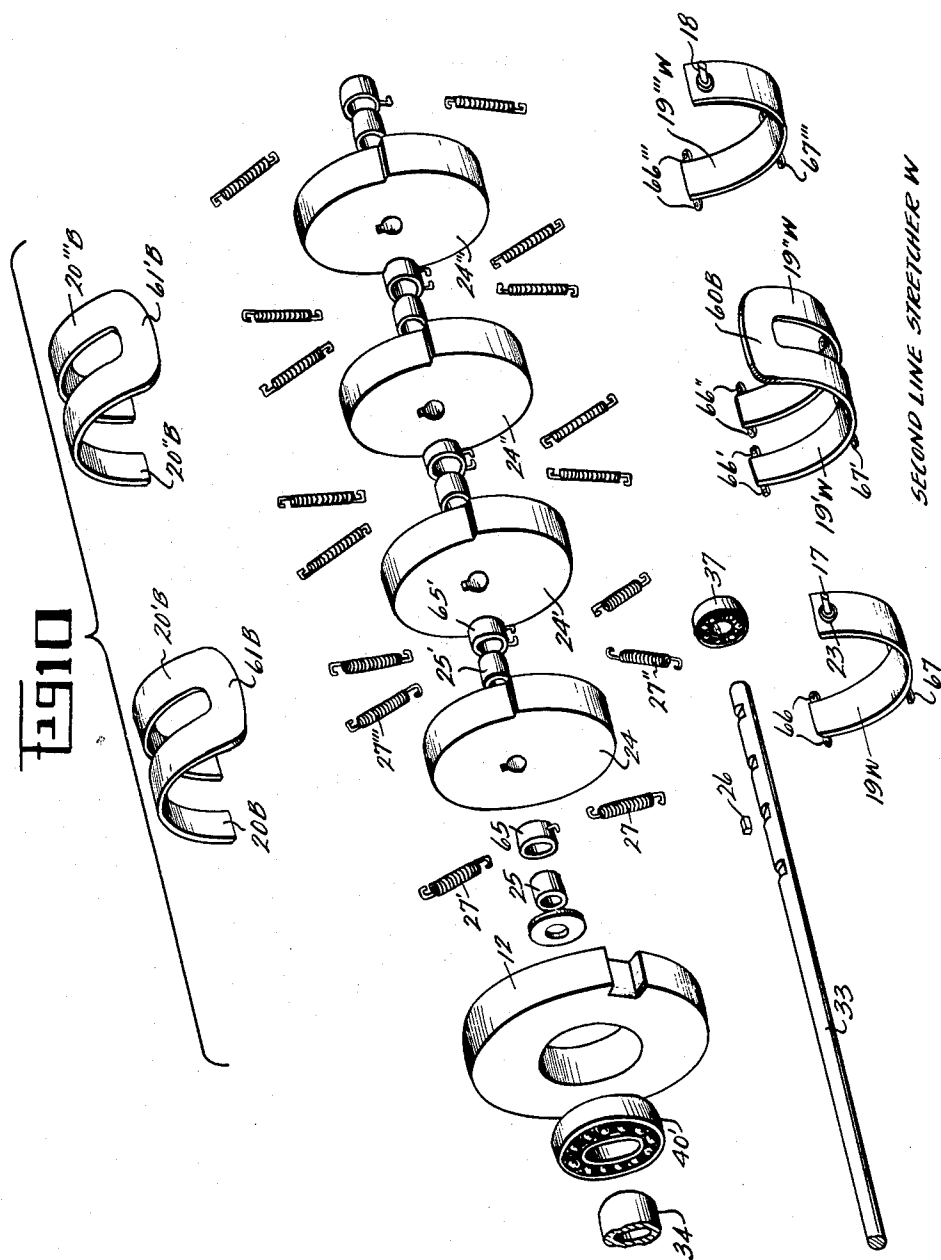
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CIRCULAR LINE STRETCHER

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4 Sheets-Sheet 4

Fig 13

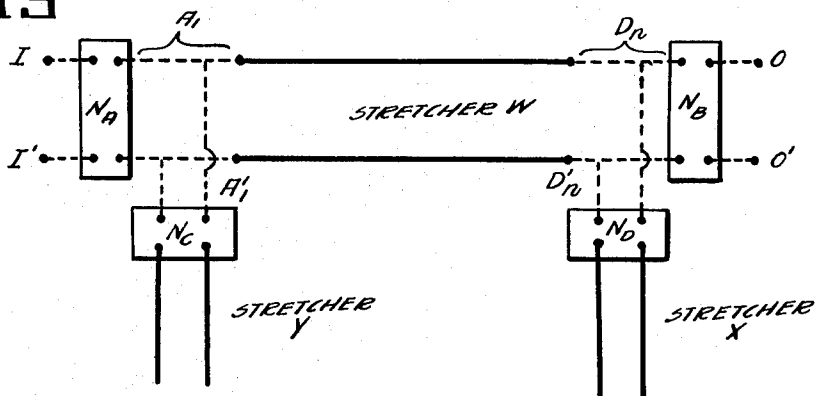


Fig 14



Fig 15

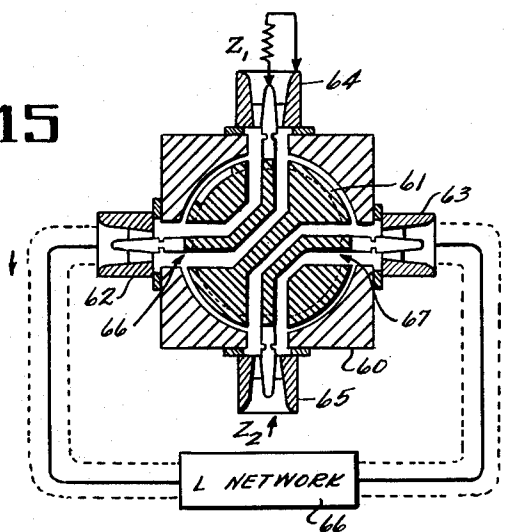
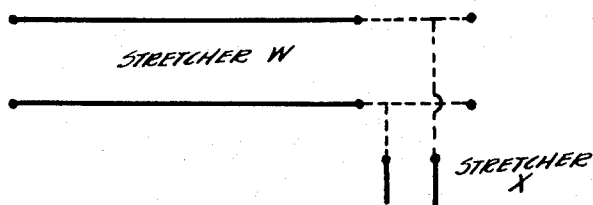


Fig 16



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2,749,522

CIRCULAR LINE STRETCHER

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Application March 24, 1952, Serial No. 278,286

7 Claims. (Cl. 333—31)

(Granted under Title 35, U. S. Code (1952), sec. 266)

This invention relates to electrical radio frequency transmission line stretchers and more particularly to a compact circular radio frequency transmission line stretcher for use in any tuning and impedance-matching networks.

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment of any royalty thereon.

In previous radio frequency transmission line stretchers length variations commonly have been obtained by telescoping or tromboning adjustments. Adjustments of this type are not mechanically desirable where good wearing quality is desired as a result of which tuning stubs have had a more extensive use than line stretchers in this particular field. A tuning stub, however, cannot serve all of the purposes that a stretcher can. As an example a pi network of three stretchers can be tuned at each frequency over a broad band to transform any impedance value to any other impedance value such as to effect a perfect conjugate match between two arbitrary impedances. In the pi network mentioned, the two stretchers used in shunt may be replaced by tuning stubs, but if a network of tuning stubs alone were used which can be connected only in shunt, it is possible to tune in general for only partial impedance matching at each frequency over the band.

The present invention provides a circular line stretcher that avoids the troublesome telescoping or tromboning adjustment of previous stretchers by rotational sliding contact between semicircular conductor strips or stretcher components. The present invention provides a line stretcher with an input and output at fixed positions; a combination of three stretchers forming an impedance matching network connected in a pi arrangement; and a combination of two stretchers with or without a crossover switch.

The objects of the present invention provide an improved line stretcher that is compact in size; is easily and accurately used or adjusted; is readily adapted for use in forming impedance matching units; is adapted for providing a desired number of sections; and that has such other objects and attributes as shall appear hereinafter.

An illustrative example of the present invention is shown in the accompanying drawings wherein:

Figure 1 is a perspective view of the outside of a line stretcher device that embodies the present invention;

Figure 2 is a perspective view of the device shown in Figure 1 with parts broken away and in section to show the arrangement of the interior thereof;

Figure 3 is a diagrammatic sketch of a section of the device in Figure 2;

Figure 4 is a sectional view taken along the line 4—4 of Figure 2 looking in the direction indicated by the arrows and with a revolving insulating disc broken away and in section to the depth of screws securing a conductor strip thereto;

Figure 5 is a fragmentary sectional view taken near line 5—5 of Figure 1 adjacent to one of the coaxial connections;

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Figure 6 is a fragmentary longitudinal view partly in section of the spring mount taken approximately from the line 6—6 of Figure 4;

Figure 7 is a fragmentary sectional view showing the mounting of the fixed semi-circular conductor strips and taken substantially along the line 7—7 of Figure 5;

Figure 8 is a perspective view of a representative array of collars consisting of fixed and revolving semicircles illustrative of those in compartments of the device shown in Figure 2;

Figure 9 is a plan view of the flattened collars shown in Figure 8 prior to their having been bent to a circular shape;

Figure 10 is an exploded view of the second line stretcher in Figure 2;

Figures 11 and 12 represent respectively equivalent circuits for a single-section line stretcher and for a four-section line stretcher;

Figures 13 and 14 represent respectively equivalent and basic circuits for the device shown in Figures 1 and 2;

Figure 15 is a sectional view of a crossover switch with an indicated connection with an L matching network; and

Figure 16 represents an L network of two line stretchers.

The circular line stretcher shown in Figures 1 to 10, inclusive, of the accompanying drawings is connected in a pi network and comprises as an outer conductor of brass or the like, a hollow cylindrical tube or shell 1 closed at its opposite ends by caps 2 and 3. Blocks 5 and 6 support the shell 1 and are attached thereto by straps 7 and 8 and screws 9 and 10.

The interior of the shell 1 is divided by conductive spacers 11, 12, 13 and 14 of brass or the like, into a plurality of illustratively three compartments each containing a line stretcher that is separately adjustable from an end of the device.

Electrical connection with the device is made by means of a pair of coaxial fittings having outer conductors 15 and 16 grounded to the shell 1 and inner conductors 17 and 18 insulated from the outer conductors 15 and 16 and connected electrically as indicated in Figures 9 and 10. In comparison with a coaxial line, the shell 1 fed from the coaxial fitting outer conductors 15 and 16 is analogous to the coaxial line outer conductor and the collar arrays comprising fixed and movable semicircles 19 and 20, respectively, fed from the coaxial fitting inner conductors 17 and 18 are analogous to the inner conductor, of a radio frequency line of variable length. An illustrative transmission line reference may be found at pages 172-197 of Radio Engineers Handbook by Frederick E. Terman, first edition, published in 1943 by McGraw Hill Book Co. The transmission line stretchers are sufficiently related to each other so that the description of one line stretcher will suffice as a description of the others.

The circular line stretcher that is contemplated hereby is derived from a single collar consisting of a first conductive semicircular strip held fixed in position and hence called herein a fixed semicircle as distinct from a second conductive semicircular strip that is revolved in sliding contact with the fixed semicircle and hence called a revolving semicircle. Such a union is represented in Figures 2, 3, 8, 9 and 10 of the drawings with the fixed semicircle 19 and the revolving semicircle 20 positioned concentrically of the cylindrical shell 101 to comprise a one-section line stretcher. The two transmission-line conductors of the one section in Figure 3 may be defined as the outer conductor or cylindrical shell 101 and the inner conductor or adjustable collar consisting of the semicircles 19 and 20. In the interest of association, the reference numerals 19 and 20 are retained in Figures 2 and 9 with the letters V, W and X added for the different line stretchers as they are referred to.

An array of collars comprises a plurality of like collars

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positioned in axially spaced alignment with respect to each other, as the collar array 70 shown in Figure 8. The array of collars are connected in tandem by jumper strips 60 and 61, preferably as shown in Figures 8 and 9, to comprise a W array of four collars that is continuous and conductive from one end to the other.

A circular line stretcher, such as the stretchers V, W and X shown in Figure 2, comprises a duplicated plurality of sections connected in tandem. Within one line stretcher, of which the second or middle line stretcher in Figure 2 and Figures 8 and 9 may be taken as being representative, the fixed semicircles 19W, 19'W, 19''W and 19'''W are clamped firmly by bolt 21 between an insulating polystyrene post 22 and a polystyrene strip 47, as shown in section in Figure 5. The post 22 extends axially of the assembly for substantially its full length and preferably is screw mounted into the metal spacers 11, 12, 13 and 14 so that during manufacture the resulting line stretcher interior assembly may be inserted as a unit from one end into the shell 1.

The fixed semicircle 19W of Figure 9 has a split hollow-shaft bolt 23 and nut mounted adjacent each of its secured ends, as shown in Figure 5 for one end thereof. The split hollow shaft in the bolt and nut assembly 23 is adapted to receive a spring pressed coaxial fitting inner conductor 17 shown in Figures 1, 5 and 9. The other coaxial fitting inner conductor 18 is spring pressed similarly into the split hollow shaft of a corresponding nut and bolt assembly indicated in Figures 9 and 10 at the opposite end of the fixed semicircle of the second line stretcher.

Each revolving semicircle is supported suitably on a rotating assembly within the shell 1 as on insulating discs 24, 24' etc. separated by slip rings 25, 25', etc. and keyed to a supporting shaft 33 by square keys 26, 26' etc., or the like. Springs 27, 27', 27'' and 27''' attached at their radially inner ends to slip rings such as 65 and 65' on opposite sides of a disc 24 and at their radially outer ends to yokes 66 and 67 straddling the disc 24 hold in uniform contact the fixed semicircle 19Y uniformly and yieldingly against the revolving semicircle 20Y that preferably is depressed into the periphery of and secured by screws 29 to the disc 24.

The shaft 33 of the line stretcher W extends axially and centrally of the cylindrical shell 1 to an end thereof where it has a knob 30 secured to the shaft by a set screw 36. The shaft 33 is suitably journaled for smooth operation, as on ball bearings 37 and 38 or the like. In a similar manner the knobs 31 and 32 turn the revolving semicircles in the line stretchers V and X, respectively of the device in Fig. 2. The knob 31 of the line stretcher V is secured to its tubular shaft 34 by a set screw 39. The tubular shaft 34 preferably is journaled in ball bearings 40 and 40' and is concentric with the shaft 33 that extends along its interior. The knob 32 of the line stretcher X is secured to its shaft 35 by a set screw 41. The shaft of the line stretcher X also preferably is journaled in ball bearings, not shown for ease of rotation.

The setting of knob 30 is indicated on a movable scale 67 inscribed along the edge of the knob 30 by a pointer 45 that is immovably secured to the tube cap 2 by screws 46. The setting of knob 31 is indicated on a scale 68 inscribed on the shell cap 2 by a pointer 48 secured to and rotating with the knob 31. The setting of knob 32 is indicated on a fixed scale, not shown, inscribed on the cap 3 by a pointer 50 that is secured to and that moves with the rotation of the knob 32.

By moving the revolving array of semicircular conductor strips with respect to the fixed array by operation of the knobs 30, 31 and 32 the line stretchers within the tube 1 may be individually increased or decreased in length.

As shown broken away in Figure 2 and as indicated in Figure 9, the opposite ends of the collar array 70W of the line stretcher W are connected by a conducting bar 55 to the adjacent right hand end of the collar array 70V of

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the line stretcher V and by a conducting bar 55' to the adjacent left hand end of the collar array 70X of the line stretcher X. Clearance holes 56 and 56' are provided in the metal spacers 12 and 13 so that the connecting bars 55 and 55' are insulated from the shell 1. The ends of the collar arrays in the line stretchers V and X remote from the conducting bars 55 and 56 are unattached or open circuited.

With respect to Figure 3 of the drawing wherein the cylindrical shell 101 and the semicircles 19 and 20 are regarded as two transmission-line elements, the letters A and B indicate remote ends of the fixed semicircle 19 and the letters C and D indicate the remote ends of the revolving semicircle. Corresponding positions on the inner surface of the shell 1 will be referred to by corresponding letters primed. The ends A, B, and D on the outer surface of the two semicircles serve as terminals in one side of the transmission line elements. Corresponding inner surface positions on the shell 101 are referred to as A', B' and D', as shown in Figure 3. The two line elements are connected in tandem at the terminal pair B—B' by virtue of the overlapping contact of the semicircles. The terminal pairs A—A' and D—D', the former fixed in position and the latter revolving in a 180 degree arc during the adjustment of the collar, define the internal ends of the circular section and are the input and the output of the section.

In Fig. 1 the coaxial fittings 15 and 16 provide externally accessible terminal pairs to which coaxial cables may be connected directly. It is within the concept of the present invention that the connections to the device may be altered or modified for particular applications.

When the circular section in Fig. 3 is connected to a radio frequency source, the electrical field in the section may be viewed as extending mainly between the outer surface of the collar and a corresponding area on the inner surface of the cylindrical shell designated by the reference numeral 1 in Figures 1, 2, 4, 5 and 6 and designated in Figure 3 as 101. This portion of the shell 101 in Figure 3, lying opposite and radially across from the inner conductor adjustable collar array 70, is similar to the collar in area and shape, provided the space between the shell 1 or 101 and the collar array 70 is sufficiently small compared with the height of the collar. Relatively few electrical lines of force terminate on the remaining portion of the shell or in the entire inner surface of the collar. These surfaces, where few electrical lines of force terminate, may be termed inactive as distinguished from the active surfaces between which the principal part of the electrical field exists.

Some electrical lines may fringe outside the region between the active conducting surfaces and thus may terminate on the inactive surfaces. Under this circumstance some degree of residual coupling exists between the region where an electrical field is mainly confined and the outlying environment.

The effect of the residual coupling caused by outward fringing of the electrical field can be represented by a small residual susceptance distributed at each point along the line elements of the circular section. This residual susceptance may depend on the position of the point concerned and may vary with the position of the revolving semicircle since, as the revolving semicircle turns, it may alter the environment at various points in the line elements. As a result, the line elements may become slightly nonuniform along their lengths. Nonuniformities along the line elements however are not consequential in the operation of the stretcher and at most can affect the sharpness of the tuning of the stretcher. In any event the residual susceptance can always be made negligible by taking the precaution of making the collar array 70 to shell 1 or 101 air spacing sufficiently smaller than the collar array 70 height because the distances to which the outward fringing of the electrical field may extend are, sub-

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ject to the above mentioned precaution, smaller than the collar to shell spacing.

Fig. 11 shows an equivalent circuit for a circular section shown in Fig. 3 comprising two line elements in tandem and three lumped admittances P, Q and T. In this connection P represents the residual coupling between the terminal pair A—A' and its nearby environment at the fixed end of the section. T represents a similar coupling between the terminal pair D—D' at the revolving end D of the section. Q represents the admittance of the overlapping contact at B in the adjustable collar and also the physical discontinuity which may exist at the tandem connection due to a slight difference in the spacing of each semicircle from the shell 101. When the adjustable part of a collar array 70, as shown in Figure 8 outside its shell for clarity, revolves with respect to the associated fixed part of the same collar, the value of P is unaffected but the values of Q and T vary slightly depending upon the mechanical uniformity in the construction of the circular section. The line elements may be slightly nonuniform because of the residual susceptance distributed at each point along the line elements. The line elements may be nonuniform also because of dielectrics in the region between the outer surface of the collar and the inner surface of the cylindrical shell 101. Polystyrene may be used in part or in the whole of this region as a means of supporting the adjustable collar.

The geometrical proportioning of the line elements in the circular section may be chosen partly for mechanical convenience and partly to reduce residual coupling between the region where the electrical field is principally confined and the overlying environment of that region.

If air is the dielectric between the collar array 70 and the cylindrical shell 1 in a circular section, the characteristic impedance Z_0 for each of the two line elements in the section may be estimated approximately from the equation

$$Z_0 = 120\pi \frac{S}{h}$$

expressed in ohms. In this equation S is the spacing between the semicircle concerned and the shell 101, and h is the height of the collar.

The equivalent circuit for a multisection stretcher is a recurrent network of the circuit for a single section. This is typified in Fig. 12 which shows a 4-section stretcher bearing the same notation as that in Fig. 1 for a single section but with numerical subscripts added to identify each section. The connection from one section to the next is represented as being made through an arbitrary 4-terminal network N₁, N₂, or N₃. These networks are included in order to permit all possible manner of making a tandem connection from one section to the next. A 4-terminal network represents the most general form of tandem connection. The residual admittances T₁, P₂, T₂, P₃, T₃, and P₄ are absorbed in the networks N₁, N₂, and N₃ and hence do not appear explicitly in the four-section circuit.

Since the revolving end of one section is connected to the fixed end of the following section, it follows that except for minor variations in the sections, the networks N₁ and N₃, N₅, etc. in an equivalent circuit for a multisection stretcher are substantially identical with each other and N₂, N₄, N₆, etc. are similarly identical. The line element on one side of each of the networks N₁, N₂, N₃, etc., is identical in this sense with the line element on the other side of the same network. All of the residual admittances Q's at the overlapping contact in each of the sections are identical. By virtue of these features the multisection stretcher is a symmetrical ladder network when it contains an equal number of sections. This is true even if the line elements in the stretcher are nonuniform.

The equivalent circuit in Fig. 12 is subject to a condition that it has no crossover coupling between any two of the transmission line elements, the coupling between

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one line element and another is assumed to occur only through a tandem connection.

An analogy of each of the multisection stretchers V, W and X shown in Fig. 2 is indicated in the multisection circuit shown in Fig. 11. A multisection stretcher may be viewed as a stack of a plurality of circular sections coaxially one above another—with the cylindrical shells directly one above another to form a single shell such as the shell 1 in Fig. 2, to form an adjustable collar array—the collars connected together in series inside of the shell. The shell 1 and the collar array (such as the array 70 in Fig. 8) constitute, respectively, the outer and inner conductors of a multisection stretcher.

The collar array 70 is represented in Figs. 8 and 9 as a continuous extension of the collars with U-shaped turns at their ends so that the array is a continuous winding strip running alternately a clockwise excursion along one collar and then, after making a U turn, running a counterclockwise excursion along the next collar. The U turns which in general may differ from the collar slightly in equivalent characteristics are considered to be part of the network N's in the equivalent circuit for the multisection stretcher.

The collars of each collar array are clamped together as represented in Fig. 7 with one end of each semicircle in the fixed semi-cylindrical array clamped between a polystyrene post 22 and a clamping strip 47. The remainder of each fixed semicircle is pressed against the cylindrical surface of a revolving disc 24 in the center rotating assembly of the device in Fig. 2.

The rotating assembly or rotor supports a number of revolving insulating discs 24, 24', 24'', etc., such that when the rotor turns it does so as a rigid body assembly. As previously described each disc 24 is recessed along one-half its circumference to accommodate a semicircle of the revolving semicylindrical array, such that the disc presents a uniform diameter in revolving contact with the fixed semicircle which presses against it. The discs 24, 24', 24'', etc., are located where little electromagnetic field exists, and may be made of Bakelite.

In the overlapping contact between the fixed and the revolving semicircles in each collar, the contact is particularly important near the end of the fixed and larger semicircle and hence a pair of tension springs 27—27' is used at this end of the fixed semicircle. One or more pairs of springs may be used at intermediate positions between the ends of the fixed semicircle where desired to maintain the shape of the fixed semicircle when the revolving semicircle turns. Insulating cords attach one end of each spring to the fixed semicircle where narrow re-enforcing metallic strips are positioned to prevent the fixed semicircle from bulging in the axial direction as a result of spring pressure. The opposite end of each spring is anchored in the center shaft through slip rings which are free to idle, such that when the shaft rotates, the spring is not subjected to a twisting action.

Since only revolving slip contact between two semi-circular metallic strips is involved in the mechanical operation of the stretcher, suitable conductors of copper or aluminum may be used for the cylindrical shell and for the revolving semicircles and phosphorous-bronze, preferably silver plated on the active side, is used for the fixed semicircles.

In the arrangement shown in Figs. 4 to 8, inclusive, of the drawings, the only dielectrics present in the line elements of the stretcher are the polystyrene post 22 and the clamping strip 47 used for supporting the fixed semicylindrical array of semicircles within the shell 1, for minimizing dielectric loss. For low-frequency applications and where desired, dielectrics may be added to increase the variable electrical length of the stretcher, such as either completely or partially to fill the space between the shell 1 and the collar array with dielectrics.

The validity of the multisection circuit in Fig. 11 is subject to the condition that there be no cross-over cou-

pling between any two of the line elements in the stretcher. Experimentally it has been determined that fringing of the electromagnetic field between a pair of parallel plates does not usually extend to distances larger than the spacing between the plates. Crossover coupling is reduced to a tolerable degree by making the height of each collar several times larger than the spacing S (along the axial direction) between the collar and the cylindrical shell, by making the separation between adjacent collars larger than the spacing S between the collar and the shell, and by not allowing the fixed and revolving ends in each collar to approach each other more closely than a circumferential gap with the magnitude of S . Since a line stretcher is used as a variable device, crossover coupling among the line elements would not adversely affect the operation of the stretcher, but merely would affect the sharpness of its tuning. The same conclusion applies with regard to nonuniformities in the line elements caused by residual distributed susceptance, mechanical variations in the individual circular sections, and variations which may occur in the residual admittances P 's, Q 's and T 's or in the 4-terminal networks N 's during adjustment of the stretcher. All of these conditions affect to a slight degree the sharpness of tuning of the stretcher. The sharpness of tuning is, in any case, a variable thing depending on the impedance values at the input end and the output end of the stretcher.

A precaution to be taken with regard to crossover coupling is to make sure that such coupling does not become so pronounced that it excessively reduces the range over which the electrical length of the stretcher is variable.

When the rotor is rotated within a 180° arc, the range R over which the physical length of the stretcher may be varied is

$$R = n \left(\pi \frac{d}{2} - a \right)$$

wherein n is the number of sections in the stretcher, d is the diameter of each revolving semicircle, and a is the arc length representing the minimum allowable separation between the fixed and the revolving ends of each collar (the length a must be exceeded by the separation between ends of the collar when these ends approach each other).

As an example, consider a 4-section stretcher with an outer cylindrical shell which has an internal diameter of 10 inches and an internal height of 10 inches. By using a collar height of $1\frac{1}{2}$ inches and a collar to shell spacing of 0.35 inch, the lowest frequency at which the physical length of the stretcher can be varied by a half wave length is about 100 megacycles per second. An equivalent trombone device would extend longer than 5 feet in its largest dimension. For frequencies above 1,000 megacycles, a two section stretcher with a 2.5 inch internal diameter and a 2.5 inch internal height is sufficient.

A perfect conjugate match between any two impedance values in the complete impedance plane can be effected by a pi network comprising a line stretcher and a variable shunt reactance at each end of the stretcher. A perfect conjugate match between any two impedances in the complete impedance plane can also be effected by an L network comprising a line stretcher and the variable shunt reactance at only one end, provided a switching arrangement is added for interchanging the input and the output connections of the L network. The circular line stretcher contemplated hereby is particularly well adapted for combination in a pi or L network so that the network can be formed as a single matching unit.

A representation is shown schematically in Fig. 13 of the accompanying drawings of three stretchers connected in a pi network. In Fig. 13 each pair of parallel lines represents a line stretcher which may or may not be equivalent to a uniform transmission-line, depending on whether the equivalent circuit of the line stretcher is symmetrical or not. The dashed lines represent "straight through" connections of zero electrical length. I—I'

and O—O' are the externally accessible terminal pairs at the input and the output of the network. A_1 — A_1' and D_n — D_n' are the internal terminal-pairs at the ends of the stretcher W in Fig. 2. N_A , N_B , N_C and N_D are 4-terminal networks. The networks N_A , N_B , N_C and N_D represent the physical connections for connecting one stretcher to another, or connecting one end of a stretcher to an externally accessible terminal-pair, and may be taken to be arbitrary to permit generality and freedom in making the necessary connections.

In Fig. 13 the line stretchers V , W and X are shown interconnected in a pi network by means of tandem connections through the 4-terminal networks N_C and N_D in essentially the same way as the individual sections of circular line stretchers are connected in tandem with one another. In the present device, a pi network of stretchers may be provided as a single unit with the elongated shell 1 replacing the individual shells of the stretchers V , W , and X , with the collar arrays of the stretchers connected in series, and with these series-connected collar arrays placed coaxially inside the elongated shell.

Fig. 9 shows a developed plane view of the series connections of the collar arrays 70V, 70W and 70X. The collars in each array are of the same length and are adjustable independently of the collars in the other arrays. Coaxial connectors are connected to the ends of the second or center stretcher for the input and the output connections to the pi network unit in Figs. 1 and 2. This assemblage is shown diagrammatically in Fig. 13 as an equivalent circuit and in Fig. 14 as a basic circuit for a pi network of stretchers. Each of the shunt stretchers may be replaced by a circular tuning stub consisting of a circular transmission line element short circuited by a revolving plunger. Such a circular stub, which is used in tuning the standing wave detector in a commercially made slotted line, has a length which is variable from nearly zero to nearly full circumference. In comparison, however, the length variation of the stretcher contemplated hereby can be increased indefinitely by increasing the number of sections.

For some ranges of impedance matching, one of the shunt stretchers or shunt stubs in a pi network is not needed so that an L network such as that shown in Figure 16 of the accompanying drawings of 2 line stretchers designate stretcher W and stretcher X may be used. The L network can effect a perfect conjugate match between any two impedances if a means is provided for interchanging the input and output connections to the network.

In Figure 15 of the drawings is shown an L network 66 applied to such a means of a commercially available crossover switch. The L network is connected by coaxial cables to connector fittings 62 and 63 secured in the housing 60 inside of which is a rotor 61. Load impedance Z_1 is connected to the fitting 64 and another impedance Z_2 is connected to the fitting 65. The operation of the L network 66 then determines the impedance Z_2 .

It is to be understood that the structure and the operation of the device disclosed herein and the parts thereof have been submitted for the purposes of illustrating and describing an operative embodiment of the present invention and that similarly operating substitutions and modifications may be made therein without departing from the scope of the present invention.

What I claim is:

1. An open end cylindrical electrical line stretcher of continuously variable electrical length, comprising an electrically conductive hollow cylindrical outer conductor, an electrically conductive inner conductor of electrically conductive flat strips arranged cylindrically in a serpentine configuration within and concentric with said outer conductor and circumferentially adjustable substantially from a half circle toward a full circle and insulated electrically from said outer conductor, an inner conductor supporting assembly, and means for adjusting the inner

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conductor supporting assembly in altering the electrical length of the line stretcher.

2. The line stretcher in claim 1 inclusive of an inner conductor operating shaft extending axially and centrally of both the inner conductor and the outer conductor for adjusting the variable inner conductor from outwardly of the line stretcher.

3. The line stretcher in claim 1 wherein an air gap disposed between the inner conductor and the outer conductor is smaller than the width of the inner conductor strip for minimizing the residual susceptance of the line stretcher.

4. The open end line stretcher defined in claim 1 inclusive of spring means maintaining a radially directed compressive force between pairs of contacting inner conductor strips during the adjustment thereof.

5. The line stretcher in claim 1 wherein the inner conductor includes a plurality of consecutively inverted flat half-circle U-shaped strips in adjacent overlapping engagement for electrically conductive continuity in a plurality of adjusted positions of said inner conductor.

6. A line stretcher of variable length comprising a hollow cylindrical outer conductor, an inner conductor within and insulated from said outer conductor and of continuously variable physical length and comprising a first fixed semicylindrical array of an even number of semicylindrical axially straight and electrically connected strips, and a second revolving semicylindrical array of the same even number of semicylindrical axially straight

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and electrically connected strips in mating circumferentially directed frictional engagement with the axially straight and electrically connected strips of said first array to impart electrical conductivity continuity throughout the length of said inner conductor, and an array mounting means providing for the adjustment of said revolving array with respect to said fixed array in adjusting the electrical length of said line stretcher.

7. A multiple line stretcher device equivalent to a plurality of variable length transmission lines, comprising an outer conductor consisting of an electrically conductive hollow cylindrical shell, and a plurality of inner conductors consisting of a plurality of interconnected circumferentially adjustable collar arrays in mutually overlapping wiping contacting electrically conductive engagement in pairs and positioned within to be substantially concentric with and substantially uniformly spaced from and at all adjusted positions in insulated relation with the cylindrical shell.

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