Dec. 20, 1955

C. F. P. ROSE

2,728,051

IMPEDANCE TRANSFORMERS

Filed Aug. 15, 1952

2 Sheets-Sheet 1

FIG. 1

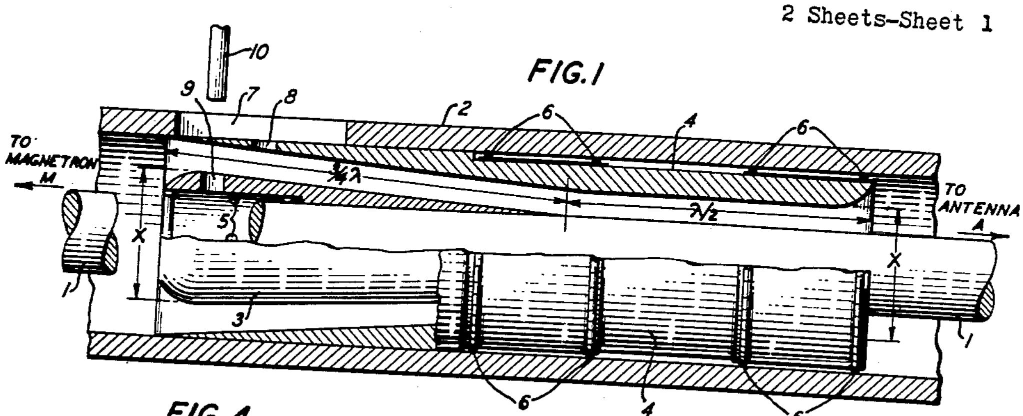


FIG. 4

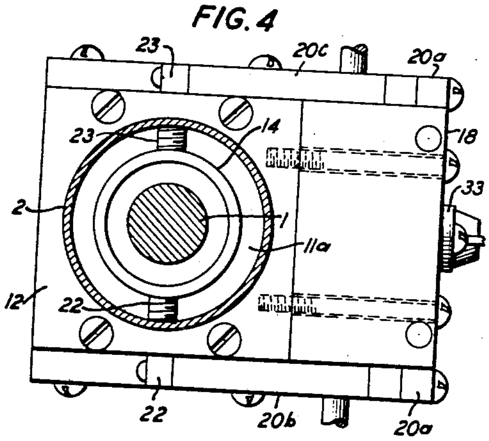


FIG. 6

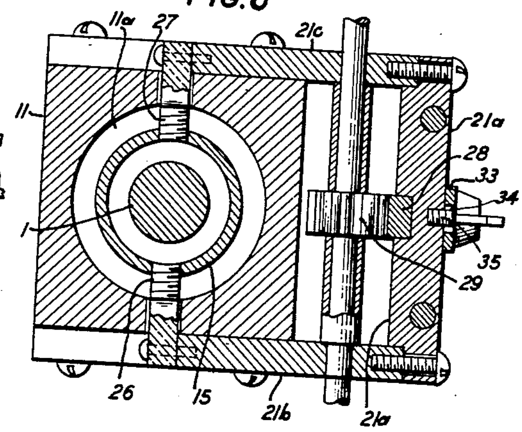


FIG. 5

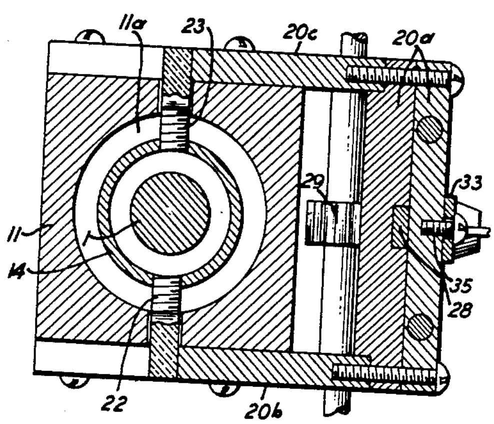
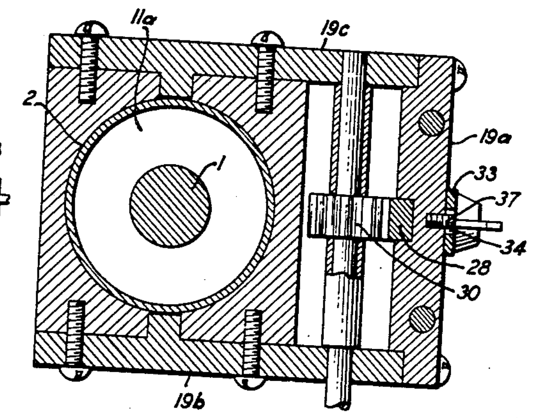


FIG. 7



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2 Sheets-Sheet 2

FIG. 2

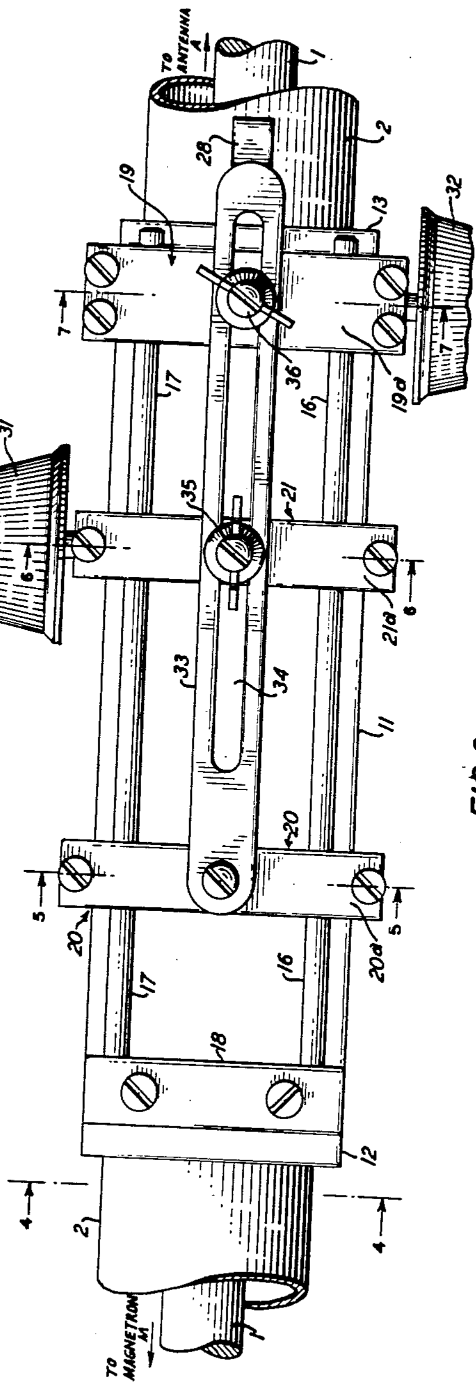
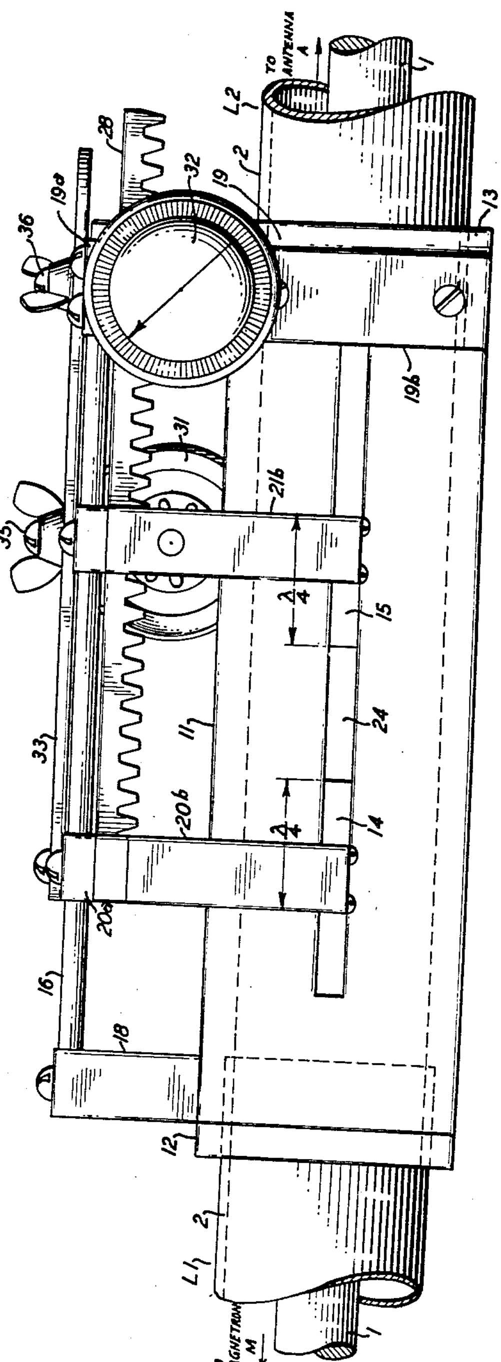


FIG. 3



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United States Patent Office

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IMPEDANCE TRANSFORMERS

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Original application May 18, 1949, Serial No. 94,013. Divided and this application August 15, 1952, Serial No. 304,460

2 Claims. (Cl. 333—35)

The invention relates to high frequency transmission systems, and particularly to impedance transformers for use in such systems to transform the impedance of one transmission device or line therein so that it may be electrically coupled to another transmission device or line having an impedance of different value or type without the introduction of detrimental transmission effects.

This application is a division of my copending application, Serial No. 94,013, filed May 18, 1949, which issued as Patent No. 2,627,550 on February 3, 1953.

The invention is applicable, for example, to a transmission line coupling between an oscillation generator or other source of high frequency electric waves, such as a magnetron. having an impedance embodying both reactance and resistance components, and a radiating antenna or other load device having a highly resistive impedance. It is known that efficient transmission of high frequency power from one such device to another requires that the device be properly matched in impedance so as to avoid the production of standing waves with consequent increase in transmission losses, due to reflections at junction points or other causes. For this purpose, it is usual to insert some sort of transformer in the connecting line to transform the impedance coupled to one end of the line to a different value of impedance at the other end. Such transformers may comprise transmission lines of either fixed or adjustable lengths. In certain known systems, they have been in the form of an additional section or sections of transmission line having an effective length equal to a quarter of a wavelength ($\lambda/4$), or an odd multiple thereof, of the wave to be transmitted, and of characteristic impedance such as to provide the desired transformation ratio.

A general object of the invention is to improve transformers of the above-described general type from the standpoint of simplicity, flexibility and reduction in manufacturing costs.

Another object is to efficiently couple transmission devices of different impedence characteristics without introducing appreciable transmission losses.

A more specific object is to match the impedance of a source of high frequency oscillations, such as a magnetron, having an internal impedance embodying resistance different from that of the usual line, and also reactance, to that of a load, such as a radiating antenna, which is highly resistive.

The impedance transformers in accordance with the invention are of the adjustable coaxial or wave guide line type. In one embodiment of the invention, the impedance transformer consists of a tapered (conical) metal core member ¾ wavelength long slidable longitudinally along the inner conductor of a coaxial line connecting a magnetron or other reactive high frequency wave generator to an antenna or other resistive load device, and an outer metal shell member 5/4 wavelengths long slidable longitudinally along the inside of the outer conductor of the connecting coaxial line. The inside of the outer shell member is correspondingly tapered at one end for ¾

wavelength so that in one adjusted position it closely surrounds the core member, and is cylindrical for the remainder of its length. Means are provided for manually sliding both members simultaneously with a fixed longitudinal relationship between them, longitudinally along the coaxial line towards or away from the reactive generator until an adjustment point is found at which the reactance component of the internal impedance of the generator is effectively neutralized; and for independently sliding one of the two members longitudinally along the line in either direction to so adjust its longitudinal proximity with respect to the other member as to match or equalize the resistance components of the impedance of the generator and antenna or other load device.

In another embodiment of the invention, the impedance transformer comprises a hollow metal housing of circular inner cross-section connecting two sections of air-dielectric coaxial line respectively extending to the reactive high frequency generator and to the antenna or other resistive load device; two cylindrical tubular sleeve members of conductive material, each ¼ wavelength long and having inner and outer diameters properly dimensioned with respect to the outer diameter of the inner coaxial line conductor and the inside diameter of the outer coaxial line conductor, respectively, to provide the required characteristic impedance for the transformer, which members are mounted in cascade relation with each other coaxially within the housing; and suitable gearing and associated locking means for causing the two cylindrical tubular members, each of which in itself is a quarter wavelength transformer, to be moved longitudinally together, i.e., in fixed longitudinal relationship with respect to each other, or independently in either direction within the housing without metallic contact with the inner wall of the latter. The joint movement of the two members may be used to adjust the distance of these members from the generator to an optimum point at which the reactance of the internal impedance of the latter is effectively neutralized; and the independent adjustment of one or the other of the two members may be used to adjust the longitudinal proximity of that element with respect to the other so as to effect the required impedance transformation between the send and receive ends of the cascaded members to match or equalize the resistance components of the impedance of the generator and antenna or other load device.

The various objects and features of the invention will be better understood from the following detailed description when read in conjunction with the accompanying drawings in which:

Fig. 1 shows a front elevation assembly view, drawn full scale, partly in cross-section and partly broken away to show structural details, of one embodiment of the impedance transformer of the invention;

Figs. 2 and 3 show, respectively, a plan and a front elevation assembly view of another embodiment of the impedance transformer of the invention; and

Figs. 4 to 7, inclusive, show respectively sectional views taken along the lines 4—4, 5—5, 6—6 and 7—7 of the assembly of Fig. 2 to illustrate various structural details of the second embodiment of the invention.

Fig. 1 shows one embodiment of the impedance transformer of the invention applied to a coaxial line having inner and outer concentric conductors 1 and 2, respectively, connecting a high frequency generator M of the magnetron type to a radiating antenna A in a radar system. The generator M may be, for example, a magnetron such as is disclosed in the United States patent of A. L. Samuel, No. 2,063,343, issued December 8, 1938, and the antenna A may be of the coaxial line type, such as disclosed, for example, in the United State patent of W. H. C. Higgins and C. A. Warren, No. 2,424,982, issued August 5, 1947. Such a magnetron may have an internal impedance somewhat different from that of the coaxial line, and also reactance; whereas the antenna may have an impedance which is predominately resistive.

The impedance transformer of Fig. 1 includes a central core member 3 and an outer shell member 4 both made from a conductive material, such as brass. The core member 3, which is of frusto-conical shape and has a length which is ¾ of a wavelength (3λ/4) of the wave to be transmitted from magnetron M to antenna A, is mounted with its thicker end nearest the lower impedance, represented in this case by the magnetron M, coaxially within the outer conductor 2 of said coaxial line, by means of a central opening of constant diameter along its longitudinal axis (axis of member 3) on the inner coaxial line conductor 1 so as to be slidable longitudinally therealong in either direction. The shell member 4, which is cylindrically shaped on the outside and has a length which is 5⁄4 of a wavelength (5λ/4) of the wave to be transmitted, is arranged to be slidable longitudinally in either direction along the inner surface of the outer coaxial line conductor 2. The inside of the shell member 4 is of circular cross-section and is tapered at one end nearest the magnetron M for ¾ of a wavelength (3λ/4) so that for one adjusted position of the two members 3 and 4 with respect to each other along the coaxial line, the tapered portion of member 4 will closely surround the frusto-conical core member 3 throughout the entire length (3λ/4) of the latter, and is cylindrical for the remainder of its length.

As shown, the outer diameter of the frusto-conical core member 3 at its thicker end equals the inner diameter of the cylindrical portion of the outer shell member 4, and the outer diameter of the member 3 at its other end is slightly larger than the outer diameter of the inner coaxial line conductor 1. The core member 3 is recessed slightly on the inside for a given length at its thicker end, and this recessed portion is provided with one or more circumferential rows of Phosphor bronze spring fingers 5 with coin silver ends to hold the member 3 in good contact with the outer surface of the inner coaxial line conductor 1. The outer surface of the outer shell 4 at its thicker end, is similarly recessed for a substantial portion of its length, and one or more circumferential rows of phosphor bronze spring fingers 6 with coin silver ends are attached thereto to provide good electrical contact of the outer shell member 4 with the inner surface of the outer coaxial line conductor 2 at all times. Preferably, as shown, the longitudinal recess in the outer surface of shell member 4 extends to the center thereof to provide adequate contact at the current maximum point and thereby reduce sparking. The other ends of the two slidable members 3 and 4 contain longitudinal slits (not shown) to provide enough flexibility of these members to maintain the associated spring fingers in close contact with the outer surface of the inner coaxial line conductor 1 and the inner surface of the outer coaxial line conductor 2, respectively, when the two members 3 and 4 are moved longitudinally in either direction. A long slot 7 is cut in the side of the outer coaxial line conductor 2, at an intermediate point of the coaxial line, and transverse apertures 8 and 9 are provided, as shown in the tapered portion of the outer shell member 4 near its thinner end, and in the inner core member 3 near its thicker end, respectively.

The manner of adjustment of the impedance transformer of Fig. 1 so that it will match the impedances of the magnetron M and the antenna A to a high degree of accuracy will now be described.

With the members 3 and 4 initially positioned so that the apertures 9 and 8, respectively, therein are aligned vertically with each other and an intermediate point along the slot 7 in the outer coaxial line conductor 2, the operator will insert the end of a rod 10 of insulating material, such as polystyrene, through slot 7 and both apertures 8 and 9. The operator will then push the rod 10 to the left or right against the sides of apertures 8 and 9 so as to slide both members 3 and 4 as a unit longitudinally along the associated inner and outer coaxial line conductors 1 and 2, respectively, towards or away from the magnetron M until these members are located at the optimum distance from the magnetron at which the reactance component of the latter is effectively neutralized. When this point is found, the inner core member 3 is maintained stationary in its adjusted position, and the end of the rod 10 is withdrawn from aperture 9 in the core member 3 but is maintained within the aperture 8 in the outer shell member 4. The operator will then push the rod to the left or right along the slot 7 so that it will bear against the side of aperture 8 in shell member 4 causing that member to slide longitudinally along the inner surface of the outer coaxial line conductor 2 until its longitudinal proximity with respect to the stationary core member 3 is properly adjusted to match or equalize the resistance components of magnetron M and the antenna A.

The optimum adjustment of the position of the core member 3 and shell member 4 of the impedance transformer of Fig. 1 may be determined by trial and error measurements of the standing wave ratio (ratio of maximum to minimum voltage) within the coaxial line for different adjustments of the members. When the observed standing wave ratio is a minimum the impedances of magnetron M and its antenna A are properly matched. Such measurements may be made with a standing wave detector of any of the well-known types, for example, one employing a movable probe within the coaxial line, coupled through a coaxial jack in the side of the line to a measuring circuit employing a crystal detector, an amplifier and an oscilloscope in tandem.

The characteristic impedance of any portion of the impedance transformer shown in Fig. 1 may be determined from the following conventional formula applicable to an air-dielectric coaxial line:

$$Z_0 = 138 \log_{10} \frac{D}{d} \qquad (1)$$

where

Z_0=the characteristic impedance of the coaxial line,

D=the inner diameter of the outer conductor of the coaxial line, and

d=the outer diameter of the inner conductor of the coaxial line.

An experimental impedance transformer such as shown in Fig. 1 was built and tested in the output circuit of a magnetron working at a wavelength of approximately 10 centimeters into a coaxial line having an inner concentric conductor of 0.625-inch diameter and an outer concentric conductor of 1.527-inches diameter. The largest diameter X of the frusto-conical member 3, which equals the inside diameter of the cylindrical portion of the outer shell member 4, was determined for this transformer as follows:

$$\frac{X}{.625} = \frac{1.527}{X}$$

$$X^2 = .955$$

$$X = .977''$$

The characteristic impedance of the coaxial line is

$$X_0 = 138 \log_{10} \frac{1.527}{.625} = 53.5\omega$$

The impedance Z_1 at the point of the largest diameter of the core member 3 when the members 3 and 4 are positioned as shown in Fig. 1 is

$$Z_1 = 138 \log_{10} \frac{.977}{.625} = 138 \log_{10} \frac{1.527}{.977} = 26.8\omega$$

The transformation ratio N of the transformer equals

$$\frac{Z_0}{Z_1} = \frac{53.5}{26.8} = 2$$

In the test referred to above, a position was found for adjustment of the inner core member 3 and outer shell member 4 of the experimental transformer which presented an optimum impedance to the magnetron and, therefore, allowed maximum power to be supplied to the load (antenna) beyond the transformer. The test showed also that movement of the inner core member 3 a ½ wavelength (λ/2) closer to the magnetron, gave essentially the same results, i. e., the same impedance Z was presented to the magnetron and the same power was delivered to the load. The latter adjustment position was advantageous in that it permitted operation of the impedance transformer of Fig. 1 at positions which will not have the undesirable breakdown voltages which it has when the two members are overlapped in position.

The other embodiment of the impedance transformer of the invention illustrated in Figs. 2 to 7, inclusive, includes a hollow housing **11**, which is shown as being of square cross-section but may be of circular, rectangular or other suitable cross-section, connecting the two sections L1 and L2 of coaxial line having inner and outer concentric conductors **1** and **2**, respectively, leading to the magnetron M and the antenna A, respectively. The inside **11***a* of housing **11**, which is cylindrically shaped and may be of the same circular cross-section as the outer conductor **2** of the coaxial line forms a connecting link between the portions of the outer coaxial line conductor **2** in line sections L1 and L2 extending through the end plates **12** and **13**, respectively, of that housing as indicated in Fig. 3. Two cylindrical tubular or sleeve members **14** and **15** of a conductive material, such as brass, each having a length of ¼ of a wavelength (λ/4) of the operating frequency of the magnetron M and inner and outer diameters determined by the desired characteristic impedance of the transformer, are mounted coaxially within the housing **11** in cascade relation with each other in the manner to be described.

Two metal rods **16** and **17** extend in parallel with each other and the longitudinal axis of the housing **11** between and are fixedly attached to the block **18** attached to and projecting vertically above the top of housing **11** at one end thereof and a fixed bracket **19** of inverted-U shape comprising an upper transverse arm **19***a* and two vertical legs **19***b* and **19***c* extending downwardly therefrom on opposite sides of the housing, which is attached to and extends above the top of housing **11** at its other end. Two movable brackets **20** and **21** also of inverted-U shape have their upper transverse arms **20***a* and **21***a* slidably mounted on the rods **16** and **17** and their two vertical legs **20***b* and **20***c* and **21***b* and **21***c*, respectively, of suitable length extending downwardly from the transverse arms on opposite sides of the outside of housing **11**. Four members **22**, **23**, **26** and **27** of dielectric material, such as polystyrene, are employed for supporting the tubular members **14** and **15** in proper position within the housing **11**. Two of the dielectric members **22** and **23**, which have their outer ends respectively attached to the bottom of a different one of the two vertical legs **20***b* and **20***c* of movable bracket **20**, extend transversely through the centrally located longitudinal slots **24** and **25**, respectively, in opposite sides of housing **11** into the interior thereof, where their other ends are respectively attached at diametrically opposite points to the circumference of the tubular member **14** so as to support that member in coaxial relation with the housing **11** when it is displaced longitudinally therein in one direction or the other by slidable movement of the movable bracket **20** along the rods **16** and **17**. Similarly, the two dielectric members **26** and **27**, which have their outer ends respectively affixed to the bottom of a different one of the two vertical legs **21***b* and **21***c* of the movable bracket **21**, extend transversely through the longitudinal slots **24** and **25**, respectively, in opposite sides of the housing **11** into the interior thereof, where their other ends are respectively attached at diametrically opposite points to the circumference of the tubular member **15** so as to support that member in coaxial relation with the housing **11** when it is displaced longitudinally therein in either direction by slidable movement of the movable bracket **21** along the rods **16** and **17**.

The longitudinal movement of the movable brackets **20** and **21** along the rods **16** and **17** is controlled by a gearing arrangement comprising a rack **28** fixedly attached at one end to the transverse arm **20***a* of the movable bracket **20** and extending, in parallel with the longitudinal axis of housing **11**, through suitable openings in the transverse arms **21***a* and **19***a* of the movable bracket **21** and the fixed end bracket **19**, respectively, and two pinion gears **29** and **30** meshing with the rack **28**. The shafts of the gears **29** and **30** are respectively journaled for rotation between the vertical legs **21***b* and **21***c* of the movable bracket **21** and the vertical legs **19***b* and **19***c* of the fixed bracket **19** under respective control of the knurled knobs **31** and **32** respectively affixed to one end of the shaft of gear **29** and to one end of the shaft of gear **30**, to cause longitudinal movement of the rack **28** in one direction or the other.

A metal strap **33** having a longitudinal slot **34** therein, has one end affixed to the top of the transverse arm **20***a* of movable bracket **20** and extends across the tops of the transverse arms **21***a* and **19***a* of movable bracket **21** and the fixed end bracket **19**, respectively. A set screw **35** having a wing nut top, inserted through the slot **34** in strap **33**, is adapted to be screwed into a threaded hole in the top of the transverse arm **21***a* of movable bracket **21** to clamp the latter to strap **33** at a desired point along slot **34**; and a similar set screw **36** having a wing nut top, inserted through the slot **34** in strap **33**, is adapted to be screwed into a threaded hole in the top of the transverse arm **19***a* of the fixed bracket **19** to clamp the latter to strap **33** at a desired point along slot **34**.

The manner of adjustment of the impedance transformer of Figs. 2 to 7, so that it will match the impedances of the magnetron M and the antenna A respectively connected to the opposite ends of the transformer through coaxial line sections L1 and L2 to a high degree of accuracy, will now be described.

With the set screw **36** loosened so as to unclamp the fixed bracket **19** from strap **33** and the set screw **35** tightened to clamp movable bracket **21** to strap **33**, the operator will rotate knob **32** attached to the shaft of pinion **30** to the left or right to cause longitudinal movement of the rack **28** and thus of the movable brackets **20** and **21**, now effectively affixed thereto, to the left or right, so as to move both tubular members **14** and **15** supported by movable brackets **20** and **21**, respectively, together with a fixed longitudinal distance between them, longitudinally towards or away from the magnetron M until the members **14** and **15** are located at the optimum distance from the magnetron at which the reactance component of the latter is effectively neutralized. When this point is found, the set screw **36** is tightened to clamp fixed bracket **19** to the strap **33**, so as to prevent further movement of the rack **28** and the movable bracket **20** and thus of tubular member **14** attached thereto and maintain the adjusted longitudinal position of the members **14** and **15** with respect to the magnetron M at which the reactance of the latter is neutralized. The operator will then loosen set screw **35** to unclamp movable bracket **21** from strap **33** and will rotate the knob **31** attached to the shaft of pinion gear **29** to the right or left to cause a corresponding right or left rotation of gear **29**. This will move the movable bracket **21**, because the latter is now unclamped from strap **33** with set screw **35** loosened, and thus the tubular member **15** within housing **11**, to the right or left until the longitudinal proximity of the tubular member **15** with respect to the stationary tubular member **14** is properly adjusted to match or equalize the resistance components of the magnetron M and antenna A. The set screw **35** will then be tightened so as to clamp the movable bracket **21** to the strap **33** and maintain the relative longitudinal position of the tubular members **14** and **15** within the housing **11** at the optimum point found.

The optimum adjustment of the positions of the tubular members **14** and **15** of the impedance transformer of Figs. 2 to 7, as in the case of the impedance transformer of Fig. 1, may be determined by a series of trial and error measurements of the standing wave ratios within the housing **11** for different adjustments of the members, using a standing wave detector.

The mean diameter of each tubular member **14** and **15** is made equal to the geometrical mean of the diameters of the inner and outer concentric conductors **1** and **2** of the coaxial line. This was done to accommodate the greatest permissible irregularity in alignment of the two members **14** and **15** in assembly of the transformer. The other dimensions of the members **14** and **15** were made such as to satisfy the following well-known equations

$$Z_B=138\left(\log_{10}\frac{d}{a}-\log_{10}\frac{c}{b}\right) \qquad (2)$$

or

$$Z_B=138\left(\log_{10}\frac{b}{a}+\log\frac{d}{c}\right) \qquad (3)$$

where

Z_B=the characteristic impedance of tubular member **14** or **15**;
a=outer diameter of inner line conductor **1**;
b=inner diameter of tubular member **14** or **15**;
c=outer diameter or tubular member **14** or **15**;
d=inner diameter of outer line conductor **2**.

$$Z_B\sqrt{Z_AZ_C} \qquad (4)$$

where Z_A=sending impedance at input of transformer; and Z_C=terminating impedance at output of transformer.

Furthermore, a ¼ wavelength (λ/4) beyond the receiver end of the transformer, an impedance Z_D is seen, where

$$Z_D=\frac{Z_A^2}{Z_C}\text{ or }\frac{Z_A^3}{Z_B^2} \qquad (5)$$

In the practical embodiment of the impedance transformer of the invention shown in Figs. 2 to 7, which was constructed for use with a coaxial line having an inner concentric conductor of 0.625 inch diameter and an outer concentric conductor of 1.527 inches diameter, the inside diameter and outside diameter of each tubular member were 0.914 and 1.039 inches, respectively, and the design of the elements determining the range of longitudinal adjustment of the members **14** and **15** was such as to allow a minimum longitudinal spacing between them of not less than a ¼ wavelength and a maximum longitudinal spacing between them at least a ½ wavelength beyond that point.

A unique feature of the impedance transformer of Figs. 2 to 7 is that the mounting of the tubular members **14** and **15** within the housing **11** is such so that they do not make metallic contact with the inner wall of the housing during adjustment of the position of these members thereby eliminating the sparking difficulties involved in transformers utilizing sliding of the variable elements along metal surfaces.

Various modifications of the impedance transformer arrangements illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. A transformer for matching the impedance of a generator of oscillations of a given high frequency to that of a load device of a different impedance characteristic connected thereto by a coaxial transmission line having inner and outer concentric conductors, comprising a hollow housing of conductive material cylindrically shaped on the inside, inserted in said line, the interior of said housing being electrically coupled through opposite ends thereof to sections of said line connected to said generator and said load device, respectively, two cylindrical sleeve members of conductive material mounted coaxially within said housing in cascade relation with each other, each of said members having an electrical length equal to ¼ of a wavelength of said given frequency and selected outer and inner dimensions proportioned with respect to the inner diameter of the outer concentric line conductor and the outer diameter of the inner concentric line conductor, respectively, to provide a predetermined characteristic impedance for the members, means for establishing said members in fixed longitudinal relationship with respect to each other, means for simultaneously moving both of said members in said fixed longitudinal relationship in either direction along the axis of said housing without metallic contact with any part thereof, to a position at which the reactance components of the impedances of said generator and said load devices are effectively neutralized and means for maintaining one of said members in that position while separately adjusting the longitudinal proximity of the other member with respect thereto to effectively match the resistance components of the impedances of said generator and said load device, said members being adapted for longitudinal positioning within said housing through the intermediary of two brackets affixed to and extending above said housing at opposite ends thereof, a plurality of rods extending in parallel with the longitudinal axis of said housing between and affixed to said brackets, two movable brackets each having a transverse arm slidably mounted on said rods and two vertical legs extending downwardly from said arm on opposite sides of said housing, a centrally-located longitudinal slot in each side of said housing and four dielectric members respectively having one end thereof affixed to the bottom of a different one of the vertical legs of said two movable brackets and extending therefrom transversely through one of said slots to the interior of said housing, the two of said dielectric members which have their said one ends respectively affixed to the bottom of one of two of the vertical legs of one of said movable brackets, having their other ends respectively affixed to one of said sleeve members at diametrically opposite points on the circumference thereof, and the other two dielectric members which have their said one ends respectively affixed to the bottoms of a different one of the two vertical legs of the other of said movable brackets, having their other ends respectively affixed to the other of said sleeve members at diametrically opposite points on the circumference thereof.

2. A transformer for matching the impedance of a generator of oscillations of a given high frequency to that of a load device of a different impedance characteristic connected thereto by a coaxial transmission line having inner and outer concentric conductors, comprising a hollow housing of conductive material cylindrically shaped on the inside, inserted in said line, the interior of said housing being electrically coupled through opposite ends thereof to sections of said line connected to said generator and said load device, respectively, two cylindrical sleeve members of conductive material mounted coaxially within said housing in cascade relation with each other, each of said members having an electrical length equal to ¼ of a wavelength of said given frequency and selected outer and inner dimensions proportioned with respect to the inner diameter of the outer concentric line conductor and the outer diameter of the inner concentric line conductor, respectively, to provide a predetermined characteristic impedance for the member, means for establishing said members in fixed longitudinal relationship with respect to each other, means for simultaneously moving both of said members in said fixed longitudinal relationship in either direction along the axis of said housing without metallic contact with any part thereof, to a position at which the reactance components of the impedances of said generator and said

load devices are effectively neutralized and means for maintaining one of said members in that position while separately adjusting the longitudinal proximity of the other member with respect thereto to effectively match the resistance components of the impedances of said generator and said load device, the mounting of said sleeve members including a pair of brackets affixed to and projecting above said housing at opposite ends thereof, one or more rods extending in parallel with the longitudinal axis of said housing between said fixed brackets and a pair of movable brackets slidable along said rod or rods for respectively suspending a different one of said sleeve members within said housing in coaxial relation therewith and said longitudinal position adjusting means comprising a rack and pinion gearing arrangement, associated with said movable brackets, manually operable control knobs for respectively controlling operation of said gearing to move a different one of said movable brackets longitudinally along said rod or rods, and thus a different one of said sleeve members longitudinally within said housing, and separate means for respectively locking a different one of said movable brackets in fixed longitudinal position with respect to the ends of said housing or with respect to the other movable bracket.

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