April 15, 1952 J. A. RADO 2,593,183

TUNABLE WAVE SIGNAL DEVICE

Filed March 30, 1946

FIG. 1

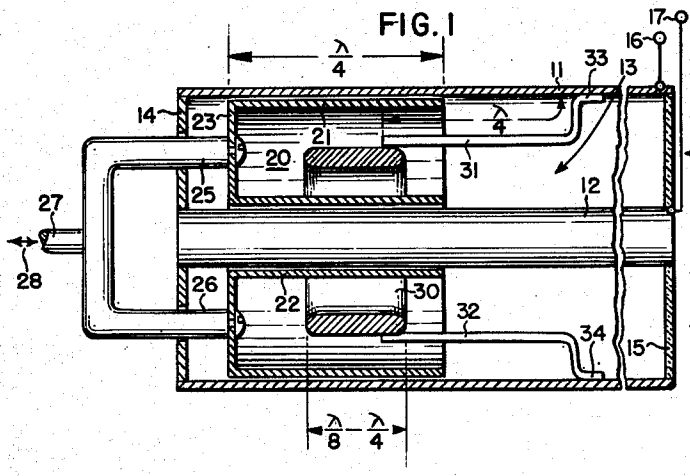


FIG. 2

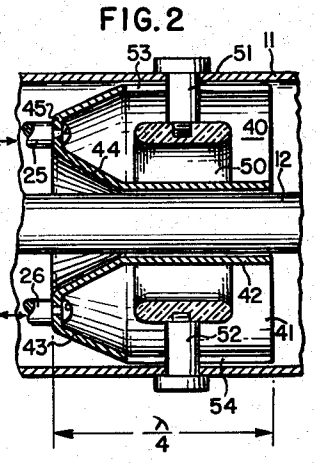


FIG. 3

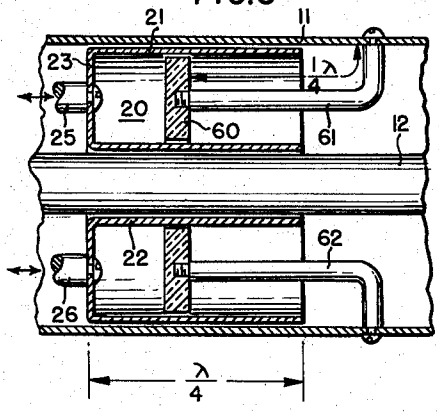


FIG. 4

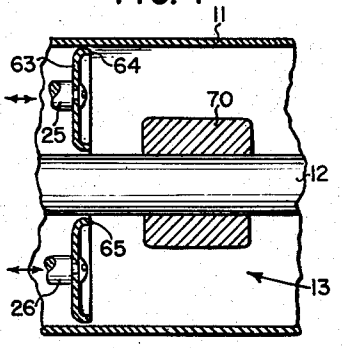
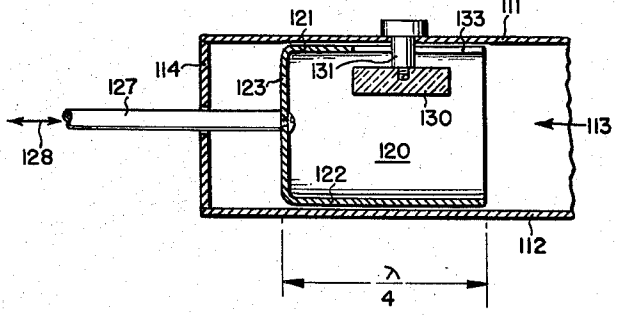


FIG. 5



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TUNABLE WAVE SIGNAL DEVICE

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7 Claims. (Cl. 178—44)

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This invention relates generally to an improved tunable wave-signal device adjustable over a given frequency range, and particularly to such a device including a resonant wave-guiding structure of adjustable electrical length.

As used broadly in this specification and in the appended claims, the term "wave-guiding structure" applies to a system of conductive surfaces which act as the boundaries of an electric wave and have the ability of directing the propagation of such a wave, much as the rigid walls of a speaking-tube guide sound by preventing the sound from spreading freely into space. Wave-guiding structures are well known in the art and may take the form of two or more separated conductors in open space, such as a power line or a telephone line. Such structures may be called transmission lines of the open-wire line type. Another type of wave-guiding structure comprises simply a single hollow conductor capable of propagating the wave through its interior; this type may be called a hollow guide. Still other types include one or more conductors enclosed within but electrically insulated from another conductor, as in the conventional coaxial transmission line. While certain details of design may depend on the type of structure and manner of its use, the term "wave-guiding structure" as used herein, refers to such resonant structures in the generic sense, including any of the types mentioned and refers also to the relatively short structures often designated as cavity resonators.

The electrical length of a wave-guiding structure may be determined by establishing a short-circuit thereacross, and the structure may be excited by the introduction of energy adaptable to the generation of electromagnetic waves. The waves travel along the guide, and reflections occasioned when the waves encounter the short circuit result in the setting up of standing waves in the cavity, which is then said to be in a resonant condition. In such a resonant condition, the alternating magnetic field in the guiding structure has a maximum intensity at the short circuit, and a point of maximum intensity of the electric field is established farther along the structure, measured in the direction from which the wave approaches the short circuit. The distance between these points of maximum magnetic and electric field intensities is equal to one-quarter of the instant operating wave length of the structure. Where the active portion of the resonant structure has a length greater than one-quarter of the operating wave length,

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the points of maximum magnetic and electric field intensities recur cyclically, each field varying sinusoidally between its maximum and minimum points but shifted 90 degrees in phase with respect to the other.

With a wave-guiding structure operating in such a resonant manner, the resonant frequency may depend on the method of excitation and on the nature and disposition of the materials within the wave-propagating space. In any case the resonant frequency is determined by the effective electrical length of the structure. If an arrangement is provided for changing the effective length, the structure becomes a tunable wave-signal device since its resonant frequency may be changed at will. At the higher radio frequencies, such tunable devices have found considerable use because of their accuracy of tuning, efficiency, and convenient dimensions.

A prior tunable wave-guiding structure includes a movable short-circuiting member adjustably placed near one end portion of the structure. Various forms have been proposed for this short-circuiting member, perhaps the simplest being merely a shorting bar or end cap. The portion of an end cap in contact with the conductive surfaces of the structure often is slit or otherwise divided into transverse segments, which press against the conductive surfaces by spring action to maintain adequate contact. Such a shorting device serves to delimit an active portion of the guiding structure, and adjustment of the device therealong changes the active physical length of the structure, causing a corresponding change in its effective electrical length, and thus accomplishing tuning.

The high magnitude of the alternating currents flowing in such a simple shorting member has prompted the addition of conductive surfaces connected to the end bar or cap and disposed in parallel relation to the surfaces of the wave-guiding structure proper. With these additional surfaces the short-circuiting member takes the form of a piston or cup slidable along the structure, the short-circuiting being effected by the closed end of the cup. The cup is usually proportioned so that it extends parallel to the wave-guiding structure for a distance equal to one-quarter wave length at the mean operating wave length. This permits electrical connection from the shorting member to the guiding structure to be made effectively in a region of high or maximum electric field intensity, where the magnetic field intensity and the currents flowing in the structure have low or minimum values.

With such a tuning piston, effective electrical connection may be made at radio frequencies by A. C coupling, eliminating the use of contact segments or fingers employing spring pressures.

The use of a short-circuiting member adjustable along a portion of the guiding structure has necessitated in some cases, in order to tune over the desired range, a distance of travel of that member equal to a substantial fraction of the over-all length of the structure. This lengthy adjustment not only makes tuning cumbersome, but also increases the mechanical complexity of the device and may be undesirable when space and weight are at a premium. In other words, since a given adjustment may produce an undesirably small tuning effect, the sensitivity of adjustment available with this tuning arrangement may be too small.

Another prior tunable wave-guiding structure utilizes a loading element movable along the structure in the wave-propagating space. With this arrangement the tuning varies with the position of the loading element, while active physical length of the structure remains the same for all tuning adjustments. The loading element changes the nature and disposition of the materials in the wave-propagating space, causing a change in the magnetic or electric fields, or in both fields, in the loaded section of the structure, that is, in the vicinity of the loading element. The change may be thought of as a phase shift brought about by the discontinuity resulting from the abrupt change in characteristic impedance caused by the loading element. The change also often may be thought of as a change in the inductance or capacitance exhibited by the loaded section. Thus, depending on the nature and disposition of the loading element, the loaded section may be considered as having a value of inductance or capacitance, or both, different from the apparent inductance or capacitance of an equal length of the structure which has no such loading. It is equally true that the loaded section may be considered as having a value of inductance or capacitance equal to the apparent inductance or capacitance of a different length of the structure without the loading and its resulting phase shift. Accordingly, the changes in the fields within the wave-propagating space, due to the loading element, have the effect of altering the electrical length of the wave-propagating structure, but without altering its active physical length.

Tuning of this prior wave-guiding structure is accomplished by moving the loading element axially along the structure. This causes the element to move relative to the points of maximum magnetic and electric field intensities, so that it enters a region where both fields have modified values. In other words, the ratio of magnetic to electric field intensities in the vicinity of the loading element changes as the element is moved along the resonant wave-guiding structure. Now, a given loading element may be made of materials having markedly different effects on the magnetic and electric fields. For instance, the element may have a strong effect on an electric field but practically no effect on a magnetic field. Hence, moving the element along the guiding structure into a region where the magnetic and electric field intensities have modified values and are in a different ratio changes the effect of the element on the fields so as to alter the effective electrical length of the guiding structure.

As with tuning by adjusting a short-circuiting member, however, instances have arisen in which it is desired to tune over such a wide range that excessive movement of a loading element, or a loading element of such a large size as to impair operation of the tuning device, would be required. In some installations the mechanical requirements of an adjustable loading element may prove bothersome. It may even prove impossible in some instances to tune over the entire desired range with any adjustable loading arrangement. The sensitivity of tuning adjustments with a loading element thus may be too small.

The described prior arrangements for tuning a resonant wave-guiding structure also may lack the nicety of adjustment desirable in certain types of equipment, particularly measuring and testing equipments. For such equipments it is often desirable to make a substantial adjustment of a tuning element or member when tuning over a relatively narrow range. In this instance the sensitivity of adjustment practically available with the known tuning arrangements, may be greater than that desired.

Accordingly, it is an object of this invention to provide a tunable wave-signal device which substantially avoids one or more of the above-mentioned limitations of prior arrangements.

It is also an object of this invention to provide a tunable wave-signal device having improved means for adjusting the device over a given frequency range.

It is a further object of the invention to provide a tunable wave-signal device including a tuning arrangement having a desired sensitivity characteristic and effective to tune the device over a given range of frequencies.

In accordance with the invention a tunable wave-signal device adjustable over a given frequency range comprises a wave-guiding structure including a plurality of longitudinally extending conductive surfaces defining a propagating space for electromagnetic waves. The device also comprises a short-circuiting member adjustable in a path extending longitudinally of the propagating space to effect tuning of the device over the frequency range, and effective to determine in accordance with its position the location of points of maximum intensity of the electric and magnetic fields within that space. The device further comprises a loading element of such cross-sectional shape and of such material as to provide in the wave-guiding structure a substantial coefficient of wave reflection, the element being positioned in a region of the propagating space subject to approximately the greatest longitudinal shifting of said fields during the tuning of the device. The tuning device further includes at least one support for the aforesaid element having a length substantially equal to one-quarter of the mean operating wave length of the device and affixed to the wave-guiding structure at a point outside of the path of adjustment of the short-circuiting member.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is an axial section through a tunable wave-signal device of the co-

axial transmission-line type embodying the present invention; Figs. 2, 3, and 4 are partial axial sections of tunable wave-signal devices similar to that shown in Fig. 1 but containing other embodiments of the invention; and Fig. 5 is an axial section through one end portion of a tunable wave-signal device of the hollow-guide type embodying the invention.

Referring to Fig. 1 of the drawing, there is illustrated a tunable wave-signal device adjustable over a given frequency range comprising a wave-guiding structure including a plurality of longitudinally extending conductive surfaces or portions 11, 12 defining a propagating space 13 for electromagnetic waves. The longitudinally extending conductive portion 11 is a hollow cylindrical outer conductor, while the conductive surface or portion 12 is a coaxially aligned inner conductor, providing therebetween the propagating space 13. The outer conductor 11 and inner conductor 12 are aligned and spaced by means of an end plate 14, which may be of either conductive or insulating material. The remote end of the structure is terminated in an end plate 15, which may be of a dielectric or a conductive material, depending on whether the structure has an effective electrical length of an odd or an even number of quarter waves, a dielectric end plate being illustrated. The structure may be excited by oscillatory means (not shown), and connections to suitable oscillatory circuits may be made at points 16 and 17 in circuit with outer conductor 11 and inner conductor 12, respectively.

In order to effect tuning of the device over a given frequency range, there is provided a piston-type short-circuiting member 20 which includes two coaxially aligned hollow cylindrical conductors, an outer conductor 21 and an inner conductor 22, forming piston walls parallel to conductors 11 and 12. The piston 20 is closed at one end by a short-circuiting ring 23, which aligns the conductors 21 and 22 and maintains them in positions adjacent to the longitudinally extending conductors 11 and 12, respectively. The piston is open at the opposite end so that it embraces a portion of propagating space 13. Conductors 21 and 22 are chosen of such a length that the piston 20 has an effective electrical length substantially equal to an odd integral multiple of one-quarter of the mean operating wave length of the device. A convenient length for the piston is usually approximately one-quarter of the mean operating wave length.

Piston 20 is adjustable longitudinally of propagating space 13 by means of rods 25, 26, fastened to the back of ring 23. These rods pass through appropriate holes in end plate 14, and are joined outside of the wave-guiding structure to a driving rod 27. As indicated by arrow 28, any suitable driving mechanism may be applied to driving rod 27 to effect displacement of piston 20.

The tunable wave-signal device further comprises a toroidal loading element 30. In the illustrated embodiment, the loading element is made of a conductive material, but a loading element of the same shape also may be made of nonconductive dielectric or magnetic material, in accordance with principles discussed hereinafter. Element 30 is supported for movement relative to piston 20 during the tuning of the device by at least one support, which may be of dielectric or conductive material, conductive supports being indicated for convenience in Fig. 1. This embodiment utilizes two radially thin supports or straps 31, 32 for supporting the element, and spacing it

from the closed end of the piston in the direction of the open end. The straps 31, 32 may be movably or fixedly connected to one of the conductors of the wave-guiding structure in such a manner that longitudinal adjustment of piston 20 produces relative movement of the loading element with respect to the piston; for convenience of illustration the straps are shown fastened to outer conductor 11 at points 33, 34, which are outside of the longitudinally extending path of adjustment of the piston.

Operation of the tunable wave-signal device of Fig. 1 will be described first neglecting the effects due to loading element 30. This discussion assumes the wave-guiding structure to be considerably longer than one-quarter wave length, for instance one and one-quarter wave lengths, but the same principles apply to shorter structures. Oscillatory energy is introduced at the fixed dielectric end plate 15 through terminals 16 and 17 so that wave energy propagates down the structure and is reflected from short-circuiting ring 23, bringing about a resonant condition as described above. When excited in this manner, the active propagating space of the structure has an effective length equal to an odd integral multiple of one-quarter wave length, and alternate points of maximum electric and magnetic field intensities appear along the propagating space and at each end thereof, these points being spaced one-quarter wave length apart. If piston 20 is moved longitudinally of the wave-guiding structure, the position of short-circuiting ring 23 with relation to the remote end 15 of the structure is changed. This causes a change in the physical length of the active portion of the structure and a like change in its effective electrical length. If properly excited, the structure remains in a resonant condition, but the quarter wave-length distance corresponding to the separation of succeeding points of maximum magnetic and electric field intensities is changed.

When piston 20 is moved, the point of maximum magnetic field intensity located at ring 23 necessarily moves with it. However, the point of maximum electric field intensity occurring at the remote end 15 of the structure is fixed and does not move. Therefore, displacement of the tuning piston, which alters the operating frequency, causes a redistribution of both the magnetic and electric fields within the wave-propagating space of the guide, shifting all points of maximum field intensity except that at end 15. It may be shown that the most pronounced longitudinal shifting of the fields takes place in the regions of the propagating space nearest to the tuning piston. Thus, it is seen that displacement of the piston 20 varies the effective electrical length of the structure to effect tuning. Further, it becomes apparent that the location of points of maximum intensity of the magnetic and electric fields in the propagating space 13 is determined in accordance with the position of the piston.

In considering the influence of loading element 30 on the described tuning process, it will be assumed that the element is located in its preferred position not very far from the short-circuiting ring, so as to be positioned in a region of propagating space 13 which is subject to the greatest longitudinal movement or shifting of the magnetic and electric fields during the tuning of the device. As shown in Fig. 1, the element is positioned at the tuning adjustment illustrated in a region of the space 13 wholly between the coaxial walls of the piston. With the

extreme tuning adjustment which gives the greatest active physical length, however, one end portion of the element 30 may protrude somewhat from the open end of the piston.

Since the loading element, as shown, is stationary during a tuning adjustment, the fields shift with reference to it during tuning and hence, place it in a region where the magnetic and electric field intensities have a ratio different from that resulting from the previous setting of piston 20. As pointed out above, this alteration in the field intensities changes the effect of the loading element on the fields, so as to alter the effective electrical length of the active portion of the guide structure. This alteration in effective electrical length is, in addition to that already described, due solely to adjustment of piston 20. Whether the tuning effects occasioned by the adjustment of the piston and by the presence of the loading element are additive, so that a more sensitive tuning arrangement is provided, or subtractive, so that a less sensitive tuning arrangement is provided, depends on the nature of the loading element and also on its position along the active part of the guiding structure.

Three types of loading elements may be mentioned. The element may be conductive, it may be of nonconductive material whose predominant characteristic is a high dielectric constant, or it may be a composition of low conductivity, the predominant characteristic of which is a high magnetic permeability. In general, the action of a conductive loading element is to decrease the effective electrical length when placed in a region of high magnetic field intensity and to increase the effective electrical length when placed in a region of high electric field intensity. A dielectric element has little effect in a region of high magnetic field intensity, but tends to increase the effective length if located in a region of high electric field intensity. A magnetic element having high permeability usually also has a rather high dielectric constant, so that it affects both magnetic and electric fields. The effect of a magnetic composition used in accordance with the present invention depends in part on the resistivity of the composition and, in part on the proportions of magnetic material and binding material ordinarily used to hold together the particles of magnetic material. Neglecting the action of dielectric or conductive materials in a so-called magnetic element, it tends to increase the effective length when positioned in a region of high magnetic field intensity.

To continue with the detailed operation of the Fig. 1 embodiment, let it be assumed that loading element 30 is of a conductive material and is positioned for the initial adjustment of piston 20 half way between the point of high magnetic field intensity at the shorting ring 23 and the nearest point of maximum electric field intensity. In this position the element is located within the quarter-wave region nearest the closed end of the piston. Adjustment of the piston toward the loading element shortens the active physical length of the structure. Simultaneously, the intensity of the magnetic field in the immediate neighborhood of the loading element increases. As mentioned above, this tends further to shorten the effective electrical length of the structure. Consequently, the described relative movement of the piston and the loading element produces additive effects and tends greatly to shorten the effective electrical length of the structure. Similarly, if the active physical length is increased by the opposite adjustment of piston 20, away from element 30, the element finds itself in a region of higher electric field intensity but lower magnetic field intensity, where it tends further to increase the effective length of the structure. Again, the two effects are additive. The net result is a more sensitive arrangement for tuning, since a smaller adjustment accomplishes the same result as would a larger adjustment of a loading element without a movable short-circuiting member, or of a movable short-circuiting member in the absence of a loading element.

If, however, the conductive loading element is located farther along the structure, so that its mean position is about one-quarter wave length farther removed from the shorting ring, its effect on tuning is very different. In this case a point of maximum electric field intensity exists near the element in the direction of the adjustable shorting ring 23, while a point of maximum magnetic field intensity exists near it in the direction of the fixed end plate 15. Its orientation with respect to the fields, thus is the reverse of the case previously considered where the element was positioned quite near the shorting ring. In the case now under consideration, a physical shortening of the propagating space brings the conductive member into a region of higher electric and lower magnetic field intensities, where it tends to increase the effective length. Thus, the two effects oppose each other, and the sensitivity of adjustment is smaller than would be obtained without the loading element.

An analysis of the operation in the case of a dielectric loading element shows its action to be similar to that of a conductive element. Similarly positioned dielectric and conductive elements produce similar effects on sensitivity of tuning, the dielectric element being responsive to the variations in the electric field alone rather than to variations in a combined field condition, such as ratio of electric to magnetic field intensities. A predominantly magnetic loading element, on the other hand, can be shown to have opposite effects on sensitivity of tuning. Thus, a dielectric element placed within a quarter-wave tuning piston increases the sensitivity, while a predominantly magnetic element in the same position decreases the sensitivity. Various combinations of element positioning, materials, and effects will be apparent to those skilled in the art.

The shape and dimensions of the loading element, as well as the material of which it is constructed, contribute to determine its effect on tuning. Within the limitations presently to be discussed, the larger the element the greater the effect. Elements having very large radial dimensions often cannot be used in wave-guiding structures on which high voltages appear, since there is the danger of arc-over. However, the axial dimension of a loading element, that is, the length of its major structural outline measured longitudinally of the wave-guiding structure, also plays an important part in determining its tuning effect. As its effective length is increased up to one-quarter of the mean operating wave length of the device, its tuning effect ordinarily increases. When longer elements are used, the effects of the two end portions may cancel each other, and further lengthening of the element until an effective length of one-half wave length is reached causes the

tuning effect of the element to become negligible.

Accordingly, the greatest tuning effect ordinarily is obtained with quarter-wave elements. However, for the special case when a conductive tuning element is placed adjacent the short-circuiting ring 23 at one tuning adjustment, a shorter element is desirable, so that at this extreme tuning adjustment the entire element occupies a region in which the magnetic field predominates. A conductive element so positioned has a large tuning effect during initial adjustment if it has a major axial dimension substantially equal to one-eighth of the mean operating wave length of the device. However, the tuning adjustments may be large enough to change the position of the element until it is centered on that point of maximum electric field intensity which exists one-quarter wave length distant from the short-circuiting ring. When in the latter position, the element is far enough removed from the shorting ring so that its length should be approximately equal to one-quarter wave length to produce optimum tuning effect during subsequent small adjustments. For optimum tuning effect over the tuning range mentioned, a conductive element supported in the vicinity of the short-circuiting member, and having a length of between one-eighth and three-sixteenths of the mean operating wave length, for instance one-sixth wave length, is desirable.

In a specific embodiment of the invention using a quarter-wave tuning piston two and three-quarters inches long in a coaxial line, a conductive loading element of toroidal shape and one and one-half inches long was positioned within the piston. In this embodiment the loading element was supported by radially thin dielectric supports of sufficient circumferential width to provide the required strength and of a polystyrene material having low dielectric loss properties. Without the loading element and its supports, one and seven-eighths inches of travel of the piston were required to tune over the desired band. With the structure of the invention, however, only seven-eighths inch of travel accomplished tuning over the same range. The presence of the loading element also substantially decreased the over-all dimensions of the device. In such an embodiment, the material of the support itself serves as an additional loading element, thus increasing the effectiveness of the toroidal element.

The support or supports employed to position the loading element in the propagating space advantageously may have a length substantially equal to one-quarter of the mean operating wave length of the device, especially when conductive supports are used. A support so proportioned has a resonant length permitting the establishment of a standing wave therealong, with the attendant differences in voltage and current between the two ends which are separated by a distance equal to one-quarter wave length. Thus, voltages and currents induced on the loading element, at its points of support, may be maintained in spite of the different electrical values existing on the wave-guiding conductors where the other ends of the supports are fastened.

Figs. 2, 3, and 4 illustrate embodiments of the invention as applied to a wave-guiding structure similar to that shown in Fig. 1, and show for simplicity only the structural features differing from Fig. 1. In each of Figs. 2, 3, and 4, however, portions of the outer and inner conductors 11 and 12 are shown, as are the ends of rods 25, 26 for effecting longitudinal adjustments of the short-circuiting member.

Fig. 2 illustrates an embodiment of the invention in which the disposition of the short-circuiting member and of the supports for the loading element differs from the embodiment of Fig. 1. A piston-type short-circuiting member 40 includes conductive portions 41 and 42 adjacent the outer and inner conductors 11 and 12, respectively. The piston 40 is open at one end but closed in a convergingly tapered section at the opposite end. This tapered section includes an extension of outer conductive portion 41 in the form of a truncated cone 43 converging toward inner conductor 12, and also includes an extension of inner conductive portion 42 in the form of an oppositely converging truncated cone 44. The outer cone 43 and inner cone 44 are truncated by a short-circuiting ring 45 having a small radial width.

A loading element 50 of generally toroidal shape is supported in fixed relation to the wave-guiding structure so as to be positioned in a region of the propagating space in the vicinity of the tapered section 43, 44, but spaced from the closed end 45. Two radially extending supports 51 and 52 pass through slots 53 and 54 in the conductive portions 41 and 42, respectively, and support the element 50. The slots permit longitudinal adjustment of the piston 40 in spite of the presence of the radial supports 51, 52.

In connection with the operation of the embodiment of Fig. 2, it has been pointed out above that positioning of the loading element in the vicinity of the short-circuiting member is advantageous because of the large shifting of the fields in that vicinity during tuning. Positioning of the element between the walls of a piston-type short-circuiting member is advantageous also because the relative nearness of the walls of the piston increases the effectiveness of the loading element. With the element in the vicinity of a tapering section of the piston, effectiveness of the loading element is further increased due to the approach of the cones 43, 44 during the adjustment to shorten the active physical length of the device. A particular advantage of this embodiment resides in the provision of mechanical clearances in a region of high electric field intensity (that is, near the point of maximum voltage), adequate to prevent arc-over, whereas the action of the loading element is enhanced by reduced clearances in the low voltage region near closed end 45 where no danger of arc-over exists. Element 50 and the supports 51, 52 may all be of conductive material, but an element of dielectric material also is effective to alter the sensitivity of tuning. In Fig. 3 there is illustrated an embodiment of the invention similar to that shown in Fig. 1, but with a loading element of a different form. As in Fig. 1, the piston 20 includes the conductors 21 and 22 adjacent the outer and inner conductors 11 and 12, respectively, of the wave-guiding structure, and the piston is closed by the ring 23. A loading element 60 is provided within the piston. Element 60 is considerably shorter longitudinally of the wave-guiding structure than loading elements of the other embodiments illustrated. In order to make this short loading element effective, it is desirable to have it extend as far as possibly radially within the portion of the wave-guiding space inside the

terminating cup. Thus, element 60 is shown with a central hole only silghtly larger in diameter than the diameter of the inner conductor 22 of the piston, and with an outer radius only silghtly smaller than the radius of the outer conductor 21 of the piston. The element 60 is supported by rods 61, 62 fastened to the outer conductor 11 of the structure.

The loading element 60 advantageously may be of a dielectric material having low dielectric loss properties, and as described, fits rather snugly within the terminating cup. When high voltages may appear, however, it of course is necessary to provide adequate spacing as a precaution against arc-over. Operation of the embodiment of Fig. 3 is similar to that of the apparatus of Fig. 1.

Referring now to Fig. 4, conductors or conductive surfaces 11 and 12 define the propagating space 13, as in Fig. 1, and a short-circuiting member 63 is disposed within the propagating space and made longitudinally adjustable by means of the rods 25, 26. To effect the necessary electrical contact with the wave-guiding structure proper, the member 63 is slit radially at its edges 64 and 65 where it makes contact with outer conductor 11 and inner conductor 12, respectively. These radial slits separate both outer and inner peripheries of member 63 into flexible segments which bear against conductors 11 and 12 as member 63 undergoes longitudinal adjustment. As with a piston-type short-circuiting member, adjustment of member 63 results in substantial longitudinal shifting of the fields along propagating space 13.

Positioned within space 13 is a conductive loading element 70 supported by and conductively connected to inner conductor 12. This conductive element may be considered a raised portion of conductor 12, in effect establishing a short length of the wave-guiding structure having a characteristic impedance different from that of the remainder of the structure. Operation of this embodiment also is similar to that of the embodiments discussed above.

In the embodiment of Fig. 5, the tunable wave-signal device comprises a longitudinally extending hollow conductive structure defining a propagating space 113. The conductive structure includes a conductive surface comprising at least two portions 111 and 112 forming a hollow conductive structure. This structure constitutes a hollow guide, which may have any suitable cross-sectional configuration. An end plate 114 is provided in the end portion of the hollow guide illustrated.

The device also comprises a piston-type short-circuiting member 120 of similar cross-sectional configuration, including conductive portions 121 and 122 adjacent to the conductive portions 111 and 112, respectively, of the hollow structure. Piston 120 is open at one end and closed at the opposite end by a plate 123, which also supports and aligns the conductive portions 121, 122 of the piston. A driving rod 127, fastened to the back of plate 123, passes through a hole in end plate 114. As indicated by the arrow 128, any suitable tuning drive may be applied to driving rod 127 to provide adjustment of the piston longitudinally of propagating space 113 and thus effect tuning of the device. Piston 120, by virtue of the conductive portions adjacent the hollow structure 111, 112, is electrically coupled to the hollow structure and provides an end portion of the active propagating space. The piston advantageously has an effective electrical length of substantially one-quarter of the mean operating wave length of the device.

A loading element 130 is supported by means of a radial support 131 for movement relative to the piston 120 during the tuning of the device. Support 131 passes through a slot 133 in conductive portion 121 of the piston. The loading element is thus illustrated as positioned within the piston 120 and spaced from the closed end 123 in the direction of the open end and, of course, is positioned in a region of propagating space 113 subject to substantial longitudinal shifting of the fields during the tuning of the device. Although the design and manner of use of the hollow guide involve detailed electrical phenomena differing from the phenomena associated with a transmission-line structure, as is well understood by those skilled in the art, the general principles governing operation of the embodiment of the invention illustrated in Fig. 5 are the same as those which govern the other embodiments illustrated.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A tunable wave-signal device adjustable over a given frequency range comprising, a wave-guiding structure including a plurality of longitudinally extending conductive surfaces defining a propagating space for electromagnetic waves, a short-circuiting member adjustable longitudinally of said propagating space to effect tuning of said device over said range, and a loading element of such cross-sectional shape and of such material as to provide in said wave-guiding structure a substantial coefficient of wave reflection, said element being supported in the vicinity of said short-circuiting member for movement relative to said member during the tuning of said device, said loading element having a major axial dimension of between one-eighth and one-quarter of the mean operating wave length of said device.

2. A tunable wave-signal device adjustable over a given frequency range comprising, a wave-guiding structure including a plurality of longitudinally extending conductive surfaces defining a propagating space for electromagnetic waves, a short-circuiting member adjustable in a path extending longitudinally of said propagating space to effect tuning of said device over said range and effective to determine in accordance with its position the location of points of maximum intensity of the electric and magnetic fields within said space, a loading element of such cross-sectional shape and of such material as to provide in said wave-guiding structure a substantial coefficient of wave reflection, said element being positioned in a region of said propagating space subject to approximately the greatest longitudinal shifting of said fields during the tuning of said device, and at least one support for said element having a length substantially equal to one-quarter of the mean operating wave length of said device and affixed to said wave-guiding structure at a point outside of the path of adjustment of said short-circuiting member.

3. A tunable wave-signal device adjustable over a given frequency range comprising, a hollow cylindrical outer conductor and a coaxially aligned inner conductor providing therebetween a propagating space for electromagnetic waves, a piston-type short-circuiting member including two coaxially aligned hollow cylindrical conductors short-circuited at one end but open at the opposite end adjustable longitudinally of said propagating space to effect tuning of said device and effective to determine in accordance with its position the location of points of maximum intensity of the electric and magnetic fields within said space, and a loading element of such cross-sectional shape and of such material as to provide in said wave-guiding structure a substantial coefficient of wave reflection, said element being supported for longitudinal movement relative to said short-circuiting member during the tuning of said device, spaced from said closed end of said member in the direction of said open end thereof, and positioned in a region of said propagating space subject to approximately the greatest longitudinal shifting of said fields during said tuning.

4. A tunable wave-signal device adjustable over a given frequency range comprising, a wave-guiding structure including at least one longitudinally extending conductive surface, said structure defining a propagating space for electromagnetic waves, a short cup-shaped piston having an effective electrical length substantially equal to an odd integral multiple of one-quarter of the mean operating wave length of said device and being adjustable longitudinally of said propagating space to effect tuning of said device over said range, and a loading element supported within said piston for movement relative thereto during tuning of said device and positioned in a region of said propagating space subject to substantial longitudinal shifting of said fields during said tuning.

5. A tunable wave-signal device adjustable over a given frequency range comprising, a hollow cylindrical outer conductor and a coaxially aligned inner conductor providing therebetween a propagating space for electromagnetic waves, a coaxial-line tuner adjustable longitudinally of said propagating space to effect tuning of said device and effective to determine in accordance with its position the location of points of maximum intensity of the electric and magnetic fields within said space, and a ring-shaped member surrounding said inner conductor in spaced relation to both said conductors and of such material as to provide in said wave-guiding structure a substantial coefficient of wave reflection, said ring-shaped member being supported for longitudinal movement relative to said tuner during the tuning of said device and being positioned in a region of said propagating space subject to substantial longitudinal shifting of said fields during said tuning.

6. A tunable wave-signal device adjustable over a given frequency range comprising, a hollow cylindrical outer conductor and a coaxially aligned inner conductor providing therebetween a propagating space for electromagnetic waves, a coaxial line tuner adjustable longitudinally of said propagating space to effect tuning of said device and effective to determine in accordance with its position the location of points of maximum intensity of the electric and magnetic fields within said space, and a ring-shaped conductive member surrounding said inner conductor in spaced relation to both said conductors to provide in said wave guiding structure a substantial coefficient of wave reflection, said ring-shaped member being supported for longitudinal movement relative to said tuner during the tuning of said device and being positioned in a region of said propagating space subject to substantial longitudinal shifting of said fields during said tuning.

7. A tunable wave-signal device adjustable over a given frequency range comprising, a hollow cylindrical outer conductor and a coaxially aligned inner conductor providing therebetween a propagating space for electromagnetic waves, a coaxial-line tuner adjustable longitudinally of said propagating space to effect tuning of said device and effective to determine in accordance with its position the location of points of maximum intensity of the electric and magnetic fields within said space, and a sleeve of conductive material surrounding said inner conductor in spaced relation to both said conductors to provide in said wave-guiding structure a substantial coefficient of wave reflection, said sleeve being supported for longitudinal movement relative to said tuner during the tuning of said device and being positioned in a region of said propagating space subject to substantial longitudinal shifting of said fields during said tuning.

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