ULTRA-HIGH-FREQUENCY TUNER

James F. Wilcox, Syracuse, N. Y., assignor to General Electric Company, a corporation of New York

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My invention relates generally to ultra-high-frequency apparatus, and more particularly to tuning-circuit arrangements operable over a relatively wide band of ultra-high-frequency values.

Hereinafter, tuning-circuit arrangements have been described for use with ultra-high-frequency apparatus, but such arrangements have either been excessively large and bulky and costly to produce, or such arrangements have comprised certain structural features such as sliding conductive contacts that require frequent adjustment and replacement. Other arrangements that have been described comprise lumped-constant circuit elements which are not very feasible in the desired frequency range. It is, therefore, a primary object of this invention generally to improve the art of ultra-high-frequency tuning arrangements.

Another object is to provide such tuning arrangements that are free from sliding conductive connections and relatively simple in construction and economical to produce.

Still another object is to provide novel and improved tuning circuit arrangements operable over relatively wide ranges of frequency values in the ultra-high-frequency band.

Another object is to provide an adjustable tuning circuit including as elements thereof a plurality of sections of resonant transmission line having adjustable reactive coupling therebetween.

Yet another object is to provide such an adjustable filter that is characterized in that a predetermined band of frequencies is readily passed by the filter, the cut off at one end of the pass band being relatively abrupt.

In accomplishing the foregoing objects, I eliminate the undesirable sliding conductive connections characteristic of conventional types of high-frequency tuners by employing a resonant section of transmission line having reactive means of the distributed constant type for varying the characteristic impedance of the transmission line. In accordance with one aspect of this invention, the transmission line is constructed as a non-parallel pair of spaced conductors connected at one end to a reactive circuit to be tuned, and having at the other end, adjustable means for varying the characteristic impedance of the line.

In accordance with another aspect of this invention, the transmission line comprises a pair of parallel-wire or rod conductors connectible at one end to a reactive circuit to be tuned and having adjustable means at the other end for varying the characteristic impedance of the line.

My invention will be better understood from 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 a side elevation view of one embodiment of my invention; Fig. 2 is a side view of the apparatus shown in Fig. 1; Figs. 3 and 4 are schematic diagrams useful in explaining the operation of the apparatus illustrated in Fig. 1; Figs. 5-8 are plan views illustrative of other embodiments of the invention; and Fig. 9 is a perspective view of a further modification of the invention.

Referring to Figs. 1 and 2 of the drawing, an adjustable tuner constructed in accordance with the present invention is shown, comprising a section of non-uniform transmission line 11 having a ground plate 13, which may be a flat strip of brass or other suitable conductive material, disposed in cooperative relation to an arcuate strip 15 of spring material. The plate 13 and strip 15 are spaced from each other and secured together by means of a spacer block 17 of any suitable insulating material, the connection of the conductors 13, 15 to the block 17 being effected in any conventional manner. Input terminals 19 are provided at the end of transmission line 11 adjacent the block 17 for connection to a circuit to be tuned or resonated. To vary the characteristic impedance of the line 11, the spacing between the plate 13 and strip 15 is adjustable by altering the curvature of strip 15, as by an insulating screw 21 that is suitably supported in an insulating frame 23.

An approximate theory of operation of the above-described tuner circuit can be obtained by consideration of the lumped-parameter equivalent circuit shown in Fig. 4, taken in connection with the diagram of Fig. 4, which is illustrative of a distributed-parameter circuit roughly equivalent thereto.

In Fig. 4, the capacitance C represents the effective capacitance of an apparatus which is desired to be tuned by the apparatus of the present invention and the resistance R represents the load resistance. The tuning reactance is represented by the reactance Z1 equivalent to the reactance of the non-uniform line 13, 15 of Figs. 1 and 2. The arrangement is, therefore, quite similar to that of a band-pass filter approximating the non-uniform transmission line of Fig. 4 of which the input impedance Z1, by well-known transmission line theory, may readily be shown to be:

\[ Z_1 = jZ_{in} \left( \frac{Z_m \tan \beta_l - Z_{in} \cot \beta_l}{Z_m + Z_{in} \tan \beta_l \cot \beta_l} \right) \]  

(1)

where \( Z_m \) is the characteristic impedance of the first section of transmission line shown having a length \( l_m \), \( Z_{in} \) is the characteristic impedance of the second section of transmission line having a length \( l_s \) and \( \beta \) is the phase constant of the line. In the case under consideration,

\[ l_m = l_s = 1 \]  

(2)

\[ Z_1 = jZ_{in} \left( \frac{\tan \beta_l - Z_{in}}{Z_m + Z_{in} \tan \beta_l \cot \beta_l} \right) \]  

(3)

The expression for \( Z_1 \) in Equation 3 yields a filter characteristic corresponding to that of a band-pass circuit and similar to that of a lumped tuned circuit for the proper line parameters. An illustrative calculation made with the following values:

\[ C = 5 \, \text{mmf}, \quad R = 370 \, \text{ohms}, \quad Z_{\text{in}} = 50 \, \text{ohms}, \quad Z_m = 100 \, \text{ohms}, \quad l_m = 8.7 \, \text{cm}, \]

discloses that the circuit tunes to 700 megacycles per second with a band width, at 70% of the voltage, of 22 megacycles per second. The characteristic of this circuit corresponds to that of a single parallel-tuned circuit with lumped constants.

By suitably changing the line parameters, wider tuning may be obtained, and it can be shown that a band width of tuning equal to 25 megacycles per second at a resonant frequency of 1230 megacycles per second can be obtained.

It will be understood that the foregoing calculations are merely exemplary and are not to be considered as limitations of the scope of the invention.
By a suitable choice of values for $l_1$ and $l_2$ for the ratio $Z_{02}/Z_{01}$, $Z_1$ can be made zero at a desired frequency value. Accordingly, the filter characteristic shows an abrupt cut off or rejection region corresponding to $Z_1$ standard in the attenuation. For example, in the case where the circuit tunes a capacitative element, such a region can be shown to occur at a frequency substantially equal to 60 megacycles per second below the tuning frequency of 1230 megacycles per second. It will thus be seen that such a characteristic is extremely useful for rejecting undesired image signals commonly encountered in the reception of radio-frequency signals. The rejection or cut-off frequency can be made to track with the tuning of the pass band, thus rendering the filter circuit extremely useful as a tuner for television receivers.

Where the circuit element is employed to tune an inductive element instead of a capacitative element, the rejection region occurs on the high-frequency side of the pass band.

In practice, it is a capacitance that is commonly sought to be tuned. Thus, if the rejection region is desired on the high-frequency side, one needs only to connect an inductive element across the capacitance so that the net reactance presented to the circuit is inductive over the desired tuning range.

Fig. 5 illustrates the principle of the present invention as embodied to an open-circuited transmission line having a flared portion all but part of its length. Thus, a transmission line 30 shown comprising a parallel-wire section 32 and a non-uniform wire section 34 directly coupled thereto. For altering the characteristic impedance of the transmission line 30, thereby to vary the resonant frequency of the filter, a wedge-shaped conductive slug 36 is made positionable in the space between the non-uniform wire section 34 as by a rack and pinion drive 38 actuating an insulating rod 39. To avoid direct or sliding contact between the slug 36 and the flared portion 34, a thin solid dielectric coating 40 may be affixed to the surfaces of the slug 36 adjacent the portion 34. The circuit as tuned is connected at terminals 41 provided at the end of the line section 30 remote from the tuning slug 36.

Fig. 6 illustrates a similar arrangement for a short-circuited line 42 which, as shown, comprises a bent section of transmission line which may be formed as a V-shape member, or in any other desired configuration. A conformable triangular slug 46 is movable in and out of the V part to vary the characteristic impedance thereof. Input terminals 47 are provided at the free ends of the transmission line section for connection to an external circuit. If desired, solid dielectric coatings may be applied as described hereinabove in connection with the embodiment of Fig. 5.

Figs. 7 and 8 illustrate further embodiments of the invention, in which the slugs 36 or 46, shown in Figs. 5 and 6, are replaced by a conductive rod or tube, as at 48 and 52, bent to form a short-circuited line section having inwardly bent portions 49 and 53, respectively, which are interconnected by cross members 49" and 53", respectively. Such short-circuited line sections may be adjustably movable into the space between the flared portions 34 of the transmission line 30 by means similar to the rack and pinion device 38 shown in Fig. 5. In Fig. 8, the arrangement is quite similar to that shown in Fig. 7 with the exception that an adjustable impedance element 50 of any suitable character and magnitude may be connected into the movable short-circuited line section 52. The impedance 50 affords an additional parameter that can be varied for further control of the filter characteristics.

Fig. 9 illustrates a modification of the basic principles of the present invention as embodied in the parallel-wire transmission line. As shown, an open-circuited parallel-wire transmission line section 51 is provided consisting of a pair of flat strips 54, 56 of suitable conductive material, which are suitably fastened to a support 58 in any conventional manner. For a major portion of their length, the strips 54, 56 are spaced from the support 58 by downwardly curved terminal parts 59, 62, thus defining a space between the strips 54, 56 and the support 58 into which a short-circuited line section 60 may be slidably positioned and in spaced relation to the overlying strips 54, 56. The short-circuited line section 60 consists of a pair of conductive strips 61, 63 of substantially the same size and shape as strips 54, 56 of the open-circuited line. A shorting bar 65 interconnects strips 61, 63 and is provided with a pair of downwardly projecting studs 67, 69 which ride in associated slots 71, 73 in the support 58. The reactive coupling between the open- and short-circuited line sections 51, 60 is readily varied in accordance with the degree of overlapping of the line sections 51 and 60. With large coupling, the lines sections 51 and 60 can be dimensioned to cooperate to act like a shorted quarter wave line. As the coupling is decreased, there is a gradual transition from the quarter-wave line mode to a half-wave line mode.

If desired, a strip of solid dielectric material 64 may be disposed between the adjacent surfaces of the strips 54, 61 and 56, 63 to alter the magnitude of the reactive coupling. A dielectric block 68 is provided for securing the short-circuited line 60 in any desired position in respect to the open-circuited line 51. To this end, an adjusting screw 70 passes through suitable aligned openings in the block 68 and the insulation strip 64, and into a threaded portion (not shown) in the support 58. Connection to a circuit to be tuned may be made at the terminals 72, 74.

While I have shown and described various specific embodiments of my invention, and certain modifications thereof, it will, of course, be understood by those skilled in the art that other modifications may be made without departing from the principles of the invention. Therefore, contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An ultra-high-frequency filter circuit comprising a first section of two-conductor transmission line having a parallel conductor part and a flared conductor part connected thereto, a second section of two-conductor transmission line of which the conductors are conformably disposed relative said flared part, said second section being movable relative said first section to define therewith a flaring having variable conductive characteristics, and variable reactance means connecting corresponding ends of the conductors of said second section remote from said first section thereby to effect alterations in the tuned-circuit characteristics of said filter in accordance with the value of the reactance of said variable reactance means.

2. An ultra-high-frequency apparatus embodied in a non-uniformly spaced transmission line comprising a section of parallel-conductor transmission line having a flared portion and a conductive member positioned in said flared portion, said transmission line and said conductive member being movable relative to each other to vary the characteristic impedance of said line, and said conductive member comprising a short-circuited section of two-conductor transmission line having portions conformable with said flared portion.

3. An ultra-high-frequency apparatus embodied in a non-uniformly spaced transmission line comprising a section of parallel-conductor transmission line having a flared portion, a conductive member movable in said flared portion to vary the characteristic impedance of said line, said conductive member comprising a short-circuited section of two-conductor transmission line having portions conformable with said flared portion, and a reactive load included in said short-circuit line section.
4. An ultra-high-frequency apparatus embodied in a non-uniformly spaced transmission line having a flared portion, a conductive member conformable to and positioned in said flared portion, said conductive member and said flared portion being movable relative to one another, said conductive member being reactively coupled to said flared portion to vary the characteristic impedance of said line.

5. The apparatus as in claim 4 wherein said conductive member is a wedge-shaped slug.

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