March 18, 1952 F. C. ISELY 2,589,259

RADIO-FREQUENCY CIRCUIT

Filed Aug. 13, 1948

FIG. 1

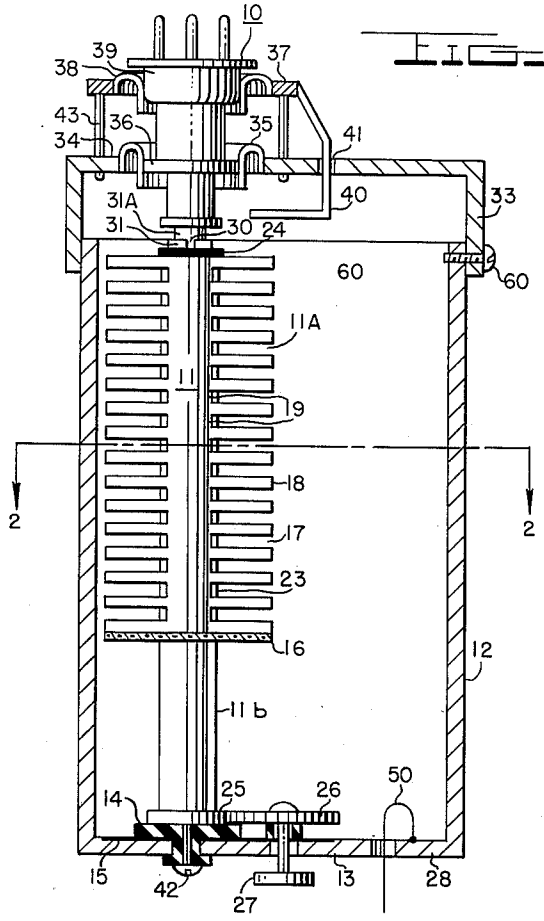
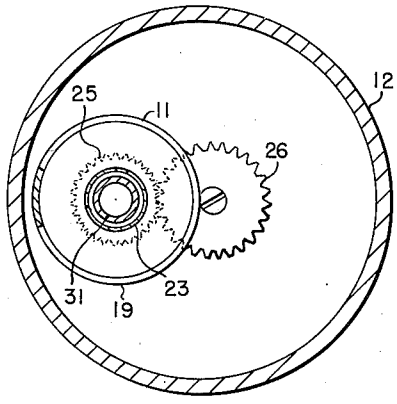


FIG. 2



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RADIO-FREQUENCY CIRCUIT

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5 Claims. (Cl. 178—44)

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The present invention relates to an improvement of the invention disclosed in my co-pending application Serial No. 35,959, filed June 29, 1948, now U. S. Patent 2,520,147, and is in particular concerned with the problem of eliminating unwanted harmonics in line controlled radio frequency circuits.

One serious disadvantage often experienced in the use of line controlled radio frequency circuits (distributed constant circuits) is that such circuits have a tendency to produce spurious responses or to break into random modes of operation. For example, a line cut for one-quarter wave operation will operate, spuriously in any odd quarter-wavelength mode. Likewise, a line cut for one-half wave resonance will operate spuriously, in any integral number of half wavelengths greater than one.

It is accordingly an object of this invention to provide a distributed constant radio frequency circuit which is substantially free of the above defects.

It is another object of this invention to construct a simple, inexpensive distributed constant radio frequency circuit offering exceptionally wide range tuning and mode stabilization at frequencies above 300 megacycles.

Other objects and features of the present invention will become apparent upon a careful consideration of the following detailed description when taken together with the accompanying drawings, in which:

Fig. 1 is a partial cross-sectional view taken along the longitudinal axis of one embodiment of the present invention;

Fig. 2 is a cross-sectional view taken through the plane 2—2 of the embodiment illustrated in Fig. 1.

In accordance with the basic concepts of the present invention, a distributed constant radio frequency circuit is constructed which comprises a parallel line section dimensioned to operate, fundamentally, in a greater than unity odd quarter wavelength mode. In the single, specialized embodiment herein exemplified a three-quarter wavelength mode is selected. The line section is constructed of a pair of dissimilar section so dimensioned, electrically, that the discontinuity formed at their juncture produces wave reflections which combine with the wave reflections produced at one end of the line in an additive manner when the line is excited in its selected mode. This action assures efficient, stable operation of the circuit.

Conversely, the phase relationship between the wave reflections from the end of the line and

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from the discontinuity is such, when the line is excited at any frequency other than the three quarter wave resonant frequency, that substantially all the harmonics are either cancelled or so thoroughly attenuated as to produce negligible effect on the operation of the circuit.

A suitable resistance such as a coating of "aquadag" may be applied to the line at any convenient point therealong to further damp out spurious modes of operation.

Tuning of the line may, as will hereinafter be described, be attained by using the novel tuning principles disclosed in my co-pending application, supra.

Referring now in particular to Figs. 1 and 2 there is disclosed the novel teachings of my invention as applied to a modified concentric line oscillator which comprises a vacuum tube component 10, and a line section including inner and outer conductors 11 and 12 respectively. In this particular embodiment the line is dimensioned to produce operation in a three quarter wave mode. The inner conductor 11 of the line is transversely slotted over a portion of its length 11*a* and is made rotatable for tuning reasons as will hereinafter be described. Inner conductor 11 is also made in two sections, one section 11*a* of a half wavelength long and the other 11*b* of a quarter wavelength long. These dimensions are taken at the highest frequency of operation. The first section 11*a* is made with a relatively large diameter whereby it cooperates with the outer cylindrical conductor 12 to form a half wave resonant line of low characteristic impedance. The second section 11*b* is made with a relatively small diameter whereby it may cooperate with the outer conductor 12 to form a quarter wave line section of relatively high characteristic impedance. The two line sections are effectively in series with one end shorted through a radio frequency bypass which comprises a fiber washer 14 and a sheet of mica 15 to the end wall 13 of the outer cylinder 12.

In operation in the three-quarter wave mode a voltage maximum will exist at the juncture of line sections 11*a* and 11*b*. Conversely a voltage minimum will exist at the shorted end of section 11*b*. At this frequency, line section 11*a* will appear to be one-half wavelength long terminated in the infinite impedance reflected by the quarter wave section 11*b*. The wave energy reflected from the discontinuity in the line, that is from the juncture of line sections 11*a* and 11*b* will be reflected without phase inversion since the half wave section 11*a* is terminated in an infinite impedance. The energy reflected from the lower end, the shorted end of quarter wave section 11*b*,

however, will be inverted since the line section is terminated in a short circuit. Now then since the propagation path extending from the juncture of sections 11*a* and 11*b* to the shorted end of section 11*b* and back is equal to one-half wavelength in the desired mode of operation, and since the energy reflected from the shorted end of section 11*b* is inverted the reflected energies from both the discontinuity and from the shorted end of the line will combine in phase. This phase relation is that which is required for efficient, stable operation of the circuit.

In the quarter wave resonant mode the reflections occurring from the end of the line are out of phase with those occurring from the discontinuity. As a result of this difference in phase in the two reflections, the oscillations in this mode are seriously attenuated. Similarly, in the five quarter wave mode and all other odd quarter wave modes (except possibly the nine quarter wave mode), the two sets of reflections (one set from the shorted end of the line and the other from the discontinuity) are out-of-phase giving little chance for sustained or efficient operation of the circuit except in the three quarter wave mode.

To further assist in the damping out of spurious modes of operation, I have found it desirable to coat a thin layer of resistance material 16 such as "aquadag" on one of the conductors at the juncture of the two line sections. In the three quarter wave mode, a current minimum exists at this point and little or no energy is dissipated in the resistance. In all other spurious modes some predetermined small current exists at this point thus giving rise to a voltage drop across the resistance which further accentuates the attenuation of these modes.

In order to permit tuning of the present circuit and in accordance with the principles disclosed in my aforementioned co-pending application, the inner conductor 11 is made rotatable relative to the outer conductor 12 and is disposed off-axis from outer conductor 12. Likewise the inner conductor is transversely slotted at uniformly spaced intervals 17 along the length 11*a*.

This construction provides a line wherein the distributed capacitance between conductors 12 and 11 is constant with rotation of conductor 11, but the distributed inductance is variable with rotation of the conductor 11. This characteristic arises by virtue of the fact that the fringe capacity between the teeth 18 of the slotted portion of conductor 11 and the inner wall of conductor 12 is essentially equal to the distributed capacity between the solid portion 19 of conductor 11 and conductor 12. Thus the distributed capacity of the line will remain the same with rotation of conductor 11.

The mutual inductance between conductors 11 and 12, however, varies with the spacing between the solid portion 19 of conductor 11 and conductor 12. Accordingly, as conductor 11 is rotated the distributed capacity between conductors remains constant while the mutual inductance between conductors varies, it being a maximum in the position illustrated in Fig. 2. In this condition, the resonant frequency of the line section is a maximum. Rotation of conductor 11 180° minimizes the mutual inductance and also the resonant frequency of the line section.

In the construction of the inner conductor neither the width of the slots 18 nor the spacing 17 therebetween is critical. In one embodiment $\frac{1}{16}$'' slots with $\frac{1}{16}$'' spacing gave a tuning range

of nearly two to one. $\frac{1}{32}$'' slots with $\frac{1}{8}$'' spacing was also found to give a tuning range of substantially two to one. Similarly, the angle of the solid portion of conductor 11 is not critical and can be varied within wide latitudes without impairing the operation and performance of the circuit, since this angle only determines the value of self inductance of the conductor. The greater the angle, the smaller the self inductance and the higher the resonant frequency.

In this application of the invention the inner conductor 11 is hollow, and is provided with a hollow reentrant sleeve 23 the extension of which forms the section 11*b*. Sleeve 23 is positioned over a suitable center post 31. Spatially separating center post 31 and reentrant sleeve 23 is a fiber washer 24. Washer 24 as well as the air dielectric between post 31 and sleeve 23 operate to provide a radio frequency connection between the center post and the inner conductor 11. Post 31 is off-set from the axis of the outer cylinder 12 sufficiently to permit a good capacitive association between the inner conductor 11 and the inner walls of the outer cylinder 12.

A gear wheel 25 is securely attached to the lower end of the inner conductor 11 for engagement with a fiber spur gear 26. Spur gear 26 is pinned or otherwise attached to a knurled knob 27 that projects from end wall 28 of the outer cylinder to provide rotation of the inner conductor 11 and therefore tuning of the line. Insulatingly separating the gears 25 and 26 from the end wall 28 is a strip of mica insulation 15. The mica 15 coacts with the end wall 28 and the lower end of cylinder 11 to provide a capacitive short circuit between the ends of the inner and outer conductors.

The upper end of the center post 31 is longitudinally slotted at 30 to provide a finger like contact engagement with the plate cap 31A of a "light house" tube 10. The lower end of the center post is anchored to end plate 28 through pin 42, which also serves as a connection for a source of plate supply potential.

The upper end of the concentric line is closed by a cup-shaped end cap 33 held to the outer cylinder 12 by screws 60 and apertured at 34 to permit entry of the tube into the line. Attached to the inner periphery of aperture 34 is a flexible annular contact ring 35 adapted to contact the grid ring 36 of tube 10 thereby to provide grounded grid operation of the tube.

Surrounding the cathode ring terminal 39 of tube 10 is an annular support 37 held in position by a plurality of stand-off insulators 43. Attached to the ring support 37 is a flexible annular contact ring 38 adapted to provide contact with the cathode of the tube 10.

To provide regenerative feedback for the production of oscillations, a capacitative feedback strap 40 is attached to the cathode support ring 37 and lead down through an aperture 41 cut in cap 33 to capacitatively engage the anode of tube 10. The output may be derived from the oscillator by means of an inductive loop 50, for example, disposed on the end walls 28.

From the foregoing it becomes apparent that I have provided a distributed constant circuit which is of simple and inexpensive construction and which is easily tunable by a simple rotation motion. It is further apparent from the foregoing that numerous modifications may be made of the present invention without exceeding the spirit thereof. For example, the principles of this invention may be applied with equal ad-

vantages to other types of line controlled circuits such as the two wire line circuit now commonly in use. Also the invention may be used as a wave trap, or for radio frequency amplification or mixing as well as for the production of mode stabilized oscillations. Accordingly, it must be understood that this invention is not to be limited except as far as defined by the appended claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. A radio frequency circuit comprising, a pair of substantially coextensive, parallel conductors dimensioned to form a resonant line of an odd multiple, greater than unity, quarter wave lengths long, said resonant line being shorted at one end and opened at the other and being formed from a pair of serially connected line sections having dissimilar characteristic impedances, the line section adjacent the shorted end of the resonant line having a characteristic impedance higher than that of the other line section, one of said line sections being shorter than the other by an odd number of quarter wavelengths.

2. A radio frequency circuit comprising, a pair of substantially coextensive parallel conductors dimensioned to form a three quarter wavelength resonant line shorted at one end and open at the other, said line being formed by the series connection of a quarter wave section of relatively high characteristic impedance and a half wave section of relatively low characteristic impedance, the free end of said quarter wave section being shorted.

3. A radio frequency circuit comprising, a pair of substantially coextensive, parallel conductors dimensioned to form a resonant line of an odd multiple, greater than unity, quarter wavelengths long, said resonant line being shorted at one end and open at the other, and formed from a pair of serially connected line sections having dissimilar characteristic impedances, the line section adjacent the shorted end of the resonant line having a characteristic impedance higher than that of the other line section, one of said pair of line sections being shorter than the other by an odd number of quarter wave-lengths and a coating of resistance material applied to said line at a point intermediate the ends thereof.

4. A radio frequency circuit comprising, a pair of substantially coextensive, parallel conductors dimensioned to form a resonant line of an odd multiple, greater than unity, quarter wavelengths long, said resonant line being shorted at one end and opened at the other, and formed from a pair of serially connected line sections having dissimilar characteristic impedances, the line section adjacent the shorted end of the resonant line having a characteristic impedance higher than that of the other line section, one of said pair of line sections being shorter than the other by an odd number of quarter wavelengths and a coating of resistance material applied to said line at the juncture of said pair of line sections.

5. A radio frequency circuit comprising, first and second transmission line sections having different characteristic impedances connected in cascade, each of said sections being at least a quarter wavelength long at a predetermined frequency, means terminating the free end of the second line section in an impedance other than its characteristic impedance to form a resonant line from said sections, the characteristic impedance of said line sections having relative values operative to produce a reflection at their junction point which reinforces the reflection which occurs at the end of the second line section when the line is excited at a predetermined frequency.

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