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FREQUENCY CONTROL LINE AND CIRCUIT

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Fig. 1

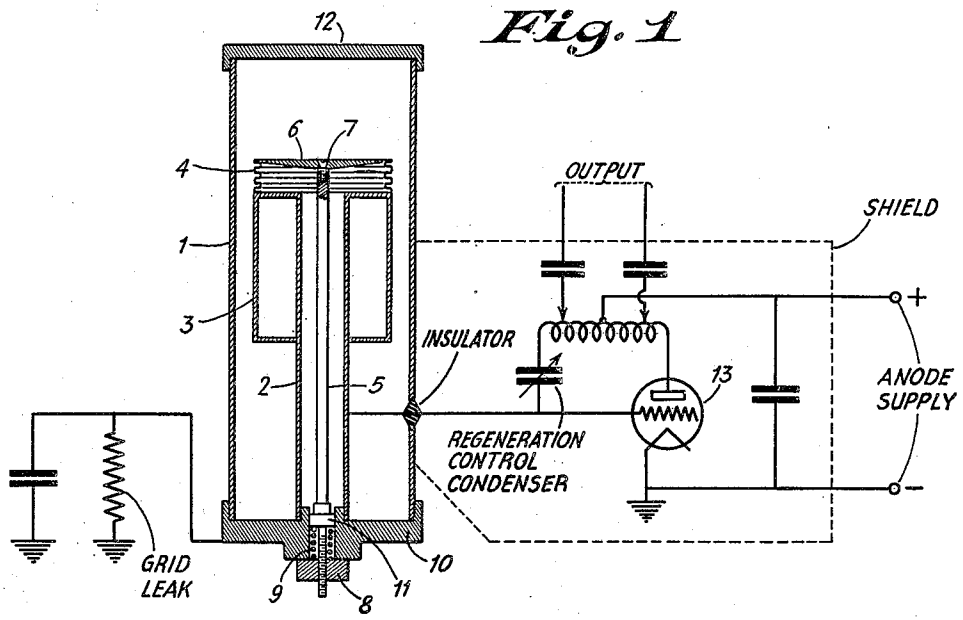
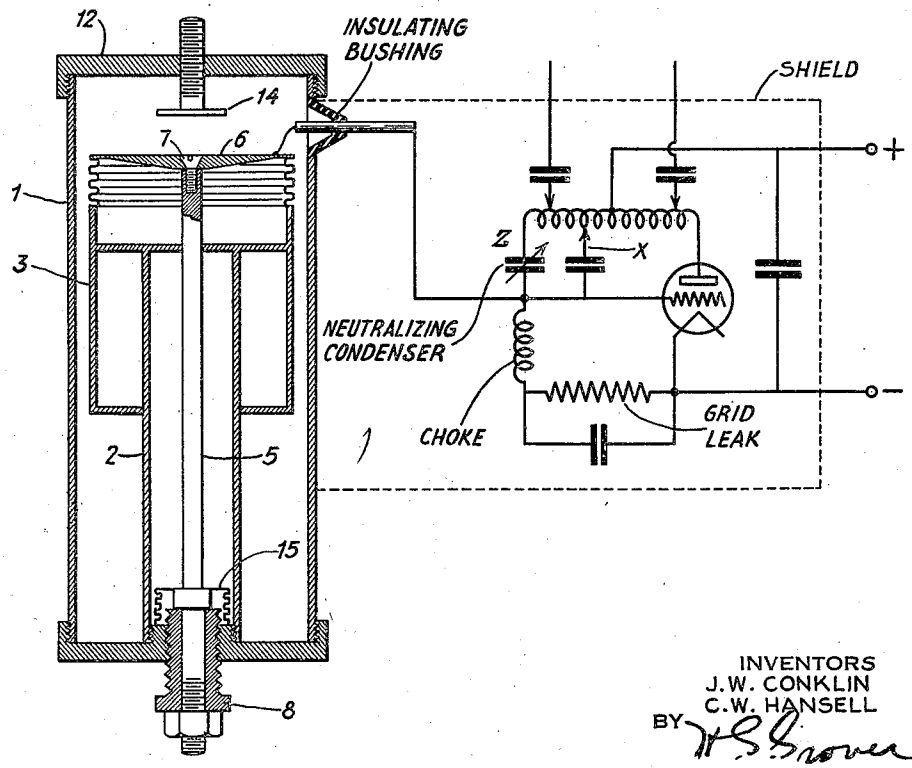


Fig. 2



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FREQUENCY CONTROL LINE AND CIRCUIT

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16 Claims. (Cl. 178—44)

This invention relates to short wave tuned circuits, and particularly to improvements in resonant transmission lines, sometimes referred to as frequency control transmission lines.

It is well known that a properly designed transmission line having uniformly distributed inductance and capacity has low losses and may be employed as a tuned circuit for maintaining constant the frequency of oscillations generated by an electron discharge device system. The line has the effect of a sharply tuned resonant circuit and therefore its reactance changes rapidly with change in frequency, and it is this characteristic which is utilized to keep the frequency of the oscillator constant. The resonant frequency of the line is determined chiefly by the length of the line, and for this reason it is important that the length be kept constant in order to maintain a high degree of frequency stability. In a concentric line it is the projection of the inner conductor upon the outer conductor which determines the length of the line. Arrangements of this type are adequately described in United States Patent No. 1,980,158, granted November 6, 1934, to Clarence W. Hansell; and United States Patents Nos. 2,077,800 and 2,108,895, granted respectively April 20, 1937 and February 22, 1938, to Fred H. Kroger, to which reference is made for a more detailed description.

In cases where freedom from ambient temperature variations has been desired, it has been obtained either by control of the temperature of the elements of the line involved, or by providing compensating units actuated by variations in temperature, or both.

One disadvantage of the prior structures has been due to the length of line necessary to obtain electrical resonance at the desired frequency. Although it is known to use quarter wave length lines, it will be appreciated that even such a line at wave lengths greater than ten meters, requires a space greater than eight feet, a length which is unwieldy and far too great for the space usually available for the transmitter.

A primary object of the present invention, therefore, is to enable the use of resonant transmission lines which are physically shorter than one-quarter of the length of the operating wave.

A further object is to provide for such resonant lines means for maintaining the effective electrical constant of the line substantially invariable with temperature changes.

In general, the invention comprises an electrically tuned circuit in the form of a coaxial resonant transmission line section constructed with two sizes of diameter for the inner conductor in such manner that the overall length of line required to tune to a given frequency is greatly reduced. The lengths of each of the two sizes of inner conductor are preferably made to be substantially equal, and the overall length of both sizes is held constant by an invar rod and bellows system. In such a line, the smaller diameter section of the inner conductor and the outer conductor form an effective inductance while the larger diameter section of the inner conductor and the outer conductor form an effective capacitance.

The inductance and capacitance are each very nearly proportional to the length of the respective conductors. Since the overall length of the two sections of inner conductor is constant, and the two are equal in length, any elongation or contraction of the smaller diameter section of the inner conductor, due to change in temperature, causes an equal and opposite percentage change in the larger diameter section of the inner conductor. Thus, changes in temperature vary the inductance and capacitance of the circuit equally and oppositely and there is little if any change in natural frequency.

Other objects, features and advantages will appear from a reading of the following detailed description which is accompanied by a drawing wherein Fig. 1 shows an oscillator circuit controlled by one form of resonant transmission line in accordance with the invention, and Fig. 2 shows a slightly modified and preferred form of resonant transmission line.

Referring to Fig. 1 in more detail, there is shown a concentric or coaxial resonant transmission line comprising an outer conductor 1 and an inner conductor composed of two sections of different diameters, namely, a smaller diameter section 2 and a larger diameter section 3. Sections 2 and 3 are made to have substantially the same length. The inner and outer conductors are conductively coupled together at one of their adjacent ends (the bottom as shown in the drawing), and capacitively coupled at their other ends. Putting it another way, we can say that the inner and outer conductors are more closely coupled together at one of their adjacent ends (i. e., at the lower end of the drawing) than at their other ends.

Attached to the free end of the inner conductor and forming a small portion of the effective inner conductor is a flexible metal bellows 4 which is arranged to open and close in response to any decrease or increase, respectively,

in length of the inner conductor due to change in temperature. A rod 5 of low temperature coefficient of expansion such as invar, is located within the inner conductor and extends substantially the entire length thereof and is connected to the metal bellows 4 at the top thereof by any suitable means, such as a plate 6 and a screw 7, for the purpose of maintaining the overall length of inner conductor and bellows 4 constant.

An important feature comprises the adjusting nut 8 which aids in making fine adjustments of the resonant frequency of the line by adjusting through a thrust collar 11 the free length of the invar rod 5 to stretch or compress the flexible bellows. If desired, a spring 9 may be used in the metal end casting 10 for cooperating with adjusting nut 8.

Outer conductor 1 is made longer than the inner conductor by an amount several times greater than the spacing between the larger diameter inner section and the outer conductor in order that the capacity between the metal end plate 12 and plate 6 be low compared with the capacity between the larger diameter inner section and outer conductor.

In the operation of the resonant line, the smaller diameter section 2 of the inner conductor forms with the outer conductor 1 an effective inductance, while the larger diameter section 3 of the inner conductor forms with the outer conductor 1 an effective capacitance. The inductance and capacitance are each very nearly proportional to the lengths of the respective sections, and since the overall length of the two inner sections is constant, and the two are equal in length, any elongation or contraction of the smaller diameter section 2, due to change in temperature, causes an equal and opposite percentage change in the larger diameter section 3. Thus, changes in temperature vary the inductance and capacitance of the line equally and oppositely.

In the transmission line resonator of the invention, the power factor is determined largely by the element having the greatest loss; in this case the smaller diameter section 2 of the inner conductor, and the ratio of the diameters of this smaller diameter section and the outer conductor 1. The power factor of such a resonator is substantially the same as that of a quarter wave concentric line resonator having inner and outer conductors of diameters respectively equal to the diameters of the smaller diameter section of the inner conductor and the outer conductor.

The theory underlying the invention is believed to be as follows: On the assumption that the inductance of the smaller diameter section of inner conductor will be large compared to the inductance of the larger diameter section of inner conductor and the capacity of the larger diameter section will be large compared to the capacity of the smaller diameter section, it may be assumed for purposes of computing thermal coefficients that the inductance is concentrated in the smaller diameter section and the capacity in the larger diameter section. On the basis of these assumptions and other approximations, the resonant frequency variation with temperature is substantially equal to $K_l+K_h+K_d-K_s$ where K_l is the percentage linear expansion of the smaller diameter section with temperature, K_h the percentage lengthwise expansion of the larger diameter section, K_d the percentage change in diameter of the larger diameter section with temperature, and K_s the percentage change of the spacing between the larger diameter section and the outer conductor with temperature. If the conductors are all constructed of one material, such as copper, K_d and K_s will be substantially equal and cancel each other and, further, if the larger diameter and smaller diameter sections have substantially equal lengths and their overall length is maintained constant by the invar rod and the compressible bellows, K_l and K_h will be equal and opposite and cancel; thus providing a structure which is substantially free from variations in frequency due to variations in ambient temperature.

We have assumed in the foregoing that the inductance of the resonator has a linear coefficient of expansion with temperature equal to K_l, the linear coefficient of expansion of the small conductor. The capacity section, however, is subject to several considerations. First, the gap or spacing between the inner and outer conductor will change linearly with temperature tending to increase the spacing and give the capacity in that respect a negative linear coefficient of change with temperature equal to K_s. Second, the effective area of the capacity will have a linear change with respect to temperature due to the temperature coefficient of the inner and outer conductors. It may be shown that this effect in itself results in a positive capacity temperature coefficient which cancels the negative effect of the change in spacing. The capacity is changed in a third respect by the change in length of the large conductor, the coefficient of which is K_h. It is well known to the art that the frequency of a resonant circuit is determined in one sense by the product of the capacity and inductance and also that if the inductance be altered by a small percentage and the capacity changed by the same percentage in the opposite sense, the resonant frequency will remain substantially the same. Specifically, if the inductance was increased 1% and the capacity decreased 1%, there would be substantially no change in the resonant frequency. Therefore, this invention provides means whereby the capacity section is automatically changed to compensate for small changes in the inductance. The reason for making the length of the two sections equal lies in the fact that the method of automatic compensation involves making a physical change in the capacity section equal and opposite to changes occurring in the inductive section. Therefore, for the two to be equivalent to the same percentage change, the overall length of the two sections must be substantially the same.

The oscillator circuit of Fig. 1 comprising vacuum tube 13 is typical of any oscillator circuit which can be used with the transmission line 1, 2. In practice, the oscillator circuit shown, which comprises an electron discharge device whose grid and anode are coupled together through a series circuit of inductance and capacitance, has several advantages over known types of circuits, and functions by adjusting the regenerative control condenser either above or below the capacity value required for a balance of the anode-grid circuit, but one adjustment or the other will be preferred depending upon the ratio of the effective resistance in the anode and grid circuits and the frequency. The grid is directly connected to the smaller diameter section, and the output is obtained from points on the inductance which are symmetrically located with

respect to a central point to which is connected the anode source of supply. Since the oscillator circuit per se forms no part of the present invention, it will not be further described herein.

Fig. 2 shows a preferred embodiment of resonant line and differs from the line of Fig. 1 in several minor respects. The external connection to the oscillator grid may either be connected to the metal plate 6 of the bellows as shown, or, as before, to the smaller diameter section. An adjustable capacity plate 14 between the upper end plate 12 and the plate 6 serves to give the line resonator a negative temperature coefficient of expansion to compensate for associated equipment which usually have positive temperature coefficients. Coordinated adjustment of the capacity plate 14 and adjusting screw 8 enables the resonator to give any desired temperature coefficient over a limited range and still maintain the same resonant frequency. If desired, the resonator may be made air tight and filled with compressed air or other gas to permit closer capacity spacing in high voltage applications by providing a small bellows section 15 in the manner shown, in which case the adjusting screw 14 should also be protected by a similar bellows, or else omitted from the assembly. The compressed gaseous fluid increases the working voltage of this type of resonator. Bellows 15 here serves the purpose of an air tight packing gland sealing the bearings of the adjusting mechanism so that the assembly may be made entirely air tight and filled with air or gas under high pressure for abnormally high voltage applications. This type of packing gland is used in a number of cases for valve stem sealing as it allows considerable motion of the moving parts while at the same time maintaining a continuous metallic structure.

Where, for mechanical reasons, it is necessary to use different metals or materials in the compound elements of this resonator, different proportions would have to be used to obtain temperature compensation. However, if the outer cylinder and the large section of the inner element be made of the same material and the expension bellows be in the large section as shown (Fig. 1), the smaller diameter section of the inner conductor may be of any other material without materially affecting the temperature compensation properties. Thus it would be possible to make the larger parts out of any light material such as duralumin and the smaller diameter section of the inner conductor, which principally determines the power factor, of a lower resistivity material such as copper and obtain lighter weight with practically the same electrical properties. Also, the entire assembly, or such parts as might be desired, could be plated with a low resistivity material such as silver without affecting the temperature compensating system.

The oscillator tube circuit shown in connection with the line of Fig. 2 is an alternative circuit to that of Fig. 1. In this case exact neutralization is first obtained by means of the variable condenser Z and then regeneration is obtained to cause oscillation by means of connection X between the anode and grid circuits. Such connection will provide direct coupling rather than capacitive or inductive coupling. The condenser in connection X is a blocking condenser for preventing the positive voltage from the anode circuit from being impressed on the grid circuit. The main difference between the two oscillator tube circuits of Figs. 1 and 2 is that the circuit of Fig. 1 requires the line to be tuned slightly off resonance while the line of Fig. 2 operates exactly on resonance. Other means of providing the feedback may also be used.

Resonators of this type may be used for all circuits to which the quarter wavelength concentric line resonator is applicable and have the advantage thereover of much shorter length and overall space requirements; consequently they permit a lower power factor structure than prior known resonators for a given total space.

By the term "line resonator" or "resonant line", used in the specification and appended claims, is meant a tuned circuit comprising a section of transmission line which can be used as an oscillatory circuit for any purpose, such as to stabilize or control the frequency of an oscillation generator.

What is claimed is:

1. A tuned circuit comprising a resonant line having inner and outer conductors, said inner conductor having two sections of different diameters, the smaller diameter section of said inner conductor contributing the main inductive component while the larger diameter section of said inner conductor contributes the main capacitive component of said tuned circuit, and means for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations.

2. A tuned circuit comprising a resonant line having inner and outer conductors coupled together at one of their adjacent ends, said inner conductor having two sections of different diameters, the section of larger diameter being at the free end of said inner conductor, the smaller diameter section of said inner conductor contributing the main inductive component while the larger diameter section of said inner conductor contributes the main capacitive component of said tuned circuit, and means for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations.

3. A tuned circuit comprising a resonant line having inner and outer conductors coupled together at one of their adjacent ends, said inner conductor being shorter than said outer conductor and having means for maintaining the overall length thereof substantially constant despite temperature fluctuations, said inner conductor comprising two sections of different diameters, the section of larger diameter forming the free end of said inner conductor, said sections being of substantially equal length, the smaller diameter section of said inner conductor contributing the main inductive component while the larger diameter section of said inner conductor contributes the main capacitive component of said tuned circuit.

4. A tuned circuit comprising a resonant line having inner and outer conductors conductively coupled together at one of their adjacent ends, said inner conductor being shorter than said outer conductor and comprising two sections of different diameter, the section of larger diameter forming the free end of said inner conductor, said sections being of substantially equal length, the smaller diameter section of said inner conductor contributing the main inductive component while the larger diameter section of said inner conductor contributes the main capacitive component of said tuned circuit, and means for maintaining

the overall length of said inner conductor substantially constant despite temperature fluctuations.

5. A tuned circuit comprising a resonant line having inner and outer coaxial conductors conductively coupled together at one of their adjacent ends, said inner conductor being shorter than said outer conductor and comprising two sections of different diameters, the section of larger diameter forming the free end of said inner conductor, said sections being of substantially equal length, the smaller diameter section of said inner conductor contributing the main inductive component while the larger diameter section of said inner conductor contributes the main capacitive component of said tuned circuit, a metallic bellows arrangement at the free end of said section of larger diameter, a rod of substantially low temperature coefficient of expansion within said inner conductor, extending substantially throughout the length thereof, and affixed at one end to said inner conductor and at its other end to said bellows for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations.

6. A tuned circuit comprising a resonant line having inner and outer hollow conductors conductively coupled at one of their adjacent ends, said inner conductor having two sections of different diameters, said outer conductor having a greater length than the overall length of said inner conductor and having a metallic covering over its free end, the smaller diameter section of said inner conductor contributing the main inductive component while the large diameter section of said inner conductor contributes the main capacitive component of said tuned circuit, and means for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations.

7. A tuned circuit comprising a resonant line having inner and outer hollow conductors conductively coupled at one of their adjacent ends, said inner conductor having two sections of different diameters, the smaller diameter section of said inner conductor contributing the main inductive component while the larger diameter section of said inner conductor contributes the main capacitive component of said tuned circuit, said outer conductor having a greater length than the overall length of said inner conductor and having a metallic covering over its free end, and an adjustable plate for varying the capacity between said metallic covering and the free end of said inner conductor, and means for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations.

8. A tuned circuit comprising a resonant line having inner and outer concentric conductors conductively coupled together at one of their adjacent ends, said inner conductor being shorter than said outer conductor and comprising two sections of different diameters, the section of larger diameter forming the free end of said inner conductor, said sections being of substantially equal length, the smaller diameter section of said inner conductor contributing the main inductive component while the larger diameter section of said inner conductor contributes the main capacitive component of said tuned circuit, a metallic bellows arrangement at the free end of said section of larger diameter, a rod of substantially low temperature coefficient of expansion within said inner conductor, extending substantially throughout the length thereof, and affixed at one end to said inner conductor and at its other end to said bellows for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations, and means for adjusting the length of said rod with respect to said inner conductor.

9. A resonant line tuned circuit comprising inner and outer conductors coupled together more closely at one of their adjacent ends than at their other, means including an adjusting screw for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations, means for increasing the working voltage of said resonator comprising a compressed gaseous fluid located between said conductors, and means surrounding said screw for tightly sealing the interior of said line.

10. A resonant line tuned circuit comprising inner and outer conductors, said inner conductor having two sections of different diameters, the inductance of said tuned circuit being substantially concentrated in said smaller diameter section of the inner conductor while the capacitance of said tuned circuit is substantially concentrated in said larger diameter section of the inner conductor, means including an adjusting arrangement for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations, means for increasing the working voltage of said resonator comprising a compressed gaseous fluid located between said conductors, and a bellows surrounding a portion of said adjusting arrangement for sealing the interior of said line.

11. A resonant line comprising inner and outer concentric conductors coupled together more closely at one of their adjacent ends than at the other, said outer conductor having means for completely enclosing said inner conductor, said line resonator having compressed air contained within said outer conductor adjustable external means extending within said outer conductor for varying the electrical relation between said inner and outer conductors, and an air tight bellows surrounding that portion of said adjustable means which is within said outer conductor for sealing the interior of said line.

12. A tuned circuit comprising a resonant line having inner and outer coaxial conductors, said inner conductor having two sections of different diameters but of substantially equal length, the smaller diameter section of said inner conductor contributing the main inductive component while the larger diameter section of said inner conductor contributes the main capacitive component of said tuned circuit, and means for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations, each of said sections of inner conductor and said outer conductor having substantially uniformly distributed inductance and capacitance.

13. A tuned circuit comprising a resonant line having inner and outer concentric conductors coupled together more closely at one of their ends than at the other end, said inner conductor having two sections of different diameters but of substantially equal length, the section of larger diameter of said inner conductor being located at said other end, and means for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations, each of said sections of inner conductor and said outer conductor having substantially uniformly distributed inductance and capacitance, the inductance of said tuned circuit being substantially

concentrated in said smaller diameter section of the inner conductor while the capacitance of said tuned circuit is substantially concentrated in said larger diameter section of the inner conductor.

14. A tuned circuit comprising a resonant line having inner and outer coaxial conductors, said inner conductor having two sections of different diameters but of substantially equal length, said sections being directly connected together, and means for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations, each of said sections of inner conductor and said outer conductor having substantially uniformly distributed inductance and capacitance.

15. A tuned electrical circuit comprising as a composite unit, inner and outer conductors, said inner conductor having two sections of different diameters, one of said sections contributing the main reactive component of one sign while the other of said sections contributes the main reactive component of the opposite sign of said tuned circuit, and means for maintaining the overall length of said inner conductor substantially constant despite temperature fluctuations.

16. A tuned high frequency circuit comprising inner and outer coaxial conductors electrically coupled together more closely at one of their adjacent ends than at the other end, said inner conductor having two sections of different diameters but of substantially equal length, each of said sections of said inner conductor and said outer conductor having substantially uniformly distributed inductance and capacitance.

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