

Oct. 18, 1949.

W. E. BRADLEY

2,485,029

FREQUENCY STABILIZER FOR OSCILLATORS

Filed Aug. 30, 1944

4 Sheets-Sheet 1

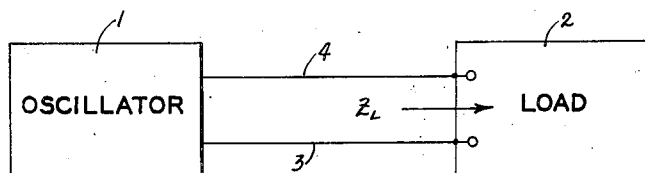


FIG. 1

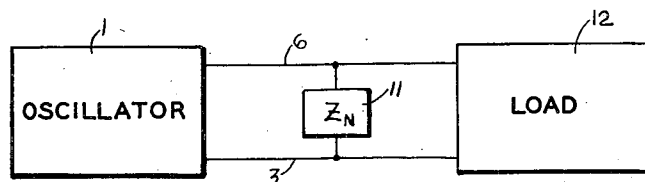


FIG. 2

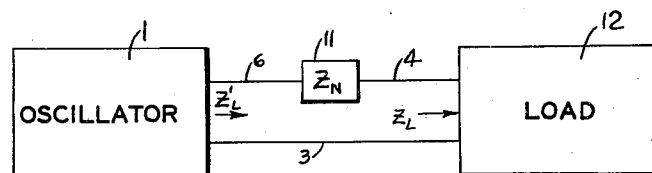


FIG. 3

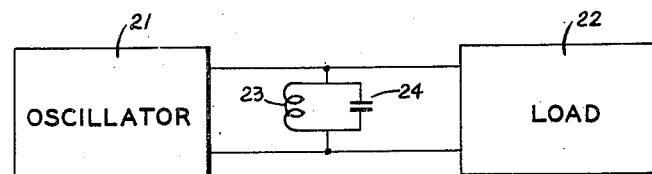


FIG. 4

INVENTOR.
WILLIAM E. BRADLEY
BY

Samuel C. Strubbe
ATTORNEY

Oct. 18, 1949.

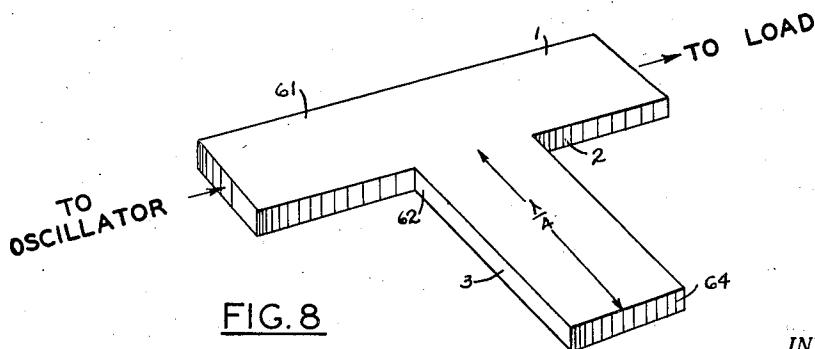
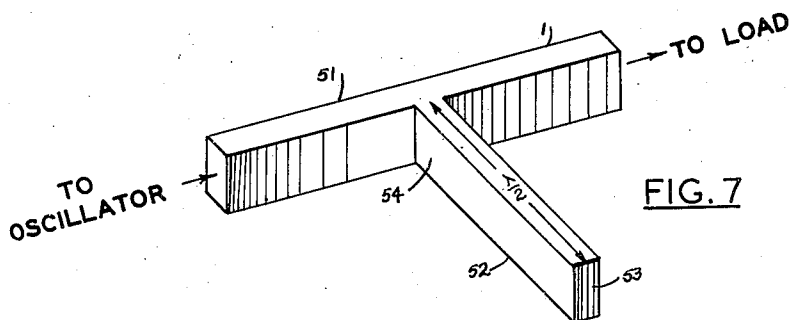
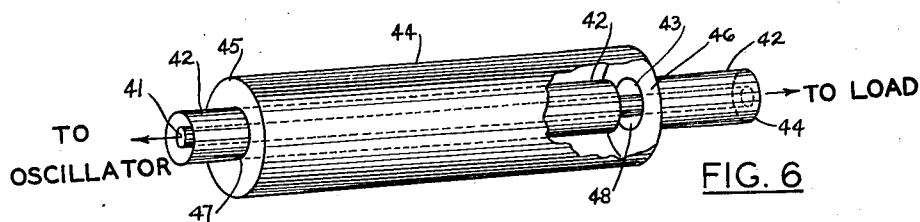
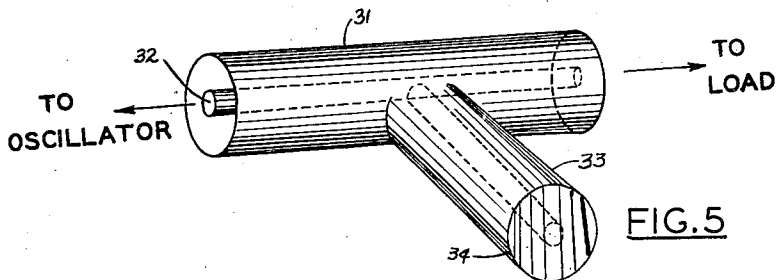
W. E. BRADLEY

2,485,029

FREQUENCY STABILIZER FOR OSCILLATORS

Filed Aug. 30, 1944

4 Sheets-Sheet 2



INVENTOR.
WILLIAM E. BRADLEY
BY
Samuel Ostrolenk
ATTORNEY

Oct. 18, 1949.

W. E. BRADLEY

2,485,029

FREQUENCY STABILIZER FOR OSCILLATORS

Filed Aug. 30, 1944

4 Sheets-Sheet 3

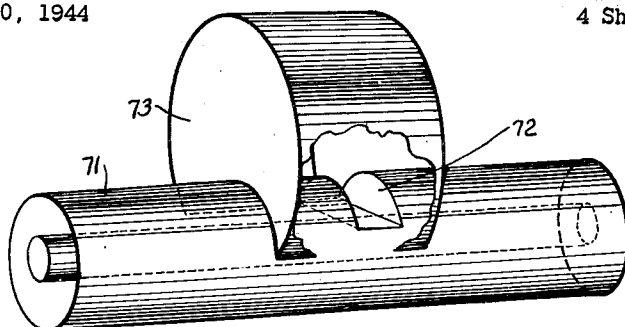


FIG. 9

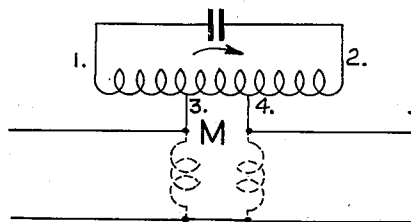


FIG. 9a

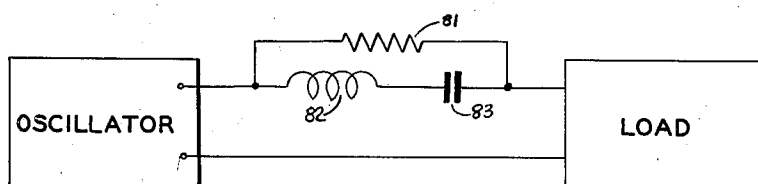


FIG. 10

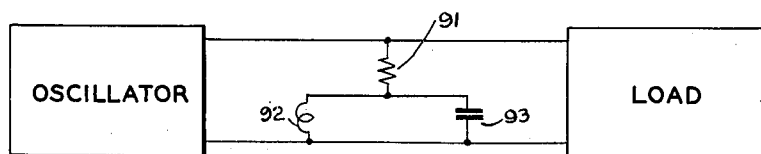


FIG. 11

INVENTOR.

WILLIAM E. BRADLEY

BY

Samuel C. Stroh
ATTORNEY

Oct. 18, 1949.

W. E. BRADLEY

2,485,029

FREQUENCY STABILIZER FOR OSCILLATORS

Filed Aug. 30, 1944

4 Sheets-Sheet 4

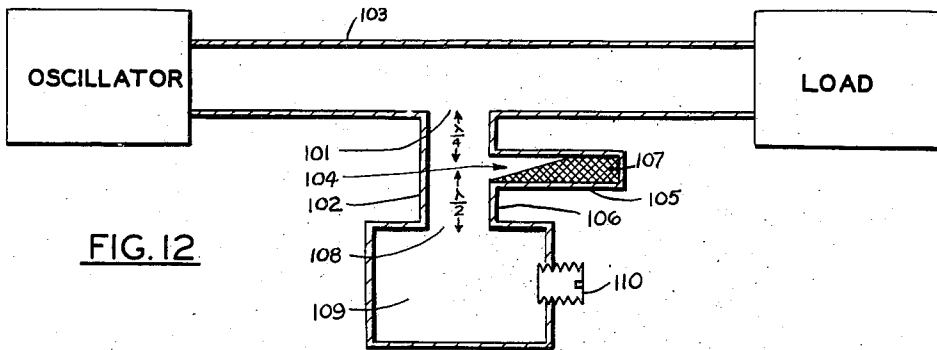


FIG. 12

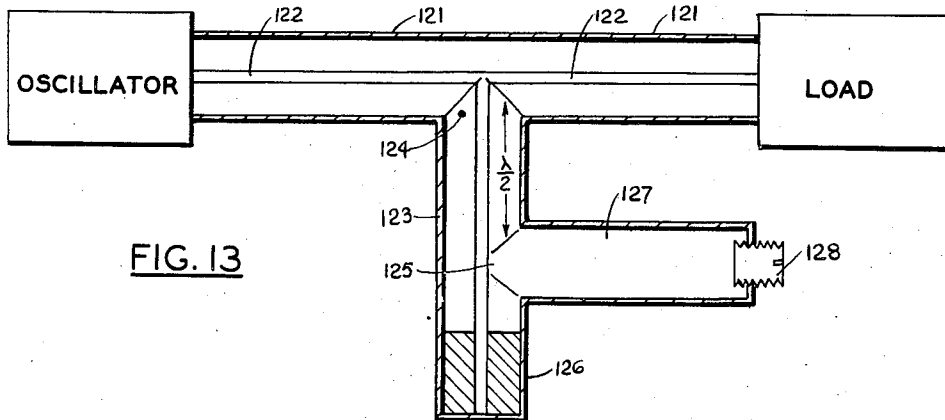


FIG. 13

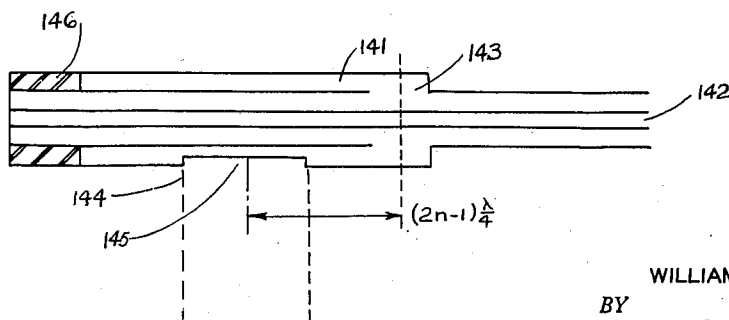


FIG. 14

INVENTOR.
WILLIAM E. BRADLEY
BY
Samuel C. Crotwell
ATTORNEY

UNITED STATES PATENT OFFICE

2,485,029

FREQUENCY STABILIZER FOR
OSCILLATORS

William E. Bradley, Swarthmore, Pa., assignor, by
mesne assignments, to Philco Corporation,
Philadelphia, Pa., a corporation of Pennsyl-
vania

Application August 30, 1944, Serial No. 551,951

11 Claims. (Cl. 250—36)

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My invention relates to a frequency stabilizing system and more particularly relates to a system for adjusting and stabilizing the frequency of high frequency oscillators as the voltage, current or load impedance varies.

In various applications of oscillators using electronic tubes, it becomes desirable at times to vary the load on the oscillator. Unfortunately, a variation in load is usually accompanied by a variation in the oscillator frequency. Such a variation in frequency may be especially serious in some types of radio communication systems in which a transmitter and a receiver, remotely disposed from each other, must be kept synchronized so that the difference between their frequencies must be maintained at a constant within a specified tolerance.

One method of isolating the load from the oscillator consists of interposing an amplifier between them. This well known buffer arrangement for preventing changes in frequency caused by load changes is, however, undesirable or impossible in certain applications of oscillators. For example, in the micro-wave region, where magnetron oscillators may be made to give very large instantaneous power outputs as oscillators, but do not function conveniently as amplifiers, such a buffer is impractical.

In accordance with my invention, frequency stabilization is effected by reflecting at predetermined points on the output transmission line of the oscillator in response to a shift in frequency from normal, the proper kind of reactance into the oscillator circuit.

In accordance with my invention, frequency stabilization is effected by reflecting a reactance into the line in response to a shift in frequency from normal of a kind that will tend to restore the frequency to its original value.

More specifically, in one form of my invention I connect a parallel reactance resonant to the frequency to be controlled across the transmission line. There are a number of points along the transmission line one half wave length apart, where an inductive reactance applied to the transmission circuit will elevate and a capacitive reactance will lower the frequency of the oscillator. At one of these points where this effect is maximum, I shunt my parallel resonant circuit across

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the transmission line which matches the impedance of the load.

If now the load impedance so changes that the frequency rises, a capacitance is presented by the parallel resonant circuit to the transmission line which lowers the frequency to its normal value.

If the load impedance so changes that the frequency falls, inductance is presented in parallel with the transmission line which raises the frequency to its normal value, by lowering the net inductance.

Halfway between the points along the transmission line referred to above because of the impedance transformation properties of a transmission line, an inductive reactance will lower and a capacitive reactance will elevate the frequency. This reactance is secured by a resonant series inductance and capacitance connected in series in the system at one of these half way points.

If the frequency rises in response to a change in load impedance above the stabilizing value and therefore above resonance frequency, an inductance is presented by the series resonant circuit to the transmission line which lowers the frequency to its normal value.

If the load impedance so changes that the frequency falls, capacitance is presented to the transmission line which raises the frequency to its normal value.

In the discussion above, I have referred to a special network. This, as will be clear from the description to follow, can also be a network in the coaxial sense, i. e., an arrangement of coaxial transmission line or it may be an arrangement of wave guide sections or resonant cavities. Arrangements can also be made using combinations of network elements, coaxial lines, wave guides and resonant cavities as will be explained hereinafter.

Accordingly, an object of my invention is to provide a novel network arrangement for effecting frequency stabilization of a system.

A further object of my invention is to provide a novel reactance network coupled to a circuit, the reactance reflected into the oscillating circuit being a function of the frequency fluctuations from normal to maintain the frequency of the system substantially constant.

Still another object of my invention is to provide a novel resonant parallel inductance capacitance circuit so connected in a transmission system that it presents capacitance to the line when the frequency rises to lower the frequency to normal and presents inductance to the line when the frequency drops to raise the frequency to normal.

Another object of my invention is to provide a novel resonant series inductance capacitance circuit so connected in a transmission system that it presents inductance to the line when the frequency rises to lower the frequency to normal and presents capacitance to the line when the frequency drops to raise the frequency to normal.

Still a further object of my invention is to provide a novel frequency controlled stabilizer which tends to maintain the net load impedance substantially constant.

These and other objects of my invention will appear from a detailed discussion which follows in connection with the drawings, in which:

Figure 1 is a schematic circuit diagram for illustrating my invention.

Figure 2 is a schematic circuit diagram of one form of my invention.

Figure 3 is a schematic circuit diagram of another form of my invention.

Figure 4 is a circuit diagram of my invention using a parallel inductance capacitance resonant circuit.

Figure 5 shows a method of connecting coaxial lines in parallel.

Figure 6 shows a method of connecting coaxial lines in series.

Figure 7 shows the corresponding arrangement to Figure 6 applied to a wave guide.

Figure 8 shows the corresponding arrangement of Figure 5 applied to a wave guide.

Figure 9 shows the invention applied to a resonant cavity with a coaxial line.

Figure 9a is the schematic equivalent of Figure 9.

Figures 10 and 11 show schematic circuits embodying my invention.

Figure 12 shows in cross-section a specific construction of wave guide embodying my invention.

Figure 13 shows in cross-section a further specific construction of a coaxial line embodiment of my invention; and

Figure 14 shows a further development of my invention utilizing the series coaxial line junction illustrated in Fig. 6.

In order to clarify the invention, a brief theoretical discussion of the principles here involved will first be given.

Referring to Figure 1, an oscillator 1 is shown connected to a load 2 over conductors 3 and 4 which are matched to the load impedance. In this system a fluctuation in reactance of the load will effect a corresponding change in frequency of the system.

To stabilize the frequency and prevent this shift, I insert at a proper point along the line in the system a special frequency stabilizing network 11 as shown in Figure 3. This stabilizing series network having an impedance Z_n is connected in series with the load in the circuit at a point where an inductive reactance most lowers the frequency and a capacitive reactance most raises the frequency. Such points exist at regular intervals one half wave length apart along the transmission line.

At regular intervals one half wave length apart and half way between the points referred to above, there exists points where an inductive re-

actance reflected into the system most raises the frequency and a capacitive reactance most lowers the frequency. At such points a parallel resonant circuit schematically illustrated in Figure 2 is inserted across the line.

In Figure 4 this is more fully shown by an inductor and a capacitor in parallel. Here the oscillator 21 is connected to the load 22 over a circuit across which there is connected a stabilizing inductor 23 and stabilizing capacitor 24 connected in parallel resonance.

This inductance and capacity tuned to resonance at the desired stabilized frequency is connected across the transmission line as shown at a point where an inductive reactance most raises the frequency and a capacitive reactance most lowers the frequency. Such points exist at points along the line a half wave apart and half way between the points hereinbefore described in connection with the series resonant circuits.

Normally with the line matched to the load, this resonant circuit has no effect on the system so long as the frequency is at the desired value. If, however, the load impedance varies, causing a rise in the oscillator frequency, the parallel reactance 23, 24 presents a capacitive reactance to the circuit which lowers the frequency to normal. If the shift in load impedance causes the frequency to fall, the parallel reactance 23, 24 presents an inductive reactance to the circuit which raises the frequency to normal.

One characteristic of the corrective network is that near the normal frequency, the reactance or susceptance as the case may be, must vary quite rapidly with frequency. This means that the Q of these elements must be high for close regulating action.

Accordingly, to secure most powerful stabilization, the inductance 23 and capacitance 24 are very small reactances, providing a good or about zero power factor. As a result, although the impedance is high at resonance, large corrective susceptances are rapidly thrown across the line for small changes of frequency.

As described above, it will be noted that with the device shown in Figure 3, if the frequency be forced by changes within the oscillator to frequencies too far removed from the normal frequency, the reactance of my special network will be very great, either positive or negative. This, however, would act as an open circuit and would tend to disconnect the load from the oscillator and cause the oscillator to operate unloaded. If the oscillator can operate in one mode only, this causes no trouble, but if the oscillator has two or more modes of oscillation, i. e., two or more frequencies of oscillation, it may elect to oscillate in a mode where there is no load. A similar situation would result in the parallel case of Figure 4 in which off resonance my special network becomes practically a short circuit. A magnetron is particularly susceptible to this type of difficulty.

In order to overcome this unloading effect, I place a resistor 81 in shunt with the tuned circuit 82, 83 of Figure 10 (the final form of Figure 3) in order that even though the tuned circuit 82, 83 became an open circuit, the load is connected to the oscillator through the resistor 81. The final form of Figure 4 is shown in Figure 11, in which a resistor 91 is placed in series with the resonant circuit 92, 93 so that the load is never completely short circuited. With these arrangements, the oscillator can never operate unloaded, and the rapid change of reactance or

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susceptance of the special network with frequency change is not lost.

These principles of stabilization can also be applied to systems using micro-wave frequencies. When the conductors between the oscillator and load are replaced by a coaxial transmission line, a modification of Figure 4 can be made as is shown in Figure 5. The coaxial line 31, 32 conducts power from the oscillator to the load. At such a position on this line that the addition of a capacitance lowers the frequency a maximum amount, a stub line 33, which is an odd number, of quarter waves long, is inserted at right angles to and in electrical parallel connection with the main line.

One end of stub line 33 is open and fits into an opening in the outer shield of coaxial line 31. The inner conductor of the stub extends through the junction of the stub and main coaxial line and is connected to the inner conductor of the main coaxial line. The opposite end of the stub is closed off at 34, so that it presents an infinite impedance to the main line 31, 32 at the normal frequency. If now the load is changed so that the frequency tends to decrease, this stub line operates as a less than quarter wave line, and thus operates to add inductance to the line and therefore to raise and restore the frequency to its normal value.

Because of its position on the line, its action counteracts the change in load impedance. Conversely, if the load impedance so changes that it acts as an inductance at the junction point of the main line and stub and the frequency rises, the stub line operates as a greater than quarter wave line and thus adds capacitance to the line causing the frequency to restore itself.

A coaxial counterpart of Figure 3 is shown in Figure 6. The central conductor 41 passes straight through the system. The outer conductor 42 of the main transmission line formed by 41 and 42 is broken at 43 at a point where a series inductance introduced into the transmission line decreases the frequency and a capacitance introduced into the line raises the frequency.

This break leads into a section of transmission line with the outer surface of 42 acting as the inner conductor and with a hollow cylindrical tube 44 acting as the outer conductor. The ends 45 and 46 of the tube are closed and in contact with conductor 42 along the circumferences 47 and 48 respectively.

The length of this section of 46 to 47 is chosen to be one half wave length or any other integral number of halves of a wave length of the frequency to be stabilized. This means that the series impedance looking into this section of the line from the main transmission line is substantially zero. Consequently, there results an effectively continuous transmission line at 43 when the stabilizing frequency exists.

At the frequency to be stabilized, the stabilizing unit does not have any effect upon a transmission through the main transmission line from the oscillator to the load.

If an impedance of the load is changed so that the impedance looking into the main section of the transmission line at position 43 appears to have a capacitance added to it, the frequency of the oscillator rises.

As the frequency begins to increase, the impedance looking into the compensator no longer appears the same as that of a similar line without the compensator, as a short circuit; instead it

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appears to be an inductance. This inductance acts in series with the equivalent capacitance seen looking towards the load and consequently tends to neutralize this capacitance. The net result of this action is to tend to hold the oscillator frequency substantially at a predetermined value.

Correspondingly, and for reasons that now will be clear, when the frequency goes below the predetermined value, a corrective capacitance to increase the frequency is applied to the line.

A form of Figure 3 using a series wave guide element is shown in Figure 7. Here the main wave guide 51 is a hollow tube of metal of rectangular cross-section, designed to carry the transverse electric mode with the lines of electric field parallel to the narrow dimension of the guide. The branch guide 52 of similar rectangular cross-section is an integral number of half wave lengths long opening into a cut in the large dimension of the main guide at the junction 54 and is closed at the end 53.

All the longitudinal current in the main guide must then flow in the branch guide and this arrangement is spoken of as a series connection. The branch guide 52 is connected to the main guide at a point where the addition of inductance lowers the frequency and the addition of capacitance raises the frequency.

A form of Figure 5 using a shunt wave guide section an odd number of quarter waves length long is shown in Figure 8. Here the main wave guide 61 is jointed at 62 to a branch guide 63 at a cut in both along the narrow edge of the guide. The branch guide is closed at its end 64, and the operation is entirely analogous to the operation of the coaxial system described in connection with Figure 5.

A combination of a resonant cavity with a coaxial line is shown in Figure 9. Here the main line 71 is broken by a slit 72 in the outer conductor. A cavity resonator 73 is fastened on the outside of this slit and serves the same function as the external line section in Figure 5. To accomplish this the cavity must be so dimensioned, in accordance with principles well known to the art, that it resonates in a mode such that it appears as a zero impedance in series with the line at the resonant frequency.

While the embodiments shown in Figures 5, 6, 7, 8 involve the principle of the invention, there are times when a more powerful stabilizing action is required. For this purpose the reactance change with frequency of the stabilizing network should be relatively great. This is obtained by having an exceedingly low L to C ratio in the tuned circuit of Figure 11 and an exceedingly high L to C ratio for the tuned circuit of Figure 10.

It is inconvenient to build straightforwardly constructed tuned circuits having the required L to C ratio, but over a narrow band the desired performance can readily be obtained by means of other types of networks, such as coaxial lines, resonators or wave guides.

A specific arrangement of my invention using wave guides is shown in Figure 12 in cross section. This is a modification of Figure 7, the cross section being taken through the narrow width of the wave guide. The coupling junction 101 of the branch guide 102 to the main guide 103 is at such a point along the main guide that an increase in the effective capacitance of the load as viewed from this junction point would cause the frequency to rise. At the normal frequency, the branch guide system presents a short circuit to

the main guide at junction 101. In order that this may be so, the distance from junction 101 to junction 104 is made close to a quarter wave length. An open circuit at junction 104 would appear as a short circuit at junction 101 because of the well known impedance inversion properties of a quarter wave length of wave guide. At junction 104 the two sub-branches 105 and 106 are in series because they are joined along their broad faces. The impedance looking into sub-branch 105 is a resistance, because 105 is partially filled with a lossy material 107 which absorbs any energy which enters 105 at 104. As viewed from 104, sub-branch 106 appears to have whatever impedance is presented to it at junction 108 by cavity resonator 109, because of the well known impedance retaining property of the half wave length section of guide between 104 and 108. At the normal frequency, this cavity resonator is tuned by adjusting screw 110, which may be placed almost anywhere in the wall of the cavity, so that the impedance of the cavity as seen from junction 108 is infinite. Then the impedance of section 106 as seen from 104 is infinite, and the series addition of 105 is of no importance.

Consequently, the impedance as seen from junction 101 is zero. When the frequency is slightly raised, the impedance transformation properties of the wave guide sections do not change very much. However, the impedance of the cavity becomes a high capacitive reactance, which then places a high capacitive reactance in series with the lossy subbranch 105 at junction 104. Again, the impedance of the lossy subbranch is insignificant compared to the impedance in series with it, so the impedance as viewed from junction 101 becomes an inductive reactance because of the impedance inversion qualities of a quarter wave guide section. This is just what is needed in order that the regulatory action described in connection with Figure 2 may become effective. At frequencies far removed from normal, the impedance of the cavity as viewed from 108 becomes low, so the impedance as viewed from junction 104 becomes substantially the impedance of the lossy subbranch 105. Consequently, a resistive impedance is presented to the main guide at 101 and the load is not disconnected, as it would be if the lossy guide section 105 were absent.

Another specific arrangement of my invention is described with reference to Figure 13. The main transmission line 121 and 122 is of the coaxial type, with an outer conductor 121 shown in section, and an inner conductor 122. A branch system is joined to the main coaxial line at a junction point 124 which is so chosen that an increase in the apparent inductance of the load as viewed from the junction point would cause the frequency to increase at a maximum rate. At the normal frequency, the impedance looking into the branch section at junction 124 is infinite.

In order for this to be true, the impedance at junction 125 which is the junction between a lossy section of line 126 and a cavity resonator 127, must be infinite because the length of line between junctions 124 and 125 is a half wave length. The impedance looking into the lossy section of line is primarily resistive, and is in series with the impedance looking into the cavity resonator from 125. This cavity resonator impedance is made infinite by adjustment of the tuning screw 128. Thus the impedance of the branch at junction point 124 is infinite.

At resonant frequency, the cavity looks like a very high impedance in series with the line.

Since the cavity is a half wave from the main transmission line when it appears as a nearly open circuit, the stub looks substantially like an open circuit to the transmission line. When, however, the cavity looks like a relatively low impedance, i. e., when off resonant frequency, the low value of impedance is limited by series mismatching resistor r , which prevents the stub from ever short-circuiting the main transmission line.

When the frequency is slightly raised, the impedance of a cavity coupled in this manner becomes a capacitive reactance, as is well known in micro-wave theory, and so the impedance in parallel with the line at 124 becomes capacitive, which is what is required for the regulatory action described for Figure 4 to take place.

When the frequency is far from the cavity resonant frequency, the impedance of the cavity is low, so the net impedance at junctions 124 and 125 is the resistance of the lossy line. This prevents short-circuiting of the load at frequencies far away from resonance, and thus acts to prevent oscillator operation at a frequency of any other oscillation mode.

Figure 14 is a coaxial line embodiment of Figure 10 and is noteworthy for its compactness. The cavity and resistive material are arranged in a manner electrically similar to the structure of Figure 13 except that the cavity is an odd number of quarter waves from the junction with the main line, which is of the type shown in Figure 6.

In Figure 14 the stub itself however is more complex than the one in Figure 6. The cavity resonator is coupled to the stub at a distance from the series junction 143 equal to an odd number of quarter wave lengths of the frequency to be stabilized. The cavity 144 is coupled to the stub line through a slot 145. The remaining part of the stub line is loaded at its end with some lossy material 146.

The cavity is coupled to the line section in physically the same but electrically a different way than the cavity 73 is coupled to line 71 in Figure 9. This electrical difference arises from the fact that now the cavity is resonating with the electrical lines parallel to the axis of the cavity.

The resonant cavity 73 is magnetically coupled to the transmission line, 71. The electric coupling cancels out over the whole interior space and accordingly it acts as if it were coupled purely by inductance at the resonant frequency of the tuned circuit shown in Figure 9a.

A very high impedance limited only by losses in the circuit appears across the terminals 1 and 2 of Figure 9a. At this same resonant frequency a very high impedance also appears across the terminals 3 and 4. However, it is only across a narrow band that the impedance across the terminals 3 and 4 is similar in form to that across 1 and 2. This impedance between terminals 3 and 4 differs in two particulars from that across 1 and 2. In the first place, it appears to be the impedance of a tuned circuit of vastly greater C to L ratio than the impedance between 1 and 2. The apparent C to L ratio depends on the proportion of inductance included between 3 and 4. The larger this inductance the less the C to L ratio. On the other hand, it differs also in the particular that at some higher frequency the impedance between 3 and 4 goes to zero. This frequency is so far removed in the actual designs of cavities used as to be immaterial and the device is used only in the neighborhood of W_0 which is the resonant frequency of the tuned circuit.

In this mode of cavity resonance, the structure

Figure 9 therefore has the property that when the cavity 73 is in a resonant condition the coaxial line is completely open-circuited opposite the slot 72.

The result in Figure 14 is that at the junction 145 the cavity presents a high resonant impedance in series with the impedance of the rest of the stub which is a resistive impedance. At the frequency to be stabilized, the resonant impedance of the cavity is infinite, so the series resistance of the lossy stub is of no consequence.

In Figure 14, the transformation action caused by the odd quarter wave length section of line makes the impedance of the stub at the series junction 143 appear as a short-circuit at the frequency to be stabilized. If, however, the load of the main line is changed so that the change in load causes the impedance looking towards the load from junction 143 to become capacitive, the frequency of the oscillator will rise because the series junction 143 is so placed on the main transmission line that this will occur.

This rise in frequency causes the resonant impedance of the cavity to become less than infinite and to become capacitive. It is still high, however, and consequently the impedance corresponding to the increase in frequency causes the impedance at the junction 145 to become capacitive. At this junction, the series resistance of the lossy section of the stub is negligible. This impedance when transformed by the odd quarter wave section of transmission line appears as a low inductive reactance at the series junction 143. This inductive reactance then compensates for the capacitive reactance of the load as seen from the location 143. As a consequence, the frequency need change only by the amount necessary for this compensation to occur.

If now the oscillator should attempt to oscillate at a frequency far removed from the desired operating frequency, the impedance of the cavity would become low. This impedance in series with the impedance of the lossy section of the line presents substantially a resistive impedance to the end of the odd quarter wave length section of stub line. The transformation property of this odd quarter wave length section is such that there will appear at the series junction a resistive impedance looking into the stub. This impedance will be in series with the load impedance and consequently the oscillator will still be loaded. This will in effect prevent the oscillator from operating at an undesired mode.

If the lossy section of stub line had not been present, the impedance at series junction 143 under these circumstances are removed from the resonant frequency of the cavity; that is, from the desired operating frequency would become an open circuit. This open circuit would effectively disconnect the load from the oscillator and might lead the oscillator to operate at a frequency far removed from the desired frequency. Not all oscillators, of course, have this difficulty, but magnetrons in particular do have a tendency to oscillate at a second frequency if they are unloaded at that frequency. The function of the lossy section will in that case prevent such undesirable oscillation frequencies.

Experimental work with frequency stabilizers of this type indicate that they are also effective in reducing the frequency change caused by variations in voltage or current in the oscillator tube. They find application in radar systems where reflected waves, such as may come from the antenna

housing, effect an impedance change in the antenna load.

Various modifications of the principles of my invention will now be evident to those skilled in the art. I therefore prefer not to be bound by the specific disclosures hereinabove set forth, but only by the appended claims.

I claim:

1. In a micro-wave electrical system having a transmission line for the transmission of energy in the microwave region, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, said line having a number of points therealong, one half wave length apart where reactance can be reflected into the line in response to a shift in frequency from a predetermined value to restore the frequency to its predetermined value, a reactance connected to said line at one of said points for effecting the frequencies of said system, and a resistance in circuit connection with said reactance for suppressing modes of oscillations other than the desired mode.

2. In a micro-wave electrical system having a transmission line for the transmission of energy in the micro-wave region, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, there being a number of points along said transmission line one half wave length apart, where an inductive reactance applied to the line will elevate and a capacitive reactance applied to the line will lower the frequency of said oscillator, a reactance shunted across said line at a point where its effect is maximum for effecting the frequencies of said system, said reactance matching the impedance of said load and presenting capacitance to the line, if the frequency rises, to lower the frequency to its predetermined value and presenting inductance in parallel to the line if the frequency falls below said predetermined value to restore said frequency to said predetermined value and a resistance connected in series with said reactance for suppressing modes of oscillation other than the desired mode.

3. In short wave electrical system having a transmission line for the transmission of short wave energy, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, said line having a number of points therealong, one half wave length apart where reactance can be reflected into the line in response to a shift in frequency from a predetermined value to restore the frequency to its predetermined value, a reactance comprising an inductance and capacitance of relatively small reactance value providing substantially zero power factor connected to said line at a point where its effect is maximum to reflect a substantially large corrective reactance into the system in response to small change in frequency of said oscillator from a predetermined frequency for maintaining the frequency thereof constant as it tends to vary from a predetermined value and a resistance in circuit connection with said reactance for suppressing modes of oscillation other than the desired mode.

4. In a short wave electrical system having a transmission line for the transmission of short wave energy, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, there being a number of points along said transmission line one half wave length apart, where an inductive reactance applied to the line will elevate and a

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capacitive reactance applied to the line will lower the frequency of said oscillator, a reactance comprising an inductance and capacitance of relatively small reactance value providing substantially zero power factor connected to said line at a point where it reflects a substantially large corrective inductive reactance into the system in response to small changes in frequency of said oscillator from a predetermined frequency for elevating the frequency thereof to normal in response to a drop in frequency and a resistance in circuit connection with said reactance for suppressing modes of oscillation other than the desired mode.

5. In an electrical system having a transmission line, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, there being a number of points along said transmission line, one half wave length apart, where an inductive reactance reflected into the line will lower and a capacitive reactance reflected into the line will raise the frequency of said oscillator, a reactance comprising an inductance and capacitance in which the L to C ratio is high, connected to said line at such a point where it reflects a substantially large corrective inductive reactance into the system for lowering the frequency thereof to normal in response to a rise in frequency, and a resistance connected across said reactance for suppressing modes of oscillation other than the desired mode.

6. In an electrical system having a transmission line, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, there being a number of points along said transmission line, one half wave length apart, where an inductive reactance applied to the line will elevate and a capacitive reactance applied to the line will lower the frequency of said oscillator, a reactance comprising an inductance and capacitance in which the L to C ratio is relatively very low connected to said line at such a point where it reflects substantially large corrective capacitance reactance into the system in response to small changes in frequency of said oscillator from a predetermined frequency for lowering the frequency thereof to normal in response to a rise in frequency and a resistance connected in series with said reactance for suppressing modes of oscillation other than the desired mode.

7. In an electrical system having a transmission line, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, there being a number of points along said transmission line, one half wave length apart, where an inductive reactance reflected into the line will lower and a capacitive reactance reflected into the line will raise the frequency of said oscillator, a reactance comprising an inductance and capacitance in which the L to C ratio is high connected to said line at such a point where it reflects a substantially large capacitance reactance into the system for elevating the frequency thereof to normal in response to a drop in frequency, and a resistance connected across said reactance for suppressing modes of oscillation other than the desired mode.

8. In short wave electrical system having a transmission line for the transmission of short-wave energy, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, there being a num-

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ber of points along said transmission line one half wave length apart, where an inductive reactance applied to the line will elevate and a capacitive reactance applied to the line will lower the frequency of said oscillator, a circuit for stabilizing the frequency of said oscillator comprising parallel inductance and capacitance whose L to C ratio is low connected across said line at a point where capacitance most lowers the frequency in response to a rise of frequency, said inductance and capacitance being tuned to resonate at the frequency to be stabilized, the reactance of said inductance and capacitance being small compared to the impedance of said transmission line and a resistance connected in series with said reactance for suppressing modes of oscillation other than the desired mode.

9. In short wave electrical system having a transmission line for the transmission of short-wave energy, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, there being a number of points along said transmission line one half wave length apart, where an inductive reactance applied to the line will elevate and a capacitive reactance applied to the line will lower the frequency of said oscillator, a circuit for stabilizing the frequency of said oscillator comprising parallel inductance and capacitance whose L to C ratio is low connected across said line at a point where capacitance most lowers the frequency in response to a rise of frequency, said inductance and capacitance being tuned to resonate at the frequency to be stabilized, and a resistance connected in series with said parallel inductance and capacitance of a value for suppressing modes of oscillation other than the desired mode.

10. In short wave electrical system having a transmission line for the transmission of short-wave energy, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, said line having a number of points therealong, one-half wave length apart where reactance can be reflected into the line in response to a shift in frequency from a predetermined value to restore the frequency to its predetermined value, a circuit for stabilizing the frequency of said oscillator comprising a series inductance and capacitance whose L to C ratio is high and tuned to resonance at the frequency to be stabilized and connected in said line at a point where it reflects a corrective impedance into said line in response to a change in frequency from normal for restoring said frequency to its normal value and a resistance in circuit connection with said reactance for suppressing modes of oscillation other than the desired mode.

11. In short wave electrical system having a transmission line for the transmission of short-wave energy, a magnetron oscillator having two or more modes of oscillation coupled to said line, a load connected to said line, said line having a number of points therealong, one half wave length apart where reactance can be reflected into the line in response to a shift in frequency from a predetermined value to restore the frequency to its predetermined value, a circuit for stabilizing the frequency of said oscillator comprising a series inductance and capacitance whose L to C ratio is high and tuned to resonance at the frequency to be stabilized and connected in said line at a point where it reflects a corrective impedance into said line in response to a change in

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frequency from normal for restoring said frequency to its normal value and a resistance shunted across said resonant circuit for suppressing modes of oscillation other than the desired mode.

WILLIAM E. BRADLEY.

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