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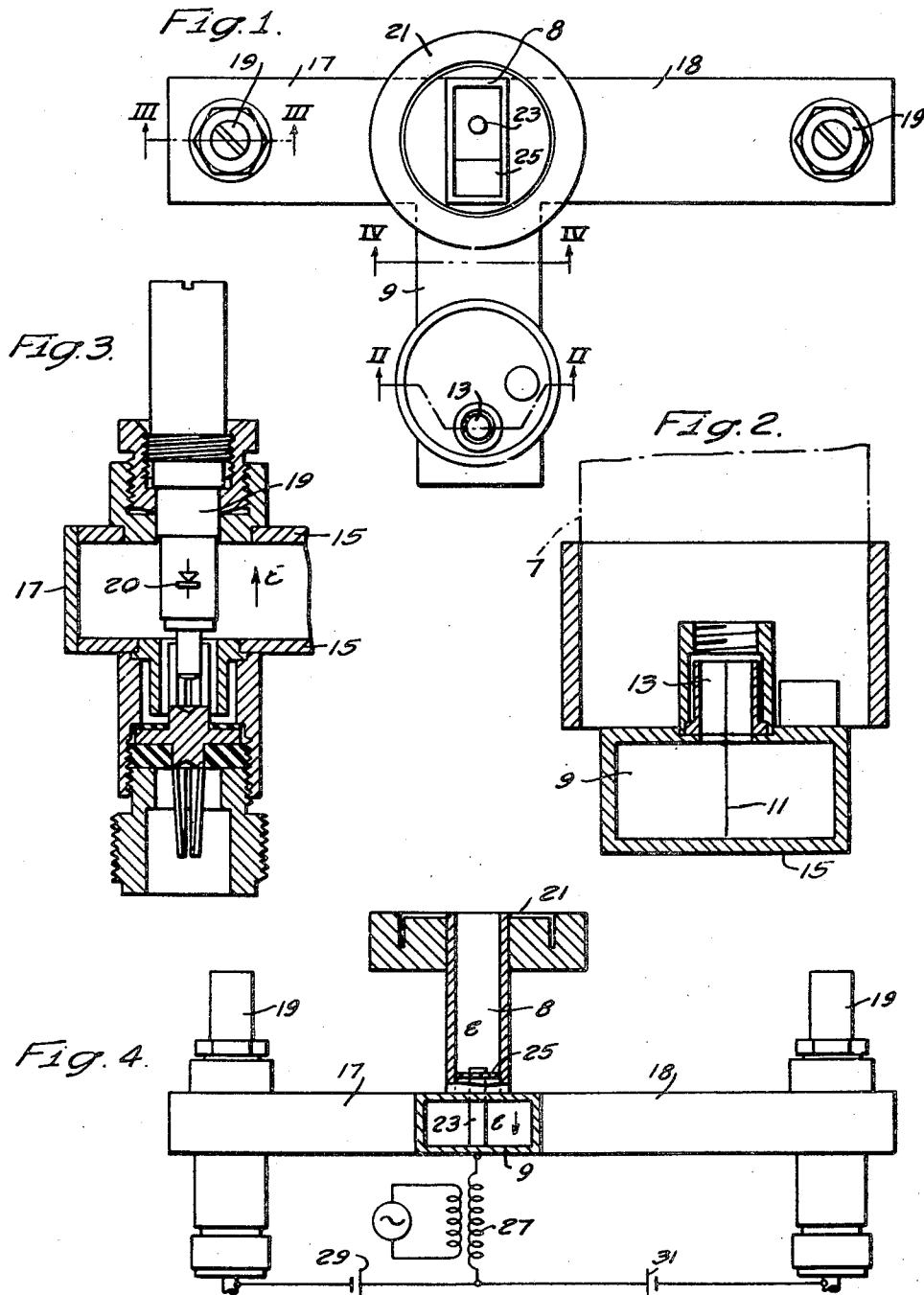
S. G. VAUGHAN

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MODULATOR

Filed April 2, 1948

2 Sheets-Sheet 1



WITNESSES:

*E. A. M. M. M.*

*Leon M. Garman*

INVENTORS  
*Sam G. Vaughan, Eugene F. Grant,  
William Altar and Marcus W. Dodd.*

BY

*Hyman Diamond.*

ATTORNEY

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S. G. VAUGHAN

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Fig. 5.

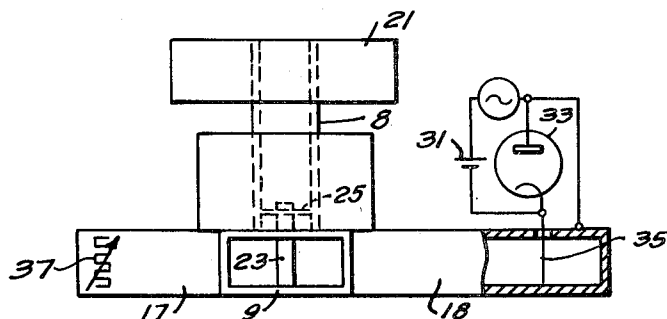
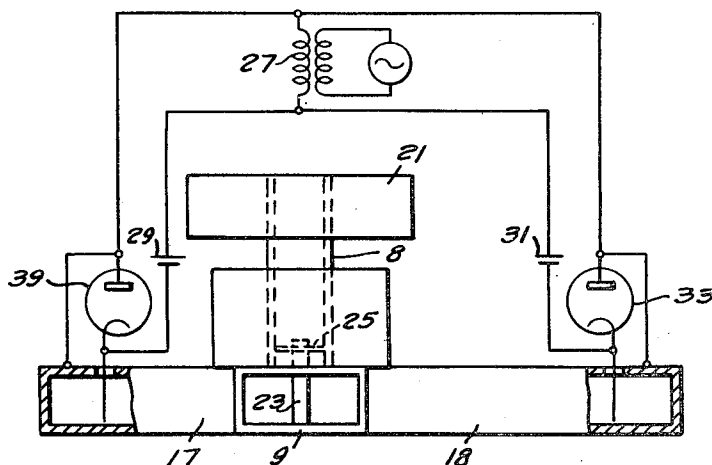


Fig. 6.



WITNESSES:

*E. A. McElroy*

*Leon M. Garman*

INVENTORS

*Sam G. Vaughan, Eugene F. Grant,  
William Altar and Marcus W. Dodd.*

BY

*Wymen Diamond*  
ATTORNEY

## UNITED STATES PATENT OFFICE

2,484,256

## MODULATOR

Sam G. Vaughan, Harlingen, Tex., Eugene F. Grant, Arlington, Mass., and William Altar and Marcus W. Dodd, Pittsburgh, Pa., assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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18 Claims. (Cl. 332—56)

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Our invention relates to modulation and has particular relation to amplitude modulation of oscillations in the micro-wave frequency range.

In accordance with the teachings of the prior art of which we are aware, modulation of such oscillations may be effected, by the application of a modulation voltage to a reflector, an accelerating grid or any other electrode of an oscillator tube, such as a velocity modulated tube known in the art as a klystron, or a magnetron. A disadvantage of modulation of this type is that undesirable frequency modulation results. Another disadvantage lies in the sluggishness of the modulated output in failing to follow with fidelity modulating voltages having high-frequency components, such as are encountered in television and frequency modulation broadcast systems. Modulation of micro-wave oscillations may also be effected by connecting a non-linear resistance element such as a crystal, to absorb the oscillations and causing the modulating voltage to vary the resistance of the element. A disadvantage of this method is that frequency modulation occurs unless power is dissipated in large quantities to suppress the frequency modulation.

It is, accordingly, an object of our invention to provide apparatus for producing amplitude modulation of oscillations of very high frequencies such as micro-wave frequencies, with substantially no accompanying frequency modulation.

Another object of our invention is to provide apparatus for producing with fidelity and at a fast rate, amplitude modulation of oscillations of micro-wave frequencies.

An additional object of our invention is to provide apparatus for producing amplitude modulation of oscillations of micro-wave frequencies with the dissipation of only a minimum fraction of the input or generated high frequency power.

An incidental object of our invention is to provide apparatus for modulating the amplitude of micro-wave oscillations in accordance with high frequency signals of the type encountered in television and frequency-modulation broadcast transmission.

In accordance with our invention we provide apparatus on which the modulation is effected in a hybrid junction known as a "magic T." Unmodulated micro-wave oscillations enter one of the branches of the T. The resistance impedance

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of two other conjugated branches are varied in accordance with the modulations to be impressed. The resulting modulated oscillations are emitted through a fourth branch.

The novel features that we consider characteristic of our invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Figure 1 is a top plan view of apparatus embodying our invention;

Fig. 2 is a sectional view taken on line II—II of Fig. 1;

Fig. 3 is a sectional view taken on line III—III of Fig. 1;

Fig. 4 is a section, partly schematic, of the apparatus shown in Fig. 1, as seen along line IV—IV with parts broken away;

Fig. 5 is a view partly schematic and partly in section and elevation of a modification of our invention; and

Fig. 6 is a view partly schematic and partly in section and elevation of another modification of our invention.

The apparatus shown in Figs. 1-4 comprises a system of wave guides of rectangular transverse cross section known in the art as a hybrid junction or magic T. The magic T as described here has four branches. A first branch 9 is joined to the face of least area of a second branch 17 and third branch 18, said second and third branches comprising a straight rectangular wave guide with the magic T junction near its center, the first branch entering through the face of least area perpendicular to that face and so oriented that the sides of greatest area of the first, second and third branches lie in parallel planes. The apparatus is so constructed that the third branch 18 is one-quarter wave length longer than the second branch 17, said quarter wave being measured for the velocity of the oscillations inside the wave guide.

Joined to the first, second and third branches at the magic T junction is a fourth branch 8 extending in a direction perpendicular to the plane of the first, second and third branches and with

the long dimension of its cross section parallel to the direction of the first branch.

A velocity modulated tube known as a klystron oscillator 7 is coupled to the first branch wave guide 9 by means of a probe 11 extending from the oscillator through the toll hole 13 into the wave guide. The probe 11 extends perpendicular to the faces 15 of greater area of the guide and couples energy from the klystron into the guide.

Inserted in the two other branch wave guides 17 and 18 are like crystal converters 20. These crystals 20 determine the termination impedance of the branches. These crystals 20 are mounted in crystal holders 19 which are insulated from the respective wave guides at one end and grounded to the wave guides at the other. As shown in Fig. 4, the two crystals and their mountings are substantially alike except that one is located further from the center of the magic T junction than the other by a difference in distance equal to one-quarter wave length of the electromagnetic wave to be modulated while passing along the wave guide.

On the fourth branch is a choke fitting 21, for connection of apparatus such as an antenna, for example, for radiating energy, preferably of characteristics which will present a matched termination to the fourth branch.

At the center of the junction of the magic T, there are an impedance matching pin 23 and diaphragm 2 designed to suppress reflection of oscillations of the frequency being transmitted at the junction. These and other methods of matching at the junction are well known in the art. For further information see Hybrid circuits for micro-waves by W. A. Tyrrell in Proceedings of the Institute of Radio Engineers, volume 35, No. 11, November 1947, page 1294.

The modulating signal may be derived from a source of any type; for example, an audio or video source such as is encountered in broadcast transmission of sound or in television or a signal such as is encountered in supervision or remote control systems. Potentials from the source of signal modulations are impressed on the crystals 20, for example by means of a transformer 27. One terminal of the secondary coil of the transformer is grounded to the wave guide. The other terminal of the secondary coil is fastened to the ungrounded end of the crystal holder through biasing potentials 29, 31. Thus the combination of biasing potential and modulating potential is simultaneously applied to both crystals, the crystals having equal properties, so that they will draw substantially equal biasing currents and operate on corresponding points of their characteristic curves. The biasing potentials are selected of such value as will cause the crystals to operate on the non-linear portion of their characteristic curves over the range of variation of the modulating signal.

The oscillating electric field entering through the first branch 9 oscillates in a direction perpendicular to the side of greatest area of the rectangular wave guide of which the first branch is comprised. At the junction of the magic T the energy is deflected to the right and left along second and third branches 17 and 18. Part of the energy will be absorbed in the crystals in the second and third branches and the rest will be reflected toward the magic T junction. According to the well-known principles of operation of magic T's, if the reflected waves in the second and third branches arrive at the magic T in phase opposition, they will be guided exclusively

into the fourth (antenna) branch 8, no reflected wave portion entering the first branch. Since the currents traversing the crystals are equal at each instant, they will produce substantially equal resistance in the crystals, and since one of these two equal resistances is one-quarter wave length farther from the magic T than the other, the above-mentioned condition of phase-opposition is always fulfilled. This results in complete protection of the oscillator from reflections which would otherwise be present. These reflections would vary with the modulated intensity and would cause undesired reactions such as frequency change, phase change, etc., in the oscillator.

The quantity of energy being guided into the fourth branch 8 depends on the degree of mismatch between the second branch of the wave guide and the crystal mounted therein which should be made the same as the mismatch between the third branch and the crystal mounted in it. If the resistance of the crystals match the characteristic impedance of the guide, there will be no energy guided into the fourth branch 8, since all of the oscillator power will be absorbed in the two crystals. The biasing voltage impressed by source 27 on the two crystals 20 may be adjusted so as to fulfill these conditions.

If the characteristics of the second and third branches are equal then for equal absorption of energy in the two branches the resistances of the crystals in the second and third branches must be equal. The equations governing the operation of this apparatus are, counting the input power as unity:

$$P_2 = \frac{2RZ_0}{(R+Z_0)^2} \quad (1)$$

$$P_3 = \frac{2RZ_0}{(R+Z_0)^2} \quad (2)$$

$$P_4 = \left( \frac{Z_0 - R}{Z_0 + R} \right)^2 \quad (3)$$

where  $P_2$ ,  $P_3$ , and  $P_4$  are the power in the second, third and fourth branches, respectively,  $R$  is the resistance of the crystals in the second and third branches and  $Z_0$  is the characteristic impedance of the second and third branches.

It will be observed from Equation 3 that the value of  $P_4$ , the output power, will vary when  $R$  changes. Thus by simultaneously varying the value of  $R$  for the two crystals in accordance with an input signal (i. e. by varying the bias voltage from source 27 in accordance with such a signal) the output power may be modulated in accordance with any desired signal.

The fields of the reflected oscillations have a direction perpendicular to the side of greatest area of the wave guides comprising the second and third branches. The proportion of absorbed energy to reflected energy will depend on the phase of the audio wave being applied to the crystals 20. If the crystals are matched, if the fourth branch presents a matched load to the micro-wave energy entering that branch, and if the modulating potentials being applied to the two crystals are equal, then all of the reflected waves will pass out the fourth branch as the two branches differ in length by one-quarter wave length; the waves entering the first branch 9 will cancel and thus no energy passes in this direction. If, on the other hand, the crystals are not matched, a portion of the reflected waves will be deflected back toward the klystron oscillator 7, distorting the carrier wave and causing undesirable frequency modulation.

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Fig. 5 is a modification of the apparatus shown in Figs. 1-4 which is similar to the latter except that the crystals in the second and third branches are replaced by a diode 33 coupled to the wave guide by a probe in the third branch and a constant load 37 connected in the second branch. This load should be substantially resistance, i. e., it should be capable of absorbing power and be matched to the characteristic impedance of the guide.

The energy from the klystron oscillator 7 enters the first branch 9 and is deflected at the junction of the magic T into the second and third branches 17 and 18. As the potential of the applied signal to the diode 33 varies, the impedance of the branch changes, causing varying quantities of energy to be reflected back toward the junction of the magic T from the third branch 18. This energy is deflected equally into the first branch 9 and the fourth branch 8 at the magic T junction, that part passing through the fourth branch 8 being radiated.

Substantial quantities of energy are dissipated in the second branch by the matched load connected therein. Under certain circumstances such dissipation may be undesirable. In such cases we introduce another modification of our invention as shown in Fig. 6. Here we have another diode 39 for varying the reactance in the second branch 17 in place of the matched load 37 used in Fig. 5. The operation of this apparatus is similar to the operation of the apparatus shown in Figs. 1 to 4 where two crystals are used, diodes being used instead of crystals to vary the reactance of the second and third branches.

The diodes as shown in Figs. 5 and 6 are mounted outside the wave guide. They can also be mounted inside the wave guide in the practice of our invention. While, in accordance with the specific aspects of our invention, crystals and diodes as shown are used for varying the branch wave-guide impedances, tubes of other types may also serve in accordance with the broader aspects of our invention. For example, reactance tubes may be used; or alternatively high vacuum triodes and gas discharge tubes (both diodes and triodes) may be used connected in ordinary modulating networks. Generally, an electronic device of any type, the resistance of which may be varied by the modulating source and which is capable of absorbing high frequency electromagnetic energy will prove satisfactory. Klystron oscillators have been shown as a source of high frequency electromagnetic energy, but other sources of oscillation, such as magnetrons and travelling wave tubes, may be used. The oscillations reflected from the second and third branches have been caused to reach the junction after reflection out of phase with each other so that the reflected energy goes out the fourth branch rather than the first by making one branch longer than the other by one-quarter wave length. This phase opposition can also be obtained by other methods such as varying the impedance in a different manner in each branch.

Although we have shown and described certain specific embodiments of our invention, we are fully aware that many modifications thereof are possible. Our invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

We claim as our invention:

1. In combination, a wave guide having a group

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of four branches, means for supplying high frequency oscillations to the first of said group, means for varying the impedance of the second and the third of said groups, the impedance variation of said second counteracting the impedance variation of said third so that the impedance looking into said first remains unchanged while the impedances of said second and said third are being changed, and means for coupling the fourth of said group to said first, second and third to derive the net energy produced therefrom.

2. In combination, a wave guide having a group of four branches, means for supplying high frequency oscillations to the first of said group, means for varying the impedance of the second and the third of said group, the impedance variation of said second counteracting the impedance variation of said third so that the impedance looking into said first branch remains unchanged while the impedances of said second and said third are being changed, said varying means being of the type capable of absorbing energy, and a fourth branch with a matched termination coupled to said first, second and third branches to radiate the net energy produced therefrom.

3. In combination, a wave guide having a group of four branches, means for supplying high frequency oscillations to the first of said group, means for varying the impedance of the second of said group, a matching impedance terminating the third of said group, and a fourth branch terminated by a matched load coupled to said first, second and third to derive the net energy produced therefrom.

4. In combination, a wave guide having a group of four branches, means for supplying high frequency oscillations to the first of said group, crystals for varying the impedance of said second and said third of said group, the impedance variation of the second counteracting the impedance variation of the third so that the impedance looking into said first remains unchanged while impedances of said second and said third are being changed, and a fourth branch containing a matched termination coupled to said first, second and third to derive the net energy produced therefrom.

5. In combination, a wave guide having a group of four branches, means for supplying high frequency oscillations to the first of said branches, diodes for varying the impedance of the second and the third of said branches, the impedance variation of said second counteracting the impedance variation of said third so that the impedance looking into said first branch remains unchanged while impedances of said second and said third branches are being changed, and a fourth branch containing a matched termination coupled to said first, second and third branches to derive the net energy produced therefrom.

6. In combination, a wave guide having a group of four branches, a klystron oscillator for supplying high frequency oscillations to a first of said branches, crystals operating in the non-linear part of their characteristic curves for varying the impedance of the second and third of said branches, the impedance variation of said second counteracting the impedance variation of said third so that the impedance looking into said first remains unchanged while impedances of said second and said third branches are being changed, and a fourth branch containing a matched termination coupled to said first, second and third branches to derive the net energy produced therefrom.

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7. In combination, a main wave guide of rectangular cross section with a first branch leaving it at right angles from the middle of its side of smallest area, said first branch having the long dimension of any cross section parallel to the length of said main wave guide, means for supplying high frequency oscillations to the said first branch, means for varying the impedances terminating said main wave guide, the impedance variation of one-half counteracting the impedance variation of the other half so that the impedance looking into said first branch remains unchanged while said impedances of said main wave guide are being changed, a second branch also joining the said main wave guide at the center of its side of greatest area and being at right angles to said wave guide and having the long dimension of any cross section perpendicular to the length of said main wave guide, said second branch to derive the net energy produced therefrom.

8. In combination, a main wave guide of rectangular cross section with a first branch leaving it at right angles from the middle of its side of smallest area, said first branch having the long dimension of any cross section parallel to the length of said main wave guide, a klystron oscillator for supplying high frequency oscillations to the said first branch, crystals operating in the non-linear portion of their characteristic curve for varying the impedances terminating said main wave guide, the impedance variation of one-half counteracting the impedance variation of the other half so that the impedance looking into said first branch remains unchanged while impedances of said main wave guide are being changed, a second branch also joining the said main wave guide at the center of its side of greatest area and being at right angles to said wave guide by having the long dimension of any cross section perpendicular to the length of said main wave guide, said second branch to derive the net energy produced therefrom.

9. In combination, a wave guide having a group of four branches, means for supplying high frequency oscillations to a first of said branches, means for varying the impedance of a second of said branches, an unmatched impedance terminating a third of said branches, and a fourth branch containing a matched load coupled to said first, said second and said third branches to derive the net energy produced therefrom.

10. In combination, a main wave guide of rectangular cross section with a first branch leaving it at right angles from near the center of its side of smallest area, said first branch having the long dimension of any cross section parallel to the length of said main wave guide, a klystron oscillator for supplying high frequency oscillations to the said first branch, crystals operating in the non-linear portion of their characteristic curve for varying the impedances terminating said main wave guide, the oscillations reflected from one-half counteracting the oscillations reflected from the other half so that the impedance looking into said first branch remains unchanged while impedances of said main wave guide are being changed, a second branch also joining the said main wave guide at the center of its side of greatest area and being at right angles to said wave guide by having the long dimensions of any cross section perpendicular to the length of said main wave guide, said second branch to derive the net energy produced therefrom.

11. In combination, a system of balanced wave

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guides including an input wave guide, an output wave guide and a pair of conjugate wave guides, a source of oscillations coupled to said input wave guide to supply oscillations thereto, facilities for deriving power from said output wave guide, impedances in said conjugate wave guide, and means for varying said impedances to a substantially equal extent.

12. In combination, a system of balanced wave guides including an input wave guide, an output wave guide and a pair of conjugate wave guides, facilities for coupling a source of oscillations to said input wave guide to supply oscillations thereto, facilities for deriving power from said output wave guide, impedances in said conjugate wave guides, and means for varying said impedances to a substantially equal extent.

13. In combination, a system of balanced wave guides including an input wave guide, an output wave guide and a part of conjugate wave guides, facilities for coupling a source of oscillations to said input wave guide to supply oscillations thereto, facilities for deriving power from said output wave guide, impedances of the type wherein resistance varies as function of current in said conjugate wave guides and means for varying said impedances to a substantially equal extent.

14. In combination, a system of balanced wave guides including an input wave guide, an output wave guide and a pair of conjugate wave guides, facilities for coupling a source of oscillations to said input wave guide to supply oscillations thereto, facilities for deriving power from said output wave guide, impedances in said conjugate wave guides, said impedances being so disposed and so selected that there is phase displacement of 180° between reflections of in-phase waves transmitted respectively along each conjugate wave guide and reflected by said impedances.

15. In combination, a system of balanced wave guides including an input wave guide, an output wave guide and pair of conjugate wave guides, a source of oscillations coupled to said input wave guide to supply oscillations thereto, facilities for deriving power from said output wave guide, impedances wherein resistance varies as function of current in said conjugate wave guides and means for varying said impedances to a substantially equal extent, one of said pair of conjugate wave guides being one-quarter wave length longer than the other wave guide of said pair.

16. In combination, a transmission system having a plurality of branches including an input and an output branch, means for supplying to said input branch high frequency oscillations, means for varying the impedances in some of the other branches in a manner such that the impedance looking into the input branch is substantially unchanged while the impedances of other branches are being changed.

17. In combination, a main wave guide of rectangular cross section with a first branch joining it at right angles from its side of smallest area one-quarter wave length further from one end than from the other said one-quarter wave length being for the desired frequency of the electromagnetic waves as measured in the wave guide, said first branch having the long dimension of any cross section parallel to the length of said main wave guide, a klystron oscillator for supplying high frequency oscillations to said first branch, crystals operating in the non-linear portion of their characteristic curve for varying the impedances terminating said main wave guide, the oscillations reflected from one-half counter-act-

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ing the oscillations reflected from the other half so that the impedance looking to said first branch remains unchanged while impedances of said main wave guide are being changed, a second branch also joining the said main wave guide at the center of its side of greatest area and being at right angles to said wave guide by having the long dimensions of any cross section perpendicular to the length of said main wave guide, said second branch to derive the net energy produced therefrom.

18. In combination, a source of oscillations, a hybrid junction associated with said source, a plurality of conductors connected to said junction, means for varying the quantity of oscillations reflected from said conductors, and means for varying the phase of oscillations reflected from said conductors toward said junction in such manner that all reflected energy goes out an

output wave guide and none is reflected back toward the source.

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SAM G. VAUGHAN.  
EUGENE F. GRANT.  
WILLIAM ALTAR.  
MARCUS W. DODD.

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