

March 20, 1951

R. T. GABLER ET AL

2,545,994

AMPLITUDE MODULATION OF MICROWAVES

Filed March 6, 1948

Fig. 2.

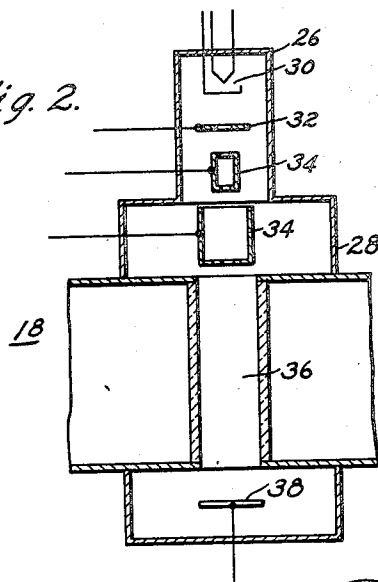
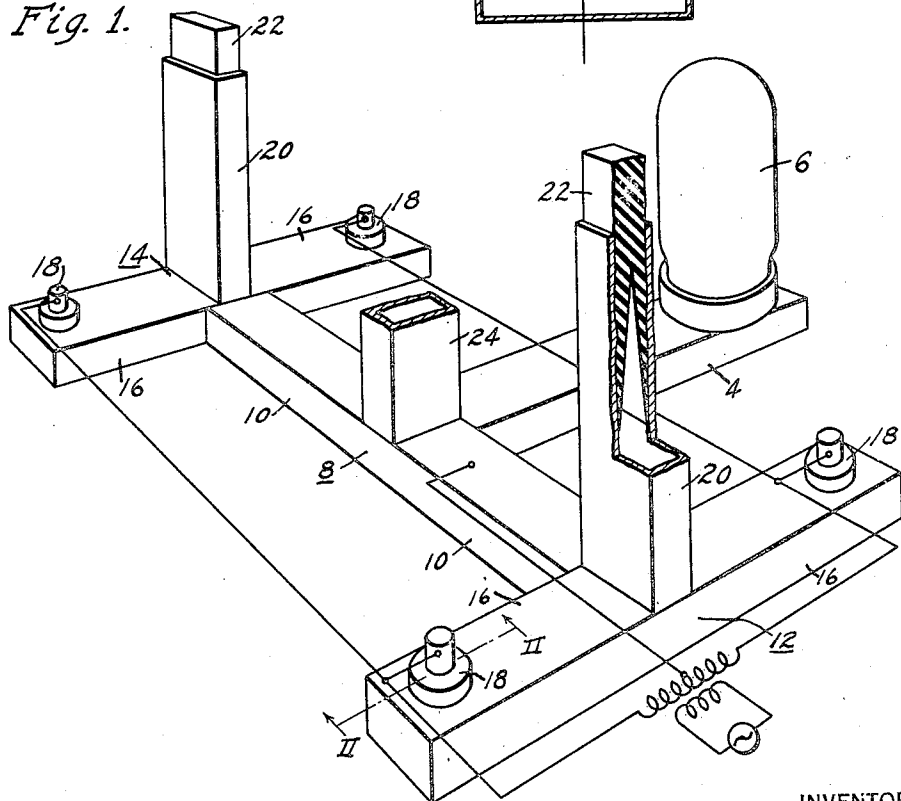


Fig. 1.



WITNESSES:

Leon M. Garman
Max W. Wood

INVENTOR

Raymond T. Gabler and
William Altar.

BY

Hyman Diamond
ATTORNEY

UNITED STATES PATENT OFFICE

2,545,994

AMPLITUDE MODULATION OF MICROWAVES

Raymond T. Gabler, Inglewood, Calif., and
William Altar, Pittsburgh, Pa., assignors to
Westinghouse Electric Corporation, East Pitts-
burgh, Pa., a corporation of Pennsylvania

Application March 6, 1948, Serial No. 13,473

9 Claims. (Cl. 332-56)

1 Our invention relates to modulation and has particular relationship to amplitude modulation of the oscillations in the microwave 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 Klystron or 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 microwave oscillation may also be effected by coupling a non-linear resistance element, as a crystal, to an oscillator so that it absorbs the oscillations. The modulating voltage is impressed on the element to vary its resistance. A disadvantage of this scheme is that the radio-frequency energy absorbable by a crystal or similar device is limited, and, therefore, the modulated power output which can be derived by this expedient is limited.

It is accordingly an object of our invention to provide apparatus for producing amplitude modulation of high power oscillations of high frequencies, such as microwave frequencies, with substantially no accompanying frequency modulation and with high fidelity.

Another object of our invention is to provide a novel system of wave guides.

An incidental object of our invention is to produce a means for varying the impedance of a wave guide by the use of a modulated electron beam.

In accordance with our invention, we provide apparatus in which the modulation is effected by the cooperation of wave guides joined in a plurality of magic tee junctions to which certain of the guides are common. Unmodulated microwave oscillations enter the input branch of a main magic tee. The coefficients of reflections of two conjugate branches of this magic tee are varied in accordance with the modulations to be impressed in auxiliary magic tees of which these branches constitute the respective input guides. These auxiliary magic tee junctions have variable impedances in their conjugate branches and a non-reflective load in the output branch. By varying these impedances, the magnitude of

2 energy being absorbed in the non-reflective loads and the magnitude of the energy being reflected back to the main magic tee can be varied. One auxiliary magic tee is one-quarter wave length or an odd integral multiple quarter wave length of the carrier oscillations to be transmitted further, as measured along the corresponding input wave guide, from the main magic tee than is the other auxiliary magic tee. Oscillations reflected from the second and third magic tees therefore counteract each other so that the oscillations are not reflected back toward the source of oscillations but are transmitted through an output branch of the main tee.

15 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 the specific embodiments when read in connection with the accompanying drawing, in which:

20 Figure 1 is a view, partly in section and partly in perspective, of an embodiment of our invention; and

25 Fig. 2 is a sectional view, partly schematic, taken along line II-II of Fig. 1.

30 The apparatus shown in Figure 1 comprises three systems of wave guides, of rectangular transverse cross-section, which are coupled together in what is known in the art as hybrid junctions or magic tees. At one end, an input wave guide 4 is connected to a source of oscillations 6, such as a high power Klystron, magnetron or resonator. At the other end, the input wave guide 4 is connected through a main magic tee junction 8 to a pair of conjugate branches 10. These conjugate branches are at right-angles to the input wave guide 4 and their sides of greatest area are parallel to the corresponding sides of the input wave guide. Connected to the ends of the conjugate wave guides 10 opposite to the main magic tee junction through second and third magic tees 12 and 14 respectively, are pairs of conjugate impedance wave guides 16. The sides of greatest area of the impedance wave guides 16 are parallel to the corresponding sides of said conjugate wave guides 10. These impedance wave guides 16 have coupled thereto, at their ends, variable impedances 18 to vary the impedance of the wave guides in accordance with the modulation to be impressed. In the preferred practice of our invention, reactance tubes are used for this purpose.

3

Also connected to each of the conjugate wave guides 10 through the second and third magic tees 12 and 14, is a load branch 20 containing a non-reflecting load 22. The load branches 20 are perpendicular to the conjugate wave guides 10 and the impedance wave guides 16. The second magic tee junction 12 is one-quarter wave length (not shown), such as an antenna, may be supplied. The output wave guide 24 is perpendicular to the other wave guides entering the junction, and the long dimension of its cross-section is parallel to the length of the input wave guide.

Connected to the input wave guide 4 and the conjugate wave guides 10 through the main magic tee 8, is an output wave guide 24 from which a load (not shown), such as an antenna, may be supplied. The output wave guide 24 is perpendicular to the other wave guides entering the junction, and the long dimension of its cross-section is parallel to the length of the input wave guide.

Oscillating energy from the source 6 flows through input wave guide 4 to the main magic tee junction 8. On reaching this junction, the energy is deflected to the right and left toward the second and third magic tee junctions 12, 14. On reaching the junction of the second tee 12, the energy is deflected into the two impedance wave guides 16. The oscillations are reflected entirely from these impedance wave guides back toward the junction of the second magic tee 12. The phase of these reflected waves will depend on the phase of the modulating potential applied to the variable impedances 18 in these impedance wave guides. The signal potential is applied to the impedances in the impedance wave guides 16 so as to cause the impedance of one impedance wave guide 16 to become more inductive while the impedance of the other impedance wave guide becomes more capacitive. This will result in a change in phase of the reflected waves. Thus, when the two waves meet at the junction of the second magic tee, they will have a component in phase and a component out of phase. That component of the reflected waves which is in phase will be deflected toward the nonreflecting load. The rest of the energy of the oscillations will be deflected toward the main magic tee. As the apparatus is symmetrical except for the quarter-wave difference in length as measured along the two conjugate wave guides 10 connected to the main tee 8, the action of the third tee 14 will be the same as the second tee 12 except that the oscillations arriving from the second tee will have traveled one-quarter wave length further than the oscillations from the third tee. The oscillations returning to the main tee will thus be substantially out of phase by 180°. As these oscillations are out of phase by 180°, and as the antenna wave guide presents a matched load to the potentials of the tee junction, substantially all of the energy will be deflected out the antenna wave guide and none of the energy will be deflected back through the input wave guide toward the source of oscillations where it would produce undesirable frequency modulation.

The reactance tube, as employed in one embodiment of our invention, is shown in Fig. 2. The container comprises a cathode stem 26 which communicates with a flanged cylindrical section 28. This cylindrical section 28 is designed to be inserted in the wave guide. The walls of the cylindrical section 28 must be substantially of a non-conducting material so the electromagnetic oscillations will not be reflected. In the interior

4

of the tube, we have a heated cathode 30, a control grid 32, two accelerating grids 34, a resonant cavity 36 and a plate or anode 38.

The electrons ejected from the cathode 30 either return to the cathode 30 or proceed past the control grid 32 depending on the phase of the modulating voltages impressed on the control grid. Those electrons passing the control grid 32 are accelerated by the accelerating grids 34, pass through the cavity 36 and impinge on the plate 38.

The operation of the reactance tubes 18 depends on the detuning of a resonant cavity by a variable electron beam. The intensity of the beam can be varied by a grid. As the resonance frequency of the tube varies, the cavity represents a varying reactive element at the operating frequency capable of covering a wide range of capacity and inductive susceptance values as a function of the beam intensity or of the grid voltage. Using these tubes, we are able to vary susceptances quickly and with practically no dissipation of power. The use of these tubes is not to be considered as the only method of varying the reactance of the wave guides.

The susceptances of the impedance branches are given approximately by

$$Y_{2a} = -Y_{2b} = Y_{3a} = -Y_{3b} \quad (1)$$

where Y_{2a} and Y_{2b} are susceptances of the two impedance wave guides connected to the second magic tee, and Y_{3a} and Y_{3b} are the susceptances of the two impedance wave guides connected to the third magic tee.

The amplitude of the wave reflected toward the source of oscillations is given by

$$R = \frac{r_2 + r_3}{2} \quad (2)$$

where r_2 and r_3 are the reflection coefficients in the two conjugate wave guides which lead from the magic tee to the second and third tees, the magnitude of the wave entering one of the conjugate branches being unity. In view of the symmetry of the arrangement except for a quarter-wave difference in length of the side branches, these two reflection coefficients are equal and opposite in sign so that the generator is presented with a matched load, no matter what the instantaneous susceptance values of the reactance tubes are, so long as they obey the equations (1). The transmission coefficient representing amplitude and phase of the wave leaving the antenna is given by

$$T_4 = \frac{(r_2 - r_3)}{2} = r_2 \quad (3)$$

since r_2 equals $-r_3$.

These equations have been given by way of explanation and are not meant to restrict the operation of this invention. This specification discloses wave guides as a means of transmission and a magic tee as the hybrid junction. Such facilities are included in accordance with the specific aspects of our invention. It must be understood, however, that any of several types of hybrid junctions employing transmission lines consistent with the nature of said junctions can be used in accordance with the broader aspects of our invention. Accordingly, coaxial lines, conductor lines, or any other conductors suitable for the operating frequency, may be utilized.

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 first magic tee having four branches, a source of oscillations connected to a first of said branches, a second magic tee connected to a second of said branches and a third magic tee connected to a third of said branches, said second magic tee being one-quarter wave length further from the junction of said first magic tee than is said third magic tee, said second and said third magic tees having variable impedances on two of their branches and a non-reflective load on a third branch of said second and said third magic tees, a fourth branch connected to said first magic tee containing a load for deriving the net energy produced therefrom.

2. In combination, a first magic tee having four branches, a source of oscillations connected to a first of said branches, a second magic tee connected to a second of said branches and a third magic tee connected to a third of said branches, said second magic tee being one-quarter wave length further from the junction of said first magic tee than is said third magic tee, said second and said third magic tees having reactance tubes on two of their branches and a non-reflective load on a third branch of said second and said third magic tees, a fourth branch connected to said first magic tee containing a load for deriving the net energy produced therefrom.

3. In combination, a first magic tee having four branches, a Klystron oscillator connected to a first of said branches, a second magic tee connected to a second of said branches and a third magic tee connected to a third of said branches, said second magic tee being one-quarter wave length further from the junction of said first magic tee than is said third magic tee, said second and said third magic tees having variable impedances on two of their branches and a non-reflective load on a third branch of said second and said third magic tees, a fourth branch connected to said first magic tee containing a load for deriving the net energy produced therefrom.

4. In combination, a first magic tee having four branches, a Klystron oscillator connected to a first of said branches, a second magic tee connected to a second of said branches and a third magic tee connected to a third of said branches, said second magic tee being one-quarter wave length further from the junction of said first magic tee than is said third magic tee, said second and said third magic tees having reactance tubes on two of their branches and a non-reflective load on a third branch of said second and said third magic tees, a fourth branch connected to said first magic tee containing a load for deriving the net energy produced therefrom.

5. In combination, a first hybrid junction

having four conductive paths, a source of oscillations connected to a first of said conductive paths, a second hybrid junction connected to a second of said conductive paths and a third hybrid junction connected to a third of said conductive paths, said second hybrid junction being one-quarter wave length further from the junction of said first hybrid junction than is said third hybrid junction, said second and said third hybrid junctions having variable impedances on two of their conductive paths and a non-reflective load on a third conductive path of said second and said third hybrid junctions, a fourth conductive path connected to said first hybrid junction containing a load for deriving the net energy produced therefrom.

6. Device for varying the reflection coefficient of a wave guide comprising a hybrid junction connected to said wave guide, two branches of variable impedance connected to said hybrid junction, and a fourth branch connected to said hybrid junction containing a non-reflecting load.

7. In combination, a hybrid circuit having four branches, a source of oscillation connected to an input branch, two substantially reactive variable elements connected to a second and third of said branches, means for varying the reactive elements in a coordinated manner such that the sum of all waves entering a fourth branch varies in a predetermined manner while the sum of all waves reflected through said first branch toward said source remains essentially constant.

8. As an article of manufacture, a first hybrid junction including an input wave guide, an output wave guide and a pair of conjugate wave guides, a second hybrid junction coupled to one of said conjugate wave guides and a third hybrid junction coupled to the other of said conjugate wave guides, said conjugate wave guides each constituting the input wave guide of its corresponding hybrid junction and said second and third wave guides each having in addition output wave guides and conjugate wave guides.

9. An article according to claim 8 characterized by the fact that the second and third hybrid junctions are disposed at distances differing by an odd integral number of quarter wave lengths of the frequency of the oscillations for which the guides are designed from the electrical center of the first hybrid junction along the corresponding conjugate wave guides.

RAYMOND T. GABLER.

WILLIAM ALTAR.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,421,725	Stewart	June 3, 1947
2,436,828	Ring	Mar. 2, 1948
2,438,768	Stewart	Mar. 30, 1948