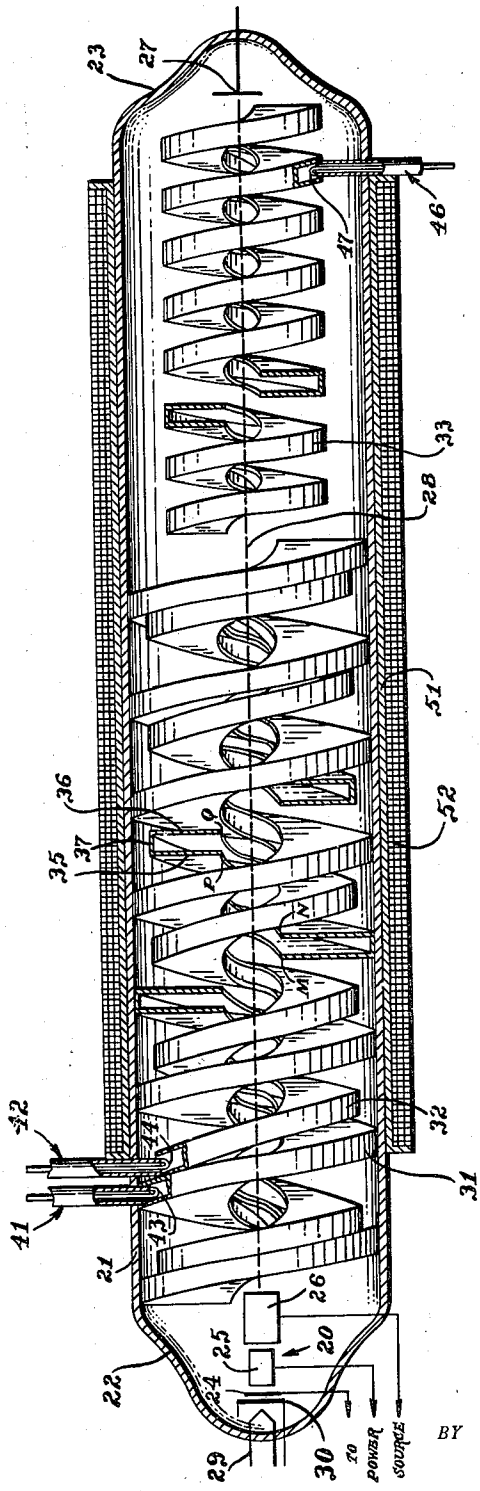
Feb. 5, 1952 J. W. TILEY 2,584,308

ELECTRONIC TUBE OF THE TRAVELING WAVE TYPE

Filed Jan. 28, 1948



INVENTOR.
JOHN W. TILEY

BY Ostrolenk & Faber

ATTORNEYS

Patented Feb. 5, 1952 2,584,308

UNITED STATES PATENT OFFICE

2,584,308

ELECTRONIC TUBE OF THE TRAVELING WAVE TYPE

John W. Tiley, Philadelphia, Pa., assignor to Philco Corporation, Philadelphia, Pa., a corporation of Pennsylvania

Application January 28, 1948, Serial No. 4,849

13 Claims. (Cl. 315—39)

1

This invention relates in general to the electron tube art, and more particularly to a novel electromagnetic traveling wave signal mixer or converter having special application in high frequency and broad band electrical systems.

The present application shows an improvement of my co-pending patent application Serial No. 761,798, now Patent No. 2,541,843, filed July 18, 1947, and reference is made thereto. For further information, reference is also made to a previously filed continuation-in-part of the aforesaid application, Serial No. 761,798, namely my co-pending application Serial No. 788,724 filed November 28, 1947.

In order to facilitate understanding of the principles of the present invention, there follows a brief discussion of the general considerations involved in traveling wave electron tubes, which have been treated in detail in the co-pending patent applications enumerated above. This material is believed to provide ample background and information concerning the differences between traveling wave tubes and those tubes more common in prior art systems.

In electrical systems such as television, pulse-position modulation and radar, it has often been extremely difficult to obtain adequate and uniform amplification and efficient signal mixing and conversion over the frequency spectrum encompassed by the signal. Ordinary triodes, even when incorporated in special circuits, fail to provide a usable gain in such applications. Recent designs, such as the lighthouse tube, and the velocity modulation tube as exemplified by the klystron, can provide reasonable gain solely in narrow band width operation. An attempt to use a klystron or like tube in the microwave region with a band width of fifty megacycles or greater will result generally in a gain of less than unity.

A recent electronic development, known as the beam traveling wave tube, overcomes the limitations of the more conventional tube types, and has previously been successfully tested as an efficient amplifier of signals having a mean frequency of the order of thousands of megacycles with an over-all band width of the order of eight hundred megacycles. Theoretically, even much wider bands may be amplified by the device without sacrifice of gain.

For a description and illustration of this development, reference is made to the publication "Bell Laboratories Record" of December, 1946, and to the article therein entitled "The Beam Traveling Wave Tube" by J. R. Pierce. In this

2

reference the traveling wave tube is described as constituted of an electron gun similar to those employed in cathode ray tubes. An electron beam generated by the gun is directed in a narrow beam along the axis of a long evacuated tube and impinged upon a collector anode. Within the tube, and surrounding the beam axis, is a closely wound wire helix which is excited at the electron gun end thereof by the weak signal to be amplified and which provides at the collector end thereof the amplified output signal. The tube contains no signal grids in the conventional sense.

Broadly speaking, the applied signal travels along the wire helix as an electromagnetic wave at a speed approaching the speed of light. As is determined by the pitch of the helix, the wave travels axially of the tube at a fraction of the speed of light; and the electron gun and collector anode potentials are arranged so that the average axial velocity of the electron beam through the helix is somewhat greater than the axial wave velocity.

Interaction of the electron beam and electromagnetic field components extending from the helix produces the signal amplification. The greater the electron current and the longer the helix, the greater is the gain. In transit through the helix the average electron velocity is reduced, and the energy drop represented by this decreased velocity is imparted to the signal. The tube does not require a tuned circuit in the signal path, the wire helix being in effect an all pass transmission line. Hence the tube is capable of operation over an exceedingly wide frequency range. In practice this range is limited somewhat by the impedance match of the helix to the external circuits.

In operation the signal appearing on the helix acts on the electron stream and gradually produces fluctuations in velocity and density. The density modulated electron beam delivers energy to the wave and over the helix section nearest the collector there is a substantially uniform gain per unit length of travel.

The present invention has as a primary object the provision of an electromagnetic traveling wave tube of novel and improved design, having wide application as a broad-band, high frequency mixer or high frequency converter. The electromagnetic traveling wave tube disclosed herein differs from prior art mixer and converter tubes in that means such as wave guides are utilized for directing signals around the path of

an electron beam for accomplishing the mixing operation. These guides, as disclosed in the above identified patent applications, permit direct coupling of the electromagnetic fields therein and the tube electron beam and preclude excessive energy radiation and undesirable coupling with external fields.

In the aforementioned patent application Serial No. 761,798, it was demonstrated that signal amplification could be obtained in an electromagnetic traveling wave tube by causing an electron beam to traverse the axis of first and second, or input and output helical wave guide sections of predetermined pitch and number of turns. The input wave guide was energized by the weak incoming signal, whereby the electron beam was bunched or density modulated. The modulated beam was then caused to traverse a second or output helical wave guide section and to deliver energy thereto to provide the amplified output signal.

In a tube of this construction, input and output wave guides are spaced axially of the electron beam. When certain conditions of beam velocity and helix structure are properly satisfied, considerable gain is obtained and the electron tubes are capable of either amplifier or oscillator operation; the latter being accomplished by coupling a predetermined portion of the output signal in the correct phase to the input wave guide.

In accordance with the principles of the present invention, means are provided for substantially simultaneously velocity modulating an electron beam by more than one traveling wave so that frequency conversion and frequency mixing is obtainable. In one form of this invention two input helical wave guides are coaxially arranged and interwound so that the electromagnetic wave energy transmitted through these guides may substantially simultaneously coact upon an axial electron beam. The simultaneous action of two signals upon a single electron beam may be considered effective as two simultaneous bunching operations, and as a result thereof the density modulated electron beam contains components of the sum and difference frequencies. A suitable output wave guide is provided for extracting energy from the bunched electron beam at either of these two frequencies, as desired.

It is therefore an object of the present invention to provide a beam traveling wave electron tube for signal mixing or conversion which permits the simultaneous interaction of a plurality of electromagnetic signals and an electron beam.

Another object of the present invention is to provide an electron tube having a plurality of interwound co-axial helical wave guide structures.

A still further object of the present invention is to provide a beam traveling wave electron tube, particularly adaptable for frequency mixing or conversion which permits maximum interaction between electrons in a beam and traveling wave high frequency energy.

Another object of the present invention is to provide a traveling wave type frequency mixer adapted to produce a sum or difference frequency signal from two electromagnetic waves of different frequencies.

A still further object of the present invention is to provide a tube structure having a plurality of helical wave guides arranged for optimum interaction and energy transfer with an electron beam.

These and other objects of the present invention will now become apparent from the following detailed specification when taken in connection with the accompanying drawing which is a general side view partially in section, of a helical wave guide frequency mixer or converter.

With reference now to the drawing there is illustrated an electron tube incorporating the feature of the present invention and comprising, generally, a large diameter glass or other dielectric cylinder 21 having tapered ends 22 and 23. The cylinder 21 is sealed off and evacuated. Sealed into the end 22 of the electron tube is an electron gun 20 similar to those utilized in conventional cathode ray tube structures. As shown the electron gun 20 comprises a heater 29 and its associated cathode 30, a centrally perforated control grid 24 and focusing and accelerating hollow cylindrical electrodes 25 and 26, respectively. When the electrodes comprising the electron gun 20 are energized from a suitable power source (not shown) an axial beam of electrons of predetermined high velocity is generated and directed along the axis 28 of cylinder 21 toward a disc shaped collector electrode 27 sealed into the right-hand end of the tube as viewed in the drawing.

Structural means required for supporting the electron gun electrodes have been omitted for clarity.

As the electron gun of the type included within the structure of the tube in the drawing is sufficiently well known in the electronic art, a further description thereof and of the energizing means therefor are considered unnecessary at this point.

In accordance with the broad principles of the present invention the axial path of travel of the electron beam through the tube 21 is substantially enclosed within a plurality of axially aligned helical wave guide structures. As illustrated in the drawing, two helical wave guide structures 31 and 32, herein designated as the input wave guides, are interwound and co-axially supported within the left-hand end of the tube. A third co-axial helical wave guide 33, herein designated as the output helical wave guide, is positioned between the interwound input helical wave guides 31 and 32 and collector anode 27.

The precise means for supporting helical wave guides 31, 32 and 33 in the physical relationship illustrated in the drawing has been omitted for purposes of simplification. It will be understood, however, that conventional supporting means as used in numerous electron tubes may herein be correspondingly employed to secure all electrodes in the desired relationship.

With the exception of differences in dimensions, the three helical wave guides 31, 32 and 33, herein illustrated, are of similar construction. These wave guides are preferably formed of coils of unitary U-shaped metallic channels comprising, for example (reference being made to wave guide 32) metallic side walls 35 and 36 rigidly spaced by integral outer metallic strip 37. As illustrated, each of the open faces of the U-shaped channels constituting the wave guides 31, 32 and 33 is formed to define a cylinder. The cylinders defined by the inner edges of wave guides 31 and 32 are coincident and co-axial with the cylinder defined by the inner edges of output wave guide 33. The differences in pitch of the helical wave

guides illustrated will be considered in detail below.

In order to preclude signal reflections and standing waves within the helical wave guides 31, 32 and 33 a dissipative block (not shown) preferably of helical form, is secured within each of the wave guide sections. These blocks are preferably uniformly tapered and constituted of a material capable of effectively dissipating micro-wave energy. The structure and function of helical dissipative blocks of this general form have been described in considerable detail in the aforementioned patent applications and for this reason are not considered in greater detail herein.

Electromagnetic wave energy at the desired frequency may be introduced into the helical wave guides 31 and 32 through co-axial lines 41 and 42, respectively. As illustrated in the drawing, the outer conductor of each of co-axial lines 41 and 42 extends through the dielectric cylinder 21 and enters its respective helical wave guide through the outer helical metallic strip thereof. Coupling loops 43 and 44 formed of the co-axial line inner conductors provide ample signal coupling to the regions within the helical wave guides. In a corresponding manner, a co-axial cable 46 is utilized to extract signal energy from the output helical wave guide 33. As illustrated in the drawing, the outer conductor of co-axial cable 46 extends through the dielectric cylinder 21 and in through the outer edge of wave guide 33. A small loop 47 formed in the inner conductor serves as the signal coupling between the co-axial cable 46 and the wave guide 33.

The outer surface of the dielectric cylinder 21 between coupling co-axial cables 42 and 46 is substantially enclosed within a cylindrical coil form upon which a uniform solenoid type coil 52 is wound. When coil 52 is energized from a direct current source (not shown) a magnetic field is established having a large component parallel to the electron beam axis which is directed from the electron gun 20 to the collector anode 27. This magnetic field minimizes de-focusing of the electron beam in its comparatively long axial transit through the cylinder 21. In the discussion below of the operation of this tube, it will be understood that the solenoid coil 52 is energized and thereby maintaining the aforementioned axially magnetic field.

Broadly speaking, and prior to entering upon a discussion of the particular dimensions of the wave guide components illustrated, mixer operation of the electron tube shown in the drawing is as follows. Microwave energy at the two frequencies to be mixed is applied through co-axial cables 41 and 42 to energize helical wave guides 31 and 32 respectively which together comprise the input section of the electron tube. These input signals travel down the helical wave guides 31 and 32 in the direction of flow of electrons in beam toward electrode 27. The actual axial velocity of each of the traveling waves is a fraction of the propagation velocity through these wave guides due to the helical path traversed. The aforementioned dissipative blocks secured within the ends of all wave guide sections ensure the absence of traveling waves in a direction other than the axial direction of electron flow.

Between any two opposed points, such as M and N of the open sided helical wave guide 31 and points P and Q of wave guide 32 electric fields are established which have components within the tube parallel to the axis 28 of electron flow. These electric field components may be visualized as spinning about the axis of the tube at somewhat less than the velocity of light as the waves travel from left to right as viewed in the drawing. The electron beam, in traversing the input section of the tube comprising wave guides 31 and 32, is bunched in accordance with the intensity variation of both applied signals. This bunching operation is, in effect, density modulation of electron beam, which modulation includes components equal in frequency to the sum and difference of the applied signal in addition to frequency components equal to those of the applied signals. Thus the electron beam emerges from the space between the input section comprising helical wave guides 31 and 32 and the output helical wave guide as a comparatively high energy bunched beam. Upon entering the region of the electron tube spanned by the output helical wave guide 33 the bunched electron beam is retarded somewhat and thereby delivers energy to the wave guide 33 by excitation of a traveling wave therein which progresses at a speed approaching the speed of light toward the output coupling loop 47 of co-axial cable 46.

The frequency of the output signal induced in wave guide 33 and delivered at co-axial cable 46 may be selected simply by arranging the dimensions of wave guide 33 for suitable response to the desired signal frequency, a component of which appears in the bunched beam. In the drawing, the output wave guide 33 is illustrated as one responsive to a frequency equal to the sum of the signal frequencies applied at co-axial cables 41 and 42.

In accordance with the principles described in the aforementioned parent patent application (but not shown herein) the pitch of the output helical wave guide 33 may be progressively diminished as it approaches elector electrode 27. In this manner maximum energy may be extracted from the bunched electron beam and delivered over co-axial cable 46 to a suitable load circuit (not shown).

The helical wave guides 31 and 32 of the tube input section are proportioned to pass the frequencies applied at co-axial cables 41 and 42. It will be noted that the physical dimensions of wave guide 32 are smaller than the corresponding dimensions for wave guide 31, indicating that the frequency of operation of guide 32 is higher than that of guide 31. Since output helical wave guide 33 is herein designed for the purpose of extracting a sum frequency, its dimensions are correspondingly smaller than those of helical wave guides 31 and 32.

It is preferable that the two input wave guides 31 and 32 be arranged to provide for slightly different axial velocities of the electromagnetic wave traveling therethrough. The drawing illustrates one manner in which this particular relationship between axial components of the traveling wave may be established. Thus, wave guides 31 and 32 are proportioned to give the same velocity propagation as measured helically around each guide, but the pitch of helical wave guide 32 is somewhat greater than the pitch of guide 31. Thus, note that there are six active turns of helical wave guide 32 to the right of co-axial coupler 42 for seven active turns of helical wave guide 31 measured to the right of co-axial cable 41. Since the space occupied by these active turns of helical wave guides 31 and 32 is substantially the same and further, since as above mentioned, the velocity of propagation as measured around the helices is equal for both, then

it follows the axial velocity components of the waves in both guides are somewhat different. Since output helical wave guide 33 is proportioned to transmit the sum of the frequencies applied to wave guides 31 and 32 it preferably contains a number of active turns in a given length thereof equal to the sum of the active turns of wave guides 31 and 32 for the same length.

By arranging for different axial velocities of propagation through helical wave guides 31 and 32 optimum operating efficiency is obtained. Thus, note that if the axial velocities of both waves in helical wave guides 31 and 32 were the same and equal to the average electron velocity in the electron beam it would be possible that an electron or group of electrons could pass through the entire input section of the tube as spanned by wave guides 31 and 32 without affect thereon by the wave energy extending into the region of the electron beam from either of the helical wave guides. For best results, it is desirable that each electron in the beam be acted upon by at least one of the two electro-magnetic waves and preferably by both. By assuring, in accordance with the structure illustrated in the drawing, that the axial velocities of the traveling waves through guides 31 and 32 are different, then interaction between each electron and at least one of the traveling fields is certain. It is desirable, therefore, that the average velocity of electrons in the electron beam 28 be equal to the mean of the axial velocities of the traveling waves in helical wave guides 31 and 32. The axial velocity of an electron in the beam, is, of course, adjustable by variation of the potentials of the electron gun and collector electrode 27. When the average electron velocity lies between the axial velocity components of the traveling waves and guides 31 and 32 the interchange of energy between traveling waves and electron beam will have minimum effect upon the average velocity of an electron in the beam.

The electron tube illustrated in the drawing may serve as a frequency converter in addition to a frequency mixer as above described. A frequency converter, as is well understood, is essentially a combination of a mixer and a local oscillator. As described in considerable detail in the aforementioned patent applications a beam traveling wave electron tube may be used as an oscillator by coupling a predetermined fraction of its signal output back to its signal input terminals.

Feed-back in an electron beam traveling wave tube may be accomplished simply by mis-matching the termination of the helical wave guide so as to provide reflections of that amplitude and phase necessary to cause oscillation. A preferable manner of obtaining a suitable stable frequency from an electron beam traveling wave electron tube is to couple a portion of the output energy from the output coupler of the tube back to the input coupler thereof through a resonant external feed-back path tuned to the desired frequency. This type of coupling is sufficient in view of the broad band capable of being handled by an electron tube of this construction.

Further details of possible means for causing self-oscillation of a portion of the electron tube shown in the drawing are not given herein. However, when such self-oscillation is established this oscillation will provide one of the two frequencies to be mixed. The second of the frequencies to be mixed may be applied at one of the co-axial lines 41 or 42.

The microwave mixer and converter electron tube illustrated in the drawing is of particular advantage in high-frequency systems, in that the band of operation covered is extremely broad; furthermore, that amplification is obtained during the mixing or conversion process. Signal amplification in microwave mixers or converters is of particular advantage to microwave system engineering, since crystals and like rectifying elements ordinarily used for mixing and conversion introduce decided energy loss rather than signal level gain.

Although the electron tube of Figure 1 has been illustrated as providing an output signal equal in frequency to the sum of applied signal frequencies it is evident that the difference frequency may be obtained by proportioning output helical wave guide 33 so that it is capable of transmitting the difference frequency. This would require that the pitch of the wave guide 33 be such that for a given length it contains a number of turns corresponding to the difference of the number of turns of helical wave guides 31 and 32, for the same length. It is to be mentioned at this point that traveling wave electron tubes need not be utilized for lowering a system frequency as gain at high frequencies can be secured.

The various features described in considerable detail in the aforementioned co-pending patent applications may be incorporated in the electron tube illustrated in the drawing of this application. As an example thereof, the spaces between turns of helical wave guides 31, 32 and 33 with the exception of the central cylindrical region through which the electron beam passes may be filled with a suitable lossy substance to preclude inter-action and deleterious coupling among the fields of the three wave guides shown. This lossy substance will preclude oscillation and undesirable frequencies.

Thus it is evident that various modifications of the disclosure set forth in the present application may become apparent to those skilled in the art. Accordingly, it is preferred that the present invention be limited solely by the scope of the appended claims.

I claim:

1. A beam traveling wave electron tube comprising in combination within an evacuated envelope, an electron gun disposed at one end of said envelope for generating an electron beam of predetermined average electron velocity, a collector electrode positioned within the opposed end of said envelope, means for directing said generated electron beam axially through said envelope and impinging said beam upon said collector electrode, means disposed adjacent said electron gun for velocity modulating said electron beam simultaneously in accordance with at least two signals and comprising a pair of interwound helical wave guides, said wave guides each comprising channel shaped conductors of substantially rectangular cross-section, the open ends of each of said channel shaped conductors defining a cylindrical surface co-axial with said electron beam, means for introducing microwave energy at predetermined frequencies to said interwound helical wave guides for establishing traveling waves therein, said interwound helical wave guides permitting the interaction of microwave energy flowing therein and said electron beam.

2. A beam traveling wave electron tube comprising in combination within an evacuated envelope, an electron gun disposed at one end of

said envelope for generating an electron beam of predetermined average electron velocity, a collector electrode positioned within the opposed end of said envelope, means for directing said generated electron beam axially through said envelope and impinging said beam upon said collector electrode, means disposed adjacent said electron gun for velocity modulating said electron beam simultaneously in accordance with at least two signals and comprising a pair of interwound helical wave guides, said wave guides each comprising channel shaped conductors of substantially rectangular cross-section, the open ends of each of said channel shaped conductors defining a cylindrical surface co-axial with said electron beam, means for introducing microwave energy at predetermined frequencies to said interwound helical wave guides for establishing traveling waves therein, said interwound helical wave guides permitting the interaction of microwave energy flowing therein and said electron beam, means disposed between said interwound helical wave guides and said collector electrode adapted to extract energy from an electron beam velocity modulated by energy flow in said interwound helical wave guides comprising a third helical wave guide co-axial with said interwound wave guides and formed substantially as each of said interwound wave guides, said third helical wave guide being adapted to propagate microwave energy at a frequency equal to the sum or difference of said predetermined frequencies.

3. A beam traveling wave electron tube comprising in combination within an evacuated envelope, an electron gun disposed at one end of said envelope for generating an electron beam of predetermined average electron velocity, a collector electrode positioned within the opposed end of said envelope, means for directing said generated electron beam axially through said envelope and impinging said beam upon said collector electrode, means disposed adjacent said electron gun for velocity modulating said electron beam simultaneously in accordance with at least two signals and comprising a pair of interwound helical wave guides, said wave guides each comprising channel shaped conductors of substantially rectangular cross-section, the open ends of each of said channel shaped conductors defining a cylindrical surface co-axial with said electron beam, means for introducing microwave energy at predetermined frequencies to said interwound helical wave guides for establishing traveling waves therein, said interwound helical wave guides permitting the interaction of microwave energy flowing therein and said electron beam, means disposed between said interwound helical wave guides and said collector electrode adapted to extract energy from an electron beam density modulated by energy flow in said interwound helical wave guides comprising a third helical wave guide co-axial with said interwound wave guides and formed substantially as each of said interwound wave guides, said third helical wave guides being adapted to propagate microwave energy at a frequency equal to the sum or difference of said predetermined frequencies, the pitches of said interwound helical wave guides being different, the number of turns for a given length of said third helical wave guide being equal to the sum or difference of the number of turns of said two interwound wave guides for the same length.

4. A beam traveling wave electron tube comprising in combination within an evacuated envelope, a source of electrons disposed at one end of said envelope, an electron collector positioned within the opposite end of said envelope, a first wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, means for exciting said first wave guide by an input signal of a predetermined frequency, a second wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, means for exciting said second wave guide by an input signal of a predetermined frequency, and a third wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, said third wave guide being axially displaced from said first and second wave guides, and means for extracting signal energy from said third wave guide in accordance with said input signals.

5. A beam traveling wave electron tube comprising in combination within an evacuated envelope, a source of electrons disposed at one end of said envelope, an electron collector positioned within the opposite end of said envelope, a first wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, means for exciting said first wave guide by an input signal of a predetermined frequency a second wave guide of a pitch different than the pitch of said first wave guide, and a third wave guide means for exciting said second wave guide by an input signal of a predetermined frequency, of a predetermined pitch surrounding a portion of the axial path from said source to said collector, said third wave guide being axially displaced from said first and second wave guides, and means for extracting signal energy from said third wave guide in accordance with said input signals.

6. A beam traveling wave electron tube comprising in combination within an evacuated envelope, a source of electrons disposed at one end of said envelope, an electron collector positioned within the opposite end of said envelope, a first wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, a second wave guide of a pitch different than the pitch of said first wave guide, and a third wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, said third wave guide being axially displaced from said first and second wave guides, the portion of the wave guide adjacent the axial path of said electron beam being open to provide coupling between the electromagnetic energy in said wave guides and said electron beam.

7. A beam traveling wave electron tube comprising in combination within an evacuated envelope, a source of electrons disposed at one end of said envelope, an electron collector positioned within the opposite end of said envelope, a first wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, a second wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, and a third wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, said third wave guide being axially displaced from said first and second wave guides, the portion of the wave guide adjacent the axial path of said electron beam being open to provide coupling between the electromagnetic energy in said wave guides and said electron beam.

8. A beam traveling wave electron tube comprising in combination within an evacuated envelope, a source of electrons disposed at one end of said envelope, an electron collector positioned within the opposite end of said envelope, a first wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, a second wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, and a third wave guide of a predetermined pitch surrounding a portion of the axial path from said source to said collector, said third wave guide being axially displaced from said first and second wave guides, the portion of the wave guide adjacent the axial path of said electron beam being open to provide coupling between the electromagnetic energy in said wave guides and said electron beam, and an electromagnetic winding encasing said envelope.

9. An electron tube having a cathode for generating an electron beam along an axial path of said tube, a collector electrode for said electron beam, a plurality of input interwound coaxial helical metallic wave guides mounted in one end of said tube, an output coaxial helical wave guide positioned in said tube between said interwound input wave guides and collector electrode, the cross section of said wave guides being U-shaped, the open face of said U-shaped channels defining a cylinder which constitutes said axial electron beam path, coupling means for introducing electromagnetic wave energy at the desired frequencies into each of said plurality of input wave guides, said wave energy travelling along said wave guides in the direction of said electron beam for establishing electric fields within said tube parallel to the axis of the electric field for density modulating the electron beam in accordance with the input signal intensities, said electron beam when entering the region of said tube spanned by said output helical wave guide being retarded and delivering energy to said wave guide by excitation of the travelling wave therein and means for extracting signal energy from the output helical wave guide.

10. An electron tube having a cathode for generating an electron beam along an axial path of said tube, a collector electrode for said electron beam, a plurality of input interwound coaxial helical metallic wave guides mounted in one end of said tube, an output coaxial helical wave guide positioned in said tube between said interwound input wave guides and collector electrode, each of said wave guides comprising metallic side walls spaced by an integral outer metallic strip and having an open face for defining a cylinder which constitutes said axial path for said electron beam, coupling means for introducing electromagnetic wave energy at the desired frequencies into each of said plurality of input wave guides, said wave energy travelling along said wave guides in the direction of said electron beam for establishing said electric fields within said tube parallel to the axis of the electric field for density modulating the electron beam in accordance with the signal intensities, said electron beam when entering the region of said tube spanned by said output helical wave guide being retarded and delivering energy to said wave guide by excitation of the travelling wave therein and means for extracting signal energy from the output helical wave guide.

11. An electron beam having a cathode for generating an electron beam along an axial path of said tube, a collector electrode for said electron beam, a plurality of input interwound coaxial helical metallic wave guides mounted in one end of said tube, an output coaxial helical wave guide positioned in said tube between said interwound input wave guides and collector electrode, said wave guides having openings into said electron beam path, coupling means for introducing electromagnetic wave energy at the desired frequencies into each of said plurality of input wave guides, said wave energy travelling along said wave guides in the direction of said electron beam for establishing said electric fields within said tube parallel to the axis of the electric field for density modulating the electron beam in accordance with the signal intensities, said electron beam when entering the region of said tube spanned by said output helical wave guide being retarded and delivering energy to said wave guide by excitation of the travelling wave therein and means for extracting signal energy from the output helical wave guide.

12. An electron tube having a cathode for generating an electron beam along an axial path of said tube, a collector electrode for said electron beam, a plurality of input interwound coaxial helical metallic wave guides mounted in one end of said tube, an output coaxial helical wave guide positioned in said tube between said interwound input wave guides and collector electrode, said wave guides having an open portion forming said electron beam path, coupling means for introducing electromagnetic wave energy at the desired frequencies into each of said plurality of input wave guides, said wave energy travelling along said wave guides in the direction of said electron beam for establishing said electric fields within said tube parallel to the axis of the electric field for density modulating the electron beam in accordance with the signal intensities, said electron beam when entering the region of said tube spanned by said output helical wave guide being retarded and delivering energy to said wave guide by excitation of the travelling wave therein and means for extracting signal energy from the output helical wave guide.

13. An electron tube having a cathode for generating an electron beam along an axial path of said tube, a collector electrode for said electron beam, a plurality of input interwound coaxial helical metallic wave guides mounted in one end of said tube, an output coaxial helical wave guide positioned in said tube between said interwound input wave guides and collector electrode, coupling means for introducing electromagnetic wave energy at the desired frequencies into each of said plurality of input wave guides, and means for extracting signal energy from the output helical wave guide.

JOHN W. TILEY.

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
2,064,469	Haeff	Dec. 15, 1936
2,300,052	Lindenblad	Oct. 27, 1942
2,367,295	Llewellyn	Jan. 16, 1945