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CARRIER SUPPRESSED FERRITE MODULATOR

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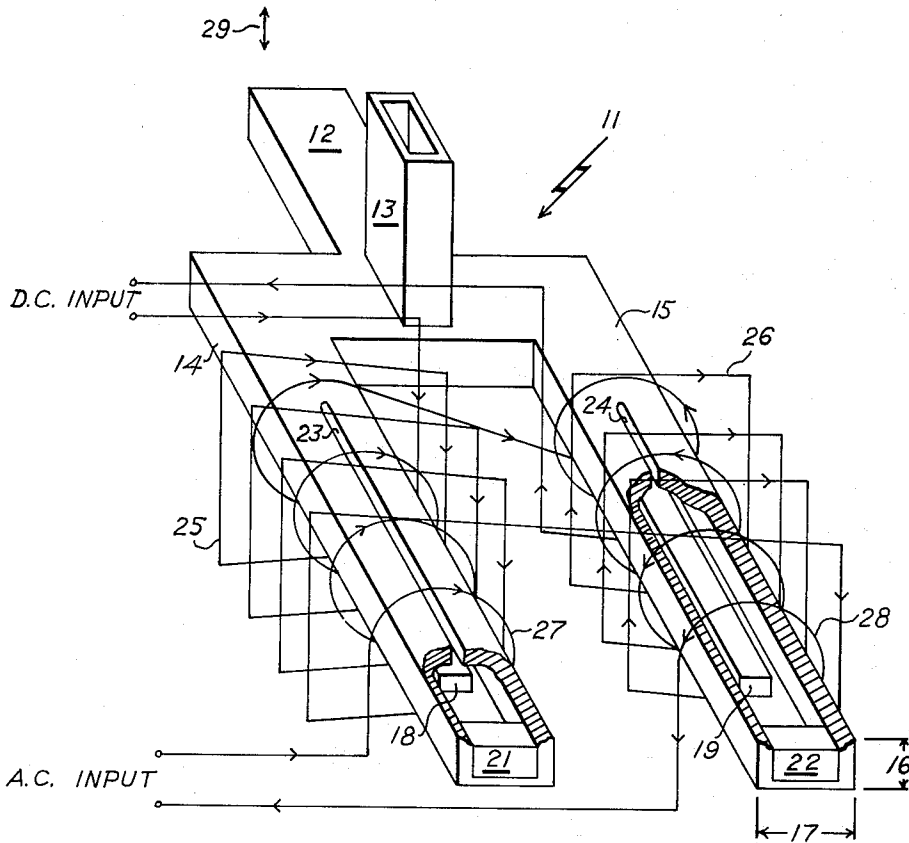


FIG. 1

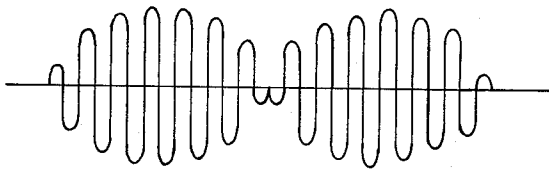


FIG. 2

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CARRIER SUPPRESSED FERRITE MODULATOR

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The present invention relates to sideband generators and more particularly to rectangular waveguide ferrite sideband generators.

In the prior art there exists several devices for providing sideband frequencies. One type, exemplarily shown in Patent No. 2,629,079, issued February 17, 1953, employs an alternating magnetic field transverse to the direction of propagation of the energy. Another type, exemplarily shown in Patent No. 2,802,183, issued August 6, 1957, employs a circular waveguide ferromagnetic rotator and output means comprising a septum mounted in the circular waveguide. A type more similar to the present invention employs a magic Tee comprised of rectangular waveguide with a cylindrical two mode transducer and cylindrical rotator in each balanced arm of the magic Tee, the output signal being taken from a specially located output arm in each two mode transducer. A principal and critical shortcoming of each of the aforementioned types of sideband generators is that the carrier cannot be satisfactorily suppressed because of non-circularity of the waveguide and non-homogeneity of the ferrite and dielectric material. Stating it another way, carrier suppression is not inherent in the prior art devices. In the latter type of device reasonably satisfactory carrier suppression can be consistently obtained only at great expense because of the necessity of exercising great care to select only perfectly cylindrical waveguides and homogeneous ferrite and dielectric materials. In the first two mentioned types of prior art devices substantial carrier suppression is not possible in practical applications.

It is an object of the present invention to provide an improved sideband generator involving no mechanical moving parts.

Another object of the present invention is to provide an improved sideband generator which is capable of producing sideband frequencies and suppressing the original carrier frequencies.

It is another object of the present invention to provide an improved sideband generator providing enhanced carrier suppression.

It is a still further object of the present invention to provide a sideband generator that allows elimination of rotator assemblies and makes carrier suppression independent of circularity of round waveguides and the homogeneity of ferrite and dielectric materials.

It is a still further object of the present invention to provide a sideband generator having enhanced carrier suppression and that is simpler in construction and more economical to manufacture.

Other and further objects of the invention will be apparent from the description of typical embodiments thereof, taken in connection with the following description and accompanying drawing.

In accordance with the present invention there is provided a hybrid junction having an input arm adapted to receive and propagate an input carrier signal of microwave, plane-polarized electromagnetic energy characterized by an electric vector having a predetermined direction of polarization. Due to the inherent and well-known action of the hybrid junction the input signal is split and supplied to two balanced arms containing ferromagnetic material and terminated by signal reflecting means. Means are provided for applying a magnetic field at each balanced arm to render the phase angle of

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signals propagated by the balanced arms substantially equal and to alternately increase the phase shift through one balanced arm a selected amount and decrease the phase shift through the other balanced arm by substantially the same amount. Because of ferrite interaction the phase of the signal in one balanced arm reflected back to the hybrid junction is advanced β° while the other similarly reflected signal is retarded β° . The difference signal, which is a double sideband carrier-suppressed signal, appears at the output arm of the hybrid junction. It is inherent from the operation of the invention that the carrier signal will be suppressed and that the sideband signals be propagated.

In the accompanying drawing:

FIG. 1 shows one embodiment of the invention; and FIG. 2 shows the waveform of the output signal.

With particular reference to FIG. 1, a hybrid junction 11 shown by way of example as a folded magic Tee has a rectangular waveguide input arm 12, output arm 13, and two balanced arms 14—15. The various arms may, for example, be constructed of copper and have one transverse dimension 16 less than a half wavelength at the operating frequency and the other transverse dimension 17 greater than a half wavelength long at the operating frequency. A rod or rectangular element 18—19 of ferromagnetic material is disposed in each balanced arm 14—15. Each ferromagnetic element 18—19 may be fixedly attached to the waveguide as by gluing as shown in FIG. 1 or if desired the waveguide may surround a ferrite rod supported in a suitable dielectric material. The end of each balanced arm 14—15 is short-circuited by short-circuiting elements 21—22 to reflect any signal incident on their exposed inner surface. While only a fixed location of the short-circuiting elements is considered necessary, it should be understood that it is not essential to the invention that the short-circuiting means be fixed and that the short-circuiting means may be rendered adjustable in any well-known manner if desired. In addition, it should be understood that any suitable waveguide short-circuiting or reflecting means may be substituted for the short-circuiting means shown.

Slots 23—24 extending the length of the ferrite material are provided in the upper wall of each balanced arm to facilitate coupling of the magnetic fields, as described more fully hereinafter, into the ferrite elements. A biasing magnetic field at each ferrite element 18—19 is provided by inductive coils 25—26 which surround the balanced arms and ferrite elements as shown in FIG. 1. The coils 25—26 are connected in series and wound in the same direction and with substantially the same number of turns to provide substantially identical biasing magnetic fields at each ferrite element 18—19. In some cases, to initially obtain identical phase shifts through each balanced arm 14—15, it may be necessary to vary, for example, the number of turns on one or both of the coils. A suitable D.C. signal is applied to the series connected coils 25—26 to provide the aforementioned biasing magnetic fields. As shown in FIG. 1, the biasing coils 25—26 are diagrammatically depicted as square turns to better illustrate the invention and permit the different coils to be more easily distinguished and identified. With respect to the provision of the biasing magnetic fields it is to be understood that they may be provided, for example, by permanent magnets.

A modulating magnetic field at each ferrite element 18—19 is provided by coils 27—28 (shown as circular in FIG. 1) which also surround the balanced arms and ferrite elements. The modulating coils 27—28 are series connected and provided with substantially the same number of turns, but are distinguished from the biasing coils 25—26 in that they are oppositely wound such that the modulating magnetic field in one balanced arm increases

as the modulating magnetic field in the other balanced arm decreases in accordance with the applied modulating A.C. input signal. A high frequency modulating voltage is applied to the modulating coils 27—28 to cause an alternating current to flow which in turn produces a longitudinal magnetic field through the ferrite elements 18—19 in each balanced arm. In accordance with the theory of ferrite loaded rectangular waveguides, the magnetic field causes the electromagnetic wave to be phase shifted in accordance with the variations of the current. The amount of phase shift that takes place is also a function of the length and size of the ferrite material. A complete discussion of phase shift due to ferrites may be found in an article entitled, "Behavior and Applications of Ferrites in the Microwave Region," by A. G. Fox, S. E. Miller and M. T. Weiss, published in the Bell System Technical Journal, volume 34, No. 1, January, 1955. If the ferrite elements are formed as rods and supported within the balanced arms in a suitable dielectric material the insulated modulating coils 27—28 may be wound on the ferrite elements 18—19 and the leads brought out through the slots 23—24.

Upon application of an input signal characterized by a vector, having polarity in the direction as shown at 29, to the input arm 12, the input signal splits between the two balanced arms 14—15 which are identical, each signal is reflected by the short circuit 21—22 in the balanced arms and unless further processed, will return to the input arm 12. Application of a D.C. current to the biasing coils 25—26 renders the phase shift through each balanced arm 14—15 equal by reason of the winding of the coils as pointed out hereinbefore. Thus, all the energy reflected by the short circuits 21—22 returns to the input arm 12 and none appears at the output arm 13. However, when a modulating A.C. signal is supplied to the modulating coils 27—28 an A.C. signal is impressed upon the aforementioned D.C. signal and by reason of the winding of the modulating coils 27—28 described hereinbefore this causes the H-field in one balanced arm to increase while the H-field in the other balanced arm decreases. Thus, because of the ferrite interaction the phase of a microwave signal in one arm is advanced β° while the phase of the microwave signal in the other balanced arm is retarded β° . The difference signal $.5E \sin 2\beta$, which is the output signal, will appear at the output arm 13 and will have a waveform approximately as shown in FIG. 2. It will be noted that the output signal is a double sideband carrier suppressed signal. Further,

$$\frac{E_{out}}{E_{in}} = K \cos \omega t \sin mt$$

where m is the modulating frequency, ω is the frequency of operation, and K is dependent on the phase shift of the device. If K in each balanced arm is not equal some of the carrier may appear in the output signal. However, a phase difference, which is not likely to occur, may be tolerated without resulting in a substantial amount of carrier in the output signal. For example, if K for one balanced arm is .20 radian and K for the other balanced arm is .285 radian, carrier unbalance will still be about 56 db down from the input power.

A single sideband generator may be provided by combining two double sideband generators constructed in accordance with the present invention with a bridge. Briefly, this may be accomplished by utilizing a hybrid junction to supply identical input signals to two double sideband generators constructed in accordance with the present invention. The output signal of each double sideband generator is supplied to a second output hybrid junction where one or both of the single sideband suppressed carrier signals may be obtained by proper adjustment of both the microwave and A.C. phase shifts.

The use of the present invention greatly enhances modern microwave techniques. From the above description the application of the present invention to problems of

modulation, attenuation, sideband generation and the like is obvious.

While there has been hereinbefore described what is at present considered a preferred embodiment of the invention, it will be apparent that many and various changes and modifications may be made with respect to the embodiment illustrated without departing from the spirit and scope of the invention. It will be understood, therefore, that all such changes and modifications as fall fairly within the scope of the present invention, as defined in the appended claims, are to be considered as a part of the present invention.

What is claimed is:

1. A sideband generator comprising: a rectangular waveguide hybrid junction having an input arm, an output arm, and two balanced arms; signal reflecting means disposed at the end of each said balanced arm; and means for causing the phase shift through one balanced arm to be increased a selected amount and the phase shift through the other arm to be decreased by substantially the same amount.

2. A sideband generator comprising: a rectangular waveguide hybrid junction having an input arm, an output arm, and two balanced arms; signal reflecting means disposed at the end of each said balanced arm; and means for causing the phase shift through one balanced arm to be increased a selected amount and the phase shift through the other arm to be decreased by substantially the same amount and in substantially the same manner as the first mentioned phase shift.

3. A sideband generator comprising: a rectangular waveguide hybrid junction having an input arm, an output arm, and two balanced arms; signal reflecting means disposed at the end of each said balanced arm; and means for simultaneously causing the phase shift through one balanced arm to be increased a selected amount from a selected value and the phase shift through the other arm to be decreased by substantially the same amount from the same value.

4. A sideband generator comprising: a rectangular waveguide hybrid junction having an input arm, an output arm and two balanced arms; means for short circuiting the end of each said balanced arm; a ferrite element disposed in each said balanced arm; means to provide a constant magnetic field at both said ferrite elements; and means to provide oppositely varying magnetic fields at said ferrite elements.

5. A sideband generator comprising: a rectangular waveguide hybrid junction having an input arm, an output arm and two balanced arms; means for short circuiting the end of each said balanced arm; a ferrite element disposed in each said balanced arm; means to provide a constant magnetic field at each said ferrite element to provide a phase shift through each said balanced arm such that microwave energy supplied to each balanced arm from the input arm will be reflected back in phase to said input arm; and means to provide oppositely varying magnetic fields at said ferrite elements to provide a varying phase shift through said balanced arms whereby a difference signal will appear at the output arm.

6. A sideband generator comprising: a hybrid junction having an input arm, an output arm and two rectangular waveguide balanced arms; means for short circuiting the end of each said balanced arm; a ferrite element disposed in each said balanced arm; means to provide a constant magnetic field at both said ferrite elements, said means including a first inductive coil surrounding one of said balanced arms and coaxial therewith and a second inductive coil surrounding the other balanced arm and coaxial therewith, said first and second coils being connected in series and wound in the same direction; and means to provide oppositely varying magnetic fields at said ferrite elements, said means including a third inductive coil surrounding the ferrite element in one of the balanced arms and a fourth inductive coil surrounding the ferrite element in the

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other balanced arm, said third and fourth coils being connected in series and wound in opposite directions.

7. A sideband generator comprising: a hybrid junction having an input arm, an output arm and two rectangular waveguide balanced arms; means for short circuiting the end of each said balanced arm; a ferrite element disposed in each said balanced arm; means to provide a constant magnetic field at both said ferrite elements, said means including a first inductive coil surrounding one of said balanced arms and coaxial therewith and a second inductive coil surrounding the other balanced arm and coaxial therewith, said first and second coils being connected in series and wound in the same direction; and means to provide oppositely varying magnetic fields at said ferrite elements, said means including a third inductive coil surrounding the ferrite element in one of the balanced arms and a fourth inductive coil surrounding the ferrite element in the other balanced arm, said third and fourth coils being connected in series and wound in opposite directions, said first and second coils being adapted upon application of a D.C. current thereto to cause signals propagated by each said balanced arm to return to said input arm in phase and said third and fourth coils being adapted upon application of a modulation signal thereto to vary the phase of signals propagated by each said balanced arm an equal amount and in opposite directions.

8. A sideband generator comprising: a rectangular waveguide hybrid junction having an input arm, an output arm, and two balanced arms; signal reflecting means disposed at the end of each said balanced arm; means to render the phase shift through said balanced arms substantially the same; and means for alternately increasing the phase shift through one balanced arm a selected amount and decreasing the phase shift through the other balanced arm by substantially the same amount.

9. A sideband generator comprising: a rectangular waveguide hybrid junction having an input arm for receiving a microwave input signal, an output arm, and two balanced arms; signal reflecting means disposed at the end of each said balanced arm; means for providing a constant phase shift through each said balanced arm whereby signals propagated by each said balanced arm are reflected

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in phase; and means for alternately increasing the phase shift of signals propagated by one balanced arm a selected amount and decreasing the phase shift of signals propagated by the other balanced arm by substantially the same amount to provide a difference signal at said output arm containing only sideband frequencies.

10. A microwave sideband generator for producing output sideband frequency signals, while suppressing input carrier signals, comprising: a magic Tee having an input arm adapted to receive and propagate a microwave input signal, an output arm, and two rectangular waveguide balanced arms; signal reflecting means disposed at the end of each balanced arm; a rod of ferrite material axially disposed in the direction of propagation within each balanced arm; dielectric insulating means holding each said rod in insulated and spaced relation to each said balanced arm; an inductive coil surrounding each said balanced arm and coaxial therewith to provide constant and substantially identical magnetic fields at each said rod to effect transmission of energy in each said balanced arm with phase shift whereby energy is reflected from each balanced arm at substantially the same phase angle, said inductive coils being connected in series and wound in the same direction; and an inductive coil surrounding each rod and coaxial therewith to simultaneously provide oppositely alternating magnetic fields at said rods to effect transmission of energy in each said balanced arm with phase variation in accordance with variations of said alternating fields, said coils being connected in series and oppositely wound one from another, each said balanced arm having a longitudinal slot extending there-through and extending about the length of each said rod to prevent the magnetic fields from being short circuited.

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