

July 11, 1950

G. C. SOUTHWORTH

2,514,679

WAVE TRANSMISSION

Filed June 16, 1944

2 Sheets-Sheet 1

FIG. 1

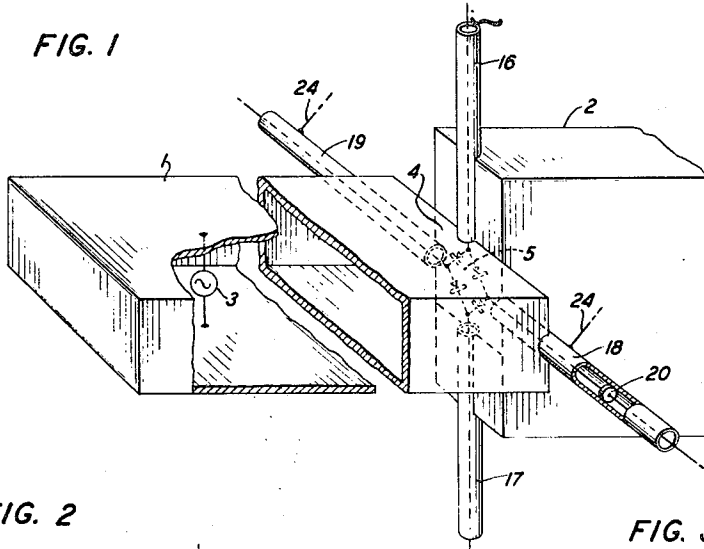


FIG. 2

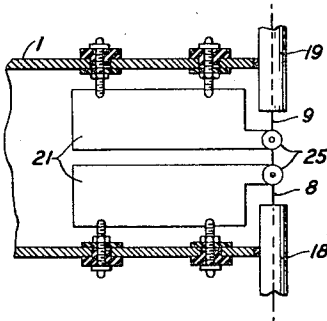


FIG. 3

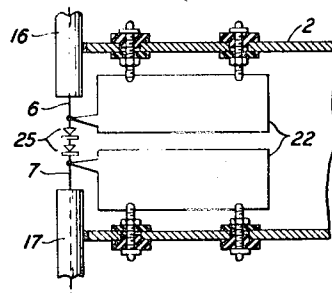


FIG. 5

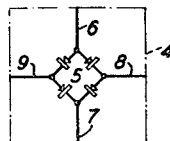


FIG. 6

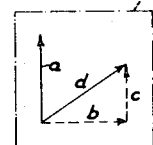


FIG. 4

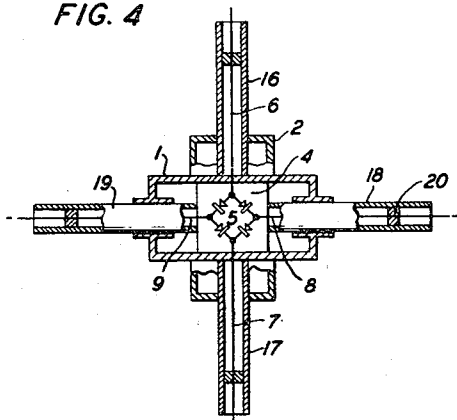
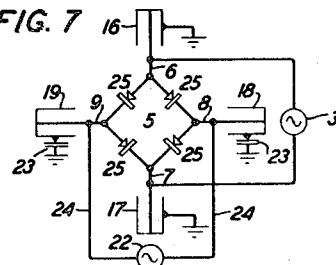


FIG. 7



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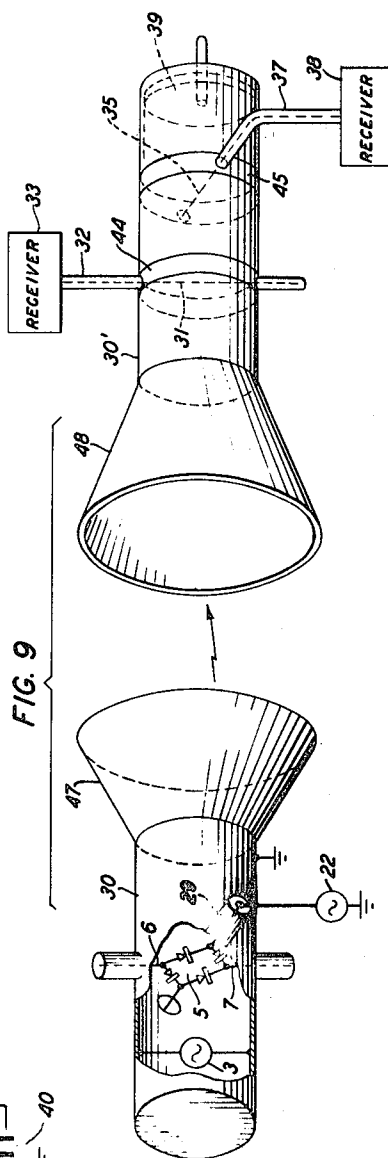
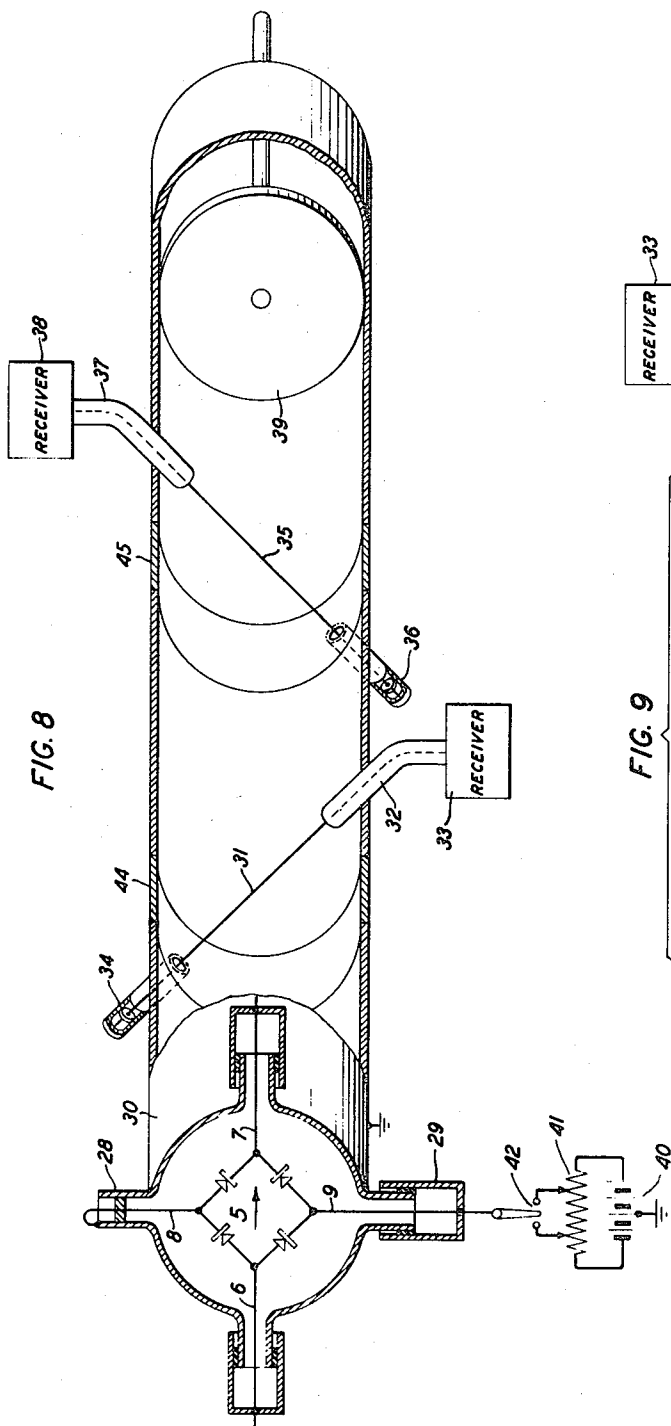
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WAVE TRANSMISSION

Filed June 16, 1944

2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,514,679

WAVE TRANSMISSION

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Application June 16, 1944, Serial No. 540,670

34 Claims. (Cl. 332—54)

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This invention relates to the employment of high-frequency electromagnetic waves and more particularly to signaling systems and methods employing electromagnetic waves of radio frequency having wavelengths in the "microwave" range below about one meter.

The present disclosure is in part the same as disclosures contained in my applications for patent, Serial No. 359,643, filed October 4, 1940, since abandoned, and Serial No. 449,102 filed June 30, 1942.

One of the broad objects of the invention is to provide new and improved methods and means for variably controlling electromagnetic waves. A further broad object is to provide an improved modulation or frequency changing system adapted for operation in the microwave range. Another object is to facilitate segregation and efficient utilization of the several waves involved in such systems. Another and more particular object is to separate the carrier or beating wave and the modulated or sideband wave in a microwave modulation system much as these waves are separated, at lower frequencies, in balanced or carrier-suppression modulation circuits.

In accordance with a principal feature of the present invention the state of polarization of an electromagnetic wave is controllably varied to produce desired effects. In one embodiment of the invention, for example, the state of polarization of an electromagnetic wave is varied at will to control the application of the wave to one or more receiving systems that are selectively responsive according to the state of polarization of waves applied to them.

In accordance with another feature of the invention, a plurality of high-frequency electromagnetic waves involved in a modulation process or the like are maintained in mutually different states of polarization such as to facilitate segregation of the several waves. In accordance with a related feature two electromagnetic waves, one derived from the other and varied in strength relative thereto, are maintained in mutually conjugate states of polarization and separated from each other by polarization-selective means.

Still other features of the invention reside in the combination of an electrical circuit and a polarization-selective conductively bounded wave-guiding passage which by virtue of its polarization selectivity is in coupled and decoupled or conjugate relation, respectively, with different parts of the circuit or with different currents therein. In one aspect the invention involves utilization of polarization-selective means oper-

ative on an electromagnetic field surrounding an electrical circuit to prevent unwanted coupling between one part of the circuit and a wave-guiding passage coupled to another part of the circuit.

In a specific carrier-suppressing modulation system embodying the present invention and to be described hereinafter, a beating or carrier wave is guided to, and excites, a signal-controlled device that produces a signal-modulated wave component having a fixed orientation differing from that of the carrier wave, and an orientation-selective device freely transmits the signal-modulated wave while substantially suppressing transmission of the unmodulated component of the carrier wave. The system comprises, more particularly, two hollow pipe guides of non-circular cross-section each of which carries, in the dominant mode, a respective different high frequency wave involved in the modulation process, the two guides communicating with each other and being so oriented and proportioned that the wave tending to be excited in one by a wave of dominant mode in the other is incapable of propagation therethrough and is rejected. The system comprises, further, a modulation circuit of the balanced or carrier-suppression type having different portions that are respective to the different high frequency waves, these circuit portions being so oriented that each is coupled to a different one of the guides with respect to a wave of dominant type therein.

Other features of the invention reside in a variably unbalanced circuit and the spatial arrangement of the conductors of the circuit in relation to the field configuration of guided waves applied thereto or radiated therefrom.

The nature of the present invention and its various features, objects and advantages will appear more fully from a consideration of the embodiments illustrated in the drawings and hereinafter to be described.

In the drawings:

Figs. 1 to 5 illustrate a modulation system in accordance with the invention;

Figs. 6 and 7 comprise vector and circuit diagrams pertaining thereto;

Fig. 8 shows an organization in accordance with the invention for switching guided waves to one or another of two wave receivers; and

Fig. 9 illustrates a radio system in accordance with the invention.

Referring more particularly now to the modulation system illustrated in Fig. 1, there are shown a pair of hollow pipe guides 1, 2 of elon-

gated rectangular cross-section, the two guides being disposed end-to-end in abutting relation with their larger transverse dimensions at right angles to each other. At the junction of the two guides the exposed ends are substantially completely closed, leaving within a rectangular opening 4. At the center of the opening 4 and disposed in the plane thereof is a bridge circuit 5 comprising four similar electrovariable impedance elements. Four conductors 6 to 9 extend from their respective corners of the bridge perpendicularly to the sides of the opening 4, as illustrated diagrammatically in Fig. 5.

Beating oscillations of a high radio frequency are supplied by a source 3 which is so connected to guide 1 that a guided wave of corresponding frequency and of dominant type is established in the guide 1, the electric lines of force in the guided wave being normal to the wider, horizontal faces of the guide. The plane of polarization of the guided wave is vertical, i. e., parallel with the narrower, vertical faces of the guide. The beating, or carrier wave transmitted through guide 1, upon reaching the opening 4, impresses itself on the vertical transverse conductor 6-7 which is aligned with the incident electric field. With the conductor so excited, alternating currents of the beating frequency tend to flow through the series combination comprising conductor 6-7 and the interposed bridge circuit 5. If the bridge be electrically balanced the bridge terminals to which the horizontal transverse conductors 8 and 9 are connected will not vary in potential relative to each other, and the conductor 8-9 will be excited neither directly by the incident wave nor indirectly by virtue of the excitation of conductor 6-7.

If now the bridge be unbalanced by external means operative on the several impedance elements, the terminals to which conductors 8 and 9 are connected will be no longer conjugate to the other pair of terminals but will vary in potential relative to each other at the beating frequency, and corresponding currents of the beating frequency will flow through the conductors connected thereto. Conductor 8-9 is thereby excited and tends to launch a horizontally polarized wave of dominant type in the guide 2, the intensity of the wave depending on the degree of unbalance of the bridge circuit 5. Thus the bridge 5 and its associated conductors partly convert the incident vertically polarized wave into a horizontally polarized wave, and both the horizontal, converted component and the unconverted vertical component tend to proceed to the right through opening 4.

The transmission cut-off characteristic of the hollow pipe guide is utilized, however, to suppress transmission of the vertically polarized component. More particularly, the shorter or horizontal transverse dimension of guide 2 is made small enough in relation to the beating frequency to preclude transmission of a vertically polarized wave of that frequency. Hence the unconverted component of the incident beating or carrier wave does not proceed substantially beyond the opening 4 but is reflected. The larger or vertical transverse dimension of guide 2, on the other hand, is made large enough that the horizontally polarized wave excited by conductor 8-9 is freely transmitted. Somewhat similarly, the smaller or vertical transverse dimension of guide 1 is so restricted that the horizontally polarized wave excited by conductor 6-7 is rejected and can proceed only to the right through guide

2. Thus the two guides are utilized as polarization selective wave transducers and reflectors.

It will be seen therefore that the intensity of the wave effectively launched into guide 2 depends on the degree of electrical unbalance of bridge circuit 5, and the unbalance can be controlled by external electrical means. If the bridge be unbalanced intermittently in accordance with a telegraphic code signal, for specific example, corresponding variations will appear in the intensity of the transmitted wave. More complex signals, such as speech waves, may likewise be impressed on the horizontally polarized transmitted wave by continually varying the degree of unbalance of the bridge in conformity with the variations in the instantaneous amplitude of the signal wave. The signal-bearing amplitude-modulated waves transmitted through guide 2 may be conveyed to any suitable utilization means, such as a distant receiver, as shown in Fig. 8.

From a somewhat different point of view the bridge 5 and its associated conductors as above described may be regarded as a reradiator or wave former that is excited by an incident guided wave. In its balanced condition the reradiator, so excited, provides excitation for only a vertically polarized wave, represented by the vector *a* in Fig. 6, and such a wave would be transmitted to the right were it not for the cut-off characteristic of the connected guide 2. When the bridge is unbalanced the reradiator converts the incident wave power into two excitation components, one a horizontally polarized component *b* and the other a vertically polarized component *c*, both as shown in Fig. 6. The resultant of the two components *b* and *c* is represented by the vector *d*. The latter is rotated or angularly displaced from the vector *a* and it represents a wave, or the excitation for a wave, the plane of polarization of which is displaced from the vertical plane. The extent of displacement or change in orientation depends on the degree of unbalance of the bridge 5 and it therefore varies with the instantaneous amplitude of the signal or other control effect.

The bridge 5 thus provides excitation for a wave with variably rotated plane of polarization, and such a wave would be transmitted to the right, as it is in the modification shown in Fig. 9, except that a polarization-selective translating element is interposed. That is, such a wave is not freely transmitted by a guide 2 of the particular shape and dimensions specified, for the guide 2 is selective according to the plane of polarization of the excited wave and accepts the wave to greater or lesser extent depending on the proximity of the wave orientation to a particular orientation. The extent to which the wave is thus accepted is measured by the vector *b* which varies in intensity in conformity with the signal variations.

Further details of the Fig. 1 structure include coaxial conductor tuners 16 to 19. The inner conductor of each tuner is a continuation of one of the conductors 6 to 9, and the tubular outer conductor of each lies in a semicylindrical recess in one of the exposed end faces of the two guides and extends outwards from the opening 4. Each of the coaxial tuners comprises also a longitudinally adjustable piston 20 which, at least for waves of the frequency transmitted through the guides, constitutes a short circuit. The several pistons 20 may be adjusted to present the most favorable reactance to the respective associated conductors 6 to 9.

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Various structural details of the Fig. 1 system are illustrated in Figs. 2 and 3. Fig. 2 is a horizontal longitudinal section taken through guide 1, and Fig. 3 is a corresponding vertical section taken through guide 2. As illustrated in Fig. 2, a pair of metal plates 21, insulated from each other and from the walls of the guide 1, are supported in the horizontal median plane near the apertured end of guide 1. A pair of metal plates 22 are likewise disposed in the vertical median plane in guide 2, as shown in Fig. 3. Portions of the plates 21 project into the opening 4 and to the projecting portions are fixed the four impedance elements 25 of the bridge 5, two elements on the upper face and two on the under face. The plates 22 may, if desired, be extended to make contact with the conductors 6 and 7 as shown in Fig. 3. The two pairs of plates 21 and 22 facilitate the suppression of wave disturbances in the vicinity of the junction of the two guides.

The electrical source for controlling the degree of unbalance of bridge 5 is represented at 22 in Fig. 7. It may be taken as a source of telephone or telegraph signals or other modulating effects to be impressed on the beating oscillations. As shown in this simplified schematic diagram of the Fig. 1 system, the source 22 is effectively connected by means of conductors 24 to the conductors 8 and 9 so that a varying difference in potential is established between the associated bridge terminals. The design must, of course, prevent short-circuiting of the source 22 through the walls of the guide. With this fact in mind, conductors 24 may be connected to the externally protruding inner conductors of coaxial tuners 18 and 19 if the pistons 20 therein are of a capacitative type adapted to pass waves of the signal or modulating frequency, the latter being a relatively low frequency. A capacitative piston suitable for this purpose is shown, for example, in Fig. 5 of United States Patent No. 2,253,503 to A. E. Bowen. Alternatively, if the coaxial tuners be insulated from the side walls and ends of the guides 1 and 2, conductors 24 may be connected to the tubular outer conductors as in Fig. 1. In Fig. 7 by-pass condensers 23 signify that the associated coaxial tuners are insulated from the guide. Insulated conductive sleeves may be provided on the insulated coaxial tuners to prevent escape of wave power from the interior of the guide.

The electrovariable impedance elements 25 constituting the bridge 5 may be non-linear or non-ohmic devices or more particularly rectifying crystals preferably of pure silicon or iron pyrites.

The effect of such a crystal on high frequencies passing through it can be varied by concurrently applying to it a varying bias, and the latter is supplied by the source 22. With the crystals poled in the manner illustrated, the varying bias or control effect has a differential effect on the several crystals and a consequent effect on the balance, or degree and sense of unbalance, of the bridge. The bridge, it may be noted, may be regarded as a signal-controlled variable coupling between the conductor system 6-7 and the conductor system 8-9.

Although the Fig. 1 modulation system has been described in terms of the modulation of a carrier wave by an applied signal, the system is inherently adapted also for the reciprocal modulation process sometimes known as demodulation. In the latter case a horizontally polarized, signal-bearing amplitude-modulated wave received through guide 2 is impressed on the bridge circuit 5 concurrently with beating oscillations sup-

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plied through guide 1, and the signals are recovered in the low frequency circuit comprising conductors 24. The only modification required is the substitution of a signal receiver for the signal source 22. The latter, in either case, may be termed a signal transceiver.

The relation of the Fig. 1 system to a typical modulation circuit of the "balanced," or "carrier-suppression" type will be evident on consideration of Fig. 7. The high-frequency carrier wave is impressed through bridge leads 6 and 7, and the modulated or sideband wave is delivered, free of unmodulated carrier, through bridge leads 8 and 9. The two pairs of leads, and also the two wave guides coupled respectively thereto, are thus in mutually conjugate circuit relation in the sense that a wave applied to the one does not give rise to a wave of the same form in the other. The poling of the crystals, it will be observed, too, is such that while one of the two waves applied to the system passes through both of a given pair of crystals in the same direction, say the direction of higher conductivity, the other applied wave passes through the same crystals in mutually opposite directions, as in typical balanced modulation circuits known heretofore. As in such systems, further, a given pair of crystals are connected differently to the carrier wave path on the one hand and to one of the other two wave paths on the other hand, the crystals being connected in series or parallel to the one and in parallel or series, respectively, to the other.

In the embodiment of the invention that is illustrated in Fig. 8, rotation of the plane of polarization of a guided wave is utilized to control the application of the wave to separate wave receiving systems. The hollow pipe guide 30 is in this case of circular cross-section, and it is assumed that a horizontally polarized (H_{11}) guided wave is received from the left. The received wave may be an amplitude-modulated signal-bearing wave. Within the guide is the bridge 5 and the four transverse conductors 6 to 9 which are associated with respective coaxial tuners substantially as in Fig. 1. Bridge 5 is so oriented that conductor 6-7 is disposed horizontally in alignment with the electric field of the incoming wave. The plane of polarization of the wave transmitted to the right from bridge 5 depends on the degree of unbalance of bridge 5 and this in turn is controlled by external circuit means for applying a biasing voltage across the bridge terminals to which conductors 8 and 9 are connected.

Within the guide 30 and to the right of bridge 5 is a transverse pick-up conductor 31. The latter is terminated at one end in a coaxial tuner 34 and in the other direction it continues through an opening in the wall of guide 30 as the inner conductor of a coaxial conductor line 32 which leads to a wave receiver 33. Conductor 31 lies in an axial plane that is rotated 45 degrees from the horizontal plane containing conductors 6 and 7. Still farther to the right and in an axial plane normal to that of conductor 31 is another pick-up conductor 35. This one is associated with a coaxial tuner 36 and it is connected through coaxial conductor line 37 to another wave receiver 38. By applying a biasing voltage of the proper magnitude and sense to the bridge 5 the plane of polarization of the incoming horizontally polarized wave may be rotated 45 degrees to coincide with the axial plane of pick-up conductors 6 and 7, in which case the incoming wave is directed to receiver 33 exclusively. With a different bias applied to the bridge the plane of polarization is rotated 45 degrees in the opposite direc-

tion and only receiver 38 is then activated by the wave. Intermediate orientations of the wave allow both of the receivers to be activated inasmuch as the pick-up conductors are not sharply selective with respect to the plane of polarization of the wave incident upon them. An adjustable piston 39 is provided within the right-hand end of guide 30 so that with proper spacing of the two pick-up conductors the piston may be adjusted to effect an impedance match between guide 30 and the respective transmission lines 32 and 37.

The voltage biasing means for bridge 5 may comprise, as illustrated in Fig. 8, a battery 40 the mid-point of which is connected to conductor 8 through ground, the wall of guide 30 and coaxial tuner 28; and a potential divider 41 that is connected across battery 40. A pair of adjustable contactors on potential divider 41 are connected to respective switch points comprising a switch 42 the arm of which is connected to conductor 9 through the insulated end of coaxial tuner 29. With the adjustable contactors set to provide the proper biasing voltages it is only necessary to operate switch 42 to direct the guided waves to either of the receivers 33 and 38 at will.

The pick-up conductors 31 and 35 in Fig. 8 may be disposed in rotatable ring-sections 44 and 45 of the guide 30, if desired, so that their orientation may be adjusted at will. This affords a means, independent of potential divider 41, for adjusting the relative amounts of wave power delivered to the two receiving systems.

The operation of the Fig. 8 system may be described alternatively, without reference to rotation of the plane of polarization of an incident wave, in terms of two superposed waves having the same form as the incident wave and transmitted away from the bridge circuit with mutually perpendicular planes of polarization. Excitation for one of these superposed waves is derived from the incident wave by way of the bridge circuit, and the amount of excitation is varied by adjusting the degree of unbalance of the bridge circuit.

The embodiment of the invention that is illustrated in Fig. 9 comprises a modulation system in which, as contrasted with Fig. 1, both the vertically and horizontally polarized waves are transmitted to the distant receiving station.

Referring to Fig. 9, a vertically polarized (H_{11}) carrier wave is transmitted from source 3 through the guide 30 of circular cross-section to bridge 5 which is so oriented that the conductor 6—7 is directly excited by the incident wave. The signal source 22 is connected to coaxial tuner 29, as the variable biasing source is connected thereto in Fig. 8, so that the bridge 5 is variably unbalanced in conformity with the variations in signal intensity, as described with reference to Figs. 1 to 7. Excitation is thereby provided for a horizontally polarized wave the intensity of which varies with the instantaneous amplitude of the signal, and such a wave is transmitted to the right from bridge 5 together with the residue of the vertically polarized carrier wave. The resultant or composite wave may be conveyed through guide 30 to a distant receiving station or, as illustrated, it may be radiated through space from a conical horn 47 that flares from the end of guide 30.

The receiving station in Fig. 9 may comprise a conical horn 48 and a connected guide 30' which has a pair of receivers 33, 38 coupled to it in the manner of Fig. 8. The pick-up conductors 31 and 35 upon which the received wave is impressed are polarization-selective. That is, the wave power intercepted by each conductor depends on

the proximity of the plane of polarization of the incident wave to the axial plane of the conductor, and it varies with the orientation of the pick-up conductor. The latter may be varied at will. It will be evident that a horizontally-polarized side-band wave and a vertically polarized carrier wave component (which may have in it certain characteristics of the signal) are concurrently established in the guides 30 and 30'. Each of the pick-up conductors may be oriented to receive equal or unequal amounts of carrier and sideband power as desired. One may be oriented, for example, to receive only the horizontally-polarized side-band power, and the other only the vertically-polarized carrier power.

Although the present invention has been described herein with reference to certain embodiments thereof, it will be understood that these embodiments are in part only illustrative and that the invention may take other and varied forms within the spirit and scope of the appended claims.

What is claimed is:

1. The method which comprises receiving a guided electromagnetic wave having a first state of polarization, converting the received wave into a guided wave having a different state of polarization, transmitting said second-mentioned wave exclusively of said first-mentioned wave, and controllably altering the extent of conversion of the wave from the said first state to said different state of polarization independently of any variations in the said received wave.

2. The method which comprises transmitting a guided electromagnetic wave having a predetermined state of polarization, deriving from the said guided wave excitation for a superposed guided wave having a different state of polarization, and varying the amount of said excitation independently of any variations in the intensity of said first-mentioned wave.

3. In combination, a conductively bounded passage, means for propagating in said passage electromagnetic waves of radio frequency having a predetermined plane of polarization, translating means excited by said propagated waves for providing excitation in said passage for waves of like form having a different plane of polarization, and means operative on said translating means for controlling the orientation of said different plane of polarization.

4. In combination, a hollow pipe guide, a four-terminal bridge of electrovariable impedance elements disposed within said guide, four conductors each connected to a respective terminal of the said bridge, one pair of said conductors extending transversely of said guide at substantially right angles to the other pair of said conductors, circuit means external of said guide connected to one of said pairs of conductors, and means for transmitting an electromagnetic wave through said guide to said conductors.

5. A combination in accordance with claim 4 in which said external circuit means comprises means for electrically controlling the state of electrical unbalance of said bridge.

6. In combination, a conductively bounded electromagnetic wave-guiding structure, circuit means configured to excite or receive electromagnetic waves having a first state of polarization in said structure, circuit means configured to excite or receive electromagnetic waves having a different state of polarization in said structure, at least a portion of said structure adjacent said circuit means having a polarization-selective

characteristic such that transmission of waves having one of said states of polarization is substantially blocked, and translating means for variably coupling said two circuit means together.

7. In a modulation system, in combination, a conductively bounded electromagnetic wave-guiding structure, two conductors disposed within said structure in perpendicular relation to each other and adapted for excitation of or by respective electromagnetic waves in said structure having mutually perpendicular planes of polarization, and a bridge circuit comprising a plurality of non-linear impedance elements, said bridge circuit having said conductors included in respective different branches thereof.

8. In combination, a conductively bounded electromagnetic wave guiding structure, two transverse conductors within said structure disposed adjacent each other in mutually perpendicular planes, and means for intercoupling said conductors comprising a bridge circuit, said bridge circuit including electrovariable impedance means for varying the coupling.

9. In combination, a conductively bounded passage, means for propagating in said passage electromagnetic waves of radio frequency having a substantially fixed plane of polarization, translating means in the path of, and adapted to be excited by, said propagated waves for exciting in said passage waves having a different plane of polarization, and means operative on said translating means for varying the intensity of said last-mentioned waves.

10. A combination in accordance with claim 9 including polarization-selective means for excluding said propagated waves and said last-mentioned waves from respective different portions of said passage.

11. In a modulation system, in combination, circuit means configured to excite electromagnetic waves having a first state of polarization, circuit means configured to excite or receive electromagnetic waves having a different state of polarization, means for exciting said first-mentioned circuit means with unmodulated ultra-high frequency oscillations, a bridge circuit comprising a plurality of non-linear impedance elements, said bridge circuit including the two said circuit means in respective diagonal branches thereof.

12. In combination, a conductively bounded electromagnetic wave guiding passage, means for transmitting through said passage electromagnetic waves having a predetermined state of polarization, polarization-selective means in said passage excited by said transmitted waves incident thereon, means for launching in said passage electromagnetic waves having a different state of polarization, and means for exciting said last-mentioned means comprising an electrovariable coupling between said polarization-selective means and said launching means.

13. In combination, a conductively bounded passage including an electromagnetic wave transducer that is substantially opaque to waves having one state of polarization and substantially transparent to waves having another state of polarization, means for transmitting through said passage toward said transducer unmodulated waves having said one state of polarization, and means in the path of said waves for exciting modulated waves having said other state of polarization.

14. In combination, two hollow pipe guides of rectangular cross-section connected end-to-end, means for transmitting guided electromagnetic

waves of dominant type through one of said guides toward the other of said guides, one of the transverse dimensions of said other guide being so restricted as to prevent the transmission of said waves therethrough, and circuit means excited by the waves in the said one guide for launching in said other guide waves of dominant type the plane of polarization of which is normal to the other transverse dimension of said other guide.

15. In combination, a conductively bounded wave transmission path comprising tandem-connected sections of hollow pipe guide, means for transmitting electromagnetic waves having a substantially fixed plane of polarization through one of said sections toward the other of said sections, said path including means preventing the said waves of the said polarization from substantially entering said other section, and circuit means excited by the said waves in the one section for launching in said other section waves having a different plane of polarization.

16. A combination in accordance with claim 15 in which said circuit means includes electrovariable means for varying the intensity of the waves launched in said other section.

17. In combination, a conductively bounded structure comprising tandem-connected sections of hollow pipe guide, means for transmitting through one of said sections toward the other of said sections electromagnetic waves having a predetermined state of polarization such that said waves are reflected from said other section, circuit means excited by the said transmitted waves, circuit means adapted for exciting or receiving waves having another state of polarization in said other section, and a variable coupling between the two said circuit means.

18. A combination in accordance with claim 17 in which said variable coupling comprises non-linear impedance means.

19. In a system for the transmission of electromagnetic waves of radio frequency, the method of distance transmission which comprises transmitting a carrier wave having a first state of polarization, intercepting the said transmitted carrier wave to derive a portion of the wave power thereof, utilizing the derived wave power in the excitation of a signal-bearing sideband wave having a different state of polarization, transmitting both said waves to a distance in superposed relation, and receiving concurrently both of the transmitted waves.

20. The method which comprises intercepting an electromagnetic wave having a predetermined plane of polarization, applying the intercepted wave to the separate excitation of two superposed waves having mutually different planes of polarization, and controllably varying the relative intensities of the said two superposed waves irrespective of any variations in the intensity of said first-mentioned wave.

21. In a system utilizing electromagnetic waves of radio frequency, the method which comprises transmitting a first wave having a predetermined plane of polarization, diverting a portion of the transmitted wave to excite a second wave that has a form differing from that of said first wave, and maintaining said first and second waves in superposed relation with the plane of polarization of the one superposed wave substantially perpendicular to the plane of polarization of the other.

22. In combination, a conductively bounded wave transmission path comprising tandem-connected sections of hollow pipe guide, means for

transmitting electromagnetic waves having a substantially fixed plane of polarization through one of said sections toward the other of said sections, a modulation circuit coupled to receive the said transmitted waves, said modulation circuit being differently coupled to the other of said sections to launch or intercept electromagnetic waves having a different plane of polarization therein, and said path including polarization-selective means preventing the waves in either of said sections from substantially entering the other of said sections.

23. In combination in a frequency changing system, a pair of uniconductor wave guides of elongated cross-section, means for transmitting through one of said guides electromagnetic waves having electric lines substantially normal to the longer cross-sectional dimension thereof, frequency changing circuit means responsive to said transmitted waves, said guides being disposed with an end of one in communicating relation with an end of the other whereby the said waves transmitted through said one guide tend to excite corresponding waves in said other guide, said other guide being oriented with its longer cross-sectional dimension substantially parallel to the electric lines of the said waves tending to be excited therein, and the said other guide having a transmission cut-off characteristic such as to suppress transmission of said last-mentioned waves.

24. In combination in a frequency changing system, a uniconductor wave-guiding passage, means for exciting in said passage for transmission therethrough waves having substantially a certain frequency and state of polarization, said passage being polarization-selective and substantially transparent to said waves, means for generating waves differing in form from said first-mentioned waves comprising non-linear impedance means and circuit means exposed to the said waves excited in and transmitted through said passage for impressing corresponding currents on said impedance means, said generating means tending to excite in said passage waves having a state of polarization differing from said first-mentioned state of polarization, and said passage being substantially opaque to said last-mentioned waves by virtue of its polarization selectivity.

25. In combination, a pair of uniconductor wave guides of elongated cross-section which are conductively joined with their ends in open communication with each other, said guides having such relative orientation at their junction that a guided electromagnetic wave of dominant type in one of them tends to excite a guided wave of non-dominant type in the other, and wave translating means coupled near the said junction to both of said guides with respect to waves of dominant type therein.

26. In combination, a uniconductor electromagnetic wave-guiding passage comprising two tandem-related sections of substantially rectangular cross-section, means for establishing in each of said sections guided waves having electric lines substantially normal to the longer cross-sectional dimension thereof, the respective cross-sections being oriented with the longer dimension of one substantially parallel to the electric lines of guided waves tending to be excited therein by the said waves established in the other, the shorter cross-sectional dimension of each said section being short enough to substantially block transmission of waves tending to be excited therein by the said waves established in the other of said sections, and an electrical circuit comprising at

least one pair of non-linear impedance elements which are coupled in series and parallel relation, respectively, to the said two sections with respect to the said waves established therein.

27. A microwave modulation system comprising a carrier wave source, a modulating wave source, a modulation circuit comprising a plurality of non-linear impedance elements in distinct branches thereof, means for effectively connecting said carrier wave source and said modulating wave source to said impedance elements whereby a modulated wave is generated in said circuit, a hollow pipe guide, said circuit having certain portions thereof that are traversed by the said modulated wave disposed in guided-wave exciting relation to said guide, said certain portions being configured to launch the said modulated wave in said guide in dominant mode, said circuit having certain portions thereof that are traversed by the said carrier wave disposed in guided-wave exciting relation to said guide, said last-mentioned certain portions being configured to excite carrier wave in a different mode in said guide, said guide having a polarization selective characteristic such as to transmit said modulated wave and reject said carrier wave.

28. A microwave modulation system comprising a carrier wave source, a modulation circuit comprising a plurality of non-linear impedance elements in distinct branches thereof, means for effectively connecting said carrier wave source to said impedance elements, a hollow pipe guide for transmitting modulated guide waves in dominant mode to said modulation circuit, said circuit having certain portions thereof disposed in guided-wave receiving relation to said guide for effectively impressing said modulated wave on said impedance elements, whereby a modulating wave is recovered in said circuit, said circuit having certain portions thereof that are traversed by the said carrier wave disposed in guided-wave exciting relation to said guide, said last-mentioned portions being configured to excite carrier wave in a different mode in said guide, said guide having a polarization-selective characteristic such as to transmit said modulated wave and reject said carrier wave.

29. In combination, a conductively bounded electromagnetic wave-guiding passage, a pair of non-linear impedance elements, a first circuit connection comprising both said elements in series circuit relation therein and a conductor that extends substantially in a first direction across the interior of said passage, a second circuit connection joined to said first connection at a point intermediate said elements and comprising a conductor that extends across the interior of said passage substantially in a direction at right angles to said first direction, at least a portion of said passage adjacent said conductors having a polarization-selective characteristic, said characteristic discriminating in favor of the transmission of a guided wave having a plane of polarization the orientation of which substantially coincides with one of the aforesaid directions.

30. In combination, a conductively bounded electromagnetic wave-guiding passage, a pair of non-linear impedance elements, a first circuit connection comprising both said elements in series circuit relation therein and a conductor that extends substantially in a first direction across the interior of said passage, a second circuit connection joined to said first connection at a point intermediate said elements and comprising a conductor that extends across the interior of said

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passage substantially in a direction at right angles to said first direction, at least a portion of said passage adjacent said conductors being of elongated cross-section, the direction of elongation substantially coinciding with one of the aforesaid directions.

31. A combination in accordance with claim 30 including a plurality of external shielded-line stubs, each stub having as a line conductor thereof an extension of one of said conductors.

32. A microwave frequency changer comprising, in combination, a hollow pipe wave guide, first and second tubular conductors connected to said wave guide and extending in opposite directions therefrom, a further conductor extending through said first tubular conductor, said wave guide and said second tubular conductor and forming with said tubular conductors, first and second coaxial transmission lines coupled to said wave guide, a crystal rectifier in series with said further conductor, means for applying to said crystal rectifier ultra-high frequency energy of a wavelength longer than the cut-off wavelength of said wave guide, movable means within said first coaxial line for providing an adjustable ultra-high frequency energy conducting path between said first tubular conductor and said further conductor, and movable means within said second coaxial line for providing an adjustable ultra-high frequency energy conducting path between said second tubular conductor and said further conductor.

33. A microwave frequency changer as defined in the preceding claim, further including means

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for applying direct bias voltage to said crystal rectifier for varying the operating characteristics thereof whereby the frequency changing efficiency of said frequency changer may be enhanced.

34. A microwave frequency changer comprising a hollow pipe wave guide, a conductor extending transversely through said wave guide, tubular conducting means connected to said wave guide and forming an outer conductor for cooperation with said first conductor as a coaxial transmission line, means for applying to said first conductor ultra-high frequency energy of a wavelength longer than the cut-off wavelength of said wave guide, a first crystal rectifier connected in series with said conductor in a first current-carrying orientation, and a second crystal rectifier connected in series with said conductor in an opposite current-carrying orientation for conduction of current during opposed half cycles of the applied ultra-high frequency energy.

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