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Wave guide modulation system

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SUMMARY:

The present invention relates to systems of communication and more particularly to the transmission and reception of electromagnetic waves. This application is a continuation-in-part of parent application Serial No. 492,167, filed June 23, 1943, by Robert Harvey Rines, matured into Letters Patent 2,539,476, on January 30, 1951.

An object of the present invention is to provide a new and improved system for modulating electromagnetic waves.

A further object is to provide a novel apparatus for modulating electromagnetic w;aves which are propagated along electromagnetic wave guides.

An additional object is to provide new and improved wave-guide and wave-guide chamber structures.

Other and further objects will be explained hereinafter and wpl be more particularly pointed put in the appended claims, The invention will now be more fully explained in connection with the accompanying drawings, Eig. 1 of which is a diagrammatic view of circuits and apparatus constructed in accordance with the present invention and illustrating a perspective of a section of wave guide along which radio waves may be transmitted, or received, the radio waves being modulated with the aid of piezoelectric means; Fig. 2 is a similar perspective view, partially cut away, in which the modulating system is disppsed within the wave-guide in accordance with a preferred embodiment of the present

invention; Fig. 3 is a view similar to Fig. 2 illustrating a multi-channel modulating system embodying a flared electromagnetic waveguide horn antenna; Fig. 4 is a sectional view of a modification in which a slidable wave-guide wall is employed; and Fig. 5 is a perspective of a further modification em bodying a wave-guide cavity resonator.

Referring first to Fig. 1, an electromagnetic wave-guide is illustrated at 1. The wave-guide 1 is of the type haying a transverse cross-sectional configuration, shown as rectangular, to permit the propagation therethrough, of electromagnetic waves above a critical frequency related to the said transverse cross-sectional configuration. It is to be understood, however, that any well-known wave guide, such as a guide of circular, elliptical, square or other well-known cross-sectional configurations, or a concentric transmission-line guide, may equally well be employed. Though the guide 1 is illustrated as a hollow air-filled pipe, furthermore, it may be filled with any other desired dielectric medium and it may, indeed, be constituted solely of a dielectric tube, as is well-known in the art.

Electromagnetic waves may be transmitted through the dielectric medium bounded by the walls of the wave-guide chamber 1 by launching the waves from a region inside the guide, as, for example, from the closed end 3 of the guide, or by receiving the waves from an end 11 of the guide. The end 11 may act as an electromagnetic-horn antenna receiver or transmitter for directionally receiving or transmitting beams of electromagnetic waves from or into outer space.

A dipole antenna 2, 4 is shown in Figs. 1 and 2, as symmetrically disposed within the wave guide 1 at the closed end 3 thereof. The antenna 2, 4 may be excited by a gen erator of electromagnetic waves 5, such as, for example, by a magnetron or by a klystron, in order to launch waves 5 down the guide 1. For the relative wave-guide and dit. pole-antenna dimensions shown, for example, waves of the fundamental Eo,i-type may be propagated down the guide. Any other well-known launching antenna or other exciter may also be used to transmit waves haying other electric vector configurations, as is well-known in the art. It is to be understood, furthermore, that the antenna 2, 4 may also be connected to a receiver, not shown, in order to receive waves propagated within the guide 1 from the end 11.

It is extremely difficult to modulate many ultra-high frequency generators, including magnetrons, since many of these generators operate with critical voltages and with tuned circuits having fixed resonant dimensions. Attempts to interfere electrically with the resonant operating conditions of these generators in order to modulate the waves produced by the generators invariably result in reduced efficiency and in other disadvantageous effects. In accordance with the present invention, on the other hand, the generator 5 is permitted to drive the antenna 2, 4 with its full power and without electrical interference with the generator 5. Modulation is produced externally to the system 5-2-4.

It has been found, as discussed in the said original parent application, that if a wall of the radio-wave cpndueting wave guide 1 is mechanically vibrated, the electromagnetic waves longitudinally propagated through the wave guide 1 during the vibration will be found to have be come modulated in response to the vibration of the wall of the guide. As is explained in the said application, the radio-wave conducting element, however, should be adapted continuously to propagate the electromagnetic waves during the vibration, so that the amplitude of vibration of the wall should maintain the guide dimensions always sufficient to propagate the waves in order to produce the desired results. This vibration may be effected with the aid of any desired mechanically oscillatory or vibratory device, such as, for example, by a piezo-electrie crystal 7 disposed adjacent an outer wall 13 of the waveguide 1. As discussed and illustrated in the said parent !."& gt; application, other mechanically oscillatory or vibratory devices such as magnetostrictiye rods, magnetomotive vibrators, diaphragms and the like may also be similarly employed, thus to modulate the waves in the guide.

The crystal 7 may, as an illustration, be vibrated by signal voltages fed to its electrodes by a modulating oscillator 9, such as, for example, a source of audio signals. As the crystal 7 transduces the signal voltages into mechanical movements and becomes periodically mechanically deformed in response to the voltages from the oscillator 9, it mechanically moves back and forth or vibrates the adjacent wall 13 of the wave guide 1 as the electromagnetic waves are propagated therealong continually during the vibration. This has been found to produce a modulation of the electromagnetic waves continually traveling through the wave guide 1 with the audio signals of the oscillator 9. In the embodiment of Fig. 1, the wall 13 is disposed parallel to the electric vector of the waves launched within the guide 1 by

the antenna 2, 4, and the wall 13 is vibrated towards and away from the waveguide wall 15, disposed opposite to and in a plane parallel to the plane of the wall 13. This results in periodically varying the dimensions of the wave guide 1, always permitting the propagation of the waves therealpng, which, in turn, correspondingly.

varies the phase velocity of the waves in the guide 1. A modulation of the waves propagated within the wave guide is thus produced.

It is, however, not necessary that the crystal or other back-and-forth mechanical vibrator 7 be disposed adjacent a wave-guide wall parallel to the electric vector of the waves. It has been found that modulation of the electromagnetic waves traveling along the guide 1 may be effected by mechanically vibrating any other wall or portion of a wall of the guide. In the embodiment of Fig. 2, as an illustration, the crystal 7 is shown disposed adjacent the wall 17 of the wave-guide 1, normal to the electric vector of the waves. The vibrator, as a further example, may vibrate the end-wall 3 of the guide in the direction of propagation of the waves, as illustrated at in Fig. 3.

The position of the crystal or other vibrator 7, moreover, is not limited to the outside surface of the walls of the guide 1, as shown in Fig. 1. When employed within the guide chamber itself, advantage, for modulation purposes, may be taken of the successively different reactive impedances presented to the waves being propagated along the guide, in response to the movement within the guide of the crystal or other movable device 7. This movement under the control of the oscillator 9, for example, would occur periodically or cyclically at the oscillation rate of the oscillator 9, or, in general, in accordance with the signal voltages applied to the device 7. The variable impedance vibrator 7, indeed, is preferably coupled adjacent at least part of an inner wall of the guide, as shown in Fig. 2, in order that the relatively movable crystal electrodes may interact with the electromagnetic waves propagated within the wave guide 1. The vibrations of the crystal 7 within the waveguide 1 have been found effectively to produce a modulation of the waves traveling down the guide 1, as before described, and may, furthermore, be used to effect modulation with any desired type of modulating signal. It is to be understood, of course, that similar results may be obtained by the periodic or other signal-controlled moving or vibrating of any timed or untuned element within the guide, such as a matching iris or diaphragm, a capacitive or inductive ring or a probe. The tuning fork disclosed in the said application, for example, constitutes a capacitive or inductive half-ring or probe, and, as explained in the said application, the tuning fork, as well as other elements, may be readily substituted for the crystal 7 and its diaphragm-like electrodes. A wall or wall portion 17 of the guide 1 may, if desired, as another illustration, be slidably mounted in a groove 19, Fig. 4, in order that it may be rigidly moved back and forth by means of a vibrating rod 23, as of magnetostrictive material. The rod 23 is vibrated in accordance with the voltage signals fed from the oscillator 9 into the windings of the coil surrounding the rod 23. The wall. 17 is preferably provided with a quarter-wave flange 21 in order that the flange 21 and the groove 19 may cooperate to form a wave-trap, thereby to prevent radiation leakage as the wall 17 is vibrated within the groove 19. At frequencies of the order of 10,000 megacycles per second, for example, power leakage for such joints has been found to be less than 0.3 decibel.

As a wall of the guide 1 is vibrated or as the vibrator 7 is vibrated within the guide 1, furthermore, a sonic or mechanical resonance within the guide may, if desired, be produced, as discussed in the said parent application. Standing sound waves may thus be set up within the guide 1. Such mechanical resonance of the guide also modulates the waves propagated within the guide. When the dimensions of the guide bear a resonant relationship to the wavelength of the mechanical vibrations, strong modulation effects are produced.

While the present invention has been described as applied to the modulation of waves transmitted by the antenna 2, 4 along the guide 1, it is to be Understood that electromagnetic waves may be received by the antenna 2, 4 from the end 11 of the wave guide 1, and these waves will also be modulated by the vibrations of the vibrator 7 or by the vibrations of the walls of the guide. If the antenna 2, 4 is connected to a receiver,not shown, the modulation may be detected.

As discussed in the said parent application, a multiplicity or plurality of mechanically moving devices such as the crystal elements 6, 7, 7 and 7" illustrated in Fig. 3, may be provided along the wave guide 1. The vibrators 7 and 7, for example, may be positioned parallel to the electric vector of the waves within the guide at voltage nodes, spaced from

one another any multiple of a half-wavelength of the electromagnetic waves, in order to minimize impedance variations along the guide. The vibrators 7 and 7 may, on the other hand, be placed at successive current nodes in order to produce large modulation effects, or at any other desired locations along the guide. If the vibrators 7 and 7 are driven by the same or similar modulating voltage sources and 9, greater, modulation effects may be produced than are obtainable with a single vibrator, since a greater region of the wave guide is subjected to the modulating vibrations. The phase relationship between the modulating signals from the oscillators 9 and 9, furthermore, may be adjusted to produce any desired resultant modulation. Though the oscillators 9 and 9 are illustrated i" Fig. 3 as sources of audio signals, it is to be understood that this is only for purposes of illustration. Any other type of modulating signal may also be employed. The use of a plurality of vibrators will also permit the simultaneous transmission of a plurality of different modulation signals. Multi-channel communication may be effected by operating the audio oscillators 9 and 9 with different modulating frequency bands, so that the respective vibrators 7 and 7 will produce corresponding independent modulation signals. The oscillators 9 and may also be operated at superaudible or ultrasonic frequencies or at ultrasonic frequencies modulated, in turn, by the desired audio signals. The crystals 7 and 7 may, indeed, constitute part of filter networks, as is wellknown in the art, to provide separate communication channels. All of the crystals need not be disposed, furthermore, along the same wall of the guide, but may be placed along any desired wall or walls.

The present invention also lends itself to the simultaneous transmission of widely different types of signals, such as audio and video signals. A vibrator 6, for example, may produce modulation of the transmitted waves in accordance with signals from a source of video signals, such as a video oscillator 8, while the vibrator 7 may modulate the electro-magnetic waves propagated & lt;;n down the guide 1 with audio signals from the oscillator 9. It may be convenient, particularly where an end of the wave guide is employed as a horn antenna and where other parts of the wave-guide system are not easily accessible, to dispose the modulating vibrator along the flared portion of the horn, as shown in Fig. 3 at 7". The directional beam of electro-magnetic waves directed into space by the horn antenna, shown, for purposes of illustration as a sectoral horn in Fig. 3, will be modulated in accordance with the principles before discussed.

en Since the horn antenna is flared, however, it may be preferable to employ the vibrators near the throat of the horn or to employ a plurality of vibrators along the horn in order to vary the flare angle and to produce strong modulation effects in response to the vibration of 6--j the vibrators.

The modulating techniques of the present invention find convenient application also for the modulation of electromagnetic waves oscillating within closed-ended resonant sections of wave-guide chambers such as tuned cavity resonators. A cylindrical cavity resonator 29, Fig. 5, may, as an illustration, be properly dimensioned to support electromagnetic waves of a particular frequency coupled into the resonator 29 by an input feed 31, shown as a coaxial line. A piezo-electric vibrator driven by a modulating oscillator 9 may be disposed adjacent an end wall of the cavity resonator 29 in order to vibrate the wall of the cavity resonator and thereby to modulate the waves within the cavity resonator. The modulated waves may be fed out of the resonator by an output coaxial line 33. Instead of vibrating a fixed cavity wall, furthermore, a wall 27 of the cavity resonator 29, may be rendered slidable, as discussed in connection with the embodiment of Fig. 4, in response to the vibrations of a magnetostrictive or magnetomotive rod 23 actuated by voltages in the coil from the modulating oscillator 9.

The present invention also finds application in testing the continuity or losses in long-line wave guides which may, for example, be under ground or under water. If the crystal 7 or other vibrator is placed adjacent a wall of the guide, it may be determined whether or not and in what strengths the modulation produced thereby is being received at various points along the guide. The present invention is also useful for the detection of submarines. By placing the guide 1 and adjacent crystal or other sound vibrators in the water, modulation of the electromagnetic waves traveling within the guide will be produced by the sound waves received from underwater objects such as a submarine. For extremely strong elastic vibrations, indeed, the walls of the guide itself may be directly vibrated to produce the modulation of the electromagnetic waves traveling within the guide.

Further modifications will occur to those skilled in the art, and all such are considered to fall within the spirit and

scope of the invention as defined in the appended claims.

ENGLISH-CLAIMS:
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What is claimed is:

1. An electromagnetic system having, in combination, a longitudinally extending wave guide, means for propagating electromagnetic waves of predetermined wavelength longitudinally along the wave guide, and a plurality of spaced mechanically movable means located at intervals of a fraction of the said wavelength longitudinally along the guide for modulating the waves.

2. An electromagnetic system having, in combination, a wave guide, means for propagating electromagnetic waves along the wave guide, a plurality of mechanically vibratory means, a plurality of signal-producing means one corresponding to each of the mechanically vibratory means for producing vibrations of the respective vibratory means in accordance with the signals of the corresponding signal-producing means, the vibratory means being adapted to vary a dimension of the guide in accordance with the vibrations thereof to modulate the waves with the signals of the signal-producing means.

3. An electromagnetic system having, in combination, a wave guide terminating in a flared electromagnetic horn antenna, means "for propagating electromagnetic waves along the waveguide and horn, and means disposed adjacent the flared horn for varying a transverse dimension of the horn during the propagation of the electromagnetic waves therealong in order to modulate the waves.

4. An electromagnetic system having, in combination, a waye-guide provided with bounding walls for propagating electromagnetic waves, a conducting element disposed within the walls and electromagnetically coupled to a wall of the wave guide, and means for instantaneously changing the electromagnetic coupling between the conducting element and the said wall during the propagation of the electromagnetic waves by the wave guide to 0 produce a corresponding change in the electromagneticwave energy propagated by the wave guide, thereby to modulate the propagated electromagnetic waves at the instants of change in the electromagnetic coupling between the conducting element and the said wall of the 7 wave guide. " 5. An electromagnetic system having, in combination, a wave guide having wave-guiding walls and of uniform transverse dimensions sufficient to permit the propagation therethrough along the wave-guiding walls of electromagnetic waves of a predetermined frequency, means for propagating electromagnetic waves of the predetermined frequency through the wave guide along the wave-guiding walls, and means controlled in accordance with a signal for mechanically vibrating one of the wave-guiding walls substantially normal to the electric vector of the electromagnetic waves through an amplitude of vibration that maintains the said transverse dimensions always sufficient to permit the waves to propagate along the wave-guiding walls in order that both the back and forward vibrational movement of the said one wall may react upon the waves, thereby modulating the waves in accordance with the signal during their propagation through the wave guide along the wave-guiding walls.

6. An electromagnetic system having, in combination, a wave guide having an end wall and wave-guiding side walls and of transverse dimensions sufficient to permit the propagation therethrough along the wave-guiding side walls of electromagnetic waves of a predetermined frequency, means for propagating electromagnetic waves of the predetermined frequency through the wave guide along the wave-guiding walls, means for vibrating the end wall, and means controlled by the vibrations of the end wall for mechanically vibrating one of the wave-guiding side walls in order to modulate the waves in accordance with the mechanical vibrations during the propagation of the waves through the wave guide along the wave-guiding walls.

7. An electromagnetic system having, in combination, a wave guide of transverse dimensions sufficient to permit the longitudinal propagation therethrough of electromagnetic waves of a predetermined radio frequency and to provide resonance to acoustic waves of a predetermined acoustic frequency, means for propagating electromagnetic waves of

the predetermined radio frequency longitudinally within the wave guide, and vibratory means oriented to vibrate in a direction transverse to the longitudinal direction of propagation of the electromagnetic waves for setting up standing acoustic waves of the predetermined acoustic frequency transversely in the guide in order to modulate the electromagnetic waves during their propagation through the wave guide.

8. An electromagnetic system having, in combination, a uni-conductor dielectric-filled wave-guide chamber of the type having a transverse cross-sectional configuration to permit the passage therethrough of electromagnetic waves above a critical frequency related to the said transverse cross-sectional configuration, means for propagating within the chamber electromagnetic waves greater than the said critical frequency, and a vibratory piezoelectric crystal having electrodes provided with means for connecting the same to an electric circuit and one of which is disposed substantially parallel to a wall of the chamber and is electromagnetically coupled thereto.

9. An electromagnetic system having, in combination, a uni-conductor dielectric-filled wave-guide chamber of the type having a transverse cross-sectional configuration to permit the passage therethrough of electromagnetic waves above a critical frequency related to the said transverse cross-sectional configuration, means for propagating within the chamber electromagnetic waves greater than the said critical frequency, and a vibratory piezoelectric crystal having electrodes provided with means for connecting the same to an electric circuit and one of which forms at least part of a wall of the wave-guide chamber.

10. An electromagnetic system having, in combination, a uni-conductor dielectric-filled wave-guide chamber of the type having a transverse cross-sectional configuration to permit the passage therethrough of electromagnetic waves above a critical frequency related to the said transverse cross-sectional configuration, means for propagating within the chamber electromagnetic waves greater than the said critical frequency, and a variable impedance element having relatively movable electrodes provided with means for connecting the same to an electric circuit and the impedance of which varies in accordance with relative movement of the electrodes, at least one of the electrodes being disposed substantially parallel to a wall of the chamber and being electromagnetically coupled thereto to provide electromagnetic interaction between the waves in the wave-guide chamber guided along the said wall and the impedance element.

11. An electromagnetic system having, in combination, a uni-conductor dielectric-filled wave-guide chamber of the type having a transverse cross-sectional configuration to permit the passage therethrough of electromagnetic waves above a critical frequency related to the said transverse cross-sectional configuration, means for propagating within the chamber electromagnetic waves greater than the said critical frequency, and a variable impedance element electromagnetically coupled to the wave-guide chamber and disposed substantially parallel to a wall thereof, and the impedance of which varies in response to electromagnetic interaction between the imduring their propagation within the wave-guide chamber along the wave-guiding walls.

17. An electromagnetic system having, in combination, a flared electromagnetic horn antenna for propagating radio waves, and vibratory means controlled in accordance with a signal for varying the angle of flare of the horn in order to signal-modulate the waves.

18. An electromagnetic system having, in combination, a uni-conductor dielectric-filled chamber of the type having a transverse cross-sectional configuration to permit the passage therethrough of electromagnetic waves above a critical frequency related to the said transverse crosssectional configuration, means for propagating in the chamber electromagnetic waves greater than the said critical frequency, and a variable impedance element electromagnetically coupled to the chamber and disposed substantially parallel to a wall thereof and the impedance of which varies in response to electromagnetic interaction between the impedance element and the waves in the pedance element and the waves in the wave-guide cham20 chamber and between the v/aves in the chamber and the ber and between the waves in the wave-guide chamber impedance element.

13. An electromagnetic system having, in combination, a longitudinally extending wave guide, means for propagating electromagnetic waves longitudinally along the wave guide, and a plurality of spaced mechanically

movable means disposed at half-wave length intervals or multiples thereof longitudinally along and within the guide for modulating the waves.

14. An electromagnetic system having, in combination, a wave guide, means for propagating electromagnetic waves along the wave guide, and a plurality of periodically movable means spaced a multiple of a half-wave length of the waves apart along a dimension of the wave guide for mechanically vibrating the wave guide to modulate the waves.

15. An electromagnetic system having, in combination, a wave guide having wave-guiding walls, means for propagating electromagnetic waves through the wave-guide along the wave-guiding walls, a plurality of elements disposed within the wave guide spaced from one another and from a wall of the wave guide to which they are electromagnetically coupled, and means for periodically varying the spacing between the elements and the said wall of the wave guide to vary the electromagnetic coupling therebetween in order to modulate the waves during their propagation through the wave guide along the wave-guiding walls.

16. An electromagnetic system having, in combination, a uni-conductor dielectric-filled wave-guide chamber having wave-guiding walls, one of which is provided with an element separate from the wave-guiding wall that may G be variably positioned at various depths within the waveguide chamber, the wave-guide chamber being of the type having a transverse cross-sectional configuration to permit the passage therethrough of electromagnetic waves above a critical frequency related to the said transverse cross-sectional configuration, means for propagating electromagnetic waves greater than the said critical frequency within the wave-guide chamber along the waveguiding walls and means for cyclically varying the said stantially parallel to a wall thereof, and the impedance of which varies in response to electromagnetic interaction between the waves in the chamber and the impedance element.

20. An electromagnetic system having, in combination, a gas-containing chamber for supporting electromagnetic waves, means for setting up modulated electromagnetic waves within the chamber to produce corresponding reactions upon the gas therein, an electro-mechanical transducer disposed mechanically vibratorily to respond directly to the said reactions produced upon the gas in order to produce acoustic waves in the gas in the chamber, the chamber being of transverse dimensions resonant to the acoustic waves in order transversely to set up standing 4.3 acoustic waves.

21. An electromagnetic system having, in combination, a gas-containing chamber for supporting electromagnetic waves, means for setting up modulated electromagnetic waves within the chamber to produce corresponding reactions upon the gas therein, a piezo-electric crystal transducer disposed mechanically vibratorily to respond directly to the said reactions produced upon the gas in order to produce acoustic waves in the gas in the chamber, the chamber being of dimensions resonant to the acoustic waves.

22. In an electromagnetic system including a uni-conductor dielectric-filled wave-guide transmission line of the type having a transverse cross-sectional configuration to permit the passage therethrough of electromagnetic waves above a critical frequency related to the said transverse cross-sectional configuration and means for propagating therealong electromagnetic waves greater than the said critical frequency, a section of wave guide through which the waves are propagated comprising a variable impedance element, means for establishing an electric field transversely of the wave-guide section for varying the impedance of the variable impedance element, and means for varying the said electric field in accordance with a signal to modulate the electromagnetic waves.

23. An electromagnetic system haying, in combination, means for developing an electromagnetic wave and interrupting it at an audio frequency, a wave guide of uniform transverse dimensions having a relatively wide wall and a relatively narrow wall, means for transmitting said 6!)

position of depth of the element to modulate the waves 75 wave through said wave guide to create an electromagnetic field, a portion of said relatively narrow wall being mechanically vibratory at said audio frequency and being free to vibrate mechanically under the influence of the periodic mechanical pressure on said vibratory wall portion due to said electromagnetic field.

24. An electromagnetic system having, in combination, means for developing an electromagnetic wave and interrupting it at an audio frequency, a wave guide of uniform transverse dimensions having a relatively wide wall and a relatively narrow wall, means for transmitting said wave through said wave guide to create an electromagnetic field, a portion of said relatively narrow wall being free to vibrate mechanically under the influence of the periodic mechanical pressure on said vibratory wall portion due to said electromagnetic field, and an acoustically resonant system mechanically coupled to said vibratory wall portion, said vibratory wall portion being mechanically vibratory at said audio frequency.

25. An electromagnetic system having, in combination, means for developing an electromagnetic wave and interrupting it at a modulation frequency, a wave guide of uniform transverse dimensions having a relatively wide wall and a relatively narrow wall, means for transmitting said wave through said wave guide to create an electromagnetic field, a portion of said relatively narrow wall being free to vibrate mechanically under the influence of the periodic mechanical pressure on said vibratory wall portion due to said electromagnetic field, and an acoustically resonant system mechanically coupled to said vibratory wall portion, said vibratory wall portion being mechanically vibratory at said modulation frequency.

26. An electromagnetic system having, in combination, a wave guide, means for propagating electromagnetic energy through said wave guide, a plurality of reactive elements distributed longitudinally of said wave guide and movable to successively disposed positions within the wave guide at which the elements present successively different reactances to the electromagnetic energy, and means for cyclically moving the said reactive elements through the said successively disposed positions within the wave guide periodically to vary the velocity of phase propagation of the electromagnetic energy within said wave guide.

27. An electromagnetic system having, in combination, a uni-conductor dielectric-filled wave guide of the type having a transverse cross-sectional configuration to permit the passage therethrough of electromagnetic-wave energy above a critical frequency related to the said transverse cross-sectional configuration, means for propagating electromagnetic-wave energy greater than the said critical frequency through said wave guide, a reactive element movable to successively disposed positions within the wave guide at which the element presents successively different reactances to the electromagnetic energy, and means for cyclically moving the said reactive element through the said successively disposed positions within the wave guide in order correspondingly to vary the velocity of phase propagation of the electromagnetic energy within said wave guide.

28. An electromagnetic system having, in combination, a rectangular wave guide, means for propagating electromagnetic energy through said wave guide, a plurality of similar reactive elements distributed longitudinally of said wave guide and movable to successively disposed positions within the wave guide at which the elements present successively different reactances to the electromagnetic energy, and means for cyclically moving the said reactive elements through the said successively disposed positions within the wave guide periodically to vary the velocity of phase propagation of the electromagnetic 5 energy within said wave guide.

29. An electromagnetic system as claimed in claim and in which there is provided means for producing a signal and means for connecting the signal-producing means to the said means for instantaneously changing the electromagnetic coupling between the conducting element and the said wall in order that the said electromagnetic waves may be modulated in accordance with the said signal.

30. An electromagnetic system as claimed in claim and in which the said signal is a periodically recurring signal.

31. An electromagnetic system as claimed in claim and in which the said means for instantaneously changing the electromagnetic coupling between the conducting element and the said wall comprises a device the impedance of which may be electrically varied, and in which means is provided for producing an electric signal for varying the impedance of the said device, thereby to modulate the said electromagnetic waves in accordance with the said signal.

32. An electromagnetic system as claimed in claim and in which the said means for instantaneously changing the electromagnetic coupling between the conducting element and the said wall comprises a piezoelectric device the impedance of which may be electrically varied, and in which means is provided for producing an electric signal for varying the impedance of the said piezoelectric device, thereby to modulate the said electromagnetic waves in accordance with the said signal.

So 33. An electromagnetic system as claimed in claim and in which the said means for instantaneously changing the electromagnetic coupling between the conducting element and the said wall comprises mechanically movable means.

34. An electromagnetic system as claimed in claim and in which the said means for instantaneously changing the electromagnetic coupling between the conducting element and the said wall comprises piezoelectric mechanically vibratory means.

35. An electromagnetic system as claimed in claim and in which the said means for instantaneously changing the electromagnetic coupling between the conducting element and the said wall comprises mechanically movable means, and in which means is provided for produc-

"0 ing a signal for controlling the mechanically movable means in accordance therewith, thereby to modulate the said electromagnetic waves in accordance with the said signal.

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