Jan. 30, 1951 R. H. RINES 2,539,476

SYSTEM AND METHOD OF COMMUNICATION

Filed June 23, 1943

Fig. 1

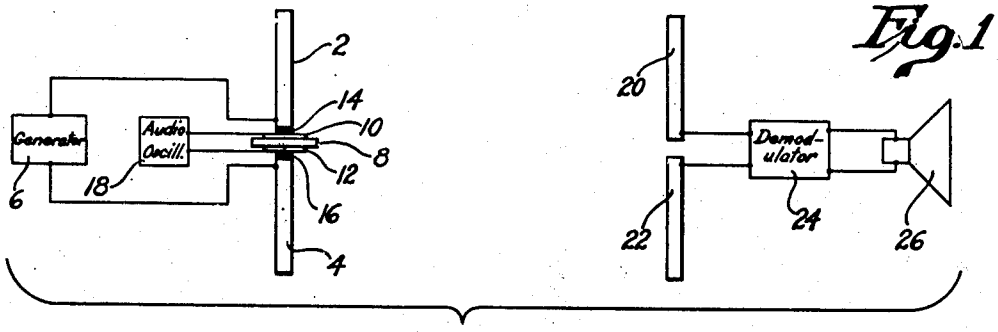


Fig. 2

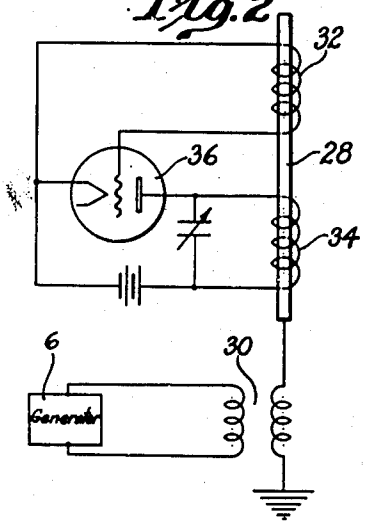


Fig. 3

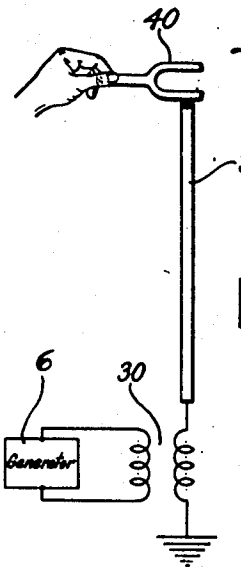


Fig. 4

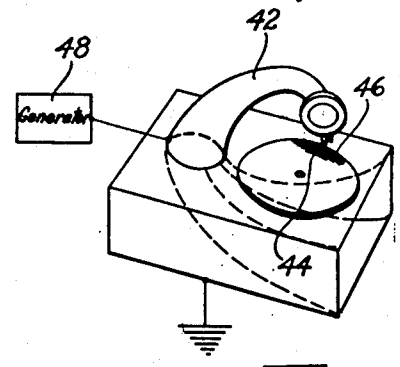


Fig. 5

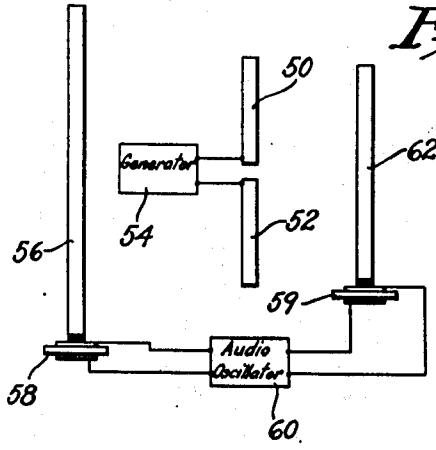
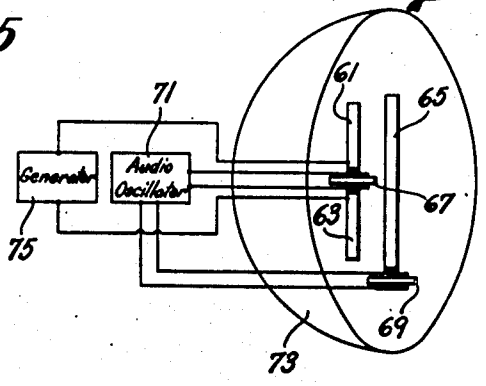


Fig. 6



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SYSTEM AND METHOD OF COMMUNICATION

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35 Claims. (Cl. 250—17)

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The present invention relates to systems and methods of communication, and more particularly to the generation, transmission and reception in radio.

An object of the invention is to provide a new and improved system and method for the modulation and demodulation of radio waves.

A further object is to provide a novel system and method for mechanically modulating radio waves.

Another object is to provide a new and improved system and method for modulating reflected radio waves.

Other and further objects will be explained hereinafter and will be particularly pointed out in the appended claims.

The invention will now be more fully explained in connection with the accompanying drawings, in which Fig. 1 is a diagrammatic view of circuits and apparatus illustrating the transmission and reception of waves modulated piezoelectrically in accordance with the present invention; Fig. 2 is a similar diagram illustrating magnetostrictive modulation; Fig. 3 is a similar diagram illustrating modulation effected with the aid of a tuning fork; Fig. 4 is a similar diagram illustrating modulation produced with the aid of a resonating air column; Fig. 5 is a similar diagram illustrating the modulation of a reflected radio wave; and Fig. 6 is a similar diagram illustrating the modulation of high-frequency waves.

Referring first to Fig. 1, the two elements of a linear dipole antenna are shown at 2 and 4. The antenna 2—4 is of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves. Antennas of this type need not take the specific form of a diplole, but may have other forms including, for example, the single elements of Figs. 2 and 3. The particular antenna 2—4 is shown oriented vertically to emit a bundle of rays of radio waves in widely separated directions, being omni-directional in the horizontal plane and directional in the vertical plane, there being no end-on radiation. A radio-frequency generator 6 may constitute the radio-frequency-energy-generating electric system or source of radio-frequency energy connected to the antenna 2—4 by a transmission line in order that the antenna may become enabled to draw radio-frequency

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energy from the electric system, thereby to produce radio waves, emitting the radio waves into space as above described.

A mechanically vibratory member comprising, for example, a piezoclectric crystal 8, is shown mounted with its conducting electrode elements 10 and 12 spaced from, but close to, the adjacent ends of the dipole elements 2 and 4 to which they are therefore electromagnetically coupled. Dielectric or insulating members 14 and 16 are shown spacing the crystal electrode members 10 and 12 from the adjacent ends of the respective antenna elements 2 and 4. The crystal 8 may be vibrated by connecting its electrodes 10 and 12 to a source of vibrational energy such as a beat-frequency or a signal audio oscillator 18. The vibrations thus produced in the piezoelectric crystal 8 will be transmitted through the electrodes 10 and 12 and the insulating elements 14 and 16 to the dipole elements 2 and 4 in a direction at an angle to all the directions in which radio waves are emitted and at right angles to the horizontal radio-wave field pattern. This results in varying the dimensions of the dipole antenna elements at frequencies dependent upon the frequency of the vibrations of the piezoelectric crystal 8. As the crystal 8 vibrates, moreover, the spacing and coupling between the electrodes 10 and 12 and the respective dipole elements 2 and 4 are periodically varied in response to the vibration of the crystal 8. These dimensional variations in the physical, and hence in the effective electrical dimensions or impedance of the antenna, have been found to produce corresponding variations in the radio-frequency energy drawn from the generating electric system 6, thereby to effect modulation of the electromagnetic radio waves emitted by the antenna 2—4.

The modulated electric waves will be received at a receiving station in any desired way, as by means of a similar dipole the two elements of which are shown at 20 and 22, adapted to be excited by and to support the radio waves received from the transmitting station. The received waves may be demodulated by a demodulator 24 of any suitable and well-known form, to make evident the signal in a loud-speaker 26.

The modulation-controlling piezo-electric crystal 8 need not necessarily be disposed, as shown, between the adjcent ends of the dipole elements 2 and 4. It may be positioned at any desired predetermined portion of either one of the elements 2 and 4. The radio waves produced by

that one element only would, of course, then become modulated. The degree of the modulation will depend upon the position of the piezo-electric crystal with respect to the dipole element 2 or 4. It was found, for the case of a hollow half-wave dipole, that the best results were obtained with the crystal at either end of the corresponding dipole element, but in all cases the before-described modulation effects were discernible, the mechanical vibration of the high-frequency-current-supporting elements producing current alternations therein of the same periodicity as the mechanical vibrations.

The dimensional variations of the antenna may be produced by other means than by vibrating with a piezoelectric crystal. According, for example, to the modification of Fig. 2, an antenna 28, shown excited or fed through a transformer 30 from the generator 6, is constituted of magnetostrictive material. It is shown enclosed in magnetostrictive windings 32 and 34 of a magnetostrictive oscillator of the Pierce type, the vacuum tube of which is shown at 36. The length and other dimensions of the antenna 28, therefore, are varied during the generation of the radio waves, in order to modulate the waves.

As illustrated in Fig. 3, the dimensions of the antenna 38, excited to produce radio waves as in Fig. 2, may be varied by means of a tuning fork 40 to effect the modulation of the radio waves. The dimensions of the antenna 38 are varied as the conducting tuning fork element, coupled thereto, vibrates towards and away from the end of the antenna 38. The tuning fork may be replaced by a vibrating bell or other mechanically vibrating member, including a diaphragm.

According to the modification shown in Fig. 4, the antenna 42, excited to produce radio waves from a generator 48, is constituted of the outer surface of the tone arm of a talking machine the needle 44 of which is shown riding over a record 46. The sound resonating in the tone arm 42 will effect the vibration of the tone arm, thus modulating the radio waves.

The present invention is also adapted for use in directive antenna arrays comprising interacting antenna elements, such as, for example, those illustrated in Figs. 5 and 6. The radio waves produced by a driven dipole 50, 52, Fig. 5, as it draws radio-frequency energy from a generator 54 may excite and thus be reflected by a parasitic antenna element 56, as it intercepts at least part of the radio waves emitted by the dipole antenna 50—52 and re-radiates the waves. The dimensions of the element 56 may be varied in any desired way, as by means of a piezo-electric crystal 58, excited from an audio oscillator 60. The radio waves received and re-radiated by the parasitic element 56 will be found to have become modulated as a result of the length and other dimensional variations of the element 56. A similar linear director parasitic antenna 62, excited by and supporting radio-frequency radiation from the driven elements 50, 52 may also be subjected to similar dimensional variations, as by means of a crystal 59, to modulate the forward radiation of the driven elements 50, 52, and to reenforce the modulation of the reflection off the reflector element 56.

Fig. 6 illustrates the dimensional variation of a dipole the elements of which are shown at 61, 63, excited electromagnetically by a generator 75 from which it draws radio-frequency energy to emit the energy as radio waves, and of a parasitic reflecting element 65, by means of crystals 67

and 69, respectively. The crystals 67 and 69 are synchronously excited by an audio-oscillator 71 to modulate the electromagnetic radiation reflected in a directional beam into space by a parabolic reflector 73.

The invention may be applied to other uses also. The production of a supersonically modulated radio wave may, for example, prove to be useful for conveying hidden information.

Further modifications will occur to persons 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.

What is claimed is:

1. An electromagnetic system having, in combination, an antenna, means for exciting the antenna to produce electromagnetic waves, and means for varying the length of the antenna to modulate the waves.

2. An electromagnetic system having, in combination, an antenna, means for exciting the antenna to produce electromagnetic waves, and piezo-electric means for mechanically varying the length of the antenna to modulate the waves.

3. An electromagnetic system having, in combination, an antenna, means for exciting the antenna to produce electromagnetic waves, and magnetostrictive means for mechanically varying the length of the antenna to modulate the waves.

4. An electromagnetic system having, in combination, an antenna having conducting outer and inner surfaces, means for exciting the outer surface of the antenna to produce electromagnetic waves, and means for mechanically resonating the antenna to modulate the waves.

5. An electromagnetic system having, in combination, an antenna, means for exciting the antenna electrically to produce electromagnetic waves, and means for varying a dimension of the antenna at an audio frequency to modulate the waves.

6. An electromagnetic system having, in combination, an antenna, means for exciting the antenna electrically to produce electromagnetic waves, and means for varying a dimension of the antenna at supersonic frequency to modulate the waves.

7. A method of modulating electromagnetic waves produced from an electromagnetic-wave emitter of the type that draws electromagnetic energy from an electromagnetic-energy-generating electric system prior to the production from the electromagnetic energy of electromagnetic waves, that comprises varying a dimension of the emitter during the production of the electromagnetic waves and reflecting the modulated waves.

8. A method of modulating the radio waves emitted by an electromagnetic-wave antenna in widely separated directions in response to electrical excitation by the electromagnetic energy drawn by the antenna from an electromagnetic-energy-generating electric system prior to the emission of the electromagnetic energy as electromagnetic waves, that comprises mechanically vibrating the antenna during the emission of the waves.

9. A method of modulating the radio waves emitted by a radio-wave antenna in a predetermined direction in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves, that comprises

mechanically vibrating the antenna at an angle to the said direction.

10. A method of modulating the radio waves emitted by a radio-wave antenna in a predetermined direction in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves, that comprises mechanically vibrating the antenna at right angles to the said direction.

11. A radio transmitter having, in combination, an antenna of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves, an electric system for generating radio-frequency energy, means electrically connecting the antenna to the electric system in order that the antenna may draw radio-frequency energy from the electric system, thereby to cause the antenna to emit radio waves into space, and means for varying a dimension of the antenna during the emission of the radio waves by the antenna, thereby to effect modulation of the radio waves emitted by the antenna.

12. A radio transmitter having, in combination, an antenna of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves, an electric system for generating radio-frequency energy, means electrically connecting the antenna to the electric system in order that the antenna may draw radio-frequency energy from the electric system, thereby to cause the antenna to emit radio waves into space, a mechanically vibratory member, means for mechanically connecting the antenna to the mechanically vibratory member to vary a dimension of the antenna mechanically in response to the mechanical vibrations of the mechanically vibratory member, thereby to effect modulation of the radio waves emitted by the antenna.

13. In a radio transmitter having an antenna of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves, a method of the character described that comprises feeding radio-frequency energy from the electric system in order that the antenna may draw radio-frequency energy from the electric system, thereby to cause the antenna to emit radio waves into space, and varying a dimension of the antenna during the emission of the radio waves by the antenna in order to effect modulation of the radio waves emitted by the antenna.

14. An electromagnetic system having, in combination, an electromagnetic-wave-reflector for reflecting a bundle of rays of electromagnetic waves, a mechanically vibratory member, means for vibrating the mechanically vibratory member, and means mechanically connecting the reflector to the mechanically vibratory member to transmit the mechanical vibrations from the mechanically vibratory member to and within the reflector, thereby to effect modulation of the reflected waves.

15. In a radio transmitter having an antenna of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves, a method of the character described that comprises feeding radio-frequency energy from the electric system in order that the antenna may draw radio-frequency energy from the electric system, thereby to emit radio waves into space, and varying the length of the antenna during the emission of the radio waves by the antenna in order to effect modulation of the radio waves emitted by the antenna.

16. In a radio transmitter having an antenna of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves, a method of the character described that comprises feeding radio-frequency energy from the electric system in order that the antenna may draw radio-frequency energy from the electric system, thereby to emit radio waves into space, producing a signal, and varying a dimension of the antenna in accordance with the signal during the emission of the radio waves by the antenna in order to effect the signal modulation of the rad o waves emitted by the antenna.

17. In a radio transmitter having an antenna of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves and piezoelectric means, a method of the character described that comprises feeding radio-frequency energy from the electric system in order that the antenna may draw radio-frequency energy from the electric system, thereby to emit radio waves into space, and varying a dimension of the antenna under the control of the piezoelectric means during the emission of the radio waves by the antenna in order to produce corresponding variations in the energy drawn from the electric system by the antenna, thereby to effect modulation of the emitted radio waves.

18. In a radio transmitter having an antenna of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves and magnetostrictive means, a method of the character described that comprises feeding radio-frequency energy from the electric system in order that the antenna may draw radio-frequency energy from the electric system, thereby to emit radio waves into space, and varying a dimension of the antenna under the control of the magnetostrictive means during the emission of the radio waves by the antenna in order to produce corresponding variations in the energy drawn from the electric system by the antenna, thereby to effect modulation of the emitted radio waves.

19. In a radio system having an antenna that receives radio waves from space, a method of the character described that comprises exciting the antenna to receive radio waves, and varying the length of the antenna during the reception of the

radio waves by the antenna in order to effect modulation of the received radio waves.

20. In a radio system having an antenna of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves, a method of the character described that comprises exciting the antenna to emit radio waves, and varying the effective impedance of the antenna during the emission of the radio waves by the antenna in order to effect modulation of the emitted radio waves.

21. In a radio transmitter having a driven antenna and a parasitic antenna, the driven antenna being of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the driven antenna from a radio-frequency-energy-generating electric system, a method of the character described that comprises feeding radio-frequency energy from the electric system in order that the driven antenna may draw radio-frequency energy from the electric system, thereby to emit radio waves into space, positioning the parasitic antenna to intercept and re-radiate at least part of the radio waves emitted by the driven antenna and varying a dimension of the parasitic antenna during the re-radiation of the radio waves by the parasitic antenna in order to effect modulation of the radio waves.

22. In a radio transmitter having an antenna and a conducting element spaced from but close to one end of the antenna to which it is electromagnetically coupled, the antenna being of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves, a method of the character described that comprises feeding radio-frequency energy from the electric system in order that the antenna may draw radio-frequency energy from the electric system, thereby to emit radio waves into space, and varying the spacing and hence the degree of electromagnetic coupling between the conducting element and the said one end of the antenna during the emission of the radio waves by the antenna in order to effect modulation of the radio waves emitted by the antenna.

23. In a radio transmitter having an antenna and a conducting element electromagnetically coupled to a predetermined portion of the antenna, the antenna being of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the emission of the radio-frequency energy as radio waves, a method of the character described that comprises feeding radio-frequency energy from the electric system in order that the antenna may draw radio-frequency energy from the electric system, thereby to emit radio waves into space, producing a signal, and varying the degree of electromagnetic coupling between the conducting element and the said predetermined portion of the antenna in accordance with the signal during the emission of the radio waves by the antenna in order to effect signal modulation of the radio waves emitted by the antenna.

24. A radio transmitter having, in combination, an electric system for generating radio-frequency energy, an antenna electrically connected to the electric system in order that the antenna may draw radio-frequency energy therefrom to emit radio waves, and means for varying the length of the antenna during the emission of the radio waves to modulate the radio waves.

25. A radio system having, in combination, a generator of radio-frequency energy, a dipole element excited by the generator to emit radio waves, and means for varying a dimension of the dipole element during the emission of the radio waves to modulate the radio waves.

26. A radio system having, in combination, an antenna of the type that may produce radio waves in space in response to electrical excitation by radio-frequency energy drawn by the antenna from a radio-frequency-energy-generating electric system prior to the production of the radio-frequency energy as radio waves, means for producing a signal, and means responsive to the signal-producing means for varying a dimension of the antenna in accordance with the signal during the production of the radio waves to signal modulate the radio waves.

27. A radio system having, in combination, an electric system for generating radio-frequency energy, an antenna of the type that emits radio waves into space in response to electrical excitation by radio-frequency energy drawn by the antenna from the radio-frequency-energy-generating electric system, means for enabling the antenna to draw radio-frequency energy from the electric system in order to emit radio waves into space, means for modulating the radio waves prior to their emission, a parasitic antenna positioned to intercept and re-radiate at least part of the emitted modulated radio waves, and means for varying a dimension of the parasitic antenna during the re-radiation of the radio waves, thereby further to modulate the re-radiated radio waves.

28. A radio system having, in combination, a linear antenna, means for exciting the antenna with radio-frequency energy, a conducting element spaced from but close to a predetermined portion near an end of the antenna to which it is electromagnetically coupled, and means for varying the spacing and hence the degree of electromagnetic coupling between the conducting element and the said predetermined portion of the antenna during the exciting of the antenna in order to effect modulation of the radio frequency energy.

29. A radio transmitter having, in combination, a source of radio-frequency energy, an antenna excited from the source to draw radio-frequency energy therefrom in order to emit radio waves, and means for vibrating the antenna mechanically during the emission of the radio waves to cause the antenna to effect modulation of the emitted radio waves as an inherent response to its mechanical vibrations.

30. In a transmitter having an antenna for emitting a bundle of rays of radio waves, each ray along a predetermined direction, a method of modulating the radio waves that comprises varying a dimension of the antenna during the emission of the radio waves to vary a property of the radio waves, and retaining for each ray its predetermined direction.

31. A radio transmitter having, in combination, a source of radio-frequency energy, an omni-directional antenna excited from the source to emit radio waves in all directions, and a vibratory member to which the antenna is mechanically

connected, vibrations of the member being adapted to modulate the radio waves.

32. A radio system having, in combination, a parasitic antenna for intercepting and re-radiating radio waves, a conducting element electromagnetically coupled to a predetermined portion of the antenna, means for producing a signal, and means controlled by the signal-producing means for varying the degree of electromagnetic coupling between the conducting element and the parasitic antenna in accordance with the signal to signal modulate the re-radiated radio waves.

33. A radio system having, in combination, a linear parasitic antenna element for intercepting and re-radiating radio waves, means for producing a signal, and means controlled by the signal-producing means for varying the length of the parasitic element in accordance with the signal to signal modulate the re-radiated radio waves.

34. In a radio system, a conducting element adapted to be disposed in an electromagnetic field in which there is an electromagnetic wave and of sufficient dimensions to permit of continuous electromagnetic interaction with the electromagnetic wave, and means for varying a dimension of the conducting element in accordance with a signal during the electromagnetic interaction with the electromagnetic wave in order to signal-modulate the electromagnetic wave.

35. An electric system having, in combination, a conducting element adapted continuously to support high-frequency current, and means for varying a dimension of the conducting element by subjecting it to mechanical vibrations to produce alternations of the supported current in the conducting element of the same periodicity as the mechanical vibrations.

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