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Electroacoustic system

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SUMMARY:

The present invention relates to the transmission and reception of intelligence, using both sound and electromagnetic energy as the agencies of communication, and more particularly to methods and means employing the directive discrimination of sound beams. The term "sound" will be employed hereinafter, in the specification, to include the supersonic, as well as the audible, part of the sound spectrum, and to include also all kinds of elastic vibrations. The invention, indeed, finds particular application to supersonic communication.

An object of the invention is to provide a new and improved combined-sound-and-electromag-netic system for communication.

A further object is to provide a new and improved system for modulating and demodulating radio waves.

Another object is to provide a new system for mechanically modulating radio waves.

Another object of the invention is to provide a new and improved combined-sound-and-radio system for communication employing a vibratory diaphragm of the character described in Letters Patent of the United States 2,063,944, issued December 15,1936, to George W. Pierce.

A further object is to provide a new and improved system for modulating a radio wave in accordance with a sound wave.

A further object is to provide a new and improved system for secret signaling.

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 embodying the invention; Fig. 2 is a similar view of a modified rotatably adjustable system; Fig. 3 illustrates an omni-directional modification; and Fig. 4 is a perspective view of a further modification embodying an electromagnetic wave guide system, illustrated as of the horn type.

Four coplanar conducting diaphragm elements 7, 9, IT and 19 of the character described in the said Letters Patent are illustrated in Fig. 1, mechanically connected together in the form of two pairs, but insulated from one another. The diaphragms may be in the form of plates or rods, or they may be of any other suitable form. The adjacently disposed boundaries or ends of the diaphragms T and 9 are shown connected together rigidly by insulating members 13, through the medium of rivets 11 and 15. The adjacently disposed ends of the diaphragms 17 and 19 are shown similarly connected together rigidly by insulating members 23 through the medium of rivets 2! and 25. It is desirable that the insulating members (3 and 23 be constituted of material that shall insulate or isolate not only electrically but also acoustically. As sound or vibration dampers they will prevent sound-vibration interference between the diaphragms 7 and 9 and between the diaphragms 17 and 1 9, respectively. The connections between the pair of diaphragms 7 and 9 and the pair of diaphragms 17 and 19 may be of the type described in Letters Patent 2,063,945, also issued to the said George W. Pierce on the said December 15, 1936. The greater the number of these diaphragms employed, the more directive will be the system. According to the modification illustrated in Fig. 2, therefore, not only the diaphragms 7 and 9, but also the diaphragms 17 and 19, as well as several further diaphragms 27 and 29, are shown connected together rigidly by insulating members, diagrammatically indicated at 13. Only two such pairs of diaphragms are shown, for illustrative purposes, however, in Fig. 1.

As described in the said Letters Patent, the said other ends of the diaphragms 1, 9, !7 and 19 may be respectively provided with units for in-terconverting vibrational and electric energy. Electric current or voltage may thus be obtained in response to mechanical vibration or pressure, or mechanical vibration or pressure may be ob3g tained in response to electric current or voltage. These interconvert-ng units may, as shown, be of the magnetostrictive type, or of any other desired type, such as piezoelectric or magnetomotive. Magnetostrictive cores 5, 45, and are shown insulatingly connected at 63 to the said other ends of the respective diaphragms 7, 9, 17 and 19. These cores are respectively associated with pickup coils 3, 43, 53 and 33, respectively connected to sound transmitters or receivers 1, 41, 51 and 3L Only a single interconverter 3, 5 of mechanical and electric energy is shown, however, in the embodiment of Fig. 2. With insulating members 13 that isolate electrically only, the transverse vibrations of the element 29 of Fig. 2, cooperating with the interconverter 3, 5, may be coupled to the other diaphragm elements as well. The energy may be amplified, as is also explained in the said Letters Patent.

When the system is used for transmitting elastic vibrations, for example, the transmitters 1, 41, 51 and 31 will excite the respective cores 5, 45, and into magnetostrictive vibration wiih the result that, at the critical frequency, a sound beam of maximum intensity will be emitted or transmitted from the diaphragm elements 7, 9, IT, 19 for propagation along the direction 66 into the sound-conducting medium in which the elements are disposed. This is effected by means of a plane-wave front at right angles to the direction of the beam of signal sound waves, making the Pierce angle 6 with the plane of the diaphragms on which the wave front is incident. This angle e is determined by the relation where V is the velocity, at the critical frequency, of the propagation of the transverse mechanical sound-wave vibration in the diaphragm, and Vo is the corresponding velocity of propagation in the medium, which here may be the air. In transmission, for example, the sound beam is produced by exciting the diaphragms 7, 9, 17 and 19 into transverse fundamental or harmonic vibrations that travel along the diaphragms with a velocity having a component, in the direction of the sound beam, equal to the velocity of the sound beam in the medium. Similar, but reverse, conditions

prevail for reception, the diaphragms being set into vibration by the received impinging sound wave. When the diaphragms T, 9, 17 and 19 are disposed at the critical angle, the diaphragms become excited into transverse vibra-tion in response to the impingement thereon of the received signal-sound beam. This is because, as explained in the said Letters Patent, at the critical angle 6, the periodic impulses of pressure of the sound beam all strike certain points of the diaphragm in the same phase, say, a push; and the rarified impulses similarly all strike other points in phase, say, a pull. Measuring distances in the direction of propagation of the sound beam in the medium, these alternate high-pressure and low-pressure points are spaced a half-wavelength apart.

It is preferred, as before stated, to employ the signal sound at supersonic frequencies or, at least, at other high frequencies above those of speech. At the critical angle e, if the half-wavelength of transverse vibration in the diaphragm is greater than the half-wavelength of the longitudinal waves in the medium, the periodic displacement of the parts of the diaphragms will be such that cumulative interaction occurs between the trans-verse vibrations of the segments of the dia-_ phragms and the supersonic or super-speech components of vibration of the sound beam, the number of segments being proportional to the frequency. The sound-wave pressure fluctuations in the medium strike all vibratory regions in the diaphragm in the proper phase to enhance the vibration, producing spacial resonance between the diaphragm and the vibrations in the medium. There results an interchange of supersonic or super-speech energy between the medium and the diaphragms 7, 9, 17 and 19 at the critical angle corresponding to resonant response ot the diaphragm.

The mechanical elements 7, 9 and 17, 19 may each, or together, be provided with means for rotatably adjusting them to the desired angle e. The rotatable adjusting means is not shown m Fig. 1, since it is desired that the units of Fig. 1 be stationary. The rotatable adjusting means may, however, be of the type described in the said Letters Patent 2,063,945, or as illustrated in Fig. 2. The adjusting means may comprise a manually controllable arm 26, rigidly secured to another insulating member 13, and rotatable about a pivot 16. The unit, as a whole, may, however, be mounted in a rotatable housing (not shown)

attached to the plates 13.

The diaphragms may be constituted merely of metal conducting strips. In accordance with the present invention, these strips may be electro-magnetically excited as at their secured-together or inner ends by the application of radio-frequency energy directed thereupon from radiofrequency transmitters 2, in order that they may support radio-frequency energy of predetermined frequency to serve as an antenna, comprising two pairs of radio dipoles 7, 9 and 17, (9, respectively. Conversely, the dipoles 7, 9 and !7, 19 may be excited by radio waves applied thereupon from space, feeding the received radio-frequency energy supported by the dipoles to the radio-frequency receiver 2 to evidence the received radio-frequency energy. This fourelement array provides a directional radio pattern with principal maxima in the direction 49, at right angles to the plane of the diaphragms. A reflector (not shown) may be employed behind the diaphragms, to eliminate back radiation.

Provision is thus made for simultaneously sending or receiving a sound wave along one direction 66, determined by the Pierce angle e, and a radio wave along another direction fl4, transverse to the plane of the diaphragm. These directions may, under certain circumstances, be the same, as hereinafter explained in connection with Fig. 4. The radio wave will be modulated by the mechanical vibrations of the diaphragm during the transmission or reception thereby of the sound wave. The modulated radio waves may be received at a distant receiving station for demodulation by a demodulator of suitable and well-known form, or by a diaphragm, as described herein.

The invention is thus applicable to the transmission of radio waves modulated by transmitted Or received sound waves. The modulation may be effected by mechanically vibrating the diaphragms by exciting them or applying vibrational energy in response to the vibration of the mag-netostrictive cores, or in response to the applying to or impinging upon the diaphragms of a sound beam received through the medium in which the diaphragms are disposed. The invention is also applicable to the reception of radio waves, as they, too, will become modulated by the transmitted or received sound waves. At least four combinations of radio and sound transmission and reception are thus possible

according to the CO present invention; namely, electromagnetic transmission and sound-wave transmission, electromagnetic transmission and sound-wave reception, electromagnetic reception and sound-wave transmission, and electromagnetic reception and 05 sound-wave reception.

If the diaphragms are constituted of vertically disposed cylindrical rods, such as the rods and of Fig. 3, as an illustration, the radio waves may be transmitted or received in all directions of azimuth, and the sound waves may be transmitted or received along conical surfaces making the critical Pierce angle e with the rods. An omni-directional combined radio - and - sound transmitter or receiver may thus be provided.

As the plurality of transmitters or receivers I, & lt;HR& gt;41, 51 and 31 may obviously transmit or receive elastic vibrations at different frequencies, it is possible, according to the present invention, to modulate the radio waves simultaneously according to different sound signals. There may be as many different modulations as there are different sound channels 1,41,51 and 31. The radio-frequency transmitters or receivers 2, moreover, may provide different radio-frequency channels to the diaphragms 7, 9 and the diaphragms 17, 19 respectively. The invention, accordingly, provides for a multiplicity of types of secret signalling, both for transmission and reception.

In Fig. 4, there is illustrated an application of the present invention to use with a different type of radio-frequency and sound-vibration conductor than the elements of Figs. 1, 2 and 3, namely, the flared truncated-cone apparatus illustrated in Fig. 17 of the said Letters Patent 2,063,944, having a flare angle of 0/2. The truncated cone is shown provided with a base disk 32, connected to an inter-converter 3, 5 of mechanical and electromagnetic energy. This apparatus yields, by reflection from the conducting wall-surfaces of the cone, a cylindrical parallel-sided or converging sound beam 28, parallel to the axis of the cone. This sound beam, whether produced by magnetostrictively vibrating the disc 32, or produced in response to a sound beam received by the disc 32, may be caused to modulate a radio beam transmitted or received by the cone, operating as a wave-guide electromagnetic horn. An antenna probe 34, positioned in the horn approximately a quarter of the radio-frequency wave-length in front of the base disc 32, may be excited, for transmission purposes, by radio-frequency energy from a radio-frequency oscillator 2, through a radio-frequency channel 38, shown as a coaxial line. The probe 3fl in the horn may serve also for reception, in which event the member 2 would serve as a detector circuit. The dimensions of the cone should, of course, be such as to support the particular radio frequency. A combined - directive - modulated - radio - fre -quency-and-sound-beam transmitter or receiver is thus provided, the apparatus constituting both a directional sound transmitter or receiver and an electromagnetic horn.

Further modifications will ,occur to persons substantially simultaneously with the supporting of the radio-frequency energy by the conducting means, means for exciting the conducting means with radio-frequency energy of said predetermined radio frequency, and means for transversely vibrating the conducting means at the mechanical resonance frequency.

3. An electro-acoustic system of the character described in claim 1 and in which the conducting means comprises a pair of elements, the said radio-frequency energy is applied to one of the elements and the said transverse vibrations are applied to the other element provided with means for coupling the said transverse vibrations to the said one element.

4. An electro-acoustic system of the character described in claim 1 and in which the conducting means comprises a wave guide.

5. An electro-acoustic system of the character described in claim 1 and in which the conducting means comprises an electromagnetic horn.

6. An electro-acoustic system having, in combination, conducting diaphragm means adapted to support radio-frequency energy of predetermined frequency directed thereupon, the diaphragm means being transversely vibratory in response to elastic vibrations of predetermined frequency and of sufficient dimensions to produce mechanical resonance therein in response to the elastic vibrations substantially simultaneously with the supporting of the radio-frequency energy by the diaphragm means, means for applying radio-frequency energy of said predetermined

radio frequency to the diaphragm means and means for applying transverse elastic vibrations to the diaphragm means at the mechanical resonance frequency.

7. An electro-acoustic system having, in combination, conducting means adapted to transmit or receive into or from space radio-frequency energy of predetermined frequency, means connected with the conducting means for energizing the conducting means with radio-frequency energy of the predetermined frequency to cause the conducting means to transmit the radio-frequency energy into space or for evidencing radio-frequency energy received by the conducting means from space, the conducting means being transversely vibratory in response to elastic skilled in the art, and all such are considered to vibrations of predetermined frequency and of fall within the spirit and scope of the invention. sufficient dimensions to produce mechanical resonance therein in response to the elastic vibra-

ENGLISH-CLAIMS:
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What is claimed is:

1. An electro-acoustic system having, in combination, conducting means adapted to support radio-frequency energy of predetermined fre-quency directed thereupon, the conducting means being transversely vibratory in response to elastic vibrations of predetermined frequency and of sufficient dimensions to produce mechanical resonance therein in response to the elastic vibrations substantially simultaneously with the supporting of the radio-frequency energy by the conducting means, means for applying radio-frequency energy of said predetermined radio frequency to the conducting means and means for apply-ing transverse elastic vibrations to the conducting means at the mechanical resonance frequency.

2. An electro-acoustic system having, in combination, conducting means adaoted to support radio-frequency energy of TOedeter ined fro-quency directed thereupon, the conducting means being transversely vibratory in response to elastic vibrations of predetermined frequency and of sufficient dimensions to produce mechanical resonance therein in response to the elastic vibrations tions in order to transmit or receive the said elastic vibrations substantially simultaneously with the transmission or reception of the radio-frequency energy by the conducting means, and means mechanically connected with the conducting means for interconverting vibrational and electric energy at the said mechanical resonance frequency.

8. An electro-acoustic system having, in combination, conducting means adapted to transmit or receive into or from space radio-frequency energy of predetermined frequency, means connected with the conducting means for energizing the conducting means with radio-frequency energy of the predetermined frequency to cause the conducting means to transmit the radio-frequency energy into space or for evidencing radio-frequency energy received by the conducting means from space, the conducting means being transversely vibratory in response to elastic vibrations of predetermined frequency and of sufficient dimensions to produce mechanical resonance therein in response to the elastic vibrations & lt; HR& gt; in order to transmit or receive the said elastic vibrations substantially simultaneously with the" transmission or reception of the radio-frequency energy by the conducting means, and means connecting the conducting means with means for 5 applying mechanical transverse vibrations of the said resonance frequency to the conducting means or for evidencing the mechanical transverse vibrations of the said resonance frequency received by the conducting means.

9. An electro-acoustic system of the character described in claim 8 and inrwhich the conducting means comprises a diaphragm.

10. An electro-acoustic system of the character described in claim 8 and in which the conducting means comprises a wave guide.

11. An electro-acoustic system of the character described in claim 8 and in which the conducting means comprises an electromagnetic horn.

12. An electro-acoustic system of the character described in claim 8 and in which the conducting means comprises a conical electromagnetic horn disposable in a medium with its axis substantially parallel to the direction of transmission or reception of the said elastic vibrations and hav- ing flared walls disposable at an angle to the said direction such that the said transverse elastic vibrations therein shall have a velocity component, in the said direction, substantially equal to the velocity of the said elastic vibrations in the medium.

3. An electro-acoustic system of the character described in claim 8 and in which the conducting means is angularly disposable in a medium at an angle to the direction of transmission or reception of the said elastic vibrations in the medium such that the transverse elastic vibrations in the conducting means have a velocity component along the said direction substantially equal to the velocity of the elastic vibrations in the medium.

4. An electro-acoustic system of the character described in claim 8 and in which the conducting means is adapted omni-directionally to transmit or receive the said radio-frequency energy.

5. An electro-acoustic system having, in com- 45 bination, conducting means adapted to transmit into space radio-frequency energy of predetermined frequency, means connected with the conducting means for energizing the conducting means with radio-frequency energy of the pre- 50 determined frequency to cause the conducting means to transmit the radio-frequency energy into space, the conducting means being transversely vibratory in response to elastic vibrations of predetermined frequency and of sufficient di- 55 mensions to produce mechanical resonance therein in response to the elastic vibrations in order to transmit or receive the said elastic vibrations substantially simultaneously with the transmission of the radio-frequency energy by the con- 60 ducting means, and means connecting the conducting means with means for applying mechanical transverse vibrations of the said resonance frequency to the conducting means or for evidencing the mechanical transverse vibrations of 65 the said resonance frequency received by the conducting means.

6. An electro-acoustic system having, in combination, conducting means adapted to receive from space radio-frequency energy of predeter- 70 mined frequency, means connected with the conducting means for evidencing radio-frequency energy" received by the conducting means from space, the conducting means being transversely vibratory in response to elastic vibrations of predetermined frequency and of sufficient dimensions to produce mechanical resonance therein in response to the elastic vibrations in order to transmit or receive the said elastic vibrations substantially simultaneously with the reception of the radio-frequency energy by the conducting means, and means connecting the conducting means with means for applying mechanical transverse vibrations of the said resonance frequency to the conducting means or for evidencing the mechanical transverse vibrations of the said resonance frequency received by the conducting means.

7. An electro-acoustic system having, in combination, a plurality of conducting elements adapted directionally to transmit or receive into or from space radio-frequency energy of predetermined frequency, means connected with the conducting elements for energizing the conducting elements with radio-frequency energy of the predetermined frequency to cause the conducting elements to transmit the radio-frequency energy into space or for evidencing radio-frequency energy received by the conducting elements from space, the conducting elements being transversely vibratory in response to elastic vibrations of predetermined frequency and of sufficient dimensions to produce mechanical resonance therein in response to the elastic vibrations in order to transmit or receive the said elastic vibrations substantially simultaneously wi h the transmission or reception of the radio-frequency energy by the conducting elements, and means connecting the conducting elements with means for applying mechanical transverse vibrations of the said resonance frequency to the conducting elements or for evidencing the mechanical transverse vibrations of the said resonance frequency received by the conducting elements.

18. An electro-acoustic system of the character described in claim 17 and in which the plurality of conducting elements are respectively energized by or respectively receive a plurali y of different predetermined radio frequencies and are transversely vibratory at the same mechanical resonance frequency.

19. An electro-acoustic system of the character described in claim 17 and in which the plurality of conducting elements are energized by or receive the same predetermined radio frequency and are respectively transversely vibratory at a plurality of different mechanical resonance frequencies.

20. An electro-acoustic system of the character described in claim 17 and in which the plurality of conducting elements are respectively energized by or respectively receive a plurality of different predetermined radio frequencies and are respectively transversely vibratory at a plurality of different mechanical resonance frequencies.

21. An electro-acoustic system having, in combination, a plurality of electrically and mechanically isolated conducting elements adapted directionally to transmit or receive into or from space radio-frequency energy of predetei mined frequency, means connected with the conducting elements for energizing the conducting means with radio-frequency energy of the predetermined frequency to cause the conducting elements directionally to transmit the radio-frequency energy into space or for evidencing radio-frequency energy directionally received by the conducting elements from space, the conducting elements being transversely vibratory in response to elastic vibrations of predetermined frequency and of sufflcient dimensions to produce mechanical resonance therein in response to the elastic vibrations in order to transmit or receive the said elastic vibrations substantially simultaneously with the directional transmission or reception of the radio-frequency energy by the conducting elements, and means connecting the conducting elements wi.h means for applying mechanical transverse vibrations of the said resonance frequency to the conducting elements or for evidencing the mechanical transverse vibrations of the said r& gt; so-nance frequency received by the conducting elements.

22. An electro-acoustic system having, in combination, conducting means adapted fo support radio-frequency energy of predetermined frequency directed thereupon, the conducting means being transversely vibratory in response to elastic vibrations of predetermined frequency and of sufficient dimensions to produce mechanical resonance therein in response to the elastic vibrations substantially simultaneously with the supporting of the radio-frequency energy by the conducting means, means for applying radio-frequency energy of said predetermined radio frequency to the conducting means, means for applying transverse elastic vibrations to the conducting means at the mechanical resonance frequency, and vibration-absorbing means at a boundary of the conducting means to damp the vibrational energy at the said boundary.

23. An electro-acoustic system having, in combination, a plurality of conducting elements adapted directionally to transmit or receive radio-frequency energy of predetermined frequency directed thereupon, the elements b ing transversely vibratory in response to elastic vibrations of predetermined frequency and of sufficient dimensions to produce mechanical resonance therein in response to the elastic vibrations substantially simultaneously with the directional transmission or reception of the radio-frequency energy by the conducting elements, means for applying radio-frequency energy of said predetermined radio 5 frequency to the conducting elements and means for applying transverse elastic vibrations to the conducting elements at the mechanical resonance frequency.

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