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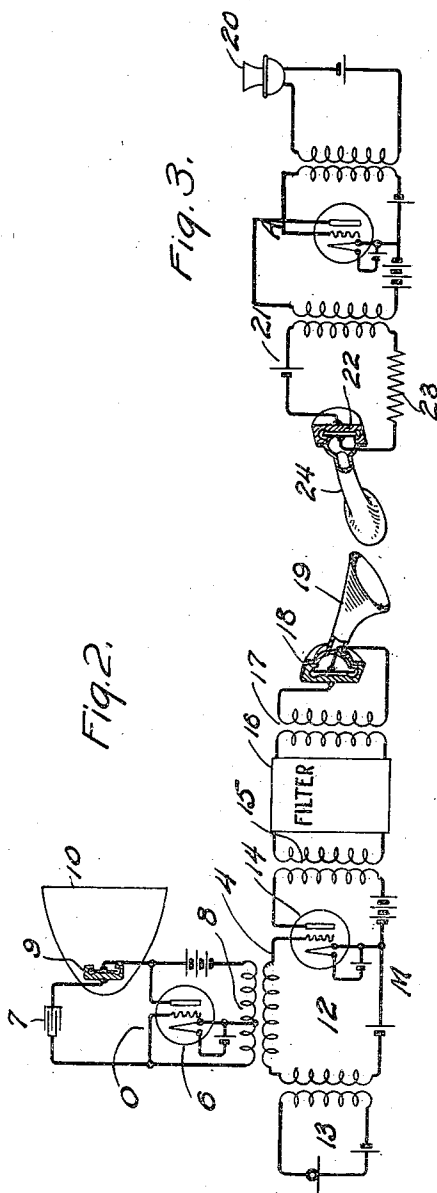
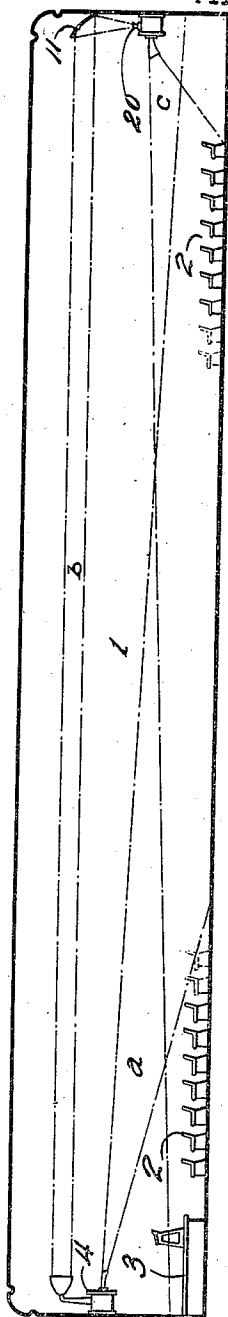
1,616,639

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HIGH FREQUENCY SOUND TRANSMISSION SYSTEM

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Fig. 1.



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UNITED STATES PATENT OFFICE.

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HIGH-FREQUENCY SOUND-TRANSMISSION SYSTEM.

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This invention relates to acoustic signaling systems and more particularly to a system of this kind in which acoustic waves of frequencies above the limits of audibility are employed to reinforce, in the rear of an auditorium, the ordinary acoustic waves set up by the voice of a speaker or other sounds produced at the front of the auditorium for instruction, entertainment or other purpose.

The invention, so far as known, is a marked departure from acoustic systems which have been previously devised, and several features employed are capable of broad application in acoustics and signaling. In order to clearly describe the invention, however, its application to auditoriums will first be described. This is the field in which the invention in its entirety will probably find its most useful application.

The need of a system for enabling auditors in the rear portions of theatres and churches and other assembly places to hear distinctly the sounds emanating from the stage or rostrum has become urgent. Recently so-called "loud speaking" telephone systems have been developed which in a measure fill this need, but all such systems have one or more of the defects mentioned below, all of which are substantially overcome in the system according to the present invention.

If the reinforcing horn or instrument is near the speaker, the reinforcement is greatest in the front of the room, where it should be least. To those near the speaker the sounds appear unnaturally loud and this effect is sometimes so great as to be very annoying.

If the reinforcing horn or instrument is in the rear of the room, or if many such instruments are distributed throughout the room, those near these instruments may receive the impression that the speaker is at their rear.

The range of frequencies employed (the audible range) is a difficult one in which to operate because in transforming sound energy to electrical energy and vice versa, distortion may be introduced, for example, by the generation of audible harmonic waves.

By employing carrier frequencies above the audible range during these transformations, as in the system of this invention, the harmonics produced are inaudible and have no effect upon the ear of the auditor.

When a single reproducing horn is employed, the distortion due to resonance within the horn is marked. This effect is overcome by using inaudible frequencies.

Referring now to the accompanying drawings, Fig. 1 is a diagrammatic view of an auditorium equipped with this invention; Fig. 2 is a diagram of the high frequency electrical circuit arrangement disposed near the speaker; and Fig. 3 is a diagram of the high frequency electrical circuit arrangement located in the rear of the auditorium.

The auditorium 1, provided with seats 2 and platform 3 is equipped with apparatus 4 placed near the speaker for transforming a portion of the energy of the speaker's voice into high frequency sound waves for transmission toward the rear of the room. These waves are modulated in accordance with the speech frequencies. Mechanical means can be used for producing these high frequency sound waves, but apparatus well adapted for this purpose has not yet been developed and it is accordingly preferred at the present time to use electrical apparatus of well known design.

Referring to Fig. 2, an oscillation generating system 5 of the audion type employing a tube 6 is adjusted to generate alternating currents of a frequency above the audible range in the oscillation circuit 7, 8, 9, in well known manner, the frequency being determined by the amount of inductance and capacity in this circuit. The instrument 9 is a device for setting up sound waves of the frequency of the generated current and may consist of what is commonly called a condenser receiver, many forms of which have previously been devised. A parabolic sound reflector 10, preferably thick-walled and of heavy metal, projects the sound waves in a beam of substantially parallel rays to the concave sound reflector 11 (Fig. 1). The latter reflects and focuses the sound beam upon the diaphragm of the sound re-

ceiving apparatus 20 to be later described.

A modulating system 12 of the audion type receives high frequency energy from generator 0 and is simultaneously supplied with voice frequency energy from a telephone transmitting circuit 13. The telephone transmitter is located where a portion of the speaker's voice will reach it.

The audion 14 amplifies the high frequency electrical waves impressed upon it and the amplifying power of the tube is controlled by the voltage impressed from the transmitting circuit 13. The result is to produce high frequency variations in the output current the amplitudes of which accord with the speech waves impressed on the input circuit. This is a well known form of modulating system and is shown merely by way of example. It was invented by E. H. Colpitts and J. H. Van der Bijl and for a more detailed description the reader is referred to U. S. Patent (Reissue) No. 14,380 to Colpitts and U. S. Patent No. 1,350,752 to Van der Bijl.

The high frequency modulated waves thus produced are impressed through transformer 15 upon an electric wave filter 16 of the type disclosed in U. S. patent to Campbell, No. 1,227,113, granted May 22, 1917, the filter being designed, in the manner described in the patent, to pass all frequencies above certain value and to suppress all frequencies below this value. It is now well known that a high frequency modulated wave is in effect a plurality of waves of different frequencies which may be separated from each other by electric filters. If C represents the frequency of waves generated by the generator 0, and S represents the instantaneous frequency of the composite speech wave, the modulated high frequency wave may be considered as made up of three waves having the frequencies $C+S$, $C-S$ and C. The component of C frequency may be looked upon as the portion of the original wave which has not been modulated, there always being such a component unless special means are used to obtain complete modulation. Since S is a constantly changing frequency, $C+S$ and $C-S$ are likewise continually varying. For example, if C is 30,000 and S varies from 100 to 5000, $C+S$ will vary from 30,100 to 35,000 and $C-S$ will vary from 29,900 to 25,000. For a detailed disclosure of a mathematical analysis of a modulated electric wave see British patent 102,503 for an invention of John R. Carson relating to modulation. The filter 16 is designed to transmit only the component $C+S$ or the component $C-S$ and to suppress the others. Therefore, although the transmitted frequency is constantly changing, it never falls to a value which is audible.

This band of changing frequencies is im-

pressed through transformer 17 upon a device 18 similar in function to 9 for transforming the electric waves into sound waves of like frequencies. A megaphone 19 transmits these sound waves in the form of a beam *a* toward the rear of the auditorium. A cross-section of this beam, due to the shape of the megaphone, is greater in its horizontal than in its vertical dimension.

If the beam *a* were to be employed alone, no effect would be produced upon the auditors; but by simultaneously producing a sound of frequency C in the region in which an amplifying effect is desired, the detecting property of the ear is brought into play and the voice of the speaker becomes audible even though his voice cannot directly be heard. This is due to the phenomenon of acoustic "beats". Whenever two sound waves of different frequencies are simultaneously impressed upon a vibratable body which distorts the waves, their energy is absorbed and reappears in the form of new waves, not only of the frequencies of the impressed waves, but a third wave which has a frequency equal to the sum of the impressed frequency waves, a fourth having a frequency equal to the difference between those of the impressed waves and others of frequencies harmonic to those of the impressed waves, that is, integral multiples of these frequencies. The amplitudes of the "sum" and "difference" frequencies will in general be much greater than those of the higher harmonics and will be proportionate to the product of the amplitudes of the impressed waves. Therefore this amplitude can be made great by increasing the amplitude of one of the impressed waves. The vibratable elements of the ear have the property of distorting high frequency waves impressed upon them to produce such a series of waves as that just described. Thus, when the frequencies C and $C+S$, for example, are impressed upon the ear there is produced a wave having a frequency equal to the difference of these waves, i. e. S. In other words speech is reproduced. At the same time other waves having frequencies of $2C+2S$, $2C$, $2C+S$ etc. are produced, but each of these is above the limit of audibility and produces no effect. If a wave of frequency $C-S$ rather than $C+S$ is impressed upon the ear simultaneously with a wave of frequency C, the result, so far as the production of audible frequencies is concerned, is the same, i. e., the difference frequency is S, and the sum frequency and harmonic frequencies are inaudible.

The purpose of the apparatus shown in Fig. 3 is to set up in the rear of the auditorium a wave of the frequency C and of constant amplitude, which reaches the auditors at the same time as the sound of frequency $C+S$ (or $C-S$) from the front of

the room. A sound generator, either mechanical or electrical, capable of producing frequency C, could be operated at the rear of the auditorium independently of the high frequency sound produced near the speaker, if it were possible to maintain the frequency C constant, or exactly the same as the carrier frequency produced at the front of the room. It is so difficult to do this, however, that it is preferable to provide synchronizing means between the generators at the front and the rear of the room. Any known means for producing the desired synchronism may be employed. The system shown in Fig. 1 is being here described by way of example. Strictly speaking, this is an amplifying rather than a synchronous generating system in that the beam *b* of sound waves is transformed into electrical waves of corresponding frequency, which are then amplified and reconverted into sound waves. The beam *b* is reflected and focused by the concave reflector 11 upon the diaphragm of telephone transmitter 20, which preferably has a natural frequency equal to or greater than that of the impressed waves but which may be provided with damping means. Any other form of device for transforming sound waves into electrical waves may be substituted for the transmitter 20. The waves thus set up are amplified by the thermionic vacuum tube amplifier A and are reconverted into sound waves by means of the converter 22 in circuit 21, 22, 23. The converter 22 may be of any known type but is shown as a so-called condenser-receiver. As the potential upon the condenser elements is varied in accordance with the waves flowing in the circuit 21, 22, 23, they are vibrated and thus set up sound waves in the air. The circuit 21, 22, 23 may be tuned to the frequency transmitted as may also the circuits of sound transmitter 18 and sound receiver 20. A damping resistance 23 may be inserted in circuit 21, 22, 23, as shown, and may be of such value as to give the circuit any damping characteristic desired. A similar resistance may be used in the other circuits just mentioned. The source 21 of direct potential provides means for polarizing the condenser-receiver 22 and may be omitted if desired. It is to be understood that whenever a condenser-transforming device is employed it may if desired be polarized in well-known manner. The sound waves thus set up are transmitted as a beam *c* toward the front of the room, a cross-section of this being, as in the case of beam *a*, greater in its horizontal than in its vertical dimension. By means of the amplifier A any desired degree of amplification may be obtained, a plurality of amplifiers being employed if necessary. The wave amplitude of the beam *c* is preferably much greater than that of beam *a*.

The operation of the system should be apparent from the above description. The sound beams *a* and *c* are simultaneously impressed upon the ears of the auditors throughout the room except in a zone near the speaker, in which his voice can readily be heard. Assuming, for example, that the beam *a* consists of a band of frequencies C+S (the effect being the same, however, whether the band is one of C+S or C-S frequencies) there is produced in the ears of each auditor who receives these waves a series of waves of frequency or frequencies S in the manner described above, i. e., the ear functions as a detector to render perceptible the low frequency modulating component of the impressed waves in a manner analogous to the operation of a so-called detector of electrical waves at a receiving radio telephone station.

The auditor therefore, if he is within the range of the speaker's voice, hears the speaker both directly and indirectly and these two effects are additive. The effect which is produced indirectly is, however, greatest in magnitude in the rear of the room and is progressively less from there toward the front and may be made of such value as to render the sum of the indirect and direct effects approximately uniform throughout the room. The reason why the effect is greatest at the rear of the room and decreases progressively from there toward the front of the room is that, as explained above, the amplitude of the "difference" frequency produced when two waves simultaneously impinge upon a detecting element is proportional to the product of the amplitudes of the impressed waves. Therefore by making the initial amplitude of the beam *c* very much greater than that of the beam *a* the product of these amplitudes will be greatest where the amplitude of the beam *c* is greatest, that is, in the rear of the room.

Since the high frequency sound wave which is proceeding from the vicinity of the speaker is varying in accordance with speech, while the wave from the rear of the room is of constant amplitude and frequency, the effect upon the ear is the same as though the entire energy received proceeded from the vicinity of the speaker. This is considered an important feature of this invention, since, by reason of it, the source or sources of amplified waves may be placed in the rear of the room or distributed throughout the room without producing the incongruous effect of seeing the speaker in one direction and hearing him in another.

As just suggested, as many sound sources of frequency C may be used as necessary to give approximately uniform sound intensity throughout the room. It would, of course, be especially desirable to employ more than one such source when the speaker is partly or wholly surrounded by his audience. The

beam *a* may be widened by a properly shaped horn or megaphone, or several sound transmitters such as 18 may be employed simultaneously and energized from the same source if desired.

In order to insure that the effect upon the ear from the high frequency sound waves is in phase with the sound which is received directly from the speaker, it may be necessary to adjust the phase of the high frequency wave. This may be done by changing to a slight extent the position of either of the sources of high frequency wave with respect to the other or the distance between the reflector 11 and the telephone transmitter 20. In this way the two high frequency waves may be made to reach the auditors in any desired phase relation and since the phenomenon is one of "beats" the phase of the beat wave with respect to that of a wave of the same frequency from the speaker depends upon the phase relation between the sound beams *a* and *c*. The wave length of the wave having the frequency *C* is a few inches or at most a few feet so that the phase relation between the two high frequency waves of beams *a* and *c* may be varied from zero to 180 degrees by a change of a few inches or at most a few feet in the position of the producing or reflecting apparatus.

In case the installation is to be permanent and indoors, it is ordinarily preferred to omit the condenser 7, the sound producer 9, the reflectors 10 and 11 and the sound receiver 20 with its battery, and to connect the amplifier A with the generator 0 by means of an electrically conductive circuit extending along the floor or wall of the room. Such a circuit may, of course, be employed also when the installation is out-of-doors if desired.

While the invention has been described as of particular utility in a sound amplifying system, it is also applicable to relatively long distance aerial or submarine secret signaling. The transmitting operator then speaks directly into the transmitter 13 and the ear of the receiving operator is placed near the sound producer 22. The amplitude of the sound from 22 may then be relatively small.

An acoustic detecting instrument may be employed in the place of the ear, or as an auxiliary thereto.

The terms sound and acoustic are herein employed in their broader sense to denote material waves of frequencies lying outside the audible range as well as those within that range.

What is claimed is:

1. An acoustic wave system comprising means for producing low frequency sound waves, a source of high frequency waves, means for modifying said high frequency waves in accordance with said low frequency

waves, means for suppressing all of the components of the modified wave except one side band of frequencies, means for directly transmitting to a receiving point an acoustic wave comprising said side band frequencies, a source of acoustic waves of the same frequency as the said first-mentioned high frequency source, a wave distorting device for producing waves of sum and difference frequencies from impressed waves, and means for impressing said acoustic wave having side band frequencies and a wave from said last-mentioned high frequency source simultaneously upon said wave distorting device.

2. An acoustic system comprising means for producing audible sound waves, a source of high frequency waves of frequency above the audible limit, means for modifying said high frequency waves in accordance with said audible waves, means for suppressing all of the components of the modulated wave except one side band of frequencies, means for transmitting to a receiving point an acoustic wave comprising said side band frequencies, a source of acoustic waves of the same frequency as the said first-mentioned high frequency source, and means for impressing said acoustic wave having side band frequencies and a wave from said last-mentioned high frequency source simultaneously upon the ear of an auditor.

3. A sound wave reinforcing system comprising means for producing audible sound waves to be reinforced, a source of high frequency waves of frequency above the audible limit, means for modifying said inaudible wave in accordance with said audible waves, means for suppressing all the components of the modulated wave except one side band of frequencies, means for transmitting to a receiving point an acoustic wave comprising said side band frequencies, a source of acoustic waves of the same frequency as said first-mentioned high frequency source, and means for impressing said acoustic wave having side band frequencies and a wave from said last-mentioned high frequency source simultaneously upon the ear of an auditor.

4. In a wave transmission system, the method of reinforcing audible frequency waves at a desired point in space which comprises combining two inaudible waves with each other and with said audible frequency waves at said point.

5. The method of signaling which comprises generating an audible wave, generating an inaudible wave, combining said waves to produce an inaudible side band of sound waves, transmitting said side band through space, and combining with said attenuated side band in space an inaudible sound wave to produce audible sound waves.

6. The method of signaling which comprises generating unmodulated inaudible waves, generating inaudible waves modu-

lated in accordance with signals, transmitting said modulated waves through space, and directly transmitting and reflecting said unmodulated waves whereby they are
 5 caused to combine at a desired point with said modulated waves.

7. A signal transmitting system which comprises means for producing unmodulated inaudible waves, means for producing inau-
 10 dible waves modulated in accordance with signals, a reflector, means for directing said unmodulated inaudible waves upon said reflector, and an amplifying relay system supplied with said waves from said reflector.

15 8. The method of acoustic wave transmission which comprises generating and transmitting an inaudible acoustic wave modified in accordance with a signal separately generating an inaudible wave, and making
 20 the signal audible by impressing upon the ear simultaneously therewith said second inaudible wave.

9. The method of acoustic transmission which comprises generating and transmitting
 25 an inaudible acoustic wave having its frequency modified in accordance with a signal separately generating an inaudible wave, and making the signal audible by impressing upon the ear simultaneously
 30 therewith said second inaudible wave.

10. The method of acoustic wave signaling which comprises impressing simultaneously upon the ear of an auditor an acoustic wave of constant frequency and a separately
 35 generated and transmitted wave of varying frequency.

11. The method of acoustic wave signaling which comprises generating and transmitting a high frequency acoustic wave modulated in accordance with the signal, separately generating an unmodulated high frequency wave and simultaneously impressing
 40 said waves upon the ear of an auditor.

12. The method of acoustic signal transmission from substantially the position of an audible frequency source to an audience, which comprises transmitting from substantially the position of said source, audible
 50 frequency waves as modulations of an inaudible frequency acoustic wave, and directly transmitting acoustic waves of said inaudible frequency from a point other than that of said source.

13. The method of acoustic signal transmission from substantially the position of an audible frequency source to an audience, which comprises transmitting audible frequency acoustic waves from said source, transmitting from substantially the position
 60 of said source an inaudible frequency acoustic wave modulated by waves of said audible frequency and directly transmitting acoustic waves of said inaudible frequency from a point other than that of said source.

14. The method of acoustic signal trans-

mission from a desired point to an audience which comprises transmitting audible frequency acoustic waves from said point to the audience, transmitting from said point waves of said audible frequency as modulations of an inaudible frequency acoustic wave, and transmitting acoustic waves of said inaudible frequency and of greater amplitude than that of said modulated waves from a point at the opposite side of the audience from said desired point.
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15. The method of acoustic signaling from a desired point to an audience which comprises transmitting an audible frequency acoustic wave from said point to the audience, modulating an inaudible frequency acoustic wave in accordance with said audible frequency wave, transmitting the modulated components of said wave to the audience, separately directly transmitting the unmodulated component to a point on the opposite side of said audience from said point, generating by means of said unmodulated component at said second point a wave of the same frequency but of substantially greater amplitude, and transmitting
 85 said wave to the audience.

16. The method of acoustic wave transmission which comprises modulating an acoustic inaudible frequency carrier wave in accordance with a low frequency wave in such manner that the resultant modulated wave has a component equal in amplitude to the product of the carrier and low frequency waves, transmitting said modulated wave to the ear of an auditor and impressing upon the ear simultaneously with the modulated wave a second inaudible wave of the same frequency as said acoustic inaudible wave.
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17. A sound operated amplifying apparatus for an auditorium comprising sound receiving means located at a point where sound from a source has become attenuated, and electrical means for reinforcing sound waves controlled by said sound responsive means.
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18. The method of producing the sensation of audible speech upon the ear of an observer which comprises impressing upon the natural physical medium in operative proximity to the ear a compressional wave of frequency above the usual audible range inherently containing the elements of speech and another wave of frequency above the usual audible range.
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19. A system comprising separate elements for producing compressional waves of frequency above the usual audible range, means for causing one of said waves to vary in accordance with speech, and means for impressing said waves upon the ear of an observer with desired relative intensities.
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20. A system for producing in one and the same physical medium at least a part of the frequency components of a compressional
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wave varying in accordance with speech and an unmodulated compressional component of said wave, and means for independently regulating the intensity of said unmodulated component.

21. A system comprising separate wave producers and associated elements for pro-

ducing in the same body of medium a compressional wave speech side band, and a compressional wave corresponding to the unmodulated component of said side band.

In witness whereof, I hereunto subscribe my name this 2nd day of June, A. D. 1921.

CLARENCE A. SPRAGUE.