

[72] Inventor **John G. Spracklen**
Chicago, Ill.
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[73] Assignee **Zenith Radio Corporation**
Chicago, Ill.

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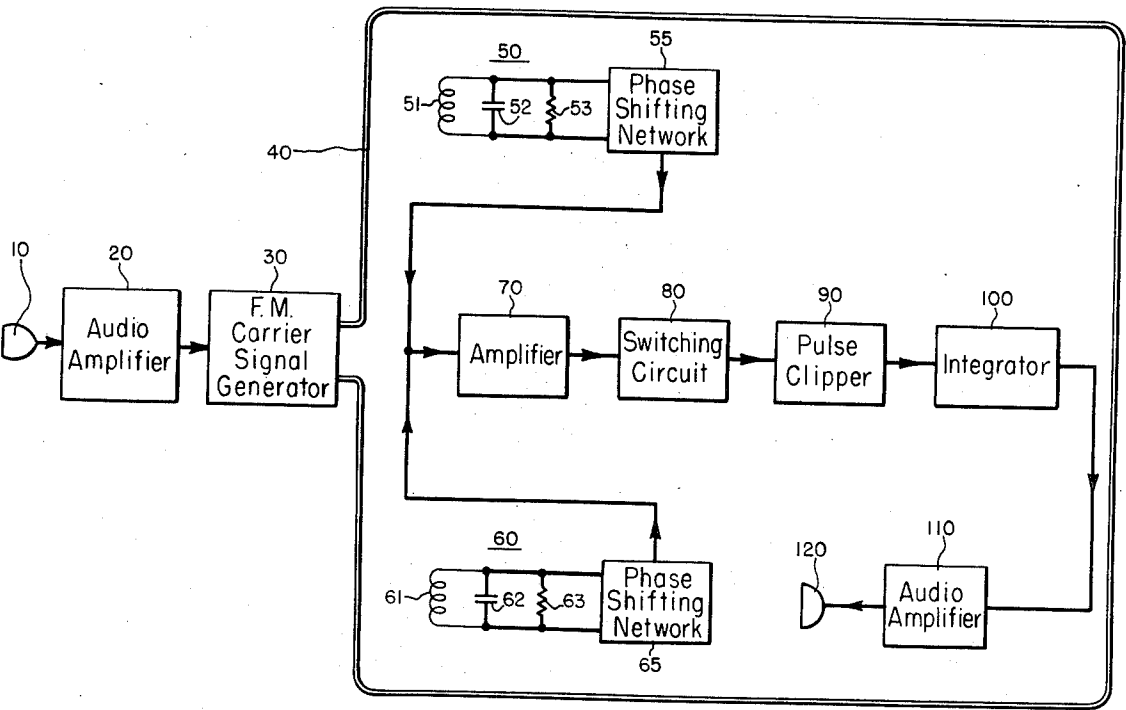
Primary Examiner—Kathleen H. Claffy
Assistant Examiner—William A. Helvestine
Attorney—John J. Pederson

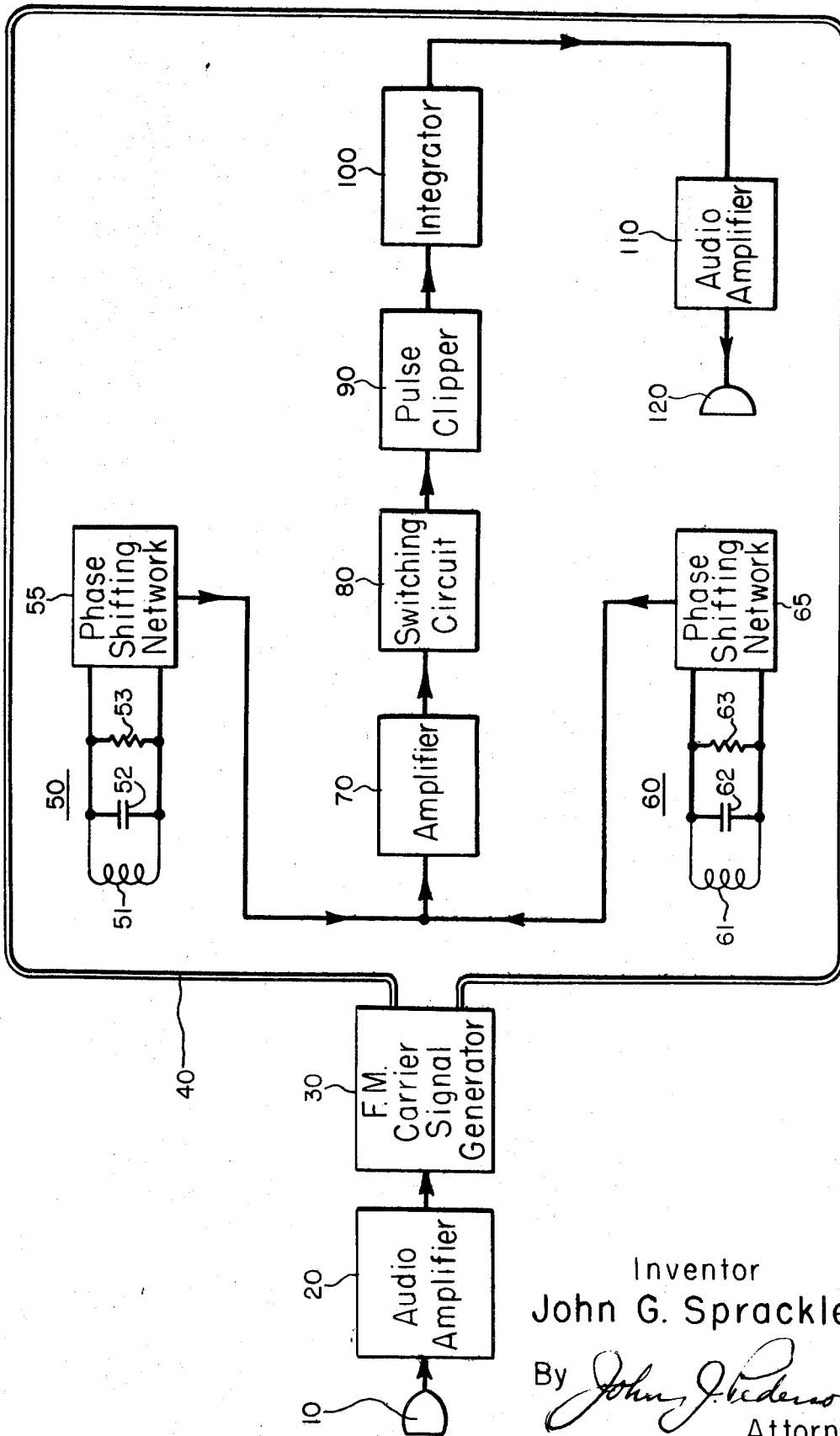
[54] **LOOP COMMUNICATION SYSTEM**
2 Claims, 1 Drawing Fig.

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325/369
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H04b 5/00
[50] Field of Search. **179/82;**
325/320, 349, 369

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ABSTRACT: A limited-range, induction-coupled loop communication system for the transmission of audio information to a receiver located within the loop uses a frequency-modulated carrier-wave signal to transmit audio information to one or more receivers located within the loop. Each receiver has a pair of pickup coils preferably mounted at 90° relative to each other and a phase-shifting network connected to each of their outputs to thereby create a quadrature relationship in the received signals to substantially eliminate the occurrence of null conditions with variations in receiver orientation.





Inventor
John G. Spracklen

By *John J. Pedersen*
Attorney

LOOP COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

There are various situations in which a limited-range, induction-coupled communication system is desirable. Hard-of-hearing members of a theatre audience, for example, can take advantage of such a system to enable them to adequately hear the audio portion of the program. By using headphones adapted to receive the transmitted signal, the audio portion of the program may be transmitted to the user's ears at a loudness level higher than that transmitted to the rest of the audience by loudspeakers. Hospitals provide another situation for a desirable application of such a system because of the need to communicate with various hospital personnel in remote locations without disturbing patients, physicians, and others. A third application involves the classroom training of hard-of-hearing students. Since such a student normally wears a hearing aid anyway, it is especially convenient to incorporate such a transmission system with the hearing aid itself and thereby eliminate the necessity on the student's part for additional equipment.

Conventional limited-range, induction-coupled communication systems typically include a transmitting antenna consisting of a closed loop of wire disposed in a horizontal plane about the periphery of the space in which communication is desired. In the classroom application, such a closed-loop antenna is placed about the walls of the classroom at a height of approximately 7 feet. The instructor's voice is picked up by a microphone and then amplified by an audio amplifier to provide sufficient signal strength for effective transmission by the antenna. The direction of the magnetic field established by the closed-loop antenna is essentially vertical within the loop, and the magnitude of the field varies proportionally with the audio signal representative of the instructor's voice. Each student has his own receiver which is preferably integrated with his hearing aid as mentioned above. A conventional hearing aid often has a pickup coil for inductively coupling a telephone output signal to the hearing aid. Hence, by means of a switch, this pickup coil may also be employed to inductively couple the closed-loop transmission signal to the receiver and thereby enable each student to adjust the volume of his receiver (hearing aid) to provide the loudness level he requires.

Such systems, however, are plagued with several limitations. The pickup coil has an axis which, when oriented parallel with the magnetic field direction, provides maximum inductive signal coupling. When this maximum-signal-coupling axis deviates from the parallel orientation, the amount of signal coupling correspondingly decreases. Quite obviously, since the loudness level of the signal delivered to the user's ear is dependent upon the amount of signal coupling, it correspondingly decreases for such a deviation. As mentioned above, the closed-loop antenna establishes an essentially vertical magnetic field. Hence, the maximum-signal-coupling axis of the pickup coil is typically oriented vertically for maximum signal coupling. When a person wearing such a receiver moves about, for example when he leans forward to read or write, this axis is no longer parallel with the direction of the magnetic field. The amount of signal coupling therefore decreases resulting in a reduction of the amplitude of the output signal delivered to the person's ear. In addition to the variations in volume level, such systems are also subject to the reception of extraneous signals (crosstalk) from adjacent classrooms utilizing a similar closed-loop transmission system.

In order to overcome the limitations of the direct audio transmission system discussed above, conventional systems have been contrived which use elaborate schemes including a plurality of closed-loop antennas connected in series or parallel configurations, and various types of neutralizing loops or circuits. Some have even replaced the direct audio type of transmission signal with an amplitude-modulated (AM) carrier-wave signal. However, these systems are inherently expensive, complicated, and not always reliable.

While the AM approach partially overcomes some of the above-mentioned limitations, it still is subject to serious crosstalk interference from adjacent rooms employing a similar system unless each room uses a carrier-signal frequency which is substantially different from and not harmonically related to that of an adjacent room. Furthermore, in order to enable a user of this type of multifrequency system to enter different rooms and receive the transmission, each receiver must be provided with tuning means for permitting the user to selectively receive the carrier-wave signal of the particular frequency assigned to each different room. This approach substantially prevents crosstalk between rooms, but it requires elaborate tuning circuitry and a good automatic volume control system, and the user must select a different communication channel for each room he enters.

Where such a closed-loop transmission system is used to aid a hard-of-hearing person, it is preferable to combine the receiver with the person's hearing aid, as mentioned above. By means of a simple switch, for example, the user may operate his hearing aid conventionally, or he may selectively operate it as a closed-loop communication system receiver. Such an incorporation should require a minimum number of additional parts in order to minimized cost and prevent an increase in the size of the person's present hearing aid.

It is therefore an object of the invention to provide a new and improved limited-range, induction-coupled communication system which is capable of uniform operation throughout a limited space and has a high degree of immunity from extraneous signals.

It is a further object of the invention to provide such a communication system which is conveniently and economically adaptable to conventional hearing aids.

SUMMARY OF THE INVENTION

A limited-range, induction-coupled communication system for the wireless transmission of information to a receiver located within a predetermined limited space, in accordance with one aspect of the invention, comprises means for providing a carrier-wave signal frequency modulated by a signal representative of the information. Transmitter means including a closed-loop antenna are provided for transmitting said carrier-wave signal to the limited space and establishing therein an electromagnetic radiation field of a predetermined magnitude, which magnitude is larger than the magnitude of any other electromagnetic radiation field present in the predetermined space. Receiver means responsive to the electromagnetic radiation field having the largest magnitude in the space, to the substantial exclusion of other electromagnetic radiation fields having a smaller magnitude in the space, are provided for developing an electrical signal representative of the transmitted carrier-wave signal. Detector means responsive to the electrical signal are provided for recovering the modulation signal, and output transducer means are included for converting the modulation signal into output information corresponding to that transmitted.

In accordance with another aspect of the invention, a limited-range, induction-coupled communication system for the wireless transmission of information to a receiver located within a predetermined limited space comprises means for providing a carrier-wave signal modulated with a signal representative of the information. Transmitter means including a closed-loop antenna are provided for transmitting the carrier-wave signal to the space and establishing an electromagnetic radiation field having a predetermined direction therein. Input circuit means are provided for receiving the carrier-wave signal, including a plurality of input transducers each having a maximum signal-coupling axis angularly oriented relative to the predetermined field direction at a different predetermined angle, each input transducer providing a separate output signal representative of the modulated carrier-wave signal. Also provided are means for combining the separate output signals and detector means responsive to the

combined output signal for recovering the modulation signal. Output transducer means are further provided for converting the recovered modulation signal into output information corresponding to that transmitted.

BRIEF DESCRIPTION OF THE DRAWING

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood, however, by reference to the following description taken in connection with the accompanying drawing, in which the single FIGURE is a block diagram of a preferred embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to the drawing, a preferred embodiment of a limited-range, induction-coupled communication system is shown in block diagram form. In accordance with one aspect of the invention, a microphone 10 converts audio information, such as an instructor's voice, into an electrical signal which is coupled to an audio amplifier 20 wherein the signal is amplified sufficiently to provide a modulation signal for the FM carrier-wave signal generator 30. Alternatively, various other means may be used for providing a suitable FM carrier signal, including a playback device (not shown) utilizing prerecorded records, magnetic tapes, etc., on which is recorded a carrier-wave signal frequency modulated with a signal representative of the information desired to be transmitted.

The output of signal generator 30 is transmitted by means of a closed-loop antenna 40 to an FM receiver situated in the space encompassed by antenna 40. The receiver may be a conventional FM receiver tuned to the frequency of the transmitted carrier-wave signal or it may preferably be of the type shown in block diagram form within antenna 40 and constructed in accordance with another aspect of the invention hereinafter described in greater detail.

Antenna 40 may take various shapes and forms including the rectangular form shown in the drawing. It may comprise a single loop of wire disposed about the desired space as shown or it may be a multi-turn loop or even several different loops respectively disposed about different portions of the room, depending upon the field strength/uniformity desired. It is typically placed at a height of approximately 7 feet about the periphery of the space in which transmission is desired in order to establish therein an electromagnetic radiation field of a predetermined magnitude which is greater than that of any other such field present in the space. Other such fields may be present, for example, when several adjacent spaces (rooms) employ this type of system and each room has a separate closed-loop antenna transmitting a similar signal. Although the closed-loop antenna essentially localizes its associated electromagnetic radiation field, there may be some signal overlapping (crosstalk) between adjacent rooms depending upon the amount of signal isolation provided by the intervening wall, the respective signal levels in adjacent rooms, etc.

In order to overcome this crosstalk limitation, some conventional systems discard a direct-audio transmission signal in favor of an amplitude-modulated (AM) carrier-wave transmission signal and, as discussed previously, employ widely separated carrier frequencies which are not harmonically related. Consequently, in order to enable a user to go from one room to another and still use the same receiver, provision must be made for selectively turning the receiver to the carrier-wave frequency of the particular room involved. On the other hand, an FM system constructed in accordance with the invention is not subject to any appreciable crosstalk and may therefore employ the same carrier-wave frequency in adjacent rooms.

By employing a frequency-modulated carrier-wave signal, in accordance with one aspect of the invention, advantage is taken of a phenomenon peculiar to FM signal reception which

is sometimes referred to as the "capture effect." The FM "capture effect" is the characteristic of an FM receiver which enables it to effectively discriminate against weaker, undesired extraneous signals. A stronger signal "takes over" when its magnitude is approximately 3 decibels greater than that of a weaker signal present at the input circuit of the receiver. At this signal difference level some crosstalk is evident, although it is manifested as merely a relatively low-level, unintelligible noise at the user's ear. As the difference between signal levels is further increased, however, the amount of crosstalk rapidly decreases.

This effect has been found to be especially useful for a closed-loop transmission system. For a typical adjacent room application, a signal difference level of at least 15 decibels exists provided there is no appreciable difference between the signal level of the transmitted signals for each individual room (i.e., the power delivered to loops in adjacent rooms must be equal). For such an adjacent room application, and with a sufficient signal level to provide good amplitude limiting in the receiver, a rejection of unwanted signals in excess of 30 decibels has been achieved. Moreover, in extreme situations where additional signal isolation is desired, the FM receiver may be designed to have a broader bandwidth than that of the transmitter so that adjacent rooms may employ carrier frequencies which are slightly staggered (e.g., one at 95 kHz. and the next at 105 kHz.), yet a receiver need not be retuned as a user transfers from one room to another.

The receiver for a limited-range, induction-coupled communication system constructed in accordance with one aspect of the invention may, as mentioned above, be a conventional FM receiver. Alternatively, and also mentioned above, it may be constructed in accordance with another aspect of the invention and take the form of the preferred embodiment shown in block diagram form within antenna 40 in the drawing. Such a receiver includes input circuit means 50 and 60 for receiving the carrier-wave signal transmitted by antenna 40. Circuits 50 and 60 are inductively responsive to the electromagnetic radiation field established by closed-loop antenna 40 to develop corresponding output signals respectively therefrom. These output signals are coupled through phase-shifting networks 55 and 65, respectively, and are then combined for application to amplifier 70 wherein the combined signal is amplified sufficiently to permit detection of the modulation signal. The modulation signal is recovered by the detector means including switching circuit 80, pulse clipper 90, and integrator 100. The output of the detector means is an audio signal which is representative of the transmitted audio information. It is amplified by audio amplifier 110 to provide a signal level sufficient to drive an earphone 120. The entire circuit requires relatively few additional components so that it may be conveniently incorporated with a conventional hearing aid without any appreciable increase in physical size. A simple switch may be provided for changing the operation from that of a standard hearing aid to that of a limited-range, induction-coupled communication system receiver. Of course, the FM receiver unit may also be made as a separate unit and then coupled to a regular hearing aid.

In accordance with this aspect of the invention, the input circuit means of the receiver comprises a plurality of input transducers for inductively coupling the transmitted signal to the receiver. In the preferred embodiment shown in the drawing, an identical pair of input circuits, 50 and 60, are provided, although various circuit modifications can of course be made to suit particular individual applications. The circuits include input transducers in the form of pickup coils 51 and 61 which may be respectively associated with capacitors 52 and 62 and resistors 53 and 63 as shown to form resonant circuits tuned to the frequency of the transmitted carrier-wave signal. Of course, the input transducers may be employed independently of resonant circuit means, depending upon design considerations. In some applications it may even be convenient and economical to utilize the telephone pickup coil of a conventional hearing aid as the input transducer.

Further in accordance with this aspect of the invention, the input transducers are preferably oriented at different angles relative to the direction of the electromagnetic radiation field established by closed-loop antenna 40. More specifically, pickup coils 51 and 61 may be mounted in the receiver such that their maximum-signal-coupling axes are oriented at a predetermined angle (e.g., 90°) relative to each other. As the receiver is moved in the plane of these axes (for example, when the receiver is embodied in a head-worn hearing aid and the wearer leans forward to read or write), the amount of signal coupling for each pickup coil varies. By mounting the two coils at right angles and combining their respective output signals, the amount of signal-coupling loss in one coil tends to be compensated by a corresponding amount of signal-coupling gain in the other coil. Thus, the total amount of signal is essentially constant.

There are, however, two situations for which the signal induced in coil 51 is equal in magnitude yet opposite in phase (polarity) from that induced in coil 61. Hence, a null condition results from the consequent signal cancellation. To overcome this, in accordance with this aspect of the invention, two phase-shifting networks 55 and 65 are respectively connected to the outputs of the input circuits 50 and 60. By making network 55 shift the phase of the output signal of circuit 50 by 45°, and by having network 65 shift the phase of the output signal of circuit 60 by 135°, the two output signals are maintained in a quadrature or near quadrature (see below) relationship; that is, they are 90° out of phase relative to each other. Thus, when combined with the physical angular orientation of the coils discussed above, there can never be a situation in which the summation of the two signals is zero; consequently, null conditions resulting from the user tilting his head forward or backward are eliminated and a relatively uniform amount of signal coupling is provided.

Of course, various modifications of the above concepts may be made to achieve substantially the same results, depending upon the particular design objective desired. One may even use a single pickup coil mounted at a given angle (e.g., 30° relative to the direction of the electromagnetic field) in order to effect an economical compromise. Alternatively, one may utilize a two-transducer embodiment yet, because a perfect quadrature relationship is not necessary for achieving satisfactory reception, a single phase-shifting network coupled to one of the input circuits may be employed, although it is much more desirable to use two phase-shifting networks (one for each input circuit) as shown in the drawing. For example, a 100kHz carrier may be employed using a deviation band of 75 to 125 kHz. Using two input circuits as shown in the drawing but only one phase-shifting network coupled to one input circuit (not shown) to provide a 90° phase difference at the center frequency results in an uneven amount of phase shift as the signal frequency varies from 75 kHz. to 125 kHz. Since only one output signal is phase shifted 90° and the other output signal is not shifted at all, and because the amount of phase shift varies with frequency, there is considerable distortion in the resulting combined signal because the amount of phase shift at 75 kHz. is quite different from that at 125 kHz. Using two phase-shifting networks, on the other hand, substantially eliminates this distortion because the amount of phase-shift variation due to frequency variation is approximately the same for each network. Thus, although the total phase shift with two such networks may vary from 90° at the center frequency to 80° at each end of the deviation band, the phase variation of the one network essentially matches that of the other network so that the combined signal has no appreciable phase distortion.

The detector circuitry in this receiver may be of the type employed in conventional FM receivers. It has been found preferable, however, to employ a switching circuit (such as a Schmitt trigger or a monostable multivibrator) in the detector means in order to enhance the detection of the FM signal by further rendering it immune to amplitude variations. With such a switching circuit, its output signal is a series of pulses

having a repetition rate that varies in accordance with the modulation signal portion of the received carrier signal. This output signal is therefore primarily a function of the number of times the leading and/or trailing portions of each cycle of the received FM signal go above or below a preset switching-voltage level, depending on the type of switching circuit employed. Thus, the detected modulation signal is essentially unaffected by the amplitude of the received FM signal so long as the amplitude is greater than the predetermined, relatively small threshold value required to exceed the switching-voltage level. The pulse clipper 90 provides additional amplitude limiting to further render the output signal of switching circuit 80 immune to amplitude variations and thereby fashion the signal into a series of pulses of uniform amplitude and duration. Detection is achieved by integrating these relatively uniform pulses with integrator 100 to recover the original audio signal for application to the audio amplifier 110 and earphone 120.

Another variation of the invention comprises a closed-loop communication system which includes a wireless microphone (not shown) for receiving an instructor's voice. The microphone may be coupled to a portable FM transmitter (not shown) worn by the instructor which transmits an FM carrier-wave signal of a given frequency (e.g., 50 kHz.) to the loop. A transponder (also not shown) is coupled to the loop and changes the frequency of the received carrier signal to a different frequency (e.g. 100 kHz.) which is transmitted to a receiver in the room.

Thus there has been shown a new and improved limited-range, induction-coupled communication system which is substantially immune to extraneous signals and provides uniform reception throughout the desired limited space. The circuit of the receiver is easily and efficiently adapted to a conventional transistorized hearing aid, thereby rendering it simple and economical to construct and easy to operate. The entire circuit may be transistorized to provide a relatively small package which may be incorporated with a conventional hearing aid without appreciably increasing the physical size thereof. Moreover, the disclosed invention lends itself to portable, battery-operated application inasmuch as it requires less power than a direct-audio loop communication system and it is not affected by signal overload. It has good noise immunity which renders it substantially free from the interfering signals created by the close proximity of fluorescent lights, radios, television, or electric motors.

While a particular embodiment of the invention has been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

1. S A limited-range, induction-coupled communication system for the wireless transmission of information to a receiver located within a predetermined limited space, comprising:

means for providing a carrier-wave signal having a predetermined center frequency and modulated with a signal representative of said information;

transmitter means including a closed-loop antenna for transmitting said carrier-wave signal to said space and establishing therein an electromagnetic radiation field having a predetermined direction;

input circuit means for receiving said carrier-wave signal, including a pair of input transducers each having a maximum-signal-coupling axis orthogonally oriented relative to each other, each said input transducer providing a separate output signal representative of said modulated carrier-wave signal;

phase-shifting networks respectively coupled to said input transducers and providing phase shifts of substantially 45° and 135° respectively for establishing a quadrature phase relation between said output signals;

means for combining said separate phase-shifted output signals;
 detector means responsive to said combined output signal for recovering said modulation signal;
 and output transducer means for converting said recovered modulation signal into output information corresponding to that transmitted

2. A receiver adaptable for use with a limited-range, induction-coupled communication system of the type including a transmitter employing a carrier-wave signal modulated with a signal representative of information for transmission to a predetermined limited space by establishing an electromagnetic field having a predetermined direction in said space, said receiver comprising:

input circuit means for receiving said modulated carrier-wave signal, including a pair of input transducers each

having a maximum-signal-coupling axis orthogonally oriented relative to each other, each said input transducer providing a separate output signal representative of said audio-modulated carrier-wave signal;

phase-shifting networks respectively coupled to said input transducers and providing phase shifts of substantially 45° and 135° respectively for establishing a quadrature phase relation between said output signals;

means for combining said separate phase-shifted output signals;

detector means responsive to said combined output signal for recovering said modulation signal;

and output transducer means for converting said recovered modulation signal into output information corresponding to that transmitted.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,601,550 Dated August 24, 1971

Inventor(s) John G. Spracklen

It is certified that error appears in the above-identified patent
and that said Letters Patent are hereby corrected as shown below:

In the claims, claim 2, column 8, line 4, delete
the word "audio-".

Signed and sealed this 28th day of March 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents