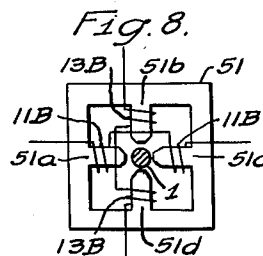
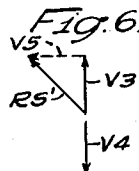
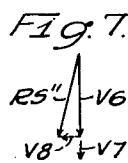
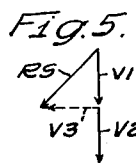
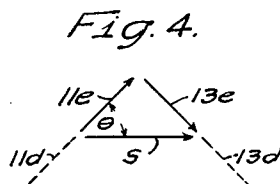
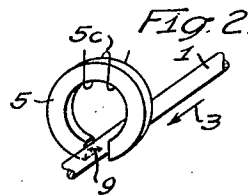
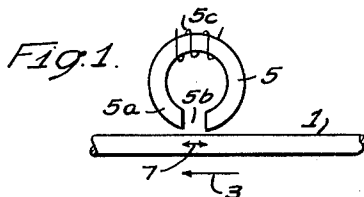
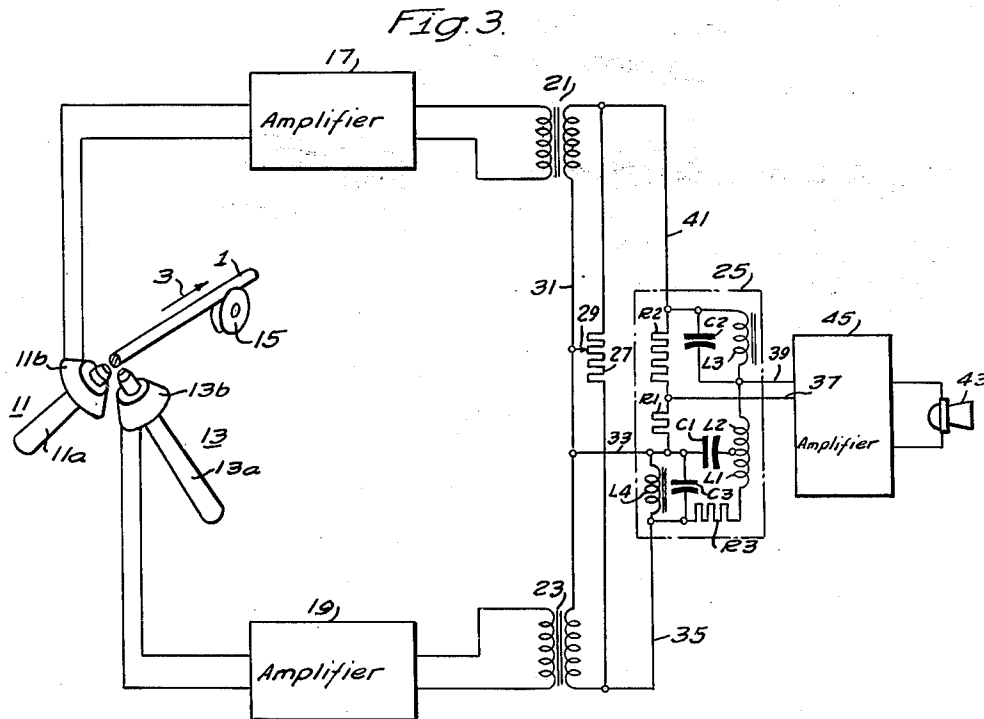


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 DEVICE FOR MINIMIZING THE EFFECTS OF TORSION
 WHEN REPRODUCING A MAGNETIC RECORD WIRE
 Filed April 29, 1948

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DEVICE FOR MINIMIZING THE EFFECTS OF
TORSION WHEN REPRODUCING A MAG-
NETIC RECORD WIREBernard E. Lenehan, Bloomfield, N. J., assignor
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This invention relates to the reproduction of signals and it has particular relation to the reproduction of a magnetic signal transversely disposed in an elongated magnetic member or wire.

In accordance with the invention, a pair of pickups is disposed adjacent a point on the path of travel of an elongated member having a signal transversely carried thereby. The elongated member may be in the form of a magnetic wire which is mounted for movement in the direction of its axis. The two pickups are disposed at an angle relative to each other about the axis of the wire. The signal components derived from the pickups are shifted in time phase relative to each other through an angle substantially equal to the space angle between the pickups, and the phase-shifted components are added to provide a resultant signal which is substantially independent of the orientation of the wire during its travel past the pickups.

It is, therefore, an object of the invention to provide an improved system for reproducing a transverse signal carried by an elongated member.

It is a further object of the invention to provide a system for reproducing a transverse signal carried by an elongated member mounted for movement in the direction of its length, wherein a pair of pickups is located adjacent the path of travel of the member and are angularly displaced about the path of travel to produce outputs or signal components in time phase with the signal but having magnitudes varying as functions of the orientation of the member with respect to the pickups and wherein a combiner is included for shifting the phases of the components relative to each other and adding the shifted components for producing a resultant signal for application to translating means having a magnitude which is substantially independent of the orientation of the elongated member.

It is a still further object of the invention to provide a combiner for two in-phase signal components having magnitudes which vary as functions of a variable angle, wherein a system is provided for changing the time phase of the signal components relative to each other and adding the resulting components to provide a resultant signal which is independent of the aforesaid angle.

It is also an object of the invention to provide an improved method for reproducing a transverse signal carried by an elongated member.

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Other objects of the invention will be apparent from the following description taken in conjunction with the accompanying drawing, in which:

5 Figure 1 is a view in side elevation with parts broken away of a prior art system for magnetically recording and reproducing signals,

10 Fig. 2 is a view in perspective with parts broken away showing a modified structure for magnetically recording and reproducing signals,

Fig. 3 is a schematic view with parts in perspective and parts broken away of a signal-reproducing system embodying the invention,

15 Figs. 4, 5, 6 and 7 are vector diagrams showing vector relationships present in the system of Fig. 3, and

Fig. 8 is a view in elevation of a modified pickup head which may be employed in the system of Fig. 3.

20 Referring to the drawing, Fig. 1 shows an elongated member 1 which is mounted for movement in the direction of its length, as shown by an arrow 3, past the poles of an electromagnet 5. The elongated member 1 may vary appreciably in composition and structure. It may take the form of a ribbon having a rectangular cross section. Alternatively the elongated member 1 may represent a round or oval wire. If desired, the member 1 may be constructed of a material or alloy having hard magnetic properties. Alternatively, the member 1 may have a non-magnetic core, such as a brass, paper or plastic core, which carries a layer or coating of hard magnetic material. Such members which are capable of receiving and storing a magnetic record are well known in the art.

25 The electromagnet 5 is illustrated as comprising a soft magnetic ring-shaped core 5a which has a gap 5b defining pole pieces located adjacent the path of travel of the member 1. A coil 5c surrounds a portion of the core 5a.

30 When an alternating signal which, for example, may represent speech, is applied to the coil 5c (a high-frequency alternating-current bias also may be simultaneously applied to the coil 5c in accordance with conventional practice), the member 1 in its travel past the electromagnet 5 is magnetized to store the signal therein. The direction of the magnetic field in the member 1 is substantially parallel to the axis of the member, as indicated by the arrows 7.

35 In order to reproduce the signal stored in the member 1, the member again may be guided in the same direction past the electromagnet 5. If the coil 5c is connected through a suitable am-

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plifier to translating means such as a loud speaker, the speech recorded in the wire is reproduced by the loud speaker.

It should be noted that the reproduction of the signal is independent of the orientation of the member 1 about its path of travel. Regardless of the rotation of the member 1 about its axis, the signal stored therein remains substantially parallel to the axis of the member. Consequently, the system of reproduction represented in Fig. 1 may be employed for substantially any shape in cross section of the member 1. It should be noted that the plane of the electromagnet 5 in Fig. 1 is parallel to the axis or path of travel of the member 1.

In Fig. 2, the member 1 is shown located between the pole faces of the electromagnet 5. The electromagnet 5 now is in a plane substantially transverse to the axis or length of the member 1. When a signal is applied to the coil 5c, a magnetic field as represented by the arrows 9 is produced in the magnetic member 1 which is substantially transverse to the axis or length of the member 1. Consequently, the signal may be said to be transversely stored in the magnetic member 1.

When the signal stored in the member 1 of Fig. 2 is to be reproduced, it again may be passed in the same direction represented by the arrow 3 between the pole faces of the electromagnet 5. If the orientation of the magnetic member 1 remains similar to that prevailing during the recording operation, a loud speaker connected through an amplifier to the coil 5c will reproduce the signal or speech stored in the member 1. However, if the orientation of the member 1 should change, the signal may not be satisfactorily reproduced.

Let it be assumed that during its travel between the pole faces of the electromagnet 5 during a reproducing operation, the member 1 together with the signals stored therein is rotated 90° from the position illustrated in Fig. 2. Under such circumstances, the direction of the arrows 9 which now represent the stored signal is parallel to the pole faces of the electromagnet 5 and the coil 5c is completely deenergized.

If the magnetic member 1 is a round wire such as the 4 mil or 6 mil wire commonly employed in magnetic sound recorders and reproducers, it is impracticable to maintain a desired orientation of the wire during its movement adjacent the associated pickup. For this reason when transverse recording and reproduction have been employed in the prior art in the manner discussed with reference to Fig. 2, it has been the practice to employ a magnetic member in a form of a tape or ribbon which can be maintained in the desired orientation during both recording and reproduction operations.

In accordance with the invention, a signal transversely disposed in the member 1 is satisfactorily reproduced. As shown in Fig. 3, a pair of pickups 11 and 13 is disclosed which include magnetic cores 11a and 13a having associated therewith, respectively, coils 11b and 13b. These pickups 11 and 13 are disposed adjacent a predetermined point in the path of travel of the member 1 but are displaced angularly relative to each other about the axis or path of travel of the member 1. Preferably, the angle of displacement is 90° but some variation in the angle is permissible with reasonably satisfactory results.

The pickups 11 and 13 may be similar to that illustrated in Fig. 2. However, in Fig. 3, the

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pickups 11 and 13 are shown having cores which are in the shape of rods extending from the member 1 for a distance sufficient that the magnetic fields adjacent the remote ends of the cores are substantially uniform. The pole faces of the cores adjacent the member 1 have a diameter or size which is dictated in part by the size or diameter of the magnetic member 1. When two cores are employed, as illustrated in Fig. 3, knots or splices in the member 1 pass readily thereover.

It will be understood that the member 1 in Fig. 3 is moved in the direction of its length or axis as represented by the arrow 3 at a uniform rate. Mechanism for this purpose is well known in the art and is represented in Fig. 3 by a capstan or pulley 15 which is rotated uniformly for the purpose of advancing the member 1. As one example of a prior art "wire" recorder reference may be made to Patent 2,351,005, issued June 13, 1944.

The voltages or signal components induced in the coils 11b and 13b depend on the orientation of the member 1 adjacent the pickups. Let it be assumed that the axes of the cores 11a and 13a fall along the lines 11d and 13d of Fig. 4. These lines are perpendicular to each other. Let the direction of the vector S in Fig. 4 represent at some instant the direction of magnetism of the signal stored in the member 1 at a point adjacent the pickups 11 and 13. In Fig. 4, this direction is such that the vector or signal S is displaced by a space angle θ from the line 11d. Under these circumstances the magnitudes of the components of the signal S effective for inducing voltages in the coils 11b and 13b may be represented by vectors 11e and 13e.

It should be understood clearly that the vectors 11e, 13e and S are all in time phase with each other. The vector diagram of Fig. 4 is a space diagram wherein the vectors indicate the direction in space of the signal S and the components 11e and 13e of the signal which are effective for inducing voltages in the pickup coils.

By inspection of Fig. 4, it will be observed that the magnitudes of the voltages induced in the coils 11b and 13b depend on the angle θ or on the orientation of the signal S with respect to the pickups. The vector 11e is equal to $S \cos \theta$ (or $S \cos \theta$), whereas the vector 13e is equal to $S \sin \theta$ (or $S \sin \theta$).

The sum of these two quantities ($S \cos \theta + S \sin \theta$), is dependent on the value of the angle θ . Consequently, the resultant signal obtained by the direct addition of the outputs of the pickup coils 11b and 13b would not provide a directly useful resultant signal representative of the signal stored in the member 1. Such a resultant signal would have a magnitude which varies with the orientation of the member 1 about its axis or path of travel adjacent the pickups.

In order to obtain a directly useful resultant signal, one of the signal components from the pickups is shifted in time phase relative to the remaining signal component through an angle substantially equal to the space angle between the pickups. To this end, the signal components derived from the pickup coils 11b and 13b are applied, respectively, through amplifiers 17 and 19 and transformers 21 and 23 to a combiner 25. In order to facilitate adjustment of the balance between the signal components applied to the combiner, the secondary windings of the transformers 21 and 23 may be connected in series across a resistor 27. This resistor has an adjustable tap 29 connected to the common lead

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31 extending between terminals of the secondary windings. By manipulation of the tap 29 the proportion of the resistor 27 connected across each of the secondary windings may be adjusted for the best condition of balance.

The outputs of the transformers 21 and 23 comprise two signal components which are always in time phase agreement or time phase opposition. However, the magnitudes of these components are dependent on the orientation of the member 1 about its axis or path of travel adjacent the pickups 11 and 13.

The output of the transformer 21 is connected across a resistor R1 which may have a resistor R2 connected in series therewith. The voltage drop across the resistor R1 is in phase with the current traversing the resistor and with the voltage across the secondary winding of the transformer 21.

The desired phase shift is effected by shifting the phase of the output of the transformer 23 through an angle of substantially 90°. To this end a series circuit is connected across the secondary winding of the transformer 23 through conductors 33 and 35 which includes a capacitor C1. It will be understood that the voltage across the capacitor lags the current therethrough by an angle of 90°. However, this voltage has a magnitude which is dependent on frequency. If a signal of only one frequency were stored in the member 1, the capacitor C1 alone might suffice in the combiner to produce the desired phase shift. However, in order to permit utilization of the combiner with signals having a substantial range of frequency, such as a range suitable for speech, an inductance coil L1 is connected in the series circuit including the capacitor C1. Further improvement may be obtained by including a resistor R3 in this series circuit.

The inductance coil L1 has mutually coupled thereto a second inductance coil L2. The inductance coil L2 is connected in series with the capacitor C1 and the resistor R1 across the output conductors 37 and 39 of the combiner.

The coil L2 has induced therein a voltage which is substantially in phase with the voltage across the capacitor C1 but which varies oppositely in magnitude in response to a change in frequency of the input to the combiner. Consequently, the magnitude of the resultant output of the capacitor C1 and the inductance coil L2 in series may be made substantially independent of frequency over a substantial range.

Conveniently, the capacitor C1 and the inductance introduced by the coil L1 across the secondary winding of the transformer 23 may be resonated to a frequency which is substantially the geometric mean of the frequency range for which the combiner is designed. As the frequency deviates from the geometric mean, the magnitude of the voltage output of the capacitor C1 and the inductance coil L2 in series may change somewhat. If this change is objectionable, it may be substantially eliminated over the desired range by means of a parallel resonant circuit comprising a capacitor C2 and an inductance coil L3. This parallel resonant circuit is connected between the conductor 39 and the conductor 41 which extends from the upper terminals of the resistor R2 to the upper terminal of the secondary winding of the transformer 21 as viewed in Fig. 3. The parallel resonant circuit is resonated to a frequency which is substantially the geometric means of the frequency range for which the combiner is designed. Consequently,

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ly, at this frequency the parallel resonant circuit draws substantially no current. As the frequency deviates from the geometric mean the parallel resonant circuit draws current through the capacitor C1 and the inductance coil L2 to produce an auxiliary voltage drop which compensates for the variation in magnitude which otherwise would result from a change in frequency.

It will be noted that the resistors R2 and R3 substantially balance the input circuits to the combiner from the standpoint of resistance. A substantially complete balance may be and preferably is provided by including a parallel resonant circuit comprising a capacitor C3 and an inductance coil L4 connected across the secondary winding of the transformer 23. The two parallel resonant circuits may be of similar construction.

As representative of suitable values for the components of the combiner, the following values have been found suitable for a combiner designed for a frequency range of 150 to 4000 cycles per second. This is adequate for transmission of speech signals.

R1=428 ohms
R2=4000 ohms
R3=4000 ohms
C1=1 microfarad
C2=.0067 microfarad
C3=.0067 microfarad
L1=.040 henry
L2=.040 henry
L3=6 henries
L4=6 henries

Mutual inductance between coils L1 and L2=.04 henries. The coils may have a Q of 18 measured at 1000 cycles per second.

The output conductors 37 and 39 of the combiner may be connected to suitable translating means 43, the type of which depends on the nature of the signal stored in the member 1. If the signal stored in the member 1 represents speech, the translating device 43 may be a transducer such as a loud speaker which is connected to the output of a suitable amplifier 45. The input to the amplifier is derived from the conductors 37 and 39.

The operation of the combiner may be considered by assuming first that an alternating signal stored in the member 1 is represented by the conventional expression $A \sin \omega t$ wherein A is a constant, ω is the frequency of the signal multiplied by 2π , and t represents time.

It will be recalled that the outputs of the pickup coils 11b and 13b are related to the stored signal in accordance with the expressions $\cos \theta$ and $\sin \theta$. Consequently, it may be assumed for the purpose of discussion that the voltage applied across the resistor R1 of the combiner is represented by the expression $A \cos \theta \sin \omega t$. It may be assumed further that the voltage applied across the capacitor C1 and the coil L1 in series is represented by the expression $A \sin \theta \sin \omega t$. The sum of these two expressions would give a signal

$$S' = A \cos \theta \sin \omega t + A \sin \theta \sin \omega t \quad (1)$$

By inspection of the equation it will be observed that the signal S' is dependent in magnitude on the angle θ or on the orientation of the member 1. In order to make the magnitude of the signal independent of the angle θ , the last term of Equation 1 is rotated in time phase through an angle substantially equal to the angle between

the pickups or 90°. This is effected by employing the voltage across the capacitor C1 and the coil L2 in series which under the assumed conditions has a value equal to $A \sin \theta \cos \omega t$. Consequently, the sum of the voltages across the resistor R1, the capacitor C1 and the coil L2 which is applied across the conductors 37 and 39 represents a resultant signal

$$RS = A \cos \theta \sin \omega t + A \sin \theta \cos \omega t = A \sin (\omega t + \theta) \quad (2)$$

Inspection reveals that the magnitude of the resultant signal RS is independent of the angle θ or the orientation of the member 1. The effect of the angle θ is to control the phase of the signal. Changes in the orientation of the member 1 under the usual conditions encountered in recorders and reproducers occur very slowly. Consequently, changes in phase represented by the angle θ in Equation 2 have substantially no effect on the output of the transducer 43.

The operation of the combiner also may be considered with reference to Figs. 5, 6 and 7. Let it be assumed first in Fig. 5 that the orientation of the member 1 is such that the secondary voltages of the transformers 21 and 23 are represented by two vectors V1 and V2 which are in time phase agreement and which are equal in magnitude. The effect of the combiner is to shift the phase of the vector V2 through an angle of 90° to provide a vector V3 which is added vectorially to the vector V1 to provide the resultant signal RS.

In Fig. 6 it is assumed that the orientation of the member 1 carrying the same signal is such that the outputs of the transformers 21 and 23 are represented by the vectors V3 and V4 which are equal in magnitude but opposed in time phase. The combiner again shifts the phase of the vector V4 through an angle of 90° to provide a vector V5 which is added vectorially to the vector V3 to provide the resultant signal RS'.

Finally, in Fig. 7 the orientation of the member 1 carrying the same signal is assumed to be such that the outputs of the transformer 21 and 23 are represented by the vectors V6 and V7 which are in time phase agreement but which are substantially different in magnitude. The combiner shifts the phase of the vector V7 to provide a vector V8 lagging the vector V7 by 90°. The vectors V6 and V8 add vectorially to provide the resultant signal RS''.

All of the resultant signals RS, RS' and RS'' are equal in magnitude but displaced in time phase from each other. Since the transducer is responsive substantially only to the magnitude of the resultant signal, the orientation of the member 1 has substantially no effect on the output of the transducer. As previously pointed out, the changes in phase encountered in conventional recorder and reproducer magnetic members is extremely gradual and slow.

The pickups 11 and 13 may be replaced by other pickups which are displaced in phase 90° about the axis or path of travel of the member 1. For example, in Fig. 8 a pickup structure is disclosed which includes a continuous annular or rectangular perimetric portion 51. The perimetric portion has four pole pieces 51a, 51b, 51c and 51d projecting inwardly to establish a central gap through which the member 1 may be guided. The aligned pole pieces 51a and 51c have windings 11B thereabout which are connected in series to replace the pickup coil 11b of Fig. 3. The remaining pole pieces have windings

13B connected in series to replace the pickup coil 13b of Fig. 3. In order to permit passage of knots or splices in the member 1, two of the pole pieces 51a and 51b may be made shorter than the remaining pole pieces. It will be understood that the pole pieces and the perimetric portion 51 all are constructed of a soft magnetic material such as soft iron.

Although the invention has been described with reference to certain specific embodiments thereof, numerous modifications falling within the spirit and scope of the invention are possible.

I claim as my invention:

1. In a system for reproducing an alternating signal having maximum and minimum frequencies which define a frequency range from an elongated magnetic movable member which is transversely magnetizable along its length to thereby produce a recording in accordance with the signal, means for guiding the magnetic movable member in the direction of its length along a predetermined path, said member being subject to rotational movement while influenced by said guiding means, a pair of pickup elements adjacent a predetermined point on the path, said pickup elements being angularly spaced about the path to pickup signal components which vary in magnitude as a function of the rotational orientation of the transverse magnetization of the member, and which have frequencies substantially equal to the signal frequencies, and combining means having terminals for receiving two inputs, said combining means including phase-shifting means for shifting the phase of one of the inputs relative to the other of the inputs by an angle substantially equal to the angular spacing of the pickup elements, means including connections for supplying the two signal components respectively from said pickup elements as inputs to the combining means, said phase shifting means comprising a resistor connected to receive a first one of said inputs, a capacitor and a first coil connected in a series circuit for energization in accordance with a second one of said inputs, and a second coil mutually coupled to said first coil, translating means, and connections to said translating means for energizing the translating means in accordance with the voltage across said resistor, said capacitor and said second coil in series.

2. A system as claimed in claim 1, wherein the capacitance value of said capacitor and the inductance value introduced by said first coil are chosen to be substantially resonant at a frequency which is substantially the geometric mean of the frequency range represented by said maximum and minimum frequencies.

3. A system as claimed in claim 1, in combination with a second resistor, and a parallel resonant circuit connected through said second resistor across the first-named resistor, the capacitor and the second coil, said parallel resonant circuit being substantially resonant to the geometric mean of the frequency range represented by said maximum and minimum frequencies.

4. A system as claimed in claim 1, in combination with balancing means including resonant circuits for substantially balancing the impedances of the circuits energized by said inputs relative to said terminals for receiving the inputs.

5. A system as claimed in claim 1, wherein said series circuit includes a resistor in series with said capacitor and said first coil.

6. In a system for reproducing an alternating

signal having maximum and minimum frequencies which define a frequency range from an elongated magnetic movable member which is adapted to be transversely magnetized along its length in accordance with said signal, means for guiding the magnetic movable member in the direction of its length along a predetermined path, said guiding means allowing rotational movement of said member, a pair of pickup elements adjacent a predetermined point on the path, said pickup elements being angularly spaced about the path to pick up respective signal components which vary in magnitude as a function of the rotational orientation of the transverse magnetization of the member, and which have frequencies substantially equal to the signal frequencies, and combining means having terminals for receiving first and second inputs, connections for supplying the two signal components respectively as said first and second inputs, said combining means including means for directly shifting the phase of said first input to produce a first output shifted in phase relative to the first input by an angle substantially equal to the angular spacing of the

pickup elements, said second input providing a second output substantially in phase agreement with the second input, and adding means for adding said outputs to provide a resultant output having substantially the same frequencies as the inputs, and translating means responsive to the resultant output of said combining means, said frequency range being sufficient in scope for the transmission of intelligible speech.

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