E. GRISSINGER.

SPEECH TRANSMITTING MECHANISM.

APPLICATION FILED SEPT. 17, 1914.

1,205,618.

Patented Nov. 21, 1916.

2 SHEETS—SHEET 1.

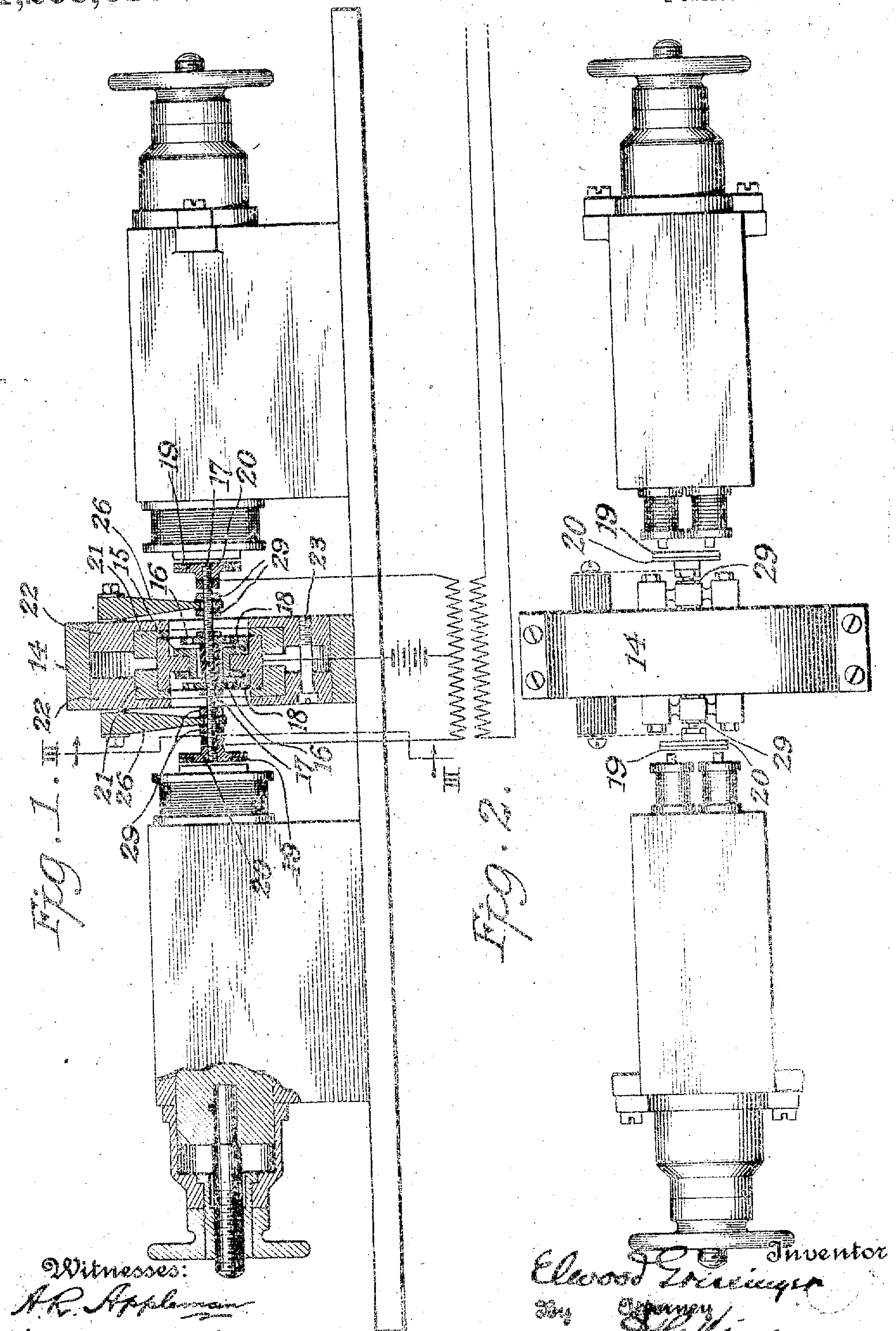

Fig. 1.

Fig. 2.

Witnesses:

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Inventor

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By Attorney

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Fig. 3.

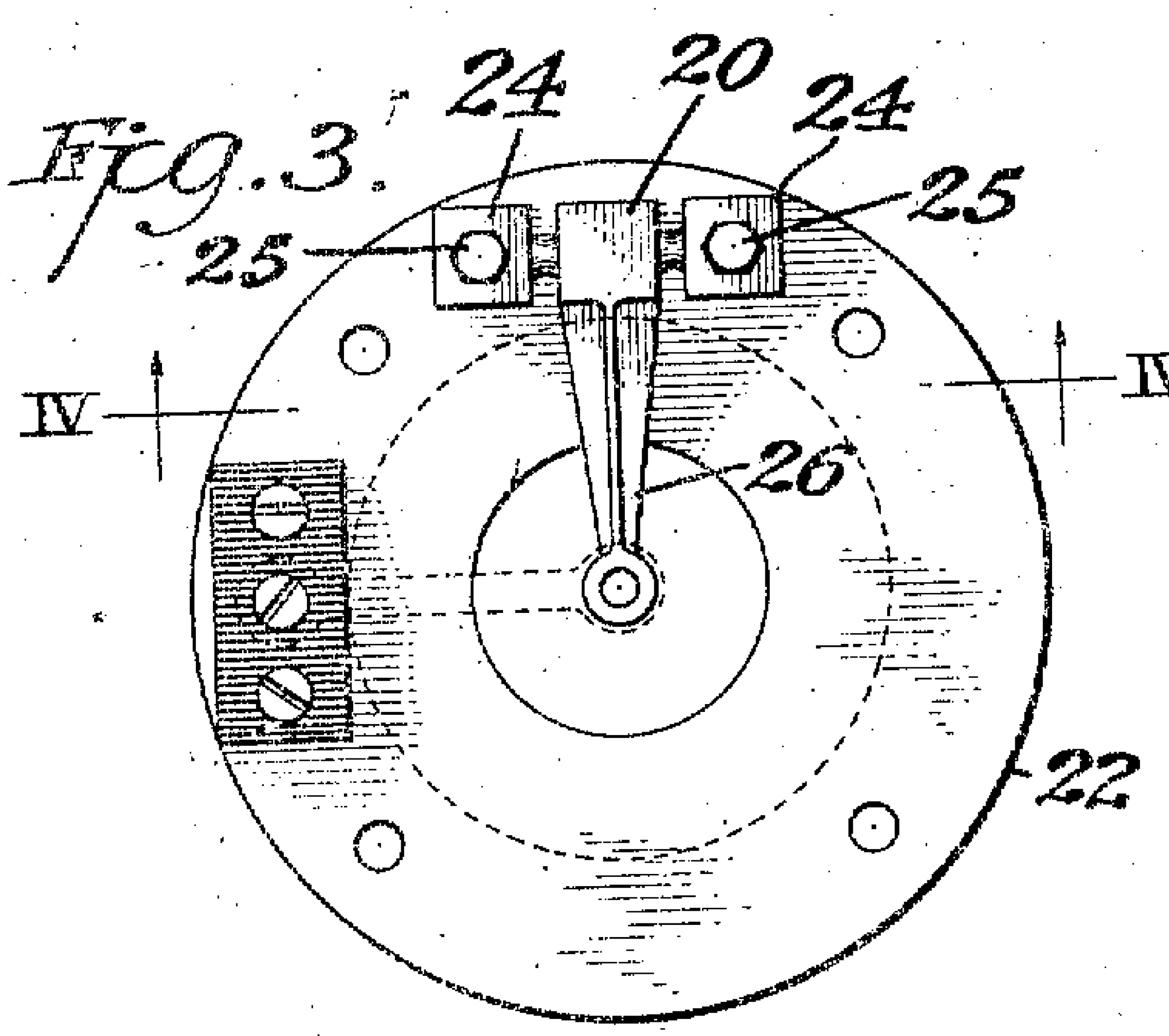
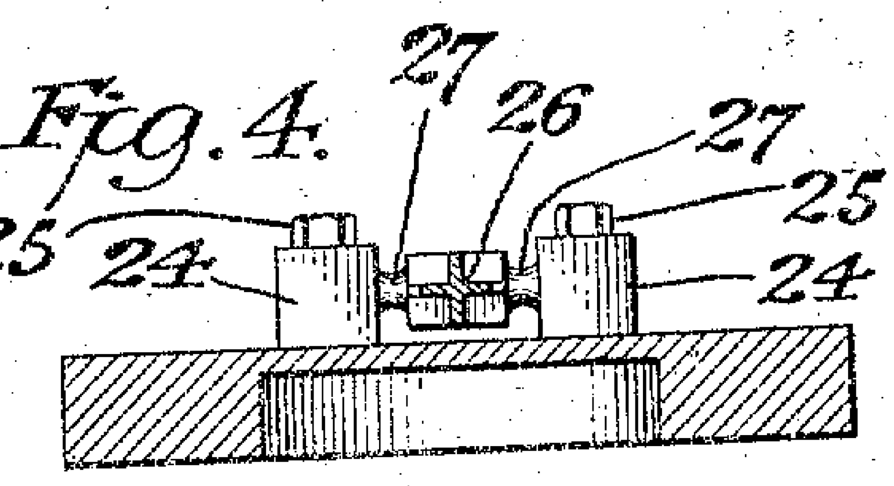


Fig. 4.



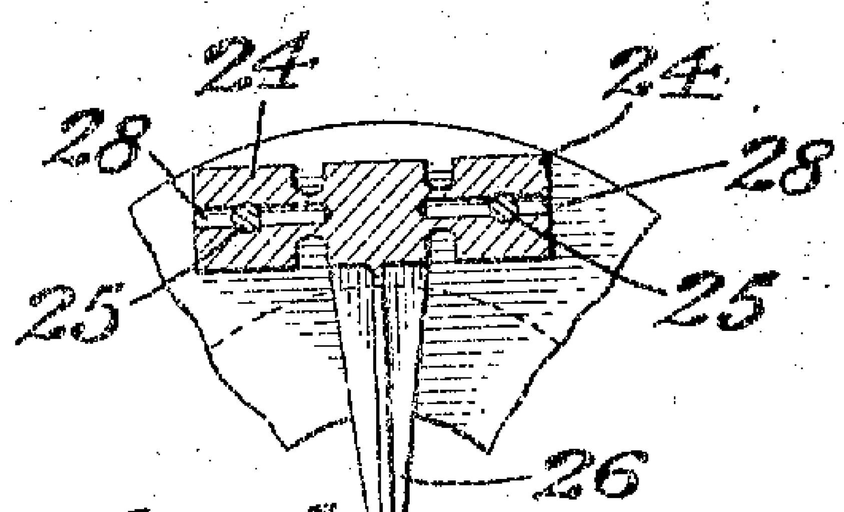


Fig. 5.

Fig. 8.

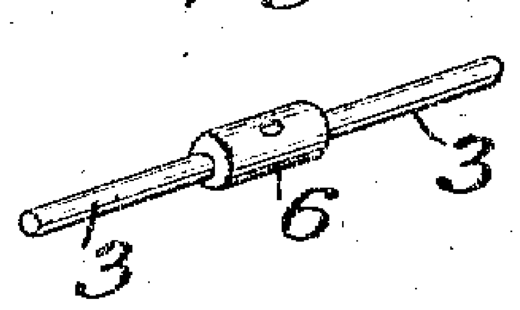
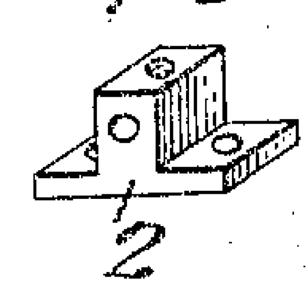


Fig. 9.



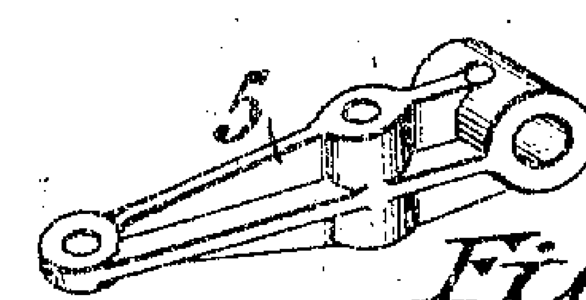


Fig. 10.

Fig. 6.

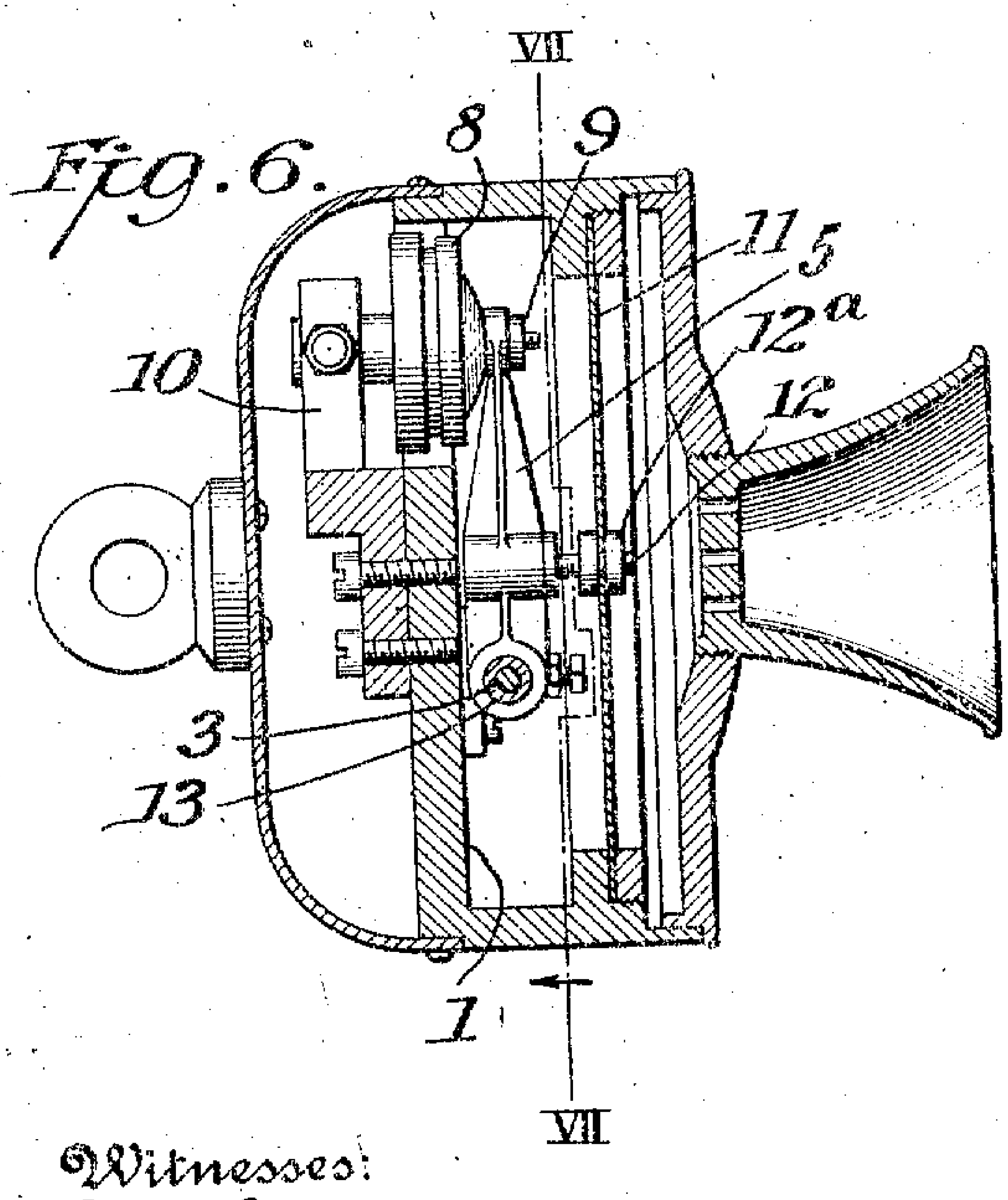
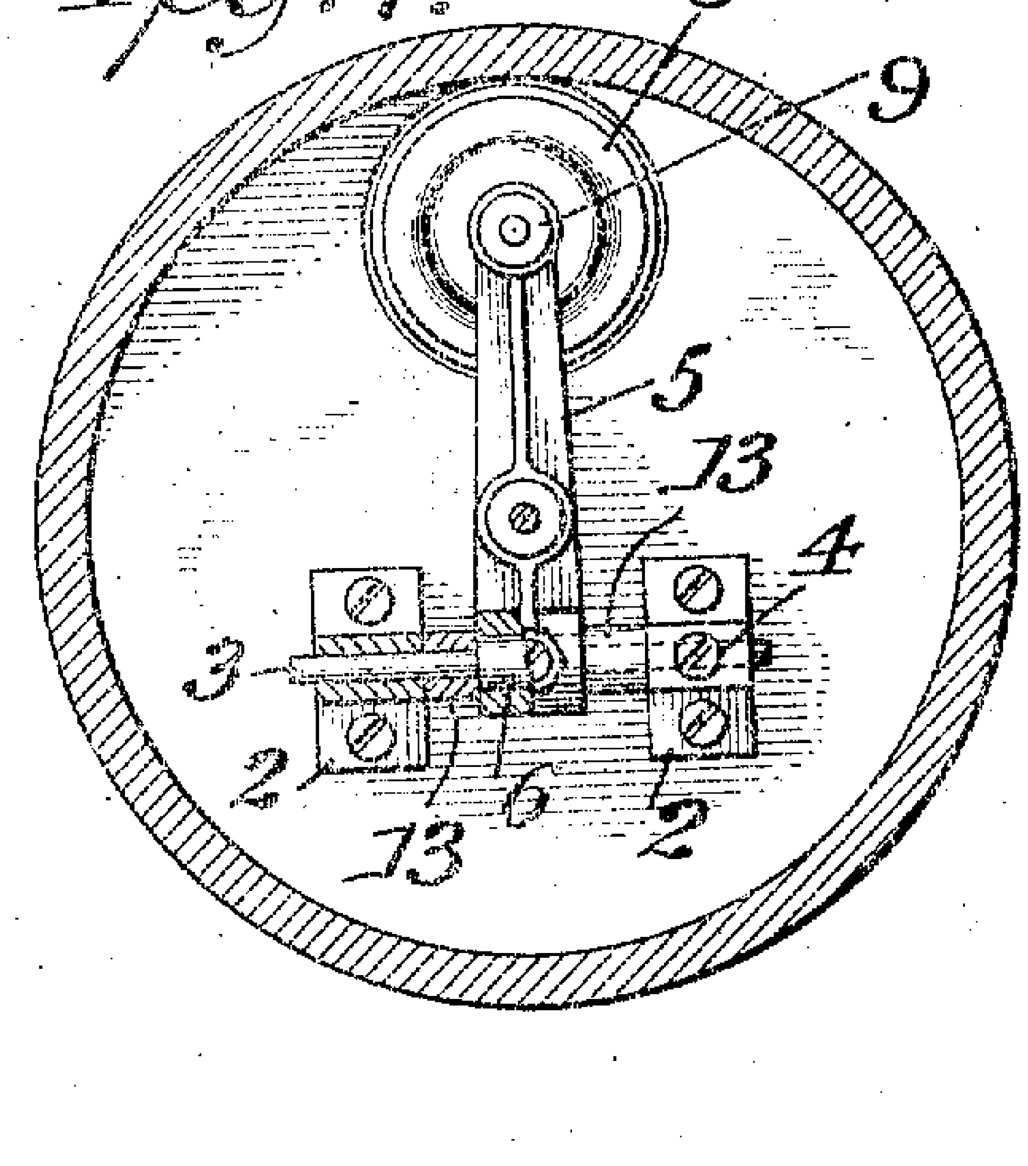


Fig. 7.



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Inventor
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W. E. Newman

UNITED STATES PATENT OFFICE.

ELWOOD GRISSINGER, OF BUFFALO, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

SPEECH-TRANSMITTING MECHANISM.

1,205,618. Specification of Letters Patent. **Patented Nov. 21, 1916.**

Application filed September 17, 1914. Serial No. 862,132.

To all whom it may concern:

Be it known that I, ELWOOD GRISSINGER, a citizen of the United States, residing at Buffalo, Erie county, and State of New York, have invented the following described Improvements in Speech-Transmitting Mechanism.

The invention is an improvement in means for faithfully reproducing as mechanical vibrations, the complex frequency wave forms such as are characteristic of human voice waves, and is particularly applicable to telephonic transmission of speech.

By my present invention, the resilience of a torsional pivot is applied through a lever element, to impart a high natural frequency or pitch to the vibratory system of the mechanism, such as will avoid the necessity of vibration at said natural frequency and thereby substantially eliminate all distorting effects such as are now commonly produced by mechanical resonance of such devices or their mechanical elements.

An important feature of my invention is the discovery that it is possible to thus eliminate mechanical vibration at the natural frequency, without making the natural frequency above the limit of audibility nor anywhere near that high; nor need it even be above the limit of frequencies important to human speech, provided the frequencies selected be substantially above the highest resonant frequencies of the vowel sounds. In fact, one very practical embodiment of my invention, involves selecting a natural frequency slightly but substantially above the highest resonant frequency of the vowel sounds. Such a device, while never effectively excited at its natural frequency, can be designed to cause a slight magnification of the higher vowel frequencies which will be progressively greater as the frequencies are higher and hence nearer the resonant frequency. Such magnification is admirably adapted for correcting the distortion due to capacity in long transmission lines, which, as is well known, operates to attenuate the higher frequencies more rapidly than the lower frequencies. In other words, while avoiding the distortion which results where the natural frequency of mechanical vibration is the same as a prominent human voice frequency, I may, in certain cases, utilize the graduated magnifying effect of approaching, though still substantially distant, mechanical resonance, to mechanically compensate for the reversely graduated, losses due to the electrical defects of the line.

In order that the invention may be fully comprehended in its relation to apparatus of the prior art, it will be useful to explain certain of the conditions affecting the transmission of speech by means of telephonic and mechanical instrumentalities.

The sound waves of speech are very complex. Their frequencies vary from somewhat below 150 periods per second to somewhat above 2000 periods per second, with corresponding variations in amplitude. There are eight fundamental vowel sounds which are represented by the words bee, gloom, pit, no, pet, raw, mat, father, and which comprise the entire range of the essential sounds of articulate speech. Harmonic analysis of the waves of vowel sounds shows that for each vowel sound, there is a fundamental frequency which controls the pitch. Superposed upon this fundamental are a number of overtones or harmonics, and these control the quality. At the same time, between the fundamental and the highest observable harmonic, there is found a point on the scale of frequencies, where the intensity of the sound is very much greater than at any other point on the scale of frequencies. This point may be termed a point or region of resonance. There is thus a resonance region for each vowel, which is probably due to the shape of the mouth cavity through which the sound passes.

I have ascertained that the regions of resonance of the different vowel sounds occur respectively at different points on the scale of frequencies and that the region of resonance of the same vowel sound is found at approximately the same point on the scale of frequencies irrespective of the individual uttering the sound, whether it be a man, woman or child. The fundamental of a particular vowel sound spoken by a man of low pitch voice may be found at 125 periods per second and the region of resonance of that vowel sound is about 900 P. P. S., or about the 7th harmonic. The fundamental of the same vowel sound spoken by a woman may be found at 250 and the region of resonance will again be found at about 900 periods per second or between the 3rd and 4th harmonic. The region of resonance of a vowel sound is that region on the scale of frequencies where is found that part of the composite sound which is of the greatest intensity, and it is hence the principal factor in speech transmission. It cannot be said, as some may have thought, that the important frequencies of speech transmission are represented by any particular harmonic, because, as stated above, the fundamental of a particular vowel sound may be found at various different points for different speakers and the harmonics accordingly, while the region of resonance of that vowel sound will always be found at about the same point on the scale. Finally, I have ascertained that the lowest region of resonance of any vowel sound is at about 250 P. P. S., and the highest region of resonance of any vowel sound at about 1000 P. P. S., and that if an instrument for transmitting or translating speech waves be so constructed or modified as to possess a natural frequency which is very high and at or somewhat above the maximum of this range, it will transmit or translate the waves without distortion, and I have disclosed and claimed such an instrument in pending applications filed by me on April 27th, 1910, Serial No. 558,045, and May 19th, 1911, Serial No. 628,148, respectively.

When distortion of a sound wave is referred to, it is intended to mean that the attempted reproduction of such wave has resulted in the reproduction of different pitched tones in different degrees of loudness, assuming the initial loudness of each tone to be the same. An instrument having a high natural frequency is one in which the frequency of the whole vibrating system when struck or set in motion and allowed to vibrate freely by itself, is high, which qualification is suitably met in a telephone repeater when the fundamental frequency of the vibratory element is about 1000 P. P. S.; for transmitters of telephones it should be about the same, but it is of no consequence if higher, except that the higher frequencies are more difficultly obtained and preserved. To meet this requirement the mass or inertia of the vibrating system may be reduced or the stiffness increased, or both. Variations in the inertia of the movable system or of the stiffness (elasticity) of the parts comprising the movable system, will cause corresponding variations in the sensitiveness of the device. The sensitiveness with which any vibrating system responds to a given exciting force is greater, the smaller its mass or inertia and the less the stiffness (elasticity), and it is therefore desirable to obtain the required high fundamental frequency for the vibrating system by reducing its mass rather than increasing its stiffness, the elimination of distortion being the prime object, but the reduction of the mass is of course limited by the practical necessities of construction requiring simplicity and permanency of adjustment.

In the accompanying drawings forming part hereof, I have illustrated the application of a member subject to torsion as a means of imparting a high natural frequency to vibratory systems, which without it would have a frequency so low as seriously to distort the transmitted waves.

Figure 1 illustrates the use of such torsion members on a repeater of the kind referred to in the applications above mentioned, the parts not directly related to the vibratory system being indicated more or less conventionally; Fig. 2 is a top plan of the parts of Fig. 1; Fig. 3 is a section on line III—III of Fig. 1; Fig. 4 is a section on line IV—IV of Fig. 3; Fig. 5 a longitudinal section through the torsion member; Fig. 6 illustrates the application of a torsion member to an ordinary speaking transmitter, the parts being shown in section; Fig. 7 is a section of Fig. 1 on line VII—VII of Fig. 6; Fig. 8 is a perspective detail of the form of torsion member shown in Figs. 6 and 7; Figs. 9 and 10 are details of the lever and the bracket as used in Figs. 6 and 7.

Referring first to the simpler structure—the transmitter—as shown in Fig. 6, etc., the chambered base 1 of the transmitter carries a pair of brackets 2 (Fig. 9) which are securely screwed to it with their sockets in alinement. The rod 3 is fitted snugly into the sockets of these brackets and is secured therein by screws 4. Between the brackets the rod supports an arm or lever 5, for which purpose it is enlarged at its center, as indicated at 6 in Fig. 8, and the hub of the lever fits the enlargement tightly and is secured fast thereon by a set screw or otherwise. The attachment of the parts mentioned is secure against any possible turning of the lever on the bracket-supported rod. The lever 5 is connected at its other end with a movable electrode of a microphone cell 8 of any suitable type, but preferably having a movable electrode of extremely light mass so as to be as sensitive as possible. The movable electrode is connected to the lever, firmly, by clamping the latter to it with the nut 9. The stationary part of the cell is held by a bracket 10 screwed to the back of the base or frame, the cell itself being conveniently disposed in an aperture in such frame. Intermediate of its ends the lever 5 is connected with the diaphragm 11 of the transmitter, such connection also being a firm one such as can be had by means of the stem 12 screwed and locked to the lever and clamped to the diaphragm by a pair of nuts 12ª or otherwise. The diaphragm is clamped to the frame by a ring-nut and is inclosed and protected by a cover bearing the mouth-piece of the transmitter, but it might be supported solely by the lever if preferred. The rear of the frame is also closed by a casing with a hinge lug by means of which the whole device may be mounted on an appropriate stand or support.

The rod 3 is the torsion member, held securely at both ends in the brackets 2, and the vibratory movement of its lever arm takes place about the axis of such rod as a center and against the said member's elastic resistance to torsional displacement, that is to say, the lever arm can be moved only by slightly twisting the two short sections of the rod which intervene between the proximate faces of the brackets and lever hub portion. The construction of the member is desirably such that only the part of the rod intermediate the brackets is subject to torsion, and various different means may be employed to this end. Depending upon the material of which the rod is made, its diameter and the amount of length subject to torsion may be greater or less, but for hardened steel, which may be assumed to be the material of the rod 3, the proportions shown are about correct, and its elastic characteristics under torsional vibration are such that the whole vibratory system of the transmitter, including diaphragm, and the moving parts of the microphone cell, is thereby raised in pitch to a high natural frequency equal to or above the highest resonance period of vowel sounds. Such system transmits the voice waves, or translates them into electrical waves, without observable distortion. The natural frequency of the torsional part or parts of the rod alone, vibrating torsionally, is of course extremely high and much higher than that of the rest of the system taken alone, that is to say, of the diaphragm itself and its connections with the cell, which would have a very low natural period, but when the high torsional frequency is applied to the other parts it produces a resultant frequency sufficiently high to give the results above explained and notwithstanding the mass and inertia of diaphragm. In order that the torsion rod shall not vibrate by lateral bending, both of its ends are supported in the brackets as above described, and, further, to guard against bending, the sleeves 13 are fitted snugly thereon between the proximate perpendicular faces of the brackets and lever hub, but not so as to restrict the torsion which takes place within them. The lever arm 5, although appearing large in proportion to the rod, is nevertheless of very slight mass, being made of aluminum or an alloy of aluminum and formed with thin deep ribs which make it substantially rigid and non-flexing to forces of any magnitude likely to occur in instruments of this kind. I prefer to make the lever out of the common aluminum alloy known as duro-aluminum, inasmuch as that particular composition affords substantially the stiffness of hardened steel but without the weight.

In the form shown, the lever is of the second class, the actuating force being applied between the rod fulcrum or axis and the microphone connection, which gives some magnification of the amplitude of the motion, but it will be evident that it might be a lever of any class and arranged to give any degree of amplification or none at all, according to circumstances and as will now be evident. Such a lever and torsion member may be applied to eliminate distortion in various different kinds of apparatus and to other devices operated by oscillating energy represented by speech or sound, provided only that the torsional frequency is selected to give the whole vibratory system of the device the desired natural frequency of about 1000 P. P. S., as above explained. It is preferable that such system will, itself, have but a single resonance period below 2000 P. P. S. I have applied such a torsion member in this way to the vibratory system of a recording phonograph with marked improvement in the result.

Each of the above described mechanical details is of importance because of the well known, but none the less phenomenal sensitiveness of the microphone cells, diaphragms, and the human ear in connection with which they are used. In such connection, there is special significance in the light but wonderfully rigid lever construction as well as the absolute fixity of the axis of vibration of the lever and of the arc of vibration of the free-end thereof, all insuring a perfect single natural vibratory period, the frequency of which may be easily made as high as desirable in practice, without unduly shortening the amplitude of the vibration, or sacrificing sensitiveness and efficiency of functioning of the device for its ultimate purpose.

The advantages of the construction will be evident when contrasted with the present commercial telephone instruments. In these, it has been found wholly impractical to use levers of any kind and even the simple diaphragm instruments that are used, have at least one and sometimes two regions of pronounced mechanical resonance within the range of frequencies characterizing the strong vowel sounds.

While my invention is a great practical improvement in such devices, it is a still greater improvement as applied to telephone repeaters wherein the slightest internal causes of distortion are far more fatal than in transmitters or receivers.

Figs. 1 to 5 illustrate the application of a preferred form of torsion member to a telephone repeater. The repeater structure includes a transmitter mechanism, as above described, and comprises a relatively massive base of nonmagnetic material with a substantial frame 14 secured thereon and supporting a double-acting microphone cell. The latter comprises a central fixed electrode 15 and two opposite movable electrodes 16, both electro-plated with platinum and provided with holes in their faces and having the space between them partly filled with granular carbon. The movable electrodes are mechanically connected by a central stem 17 passing through a hole in the fixed electrode and through the granule-containing chamber, but are insulated from each other by an interposed insulating section which forms a positive mechanical connection between the two end portions of the stem. The stem and movable electrodes are insulated from the casing by means of the thin septum walls 18 to which they are clamped by means of nuts threaded on the rod. These walls may be of thin insulating or flexible material, mica, for instance, and the stem is threaded so that the electrodes may be clamped thereon as indicated. The ends of the stems each carry an armature 19, which is also light in weight, and in front of each armature there is mounted an electro-magnet the magnetic field whereof is controlled by the telephonic current fluctuations to be repeated. The coils of these magnets are connected in multiple with the sending line, but in opposite directions, so that a current wave tending to increase the magnetic field of one magnet will diminish that of the other, and vice versa. The two halves of the double microphone cell are connected in the halves or branches of the differential primary circuit of an induction coil, the secondary whereof is connected with the outgoing line, as shown in the diagram. In order to reduce the weight of the vibratory system toward or to the absolute minimum requisite for a maximum efficiency, the armature 19 is formed as a ring seated in a circumferential rabbet groove in a backing 20 which may be made of aluminum and is preferably of the duro-aluminum alloy above referred to. The mass of iron in the ring 19 is sufficient only to respond with requisite force to the magnetic fluctuation of the electro-magnets, and its support or backing 20 is extremely light, so that the inertia of the parts is thus very low.

The septum walls 18 are clamped against the ends of the granule chamber by means of a pair of rabbeted rings 21, and the latter are clamped between two similar but larger rings 22 which are screwed together by means of a set of bolts, one of which appears at 23. The rings 22 form the support or rigid base for the torsionally vibrating members of this form of the invention. As shown more clearly in Figs. 3 to 5, the torsion member consists of a single piece or block formed with squared ends 24, by means of which it may be secured directly to the face of the ring. Two relatively heavy bolts 25, one passing through each squared end and screwed tightly into the ring, serve this purpose. Between the squared ends the block or piece is formed with relative enlargement for connection to the lever arm 26, such enlargement representing the hub of the lever but being in fact an integral part of the torsion member. Between the lever hub and the squared attachment ends, the member is reduced in diameter so as to form two, short, taper-curved posts 27, the cross sectional area of which is further reduced by boring the member longitudinally from each end into and through the posts, as indicated at 28 in Fig. 5. The two posts are thus tubular in cross section and their cross-sectional area is such, vibrating torsionally, as will cause the lever arm to have a natural frequency of vibration which is very high, high enough so that when the other parts of the vibratory system are connected to it, the whole will have the high frequency above referred to. By making the torsionally vibratory post portions tubular, they may be of somewhat larger diameter than if solid, and by virtue of their larger diameter are less likely to bend laterally than would otherwise be the case, although some bending will do no harm, provided the natural frequency of the bending movement is also high. The lever arm 26 may either be formed integrally with the hub portion or separately, as desired. If formed separately, it must be secured to the hub portion with absolute tightness of fit so that there can be no lost motion between the lever and its torsion posts. The lever itself is longitudinally ribbed, as above explained, so as to be practically unbending to the forces employed and as light as possible. The general proportions of the torsion member, as well as of the lever shown in these figures, are such as are suitable for duro-aluminum alloy. Some modification thereof might be necessary if another material is selected. The lever itself is, in any event, aluminum or its equivalent for sake of lightness. A torsion member with its lever 26, made as above described, is secured to the face of each ring 22 on opposite sides of the microphone cell and the ends of the levers are clamped to the opposite ends of the stem 17 between insulated nuts 29 thereon. In this repeater the vibratory system comprises the stem 17 carrying the active electrodes, the septum walls inclosing the granules, the nuts and armatures as well as the two torsion levers. The effect of the torsion posts is to impart to such system, as a whole, the desired high frequency equal to or exceeding the highest resonance period of vowel sounds, and thereby the repeater becomes capable of transmitting telephonic voice currents without causing any appreciable distortion of the wave forms such as commonly occurs where the vibratory member responds disproportionately to one of the prominent frequencies of human speech.

There is special advantage in making the natural frequency of the system about 1000 because human speech does not contain any prominent sounds of this frequency and the only resonance effect will be a tendency to stronger response to the upper part of the range of frequencies characteristic of the vowel sounds say from 600 to 900 per second. This resonant response is progressively greater for the higher of these frequencies and these are the very frequencies which are most attenuated on long lines. Consequently, while the instrument does not actually prevent the unequal, distorting losses on the line, it does compensate for them by responding most strongly to the frequencies which have suffered most in transmission. By actual test, it has been found that where instruments properly designed in accordance with my present invention, are located at proper distances from the sending station, the reproduced vowel wave forms are substantially as perfect as if there had been no unequal attenuation of the higher frequencies, and the resulting effect is substantially that of distortionless transmission.

From the description given, the principle of the invention and the manner of applying it to other forms of instruments will now be apparent. It need only be added that the torsion member may have greater or less length between points of attachment, or greater or less cross sectional area, according to the frequency characteristics it is desired that it or they shall impart to the other parts of the system. Generally speaking, the shorter the length and greater the diameter, the higher will be the frequency, and the maker will proportion these factors so that the desired result will be gained with a minimum degree of stiffness, thus promoting the sensibility of the instrument as above explained. The torsion members may be put under initial, permanent stress if desired by manipulating the nuts 29 one way or the other, although this is not necessary and tends to increase the work to be performed in moving the system. In such case, the initial stress in one member may counteract that of the other, producing a static equilibrium when the parts are at rest, and such condition may operate to increase the frequency of the system as a whole and may be used for that purpose. In case of the repeater, and also to some extent in the transmitter, the torsionally-vibrating members serve as a support for the other parts of the system and may constitute the chief or sole support, if desired, thus providing for a minimum weight or thickness of the microphone septum without rendering the instrument unduly delicate. Such septum can be made of flexible but non-elastic material such as fabric, which opposes the least inertia or resistance to the movement of the electrodes. In the repeater, the magnet pole pieces are set up closely to their respective armatures and carefully adjusted by means of the thumb-wheels at the ends of the permanent magnets, to produce a substantial balance of magnetic attraction on opposite sides. The double-acting or two-part microphone cell contributes to the symmetry of the vibratory motion since thereby the physical resistance to movement in either direction is made approximately equal,—a matter of importance when the extent of vibratory motion is small.

I claim:

1. An instrument of the kind described having a vibratory system including an arm supported on a member resisting vibration by its elastic resistance to torsion and such resistance being sufficient to impart to the system as a whole a frequency below the limit of audibility but in excess of the frequency of the highest resonance period of vowel sounds.

2. An instrument of the kind described having a vibratory system including a rod or member fixed at both ends and subject to torsion by force applied between its ends and having a torsional resistance suited to give a natural frequency to the said system as a whole, below the limit of audibility but in excess of the resonance region of vowel sounds.

3. A telephonic transmitting device comprising a microphone cell, means connected therewith to operate it and a torsion member connected to such means and impressing thereon a natural frequency period below the limit of audibility but higher than the highest resonance region of vowel sounds.

4. A transmitting means for telephonic apparatus comprising a microphone, means for operating the same, comprising a lever, said means and lever having a natural frequency above 1000 vibrations per second and said microphone lever and parts thereof having only one resonance region below 2000 vibrations per second, in combination with means for operating said parts by human speech waves.

5. In a telephone repeater, the combination of opposed electro-magnets, a variable resistance medium located between said magnets and having relatively movable electrodes, one of said electrodes having an armature on each side thereof, and torsion means for imparting to the movable system

a natural frequency below the limit of audibility but in excess of the frequency of the highest resonance period of vowel sounds.

6. In a telephone repeater, the combination of opposed electro-magnets, a variable resistance medium located between said magnets and having a stationary electrode and a movable electrode provided with armatures on opposite sides thereof, and torsion means for imparting to the movable system a natural frequency below the limit of audibility but in excess of the frequency of the highest resonance period of vowel sounds.

7. A telephone repeater comprising an exciting field, a double-acting microphone and a vibratory system including two torsion members, each under permanent stress and counteracting each other, said torsion members imparting to the system a natural frequency below the limit of audibility but in excess of the highest resonance period of vowel sounds.

8. An instrument for utilizing complex frequency variations characteristic of human voice waves, said instrument having a vibratory system of which one of the members comprises an elastic torsion shaft or pivot substantially inflexible transversely of its axis together with a lever element substantially rigid transversely of its length, whereby oscillatory movements of said lever element are unitary and are confined to arcs having said axis as a center, the torsional resilience of said pivot being sufficient to impart to the system as a whole a natural frequency slightly but substantially higher than the highest important resonant frequency characteristic of the vowel sounds, in combination with means for applying to said system, the complex variations characteristic of human speech.

9. An instrument for utilizing complex frequency variations characteristic of human voice waves, said instrument having a vibratory system of which one of the members comprises an elastic torsion shaft or pivot substantially inflexible transversely of its axis and a lever element substantially rigid transversely of its length, whereby oscillatory movements of said lever are unitary and are confined to arcs having said axis as a center, the torsional resilience of said pivot being sufficient to impart to the system as a whole a natural frequency far below the limit of audibility but substantially higher than the highest important resonant frequency characteristic of the vowel sounds, in combination with means for applying to said system, complex variations of various frequencies substantially different from the said natural frequency of said vibratory system.

10. An instrument for utilizing complex frequency variations characteristic of human voice waves, said instrument having a vibratory system of which one of the members comprises an elastic torsion shaft or pivot, rigidly secured at both ends and substantially inflexible transversely of its axis, together with a lever element rigidly secured thereto and substantially rigid transversely of its length, whereby oscillatory movements of said lever element are unitary and are confined to arcs having said axis as a center, the torsional resilience of said shaft or pivot being sufficient to impart to the system as a whole a natural frequency below the limit of audibility but higher than the highest important resonant frequency characteristic of the vowel sounds, in combination with means for applying to said system, complex variations of various frequencies all substantially different from the said natural frequency of said vibratory system.

In testimony whereof, I have signed this specification in the presence of two witnesses.

ELWOOD GRISSINGER.

Witnesses:

FRANKLIN R. BROWN,

DAN'L. W. EMERLING.