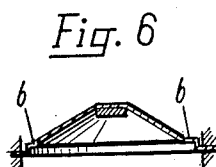
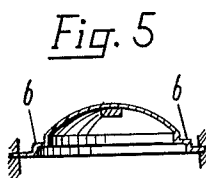
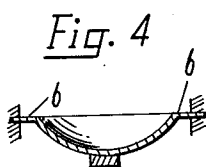
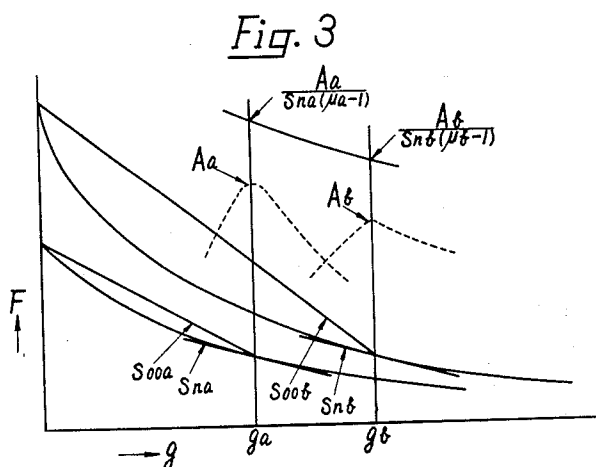
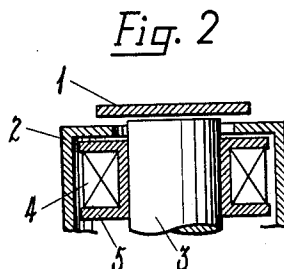
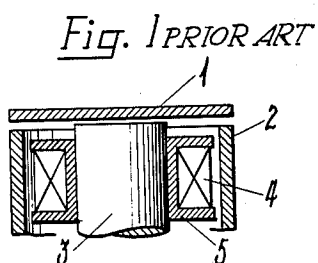


TOSHIO HAYASAKA ETAL
ELECTROMAGNETIC RECEIVER

4 Sheets-Sheet 1

Filed Dec. 12, 1960



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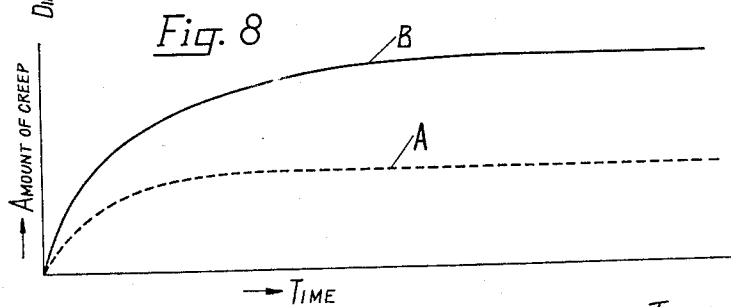
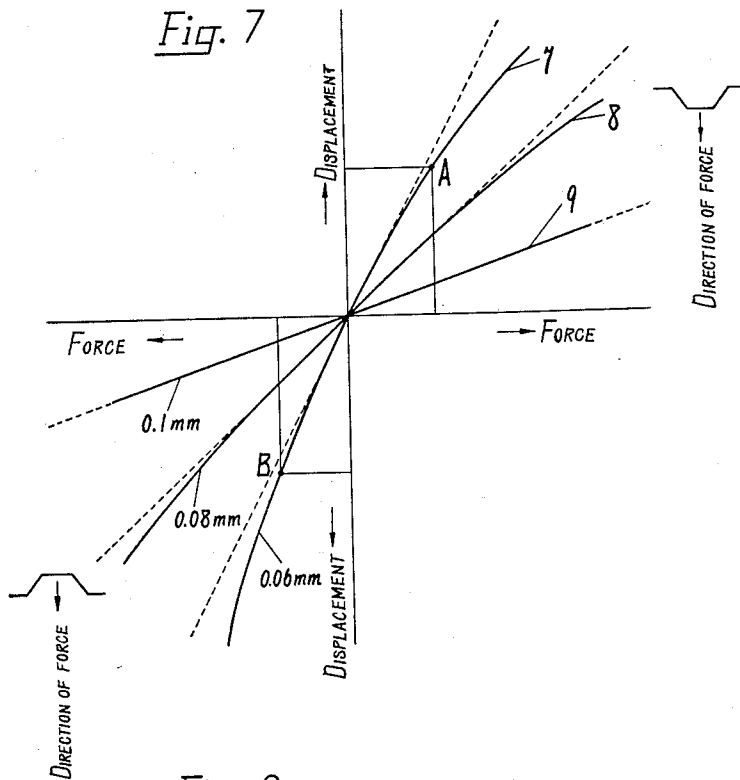
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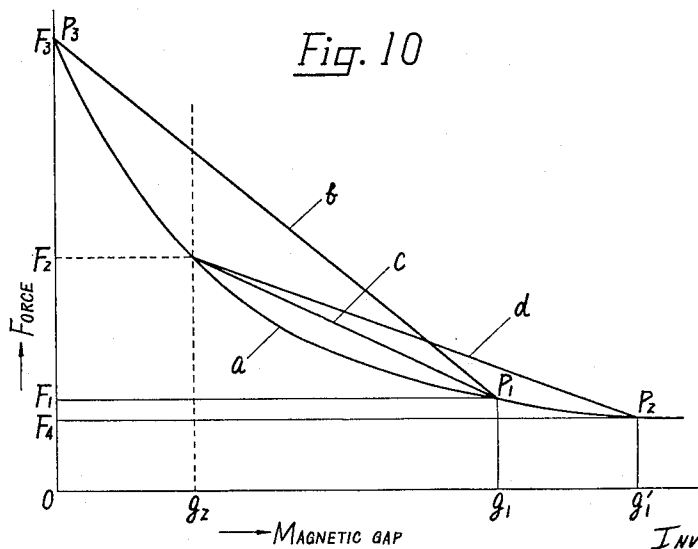
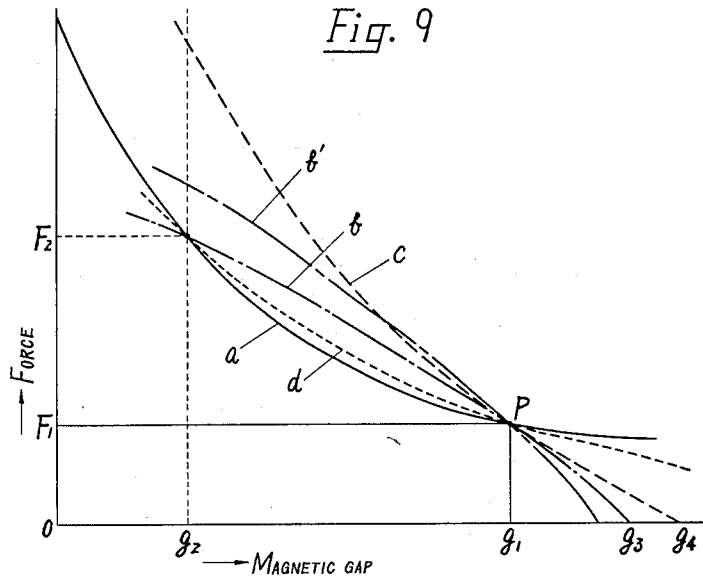
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4 Sheets-Sheet 4

Fig. 11

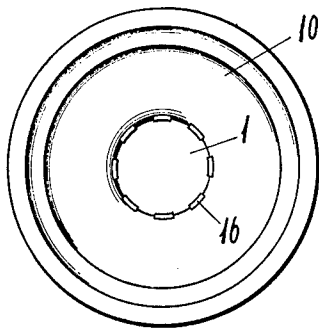


Fig. 12

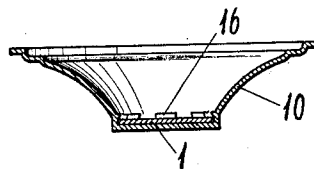


Fig. 13

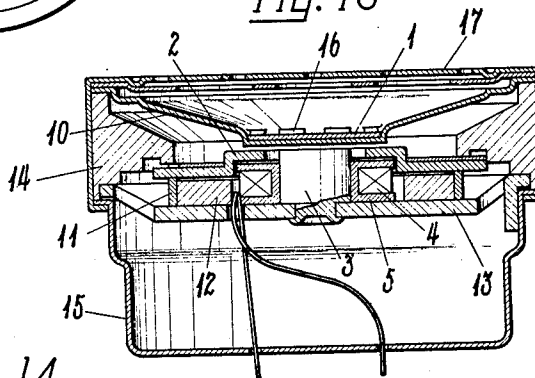
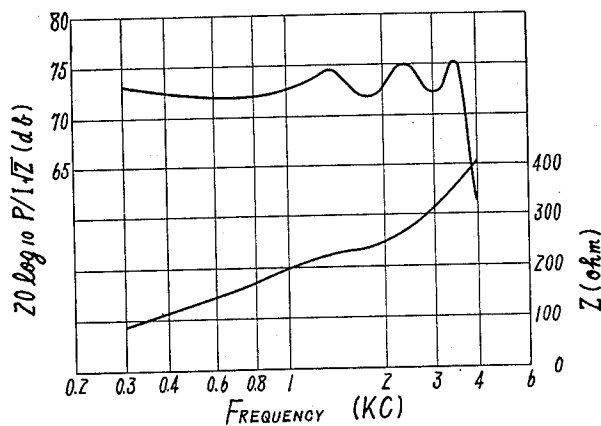


Fig. 14



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ELECTROMAGNETIC RECEIVER

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Filed Dec. 12, 1960, Ser. No. 75,164
16 Claims. (Cl. 179-115)

This invention relates to an unbalanced-type electromagnetic receiver for telephones. The unbalanced type electromagnetic receiver mentioned herein is defined as a receiver, which has a magnetic pole on only one side of the armature and no magnetic members on the other side.

In the electromagnetic receiver according to the present invention, an armature is provided on the opposite side of the magnetic pole face of a magnetic circuit through a diaphragm made of a non-magnetic body.

An object of the present invention is to provide a stable and highly sensitive receiver.

Another object of the present invention is to provide a receiver wherein a magnetic gap is made large through a diaphragm of a non-magnetic body located between the magnetic pole face of a magnetic circuit and an armature and without varying the air gap so that the influence of the amount of creep of the diaphragm due to the magnetic attractive force normally acting on the diaphragm may be reduced and the accident of contact due to impurities entering said air gap may little occur.

In the accompanying drawings,

FIGURE 1 is a sectional view of a magnetic circuit in a conventional receiver.

FIGURE 2 is a sectional view of the magnetic circuit of a receiver according to the present invention.

FIGURE 3 is a characteristic diagram for explaining a conventional receiver.

FIGURES 4, 5 and 6 are sketches showing the correlations between the diaphragm and the armature.

FIGURE 7 is a characteristic diagram of the force added to the diaphragm and the displacement.

FIGURE 8 is a diagram showing the relation between the amount of creep of the diaphragm and the time.

FIGURES 9 and 10 are diagrams showing the relations between the magnetic gap between the pole piece face and the armature and the force.

FIGURE 11 is a plan view showing the relation between the diaphragm and the armature.

FIGURE 12 is a vertically sectioned view of FIGURE 11.

FIGURE 13 is a vertically sectioned view showing an embodiment of the receiver according to the present invention.

FIGURE 14 is a characteristic diagram of the receiver shown in FIGURE 13.

The most important to the performance of an unbalanced-type electromagnetic receiver for telephones is that the sensitivity should be high over the required frequencies and the operation should be stable.

The formula representing the sensitivity of a receiver is given by the frequency of stiffness control as in the Formula 1:

$$\frac{P}{I\sqrt{Z}} = \frac{A}{\sqrt{Z}} \cdot \frac{KS_0}{V_c s_0} \quad (1)$$

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wherein

P =Produced sound pressure,

Z =Receiver impedance,

A =Force factor of the receiver,

K =Bulk modulus of air,

S_0 =Effective area of the receiver diaphragm,

V_c =Volume of the coupler and

s_0 =Stiffness of the receiver vibrating system.

In the Formula 1,

$$s_0 = \omega_0^2 m_0 \quad (2)$$

wherein

$\omega_0 = 2\pi f_0$ =Resonant angular frequency and

m_0 =Effective mass of the receiver diaphragm.

Further, if the stiffness of the air chambers in front and rear of the diaphragm is ignored, s_0 in the Formula 2 will be as follows:

$$s_0 = s_{00} - s_n \quad (3)$$

wherein

s_{00} =Stiffness of the receiver diaphragm and

s_n =Negative stiffness, or derivative of magnetic attractive force with respect to magnetic gap length.

In order to increase the sensitivity, the right side of the Formula 1 may be made larger. If the size of the telephone receiver is of a proper value (not varying S_0) and Z is separately determined from the design of an anti-side tone circuit, what is to be a reference in the design will be

$$\frac{A}{s_0}$$

If the relation in the Formula 3 is rewritten, it will be as follows:

$$S_0 = S_n(\mu - 1) \quad (4)$$

wherein

$$\mu = \frac{S_{00}}{S_n} = \text{Stability factor}$$

Thus, if s_n is determined by the design of a magnetic circuit, it will be possible to make s_0 smaller by reducing the stability factor μ .

The method of designing a conventional receiver shall be explained with reference to FIGURE 3. In the conventional receiver, A and μ are made separate references in the design. As a method of making A larger, it is designed to make the magnetic gap g smaller so that s_{00} may approach the critical stability force μ crit. that can be taken against s_n appearing in said magnetic gap. When this is realized, for the critical value of the sensitivity, as shown in FIGURE 3,

$$\frac{A}{S_n(\mu \text{ crit.} - 1)}$$

will be larger and more effective as the magnetic gap is made smaller. However, the defect of this method shall be pointed out. If the normal magnetic gap is gb , the rise of the sensitivity will be able to be expected by making it a magnetic gap ga smaller than it. On the other hand, as the magnetic gap or air gap becomes narrower, there will be caused the following disadvantages. First of all, unless the tolerance of the mass production parts is made strict, it will be difficult to limit g and therefore the sensitivity in a fixed range. Then, in case g varies due to the creep always existing in the diaphragm of an elec-

tromagnetic receiver, the amount of variation of the sensitivity will become large. Lastly, in case any dusts or impurities come into or are generated in the air gap by any cause during the manufacture or use, the narrower the air gap, the more the contact accident will be likely to occur.

According to the present invention, a non-magnetic diaphragm is placed on the armature side of the magnetic gap so that the magnetic gap may be made larger without varying the air gap and the rise of the sensitivity may be expected without causing the above mentioned three defects. For experiments necessary therefore, there have been made precise measurements of the relation between the magnetic attractive force and the magnetic gap and of the displacement by the force of the diaphragm and experimental measurements to see whether the influence that can be newly caused by an eddy current flowing to the metallic non-magnetic body placed in the magnetic gap is small as compared with the advantage. As a result, it has been discovered that, by adopting the method of the present invention, stable and highly sensitive receivers can be designed.

The transmission band of the sensitivity of the receiver will be determined by the resonant frequency f_0 and the upper limit frequency of the transmission band must satisfy the value given in advance by design conditions. For example, in a receiver of the three-freedom vibrating system, in case a deviation of about 3 db is given in the range of 300 to 3600 cycles of the sensitivity frequency characteristics, the resonant frequency f_0 will be about 1700 cycles. Therefore, it will serve for the increase of sensitivity to simultaneously make s_0 and m_0 smaller while satisfying the Formula 2.

A highly sensitive and stable receiver can be obtained by making

$$\frac{A}{s_0}$$

larger by contriving the diaphragm and its driving method as in the above.

In FIGURE 1 is shown a magnetic circuit for a conventional receiver. In FIGURE 2 is shown a magnetic circuit for a receiver according to the present invention. 1 is an armature. 2 is an outer pole. 3 is an inner pole. 4 is a coil. 5 is a bobbin. In FIGURES 1 and 2, the inner pole 3 is cylindrical. The coil 4 is wound on the bobbin 5 fitted to the outside of said inner pole 3. However, in FIGURE 1, the outer pole 2 is wound concentrically and cylindrically on the outside of the coil 4. The armature 1 is provided opposite the upper surfaces of the inner pole 3 and outer pole 2. On the other hand, in FIGURE 2, the outer pole 2 is bent inward, the armature 1 is made smaller and the opposed area of the armature 1 and outer pole 2 is the same as before. And yet the coil 4 is of the same size.

In case the outside diameter of the inner pole 3, the thickness of the outer pole 2, the dimensions of the coil 4 and the thickness of the armature 1 in FIGURE 2 are made respectively the same as those in FIGURE 1, the outer pole 2 is bent inward as shown in FIGURE 2 and the outside diameter of the armature 1 is made smaller accordingly, if the electric performance, that is,

$$\frac{A}{\sqrt{Z}}$$

in the Formula 1 is measured, the same value as in FIGURE 1 will be obtained. In other words, without reducing the driving force, the mass of the armature can be reduced.

On the other hand,

$$m_0 = m_d + m_a \quad (5)$$

wherein

m_d = Effective mass of the non-magnetic body part of the diaphragm and

m_a = Mass of the armature.

m_d is so closely related with s_{00} and the creep of the diaphragm that it can not be made so small. Therefore, as stated with reference to FIGURE 2, by making m_a smaller, m_0 can be made smaller.

Next, the diaphragm shall be considered. It is already well known that the structure wherein, as shown in FIGURES 4, 5 and 6, a flexible part 6 is provided rather inside the clamping surface on the periphery and the part inside it is made spherical, conical or horny so as to vibrate integrally is good to make S_0 in the Formula 1 large. However, when the relative characteristics of the force and displacement in a formed diaphragm in which is adopted such clamping method as in FIGURES 5 and 6 are measured, they will be as shown in FIGURE 7 in which 7, 8 and 9 are of the case that the thickness of the diaphragm is 0.06, 0.08 and 0.1 mm., respectively. That is to say, the state of displacement when a force is applied to the diaphragm will be linear when the force is small or the thickness of the diaphragm is large or, in other words, when the stress applied to the material of the diaphragm is small. But, as the thickness of the diaphragm becomes smaller, the displacement will deviate from the linear state even with a smaller force. Further, the deviation will not be symmetrical when the direction of the force is changed but, as shown in FIGURE 7, the displacement will be smaller when the diaphragm is pulled in the direction of its convex surface than in the case reverse to it.

In the case that a diaphragm is to be used in an actual electromagnetic receiver, a magnetic attractive force will act statically and a restoring force due to the deformation of the diaphragm and said magnetic attractive force will act in a balanced position. Therefore, for example, if a diaphragm 0.06 mm. thick is used, it will be to be used in such position as the point A or B in FIGURE 7. In order to reduce s_{00} and m_0 which are conditions to obtain high sensitivity as described above, it will be necessary to use a diaphragm thinner than 0.1 mm. having such non-linear displacement. There is a difference between the case of using it at the above mentioned point A and the case of using it at the point B. The former, that is, the case of placing the magnetic circuit in the direction of the convex surface of the diaphragm is more advantageous and has such two advantages in stability as are described below.

The first advantage is in the matter of creep. In case a diaphragm is used in an electromagnetic receiver, its magnetic gap will be made smaller than the initial value by the creep of the diaphragm after the use for a long time due to the magnetic attractive force constantly acting on the diaphragm. If this phenomenon is large, the sensitivity and other performances will vary until the telephone receiver can be no longer used as such.

The amounts of creep of the same diaphragm in the case of using it at the point A in FIGURE 7 and in the case of using it at the point B as described above were actually measured. An example of the results is shown in FIGURE 8, in which the curve A represents the amount of creep shown when only a load was applied to the concave surface part and a force was made to work in the direction of the convex surface and the curve B represents the amount of creep when a force was made to work in the direction reverse to that in the curve A, respectively corresponding to the cases that it was made to work at the points A and B. The amount of creep of the former is about $\frac{1}{2}$ that of the latter. That is to say, a stable receiver can be formed in such manner.

The second advantage is in the matter of stability represented by μ before. A diagram explaining this state is shown in FIGURE 9 in which the abscissa represents the magnetic gap between the pole piece surface and the armature and the ordinate represents the force. In FIGURE 9, the curve *a* represents the magnetic attractive force acting on the armature. The curves *b* to *d* represent the restoring force due to the displacement of the dia-

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phragm. The curve b is of the case that the magnetic circuit was placed in the direction of the concave surface of the diaphragm, showing that the magnetic gap g_3 when no attractive force of the magnetic circuit acts is pulled by the attractive force so as to be displaced by g_3 to g_1 and its restoring force F_1 is equal to and balanced with the magnetic attractive force F_1 at g_1 and is in a stationary state. As shown in FIGURE 7, the curve b is curved downward in FIGURE 9. Now, if a non-magnetic body of a thickness corresponding to the magnetic gap g_2 is present in the air gap, for example, on the surface of the armature or the pole piece and the minimum value (the air gap being zero) of the magnetic gap is g_2 , as in the relation between the curves a and b in FIGURE 9, between the magnetic gaps g_2 and g_1 , the curve b will be always above the curve a and the restoring force of the diaphragm will be always stronger than the magnetic attractive force. Therefore, as soon as the armature is brought into contact with the surface of the pole piece by any vibration, it will be returned to the original position by the restoring force of the diaphragm and will operate stably as of a receiver. The stability factor μ at this time will be given by the ratio

$$\mu_b = \frac{s_{00}}{s_n}$$

of the tangent s_{00} of the curve b at the point P to the tangent s_n of the curve a at the point P . Now, if the balanced position is selected at the point P by varying the stiffness of the diaphragm by varying the thickness or any other dimension of the diaphragm, a curve like the curve b as rotated around the point P or, for example, such restoring force curve as the curve b' will be obtained. As described above, it is a requirement for the receiver to exist stably that these curves should not intersect the curve a between the magnetic gaps g_2 and g_1 . In order that μ may be the smallest in the range meeting this requirement, evidently the curve b should be taken. That is to say, in the case of the curve b

$$\mu_b = \frac{s_{00}}{s_n}$$

will be the critical stability force that can be reduced.

In case the magnetic circuit is placed in the direction of the convex surface of the diaphragm, from the curve in FIGURE 7, the restoring force will be, for example, as represented by the curve c . If such curve as will give the critical stability force is sought by reducing the stiffness of the diaphragm in the same manner as in the preceding case, the curve d will be obtained. The stability factor μ_d in such case will be evidently of a value smaller than that of the previously obtained μ_b . It is found that the rise of the sensitivity can be thereby expected. Further, the curve c is represented to be a curve whose tangent s_{00} at the point P is equal to that of the above described curve b . The stability μ and sensitivity of each are respectively equal to those of the other. However, the difference between the restoring force of the diaphragm and the magnetic attractive force in the curve c is so larger than in the curve b that the curve c can be said to be stabler.

The effect of the non-magnetic body provided in the air gap shall be described. It has already been described in the explanation on FIGURE 9 to insert a non-magnetic plate of a thickness corresponding to g_2 into the air gap. As the magnetic gap may be represented to be zero instead of g_2 in FIGURE 9, it can be readily understood that, even in case no non-magnetic plate is inserted, there will be the same effect and exactly the same explanation may be repeated. However, the non-magnetic plate is effective in itself to reduce the stability factor μ .

In order to explain this point, reference is made to FIGURE 10 in which the curve a is a magnetic attractive force curve and the curves b to d are diaphragm restoring force curves and are curved as described above. (In the

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drawing, they are represented in straight lines to avoid complicacy, because curves in two directions and straight lines are all represented. Exactly the same explanation can be established on each curve.) The critical value to which the stiffness of the diaphragm can be reduced in case it is used in the magnetic gap g_1 without placing the non-magnetic plate as in a conventional receiver is given by the curve b intersecting at the point P_3 . The critical stability force at the point P_1 in this case shall be μ_b . Then, in case the non-magnetic plate g_2 is placed, the critical value of the diaphragm restoring force will be as shown by the curve c and the critical stability force μ_c will evidently become smaller than μ_b . However, the air gap length in this case will be $g_1 - g_2$ and will be smaller than the air gap length g_1 in the case of the curve b . With this only, in the case of an accident that dusts or any other impurities enter the air gap due to any cause, the operation as for a receiver will be likely to become insufficient. Thus, it is not always advisable. Therefore, when the non-magnetic plate g_2 is put in, if the magnetic circuit is made longer by the same length as the thickness and is operated with g_1' , the critical stiffness will be as in the curve d and the stability factor in such case will be μ_d . Now, by the actually measured results, the stability factor and other characteristics in the case that the diaphragm of the curve d was used at the point P_2 shall be compared with those in the case that the curve b was used at the point P_1 . As an example, the values in the case that the thickness of the non-magnetic plate was 0.05 mm. are as shown in the following table:

	Magnetic gap, mm.	s_n , 10 ⁸ dyne/cm.		Critical stability force, μ	A, dyne/amp.	$\frac{A}{s_0}$
In the case of point P_2 and curve d	0.20	0.185	0.320	1.73	1.0×10^6	0.19
In the case of point P_1 and curve b	0.15	0.242	0.627	2.59	1.1×10^6	0.14

As understood from the table, the effect of reducing the stability μ by placing a non-magnetic plate is larger than the reduction of the force factor due to the necessity of enlarging the air gap and is about 1.36 times as large in

$$\frac{A}{s_0}$$

as combined. When this value is used in the Formula 1, the sensitivity will rise by about 2.6 db. In the range of carrying out the above operation, the amounts other than A and s_0 in the Formula 1 will not be varied at all.

FIGURES 11 and 12 show an embodiment in which a non-magnetic plate is arranged. In the structure, an armature 1 is caked with several extrusions 16 in the center of a conical diaphragm 10. The magnetic circuit is arranged and driven in the direction of the convex surface of the diaphragm 10 (downward in FIGURE 12). The thickness of the material of the diaphragm corresponds to g_2 shown in FIGURES 9 and 10. Thus there is an advantage that, even if the strength of caking the armature is weaker than in a conventional receiver in which the armature is directly opposed to the magnetic surface, the armature will not be peeled off by the magnetic attractive force. Further, there is another advantage that the magnetic attractive force at the point g_1' in FIGURE 10 is so smaller than at g that the fear of the creep of the diaphragm is less.

FIGURE 13 illustrates an embodiment of an electromagnetic receiver according to the present invention. A coil 4 is wound on a bobbin 5 fitted to the outside of a cylindrical inner pole 3. An outer pole 2 is arranged on the outside of said coil 4. The forward end of said outer pole 2 is bent inward. A magnet 12 is arranged outside the bobbin 5. A magnetic circuit is formed of said re-

spective parts. Further, the inner pole, bobbin, outer pole, a ring 11 and a yoke 13 are fixed by the peripheral part of the frame 14 so as to form a magnetic circuit. On the other hand, an armature 1 is secured by being calked with several extrusions 16 in the center of a diaphragm 10 made of a non-magnetic body. After said armature 1 is arranged opposite said magnetic circuit through the diaphragm, said diaphragm is fixed by a casing 15 and cover 17.

FIGURE 14 shows the frequency characteristics of the receiver according to the present invention illustrated in FIGURE 13.

What we claim is:

1. An unbalanced-type electromagnetic receiver comprising a conical diaphragm, an armature provided at the center portion on the concave surface side of said conical diaphragm and a magnetic circuit including a cylindrical inner pole juxtaposed the center portion on the convex surface side of said diaphragm to define an air gap therebetween and an outer pole arranged concentrically on the outside of said inner pole.
2. An unbalanced-type electro-magnetic receiver comprising a non-magnetic conical diaphragm, an armature provided at the center portion on the concave surface side of said diaphragm and having the thickness of less than 0.08 mm., and a magnetic circuit including a cylindrical inner pole provided at the convex surface side of said diaphragm to define therewith an air gap having a length greater than the displacement length wherein the relation between the force and the displacement of said diaphragm has a non-linear relation and an outer pole arranged concentrically on the outside of said inner pole.
3. An unbalanced-type electro-magnetic receiver comprising a conical diaphragm, an armature calked with several extrusions at the center portion on the concave surface side of said diaphragm and a magnetic circuit including a cylindrical inner pole provided through an air gap on the opposite side of said diaphragm from the armature and an outer pole arranged concentrically on the outside of said inner pole.
4. An unbalanced-type electro-magnetic receiver comprising a conical diaphragm, an armature provided at the center portion on the concave surface side of said diaphragm and a magnetic circuit including a cylindrical inner pole provided on the side of said diaphragm opposite said armature to define an air gap therebetween and a hollow cylindrical outer pole provided at the outside of said inner pole, the end of which is bent inwardly.
5. An unbalanced-type electro-magnetic receiver comprising a conical diaphragm, an armature provided at the center portion on the concave surface side of said diaphragm and a magnetic circuit including cylindrical inner and outer poles arranged concentrically with each other to define an air gap on the convex surface side of said diaphragm whereby the stability factor is less than 2.
6. An unbalanced-type electro-magnetic receiver comprising a conical diaphragm, an armature provided at the center portion on the concave surface side of said diaphragm and a magnetic circuit including a cylindrical inner pole positioned to define an air gap at the opposite side of said diaphragm from the armature and an outer pole arranged concentrically at the outside of said inner pole, said outer pole having a parallel face with the armature.
7. An unbalanced-type electro-magnetic receiver comprising a diaphragm having a flat flexible part, the inside part of which is conical, a disc-shaped armature mounted on the concave surface side of the center portion of said conical part and a magnetic circuit including a cylindrical inner pole and an outer pole arranged concentrically with said inner pole, whereby the convex surface side of said diaphragm is arranged to oppose the inner and outer pole faces of said magnetic circuit.
8. An unbalanced-type magnetic receiver comprising a conical diaphragm, a disc-shaped armature being calked

with several extrusions at the center portion on the concave surface side of said diaphragm made from non-magnetic material having thickness of 0.08 mm. and a magnetic circuit including a cylindrical inner pole provided opposite to the center portion on the convex surface side of said diaphragm to define an air gap having a corresponding length to the range of non-linear displacement of said diaphragm and an outer pole arranged concentrically with said inner pole, said outer pole has a parallel face in the outer diameter direction.

9. An unbalanced-type electro-magnetic receiver comprising a diaphragm having a flat flexible part, the inside part thereof is conical and a disc-shaped armature being provided at the flat part of the center portion on the concave surface side of said conical part, wherein the thickness of non-magnetic diaphragm is made less than 0.08 mm. and an inner pole and an outer pole are positioned to define an air gap on the convex surface side of said diaphragm so that the relation between the force and the displacement of the diaphragm is made non-linear within the range of the length of the air gap.

10. An unbalanced-type electro-magnetic receiver comprising a cylindrical inner pole, a conical diaphragm, a bobbin wound with a coil on the outside of said pole, an outer pole, the forward end of which is bent inwardly at the outside of said inner pole, a magnet and a ring arranged at the outside of said bobbin, a magnetic circuit formed with said inner pole, bobbin, outer pole and ring, said diaphragm structure being formed with an armature calked with a plurality of extrusions at the center portion on the concave surface side of said diaphragm, said diaphragm being made of non-magnetic body in such manner that the convex surface side of the diaphragm defines an air gap with the magnetic poles of the magnetic circuit, and a casing and a cover supporting said electro-magnetic receiver.

11. An unbalanced-type electro-magnetic receiver comprising a diaphragm having a flat flexible part, the inside part of which is conical, a disc-shaped armature coupled to the flat part of the center portion on the concave surface side of said conical part, and a magnetic circuit including a cylindrical inner pole and a cylindrical outer pole arranged concentrically with said inner pole and having a part of one pole bent inwardly, wherein the convex surface side of the diaphragm is opposed to define an air gap with the pole heads of said inner and outer poles.

12. An unbalanced-type electro-magnetic receiver comprising a conical diaphragm, an armature calked with a plurality of extrusions at the center portion on the concave surface side of said diaphragm and a magnetic circuit including a cylindrical inner pole provided through an air gap at the center portion on the convex surface side of said diaphragm, opposite the armature and a hollow cylindrical outer pole arranged on the outside of said inner pole, the end of said outer pole adjacent said diaphragm being bent inwardly.

13. An unbalanced-type electro-magnetic receiver comprising a diaphragm, an armature calked with a plurality of extrusions at the center portion on the concave surface side of said diaphragm and a magnetic circuit including a cylindrical inner pole defining with said diaphragm an air gap at the center portion on the convex surface side of said diaphragm and an outer pole arranged concentrically on the outside of said inner pole and having a face parallel with the armature.

14. An unbalanced-type electro-magnetic receiver comprising a conical diaphragm, an armature provided at the center portion on the concave surface side of said diaphragm, said diaphragm being of non-magnetic material having the thickness of less than 0.08 mm. and a magnetic circuit including an inner pole defining with said diaphragm an air gap on the convex surface side of said diaphragm and an outer pole, the end adjacent said diaphragm being bent inwardly, said outer pole being ar-

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ranged concentrically around said inner pole and having a face parallel with the armature.

15. An unbalanced-type electro-magnetic receiver comprising a conical non-magnetic diaphragm, an armature calked with a plurality of extrusions at the center portion on the concave surface side of said diaphragm and having the thickness of less than 0.08 mm. and a magnetic circuit including a cylindrical inner pole positioned to define with said diaphragm an air gap on the convex surface side of said diaphragm and an outer pole arranged concentrically with said inner pole.

16. An unbalanced-type electro-magnetic receiver comprising a diaphragm having the thickness of less than 0.08 mm., the peripheral part of which is a flat flexible part formed with non-magnetic material, the inside of which is conical, the center portion of the conical part being a substantially flat surface, an armature provided on said

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substantially flat surface and a magnetic circuit including an inner pole positioned adjacent said diaphragm to define an air gap on the opposite side of the diaphragm from said armature and an outer pole concentric with said inner pole.

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