July 4, 1967 D. S. HOYNES 3,329,957

ANTENNA SYSTEM EMPLOYING HUMAN BODY AS RADICATOR

Filed May 5, 1959 3 Sheets-Sheet 1

Fig. 1

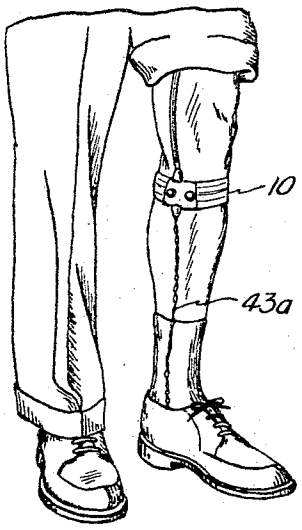
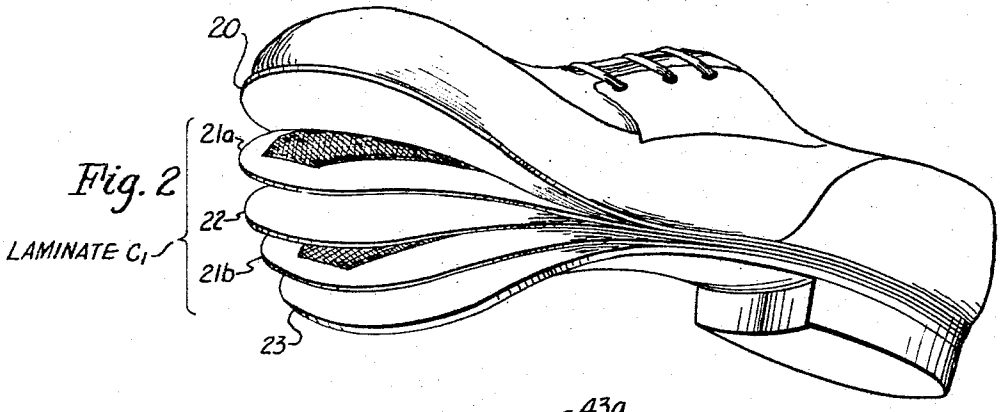


Fig. 2



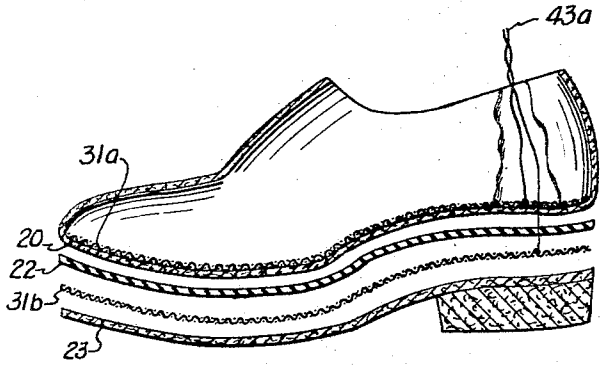


Fig. 3

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ANTENNA SYSTEM EMPLOYING HUMAN BODY AS RADICATOR

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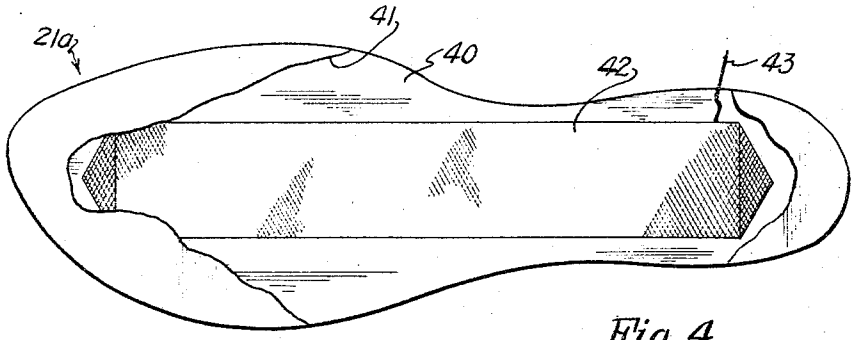


Fig. 4

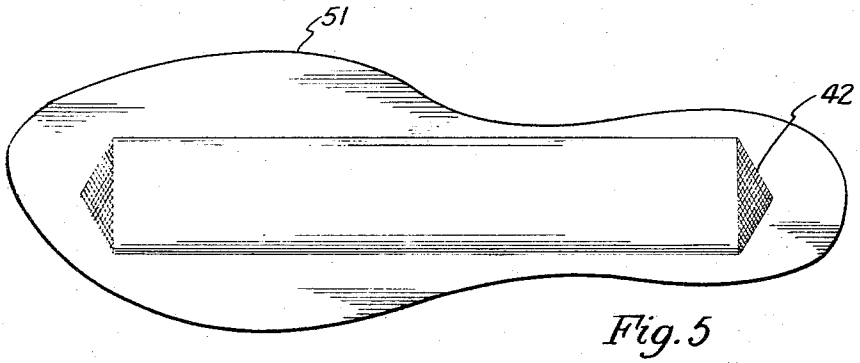


Fig. 5

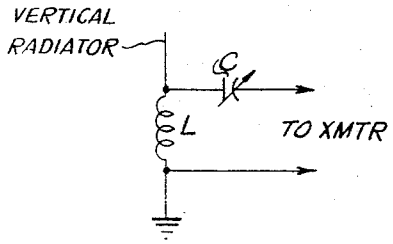


Fig. 6

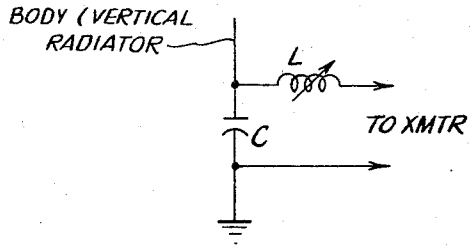


Fig. 7

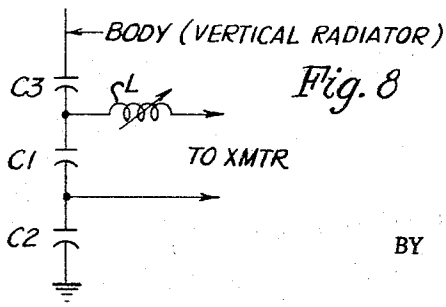


Fig. 8

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ANTENNA SYSTEM EMPLOYING HUMAN BODY AS RADICATOR

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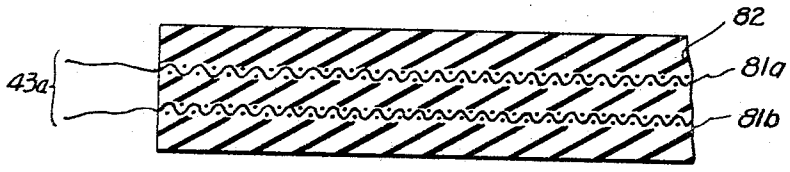


Fig. 9

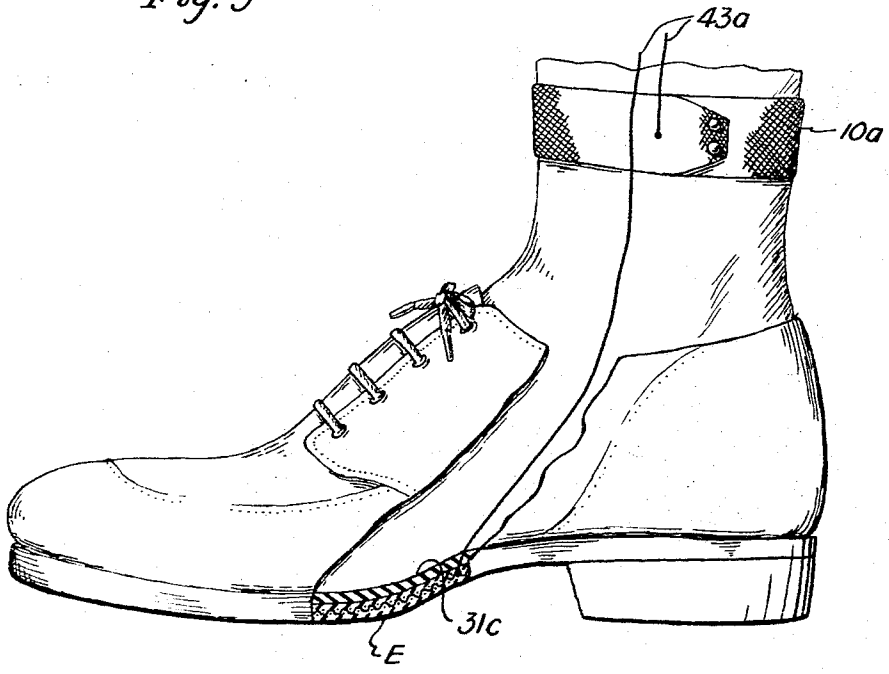


Fig. 10

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United States Patent Office

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ANTENNA SYSTEM EMPLOYING HUMAN BODY AS RADIATOR

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8 Claims. (Cl. 343—718)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalities thereon or therefor.

This invention relates to antenna systems and particularly to an improved antenna system which is inconspicuous and particularly suitable for use in man-to-man radio communication.

In connection with portable man-carried communication systems there has always been a great deal of difficulty encountered in providing a satisfactory antenna which can be inconspicuously carried on a person's body either for purposes of concealment or so as not to be an encumbrance. Specifically, the antenna should possess several desirable characteristics with regard to frequency of operation, stability, nondirectionality, and should also allow freedom of movement of the bearer without appreciably affecting the operating characteristics.

To achieve such results, so far as is known, presently employed systems have been restricted to the higher frequency ranges such as the very high frequency range, because only at such frequencies is it practicable to provide antennas which are sufficiently small to be concealable or inconspicuously located on a person's body and at the same time to operate with sufficient efficiency to permit man-to-man radio communication even for restricted distances of approximately one-quarter mile under favorable conditions. Moreover, for the most part, antennas of such type are generally directional and require proper orientation for maximum usefulness. In addition, such systems are subject to the usual known vagaries associated with the transmission of radio-frequency energy in the VHF region, such as reflections, cancellations, criticalness due to the physical attitude of the wearer, and attenuation of the signal due to movements of the hands and body.

While a great deal can be done to minimize the undesirable attributes of VHF systems and the proper design of the associated transmitting and receiving equipment, the primary drawbacks of the systems as a whole still remain, and the reliability of such systems under a variety of conditions is considerably restricted.

The advantages on the other hand of receiver-transmitter systems which operate in the HF and MF regions are well known and the present invention particularly pertains to an antenna system which permits operation as well in the HF and MF frequency bands thereby eliminating the undesirable features inherent in systems operating in the VHF band. The efficiency of the antenna system constructed in accordance with the principles of the present invention is such that it is possible to provide man-to-man communication in the HF and MF region for distances up to one mile with available transmitter powers on the order of 150 milliwatts or less. In addition, the use of the HF and MF regions for communication systems considerably reduces the effects of reflections and cancellations which are manifest in the VHF region, since, as is well known, propagation at the lower frequencies contemplated by the HF and MF bands follows predictable laws of propagation with considerably more uniformity.

In accordance with the principles of the present invention the antenna system contemplates an arrangement by which the body of the user is employed as a radiator by providing means for coupling the user's body and ground to the communication apparatus to form an antenna system which is somewhat similar to a short grounded vertical antenna system.

It is accordingly an immediate object of the present invention to provide an improved antenna system for use in body-carried man-to-man communicators which is inconspicuous.

It is a further object of the present invention to provide an antenna system for use in man-to-man communications no portion of which is apparent on the body of the user.

A still further object of the present invention is to provide an improved antenna system for use in connection with personal radio systems in which the body of the user becomes the radiator of a vertical antenna.

Still another object of the present invention is to provide an improved antenna system, components of which can be built in an article of clothing adapted to be worn by the user.

Still another object of the present invention is to provide an improved antenna system, the components of which may readily be incorporated in an article of wearing apparel, such as a shoe.

A further object of the invention is to provide a vertical antenna system employing means for coupling the body of a person and ground to a radio instrument in a manner such that the person's body becomes the radiator of a vertical antenna.

Other uses and advantages of the invention will become apparent upon reference to the specification and drawings, in which

FIG. 1 is a view showing the general arrangement of the vertical antenna system of the present invention;

FIG. 2 is a view of the coupling means of the present invention incorporated in the sole portion of a shoe;

FIG. 3 is a more detailed view of a shoe incorporating one embodiment of the coupling means in the present invention;

FIG. 4 is a plan view of one form of an electrode employed in the present invention, portions being broken away;

FIG. 5 is a view similar to FIG. 4 showing another embodiment of an electrode construction employed in connection with the present invention;

FIGS. 6–8 are electrical diagrams illustrating the principles of operation of the antenna system;

FIG. 9 is a sectionalized view of a modified electrode-dielectric assembly which may be employed; and

FIG. 10 shows a modified version of the antenna system of this invention.

In accordance with the principles of the present invention the body of the user of a portable radio communication instrument is employed as the radiator in a vertical antenna system by providing means for coupling the user's body and ground to the radio instrument. Such coupling may conveniently be provided by capacitive means which may readily be combined in an article of apparel, such as the user's footwear. Conveniently, the coupling means may be applied to a conventional shoe sole, or such coupling means may be specially incorporated in the shoe during the construction thereof. For example, the shoe sole can be constructed as the coupling device.

Referring to the drawings, FIG. 6 is a schematic diagram illustrating the electrical components in a conventional short vertical grounded antenna system, which has an inductance L located in its base and which is excited through a series capacitor C.

FIG. 7 is a similar schematic diagram in which the inductance L and capacitor C have been interchanged

from the conventional configuration shown in FIG. 6. Such interchange of L and C from the conventional configuration illustrated in FIG. 6 in no way reduces the effectiveness of the antenna since in accordance with established principles equal voltages will be developed across either arrangement of the vertical radiator.

The antenna system employed in connection with the present invention provides a capacitor located electrically in the manner illustrated in FIG. 7, the electrodes of which may be used for coupling the vertical radiator and ground to the utilization device, and such capacitance may conveniently be obtained, as above indicated, in the wearing apparel, such as the footwear of the user, as will be described. The footwear may be of any conventional type in which electrodes have been included together with a suitable dielectric material between the electrodes so as to form a capacitor. Such capacitor may conveniently be used in connection with conventional shoe soles or may be constructed in a form which takes the place of the shoe sole when the shoe is made.

Connections between the capacitor and the associated communication equipment is provided by means of a transmission line which may readily be led from the shoe without interfering with the comfort of the wearer.

Since it is difficult to provide a uniform direct contact from the top electrode of the capacitor to the bottom of the user's feet and also from the bottom electrode of the capacitor to ground or earth, in accordance with the principles of one embodiment of the present invention a capacitive path is provided, as is schematically shown in FIG. 8. In FIG. 8, L represents the loading coil, or inductance described in connection with FIGS. 6 and 7, and C1 designates the capacitor constructed into the sole of the shoe which forms the principal capacitance to which the inductance L is resonated. C3 in FIG. 8 represents the capacitance between the user's foot and the top electrode of the capacitor C1 consequent to the particular dielectric material separating the user's foot from the electrode, such as a sock or insole, and C2 is the capacitance between the bottom electrode of the capacitor and earth, and would normally comprise a thin wear sole covering the bottom electrode of the capacitor, or which may comprise a portion of a specially constructed capacitor, as will be described.

Coupling of the user's body, which now becomes effectively the radiator, and earth through the capacitive path C_1–C_3 indicated in FIG. 8 does not greatly reduce the effectiveness of the antenna system, and with the proper choice of values such system tends to minimize variations that would normally take place with varying ground or earth conditions.

One construction in which the capacitor may conveniently be incorporated in a shoe sole in accordance with the principles of this invention is illustrated in FIG. 2. In FIG. 2, **20** represents the insole of a conventional shoe. The remainder of the sole is constructed as a laminate comprising a first electrode sheet **24***a*, a dielectric sheet **22**, a second electrode sheet **21***b*, and an outer or bottom thin wear sole **23**. Each of the electrode sheets **21***a* and **21***b* may take a variety of forms. Conveniently, sheets of paper, fabric, or other electrically insulating material having an outline corresponding to the shoe sole, are provided with the electrode in the form of a fine wire mesh, conducting foil, or other substantially flexible, electrically conductive material sandwiched in between the sheets of paper or fabric. Referring to FIG. 4, for example, which illustrates one form of electrode construction, the electrode may consist of a first sheet **40** approximating the outline of a shoe sole made of paper, fiber, cloth, leather, or any suitable thin insulating material. A second sheet **41**, shown partly broken away in FIG. 4, is superimposed over the first sheet **40**, the second sheet having the same structure as the sheet **40**. A strip of conducting material **42** is applied between the sheets **40** and **41** and the laminations may then be fastened together as by cementing. The sheets **40** and **41** may also be made of any conventional plastic such as polystyrene and may be bonded together by heat and pressure or by a suitable plastic cement. To provide the necessary electrical connection to the electrode **42** a flexible conductor **43**, forming one conductor of the transmission line of the antenna system, is soldered or otherwise fastened to the electrode **42** and is brought out at the edge of the electrode assembly between the laminations **40** and **41**.

The electrode construction shown in FIG. 4 may be implemented in a variety of other ways as will be readily apparent. For example, as shown in FIG. 5, instead of a laminated sheet construction, as described in connection with FIG. 4, the electrode **42** may be integrally molded in a plastic or rubber matrix **51**, as shown in FIG. 5. Portions of the end of the electrode may be left exposed as illustrated in FIG. 5 to provide electrical circuit connections to the transmission line. In accordance with one embodiment of the electrode the matrix may consist of electrically conducting rubber.

The dielectric **22** shown in FIG. 2 is provided in the form of a laminate of dielectric material between the electrodes **21***a* and **21***b* as shown in FIG. 2. The dielectric **22** may consist of any suitable flexible dielectric material. An additional wear sole **23** may be provided in accordance with the construction of FIG. 2 to protect the electrode of the capacitor and provide the necessary wear quality for the shoe.

The construction of the embodiment of FIG. 2 is considered apparent. The referred-to laminates **21–23** are assembled and either cemented or sewed to the inner sole of the shoe in a conventional manner. The resulting construction resembles any conventional shoe in outward appearance, and there is no indication of any electrical apparatus to the eye of an observer.

FIG. 3 illustrates how the capacitor forming the coupling means of the present invention may be otherwise incorporated in a shoe. As shown in FIG. 3, one electrode **31***a* of the capacitor, which may be of the types shown in either FIG. 4 or 5, is applied as an insole inside the shoe. A sheet of dielectric material **22** is then applied against the inner sole **20** of the shoe and a second electrode **31***b* of the type shown in either FIG. 4 or 5 is applied over the dielectric material, following which a wear sole **23** is applied. In either of the constructions illustrated in FIG. 2 or 3, connection between the electrodes and the utilization apparatus is readily implemented by means of a thin flexible transmission line **43***a* which is led up through the side lining of the shoe as is clearly shown in FIG. 3. The transmission line may then be strapped to the leg of the user by a band **10** as is clearly shown in FIG. 1. Connection to the utilization apparatus is then provided in a known manner by means which does not form a part of the present invention.

The various described coupling-means embodiments suggest alternatives in which electrodes of the type shown in FIGS. 4 and 5, respectively, can be used separately or together. For example, in the particular constructions illustrated in FIGS. 2 and 3, one electrode **21***a* may be of the type shown in FIG. 4 while the other electrode **21***b* may be represent the modified constructions described in connection with FIG. 5.

Alternatively, both electrodes may be integrally molded or bonded within a matrix of dielectric material to form an integral coupling device. Such construction is illustrated in FIG. 9 in which the sheets of wire mesh **81***a*, **81***b* are shown embedded in a matrix **82** of a suitable dielectric material such as rubber or plastic. By using a material such as rubber, neoprene, etc. as the matrix, the resulting coupling material can readily be made in sheets which are flexible and durable and can therefore be used as sole material in the construction of a shoe.

FIG. 10 shows a still further modification of the present invention in which only a single electrode is employed in the antenna system. In accordance with the modifica-

tions of FIG. 10 a single electrode E, which may be one of the types shown for example in FIG. 5 or 9, is employed as the shoe sole. The conductors of the transmission line **43***a* are connected respectively to the conducting portion of electrode E and to a strap **10***a* of conducting material applied in the form of a band to the body of the user as is clearly shown in FIG. 10.

The circuit corresponding to the modified construction of FIG. 10 is illustrated in FIG. 7. Specifically, the principal tuning capacitance as illustrated by C in FIG. 7 is in this case formed between the user's foot and electrode E in FIG. 10 by the dielectric material **31***c* separating electrode E and the user's foot. This arrangement makes it possible to provide a direct electrical connection to the user's body from one terminal of the transmission line.

Tests with an antenna system of the type disclosed, using a person's body as the radiator in low power applications, have not only proved the system to be entirely practicable, but the results compare favorably with those obtained by substituting a 6-foot metallic radiator using conventional direct connections, as explained in connection with the circuit diagram of FIG. 6. Field intensity measurements made with the antenna system of the present invention showed that the field varies inversely with distance in a predictable manner for short ranges with losses on the order of 6 decibels when shifting from moist ground conditions to dry pavement. Using low power transmitting equipment (i.e., less than 150 milliwatts) field intensities on the order of 150 microvolts per meter have been recorded at distances of one-half mile under favorable circumstances. Furthermore, the antenna system of the present invention when employed with communication equipment in the HF or MF region is characterized by uniformity of received signal strength with a general absence of the above-noted defects of cancellation, reflections, and interference due to the near presence of objects such as automobiles, etc. which are extremely troublesome in connection with VHF systems.

The shoe antenna system of the present invention is also stable in operation and noncritical in tuning. These factors are achieved by the relatively high values of capacitors which may be constructed into the shoe system. The capacitors are fixed in value and tuning of the system to resonance may be accomplished by means of a variable inductance loading coil, which preferably may be contained in the transmitting-receiving apparatus.

The described system is not necessarily restricted to the arrangement shown in connection with FIG. 8, since other types of coupling, such as link coupling, series, or parallel feeding may be used with equally good results.

Although the present invention has been illustrated in connection with application to a single shoe, it will be apparent that the same principles are involved in connection with the use of both shoes of a wearer. The construction and coupling principles employed would, of course, be identical and it is only necessary to connect the described electrical means in parallel and in proper phase relationship by using separate transmission lines to the utilization means or communication equipment.

When thus utilizing one coupling shoe or system on each foot of the user, variation in radiating ability is held to a minimum even though the user is walking since it is evident that one foot is on the ground at all times.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of the invention as defined in the appended claims.

What is claimed is:

1. An antenna system for use with a radio communication instrument comprising: means for coupling the body of a user of said communication instrument and ground to said communication instrument with the user's body as a vertical radiator of the antenna system operating against ground, said coupling means comprising capacitive means mounted in the user's footwear.

2. An antenna system for use with a communication instrument comprising: an impedance element mounted in the wearing apparel of the user of said instrument, means for coupling said impedance element to the body of said user and to said communication instrument.

3. An antenna system for use with a communication instrument comprising: capacitive means mounted in the user's footwear, and a transmission line having one end connected to said capacitive means and the other end coupled to said user's body and to said communication instrument.

4. The antenna system set forth in claim **3** where said capacitive means comprises a sheet of conductive material sandwiched between two sheets of dielectric material positioned in the sole of said footwear.

5. The antenna system set forth in claim **3** wherein said capacitive means comprises conductive material encased in dielectric material positioned in the sole of said footwear.

6. The antenna system set forth in claim **3** wherein said capacitive means is positioned in the sole of said footwear and comprises a sheet of first conductive material sandwiched between two sheets of first dielectric material and second conductive material encased in second dielectric material.

7. The antenna system set forth in claim **3** wherein said capacitive means comprises an insole for said footwear comprising first conductive material, dielectric material positioned against the bottom of the inner sole of said footwear, and second conductive material positioned between said dielectric material and the outer sole of said footwear.

8. The antenna system set forth in claim **3** wherein said capacitive means comprises an insole of footwear comprising first conductive material, and second conductive material encased in a dielectric material positioned between the inner and outer sole of said footwear.

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