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[54] **PASSIVE MICROWAVE RECEIVER-TRANSMITTER**

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[52] **U.S. Cl.** ..... **343/6.8 R,** 332/56, 333/83 R, 333/771, 343/18 D

[51] **Int. Cl.** **G01s 9/56**

[58] **Field of Search** ..... 343/18 R, 18 RM, 771; 332/56; 333/8 B

[56] **References Cited**

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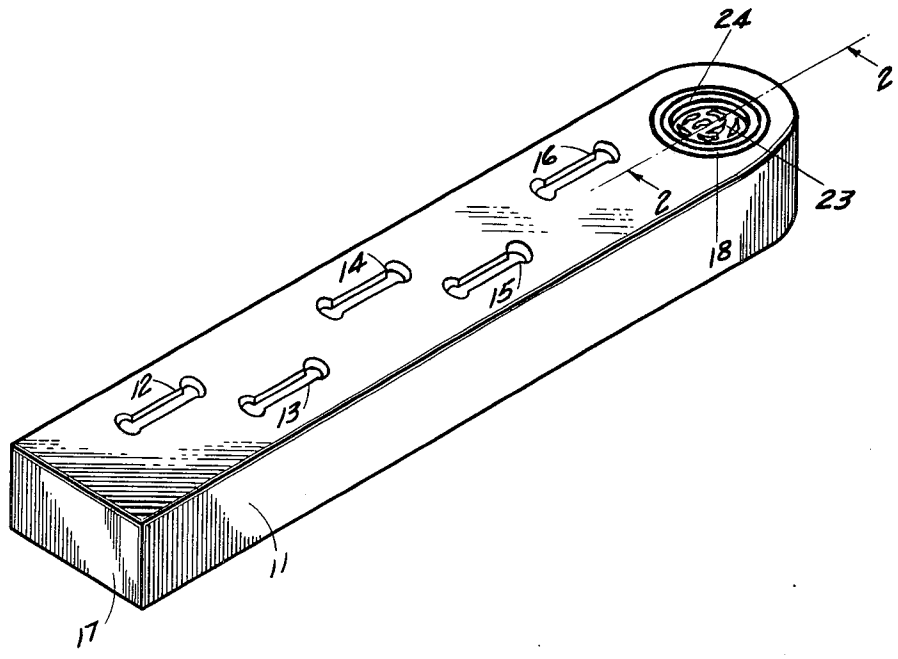
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EXEMPLARY CLAIM

1. A microwave transducer comprising, a microwave resonant cavity, a randomly embossed thin metallic diaphragm closing one face thereof, a conical metallic post extending from one wall of said cavity towards said diaphragm having a sharp tip in close proximity to but spaced from said diaphragm, and means for coupling microwave energy into and out of said microwave resonant cavity.

14 Claims, 5 Drawing Figures



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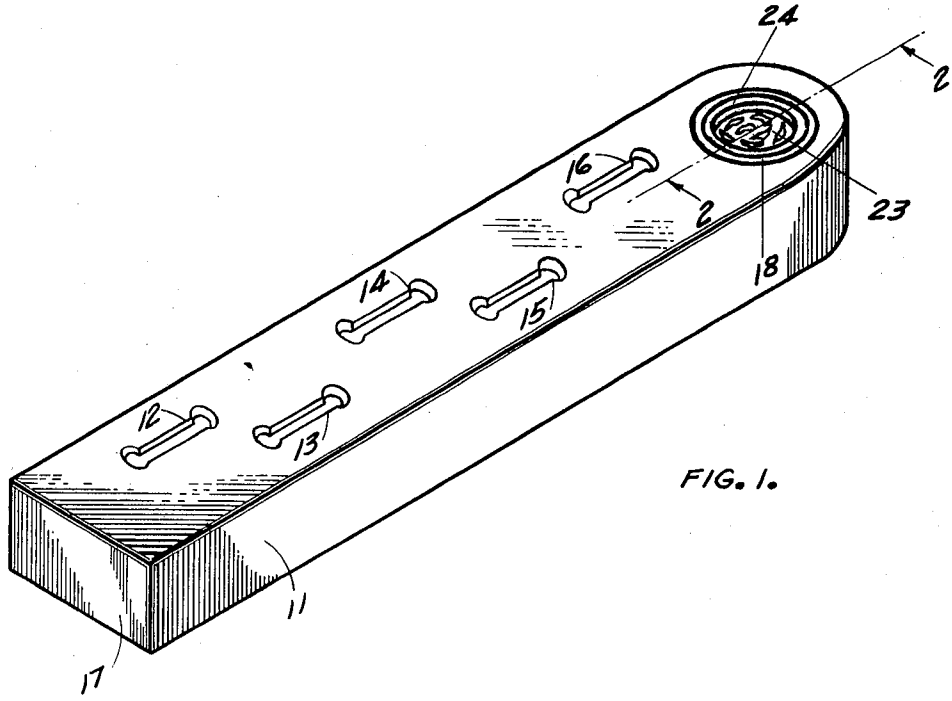


FIG. 1.

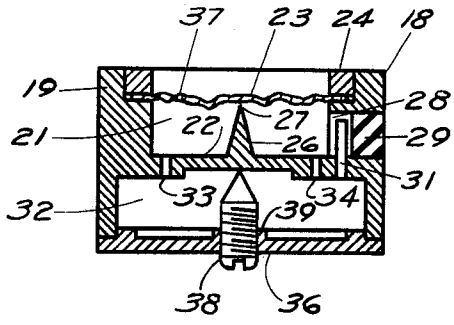


FIG. 2

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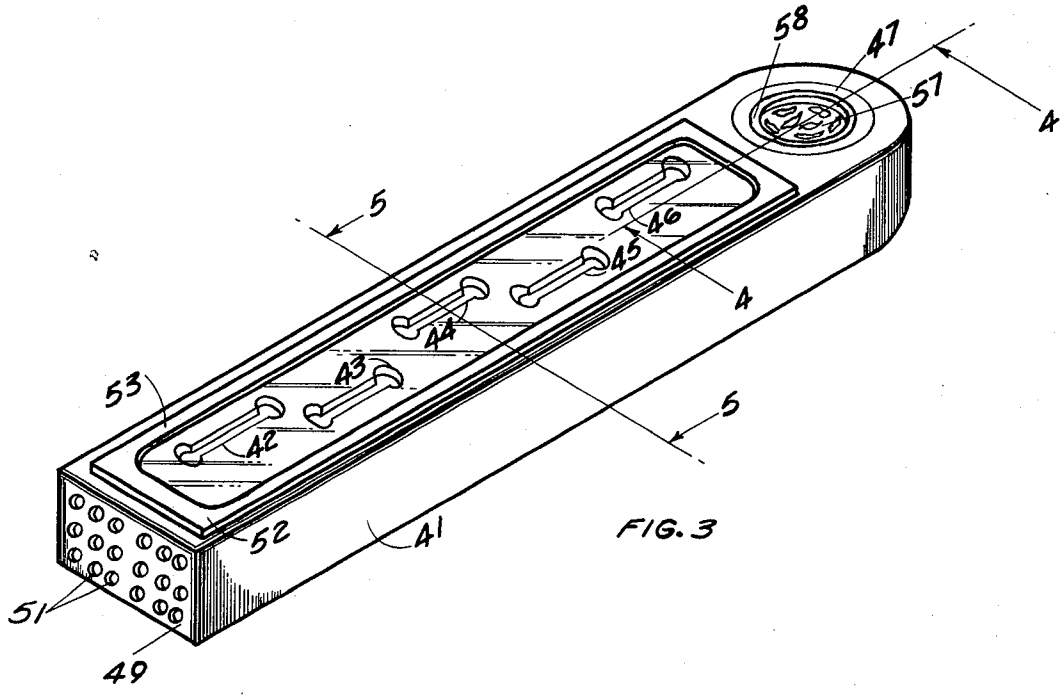


FIG. 3

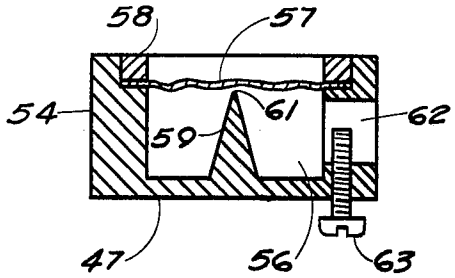


FIG. 4

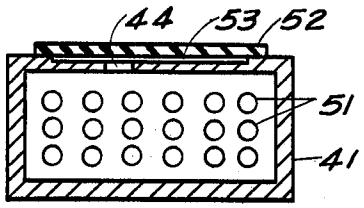


FIG. 5

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PASSIVE MICROWAVE RECEIVER-TRANSMITTER

This invention relates to a passive microwave receiver and transmitter and particularly to a device wherein microwave energy transmitted from a location remote thereto is received, modulated by adjacent acoustical energy and the microwave energy so modulated retransmitted for reception at the transmitting or other location.

Frequently it is desirable that audible sounds present at some particular location be transmitted to points remote therefrom by radio links. At the same time because of lack of power facilities, presence of explosive atmosphere, or other reasons it is undesirable or impossible to provide such location with power supplies, apparatus for generating electro-magnetic waves and the attendant equipment required to generate and radiate modulated signals. To this end the present invention contemplates the provision of a small compact device which requires no power supplies, contains no equipment liable to produce igniting electrical discharges and at the same time will receive microwave energy generated at and transmitted from a remote point, modulate the energy so received in accordance with locally produced acoustical signals, and retransmit the modulated energy to the remote transmitting or other points where the intelligence may be suitably extracted.

In general the invention comprises a microwave resonant cavity of small compact design having associated therewith an acoustically actuated member so arranged and integrated with the resonant cavity structure as to modulate microwave energy caused to impinge thereon in a highly efficient manner. At the same time the acoustical member is so designed and so combined with the microwave elements associated therewith that the acoustical characteristics are maintained uniform over a wide band of acoustical frequencies. Where extreme compactness is desired the acoustically modulated microwave cavity may itself constitute the mechanism for receiving microwave energy, modulating it and reradiating the modulated energy. In other instances where higher levels of energy return are desired the acoustically modulated microwave cavity may be coupled to a small microwave antenna which acts as the receiving and reradiating instrumentality.

It is also contemplated that when a microwave antenna is used in conjunction with the acoustically modulated microwave cavity, the antenna may itself be so constructed as to constitute an acoustic matching impedance for the acoustic elements of the system so that broad band acoustic properties are maintained.

A purpose of the invention, therefore, is to provide a compact device requiring no power supply which will transmit required intelligence to remote locations.

Another purpose of the invention is to provide a passive device for transmitting intelligence to remote locations which has a broad acoustical range of substantially uniform flat characteristic.

Another purpose of the invention is to provide a device having good acoustical properties which will efficiently modulate and transmit remotely generated electromagnetic energy.

The invention will be more readily understood from the following detailed description, considered together with the attached drawing in which:

FIG. **1** is an exterior view of one form of the invention.

FIG. **2** is a sectional view of the microwave cavity and its associated acoustical elements taken on the line **2—2** of FIG. **1.**

FIG. **3** is an exterior view of a modified form of the invention.

FIG. **4** is a sectional view of the microwave cavity taken on the line **4—4** of FIG. **3.**

FIG. **5** is a sectional view taken on the line **5—5** of FIG. **3.**

Referring now to FIG. **1,** a section of rectangular waveguide **11** is provided along one broad face thereof with a plurality of shunt slots **12, 13, 14, 15** and **16** which constitute the radiating and receiving elements. These shunt slots, as is well known in the art, may have a dumbbell configuration in order to conserve space and are alternately disposed on opposite sides of the longitudinal centerline of the waveguide section **11** by distances selected to give the requisite amount of coupling for microwave energy.

The waveguide section **11** may be closed at one end **17,** and at the other end has a microwave-acoustical transducer inserted therein extending between the broad faces of the waveguide section. The waveguide section **11** together with the shunt slots **12–16** constitutes the instrumentality for receiving and radiating microwave energy, that is, constitutes the antenna section of the device, while the microwave-acoustical transducer **18** acts to convert the acoustical energy received thereby into a modulation of the microwave energy received by the antenna portion, which modulated microwave energy is then reradiated by the antenna section so that intelligence may be derived therefrom at a remote point.

The detailed structure of the microwave-acoustical transducer can be best ascertained from the sectional view thereof as illustrated in FIG. **2.** As shown in this figure the transducer comprises a body **19** of cylindrical configuration. A microwave cavity **21,** resonant at the frequency of the microwave energy to be utilized is formed in one end thereof extending between a partition **22** and a diaphragm **23.**

The diaphragm is composed of a very thin sheet of aluminum so that its lateral displacement by acoustical energy impinging thereon is relatively great. It has been found that a thickness of 0.0002 inch is suitable since any lesser thickness approaches the skin penetration of microwave energy, such penetration being of the order of 0.0001 inch at the microwave frequency selected as the most desirable for use. The diaphragm **23** is fastened to the body **19** in untensed condition by means of a retaining ring **24** which may be fixed to the body by machine screws or any other suitable means, not shown.

Because of the extreme thinness of the diaphragm **23** and its untensed or unstretched condition it is necessary to add stiffness thereto. This is accomplished by irregularly pebbling or embossing the aluminum sheet which constitutes the diaphragm. At the same time the embossing must be entirely irregular or random in pattern since any regularity of such deformation produces a regularity of pattern of those portions which boarder the deformations and these portions act in the manner of structural struts which by the nature of their regularity introduce acoustical resonance characteristics in the diaphragm mitigating against uniformity of re-

sponse. On the other hand random configurations of these deformations avoids producing any regularities which have inherent acoustic resonances so that the overall characteristic of the diaphragm is uniform over a wide range without substantial peaking at any audible frequency.

A post **26** projects from the center of the wall **22** towards the diaphragm **23** and the end of the post is spaced from the diaphragm by a distance of from 0.001 to 0.005 inch. The post **26** is made conical so that its end **27** has an exceedingly small diameter. Theoretically, the sharper the end **27** the better since there will be a greater capacity change in the microwave cavity **21** and it is in general this change in capacity which constitutes the means for modulating the microwave energy of the cavity, although some modulation may also take place by reason of the variation of concentration of the microwave field between the sharp end of the post and the diaphragm. Likewise by reason of the sharp post end there is no air layer entrapped between the end of the post and the diaphragm which would unduly air load the diaphragm to the detriment of efficiency and characteristic of response. As a practical matter, however, the ultimate objectives obtainable by extreme sharpness cannot be achieved in a commercial device. If the post is made extremely sharp, say having an end diameter of only a few Angstrom units, then the spacing between the end of the post and the diaphragm must also be in the order of Angstrom units and such close tolerances and fine adjustments are not obtainable as a practical matter.

In order to obtain the advantages of a sharp post end in a practical adjustable instrument, therefore, the post **26** is made to be as sharp as possible and then the end **27** thereof is flattened by a very small amount so that the extreme end has a diameter of approximately 0.010 inch. This allows a feasible spacing between post and diaphragm of from 0.001 – 0.005 inch as heretofore set forth while still retaining essentially all of the advantages accruing from using extreme sharpness at the post tip.

Microwave energy is introduced into and the modulated energy abstracted from the microwave cavity **21** through a circular coupling orifice **28** which is closed to air and acousitical energy passage by a dielectric block **29** which may be of polystyrene, tetrafluoroethylene or other similar substance which permits the passage of microwave energy.

It is highly desirable that the greatest percentage of modulation consonant with the greatest amount of energy transfer into and out of the cavity **21** be obtained. As the coupling is increased, however, the Q of the cavity is reduced and a reduced Q reduces the percentage of modulation. Thus there is a critical point at which any further increase in coupling will so reduce the percentage of modulation as to reduce the net amount of intelligible signal which is reradiated. In order to adjust to this critical point so that the maximum amount of intelligence is reradiated a post **31** is provided extending from the partition **22** into the coupling orifice **28.** By adjusting the distance the post **31** projects into the orifice **28** the required critical coupling can be easily attained.

In order to produce a device giving a flat response over an extended range of acoustical frequencies it is necessary to air load the thin, and therefore high compliance, diaphragm **23** to provide an acoustical impedance match therefor. This may be done by disposing an air chamber on one side of the diaphragm. Of course, the microwave resonant cavity will form an air chamber but it has been found that proper acoustical impedance match requires a larger chamber than can be provded by the microwave resonant cavity designed to have small size and hence operating at appropriate microwave energy frequencies. In order to meet these limiting conditions the body **19** is recessed to provide an additional chamber **32** and communication for the air mass between the microwave resonant cavity **21** and the chamber **32** is provided by an annular circumferential series of holes such as **33** and **34** drilled through the partition **22.** These holes are made of sufficiently small diameter as to be below the cut-off frequency of the microwave energy utilized so that no microwave energy leaks into the chamber **32.** The microwave resonant cavity, therefore, is composed of the cavity **21** alone and is designed to be of the proper size for the frequency of the microwave energy utilized. On the other hand the acoustic impedance matching chamber includes both the microwave resonant cavity **21** and the air chamber **32** which is closed by fastening a plate **36** to the body **19** by any suitable means, not shown.

As so far described, the cavity **21** and chamber **32** taken together would form a completely enclosed space impervious to air which would unduly damp the displacement of the diaphragm producing poor response, particularly to high frequencies. To obviate this undue air loading a vent **37** produced by drilling or punching a small hole in the diaphragm is provided.

In order to provide a means for adjusting the spacing between the tip **27** of the post **26** and the underside of the diaphragm **23,** a set screw **38** is threaded through a boss **39** formed in the closure plate **36** and the end of this set screw bears against the underside of the partition **22.** Inasmuch as the adjustment of this spacing will be very small in extent the distortion of the partition **22** by the force exerted thereagainst by the set screw is sufficient.

In operation, for short distances which do not require a relatively high level of power return, the microwave-acoustical transducer **18** as depicted in FIG. **2** may be used alone. In other situations where higher levels of return are desired the microwave-acoustical transducer is combined with the antenna section **11** as illustrated in FIG. **1.** In either event the microwave energy transmitted from the remote point is introduced into the resonant cavity **21** through the microwave transparent window **29** and coupling structure composed of the orifice **28** and post **31.** When the microwave-acoustical transducer is used alone the energy is so introduced directly from free space, whereas when this device is used with the antenna section, the antenna receives the microwave energy from free space and then introduces it to the microwave cavity in the manner described. At the same time acoustical energy impinging on the device results in proportional deflection of the diaphragm **23** varying the capacity between the tip **27** of the post **26** and the diaphragm **23** to vary the resonance frequency of the cavity **21.** This results in the resonance frequency of the cavity being varied between points above and below the frequency of the transmitted microwave and gives rise to at least two different types of modulation.

In the first instance an amplitude modulation is produced by reason of the fact that when the cavity **21** is

resonant to the frequency of the impressed microwave energy a relatively large amount of power is absorbed so that less power is reradiated. As the resonant frequency of the cavity departs from the frequency of the impressed microwave energy lesser amounts of power are absorbed and more power is reradiated.

Secondly and perhaps more important, the impressed energy is phase modulated by reason of the fact that as the resonant frequency of the cavity varies from below to above the frequency of the impressed microwave energy, the cavity changes from an inductive to a capacitive character producing a large change in phase of the reflected signal.

After having been so modulated, the energy is retransmitted through the coupling orifice and post structure and window **29** to free space, if the microwave-acoustical transducer **18** is used as a separate element, or to the antenna section **11** to be radiated to free space by the radiators **12–16** if the combination structure of FIG. **1** is utilized. In either case the reradiated energy is modulated over a wide band of acoustical frequencies so that it may be received at a remote point, appropriately demodulated and the intelligence information derived therefrom.

In the form of the invention disclosed in FIGS. **3** to **5** the antenna section performs both the function of a receiver and radiator of microwave energy and an acoustical load on the microwave-acoustical transducer to prevent undue acoustical resonance thereof.

Referring to FIG. **3** the device therein disclosed is similar to that of FIG. **1** in that it comprises an antenna section **41.** provided with shunt receiving and radiating slots **42–46** in its broad face. Likewise, a microwave-acoustical transducer **47** is inserted in one end thereof positioned so as to extend between the broad faces of the waveguide section **41.**

In this case, however, since the antenna section **41** also functions as the acoustical load and path, the end **48** thereof is closed by a plate **49** provided with a plurality of apertures **51** to allow acoustical transmission through the waveguide section.

Because it is extremely desirable that the acoustical response be flat over an extended range, it is necessary that the waveguide section **41** should not introduce acoustical resonant conditions. The radiating slots **42** to **46,** however, and particularly those adjacent the microwave-acoustical transducer **47** if left open to the atmosphere are liable to introduce just such unwanted acoustic resonance. To prevent such an occurrence a sheet **52** of mica, tetraflouroethylene or other suitable dielectric is affixed to the waveguide section **41** over the area occupied by the radiating slots **42** to **46.** As a further means of providing a proper acoustic impedance match between the acoustic path provided by the waveguide section **41** and the microwave-acoustical transducer **47,** the area occupied by the radiating slots **42** to **46** and lying under the dielectric sheet **52** is recessed as at **53.** Such structure introduces just the proper amount of acoustic loss in the acoustic path to prevent acoustic resonance and provides the proper acoustic impedance match.

The microwave-acoustical transducer **47** used with this form of the invention is somewhat simpler than that disclosed in FIG. **2** since no acoustical loading chamber need be provided, this function being accomplished by the antenna section itself. This form of the microwave-acoustical transducer may be best understood by referring to FIG. **4.** As therein illustrated the transducer **47** consists of a cylindrical body **54** recessed to provide a suitable resonant microwave cavity **56.** A diaphragm **57** in all essential details like that of the diaphragm **23** of FIG. **2,** except that it contains no vent is fastened to the body **47** through the medium of a retaining ring **58,** the retaining ring in turn being fastened to the body by any suitable means such as machine screws not shown. The diaphragm **57** like that of FIG. **2,** is composed of a thin sheet of aluminum having a thickness of approximately 0.0002 inch and similarly is irregularly embossed for the same reason as heretofore set forth.

Likewise, a post **59** tapered to a sharp point **61** extends upwardly from the base of the microwave cavity **56** and is spaced from the underside of the diaphragm a distance of from 0.001 – 0.005 inch. Additionally the discussion relative to the sharpness of the tip **61** heretofore set forth with respect to the post **26** of FIG. **2** applies with equal force and to that end the tip **61** is made to have an extreme tip diameter pf approximately 0.010 inch.

In order that microwave energy may be coupled into and out of the microwave cavity **56,** a coupling orifice **62** is provided and in this instance since it is desired that an acoustical path extend from the diaphragm **57** through the microwave resonant cavity **56** and the antenna section **41** the orifice **62** is not closed but left open to the atmosphere.

Again in order that the coupling may be adjusted to such critical point as to give the largest possible modulated signal return, an adjustable post **63** extending through the body **54** and into the orifice **62** is provided.

In operation the modification of FIGS. **3** to **5** functions similarly to that of FIGS. **1** and **2** insofar as the acoustical modulation of the impressed microwave energy is concerned. However, because the acoustical impedance matching structure is incorporated in the antenna section, the microwave-acoustical transducer **47** cannot advantageously be utilized when divorced from the antenna section.

In either modification of the invention an extremely compact but nevertheless efficient structure is produced. For example, the antenna section may be a short length of standard waveguide of exterior 1 × ½ inch dimensions and either microwave-acoustical tranducer may be, and is, made of such small size as to be wholly encompassed within the interior of such waveguide section.

What is claimed is:

1. A microwave transducer comprising, a microwave resonant cavity, a randomly embossed thin metallic diaphragm closing one face thereof, a conical metallic post extending from one wall of said cavity towards said diaphragm having a sharp tip in close proximity to but spaced from said diaphragm, and means for coupling microwave energy into and out of said microwave resonant cavity.

2. A microwave transducer comprising, a microwave resonant cavity, a randomly embossed thin metallic diaphragm forming a closure for one wall thereof, a conical metallic post extending from the opposite wall of said cavity towards said diaphragm having a sharp tip in close proximity to but spaced from the underside of said diaphragm, means for acoustically impedance matching said diaphragm, and means for coupling mi-

crowave energy into and out of said microwave resonant cavity.

3. A microwave transducer comprising, a waveguide section, a plurality of microwave radiating elements positioned along the length thereof, a microwave resonant cavity positioned internally of said waveguide section, microwave coupling means between said cavity and said waveguide section, said microwave cavity being provided with a randomly embossed thin metallic diaphragm forming a closure for one wall thereof, one face of said diaphragm being exposed to the atmosphere through an aperture formed in the wall of said waveguide section, and a metallic post positioned interiorly of said cavity extending from the wall thereof opposite said diaphragm towards said diaphragm and terminating in a sharp tip positioned in close proximity to but spaced from the underside of said diaphragm.

4. A microwave transducer comprising, a waveguide section, a plurality of microwave radiating elements positioned along the length thereof, a microwave resonant cavity positioned internally of said waveguide section having one face thereof exposed to the atmosphere through an aperture formed in the wall of said waveguide section, microwave coupling means between said cavity and said waveguide section, the exposed face of said cavity being constituted by a randomly embossed thin metallic diaphragm affixed to said cavity, a metallic post positioned interiorly of said cavity extending from the center of the wall thereof opposite said diaphragm towards said diaphragm and terminating in a sharp tip positioned in close proximity to but spaced from the underside of said diaphragm, and means for acoustically impedance matching said diaphragm.

5. A microwave transducer comprising, a rectangular waveguide section, a plurality of microwave radiating slots positioned along one broad face thereof, a microwave resonant cavity member positioned at one end of said waveguide section internally thereof with one face of said cavity substantially coextensive with said broad face of said waveguide section and exposed to the atmosphere through an aperture in said waveguide wall which encompasses said cavity member, said cavity member being provided with a randomly embossed thin metallic diaphragn affixed to said cavity member and forming the exposed face thereof, a conical metallic post extending centrally of the wall of said cavity opposite said diaphragm in a direction towards said diaphragm and terminating in a sharp tip positioned in close proximity to but spaced from the underside of said diaphragm, and microwave coupling means between said cavity and said waveguide section.

6. A microwave transducer comprising, a rectangular waveguide section, a plurality of microwave radiating slots positioned along one broad face thereof, a microwave resonant cavity member positioned at one end of said waveguide section extending between the broad faces thereof with one face of said cavity exposed to the atmosphere through an aperture formed in a broad face of said waveguide section of a size such as to encompass said cavity member, a randomly embossed thin metallic diaphragm affixed to said cavity member and forming the exposed face thereof, a conical metallic post positioned internally and centrally of said cavity member and extending axially of said cavity member in a direction toward said diaphragm, said conical post terminating in a sharp tip positioned in close proximity to but spaced from the underside of said diaphragm, microwave coupling means between said cavity and said waveguide section, and means for acoustically impedance matching said diaphragm.

7. A microwave transducer comprising, a rectangular waveguide section, a plurality of microwave radiating slots positioned linearly along one broad face thereof, a cylindrical body member inserted through an aperture in said broad face at one end of said waveguide section, said body member extending between the broad faces of said waveguide section and having one end thereof exposed through said aperture, a cylindrical microwave resonant cavity formed in said body member concentric therewith, a randomly embossed thin metallic diaphragm affixed to said one end of said body member and forming a face of said cavity substantially contiguous with the broad face of said waveguide section, a conical metallic post positioned axially of said cavity and extending in a direction towards said diaphragm, said conical post terminating in a sharp tip positioned in close proximity to but spaced from the underside of said diaphragm, and microwave coupling means between said cavity and said waveguide section.

8. A microwave transducer comprising, a rectangular waveguide section, a plurality of microwave radiating slots positioned linearly along one broad face thereof, a cylindrical body member inserted through an aperture in said broad face at one end of said waveguide section, said body member extending between the broad faces of said waveguide section and having one end thereof exposed through said aperture, a cylindrical microwave resonant cavity formed in said body member concentric therewith, a randomly embossed thin metallic diaphragm affixed to said one end of said body member and forming a face of said cavity substantially contiguous with the broad face of said waveguide section, a conical metallic post positioned axially of said cavity and extending in a direction towards said diaphragm, said conical post terminating in a sharp tip positioned in close proximity to but spaced from the underside of said diaphragm, microwave coupling means between said cavity and said waveguide section, and means for acoustically impedance matching said diaphragm.

9. A microwave transducer comprising, a body member having a microwave resonant cavity formed in one end thereof and extending longitudinally of said body for a portion of the length thereof, a recess extending longitudinally into said body from the other end thereof and terminating short of said cavity whereby a partition extends between said cavity and said recess, a randomly embossed thin metallic diaphragm affixed to said body member adjacent the first mentioned end thereof forming a face of said microwave cavity, a conical metallic post affixed to said partition and extending axially of said microwave cavity towards said diaphragm, said post terminating in a sharp tip positioned in close proximity to but spaced from the underside of said diaphragm, a plurality of apertures formed in said partition of a size to permit air communication between said cavity and said recess but below the cut-off frequency for microwave energy whereby said microwave cavity and said recess together constitute an acoustical impedance match for said diaphragm, air vent means in said diaphragm, and means for coupling microwave energy to said microwave cavity.

10. A microwave transducer as set forth in claim 9 in which said body member is contained in a rectangular waveguide section between the broad faces thereof with the diaphragm exposed to the atmosphere, and said waveguide section is provided with microwave radiating elements along the length thereof.

11. A microwave transducer comprising, a cylindrical body member having a cylindrical microwave resonant cavity formed in one end thereof concentric therewith and extending longitudinally of said body member for a fraction of the length thereof, a cylindrical recess formed in the other end of said body member concentric therewith and extending longitudinally of said body for such fraction thereof as to provide a partition wall between said cavity and said recess, a plate member closing the face of said recess remote from said partition, a randomly embossed thin metallic diaphragm affixed to said body forming an end closure for said resonant cavity, a conical metallic post extending from said partition axially of said cavity towards said diaphragm, said post terminating in a sharp tip positioned in close proximity to but spaced from the underside of said diaphragm, a plurality of communicating apertures in said partition having dimensions less than the cut-off frequency for which the resonant cavity is designed whereby said microwave cavity together with said recess constitute an acoustical impedance matching chamber but microwave energy is precluded from entering said recess, an air vent in said diaphragm, and means impervious to air for coupling microwave energy to said cavity.

12. A microwave transducer as set forth in claim 11 in which said body member is contained in a rectangular waveguide section between the broad faces thereof with the diaphragm exposed to the atmosphere, and said waveguide section is provided with microwave radiating elements along the length thereof.

13. A microwave transducer comprising, a rectangular waveguide section, a plurality of radiating slots positioned along one broad face thereof, said broad face being recessed over the area occupied by said slots, a dielectric membrane covering said recessed area, a microwave resonant cavity member positioned at one end of said waveguide section and extending between the broad sides thereof with one face thereof exposed to the atmosphere through an aperture in one of said broad sides encompassing said cavity member, a randomly embossed thin metallic diaphragm affixed to said cavity and forming the face thereof exposed to the atmosphere, a metallic post extending from the wall of said cavity opposite said diaphragm in a direction towards said diaphragm, said post terminating in a sharp tip positioned in close proximity to but spaced from said diaphragm, microwave coupling means between said waveguide section and said cavity, and a closure plate for the end of said waveguide section opposite the end to which said cavity is affixed, said closure plate being perforated for acoustical and air transmission therethrough.

14. A microwave transducer comprising, a rectangular waveguide section, a plurality of shunt radiating slots positioned linearly along one broad face thereof, said broad face being recessed over the area occupied by said slots, a dielectric membrane affixed to said waveguide section covering said recessed area, a cylindrical body member set into said broad face at one end of said waveguide section with its surface substantially flush therewith and its axial length extending between the broad faces of said waveguide section, a resonant microwave cavity formed in said body member concentric therewith, a randomly embossed thin metallic diaphragm affixed to said body member and forming a closure for said cavity at the end thereof adjacent said one broad face, a conical metallic post positioned axially of said cavity terminating in a sharp tip positioned in close proximity to but spaced from said diaphragm, microwave coupling means between said waveguide section and said cavity, and a closure plate affixed to the end of said waveguide section opposite the end to which said cavity is affixed, said closure plate being perforated for acoustical and air transmission therethrough.

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