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SURFACE WAVE ANTENNA

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Fig. 1

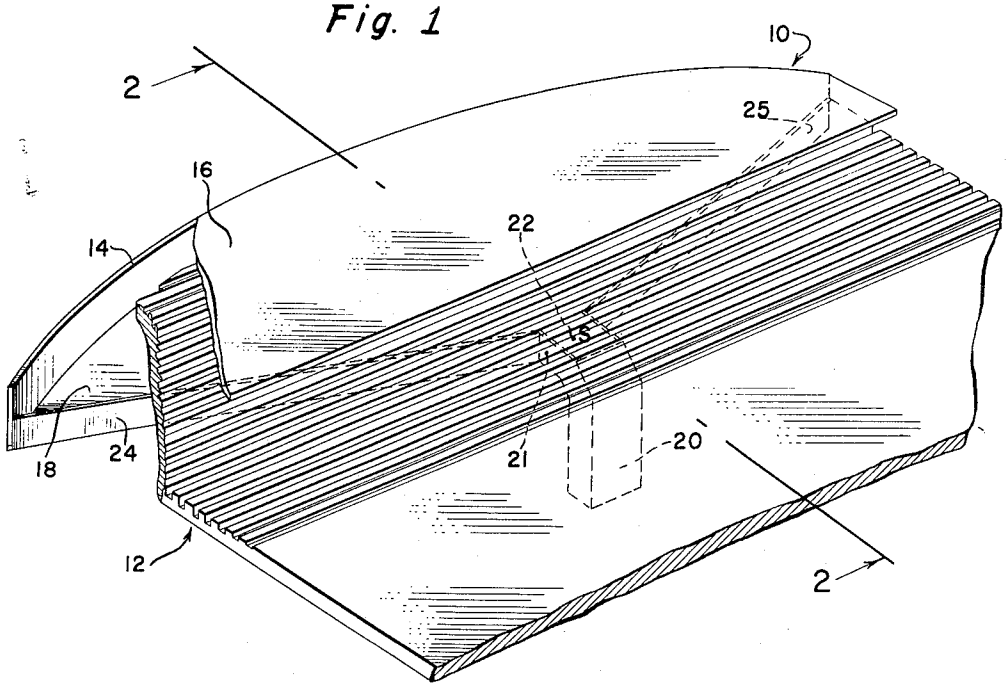


Fig. 2.

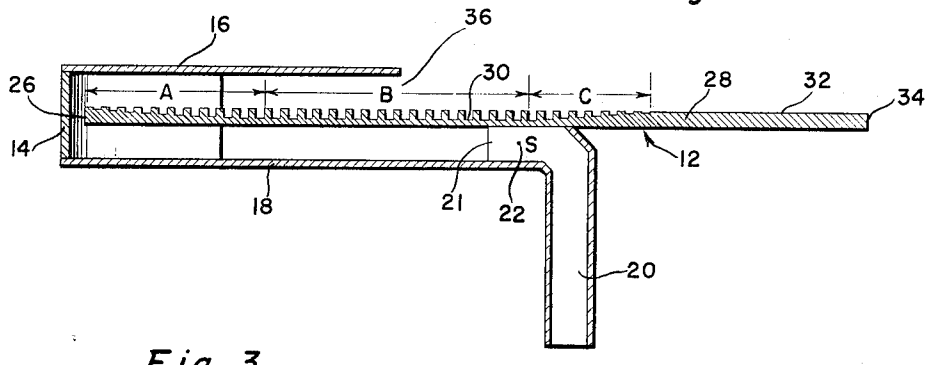
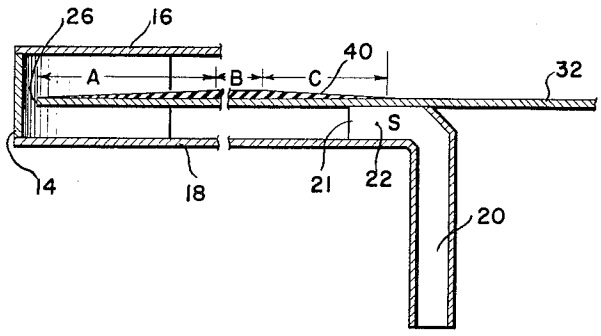


Fig. 3.



Morris J. Ehrlich,
Lester C. Van Atta,
Robert S. Wehner,
INVENTORS.
BY.

ATTORNEY.

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SURFACE WAVE ANTENNA

Lester C. Van Atta, Morris J. Ehrlich, and Robert S. Wehner, Los Angeles, Calif., assignors to Hughes Aircraft Company, Culver City, Calif., a corporation of Delaware

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This invention pertains to surface wave antennas and more particularly to a new and novel combination of a pillbox type antenna and a surface wave transmission line.

Heretofore known wave detection devices which may be mounted on submarines have been found unsatisfactory. Some of the tactical requirements of such wave detection devices are to provide a large gain and directional sensitivity. At the same time the wave detection device itself should offer a minimum size reflection area to avoid wave detection by the approaching aircraft, be able to withstand the tremendous water slap resulting from crash dives when submerging as speedily as possible to greater depth for the protection, and to offer a minimum amount of drag when the submarine is operating under water. Such requirements result in conflicting design criteria since the reflector dimensions which provide for the greatest gain and selectivity produce the greatest reflection area for detection by the incoming aircraft as well as the greatest drag on the submarine after submersion and the greatest amount of water slap.

It is therefore an object of this invention to provide an improved and new type of antenna for submarines having a large gain and selectivity, a small reflection area when above the water, and a minimum amount of drag when submerged.

It is a still further object of this invention to provide a surface wave antenna mounted on a retractable torque tube having a minimum vertical aperture dimension and providing a cosecant squared elevation-plane radiation pattern of predetermined selectivity and a narrow-beam low-side-lobe azimuth-plane pattern, of rugged construction and small aperture area to permit crash dives without danger of shearing off the antenna from the torque tube.

It is a still further object of this invention to provide an antenna capable of being rotatably mounted on a submarine by a single torque post containing the antenna feed and whose effective frontal area is only a fraction of that of a conventional reflector area.

In accordance with this invention, a surface wave transmission line is adapted to function like an end-fire array. A 180 degree parabolic focusing bend, such as a pillbox antenna is used to convert a point source feed on the underside of the surface wave transmission line to a line source on the top of the surface wave transmission line which is provided with a wave trapping agent. The plane wavefront formed by the focusing bend is almost wholly converted into a surface wave in the conversion region. The conversion region is a parallel-plate transmission line whose lower plate is a surface section provided either with tapered depth corrugations or with a tapered depth dielectric and whose upper plate is an extension of the outer conductor of the focusing bend. The surface wave leaves the conversion region, propagates along the trapping surface and is eventually radiated into space at the end of the trapping surface. The effective plane frontal area of this antenna is that of the opening formed by the parallel plate transmission line on the top part of the pillbox plus the subtended area of the flat or curved corrugated surface radiator and its supporting structure. This area is only a fractional part of that of a standard reflector while the gain of this antenna may be made equal to that obtained with a standard reflector.

FIG. 1 is a perspective view of one embodiment of a surface wave antenna provided in accordance with this invention.

FIG. 2 is a cross-sectional view taken along the line 2—2 of the surface wave antenna of FIG. 1.

FIG. 3 is a cross-sectional view illustrating a second embodiment of the surface wave antenna of FIG. 2 wherein a dielectric clad surface has been substituted for the corrugated surface.

Referring now to the drawing, and more particularly to FIG. 1, a pillbox type antenna **10**, is provided with a surface wave transmission line **12** which is inserted therein like a septum. The pillbox type antenna **10** comprises a 180 degree focusing bend **14**, an upper plate **16** and a lower plate **18**. The focusing bend **14** is a thin-walled parabolic cylindrical sector whose axis is parallel to both of the plates **16** and **18** and whose focal point is located at "S." An open-ended waveguide **20** has a 90 degree bend forming a horizontal portion at one end which provides the wave energy input terminal to the surface wave antenna and at the same time supports the pillbox type antenna **10** and the surface wave transmission line **12**. The open end **21** of the waveguide **20** faces the inner surface of the focusing bend **14** and is positioned along the axis of the parabola so that wave energy supplied by the waveguide **20** acts as a point source **22** at the focal point "S" of the parabolic cylindrical sector **14**. The two end plates **24** and **25** provide closure members for the lower parallel plate transmission line formed by the septum plate **12** and the lower plate **18**. The lower parallel plate transmission line may also be considered as an H-plane sectional horn having flared sides which is attached to the waveguide **20** and wherein wave energy is converted from the TE_{01} mode in the waveguide to the TEM mode in the horn feeding the focusing bend, as is well known to those skilled in the art.

FIG. 2 shows further details of the surface wave antenna of FIG. 1. The edge of the bottom wall of the open end **21** is directly joined to and becomes part of the lower plate **18**, while the edge of the top wall is joined to the septum plate **12** forming a corner therewith. Therefore the horizontal portion of the top wall of the waveguide is provided by the septum plate itself. The 180 degree focusing bend **14** is firmly bolted to the lower plate **18** and the upper plate **16** is bolted firmly to the 180 degree bend **14**. The vertical portion of the waveguide **20** may form the inner core of a torque tube which provides rotational support to the surface wave antenna.

The terminating edge **26** of the septum plate **12** is parallel to and separated by an air gap from the 180 degree focusing bend **14**. The width of the air gap is not critical and should be chosen large enough to permit transfer of wave energy from one surface of the septum plate to the other, and small enough to prevent too large an impedance mismatch caused by reflection of higher-order modes.

The surface antenna described hereabove provides an end fire beam. To improve the beam pattern in the vertical plane and to achieve a cosecant square pattern, a portion of the upper surface **28** of the septum plate **12** is provided with trapping agents such as the corrugations **30**. The uncorrugated portion **32** at the end of the septum plate **12** is referred to as the ground plane extension of the surface wave transmission line. The corrugated portion of the septum plate **12** is divided into three distinct regions. The first region label "A" is provided with corrugations which are tapered from zero depth to maximum depth. The second region label "B" is provided with corrugations of constant depth, the

depth being the maximum depth of the tapered region "A." The third region "C" is provided with tapered corrugations the depth of which varies from the maximum to zero. The purpose of the conversion regions "A" and "C" is to provide an impedance match between the different regions of the septum plate **12** as is well known to those skilled in the art.

The operation of the surface wave antenna of this invention may be understood by referring to FIG. 2. The space between the lower plate **18** and the septum plate **12** forms the lower parallel plate transmission line and the space between the upper plate **16** in the septum plate **12** forms the upper parallel plate transmission line. Wave energy propagated through waveguide **20** passes through the open end **21** into the lower parallel plate transmission line. For all practical purposes the wave energy supplied in this manner may be considered as coming from the point source located at the focal point **22**. The distance between the parallel plates is made as small as possible so that the total thickness of the antenna is a minimum and thereby offers little drag resistance to water and a small reflection area to enemy wave detection. Wave energy leaving the waveguide mouth **21** is converted to the TEM mode characteristic of parallel plate transmission lines so that plate separation is not critical as long as it is well below one-half wavelength to avoid higher-order modes. The 180-degree focusing bend **14** transfers the wave energy from the lower parallel plate transmission line to the upper parallel plate transmission line. The result of this transfer of wave energy is a transformation of the wave energy from a point source below the septum plate into a cophasal line source above the septum plate having an equiphase planar surface. Wave energy received by the upper parallel plate transmission line enters region "A" of the trapping agent where a large portion of the wave energy is transformed from the TEM mode into the TM mode. The tapered trapping agent provides a minimum impedance mismatch and reflection is negligible. Region "B" of the upper parallel plate transmission line conducts the trapped portion of the wave energy to region "C" of the surface wave transmission line **12** which region will reconvert the wave energy to the TEM mode with a minimum of reflection. The tapered region "C" provides a good impedance match to the ground plane and free space. Finally the surface wave is guided over the ground plane extension **32** and radiated into space by the diffraction edge **34**. The portion of the wave energy not converted into surface wave during propagation through conversion region "A" is radiated from the aperture **36** and combines with the radiation from the diffraction edge **34** to form a consecant squared radiation pattern.

Beam shaping with the surface wave antenna of this invention is accomplished by changing the physical dimension of the antenna. For instance, the width of the conversion region "A" will determine the amount of the wave energy converted into a surface wave which is eventually radiated from the diffraction edge **34**. The lengths of the upper plate **16** will determine to a considerable extent the amount of leakage which will occur in region "B" and which may provide null filling. The length of region "C" is also very important in that it will determine the amount of wave energy which is launched upon the ground plane extension **32**. Consequently, by proper choice of the above mentioned dimensions, the direction, shape and side lobe level of the resulting radiation elevation-plane patern may be adjusted. Further, even though the surface wave transmission line is shown to be planar, it is often advantageous to curve the surface and thereby lower the radiation pattern. The effect of curving the surface guiding the wave is discussed in detail in "Azimuthal Surface Waves on Circular Cylinders" by R. S. Elliott, published in the Journal of Applied Physics, vol. 26, No. 4, pp. 368–376, April 1955.

The surface wave antenna shown in FIG. 3 is a trapping agent modification of the surface wave antenna of FIG. 1 wherein the corrugations **30** have been replaced with a slab of dielectric material **40**. The depths of the layer in region "A" is tapered from zero to a maximum thickness which maximum thicknes prevails throughout the region "B." Region "C" provides a second tapered section starting with maximum thickness and ending in zero thickness. The effect of the dielectric slab is similar to that of the corrugations namely to trap the wave energy by converting the TEM mode to a TM mode. The tapered region of the dielectric slab provides impedance matches. It may be noted that corrugations are preferable to dielectric clad surfaces because of the mechanical ruggedness of the former. Also, binding a dielectric to a metallic surface is difficult and not very permanent.

The surface wave antenna, in accordance with the present invention, therefore provides a wave detection system having a large gain, a small reflection area and a minimum amount of drag. Furthermore, sudden immersion into water during crash dives will not shear the antenna from the torque tube since the water slap is relatively small.

What is claimed is:

1. A surface wave antenna comprising: a pillbox type antenna having a 180 degree reflector bend a lower plate fastened to the lower edge of said bend, and an upper plate in parallel relation to said lower plate fastened to the upper edge of said bend, said bend having a parabolic cross section in a plane parallel to said plates; a septum plate supported in parallel relation between said upper and said lower plate and extending out of said pillbox type of antenna, the space between said lower plate and said septum plate defining a lower parallel-plate transmission line and the space between said upper plate and the associated surface of said septum plate defining an upper parallel-plate transmission line, a selected portion of said septum plate within said upper parallel plate transmission line including corrugations for propagating a surface wave; and an open-ended waveguide feed, said feed coupled to said lower parallel-plate transmission line and the open end of said feed facing the inner surface of said bend.

2. A surface wave antenna comprising: a pillbox type antenna having a 180 degree reflector bend, a lower plate fastened to the lower edge of said bend, and an upper plate in parallel relation to said lower plate fastened to the upper edge of said bend, said bend having a parabolic cross section in a plane parallel to said plates; a septum plate supported in parallel relation between said upper and said lower plate and extending out of said pillbox type of antenna, the space between said lower plate and said septum plate defining a lower parallel-plate transmission line and the space between said upper plate and the associated surface of said septum plate defining an upper parallel-plate transmission line, said upper parallel-plate transmission line being provided with a trapping agent at the septum plate adapted to trap and propagate a predetermined portion of electromagnetic waves transmitted therealong as a surface wave; and an open-ended waveguide feed, said feed coupled to said lower parallel-plate transmission line and the open end of said feed facing the inner surface of said bend.

3. A corrugated surface wave antenna for radiating a substantially horizontally directed search beam having a cosecant squared cross-sectional pattern in a vertical plane, said surface wave antenna being mounted upon a vertical torque tube enclosing a waveguide feed and comprising: a lower and an upper horizontal surface member; a focusing bend of parabolic cross-section in a plane parallel to said surface members connected to both said surface members and forming a pillbox type antenna

therewith, said pillbox type antenna being coupled to said torque tube; a septum plate interposed between and parallel to said surface members and separating the space between said surface members, said plate extending into said pillbox type antenna so as to leave a small gap between said focusing bend and its edge, an aperture in said lower surface member, said waveguide feed being coupled to said aperture, said aperture being positioned such that said waveguide feed effectively radiates as a point source at the focal point of said focusing bend; horizontal guide bars provided between the lower surface of said septum member and said lower surface member to confine radiation from said point source to a triangular sector defined at one extremity by the ends of said focusing bend and the other extremity by the width of said waveguide feed, said septum plate being provided with corrugations over the surface facing the upper surface member, whereby energy from said waveguide is radiated as a point source from said waveguide feed into the space between the lower surface member and said plate as a divergent line source is then reflected by said focusing bend to form a planar line source and at the same time transferred to the space between the corrugated surface and said upper surface member, its direction of energy flow being thereby reversed, said wave energy being converted into a surface wave and conducted over said plate by said corrugations to finally be radiated into free space as an end-fire substantially horizontal search beam having a cosecant squared cross-section in a vertical plane.

4. A corrugated surface wave antenna for radiating a substantially horizontally directed search beam having a cosecant squared cross-sectional pattern in a vertical plane, said surface wave antenna being mounted upon a vertical torque tube enclosing a waveguide feed and comprising: a lower and an upper planar horizontal surface member in parallel relationship; a focusing bend of parabolic cross section in a plane parallel to said surface members connected to both said surface members and forming a pillbox type antenna therewith, said pillbox type antenna being coupled to said torque tube; a septum plate interposed substantially midway between and parallel to said surface members and extending into said pillbox type antenna such as to leave a small gap between said focusing bend and its edge; an aperture in said lower surface member, said waveguide feed being coupled to said aperture, said aperture being positioned so that said waveguide feed effectively radiates as a point source at the focal point of said focusing bend; horizontal guide bars provided between said septum member and said lower surface member to confine radiation from said point source to a triangular sector defined at one extremity by the ends of said focusing bend and the other extremity by the width of said waveguide feed, said septum plate having corrugations over a portion facing said surface of the upper surface member, said corrugations being tapered in depth on either side of a center portion having constant depth corrugations, said tapered corrugations providing transition regions, whereby energy from said waveguide is radiated as a point source from said waveguide feed into the space between the lower surface member and said plate as a divergent line source, is then reflected by said focusing bend to form a planar line source and at the same time transferred to the space between said corrugated surface and said upper surface member, its direction of energy flow being thereby reversed, said wave energy being converted into a surface wave and conducted over said plate by said corrugations to finally be radiated into free space as an end fire substantially horizontal search beam having a cosecant squared cross-section in a vertical plane.

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