

[54] **APPARATUS FOR SIMULTANEOUSLY TRANSMITTING AND RECEIVING AS WELL AS MIXING TRANSMITTED AND RECEIVED WAVES**

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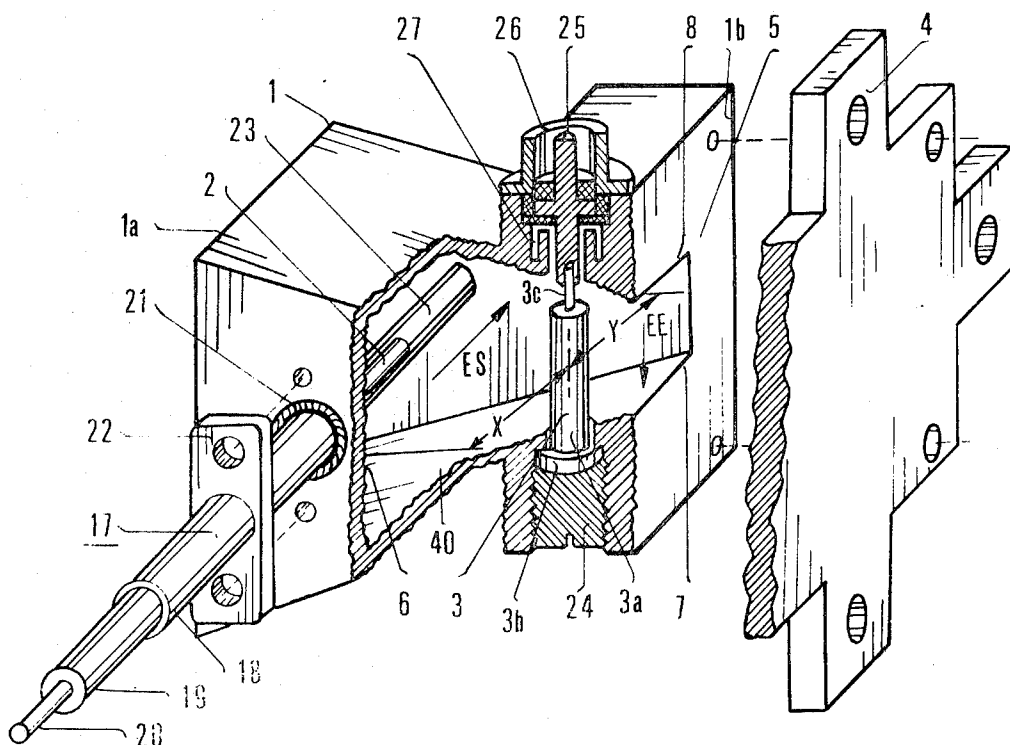
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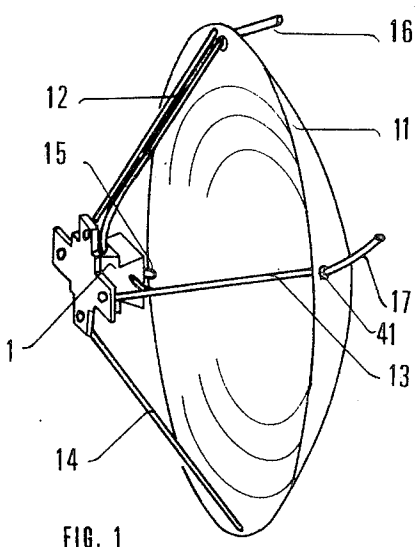
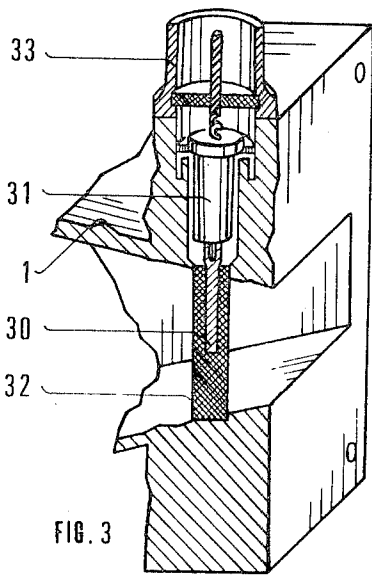
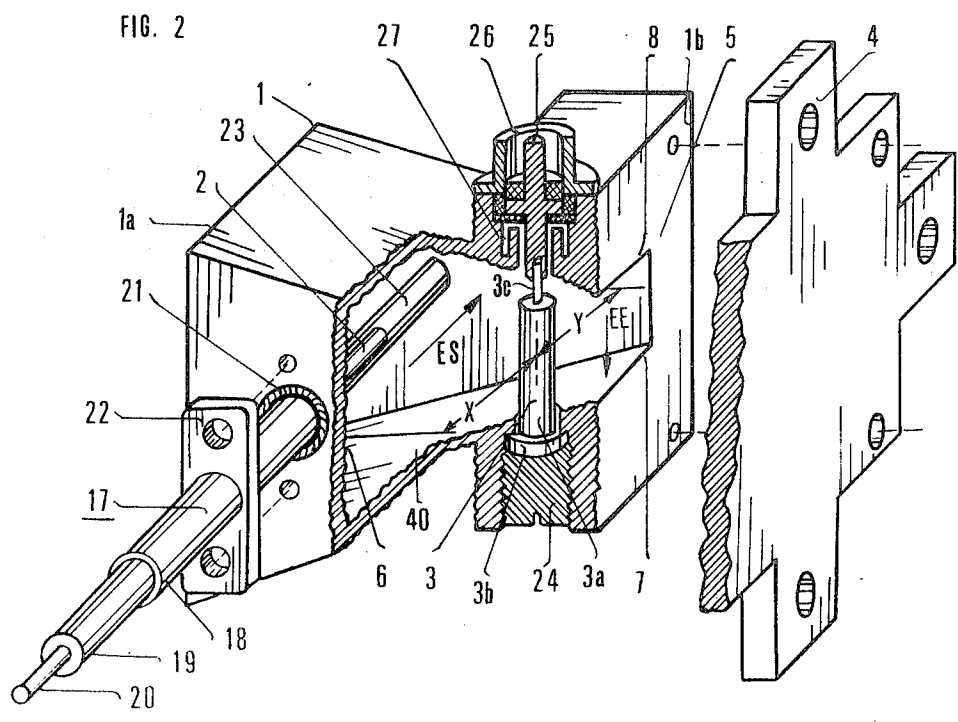
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ABSTRACT

An apparatus for simultaneously transmitting and receiving as well as mixing transmitted and received waves. The transmitted and received waves respectively having perpendicular polarization directions with respect to one another. The apparatus comprises a reflector with an associated primary horn radiator impinging upon the reflector. The primary horn radiator is advantageously flared throughout its length from front to back thereof to provide a tapered hollow space therein. An excitation conductor delivers the waves to be transmitted to the horn radiator. There is provided means for receiving waves captured by the radiator, such receiving means being arranged in the tapered hollow space of the horn radiator and serves to filter out and remove the received waves as well as a portion of the transmitted waves and to mix these filtered out waves. For the purpose of compensating for non-symmetry in the field of the received wave the receiving means is advantageously arranged in offset relationship with respect to the central lengthwise axis of the horn radiator. Such apparatus has typical utilization in electronic distance measuring environments.

7 Claims, 3 Drawing Figures





APPARATUS FOR SIMULTANEOUSLY TRANSMITTING AND RECEIVING AS WELL AS MIXING TRANSMITTED AND RECEIVED WAVES

CROSS-REFERENCE TO RELATED CASE

The present application is a continuation of my commonly assigned, previously co-pending, now abandoned, United States application, Ser. No. 856,269, filed Sept. 9, 1969, and entitled APPARATUS FOR SIMULTANEOUSLY TRANSMITTING AND RECEIVING AS WELL AS MIXING TRANSMITTED AND RECEIVED WAVES.

BACKGROUND OF THE INVENTION

The instant invention generally relates to high-frequency radiation apparatus and particularly concerns an improved apparatus for simultaneously transmitting and receiving as well as mixing transmitted and received waves, the transmitted and received waves having respective polarization directions oriented perpendicular to one another.

The improved apparatus is of the type incorporating a reflector and a primary horn radiator impinging upon the reflector and further includes an excitation conductor for delivering waves to be transmitted to the horn radiator, as well as means for receiving waves captured by the horn radiator.

Arrangements of the above-described type are typically used in electronic distance measuring environments in which a respective combined transmitter and receiver is mounted at the terminal or end points of the particular path to be measured. The respective polarization directions of the transmitted waves and the received waves are displaced with respect to one another through 90° so as to separate the transmission path from the receiving path.

One known arrangement consists of a reflector antenna having a subsequent transmitting-receiving network branch. The network branch, apart from filtering-out and removing the received waves also serves to filter out a small portion of the transmitted waves and couple same into the mixing stage of the receiver. The transmitting-receiving network branch of the known arrangement, consists of a first waveguide section having a circular-shaped cross-section, a transition member to a second waveguide section having rectangular cross-section, as well as a third rectangular waveguide section which is coupled to the connection location of the first and second waveguides. The third waveguide section is disposed such that its lengthwise axis encloses a small angle with the narrow side of the second waveguide. Due to this disposition the received wave delivered from the antenna by means of the first circular waveguide section and a small portion of the transmitted wave supplied from the second rectangular waveguide section is filtered out and coupled to the third waveguide section and then delivered to the receiver-mixer stage connected to this branch.

A further prior-art arrangement provided for the same purpose likewise can be seen to comprise a transmitting-receiving branch. This branch is composed of a first waveguide section having square or quadractic cross-section, a transition portion or region leading to a second rectangular waveguide section, as well as a third rectangular waveguide section which is coupled at the connection point of the first and second sections.

The third waveguide section is disposed such that its lengthwise or longitudinal axis extends parallel to the narrow side of the second rectangular waveguide. Means are also provided herein which ensure that the transmitted wave which is supplied to the second rectangular waveguide arrives at the antenna coupled to the first quadratic or square waveguide but does not, however, arrive at the receiver via the third rectangular waveguide. Additionally, means are provided which ensure that the received waves which arrive from the antenna via the first quadratic waveguide also arrive via the third rectangular waveguide to the receiver but, however, do not arrive in the second rectangular waveguide section.

With this arrangement, two probes are disposed in the first quadratic waveguide section between the filtering-out or decoupling location of the third waveguide and the antenna. With respect to the transmitting- and receiving polarization, these probes exhibit an angle of 45° and are physically spaced from one another in the propagation direction of the waves by a quarter wave-length. Each of the probes are excited by the passing transmitting waves such that the probes, in turn, generate waves. The wave generated at each probe consists of two components having the same magnitude, the first component being polarized parallel to the transmitting wave whereas the second component is polarized perpendicular to the transmitting wave. The second component, therefore, exhibits a polarization which corresponds to that of the received waves. Now, considering the waves radiated back by both probes to the device, the waves polarized in the receiving plane are added whereas those waves polarized in the transmitting plane serve to cancel one another out. Hence, at the receiver, a reference wave arrives which is polarized in the receiving plane and which is derived from the transmitted wave.

Each of the above-described prior-art arrangements exhibits disadvantages. For example, the first-mentioned arrangement is prone to exhibiting considerable error in distance measuring since, apart from the transmitted wave coming directly from the transmitter, a transmitted wave reflected by the antenna can also arrive at the receiver. With the second-mentioned prior-art arrangement, this particular drawback is overcome but, however, only through a quite considerable expenditure. In addition, the second-mentioned arrangement is only suitable for operation within a narrow frequency range since the quarter wave-length spacing of the probes can only accurately be maintained for a single frequency.

SUMMARY OF THE INVENTION

Thus, a need exists in the art for an improved apparatus for simultaneously transmitting and receiving as well as mixing transmitted and received waves, which apparatus eliminates the drawbacks associated with prior-art constructions. It is a primary object of the instant invention to satisfy this need. Other, more specific, yet equally important objects of the instant invention are the provision of an apparatus of the type described which can be manufactured at relative low cost and which is capable of operation over a relatively wide frequency range.

Now, in order to implement these and still further objects of the instant invention which will become more readily apparent as the description proceeds, the inven-

tion will be seen to comprise an apparatus for simultaneously transmitting and receiving as well as mixing the transmitted and received waves, the respective polarization directions of such waves being disposed perpendicular to one another. The novel apparatus embodies a reflector as well as a primary horn radiator, the horn radiator being provided with both an excitation conductor which delivers the waves to be transmitted as well as with means for receiving the waves that are captured.

The inventive apparatus is manifested by the features that the primary horn radiator is advantageously flared throughout its length from front to back to provide a tapered hollow space therein. The receiving means comprising a receiving element arranged in such tapered hollow space of the horn radiator and which filters-out or de-couples the received wave as well as a portion of the transmitted wave, and which mixes these filtered-out or de-coupled waves. A further aspect of the invention contemplates arranging the receiving means in offset relationship with respect to the central lengthwise axis of the horn radiator, and specifically, wherein such receiving means is located at a greater spacing from the inside wall surface where the excitation conductor is introduced than from the oppositely situated inside wall surface.

Some of the more notable advantages of the apparatus of the invention over the prior-art resides in the fact that separate transmitting-receiving branches are not required. Due to the arrangement of the receiving means within the tapered hollow space of the flared primary horn radiator there is ensured that a dampened portion of the transmitted wave definitely arrives at the receiver means. The offset arrangement of the receiving means within the flared horn radiator is discussed above advantageously compensates for non-symmetry in the field of the received wave, thus ensuring that the primary radiation direction of the horn radiator will substantially coincide with the axis of such horn radiator. Furthermore, due to the simple construction of the invention, lower manufacturing costs result. Since no components are utilized which are critically dimensioned or matched to a particular wave-length, the apparatus is therefore usable for a large or wide frequency range. With the novel apparatus, an intermediate frequency signal will be produced in the receiving apparatus of the primary horn radiator, the frequency of this signal being lower than the received frequency. This intermediate frequency signal does not place as great a demand upon the transmission or conductor means between the primary radiator and the receiver device as does the received signal.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and objects other than those set forth will become apparent when consideration is given to the following detailed description of the preferred inventive embodiment, such description making reference to the annexed drawing wherein:

FIG. 1 schematically depicts a first embodiment of the inventive arrangement comprising a primary horn radiator and a reflector upon which the horn radiator impinges;

FIG. 2 is an illustrative, exploded perspective view with parts broken away for illustrative clarity and so as to expose internal structure, of a horn radiator in which

a semi-conductor element is provided as the means for receiving, the element being arranged in the hollow space of the horn radiator; and

FIG. 3 depicts a further inventive embodiment of a receiving device disposed in the horn radiator, the means for receiving consisting of a filtering-out or de-coupling pin extending into the hollow space of the horn radiator and a subsequently connected semi-conductor element.

DETAILED DESCRIPTION OF THE PREFERRED INVENTIVE EMBODIMENTS

Now, referring to the drawings and particularly to FIG. 1 thereof, the arrangement therein illustrated will be seen to consist of a primary horn radiator 1 and a reflector 11 upon which horn radiator 1 impinges. The primary horn radiator 1 is advantageously flared throughout its entire length from the front 1a to the back thereof to provide a tapered hollow space 40 therein. Horn radiator 1 is secured to the reflector 11 by means of brackets or supports 12, 13, 14 and 15. A coaxial cable 17 is provided as the infeed for a wave to be transmitted, this cable leading from a non-illustrated transmitter-receiver device through an opening 41 in reflector 11 and along support 13 to the flared horn radiator 1. An intermediate frequency signal produced at a receiving means 3 of flared horn radiator 1 is removed by means of coaxial cable 16. Coaxial cable 16 is disposed along support 12 and is likewise fed through an opening of the reflector 11 to the transmitter-receiver device. The general arrangement of a primary radiator constructed as a horn impinging upon a reflector as illustrated is sufficiently known in the art and greater detailed explanation with respect thereto is thus not thought to be necessary.

Flared horn radiator 1 as depicted in FIG. 2 is closed or terminated at its back or rear end 1b by a short-circuit plate member 4. The horn radiator, at the region of the short-circuit plate member 4, exhibits a cross-sectional configuration corresponding to a rectangular waveguide for conducting the fundamental or base mode of the received wave EE. The opening or front end cross-sectional configuration of horn radiator 1 is also rectangular with the longer walls or sides 5 and 6 of the rectangle being disposed parallel to one another and to the electric field EE of the received waves. The primary horn radiator 1 comprises planar inside wall surfaces 5, 6, 7 and 8 delimiting the tapered hollow space 40 within such flared horn radiator. The rearwardly tapered inside wall surfaces 7 and 8, converging from the front towards the back of the flared horn radiator, serve to connect the respective parallel sides 5 and 6 of both rectangular cross-sections of the horn radiator at the region of the short-circuit plate member 4 and at the front end opening 1a thereof. The direction of the electric field of the received wave is represented by arrow EE, whereas the electric field direction of the transmitted wave is depicted by arrow ES.

Horn radiator 1 is excited by an excitation conductor 2 which, in the preferred inventive embodiment, comprises the end of the internal conductor 20 of a coaxial cable 17 extending into the hollow space or compartment 40 of the horn radiator. The shield or screen covering 18 of coaxial cable 17 is formed into a flange 21 and is pressed against the outside of horn radiator 1 by means of a plate member 22. The dielectric or insulation 19 of the coaxial cable 17 is removed at the plane

of the inside wall surface where such coaxial cable enters the hollow space 40. A rod 23 formed of dielectric material is provided so as to improve the matching of the excitation conductor 2 to the horn radiator 1. Rod 23 encompasses or surrounds the excitation conductor 2 and extends to the opposite inside wall surface 5 of horn radiator 1. The provision of an excitation conductor along with the surrounding dielectric rod for exciting a waveguide system is known in the art and a further detailed description thereof is thus not deemed necessary.

The receiving means 3 is provided between the excitation conductor 2 and the short-circuit plate member 4 and is advantageously arranged within the tapered hollow space 40. This receiving means 3 serves for filtering-out or de-coupling the received wave EE as well as a portion of the transmitted wave ES, and for mixing both of these filtered-out waves ES and EE. In the exemplary embodiment as depicted in FIG. 2, the receiving means 3 will be seen to consist of a semi-conductor element disposed in the hollow space or compartment of horn radiator 1. A commercially available receiving diode designated 1N23 can be utilized as the semi-conductor element 3. The construction of the receiving means corresponds to the construction of a known waveguide detector. The diode casing or cartridge 3a is secured to the wall 7 at a collar-shaped connection 3b by means of screw member 24. The opposite pin-like diode connection 3c is coupled with an internal conductor 25 of a coaxial jack 26. In known manner, a choke joint 27 is provided and serves to match the receiving means 3 to the flared horn radiator 1.

During the following description of the operation of the above-described preferred inventive embodiment, it is to be assumed that two similar combined transmitting/receiving arrangements are provided spaced-apart from one another, the directional beam or wave produced by each arrangement being aligned with and impinging onto the reflector antenna of the other arrangement. Furthermore, it is to be assumed that the polarization direction of one transmitted wave is perpendicular to the polarization direction of the other transmitted wave. Thus, the received waves EE arriving at each respective arrangement are polarized perpendicular to their respective transmitted waves ES. Additionally, it should be understood that the frequencies of both transmitted waves ES are maintained different from one another.

Now, the transmitted wave ES emanating from excitation conductor 2 is, on one hand, radiated towards the reflector 11 via the front end opening 1a of the horn radiator 1, and on the other hand, a portion of the transmitted wave ES propagates towards the receiving diode 3. The internal dimensions are such that the cross-section of the horn radiator 1 at the region of the diode forms an effective short-circuit for the transmitted wave ES. The portion of the transmitted wave ES emanating from the excitation conductor 2 in the direction of the diode 3 is therefore reflected at this short-circuit location and radiated back towards the reflector 11. The transmitted wave ES thus appears strongly damped at the region of the diode. Although the diode 3 is disposed in such manner that it is suitable for the reception of the received wave EE captured by the horn, which wave is polarized perpendicular to the transmitted wave ES, it will be understood that a small portion of the transmitted wave ES is also filtered-out

or detected by the diode 3. As previously explained, the flaring of the primary horn radiator from the front end to the back or rear thereof throughout its length and the arrangement of the receiving diode 3 within the tapered hollow space thus formed within the primary horn radiator ensures that a portion of the transmitted wave arrives at such receiving diode.

With respect to the received wave EE transmitted from the oppositely disposed arrangement, the novel apparatus represents a conventional receiving detector. With the disposition of the receiving means in the middle of the cross-section of the horn radiator 1, a small non-symmetry in the receiving field or antenna diagram results due to the influence of the excitation conductor 2. This non-symmetry, however, is corrected in that the spacing of the receiving device from the inside wall surface 6 of horn radiator 1 at which the coaxial cable 17 is introduced, is chosen to be greater than the spacing from the oppositely situated inside wall surface 5, i.e., wherein the dimension X is greater than the dimension Y. Due to this arrangement, received wave EE is barely influenced by the excitation conductor 2. Hence, by virtue of the offset arrangement of the receiving diode 3 with respect to the central lengthwise axis of the flared horn radiator 1 adequate measures are provided to ensure that the primary radiation direction of the horn radiator 1 substantially coincides with the lengthwise axis of such horn radiator, in other words there is ensured that the primary radiation direction is not off-line.

A respective current derived from the transmitted wave ES and from the received wave EE now flows through diode 3. Due to the non-linear conductivity characteristics of diode 3, a mixed output appears from these two component signals which, inter alia, comprises the sum and/or difference frequencies of both signals. The desired intermediate frequency signal is then removed at the coaxial jack 26.

Referring now to FIG. 3, a further embodiment of the receiving means is illustrated and, if desired, can be utilized instead of the receiver means employed in the embodiment of FIG. 2. The modified receiving means comprises a filtering-out or decoupling pin 30 which extends into the hollow space of the horn radiator 1 and cooperates with a subsequent semi-conductor element 31. A dielectric rod 32 is provided so as to improve matching of the filtering pin 30 to the horn radiator 1. The semi-conductor element 31 which, for example, can comprise a commercially available diode 1N23, is utilized as a coupler connecting the filtering pin 30 with a coaxial jack 33 and providing a mixing function.

The receiving means, as illustrated in FIG. 3, generally corresponds to a known physical waveguide detector construction. As the function of such a detector is well known in the art, further description thereof is not necessary.

While there is shown a described present preferred embodiments of the invention, it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied and practiced within the scope of the following claims. ACCORDINGLY,

What is claimed is:

1. An apparatus for simultaneously transmitting and receiving as well as mixing transmitted and received waves which have respective polarization directions

perpendicular to one another, said apparatus comprising: a reflector means; a primary horn radiator means impinging upon said reflector means, said primary horn radiator means being flared throughout its length and possessing a tapered internal hollow space; an excitation conductor connected to said primary horn radiator means for delivering waves to be transmitted thereto; and receiving means for receiving waves captured by said primary horn radiator means, said receiving means being disposed in said tapered hollow space of said primary horn radiator means and in sufficient proximity to said excitation conductor that a portion of the transmitted wave emanating from said excitation conductor arrives at said receiving means, said receiving means being located in offset relationship with respect to the central lengthwise axis of said primary horn radiator means to compensate for non-symmetry in the field of the received wave, said receiving means filtering-out the received wave, said portion of the transmitted wave, and also mixing these filtered-out waves.

2. An apparatus as defined in claim 1, wherein said receiving means consists of a semi-conductor disposed in the hollow space of said primary horn radiator means.

3. An apparatus as defined in claim 1, wherein said receiving means consists of a de-coupling member at least partially extending into the hollow space of said primary horn radiator means, and a subsequently disposed semi-conductor.

4. An apparatus as defined in claim 1, wherein said primary horn radiator means is open at the front end thereof, and is terminated at the rear end thereof by a short-circuit plate, and wherein said receiving means is disposed in the tapered hollow space of said horn radiator means between the connection location of said excitation conductor and said short-circuit plate.

5. An apparatus as defined in claim 4, wherein said excitation conductor is disposed through one inside wall surface delimiting the hollow space of said horn radiator means and wherein said offset arranged receiving means is disposed in the tapered hollow space such that the spacing of said receiving means from said one

inside wall surface is greater than the spacing of said receiving means from an oppositely situated inside wall surface of said tapered hollow space.

6. An apparatus as defined in claim 5, wherein said primary horn radiator means, at the region of said short-circuit plate thereof, defines a cross-section corresponding to a rectangular waveguide for conducting the fundamental mode of the received wave, and wherein the front end cross-sectional opening of said primary horn radiator means is also rectangular with the longer sides of the rectangle being disposed parallel to the electric field of the received waves, and wherein the wall surfaces of the internal hollow space of said horn radiator means are planar surfaces and connect the respective parallel sides of both rectangular end cross-sections of said primary horn radiator means.

7. An apparatus for simultaneously transmitting and receiving as well as mixing transmitted and received waves which have respective polarization directions perpendicular to one another, said apparatus comprising: a reflector means; a primary horn radiator means impinging upon said reflector means, said primary horn radiator means being flared throughout its length and possessing a tapered internal hollow space; an excitation conductor connected to said primary horn radiator means for delivering waves to be transmitted thereto; and receiving means for receiving waves captured by said primary horn radiator means, said receiving means being disposed in said tapered hollow space of said primary horn radiator means and in sufficient proximity to said excitation conductor that a portion of the transmitted waves emanating from said excitation conductor arrives at said receiving means, said receiving means being located in offset relationship with respect to the central lengthwise axis of said primary horn radiator means and which offset relationship is so proportioned as to compensate for non-symmetry in the antenna diagram of the received wave, said receiving means filtering-out the received wave, said portion of transmitted wave, and also mixing these filtered-out waves.

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