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SLOTTED RESONATOR ANTENNA FOR WIMAX APPLICATIONS

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Abstract: A Dielectric Resonator antenna has been proposed for WiMaX application. Fabrication is done for 3.5GHz band. Reflection coefficients for different stub lengths has been studied and the maximum performance is obtained near 3.5GHz. Radiation patterns in the E and H field show good cross polarization isolation..

***Index Terms* - WiMAX application, dielectric resonator antenna, semicircular slot.**

I. INTRODUCTION

Dielectric resonator antennas are those which consist of dielectric material as the radiating element. It is placed on the surface of the metal and a feeding circuit is used to implement required excitation in the form of electromagnetic energy. The resonator walls are partially transparent to the electromagnetic waves, enabling the electromagnetic power to penetrate into free space. As the conductor loss increases with the square root of the operating frequency, when operating at higher frequencies, traditional metal antennas such as microstrip antennas may have poor radiation efficiencies. The impedance bandwidth is much wider compared to the metallic patch antennas.

The evolution of dielectric resonators started at 1939 when R.D Richtmyr discovered that unmetallized dielectric objects could function similar to metallic cavities. He named it as dielectric resonators. They can radiate very efficiently when excited at certain frequencies. In a dielectric resonator antenna, the radiation function is due to the displacement current that circulates in the dielectric medium. The energy contained in the dielectric medium is very strong and the external materials make it challenging to disrupt the object's resonance. In various applications, dielectric resonator antennas have gained increased attention because of their attractive characteristics in terms of high radiation efficiency, light weight, compact size and low profile. The size of the antenna is inversely proportional to the permittivity of the material to the square root. Hence, if we choose higher permittivity material, size of the antenna can be made much smaller without affecting the bandwidth of operation. Whereas in case of metallic patch antennas, higher permittivity leads to narrow bandwidth of operation. The microstrip patch antenna radiates only through two narrow edges available in the patch whereas dielectric resonator radiates through all the possible faces except the grounded part. Once a DRA starts resonating for a frequency, it is not possible for any external devices to disturb its resonance. The size of the dielectric antenna used is also inversely proportional to the material's dielectric constant. Hence, as we choose a higher dielectric material, size can be reduced to a very smaller scale. It also has some added advantages such as very less phase noise, high bandwidth of operation, high radiation efficiency, low production cost and is stable independent of frequency of operation and temperature compared to microstrip patch antennas. Millimeter wave frequencies are the extremely high frequencies(30 to 300 gigahertz) which has higher data transmission rate. As the frequency of operation increases, the ohmic loss also rises in the metallic parts. Also there is greater chance of surface wave formation on the metal surface at high frequencies. Hence, using a patch antenna will be less appropriate and hence a dielectric resonator antenna is the most suitable type one to be used in those frequencies. Dielectric loss is the only loss in a DRA that is very negligible. There is a special interest in a spherical dielectric resonator antenna since this is the only type for which an analytical solution is feasible. TEnmr and TMnmr modes (m<=n) can accommodate a spherical dielectric antenna. The indices n, m and r denote the order in the height, azimuth and radial directions of the variance of the fields, respectively. Like an isolated spherical antenna, a practical hemispherical dielectric resonator antenna mounted on a metallic plane is identical. For example, the TE111 mode of hemispherical dielectric resonator placed on the ground plane is equivalent to the TE111 mode of isolated spherical DR and it radiates like a horizontal magnetic monopole.

Likewise, the TM101 mode of hemispherical DR is equivalent to that of isolated spherical DR and it radiates like a vertical electric dipole

II. BACKGROUND

Dielectric resonator antennas are a good replacement of microstrip patch antennas because of the wider bandwidth available and the higher power handling capability. DRAs can be excited with a large number of feeding mechanisms including microstrip line feed, aperture coupled, probe, slot coupled, coplanar waveguide and image waveguide feed. Coupling is the method by which power is coupled to an antenna. It has a major influence on the frequency of resonance and the Q factor. Hence the coupling method must be properly selected to have better efficiency. The radiation efficiency of DRA is higher at millimeter wave frequencies since the conductor losses can be reduced compared to microstrip patch antennas. A better way to couple a DRA is to use coplanar waveguide which is planar in structure. A wide range of configurations are available in dielectric resonator antennas such as rectangular[1] , cylindrical[2], triangular disc[3], hemispherical including multilayer structures[4],spheroidal[5], which offers higher radiation efficiency when proper feeding method is used with appropriate dimensions. The rectangular DR Antenna in [6] is fed here through a metallic feed which ensure better coupling. The geometry of coupling is given in the figure below.

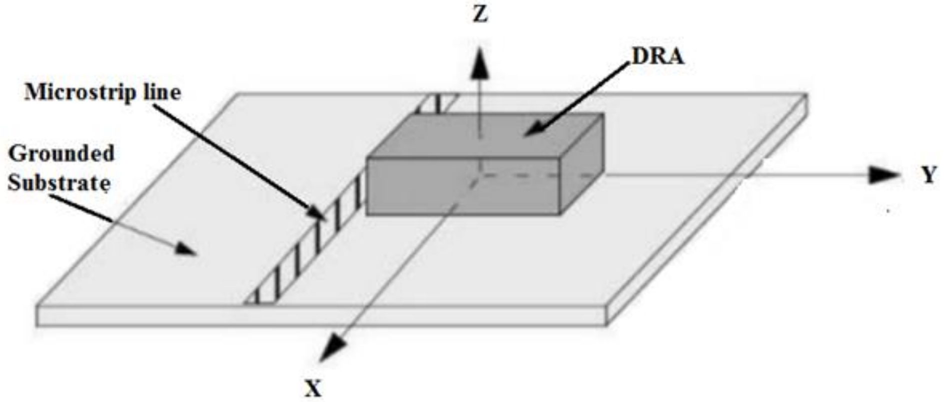

Fig 1: Microstrip Line fed Rectangular DRA

A high input impedance, far greater than 50 Ω has been achieved with a narrow strip width. Therefore, if its dimensions (width and length) are optimized, a wide strip that actually provides 4 the requisite impedance matching can be used. While changing the position of inset feed, we can easily change the coupling. But the major disadvantage is that there is effect of spurious radiation since the radiating element is in direct contact with the feed. Also, comparing to rest of the coupling methods return loss is very poor.

The coupling method in which the outer most conductors have been grounded and the inner conductor is directly coupled to the dielectric resonator antenna is the coaxial probe feed. [2]. The upper surface of the substrate has finite conductivity layer. This has been done to minimize the backlobe radiation. The advantage of using such technique is that there is direct coupling of power to the DRA without using a metallic strip so that radiation loss at higher frequencies due to presence of metallic strips can be completely eliminated. Also this method provides an easy feeding. But the limitation is that the conductor is made to intrude in to the DRA structure and it has a complex structure with two conductors in parallel. Drilling the DRA to connect a probe introduces air gap in the antenna which leads to undesirable radiation effects. Coaxial probe has low polarization purity and lower pattern symmetry.

The coplanar waveguide is an effective method of coupling the DR Antenna mounted on the slot linear to the coplanar waveguide's ground plane [3]. The coupling scheme considered in this paper [3] consists of a Coplanar WG terminated in a narrow linear slot in which, as shown in the figure below, a rectangular dielectric resonator is mounted.

It was found, however, that good rectangular WG coupling can only be accomplished with a high permittivity DR Antenna with a dielectric constant of 82.0[6]. The coupling we see is insufficient when the low permittivity cylindrical DR Anetnna of 10.5 was coupled to the wide-end of the rectangular waveguide[7]. For a hemispherical permittivity DRA 10.5 coupled to the short end of a rectangular waveguide, weak coupling is also obtained [7].

We can improve the coupling only when using a coaxial probe-fed DRA and a stacked DRA[8] or embedded DRA configurations connected to the WG by placing an aperture in the waveguide wall, which might require drilling a hole into the DR Antenna to put up the probe. The coupling level can be further improved if we increase the size or the length of slot. Coplanar waveguide can be implemented in one of the two ways: inductive and capacitive [9].

In capacitive type of feeding, the inner conductor is disconnected from the slot. As we move from inductive to capacitive coupling, the resonant frequency will be shifted to lower range. This is because of the additional inductive type of current produced in the slot. The slot is not an efficient radiator on its own but it represents the coupling mechanism between DRA and the coplanar waveguide line.

III. DESIGN AND SIMULATION.

The proposed structure consists of a hemispherical dielectric resonator antenna of radius 12.7 mm and permittivity 10 placed above the substrate and an open ended microstrip line beneath the substrate. The substrate is made of FR4 epoxy having a dielectric constant of 4.4. There is a ground plane above it on which the slot is etched. The total size of ground plane is 140mm x100mm

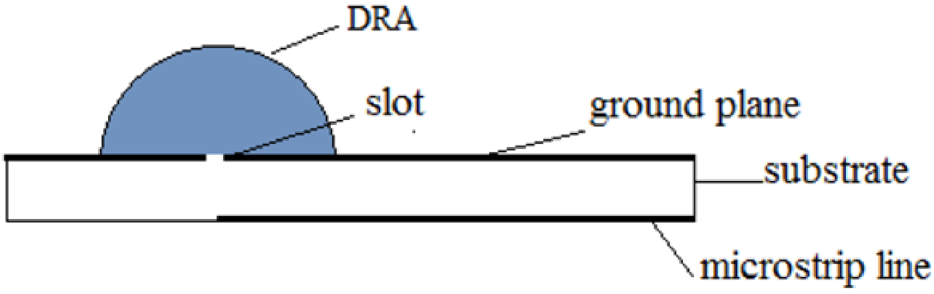

Fig 2: Proposed DR Slot Antenna

On the ground plane, a semicircular form aperture is etched to pair the field from the 50 ohm microstrip line to the DR antenna. The semicircular slot provides the coupling between the microstrip line and the dielectric resonator antenna. The DR is located above the slot and is symmetrically arranged with respect to the slot. To ensure impedance matching, a stub of the microstrip line beneath the slot is built. The hemispherical DRA has the advantage of uniform field distribution all around.

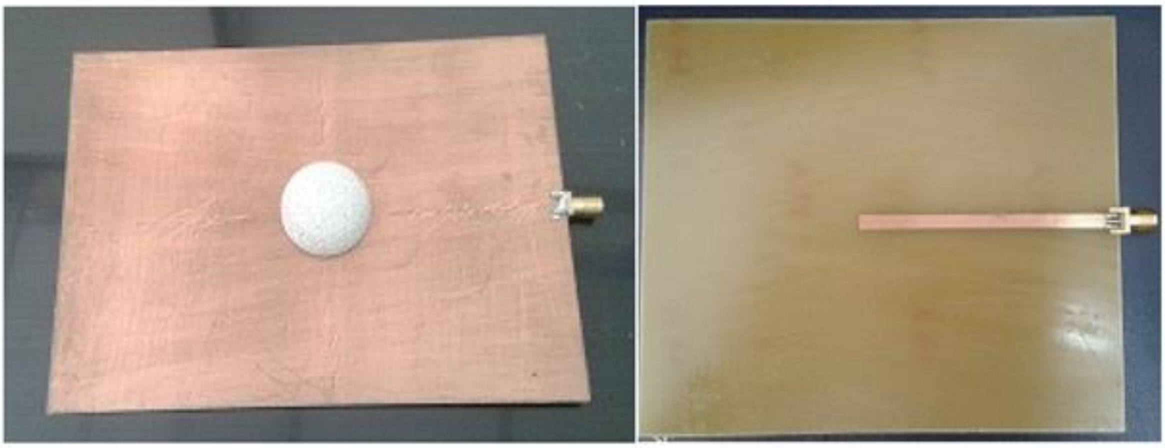

Fig 3: (a) front view and (b) back view of fabricated antenna

The parameters that determine the frequency of radiation for the slot are primarily the permittivity of substrate and the DRA, as well as the area of slot. From other side, the DRA modes occur at frequencies determined by the permittivity of DRA as well as its radius. As the length of slot is increased, the resonant frequency of slot mode drops and at a certain value of slot length, the slot mode and DRA mode coincides, the whole structure now starts resonating for a single frequency as shown in figure.

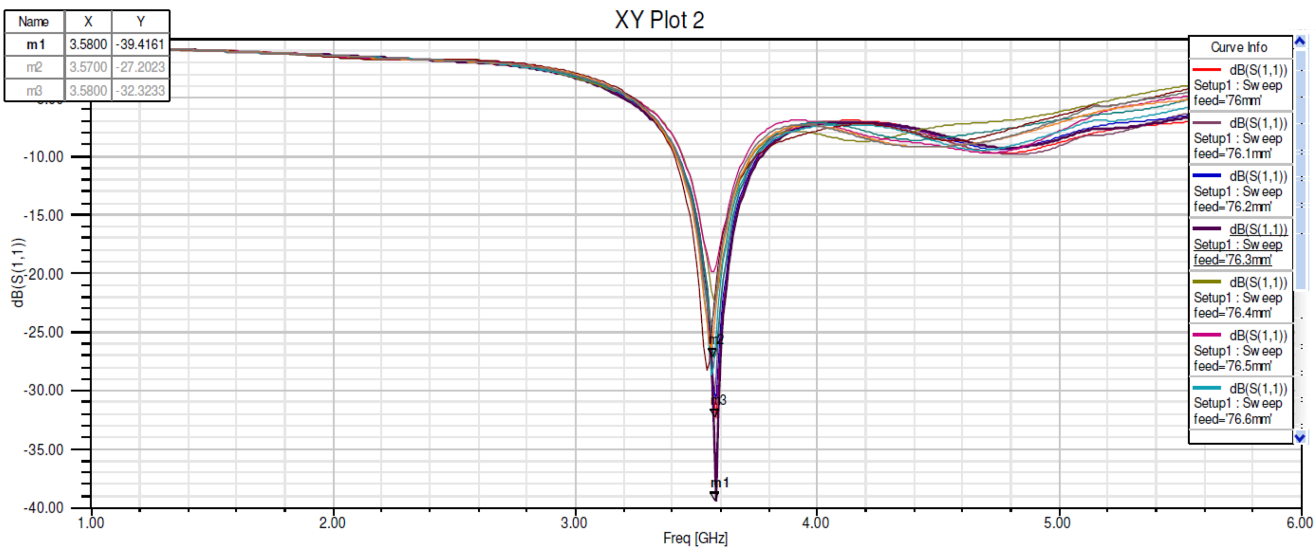

Fig 4: Reflection coefficients for different Stub lengths

The incident field in the microstrip line excites a magnetic current in the slot. The slot has to be placed in the strong magnetic area of the dielectric resonator antenna so that maximum energy is coupled. For that, the slot is displaced from the center on both the directions. On detailed study, the strong magnetic area corresponds to slot with its center at 0.2 mm downwards from origin along X-axis.

As the length of the microstrip length is increased, there is an increased level of coupling since it leads to improved level of impedance matching. The optimum stub length thus obtained is 6.3 mm.

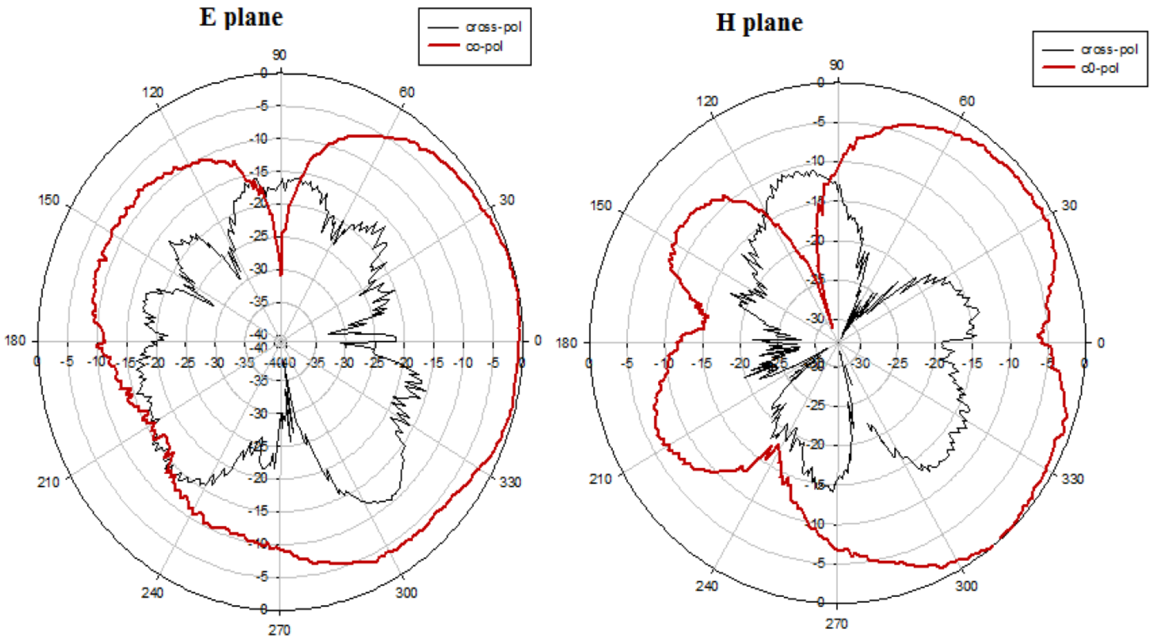

Fig 5: Measured Radiation pattern in (a) E plane and (b) H plane

The simulated radiation pattern in both the E plane and H plane shows more than 40dB of isolation between the copolarized signal and the crosspolarized signal in the maximum direction.

The cross polarization occurs mainly due to the unwanted radiation from the feeder network. The semicircular slot coupled hemispherical dielectric resonator antenna proposed here resonates at 3.5 GHz and gives an impedance bandwidth of nearly 9.8% and works under circular polarization.

IV. Conclusion

The proposed antenna resonates nearly at 3.5GHz which has a wide range of applications in WiMaX and IEEE 802.16e. This frequency is a part of S-band which is included in the microwave band of electromagnetic spectrum (2GHz to 4GHz). The antenna is mainly useful for WiMaX applications, since most of its vendors are now manufacturing equipment in the range of 3.5GHz.

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