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Octagonal-Shaped Microstrip Antenna for Multiband Application

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Abstract

Antennas are essential components of all equipment that uses radio. They are used in systems such as radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, and satellite communications, as well as other devices such as garage door openers, wireless microphones, Bluetooth-enabled devices, wireless computer networks, baby monitors, and RFID tags on merchandise. In this proposed `work, a co- planar waveguide (CPW) patch antenna with octagonal-shaped ring has to be design for WiMAX application of 3.5 GHz. The CPW antenna is using FR-4 substrate with dielectric constant, εr = 4.4 and the electrical conductivity tangent loss, tanΔ = 0.019. A parametric study of CPW length, LCPW has to be done to make sure the best return loss performance and the location of the resonant frequency near to WiMAX frequency range, Further we demonstrated for multiband antenna. In this work we demonstrated for antenna parameters viz. return loss.

Keywords:— *VSWR, Radiation Pattern, gain, Bandwidth etc.*

I. Introduction

An antenna is a specialized transducer that converts radio-frequency (RF) fields into alternating current (AC) or vice-versa. It transform an RF signal, travelling on a conductor, into an electromagnetic guided wave in free space, and vice versa (i.e., in either transmitting or receiving mode of operation). Antennas are frequency dependent devices. Each antenna is designed for a certain frequency band, and it rejects signals beyond the operating band. For that reason, antennas can be considered band pass filters and transducers. In addition, an antenna in advanced wireless systems is usually required to optimize or accentuate the radiation energy in some directions and suppress it in others. Nowadays, these devices constitute an essential part of wireless communication systems.

Typically an antenna consists of an arrangement of metallic conductors (elements), electrically connected (often through a transmission line) to the receiver or transmitter. An oscillating current of electrons forced through the antenna by a transmitter will create an oscillating magnetic field around the antenna elements, while the charge of the electrons also creates an oscillating electric field along the elements. These time-varying fields radiate away from the antenna into space as a moving transverse electromagnetic field wave. Conversely, during reception, the oscillating electric and magnetic fields of an incoming radio wave exert force on the electrons in the antenna elements, causing them to move back and forth, creating oscillating currents in the antenna.

Antennas can be designed to transmit and receive radio waves in all horizontal directions equally (omni directional antennas), or preferentially in a particular direction (directional or high gain antennas). In the latter case, an antenna may also include additional elements or surfaces with no electrical connection to the transmitter or receiver, such as parasitic elements, parabolic reflectors or horns, which serve to direct the radio waves into a beam or other desired radiation pattern.

The first antennas were built in 1888 by German physicist Heinrich Hertz in his pioneering experiments to prove the existence of electromagnetic waves predicted by the theory of James Clerk Maxwell. Hertz placed dipole antennas at the focal point of parabolic reflectors for both transmitting and receiving.

1.1 Microstrip Patch Antenna

Microstrip antennas are planar resonant cavities that leak from their edges and radiate. Printed circuit techniques can be used to etch the antennas on soft substrates to produce low- cost and repeatable antennas in a low profile. The antennas fabricated on compliant substrates withstand tremendous shock and vibration environments. Manufacturers for mobile communication base stations often fabricate these antennas directly in sheet metal and mount them on dielectric posts or foam in a variety of ways to eliminate the cost of substrates and etching. This also eliminates the problem of radiation from surface waves excited in a thick dielectric substrate used to increase bandwidth.

In its most basic form, a Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch is generally made of conducting material such as copper or gold and can take any possible shape. Due to its planar configuration and ease of integration with microstrip technology, the microstrip patch antenna has been heavily studied. There are different structures of microstrip antennas, but on the whole we have four basic parts in the antenna are the patch, dielectric substrate, ground plane and the feed line. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. The rectangular and circular patches are the basic and most commonly used microstrip antennas. These patches are used for the simplest and the most demanding applications. The microstrip patch antennas are well known for their performance and their robust design, fabrication and their extent usage.

A feed line is used to excite, radiate by direct or indirect contact. Arrays of antennas can be photo etched on the substrate, along with their feeding networks. Microstrip circuits make a wide variety of antennas possible through the use of the simple photo etching techniques.

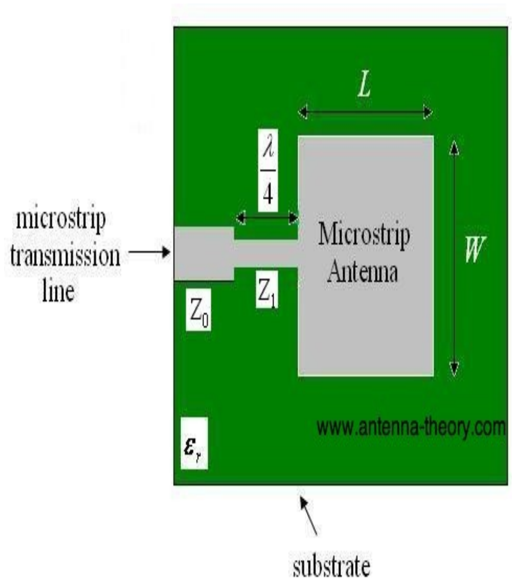

Figure (a): Patch

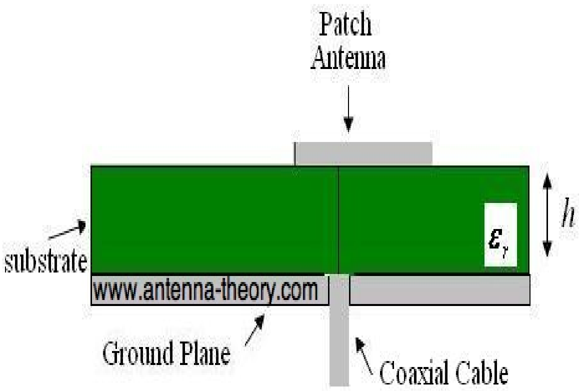

Figure (b): Ground Plane

Figure 1: Microstrip patch Antenna

1.2 Basic Principle of Operation

The patch acts approximately as a resonant cavity (short circuit walls on top and bottom, open-circuit walls on the sides). If the antenna is excited at a resonant frequency, a strong field is set up inside the cavity, and a strong current on the surface of the patch. This produces significant radiation.

The radiating patch can be of any shape such as circular, rectangular, triangular, sectral, annular ring, semicircular, Low profile, conformable to various surfaces, inexpensive, durable, but narrow-band. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation.

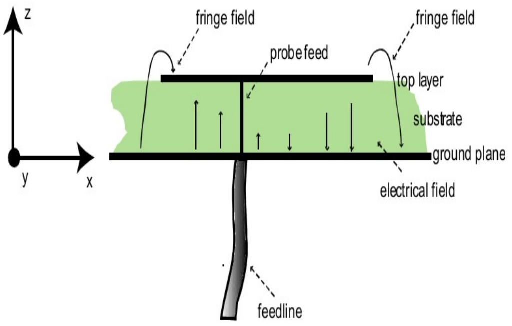

Figure 2: Basic principle of Microstrip Antenna

Microstrip patch antenna or patch antenna is a narrow band, wide-beam antenna. A thicker substrate will increase the radiation power, reduce conductor loss and improve Band width.

III. LITERATURE SURVEY

Standing with rivalry standard called 'LTE', the Worldwide Interoperability for Microwave Access or well-known as WiMAX represents the fourth generation of wireless communication. This enhanced technology is almost alike with Wi-Fi which gives users connections to the Internet without wires. But, Wi-Fi only able to cover within a range of 100 feet while WiMAX can cover huge distances like the cellular network. WiMAX also offers high-speed Internet access like broadband's. WiMAX might rather be called a wireless broadband. Under a single base station, the coverage is much wider than WLAN and can reach a transmission rate of 70 Mbps [1]. This means any Internet user can use the Internet from any geographical area. The networking of WiMAX purposes nearly alike with Wi-Fi connection, but only differs in a few aspects. WiMAX system has two prior components which is WiMAX tower and WiMAX receiver. Just as same as Wi-Fi, WiMAX can connect immediately to the Internet by transmitting a signal from WiMAX tower to any WiMAX- enabled computer through a wired connection. The WiMAX tower is able to connect to a second tower which allows the network to provide a long distance wireless service.

WiMAX tower can cover up to 30-miles radius which leads Wi-Fi that only cover up to 100-feet range. The network of the coverage area is more than 3G towers about 10 times [2]. Frankly, it is just like scattered hotspots combined into a huge wireless hotspot. Based on IEEE, 802.16 WiMAX standard authorizes data transmission using many broadband frequency range. The original 802.16a standard identified transmissions in the range of 10–66 GHz but 802.16d permitted lower frequencies in the range of 2–11 GHz. The lower frequencies used in the later descriptions which shows that the signals have less attenuation and they provide better coverage within blocks and buildings and an improved range. Different part of the world requires different bands. The often- used frequencies are 3.5 and 5.8 GHz for 802.16d and 2.3, 2.5 and 3.5 GHz for 802.16e and depending on the country itself. A MAC (Medium Access Control) layer is a sub-layer inside the Data Link Layer. It is also known as Layer 2 in OSI model standard seven-layer.

The WiMAX MAC has been created perfectly to enable point to multipoint wireless application and gives an interface between the physical layer and the application layer. This WiMAX MAC layer has a few requirements to be met such as point to multipoint, supports communication in all conditions, efficient spectrum use and variety of QoS options. WiMAX MAC layer also supports high bandwidth and hundreds of users per channel and utilizes spectrum efficiently by supporting burst traffic [3].

The basic rectangular and circular patch antennas were designed by Howell. His low profile antenna consisted of planar resonating element separated from the ground plane by a dielectric substrate whose thickness was very small compared to the wavelength. Feeding to the antenna was effected either by coaxial line from behind or by a microstrip line deposited on the same side. Design procedures were presented for linearly and circularly polarized antenna and for dual frequency antennas from UHF through C band. The bandwidth obtained was very narrow and was found to be depending on the permittivity and thickness of the substrate [4].

Theoretical analysis of microstrip radiator was first carried out by applying transmission line analogies. Derneryd utilized the transmission line theory to model the rectangular patch fed at the center of a radiating wall. The radiating edges were considered as narrow slots radiating into half space and separated by a half wavelength. This model gives the interpretation of the radiation mechanism and provides expressions for the radiated fields, radiation resistance, input impedance etc. This method is applicable only for patches of rectangular shape and was not adaptable for the inclusion of feed point and thus not adequate in many cases[5].

Kerr developed various configurations for dual frequency operation of the patch. One among them is the Shepherd crook feed for 1.22m dish antenna. He mounted an L band patch antenna at the flange of an X-band wave guide which illuminates the dish antenna through a hole in the center of the L -band patch. The system worked at 1250 MHz and 9500 MHz. He also employed a single rectangular patch with two feed points to obtain dual frequency operation. The impedance loading on one port is used to effect a measure of frequency control[6].

The use of an annual ring antenna instead of circular patch to achieve larger bandwidth was reported by Chew. It was found that TM12 mode is suited for antenna performance where the stored energy is small yielding a small Q factor. For TM 12 mode, the bandwidth increases with decrease in the outer to inner radius ratio of the annual ring[7].

Poddar et al. obtained considerable improvement in bandwidth by constructing the patch antenna on stepped and wedge shaped dielectric substrates. They reported a 2:1

VSWR bandwidth of 28% on a wedge shaped substrate and 25% on a stepped substrate where the bandwidth of equivalent rectangular resonator is 13%[8].

A compact printed antipodal Vivaldi antenna is proposed for UWB applications. The elliptical slot edge (ESE) structure is applied to extend the low end bandwidth limitation and improve the radiation characteristics at the lower frequencies. In addition, a pair of planar directors is used to improve the value of gains at high frequency bands. The impedance bandwidth of the proposed antenna ranges from 1.69 to 11 GHz, which covers the UWB frequency bands[1].

A small antipodal Vivaldi antenna is designed for two substrates, FR4 and RO3006. Both antennas operate across the entire UWB spectrum with few locations that might cause problems if the dimensions were not precisely tuned. While it has been known for over a decade that a traditional DETSA can more than satisfy UWB requirements, all of the antennas have been bulky. The FR4 and RO3006 antipodal Vivaldi antennas represent size reductions by a factor of approximately 5 and 6, respectively. The FR4 antenna is particularly significant because it could easily be integrated with a circuit. Both the gain and directivity might improve if the straight edges were rounded to decrease diffraction in the corners. While these antennas lack the typical 10–15 dB gain of a Vivaldi antenna, their compact form makes them ideal for short-range, low-power mobile electronics[2].

Proposed octagonal antenna simulation setup is presented in figure 3, the proposed design is simulated for dual and triband resonance frequency.

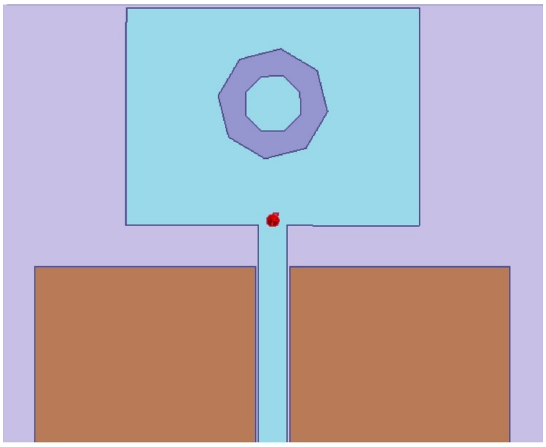

Figure 3: Proposed Design

We analyzed for different dimension of octagonal shape, length/width of patch and ground, it is observed that optimum result of antenna is obtained for different dimension. The above design is simulated for parameters.

IV. Antenna Parameters

An antenna is an electrical conductor or system of conductors Transmitter Radiates electromagnetic energy into space, Receiver Collects electromagnetic energy from space. The IEEE definition of an antenna as given by Stutz man and Thiele is, “That part of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves”. The major parameters associated with an antenna are defined in the following sections. Antenna Gain is a measure of the ability of the antenna to direct the input power into radiation in a particular direction and is measured at the peak radiation intensity.

Power Density

Antennas, an isotropic radiator are a theoretical, lossless, unidirectional (spherical) antenna. That is, it radiates uniformly in all directions. The power of a transmitter that is radiated from an isotropic antenna will have uniform power density (power per unit area) in all directions.

Antenna Efficiency

The surface integral of the radiation intensity over the radiation sphere divided by the input power P is a measure of the relative power radiated by the antenna, or the antenna efficiency.

Effective Area

Antennas capture power from passing waves and deliver some of it to the terminals. Given the power density of the incident wave and the effective area of the antenna, the power delivered to the terminals is the product.

Directivity

Directivity is a measure of the concentration of radiation in the direction of the maximum.

Input Impedance

The input impedance of an antenna is defined as “the impedance presented by an antenna at its terminals or the ratio of the voltage to the current at the pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point”.

Bandwidth

Bandwidth is the difference between upper and lower operating frequencies of the antennas. Bandwidth of an antenna refers to the range of frequencies over which the antenna can operate correctly.

Return Loss

It is a parameter which indicates the amount of power that is “lost” to the load and does not return as a reflection.

Polarization

EM field is composed of electric [3] Gibson, P. J., “The Vivaldi aerial,” 9th European Microwave Conference, 101–105, & magnetic lines of force that are orthogonal to each other. Polarisation refers to the path traced by the tip of the electric field vector as a function of time. E determines the direction of polarization of the wave.

Radiation Pattern

The radiation pattern of an antenna is a plot of the far-field radiation properties of an antenna as a function of the spatial co-ordinates, which are specified by the elevation angle (θ) and the azimuth angle (φ).

Beam Width

Beam width of an antenna is easily determined from its 2D radiation pattern and is also a Very important parameter. Beam width is the angular separation of the half-power points of the radiated pattern.

V. Conclusion

The double octagonal shape coplanar antenna with CPW for multiband application has to be be designed. Fabrication and simulation of the antenna has to be simulated by using HFSS simulator software and the result obtained from the simulation has to be demonstrated. A parametric study of CPW length, LCPW has to be done to make sure the best return loss performance and the location of the resonant frequency near to WiMAX frequency range.

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