Wide Band Dual-Beam U-slot Microstrip Patch Antenna

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Abstract— A dual beam wide band microstrip patch antenna is expressed in this paper. Radiation beams of two broadside are obtained by operating the patch antenna at the higher order 〖TM〗_02 mode instead of the fundamental 〖TM〗_01 mode, it radiates a broadside beam. Broadening the antenna bandwidth is achieved by using the U-slot technique. The antenna analysis is carried out with the full wave simulation, and an antenna prototype is fabricated and measured for the validation. When the two operating frequencies are far apart, a dual-frequency patch structure can be conceived to avoid the use of separate antennas. The resonating frequency is of 3.5GHz. The designed antenna operates at two frequencies namely 3.232GHz and 5.008GHz. Simulation of wide band dual beam microstrip patch antenna using ANSYS HFSS software.

Key words: Dual-Beam, Microstrip Patch Antenna, Wideband

I. Introduction

In telecommunication, a microstrip antenna (also known as a printed antenna) usually means an antenna fabricated using microstrip techniques on a printed circuit board (PCB). They are mostly used at microwave frequencies. An individual microstrip antenna consists of a patch of metal foil of various shapes (a patch antenna) on the surface of a PCB, with a metal foil ground plane on the other side of the board. Most microstrip antennas consist of multiple patches in a two-dimensional array. The antenna is usually connected to the transmitter or receiver through foil microstrip transmission lines. The radio frequency current is applied (or in receiving antennas the received signal is produced) between the antenna and ground plane. Microstrip antennas have become very popular in recent decades due to their thin planar profile which can be incorporated into the surfaces of consumer products, aircraft and missiles; their ease of fabrication using printed circuit techniques; the ease of integrating the antenna on the same board with the rest of the circuit, and the possibility of adding active devices such as microwave integrated circuits to the antenna itself to make active antennas.

Indoor wireless links have intrinsic characteristics that affect the system performance, such as the multipath effect that causes signal fading, and interference effect from adjacent cells that degrades the bit error rate. From the physical layer perspective, one solution to combat these impairments is the use of directional antennas rather than the traditional omnidirectional ones [1]. They have the ability to confine the power in certain directions instead of scattering the power everywhere. As a result of less power loss toward unwanted directions, the multipath and interference effects are reduced. Directional antennas can be single or dual/multi-beam. Dual/multi-beam antennas are antennas that have more than one directive beam from a single aperture. These antennas are useful for indoor wireless systems which require coverage of multiple areas [2], as they reduce the required number of antennas and are found to improve the link quality [3], resulting in easier network deployment.

Microstrip antennas have been widely used in many modern communication systems, because of its robustness, planar profile, and low cost. Most of these antennas operate at their fundamental mode TM_{01},which gives a broadside beam [4]. Microstrip antenna operating at the higher order TM_{02} mode has dual symmetric radiation beams, with each beam directed at respectively [5][7]. It is well known that the major drawback of a microstrip antenna is its narrow bandwidth (3%). One of the popular techniques for broadening the patch antenna bandwidth is to incorporate a U-slot on its surface as proposed in [8][9].

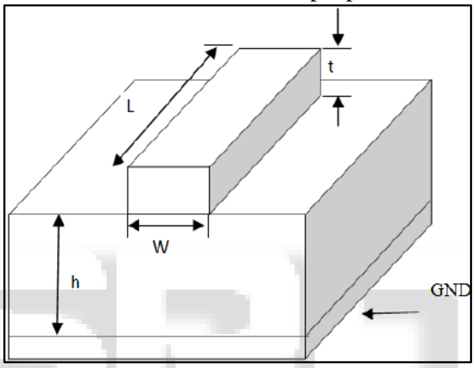

Fig. 1: Microstrip patch antenna.

II. Microstrip Patch Antenna Design and Configuration with U-Slot

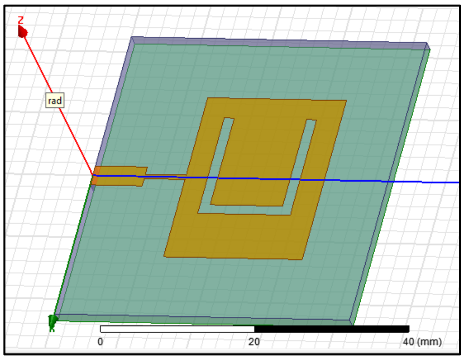

Fig. 2: U-slot microstrip patch antenna at the higher order TM_{02} mode.

In this paper, a U-slot microstrip antenna operating at the TM_{02}mode to attain dual radiation beams with wideband performance is proposed. The U-slot inclusion on the patch's surface introduces asymmetry, which affects the radiation, such as pattern symmetry, pattern stability, cross-pol level, and the direction of the beams. An investigation on how these parameters are affected is presented. The realized gain and efficiency for each beam, and the difference between their maxima levels are also presented. The proposed design is validated with experimental measurement of a fabricated prototype.

A. Antenna Geometry

The proposed antenna geometry is shown in Fig. 3, where a coaxial-fed rectangular patch is printed over a FR4 substrate of thickness 1.6mm and permittivity 4.4.A U-slot is cut on the patch's surface, which is mounted over the substrate of size$L_g \times W_g = 41.9 \times 44.95$mm. The other side of the substrate is coated with metal, which is the ground plane of the antenna. The dimensions of the antenna that give a broad impedance bandwidth are listed in Table I, which are obtained via iterative process.

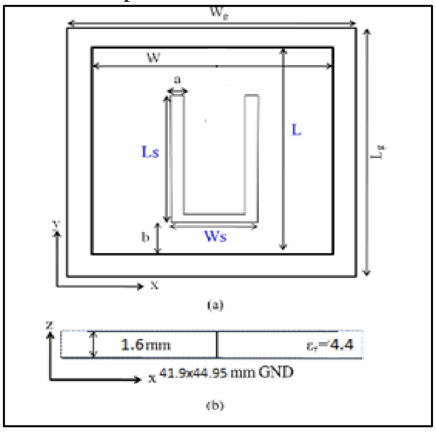

Fig. 3: Geometry of the proposed U-slot microstrip antenna: (a) top view; (b) side view.

Parameter	Units(mm)
L	19.66
W	25.76
L_s	15.4035
W_s	13.1377
a	1.43128
b	4.06352

Table 1: Dimensions Of Proposed U-Slot Microstrip Antenna

III. U-SLOT ANTENNA CALCULATIONS

The resonant frequency is set to f_r= 3.5 GHz and the specified relative permittivity of FR4 epoxy substrate is ε_r= 4.4 and assuming height of substrate as h=1.6mm. Considering these specifications, the calculated values of the prototype microstrip patch antenna with resonant frequency f_r= 3.5GHz.[11][13]

Parameter	Values
Operating frequency	3.5GHz
Length of patch	19.66mm
Width of patch	25.76mm
Di-electric constant	4.4
Height of substrate	1.6mm

Table 2: Specifications Of Microstrip Patch Antenna

Parameters	Calculated values(mm)	Optimised values(mm)
Length of ground	39.18	41.9
Width of ground	45.28	44.85
Length of patch	19.98	19.66
Width of patch	26.08	25.76
Feed line	5.358	7.369
Edge feed	4.242	5.781

Table 3: Design Parameters Of Dual Band U-Slot Microstrip Patch Antenna

IV. RESULTS AND ANALYSIS

The prototype of proposed antenna in Fig. 2 was investigated experimentally. The overall size is 41.9 x 44.85 x1.6 mm at 3.5 GHz. According to the simulated results, the U-slot technique increases the impedance bandwidth. To study the effect of the U-slot inclusion, as well as the variation of the pattern along the frequencies of the entire bandwidth.[10]

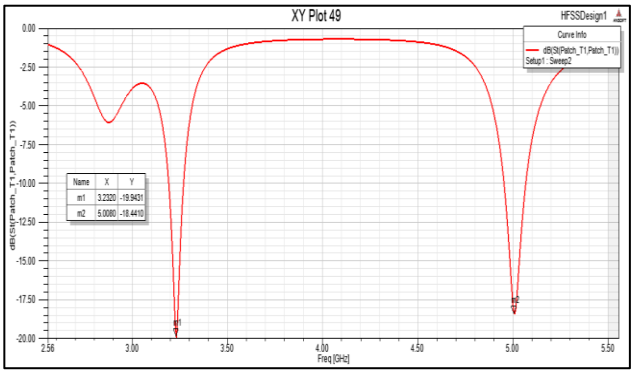

Fig. 4: Return loss (S_{11}) of Dual band U-slot Microstrip Patch Antenna.

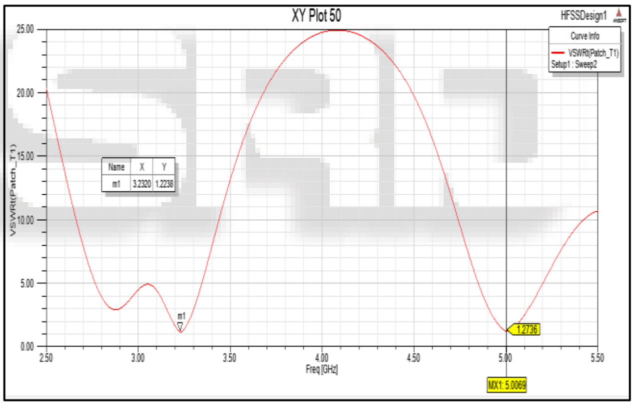

Fig. 5: VSWR of Dual band U-slot Microstrip Patch Antenna.

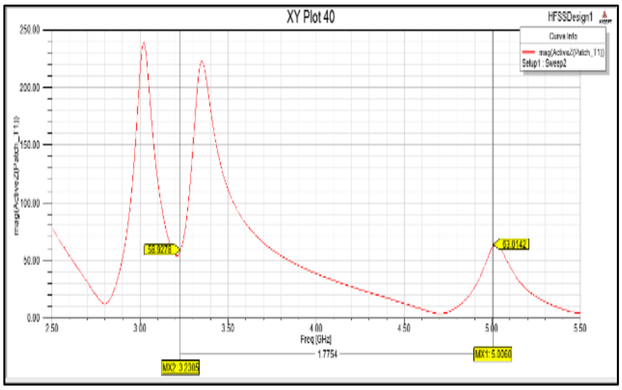

Fig. 6: Z-Parameter of Dual band U-slot Microstrip Patch Antenna.

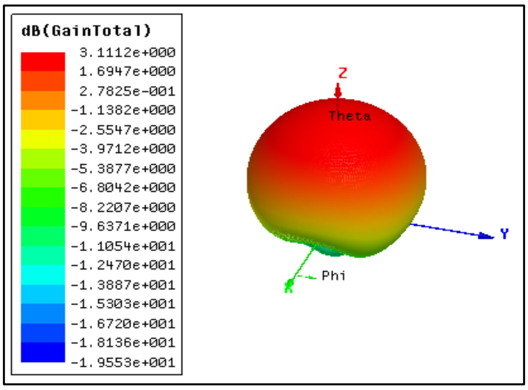

Fig. 7: Gain at 3.232 GHz for Dual band U-slot Microstrip Patch Antenna.

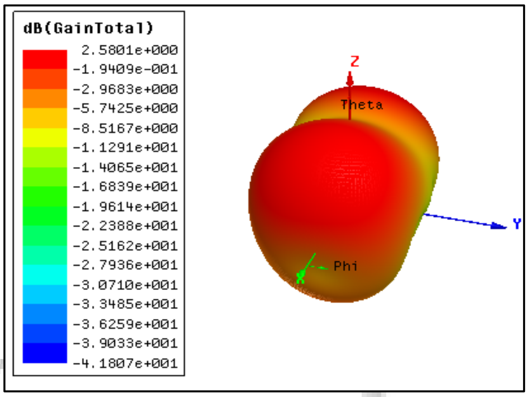

Fig. 8: Gain at 5.008 GHz for Dual band U-slot Microstrip Patch Antenna.

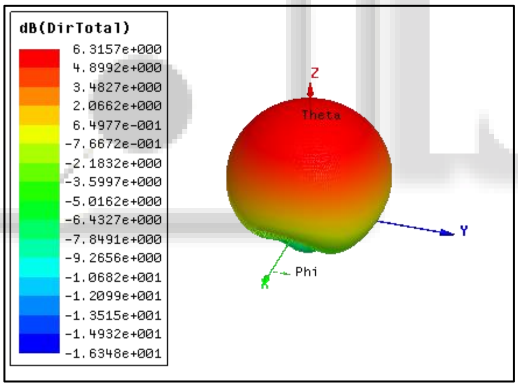

Fig. 9: Directivity at 3.232 GHz for Dual band U-slot Microstrip Patch Antenna.

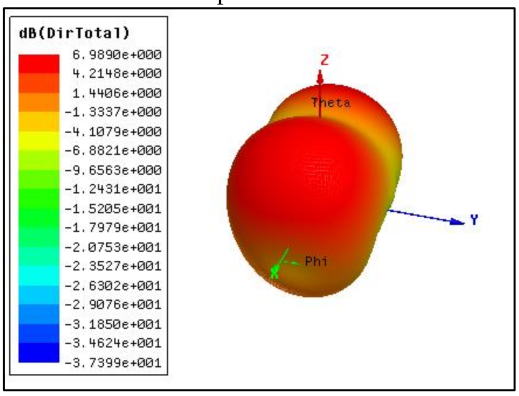

Fig. 10: Directivity at 5.008 GHz for Dual band U-slot Microstrip Patch Antenna.

V. Conclusion

Thus, we have successfully simulated aU-slot microstrip antenna using HFSS software. The Return loss and VSWR on both the operating frequency are improved to a better and high value with an increased bandwidth and gain. This prototype can be integrated into the design of microwave or millimetre wave integrated circuit where the compactness is crucial.

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