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A very small Dual-Band MIMO Slot Antenna for WLAN and Wi MAX Applications

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Abstract : *A very small dual band two element MIMO antenna for wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (WIMAX) applications is presented in this project.A micro-strip line-fed antenna with two quarter wavelengths slots of different lengths, which radiate at 2.5GHz and 5.6GHz, is used as an antenna element. The antenna is designed on 1.6 mm thickness FR-4 substrate with* $\mathcal{E}r=4.4$ *.Since WiMAX application is divided into two categories based on its radius of coverage area, the antenna design is varied by shifting the ground slot to new coordinates and resonant frequency is attained at 17.2 GHz for larger coverage area (>100feet).For smaller coverage area of WiMAX, the frequencies 2.5GHz and 5.6GHz would give the required response.*
The desired antenna design is achieved using HFSS 13.0. The antenna occupies an overall area of $24x25\ mm^2$*. The antenna elements are fed by two 50 Ω stepped microstrip lines ,which is used as a simple decoupling network, based on a wide slot and a pair of narrow slots, to achieve good isolation (better than 20 dB) between the ports. The antenna is designed Moreover, the Envelope Correlation Coefficient (ECC) of the proposed antenna is within the acceptable limit. By placing a ground slot in a finite antenna ground plane, other reconfigurable features can be included. Thus such antennas that are small in size and have multiband capability can be promising for many wireless applications.*

Index Terms**—***Dual-band, envelope correlation coefficient(ECC), multiple-input-multiple-output (MIMO), slot antenna, Wireless Local Area Network (WLAN).*

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I. Introduction

Recently the advancement in wireless communication technology has entered in to a new age, where the demands of reliable data transfer rate are steeply increasing day by day. On the other hand, there are limitations of available wireless communication spectrum that faces high traffic due to sharp increase in the number of users every day. Multiple- input multiple-output (MIMO) technology has received significant attention of researchers in recent years, as this technology offers higher data rate, better reliability and spectral efficiency within the same bandwidth and power level along with better ability to overcome multipath fading in rich scattering environment. Moreover, modern mobile wireless devices require to be operated in more than one frequency, which consequently demand miniaturized multiband antennas, while, maintaining the compact size and portability of the devices. Designing a dual-band MIMO antenna is also a challenging task considering the fact that, in most of the cases, same isolation mechanism does not work at different frequency bands. Several dual-band MIMO antennas are reported earlier in the literature [2-11]. In [3], isolation between two back-to back dual-band monopole antennas is increased by introducing multiple branches and a shorting pin. Two folded monopoles are used in [4], where mutual coupling is reduced by adding two transmission lines on the top surface and a pair of slots at the ground plane. In [5], a 4-shaped monopole antenna is used as an antenna element. The isolation in this case is enhanced by introducing the defected ground structure (DGS). Dual band monopole antennas are used to design MIMO antenna in [6], which uses Eigen mode feed network and complex reactive decoupling network, comprised of a four port 180° hybrid coupler. In [7], dual-band is achieved by using a combination of C-shaped and T-shaped slots fed by microstrip lines. Six pairs of slits are etched on the ground plane of it to lower the mutual coupling between the elements. Another dual-band MIMO antenna, designed with two closely spaced elevated chip antennas, is reported in [8], where a pair of open ended stubs is used as decoupling network at the higher frequency. A dual band MIMO antenna designed by two parallel folded branch monopoles with coupled feed and having built-in isolation mechanism is reported in [9]. In [10], a folded Yshaped isolator is used as decoupling network between the dual band antennas, designed by meandered monopoles. In [11], two-port and four-port operations are realized at lower band and upper band, respectively in a dual-band MIMO antenna. To enhance isolation, two λ/4 slits at two resonant frequencies are etched. However, most of these aforementioned designs occupy a large area and the isolation is not achieved up to 20 dB. It is, therefore, a challenging task to design a planar miniaturized dual-band MIMO antenna with a good isolation between the ports at both the operating bands. In this letter, a very compact dual-band low cost MIMO antenna, which occupies an area of 24 × 25 mm2, is presented. The antenna elements are fed by two 50 Ω stepped microstrip lines. The operating bands of the antenna are generated by etching two open-ended quarter wavelength slots of different lengths, which radiates at two distinct resonant frequencies. The simple decoupling network consists of three open-ended slots— the wide one for the higher resonant frequency and a combination of the wide one and a pair of narrow slots for the lower resonant frequency. These slots basically perturb the surface current distribution at the ground plane and the path length within the ports in such a manner that the electromagnetic energy coupling between the ports is reduced and hence good isolation is achieved.

II. Proposed Antenna Design

2.1 BASE ANTENNA DESIGN: The base two-element dual-band MIMO antenna is shown in Fig. 1. The antenna is designed on FR-4 substrate (εr=4.4, tan δ=0.02) of 1.6 mm thickness.

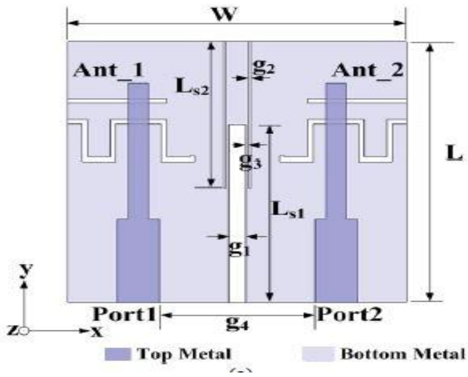

Fig. 1 Geometry of the base MIMO antenna

[*L*=25,*W*=24, *Ls1*=17,*Ls2*=14, *g1*=1.2, *g2*=0.2, *g3*=0.2, *g4*=11 (all are in mm)]

2.3 PROPOSED DESIGN: By inserting a ground slot at both the ports we can make the antennas radiate at required frequencies. In this design, one antenna is made to radiate at 17.2 frequency and the other antenna is shorted with matched impedance. The proposed antenna design is shown in Fig.2 .

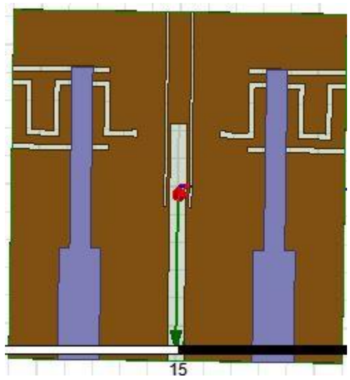

Fig.2 Proposed antenna design

2.2 UNIT ELEMENTS: The unit element used to design the proposed MIMO antenna is a dual-band microstrip-based slot antenna, shown in Fig. 3. The antenna is fed by a 50 Ω stepped microstrip line. The stepped feed line provides good impedance matching at both the resonant frequencies. Two open-ended slots, etched at the ground plane, of approximately quarter-wavelength are used as radiator.

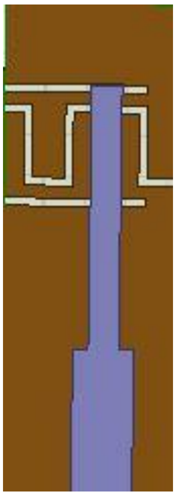

Fig.3 Unit element design

While, the long and meandered shaped slot radiates at 2.5 GHz, the second slot of dimension *L7×g* creates another resonant frequency at 5 GHz. The simulated |S11| parameter of the dual-band antenna element is presented in Fig. 2(b). The two operating bands (|S11|≤-10 dB) of this antenna are obtained within 2.35-2.69 GHz and 4-68 GHz. This antenna is designed by placing two unit antenna elements, Ant_1 and Ant_2, side by sidey. The inter-element spacing between two unit elements is 4 mm, which is equal to λ0/30 at lowest resonant frequency. When port 1 is excited, keeping port 2 matched, strong electromagnetic energy coupling takes place between two unit elements, caused by near-field and ground surface current, at both the operating bands

2.3 ISOLATION IMPROVEMENT

The isolation between the two ports can be further improved by increasing the distance between Ant_1 and Ant_2, though it will enhance the physical area of the MIMO antenna. To maintain the compactness of the antenna, instead of further increasing the inter-element distance, a wide open-ended slot is etched on the ground plane. Second band is increased from 17.5 dB to 22 dB. However, the effect of this slot on the first operating band is insignificant and hence the isolation in this band remains almost unchanged. To reduce the electromagnetic energy coupling at the lower band, a pair of narrow open-ended slots is etched at the ground plane. Moreover, the strong loading effect of the narrow slots changes the effective length of the meandered slot and hence, the lower resonant frequency shifts from 2.72 GHz to 2.5 GHz. The combination of the narrow and wide slots is more advantageous, as, it improves the isolation in first operating band significantly (12.7 dB to20 dB) However, the inter digital slot does not affect the isolation obtained at second operating band in Antenna B and it remains unchanged at 22 dB As mentioned earlier, the vertical wide open-ended slot is responsible for reducing the coupling between the ports at this frequency. The introduction of this wide slot not only changes the surface current distributions but also effectively extends the path between port 1 and port 2, which consequently diminishes the mutual coupling at higher resonant frequency.

III. Results

A prototype of the proposed MIMO antenna for WLAN is designed and its **S** parameters are simulated, which are shown in Fig .4 and Fig 15.

3.1.WLAN:

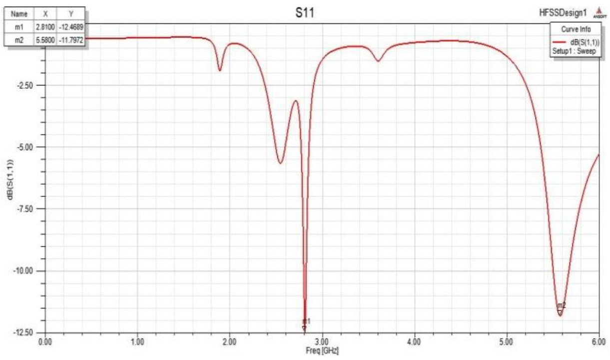

Fig.4 Simulated S11 Parameter

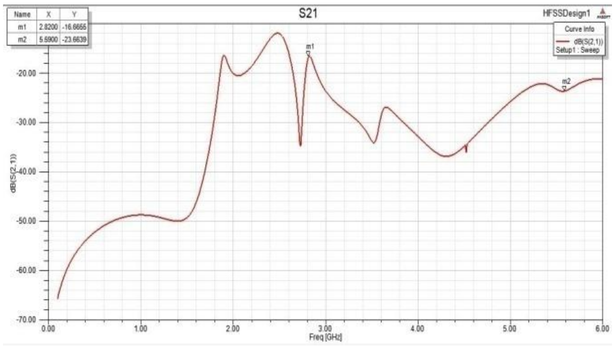

Fig.5 Simulated S21 Parameter

The first and second operating frequencies are 2.8 GHz and 5.6 GHz.The normalized 2D radiation patterns at x-y, x-z and y-z planes of the proposed MIMO antenna are shown in
Fig 6

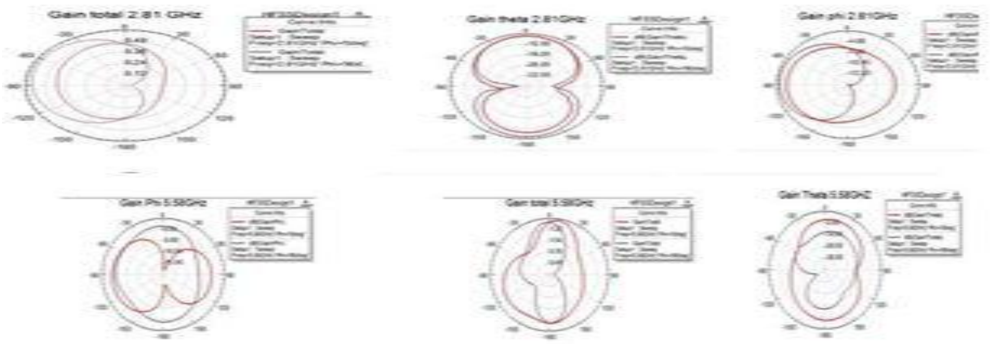

Fig.6 simulated normalized 2-d radiation pattern at 2.8 and 58GHz

The proposed MIMO antenna are shown in Fig. 2.Since both the antenna elements are identical, the radiation pattern of Ant_1 is measured only, while, the port 2 is match determinate with 50 Ω load.The variation of ECC of the MIMO antenna with respect to frequencies 2.8GHz and 5.8GHz is shown in Fig 7.

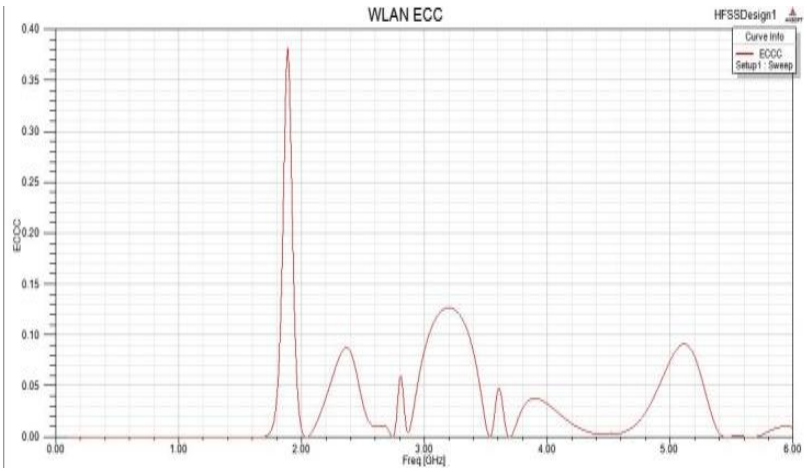

Fig.7 ECC at lower frequencies

3.2. WiMAX:

A prototype of the proposed MIMO antenna for WiMAX is designed and its **S** parameters are simulated, which are shown in Fig 8 and Fig 9.and VSWR are also simulated which are show in Fig 10 and Fig.11.

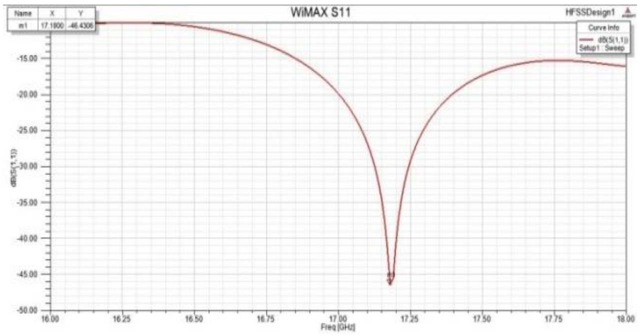

Fig.8 Simulated S11 Parameter

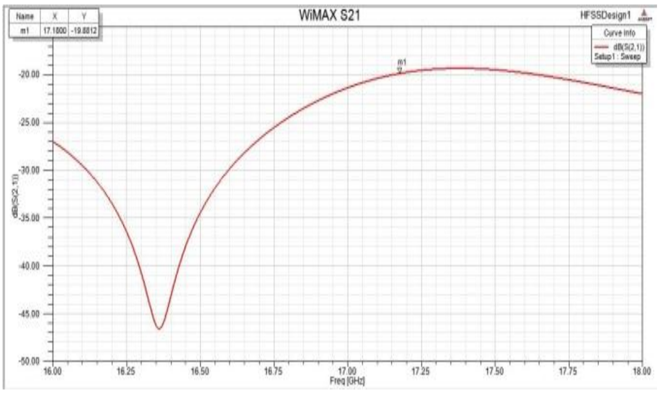

Fig.9 Simulated S21 Parameter

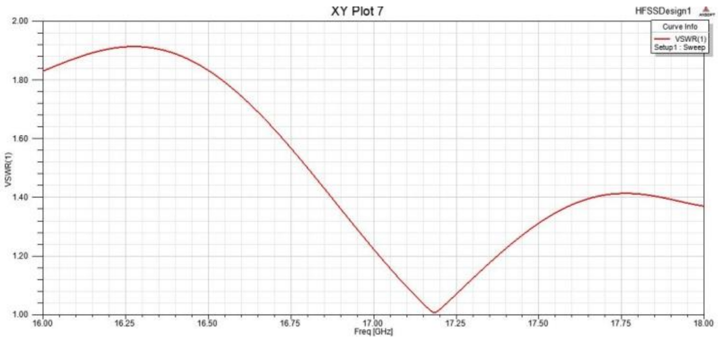

Fig.10. Simulated VSWR (1)

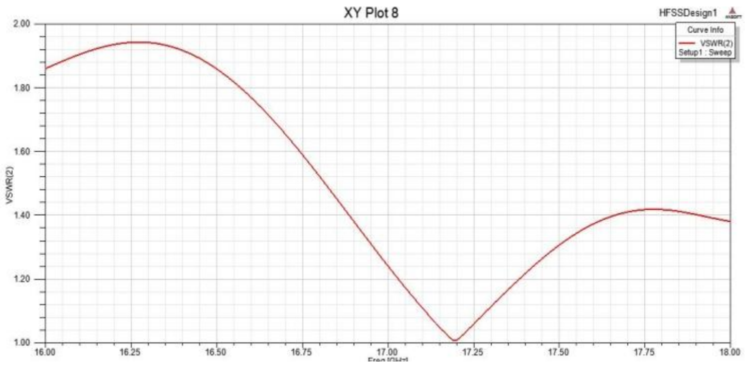

Fig.11. Simulated VSWR (2)

The variation of ECC of the MIMO antenna with respect to frequency 17.25GHz is shown in Fig 12.

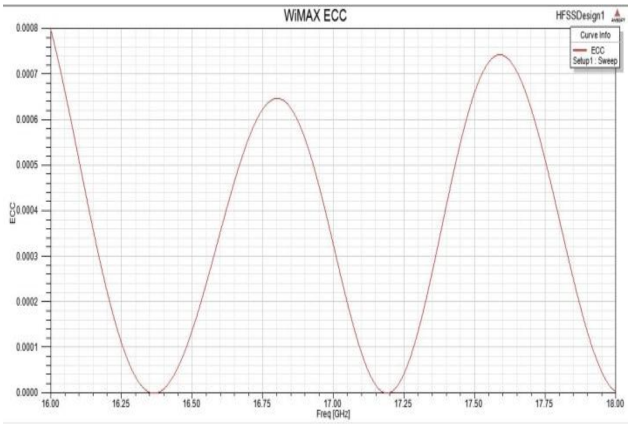

Fig .12 ECC at higher frequencies

Envelope Correlation Coefficient (ECC) is an important parameter to analyze the performance of a MIMO antenna.
The 3-D Radiation of the MIMO antenna with respect to frequency 17.25GHz is shown in Fig.13.

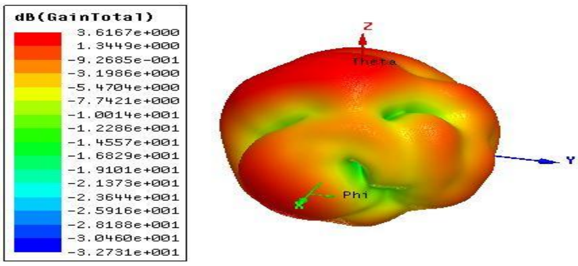

Fig.13 3-D Radiation at 17.25 GHz

The 2-D Radiation of the MIMO antenna with respect to frequency 17.25GHz is shown in Fig.14

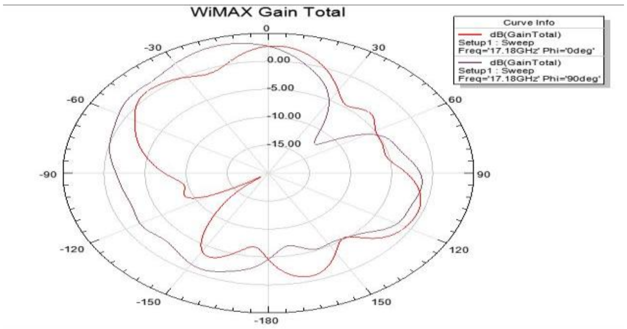

Fig.14 . 2-D Radiation of the MIMO antenna with respect to frequency 17.25GHz

The variation of ECC of the MIMO antenna with respect to frequency is shown in Fig. 12.and 17 The acceptable limit of ECC is less than 0.5, while, in case of the present work, the value of ECC at both the operating bands is below 0.004. Hence, the MIMO antenna parameter ensures good spatial multiplexing performance, which in turn ensures the enhanced data rate too. In Table 9, the dimension, operating bands and minimum Isolation of the proposed antenna are compared with some of the previously reported dual-band MIMO antennas. The study shows that the proposed design is very compact and exhibits comparable performance as well.

IV. Conclusion And Future Work

A very small sized dual-band planar MIMO antenna for WLAN and WiMAX applications is presented in this project. The antenna elements are slot antennas, having two quarter wavelength slots of different lengths at the ground planes which radiate at two distinct frequencies. The antenna is very compact having a total area of $24\times25mm^2$. The operating bands of the antenna are from 2.5GHz to 2.8GHz and 5.4GHz to 5.8GHz. For larger coverage area (>100feet radius) the operating band chosen is 17.15GHz to 17.25GHz.The ECC of the antenna is within the acceptable threshold limit, which is required for enhancing the data rate through spatial multiplexing in wireless communication channels. Since the antenna occupies a very small area, allows multibands and provides good isolation it can be used in many more applications. By inserting a ground slot at various coordinates antenna can be made to radiate at other frequencies and thus the design can be extended to further applications like Bluetooth, GPS etc.

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