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Planar Monopole MIMO Antenna for Portable Wireless Adapters

R. Karthikeyan, Assistant Professor
Department Of ECE
Kumaraguru College of Technology
(Affiliated to Anna University Chennai)
Coimbatore
karthikeyan.r.ece@kct.ac.in

Dr. G. Srivatsun, Associate Professor
Department Of ECE
PSG College of Technology
(Affiliated to Anna University Chennai)
Coimbatore
gsn@ece.psgtech.ac.in
srivatsunece@yahoo.co.in

R. Darwin, Assistant Professor
Department Of ECE
Kumaraguru College of Technology
(Affiliated to Anna University Chennai)
Coimbatore
darwin.r.ece@kct.ac.in

Abstract- **A thick engraved Multiple-Input Multiple-Output (MIMO) antenna is presented in portable wireless modem or adapters with a functionality to embed WLAN(2.4 -2.48 GHz), Wi-MAX(3.4-3.8 GHz) and Hiper LAN(4.7-5.83 GHz).The location of two monopoles are at a spacing of 0.094λ_0 minimum resonant frequency in the PCB. In order to achieve the expected frequency bands with minimum mutual coupling between the ports, sequence of cancellation line and Defected Ground Structure (DGS) are used. Then its responsive functions are evaluated based on S-parameters. The Envelope Correlation Coefficient (ECC) and scale of Mean Effective Gain (MEG) are computed which are noticed to be well slighter than 0.3 and near to unity respectively.**

Keywords—Wi-Max, HiperLAN, Neutralization Line, DGS, ECC

I. INTRODUCTION

Now-a-days, Wireless communication system plays an essential role in human's life where a person can exchange information in the world with fast forward proficiency and high speed .Such a need for fast forward and high speed exchanges can be achieved by a assuring technology like MIMO. In September 2009, IEEE Union has endorsed the IEEE 802.11n standard [2]. MIMO is a wireless technology that handles various transmitters and receivers to transfer limitless amount of data at the same time. In recent days, it is perceptible that multiple antennas are having a better quality of demand and are most of expected to be tightly packed within devices that do not cover a huge area. It creates a great challenge to incorporate these many antennas into smaller devices like USB due to the limited availability of area. Another difficulty that arises is that the effect of coupling that directs us to think a serious issues in multiple antennas.

In recent days, there is a need for high speed USB dongles that enables us to access Broadband internet services. A proper implementation of a numerous antenna for UWB USB application will give rise to an excess need of isolation between the radiating elements over smaller region of space. It is evident from the recent studies that to improvise the isolation among antenna elements so that it will perform independently. In order to increase the isolation between the antenna elements, a technique of neutralization line is used, then the size of PCB is large which covers only WLAN band (2.45 GHz) by Lee et al [4]. The open ended stubs are instigated to establish the functions like stop filter and elevation of port isolation. The proposed structure by the authors uses a 3-Dimensional layout which resonates over WLAN, WiMAX and HiperLAN. Liao, Kim et al [5, 6] proposes a 3-Dimensional structure with a protruded ground plane to improve isolation between ports. An area covered by the antenna is quite big which tends to occupy most regions in the PCB of the Dongle. The facilities of Broadband mobile internet services are given access for incorporation of WiMAX in the later stages at higher data transfer speeds. The combination of WLAN and WiMAX range of frequencies is highly required for USB Dongles. The periodical evolution of antennas in cost effective, less complexity of fabrication and simple design understand us to move with printed types. Eventually, this explicates the necessity for an antenna with a simple geometry and better isolation techniques.

Here, we have designed a small printed UWB monopole antenna that resonates WLAN, WiMAX, and HiperLAN for USB dongles. The prime work of this antenna is to provide the services offered by the desired frequency ranges while it can be plugged to the USB port of the PC or a compatible device. The most commonly arising problem in these antenna is the mutual coupling that worsen the effectiveness of the proposed antenna. This problem is avoided by using neutralization line and Defected Ground Structure (a modified Ground). The simulation process for this antenna is carried out with the help of Finite Element Method (FEM) which corresponds to the Ansoft's High Frequency Structure Simulator (HFSS). Here we are going to compare the proposed antenna with previous literature works in terms of the characteristics such as diversity techniques, isolation methods, operating bands and radiation characteristics. The performance comparison of proposed antenna with the existing antennas are summarized in Table [1].

II.ANTENNA SPECIFICATION AND DESIGN PARAMETERS

The fabricated model of the proposed antenna and its configuration is depicted in the Figure [1]. The antenna is printed on a FR4 substrate which consists of two monopoles which are identical and is printed symmetrically in accordance with the symmetrical line. Arm 1 and Arm 2 are the proposed antenna elements of the MIMO antenna system. The length and width of the arms are optimized along with the meeting point of the neutralization line with radiating elements to obtain desired resonance. This is achieved with the help of an electromagnetic simulator such as Ansoft's HFSS with much ease. The concept of monopole by Ogawa et al [11] is used to design Arm 1 and Arm 2. The figure 2 represents the total physical length of the first Arm which is around quarter wavelength at 2.18 GHz. This is the lower cut-off frequency. The Arm 1 provides a wide bandwidth from 2.18 to 4.26 GHz but the problem is that it cannot cover HiperLAN frequency range. The Arm 2 has a total physical length around quarter wavelength at 2 GHz. Here the independent operation of Arm 2 covers a range from 2.2 to 3.4 GHz. Still it cannot cover all the three bands WLAN, WiMAX and HiperLAN. So it is evident that the independent operation of the two Arms doesn't cover the exact ranges of frequencies we needed. Hence in order to make the antenna resonate all the three bands (i.e) WLAN, WiMAX and HiperLAN, we amalgamate the two arms with the help of a neutralization line.

Table 1.Performance comparison of existing antennas with proposed MIMO antenna

Published literature	Antenna size in mm (volume in mm^3)	Operating bands	Peak gain(dBi)/ total efficiency (%)	Isolation(dB)	ECC/EDG
Hari et al. [1]	25 × 60 × 1.6(2400 mm^3)	WLAN (2.4-2.48 GHz)	0.18/65	$\leq$ -15	0.16/6.4
		WiMAX (3.4-3.8 GHz)	3.6/85	$\leq$ -14	0.015/8.5
		HiperLAN (4.7-5.83 GHz)	2.74/84	$\leq$ -15	0.001/8.45
Su et al. [4]	30 × 65 × 1(1950 mm^3)	WLAN (2.4GHz)	2.1/70	$\leq$ -19	<0.006/9.8
Liao et al. [5]	15 × 60 × 4(3600 mm^3)	WLAN (2.4-2.5 GHz)	0/40	$\leq$ -15	<0.46/4
		HiperLAN(5-6 GHz)	3/70	$\leq$ -20	<0.04/8
Kwon et al. [6]	25 × 63.5 × 4(6350 mm^3)	WiMAX (3.5-3.7 GHz)	4.53/NA	$\leq$ -20	<0.2/NA
Proposed	25 × 60 × 1.6(2400 mm^3)	WLAN (2.4-2.5 GHz)	3/	$\leq$ -14	
Antenna		WiMAX(3.4-3.8 GHz)	3.75	$\leq$ -15	
		HiperLAN(4.7-5.83 GHz)	6	$\leq$ -15	

The figure [2a, 2b] provides a layout structure for antenna element and neutralization line which will be going to responsible for peak cutoff resonance bands with respect to (-10dB) reflection coefficient and isolations between ports is better than (-14dB) over all frequency bands.

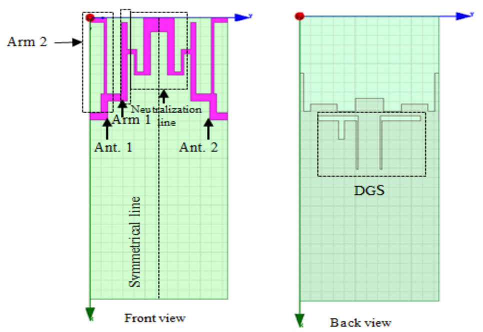


Fig [1]. Description of Proposed UWB MIMO antenna for dongle applications.

The isolation is very poor around -5dB at the lower frequency side in non-appearance of isolation techniques. This poor isolation would be effectively increased by integrating the neutralization line along with DGS.After the precise optimization, expected frequency bands and good isolation characteristic between antenna elements are obtained.

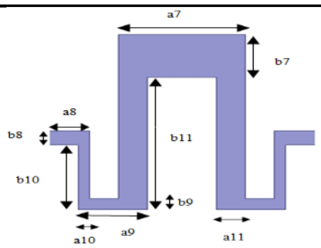


Fig [2].a. Single antenna element

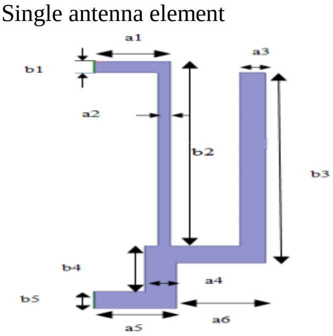


Fig [2].b. Neutralization line

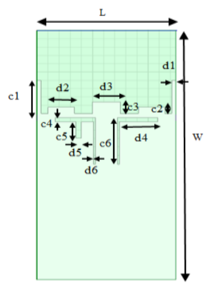


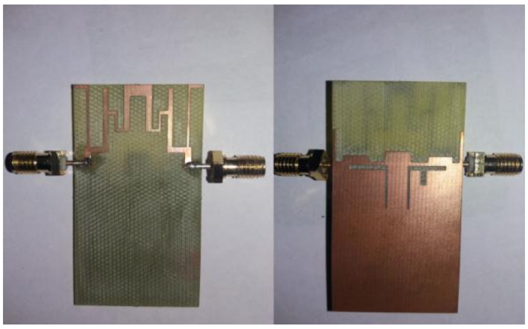
Fig [3]. Back view

Table 2.Dimension of the antenna

Parameters	Size(mm)	Parameters	Size(mm)	Parameter	Size(mm)
a1	3	a7	5.5	c1	8
b1	1	b7	3	d1	0.75
a2	0.5	a8	1.75	c2	1.5
b2	15.25	b8	0.5	d2	4.75
a3	1	a9	3	c3	2.75
b3	15.25	b9	0.75	d3	5
a4	1.25	a10	0.5	c4	1
b4	4	b10	5	d4	7.2
a5	3.25	a11	1.25	c5	3.9
b5	1.5	b11	9.25	d5	1
a6	3.5	L	60	c6	10.75
b6	1.25	W	25	d6	0.3

III. RESULT AND ANALYSIS

The designed MIMO antenna is fabricated using micro-milling machine. The following simulated S-Parameters are shown in Fig. [4]. And also simulated reflection coefficient which covers WLAN (2.4-2.5 GHz), WiMAX (3.4-3.8 GHz) and HiperLAN (4.7-5.8 GHz) bands and simulated isolation between ports is below -13 dB for over all the operating bands. Certain variations between the simulated and measured results are noticed due to fabrication acceptance. The effect of different S-parameters are shown in Fig [5].



Front view Back view

Fig [4].Fabricated model

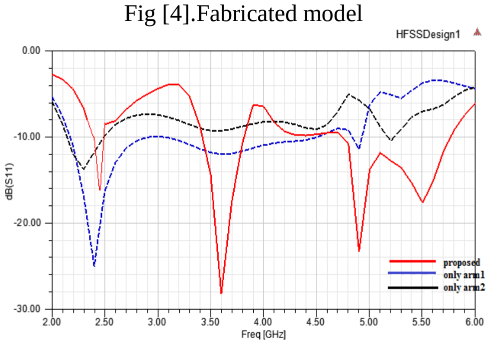


Fig [5]. Reflection coefficient (S_{11}) vs frequency plot

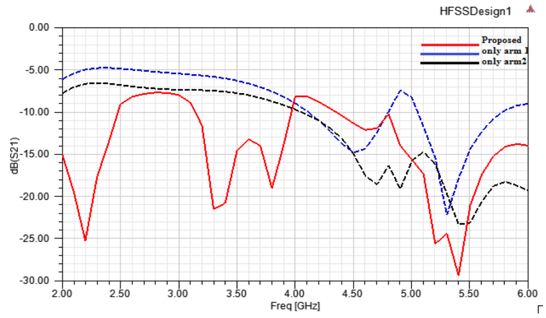


Fig [6]. Effect of different configuration on S-parameters

Effect of Ground modification:

The Reflection coefficient (S_{11}) vs frequency plot of with and without modification on the ground plane is shown in Fig [6]. It is noticed that the impedance matching and isolation are increased for all the operating frequency bands after changing the ground plane layout by adding stubs or introducing the slots in the ground structure. By introducing half wavelength slots for any band of frequencies [22], the intermediate slots that has to be kept isolated from other slots to reduce the coupling effects. Finally, WLAN, WiMAX and HiperLAN bands are attained through this progressive workouts.

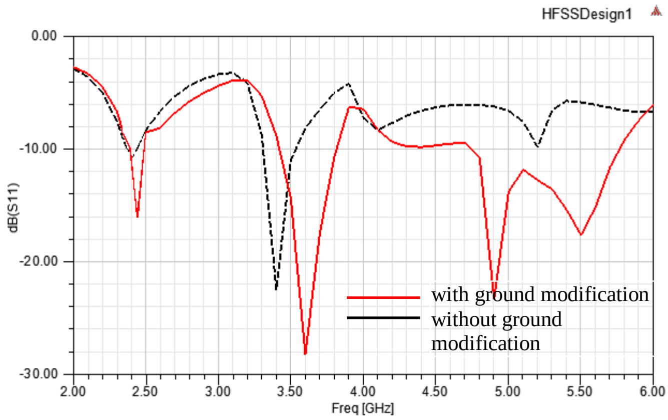


Fig [7].Reflection coefficient (S_{11}) vs Frequency plot

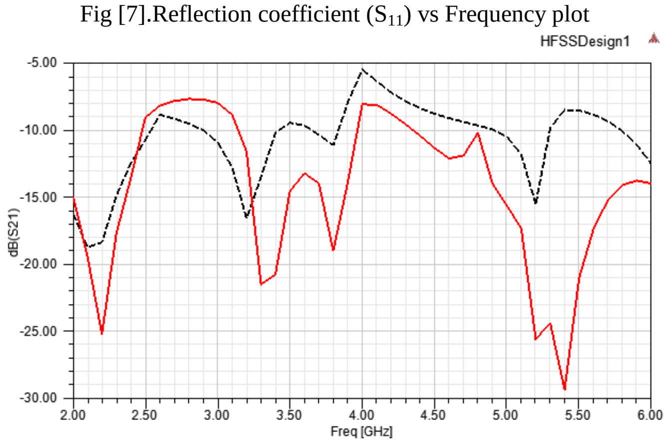


Fig [8].s21 vs Frequency plot

The peak realized gain of the proposed MIMO antenna is shown in Fig [9] and the gain is found to be higher as compared to that of the existing structure. The change in any one of the slot width will make an entire attribute to become complex and tends to increase in mutual coupling effect [17]. Two monopoles are same and equally placed with respect to the symmetrical line on the PCB. The peak realized gain and total efficiency are same for each antenna elements. The measured peak gain at port 1 is calculated to be 3.0, 3.75 and 5.75 dBi at 2.4, 3.6, and 5.2 GHz respectively.

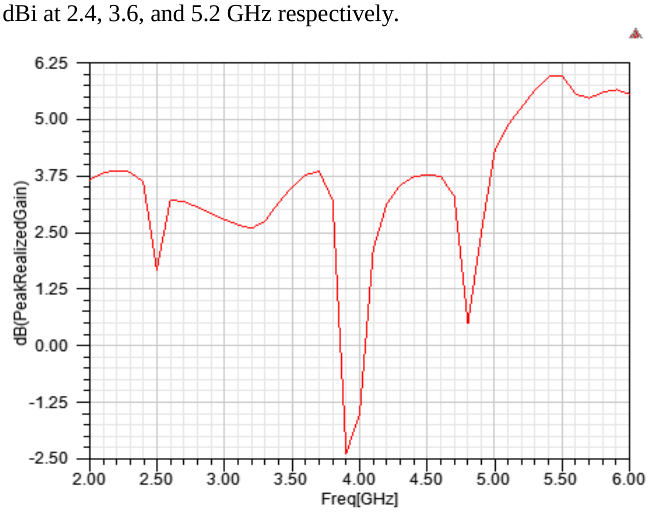


Fig [9]. Peak Realized Gain vs Frequency plot

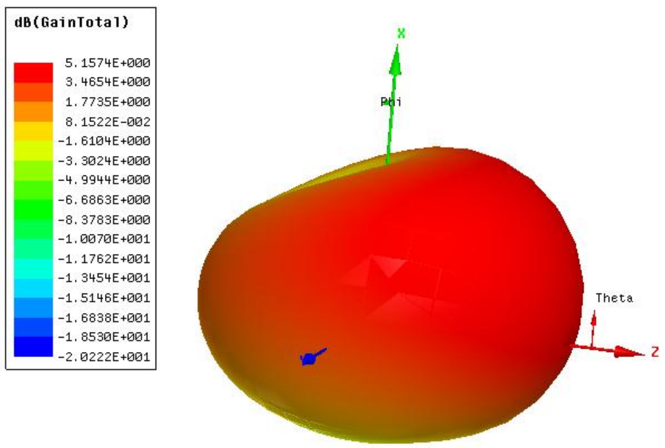


Fig [10].Radiation pattern

Modeling of the Neutralization Line:

When port 1 is exciting by a current 'I' then the small amount of current 'I' (i.e) 'cI' is coupled to the Antenna 2. To decrease this mutual coupling, a method of neutralization is incorporated which is connected between antenna elements at points 'A' and 'B'. The coupling current 'nI' induced at neutralization and remaining 'aI' enters antenna 1. So, a coupling current 'c* I' is coupled to the antenna 2.

$$\mathbf{cI + c^*I = 0} \qquad (1)$$

From equivalent circuit model, it is observed that at point 'A', $Z_{antenna}$ is input impedance looking towards the antenna elements whereas $Z_{neutralization}$ is input impedance looking towards neutralization line.

From the circuit model, the coefficient 'n' can be represented as

$$n = \frac{Z_{antenna}}{Z_{antenna}+Z_{neutralization}} \qquad (2)$$

IV.DIVERSITY CHARACTERSTICS

To analyze the diversity performance of designed MIMO antenna, important parameters such as the envelope correlation coefficient, effective diversity gain and mean effective gain values are obtained.

Envelope Correlation Coefficient (ECC):

Generally, ECC is used to analyze the diversity capability of MIMO antenna. This parameter is calculated either by using S-parameters or 3D radiation patterns.

a) *ECC Defined in terms of S-parameters:* The most suitable way to conclude the mutual coupling between antennas through the use of ECC defined in Eq. [3], which presumed antenna terminal would be matched and uniformly distributed incoming waves and formula given as [14],

$$\rho_{eij} = \frac{\left|S_{ii}^{*}S_{ij}+S_{ji}^{*}S_{jj}\right|^2}{\left(1-\left(|S_{ii}|^2+|S_{ji}|^2\right)\right)\left(1-\left(|S_{jj}|^2+|S_{ij}|^2\right)\right)} \qquad (3)$$

Where, ρ_{eij} is completely defined by S-parameters of i^{th} and j^{th} elements in a multi-antenna system, this parameter can be easily accessed. This equation needs reflection coefficient of each antenna and transmission coefficient between them. The mentioned formula is valid for ideal antenna cases but practically the above prediction is failed. Otherwise, we can use far field method for ECC calculation.

b) *ECC Defined in terms of radiation patterns:* The ECC can also be defined in terms of antenna radiation pattern which is given by [15],

$$\rho_e = |\rho_c|^2 \qquad (4)$$

using the radiation patterns, the simplified complex cross-correlation is given by,

$$\rho_e = \frac{\int_0^{2\pi}\int_0^{\pi} A_{12}(\theta,\varphi)\sin\theta d\theta d\varphi}{\sqrt{\int_0^{2\pi}\int_0^{\pi} A_{11}(\theta,\varphi)\sin\theta d\theta d\varphi \int_0^{2\pi}\int_0^{\pi} A_{22}(\theta,\varphi)\sin\theta d\theta d\varphi}} \qquad (5)$$

Where, $A_{mn} = XPRE_{0,m}(0,\phi)\,E^{*}_{0,m}(0,\phi) + E_{0,m}(0,\phi)\,E^{*}_{0,n}(0,\phi)$

E represent the electric far field of the antenna (m, n=1, 2 but m $\neq$ n).

It is noticed that the computed ECC satisfies the criteria of $\rho_e < 0.5$ and P1 $\cong$ P2, which show good diversity gain can be obtained.

Effective Diversity Gain (EDG):

The next significant antenna diversity parameter is apparent diversity gain (G_{app}) and is given in terms of correlation coefficient [16],

$$\mathbf{G_{app} = 10 * e_p} \qquad (6)$$

Where, 10 is the maximum apparent diversity gain at the 1% probability level with selection combining and

e_ρ is the diversity gain reduction factor

The e_ρ is from Su et al [17] and expressed as,

$$\mathbf{e_\rho} = \sqrt{1-|\rho_e|^2} \qquad (7)$$

The apparent diversity gain which is based on selection combining w.r.t % distribution level does not include the antenna total efficiency. So we cannot achieve effectiveness of diversity capability without considering antenna efficiency into account. The EDG of antenna system is calculated by multiplying the apparent diversity gain with total antenna efficiency.

Mean Effective Gain (MEG):

In the multipath propagation environment, MEG defined as the ratio between the mean received power of antennas over a random route and the total mean incident power at the antenna element [20],

$$MEG = \int_0^{2\pi}\int_0^{\pi} \frac{XPR \,.\, G_{\theta i}(\theta,\varphi)\,.P_{\theta}(\theta,\varphi) + G_{\varphi i}(\theta,\varphi)\,.P_{\theta\varphi}(\theta,\varphi)}{1+XPR} \sin\theta d\theta d\varphi \qquad (8)$$

Where,

XPR represents the cross-polarization ratio,

G_θ and G_φ the power gain patterns,

P_θ and $P\varphi$ are the θ and ϕ components of angular density functions of the incident power, respectively.

Where i, j = 1, 2 and i ≠ j.

The angular density function distributions are rely on the surrounding environment. In this proposed paper, P_θ and $P\varphi$ are assumed to be in elevation and uniform in azimuth, and are expressed as,

$$\boldsymbol{P_\theta(\theta,\varphi) = A_\theta\left[-\frac{\left\{\theta-\left(\frac{\pi}{2}-m_v\right)\right\}}{2\sigma_v^2}\right], (0 \le \theta \le \pi)} \quad (9)$$

$$\boldsymbol{P_\theta(\theta,\varphi) = A_\theta\left[-\frac{\left\{\theta-\left(\frac{\pi}{2}-m_v\right)\right\}}{2\sigma_v^2}\right], (0 \le \theta \le \pi)} \quad (10)$$

Where,

m_v , m_H are the mean elevation angles of each vertically-polarized (VP) and horizontally-polarized (HP) wave distribution observed from horizontal direction and vertical direction, respectively.

σ_v , σ_H are the standard deviations of each VP and HP wave distribution.

A_θ , A_ϕ are constant and determined by,

$$\boldsymbol{\int_0^{2\pi}\int_0^{\pi} P_\theta(\theta,\varphi)\sin\theta d\theta d\varphi = \int_0^{2\pi}\int_0^{\pi} P_\theta(\theta,\varphi)\sin\theta d\theta d\varphi = 1}$$

V.CONCLUSION

This paper helps us to understand the progress and performance of a small printed monopole diversity antenna that is voluntary for the UWB USB dongle platform which helps us to access the Broadband services. The inference of Defected Ground Structure and the neutralization line helps us to achieve a better isolation performance of (below -14 dB). It is evident from the measured radiation patterns that mitigation of the fading effect in multipath propagation is possible in this proposed antenna. Further the ECC and MEG values are found to be providing better diversity performances. The proposed antenna can be realized on actual platform which covers the operating bands with superior isolation attributes.

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