A Tunable Multi-band Meander Line Printed Monopole Antenna for MIMO Systems

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Abstract**—In this papera Tunable multi-band meander line printed monopole antenna for multiple-input–multiple-output (MIMO) system is presented. The proposed meander line monopole antenna can create a single resonance within the WLAN range. Placement of two resonance paths with length $_g$/2 vertical on it,leads to creating two extra resonances. The antenna parameters covering 2.4, 5.8 GHz for WLAN and 3.5GHz for WiMAX application, are provided.A two element array of such antennas is suitable for MIMO applications. The array has sufficientradiation efficiency, peak gain, low envelope correlation, and omnidirectional pattern. Further, Simulation results are compared and discussed.**

I. Introduction

Wireless communication has been developed rapidly in the modern communication systems, leading to a great demand for designing compact, low-cost, and multiband antennas. Moreover, there is increasing appeal for higher data rates, more appropriate service quality, and higher network capacity. In recent years, Multiple-Input Multiple-Output (MIMO) systems by considering that multiple antennas are used at the transmitting end as well as at the receiving end have been emerged as the most promising technology in these measures.

A couple of years ago the use of antenna arrays at one end of the link was mainly oriented to the estimation of directions of arrival as well as diversity, leading to beam forming and spatial diversity. Also,antenna arrays were used for increasing the capacity of wireless links, creating enormous opportunities beyond just diversity. Nowadays, MIMO system appears as an ideal technology for the communication system. [1]

Different antenna structures are used for MIMO application. One of these structures which is proper for planar antennas such as planar inverted-F antennas (PIFAs) and printed antennas have been reported. A dual-element PIFA operating at 2.5 GHz is discussed in [2]. Small size, low cost and straightforward manufactures of printed antennas motivaterational tendency to it.

One of the upsides of Monopole printed antenna is owning Omni-directional Pattern for achieving maximum channel capacity. The design of a four element U-shaped printed MIMO antenna by using optimization operating over 5.8 GHz WLAN is reported in [3].

Moreover, Multi band antennas for requirement of modern communication system are desirable. A dual-band back-to-back printed monopole antenna operating at UMTS and WLAN is provided in [4]. A designated internal dual-band

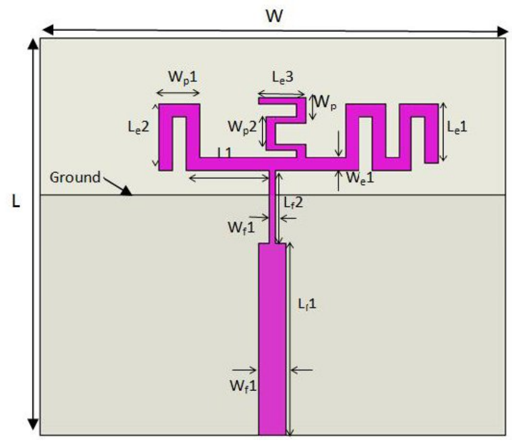


Fig.1. Configuration of the triband meander line printed monopole antenna.

planar inverted-F antenna(PIFA) diversity system for portable devices, operating in the in the 2.4and 5.2-GHz band is given in [5]. Therewith, a tri-band printed E-shaped MIMO antenna is presented in [6]. The configuration of antenna just can cover WLAN bands.

A useful method for making an antenna shorter is the meander line structure. These antennas are made from a continuously bent wire to reduce the resonant length.The formula for the relationship between the geometrical size and the resonant frequency of the meander line structure is explained in [7].

This paper presents a triband meander line printed monopole antenna appropriate for MIMO systems. With creating three separated meander line arms, each one's length $_g$/2, three adequate resonance bands for WLAN and WiMAX application, from the antenna can be attained. WLAN operation bands of the proposed antenna consist of 2.4 GHz band (2.4 GHz - 2.53 GHz for IEEE 802.11b), and 5.8GHz bands (5.725GHz- 5.825 GHz for IEEE 802.11a)and itsWiMAX operation band is 3.5GHz (IEEE 802.16). This antenna can be arrayed for using in MIMO system. It is shown that the proposed antenna has Tunable operating bands, proper isolation between two ports and small size, either. The radiation pattern is approximately omnidirectional in each of the associated frequency band.

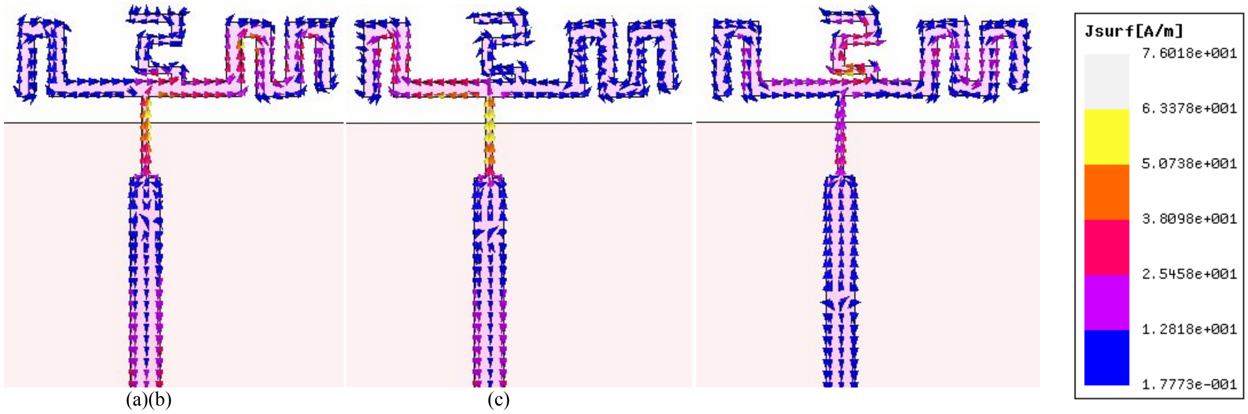


Fig.2. (a) Surface current distribution on the triband meander line antenna structure at 2.4 GHz, (b) at 3.5GHz, and (c) at 5.

II. . ANTENNA DESIGN

To accomplish a multi-band printed monopole antenna, several resonance paths can be used, producing separated resonance behaviour. Several resonance paths are obtained by meander line open stub with length $_g/2$. As Meander Line antennas are small, and they are useful for Wireless communication. Fig. 1 depicts the geometry of the proposed triband Meander Line printed monopole antenna suitable for WLAN and WiMAX applications. The proposed antenna was simulated on a 0.8 mm thick arlon AR 450(tm) substrate of relative permittivity 4.5.

To design the Meander Line printed monopole antenna, first the meander shape, with the width 0.5 mm, respectively, has been tuned to resonate at 5.8GHz is considered whichits dimension is 14mm≅ $_g/2$. For achieving other frequencies two vertical resonance paths on it are considered. Their dimensions are about $_g/2$, either. Based on this structure, the antenna was designed for 2.4, 3.5 and 5.8 GHz frequencies. .

This structure make separated resonance behaviour that is the desirabletarget. For proving this claim Fig.2 illustrates the surface current distribution on the proposed antenna structure at frequencies 2.4, 3.5, and 5.8 GHz. The surface current distributions are obtained through HFSS. By this figure, it is obvious that surface current in each frequency results in the corresponding resonance path with length $_g/2$. Indeed, creating resonance path with length $_g/2$ does not have any coupling on other frequencies; it means the independent behaviour in operating frequencies.

Having desirable impedance matching in all of the operating frequencies to maximizetransferring power from the generator to the load is important matter. Inserting two paths in antenna's feedline leads to have an appropriate impedance matching. It is noted that selectingseveral feed paths with $_g/4$, approximately, for antenna ones of a practical case. Quarter-wavelength impedance allows the

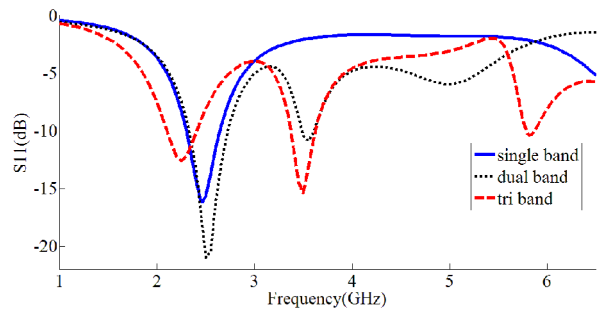


Fig.3. Simulated (S) meander line printed monopole antenna, Meander line antenna with single meander arm, and simulated antenna with two and three arm meander current path.

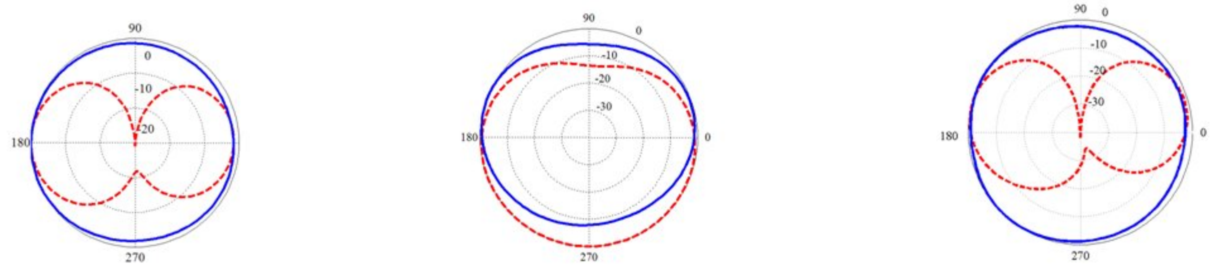
real-valued load impedances Z_L to real-valued line impedances Z to be matchedand can be designed to approach desired attenuation and bandwidth specification.

The tri-band MIMO antennas parameters' dimensions are adjusted as follows, W=35mm, L=30mm, Lf1=14.5mm, Wf1=2mm, Lf2=5.5mm, Wf2=0.2mm, Le1=4.5mm, Le2=5mm, Le3=3.5mm, We1=1mm, Wp1=3mm, p2=2.5mm, Wp=2mm and L1=6.3mm.

III. RESULTS

A. Meander Line Printed Monopole Antenna

Fig.3 shows the S-parameters of the antenna, which illustrates a propersimulation result. Displayed in this figure are the results of the simulated meander line printed monopole antenna, the simulated the antenna with single meander arm, and its simulation with two and three meander current path. According to these results, it is identified that creation of the second or third resonances does not have any effect on the return loss behaviour of the antenna at other frequencies(see Fig.3).



(a) (b) (c)

Fig.4. Measured E- and H-plane radiation pattern of the proposed triband antenna at (a) 2.4, (b) 3.5, and (c) 5.8 GHz. —— H-plane and ----- E-plane

A meander line antenna with three vertical resonance paths, each on one another, has three frequencies resonant at 2.4, 3.5 and 5.8 GHz. Also, the measured E and H-plane radiation patterns of the proposed triband band antenna at 2.4, 3.5, and 5.8GHz are shown in Fig. 4. The omnidirectional H-plane pattern of proposed antenna in all of the operating frequencies is specified.

B. *Tunable Multi-band Meander Line Printed Monopole Antenna for MIMO Systems*

Multiple-input multiple-output (MIMO) systems are employed to improve the characteristics of wireless communication systems. These systems are suitable for increasing capacity in high-bit-rate Wireless communication as compared with the single-input single-output (SISO) systems. To obtained maximum channel capacity for MIMO is also required to have high gain and omnidirectional pattern. [8]

Antenna arrays naturally constitute an essential part of a MIMO system. Proposed antenna can be arrayed forusing in MIMO application. A large number of different array configurations exist. For achieving desirable parameters of antenna array being suitable for MIMO application such as minimum mutual coupling, envelope correlation, and proper radiation pattern, the antenna elements are orthogonal. Based on the five possible configurations that any two suchmonopole antennas can be arranged beside each other, it was studied in [6], when the antenna elements are orthogonal, the parameters of antenna are better than those structures in which the elements are parallel. Hence, the antenna was arrayed and proposed. Fig.5 presents the array structure of antenna. In order to identify how good the result is see, fig.6 which presents S-parameter with VSWR less than 2.5 for resonance frequencies. Antenna spacing might play an important role, leading to a compromise between the size of the array and the captured diversity. Small spacing is also responsible for antenna coupling.

The space between array elements is set at 7 mm≅ $_{g}$/10 (of the lowest frequency band). The measured E and H-plane

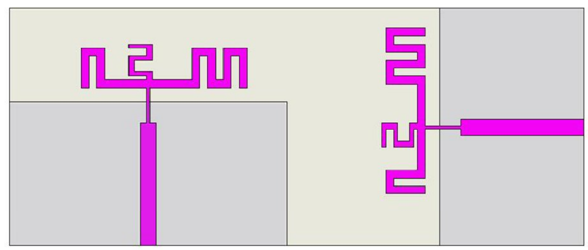


Fig.5. Configuration of the array structure of antenna.

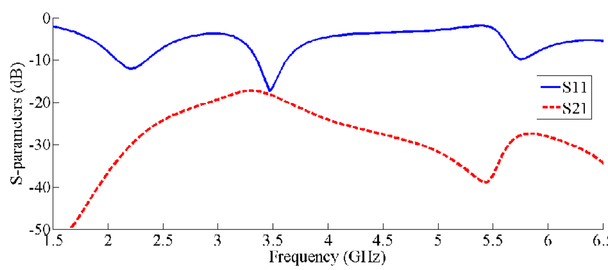
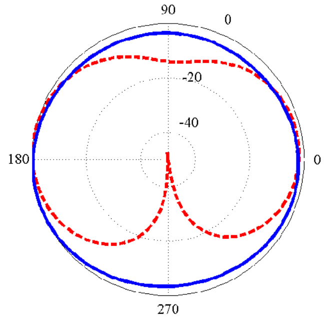


Fig.6. S-parameters of the MIMO antenna

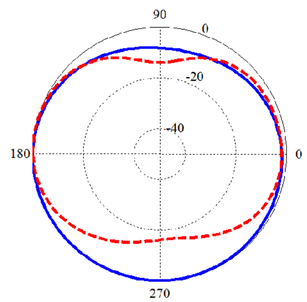
radiation patterns are depicted in Fig. 7.In accord with these results, evidently the antenna has an omnidirectional pattern. The envelope correlation obtained from the S-parameters using the following formula. [6]

$$\rho_e = \frac{| \quad * \qquad * \quad |}{|(\;|\; \;|\; \;|\; \;|\;)(\;|\; \;|\; \;|\; \;|\;)|} \quad (1)$$

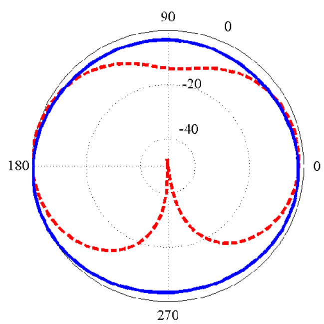
Table I gives the simulated peak gain, envelope correlation and radiation efficiency of the antenna array structure, either. For the antenna diversity, the practically acceptable envelope correlation is less than 0.5. The calculated envelope correlation of the proposed antenna array structure of Fig.5 is less than 0.02. The radiation efficiency is obtained by



(a)



(b)



(c)

Fig.7. Measured E- and H-plane radiation pattern of the proposed triband MIMO antenna at (a) 2.4, (b) 3.5, and (c) 5.8 GHz.
—— H-plane and ----- E-plane

calculating the ratio of the total radiated power of the array antenna to the total input power. For all frequency bands of the interesting radiation, efficiency is between 75-95%. In addition, average peak gain over all operating frequencies is -0.5dBi. The low mutual coupling, the low envelope correlation, and the approximately omnidirectional radiation patterns confirm that the proposed antenna array is a proper candidate for using in MIMO applications.

TABLE I
Envelope correlation, Peak Gain and Radiation Efficiency Results

Frequency(GHz)	2.4	3.5	5.8
Envelope correlation	0.002	0.02	0.012
Radiation efficiency(%)	80	96	75
Peak gain(dBi)	-1.7	-1.2	1.4

IV. Conclusions

The paper aimed at investigating aTunable multi-band meander lineprinted monopole antenna suitable for MIMO application. The antenna parameters for WLAN and WIMAX application, covering the 2.4, 3.5, 5.8 GHz are given. The proposed MIMO array configuration provides envelope correlation of lower than 0.02, average peak gain of -0.5dBi, higher efficiency, morethan 75% and omnidirectional patterns over all three frequencies.

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