Design and Analysis of Reconfigurable Antennas for WiMAX Applications

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***Abstract*—In this paper, the design of a pattern reconfigurable antenna for applications that operate in the WiMAX frequency band between 2.5 – 2.7 GHz is presented. The proposed antenna system consists of an array of two reconfigurable microstrip dipoles, whose active elements can be reconfigured in length using PIN diode switches. The setting of the different switches results in different geometries of the antenna and, consequently, different levels of inter-element mutual coupling and array far-field radiation patterns. The characteristics of the antenna parameters and patterns is analyzed. And, through experimental field testing, the performance of the proposed antenna array is evaluated based on the received Carrier to Interference–plus–Noise Ratio (CINR) as a metric.**

***Index Terms*—Reconfigurable Antennas, Antenna Arrays, and WiMAX**

I. Introduction

With the emergence of high-speed data standards for wireless communications, the need for compact and efficient antenna systems for next generation communication technologies is on the rise. Tremendous progress has been made in the research of adaptive antenna systems such as reconfigurable antennas with numerous designs that are reconfigurable in frequency, pattern, polarization, or a combination of these parameters [1].

Pattern reconfigurable antennas are of special interest due to their ability to dynamically change their radiation properties to the wireless channel characteristics. These antennas are able to generate uncorrelated radiation patterns which can produce uncorrelated channel realizations in a multipath rich wireless channel for a given frequency [2]. As a result, "two co-located antennas with different patterns "see" differently weighted multi-path components so that they interfere differently resulting in better reception; this improves link reliability [3], and channel capacity [4].

In this paper, we present a pattern reconfigurable antenna for WiMAX application and demonstrate through field measurements how the pattern reconfigurability can improve link reliability. The proposed solution is based on the reference design in [3], which, proposed a reconfigurable antenna array system operating in the Wireless Local Area Network (WLAN)/Wi-Fi frequency band in the range 2.4 – 2.48 GHz for a 2x2 MIMO system. The paper focuses on exploiting the effects of antenna geometry and mutual coupling between radiating elements to generate different radiation patterns. Our work extends that presented in [3] by designing a reconfigurable antenna for applications that operate in the frequency band between 2.5 – 2.7 GHz.

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We evaluate the performance of the proposed antenna array against a commercial WiMAX antenna in an indoor environment through experimental measurements. In Section II,we present the antenna design specifications of the reconfigurable antenna, and then, the antenna parameters and radiation pattern measurements in Section III. In Section IV, we analyze CINR results from field-measurements using the proposed antenna system and a commercial WiMAX antenna; and finally, give a brief conclusion in Section V.

II. Antenna Design Specifications

The geometrical specification of the proposed antenna design is illustrated in Fig. 1. The antenna structure was first designed using Ansoft electromagnetic simulator – High Frequency Structure Simulator (HFSS). The reconfigurable antenna array, consisting of two symmetrically microstrip dipoles is printed on a FR4-epoxy substrate with relative permittivity, ϵ_r, of 4.4 and dielectric loss tangent of 0.02. The detailed dimensions of the dipole are illustrated in Fig. 1(b). A quarter–wavelength microstrip balun acts as unbalanced–to–balanced transformer from the feed coaxial line to the two printed dipole strips [6]. The presence of a via-hole permits feed point, pt 2, to be shifted in phase by 180^o with respect to the feed point pt 1 of the other printed dipole strip (refer to Fig. 1(a)). "This occurs because of the 180^o phase difference between the top strip and the ground plane of the microstrip line" [3].

For each dipole, the geometry of the antenna, and thus, the length of the dipole-arm strip is changed using PIN diode switches; this changes the radiation structures which lead to different radiation patterns. The PIN diode model number is BAP64-03; it has an insertion loss of 0.3 dB and an isolation of 7.8 dB. The biased circuits are located at the sides of the 50–Ω microstrip feed line. When a direct bias voltage of 1.1 V is supplied with the two thin DC-bias traces the PIN diode

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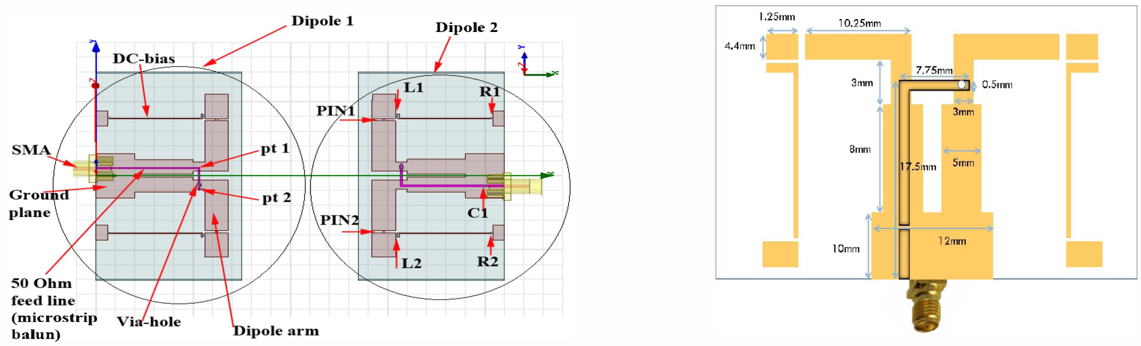
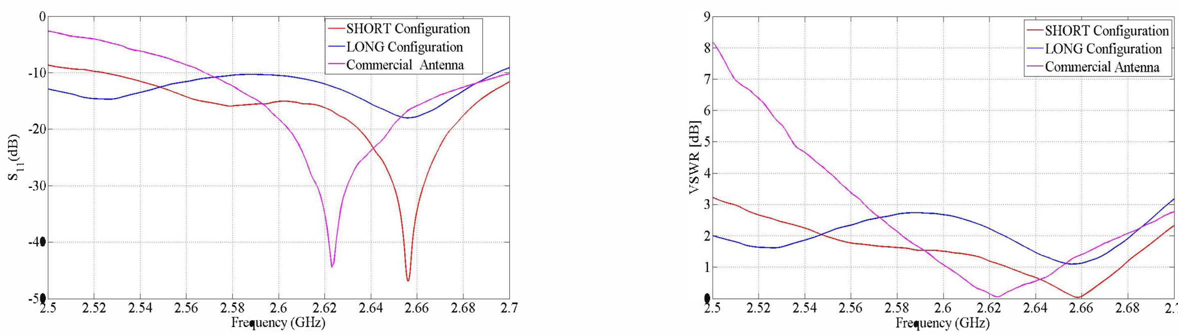


(a) (b)

Fig. 1. The design and geometry of the proposed antenna: (a) general view; (b) dimensions of the proposed antenna element



(a) (b)

Fig. 2. Measured Antenna Parameters of one antenna element: (a) Return loss (S11) (b) Voltage Standing-Wave Ratio (VSWR)

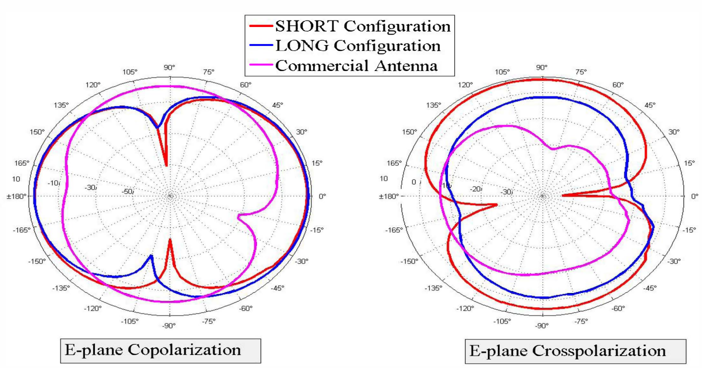


Fig. 3. Elevation patterns (left: E-plane Copolarization; right: E-plane Cross polarization)

switches are turned on; PIN1 and PIN2 are operating in the ON–state. Otherwise, the switches are turned off and are in the OFF–state. It is therefore, possible to define two configurations for each antenna, one when both of the switches are in the ON–state ("LONG" configuration) and another when they are in the OFF-state ("SHORT" configuration). Thus, the antenna array has four operating configurations. Other elements of the RLC circuit include: a capacitor (C1), inductors (L1 and L2), and resistors (R1 and R2).

III. Antenna Parameters and Radiation Patterns

The S-parameters of the antenna element are measured using an Agilent PNA-L N5230A Network Analyzer. Fig. 2(a) shows the return loss or S_{11} and Fig. 2(b) depicts the Voltage Standing Wave Ratio (VSWR) of one antenna element. The two configurations (SHORT and LONG) share a common operating bandwidth, defined by $S_{11} < -10$ dB, from 2.525–2.685 GHz. At frequency 2.656 GHz, both configurations have their lowest S_{11} values of -18 dB for the LONG configuration and -46.8 dB for the SHORT configuration. During the shared band, the VSWR of both configurations is below 2.6 as shown in Fig. 2(b). At the resonant frequency 2.656 GHz, the VSWR values are less than 1.2 which, indicates that the impedance of the antenna is nearly matched to the characteristic impedance of the transmission line. The commercial antenna performs poorly at frequencies lower than 2.57; this is reflected in Fig. 2(a) by return loss values of greater than -10 dB.

Fig. 3 illustrates the measured elevation radiation patterns for one element of the proposed antenna when operating a the SHORT and LONG configurations; and, the patterns for the commercial antenna. The antenna patterns were measured in the anechoic chamber facility of Drexel University. It depicts donut-shaped patterns for both antennas; however, the proposed antenna is horizontally polarized while the commercial antenna is vertically polarized.

IV. Experimental Setup and Results

In the experimental setup, the antenna array was hooked up to a WiMAX modem that is connected to a laptop computer via ethernet; this setup was used as a fixed WiMAX Subscriber Station. The Subscriber Station is then set to transmit 1500 pilot-based training packets using each of the four configurations of the antenna array: SHORT – SHORT; LONG – LONG; SHORT – LONG; and LONG – SHORT. The antenna array configuration, SHORT – SHORT, indicates that both antenna elements of the array are configured to use the "SHORT" configuration. The Carrier to Interference–plus–Noise Ratio (CINR) was then measured as a performance metric for the downlink reception channel. Similar measurements were made using the commercial WiMAX antenna of the service provider device. All experiments were carried out in a typical indoor laboratory environment; and, the test location is situated on the third floor of Bossone research center at Drexel University. The nearest base station is located on the rooftop of an 8–story building about 400 meters away from the test location.

Fig. 4 shows the percentile CINR performance for the proposed antenna array and the commercial WiMAX antenna. Each bar indicates the percentage of time that a particular CINR value was measured using a given antenna array configuration during the training packets transmission interval. The results show an improved CINR performance with the proposed solution compared to the commercial antenna. The antenna array out-performs the commercial antenna 80% of the time and some of the antenna array configurations perform better than the others.

The proposed antenna solution, therefore, enables the flexibility of selecting a configuration that yield the highest received CINR for a given transmission period or environment. Each of the reconfigurable antenna element used is able to adaptively modify its radiation characteristics and thus can leverage pattern diversity to impact the manner in which the transmitter and receiver "perceive" the wireless channel. As established in [3], "two co-located antennas with different patterns "see" differently weighted multi-path components so that they interfere differently for the two antennas resulting in better reception." This enables us to merge the benefits of antenna diversity and antenna reconfigurability to improve link capacity and CINR or the signal strength at the receiver [4].

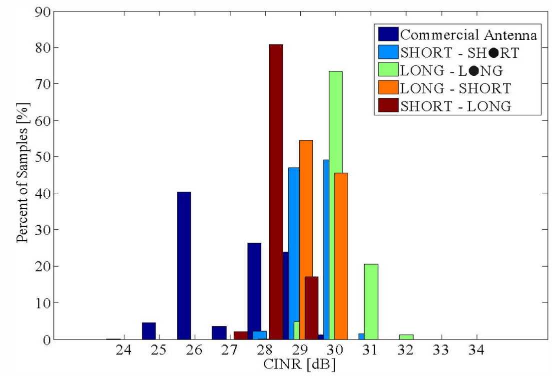


Fig. 4. WiMAX Measurements: Percentile CINR Performance for the reconfigurable antenna and the Commercial Antenna

V. Conclusion

A pattern reconfigurable antenna array for adaptive systems that operate at frequencies between 2.5 – 2.7 GHz has been proposed. Measurement results demonstrate potential performance improvement from using the proposed antenna array in adaptive wireless communication systems. Our solution therefore, provides a great alternative that can easily be adopted for WiMAX commercial application. Further study will focus on configuration selection algorithms in real-time WiMAX applications.

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