POS1-59

A Tunable Rotary-Patch Loaded PIFA

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1. Introduction

Designing and developing antenna system is one of the most important works in wireless communications systems for the transmission and reception of electromagnetic waves since the performance of an antenna is fairly sensitive to its surrounding environments, e.g., even the each of antenna and circuit components show reasonable performance, but it may show performance degradation after integrating both modules. Especially, electronic components nearby may will cause the variation of the resonant frequency of the antenna. In a legacy antenna system without having tuning feature, the antenna system needs to be newly designed or other RF-related components on the circuit need to be tuned after operating frequency shifting happens caused from circuit integration. With this reason, the demand for an antenna with tuneable, especially embedding inside the casing of a portable device is highly increasing. Therefore, developing an easy and simple method for tuning the operating frequency of the antenna causes reduction of the overall product developing cost. If a tuneable antenna provides wide enough frequency range, a single antenna design can be used in different operating frequency bands [1] .

The planar inverted-F antenna (PIFA) [2], [3] is one of the most popular antenna types for portable devices because of its easiness of designing, low profile, and low cost. The main characteristic of utilizing PIFA is that its resonant frequency depends on not only the length of the shorted patch, but also other dimensions such as the width and height of the patch and the width of shorting straps. Therefore to provide multiple frequency resonance on PIFA, the gap width and length need to be carefully considered. Recently antenna designers have made many efforts to change the effective dimensions of the PIFA, without changing the physical dimensions for compactness.

In this paper, a frequency tuneable PIFA by utilizing a simple mechanical rotator is presented. To design an antenna, it is considered that a small patch with rotation to provide electronically variation of any of above parameters may be affected on the variation for the resonant frequency of an antenna. By varying weight value of a patch, the proposed antenna is designed to have multiple resonant frequencies, for selective multiple applications (Wibro, WLAN, LMDS/MMDS) without mutual interferences. In simulation and experiment works, the proposed antenna operates at the frequency band of 2.3 GHz, 2.5 GHz and 2.7 GHz when rotary degrees of the small patch are 0˚, 90˚ and 180˚, respectively. Performance of the proposed rotary-patch loaded PIFA shows a 10-dB return-loss tuning range of 0.7 GHz from 2.2-2.9 GHz.

2. Design

Initial modelling is carried out using HFSS, Ansoft simulation tool. The PIFA is studied in its basic structure, i.e. without switched components. This is shown that the proposed antenna can adopt the structure with simple concept rotary switches to tune the antenna to the required resonant frequency. Figure 1 illustrates the design of the proposed antenna. It consists of one radiating patch (PIFA) on bottom of a rotary-patch. Both of the radiating patch and the rotary-patch are made of FR4 (t=1.6 mm and ε_r = 4.4). They are 7 mm in height above the phone ground plane (45 mm x 80 mm). The impedance matching is obtained mainly by optimizing the structure of the radiating patch, the dimension of the rectangular-slot, and the position of the feeding point.

2.1 PIFA Element

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The geometry of the PIFA element is shown in Figure 2. The coaxial feed line is connected to the patch with a rectangular-slot and a meanderline-slot. The short pin is at the nearby of the coaxial feed position connecting the radiation element and the ground. Slots [4] are elements for resonant frequency at 2.8 GHz and also enough space of rotary patch that can switch the operating frequency band of interest.

2.2 Rotary Patch

Figure 3 illustrates the rotary patch structure. It has two elements. The exciting rectangular patch has 6 mm x 6 mm which is etched on FR4 and the parasitic patch size is 3 mm by 2 mm that is made of 0.2 mm thick brass sheet. The only rotary patch with a short pin is designed for 2.8 GHz frequency band. The rotary patch is fixed on the radiating PIFA with swing from 0˚ to 180˚.

3. Results

Figure 4 shows that three switches (S1, S2 and S3) act to lengthen the three resonant modes present on the antenna, when the rotary patch is placed at 0˚, 90˚, and 180˚. In this paper, Mode 1 corresponds with the resonant band covering 2.2-2.4 GHz. Mode 2 covers 2.4-2.6 GHz. Mode 3 covers 2.6-2.9 GHz. Table 1 shows the switch settings of Mode 1, 2, and 3. Figure 5 shows results for the matched resonance of the proposed PIFA in the three modes, As it can be seen, Mode 1(the continuous line) operates at 2.3 GHz and the input RL is 23 dB (6.5% BW), Mode 2(the dashed line) operates at 2.5 GHz and the input RL is 25 dB (4.8% BW) and Mode 3 (the red line) operates at 2.7 GHz and the input RL is 20 dB (7.4% BW), respectively. By simply replacing the rotary patch, a tuning range of 0.7 GHz from 2.2-2.9 GHz can be achieved. Figure 6 shows the measured return loss of the proposed PIFA. As shown in this figure, both results from simulation and experiment show similar performances in terms of return loss. Figure 7 and Figure 8 show the simulated and measured radiation patterns at 2.7 GHz, respectively. The radiation patterns are approximately omnidirectional. The maximum radiation gains are 3.51 dBi at simulation and 3.19 dBi at experiment, respectively. Table 2 shows that performance of the radiation maximum gain from simulation and experiment are almost similar.

4. Conclusions

The design and development of a tunable rotary patch loaded PIFA have been presented. A rotary patch is integrated to the centre of the slots of the PIFA to make it a frequency agile antenna in a compact package. The proposed antenna has relatively broader impedance bandwidths covering the Wibro, WLAN and LMDS/MMDS bands with approximately omnidirectional radiation patterns and high gain. The proposed structure with more number or small size of a rotary patch can be widening the bandwidth. Finally the presented antenna performance is very promising for present and future wideband applications.

References

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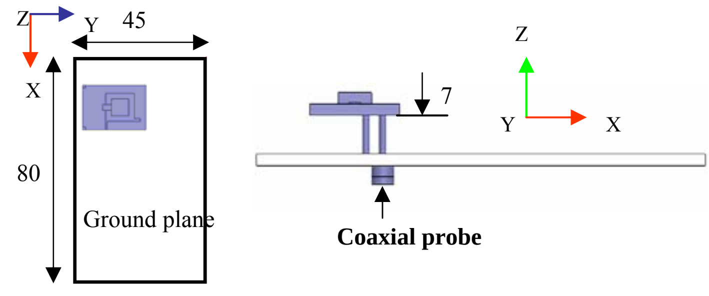


(a) Top view. (b) Side view

Fig. 1. Configuration of the proposed PIFA with the rotary-patch loading (units: mm)

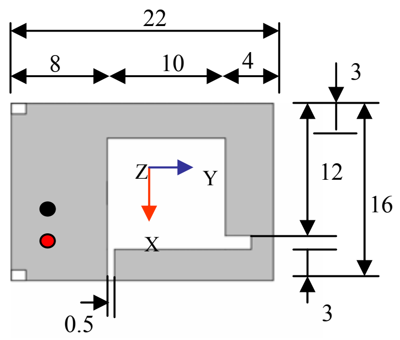
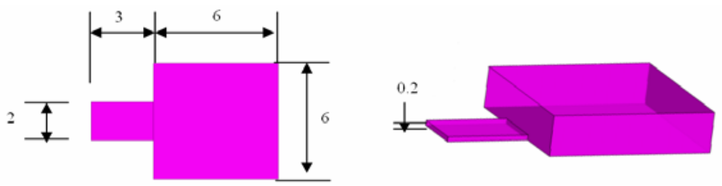
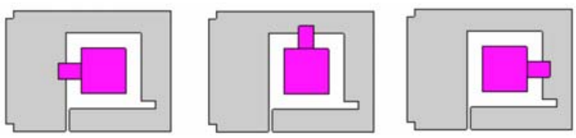


Fig. 2. Geometry of the PIFA element (units: mm)



(a) Top view (b) 3-D view

Fig. 3. Configuration of the Rotary patch (units: mm)



(a) S1 (0˚) (b) S2 (90˚) (c) S3 (180˚)

Fig. 4. Three switches (S1, S2 and S3) according to swing of the Rotary patch.

Table 1. Switch settings Modes 1, 2 and 3

Switch	Mode	Rotary Position	Resonant Bands (GHz)
S1	1	0˚	2.2-2.4
S2	2	90˚	2.4-2.6
S3	3	180˚	2.6-2.9

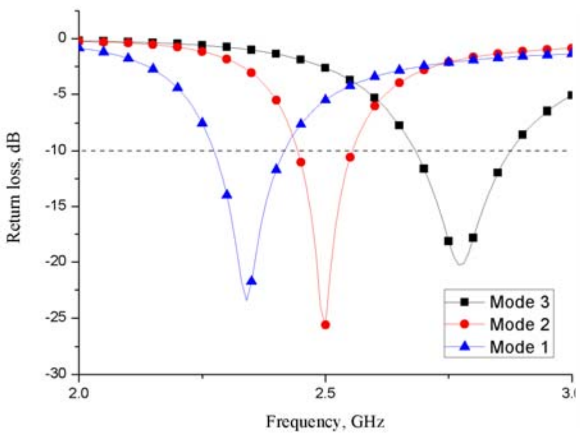


Fig. 5. Simulated results (matched resonance of the antenna)

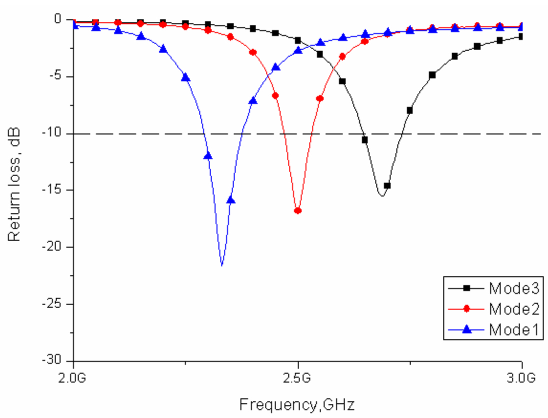
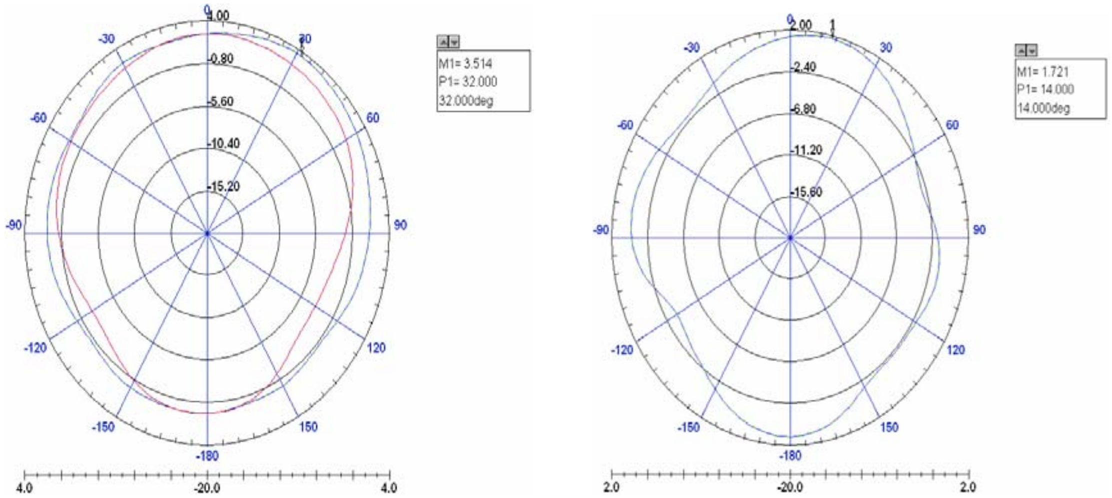
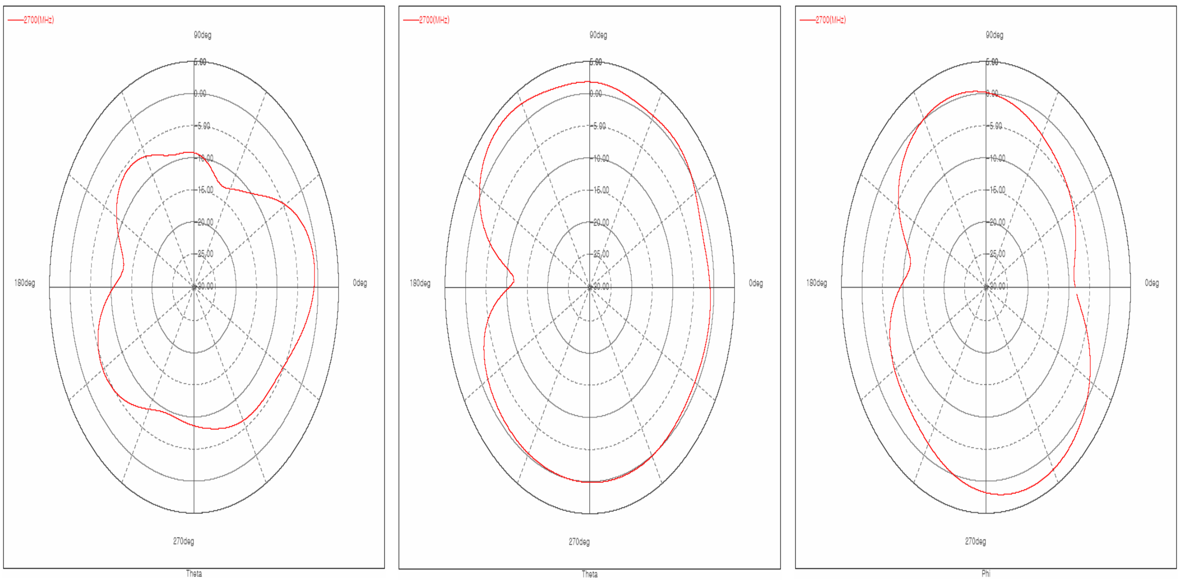


Fig. 6. Measured results (Return loss of proposed PIFA vs Frequency)



(a) φ = 0˚, 90˚ f = 2700 MHz (b) θ = 90˚ f = 2700 MHz

Fig. 7. Simulated radiation pattern at 2700 MHz



(a) φ = 0˚ f = 2700 MHz (b) φ = 90˚ f = 2700 MHz (c) θ = 90˚ f = 2700 MHz

Fig. 8. Measured radiation pattern at 2700 MHz

Table 2. Radiation maximum gain

Frequency (MHz)	Simulated results (dBi)		Measured Results (dBi)	
2300	φ = 0˚	2.82	φ = 0˚	-3.57
	φ = 90˚	3.0	φ = 90˚	2.9
	θ = 90˚	1.45	θ = 90˚	2.75
2500	φ = 0˚	1.79	φ = 0˚	-2.59
	φ = 90˚	1.83	φ = 90˚	2.99
	θ = 90˚	1.34	θ = 90˚	2.56
2700	φ = 0˚	3.12	φ = 0˚	-0.7
	φ = 90˚	3.51	φ = 90˚	3.19
	θ = 90˚	1.72	θ = 90˚	2.75