A Review of Reconfigurable Frequency Switching Technique on Microstrip Antenna

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Abstract. This paper is briefly describes review of techniques design a reconfigurable frequency on microstrip antenna. There are several methods have been consequential or developed used to provide as well as improve the switching frequencies technique in a single terminal antenna by researchers. This paper investigates different techniques undergoes by some of the research that has been performed to achieved various operating frequencies.

Keywords: reconfigurable frequency, switching technique, microstrip antenna.

1. Introduction

Reconfigurable frequency are gaining popularity among researcher due to constraint design improvements and their need in many wireless communication. Reconfigurable antenna can be defined as the antenna with the capability to reconfigure certain characteristics such as frequency, polarization and pattern. The reconfiguration is not limited to a single characteristic, but it can be a combination of characteristics depending to the application. The reconfigurable antenna idea was first introduced in early 1930 [1]. However the practical demonstration started from 1999. Since then, microstrip antenna has undergone significant improvement and been used as a platform to design reconfigurable antenna [2-6].

In designing reconfigurable antenna, the recent state of RF switches used is FET switches, PIN diodes and MEMS switches. The switch is a device to act as either a circuit maker or circuit breaker in order to configure the antenna parameters. For a reconfigurable antenna, there are several types of suggested RF switch such as PIN diode or micro-electro mechanical system (MEMS) to design. Generally, the RF switch performs as a circuit breaker. The principle of this switch is to regulate the number of the RF current to flow along the desired direction. Hence, to achieve reconfgurability, the position of the RF switch is crucial and has to be optimized in the antenna design. The common approach to realize switchable frequency is using PIN diodes due to the high handling competency and cost efficient if compared to the MEMS [7-8].

The PIN diode switch capable to perform switching in fast times and relatively high current handling, it’s very common in microwave circuit applications capabilities. Due to contact potential and inertial effects, old-fashioned electromechanical RF switching elements is naturally slow response devices [9-12]. The advantage of PIN diode switches are it’s speed of operation and ease of packaging. Typical PIN diode switches has less than 100 ns switching speeds. An important characteristic of PIN
diode is it consist of nearly pure resistance at microwave frequencies. For biasing purpose, the resistance could range from a value of $1 \, \Omega$ to $10k \, \Omega$. Normally, $10mA$ bias current required for ON state operation.

2. Literature Review
The reconfigurable frequency antenna can control the antenna performance in terms of different operating frequencies in a single terminal. Such operation is intended for performance improvement, especially to minimize interference with other wireless system and maximizing throughput [13]. In general, the resonant of antenna is determined by the effective length of the radiator. The antenna includes the type of dipole, monopole, loop, slot and microstrip antennas. The effective length plays a significant role to determine the operating frequency of the antenna hence, by controlling the effective length, frequency can be configured. By several methods of switching, frequency reconfiguration can be achieved. As an example; varying the patch size; reconfigurable matching network; changing the current flow; mechanically configuring using metasurface; and varying the length of the slot. All this switching technique is explained in the following subsection.

2.1. Frequency Switching Method: Varying the Patch Size
A reconfigurable monopolar patch antenna has been reported in [14], which capable to reconfigure up to eight different frequency bands using four PIN diodes. The PIN diodes are used to connect main patch to four different sizes of small patches. The resonant frequency can be tuned from 1.82 GHz to 2.48 GHz by controlling the total patch size. Figure 1 shows the biasing circuit of the proposed antenna [14].

Another design that used the similar method has been done by [15]. The proposed tunable antenna made of a slotted rectangular patch loaded by a number of posts close to the patch edge. Three posts are short circuited to the ground plane connected with a set of PIN diode switches. Reconfigurability is obtained by selecting the appropriate post to be shorted thus provides four different frequency reconfiguration. The geometry of the proposed switchable antenna is shown in Figure 2. This technique can easily achieved the desired operating frequency by analysed the total size of patches. However, the drawback of this method is complicated antenna design and biasing circuit.
2.2. Frequency Switching Method: Reconfigurable Matching Network (Stub Tunner)

Antenna with the reconfigurable matching network has been presented by [16], where three different frequency bands can be switched using two PIN diodes. The antenna is matched at 5.2 GHz by forward biasing the diode on the left and by forward biasing on the right, the antenna is matched to 6.4 GHz. Meanwhile, when neither of two diodes is biased, the antenna is matched at 5.8 GHz. The described matching network is illustrated in Figure 3. This design offers a simple antenna geometry, but gives limited frequency reconfiguration.

![Figure 3: Reconfigurable matching network antenna [16]](image)

2.3. Frequency Switching Method: Changing the Current Flow

A reconfigurable cedar-shaped microstrip antenna for wireless applications are presented by [17], invented the switching frequency method by changing the current flow of the patch. The author used is switched to reconfigure four different frequency bands. Slits are introduced at the edge of the cedar shaped patch. The proper configuration of the switches alters the current flow and changes the operating frequencies. The geometry of proposed antenna shown in Figure 4 (a). The current flow of cedar-shaped antenna at a different state of configuration is illustrated in Figure 4 (b). Meanwhile, the resonance frequency gain results of the antenna are tabulated in Table 1.
Figure 4: (a) Geometry of Cedar-shape microstrip antenna, (b) Current distribution for switching case 0, 1, 2 and 3 presented in Table 1 [17].

Table 1: Switch states and the antenna performance results [17]

| Case | \(S_1, S_1'\) | \(S_2, S_2'\) | \(S_3, S_3'\) | Resonance Frequency (GHz) | Gain (dB) |
|------|----------------|----------------|----------------|---------------------------|-----------|
| 0    | OFF           | OFF           | OFF           | 2.075                     | 0.2798    |
| 1    | ON            | OFF           | OFF           | 2.145                     | 1.0373    |
| 2    | ON            | ON            | OFF           | 2.295                     | 2.1824    |
| 3    | ON            | ON            | ON            | 2.325                     | 2.5098    |

On the other hand, this paper used the copper strip to represent a switch. Hence, in order to implement PIN diodes into the proposed antenna becomes difficult as the biasing circuit will become more complicated. The biasing circuit requires components such as capacitor, inductor and PIN diode to be properly located so the antenna is not becomes a short circuit. Moreover, the antenna needs to add small slot between switches to provide different state of configuration. Furthermore, the changing structure of the antenna will affect the operating frequency and antenna performances.

2.4. Frequency Switching Method: Mechanically Configure using Metasurface

Another method to configure frequency is by using metasurface instead of the embedded switching circuit. Zhu et al. [18] invented frequency-reconfigurable antenna using metasurface. The proposed antenna consist of a simple circular patch antenna, design on Rogers substrates RO4350B with full ground plane. The metasurface of the proposed antenna is designed on a single-side substrate and composing of a number of rectangular-loop unit cells as shown in Figure 5.

The metasurface of the proposed antenna constructed by placing rotating the metasurface around the center and relative to the patch antenna. As the rotation angle of metasurface increase from 10°, 25°, 35°, 55° and 80°, the resonant frequency shifted to 4.77 GHz, 4.9 GHz, 5.07 GHz, 5.31 GHz and 5.5 GHz, respectively. This kind of method categories is mechanically reconfigurable antennas, where the parts of the antenna structures (metasurface) consist of movable parts for turning the frequency. The drawback of such designs was the difficulties of the fabricated process to ensure the moveable part can be still attached to the antenna and the same time can be flexible tuneable.
2.5. Frequency Switching Method: Varying the Length of the Slot

Micostrip slot antenna has the potential to be a better candidate for frequency reconfiguration because it offers a wide frequency range turning and conveniences of the resonant frequency turning with switches of varactors across the slot. A PIN diodes are used to vary the slotted size of the antenna [19]. Four PIN diodes used along the slotted of the antenna are capable to configure up to five different band frequencies. Figure 6 shows the switchable frequency structure on the ground plane of the proposed antenna. The different size and structure of the slot was produce when PIN diode is on and off. Hence, the frequency can vary from 2.11 GHz up to 10.92 GHz.

Similar approach for configurable frequency using the slotted technique on the ground plane has been reported in [20]. Five PIN diodes were placed in the slot to tune the length of the slot, thus provides operating frequency from 1.98 GHz to 3.59 GHz. The antenna is capable to switch up to nine frequency bands by turning on and off five switches at different configuration in order to varying the length of the slot. Six small slots with a width of 0.3 mm are introduced to separate between switches for biasing proposed. Since the small slots separation effected the ground plane efficiency, a surface mount RF capacitor with a value of 100 pF is used to provide RF wave connection throughout the ground plane. Figure 7 illustrates the proposed reconfigurable frequency antenna.
3. Conclusions

A several technique to design reconfigurable frequency antenna has been accomplished in this study. The reconfigurable frequency include varying the patch size; reconfigurable matching network; changing the current flow; mechanically configuring using metasurface; and varying the length of the slot is presented. The understanding on the microstrip antenna properties and their frequency response behaviour are necessary in order to improve the antenna performances without affected other parameters.

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Figure 7: Frequency reconfigure microstrip patch slot antenna: (a) front view and (b) back view [20]
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