Reconfigurable Communicating Patch Antenna for Cognitive Radio Applications

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***Abstract*: This paper presents a microstrip wideband antenna and its utilization in integration of multiple wireless communication systems. A simple fork-like strip antenna, fed by a coplanar-waveguide (CPW) transmission line. Due to shortage of fabrication utilities; both simulation methods results are in agreement with the design principles. This reconfigurable multi-band new-shaped patch antenna can be applied to any desired frequency band used for communication or satellite applications. The frequency of the reconfigurable antenna obtained and it work on two frequencies 5.3 and 6.1 with return loss less than -10dB, VSWR less than 2 and gain more than 7 in all cases.**

***Keywords*: microstrip wideband antenna, fork-like strip antenna,CPW**

Introduction

In now day's the wireless system has become a part of human life. Most of the electrical and electronics equipment around are using the wireless system. An antenna is an essential element of the wireless system. Antenna is an electrical device which transmits the electromagnetic waves into the space by converting the electric power given at the input into the radio waves and at the receiver side the antenna intercepts these radio waves and converts them back into the electrical power. There are so many systems that uses antenna such as remote controlled television, cellular phones, satellite communications, spacecraft, radars, wireless phones and wireless computer networks. Day by day new wireless devices are introducing which increasing1 demands of compact antennas. Increase in the satellite communication and use of antennas in the aircraft and spacecraft has also increased the demands a low profile antenna that can provide a reliable communication.

A microstrip antenna is one who offers low profile and light weight. It is a wide beam narrowband antenna can be manufactured easily by the printed circuit technology such as a metallic layers in a particular shape is bonded on a dielectric substrate which forms a radiating element and another continuous metallic layer on the other side of substrate as ground plane not only the basic shapes any continuous shape can be used as the radiating patch. Instead of using dielectric substrate some of the microstrip antennas use dielectric spacers which results in wider bandwidth but in the cost of less ruggedness. Microstrip antennas are low profile antenna and mechanical rugged and can be easily mounted on any planar and nonplanar surfaces. The size of microstrip antenna is related to the wavelength of operation generally $\lambda/2$. The applications of microstrip antennas are above the microwave frequency because below these frequencies the use of microstrip antenna doesn't make a sense because of the size of antenna. At frequencies lower than microwave, microstrip patches don't make sense because of the sizes required. Now a day's microstrip antenna is used in commercial sectors due to its inexpensiveness and easy to manufacture benefit by advanced printed circuit technology. Due to the development and ongoing research in the area of microstrip antenna it is expected that in future after some time most of the conventional antenna will be replaced by microstrip antenna.

1.2 Types of antenna reconfiguration

Re-configurable antennas can be classified according to the antenna parameter that is dynamically adjusted, typically the frequency of operation, radiation pattern or polarization (Huff and Bernhard, 2008).

- Frequency reconfiguration
- Radiation pattern reconfiguration.
- Polarization reconfiguration.
- Compound reconfiguration.

1.2.1Frequency reconfiguration

Frequency reconfigurable antennas can adjust dynamically theirfrequency of operation. They are particularly useful in situations where several communications systems converge because the multiple antennas required can be replaced by a single reconfigurable antenna. Frequency reconfiguration is generally achieved by modifying physically or electrically the antenna dimensions using RF-switches, (Panagamuwa, Chauraya, and Vardaxoglou. 2006). Impedance loading (Erbil, Tonally, Ulna, Civil, and Akin, 2007). Or tunable materials (Liu, and Langley, 2008).

1.2.2 Radiation pattern reconfiguration

Radiation pattern reconfigurability is based on the intentional modification of the spherical distribution of radiation pattern. Beam steeringis the most extended application and consists in steering the direction of maximum radiation to maximize the antenna gain in a link with mobile devices. Pattern reconfigurable antennas are usually designed using movable/rotatable structures (Rodrigo, Joffre, and Center, 2012). Or including switchable and reactively loaded parasitic elements (Aboufoul, Parini, Chen, and Alomainy, 2013).

1.2.3 Polarization reconfiguration

Polarization reconfigurable antennas are capable of switching between different polarizations modes. The capability of switching between horizontal, vertical and circular polarizations can be used to reduce polarization mismatch losses in portable devices. Polarization re-configurability can be provided by changing the balance between the different modes of a multimode structure (Simons, Donghoon, and Katehi, 2002).

1.2.4 Compound reconfiguration

Compound reconfiguration is the capability of simultaneously tuning several antenna parameters, for instance frequency and radiation pattern. The most common application of compound reconfiguration is the combination of frequency agility and beam scanning to provide improved spectral efficiencies. Compound configurability is achieved by combining in the same structure different single- parameter reconfiguration techniques (Aboufoul , Chen,Parini, and Alomainy, 2014)

1.3 Advantages and Disadvantages of reconfigurable antenna

The advantages are significant:

- Have a multiband antenna in a single terminal for various applications.
- Easy to integrate with switching devices and control circuit.
- Small in size.
- Can easily design antenna with desired polarization.
- Mechanically robust, Resistant against vibration and shock.

However, the design of reconfigurable antenna are typically driven by the balance of trade-offs. Compared with fixed-tuned antenna, due to its short developing time, there are still some disadvantages waiting to be solved:

- The technology of reconfigurable relies largely on RF switch technology, which is not mature enough yet.
- Increased complexity and cost to the mobile phone.
- Reduced Efficiency.
- Low gain and power handling capability.
- Sensitive to environment conditions like temperature and humidity.

Antenna

An antenna can be defined as a usually metallic device which radiates and receives electromagnetic waves (EM waves – see section), more specifically,(Kraus and Marhefka, 2003). Another explanation says that an antenna is the transition between a guided EM wave and a free-space EM wave (Balanis, 2005). And vice-versa. This process is explained by a general communication between a transmitting antenna and a receiving antenna.

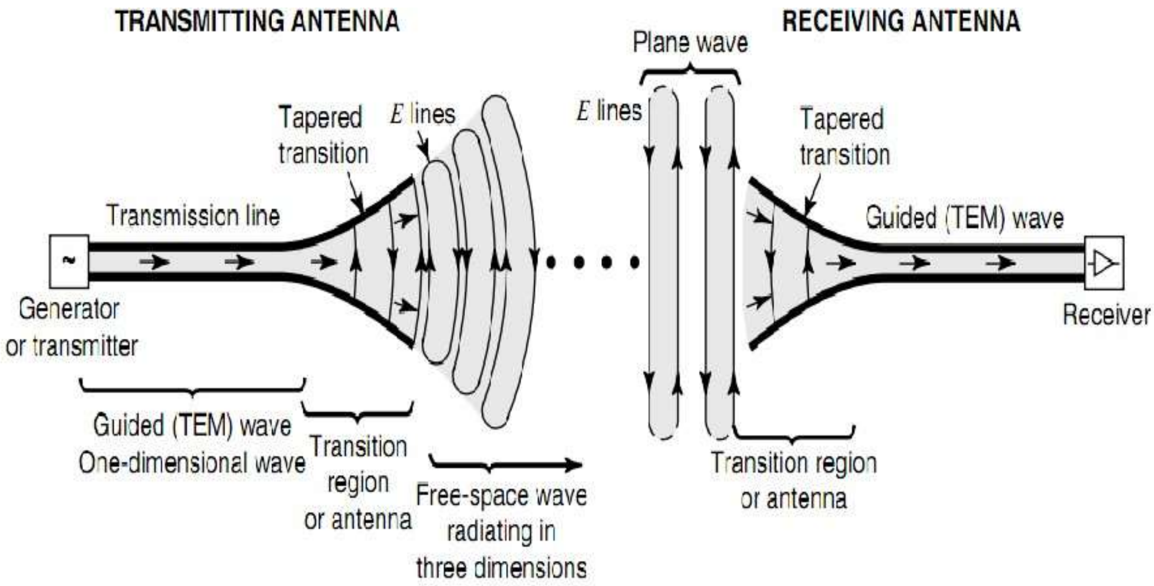


Figure (3.1): Antenna as a transition structure, for a transmitting antenna and for a receiving antenna.

As shown above, for both antennas, the transmission line has the form of a coaxial line or a waveguide. The latter, when a transmitting antenna is considered, is connected to a transmitter that generates radio-frequency (RF) energy that is guided through the uniform part of the line as a plane. Transverse Electromagnetic (TEM) wave with little loss, transformed into a signal that is amplified, modulated and applied to the antenna; otherwise, when a receiving antenna is considered, the transmission line is connected to a receiver which collects the alternating currents that resulted from the transformation process of the received radio waves by the antenna (Kraus and Marhefka, 2003).

Antenna characteristics concerning to radiation are basically the same regardless of its type. Therefore, if a time-changing current or an acceleration (or deceleration) of charge occurs, the radiation will be created in a certain length of current element. This can be described by (Balanis, 2005).

$$l.\frac{dl}{dt} = l.q_l.\frac{dv}{dt}\left(A.\frac{m}{s}\right) \quad 3.1$$

Where:

l - Length of the current element in meters (m); di/dt Time-changing current in ampere per second (A/s). q_lCharge per unit length (coulombs/m). Note that q = I. t = 1.602×10-19 Q. Furthermore, the radiation is always perpendicular to the acceleration and its power is proportional to the square of both parts of the equation (3.1). It is important to refer that the spacing between the two wires of the transition line is just a small part of a wavelength ; therefore, the more the transition curve of the antenna opens out the more the order of a wavelength or more is reached; consequently, the more the wave tends to be radiated and launched into the free-space(Kraus and Marhefka, 2003).

Looking at the antenna structure as a whole, the transition region of the antenna is like a

radiation resistance (R_r) to the transmission line point of view, which represents the radiation that the antenna emits, analyzing it as a circuit. Figure 3.2 shows the complete circuit of an antenna; where the source is an ideal generator with a tension V_g(or V_s) and with an impedance Z_g(or Z_s); the transmission line is a line with characteristic impedance Z_c(or Z_o), and the antenna itself is represented by a load impedance Z_A [$Z_A=(R_L+ R_r) + jX_A$] connected to the transmission line. The load resistance R_L is used to represent the conduction and dielectric losses associated with the antenna structure while

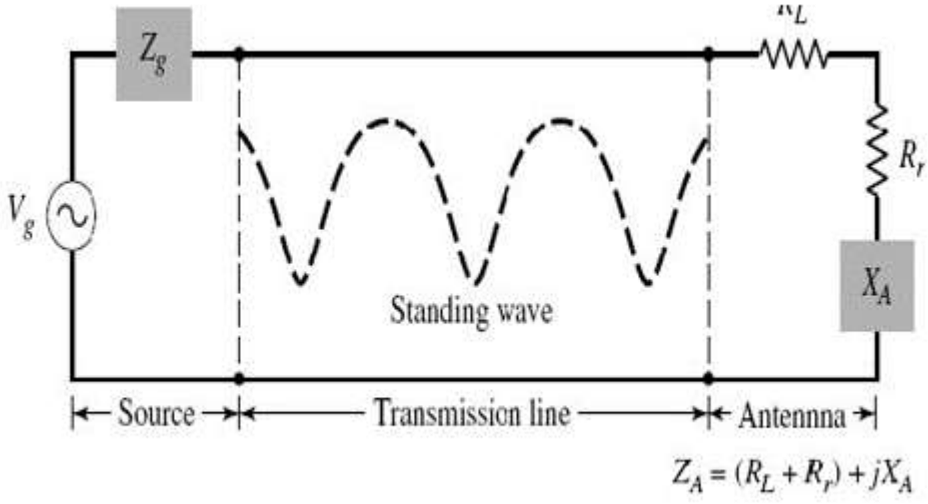


Figure (3.2): Circuit representing antenna as whole structure

R_r, referred to as the radiation resistance, is used to represent radiation by the antenna. The reactance X_A is used to represent the imaginary part of the impedance associated with radiation by the antenna. Therefore, if ideal conditions are applied, the radiation resistance R_r, which is used to represent radiation by the antenna, will get all the energy that is generated by the transmitter (Balanis, 2005).

Discussion and Design

Unlike E-shaped broad band and dual band antennas [2, 3], the antenna shape proposed is a sweeping reconfigurable frequency that can use pin diode in successive switching to jump from one frequency to the next. The performance of the antenna shows much better responses in frequency agility, gain and radiation pattern compared to those presented in [4]. There are three steps in designing a reconfigurable multi-band fork shaped antenna. The initial antenna follows the traditional patch design equation presented in [5]. The next step is to introduce a gap at the upper center of the patch to prevent excitation of other resonance frequency by forcing the current distribution to follow designed path. Finally two slots are introduced at the sides of the gap to divide the remaining area to two arms where the outer arms are with known width to satisfy the commercial pin diode. The sweeping function is then done by moving the length of these arms up and down using switches to get the required frequencies in succession. The traditional rectangular patch is designed at 14GHz accordingly, W=8.47mm, L=7.1028mm, L_f=3.9mm, W_f=0.783, x_o=0.32mm, y_o=2.2mm over a RT-Duroid substrate with ε_r=2.2 and height 0.254mm. Then a parametric study (not included) is used to optimize the dimensions of the upper gap where W_g=2.2, L_g=3mm. Finally slots are introduced with Ws=1mm, Ls=4mm keeping outer arms as shown in figure 5.1.

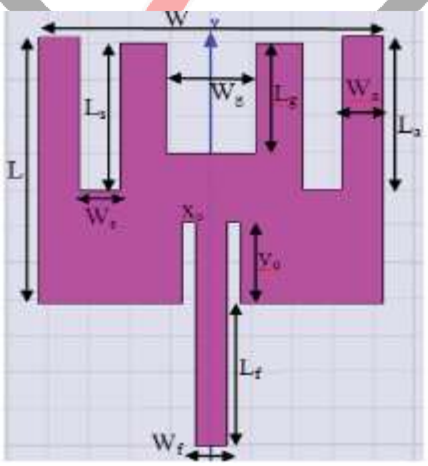


Fig 5.1 Earlier design of forked shape Reconfigurable antenna

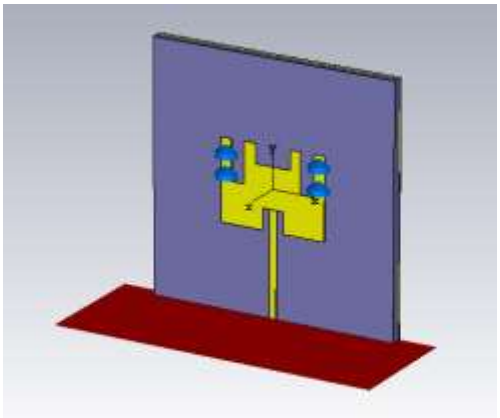
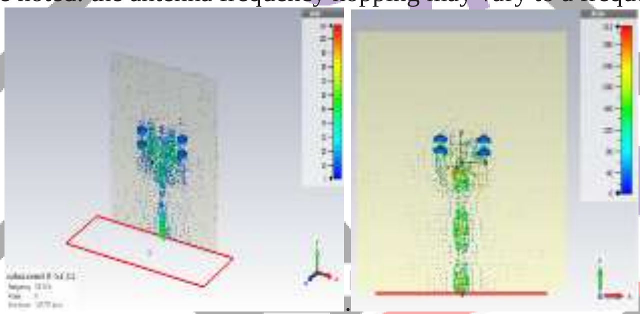


Figure 5.2 Proposed fork shaped patch reconfigurable antenna implemented by introducing PIN diode at gaps

After setting the new antenna shape, the outer arms lengths L_a are swept up and down to satisfy the required frequencies, ranging from 2mm (corresponding to 27 GHz) and up to 5.5mm (corresponding to 25 GHz) and sweeping any desired frequency of Ku band in between by introducing pin diodes at the proper lengths as shown figure (5.2).

Simulation and Results

Figure 5.3 a shows the current distribution of the main resonance frequency, while (5.3b) shows that the dependence of current distribution relies on the arms where the center gap prevents excitation of any other resonance. PIN diode, along gap spacing 0.5mm, is simulated as an ideal short and open circuit and the results show the reconfigurable frequency hopping when the pin diode turns from ON to OFF state and as can be noted: the antenna frequency hopping may vary to a frequency



(a) (b)

Figure 5.3 surface current distribution of proposed antenna

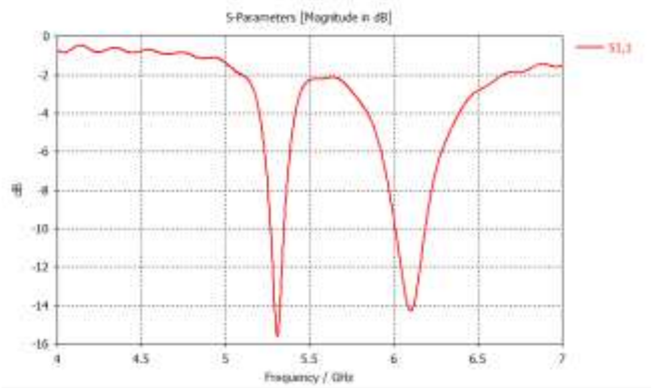


Figure 5.4 S parameter of proposed antenna

Figure 5.4 S parameter of proposed antenna clearly shows that it works on both 5.3 & 6.1 GHz frequency.

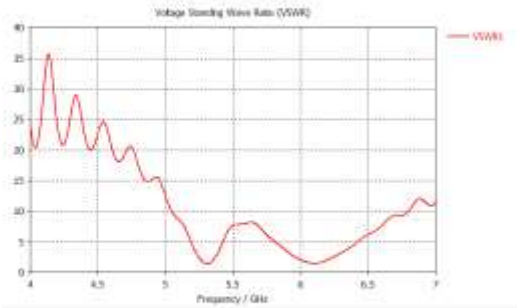


Figure 5.5 VSWR Graph

Figure 5.5 also shows that VSWR graph is nearly 1 at 5.3 GHz and 6.1 GHz frequency.

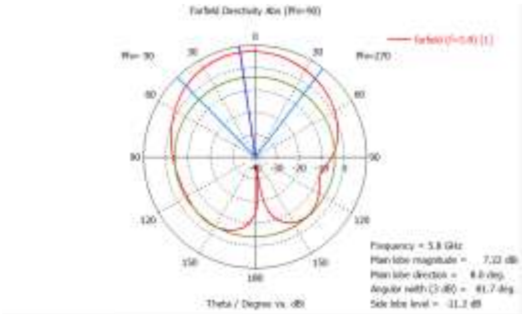


Figure 5.6 Farfield Directivity

5.3 Comparison

The comparison of return loss between proposed antenna and existing reconfigurable fork shaped antenna at different frequencies is shown in figure 5.7.

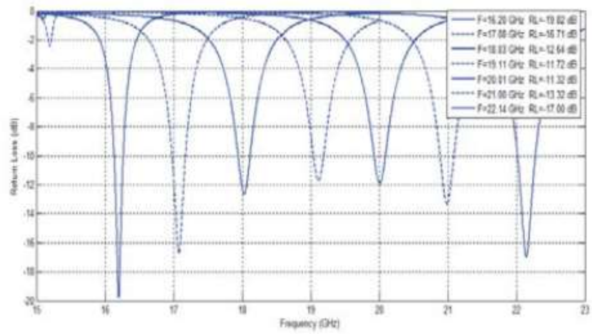


Figure 5.7 comparison of return loss between proposed and existing antenna

Conclusion

In this paper, simulation results of reconfigurable dual frequency fork-shaped microstrip patch antenna are presented and explained. Due to shortage of fabrication utilities; both simulation methods results are in agreement with the design principles. This reconfigurable multi-band new-shaped patch antenna can be applied to any desired frequency band used for communication or satellite applications. The frequency of the reconfigurable antenna obtained and it work on two frequencies 5.3 and 6.1 with return loss less than -10dB, VSWR less than 2 and gain more than 7 in all cases.

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