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Design and Implimentation of Slotted Reconfigurable Microstrip Antenna for Wireless Application

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Abstract

This paper presents slotted reconfigurable antennas for multi-standard personal communication systems, using varactor diodes as switches.The configuration is studied with dual-band behavior, a patch antenna with two switchable slots using varector diodes. One of the objective is to design and predict the performance of reconfigurable antennas with embedded active elements. These antennas were fabricated and the measured results show good performance. Each of the designed antennas enables electronic switching of the operating frequency, while maintaining good input impedance. A square patch loaded with a two slots having extended slot arms constitutes the fundamental structure of the antenna. The tuning of the two resonant frequencies is realized by varying the effective electrical length of the slot arms by connecting the varactor diodes across the slots. Further, the impedance bandwidth about 3.1% and 3.4% have been achieved for selectable frequencies using varactor diode. The two frequency bands are obtained for the parameters chosen in this paper are 1.71-1.745 GHz and 2.38-2.43 GHz.

Keywords:-Reconfigurable antenna, dual band antennas, varactor diodes, switches.

I. INTRODUTION

Reconfigurable antennas are very attractive in wireless communication systems, because single antenna is capable operate for more than one band of frequencies. The resonant frequency adjustment is accomplished by changing the shape of the radiating element. Microstrip antennas are widely used to provide reconfigurability due to their advantages of low profile, lightweight, low fabrication cost, and ease of integration with RF devices. But the drawback of mocrostrip antenna designs is its narrow impedance bandwidth. Dual frequency reconfigurable microstrip antenna can offer additional advantages of frequency reuse for doubling the system capability and transmission or to integrate the receiving and transmitting functions into one antenna. Polarization diversity for good performance of reception and the non-ideal RF characteristic of the varactor diodes or MEMS or PIN diodes must be carefully considered here in order to obtain a reliable prediction of the antenna frequency behaviors.

The objective of this work is to evaluate how well the RF behavior of the varactor diode can be known with the measurements.

With this objective, this paper presents simple configurations of frequency reconfigurable antennas using varactor diodes switches [1], to operate at the UMTS TDD (1900-2025 MHz) and Bluetooth (2400-2434 MHz) frequency bands. Recently, there are rapid developments in wireless communications, in order to satisfy the IEEE UMTS TDD and Bluetooth standards in the 1.9 GHz and 2.4 GHz bands [3]. The configuration is a two slotted-rectangular patch, where switches are placed near the center of the slots and are used to increase or decrease the average electrical current path length on the patch [2]. Varactor diodes are commonly used as RF switches, because of their characteristics, small dimensions, low cost, low insertion loss, reasonable isolation and good switching characteristics.

However, the integration of diodes in the antennas requires a biasing circuit and DC blocks to avoid interference with the RF signal.

II. ANTENNA DESIGN CONSIDERATION.

The patch is printed on the dielectric substrate, connected to direct coaxial feeding. Conducting plane backs antenna. Dielectric substrate has permittivity of 4.2 and thickness (h) of 1.6 mm. The size of square substrate is 60 mm X 60 mm and square patch (P) in the center configures at 1.98 GHz operation.

First, a conventional patch antenna with patch size of length L=36.33 mm and width W=36.33 mm fed by 50Ω coaxial single probe feed is designed for operating frequency of 1.98 GHz. The proposed conventional patch antenna geometry is as illustrated in Fig.1. A measured return loss is also shown in Fig.2.

Square microstrip patch antenna with side dimensions L=W=36.33 mm and is fabricated on a single sided dielectric substrate of thickness h=1.6 mm and relative permittivity ε_r=4.2. A single slot of vertical length L_1=20.16 mm on either side of the patch and the slots are positioned at Ps=29.25 mm.

The patch antenna is reconfigured and made of two slots of length L_1=20.16 mm and L_2=0.75L_1.mm, and slot width SW1=3.54 mm as shown in fig.3 and for width of the configured section for loading the two slots and two varactor diodes are placed at a center of the slots in order to get maximum tuning range and better matching. The DC bias voltage is supplied from battery and the antenna is electromagnetically coupled using a 50Ω in single coaxial feed line as shown in Fig.3.

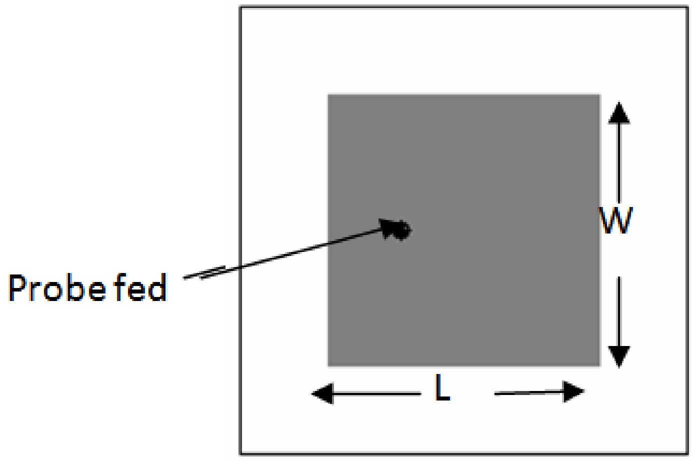

Fig-1: Geometry of patch antenna

The patch antenna is reconfigured and made of two slots of length L_1=20.16 mm and L_2=0.75L_1.mm, and slot width SW1=3.54 mm as shown in fig.3 and for width of the configured section for loading the two slots and two varactor diodes are placed at a center of the slots in order to get maximum tuning range and better matching. The DC bias voltage is supplied from battery and the antenna is electromagnetically coupled using a 50Ώ in single coaxial feed line as shown in Fig.3.

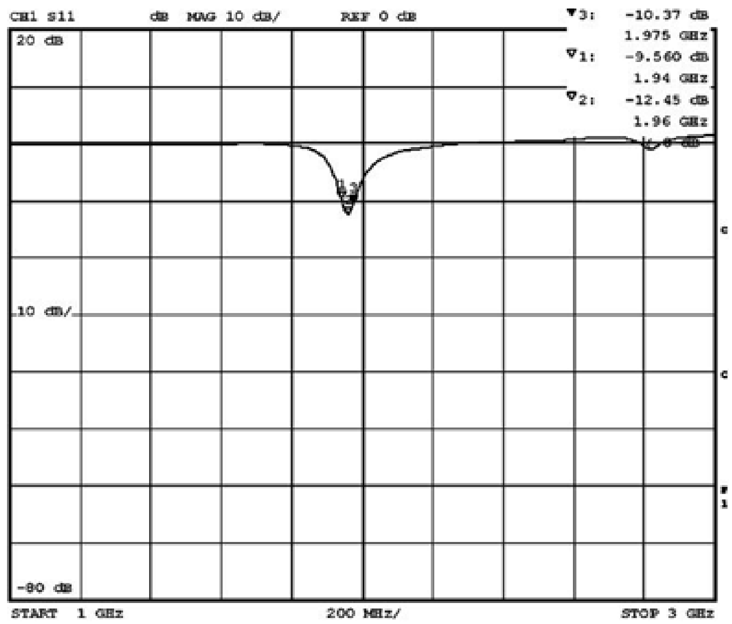

Fig:2-Measured return loss of the antenna for 1.98 GHz.

For the design of slotted reconfigurable microstrip antenna, the most commonly considered specifications are dielectric constant of substrate materials (ε_r), thickness of the substrate material (h), resonant frequency (f_r), and free space wave length (λ_0), etc. The following basic equations are used to design proposed patch antenna:

Elemental width(W):

The width of the SRMSA is given by $W=(c/2f_r)\ [(\ \varepsilon_r+1)/2)]^{-1/2}$------------ (1)

Extension length (Δl):

The extension length(Δl) is given by

$\Delta l=0.412h[(\varepsilon_r+0.3)((w/h)+0.264)/\ \varepsilon_e-0.258)((w/h)+0.8)]$.------------- (2)

where ε_e is effective constant, which is calculated using the formula

$\varepsilon_e=[(\ \varepsilon_r+1)/2]+[(\varepsilon_r-1)/2][1+12h/w]^{-1/2}$ (3)

The elemental length (l):Once the elemental width (w), extension length(Δl), the effective dielectric constant (ε_e) are determined using the above equations then the elemental length is found by using the formula:

$L=c/2f_r\sqrt{\ }\varepsilon_e-2\Delta l$. (4)

The frequency band selectivity can be achieved by controlling the state of switches inserted in the antenna, which can be varactor diode or PIN diodes or RF MEMS. The switches can encompass several functions on reconfigurable antennas, for example: modify the antenna feed location and, therefore, adjust the resonant frequency [1-2], control the electrical length of slots placed along the patch [3-5], connect or disconnect several elements in antenna arrays [6-7], or, similarly, connect parasitic elements to the radiating patch in order to increase the total length of the antenna [8-9].

The antenna configuration, shown in fig 3, basically consists a patch antenna with two slots incorporated, each one closed by a switch near the center. When the switches are in the off-state, the currents flow around the slots and the average length of the current path is the longest and hence the antenna resonates at the minimum operating frequency. Conversely, when the switches are turned on, some of the electric currents flow through the switches, the length of the current path decreases and the resonance frequency increases.

The antenna patch with an inscribed rectangular slot fed with a coaxial probe in the inner patch. When the switches are turned off, the resonant frequency is basically defined by the inner patch, although, due to the proximity, the parasitic element produces some influence in the antenna operation. In the closed configuration, the switches connect the parasitic element to the radiating element thus increasing the antenna size, consequently lowering the resonance frequency.

For set-up simplicity, the DC control voltage of the diode was chosen to be supplied from the antennas RF coaxial probe shown in fig. 3.

The antenna was fabricated and measured and the results for the return losses show reasonable agreement between forward and reversed biased conditions of varactor diode as shown in fig-4 and fig-5.

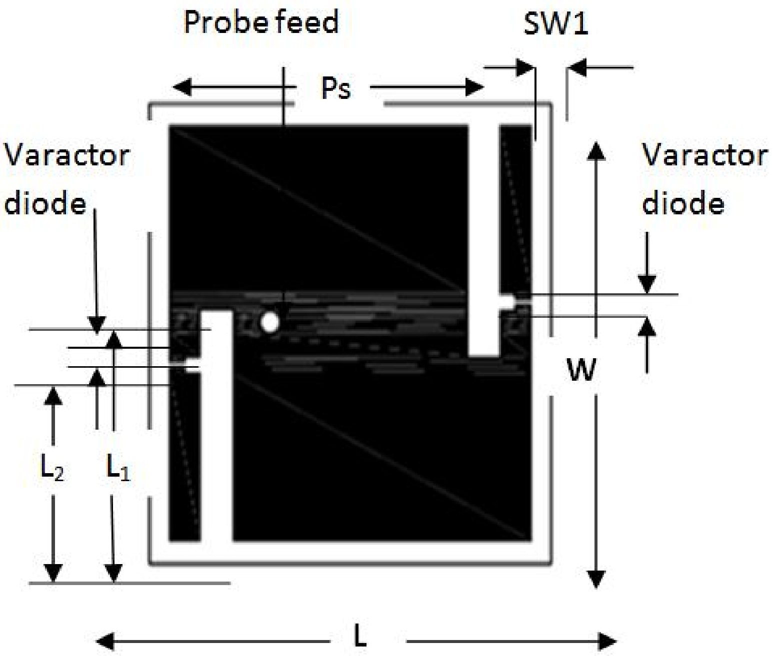

Fig:3-Geometry of a frequency reconfigurable patch antenna with two switchable slots

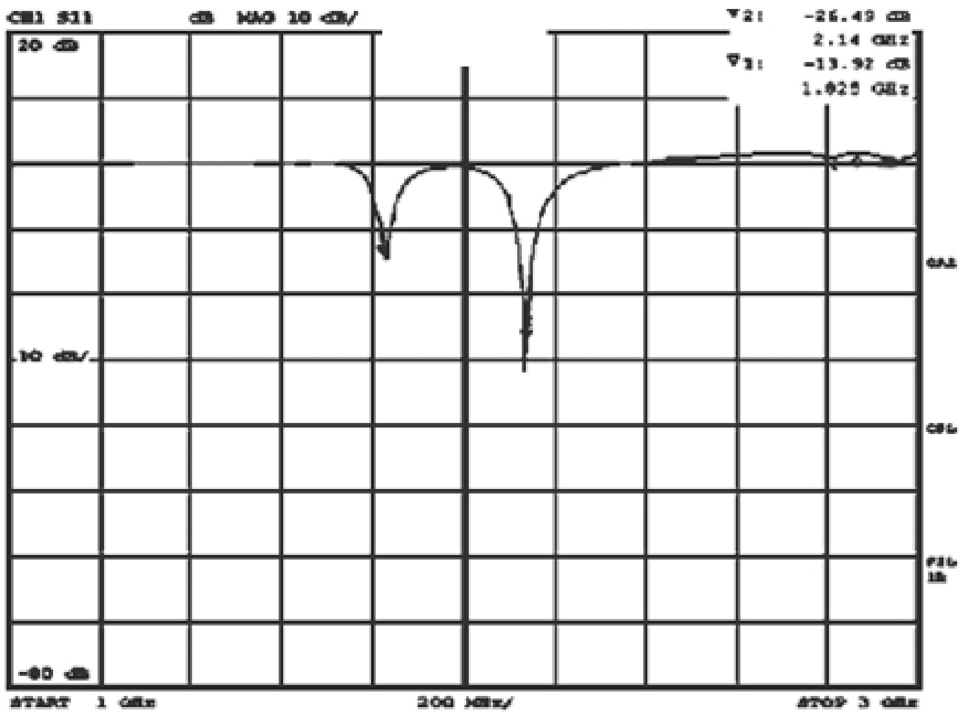

Fig:4-Measured return loss for forward biased with two slots.

The antenna resonates at f_1=1.82 GHz and f_2=2.14 GHz, with an impedance bandwidth of 3.1% and 3.4%, respectively. This configuration retains a larger impedance bandwidth, because the varactor diodes increase the bandwidth due to their capacitance and because the influence of the thin slot is not significant. The difference between calculated and experimental operating frequencies corresponds to a shift towards higher values of 3% for f1 and 1.8% for f2 towards lower values f_1=1.82 GHz and f_2=2.14 GHz.

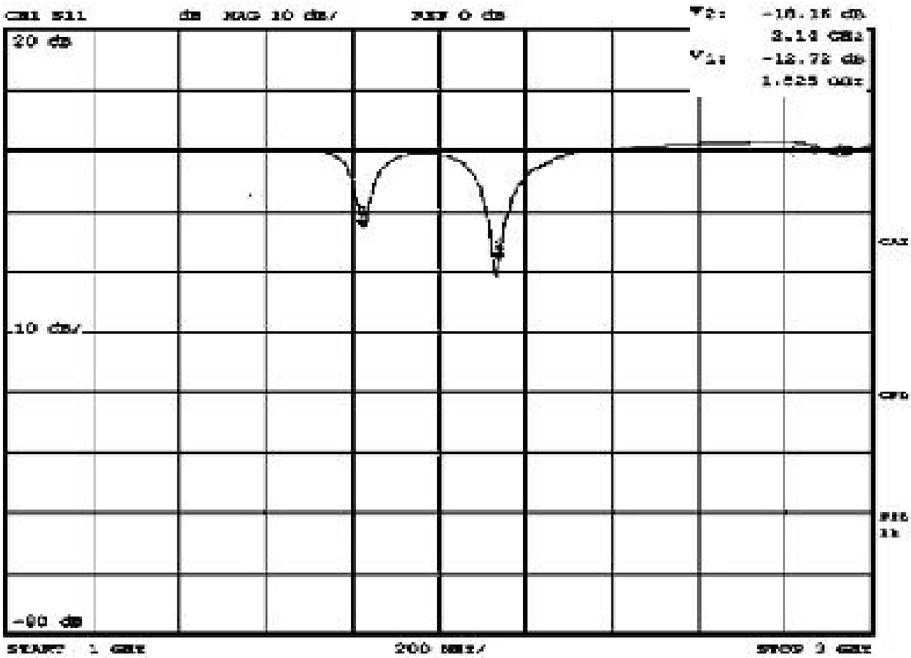

Fig:5-Measured return loss for reverse biased with two slots.

III. FUTURE WORK

Due to their less insertion loss, low power consumption and excellent switching capabilities, RF MEMS switches are being used instead of varactor diodes, especially at frequencies of operation above 1 GHz. The RF MEMS can be of two types: manufactured and integrated with the antenna; and packaged MEMS. For this reasons, the next step is to replace the varactor diodes switches by RF MEMS and reduce the number of active and passive elements in the antennas.

Another aspect is to obtain larger impedance bandwidths in order to fulfil the services requirements without significantly increasing the antennas dimensions.

IV. CONCLUSIONS

Two frequency-reconfigurable antenna was studied in this paper with the model printed antenna integrated with active elements. Varactor diodes were used as the switching elements. The measured return loss curve show a slight shift in frequency.

The referred discrepancy, especially when the diode is at the on-state, is mainly justified by the dispersion of the diode characteristics with respect to manufacturer nominal values. Although these characteristics were obtained experimentally for all the active and passive elements used in the above antennas, clearly there are some other factors that cannot be easily overcome. This is in part related with the S-parameters de-embedding procedure.

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