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Reconfigurable Multi- Band Antenna Using RF MEMS

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Abstract: The design methodology, analysis and characterization of a radio frequency micro electromechanical systems (RF MEMS) based on reconfigurable antenna operating in wireless communications are been presented in this paper. Now- a -days multi- band antennas have became very important in the applications of wireless local- area networks (WLANS) which are been employed for different multiple standards. Some of these standards are like IEEE 802.11b/g having a band of 2.4-2.484 GHZ; IEEE 802.11a has 5.15-5.35 GHZ and an additional band of 5.725- 5.825 GHZ and HiperLANS having a band from 5.47-5.725 GHZ. Apart from the Local area networks we have some of the other frequency ranges in the mobile networks which use RF MEMS. Some of them are like Airtel requires GSM- 900/1800 (EDGE) and 2100 MHZ HSPA, and Reliance of CDMAOne, GSM - 900/1800 and HSPA- 2100 MHZ. In this paper we can see the designing of a compact antenna that can support 2.4/5 GHZ bands. Design and characterization of the RF MEMS on reconfigurable antenna in the wireless Local area network is done and in addition mobile networks frequency can be added.

INTRODUCTION:

In 1990's the radiofrequency (RF) technologies have brought a profound change in driven largely by economic and geopolitical events [1]. We can say that the transition of RF Technology from one era to other has been the challenging and opportunistic. For the RF systems Engineers, it has a shift of thinking from large centralized systems to smaller distributed systems [2]. With this shift there comes a change from long- range systems, having large RF transmit power, to shorter range systems, having relatively modest RF power.

Now -a -days MEMS represents the new revolution in microelectronics. MEMS are nothing but the miniaturization of the sensors and transducers that were constructed on a highly integrated VLSI circuit or processor. In large RF MEMS devices and components, the micro electromechanical operation is used for the actuation or the adjustment of a separate RF device or components, like varactor capacitor [3]. Development of the high performance modern wireless communications is resulting in the tremendous increase in the number of antennas. For the multi-standard wireless communication services they are been necessary for supporting different radiation characteristics.

For a single antenna to cover the multiple frequency bands, there are various design approaches they are like- a multifrequency antenna covering each individual band[4], a broadband antenna covering the entire frequency bandwidth(BW) [5], or by frequency- reconfigurable antenna (FRA) [6] with a narrow operating bandwidth that can be turned over the entire band. We can say that among the three approaches, the frequency - reconfigurable antenna approach provides an optimum solution. This can be achieved by using a single RF MEMS ohmic contact switch, which is been integrated at a strategic location of the antenna geometry. Here we use the switch to change the path length of the current on the antenna [7]. By changing the path length, the frequencies are also been tuned to different frequencies. The tenability makes the system to act as an intelligent system. The tenability property is also known as reconfigurability characteristic. There are some reconfigurable devices such as antennas, impedance tuners, filters, amplifiers and phase shifters. For the conventionally used antennas the patterns, bandwidth, polarization and resonant frequency some of the fixed radiation parameters. These parameters can be changed dynamically. Microwave switches, such as PIN diodes, GaAs FETs (semiconductor active switches), varactor diodes and Radio Frequency micro Electromechanical Systems (RFMEMS) are some of the mechanisms often achieved by the reconfiguration. The major advantages of the RF MEMS switches with respect to the semiconductors active switches are high linearity, low power consumption, low insertion loss and good isolation.

For designing the reconfigurable antennas, slot antennas are good candidates which can be used as building blocks. The name slot is given, if there is a proper placement of switches on the slot, it is possible to change the radiation characteristics of antenna. This can be done by manipulation of current distribution around the slot or by changing the electrical length of the current path. The shunt and series types are the two different types of RF MEMS switches that are commonly used in design of reconfigurable antennas. As the switches have two states 'ON' and 'OFF' operation, this limits the tenability capability of the switches and results in the increment of number of switches due to reconfigurability which in turn results in complicated antenna structure.

OVERVIEW OF RF MEMS COMPONENTS:

RF MEMS devices are Microsystems manufactured in a suitable technology platform, typically characterized by having movable micro-parts capable of reconfiguring the RF characteristics of a device. By the RF point of view, the MEMS devices are classified by RF-circuit component they are contained in. Now from the MEMS point of view, there are three distinct classes depending on how the MEMS actuation is carried out relative to the RF circuit. The three classes are given as[8]: 1) By placing the MEMS structure outside the RF circuit, even though it actuates or controls other devices in the circuit (usually micromechanical ones), 2) The MEMS

structure is located inside the RF circuit and has dual roles, decoupled, of actuation and RF - circuit function, and
3) The MEMS structure is located inside the circuit where it has an RF function that is been coupled to an actuation. Each of these are referred as some classes called: 1) RF Extrinsic 2) RF Intrinsic and 3) RF Reactive.

For each of the MEMS classes produced the compelling examples are given as, e.g., in RF- extrinsic class- the tunable micro machined transmission line, in RF- Intrinsic class- shunt electrostatic micro switch and comb capacitors, and in the RF- Reactive class- capacitive coupled micromechanical resonator. The tunable capacitors and inductors used in the RF functionality are expected to operate up to at least a few Gigahertz in frequency and we also have RF- Embedded switches that operate well from a few GigaHertz up to at least 100GHz.

Besides these there are variety of RF components manufactured with MEMS technologies which are been quite wide and ranges from lumped components, such as Ohmic and Capacitive Switches, fixed and variable capacitors (varactors), variable inductors and resonators- which are been mainly used for more complex networks based on a combination of these basic components[9]. At high frequencies the capacitive switches show better performance, whereas Ohmic switches are good at low frequencies (<10GHz).

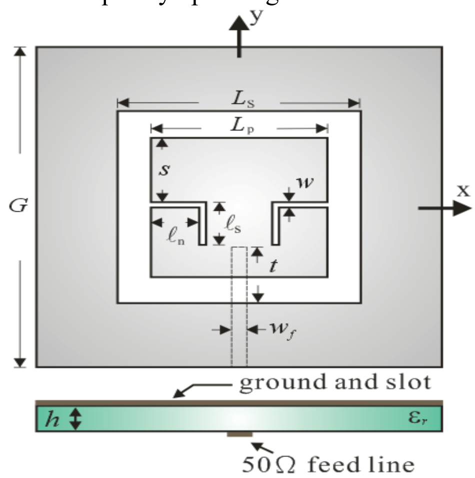
SQUARE- RING SLOT ANTENNA IN DUAL- BAND:

Now -a- days dual- band antennas have became very important in the applications of the wireless Local Area Networks (WLANS) that employ multiple standards. Among these standards as we already discussed in the above section, IEEE 802.11b/g requires a band of 2.4-2.484 GHz and HyperLAN2, an band of 5.47- 5.725 GHz. As the aim of this paper is to build a single antenna which is having some number of frequencies, we need to design a single antenna that can simultaneously cover all these bands. Let us first do the operation with the dual- band antenna where two frequency bands are been considered. In recent years, many microstripline- fed slot antennas have been developed for the dual- frequency operations.

Now a compact antenna that can cover the 2.4/5 GHz of bands is seen in this section. In the frequency range of interest, the antenna which we take here is consisting of three resonant modes, whereas if the antenna which is taken without the embedded slots possess only two resonant modes.

(a) Antenna Structure:

The proposed antenna structure here, is printed on a square microwave substrate with a side length of G, a thickness of h, a dielectric constant of Ɛr and a loss tangent of tanδta. On the topside of the substrate is a placement of a metal ground plane, which is been, etched with a square- ring slot of outer side length Ls and inner side length Lp. Now on the bottom side of the substrate is a 50Ω feeding microstripline with a width of wf. As we are designing a antenna with a miniaturization, we purposely fixed the ground plane size at G=30mm, inner and outer side lengths as Lp=16mm and Ls=18mm, these are for the radiating square- ring slot. On to the fixed ground plane which is been etched with the pre- determined ring slot, a pair of bent slots with a width of w=0.5mm was been embedded in the center square patch of a conventional square- ring slot antenna for obtaining the desired operating bands of 2.4 and 5 GHz. The bent slots are been composed of a horizontal section of length in and a vertical section of length ls are been embedded at the distance of s away from the upper edge of the square patch. A protruded length of t is extended across the square- ring slot along the y- axis with 50Ω feeding microstripline. This protruded length of t here acts as a tuning stub. These tuning stub is used for the impedance matching. When the sizes of the bent slots are varied, the tuning stub has to be tuned for the optimized impedance matching in the two operating bands, as here we consider two frequency operating bands.



(b) Return - Loss Characteristics:

The return loss of many antenna protocols was measured by using An soft HFSS, a full wave electromagnetic simulator. The return losses of three different antennas are seen in this section. The three antennas considered as the reference antenna, antenna 1 and antenna 2. The reference antenna is the one without any embedded slots in the center square patch. Other two antenna protocols are having the parameters of w= 0.5mm, ln=5mm, ls=6.5mm and are fabricated with s set equal to 3 and 8.5mm (for antenna 1 and 2 respectively). For Antenna 1 with s=3mm, the upper edge of the bent slot is positioned above the horizontal line bisecting the center square patch. And for the other antenna 2 with s=8.5mm the upper edge of bent slot is positioned below the horizontal line. The measured data of impedance bands, parameters of the different antennas which has to be changed and frequency ranges for the each antenna is been summarized in the Table of comparison.

	s (mm)	ℓ_n (mm)	ℓ_s (mm)	w (mm)	t (mm)	f_{c1}, BW_1, % (MHz)	f_{c2}, BW_2, % (MHz)	f_{c2}/f_{c1}
Reference	0	0	0	0	3.6	3191, 177, 5.5	6038, 296, 4.9	1.89
Ant. 1	3	5	6.5	0.5	3.0	2696, 110, 4.0	4610, 397, 8.6	1.70
Ant. 2	8.5	5	6.5	0.5	3.8	2570, 98, 3.8	5452, 1213, 22.2	2.12
Ant. 3	8.5	5.2	6.5	0.5	4.0	2436, 103, 4.2	5345, 1375, 25.7	2.19

Now coming to the return losses of each antenna, for antenna 1 both the first and second resonant modes are excited at lower frequencies when compared to those of the reference antenna and the third resonant mode is not impedance matched. But in antenna 2 all the three resonant modes are impedance matched. By comparing with the last two resonant modes of antenna 1, the second resonant band of antenna 2 is moved to a higher frequency location and the third one to the lower frequency. These two resonant bands are been moved like this, to form a wide upper operating band. We calculate the dual frequency ratio, f2/f1, as the center frequency of the first resonant- band of antenna 2 is lower than that of antenna 1. In the dual frequency ration f1 and f2 refers to the first and second operating band center frequencies, they are been raised from 1.7 for antenna 1 to 2.12 for the antenna 2. Here the upper operating band of antenna 2 can cover 5GHz WLAN band, but none of the antenna can cover or cannot be used for 2.4GHz WLAN band.

In this case we consider the antenna 3, by changing the parameters of the slots which are been tuned to ln=5.2mm and ls=6.5mm. By these changes in parameters we calculate the return losses of this antenna. We get them as the first resonant band of antenna 3 is lowered to 2385.5- 2487.5 MHz, which is wide enough to cover the required 2.4 GHz WLAN band. In real, antenna 3 is having a wider upper operating band than that of antenna 2, inside the upper operating band of antenna 3 it can cover 5GHz WLAN band, impedance matching is also been improved. The simulated return loss curve for antenna 3 is shown in the figure, which agrees reasonably well with the measured one.

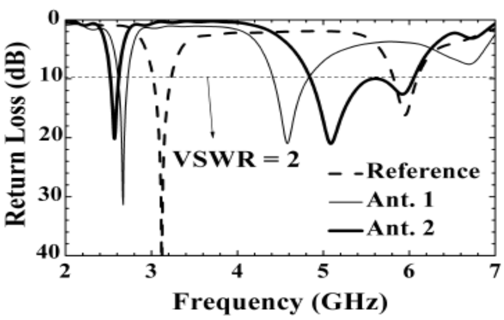


Fig: measured return losses of reference antenna, antenna 1 and 2

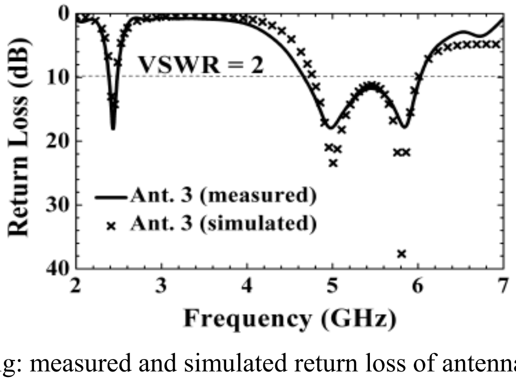


Fig: measured and simulated return loss of antenna 3

CONCLUSION:

In this paper, a design of a microstripline- fed square ring slot antenna with a center patch embedded with the bent slots has been proposed for 2.4/ 5 GHz Dual- band application. There is a restriction that the proposed antenna can be reduced to only 58% than that of a conventional square ring antenna when the both antenna are designed to have in a same lower operating bands. Dual- band application is made for implanting any of the frequency ranges, we can also try for the better frequency ranges like any of the mobile networks, and there is even a chance of making these signal to be jammed. It is also one of the application by using the reconfigurable multi- band antenna in RF MEMS.

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