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Reconfigurable Stacked Microstrip Patch Antenna for Multi-Band Application

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Abstract—*A novel design of reconfigurable stacked multipurpose broadband microstrip antenna for Wi-Max application is presented. The antenna is fed by single coaxial probe in lower patch element. The tunable operation is obtained by varying the feed location of antenna. The antenna efficiency for all configurations has been found in the range of 90% to 100%. The return loss measured in all the frequency bands, are better than 10db. The basic advantage of this design is its simple structure with no active element, no extra slots, no shorting pins and no vertical walls between the patches and the ground. The typical impedance behavior and far field radiation pattern characteristics of proposed configuration are presented. The antenna is designed, optimized and simulated using Transmission line Matrix (TLM) based software Microstripes 7.5.*

Keywords— **Microstrip antenna, Rectangular patch, Stacking, reconfigurable microstrip antenna, Wi-Max.**

I. INTRODUCTION

Wireless application systems have been in constant demand these days. Reconfigurable antennas are a new generation of antennas that will not be limited to a certain function or resonance but will change their functionality depending on the implementation requirements. Compared to broadband antennas, reconfigurable antennas offer many advantages, such as compact size, similar radiation patterns for all designed frequency bands, and frequency selectivity which helps in reducing adverse effects like co-site interference and jamming. Many interesting approaches for the design of tunable antennas were presented. A slot antenna utilizing shunt switches [1], a tunable small patch antenna able to switch between 800 MHz and 900 MHz using variable capacitors and transistors [2], by loading a slot antenna with two lumped variable capacitors (varactors) placed in proper locations along a slot [3] a dual band antenna was obtained whose first and second resonances can be controlled individually. The frequency ratio ranges from 1.3 to 2.67, an ohmic contact cantilever RF-MEMS switches integrated with self-similar planar antennas provided reconfigurable properties to them [4]. RF MEMS were used to design a reconfigurable triangular microstrip patch antenna for monolithic integration with RF MEMS phase shifters to demonstrate a low-cost monolithic passive electronically scanned array (PESA) [5] and a switching diode was mounted at the center of a slot cut on a patch antenna [6]. Different resonant frequencies were obtained according to the state of the cutting slots, bias diodes and state of switches which increase the complexity in design and fabrication.

In the proposed design tuning operation is achieved by varying the feed location. For example, the proposed antenna with centered feed location exhibits a –10dB bandwidth of 171 MHz at the center frequency of 5.62GHz with antenna gain 8.515 dBi and 300 MHz at center frequency of 6.8 GHz with antenna gain 7.602 dBi. The antenna efficiency and radiation efficiency at both the frequency is 90% to 100%. Same antenna resonates at different dual band of 3.5 GHz and 5.8 GHz if the feed location is changed to the point (7.5, 0). In the proposed antenna structure the tuning range is 3.3 GHz to 9GHz. Several Studies and measurements are carried out on the design structure which tally well with the simulated results. The antenna is designed, optimized and simulated using Transmission line Matrix (TLM) based software Microstripes 7.5 [7].

II. THEORY AND ANTENNA DESIGN

The concept of using stack patch antenna over basic radiating patch with a probe displacement produces good results at different resonant frequencies. A patch placed above to the feed patch gets excited through the coupling between the two patches. If the resonance frequencies f_{r1} and f_{r2} of these two patches are close to each other, then broad bandwidth is obtained. The overall input VSWR will be the superposition of the responses of the two resonators resulting in a wide bandwidth.

The dimension of rectangular patch is 24.5mmX30.3mm, which is formed on dielectric substrate of dielectric constant 3 and thickness 1.524mm. The electromagnetic coupled patch having equal dimensions is formed on another dielectric layer. The dielectric constant of second layer is the same as the lower one with thickness 0.127mm. The thickness of the radiating patch is kept 0.035mm. (Fig 1) The dimension of the patch is calculated by using the following formula:

$$f_r = C/(2L\sqrt{\varepsilon r})$$

Where, f_r = Resonant Frequency of the antenna

L = length of antenna

εr = Dielectric constant of the substrate

Similarly, the height and thickness of substrate is selected by maintaining the effective dielectric constant less than 4.

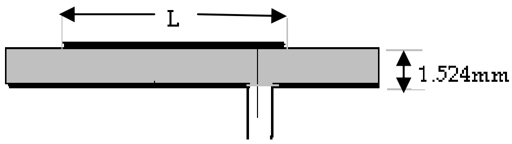


Fig 1: Cross sectional view of basic radiating patch (L=24.5mm)

Concept behind stack configuration is the bottom patch of the stacked configuration gives lower resonant frequency whereas the higher resonant frequency is due to top identical patches. If these two resonances are separated, the same configuration will give dual band response. In this design the stacked geometry is placed on the basic radiating patch at the height of 8 mm where air as dielectric is used. With increase in height between two patches, the effective dimension of the top patch increases due to increase in the fringing fields. Also, the coupling between the bottom and the top patch decreases. Therefore, to maintain the good coupling the height is optimized at 8 mm, here the edges of the feed patch, act as magnetic currents, which will give maximum coupling to the top patches when its edges coincide with the maximum magnetic field region (i.e. the center) of the top patches.

The cross sectional view and 3D view of the antenna is shown in fig 2 and fig 3 respectively.

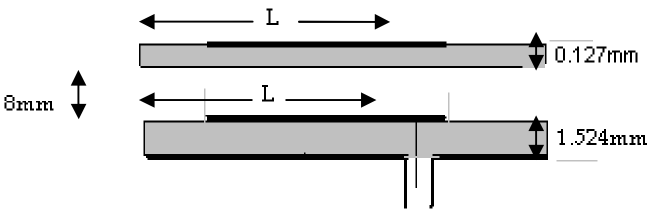


Fig 2: Cross sectioned view of MSA with stacking element of dimension 24.5X30.3 mm

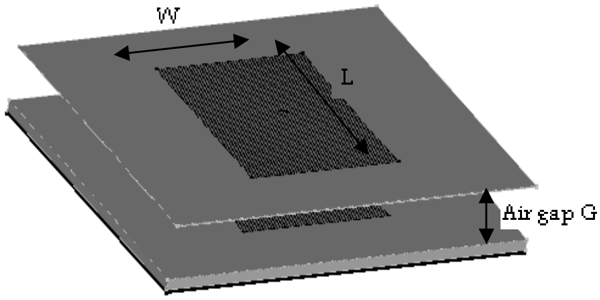


Fig 3: 3D view of MSA with stacking element with L=24.5, W=30.3, t=.035, G=8, Ground 50X50 (all dimensions are in mm)

III. RECONFIGURABLE STUDY OF THE DESIGN ANTENNA

The proposed antenna with L=24.5mm, W=30.3mm operates at many frequencies corresponding to its various feed locations and various resonant modes, which makes it natural choice for multiband application e.g the fundamental mode TM01 appears at the feed location x=8.16mm and y=0mm, in this mode voltage is uniform along the length of the patch. As the feed location is shifted in y direction higher order modes starts appearing, while shifting in x direction gives lower order modes. The resonant frequencies for various feed location and their corresponding modes are shown in table 1 and table 2 respectively. The proposed antenna gives interesting results at the feed location x=7.5mm and y=5mm by producing quad band antenna for Wi-Max application shown in fig.4 (e).

TABLE I

RESONANT FREQUENCIES CORRESPONDING TO VARIOUS FEED LOCATIONS

Feed location x,y	*f*1 BW (GHz) (MHz)	Resonant frequency BW (MHz)	*f*2 (GHz)	
0,0	5.62 (4.2%)	167 (2.9%)	6.88	288
0,10	7.863	377 (4.7%)	8.82	126
0,12.5	(1.4%)			
0,15	7.761	520 (6.7%)		
2.5,0	5.5	197 (3.5%)		
5,2.5	5.62	178 (3.2%)	6.83	246
8.16,0	(3.6%)			
	5.51	170 (3.1%)	6.68	144
	(2.2%)			
	3.384	171 (5.1%)	5.616	164

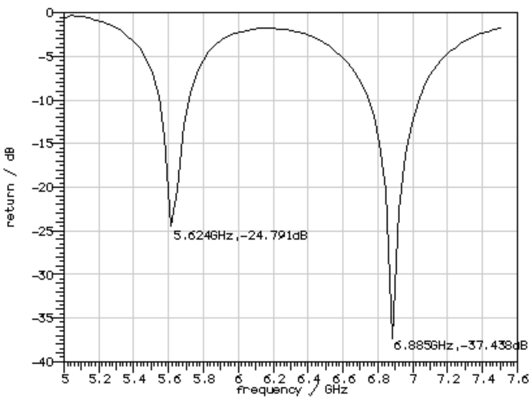
(2.9%)

TABLE 2

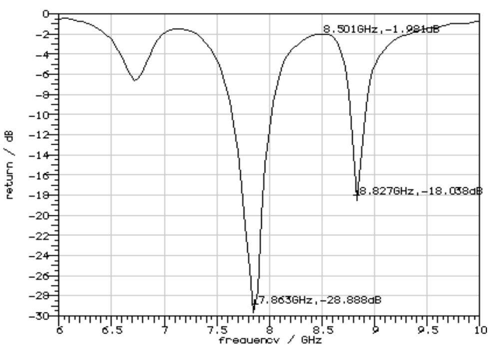
RESONANT FREQUENCIES FOR VARIOUS MODES

Mode	Resonant frequencies at corresponding mode (GHz)
TM01	3.5
TM1δ	3.255, 3.38, 3.4
(1<δ<2)	5.55, 5.62
TMδ2	7.761, 7.863
(1<δ<2)	
TM2δ	
(2<δ<3)	

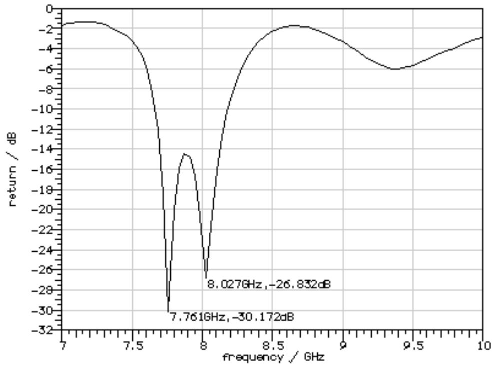
The impedance bandwidth of the proposed structure is found in the range of 150MHz-520MHz for various feed locations. The VSWR is less than 1.5 throughout the entire bandwidth; this provides sufficient impedance matching and proper return losses. The Return losses of corresponding frequencies of table 1 and table 2 are shown below in fig 4(a) to fig.4 (f).



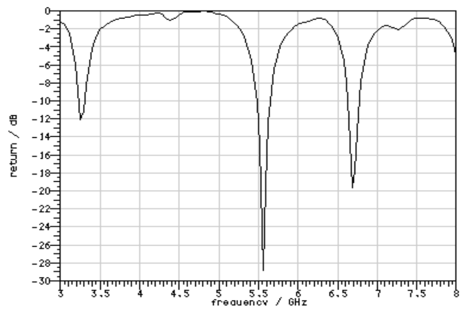
4.(a) feed point (x=0,y=0)



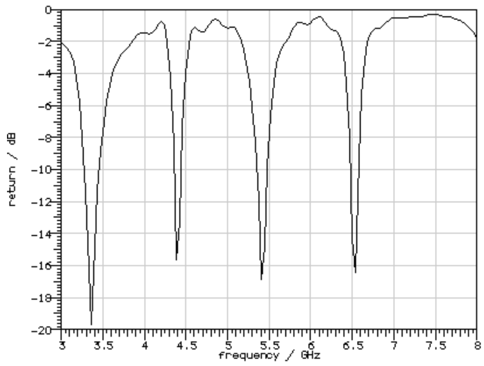
4.(b) feed point (x=0,y=10)



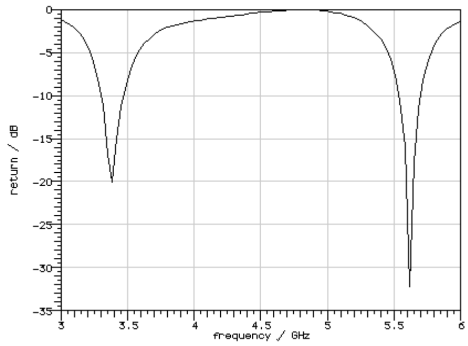
4.(c) feed point (x=0,y=12.5)



4.(d) feed point(x=5,y=2.5)



4. (e) feed point(x=7.5,y=5)



4. (f) feed point(x=8.16,y=0)

Fig 4: Effect on return losses of various feed locations for presented stacked MSA

IV. MEASUREMENTS AND RESULTS

We had considered the two cases for the measurements Fig 4(e) and 4 (f) as shown above. These two cases show the multi band & dual band operation of antenna considering the first resonance of around 3.4 GHz. In Case of fig 5(a) the simulated resonance occurs at 3.35 GHz while the measured resonance is at around 3.48 GHz with a bandwidth of approximately 5 %. In fig 5(b) simulated first resonance occurs at 3.384 and 5.1% bandwidth and the second resonance occurs at 5.616 with 2.9% bandwidth while the measurement study shows the first resonance at around 3.42 GHz with 5% bandwidth and second resonance at 5.52 GHz with 3.3% bandwidth. The measured response is slightly shifted because of non uniformity of the air gap in the fabricated configuration.

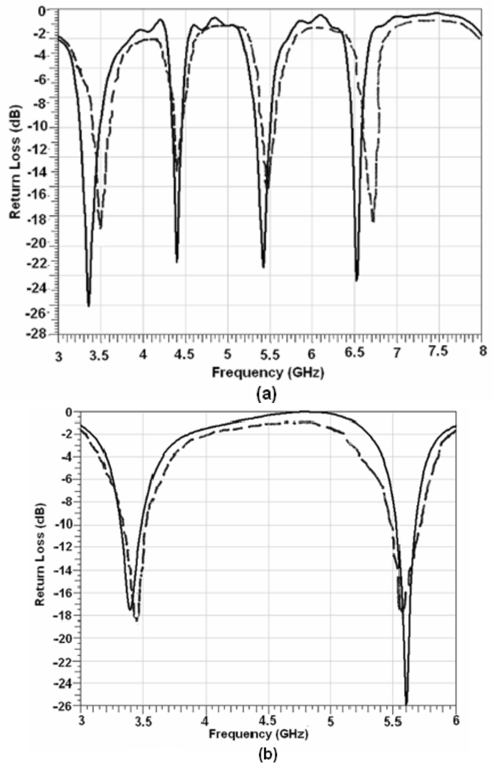


Fig 5. Simulated at measured return loss for (a) Multi band operation (b) Dual band operation

Simulated ———

Measured — — —

Radiation Pattern measurement is done for dual band operation whose return loss shown in fig 5(b). It is noted from Fig 6 that radiation patterns remain in the broadside direction throughout the range of VSWR bandwidth. As patch on the top layer is along the E-plane, E plane half power beam width (HPBW) is almost half as compared to that of a single patch in H plane. The E cross-polar level is about 40 dB down as compared to co polar level in the broadside direction, which increases to almost -20 dB in the end-fire direction. The H cross-polar level is less than -40 dB.

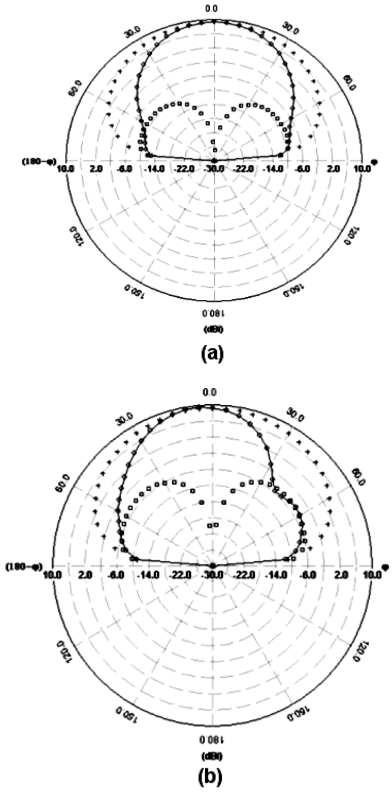


Fig 6. Radiation patterns at (a) 3.5 GHz, (b) 5.5 GHz

E-CO +++ H-CO ▫▫▫▫ E-CROSS ▪▪▪▪ H-CROSS

V. CONCLUSION

By using the bandwidth enhancement technique and tunable feed location, many different antenna configurations has been produced, analyzed and measured. All the configurations incorporate two simple patch antennas with layered structure and only one probe feed to excite lower one. The main effect of altering the feed location is studied and concluded that by shifting feed point in x-direction increases the lower order modes and by shifting the feed location in y-direction makes the antenna to resonate at higher frequencies which makes suitable for Wi-Max application.

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