# Design of dual band broadband modified rectangular microstrip antenna with air gap for wireless applications

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Abstract: This paper demonstrates the Dual band Broadband microstrip patch antenna with air gap for wireless applications with improved bandwidth and gain. The antenna have dual bandwidths of 860MHz (4.40GHz – 5.26GHz) or 17.61% and 1670MHz (5.33GHz – 7GHz) or 27.08% covers four bands of WLAN and one band of Wi-Max and one band of IMT. The designed antenna has four resonant frequencies 4.52GHz, 5.67GHz, 6.17GHz and 6.72GHz. The rectangular microstrip patch antenna presented in this paper has six rectangular parallel slits with multilayer arrangement, using Airgap coupling. This antenna is designed and simulated using IE3D simulation software.

Index Terms : Airgap coupling, Dual band, Broadband, parallel slits, Microstrip Antenna

#### **1. INTRODUCTION**

Now days the communication plays an excellent role in the worldwide society and almost all the communication systems are changing rapidly from wired to wireless. Wireless communication is much more flexible way of communication and antenna is the most important part of it. Recently the microstrip antenna is very useful due to its low cost, ease of Installation and integration with feed networks, low profile and small size [1-9]. On the move internet browsing, E banking, digital cable TV, etc and small handheld devices it is often require that the antenna to be achieve low profile good gain and wideband/multi-band characteristics. A number of approaches have been reported to obtain compact dual band micro-strip antenna such as loading of rectangular, circular and triangular patches by shorting pins, crossed slot and the use of a rectangular ring [2]. But the microstrip patch antenna has one serious drawback of narrow bandwidth as it limits the useful frequency band [2-3]. Several techniques have been used to enhance the bandwidth by interpolating surface modification into patch configuration. The most common techniques used to enhance the bandwidth and reduce the size of patch are multilayer techniques in which multiple layers of substrates are either stacked or arrange with airgap between them. In these kind of arrangements one layer is fed by coaxial Probe feeding techniques and others are been excited electromagnetically. In Airgap coupling generally we used three layers, two substrate's layer and between them an airgap. In this arrangement lower layer is of same substrate on which we designed our patch. Over this layer we create an airgap and over this airgap we create another substrate layer on which we designed our patch. The substrate used to designed this antenna is FR4 substrate.

The bands for WLAN application are 2.4 GHz (2.400 GHz -2.484 GHz), 4.9GHz (4.940GHz-4.99GHz), 5GHz (5.25GHz-5.35GHz) and (5.470GHz-5.725GHz), 5.2 GHz (5.150 GHz- 5.350 GHz), 5.8 GHz (5.725 GHz to 5.825 GHz) and 5.9GHz (5.85GHz-5.9GHz). The WiMAX has three licensed bands 2.5 GHz (2.5-2.69 GHZ), 3.5 GHz (3.4-3.69 GHZ) and 5.5 GHz (5.25-5.85 GHZ) [8].The IMT has (2.700 GHz-2.900 GHz), (3.400 GHz-4.200 GHz) and (4.400 GHz-4.900GHz). In this paper the designed wideband microstrip patch antenna have five bands of WLAN and one band of each of IMT and Wi-Max.

# **II. SINGLE LAYER MICROSTRIP ANTENNA DESIGN CONSIDERATIONS**

Designing process for this Microstrip patch antenna is carried out in following manner:

At the beginning of designing process, first we considered a single layer conventional microstrip patch antenna. Dimensions for this conventional patch were taken as 53mm x 79mm. FR4 substrate was used to design this conventional patch. The Z top for FR4 substrate is 1.6mm and loss tangent for FR4 is 0.025 and Dielectric constant is 4.4. Simple probe feed technique was used for excitation. Design and simulation process were carried out using IE3D simulation software 2007 version 12.30. Fig. 1 shows the conventional patch.



Fig. 1 Geometry of RPAWTRS structure with coordinate system

Simulated reflection coefficient curve for conventional patch is shown in fig. 2. From this curve we saw that conventional patch is resonant at three frequencies 3.18GHz, 4.09GHz and 4.24GHz with respective bandwidths of 3.13% and 6.71%.



Fig.2 Return loss graph for conventional patch

Since conventional patch has low bandwidth, further modifications are required.Smith chart for conventional patch is shown in fig. 3.



Fig. 3: Smith Chart for Conventional Patch

In our next step of designing process we modified our conventional patch to get enhance bandwidth. In modified patch, six rectangular parallel slits were inserted into conventional patch. Dimensions of modified patch were remained same as in conventional patch. Dimension of slits were taken as 3mm x 37mm. All basic parameters for modified patch were same as in conventional patch because we used FR4 substrate again. Fig. 4 represent modified single layer microstrip patch antenna.



Fig 4: Modified single layer patch

Simulated return loss curve and smith chart for modified single layer patch antenna were shown in fig 5 and in fig 6 respectively.



Fig 5: Return loss curve for Modified single layer patch Antenna

From return loss curve we saw that modified antenna is resonant at three frequencies 2.68GHz, 2.89GHz and 4.87GHz with respective bandwidths of 10.89% and 15.13%. Since both bands were broadband we referred this antenna as Dual Band Broadband Microstrip Antenna. Since these results were so far the best results on single layer patch and because these results were not satisfactory, we shifted from Single layer configuration to Multilayer configuration. Fig 6 shows smith chart for modified single layer microstrip patch antenna.



Fig 6: Smith chart for modified single layer microstrip patch antenna

Patch	Geometries	Slot No	Length of Slot (mm)	Width of Slot (mm)	Frequency (GHz)	Gain (dBi)	Band Width (%)
Conventional		Without slot	0	0	3.18 4.09 4.24	-5.79 1.45 2.96	3.13% 6.71% 6.71%
Patch 1		1-6	37	5	4.59	0.35	3.04%
Patch 2		1,2, 3,4,5,6	37 37	3 5	4.14	4.77	7.55%
Patch 3		1,2,3,4 5.6	37 37	3 5	4.97	3.92	12.83%
Final patch		1-6	37	3	2.68 4.87	1.93 3.82	10.79% 15.13%

 TABLE I: Variation of antenna parameters of modified single layer patch antennas with length and width of rectangular slits

So far the best results achieved by single layer microstrip patch antenna were a dual band broadband antenna with peak bandwidth of 15.13% and peak gain for this antenna was 3.82dBi. But still bandwidth obtained by single layer configuration was not enough for wireless applications. So we shifted our work from single layer to multilayer configuration.

In multilayer configuration we designed two layers, both layers were designed on FR4 substrates and both layers were separated by an airgap. In this arrangement, patch was designed on top most layer and coaxial probe feed technique was used to energized the patch.

# **III. MULTILAYER MICROSTRIP PATCH ANTENNA DESIGN CONSIDERATIONS**

In multilayer configuration first we studied a conventional multilayer microstrip patch antenna. Dimensions of this patch were taken as 53mm x 79mm, same as in single layer. Again we used FR4 substrate to design this patch. Fig 7 shows multilayer conventional patch.



Fig 7 Side view of Conventional Rectangular patch Antenna with Air Gap

Simulated return loss curve and smith chart for multilayer conventional patch with air gap are shown in fig 8 and in fig 9.



Fig 8 Return loss curve for Multilayer conventional patch

Conventional patch is resonant at two frequencies 6.1GHz and 6.4GHz with 8.32% bandwidth. This patch can be referred as single band dual frequency antenna.



Fig 9 Smith chart for multilayer conventional patch with air gap

## MODIFIED MULTILAYER MICROSTRIP PATCH ANTENNA WITH AIR GAP

Since the best results in single layer configuration were achieved with modified patch which is shown in fig 4, so now we take this patch and designed it on multilayer configuration. The Dimensions of multilayer modified patch are taken as, length is 79mm and width is 53mm. In this modified patch we have inserted six rectangular parallel slits each of 37x3 mm. The substrate which is used to design the antenna is FR4 substrate. The thickness of FR4 substrate is 1.6mm and Dielectric constant is 4.4. We take loss tangent of FR4 substrate 0.025. For getting enhance bandwidth and gain on compact size antenna we use multilayer configuration with airgap coupling. In this antenna we designed three layer configuration. Dimensions for Lower layer or ground layer are generally taken as four times of dimension of patch. Airgap between two substrate layers are taken as 0.2 mm. In simulation process meshing (cells per wavelength) is taken as 8. The designed and simulation work is carried out using IE3D Simulation Software.



Fig 10: Modified Multilayer Microstrip Antenna with air gap 0.02mm

## **IV. SIMULATED RESULTS**

#### **Return Loss Curve**

Return loss curve for designed Patch is shown in fig 10.



Fig 10 Return loss for designed patch

As from the return loss, we can see that our designed patch is resonant at four frequencies 4.52GHz, 5.67GHz, 6.17GHz and 6.72GHz. This antenna covers the frequency range from 4.40GHz to 5.26GHz with a bandwidth of 860MHz and 5.33GHz to 7.00GHz with a bandwidth of 1670MHz, so this antenna covers bands of WLAN and one band of IMT.

#### Smith Chart and VSWR

Smith chart represents the impedance matching. Fig. 11 shows smith chart for designed patch.



Fig 11 smith chart for designed patch

Smith chart represents that impedance matching at all four resonant frequencies is good. The ideal value of impedance is defined as 50, 0 ohm.



Fig 12 VSWR for designed patch

The acceptable value of VSWR for microstrip antennas is defined as 0 to 1.5 and from VSWR curve it was observed that at all four resonant frequencies VSWR is 1.08, 1.14, 1.04, 1.04 respectively, hence in the defined range. **Gain Curve** 

Gain is an important factor for every antenna. Fig 13 shows gain vs frequency curve for designed patch.



Fig 13 gain vs frequency curve for designed patch

It is clear from the gain curve that both our bandwidths are completely useful, because the gain is positive in entire bandwidths. Gain at all four resonant frequencies is 5.69dB, 4.12dB, 3.29dB and 3.70dB is positive with good values.

## Directivity

Directivity vs frequency curve is shown in fig 14.



Fig 14 directivity vs frequency curve for designed patch

A good value of directivity for microstrip antennas is 8dBi, and from the curve we see that directivity at all four resonant frequencies is above 8dBi.

#### **Radiation Pattern**

Fig 15, fig 16, fig 17 and fig 18 shows radiation pattern at four resonant frequencies 4.52GHz, 5.67GHz, 6.17GHz and 6.72GHz respectively. The normalized simulated E and H plane radiation patterns at four resonance frequencies are shown in below figures 2, which indicate that the maximum radiations are obtained normal to the patch geometry and patters are more or less systematic in nature.



#### V. CONCLUSION AND FUTURE WORK

The designed dual band broadband rectangular multilayer microstrip patch antenna with air gap 0.2mm, is operating in two frequency range first is 4.40GHz – 5.26GHz and second is 5.33GHz – 7.00GHz, Thus the antenna Resonates at four frequencies 4.52GHz, 5.67GHz, 6.17GHz and 6.72GHz covering IMT/WLAN/WI-Max standards. This modified antenna having band width of 17.61% and 27.08% corresponding to the central frequency 4.825GHz and 6.165GHz. The designed antenna has a simple structure and enhances gain up to 5.69dBi with multilayer configuration. The designed antenna represents the better directivity and radiation pattern. Proposed future work for this antenna is we will try to make it circularly polarized by using other different techniques.

#### TABLE II: Variation of Antenna Parameters of Modified Multi layer MSA with Airgap

Patch	Airgap (mm)	Frequency (GHz)	Gain (dBi)	Bandwidth (GHz)	Effective Bandwidth (GHz)	
Modified Multilayer MSA	0.1 mm	4.24	5.98	4.12 to 4.93	4.12 to 4.55	
		5.38	3.46		5.09 to 5.90	
		6.40	1.76	5.09 to 6.66	6.14 to 6.14	
	0.2 mm	4.52	5.69	4.40 to 5.25	4.40 to 5.25	
		5.67	4.12		(mar.)	
		6.17	3.29	5 22 4- 7.0	5.33 to 7.0	
		6.72	3.70	5.55 to 7.0		
	0.3mm	5.56	<mark>4.6</mark> 6	5.27 to 6.08	5.27 to 6.08	

TABLE III: Comparison of Single layer and Multilayer Microstrip Patch Antennas

Patch	Frequency	Gain	Directivity	Bandwidth
	(GHz)	(dBi)	(dBi)	(%)
Conventional	3.18	-5.79	9.06	3.13 %
Single laver	4.09	1.45	11.40	
MSA	4.24	2.96	11.85	6.71 %
Conventional	6.1	3.42	9.77	8.32 %
Multilayer MSA	6.4	2.98	8.57	
Modified Single	2.68	1.96	8.58	10.79 %
layer MSA	4.87	3.81	8.06	15.13%
Final Modified	4.52 5.67	5.69 4.12	11.58 9.78	17.61 %
Multilayer MSA	6.17 6.72	3.29 3.70	9.40 9.87	27.08 %

#### References

- [1]. Indrasen Singh, V.S. Tripathi, "Microstrip Patch Antenna and its Applications: a Survey" International Journals of Computer Applications in Technology, Vol. 2, No.5, pp. 1595-1599.
- [2]. Constantine A. Balanis, "Antenna theory Ana
- [3]. lysis and Design" 2nd edition, John Wiley and Sons, 2003, Vol14, pp 812.
- [4]. K. L.Wong, "Compact and Broadband Microstrip Antennas" John Wiley & Sons, 2003.
- [5]. L. H. Weng, Y. C. Guo, X W. Shi, and X. Q. Chen. 2008, "An Overview On Defected Ground Structure", Progress In Electromagnetics Research B, Vol. 7, pp. 173–189, 2008.
- [6]. Ashwini K. Arya, M.V.Kartikeyan, A.Patnaik "Defected Ground Structure in the perspective of Microstrip Antennas: A Review" frequenz, Vol.64, pp. 79–84,2010.

- [7]. Ashwini K. Arya, M.V. Kartikeyan, A.Patnaik, "Microstrip patch antenna with Skew-F shaped DGS for dual band operation" Progress In Electromagnetics Research M, Vol. 19, pp. 147-160,2011.
- [8]. Rajeshwar Lal Dua, Himanshu Singh, Neha Gambhir, "2.45 GHz Microstrip Patch Antenna with Defected Ground Structure for Bluetooth" International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-1, Issue-6, January 2012.
- [9]. Patil V. P., "Enhancement of bandwidth of rectangular patch antenna using two square slots techniques" International Journal of Engineering Sciences & Emerging Technologies, ISSN: 2231 6604, Volume 3, Issue 2, pp: 1-12, Oct. 2012.
- [10].Deepak Verma, Dheeraj Bhardwaj and Komal Sharma "Design of Modified Broadband Microstrip Rectangular Shaped Slotted Antenna for WLAN Application" © 2014 National conference ECTME 2014.
- [11].Mayank Dwivedi, Mandeep singh, Vinod kumar, "Compact Dual Band Slotted Antenna for IEEE 802.11b Applications", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 2, Issue 10, October 2012, Volume 2, Issue 10, pp. 406-409, October 2012.
- [12].K.P. Ray and Girish kumar "Compact and Broadband Microstrip Antennas" ISBN 1-58053-244-6 © 2003 Artech house Inc.
- [13]. http:en.wiki .edia.org/wiki/WiMAX/Wlan.
- [14].Gagandeep Kaur, Geetanjali Singla, Simarjit Kaur, "Design of Wideband Microstrip Patch Antenna Using Defected Ground Structure for Wireless Applications", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 10, October 2013, ISSN 2277 128x.
- [15].Komal Sharma, Dheeraj Bhardwaj and Brajraj Sharma, "Dual band square Microstrip Patch Antenna with two Slots for Wi-Max Applications" SKIT Research Journal, ISSN2278-2508, pp 178-180, Vol-3, 2013.

