Design and Analysis of Coplanar Capacitive Fed Slotted Patch Antenna for S Band Applications

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Abstract: This article presents the suspended truncated rectangular patch coplanar capacitive fed slotted antenna for S- band applications. In this paper a center slot rectangular antenna with truncated corner are presented. Proposed antenna geometry consists of two truncated corners and a center slot to obtained antenna resonance at multiple overlapping frequencies so that it increase the impedance bandwidth and also for proper impedance matching. After presenting the basic geometry, the proposed configuration (with truncated corner and center slot) which increases the impedance bandwidth is presented. Both rectangular patch and square feed strip is on the same surface a long SMA probe is used to feed the antenna configuration. Finally a proposed geometry is analyzed and optimized by using simulation software HFSSv15.

Keyword— **Capacitive Feed, Microstrip antennas, impedance bandwidth, wide band, and gain.**

1. INTRODUCTION

Now a day's Microstrip antennas are the right candidates for several wireless applications (GSM, Wi-Max, RFID etc.) because of their numerous advantages including easy design and fabrication procedure [1, 2]. However, these antennas exhibit a few serious limitations such as low Impedance bandwidth and gain in their conventional form. Hence, several researchers reported numerous techniques to improve these restrictions especially enhancing the impedance bandwidth. These alterations include, cutting slots in the basic shapes [3], changing the shape of the geometry [4], or using multi-layer technique. A dual band characteristic in a microstrip antenna is obtained by embedding a slot in the patch as the structure proposed in [5,6] in which the radiating patch includes a pair of step-slots. In microstrip antennas, embedded slots can also be used to enhance the impedance bandwidth of a single band antenna. A circular arc slot [7] and a U-shaped slot [8] have been investigated in order to broaden the bandwidth of a single band antenna. To realize a broadband characteristic in feeding a microstrip antenna, an L-probe can be used. This feeding structure is also known as broadband electromagnetic coupling probe [9].

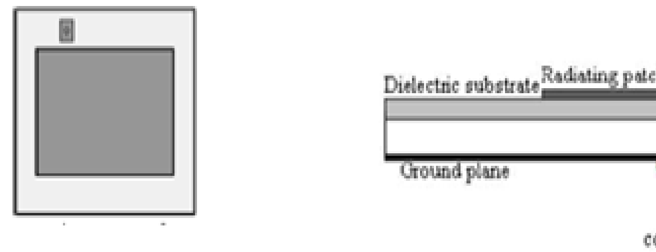
It is well known that considerable bandwidth enhancement can be achieved by increasing the overall height of the composite air dielectric medium [9–14]. However, the use of air gap increases the height/volume of the antenna which is undesired in several (compact) applications [15]. Therefore, a design that uses small air gap for the similar antenna design is reported earlier [13] There are several microstrip patch antennas available in literature, which operate at dual resonant frequencies [14, 18–34]. For example antenna reported in [18] uses stacked configuration [18], whereas geometry presented in [19] uses suspended configuration (with air gap) [19]

As stated in above paragraphs, several applications require compact antenna geometries which occupy small area/volume of the wireless device. Hence, in this work we propose a design that uses small air gap for the similar antenna designs reported earlier. The antenna developed here is suitable for various wireless applications like ISM (2.4–2.5 GHz), PCS cellular spectrum widely licensed across the US at 1.9 GHz, broadband wireless commercial service delivery in US (2.3 GHz) etc.. However, this configuration is useful where wireless devices operate at fixed resonant frequencies. In the U.S., the FCC approved satellite-based Digital Audio Radio Service (DARS) broadcasting in the S band from 2.31 to 2.36 GHz, currently used by Sirius XM Radio. More recently, it has approved for portions of the S band between 2.0 and 2.2 GHz the creation of Mobile Satellite Service (MSS) networks in connection with Ancillary Terrestrial Components (ATC).

The basic geometry and its working are presented in Section 2. The design starts with the selection of center frequency and it may be noted that the design approach can be easily scaled to any frequency of interest. The proposed antenna with truncated corner and rectangular slot at the center of radiating patch and effect of air gap is presented in Section 3. Simulation studies to determine the dimensions of the key design parameters and the slot are also presented there. Experimental validation of the basic geometry is presented in Section 4. Conclusions of this study are given in Section 5.

2. BASIC ANTENNA GEOMETRY

The geometry of antenna is basically a suspended microstrip antenna which is shown in (Figure 1). The configuration is basically a suspended microstrip antenna in which radiating patch and the feed strip are etched on the substrate of thickness “h” mm. A long pin SMA connector is used to connect the rectangular feed strip which couples the energy to a radiating patch by capacitive means. The length and width of the patch are designed for 2.4 GHz operation.



(a)

(b)

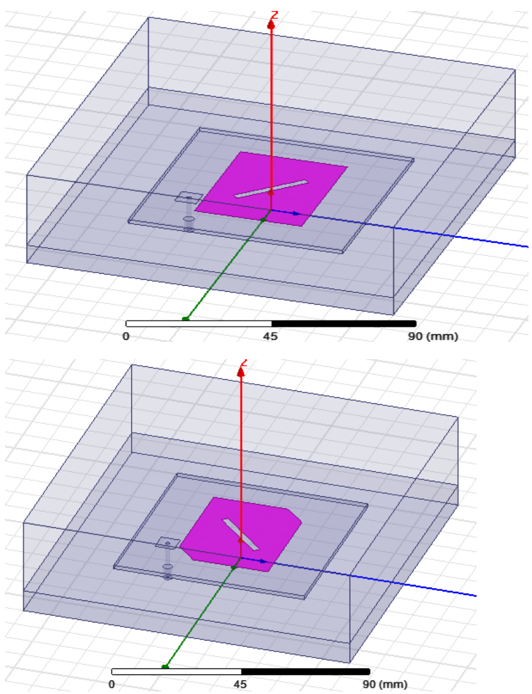
Figure 1: (a) Top view of basic antenna geometry (b) Side view of basic antenna geometry

Figure explain the basic configuration of the antenna in which a square capacitive patch is used to couple energy to the antenna.

3. PROPOSED ANTENNA GEOMETRY AND PARAMETER STUDY

The proposed geometry of antenna is basically a ractangular patch with a rectangular slot microstrip antenna in which rectangular patch and feed strip etched on same substrate. A long SMA feed is used to provide energy to the basic arrangement the length and width are designed for dual resonant frequency. In this rectangular patch antenna with slot and truncated corner antenna is designed. The dielectric substrate is used for the simulation with dielectric constant (ε_r) = 4.4, loss tangent ($\tan\delta$) = 0.02, and the height of the substrate is equal to 1.6mm.

In this HFSS v15 simulation software is used for simulation study of antenna.



(a)

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Figure 2: (a) Antenna geometry with rectangular slot. (b) Antenna geometry with truncated corner and rectengular slot.

Figure shows the proposed antenna geometry with truncated corner and rectengular slot at the center.

The antenna was designed to operate with a center frequency of 2.4 GHz. Radiator patch dimensions can be calculated from standard design expressions after making necessary corrections for the suspended dielectric [1, 2]. These corrections incorporate the total height above the ground (g + h) and effective dielectric constant of the suspended microstrip [16]. It has been shown that the impedance bandwidth of the antenna may be maximized by using the design expression [9]

$$g = 0.16\lambda 0 - h \sqrt{\varepsilon_r}. \quad (1)$$

Where g is the height of the substrate above the ground, and h and ε_r are the thickness and dielectric constant of the substrate. However, it should be noted that Equation (1) enables us to predict only initial value and the final value may be optimized with the simulation tools like HFSS. The parameters that can be used to optimize the antenna are air gap (g), separation between feed strip and the radiator patch (d), and the feed strip dimensions (length (t) and width (s)).

4. SIMULATION AND EXPERIMENTAL RESULTS AND DISCUSSION OF THE PROPOSED ANTENNA

In this, we study different design and comparison between them. We change the slot width by 0.5mm and slot length by 10mm and simulate the design and got the different result for each design. We selected design by comparing with other design.

Table 1: Geometry and parameter value

Geometry parameter	**Value (mm)**
Length of the radiator patch (L)	45
Width of the radiator patch (W)	35
Length of the feed strip (s)	7
Width of the feed strip (t)	7
Separation of feed strip from the patch (d)	1.2
Slot length (L_s)	25
Slot width (W_s)	3.5
Slot position (p : from center of patch)	0
Air Gap (g)	5

(a)

(b)

Figure 3: Fabricated prototypes. (a) Basic geometry with center rectangular slot. (b) Geometry with truncated corner and center slot.

In this demonstration we uses substrate of dielectric constant (ε_r) = 4.4, loss tangent (tanδ) = 0.02, and the height of the substrate is equal to 1mm and 1.6mm. The optimized geometry parameters with slot are given in (Table). All these geometrical parameters are optimized with the HFSS. It is very difficult to explain and compare the experimental and simulated results, by considering few parameters and experimental result one can validate proposed geometry.

4.1 Effect of Slot Length

In this step, we tried to optimize the slot length, keeping the same slot position.

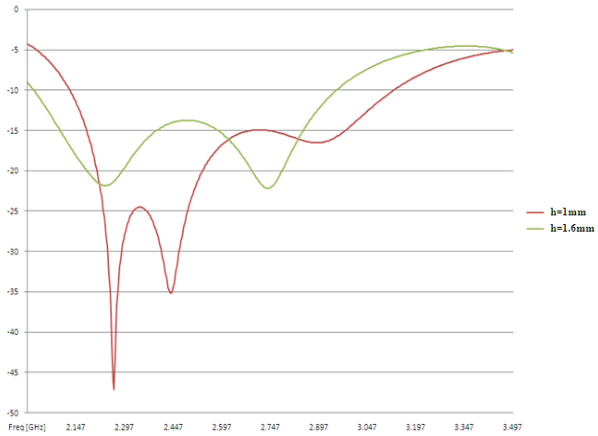


Figure 4: Experimental returnloss parameter of the proposed antenna with h=1 and 1.6mm.

Here, the slot length was varied from 25mm to 40mm in steps of 5mm. These characteristics are depicted in (Figure 5). From the return loss characteristics it is clear that the slot length parameter (L_s) does not shift the frequency. However, it helps in optimizing the depth of S_{11} below -10 dB. From these characteristics it may be noted that the slot length of 25mm exhibits optimum response.

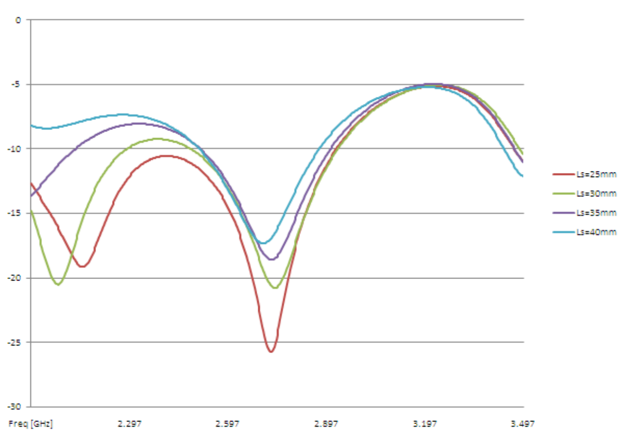


Figure 5: Simulated returnloss parameter of the proposed antenna for different Ls.

4.2 Effect of Slot Width

In this step, slot width was varied from 1.5mm to 4.5mm in steps of 1mm keeping Ls = 25mm constant. The return loss characteristics for this case are presented in (Figure 6). Like slot length this parameter helps in optimizing the depth of S_{11} curve. From all the cases studied, the optimum set of slot dimensions is L_s =25mm, and w_s =3.5mm.

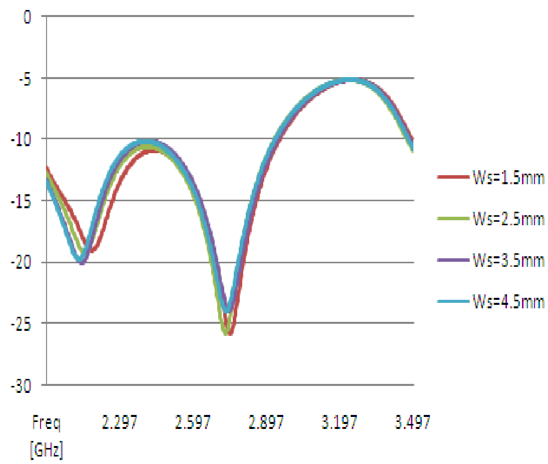
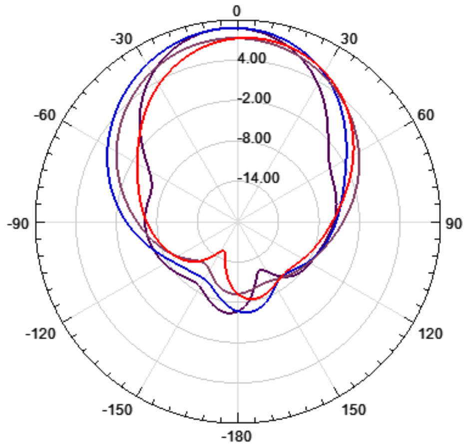


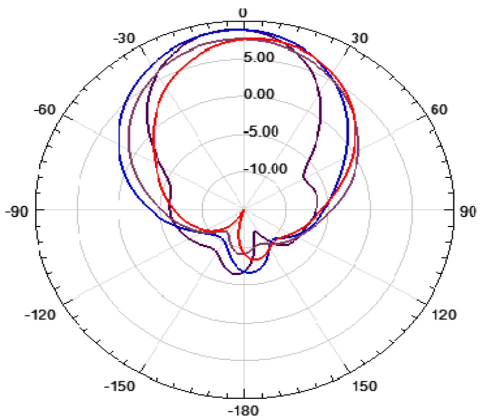
Figure 6: Simulated returnloss parameter of the proposed antenna for different Ws.

4.3 Radiation Pattern

Radiation pattern is one of the very important parameter for the antenna design, it gives the information about the gain of the antenna and the pattern of the electromagnetic field distribution. Figure shose that the rasiation pattern of the slot loded and slot eith truncated antenna design. Both antenna configuration have high gan aproimatly 7 dBi.



(a)



(b)

Figure 7: Simulated Radiation pattern at designed central frequency (2.4 GHz) (a) For rectangular slot (b) For rectangular slot and truncated corner antenna.

The prototype of the antenna with dimensions listed in Table 1 was fabricated (Figure 3), and the return loss characteristics, and radiation patterns were measured. Return loss comparison plots are shown in Figure 4. The simulated gains are compared in Figure 7. Gain of the antenna is very high (nearly 8 dB) throughout the band of operation.

5. CONCLUSION

The coplanar capacitive coupled probe fed microstrip antennas (with center rectangular slot and truncated patch) suitable S-band wireless applications have been presented. The basic antenna with truncated corner uses small air gap offers wide bands with impedance bandwidth of 41.2%, good radiation patterns, and high gain of about 8 dB in the bands of operation have been obtained. Besides reducing the air gap, it (slot) also enables the antenna to operate at lower frequencies due to reactive loading. After presenting the basic geometry, the same configuration with rectangular slot and truncated corner with air gap was presented which also yields wide band operation. The measured antenna characteristics are found to be in good agreement with the simulated results in the desired band of frequencies. The probe connected to the patch gives a good impedance matching between the ground plane and the substrate. The Gain of the fabricated antenna for wide band of 2 GHz - 3 GHz obtained is above 5 dBi.

REFERENCES

[1] Kumar, G. and K. P. Ray, *Broadband Microstrip Antennas*, Artech House, 2003.

[2] Luk, K. M., K. F. Lee, and W. L. Tam, “Circular U-slot patch with dielectric superstrate," *Electronics Letters*, Vol. 33, No. 12, 1001-1002, 1997.

[3] Ooi, B. L. and I. Ang, “Broadband semicircle fed flower-shaped microstrip patch antenna," *Electron. Lett.*, Vol. 41, No. 17, 2005.

[4] Targonski, S. D., R. B. Waterhouse, and D. M. Pozar, “Wideband aperture coupled stacked patch antenna using thick substrates," *Electronics Letters*, Vol. 32, No. 21, 1941-1942, 1996.

[5] Lu, J. H., “Single-feed dual-frequency rectangular microstrip antenna with pair of step-slots,” *Electronics Letters*, Vol. 35, 354-355, 1999.

[6] Bhalla, R. and L. Shafai, “Broadband patch antenna with a circular arc shaped slot”, IEEE AP-S Int. Symposium, Vol. 1, 394-397, 2002.

[7] Bhalla, R. and L. Shafai, “Resonance behavior of single U-slot microstrip patch antenna”, Microwave and Optical Technology Letters, Vol. 32, 333-335, 2002.

[8] Tada, S., R. Chayono, Y. Shinohe, Y. Kimura, and M. Haneishi, “ Radiation properties of modified fractal microstrip antennas”, IEICE Transactions on Communications, Vol. 89, 1519-1531, 2006.

[9] Kasabegoudar, V. G., D. S. Upadhyay, and K. J. Vinoy, "Design studies of ultra wideband microstrip antennas with a small capacitive feed," *Int. J. Antennas Propagat.*, 1-8, 2007.

[10] Kasabegoudar, V. G. and K. J. Vinoy, "A wideband microstrip antenna with symmetric radiation patterns," *Microw. Opt. Technol. Lett.*, Vol. 50, No. 8, 1991-1995, 2008.

[11] Kasabegoudar, V. G. and K. J. Vinoy, "Coplanar capacitively coupled probe fed microstrip antennas for wideband applications,"*IEEE Trans. Antennas Propagat.*, Vol. 58, No. 10, 3131-3138, 2010.

[12] Kasabegoudar, V. G. and K. J. Vinoy, "A broadband suspended microstrip antenna for circular polarization," *Progress In Electromagnetics Research*, Vol. 90, 353-368, 2009.

[13] Kasabegoudar, V. G. and K. J. Vinoy, "A coplanar capacitively coupled probe fed microstrip antenna for wireless applications," *The 2009 International Symposium on Antennas and Propagation*, 297-300, 2009.

[14] Kasabegoudar, V. G., "Dual frequency ring antenna with capacitive feed," *Progress In Electromagnetics Research C*, Vol. 23, 27-39, 2011.

[15] Kasabegoudar, V. G., "Low profile suspended microstrip antennas for wideband applications," *Journal of Electromagnetic Waves and Applications*, Vol. 25, No. 13, 1795-1806, 2011.

[16] Ajit Kumar and V. G. Kasabegoudar, "Dual band coplanar capacitive coupled microstrip antennas with and without air gap for wireless applications," *Progress In Electromagnetic Research C,* vol. 36, 105-117, 2013.

[17] Ajit kumar, and jitendra kumar singh, "A compact dual square ring slots microstrip antenna for dual band wireless application," *International Journal of Electronics and Communication Engineering (IJECE)*, vol. 2, Issue 5, Nov 2013, 37-44.

[18] Ajit Kumar, and V. G. Kasabegoudar, "A coplanar capacitive coupled suspended circular patch antenna with circular polarization for wireless applications," IJMER; ISSN: 2277-7881; IF-2.735; V:5.16; vol 3, Issue 3(11), March 2014.

[19] Ajit Kumar, and V. G. Kasabegoudar, "Suspended rectangular and circular broadband patch antennas for circular polarization," 2015 IEEE INTERNATIONAL CONFERENCE ON ELECTRICAL, COMPUTER AND COMMUNICATION TECHNOLOGIES.

[20] R. Joseph and T. Fukusako, "Bandwidth enhancement of circularly polarized square slot antenna," *Progress In Electromagnetic Research B, Vol. 29, 233-250, 2011*

[21] Mayhew-Rydgers, G., J. W. Avondale, and J. Joubert, "New feeding mechanism for annular-ring microstrip antenna," *Electronics Letters*, Vol. 36, 605-606, 2000.

[22] Sze, J. Y., T. H. Hu, and T. J. Chen, "Compact dual-band annular-ring slot antenna with meandered grounded strip," *Progress In Electromagnetics Research*, Vol. 95, 299-308, 2009.

[23] Lee, B. M. and Y. J. Yoon, "A dual fed and a dual frequency slots loaded triangular microstrip antenna," *IEEE Antenna and Propagation Society Int. Symp.*, Vol. 3, 1600-1603, 2000.

[24] Ren, W., "Compact dual-band slot antenna for 2.4/5 GHz WLAN applications," *Progress In Electromagnetics Research B*, Vol. 8, 319-327, 2008.

[25] Su, C. W., J. S. Row, and J. F. Wu, "Design of a single feed dual-frequency microstrip antenna," *Microw. Opt. Technol. Letters*, Vol. 47, No. 2, 114-116, 2005.

[26] Liao, W. and Q.-X. Chu, "Dual-band circularly polarized microstrip antenna with small frequency ratio," *Progress In Electromagnetics Research Letters*, Vol. 15, 145-152, 2010.

[27] Alkanhal, M. A. and A. F. Sheta, "A novel dual-band reconfigurable square-ring microstrip antenna," *Progress In Electromagnetic Research*, Vol. 70, 337-349, 2007.

[28] Chen, H.-M., "Single-feed dual-frequency rectangular microstrip antenna with a π-shaped slot," *IEE Proc. --- Microw. Antennas Propag.*, Vol. 148, No. 1, 60-64, 2001.

[29] Arya, A. K., A. Patnaik, and M. V. Kartikeyan, "Microstrip patch antenna with skew-F shaped DGS for dual band operation,"*Progress*

In Electromagnetics Research M, Vol. 19, 147-160, 2011.

[30] Yuan, H., J. Zhang, S. Qu, H. Zhou, J. Wang, H. Ma, and Z. Xu, "Dual-band dual polarized microstrip antenna for compass navigation satellite system," *Progress In Electromagnetics Research C*, Vol. 30, 213-223, 2012.

[31] Zhuo, Y., L. Yan, X. Zhao, and K.-M. Huang, "A compact dual-band patch antenna for WLAN applications," *Progress In Electromagnetics Research Letters*, Vol. 26, 153-160, 2011.

[32] Liu, W.-C. and Y. Dai, "Dual-broadband twin-pair inverted-L shaped strip antenna for WLAN/WiMAX applications," *Progress In Electromagnetics Research Letters*, Vol. 27, 63-73, 2011.

[33] Li, W.-M., Y. Jiao, and D. Li, "Dual-band circularly polarized slot antenna for WiMAX/WLAN application," *Progress In Electromagnetic Research Letters*, Vol. 33, 101-108, 2012.

[34] Y.B.chen, “CPW-fed circularly polarized square slot antenna,” *electronics letters 14th September 2006 vol. 42 No. 19*