# Bandwidth Enhancement by Corner Truncation in Rectangular Patch Antenna

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## Abstract
A method of improving operating bandwidth of a microstrip patch antenna by simply improving the structural shape, without affecting the size of an antenna is proposed in this paper. Simple calculations proved that Rectangular Microstrip Patch antenna of bandwidth 845.1 MHz can be efficiently transformed into microstrip patch antenna having bandwidth 9147.4 MHz . Two different approaches have been proposed and compared for better results.

**Keywords:** Patch Antenna, Bandwidth improvement, RMSA(Rectangular Microstrip Patch Antenna) ,UWB(Ultrawide Band) ,truncation.

## 1. Introduction
The recent progress in UWB wireless communications have remarkably increased the demand of wideband antenna with smaller dimensions than conventionally possible(H.N. Kritikos et al., 1990).The antenna size with respect to the wavelength is the parameter that will have influence on the radiation characteristics, gain and efficiency. Conventional microstrip antenna has limitation of narrow bandwidth, low gain and size of $\lambda/2$ (H.N. Kritikos et al., 1990 - Werner, D. H et al., 2003). There are several techniques reported in the open literature to improve the bandwidth of the microstrip patch antenna such as insertion of air gap, stacking, ground coupling etc. The coupling effect is possible by changing the feed type and proper values of its parameters[Jiechen Ding, et al., 2007].CPW feed offers better resonant characteristics and impedance bandwidth (J. Liang et al., 2004 - J. Liang,et.al,2005). Use of metal flared array is very inefficient way to obtain wideband(Rick W. Kindt et al., 2010). Use of mathematically designed fractal structures is also a favorite method acquainted worldwide to obtain multiple bands and overlapping multiple bands will result in bandwidth improvement (Min Ding et. al. 2007).
All methods of improving bandwidth mentioned above needs some kind of extra space by increasing size, or increase fabrication complexity as in case of fractals. Furthermore understanding of fractals involves complex mathematics. Keeping all above things in mind, this paper provides a simple but very efficient way to improve bandwidth. 3 types of antennas are considered; Type A is simple Rectangular Microstrip Patch Antenna with narrow bandwidth. Type B-Straight Edge Cut RSMA with slight improvement in bandwidth and Type C- Circular Edge Cut RSMA with more bandwidth improvement. All the results are obtained using AnSoft- HFSS v.11

## 2. Simple RSMA Design

### *2.1 Type A - Basic Rectangular Microstrip Patch Antenna)*
Basic Rectangular Microstrip Patch Antenna consists of simple Coplanar Microstrip Patch Antenna with no any modifications in patch or ground shape. Hereafter termed as simple RMSA. Design and dimensions are described in brief in next section.

### *2.2 Structure of simple RMSA*

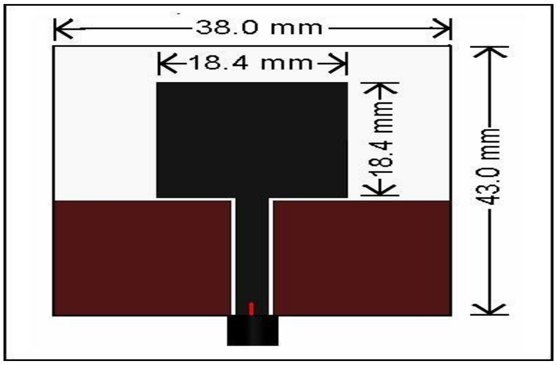


Figure 1. Structure of Basic Rectangular Microstrip Patch Antenna (Type A)

CPW fed RMSA i.e. Rectangular Microstrip Patch Antenna is designed in HFSS on generally available FR4 substrate of size 38mm X 43mm X 1.53mm and having dielectric constant of 4.4 and loss tangent (tan δ)=0.02. As shown in figure 1 both sides of actual radiating copper patch are chosen to be 18.4mm and structure is known to be coplanar as both ground and patch are on same plane. Thickness of the copper material is assumed 0.1mm which negligible in comparison with 1.53mm thickness of FR4 substrate material. As the structure is monopole, length of patch and ground are same. Dimensions of ground are 18.4mm X 16.9mm X 0.1mm. Feed width is 3.1mm fixed. Gap between feed and ground is optimized to 0.55mm and gap between patch and ground is 0.5mm.

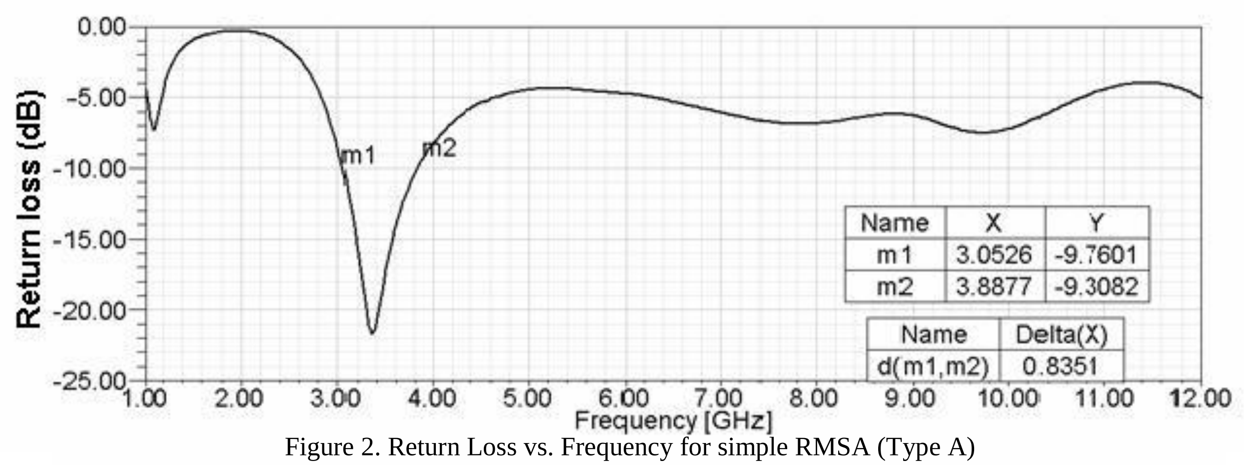


Figure 2. Return Loss vs. Frequency for simple RMSA (Type A)

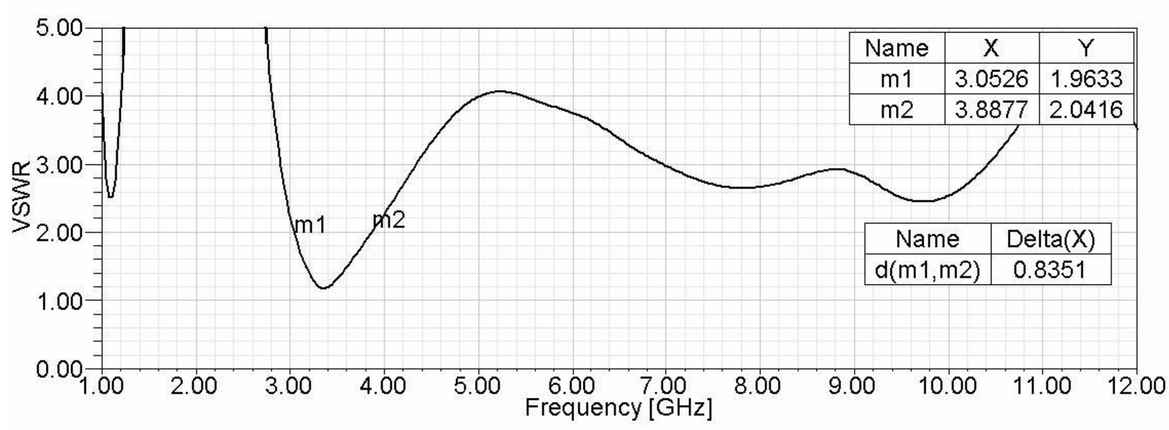


Figure 3.VSWR vs. Frequency for simple RMSA (Type A)

### 2.3 Simulation Results

The structure is designed and simulated over HFSS v11. Figure 02 and 03 shows simulation results. The operating band of any antenna is described by return loss less than -10 dB or VSWR less than 2. Return loss of -10dB indicates that, 90% of the power fed to antenna is accepted and only 10% is reflected at the feed. Thus Return Loss<-10dB is universally accepted convention to decide operating band of an antenna. In figure 02 and 03, m1 is lower end operating frequency and m2 is higher end operating frequency, marking the -10dB crossing line. As can be seen from following figures, simple rectangular microstrip patch antenna covers bandwidth of 835.1 MHz, starting from 3.0526 GHz to 3.8877GHz.

## 3. Bandwidth Increment by Cutting Corner Edges

Bandwidth of operation of antenna is depend upon different parameters like size of an antenna, thickness and dielectric constant of substrate material used, proper impedance matching of connector and antenna etc. apart from these parameters, structure (M.Ramkumar Prabhu et al.,2017) of an radiating patch and ground also plays important role in deciding the bandwidth. Cutting corners of RMSA will induce more discontinuity in the flow of wave and increasing reflections will ultimately results in improved bandwidth.

### 3.1 Type B-Straight Edge Cut Structure

Keeping all parameters of design of simple RMSA constant, design is modified by cutting the corners of rectangular patch by straight edges. As shown in figure 04, antenna is of dimension (38.0mm X 43.0mm X 1.53mm) with patch (18.4mm X 18.4mm X 0.1mm) i.e. same as Type A. Corners of the radiating patch are truncated with variable length called 'CUT'. This truncation is varied from 3.00mm to 7.00mm length with step size of 2.00mm and simulated in software.

### 3.2 Simulation Results

Figures 05 and 06 shows simulation result of Modified RMSA with straight edge cut. Three different graphs are combined showing variation in results for truncated length i.e. CUT equal to 3mm, 5mm and 7mm successively increasing by 2mm. From the figures 05 and 06 it can be observed that bandwidth of operation of antenna increases as CUT length increase. Due to physical limitations of radiating patch dimensions this truncation length can't be further increased.

The results observed from simulation of modified RMSA with straight edge cut are summarized in table 01. $f_L$ and $f_H$ indicate lower cut off and upper cut off frequency of the corresponding operating band in GHz. As cut length increases from No CUT to CUT length of 7.00mm, bandwidth is increase from 835.1 MHz to 5070.2 MHz.

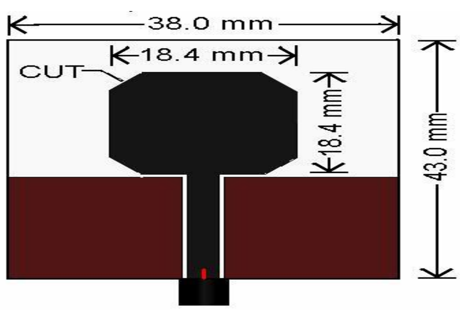


Figure 4. Structure of Modified RMSA with Straight Edge Cut(Type B)

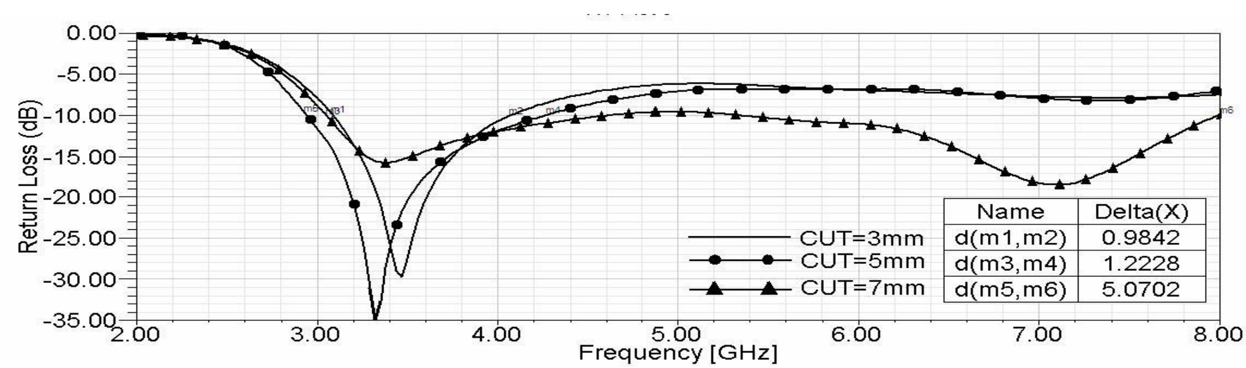


Figure 5. Return Loss vs. Frequency for modified RMSA with straight edge cut

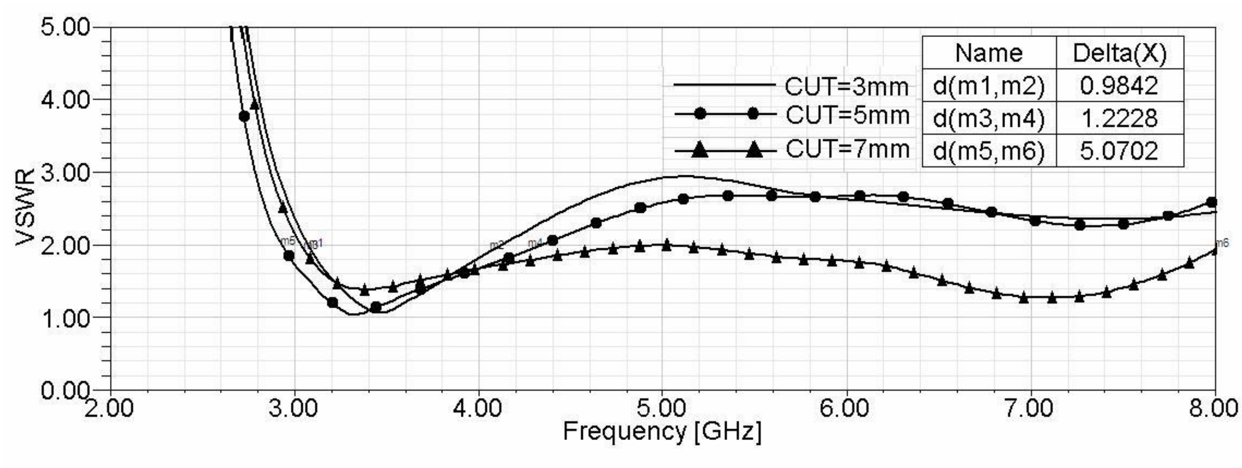


Figure 6.VSWR vs. Frequency for modified RMSA with straight edge cut

## 4. Type C-Circular Edge Cut

### *4.1 Type C- Circular Edge Cut Structure*

It is observed in previous section that, increase in discontinuity increases bandwidth of operation of an antenna. Truncation made with circular edges instead of straight edge will add more discontinuity. This can be achieved by intersecting circle of radius-'RAD' with radiating patch. All the dimensions of RMSA are kept constant as in previous design. Black portion in figure 7 shows radiating metal patch, while light gray portion is removed from the design.

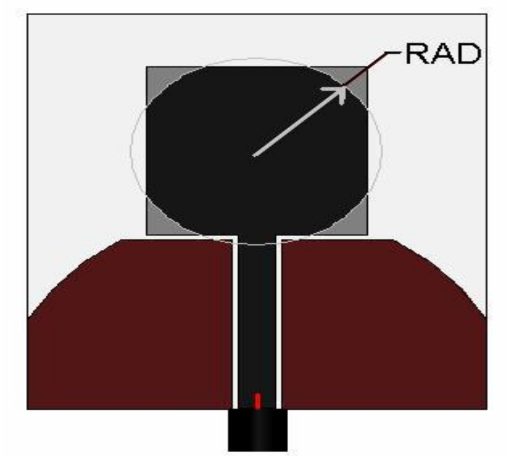


Figure 7. Structure of Modified RMSA with Circular Edge Cut(Type C)

### *4.2 Simulation Results*

Figures 08 and 09 shows simulation result of Modified RMSA with Circular edge cut. Five different graphs are combined showing variation in results for truncation circle radius i.e. RAD equal to 13mm, 12mm, 11mm, 10mm and 9.2mm successively decreasing by 1mm. From the figures 08 and 09 it can be observed that bandwidth of operation of antenna increases as radius of intersecting circle decreases. In other words, bandwidth is inversely proportional to RAD. Benefit of using circular edge cut over straight edge cut can be observed. From RAD=11 two different bands of operation can be seen, one at lower frequency and other at higher frequency side of frequency axis which was not the case in straight edge cut. At Radius of 9.2mm total UWB band is covered by the structure.

Table 02 summarizes results observed by variation in radius of truncating circle. Two distinct conclusions can be drawn from table 02. First with increase in truncating length i.e. decrease in RAD from 13 mm to 9.2mm, operating bandwidth increases from 835.1 MHz to 8947.4GHz covering entire UWB band of operation. Second conclusion drawn is related with the fact that two distinct operating bands are observed at lower and higher end of frequency band at RAD=11mm and RAD=10mm. these two distinct bands come close to merge into each other and cover entire band starting from 3.0526 GHz to 12.00GHz. thus percent increase of 972% is observed in type C-antenna.

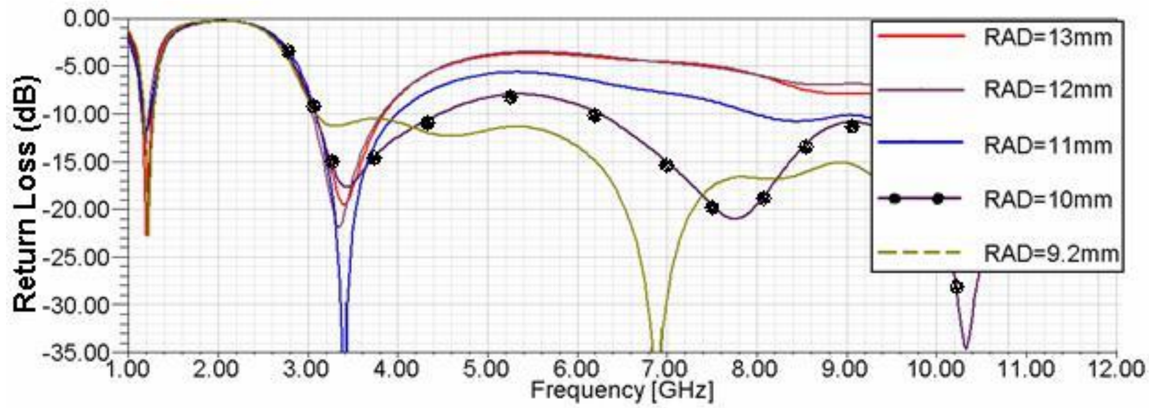


Figure 8. Return Loss vs. Frequency for modified RMSA with circular edge cu

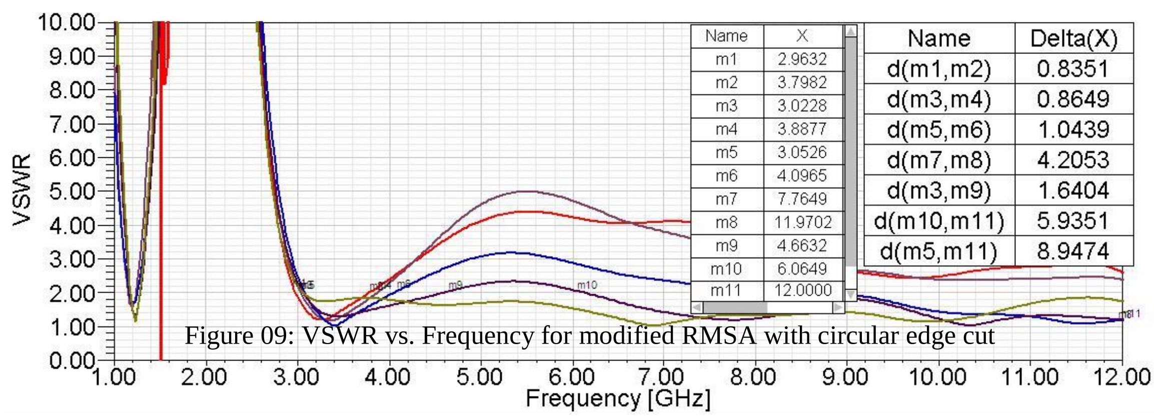


Figure 09: VSWR vs. Frequency for modified RMSA with circular edge cut

Figure 9. VSWR vs. Frequency for modified RMSA with circular edge cut

Table 2. Comparison of Bandwidth of Modified RMSA with Circular edge cut (Type C)

| RAD(mm) | $f_L$ (GHz) | $f_H$ (GHz) | Bandwidth(MHz) |
|---|---|---|---|
| 13.00 | 2.9632 | 3.7982 | 835.10 |
| 12.00 | 3.0228 | 3.8877 | 864.90 |
| 11.00 | 3.0526 | 4.0965 | 1043.90 |
| | 7.7649 | 11.9702 | 4205.30 |
| 10.00 | 3.0228 | 4.6632 | 1640.40 |
| | 6.0649 | 12.0000 | 5935.10 |
| 9.20 | 3.0526 | 12.0000 | 8947.40 |

## 5. Conclusion

Above simulated results and their comparison provides a brief idea of how narrow band simple RSMA can be transformed to Ultra Wide Band modified RSMA without changing its physical dimension. Circular edge truncation proves to be more efficient than straight edge truncation. Smoothening of corner of rectangle increases reflection and current at the boundary of patch. This lingering of current or wave must have improved bandwidth of antenna. Truncation of RSMA with circle of radius 9.2 mm leads to required UWB operation of antenna.

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