

Comparative Analysis of Non-Contacting Feed Mechanism in Square Micro Strip Patch Antenna

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ABSTRACT: Due to the increasing bandwidth requirement of modern wireless communication systems, developing antennas having wider bandwidth have been receiving significant attention in the recent years. In this context, a comparative analysis of the non-contacting feed mechanism (both Aperture Coupling and Proximity Coupling) in micro strip patch antenna has been done in this paper. Non-contacting feed mechanism makes use of thick antenna substrates which is the most convenient as it has only single ground plane. Apart from this, non-contacting feeding technique provides greater ease of design for higher impedance band width owing to a large number of design parameters. Here, both the linearly polarized aperture coupled and proximity coupled micro strip patch antenna were characterized and optimized using CST Microwave Studio software. We have analyzed and compared the return loss and corresponding bandwidth of these two types of antenna at different frequencies within the range from 3 GHz to 10 GHz. This frequency range is chosen so that this antenna may be used in Medical Tomography and Wireless Communication.

KEYWORDS: MSPA, aperture coupling, proximity coupling, bandwidth optimization, substrates.

I. INTRODUCTION

Micro strip patch antennas are considered as an indispensable tool in today's research oriented activities. This kind of antenna can be of different shapes like circular, rectangular, elliptical etc. The design and manufacturing cost of micro strip antenna is very cheap because of its 2D geometrical structure. The patch antenna is a popular resonant antenna used for microwave wireless communications that require semispherical coverage. Some patch antennas avoid using a dielectric substrate and suspend a metal patch in the air above a ground plane using dielectric spacers; the resulting structure provides increased bandwidth. With an increase in frequency, the input impedance moves to the clockwise direction on the Smith chart. The width of the patch antenna has significant effect on the Input impedance, Bandwidth, and Gain of the antenna.

Figure 1 shows a typical structure of a rectangular micro strip antenna. It consists of a flat rectangular sheet or patch of metal mounted over a larger sheet of metal called a ground plane.

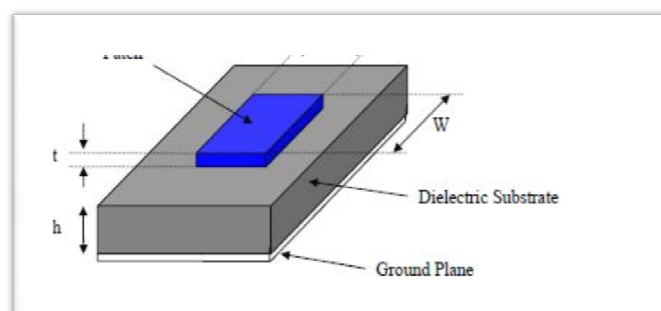


Fig. 1: A micro strip patch antenna showing the associated dimensions

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II. FEEDING MECHANISM

Suitable feeding technique plays an important role for antenna efficiency and better impedance matching. The feeding techniques used in the micro strip antenna are given below:

A. Contacting Feed:-

In this method, contacting element such as micro strip line or coaxial line is used to help the patch so that it can be fed directly to RF power. The most commonly used contacting feed methods are –

1. Line Feed
2. Co-axial probe Feed

B. Non Contacting Feed:

In this method, the RF power is transferred to the patch from the feed line through electromagnetic coupling instead of feeding directly. The commonly used non-contacting feed methods are -

1. Aperture Coupled feed
2. Proximity Coupled feed

In this paper, the Aperture Coupling and Proximity coupling feeding techniques has been thoroughly discussed for having a comparative study.

• Aperture CouplingFeed:

In the aperture coupled feed technique, the radiating patch and the microstrip feed line are separated by the ground plane. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane.

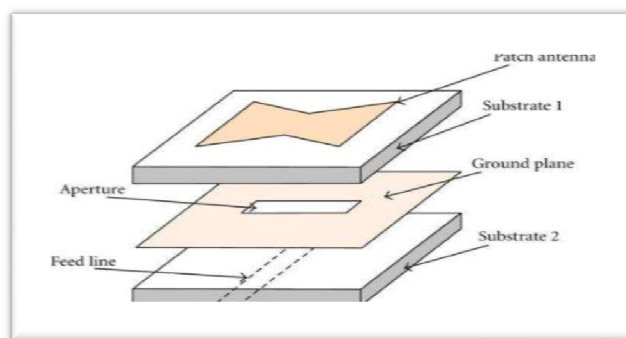


Fig 2: Aperture Coupled feeding

• Proximity Coupling Feed:

In this method, two dielectric substrates are placed such that the feed line lies in between the two substrates and the radiating patch is placed at the top of the upper substrate.

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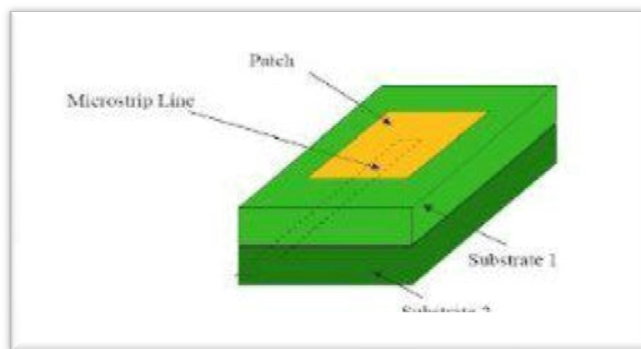


Fig 3: Proximity Coupled feeding

The two dielectric substrates can be selected independently to optimize both micro strip guided waves and patch radiating waves. The ranges of operating thickness of the substrate have a big effect on the resonant frequency and bandwidth of the antenna. Bandwidth of the micro strip antenna will increase with increasing substrate thickness. However, certain limits must not be exceeded, and otherwise the antenna will stop resonating. Therefore, the measures for selecting a substrate may include the following:

- (a) Surface-wave excitation.
- (b) Dispersion of the dielectric constant and loss tangent of the substrate.
- (c) Anisotropy in the substrate.
- (d) Cost Effective

III. STUDY OF ANTENNA DESIGNING PARAMETERS

There are three essential parameters for design of a rectangular micro strip Patch Antenna. Firstly, the resonant frequency (f_0) of the antenna must be selected appropriately. The frequency range for ultra wide band applications is from 3.1GHz to 10.6 GHz and the design antenna must be able to operate within this frequency range.

The second important parameter of good antenna design is dielectric substrate (ϵ_r). A thick dielectric substrate having low dielectric constant is desirable. This provides better efficiency, larger bandwidth and better radiation. FR-4 Epoxy which has a dielectric constant of 4.4 for lower substrate and RT –Duroid for upper substrate having dielectric constant of 2.2 and loss tangent equal to 0.009 can be used for new antenna design. The other antenna parameters to be considered for design are length of the patch L , width W , height of dielectric substrate h and Loss Tangent. The patch length is considered around $L_g/2$ (L_g : Length of the ground plane) to initiate the radiation. The antenna is typically fed at the diverging edge on the dimension W because it offers sensible Polarization. The antenna parameters can be calculated by the transmission line method as exemplified below:

A. Width of the Patch (mm):

Having specified the height of the patch antenna, the first step in the design procedure is to determine the width of the patch. This can be calculated using the following equation:

$$W = \frac{c}{2f_0\sqrt{\epsilon_r + 1/2}} \quad \text{.....(1)}$$

Where,

c = Speed of light in free-space (3×10^8 m/s)

f_0 = Resonating frequency

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B. Calculation of Effective Dielectric Constant(ϵ_{reff}):

This is calculated using the following equation:

$$\epsilon_{\text{reff}} = (\epsilon_r + 1)/2 + (\epsilon_r - 1)/2 \left[1 + 12 \frac{h}{w} \right]^{-0.5} \dots\dots\dots(2)$$

Where,

h= height of the patch (mm)

W= width of the patch (mm)

C. Calculation of Effective Length (L_{eff}):

This is calculated using the following equation:

$$L_{\text{eff}} = \frac{c}{2f_0 \sqrt{\epsilon_{\text{reff}}}} \dots\dots\dots(3)$$

D. Calculation of Length extension(ΔL):

The length extension is calculated using the following equation;

$$\Delta L = \frac{0.412h (\epsilon_{\text{reff}} + 0.3)(w/h + 0.264)}{(\epsilon_{\text{reff}} - 0.258)(w/h + 0.8)} \dots\dots\dots(4)$$

Where,

L= Patch length extension (mm)

h = height (mm)

W = width of the patch (mm)

E. Calculation of Actual Length :

The actual length of the patch antenna is calculated using the following equation;

$$L = L_{\text{eff}} - 2\Delta L \dots\dots\dots(5)$$

IV. DESIGN AND SIMULATION OF APERTURE COUPLED PATCH ANTENNA

We have used a square patch antenna and two dielectric substrates to design an aperture coupled antenna. The antenna is designed using transmission line model and is being simulated at different resonant frequencies: 3GHz, 5GHz, 7GHz, 9GHz and 10GHz.

With reference to the structure shown in Fig.2, the simulated structure of Aperture coupled antenna in CST Microwave studio is depicted in Fig.4.1.

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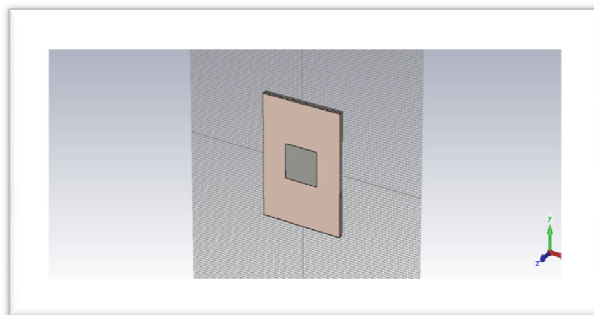


Fig. 4.1. Designed Structure on CST Studio

1) Return Loss at 3 GHz :

The design specifications for the aperture coupled antenna at the resonating frequency of 3GHz is given below:

| | |
|----------------------------|-----------------|
| Patch Length | 30.2mm |
| Patch Width | 30.2mm |
| Feed Length | 25mm |
| Feed Width | 2.9mm |
| Upper Dielectric Substrate | RT Duroid (2.2) |
| Lower Dielectric Substrate | FR4 (4.4) |
| Height of the Substrate | 1.63mm |

Table A: Design specification of Aperture Coupled Patch at 3 GHz

Fig 4.2 shows the S_{11} parameters (Return Loss = - 43dB) for the proposed antenna.

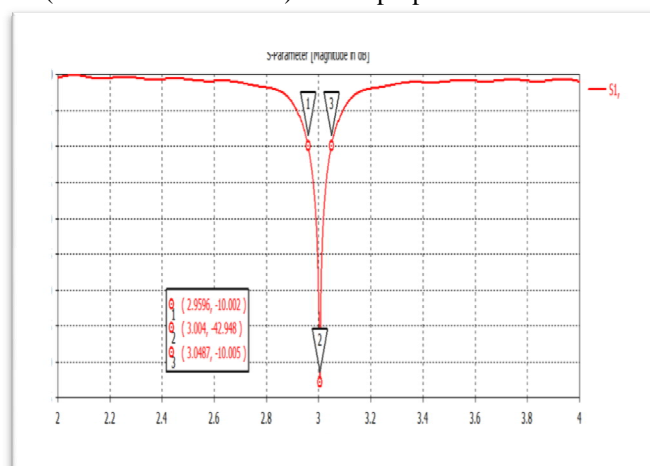


Fig 4.2 S_{11} of simulated antenna at 3 GHz

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2) Return Loss at 5 GHz :

The design specifications for the aperture coupled antenna at the resonating frequency of 5 GHz is given below:

| | |
|----------------------------|-----------------|
| Patch Length | 25.8 mm |
| Patch Width | 25.8 mm |
| Feed Length | 25mm |
| Feed Width | 2.9mm |
| Upper Dielectric Substrate | RT Duroid (2.2) |
| Lower Dielectric Substrate | FR4 (4.4) |
| Height of the Substrate | 1.63mm |

Table B: Design specification of Aperture Coupled Patch at 5 GHz

Fig 4.3 shows the S_{11} parameters(Return Loss = - 41dB) for the proposed antenna.

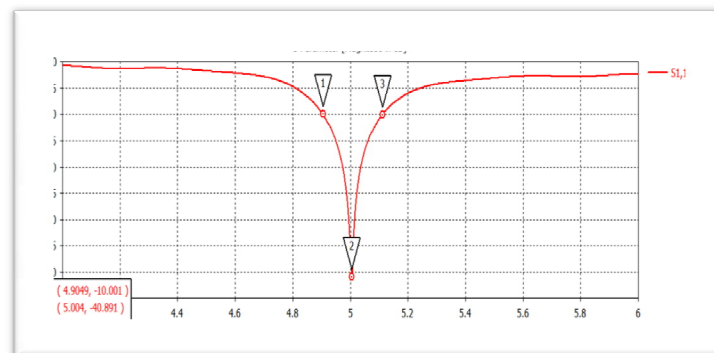


Fig 4.3: S_{11} of simulated antenna at 5 GHz

3) Return Loss at 7 GHz :

The design specifications for the aperture coupled antenna at the resonating frequency of 7 GHz is given below:

| | |
|----------------------------|-----------------|
| Patch Length | 14.8mm |
| Patch Width | 14.8mm |
| Feed Length | 25mm |
| Feed Width | 2.8mm |
| Upper Dielectric Substrate | RT Duroid (2.2) |
| Lower Dielectric Substrate | FR4 (4.4) |
| Height of the Substrate | 1.63mm |

Table C: Design specification of Aperture Coupled Patch at 7 GHz

Fig 4.4 shows the S_{11} parameters(Return Loss = - 36dB) for the proposed antenna.

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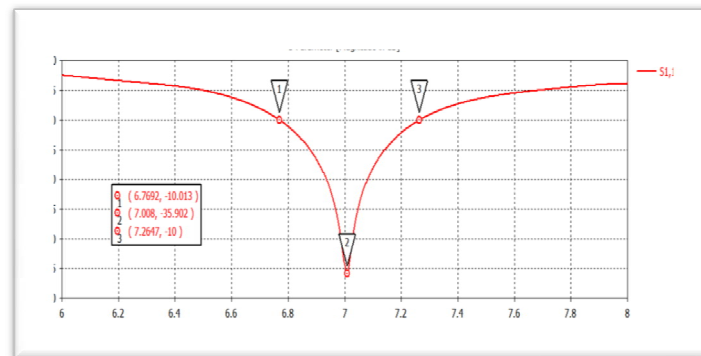


Fig.4.4.S₁₁ of simulated antenna at 7 GHz

4) Return Loss at 9 GHz :

The design specifications for the aperture coupled antenna at the resonating frequency of 9 GHz is given below:

| | |
|-----------------------------------|------------------------|
| Patch Length | 12.9mm |
| Patch Width | 12.9mm |
| Feed Length | 25mm |
| Feed Width | 2.8mm |
| Upper Dielectric Substrate | RT Duroid (2.2) |
| Lower Dielectric Substrate | FR4 (4.4) |
| Height of the Substrate | 1.63mm |

Table D: Design specification of Aperture Coupled Patch at 9 GHz

Fig 4.5 shows the S₁₁ parameters(Return Loss = - 60 dB) for the proposed antenna.

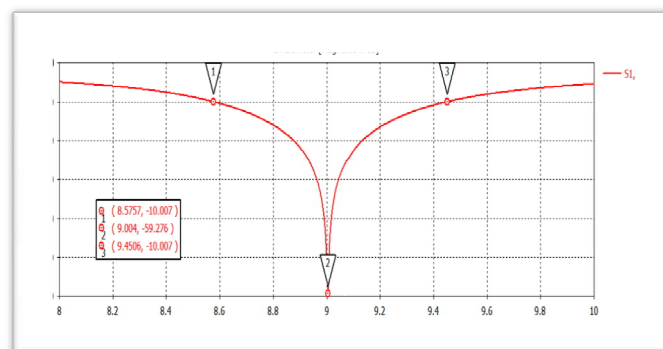


Fig.4.5. S₁₁ of simulated antenna at 9 GHz

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5) Return Loss at 10 GHz :

The design specifications for the aperture coupled antenna at the resonating frequency of 10 GHz is given below:

| | |
|----------------------------|-----------------|
| Patch Length | 10.8mm |
| Patch Width | 10.8mm |
| Feed Length | 25mm |
| Feed Width | 2.9mm |
| Upper Dielectric Substrate | RT Duroid (2.2) |
| Lower Dielectric Substrate | FR4 (4.4) |
| Height of the Substrate | 1.63mm |

Table E: Design specification of Aperture Coupled Patch at 10 GHz

Fig 4.6 shows the S_{11} parameters(Return Loss = - 52dB) for the proposed antenna.

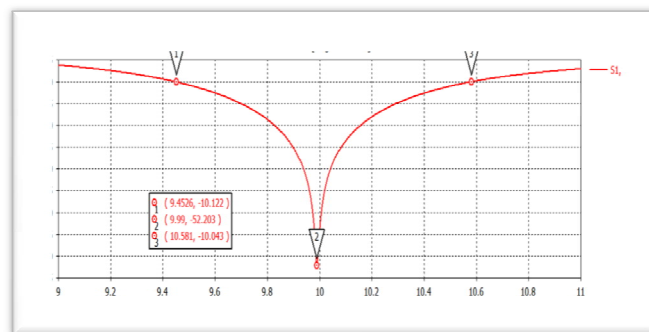


Fig..4.6. S_{11} of simulated antenna at 10 GHz

V. DESIGN AND SIMULATION OF PROXIMITY COUPLED PATCH ANTENNA

In this case also, we have used a square patch antenna and two dielectric substrates to design proximity coupled antenna. The antenna is designed using transmission line model and is being simulated at different resonant frequencies: 3GHz, 5GHz, 7GHz, 9GHz and 10GHz.

With reference to the structure shown in Fig.3, the simulated structure of Aperture coupled antenna in CST Microwave studio is depicted in Fig.5.1

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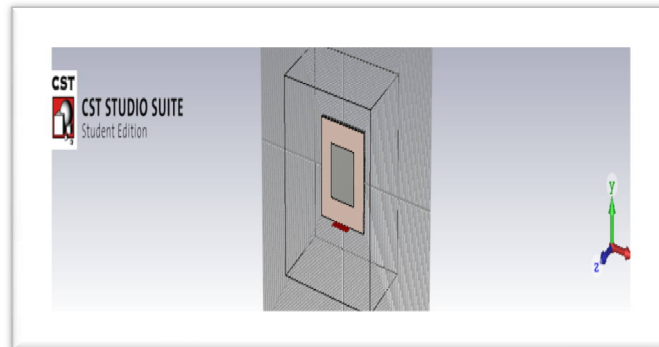


Fig 5.1 Designed Structure on CST Studio

1) Return Loss at 3 GHz :

The design specifications for the proximity coupled antenna at the resonating frequency of 3GHz is given below:

| | |
|----------------------------|-----------------|
| Patch Length | 35.5mm |
| Patch Width | 35.5mm |
| Feed Length | 25mm |
| Feed Width | 2.9mm |
| Upper Dielectric Substrate | RT Duroid (2.2) |
| Lower Dielectric Substrate | FR4 (4.4) |
| Height of the Substrate | 1.63mm |

Table F: Design specification of Proximity Coupled Patch at 3 GHz

Fig 5.2 shows the S_{11} parameters (Return Loss = -27dB) for the proposed antenna.

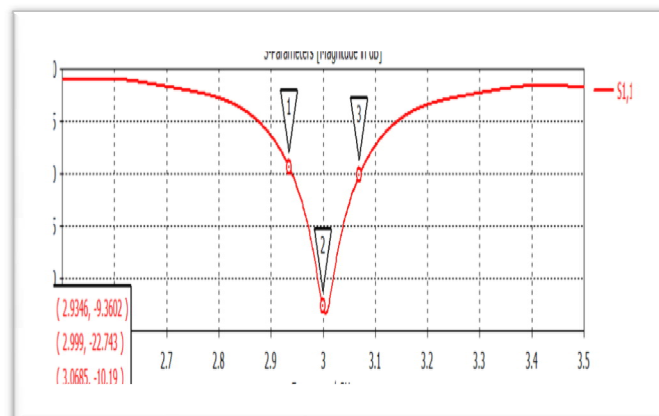


Fig.5.2. S_{11} of simulated antenna at 3 GHz

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2) Return Loss at 5 GHz :

The design specifications for the proximity coupled antenna at the resonating frequency of 5 GHz is given below:

| | |
|----------------------------|-----------------|
| Patch Length | 29.6 mm |
| Patch Width | 29.6 mm |
| Feed Length | 25mm |
| Feed Width | 2.9mm |
| Upper Dielectric Substrate | RT Duroid (2.2) |
| Lower Dielectric Substrate | FR4 (4.4) |
| Height of the Substrate | 1.63mm |

Table G: Design specification of Proximity Coupled Patch at 5 GHz

Fig 5.3 shows the S_{11} parameters(Return Loss = - 32dB) for the proposed antenna.

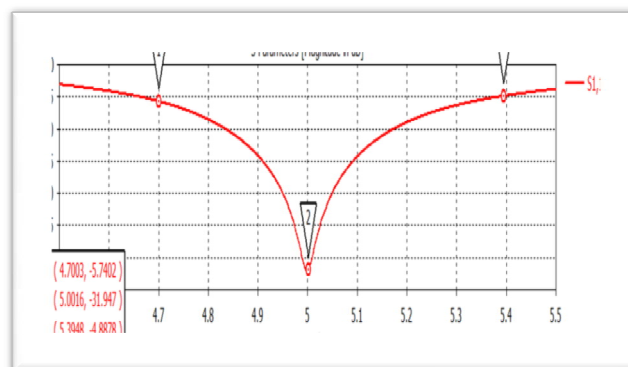


Fig.5.3.S₁₁ of simulated antenna at 5 GHz

3) Return Loss at 7 GHz :

The design specifications for the proximity coupled antenna at the resonating frequency of 7 GHz is given below:

| | |
|----------------------------|-----------------|
| Patch Length | 17.2mm |
| Patch Width | 17.2mm |
| Feed Length | 25mm |
| Feed Width | 2.8mm |
| Upper Dielectric Substrate | RT Duroid (2.2) |
| Lower Dielectric Substrate | FR4 (4.4) |
| Height of the Substrate | 1.63mm |

Table H: Design specification of Proximity Coupled Patch at 7 GHz

Fig 5.4 shows the S_{11} parameters(Return Loss = - 28 dB) for the proposed antenna.

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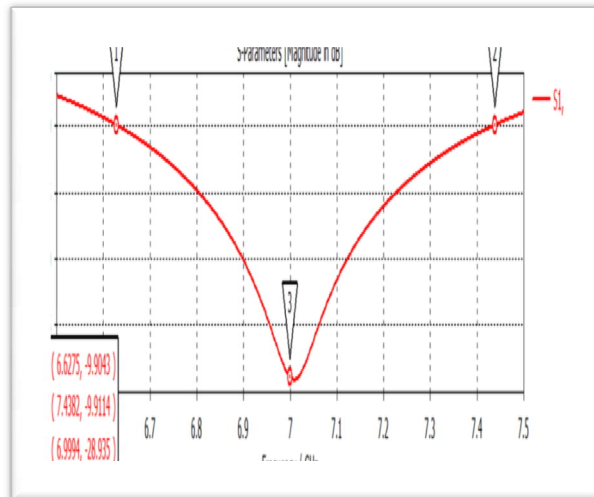


Fig.5.4. S_{11} of simulated antenna at 7 GHz

4) Return Loss at 9 GHz :

The design specifications for the proximity coupled antenna at the resonating frequency of 9 GHz is given below:

| | |
|-----------------------------------|------------------------|
| Patch Length | 12.9mm |
| Patch Width | 12.9mm |
| Feed Length | 25mm |
| Feed Width | 2.8mm |
| Upper Dielectric Substrate | RT Duroid (2.2) |
| Lower Dielectric Substrate | FR4 (4.4) |
| Height of the Substrate | 1.63mm |

Table I: Design specification of Proximity Coupled Patch at 9 GHz

Fig 5.5 shows the S_{11} parameters(Return Loss = - 22dB) for the proposed antenna.

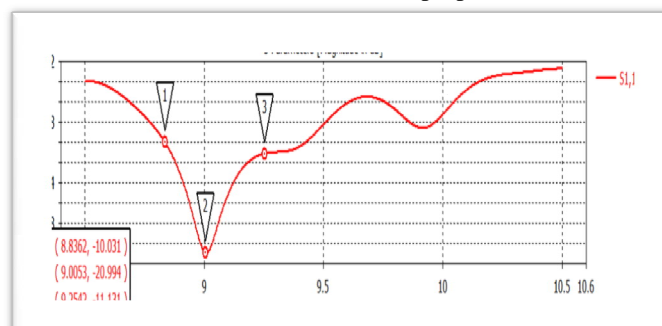


Fig 5.5 S_{11} of simulated antenna at 9 GHz

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5) Return Loss at 10 GHz :

The design specifications for the proximity coupled antenna at the resonating frequency of 10 GHz is given below:

| | |
|----------------------------|-----------------|
| Patch Length | 9.1mm |
| Patch Width | 9.1mm |
| Feed Length | 25mm |
| Feed Width | 2.9mm |
| Upper Dielectric Substrate | RT Duroid (2.2) |
| Lower Dielectric Substrate | FR4 (4.4) |
| Height of the Substrate | 1.63mm |

Table J: Design specification of Proximity Coupled Patch at 10 GHz

Fig 5.6 shows the S_{11} parameters(Return Loss = - 15dB) for the proposed antenna.

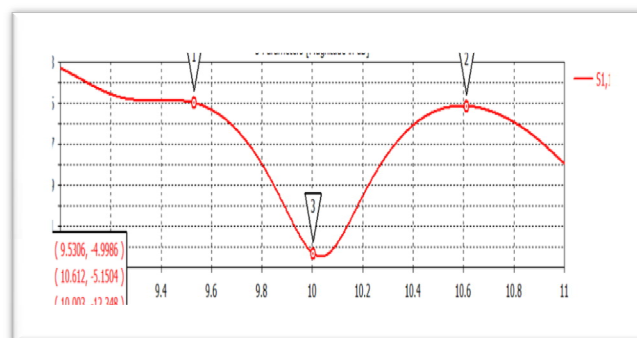


Fig.5.6. S_{11} of simulated antenna at 10 GHz

VI COMPARITIVE STUDY

In this section a comparative analysis has been done between the said feeding techniques in terms of their return loss and corresponding bandwidth.

From the Fig.6.1, it is clear that the return loss is maximum (-60dB) in case of aperture coupled micro strip antenna at 9 GHz.

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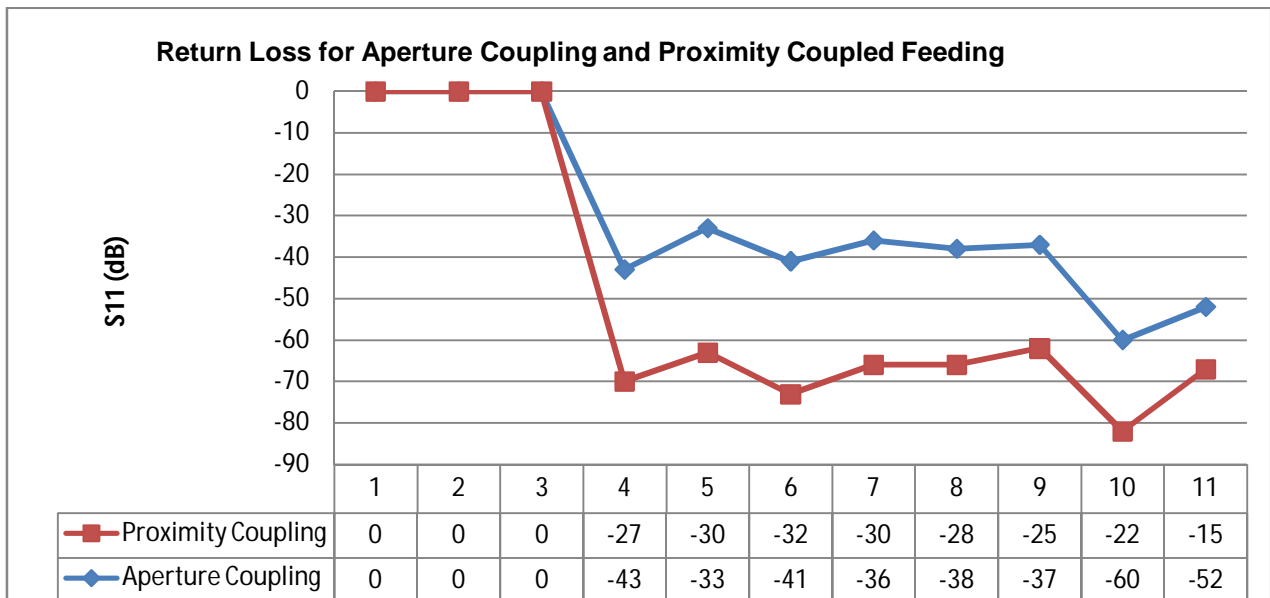


Fig: 6.1. Return loss Comparison for Aperture and Proximity coupling

From Fig.6.2, it is observed that the bandwidth of both aperture coupled and proximity coupled micro strip antenna varies non-linearly with frequencies. Still, the variation is less in case of aperture coupled patch antenna as compared to that of proximity coupled patch antenna.

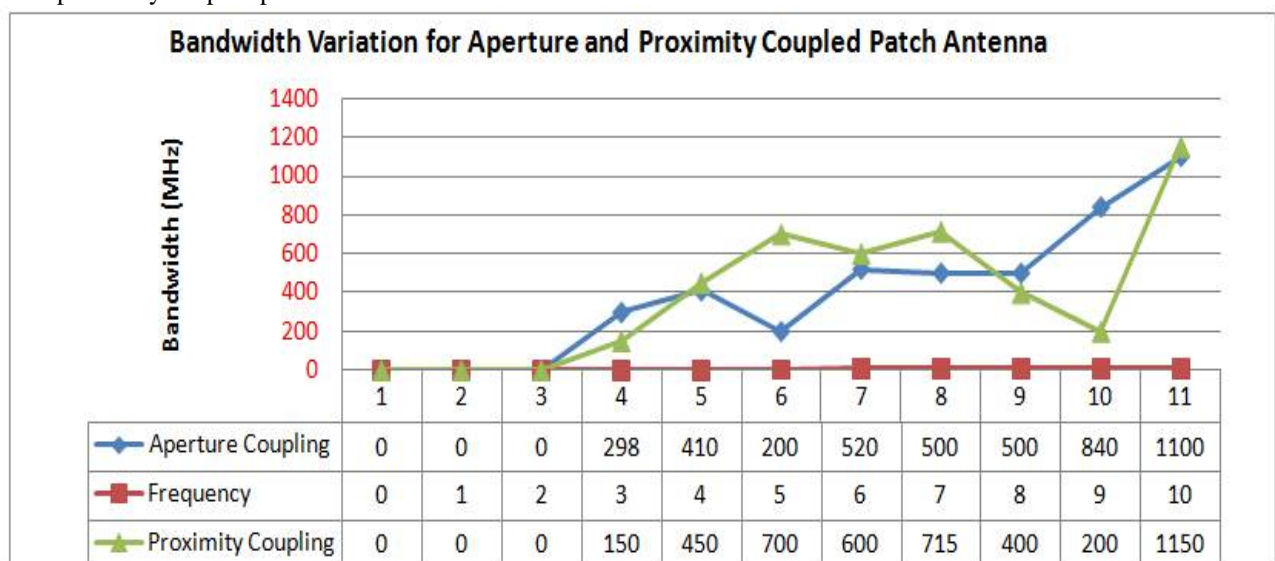


Fig: 6.2 Bandwidth Comparison for Aperture and Proximity coupling

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VII CONCLUSION

The microwave technique is a currently very attractive technique for medical applications. It uses non-ionizing electromagnetic waves and has good penetration capability into human tissues (in the GHz range). Since the ultra-wide band (UWB) technology features high resolution imaging and low system complexity, the making of a flexible yet portable device for medical diagnosis can be achieved. Moreover wireless data transmission of physiological and vital signs of patients for monitoring purposes are also feasible due to the high data transmission capability of wideband microwave signals. From the above two graphs, it is clearly seen that aperture coupled antenna outperforms the proximity coupled antenna in terms of return loss measurement as well as in terms of acceptable bandwidth. Due to the higher return loss, the directivity is also high in case of aperture coupled antenna in the chosen frequency range. As in biomedical applications or in case of body implanted antenna, the required directivity must be very high, the aperture coupled type microstrip patch antenna can be used to serve the purpose. The fabrication part of the above antenna is in process and henceforth we can have the comparison between the simulated and measured results.

VIII ACKNOWLEDGMENT

The authors of this paper would like to thank University Grant Commission (UGC) for giving the opportunity to work in Modern Biology Group B: "Image and Imaging" under UPE-II, where the research work has been carried out in "Microwave Tomography for Medical applications". We also acknowledge all the contribution of corresponding IEEE authors and most importantly the publishers of related books and journals which gave immense support and inspiration in preparing this manuscript. Above all, the extreme mental support and source of inspiration from all the family members and friends are widely acknowledged.

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