DOI: 10.21917/ijme.2018.0095

DESIGN AND ANALYSIS OF UWB RECTANGULAR SLOT MICROSTRIP PATCH ANTENNA FOR SMART IMPLANT APPLICATION

P. Saraswathy and K. Madhan Kumar
Department of Electronics and Communication Engineering, PET Engineering College, India

Abstract

Microstrip patch antennas are recently used in implant applications due to their low power consumption, low cost, versatility, field excitation, ease of fabrication etc. The microstrip patch antenna suffers with an array elements of antenna and narrow bandwidth. To overcome the above drawbacks, Flame Retardant Material is used as the substrate. Rectangular shape of microstrip patch antenna with FR4 material as the substrate which is more suitable for the implant applications. The proposed microstrip patch antenna was designed with the dimension of 20×26mm^2. FR-4 material has a dielectric constant value of 4.4 with thickness 1.4mm. One side of the substrate contains the ground plane of dimensions 20×26mm^2 made of copper and the backside of the substrate contains the ground plane of dimensions 20×26mm^2 made up of copper. The top of the substrate is the patch copper with dimensions 12×12.5mm^2 and thickness 0.05mm. MPA without slot, Vertical slot MPA, Horizontal slot MPA and Cylindrical slot MPA structures were designed and the performance of the antenna were analyzed with various parameters such as gain, directivity, E-field, VSWR and return loss. From the performance analysis, horizontal slot antenna provides a better result and it provides maximum E-field of 20dBV/m at 10.846GHz and MPA without slot produces low return loss of -36.539dB. Furthermore, successfully access the response of an antenna embedded in a tooth, mimicking a dental implant. Based on the E-field excitation value the investigating the tooth decay and it was simulated using CST software.

Keywords:

Gain, Directivity, Return Loss, E-field, H-field

1. INTRODUCTION

Microstrip patch antenna consists of ground, substrate and patch. Ground and patch of the microstrip patch antenna are copper material for low resistivity and high mechanical strength. The substrate material is Flame Retardant material which contains fiber glass and epoxy resin. In this, the fiber glass is for zero water absorption and epoxy resin for directly union with metal. Rectangular slot used for improving the feed without any losses. The microstrip line feed used that transfer the power from feed line to the patch act as the radiator. Microstrip patch antenna cares for microwave frequencies. The antennas connected to transmitter or receiver via microstrip transmission lines. These are applied to the antenna and ground plane. These antenna plays main roles to reduce the size, price and applicable in the airspace, bio medical. The values obtained from these networks are very close to target values. The difference between the outputs of the artificial neural network against target measured in terms of Performance which is very close to set a goal to be achieved in testing for better performance of the network [3]. The ground plane is increased to 60mm; the beam is almost directed towards the boresight (0°) direction irrespective of the switching states [7]. It was found that 1×8 array of rectangular slotted patch antenna gives return loss of -30.2dB and bandwidth of 68MHz which better as when compared with 1×8 array of rectangular patch antenna [8]. The mismatch between the antenna and feed line is calculated by VSWR. Higher the VSWR means more mismatch between feed line and patch of the antenna [9]. The length and dimension of the patch are constant, probe position modified and the network is trained for similar adjustment [10].

2. SLOTTED BASED METHOD

The proposed Rectangular shape of microstrip patch antenna designed using a flame retardant material (FR4) having a dielectric constant of 4.4 and this material is used as the substrate which is loaded over the ground plane of copper. The same copper material is used as the patch and feed of antenna. The Fig.1 shows the structure of basic Microstrip Patch Antenna. The Fig.2 shows the proposed method for investigating tooth decay.

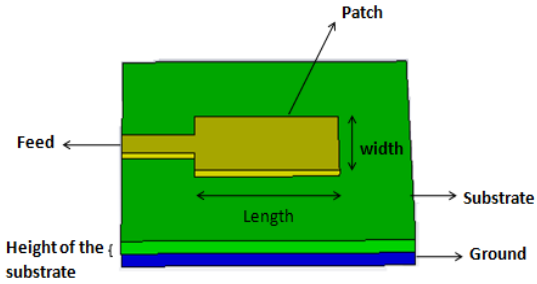


Fig.1. Basic Microstrip patch antenna

Fig.2. Proposed designs to detect the tooth decay

2.1 DESIGN OF MPA WITHOUT SLOT

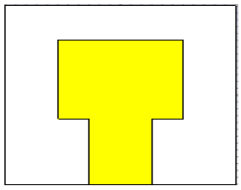


Fig.3. Design of MPA without slot

The Fig.3 shows the Microstrip patch antenna has a substrate made up of FR-4 which has a dielectric constant of 4.4. The ground plane is made up of copper with pure metal which is placed one side of the substrate. The other side of the substrate contains the patch that is made up of copper with pure metal. The

proposed antenna is fed with microstrip line feed. The Table.1 shows the specifications of rectangular microstrip patch antenna without slot.

Table.1. Design specifications of MPA without Slot

Antenna Specifications	Dimension
Thickness of the Ground	0.05mm
Width of the Ground	20mm
Height of the Ground	26mm
Thickness of the Substrate	1.4mm
Width of the Substrate	20mm
Height of the Substrate	20mm
Thickness of the Patch	0.05mm
Width of the Patch	12mm
Height of the Patch	12.5mm
Thickness of the Feed	0.05mm
Width of the Feed	7mm
Height of the Feed	8.5mm
Operating frequency	10 to 16GHz

2.2 DESIGN OF VERTICAL SLOT RMPA

The Fig.4 shows the vertical slot Microstrip patch antenna it uses the same ground, substrate, patch and feed dimensions of the Microstrip patch antenna without slot along with vertical slot is created. The Table.2 shows the specifications of vertical slot MPA.

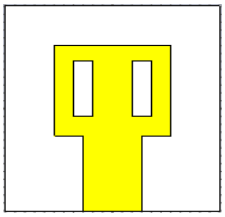


Fig.4. Design of vertical slot MPA

Table.2. Design specifications of single vertical slot RMPA

Antenna Specifications	Dimension
Thickness of the Ground	0.05mm
Width of the Ground	20mm
Height of the Ground	26mm
Thickness of the Substrate	1.4mm
Width of the Substrate	20mm
Height of the Substrate	20mm
Thickness of the Patch	0.05mm
Width of the Patch	12mm
Height of the Patch	12.5mm
Thickness of the Feed	0.05mm
Width of the Feed	7mm
Height of the Feed	8.5mm
Thickness of the Slot	0.05mm
Width of the Slot	2mm
Height of the slot	7mm
Operating frequency	10 to 16GHz

2.3 DESIGN OF HORIZONTAL SLOT MPA

The Fig.5 shows the double horizontal slot MPA it uses the same Ground, Substrate, Patch and Feed dimensions of the rectangular microstrip patch antenna without slot along with horizontal slot is created on the patch. The Table.3 shows the specifications of horizontal slot MPA.

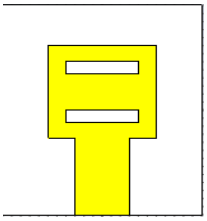


Fig.5. Design of horizontal slot MPA

Table.3. Design specifications of horizontal slot MPA

Antenna Specifications	Dimension
Thickness of the Ground	0.05mm
Width of the Ground	20mm
Height of the Ground	26mm
Thickness of the Substrate	1.4mm
Width of the Substrate	20mm
Height of the Substrate	20mm
Thickness of the Patch	0.05mm
Width of the Patch	12mm
Height of the Patch	12.5mm
Thickness of the Feed	0.05mm
Width of the Feed	7mm
Height of the Feed	8.5mm
Thickness of the Slot	0.05mm
Width of the Slot	8mm
Height of the slot	1.5mm
Operating frequency	10 to 16GHz

2.4 DESIGN OF CYLINDRICAL SLOT MPA

The Fig.6 shows the cylindrical slot MPA it uses the same Ground, Substrate and Patch of the rectangular microstrip patch antenna without slot along with cylindrical slot is created on the patch. The Table.4 shows the specifications of cylindrical slot MPA.

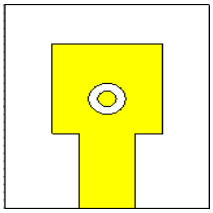


Fig.6. Design of cylindrical slot MPA

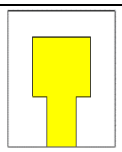
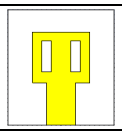
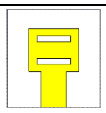
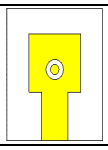
Table.4. Design specifications of cylindrical slot MPA

Antenna Specifications	Dimension
Thickness of the Ground	0.05mm
Width of the Ground	20mm
Height of the Ground	26mm
Thickness of the Substrate	1.4mm
Width of the Substrate	20mm
Height of the Substrate	20mm
Thickness of the Patch	0.05mm
Width of the Patch	12mm
Height of the Patch	12.5mm
Thickness of the Feed	0.05mm
Width of the Feed	7mm
Height of the Feed	8.5mm
Thickness of the center slot	0.05mm
Inner radius of the slot	1mm
Outer radius of the slot	2mm
Operating frequency	4 to 5GHz

3. RESULTS AND DISCUSSIONS

The performance of the various microstrip patch antenna with and without slots are evaluated by calculating Return loss, VSWR, Directivity, Gain. The performance of the proposed method is compared with the existing method. The Table.5 shows the performance parameter comparison of MPA.

Table.5. Performance comparison of Microstrip patch antenna

Antenna Type		Return Loss	VSWR
Rectangular MPA without slot		-36.539	1.032
Single vertical slot RMPA		-21.095	1.284
Double horizontal slot RMPA		-18.131	1.2777
Centre slot RMPA		-8.2772	2.293

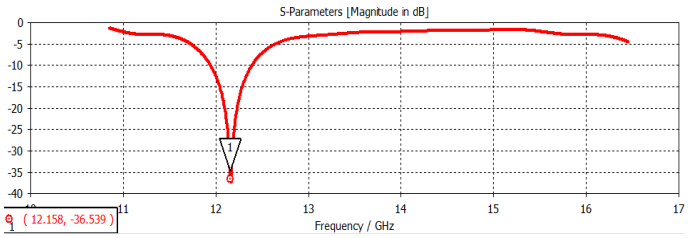


Fig.7. Return loss of MPA without slot

The Fig.7 shows the return loss (s_{11}) curve of the proposed antenna obtained by CST simulator. It produces the return loss value of -36.539dB resonate at the frequency of 12.158GHz.

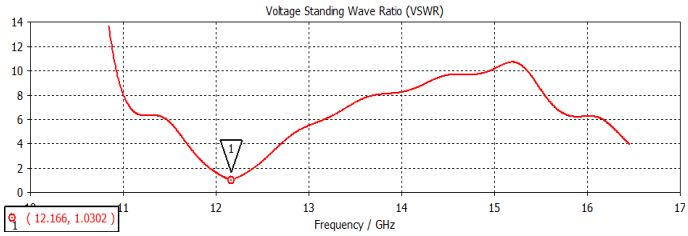


Fig.8. VSWR of MPA without slot

The Fig.8 shows the VSWR curve of the proposed antenna obtained by CST simulator. It produces the VSWR value of 1.032 resonates at the frequency of 12.166GHz. From the Table.6 Performance comparison table of Microstrip Patch Antenna, it was observed that the horizontal slot MPA provides high E-field.

Table.6. Performance parameter comparison of MPA

Antenna types	Resonant Frequency (GHz)	Directivity (dBi)	Gain (dB)	E-Field (dBV/m)
MPA without slot	10.846	7.57	7.87	16.7
	13.649	6.56	5.2	16
	16.452	7.61	5.3	18.1
Vertical slot MPA	10.846	7.79	7.86	16.6
	13.649	6.47	5.12	17.7
	16.452	8.96	7.03	18.3
Horizontal slot RMPA	10.846	7.32	7.6	20
	13.649	7.32	6.14	16.5
	16.452	7.69	5.4	14.5
Cylindrical slot RMPA	10.846	7.18	6.77	17.8
	13.649	6.79	5.43	16.2
	16.452	9.05	6.9	17.7

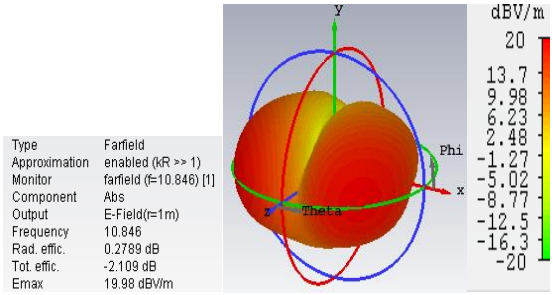


Fig.9. E-field of Horizontal slot MPA at 10.846GHz

The Fig.9 shows E-field of the proposed antenna obtained by CST simulator. It produces the E-field of 20dBV/m at the frequency of 10.846GHz.

Table.7. Field pattern for the normal condition tooth with dimension of 70×50×10mm^3

Distance from tooth	Resonant Frequency (GHz)	E-Field (dBV/m)	H-Field (dBA/m)
No distance	10.846	15.4	-36.1
	13.649	11.7	-39.8
	16.452	7.83	-43.7
Near field	10.846	15.9	-35.6
	13.649	12.2	-39.3
	16.452	7.27	-44.3
Far field	10.846	15.8	-35.7
	13.649	11.3	-40.3
	16.452	7.75	-43.8

From Table.7 and Table.8, Tooth with dimension of 70×50×10mm^3 produces E-field of 15.8dBV/m and H-field of -35.7dBA/m at 10.846GHz were obtained when an antenna placed far field to tooth model which shows the tooth in normal condition. Tooth is in decay condition when produces lower than this value.

Table.8. Field pattern for the decay condition tooth with dimension of 70×50×10mm^3

Distance from tooth	Resonant Frequency (GHz)	E-Field (dBV/m)	H-Field (dBA/m)
No distance	10.846	14.9	-36.6
	13.649	10.7	-40.8
	16.452	7.96	-43.6
Near field	10.846	15.9	-35.6
	13.649	11.3	-40.3
	16.452	7.94	-43.6
Far field	10.846	15.6	-35.9
	13.649	11.1	-40.4
	16.452	7.69	-43.8

Table.9. Field pattern for the normal condition tooth with dimension of 60×40×10mm^3

Distance from tooth	Resonant Frequency (GHz)	E-Field (dBV/m)	H-Field (dBA/m)
No distance	10.846	15.3	-36.3
	13.649	10.8	-40.7
	16.452	7.21	-44.3
Near field	10.846	15.8	-35.7
	13.649	12.7	-38.8
	16.452	7.38	-44.1
Far field	10.846	15.9	-35.6
	13.649	10.7	-40.8
	16.452	7.58	-43.9

From Table.9 and Table.10, tooth with dimension of 60×40×10 produces E-field of 15.9dBV/m and H-field of -35.6dBA/m at 10.846GHz were obtained when an antenna placed far field to tooth model which shows the tooth in normal condition. Tooth in decay condition when produces lower than this value.

Table.10. Field pattern for the decay condition tooth with dimension of 60×40×10mm^3

Distance from tooth	Resonant Frequency (GHz)	E-Field (dBV/m)	H-Field (dBA/m)
No distance	10.846	7.03	-1.75
	13.649	6.05	-0.85
	16.452	7.63	-0.34
Near field	10.846	7.76	-1.38
	13.649	7.57	-0.89
	16.452	7.89	-0.24
Far field	10.846	7.89	-1.40
	13.649	5.75	-0.86
	16.452	8.05	-0.24

4. CONCLUSION

Various Microstrip patch antennas using FR4 material were designed and performances of these antennas were analyzed with various parameters such as gain, directivity, VSWR and return loss. Various structures like MPA without slots, vertical slot, horizontal slot and cylindrical slot were proposed. From the performance analysis, MPA without Slot produces minimum return loss (-36.539), horizontal slot provides maximum E-field (20dBV/m). Thus the horizontal slot antenna produces the better field pattern than the other antennas. Based on the E-field of MPA the tooth is investigated. Antenna placed on the tooth model for three different conditions are no distance, near field and far field. Antenna produced the highest field pattern in the far field for E-field of 15.8dBV/m and for H-field of -35.7dBA/m at the dimension of 70×50×10mm^3 and E-field of 15.9dBV/m and for H-field of -35.6dBA/m at the dimension of 60×40×10mm^3. This result shows that the tooth in normal condition. Tooth in damaged

condition when the field pattern becomes lower than this value. In future work, the proposed antenna will be further developed for the other implant application.

REFERENCES

[1] Akshay Kumar, Amarveer Singh and Ekambir Sidhu, "Equivalent Circuit Modelling of Microstrip Patch Antenna (MPA) using Parallel LCR Circuits", *International Journal of Engineering Trends and Technology*, Vol. 25, No. 4, pp. 183-185, 2014.

[2] Arvind Yadav and Kuldip Pahwa, "Microstrip Patch Antenna for Ultra Wideband Applications in S Band, C Band and X Band" *International Journal of Research in Information Technology*, Vol. 2, No. 4, pp. 121-132, 2014.

[3] Avneet Kaur, Upasana Malhotra and Ekambir Sidhu, "Step Notched Flexible Microstrip Patch Antenna with Reduced Ground for Bluetooth, ISM and WLAN Applications", *Proceedings of 5th International Conference on Wireless Networks and Embedded Systems*, pp. 978-991, 2016.

[4] Chandan Tilak Bhunia, "Performance Enhancement of Implantable Medical Antenna using Different Feed Techniques", *International Journal Engineering Science and Technology*, Vol. 19, No. 4, pp. 642-650, 2016.

[5] Dmitriy Karnaushenko, et al., "Compact Helical Antenna for Smart Implant Applications", *NPG Asia Materials*, Vol. 7, No. 9, pp. 188-195, 2015

[6] Ekambir Sidhu, Akshay Kumar and Amarveer Singh, "Horse-Shoe Shaped Stacked Microstrip Patch Antenna for WLAN, WiMAX and IMT Applications", *International Journal of Engineering Sciences*, Vol. 17, pp. 525-531, 2016.

[7] M. Gurnoor Singh Brar, Jaspreet Singh and Ekambir Sidhu, "High Gain Pentagonal Slotted Microstrip Patch Antenna Design for Radio Location Applications", *International Journal of Engineering and Technical Research*, Vol. 5, No. 2, pp. 126-128, 2016.

[8] N. Mahalakshmi, "Design of Hexagon Shape Bow-Tie Patch Antenna for Implantable Bio-Medical Application", *Alexandira Engineering Journal*, Vol. 56, No. 2, pp. 235-239, 2017.

[9] Nick Timmons and Jim Morrison, "Microstrip Patch based Switched Beam Antenna at 2.45 GHz for Wireless Sensor Network Applications", *Journal of Electromagnetic Waves and Applications*, Vol. 10, pp. 1-12, 2017.

[10] R.K. Sharin, "Design and Performance of Two-Sleeve Low Profile Antenna for Biomedical Application", *Journal of Electrical Systems and Information Technology*, Vol. 4, No. 1, pp. 49-61, 2017.

[11] Renu Kumari and Jharkhand Rai, "To Study The Bandwidth Of Microstrip Antenna using Artificial Neural Network", *International Journal of Advanced Technology in Engineering and Science*, Vol. 4, No. 6, pp. 255-261, 2016.

[12] Shanmugapriya Rajan, "Design and Analysis of Rectangular Microstrip Patch Antenna using Inset Feed Technique for Wireless Application", *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 4, No. 4, pp. 34-40, 2015.

[13] Sudhir Shresth, "Flexible Microstrip Antenna for Skin Contact Application", *International Journal of Antennas and Propagation*, Vol. 2012, pp. 1-5, 2012.

[14] Sukhmandeep Singh, "Design and Simulation of Rectangular Microstrip Patch Antenna for C-Band Applications", *International Journal of Innovative Science, Engineering and Technology*, Vol. 2, No. 10, pp. 34-40, 2015.

[15] Yasir Ahmed, "A 31.5GHz Patch Antenna Design for Medical Implants", *International Journal of Antennas and Propagation*, Vol. 2008, pp. 1-6, 2008.

[16] Welcome to Antenna-Theory, Available at: www.antenna-theory.com.

[17] Antenna Web, Available at: www.antennaweb.org