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ANALYSIS OF MICROSTRIP PATCH ANTENNA FOR FOUR DIFFERENT SHAPES AND SUBSTRATES

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Abstract

In general, antenna is designed for transmit or receive electromagnetic waves. Among different kinds of antenna Microstrip patch antenna is most widely used antenna because of its low profile, easy fabrication and inexpensive. The microstrip patch antenna has another advantage that it can be designed for any shape. There are four different shapes are taken for this analysis. But the major problem with these antennas is narrow bandwidth. In this paper microstrip patch antenna is designed for four different shapes and substrates. The substrate materials are taken according to the dielectric constant values. And the antenna parameters such as gain, directivity, bandwidth and returnloss are variable with different shapes and substrates. Then the antenna parameters are noted and compared using Advanced Design System (ADS) software.

Keywords:

ADS, Bandwidth, MSPA, Shape, Substrate Material

1. INTRODUCTION

In general an antenna is a part of transmitting or receiving system that can transmit or receive electromagnetic waves. There are different kinds of antenna that used in several applications. Some of them are: wire antenna, aperture antenna, printed antenna, array antenna, reflector antenna, and lens antenna. Among these antennas printed antenna is fabricated using photolithography technique. Most common version of the printed antenna is microstrip antenna. It is constructed using conventional microstrip fabrication technique. Microstrip antenna consist of a radiating patch on one side of a dielectric substrate and has a ground plane on the other side.

There are three types in microstrip antenna: Microstrip patch antenna, Microstrip slot/travelling antenna and Printed dipole antenna. Among the above three types microstrip patch antenna can have any shape. Microstrip slot/travelling antenna is mostly rectangular or circular shape. Printed dipole antenna have triangular and rectangular shape. The most important thing in antenna design is to select the appropriate substrate material.

In this paper there is an analysis which gives the appropriate material for designing a microstrip patch antenna according to its application. Design microstrip patch antenna for wireless applications includes following objectives: Selection of substrate material among the four: FR-4, RO4003, GML1000 and RT/Duroid 5880. Selection of appropriate shape among the four: H-shape, E-shape, S-shape and U-shape.

2. MICROSTRIP PATCH ANTENNA

Microstrip antenna is a most common version of printed antenna. Microstrip patch antenna is one kind of microstrip antenna and it is most widely chosen among other kinds because of its different shapes. In microstrip patch antenna (MSPA), the patch is generally made of a conducting material such as copper or gold. The microstrip patch antenna can have any shape but, rectangular, circular, triangular and elliptical are some common shapes. The radiating patch and the feed lines are usually photo-etched on the dielectric substrate.

2.1 ADVANTAGES OF MSPA

- Low profile, simple and inexpensive to manufacture using modern printed circuit technology
- Mechanically robust when mounted on rigid surface
- Compatible with MMIC designs
- Conformable to planar and non-planar surfaces

2.2 SUBSTRATE MATERIAL CHANGE

In this paper, four different substrate materials are taken for designing the MSPA. FR-4, RO4003, GML1000 and RT/Duroid5880 are the four substrate materials taken according to the dielectric constant value. With changing the substrate material, the dielectric constant of the substrate changes i.e., changing the substrate material means the changing the dielectric constant (ε_r). The performance parameters such as gain, directivity and bandwidth are changed with dielectric constant. The dielectric constant values of the different substrate materials are given below.

Table.1. Dielectric constant value for different substrate material

Substrate material	Dielectric constant (ε_r)
FR-4	4.4
RO4003	3.4
GML1000	3.2
RT/Duroid5880	2.2

2.3 DIFFERENT SHAPES

Microstrip patch antenna can have any shape. In this paper, there are four shapes are taken for the MSPA design. H-shape, E-shape, S-shape and U-shape are the four different shapes discussed below. The shape variations are helpful for the compactness of the patch antenna in its applications.

For this analysis there are four different substrate materials are taken according to their dielectric constant values. FR-4, RO4003, GML1000 and RT/Duroid5880 are the four different substrate materials. And four different shapes are taken as H-shape, E-shape, S-shape and U-shape. First the microstrip patch antenna is designed for the four different substrates and shapes. Then the design is simulated using Advanced Design System (ADS) software. The antenna parameters such as gain, directivity, return loss and bandwidth are evaluated and noted on Table.1. Finally the parameters are compared with each other to find out the desirable design.

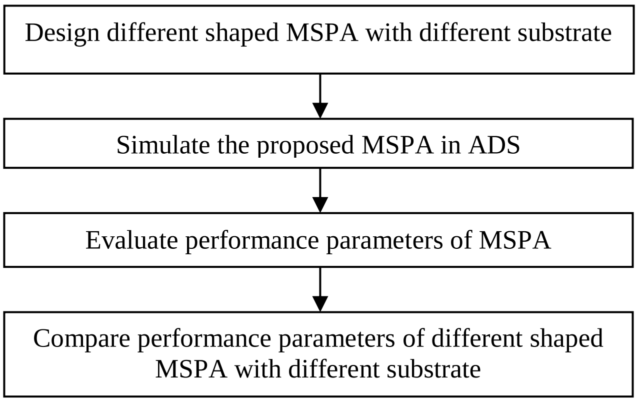

Fig.1. Block diagram of MSPA design

3. DESIGN OF PROPOSED MSPA

Step 1: Calculation of the Width (W)

$$w = \frac{c}{2 f_0 \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

Step 2: Calculation of the Effective Dielectric Constant.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + 12\frac{h}{W}}}\right] \quad (2)$$

Step 3: Calculation of the Effective length

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{eff}}} \quad (3)$$

Step 4: Calculation of the length extension ΔL

$$\Delta L = 0.412h \frac{\left(\varepsilon_{eff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{eff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \quad (4)$$

Step 5: Calculation of actual length of the patch

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

Different substrates have different dielectric constant values. So, the dimensions for different substrates are changed. The thickness of the substrate is taken as 3mm. The Operating frequency is 2.4GHz.

The proposed H-shaped MSPA design is shown below.

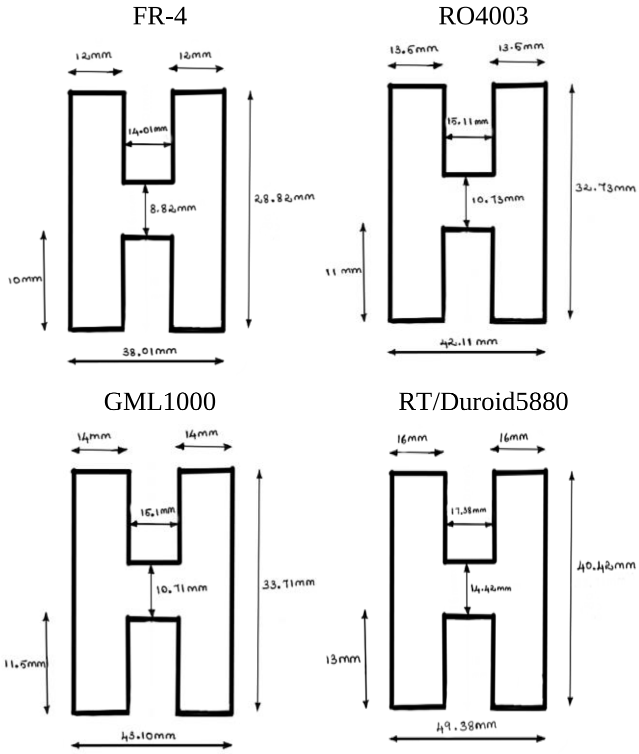

Fig.2. Geometry of H-shaped MSPA

The proposed E-shaped MSPA design is shown below.

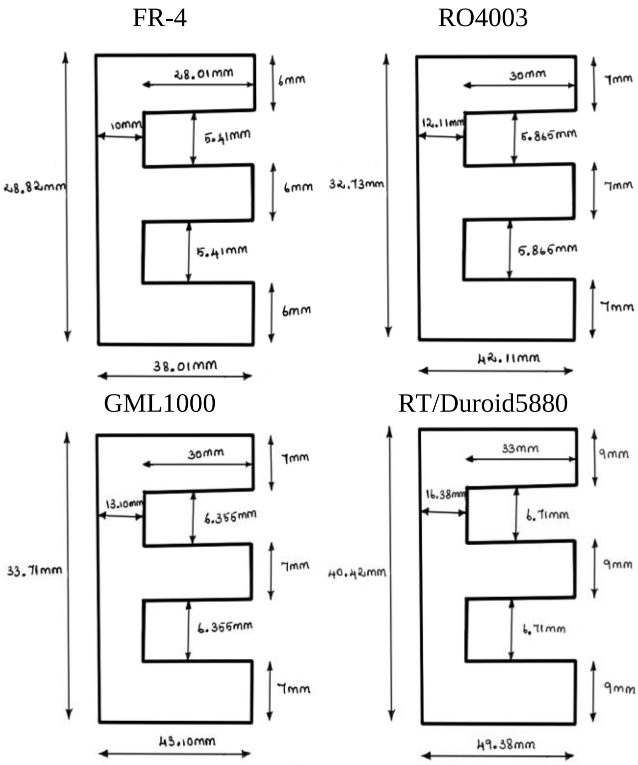

Fig.3. Geometry of E-shaped MSPA

The proposed S-shaped MSPA for different substrates is shown below.

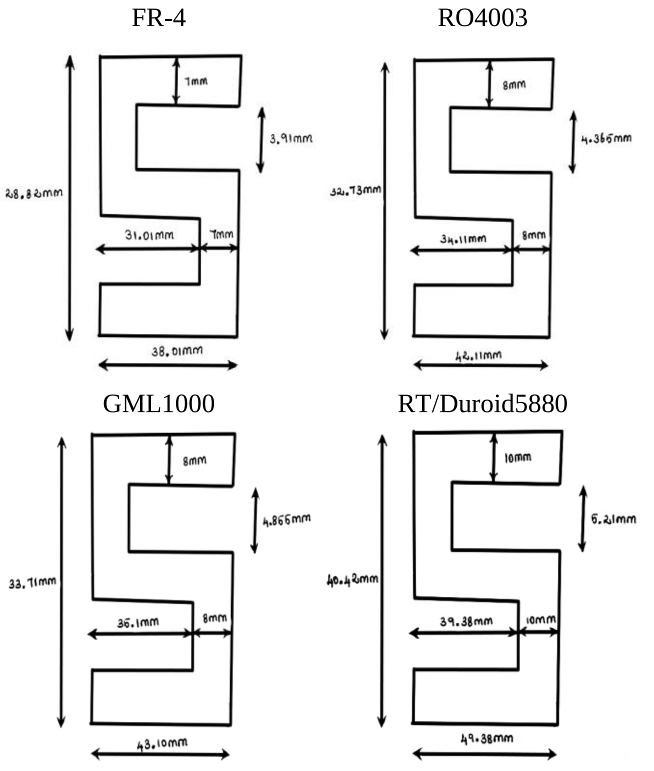

Fig.4. Geometry of S-shaped MSPA

The proposed U-shaped MSPA for different substrates is shown below.

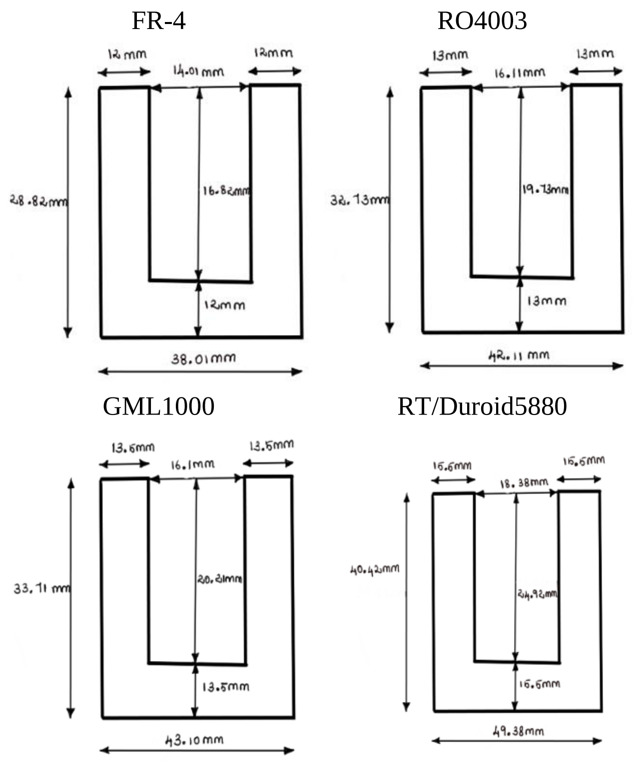

Fig.5. Geometry of U-shaped MSPA

4. RESULTS AND DISCUSSION

The MSPA is designed for four different shapes such as H-shape, E-shape, S-shape, U-shape with four different substrates such as FR-4, RO4003, GML1000 and RT/Duroid5880. The resulting gain, directivity, return loss and bandwidth are calculated.

4.1 H-SHAPED MSPA

The proposed H-shaped Microstrip patch antenna is shown below.

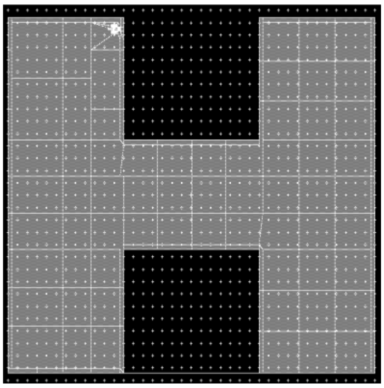

Fig.6. H-shaped MSPA

4.1.1 FR-4:

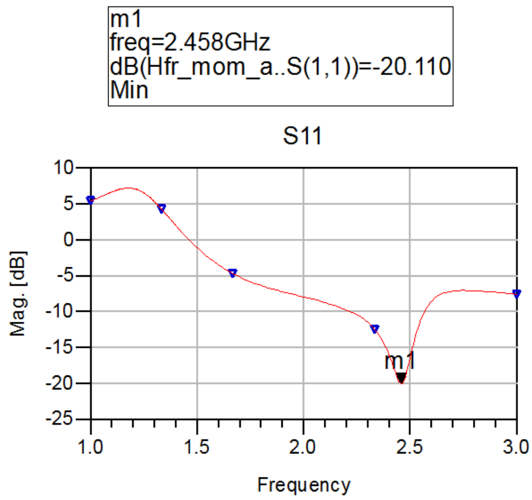

Fig.7. Bandwidth and return loss of H-shaped MSPA for FR-4 substrate

The Fig.7 shows that the 3dB Bandwidth for FR4 substrate is calculated as (2.49 - 2.41)GHz = 0.08GHz and Return loss is -20.110.

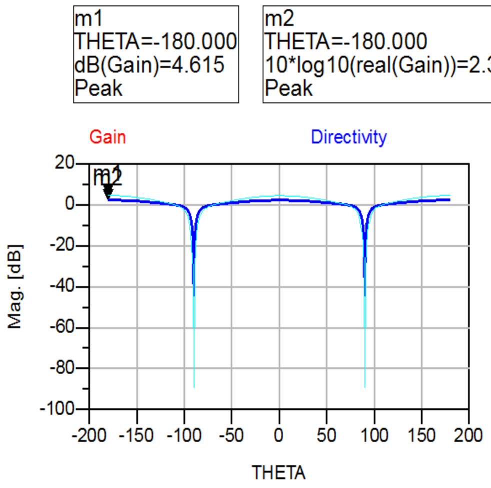

Fig.8. Gain and Directivity of H-shaped MSPA for FR-4 substrate

For the proposed H-shape MSPA, FR4 substrate gives the gain value as 4.615dB and directivity as 2.308dB.

4.1.2 RO4003:

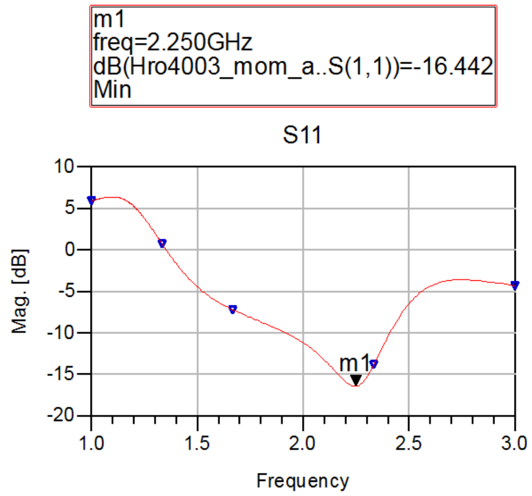

Fig.9. Bandwidth and return loss of H-shaped MSPA for RO4003 substrate

The Fig.9 shows that the 3dB Bandwidth for RO4003 substrate is calculated as (2.35 – 2.1)GHz = 0.25GHz and Return loss is -16.442.

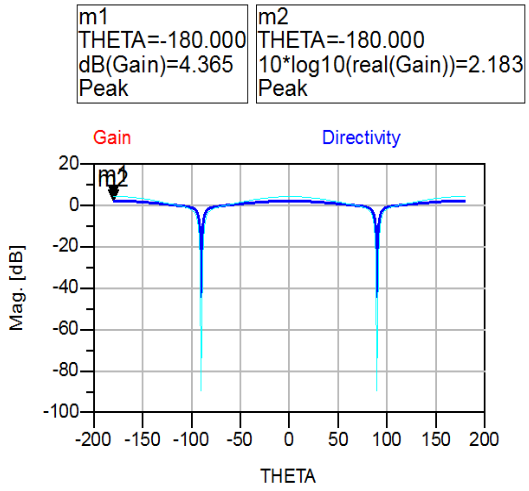

Fig.10. Gain and Directivity of H-shaped MSPA for RO4003 substrate

For the proposed H-shape MSPA, RO4003 substrate gives the gain value as 4.365dB and directivity as 2.183dB.

4.1.3 GML1000:

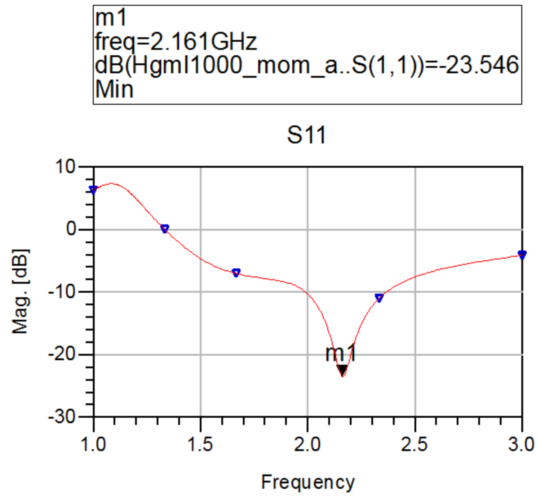

Fig.11. Bandwidth and return loss of H-shaped MSPA for GML1000 substrate

The Fig.11 shows that the 3dB Bandwidth for GML1000 substrate is calculated as (2.2 – 2.11)GHz = 0.09GHz and Return loss is -23.546.

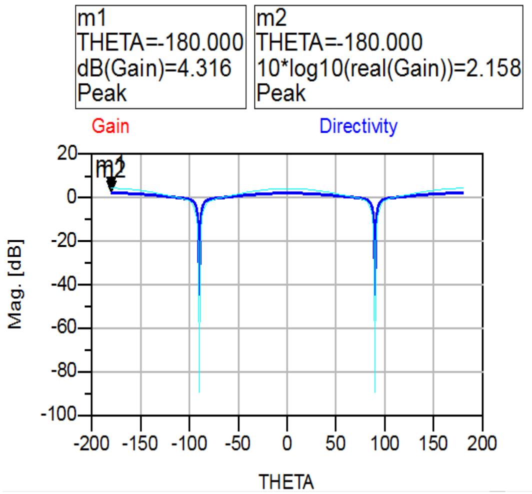

Fig.12. Gain and Directivity of H-shaped MSPA for GML1000 substrate

For the proposed H-shape MSPA, GML1000 substrate gives the gain value as 4.316dB and directivity as 2.158dB.

4.1.4 RT/Duroid 5880:

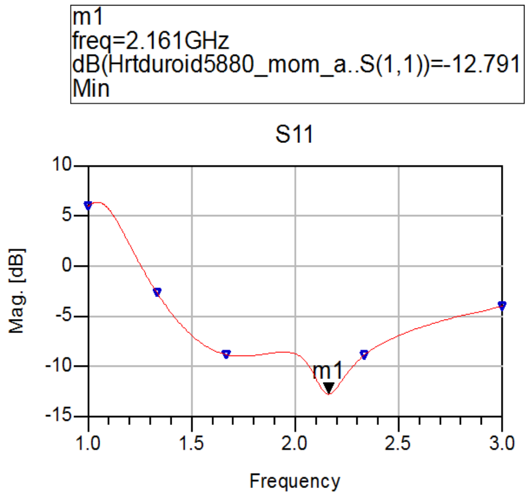

Fig.13. Bandwidth and return loss of H-shaped MSPA for RT/Duroid 5880 substrate

The Fig.13 shows that the 3dB Bandwidth for RT/Duroid 5880 substrate is calculated as (2.31 – 2.01)GHz = 0.3GHz and Return loss is -12.791.

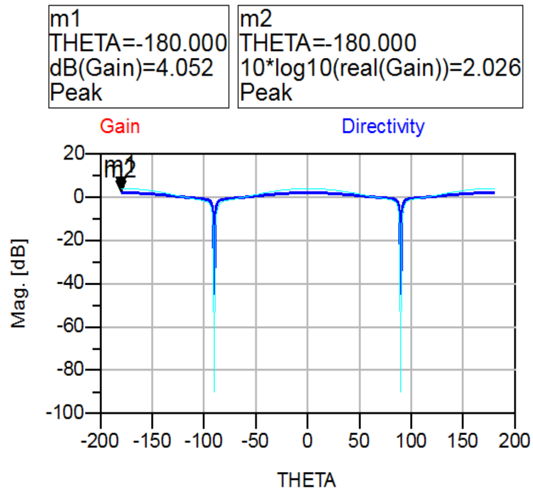

Fig.14. Gain and Directivity of H-shaped MSPA for RT/Duroid 5880 substrate

For the proposed H-shape MSPA, RT/Duroid5880 substrate gives the gain value as 4.052dB and directivity as 2.026dB.

4.2 H-SHAPED MSPA

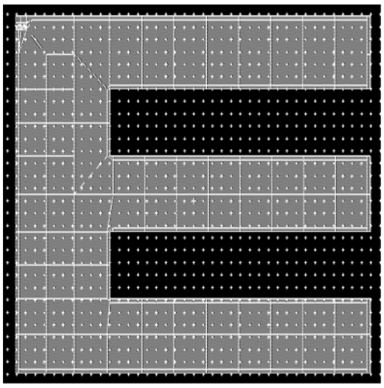

Fig.15. E-shaped MSPA

4.2.1 FR-4:

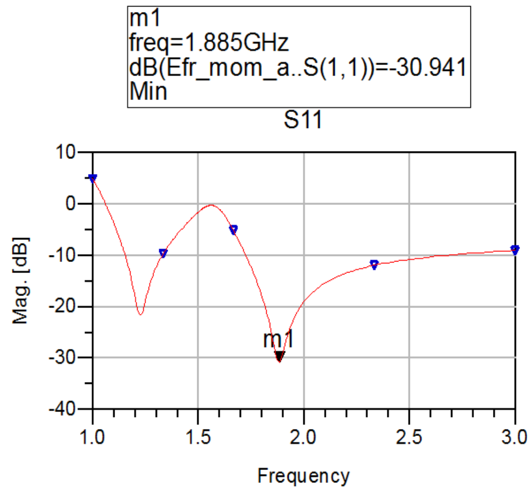

Fig.16. Bandwidth and return loss of E-shaped MSPA for FR-4 substrate

The Fig.16 shows that the 3dB Bandwidth for FR4 substrate is calculated as (1.91 – 1.85)GHz = 0.06GHz and Return loss is -30.941.

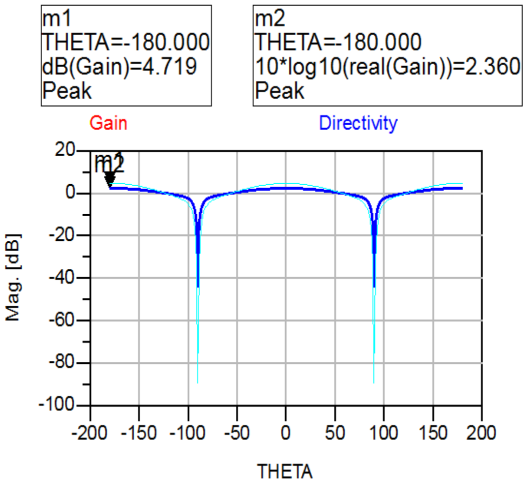

Fig.17. Gain and Directivity of E-shaped MSPA for FR-4 substrate

For the proposed E-shape MSPA, FR4 substrate gives the gain value as 4.719dB and directivity as 2.360dB.

4.2.2 RO4003:

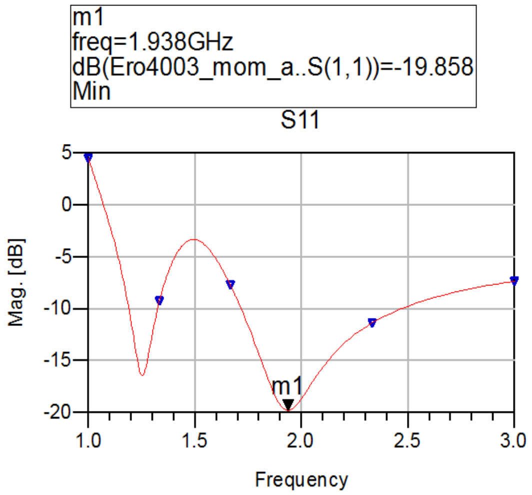

Fig.18. Bandwidth and return loss of E-shaped MSPA for RO4003 substrate

The Fig.18 shows that the 3dB Bandwidth for RO4003 substrate is calculated as (2.03 – 1.85)GHz = 0.18GHz and Return loss is -10.858.

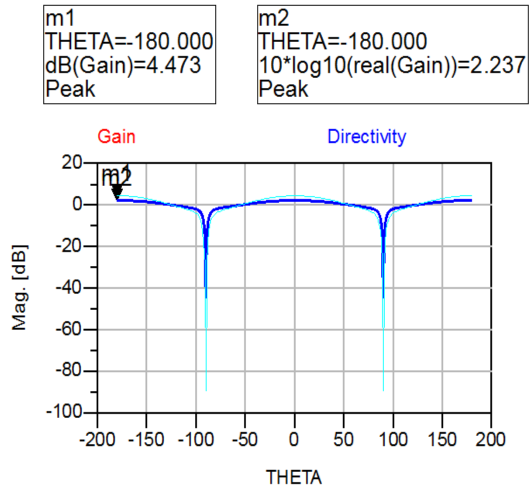

Fig.19. Gain and Directivity of E-shaped MSPA for RO4003 substrate

For the proposed E-shape MSPA, RO4003 substrate gives the gain value as 4.473dB and directivity as 2.237dB.

4.2.3 GML1000:

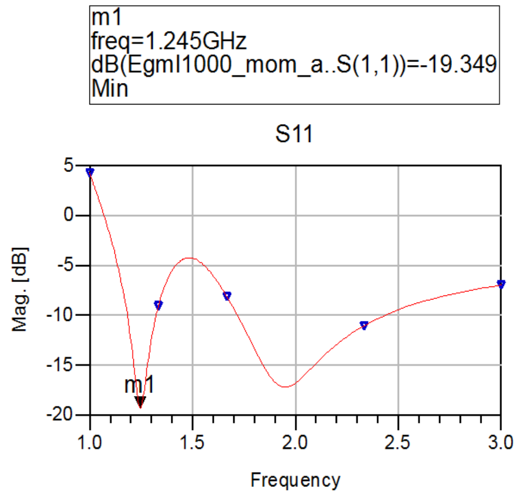

Fig.20. Bandwidth and return loss of E-shaped MSPA for GML1000 substrate

The Fig.20 shows that the 3dB Bandwidth for GML1000 substrate is calculated as (1.38 - 1.31)GHz = 0.07GHz and Return loss is -19.349.

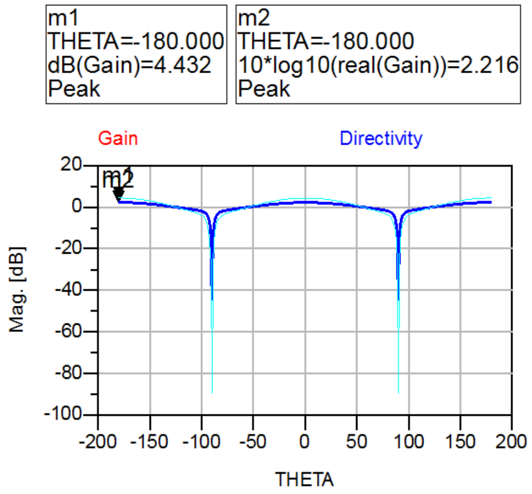

Fig.21. Gain and Directivity of E-shaped MSPA for GML1000 substrate

For the proposed E-shape MSPA, GML1000 substrate gives the gain value as 4.432dB and directivity as 2.216dB.

4.2.4 RT/Duroid 5880:

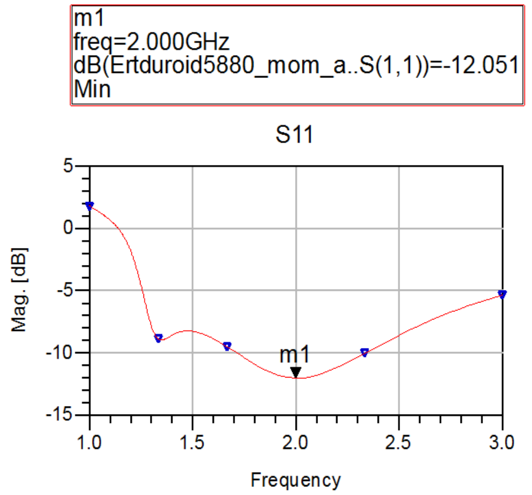

Fig.22. Bandwidth and return loss of E-shaped MSPA for RT/Duroid 5880 substrate

The Fig.22 shows that the 3dB Bandwidth for RT/Duroid 5880 substrate is calculated as (2.45 – 1.6)GHz = 0.85GHz and Return loss is -12.051.

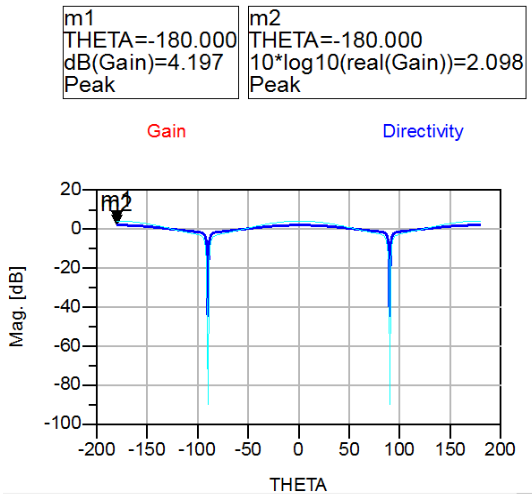

Fig.23. Gain and Directivity of E-shaped MSPA for RT/Duroid 5880 substrate

For the proposed E-shape MSPA, RT/Duroid5880 substrate gives the gain value as 4.197dB and directivity as 2.098dB.

4.3 S-SHAPED MSPA

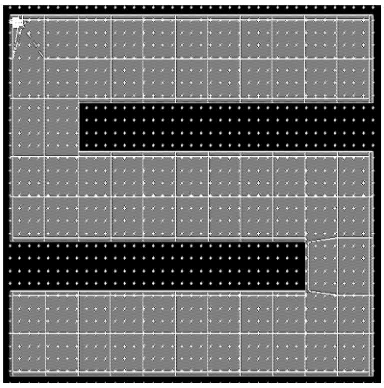

Fig.24. S-shaped MSPA

4.3.1 FR-4:

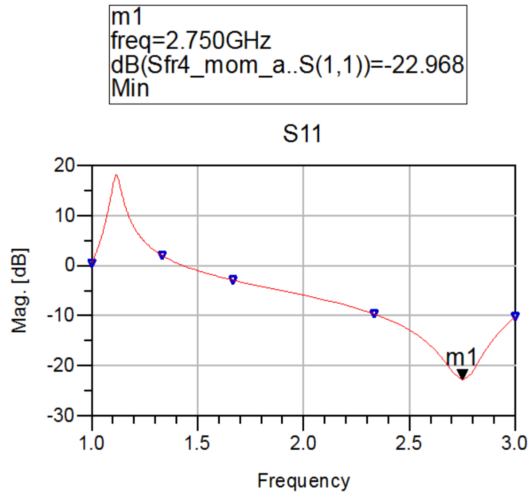

Fig.25. Bandwidth and return loss of S-shaped MSPA for FR-4 substrate

The Fig.22 shows that the 3dB Bandwidth for FR4 substrate is calculated as (2.81 – 2.69)GHz = 0.12GHz and Return loss is -22.968.

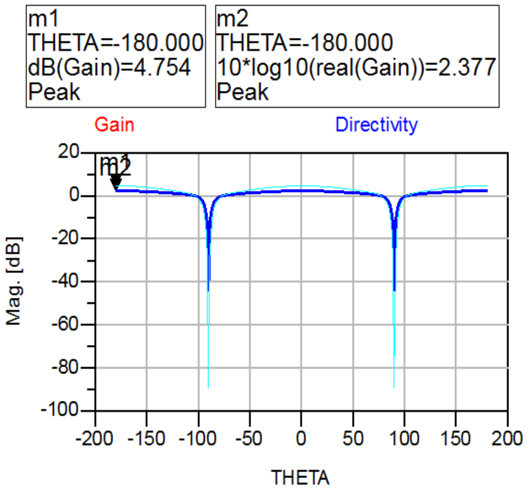

Fig.26. Gain and Directivity of S-shaped MSPA for FR-4 substrate

For the proposed S-shape MSPA, FR4 substrate gives the gain value as 4.754dB and directivity as 2.377dB.

4.3.2 RO4003:

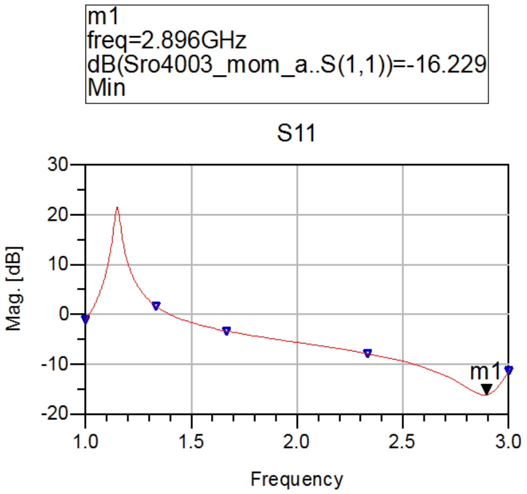

Fig.27. Bandwidth and return loss of S-shaped MSPA for RO4003 substrate

The Fig.27 shows that the 3dB Bandwidth for RO4003 substrate is calculated as (2.98 – 2.74)GHz = 0.24GHz and Return loss is -16.229.

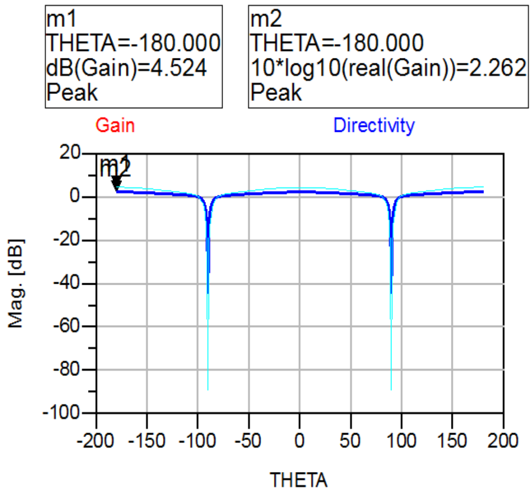

Fig.28. Gain and Directivity of S-shaped MSPA for RO4003 substrate

For the proposed S-shape MSPA, RO4003 substrate gives the gain value as 4.524dB and directivity as 2.262dB.

4.3.3 GML1000:

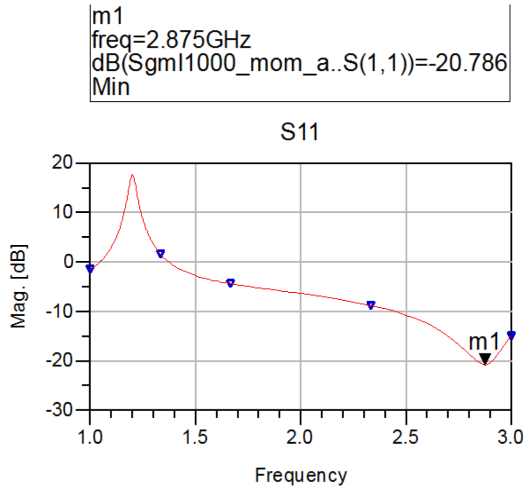

Fig.29. Bandwidth and return loss of S-shaped MSPA for GML1000 substrate

The Fig.29 shows that the 3dB Bandwidth for GML1000 substrate is calculated as (2.96 – 2.78)GHz = 0.18GHz and Return loss is -20.786.

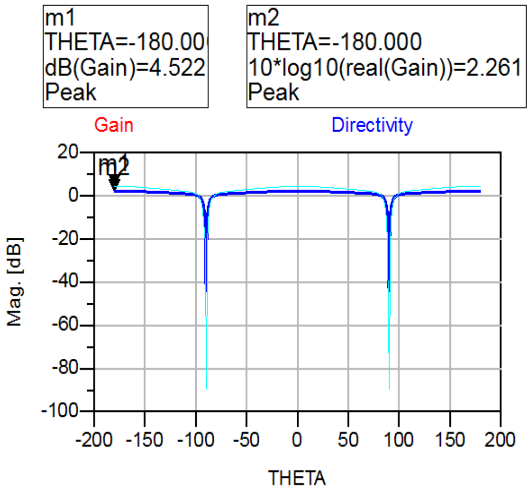

Fig.30. Gain and Directivity of S-shaped MSPA for GML1000 substrate

For the proposed S-shape MSPA, GML1000 substrate gives the gain value as 4.522dB and directivity as 2.261dB.

4.3.4 RT/Duroid 5880:

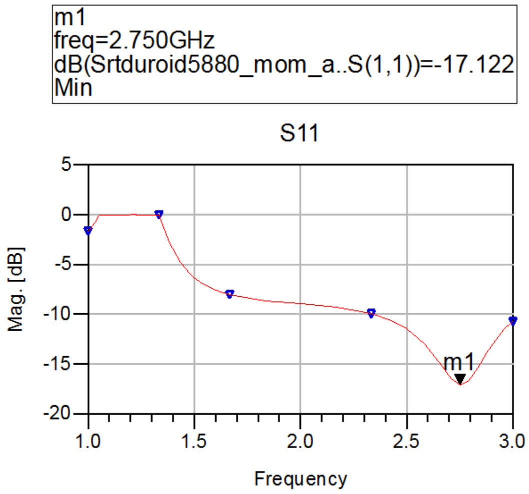

Fig.31. Bandwidth and return loss of S-shaped MSPA for RT/Duroid 5880 substrate

The Fig.31 shows that the 3dB Bandwidth for RT/Duroid 5880 substrate is calculated as (2.89 – 2.6)GHz = 0.29GHz and Return loss is -17.122.

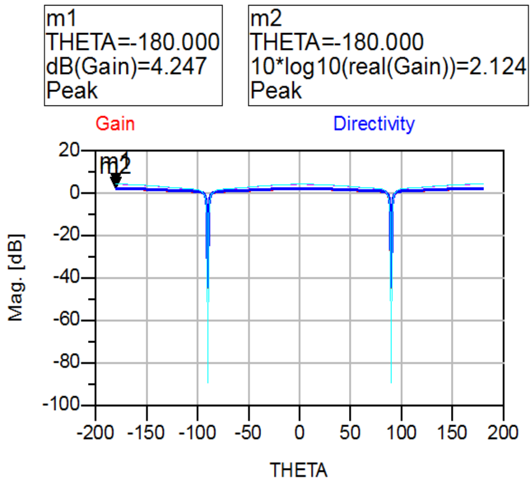

Fig.32. Gain and Directivity of S-shaped MSPA for RT/Duroid 5880 substrate

For the proposed S-shape MSPA, RT/Duroid5880 substrate gives the gain value as 4.247dB and directivity as 2.124dB.

4.4 U-SHAPED MSPA

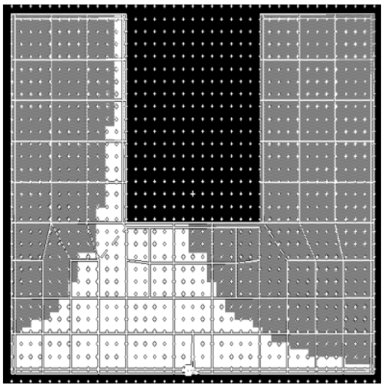

Fig.33. U-shaped MSPA

4.4.1 FR-4:

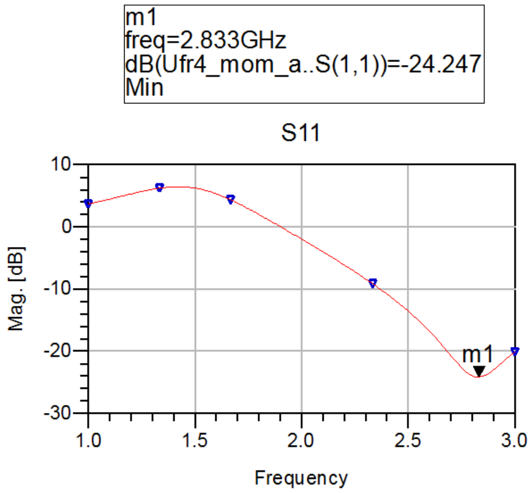

Fig.35. Bandwidth and return loss of U-shaped MSPA for FR-4 substrate

The Fig.35 shows that the 3dB Bandwidth for FR4 substrate is calculated as (2.96 – 2.7)GHz = 0.26GHz and Return loss is -24.247.

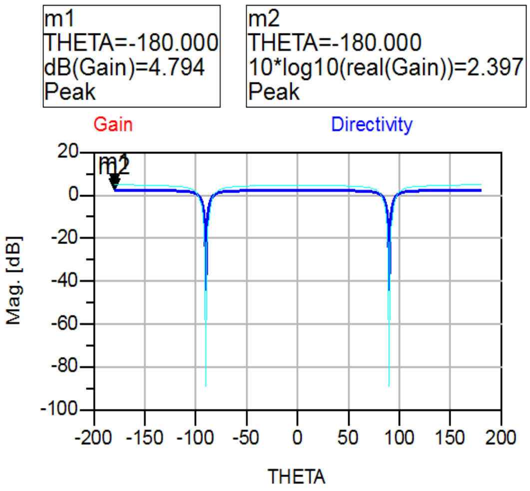

Fig.35. Gain and Directivity of U-shaped MSPA for FR-4 substrate

For the proposed U-shape MSPA, FR4 substrate gives the gain value as 4.794dB and directivity as 2.397dB.

4.4.2 RO4003:

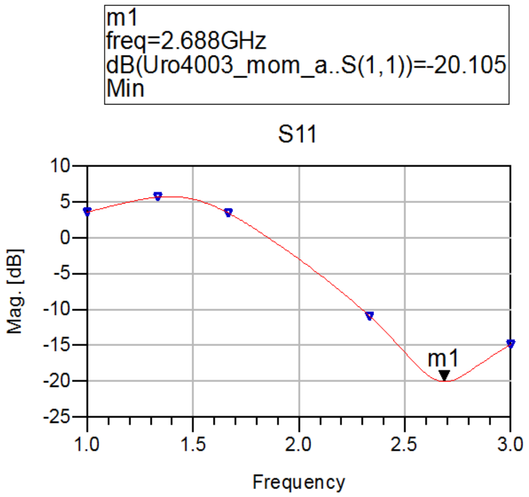

Fig.36. Bandwidth and return loss of U-shaped MSPA for RO4003 substrate

The Fig.36 shows that the 3dB Bandwidth for RO4003 substrate is calculated as (2.89 – 2.52)GHz = 0.37GHz and Return loss is -20.105.

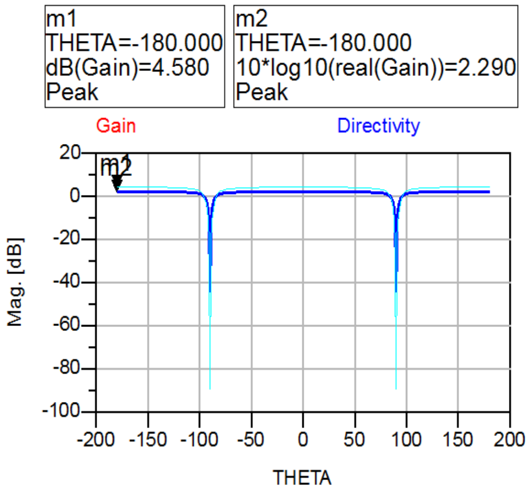

Fig.37. Gain and Directivity of U-shaped MSPA for RO4003 substrate

For the proposed U-shape MSPA, RO4003 substrate gives the gain value as 4.580dB and directivity as 2.290dB.

4.4.3 GML1000:

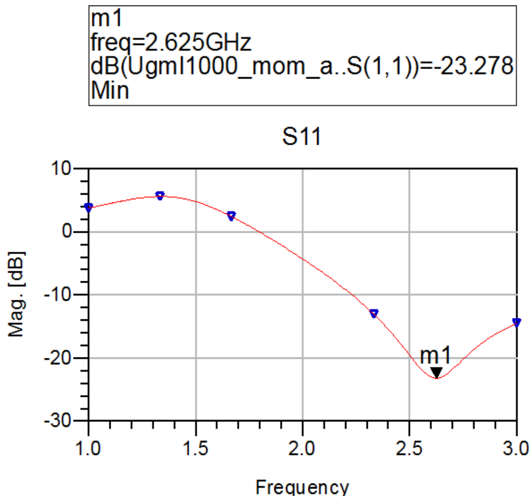

Fig.38. Bandwidth and return loss of U-shaped MSPA for GML1000 substrate

The Fig.38 shows that the 3dB Bandwidth for GML1000 substrate is calculated as (2.77 – 2.5)GHz = 0.27GHz and Return loss is -23.278.

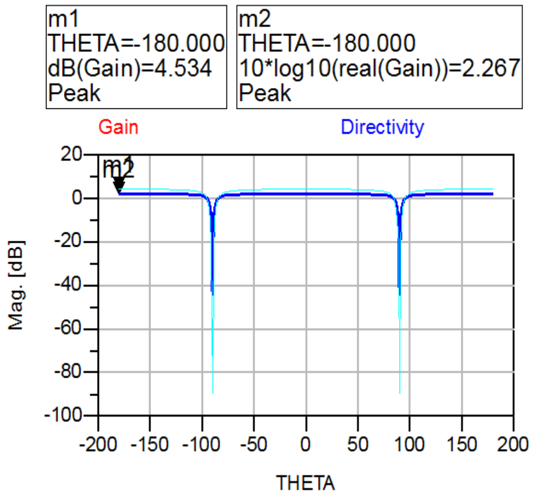

Fig.39. Gain and Directivity of U-shaped MSPA for GML1000 substrate

For the proposed U-shape MSPA, GML1000 substrate gives the gain value as 4.534dB and directivity as 2.267dB.

4.4.4 RT/Duroid 5880:

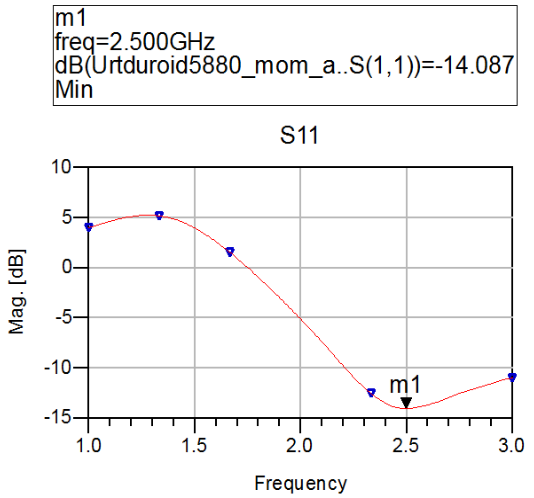

Fig.40. Bandwidth and return loss of U-shaped MSPA for RT/Duroid 5880 substrate

The Fig.40 shows that the 3dB Bandwidth for RT/Duroid 5880 substrate is calculated as (3 – 2.25)GHz = 0.75GHz and Return loss is -14.087.

For the proposed U-shape MSPA, RT/Duroid5880 substrate gives the gain value as 4.358dB and directivity as 2.179dB.

4.5 PERFORMANCE ANALYSIS OF MSPA FOR DIFFERENT SHAPES AND SUBSTRATES

The Table.2 shows the performance parameters of microstrip patch antenna for four different shapes as H-shape, E-shape, S-shape and U-shape with different substrates as FR-4, RO4003, GML1000 and RT/Duroid5880. Gain, Directivity, Return loss and bandwidth are taken as the performance parameters. The highest gain, directivity, bandwidth values are highlighted in the Table.2. And minimum returnloss is also highlighted in the Table.2.

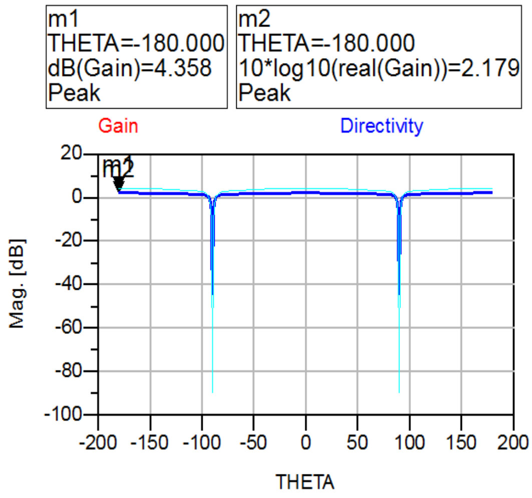

Fig.41. Gain and Directivity of U-shaped MSPA for RT/Duroid 5880 substrate

Table.2. Performance analysis of different shaped MSPA for different substrates

Shape	Substrate Materials	Gain (dB)	Directivity (dB)	Return Loss	Band width (GHz)
H-shape	FR-4	4.615	2.308	-20.110	0.08
	RO4003	4.365	2.183	-16.442	0.25
	GML1000	4.316	2.158	-23.546	0.09
	RT/Duroid 5880	4.052	2.026	-12.791	0.3
E-shape	FR-4	4.719	2.360	-30.941	0.06
	RO4003	4.473	2.237	-19.858	0.18
	GML1000	4.432	2.216	-19.349	0.07
	RT/Duroid 5880	4.197	2.098	-12.051	0.85
S-shape	FR-4	4.754	2.377	-22.968	0.12
	RO4003	4.524	2.262	-16.229	0.24
	GML1000	4.522	2.261	-20.786	0.18
	RT/Duroid 5880	4.247	2.124	-17.122	0.29
U-shape	FR-4	4.794	2.397	-24.247	0.26
	RO4003	4.580	2.290	-20.105	0.37
	GML1000	4.534	2.267	-23.278	0.27
	RT/Duroid 5880	4.358	2.179	-14.087	0.75

5. CONCLUSION

The proposed microstrip patch antenna was designed using four different substrate materials such as FR-4, RO4003, GML1000, RT/Duroid5880 and four different shapes such as H-shape, E-shape, S-shape, U-shape. The performance parameters such as gain, directivity, bandwidth and returnloss were noted for different shapes and substrate materials. The proposed methodology revealed better performance in RT/Duroid5880 substrate material in terms of bandwidth and gives better gain in FR-4 substrate material for any shape. From this analysis it was found that the substrate materials which have lower dielectric constant values have provide the better bandwidth and the substrate materials which have higher dielectric constant values have provide the better gain and directivity.

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