International Journal of Electronics and Communication Engineering.
ISSN 0974-2166 Volume 4, Number 2 (2011), pp.161-170
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Comparative Study of Microstrip Rectangular Patch Array Antenna on Liquid Crystal Polymer and Rt-Duroid Substrates

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Abstract

Microstrip rectangular patch array antenna was designed and comparative study is done on two promising materials namely liquid crystal and RT-duroid substrates. The antenna parameters are simulated using commercial Ansoft HFSS software and the detailed explanation of performance evaluation is presented. A 4x4 rectangular patch array was designed on two substrate materials and their return loss, input impedance, gain, radiation patterns and antenna parameters are studied at 10GHz and presented in this paper. The applicability of the rectangular patch array antennas on these two substrate materials are discussed regarding the applications, cost, weight and performance.

Keywords: Microstrip rectangular patch array, Liquid crystal polymer substrate, RT-duroid substrate.

Introduction

The microstrip patch antennas are widely used antennas in different applications in these days due to their advantages like low weight, low cost, low volume and ease of fabrication. The main drawback is that, they are having narrow bandwidth [1-3].

Microstrip patch antennas are having three main objects for their construction namely ground plane, substrate and patch element. In the antenna design the substrate material and its physical parameters play a vital role [4-5]. There are different substrate materials that are available with different dielectric constant and dielectric loss tangent values. Two substrate materials performance in the design of rectangular patch array antenna is discussed here and their output parameters are given.

Substrates

Liquid crystal polymer (LCP)

LCP is an emerging dielectric microwave flexible substrate material and it is cheaper than other available dielectric materials. LCP is having dielectric constant of 2.9 to 3.2 for f<105GHz and having low loss tangent between 0.002 to 0.0045. LCP is having low moisture absorption and it offers excellent thermal, mechanical, electronic and chemical properties. So in this present work we selected LCP substrate material of dielectric constant 2.91 and loss tangent of 0.0032[6-8].

RT-duroid

RT/duroid 5880LZ filled PTFE composites are designed for exacting stripline and microstrip circuit applications. The RT-duroid is a low density, lightweight material for high performance weight sensitive applications. The very low dielectric constant of RT/duroid 5880LZ laminates is uniform from panel to panel and is constant over a wide frequency range. Applications include Airborne antenna system, lightweight feed networks**,** Military radar systems**,** Missile guidance systems and Point-to-point digital radio antennas. The RT-duroid substrate of dielectric constant 2.2 and loss tangent of 0.0009 is taken in this present work.

Antenna design specification

Microstrip rectangular patch array antenna was simulated at 10GHz frequency with patch dimensions 7mm and 3mm along X and Y directions respectively. For both LCP and RT -duroid substrates the thickness is taken as 1.6mm with dimensions 30mm along X and Y axis respectively. The coaxial inner radius, outer radius and feed length are 0.25mm, 0.85mm and 2.5mm respectively. And the feed location taken along Y direction is 3 mm. figures (1) and figure (2) shows the 4x4 patch array on Liquid crystal polymer substrate and RT-duroid substrate. Coaxial feeding is used in this designing and all the patches are connected to the central coaxial feeding as shown in the figures. The probe position is inset for matching the patch impedance with the input impedance. This type of insetting is easy and minimizes the probe radiation [9-10].

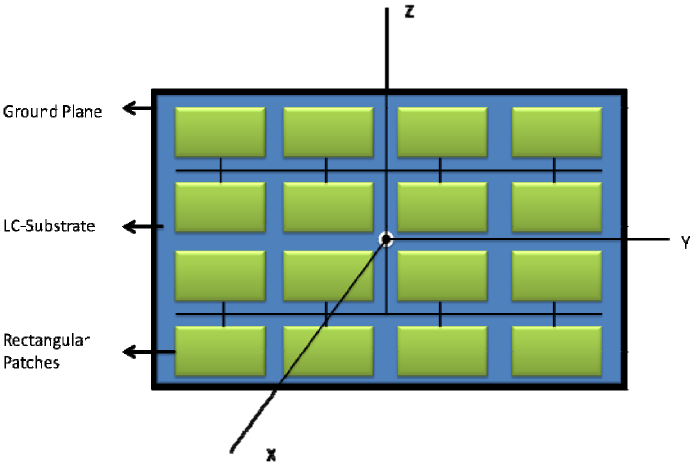

Figure 1: 4x4 patch array on LCP substrate.

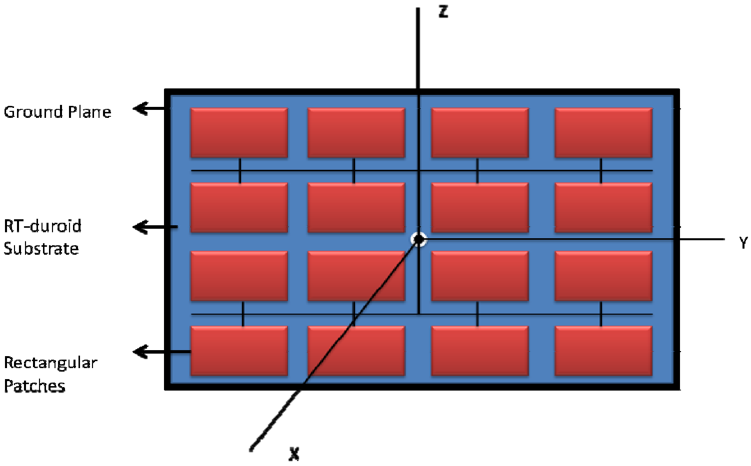

Figure 2: 4x4 patch array on RT-duroid substrate.

Results and analysis

Figure (3) shows the return loss curve for the antenna on liquid crystal polymer substrate and RT-duroid substrate. By using the LCP substrate a return loss of -31.2dB and by using the RT-duroid substrate a return loss of -29.4dB is obtained. The LC-substrate antenna is giving better return loss compared with the RT-duroid substrate antenna. The VSWR curve shown in figure (4) indicates the standing wave ratio for both the substrates. A VSWR of 1.4 for LCP substrate and 1.6 for RT-duroid substrate is giving VSWR<2.

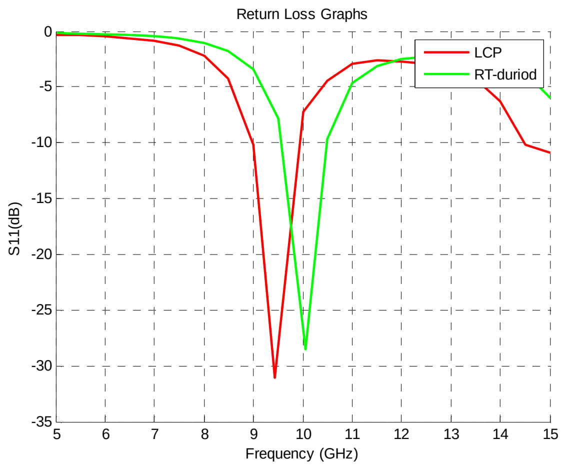

Figure 3: Return loss curve.

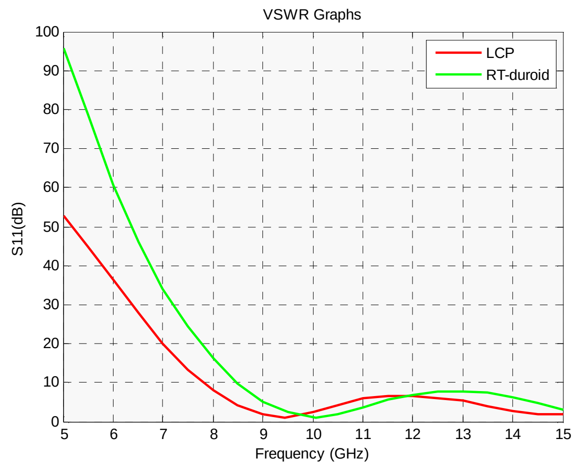

Figure 4: VSWR curve.

Figure (5.1) and figure (5.2) shows the input impedance smith chart for the antenna on LCP substrate and RT-duroid substrate.

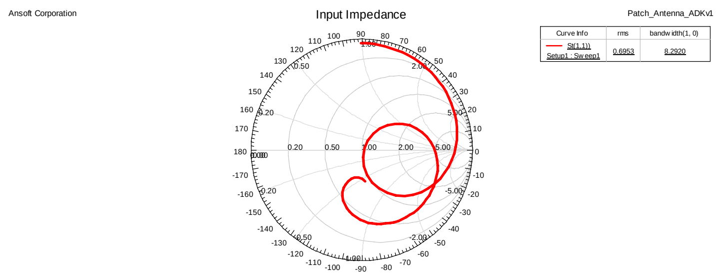

Figure 5.1: input impedance for LCP-substrate.

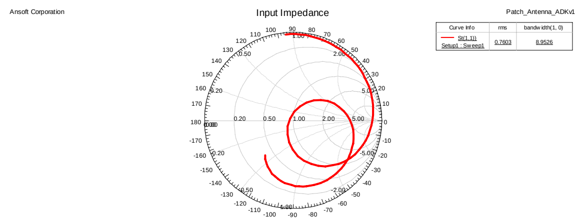

Figure 5.2: input impedance for RT-duroid substrate.

The rms and bandwidth obtained from the input impedance smith chart of figure (5.1) are 0.695 and 8.29. Whereas the rms and bandwidth obtained from figure (5.2) are 0.7603 and 8.95. By comparing these two parameters the RT-duroid material used antenna is giving slight marginal better values than LC-Substrate used antenna. The phase margin, gain cross over and upper cutoff values for both the materials are tabulated in the table (1).

Table 1: parameters obtained from input impedance smith chart.

S.No.	Quantity	For LC Substrate €= 2.91, δ=0.0032	For RT Duriod substrate €=2.2, δ=0.0009
1	Rms value	0.695	0.7603
3	Phase margin	270.40	274.98
4	Gain cross over	5.00	5.00
6	Upper cut off	8.29	8.95
7	Band width	8.29	8.95
8	Gain	10.61	12.03

Figure 6.1: 3D gain of antenna for LCP-Substrate.

Figure 6.2: 3D gain of antenna for RT-duroid substrate.

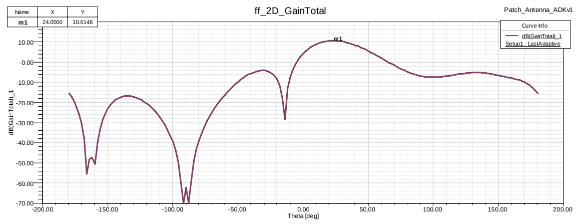

Figure 7.1: 2D gain of antenna for LCP-Substrate.

Figure 7.2: 2D gain of antenna for RT-duroid Substrate.

Figure (6.1) and (6.2) shows the 3D gain of the antenna for LCP-substrate and RT-duroid substrate. Figure (7.1) and (7.2) shows the 2D gain of antenna for LCP-substrate and RT-duroid substrate. The gain of 10.61dB is obtained by using the LCP-substrate and a gain of 12.03dB is obtained by using the RT-duroid substrate. The gain factor is increased by 2 percent by choosing the material RT-duroid instead of LCP-substrate in the designing of the antenna at 10GHz.

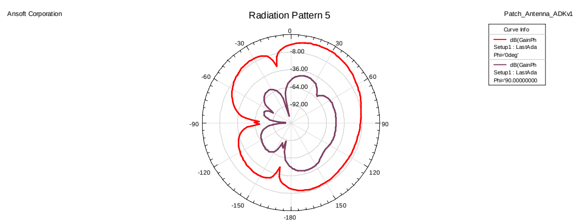

Figure 81: gain phi for LCP Antenna.

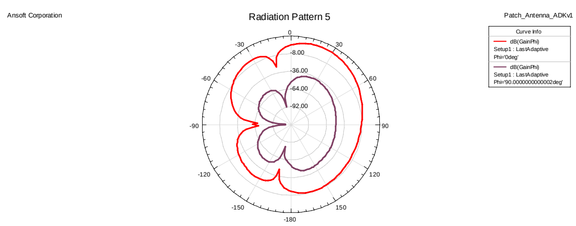

Figure 8.2: gain phi for RT-duroid Antenna.

Figure (8.1) and (8.2) shows the gain phi at 0^0, 90^0 for proposed antenna on LCP substrate and RT-duroid substrate. From the figures it is clear that the patterns are broad sided and linearly polarized. Similarly Figure (9.1) and (9.2) shows the gain theta at 0^0, 90^0 for proposed antenna on LCP substrate and RT-duroid substrate. As per the radiation pattern is considered both the antennas with different substrate materials are showing good results.

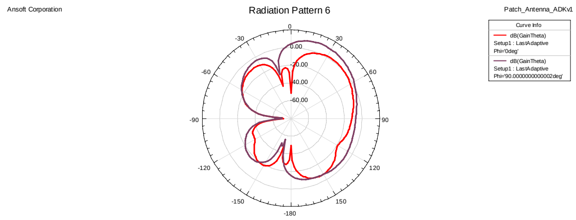

Figure 9.1: gain theta for LCP Antenna.

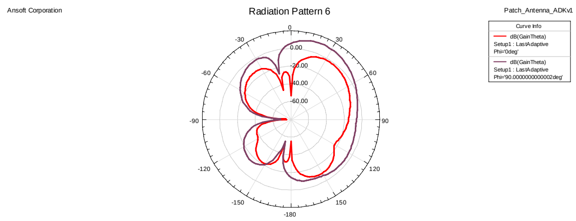

Figure 9.2: gain theta for RT-duroid Antenna.

The antenna parameters and their maximum field data are obtained from the simulation results and they are tabulated in the table (2) and table (3).

Table 2: Antenna parameters at 10GHz.

S.No	Quantity	For LC Substrate Єr= 2.91, δ=0.0032	For RT-duroid substrate Єr=2.2, δ=0.0009
1	Max U	0.254 w/sr	0.832 w/sr
2	Peak Directivity	57.77	59.79
3	Peak gain	44.01	59.53
4	Peak realized gain	36.78	59.34
5	Radiated power	0.055 w	0.174 w
6	Accepted power	0.072 w	0.175 w
7	Incident power	0.086 w	0.176 w
8	Radiation efficiency	0.761	0.995
9	Front to back ratio	3.14E+005	2.20E+005

Considerable amount of peak directivity, peak gain and peak realized gain can be noticed from the simulation results. When RT-duroid substrate material is used then these parameters are giving better values compared with the LCP substrate. When it comes to the radiated, accepted and incident power the LCP substrate is preferable. The radiation efficiency is also greater for RT-duroid antenna over the LCP substrate antenna.

Table (3) is giving the maximum field data values that are simulated from the Ansoft HFSS. The rE-field values are also showing good agreement for the RT-duroid substrate material antenna instead of LCP substrate material antenna. The LHCP and RHCP 15.22 and 20.15 are obtained with RT-duroid, whereas 7.61 and 11.87 are obtained in the case of LCP substrate material antenna.

Table 3: maximum field data.

Maximum field data values at 10G							
		For LC substrate ϵ_r=2.91, δ=0.0032			For RT Duroid ϵ_r=2.2, δ=0.0009		
S.No	rE field	Value (v)	At Phi (degrees)	At Theta (degrees)	Value (v)	At Phi (degrees)	At Theta (degrees)
1	Total	13.85	45	32	25.05	45	32
2	X	4.22	35	38	5.11	40	40
3	Y	12.07	45	28	22.48	45	28
4	Z	7.63	50	44	13.59	50	44
5	Phi	9.02	25	26	17.38	25	28
6	Theta	12.20	55	32	21.93	55	32
7	LHCP	7.67	55	28	15.22	50	28
8	RHCP	11.81	40	34	20.15	45	34

Conclusion

The microstrip rectangular patch array was tested for both the substrate materials of LCP substrate and RT-duroid. As per the cost is concerned the LCP substrate antenna is cheaper than the RT-duroid antenna when we go for fabrication, but as per the performance is concerned there is a slight difference in the antenna parameters. The RT-duroid substrate antenna is having good gain, directivity and bandwidth values in compared with LCP substrate antenna. As the dielectric constant value increases the size of the antenna will be decreases and as well as its efficiency, whereas the dielectric constant value decreases the size increases as well as efficiency. So here the LCP substrate is having slight greater dielectric constant value compared with RT-duroid. Both the substrate materials are having advantages and disadvantages as per the applications are concerned.

Acknowledgments

The authors B.T.P.Madhav, Prof. VGKM Pisipati, Prof. Sarat Kumar, Prof. Habibulla Khan and D. Rakesh, Anusha, Atulya and Sreyash like to express their thanks to the department of ECE and management of K L University for their continuous support and encouragement during this work. Further, VGKM Pisipati acknowledges the financial support of Department of Science and Technology through the grant No.SR/S2/CMP-0071/2008.

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