International Journal Of
Recent Scientific
Research
ISSN: 0976-3031
Volume: 7(11) November -2015

PERFORMANCE ANALYSIS OF CIRCULAR PATCH ANTENNA USING DIFFERENT HYBRID SUBSTRATES

Lyrin K Vincent, Lekshmi B S and Basil K Jeemon

THE OFFICIAL PUBLICATION OF
INTERNATIONAL JOURNAL OF RECENT SCIENTIFIC RESEARCH (IJRSR)
http://www.recentscientific.com/ recentscientific@gmail.com

Available Online at http://www.recentscientific.com

ISSN: 0976-3031

International Journal of Recent Scientific Research
Vol. 6, Issue, 11, pp. 7300-7303, November, 2015

International Journal of Recent Scientific Research

RESEARCH ARTICLE

PERFORMANCE ANALYSIS OF CIRCULAR PATCH ANTENNA USING DIFFERENT HYBRID SUBSTRATES

Lyrin K Vincent*, Lekshmi B S and Basil K Jeemon

Department of Electronics and Communication, FISAT, Kerala, India

ARTICLE INFO

Article History:

Received 16th August, 2015
Received in revised form 24th September, 2015
Accepted 23rd October, 2015
Published online 28st November, 2015

Key words:

Patch antenna, Antenna gain, Ferrite ring, hybrid substrate

ABSTRACT

This paper introduces circular micro strip patch antenna using hybrid substrate and performance analysis of circular micro strip patch antenna using different hybrid substrate. Here comparing the gain to show better performance analysis on the basis of design and simulation results by circular patch antenna without ferrite ring and with ferrite around patch at operating frequency of 5.8 GHz. The ferrite ring of width d2 is placed at distance d1 from circumference of patch. The ferrite ring with relative permeability of μ_{r2}=14 , relative permittivity of ε_{r2}=10, dielectric loss tangent tanδ_e=0.0017 and magnetic loss tangent tanδ_m=0.0391 , is used. The proposed antenna attained a gain about 8dBi which means there is enhancement of 4dBi in gain than conventional substrate. Three hybrid substrate materials such as polymide quartz,TMM4 and Bakelite is used for analyzing antenna gain and FR4 is also used as special case .All the simulation is carried out by HFSS software.

INTRODUCTION

Microstrip Patch antennas is type of antenna which have metallic patch on the top of dielectric substrate and ground plane on the bottom of substrate. Microstrip Patch antennas having advantages light weight, low volume, low fabrication cost,handle both linear and circular polarizations. So it can have wide range of applications in mobile communication, satellite communication etc. When antenna is connected to an external energy source to energize the antenna, patch can radiates waves in all direction. The waves which is travelling into the substrate are called as surface waves. These do not contribute into the main radiation, so some of the energy lost in these direction. The surface waves presence inside the substrate will limit maximum achievable gain[1].So along the advantages of patch antenna, disadvantages like lower gain limited to 4-8dB, surface wave losses when substrate thickness >1mm and narrow bandwidth are also affected.

Several approaches are developed for increasing the gain with decrease of bandwidth. Surface wave losses, dielectric losses and conductor losses degrades the performance of microstrip patch antennas in terms of gain and directivity . Lot of work is carried out to overcome these three types of losses. By using better quality of the substrate and conducting materials will minimize dielectric and conductor losses. Surface wave losses can be reduced by using high impedance surfaces such as electromagnetic and photonic band gap structures [3] that allow and forbid the electromagnetic waves in certain frequency band. The other methods which reduces the surface wave losses are by using superstrates [4], surface mounting horn etc. But limitation features of these techniques was fabrication difficulties because these techniques requires a large number of holes and vias. compact nested tridimensional split-ring resonators (SRRs) are embedded in low temperature co-fired ceramic (LTCC) substrate integrated with a single patch antenna to improve the gain. The SRRs generate an effective magnetic response and give rise to negative effective permeability, which can be designed as a metamaterial insulator to reflect surface waves in order to improve the gain. It can be seen that the proposed negative permeability metamaterial has little effect on the resonance frequency and bandwidth[5].

In this paper, comparing the performance of antenna to enhancing the gain using different hybrid substrates. To provide hybrid structure a unbiased ferrite ring is introduced between original substrate So here we propose to reducing the surface propagation into the substrate by placing ferrite ring into the substrate to enhance the gain without compromising the bandwidth. The gain is compared for different hybrid materials.

*Corresponding author: **Lyrin K Vincent**
Department of Electronics and Communication, FISAT, Kerala, India

Design Of Proposed Antenna

The characteristics of the substrate can be modified by using two or more materials in order to design the proposed antenna. Thereby reducing the surface wave propagation in the substrate. The basic idea behind this is When a wave incident on the interface between two materials, part of the energy is transmitted, and some of get reflected[6]. Then create constructive or destructive interferences by combining reflections, with the incident field. The formation of constructive or destructive interferences depends on the characteristics of the materials. So our proposed antenna used this basic concept and applied into the design to reflect the surface waves. These reflected field is enhancing gain by reducing the propagation of surface wave into the substrate and proposed antenna is shown in figure 1.

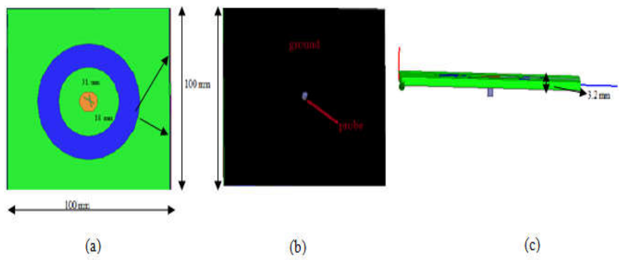


Figure 1 (a) Top view, (b) Bottom view, (c) Side view

The antenna is designed at frequency of 5.8GHz.The conventional dielectric is placed above the ground and ferrite ring has same thickness as that of substrate. As can be seen from the fig.1, that circular patch is surrounded by a ferrite ring at a distance of d1 from patch with ferrite ring width of d2. The values *d1* and *d2* are chosen as one-quarter of free space wavelength (*d1*=*d2*=λ0/4)from edges of the circular patch. Two interfaces are created between the dielectric and the ferrite. The first interface is dielectric-ferrite at a distance ρ1 from the center of the patch and the second interface is ferrite-dielectric at a radial positionρ2 . Therefore,d1=ρ1-a(a= radius of patch) denotes the distance from the patch circumference to the first interface, and d2=ρ2-ρ1 is the width of the ferrite ring. The interference between the incident and reflected waves is created by the permittivities of both materials, the permeability of the ferrite, and the distances d1 and d2.

Design parameters

Patch design

The radius of the patch[1] is

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ell_n\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \quad (1)$$

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

Patch is designed with radius 5.5mm.Two slots are introduced in the patch with length of 7mm and width of 0.6mm[9] to increase the bandwidth. The patch design shown in the fig.2.

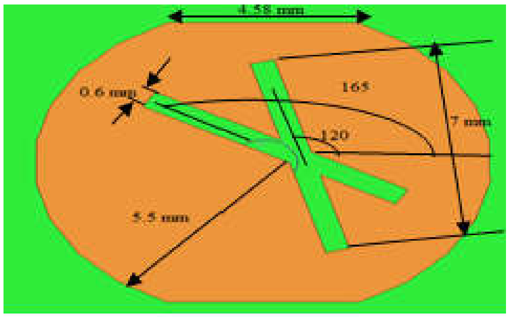


Figure 2 Patch View

Substrate design

The antenna is designed using Rogers TMM4,polyimide quartz and bakelite as dielectric substrate and substrate size is 100x100. Thickness is 3.2mm.The antenna is designing at a frequency of 5.8GHz. FR4 is used as for substrate material for special case.

Table 1 Substrates

Substrate	Relative permitivity
polyimideQuartz	4
TMM4	4.5
Bakelite	4.8
FR4	4.4

Ferrite ring specification

It has relative permeability of μ_{r2}=14, relative permittivity of ε_{r2}=10, dielectric loss tangent tanδ_e=0.0017 and magnetic loss tangent tanδ_m=0.0391[7], is used. 50Ω coaxial cable is used to feed the patch antenna with probe radius 0.805mm. The combination of the two material substrates dielectric- ferrite are called as hybrid substrates. . The patch antenna without ferrite ring is referred as conventional substrate and patch antenna with ferrite ring is referred as hybrid substrate. In order to feed the antenna coaxial probe feeding is used.

Table 2 Parameters Of Proposed Design

COMPONENTS	PARAMETER	VALUES
Substrate	Length	100 mm
	Width	100 mm
	Thickness	3.2 mm
Patch	Radius	5.5 mm
Slot	Length	7 mm
	Width	0.6 mm
Probe	Radius	0.765 mm
	Height	3.2 mm
Ferrite Ring	Dielectric constant	10F/m
	Width	13 mm
	Inner Radius	18 mm
	Outer Radius	31 mm

SIMULATED RESULTS

The designed micro strip patch antenna simulated by HFSS software. The gain is compared by using different substrate materials such as polyimide Quartz,Bakelite,TMM4 and FR4 is used as special case.

The figure 3 shows gain for various hybrid substrates. Polyimide quartz attains maximum gain of 8.2dBi within the frequency range of 5.5. to 6 dB which is higher than TMM4 substrate and Bakelite have maximum gain of 8dBi within the

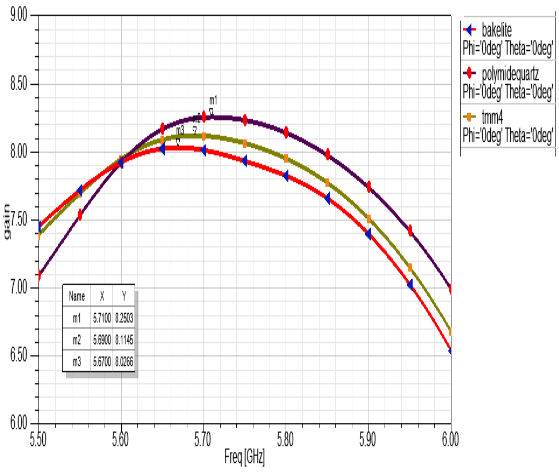
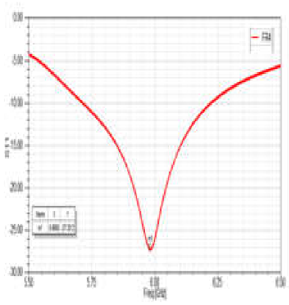


Figure 3 Gain comparison of different hybrid substrate

same frequency range. The reason why a significant gain enhancement can be achieved for the polyimide quartz hybrid substrate is that the field is increased when permittivity is decreased by the relation D =εE where D is the flux density. Similarly field is decreased when permittivity is increased for the case of Bakelite and also speed of wave propagation is decreased when permittivity is increased and another reason of gain enhancement is that surface wave losses decreased with increase of permittivity by the relation

$$k = \omega\sqrt{\varepsilon_0 \mu_0} \tag{3}$$

Where K is surface wave number,ε_0 is dielectric constant and μ_0 is permeability. But these reasons are not true for all cases because some materials have loss tangent factor which represents how lossy the material and is defined as angle between the capacitance's impedance vector and the negative reactive axis or ratio of imaginary part of dielectric constant to that of real part of dielectric constant. It ensure that low power loss for good dielectric material. so gain is reduced which materials exhibit loss tangent factor because it produces some losses which affect the gain. For example FR4 which has loss tangent factor of 0.02 and low permittivity as compared to TMM4.so its return loss curve and gain plot is shown in the figure 4 and 5 respectively.FR4 with ferrite combination achieves maximum gain of 7.05dB.



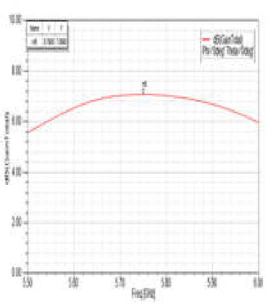


Figure 4 Return loss curve for FR4 **Figure 5** Gain plot of FR4

The 2 dimensional E-plane radiation pattern is shown in the figure 6. Due to the presence of ferrite ring, hybrid substrate focuss more energy towards broadside and makes it radiate less energy toward low elevation angles compared to antenna without ferring ring. Figure 7 shows how magnetic loss tangent affects the gain for various values of magnetic loss tangent of ferrite ring ranging from tan δ_m=0.01 to 0.05.

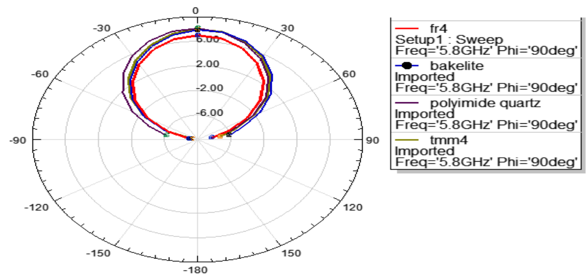


Figure 6 Radiation pattern of different hybrid substrates

A value of tan δ_m is selected from to generate the results shown in this paper. The gain is increases up to maximum of 8.7dB when magnetic loss tangent is decreases. Loss tangent increases means conductivity increases which will reduce the electric field by (4) This is the reason of gain enhancement can be obtained up to the value of tan δ_m= 0.05.

$$\bar{E} = \frac{\bar{J}_c}{\sigma_s} \tag{4}$$

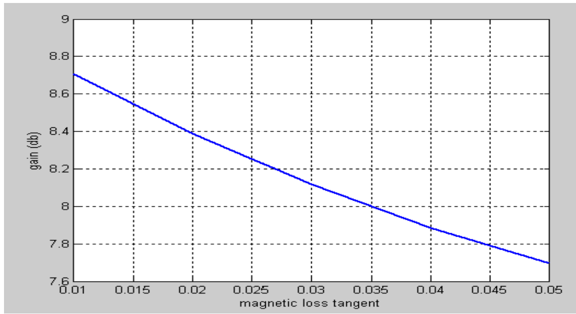


Figure 7 Gain variation as a function of the magnetic loss tangent tanδ_m

Figure 8 indicates normalized –e field for various values of distance in the two designs. Distance is the from the periphery of the patch to the edge of the substrate. In the case of conventional substrate, field intensity is very low and hybrid substrate has high field intensity. In hybrid substrate, there is low field intensity in dielectric (distance=0 to 12.9 and 25.8 to 38.7mm) and high field intensity inside the ferrite ring (distance=12.9 to 25.8mm).When signals enter into the ferrite ring, that will form constructive interference. This will enhance the signal strength thereby enhancing the field distribution inside the ring. So field intensity is high as six times higher than conventional substrate.

By taking maximum gain as a criterion, a parametric study is performed to determine the optimal distances d1 and d2.The gain is calculated for various values of d1 and d2 ranging from 0.125λ_0 to 0.375 λ_0 in steps of 0.0625 λ_0. Figure 9 shows the result of parametric study where gain is calculated for different values of d1 as a function of d2.Maximum gain is achieved when d2=λ0/4 for all d1 and at the same time maximum gain is achieved when is d1= λ0/4 and 3λ0/4. So the optimal values for d1 as well as d2 are chosen as near one-quarter of the free-space wavelength(λ0). At these values, maximum signals can be gathered inside the ferrite. At other higher values, signal cannot reach into ferrite and at the lower values, signals goes out from the ferrite ring. So these signals goes into substrate thereby gain reduced.

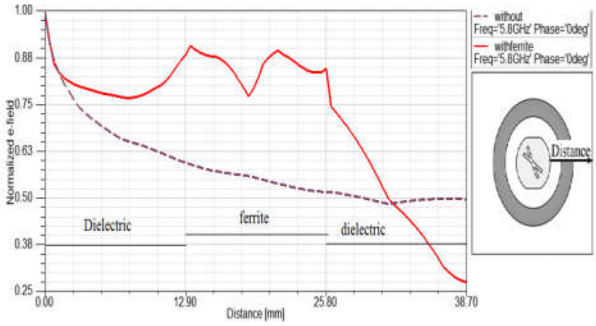


Figure 8 E-field normalized magnitude inside the substrate for conventional(violet) and hybrid (red)

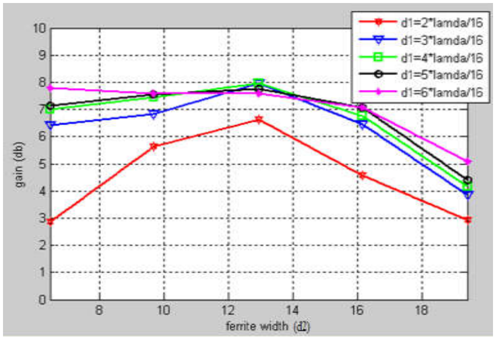


Figure 9 Maximum gain as a function of d1 and d2 for a circular patch

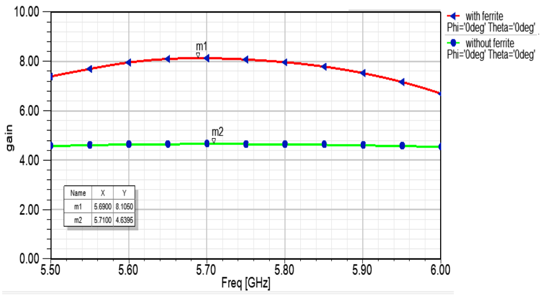


Figure 10 Gain comparison plot

The gain is plotted at an angle, ϴ and Φ = 0^0 for conventional antenna (without ferrite) and hybrid substrate antennas. The conventional substrate attains a maximum gain of 4.63 dBi. On the other hand, the hybrid substrate achieves a gain greater than 6 dB within the same frequency range, with maximum of 8.1 dBi as shown in Figure 10. Inside the ferrite ring, signal strength is increased due constructive interference then gain is increased and at ferrite-substrate interface some of the signals get reflected, so it reduces surface wave propagation in to the substrate thereby gain is enhanced also.

CONCLUSIONS

A hybrid substrate design is the combination of dielectric substrate ad ferrite ring which will enhance the gain as well as bandwidth also. Such a hybrid design has high gain characteristic than conventional antenna. A gain comparison study is carriedout for different hybrid substrate in which polyimide quartz obtained high gain of 8.2dBi and concluded that gain increases when permittivity decreases and surface waves number is also depends on dielectric constant that is they are directly related. But this is not true for all the cases because losses affects the antenna gain, for example FR4 has loss factor of 0.02,so it produces low gain of 7dBi even it has low permittivity compared with TMM4. . Several factors like magnetic loss tangent of ferrite ring and optimal values of d1 and d2 is affecting the maximum gain. The gain increased as magnetic loss tangent is decreased vice versa and maximum gain is obtained for optimal values d1 and d2 is equal to near one-quarter of the free-space wavelength($\lambda 0$). In hybrid substrate design, inside the ferrite ring has higher E-field distribution than in the dielectric. The higher E-field distribution inside ferrite is due to constructive interference and this is the another reason of gain enhancement.

Acknowledgement

This work is supported and guided by my research guides. I am very thankful to my guides Mr. Basil K Jeemon and Ms. Lekshmi B S, Assistant Professors of Electronics and Communication Department, Federal Institute of Science and Technology, (FISAT) Mookkannoor for their guide and support.

References

1. C. A. Balanis*, Antenna Theory: Analysis and Design*, 3rd ed. New York, NY, USA: Wiley, 2005
2. Alix Rivera-Albino and A. Balanis "Gain enhancement in microstrip patch antennas using hybrid substrates" *IEEE Antennas Wireless Propag. Lett.,* VOL. 12, 2013.
3. Gonzola and De Maagt and sorola ―Enhanced patch-antenna performance by suppressing surface waves using photonic-bandgap substrates‖ IEEE Trans. Microwave Theory Techn., vol. 47, pp. 2131-2138, Nov. 1999.
4. Hussein Attia and Leila Yousefi ―High-gain patch antennas loaded with high characteristic impedance superstrates‖ IEEE Antennas And Wireless Propagation Letters, vol. 10, pp.858-861, August 2011.
5. Zhenzhe Liu, Peng Wang, and Zhiyi Zeng" Enhancement of the gain for microstrip antennas using negative permeability metamaterial on low temperature co-fired ceramic (LTCC) substrate"*IEEE Antennas Wireless Propag. Lett.,* VOL. 12, 2013
6. H. Boutayeb, T. Djerafi, and K. Wu, "Gain enhancement of a circularly polarized microstrip patch antenna surrounded by a circular mushroom- like substrate," in *Proc. EuMC*, Sep. 2010, pp. 257–260
7. L. Yang, L. Martin, D. Staiculescu, C. P. Wong, and M. M. Tentzeris, "Comprehensive study on the impact of dielectric and magnetic loss on performance of a novel flexible magnetic composite material," in *Proc. EuMC*, Oct. 2008, pp. 131–134.

****

ISSN 0976-3031

9 770976 303009 >