International Journal of Computer Science, Communication & Information Technology (CSCIT)
Vol.7 pp. 58-61

Simulation and Analysis of Surface Wave Loss on Dielectric Substrate Materials at 94GHz Band

Adel Saad Emhemmed (1), Daw Ali Mohamed(2) , Abdulbast Kriama (3)
[1]Electrical and Electrronic Engineering Department, University of Tripoli, Tripoli, Libya, dr.adel.elec@gmail.com
[2]Electrical and Computer Engineering Department, The Libyan Academy, Tripoli, Libya, Daw.Ali.Mohamed@gmail.com
[3] Faculaty Of Engineering , University Of Zawia, Zawia, Libya, kriama@zu.edu.ly.

Abstract **– Abstract- In this paper surface wave loss in two grounded dielectric substrates has been analyzed and simulated at 94GHz band using HFSS simulation software. The first material was Duroid (εr=2.2) since it has lower dielectric constant. The second material was Gallium Arsenide (εr=12.9) which is has high dielectric constant and it is used for integrated circuits. In order to study the effect of surface wave, two grounded dielectric substrates are simulated for different thickness. The thickness of substrate and size is same for valid comparison of surface wave level. The grounded Gallium Arsenide substrate with 0.2mm thickness gives high insertion loss of 5dB and surface wave level of 2.1x10^5V/m , therefore substrate type and thickness must be chosen to avoid coupling to the first higher surface wave mode.**

Keywords **– Surface wave loss, high order mode, grounded dielectric substrate, HFSS software.**

I. INTRODUCTION

There are wide variety of substrate materials have been found for microstrip patch antenna design with mechanical, thermal and electrical properties which are attractive for use in both planar and conformal antenna configurations. The material used for substrate can be dielectric constant in the range of 2.2 ≤ r ≤ 12.9. If we change the material of substrate and the thickness of substrate of a microstrip antenna, it changes the system performance by changing the dielectric constant (ε_r). Cost, power loss and performance are trade-off considerations in choosing the substrate material. The patch size reduces for higher dielectric constant and it also reduces bandwidth and radiation efficiency [1].

The purpose of an antenna is of course to radiate space waves. These waves move towards the free space where they do not find any further interfaces. However, there are also other types of waves such as surface waves and leaky waves can be excited in the microstrip antenna substrate depending on its thickness, and angles of reflection at the substrate metallic boundaries [2]. The excitation of surface wave is often considered to be a disadvantage in all microstrip patch antennas application. The reason for this is that most surface waves are generally difficult to control and are not radiated in the main-beam direction, but in the direction parallel to the air-dielectric interface, distorting the main beam radiation pattern and increasing the level of the side lobes as well as the back lobes. Hence, the surface wave power is treated as a loss mechanism when calculating the radiation efficiency [3].

Surface waves in the substrate can be existed in the form of Transversal Electric (TE) and Transversal Magnetic (TM) modes, because ground dielectric cannot support TEM wave. The phase velocity of these modes is a function of dielectric constant (ϵ_r) and substrate thickness (h). If a quasi-TEM wave is present under the antenna radiator with a phase velocity close to the phase velocity of a surface wave mode, strong mode coupling can occur. For higher order TE and TM modes, the cut-off frequency is given by [1]-[3]:

$$F_c = \frac{nc}{4h\sqrt{\epsilon_r - 1}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (1)$$

For TE_n modes n = 1, 3, 5,… , n = 0, 2, 4,... for TM_n modes and c equal the speed of light in vacuum $(c = 3\times10^8 m/s)$. TM_0 mode has zero cut off frequency, the power coupled into this mode can be reduced by choosing small (h) and (ϵ_r).If dielectric has finite thickness and dielectric constant slightly large than one, there is always at least one propagating (TM) mode, designated as: (TM_0) mode, which has zero cut off frequency. (TM_0)mode can have some field lines aligned with field line of (QTEM) mode of microstrip line, which are often used to construct feeding structures of integrated antennas on dielectric [4]- [8].

Therefore, reducing surface-wave excitation from microstrip antennas can be beneficial for various reasons. First, the reduction of surface-wave excitation will increase the radiation efficiency of the antenna. Second, the reduction of surface-wave excitation will result in less diffraction from the edges of the substrate or ground plane supporting the antenna, resulting in less back radiation and interference with the main pattern in the forward region. Also, reduced surface-wave excitation usually results in reduced coupling between antenna elements [6]- [10].

In this paper two different substrates with different dielectric constant and different thickness have been analyzed the surface wave effect using HFSS simulation software

II. HIGHER ORDER MODES EFFECT IN DIELECTRIC

surface wave losses are always present in the case of a grounded substrate, even if the amount of lost power can be considered negligible for thickness $d<0.01\lambda_0$ of the dielectric. Generally, the power lost in substrate modes increases significantly as higher order modes appear.

ISSN 1737-930X

International Journal of Computer Science, Communication & Information Technology (CSCIT)
Vol.7 pp. 58-61

Fig. 1 and Fig. 2 show the relation between cut off frequencies of surface waves and the thickness of substrate (h) by using Matlab software for gallium arsenide and Duroid substrates. From the results, we note that the surface wave modes increase by increasing the thickness (h) and dielectric constant substrate(ε_r). When we using Gallium Arsenide material value cut off frequency increasing compared with Duroid, this will reduce the efficiency

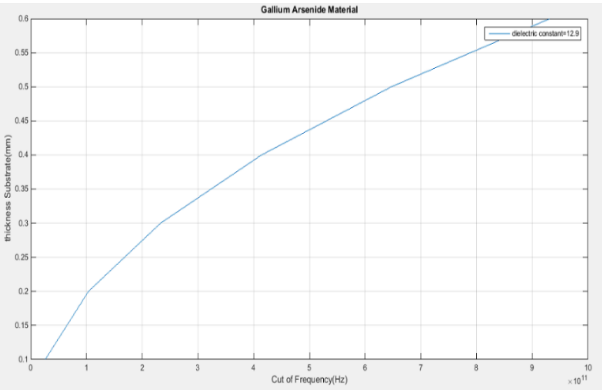

Fig. 1: Relation between cut of frequency and thickness of the Gallium Arsenide material

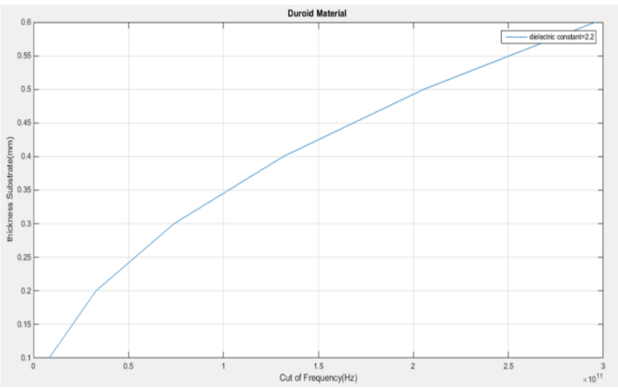

Fig. 2 Relation between cut of frequency thickness of the Duroid material

III. ANALYSIES SURFACE WAVES

In order to study the effect of surface wave, two grounded dielectric substrates are simulated for different thickness. The thickness of substrate and size is same for valid comparison of surface wave level. The first material was Duroid (*ε_r=2.2*) since it has lower dielectric constant. The second material was Gallium Arsenide (*ε_r=12.9*) which is has high dielectric constant and it is used for integrated circuits. The simulation was done by using HFSS software for two different thickness (*h=0.1mm, h=0.2mm*) to study the effect of surface wave loss by measuring insertion losses (S_{21}).

a) Surface Waves in Two Different Material at h=0.1mm

The 3D surface wave level for two different materials is shown in Fig. 3. The maximum value of surface wave was 5.1x10^4 V/m at 94GHz for Gallium Arsenide material, while the maximum value at the same frequency was 4.7x10^4 V/m for Duriod.

The insertion loss in two materials at 94GHz band is shown in Fig. 4. The insertion loss of grounded dielectric increase by increasing the frequency. The loss of Gallium Arsenide material has 1.07dB at 110GHz and 0.42 dB for Duroid at the same frequency.

Table (I) shows the comparison between two materials. From the comparison table, it has been concluded that with the decrease in relative permittivity of substrate material the effect of surface wave can be ignored. This will enhance the efficiency of the devices.

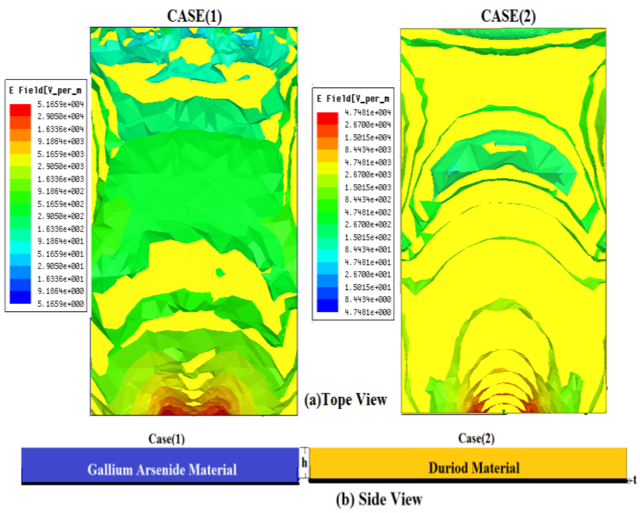

Fig. 3 Surface Waves in Two Different Material at h=0.1mm

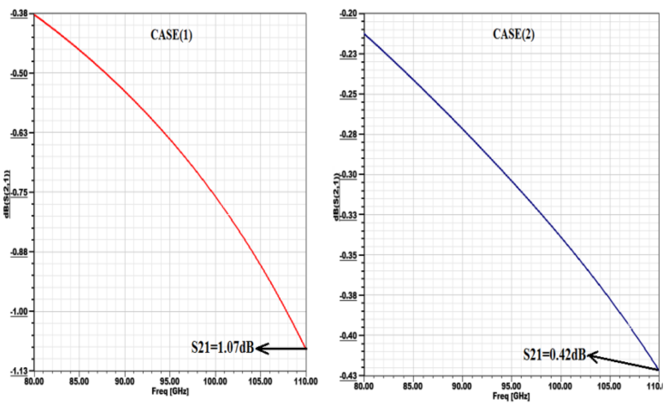

Fig.4 Insertion Loss in Two Different Material at h=0.1mm

Table(I): Comparing Gallium Arsenide with Duroid Materials at(h=0.1mm)

ISSN 1737-930X

Parameters with Thickness Substrate=0.1mm	**Gallium Arsenide Material**	**Duroid Material**
Wave Length of Cut-off frequency	1.38mm	0.438mm
Insertion Loss	1.07dB	0.42dB
Elevation angle (θ)	90°≤θ≤163.8°	90°≤θ≤137.6°
Surface waves level	High	Low

b) Surface Waves in Two Different Material at h=0.2mm

From Fig. 5 and Fig 6 we can see that the surface waves level inside Gallium Arsenide material more than Duriod material. Gallium Arsenide material has maximum value of surface wave is 2.1x10^5 V/m and insertion loss is 5dB while Duroid material has 1.04x10^5 V/m of insertion loss and insertion loss is 0.56 dB. Table II shows the comparison between two materials.

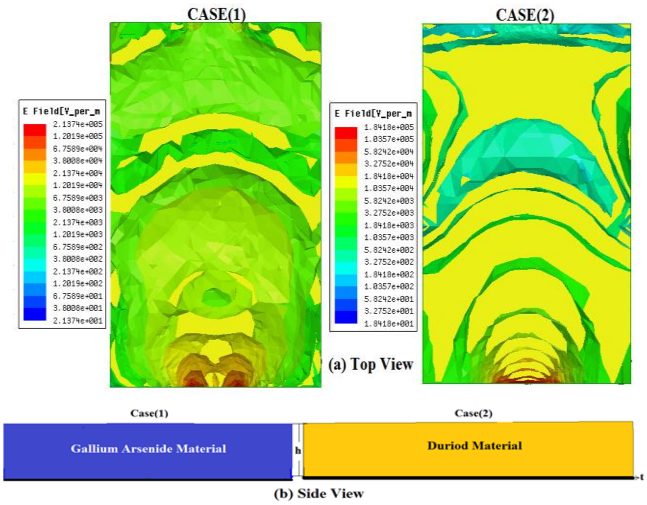

Fig.5 Surface Waves in Two Different Material at h=0.2mm

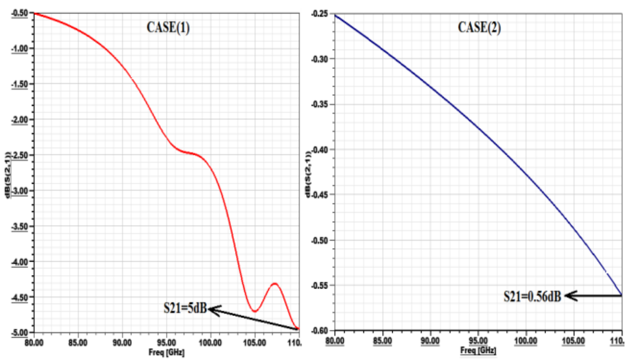

Fig.6 Insertion Loss in Two Different Material at h=0.2mm

Table(II): Comparing Gallium Arsenide with Duroid Materials at (h=0.2mm)

Parameters with Thickness Substrate=0.2mm	**Gallium Arsenide Material**	**Duroid Material**
Wave Length of Cut-off frequency	5.55mm	1.75mm
Insertion Loss	5dB	0.56dB
Elevation angle (θ)	90°≤θ≤163.8°	90°≤θ≤137.6°
Surface waves level	High	Low

IV. CHARACTERIZATION AND DISCUSSIONS

The phase velocity of the surface waves is strongly dependent on the substrate parameters (h , ε_r). From equation (1) we can calculate (TE_1) mode at n=1 with Gallium Arsenide material has $\epsilon_r = 12.9$, Hence the value of $(\frac{h}{\lambda c})^1$ will be :

$$(\frac{h}{\lambda c})^1 = \frac{n}{4\sqrt{\varepsilon_r - 1}} = \frac{1}{4\sqrt{12.9 - 1}} = 0.072$$

where $\lambda c^1 = (\frac{c}{F_c})^1$

Can calculate (TE_1) mode at n=1 with Duroid material has dielectric constant ($\epsilon_r = 2.2$)

$$(\frac{h}{\lambda c})^1 = \frac{n}{4\sqrt{\varepsilon_r - 1}} = \frac{1}{4\sqrt{2.2 - 1}} = 0.228$$

Since TM_0 mode has no cutoff frequency then, the lowest order TM_0 mode will excited at all grounded dielectric materials. At 94GHz frequency the lowest order (TE_1) mode is excited at h=0.22mm in grounded Gallium Arsenide material and with Dourid material (TE_1) mode is excited at h=0.72mm.

If we decreasing the frequency to 10GHz the lowest order (TE_1) mode is excited at h=2.17mm with Gallium Arsenide material and at h=6.8mm for Dourid material.

From this comparison we can conclud that with the decrease in relative permittivity and thickness of substrate material surface wave loss will be decreasing.

V. CONCLUSION

This paper introduces effect surface waves in two different grounded dielectric substrates. The grounded Gallium Arsenide substrate with 0.2mm thickness gives high insertion loss of 5dB and surface wave level of 2.1x10^5 V/m, therefore substrate type and thickness must be chosen to decrease the surface wave level.

It has been concluded that RF circuits on high dielectric substrate at mm-wave frequencies suffer greatly from surface wave losses because typical substrates become electrically thick at these frequencies. The excitation of surface wave

ISSN 1737-930X

modes is often considered to be a disadvantage in all RF circuits. The reason for this is that most surface waves are generally difficult to control and are not flow the main field. Hence, the surface wave power is treated as a loss mechanism when calculating the efficiency of the system

REFERENCES

[1]. David M- Pozar,"microwave engineering" , fourth edition ,2012
[2]. Adel Saad Emhemmed, Abdulmagid A. Aburwein, "Surface Waves Reduction in Microstrip " IEEE,2013
[3]. Ankit S. Solanki , Ayush Agarwal **,** "Millimeret-w-Wave integrated circuits preview or an overview on monolithic microwave integrated circuits (MMIC)" , International Journal of Industrial Electronics and Electrical Engineering, Dec.-2014
[4]. Varadarajan Komanduri, David R. Jackson," Reducing surface wave Excitation from MSA by using a Cavity Filling", Institute of Electrical and Electronics Engineers (IEEE) ,2007
[5]. Shruti Dhamankar, Snehal Lopes- "MUTUAL COUPLING REDUCTION TECHNIQUES IN MSA", International research journal of engineering and technology(IRJET), Mar-2016.
[6]. Hyung Suk Lee, Jeong-Geun Kim, Songcheol Hong, "Micromachined CPW-Fed Suspended Patch Antenna For 77 GHz Automotive Radar Applications", IEEE Transactions on Antenna and Propagation, Vol. **45,** No. **6,** March 2008
[7]. D. M. Pozer, ''Consideration for Millimetre Wave Printed Antennas'', IEEE Transactions on Antennas and Propagation, Vol. AP-31, NO. 5, pp. 740-747, Sep 2005.
[8]. Adel Emhemmed, I. McGregor, K. Elgaid, " Elevated conductor coplanar waveguide-fed three-level proximity-coupled antenna for G-band applications'', IEEE Microwaves, Antennas &Propagation Journal, Vol. 4, No. 11, pp 1910-1915, Oct 2010.
[9]. Adel Saad Emhemmed**,** Daw Ali Mohamed **"** High Performance 94GHz Holes-backed Integrated Antennas Fed by Inset Tapered Microstrip Line**",** 5th International Conference on Control & Signal Processing (CSP-2017) - Kairouan . Tunisia
[10]. Punita Mane, S.A Patil and P.C.Dhanawade, "Comparative Study of Microstrip Antenna for Different Subsrtate Material at Different Frequencies", International Journal of Emerging Engineering Research and Technology Volume 2, Issue 9, PP 18-23,December 2014.

ISSN 1737-930X