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The study of the miniaturisation effect on the characteristics of patch antenna using the WCIP method

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Abstract

The demand of miniature electronic systems has been increasing for several decades. The physical size of systems is reduced due to advancements in integrated circuits. With reduction in size of electronic systems, there is also an increasing demand of small and low cost antennas. Patch antennas are one of the most attractive antennas for integrated RF systems due to their compatibility with microwave integrated circuits. In this paper, the effects of substrate dielectric constant and particularly the miniaturization of the antenna size on the return loss characteristics of patch micro strip antenna (MSPA) have been investigated using the wave concept iterative procedure (WCIP) method. Accuracy of the present results is compared with previous work which has been done theoretically and experimentally.

keywords : Patch antenna ;substrate materials; miniaturization; WCIP method.

1. Introduction

Recently, communication system using electromagnetic waves and especially microwaves became very efficient in many applications such as short range transmission of signals, medical applications, mobiles and laptops where there is a requirement for an antenna which consumes very less space and can be mounted easily in the equipment and still have efficient directive radiation pattern. One such antenna design, which is very famous these days, is micro strip patch antenna MSPA. [1, 2]

Different techniques have been suggested to achieve antenna integration within a single chip. In this paper a simple design by simulation of micro strip patch antenna for microwave applications is proposed by investigating the effects of substrate material nature and antenna size miniaturization on the return loss characteristics of the antenna. Electromagnetic simulations were performed using MATLAB code program witch employs the wave concept iterative process method WCIP based on wave concept and fast modal transformation FMT.

2. The theory of the iterative method

The Fast Wave Concept Iterative Process (FWCIP) is introduced firstly in (Azizi et al. 1995; Azizi et al. 1996). It is based on the Definition of transverse waves based on the tangential electric and magnetic fields on some active surface. The same method is denoted in literature as Transverse Wave Formulation - TWF (Wane et al. 2005) and more recently Wave Concept Iterative Procedure – WCIP (Baudrand et al. 2007, Raveu et. al 2007).WCIP compares favorably (Wane and Bajon 2006) with other commercially available software regarding the precision and promises better performance in computation efficiency in structures with very different layer heights.[3]

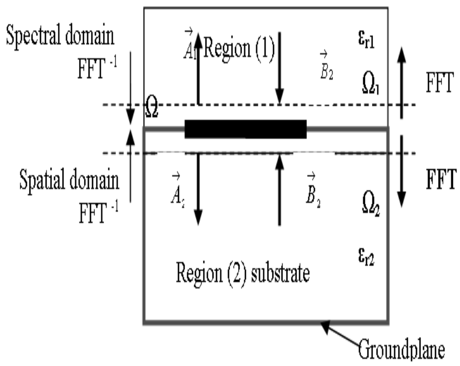

Figure 1. Wave concept iterative procedure definitions

Let Ω be a discontinuity plane inside a metallic box (package)(see figure 1) .the regions on both sides are filled with homogenous electric .the tow regions are designated as region 1(ε_{r1} , h_1, etc.) and region 2 (ε_{r2} , h_2, etc.). Let Ω_i be a surface infinitely close to Ω in region i, n_i the unit vector normal to Ω and directed into region i, i=1or 2 (as shown in figure 1)

We define the transverse incident and reflected wave in Ω_i by the follow relation:

$$\vec{A}=\frac{1}{2\sqrt{Z_{0i}}}\left(\vec{E}+Z_{0i}\vec{J}\right), \vec{B}=\frac{1}{2\sqrt{Z_{0i}}}\left(\vec{E}-Z_{0i}\vec{J}\right) \quad (1)$$

where i indicates the medium 1 or 2, E the tangential electric field, Zoi stands for the characteristic impedance of the same medium,
J is the surface current density.

The waves are subject to constraints imposed by the discontinuity (2) and by the reflection over the metallic walls of the box (3).

$$\vec{A}=\hat{\Gamma}_{\Omega}\vec{B}+\vec{A}_0 \quad (2)$$

$$\vec{B}=\hat{\Gamma}\vec{A} \quad (3)$$

A_0 is the incident wave generated by the source in the two regions .Γ and Γ_Ω denote the reflection operator on the discontinuity surface Ω and on the metallic walls respectively. The WCIP method solves (2) (3) by an iterative procedure. In (4), (5) k denotes the current iteration and the starting conditions are imposed by the source (6).

$$\vec{A}^{(k+1)}=\hat{\Gamma}_{\Omega}\vec{B}^{(k)}+\vec{A}_0 \quad (4)$$

$$\vec{B}^{(k)}=\hat{\Gamma}\vec{A}^{(k)} \quad (5)$$

$$\vec{A}^{(0)}=\vec{A}_0 \quad (6)$$

Equation (2) is applied in the space domain, while (3) is easily implemented in the modal domain, so a fast modal transform (FMT), based on FFT (N'gongo and Baudrand 1999), can be developed in order to go from (4) to (5) and vice versa through the iterative procedure. While this method found its best applications in the analysis of microwave multilayer structures (Akatimagool et al. 2001, Wane et al. 2005, Wane and Bajon 2006). .[4,5,6]

2.1. Design considerations

In its simplest form, the micro strip antenna consists of a sandwich of two parallel conducting layers separated by a single thin dielectric substrate (see figure 2). The lower conductor functions as a ground plane and the upper conductor functions as radiator. The larger ground plane gives better performance but makes the antenna bigger.

Among different shapes of micro strip patch elements such as rectangular, square, dipole, triangular, circular and elliptical for better radiation characteristics we use rectangular micro strip patch antenna. In this paper the substrate dimensions taken along X-axis is a mm and along Y-axis is b mm. The substrate thickness along Z-axis is h_2 mm.

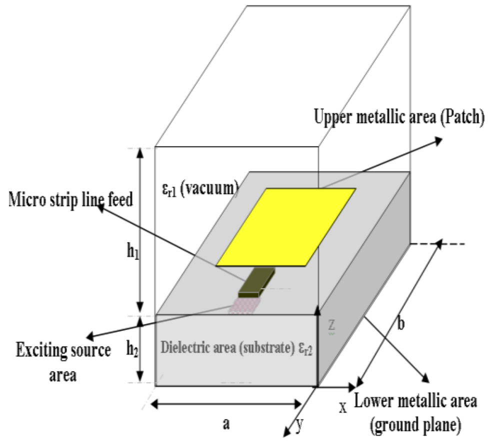

Figure 2- MPA model encapsulated in box

The feed location is in the middle of the patch. For good performance, a substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. The design also checks for maximum power transfer by matching the feed line impedance to the impedance of the patch antenna. As an imposed solution we use the Micro strip line feeding technique for impedance matching witch is easier, and feed can be fabricated on some substrate as single layer to provide planner structure. [7]

2.2. simulation results

1. simulations

The Structure Interface used in our study and introduced in our MATLAB code is shown in figure 3.

a–Substrate dielectric constant effect

Figure (1) shows the model for micro strip patch antenna. The different physical parameters simulated by placing them on the proposed model
We have chosen the follow simulation parameters values: axb = 10x10mm; h1 = 2 mm h2 = 1mm; εr1 = 1; Nit (iteration number) =300; frequency band [2-250] GHz, Frequency step = 0.1 GHz.

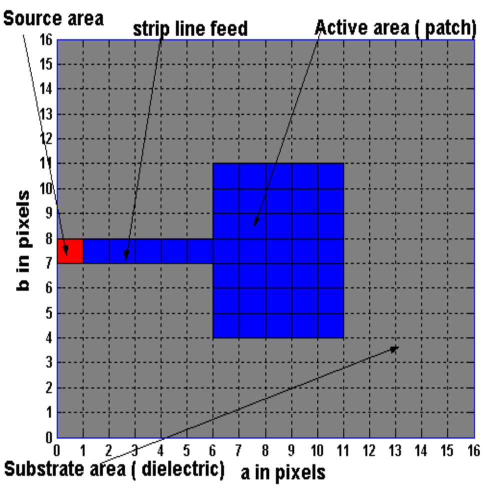

Figure 3. Interface structure

Different substrate materials are considered and the table (1) shows the physical parameters of the different substrate materials used in our simulations

Substrate material	Dielectric constant ε_r	Effective Dielectric constant	Loss tangent value
RT-Duroid-5880	2.2	2.1144	0.0011
Neltec NX 9240	2.4	2.3002	0.0010
Benzocy-clobuten	2.6	2.4859	0.0010

Table (1) Physical parameters of substrate materials used in our simulations

We launched the simulation program for the same structure by varying only the substrate dielectric constant . We have taken three structure cases: I (ε_{r2} = 2.2); II (ε_{r2} = 2.4); III (ε_{r2} =2. 6).
We obtain results shown in figures 4, 5 and 6.

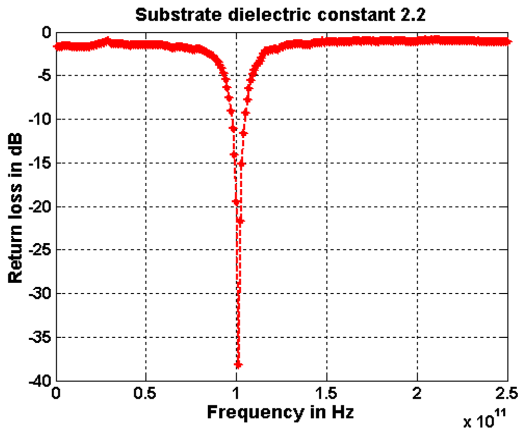

Figure 4.Rreturn loss characteristics for antenna with substrate dielectric constant 2.2

Parameter	Conventional antenna	Antenna N°01	Antenna N°02
Active area 7x5x pixel size in mm^2	22,00	21.33	20.80
Volume of antenna axbxh2 mm^3	100.00	71.30	45.12
Active area reduction in %	/	3	5.40
Volume Reduction in %	/	28.70	54.88

Table 2.Analysis of antenna miniaturization

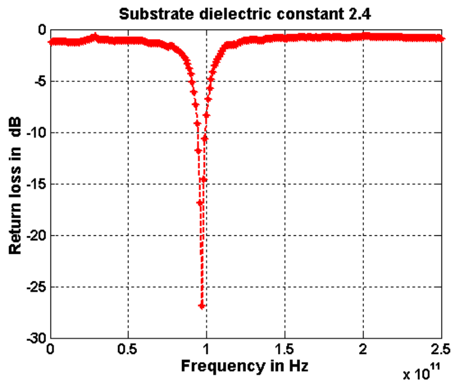

Figure 5. Return loss characteristics for antenna with substrate dielectric constant 2.4

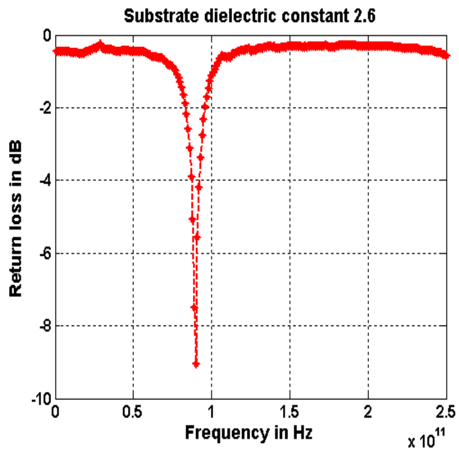

Figure 6 .Return loss characteristics for antenna with substrate dielectric constant 2.6

b- Substrate size effect

For an antenna considered as conventional antenna we have chosen the follow simulation parameters values: axb = 10x10mm; h1 = 2 mm h2 = 1 mm εr1 = 1; ε_{r2} =4.22 Nit =300; frequency band [0-250] GHz, frequency step = 0.1 GHz.

We launched the simulation program for two antennas N°1 and N°2 with the same conventional antenna parameters but by varying substrate sizes and also active patch area as it is presented in table 2

For the miniaturization effects we obtain results depicted in figures 7, 8 and 9.

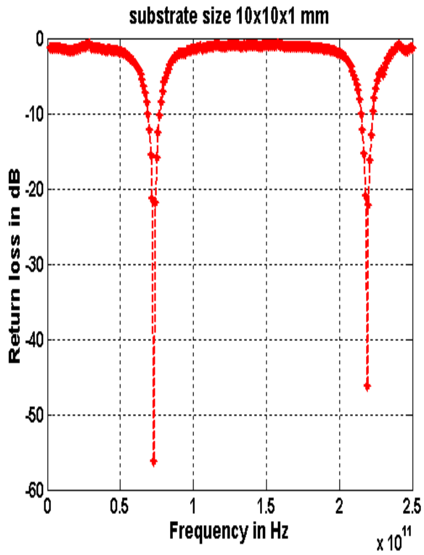

Figure 7. Variation of return loss versus frequency for the conventional antenna.

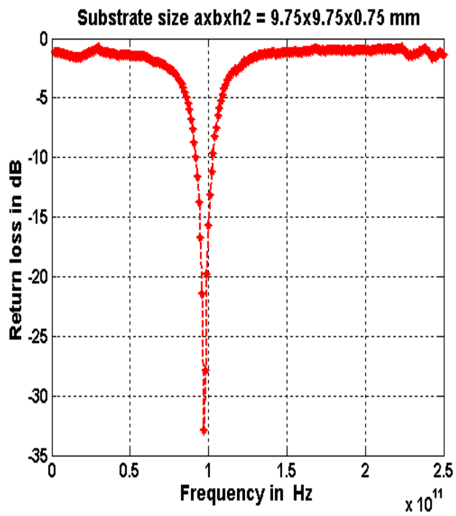

Figure 8. Variation of return loss versus frequency for antenna.N°1

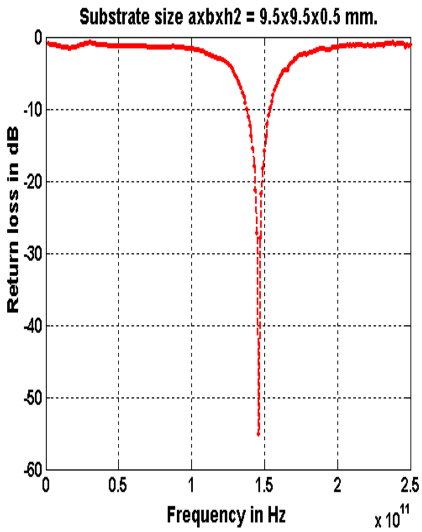

Figure 9. Variation of return loss versus frequency for antenna. N°2

3. Results

The return loss values obtained for different substrate materials with different dielectric constants 2.2, 2.4, 2.6 are -38.5dB, -27 dB -9 dB with resonant frequencies at 105GHz, 96GHz and 90GHz respectively. All the values are having the return loss of <-8dB and bandwidths are everywhere constant

Concerning miniaturization, the return loss characteristics is observed for the conventional antenna configuration and depicted in Figure.7 witch shows two-band of operation in the frequency band [0-250] GHz. The first band is around 75 GHz with -56dB the second band is around 210 GHz with - 46dB. Figure 8 gives return loss characteristics for antenna N°1 witch is miniaturized by about 28.70 % in volume compared to the conventional antenna, we observe one band of operation around 95GHz with -37dB and Figure 9 gives return loss characteristics for antenna N°2 (miniaturized by about 54.88 % in volume compared to the conventional antenna) we observe one band of operation around 148GHz with -55dB

4. Conclusion

We conclude that by increasing the dielectric constant of the substrate material gain values are decreased and resonant frequency is shifted left. Concerning miniaturization we observe that by decreasing antenna volume we have significant fluctuation in gain and resonant frequencies are shifted right.

By using simple relations of the WCIP method without leading to a heavy computing time, we have investigated performances of micro strip patch antenna based on different substrate materials and the effect of miniaturization on these performances. The simulated results obtained by WCIP are, mostly, in good agreement with measurements and the literature.

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