IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 11, Issue 6 Ver. II (Nov. – Dec. 2016), PP 01-09
www.iosrjournals.org

Novel Microstrip B Patch Antenna Embedded in Superstrates Anisotropic Media

Adnan Affandi[1], Mamdoh Gharbi[2]
[1]*(Department of Electrical and Computer, Engineering/ King Abdul Aziz University, Saudi Arabian)*

Abstract: *A compact method to analyze the input impedance of sources in a multilayers media has been developed. The dielectric layers are assumed to be anisotropic where all optic axes are perpendicular to the stratification. A novel Microstrip B patch antenna has been presented. The effect of anisotropic Superstrate layers on B shaped Microstrip Patch antenna is investigated. A variation formulation and a simulating results are employed to enhance the performance of Return loss (S-parameters), Axial Ratio, Directivity and Gain of B shape Patch Antenna. The comparison of input impedance for rectangular Microstrip patch using our method and a published data are found to be in good agreement.*
Keywords: *Anisotropic Superstrate, Patch Antenna, Gain, Directivity, Return loss.*

I. Introduction

Several works have been conducted for analyzing the different antenna parameters on anisotropic media [1-4]. The anisotropy ratio of the material can affect the input impedance, resonant frequency, and far-field radiation pattern, of an antenna [5].Calculation of the resonant frequencies and half-power bandwidth of circular Microstrip patch printed on an anisotropic substrate using Galerkin's method in the vector Hankel transform domain has been done [6]. One study used Volume surface integral Equation for calculating the electromagnetic radiation of arbitrary shaped patch antennas on anisotropic substrate [7].

This study used the mixed boundary value problem of a patch antenna placed under anisotropic superstrate as shown in Fig. 1. The superstrate layer can be either isotropic or anisotropic dielectric. The patch antenna excited by probe fed source. The spectral domain electric field integral equation (EFIE) used to calculate the current of on the surface of the patch using the Dyadic Green's Function. The EFIE was solved using the Moment Method (MM) to find the unknown induced surface current on the patch. Return loss, Axial Ratio, Directivityand Gain obtained for different electrical and geometrical Antenna parameters. One purpose of design patch antenna is to explore various methods of designing an antenna that operates both effectively and efficiently. A B patch antenna is presented in this study because of its high gain and directivity. The ideal outcome of the design is to produce a highly directive antenna with better return loss and good Axial Ratio.

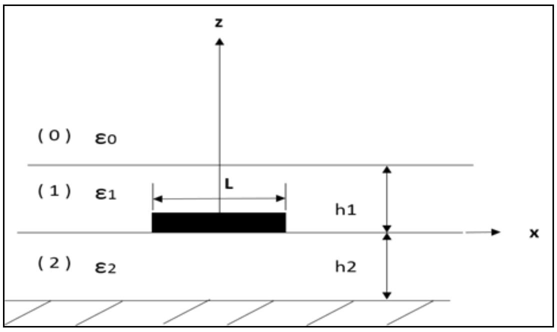

Fig. 1. Geometry of the Problem

II. Spectral Domain Intgral Equation

Assume the Microstrip patch considered in Fig. 1 is a dipole. So the width of the dipole is very small compared to the free-space wavelength ($W<<\lambda_o$), and therefore the current on the dipole can be assumed to have only one component in the *x*-direction. That is $\overline{J}_s = \hat{x}\, J_s$. Also, assume that dielectric layers are anisotropic

$$\overline{\overline{\varepsilon}}_j = \begin{bmatrix} \varepsilon_j & 0 & 0 \\ 0 & \varepsilon_j & 0 \\ 0 & 0 & \varepsilon_{jz} \end{bmatrix} \qquad (1)$$

$$\overline{\overline{\mu}}_j = \mu_0 \overline{\overline{I}}$$

Where, $\overline{\overline{I}}$ is the unit dyadic.

The tangential components of the electric field can be written (in the integral equation form) as:

$-\overline{E}_t^{(s)} = \overline{E}_t^{(\mathrm{i})}$, where ($t$) stands for tangential components.

And

$$\overline{E}_t^{(s)}(\overline{r}) = i\omega \iint_S d\overline{r}' \overline{\overline{G}}_{11}^T(\overline{r},\overline{r}') \cdot \overline{J}_s(\overline{r}') \tag{2}$$

Where

$$\overline{\overline{G}}_{11}(\overline{r},\overline{r}')\Big|_{z'=0} = \int \int_{-\infty}^{\infty} d\overline{k}_s e^{\overline{k}_s \cdot (\overline{r}_s - \overline{r}_s')} \ \overline{\overline{g}}_{11}(\overline{k}_s, z)$$

$$\overline{\overline{g}}_{11}(\overline{k}_s, z) = \frac{i\mu_0}{8\pi^2}\left\{ \frac{r_1^{TE}}{k_{1z}^{(h)}}\left[\hat{h}(k_{1z}^{(h)})e^{ik_{1z}^{(h)}z} + R_{\cup 1}^{TE} e^{2ik_{1z}^{(h)}h_1}\hat{h}(-k_{1z}^{(h)})e^{-ik_{1z}^{(h)}z}\right]\left[\hat{h}(k_{1z}^{(h)}) + R_{\cap I}^{TE}\ \hat{h}(-k_{1z}^{(h)})\right]\right.$$

$$\left. + \frac{r_1^{TM}}{k_{1z}^{(e)}}\left[\hat{v}(k_{1z}^{(e)})e^{ik_{1z}^{(e)}z} + R_{\cup 1}^{TM} e^{2ik_{1z}^{(e)}h_1}\hat{v}(-k_{1z}^{(e)})e^{-ik_{1z}^{(e)}z}\right]\left[\hat{v}(k_{1z}^{(e)}) + R_{\cap 1}^{TM}\ \hat{v}(-k_{1z}^{(e)})\right] \right. \tag{3}$$

which

$$R_{\cup 1}^{TE} = R_{10}^{TE} = \frac{k_{1z}^{(h)} - k_{0z}}{k_{1z}^{(h)} + k_{0z}} \tag{4}$$

$$R_{\cap 1}^{TE} = \frac{k_{2z}^{(h)} + ik_{1z}^{(h)} \tan k_{2z}^{(h)} h_2}{-k_{2z}^{(h)} + ik_{1z}^{(h)} \tan k_{2z}^{(h)} h_2} \tag{5}$$

$$R_{\cup 1}^{TM} = R_{10}^{TM} = \frac{k_{1z}^{(e)} - \varepsilon_1 k_{0z}}{k_{1z}^{(e)} + \varepsilon_1 k_{0z}} \tag{6}$$

$$R_{\cap 1}^{TM} = \frac{\varepsilon_2 k_{1z}^{(e)} + i\varepsilon_1 k_{2z}^{(e)} \tan k_{2z}^{(e)} h_2}{\varepsilon_2 k_{1z}^{(e)} - i\varepsilon_1 k_{2z}^{(e)} \tan k_{2z}^{(e)} h_2} \tag{7}$$

$$r_1^{TE} = \frac{1}{1 - R_{\cap 1}^{TE}\ R_{\cup 1}^{TE}\ e^{2ik_{1z}^{(h)}h_1}} \tag{8}$$

$$r_1^{TM} = \frac{1}{1 - R_{\cap 1}^{TM}\ R_{\cup 1}^{TM}\ e^{2ik_{1z}^{(e)}h_1}} \tag{9}$$

$$k_{jz}^{(h)} = \left(k_j^2 - k_s^2\right)^{1/2} \tag{10}$$

$$k_{jz}^{(e)} = \left(k_j^2 - \frac{\varepsilon_j}{\varepsilon_{jz}} k_s^2\right)^{1/2} \tag{11}$$

$$k_j^2 = \omega^2 \mu_0 \varepsilon_j \tag{12}$$

$$k_{0z} = \left(k_0^2 - k_s^2\right)^{1/2} \tag{13}$$

$$k_0^2 = \omega^2 \mu_0 \varepsilon_0 \tag{14}$$

where $j = 1,2$.

Thus,

$$\overline{\overline{g}}_{11}^{(x,x)}(\overline{k}_s) = \frac{i\mu_0}{8\pi^2}\left\{ \frac{k_y^2}{k_s^2} \cdot \frac{r_1^{TE}}{k_{1z}^{(h)}}\left(1 + R_{\cup 1}^{TE} e^{2ik_{1z}^{(h)}h_1}\right)\left(1 + R_{\cap 1}^{TE}\right) + \frac{k_x^2}{k_s^2}\frac{k_{1z}^{(e)}}{k_1^2} r_1^{TM}\left(1 - R_{\cup 1}^{TM} e^{2ik_{1z}^{(e)}h_1}\right)\left(1 - R_{\cap 1}^{TM}\right)\right\}\ \hat{x}\,\hat{x} \tag{15}$$

Using the 2-D Fourier Transform, to get:

$$\bar{E}_t^{(s)}(\bar{r}_s) = i\omega \int \int_{-\infty}^{\infty} d\bar{k}_s e^{i\bar{k}_s \cdot \bar{r}_s} \; \bar{\bar{g}}_{11}^{(x,x)}(\bar{k}_s) \cdot \bar{J}_s\left(\bar{k}_s\right) \tag{16}$$

where $\bar{J}_s(\bar{k}_s)$ is the Fourier Transform of the surface current density $\bar{J}_s(\bar{r}_s)$.

The unknown $\bar{J}_s$ can be determined by using the Moment Method technique.
So,

$$-i\omega \int \int_{-\infty}^{\infty} d\bar{k}_s e^{i\bar{k}_s \cdot \bar{r}_s} \; \bar{\bar{g}}_{11}^{(x,x)}(\bar{k}_s) \cdot \bar{J}_s\left(\bar{k}_s\right) = \bar{E}^{(i)}(\bar{r}_s), \bar{r}_s \in S \tag{17}$$

$$\int \int_{-\infty}^{\infty} d\bar{k}_s e^{i\bar{k}_s \cdot \bar{r}_s} \; \bar{J}_s\left(\bar{k}_s\right) = 0, \bar{r}_s \notin S \tag{18}$$

Where S is the surface of the patch.

III. Application of The MM Solution

Expand equations (17 and 18) by modes $\bar{f}_n(x,y)$, with unknown coefficients I_n:

$$\bar{J}_s(\bar{r}_s') = \hat{x} \sum_{n=1}^{N} I_n \; f_n(x', y') \quad \text{(A/m)} \tag{19}$$

where

$$f_n(x', y') = \Phi_n(x') \, \Psi_n(y') \tag{20}$$

Selecting Piecewise sinusoidal (PWS) expansion modes to represent the current variation in the x-direction.
The expansion function may be expressed mathematically as:

$$\Phi(x') = \begin{cases} \dfrac{\sin k(x' - x_{n\text{-}1})}{\sin kd}, & x_{n\text{-}1} \le x' < x_n \\ \dfrac{\sin k(x_{n+1} - x')}{\sin kd}, & x_n \le x' < x_{n+1} \\ 0, & \text{otherwise} \end{cases} \tag{21}$$

where $x_n = nd$, and d is the half length of each expansion mode given by $d = L / N$.
In Case of an isotropic substrate, the value k equal to the "effective" wave number for the substrate is a good choice,

$$k = k_e = \sqrt{\varepsilon_e} \; k_0 \tag{22}$$

Chose the *y*-variation of the current density, so

$$\Psi_n(y') = \frac{1}{W} \quad , \qquad -\frac{W}{2} < y' < \frac{W}{2} \tag{23}$$

After use the Fourier transform of the current density $\bar{J}_s(x', y')$, than

$$\bar{J}_s\,(\bar{k}_s) = \hat{x} \sum_{n=1}^{N} I_n \; \tilde{F}_n\,(\bar{k}_s) \tag{24}$$

where

$$\tilde{F}_n\,(\bar{k}_s) = \tilde{\Phi}_n(k_x)\, \tilde{\Psi}_n(k_y) \tag{25}$$

and

$$\tilde{\Phi}_n(k_x) = \frac{2k_e\,(\cos k_e d - \cos k_x d)}{\sin k_e d \;\, (k_x^2 - k_e^2)} e^{-ik_x\, nd} \tag{26}$$

$$\tilde{\Psi}_n(k_y) = \frac{\sin k_y \frac{W}{2}}{k_y \frac{W}{2}} \tag{27}$$

Thus,

$$-\sum_{n=1}^{N} I_n \, \bar{E}_n^{(s)}(\bar{r}_s) = \bar{E}^{(i)}(\bar{r}_s), \quad on\, S \tag{28}$$

where $\bar{E}_n(\bar{r}_s)$ is the scattered electric field due to the n^{th} expansion mode $\bar{f}_n$ of the surface current density $\bar{J}_s$, and is given by

$$\bar{E}_n^{(s)}(\bar{r}_s) = \hat{x} i\omega \int\int_{-\infty}^{\infty} d\bar{k}_s \, e^{i\bar{k}_s\cdot\bar{r}_s} \, g_{11}^{(x,x)}(\bar{k}_s)\, \tilde{F}_n(\bar{k}_s) \quad n = 1,2,..,m,...,N \tag{29}$$

Applying the Galerkin's method to get

$$-\sum_{n=1}^{N} I_n \iint_{S_m} \bar{f}_m(x,y)\cdot \bar{E}_n^{(s)}(x,y)\, dx\, dy = \iint_{S_m} \bar{f}_m(x,y)\cdot \bar{E}^{(i)}(x,y)\, dx\, dy, \quad m = 1, 2,.., N \tag{30}$$

where S_m is the surface of the m^{th} test mode and $\bar{E}_m^{(s)}(x,y)$ is the scattered field in layer (1) by the m^{th} test mode $\bar{f}_m$ at the position of the n^{th} expansion mode.

In case of use current source (probe excitation) the reciprocity theorem can be used, so

$$-\sum_{n=1}^{N} I_n \iint_{S_n} \bar{E}_m^{(s)}(x,y)\cdot \bar{f}_n(x,y)\, dx\, dy = \iiint_V \bar{E}_m^{(s)}(x,y,z)\cdot \bar{J}^{(i)}(x,y,z)\cdot dx\, dy\, dz, \quad m = 1, 2,.., N \tag{31}$$

where, $\bar{E}_m^{(s)}(x,y,z)$ is the field in layer (2) of the test mode at the position of the probe and $\bar{J}^{(i)}$ is the impressed (source) current of the probe.

After that,

$$\sum_{n=1}^{N} Z_{mn} I_n = V_m^P, \quad m = 1, 2, \ldots, N \tag{32}$$

where

$$Z_{mn} = -\iint_{S_n} \bar{E}_m^{(s)}(x,y)\cdot \bar{f}_n(x,y)\, dx\, dy \tag{33}$$

$$V_m^P = \iiint_V \bar{f}_m(x,y)\cdot \bar{E}^{(i)}(x,y) dV \tag{34}$$

or

$$V_m^P = \iiint_V \bar{E}_m^{(s)}(x,y,z)\cdot \bar{J}^{(i)}(x,y,z) dxdydz \tag{35}$$

Getting,

$$Z_{mn} = -i\omega \int\int_{-\infty}^{\infty} dk_x dk_y \, \tilde{F}_m^*(k_x,k_y)\, g_{11}^{(x,x)}(k_x,k_y)\, \tilde{F}_n(k_x,k_y), \quad \begin{matrix} m = 1,2,\ldots,N \\ n = 1,2,\ldots,N \end{matrix} \tag{36}$$

For more general case, we used B Patch Microstrip Antenna fed with Coaxial Probe instead of Dipole. The geometry of Star Patch was shown in Fig. 2. The Width of the B Patch was much larger than that of the Dipole. Now, the current has two components (in x and y directions) [8].

For,

$$Z_{in} = \frac{P_s}{I_{in}\; I_{in}^*} \tag{37}$$

Where P_s is the input power and I_{in} is input current [9].

Than

$$P_s = -\iint_{S'} \bar{E}_{i,\tan}\cdot \bar{J}_c^*\, dys' \tag{38}$$

$\bar{E}_{i,\tan}$ is tangential electric field for vertical current, while $\bar{J}_c^*$ is complex conjugate induced current.

IV. Results And Discussion

i. Input Impedance of Rectangular patch with superstrate anisotropic layer

A code has been written for general shape Microstrip patch antenna based in the previous analysis to calculating input impedance. For validation propose, a rectangular shape Microstrip patch has been proposed. Using the data results [10] to validate our numerical results.

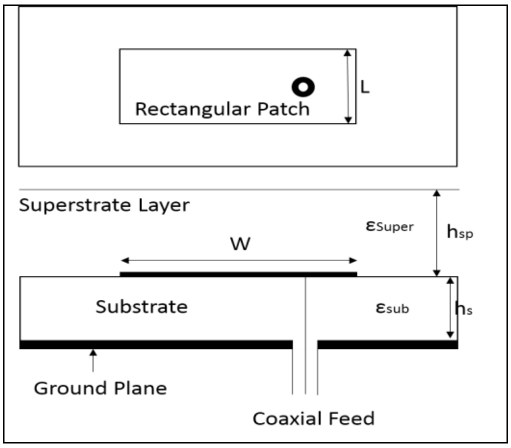

Fig. 2. Rectangular Shape Microstrip Patch Antenna

Figure 2 shows a rectangular patch antenna with length L = 76.2mm, width W = 114.3mm, isotropic substrate layer relative permittivity εsub= 2.64 and Anisotropic Superstrate Layer relative permittivity εsup(ε_{xx}= 3.168; ε_{zz}= 2.64).

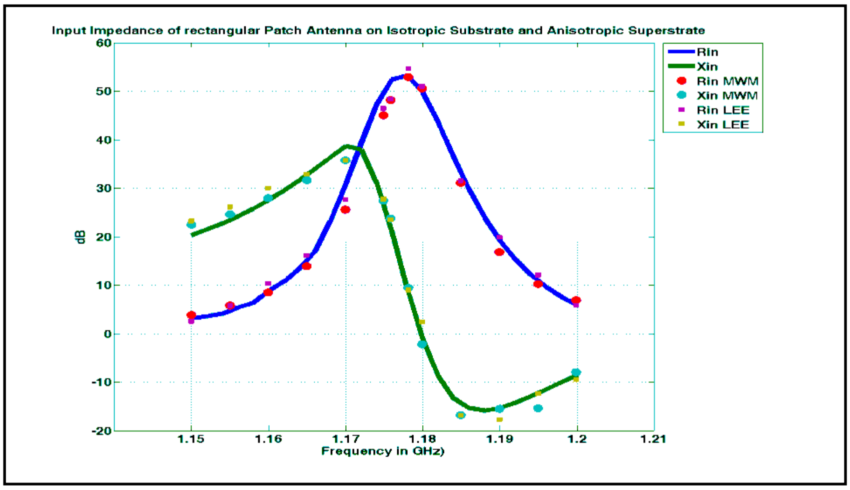

Fig. 3 . Input Impedance of rectangular patch in Anisotropic Superstrate Layer and on isotropic Substrate Layer

Figure 3. shows input impedance (real and imaginary parts) for rectangular patch on isotropic substrate layer and in superstrate layer, respectively. Our numerical results are in good agreement with test data as shown in Fig. 3. Due to miss some antenna parameters like substrate length and width in test data [10], there is some error in our numerical results validity.

ii. Farfield Directivities and gains of B patch embedded in SuperstrateLayers

B patch Microstrip antenna structures embedded in anisotropic superstrate is shown in Fig. 4. The effects of anisotropy of Superstrate layers in S-parameters, Axial Ratio, Directivity and gain are investigated. To simulate the Far Field Radiation of B Patch Antenna, a code program is written. A Microstrip B patch of length *Lp* = 7 mm and width Wp = 5.5mm on the top of Rogers an isotropic substrate of permittivity εr = 3.38, and thickness hs = 1.5mm. The Ground plate of rectangular shape with length L= 12mm and W=8mm.. The B patch is fed with coaxial probe**.** The following anisotropic superstrates are used: pirolytic boron nitride, or pbnε_{xx}= 5.12; ε_{zz}= 3.4), sapphire (ε_{xx}= 9.4; ε_{zz}= 11.6), Epsilam-10 (ε_{xx}= 13; ε_{zz}= 10.6). For ε_r = 1(vacuum or Air) use Foam flakes ε_r =1.1, which is good approximation. The thickness of each Anisotropic Layer is 1.6 mm length.

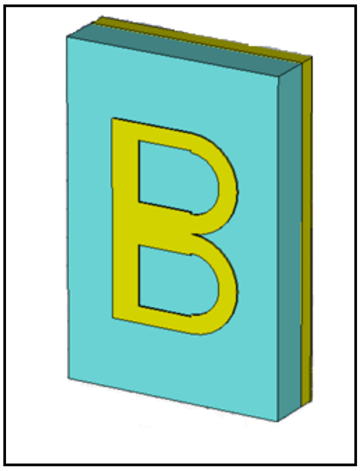

Fig. 4, B Patch Antenna

To enhance the Gain of Microstrip patch antenna, a method depending on Anisotropic Superstrate Layers has been proposed. Our Design has four cases:

Case 1 : B patch antenna without any Superstrate Layer as shown in Fig. 4.

Case 2 : B patch antenna with one Superstrate Anisotropic Layer media made of Epsilam-10 (ε_{xx}= 13; ε_{zz}= 10.6) as shown in Fig. 5.

Case 3 : B patch antenna with two Superstrate Anisotropic Layers media made of Foam (ε_r =1.1) for layer one and sapphire (ε_{xx}= 9.4; ε_{zz}= 11.6) for layer two as shown in Fig. 6.

Case 4 : B patch antenna with three Superstrate Anisotropic Layers media made of Foam (ε_r =1.1) for Layer one and sapphire (ε_{xx}= 9.4; ε_{zz}= 11.6) for Layer two and three as shown in Fig. 7.

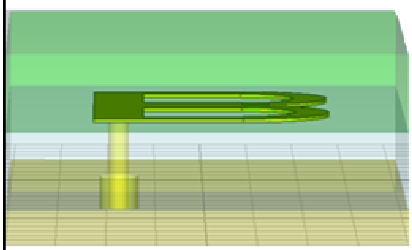

Fig. 5. B Patch Antenna with one anisotropic superstrate Layer, ε_{xx}= 13; ε_{zz}= 10.6

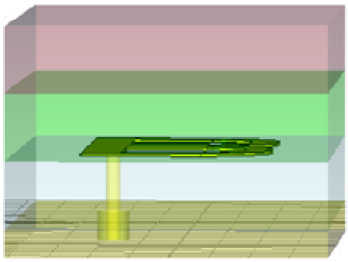

Fig. 6. B Patch Antenna with two anisotropic superstrate Layers, ε_r =1.1(layer 1), $\varepsilon2_{xx}$= 9.4; $\varepsilon2_{zz}$= 11.6 (layer 2).

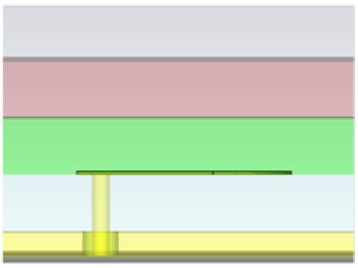

Fig. 7. B Patch Antenna with three anisotropic Superstrate Layers, ε_r =1.1(layer 1) and $\varepsilon2_{xx}$= 9.4; $\varepsilon2_{zz}$= 11.6(layer 2) , $\varepsilon3_{xx}$= 9.4; $\varepsilon3_{zz}$= 11.6(layer 3)

Table 1, Directivities and Gains of B Microstrip Patch Antenna

F GHz	Directivity dBi				Gain dBi			
	No Superstrate Layer	1 Superstrate Layer	2 Superstrate Layers	3 Superstrate Layers	No Superstrate Layer	1 Superstrate Layer	2 Superstrate Layers	**3 Superstrate Layers**
27	10.3	10.6	10.7 (25GHz)	11.7(28GHz)	10.2	10.5	10.69(25GHz)	**11.69(28GHz)**
29	9.19	4.61	8.88	9.93	9.1	4.57	8.86	**9.93**
31	7.49	3.5	7.28	9.25	7.41	3.49	7.26	**9.15**
33	6.45	3.45	5.6	5.2	6.39	3.33	5.54	**5.13**
35	5.94	7.55	7.09	9.06	5.9	7.49	7.01	**8.99**
37	4.56	6.62	4.94	3.79	4.53	6.55	4.87	**3.74**
39	6.46	5.58	7.83	5.22	6.41	5.34	7.66	**5.19**
41	7.52	7.08	9.64	8.39	7.43	6.93	9.43	**8.24**
43	4.89	5.3	8.88	5.59	4.79	5.22	8.84	**5.47**
45	4.21	9.25	9.43	7.21	4.09	9.11	9.36	**7.08**
47	2.83	9.24	7.78	4.01	2.71	9.11	7.62	**3.91**
49	6.01	8.93	7.56	5.09	5.91	8.8	7.47	**4.89**

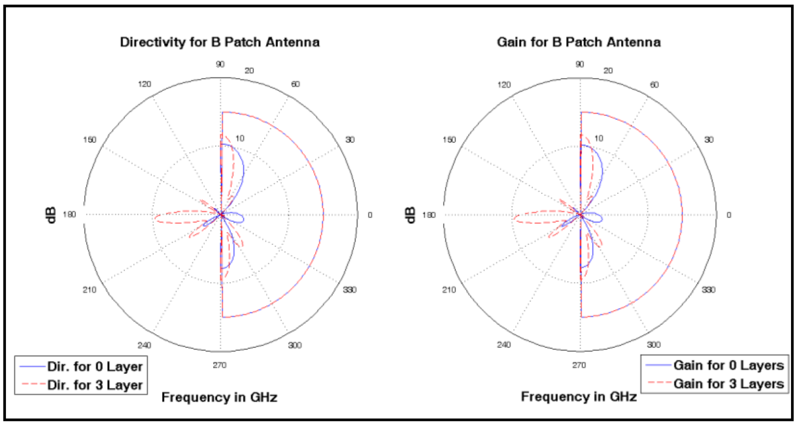

Fig. 8, Directivities and Gains of B Patch Antenna for case 1 and case 4

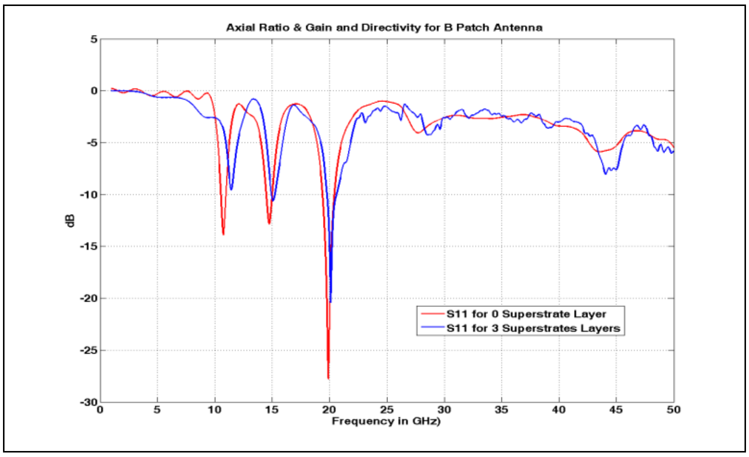

Fig.9, S11 of B Patch Antenna for case 1 and case 4

The improvement in Directivity and Gain was clear in Fig. 8 using Anisotropic Superstrate Layers media method. In Table 1 , the Directivity and Gain versus number of Anisotropic Superstrate Layers is illustrated. It is shown that the Directivity and Gain increased as number of Layers increased. This is not all time true, you should chose the type of Anisotropic metrical and thickness of layers carefully to enhance the Gain , otherwise the performance will be effected. The best Gain value is 11.69 dBi at 28 GHz for case 4,Re As shown in Table 1.

The Comparison between Case 1 (without any Superstrate Layer) and Case 4 (with three Superstrate Layers) for return loss (S11) was illustrated in Fig. 9.

The best Design requirements for B Patch Antenna are :

1) S11 ≤ -10 dB
2) Axial Ratio ≤ 3 dB
3) Gain should be maximum
4) Directivity should be maximum

Table 2. Best Antenna Parameters Design for B shaped Microstrip Patch Antenna

Case #	Frequency (GHz)	S11 (dB)	Axial Ratio (dB)	Gain (dB)	Directivity (dB)
1	No Design	No Design	No Design	No Design	**No Design**
2	12.858	-13.06	2.22	3.58	**5.12**
3	21.58	-10.04	1.72	8.46	**8.64**
4	14.965	-10.31	1.311	8.69	**8.72**

There is no design parameters that meet above requirement for Case 1 (no Superstrate Layer) as shown in Table 2. The best Design requirement met Case 3 (there are three Superstrate Layers) as illustrated in Table 2

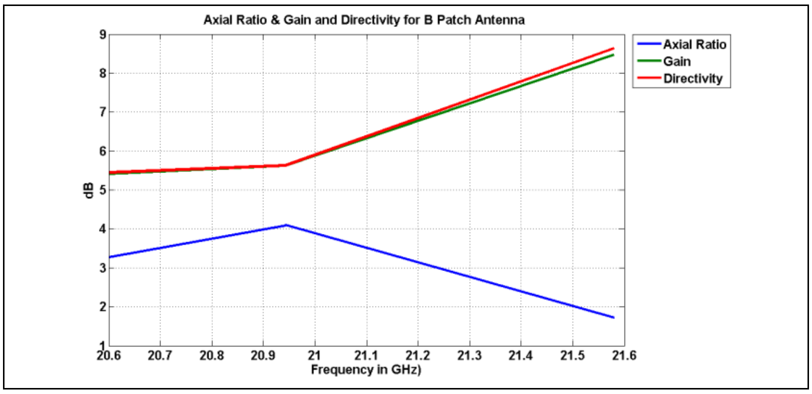

Fig. 10, Axial Ratio, Gain and Directivities for best Design of B Patch Antenna

Input Impedance of reticular Microstrip patch antenna embedded in Superstrate Anisotropic media and excited by coaxial feed is investigated. A rigorous analysis is performed using a dyadic Green's function formulation to calculating the input impedance. A Novel B Patch Microstrip Antenna has been designed. The Directivity and Gain for B patch Microstrip antenna are calculating as function of increased number of Superstrate Anisotropic Layers. Axial ratio, Gain and Directivity may be achieved. This work shows how the anisotropic phenomena can improve the performance of the patch antenna.

References

[1] B. Braaten, R. Nelson, I. Rogers, Input Impedance and Resonant Frequency of a Printed Dipole With Arbitrary Length Embedded in Stratified Uniaxial Anisotropic Dielectrics,*IEEE Antennas and Wireless Propagation Letters. **8,*** 2009, 806-810.

[2] C. Gürelm, E.Yazga, Characteristics of a Circular Patch Microstrip Antenna on Uniaxially Anisotropic Substrate,*IEEE Trans. on Antennas and Propagation, **52** (10),* October, 2004, 2532-2537.

[3] F. Bouttout,F. Benabdelaziz, A.Benghalia, D.Khedrouche, T.Fortaki, Uniaxially anisotropic substrate effects on resonance of rectangular microstrip patch antenna, *Electronics Letters, **35** (4),* 18th February, 1999, 255-256.

[4] R. Nelson, D. Rogers, D'assungao, Resonant Frequency of a Rectangular Microstrip Patch on Several Uniaxial Substrates,*IEEE Trans. on Ante.Propagation, **38** (7)*,July, 1990, 973-981.

[5] A. Eroglu, J. K. Lee, Far field radiation from an arbitrarily orientated Hertzian dipole in the presence of layered anisotropic medium,*IEEE Trans. Antennas Propag*., ***53*** *(12)*,December, 2005, 3963–3973.

[6] V. Losada, R. Boix, M. Horno, Full-Wave Analysis of Circular Microstrip Resonators in Multilayered Media Containing Uniaxial Anisotropic Dielectrics, *Magnetized Ferrites, and Chiral Materials. IEEE Trans. on Micro. Theory and Techniques,* ***48*** *(6)*,2000, 1057-1064.

[7] M. Gharbi, A. Affandi, S. Ali, S. Application of The Moment Method in The Spectral Domain,*Life Science Journal,* ***5,***2015,1 – 23.

[8] G. Pettis, Hertzian Dipoles and Microstrip Circuits on Arbitrarily Oriented Biaxially Anisotropic Media,*PhD Dissertation, Syracuse University, Syracuse, NY*, December, 2008.

[9] J. Graham, Arbitrarily Oriented Biaxially Anisotropic Media:Wave Behavior and Microstrip Antennas,*PhD Dissertation, Syracuse University, Syracuse, NY*, 2012.

[10] A. K. Verma, Input Impedance of Rectangular Microstrip Patch Antenna With Iso/Anisotropic Substrate-Superstrate,*IEEE Mic. and Wir. Lit.,* ***11***, 2001, 456-458.

[11] A. Affandi, M. Gharbi, S. Ali, Plane Wave Spectral Integral Representation of the Dyadic Greens Function of Layered Media, *Life Sci. Journal,* ***4,*** 2015,164 – 174.