Design And Simulation of Wideband Planar Antenna for Microwave and Millimeter Wave Applications

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Abstract:- A practicability review concerning the geometry, the manufacturing technologies, adopted for the analysis of super wide impedance planar antenna is proposed by constructing 2x2 Microstrip patch antenna (MPA) making use of ANSYS HFSS. Four patches are arranged in symmetrical arrangement in an antenna, this patch is interrelated to one another along the cross-shaped high impedance microstrip line. Effective single feedline is given to one of the patches where antenna array is excited. This presented antenna array structure gets rid of the principal drawback of standard microstrip patch antenna which has a narrow bandwidth. The antenna presents a super wide frequency bandwidth. This paper focuses on design of planar antenna for high frequencies both microwave and millimeter wave applications. The main feature of this antenna is to obtain a wider frequency bandwidth by inclusion of slots on the patches and cross coupled microstrip lines. The resonant frequency chosen as 30GHz with the substrate Rogers AD300D whose dielectric constant 3. The MPA is designed for ultra-wideband (UWB) transmission and Vehicular communication.

***Keywords:-** 5G; Super Wide Impedance; Cross-Shaped High Impedance Lines; Super Wide Frequency Bandwidth.*

I. INTRODUCTION

The immense importance to patch antennas is a result of higher demand of compact and cheaper antennas. This leads to a situation where in many scientists and antenna researchers started exploring different ways of harnessing the qualities of patch antennas. As there are numerous techniques to increase the bandwidth behavior of the antenna and our principal is to overcome the drawback of conventional microstrip patch antenna that is narrow bandwidth. There are various techniques to improve the Bandwidth enhancement, by employing the wide band impedance matching technique to turn down the return loss at the input to the resonant patch antenna, also by increasing the slots in the patches and by increasing the thickness of radiating patch also decreasing the dielectric constant of the antenna substrate.

The paper [1] explains detailed theory of the antenna design equations. The Author in [2] demonstrated a U-shaped slot on the microstrip patch antenna helping in bandwidth enhancement. The paper [3] implemented another method to improve the bandwidth by inclusion of slots and using high shaped impedance lines. Antenna designs with wide bandwidth and high gain is described in [4-5].Bandwidth improvement can also be made using AMC multiple slots[6].By changing the shapes of slots also enhances a good gain and bandwidth [7].The various antenna configurations are used in high frequency wave applications in frequency range of 30-300GHz[8] and also in Bluetooth and WIMAX applications[9] and smart car radar application [10] using a switched beam grid array.

Antenna bandwidth is where the antenna exhibits the SWR less than 2:1. Super Wide impedance is that circuit possessing stable impedance over all environmental conditions.

II. ANTENNA DESIGN

The antenna is constructed by designing four associated patches in direct presence, are ordered in an array arrangement. The antenna which consists of four patches is designed by cutting a slot in each patch. The antenna geometry composes of 2X2 array designed with Rogers AD300D substrate material with a relative permittivity of 3 and with the suitable dimensions of substrate thickness of 0.8 mm and center frequency taken is 30GHz. The design is started by taking a rectangular patch as the basic antenna at desired frequency 30GHz.Microstrip line feed is chosen among the types of feeding techniques, since it provides good impedance matching and easy to fabricate.

Various antenna designs are done starting from a basic single patch antenna without and with slot and then 1x2 array antenna without and with slot for the same desired frequency. Finally, 2x2 array antenna is designed with and without slot configurations. Here in the antenna array, the patches are interrelated to one another along the cross-shaped high impedance microstrip line.

Cross shaped high impedance microstrip line is chosen for the following benefits as it enhances the antenna gain, minimises backward radiation, reduces mutual coupling, surface losses and improves the antenna bandwidth[3].The patch antennas were designed using the standard empirical formulas, and effective width and length of the patch were calculated using the following design equations (1) – (13).

WIDTH (W)

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \quad (1)$$

Effective length (L_{EFF}):

$$\mathrm{L} = \frac{\mathrm{C}}{2\mathrm{f_r}\sqrt{\epsilon_{\mathrm{reff}}}} \quad (2)$$

Dielectric constant (E_{REFF})

$$\epsilon_{\mathrm{reff}} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} + [1+12\frac{\mathrm{h}}{\mathrm{w}}]^{-1/2} \quad (3)$$

Calculation of length extension

$$\frac{\Delta l}{h} = 0.412\frac{(\epsilon_{reff+0.3})(\frac{W}{h}+0.264)}{(\epsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \quad (4)$$

Length of patch (L)

$$L = L_{eff} - 2\Delta L \quad (5)$$

Substrate length and width

$$L_g = L + 6h \quad (6)$$

$$W_g = W + 6h \quad (7)$$

Feed length

$$l = \frac{\lambda_g}{4} \quad (8)$$

Where

$$\lambda_g = \frac{c}{f\sqrt{\epsilon_r}} \quad (9)$$

Cross shaped line

Width==0.1x width of the patch (10)

Length==$\frac{\lambda_0}{4}$ (11)

Slot length

Length =0.52x length of the patch (12)

Width= 0.1 x width of the patch (13)

Below table 1 shows the calculated dimensions of 2x2 antenna array structure, calculated using the above design equations.

Parameters	Values
Width of the patch(W)	3.53 mm
Length of the patch (L)	2.51 mm
Width of the substrate (W_s)	8.33 mm
Length of the substrate (L_s)	7.31 mm
Thickness/height of the substrate(h)	0.8 mm
Width of the feed line (W_f)	0.8 mm
Length of the feed line (L_f)	1.71 mm
Cross shaped length (l_c)	2.5 mm
Cross shaped width (w_c)	0.24 mm
Slot length (l_s)	0.35 mm
Slot width (w_s)	1.30 mm

Table 1:- Dimensions of Antenna Design

III. RESULTS AND DISUSSION

The antenna design of 2x2 array structure without and with slot shows the following results using High Frequency Structure Simulator (HFSS).

A. Geometry Structure

The figure 1 and 2 shows the geometry structure of 2x2 antenna array without and with slot configuration where it is designed for desired 30GHz frequency.

The four patches are interconnected with each other with cross shaped high impedance line where feedline is given to one of the patches.

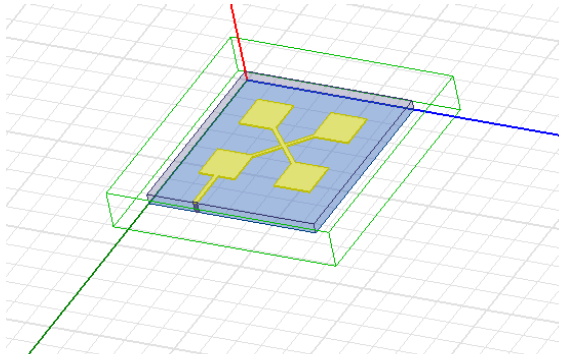

Fig 1:- Geometry structure of 2x2 array antenna without slot

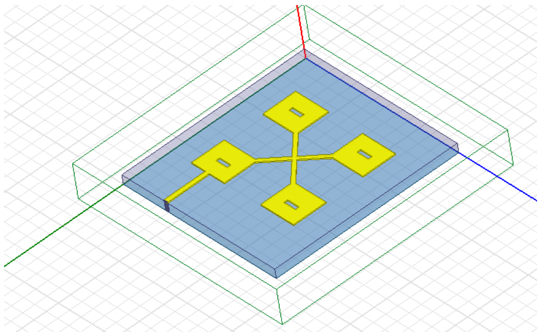

Fig 2:- Geometry structure of 2x2 array antenna with slot

B. Return Loss- S11(dB)

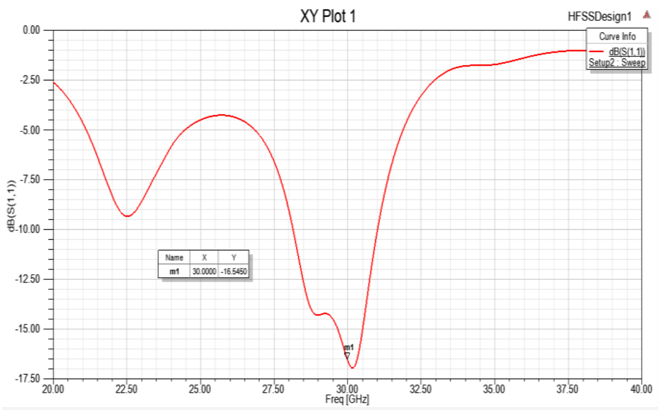

Fig 3:- S11 (in dB) of 2x2 array antenna without slot

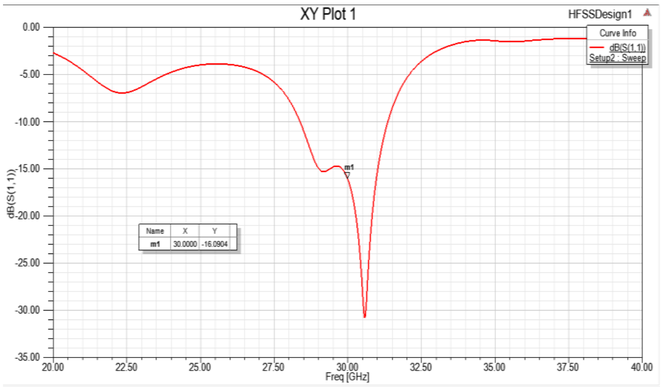

Fig 4:- S11 (in dB) of 2x2 array antenna with slot

The Return loss obtained for 2x2 array antenna without and with slot configuration as shown in figure 3 and 4, the S11 obtained is -16.54 and -16.09.

The bandwidth of 2x2 array antenna structure without and with slot is compared and obtained is 2.85GHz ,3GHz as shown in figures 3 and 4.

Various other parameters of planar antenna like VSWR, Gain pattern and Radiation Efficiency are obtained.

C. *Gain Pattern*

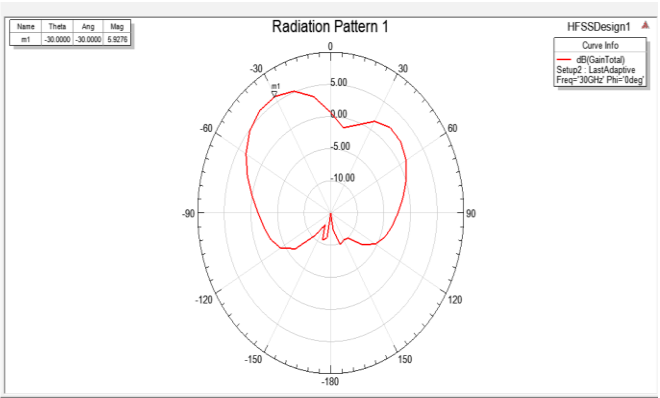

Fig 5:- Gain pattern of 2x2 array antenna without slot

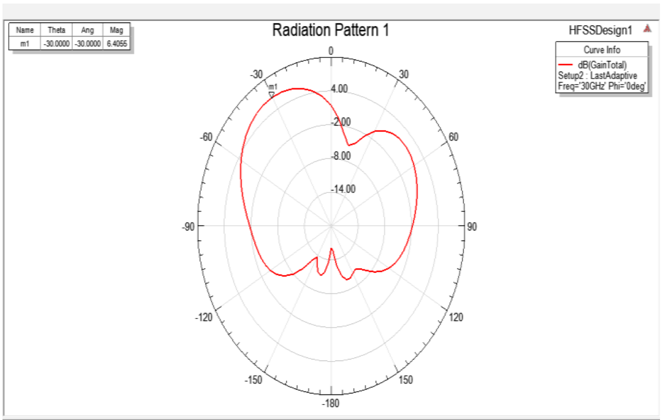

Fig 6:- Gain pattern of 2x2 array antenna with slot

The gain pattern is obtained as shown in figure 5 and 6 for 2x2 array antenna without and with slot, gain obtained are 5.92 dB and 6.40 dB.

D. *VSWR*

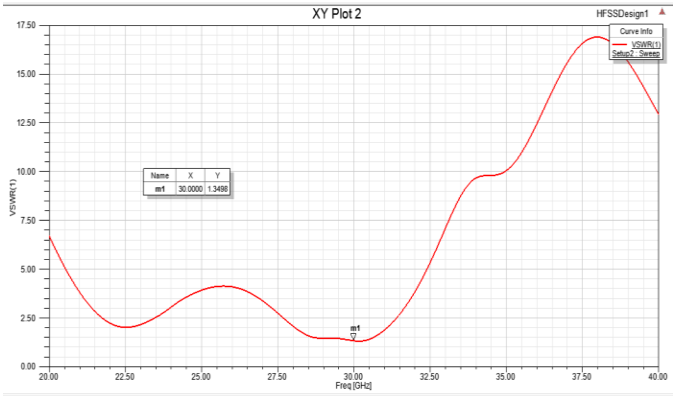

Fig 7:- VSWR plot of 2x2 array antenna without slot

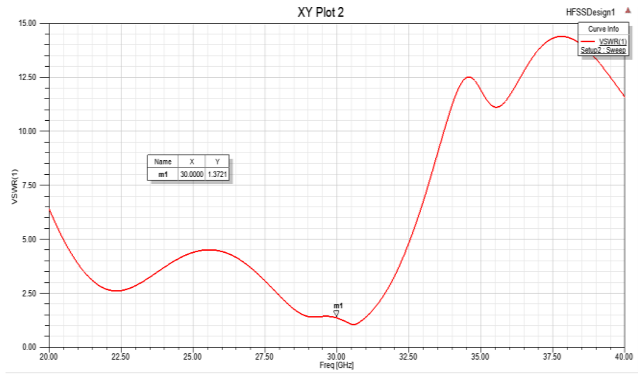

Fig 8:- VSWR plot of 2x2 array antenna with slot

Figure 7 and 8 shows the VSWR plots for 2x2 array antenna without slot and with slot, it is 1.34 and 1.37 respectively.

E. *Radiation Efficiency*

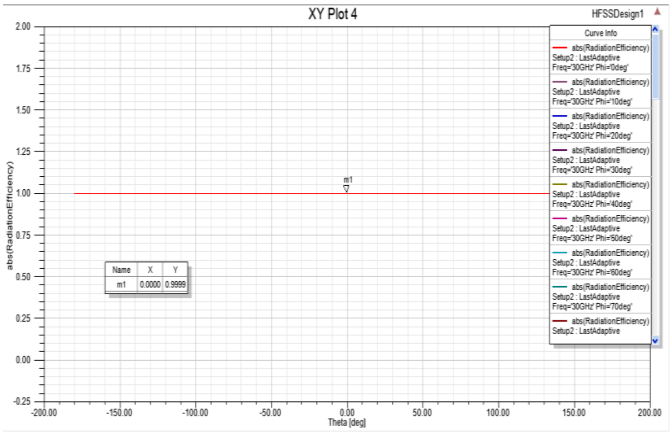

Fig 9:- Radiation Efficiency of 2x2 array antenna without slot

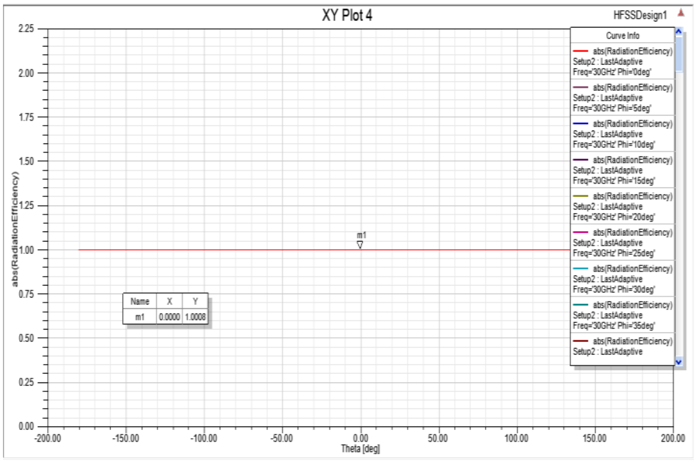

Fig 10:- Radiation Efficiency of 2x2 array antenna with slot

The radiation efficiency can be seen in figure 9 and 10 for 2x2 array antenna without and with slot which is 99% and 100% efficient.

Antenna Designs	Bandwidth (GHz)	Gain (dB)	Return loss(dB)	VSWR
1x2 array antenna without slot	2.63	5.78	-14.08	1.49
1x2 array antenna with slot	2.78	5.98	-14.85	1.44
2x2 array antenna without slot	2.85	5.92	-16.54	1.34
2x2 array antenna with slot	3	6.40	-16.09	1.37

Table 2:- Comparison of results obtained

IV. CONCLUSION

In order to realize a super wide impedance bandwidth for microwave and millimeter wave applications, a 2x2 microstrip patch antenna (MPA) with cross coupled feed lines is designed using Ansys HFSS. This antenna array overcomes the main drawback of standard MPA with narrow bandwidth.

Millimeter waves has high frequency of operation that ranges from 30-300GHz and the wavelength is small, and wide bandwidth is capable of providing a high data rate information, also meets the requirements of future 5G communications and high performance hence wide bandwidth is appreciable for millimeter wave applications. The designed antenna hence supports a wide bandwidth and is suitable for millimeter wave applications.

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