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Waveguide Feed Microstrip Patch Antenna

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Abstract: *This paper shows a novel approach of feeding the microstrip patch antenna by using a waveguide.Compared with conventional antenna feeding techniques, this technique have more advantages and better prospects because as we know that the method we use for feeding the microstrip patch antenna are having a coaxial or a microstrip line, have the limitation for high frequency applications. Here we can use waveguide to overcome the disadvantages of microstrip feed or coaxial feedbecause the waveguide are used at high frequency operations. So in this way we can take advantage of microstrip patch antenna and waveguide both. In this paper the frequency for optimization we used is 2.4 GHz frequency*

Keywords: *Microstrip patch, Waveguide fed, High Frequency Structure Simulation(HFSS).*

I. Introduction

Traditional techniques for feeding microstrip antennasare the direct-contact feeds where the feeder linelike a microstrip is connected directly to the patch [1]–[4]. Apopular variant of these is the probe-coupled feed that avoidsencroaching substrate space by connecting from the undersideof the ground plane using a coaxial probe [5]–[8]. A secondcategory of feeds, called proximity-or electromagnetically-coupledfeeds avoid the need for a direct junction [9]–[13]. Inthis case, coupling occurs through fringing

fields from the endor side of a microstripfeeder or the line may be embeddedbetween the patch and ground plane. A significant advance wasachieved by pozar when he proposed the aperture-coupled feed[14], [15]. The patch is excited through a slot (aperture) [19] placed beneath it in the ground plane while the feeder line[23], placed on the lower side, couples energy through it[16]–[18].

In this paper, awaveguide feeding technique is proposedthat uses a waveguide to directly feed the microstrip patch antenna.

II. Proposed Model& Design

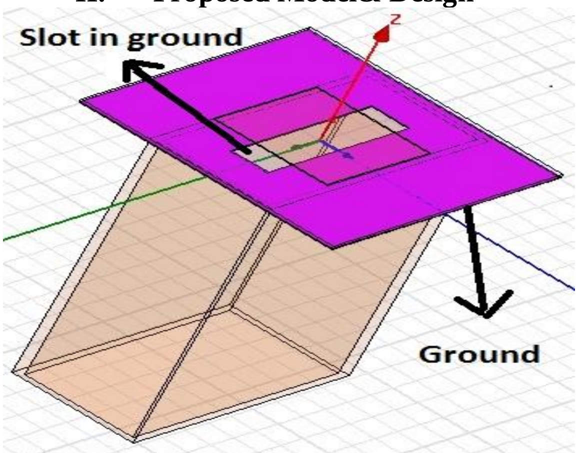

Fig. 1. Basic concept model

As shown (see Fig. 1) the idea is to combine the advantages of waveguide at high frequency and microstrip patch antenna. The waveguide is directly feed to the ground. As the microstrip patch antenna consist of a ground a patch and a substrate. The best feeding point from the geometry of microstrip patch antenna we can understand that to couple the maximum energy to it the feed is provided beneath the ground directly (see Fig. 1).

The actual HFSS model is shown (see Fig. 2). This method is also known as indirect feeding method because as there is no direct excitation is provided by the cable or microstrip.

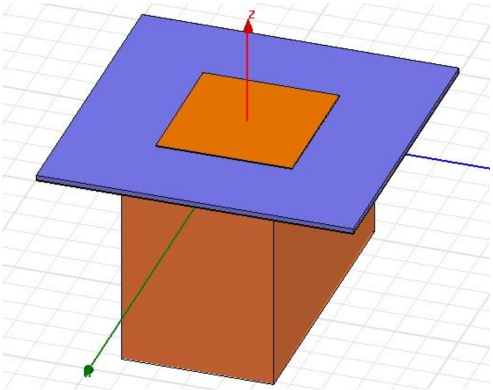

Fig. 2. HFSS model

The material used for waveguide is copper which have relative permittivity and permeability is approximately 1. Microstripantenna which consist of patch substrate and ground. In which both patch and ground are of copper. The main aim behind selecting copper [20] is that it shows bulk resistivity very low around $1.69\times10^{-8}\Omega$m.[22] Bulk resistivity should be as low as possible while the waveguide is in picture. It shows the amount of resistant the material will absorb the energy.

bulk resistivity=sheet resistance×thickness

The waveguide dimensions are 90mm×43mm. As we are simulating in the S-Band the actual inner dimensions are 86.36 mm x 43.18 mm. But the simulations (see Fig. 3) the S_{11} scattering parameter plot shows the deep at 2.4 GHz at 90mm×43mm. Waveguide simulation result (see Fig. 4) shows S_{11} is approximately – 46 db at 2.4 GHz frequency. The results are obtained by using two waveports on either side of the waveguide. We can also use aluminium instead of copper.

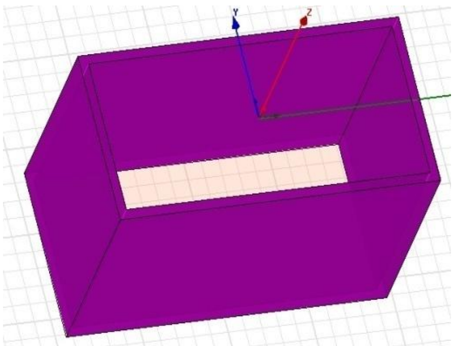

Fig. 3. Waveguide Structure

Fig. 4. Waveguide S_{11} Results

Waveguide also shows better result if we consider the concept of copper losses, skin effect, dielctriclosses.The lower cutoff frequency (or wavelength) for a particular mode in rectangular waveguide is determined by the following equations [21] (note that the length, x, has no bearing on the cutoff frequency). In our caseis around 1.66 GHz theoretically and we get it around 1.65 GHz.

(Hz)

$$f_c = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2} \text{ Hz}$$

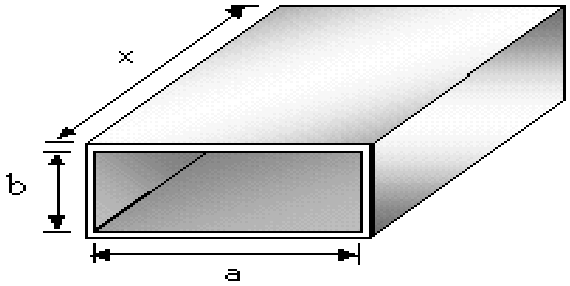

Fig. 5. Waveguide [21]

We have used TE_{10} mode so in cut off frequency above equation it is not dependent on the b dimension of waveguide (see Fig 5). The m=1 and n=0 are half wave variations in a and b direction respectively. Now we move on to the next part that is patch antenna. Patch antenna consist of a ground substrate and a patch on top of it (see Fig .6a, 6b, 6c). The design procedure with design equation is as follows:

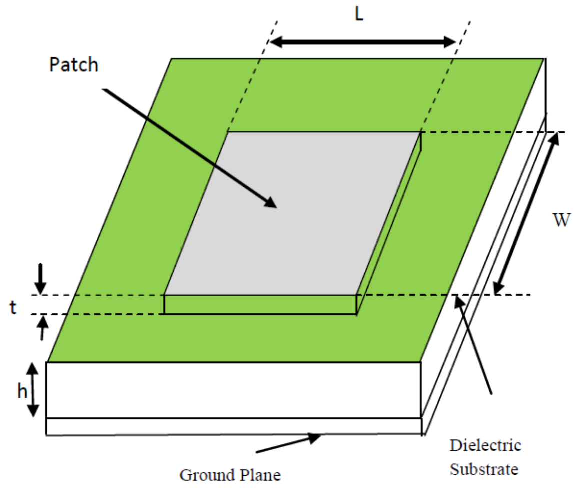

Fig. 6(a). Patch antenna [21]

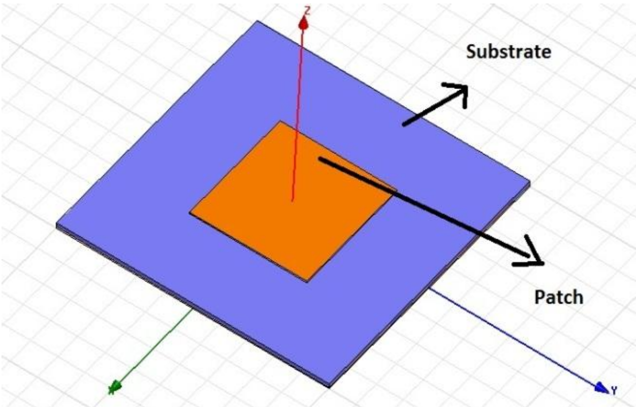

Fig. 6(b) Substrate, Patch

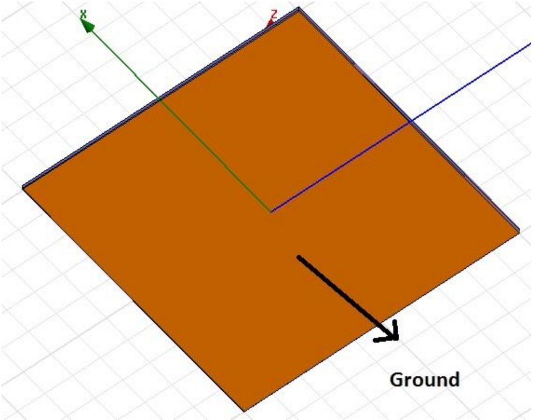

Fig. 6(c) Ground

Calculation of the Width (W)
The width of the Microstrip patch antenna is given as[21]:

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

Where,c is velocity of light ,fo is Resonant Frequency &$\varepsilon_r$is Relative Dielectric Constant Of course other widths may be chosen but for widths smaller than those selected according width equation, radiator efficiency is lower while for larger widths, the efficiency are greater but for higher modes may result, causing field distortion. In this work upon Substituting c = 3.0×10^(11)mm/s, εr = 2.2 and fo = 2.4 GHz,
we get: W = 49 mm.

Calculating the Length (L)
Effective dielectric constant (ε_{re})

Once W is known, the next step is the calculation of the length which involves several other computations; the first would be the effective dielectric constant. The dielectric constant of the substrate is much greater than the unity; the effective value of ε_{re} will be closer to the value of the actual dielectric constant ε_r of the substrate. The effective dielectric constant is also a function of frequency. As the frequency of operation increases the effective dielectric constant approaches the value of the dielectric constant of the substrate is given by:

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{\frac{-1}{2}}$$

In our design for the above mentioned values the effective dielectric is found to be ε_{re} = 2.11

Effective length (L_{eff})
The effective length is: which is found to be

$$L = \frac{c}{2f_o\sqrt{\varepsilon_{re}}}$$

L_{eff} = 43 mm

Length Extension (ΔL)

Because of fringing effects, electrically the micro strip antenna looks larger than its actual physical dimensions.For the principle E – plane (x-y plane), where the dimensions of the path along its length have been extended on each by a distance, ΔL, which is a function of the effective dielectric constant and the width-to-height ratio (W/h).The length extension is:

$$\Delta L = 0.412\, h \frac{(\varepsilon_{re} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{re} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Substituting ε_{re} = 2.2, W = 49 mm and h = 1.6 mm we get:
ΔL = 0.79 mm

Calculation of actual length of patch (L)
Because of inherent narrow bandwidth of the resonant element, the length is a critical parameter and the above equations areused to obtain an accurate value for the patch length L [21]. The actual length is obtained by:

$$L_{eff} = L + 2\Delta L$$

Substituting L_{eff} = 43 mm and ΔL = 0.79 mm we get: L = 42 mm

Hence our simulation results shows fruit full outcome at W = 45mm and L = 45mm which is near to our theoretical derivations.The middle substrate, which is made of Rogers RT/duroid 5880(tm), has a relative dielectric constant ε_r= 2.2 and height of 1.5mm.

III. Results

As a prototype, the proposed waveguide fedmicrostrip patch antenna is designed at 2.4 GHz which lies inthe S-Band of the spectrumallocation.The patch dimensions are obtained from a design procedurebased on [22]. The slot lengthwas originally selected as 60mm×10mm but the parametric analysisgave at 62mm×15mm as the optimum(see fig 7).

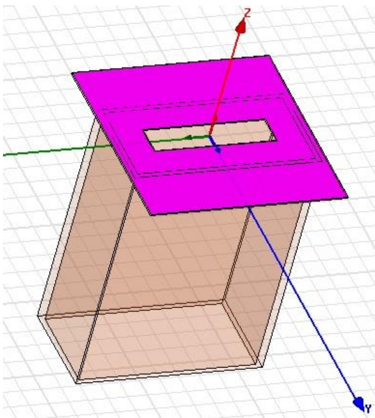

Fig. 7 Cut In the Ground Plane

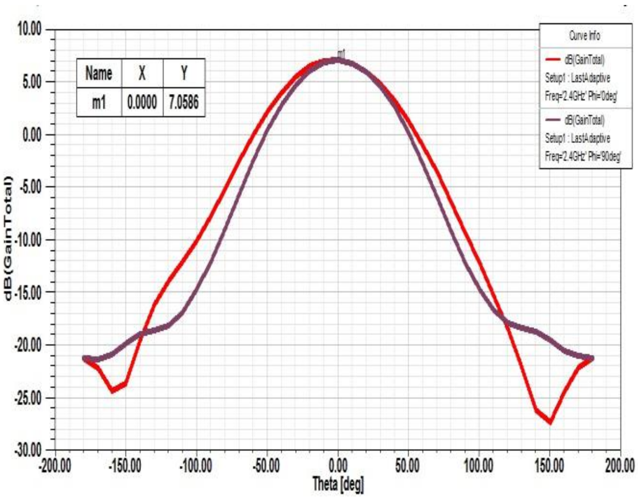

Fig. 8a Gain Plot 2D

The Gain Plot 2D and 3D (see Fig 8a, 8b) shows 7.05db at theta = 0. Further improvement in gain can be obtained by keeping waveguide length of 250mm but at that the S_{11} shows very poor result.

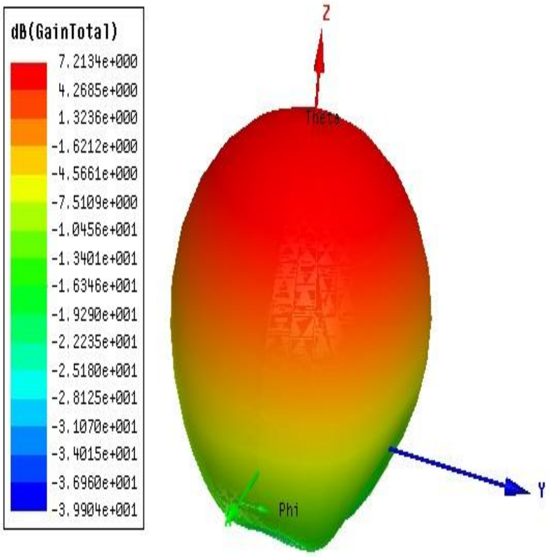

Fig. 8b 3-D Gain Plot

Scattering parameter plot (return loss) shows optimum result at 2.4 GHz which is -23.27db(see Fig 10). The radiation pattern is also shown for Phi = 0^o,90^o(see Fig 9).

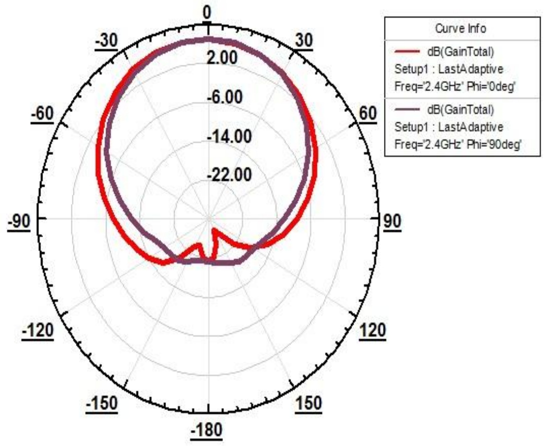

Fig. 9 Radiation pattern

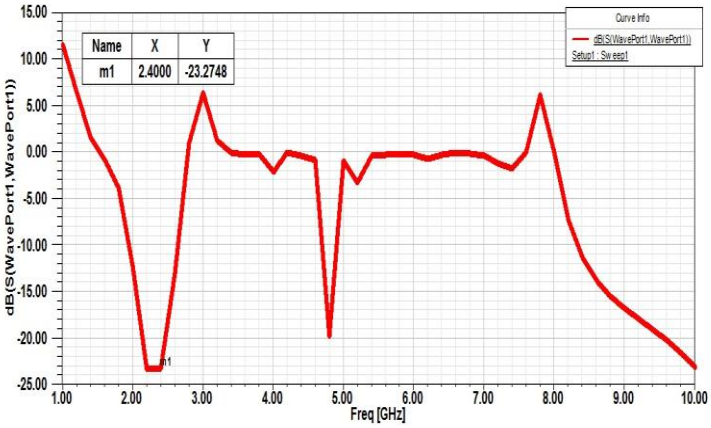

Fig. 10 S_{11} parameter plot (Return Loss)

IV. Conclusion

Finally, the conventional feeding techniques and the proposed techniques shows significant improvement in power handling capacity and mostly at very high frequency applications. This can be used in satellite communication, RFID technology WiMAX, RADAR and Rectennaapplications. Further we can get optimum result by changing dimension of patch to use at different frequency. In future we can also increase the gain by putting cavity and hybrid patch design. Array of the proposed method using above mentioned technique can also create multi directional or high directive antenna.

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