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Probe Fed Patch Antenna Array Using Rohacell Dielectric Material

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Abstract: ***This paper focuses on the design and development of a patch antenna array on a very low dielectric constant substrate, such as a rohacell material. Use of lower dielectric constant provides better efficiency, larger bandwidth, loosely bound fields for radiation. However the patch size increases and the power divider for feeding the antenna array has to be designed separately using a higher dielectric constant substrate. The patch antenna array is developed at S & C- bands and finds application in array based spatial processing receiver for smart antennas and FM-CW radar respectively. Simulation results using LMS algorithm and experimental results of the product are presented. This paper concludes with a discussion on some future directions of research in this area.***

Keywords: Spatial processing, smart antennas, mobile communications, FM-CW radar, rohacell material, microstrip patch antenna, LMS-algorithm.

1. Introduction

There are many efforts on the design of microstrip patch antennas. The patch antenna has many unique and attractive properties, such as low profile, light weight, compact and comfortable to many mounting structures. They are easy to fabricate and integrate with solid state devices. Although patch antennas have narrow bandwidths, recent technology advances have made them to operate over wider bandwidths. A coax fed microstrip patch antenna element has been designed using the cavity model. A probe fed microstrip patch antenna element has been designed and tested. A microstrip array antenna on a rectangular rohacell sheet with four radiating elements has been developed and tested. A separate power divider is used for feeding the four element array. The return loss of the element is measured using a dual directional coupler, model 11692D of Hewlett Packard. The element pattern is measured and it is compared with simulated pattern. The array pattern is also simulated by the principle of pattern multiplication. Complex weighting has been implemented using LMS algorithm. This paper therefore addresses itself to the problems of design, development and testing of microstrip patch antenna with rohacell substrate material.

2. Element Design and Construction

A. Design

The most commonly used microstrip element consists of a rectangular patch, backed by a ground plane spaced in between by a dielectric substrate. There are many choices in the selection dielectric substrate including rohacell material. For excitation there are many methods, and we have chosen a coaxial probe feed. The length L of the patch is the most critical dimension and is slightly less than λ/2 in the dielectric substrate.

$$L \approx 0.49\lambda_d = 0.49\frac{\lambda_o}{\varepsilon_r} \quad (1)$$

Where,
L= length of the element
ε_r = relative dielectric constant of rohacell material
λ_0= free space wavelength
The effect of dielectric constant on the performance of patch antenna can be described on the basis of Gauss law from electrodynamics.

$$\Delta E = \frac{\rho}{\varepsilon_o \varepsilon_r} \quad (2)$$

The law states that the divergence of electric field is inversely proportional to the relative dielectric constant and proportional to the volume density of charge. If the relative dielectric constant is higher, the fields are tightly bound and less radiation occurs into the free space. This helps us in the selection of substrate material with different dielectric constants. Usually the value of dielectric constants chosen for patch antenna design is in the range of 2 to 5. The loss tangent of these substrates is relatively high. However, we have chosen rohacell material as a substrate. Since the relative dielectric constant of rohacell material is 1.05, it is a good choice for antenna design, as the loss tangent of the material is around 0.0015. Other advantage of rohacell, particularly at HF are its extremely fine cell structures that ensures minimal resin uptake and problem free compatibility with metallic facing materials due to the absence of corrosive effects.

The thickness of the rohacell dielectric material chosen for our design is 10 mm. The width **W** of the patch must be less than a wavelength in the dielectric substrate material so that higher-order modes are not excited. We have chosen a frequency of 2.45GHz for ISM band. A rectangular patch was chosen and for this case with **L**=4.7 cm and **W**=6 cm and simulations were carried out for the antenna radiation pattern [3]. The edge impedance of the patch works out to be 191.48 Ω. To match this edge impedance to the input

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impedance of the coaxial connector the following formula is used.

$$x = L/\pi \arcsin\sqrt{(R_i/R_e)} \quad (3)$$

Where 'x' is the location of the pin of the coaxial connector from the center of the radiating patch along the length, **L**. In our case R_i = 50 Ω and R_e = 191.48 Ω. Then x becomes 1.54 cm. Figure 1 illustrates the coax fed microstrip patch antenna element. The coaxial feeding is from the bottom and the position of the feed is along the resonant length. Radiation occurs from the fringing fields.

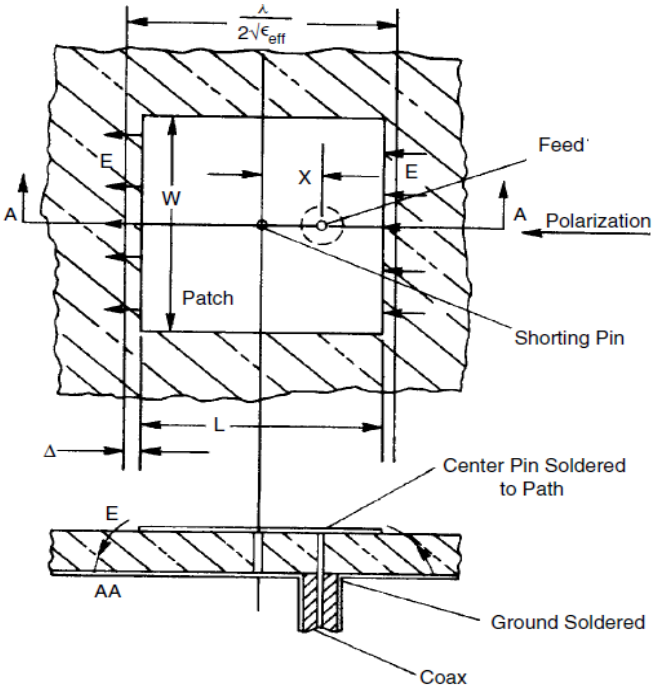


Figure 1: Coax-fed microstrip patch antenna element

Similarly, a patch antenna has also been designed at 5.7GHz required for an FM-CW radar application. For this case x = 2.10 mm, R_i = 50 Ω and R_e = 275.3 Ω.

The antenna is fed by a coaxial connector and is soldered to the back of the ground plane, the feed pin is soldered to the microstrip element has shown in figure 1. It is important that the feed pin be securely soldered to the microstrip element since the most failures of microstrip antennas occur at this point.

B. Construction

A rohacell material sheet of 10 mm thick was cut into a size of 343x120 mm for 2.45 GHz. one side of the sheet was covered with a sticking metal foil. The other side of the sheet has four patches of same metal foil cut into a size of 62x48 mm. the distance between the adjacent patches is chosen to be point $0.5\lambda_d$ = 30 mm. Where λ_d is the wavelength in the dielectric. The metal patches are symmetrically placed on the rohacell sheet.

For the 5.7 GHz design, the rohacell material sheet of 10 mm thick was cut into a size of 66X54 mm. one side of the sheet was covered with a sticking metal foil. The other side of the sheet has four patches of same metal foil cut into a size of 26x14 mm. The distance between the adjacent patches is chosen to be point $0.5\lambda_d$ = 20mm. Where λ_d is the wave length in the dielectric and the metal patches are symmetrically placed on the rohacell sheet.

The photograph of patch antenna array is shown in figures 2 & 3. Since the combining is done at IF the spacing between adjacent elements is not critical. Hence the problem of grating lobes does not arise. Also, the spacing between the elements can be increased to avoid mutual coupling without worrying about the grating lobes.

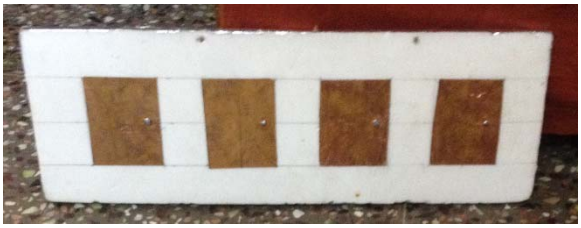


Figure 2: 4-element array @ 2.45GHz

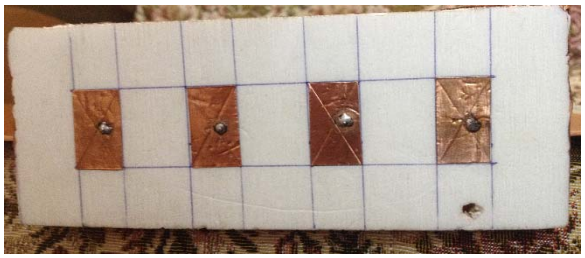


Figure 3: 4-element array @ 5.7 GHz

3. Simulation

Microstrip antennas have radiation patterns that can be accurately calculated. The patterns are calculated using cavity model [1]. The simulated patterns in both E and H planes at frequencies of 2.45 GHz and 5.7 GHz are shown in figures 4 and 5.

Array patterns of antenna for four element and eight element radiators in both polar and rectangular coordinates are shown in figures 6, 7, 8 and 9. The appearance of sidelobes in the visible region occurs when the number of radiating elements is more than 4. Creating a radiation pattern with the main beam at SOI and null at SNOI is more meaningful when the number of elements is more than 8. In the case of radar creating a null in the direction of the jammer is easier when the number of elements is more than 8.

Table 1 provides a summary of the beamwidths and directivity of the patch antenna at frequencies of 2.45 GHz and 5.7 GHz. The gain of the antenna will be lower than the directivity as the efficiency factors comes into picture.

Table 1: The directivity and Beamwidths of the patch antennas

Frequency (GHz)	Beamwidths(degree)		Directivity (dB)
	E plane	H plane	
2.45(ε_r=1.05)	60	70	9.1215
5.7 (ε_r=1.05)	62	72	8.9737
2.45(ε_r=3.2)	122	78	6.4421
5.7 (ε_r=3.2)	118	78	6.4869

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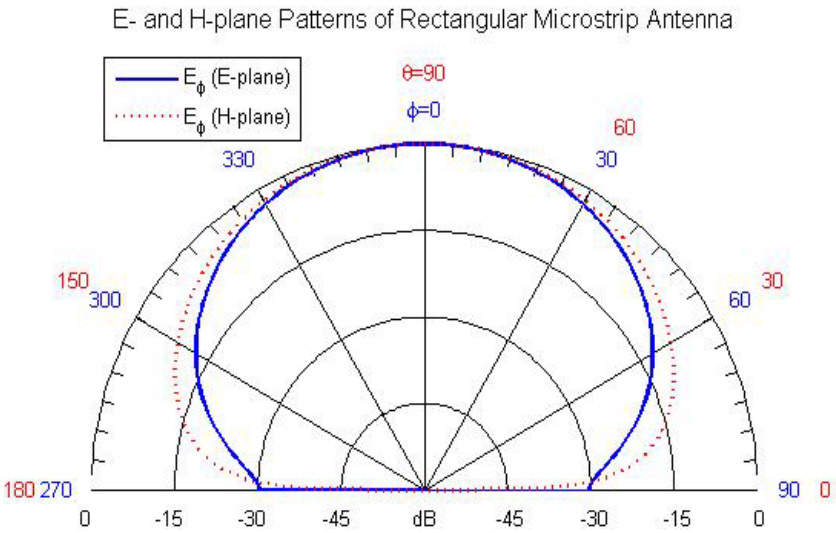


Figure 4: E and H plane patterns of Rectangular patch antenna at 2.45. GHz

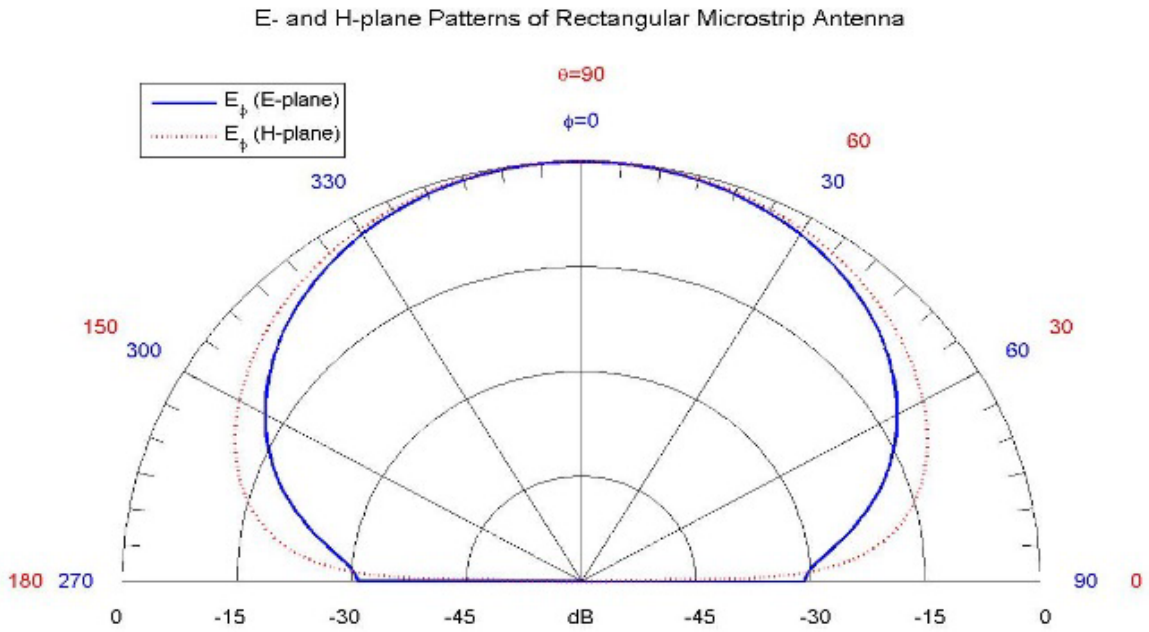


Figure 5: E and H plane patterns of Rectangular patch antenna at 5.7 GHz.

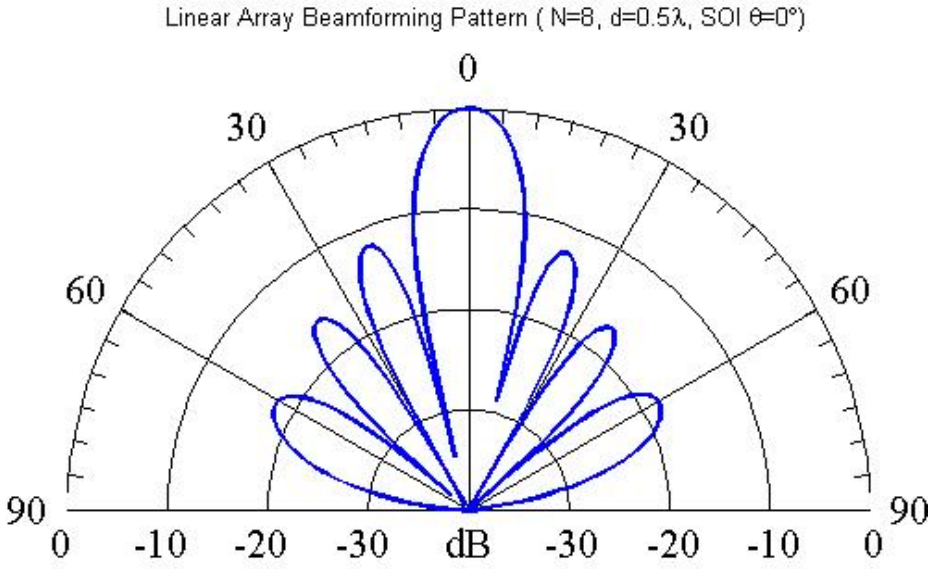


Figure 6: Beam pattern in polar coordinates; N=8

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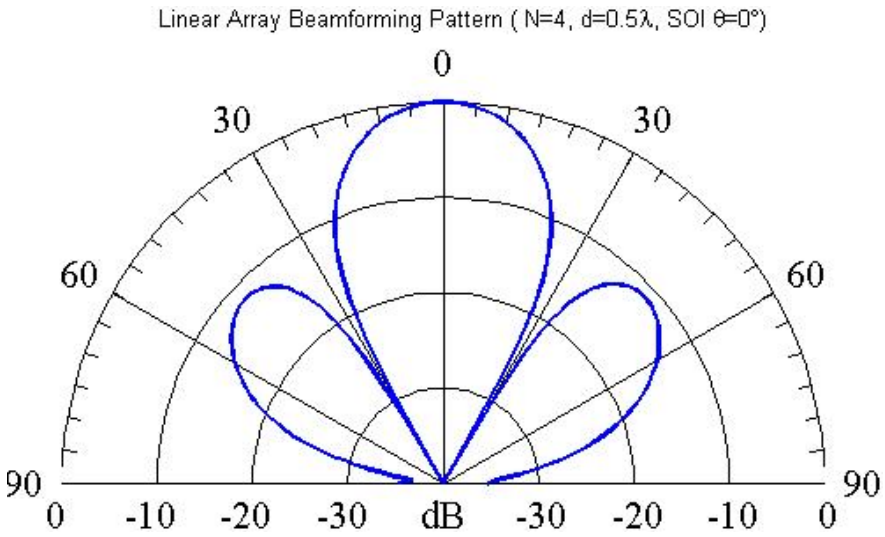


Figure 7: Beam pattern in polar coordinates; N=4

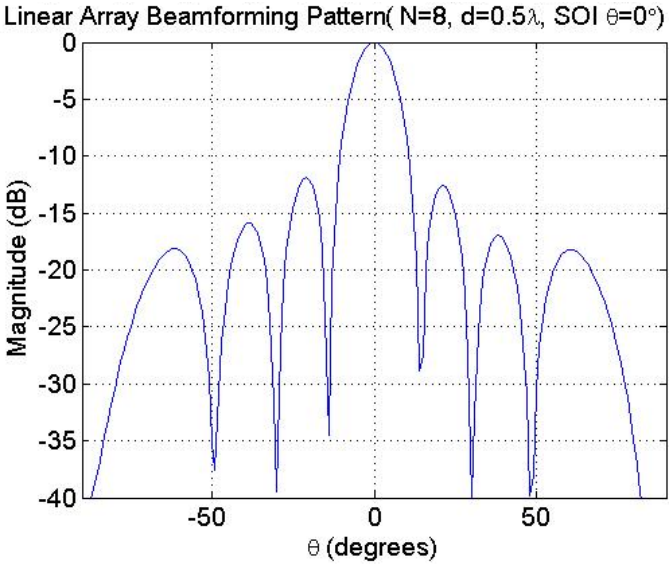


Figure 8: Beam pattern in rectangular coordinates; N=8

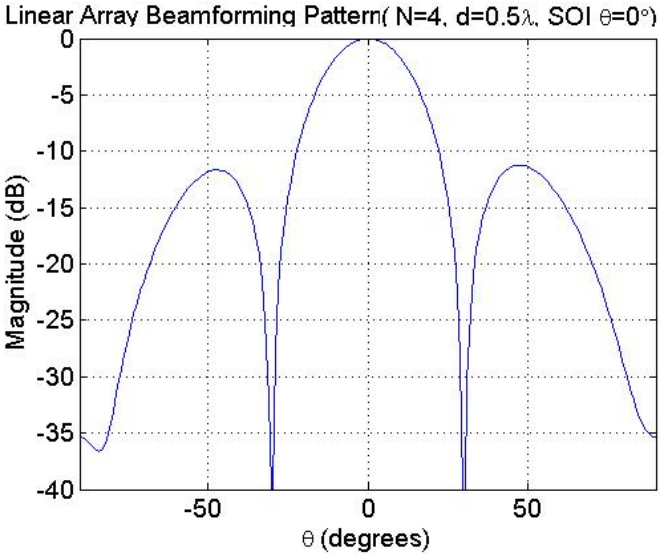


Figure 9: Beam pattern in rectangular coordinates; N=4

4. Measurements

Measurements of the Patch antenna with rohacell dielectric material have been carried out at C and S band. The measurements carried out are (a) Return loss (b) Radiation pattern (c) Gain and Directivity. The return loss measurement was carried using a high directivity dual directional coupler model number 11692D of Hewlett Packard with a frequency range of 2-18 GHz. The device has a nominal coupling of 22 dB for incident and reflected ports. The source used for this measurement is a VCO in the frequency range of 4-6 GHz for C-band and 2-3 GHz for S-band. The values of the measured antenna pattern are shown in table 2.

The measured values differ considerably from the simulated values as can be seen from figure 8. The simulated values are also plotted in the figure 8 for the quick comparison. The measurement could not be carried out in an anechoic chamber and due to the reflections from the surroundings has caused an anomaly in the measurements. The reflection co-efficient can be calculated by taking the ratio of reflected voltage with incident voltage. The reflection co-efficient calculated by this method is 0.3333 at the center frequency of 5.7 GHz and 0.25 at the center frequency of 2.45 GHz. The VSWR can be calculated using the standard formula. The results obtained on the measurements are shown in table 2 and 3. From the results it can be seen that the Patch antenna bandwidth is 2%.

Table 2: Variation of reflection coefficient and VSWR at frequency 5.7 GHz.

Frequency (GHz)	Reflection Coefficient (Γ)	VSWR
5.600	0.310	1.898
5.620	0.320	1.941
5.640	0.325	1.962
5.660	0.315	1.919
5.680	0.321	1.945
5.700	0.333	1.998
5.720	0.315	1.919
5.740	0.310	1.898
5.760	0.333	1.998
5.780	0.325	1.962
5.800	0.320	1.941

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Table 3: Variation of Reflection coefficient and VSWR at frequency 2.45 GHz.

Frequency (GHz)	Reflection Coefficient (Γ)	VSWR
2.2	0.31	1.989
2.25	0.33	1.985
2.3	0.32	1.941
2.35	0.31	1.989
2.4	0.32	1.941
2.45	0.25	1.666
2.5	0.3	1.857
2.55	0.25	1.666
2.6	0.33	1.985
2.65	0.3	1.857
2.7	0.25	1.666

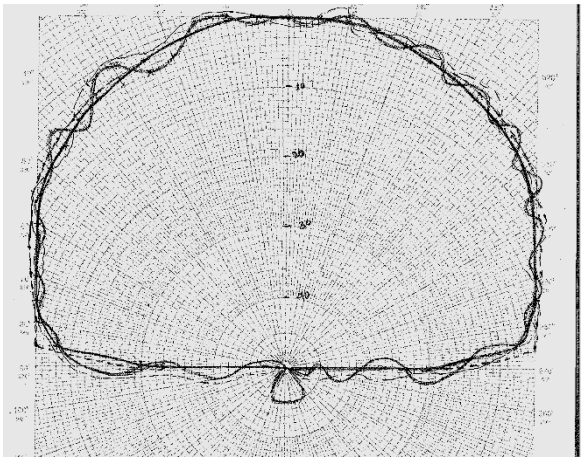


Figure 10: Antenna radiation pattern at 5.7GHz

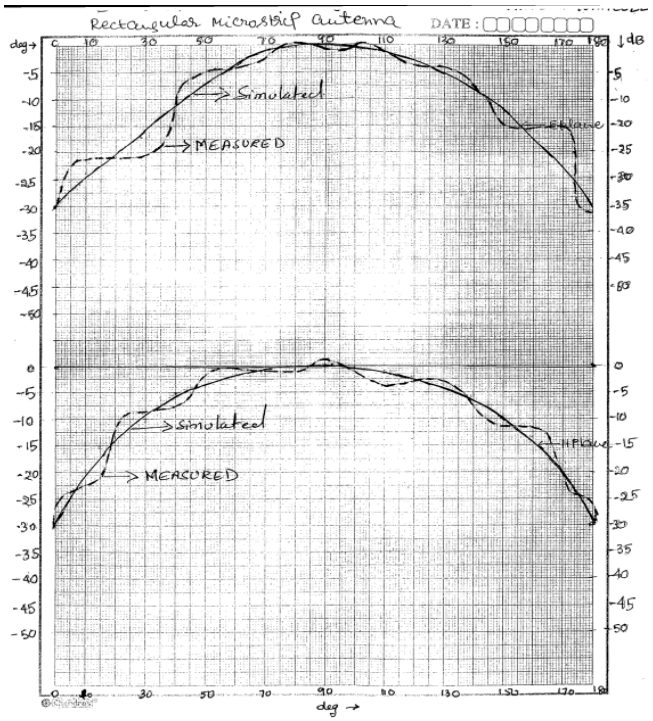


Figure 11: Antenna radiation pattern at 2.45 GHz

5. Conclusion

The design and development of patch antenna using rohacell material are provided. Though the size of the radiating patch increases marginally compared to the standard dielectric materials, the loss tangent of the rohacell material is very low, leading to achieving higher gain figures. One of the disadvantages of the rohacell material is that a separate power divider is required when building array antennas. A higher dielectric constant value for the substrate material greater than 5 is preferred for power dividers. This may not be a problem when building large arrays.

6. Acknowledgement

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