Enhanced-Gain Antenna Array Design for Millimeter-Wave Systems

Kashyap Kalavapudi, Steve C. Chiu, Ph.D., Electrical Engineering, Idaho State University, Pocatello ID

Abstract

Rectangular patch antenna 8X1 linear phased array is designed to work in a broader band with a gain of 16dBi approximately. The proposed stacked patch to improve the bandwidth, directivity and gain. An equiangular array has an advantage of large bandwidth, but has very high input impedance.

Introduction

From Friis transmission relation it is easy to understand that increasing the gain of transmitter and the gain of receiver antenna, will significantly improve the quality of the signal received.

$$P_r \propto P_t . G_t . G_r$$

Where, P_r =Power received, P_t=Power transmitted, G_t= transmiting antenna Gain, G_r=receiving antenna gain.

Design

Rectangular patch antenna design equations are

Width : $W = \frac{1}{2f\sqrt{\mu_0 \varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}}$

Effective permittivity: $\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+\frac{12h}{w}}}$

Effective patch length: $\Delta L_{eff} = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.264)}$

Patch length: $L = \frac{1}{2f\sqrt{\mu_0 \varepsilon_0 \varepsilon_{reff}}} - 2\Delta L_{eff}$

Where, μ_0= Permeability of free space, ε_0= Permittivity of free space, ε_r= Relative permittivity,

Corporate feed is designed to match the impedence and reduce reflection losses.

The dimensions of the designed patch array is 22.538mm X 4.3519 X 0.180mm. Size of each element is 1.8961mmX1.587mm, with a spacing of 2.94mm. The microstrip feed line is designed for 75Ω.

Increasing the thickness improves bandwidth further, but causes losses

Array

Phased array has an advantage of adjusting the beam in desired direction. The equations for linear phased array are given below

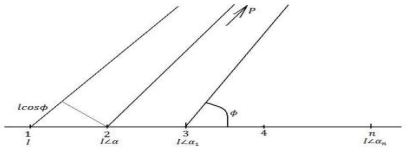

Figure 1: Uniform linear array of n elements

$$E = E_1\left[1 + e^{j\psi} + e^{j\psi} + e^{j\psi}\right]$$

$$E = E_0\left|\frac{sin\left(\frac{n\psi}{2}\right)}{sin\left(\frac{\psi}{2}\right)}\right|$$

$$\psi = \beta cos\phi + \alpha$$

Magnitude is maximum at $\psi = 0$ i.e $\phi = \cos^{-1}\left(\frac{-\alpha}{\beta}\right)$

By changing ϕ it is possible to control direction of radiation.

mmW Antenna

The Corporate feed 8x1 rectangular patch antenna array is given in Figure 1. Figure 2. is stacked patch antenna that is proposed for enhanced directivity and gain. Figure 3 is 2X2 equiangular spiral array for wider bandwidth and circular polarization.

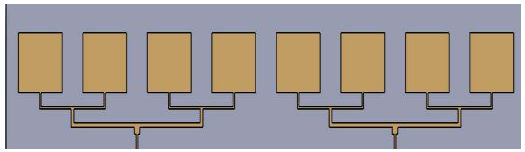

Figure 2: Corporate feed 8X1 Patch Array Design

Figure 3: Stacked patch

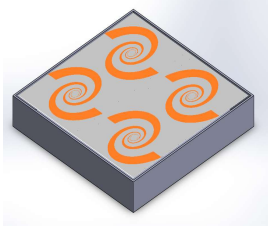

Figure 4: 2x2 Equiangular Spiral Array

Results

Designed 8X1 antenna array is simulated using Antenna Magus. Figure 5 is the Voltage wave standing ratio (VSWR). Figure 5 and Figure6 are radiation patterns.

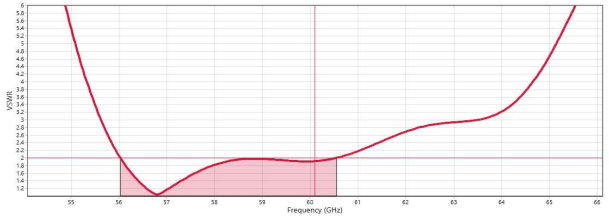

Figure 5: VSWR

Table 1: VSWR details

Parameter	Value
Minimum VSWR Value	1.040
Minimum VSWR frequency	56.81GHz
Bandwidth (below 2.0)	4.523Ghz
Bandwidth (%)	7.759%

Table 2: Radiation pattern details

Parameter	H-Plane	E-Plane
Maximum Gain	16.03dBi	16.17dBi
Squint angle (main beam)	0^o	5^o
HPBW	10.28^o	61.62^o
FNBW	50^o	-

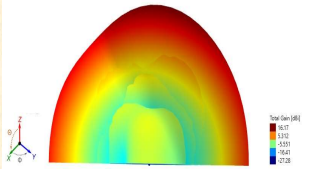

Figure 6: Radiation pattern E-plane at 60Ghz

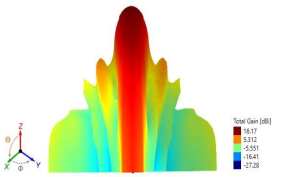

Figure 7: Radiation pattern H-plane at 60Ghz

Conclusions

Patch antenna is simulated to work over millimeter wave frequencies which is being worked out to work in a band of 56.09-60.61GHz with a 16dBi gain. To further, the antenna is being worked to be adaptive and provide higher gains for a significantly higher quality of communications.

References

1. *Microstrip Antennas*, D. R. Jackson, Ch. 7 of Antenna Engineering Handbook, J. L. Volakis, Editor, McGraw Hill, 2007.
2. *Microstrip and Patch Antennas Design, 2nd Ed.*, R. Bancroft, Scitech Publishing, 2009.

Idaho State UNIVERSITY