24 GHz Fixed Point Antenna Based on Starry Inc's Comet Antenna

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***Abstract*—A 24 GHz fixed point antenna is modelled using application requirements related to Starry Inc's Comet Single Home/Small Business Antenna. This was done by first creating a single element probe fed patch (PFP) antenna and using an array model to create a finite linear array. The main antenna specifications we focus on are gain, directivity, half power beam width (HPBW) and bandwidth. Simulated results suggest that this antenna model compares well with Starry Inc's product.**

***Index Terms*—Fixed point antenna, Patch Antenna, Probe Fed, Linear Array**

I. Introduction

A. Background

The internet has become a necessity in our everyday society. The most common type of internet connection is through fiber or cables between buildings. This method is problematic for lower income areas as the fiber or installation is expensive. A cost effective method of internet connectivity is through fixed point wireless antennas [1]. Starry Inc has made it their goal to help provide high speed internet to under privileged communities over the 24 and 37 GHz bands [2]. I greatly respect and am interested in their goals as to why I chose to investigate and model their 24 GHz Comet antenna.

B. Antenna Requirements

Starry Inc's Comet antenna is used to interact with their Titan antenna on radio towers and skyscrapers [2]. As important internet is, it is only as useful as how stable the connection is. This Comet antenna requires a high directivity to interact with the Titan antenna from farther distances, if needed, and to distinguish its signal from other ones in higher density communities. A good directivity for this antenna model should be between 11 and 14 dBi. A reasonable gain for such an antenna ranges between 8 and 20 dBi [3], calling the need of decent antenna efficiency.

Each Comet antenna focuses on one Titan antenna requiring a narrow horizontal beam, while a wider vertical beam is needed since Titan antennas are at least 100 feet in elevation [2]. A good HPBW is around 30/25 degrees horizontally and around 80/75 degrees vertically. Lastly, it is also important to have a good bandwidth to allow for more data to travel at a time. While it was not possible for me to know what channels they use in the 24 GHz band, I decided to cover at least 500 MHz. Bandwidth was determined using a common rule of thumb where the return loss is equal to or below -10 dB or the voltage standing wave ratio (VSWR) is equal to or below 2 [3].

II. Antenna Design

A. Antenna Type

The patch antenna was chosen because of its directivity, lower profile, lower cost, lighter weight, good mechanical strength and easier to fabricate [4]. Related to the feeding mechanism, I chose to use probe feed to further support easier fabrication and to allow for easier alignment of elements in an array [3]. Lastly, a linear array was chosen since we are interested in narrowing the beam in one plane rather than two.

B. Single Element Design

Before modeling a finite array, a single element needs to be designed. The dimensions of the patch were done using these equations [4]:

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

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

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)} \tag{3}$$

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \tag{4}$$

$$L = L_{eff} - 2\Delta L \tag{5}$$

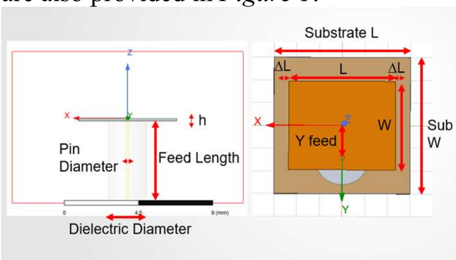
where L is the length of the patch, W is the width of the patch, h is the thickness of the substrate, ΔL is the length of the patch related to fringing fields, L_{eff} is the length of the patch including the fringing lengths, c is the speed of light ($3\text{x}10^8$ meters per second) and ε_r is the dielectric constant of the substrate.

Related to the probe feed, a 2.4 mm coaxial cable was used since it is rated from DC to 50 GHz. A 3.5 mm coaxial cable can be used as well since it is rated up to 26.5 GHz, however I chose 2.4 mm due to preference. The length of the coaxial feed doesn't affect the impedance, so any length should work. Both coaxial types use air as a dielectric.

The location of the probe feed was determined using parametric sweeps on the X and Y distance away from the center of the patch. I only swept the location within one quadrant of the patch as each quadrant should provide the same results due to the patch's symmetry. The ideal probe location was determined by the best return loss.

Regarding the substrate, RT/Duriod 5080 was chosen because it's material properties are suitable for higher frequency applications, specifically its low dielectric constant of 2.2 [4]. The dimensions of the substrate are related to the λ of the center frequency. The λ is found by dividing the speed of light by the center frequency (24.5 GHz) [4]. With this, the substrate is made to be λ/2 by λ/2. This size will be explained in the next section. Also, high antenna efficiency was desired to create an idealized model. That means the thickness of the substrate should be less than or equal to 0.015λ [3].

MATLAB was used to solve equations (1)-(5) and results can be seen in *Figure 1*. Visualizations of these dimensions are also provided in *Figure 1*.



Dimension	Value [mm]
Patch Length	4.7
Patch Width	3.9
Substrate Length (λ/2)	6
Substrate Width (λ/2)	6
Substrate Permittivity (RT/duroid® 5880) [F/m]	2.2
Substrate Thickness	0.18
SMA Pin Diameter	0.25
SMA Dielectric Diameter	2.4
SMA Dielectric Permittivity (Air) [F/m]	1.0006
Probe Feed X (from center)	0
Probe Feed Y (from center)	1.4
Feed Length	5

Figure 1. Side View (Left) Top view (Middle) Table of Values (Right)

C. Finite Linear Array Model

Based on the results of the single element, the directivity can be strengthened by increasing the number of elements. Since the antenna requirements only call for a narrower beam in one plane, the number of elements only needs to increase in one direction. The spacing between each element was chosen to be λ/2 because that is known to be the sweet spot between getting grating lobes and getting good coupling [5]. *Figure 2* was used to determine the number of elements needed to reach the directivity requirement.

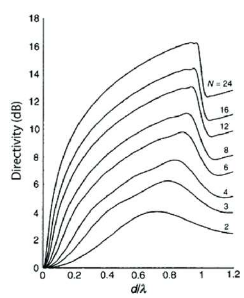


Figure 2. Relationship between element spacing, number of elements and directivity [5]

III. Results

A. Single Element

Figure 3 shows the results of simulating a PFP antenna using the dimensions and layout shown in *Figure 1*.

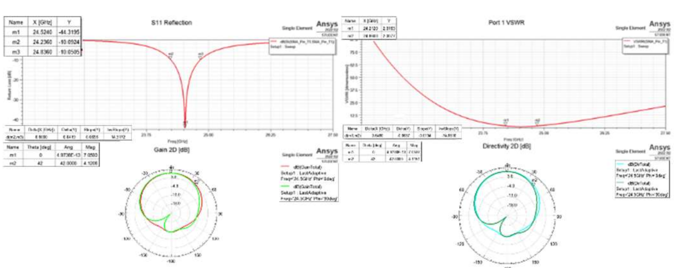


Figure 3. Simulated results showing Return loss (Top Left) VSWR (Top Right) Gain in E & H Plane (Bottom Left) Directivity in E & H Plane (Bottom Right)

B. Finite Linear Array

As seen in *Figure 3*, the directivity of the simulated single element PFP antenna is 7 dBi. Using *Figure 2* and an element spacing of λ/2, four linear elements should increase the single element directivity around 6 dBi, which is within the range we are hoping for related to the antenna requirements.

Using the array model tool in high frequency structure simulator (HFSS) a four element array in the Y direction was simulated. *Figure 4* shows this model.

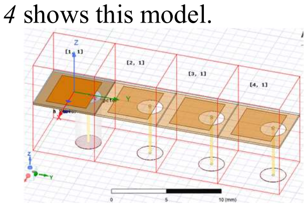


Figure 4. Four element linear array model using element in *Figure 1*

Figure 5 shows the results of simulating the four element linear array shown in *Figure 4*.

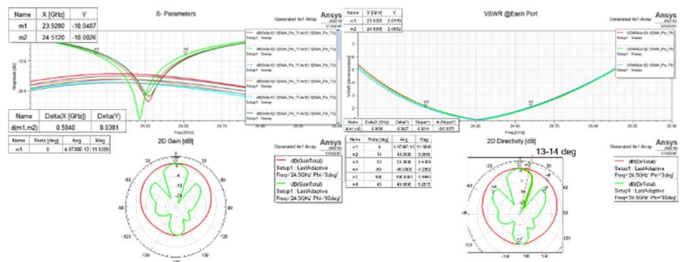


Figure 5. Simulated results showing S Parameters (Top Left) VSWR (Top Right) Gain in E & H Plane (Bottom Left) Directivity in E & H Plane (Bottom Right)

IV. Conclusion

An idealized finite linear PFP array model is presented. *Figure 5* shows the center frequency shifted to 24.25 GHz and the bandwidth lowered to 584 GHz compared to the results in *Figure 3*. This bandwidth was determined by return loss being less than or equal to -10 dB instead of VSWR since it showed to be the stricter measurement. The bottom traces in the S Parameter results of *Figure 5* are the transmissions between ports. The transmission values show a decent isolation. Using four elements, the directivity increased 5dB. Since the antenna efficiency was made to be very high, the gain was of similar value to the directivity. The final results of the PFP linear array provides a directivity of 12 dBi, gain of 12 dBi, bandwidth of 584 MHz, and HPBW of 26 degrees horizontally and 84 degress vertically. All results compare well to Starry Inc's Comet Antenna requirements supporting that this PFP Linear Array is a suitable model

References

[1] S. Ndungu, "Fixed Wireless," TechTarget Mobile Computing. December 2022

[2] "How we deliver net gen wireless internet," *Starry.*

[3] K. Nordin and S. Shamekhi, "24 GHz Patch Antenna Design for RADAR," *EIT Electrical and Information Technology.* June 2016

[4] C. Fung, "Basic Antenna Theory and Application," *Worchester Polytechnics Institute,* Worchester , MA, USA, March 2011.

[5] V. Rabinovich and N. Alexandrov, "Typical array geometries and basic beam sterring methods," *Antenna Arrays and Automotive Applications,* Clermnt Auvergne University, Mitterrand, France, May 2012.