# Simulation of Fractal Shape Geometry for Reflectarray Antenna Design

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## 1. Introduction

Microstrip reflectarray consists of planar arrays of microstrip patches with different sizes, shapes and fed by a primarily illuminator, typically a horn antenna [1]. The microstrip patches will be acting as a radiating element whereas it will receive and re-radiate the illuminating power from horn antenna back into space [1]. Since the microstrip reflectarrays have a number of advantages, they have been considered as an attractive object to be discovered and published by researchers from all over the world. The best features of microstrip reflectarray can be partially divided into two points of view which are from electromagnetically and mechanically point of view. From an electromagnetically point of view, they are high gain antennas, low side lobes, capable of beam steering, and from a mechanically point of view, they have lightweight structures, easy to fabricate and manufacture and also robust [2].

In this paper, simulation results of an identical unit cell with different shape of printed radiating element have been briefly discussed. Since the most severe problem in reflectarrays is narrow bandwidth, there are much efforts have been done in recent years to overcome this limitation [3]. There are two factors that causing a narrow bandwidth of the reflectarrays which are the narrow band of the radiating elements and the differential spatial phase delay between elements on the reflectarray itself [4].

The main purpose of this paper is to investigate the suitable shapes of element for a better reflectarray cells development. The suitable shape means it has wider linear phase range and better gradient in degree per micrometer (°/µm) which means the smaller value of gradient, so that when the frequency changes, the phase distribution only varies in a constant which is a little bit in degree (°) for the whole reflectarray structure [4].

## 2. Unit Cell Design

Most commonly used resonant element shapes have been researched and developed for example dipole, loaded dipole, tripole, jerusalem cross, cross-dipole, square-loop and rings [5]. The choice of element type and its geometry is very important as well as the substrate selection because there are large number of parameters involved in designing reflectarray.

In this section, basic building block for a single layer unit cell of reflectarray with different shape of radiating element is designed at X-band frequency range (8.0 to 12.0 GHZ). It has been specified to resonate at frequency band of 11 GHz. A few element geometries have been proposed to be a resonant element shape for periodic reflectarray structure. These geometries which are from the 1st iteration of fractals, namely koch and minkowski. Figure 1 illustrates the proposed geometries of resonant element of unit cell reflectarray.

Substrate selection including its material such as relative permittivity ($\varepsilon_r$), tangential loss ($\tan\delta$), thickness ($t$) and the element periodicity ($a$) has to be taken into account. In design stage, each element is designed to be printed on a substrate with the thickness, $t$ = 1.524 mm; tangential loss, $\tan\delta$ = 0.0018; and relative permittivity, $\varepsilon_r$ = 3.54. The periodicity of the array which is $a$ = 11 mm and the copper thickness used is 0.035 mm.

## 3. Simulation of a Unit Cell

CST Microwave Studio (CST MWS) has been used as a tool in order to simulate a single layer unit cell of reflectarray. A block of unit cell reflectarray is modelled and parameters such as permittivity which is dielectric constant, substrate and copper thickness, tangential loss and geometry of radiating element are defined. Three main things need to be concerned about which are include the boundary condition, mesh-cell and port location.

Perfect Magnetic Conductor (PMC) boundary condition was setup on the left and right hand side of a unit cell reflectarray in x-axis and Perfect Electric Conductor (PEC) boundary condition was setup on the bottom and top of a unit cell in y-axis. The incident wave will propagates along z-axis whereas the E-field of the incident energy is polarized in y-axis and the H-field of the incident energy is polarized in x-axis. Figure 2 illustrates the example of simulated unit cell reflectarray with minkowski patch as a resonant element.

Mesh cell or meshing size is very important parameter since this value can gives a significant impact on the accuracy and speed of the simulation. Usually, a user may use a default setting from the software (CST MWS) to determine the suitable mesh cell size. However, the meshing size often needs an adaptive mesh refinement in order to make sure the simulation accuracy will achieve the satisfactory condition, so that any further increment in mesh cell, it will not change the response.

Another important consideration that needs to be taken into account is the port location. Since the port will play an important role as an excitation source to capture the response (reflection), it is required to be located at least λ/4 from the unit cell of reflectarray in order to ensure that unit cell will receive a normal incident wave (0 degree).

## 4. Result and Discussion

Parameter sweep has been conducted on a single layer of unit cell reflectarray. The geometry of resonant element patch is swept with a variation ±20% to come out with the reflection phase at desired frequency band of 11 GHz.

Figure 3 and Figure 4 shows a simulated return loss and reflection phase of three different shapes as a resonant element for a unit cell reflectarray respectively. As can be seen from Figure 3, all unit cells of reflectarray have resonant frequency band at 11 GHz and they all have good return loss, therefore they can be considered as a good reflector as their reflection is more than 90%.

Better linear phase range can be predicted from Figure 3 as shown in Figure 4, since the return loss of minkowski element patch is narrower than koch-triangle and koch-square element patch. From Figure 4, it can be observed that minkowski patch has wider linear phase range (296°) which is better than koch-square (250°) and koch-triangle (243°). Even though the results of this single layer of unit cell of reflectarray gives a linear phase range less than 360° which is not sufficient for a practical design, it still can be optimized and modified in order to improve its linearity and increase the phase range.

In term of gradient of linear phase range, researcher has attempted to reduce a rapid phase variation around the resonance region due to the manufacturing tolerances. From Figure 4, it can be seen that koch-square and koch-triangle element patch have better sensitivity to manufacturing tolerances if compared to minkowski element patch. Therefore, minkowski element patch is quite sensitive to the changes in its parameter because there will be a drastic changes in the reflection phase when patch variation at ±0.6% around its resonance region (n=0). Besides, koch-triangle element patch is sensitive when patch size is varies from -0.2% to 1.2% while koch-square element patch is around -0.8% until 0.6% patch variation.

Table 1 shows the summary of the linear phase range including its gradient around their resonance region for every simulated element patch of unit cell reflectarray.

## 5. Conclusion

Three new shapes from the 1st iteration of fractals have been introduced as element geometry for unit cell of reflectarray. From the simulation results, it can be observed that these geometries may become a good reflector for the reflectarray antenna as their reflection parameter is more than 90%. Furthermore, those geometries are expected to be better in terms of linear phase range and gradient around resonance region if some optimizations by doing parametric studies on the substrate thickness (*t*), relative permittivity ($\varepsilon_r$) and element periodicity (*a*).

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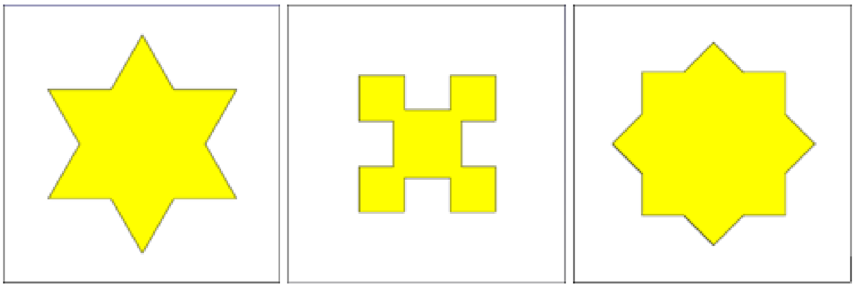
Table 1: Analysis of unit cell reflectarray

| Analysis | Koch-Square | Koch-Triangle | Minkowski |
|---|---|---|---|
| **Linear Phase Range (°)** | 250 | 243 | 295 |
| **Gradient around resonance (°/µm)** | 0.179 | 0.144 | 0.295 |



(a) (b) (c)

Figure 1: (a) Koch-triangle. (b) Minkowski. (c) Koch-square.

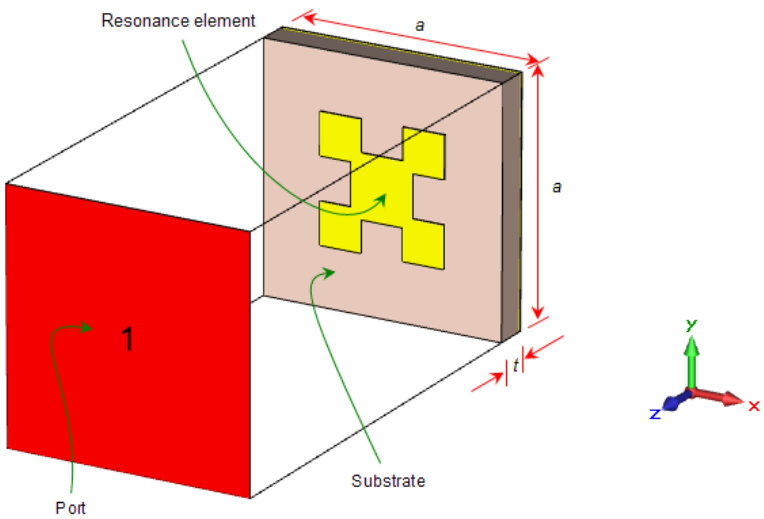



Figure 2: Boundary condition for simulation setup.

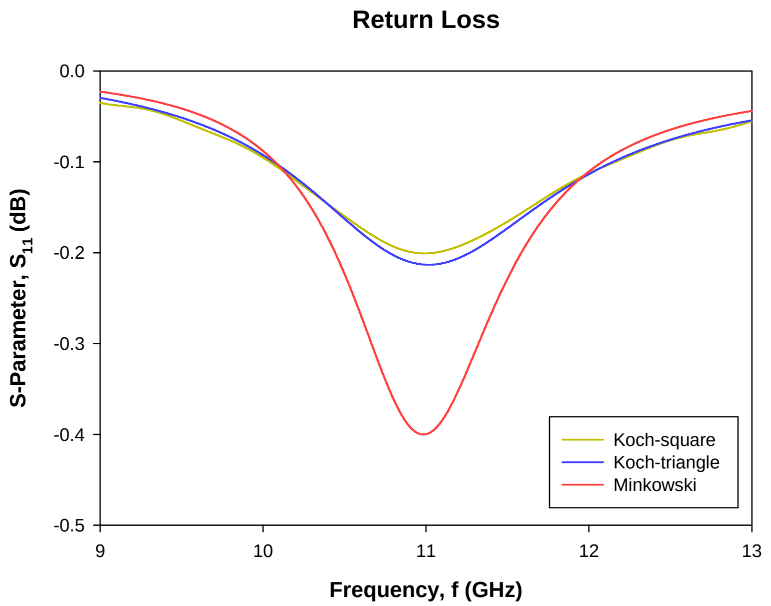



Figure 3: Simulated Return Loss.

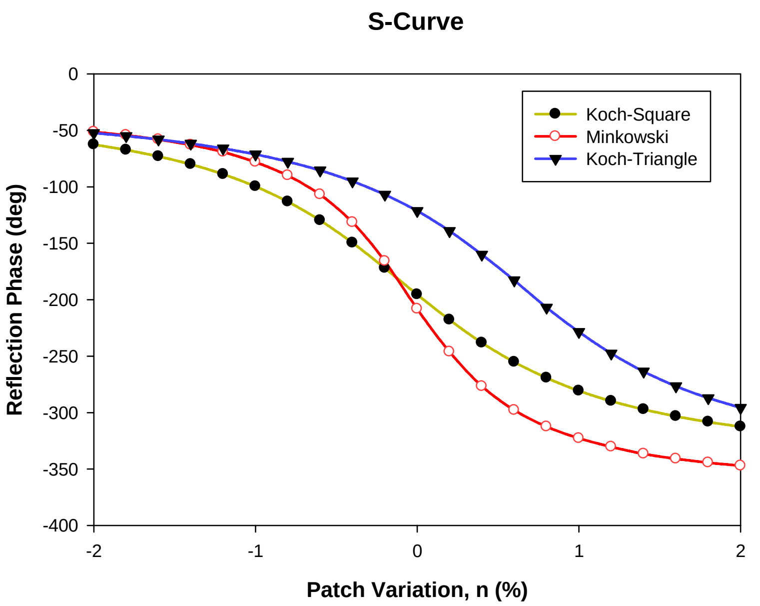



Figure 4: Simulated Reflection Phase.

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