

# Study Of Phasing Distribution Characteristics Of Reflectarray Antenna Using Different Resonant Elements

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## Abstract

There has been much interest recently in developing reflectarray antenna due to the combination of some of the best features between the parabolic reflector and phased array antennas. This paper presents the study of the relationship between phasing distribution characteristics and the bandwidth of different resonant reflectarray elements. The gradient characteristics of different elements of patch, dipole and ring printed on a grounded dielectric substrate have been investigated at X-band frequency range using CST computer model. The preliminary simulated results generated from CST computer model demonstrate that ring elements contribute the highest reflection loss performance of 1.74 dB compared to the other two element of dipoles and patches. The attainable static linear phase range of  $177^\circ$  for ring elements is shown to offer a trade off between the static phase range and the bandwidth of the reflectarray elements. In measurement ring element also contribute the highest reflection loss performance of 2.95 dB compared to other two elements.

Keywords: bandwidth, phasing distribution, reflectarray, reflectarray elements.

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## 1. INTRODUCTION

A microstrip reflectarray consists of a flat array of microstrip patches or dipoles printed on a thin dielectric substrate [1]. The incident signal illuminating from feed antenna to the array elements to scatter the incident field with the proper phase required to form a planar phase. Many types of resonant elements can be used in printed reflectarray antenna depending on its applications. For examples variable size patch elements [2], [3], spiral patch element [4], cross dipole elements [5], [6] and ring elements [7], [8]. The applications were such as dual frequency [7] and for the solar panel reflectarray [5]. There are some feeding method that can be used such as prime-focus feeding, offset feeding and cassegrain feeds [1]. Feed horn is usually used and situated at its focus. This feeding can eliminates the complexity and losses of a microstrip feed. In this project the phasing distribution characteristics will be analyzed using different resonant elements. The operating frequency used for this project will be in X band frequency range (8-12 GHz).

## 2. THEORY

### 2.1 Reflectarray antenna

Due to the introduction of the printable microstrip antennas, the technologies of combining the reflectarray and microstrip radiators were investigated [9].

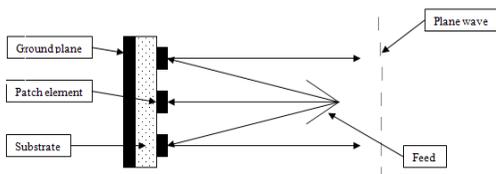


Fig. 1 Geometry of the microstrip reflectarray.

A feed antenna illuminates the array whose individual elements are designed to scatter the incident field with the proper phase required to form a planar phase surface in front of the aperture, as suggested in Fig. 1. The bandwidth performance of a reflectarray is no match to that of a parabolic reflector. For a printed microstrip reflectarray, its bandwidth is primarily limited by two factors that are narrow bandwidth of the microstrip patch elements on the reflectarray surface and the differential spatial phase delay [10]. The path length of the energy reflected from each of the resonant elements is different. This leads to different phase delays. In order to compensate for the different path length, the elements must have corresponding phase advancements design.

### 2.2 Scattering parameter, $S_{11}$

The scattering parameter,  $S_{11}$  is referring to the reflection loss of an antenna in which the reflection loss of a reflectarray antenna should be 0 dB at resonance in order to get a maximum reflected energy.

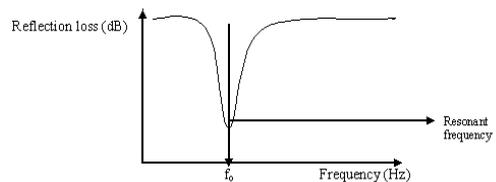


Fig. 2 Typical reflection loss plot of a reflectarray antenna

Minimum reflection loss can be achieved as shown in Figure 2 when the signal energy reflection is the same as when signal energy is illuminated.

### 2.3 S-shaped phase curve plots

The slope of the phase versus frequency is a measure of the bandwidth of reflectarray as a curve with a smaller slope will lead to less phase error [1]. There is tradeoff between phase range and the bandwidth. This is indicated by the gradient of the S-shaped phase curve.

In order to provide a suitable compensation for all the elements in array, the phasing range needs to be close to  $360^\circ$  at a given frequency [11]. At  $180^\circ$  phase difference, resonant frequency is achieved due to maximum reflection of the signal.

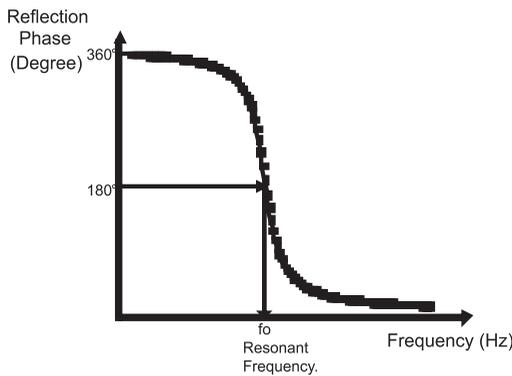


Fig.3 Reflection phase versus frequency.

### 2.4 Differential Spatial Phase Delay

The differential spatial phase delay,  $\Delta S$  is the phase difference between the two paths  $S_1$  and  $S_2$  from the feed to the reflectarray elements. The differential spatial phase delay is due to the different lengths from the feed to each point on the wave front of the radiated beam [12].

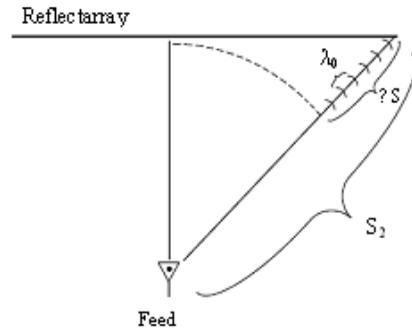


Fig. 4 Differential spatial phase delay of reflectarray [12].

Bandwidth in large reflectarrays, as in the case of space applications, is drastically reduced because of the different path length. The different lengths from the feed to each patch location, has to be compensated by the reflection coefficient in order to produce a reflected field with progressive phase [9].

### 2.5 Phase Delay

Phase errors can be introduced by fabrication tolerances in flatness of array and etching of elements [1]. Phase errors can also be introduced by the feed antenna if its phase center is not well-defined [13]. Phase errors related to the changes in patch size [14].

## 3. DESIGN AND FABRICATION OF THE ANTENNA

### 3.1 Fabrications of Antennas

Based on the results CST computer model simulation fabrications of different resonant elements have been carried out. There are several stages in fabrication process that required to produce the antennas.

The fabrication process was prepared using facilities in UTHM PCB laboratory and using the material supplied. The material for substrate is Rogers RT5870 with dielectric constant,  $\epsilon_r$  2.33 and dissipation factor,  $\tan \delta$  0.0012. The fabrications processes include three steps:

#### a) Dry Film Lamination

Substrate board was cut to match with the size of patch elements:

1. The film laminator machine was set to preheat.
2. Substrate board was placed into laminator machine.

#### b) UV Exposure

1. The film of patch layout was attached to the laminated substrate board.
2. The substrate board was placed under UV exposure around 2 minutes.
3. The film was taken off and can be seeing printed on the surface of the substrate board.

#### c) Etching Process

##### i. Photo Resist Developer

1. In this process laminator film was varnished.

##### ii. Copper Etching and Resist

#### Strip

1. In copper etching process unwanted copper remove by Etching Machine.
2. The unwanted surface substrate board was placed into Spray Stripping Machine.
3. PCB Dryer Machine was used to dry up the substrate board.

### 4. RESULTS AND DISCUSSIONS

This section reports on simulated results for the phase characteristic of different type of resonant reflectarray element as obtained with CST Microwave Studio. The relationship between the static linear phase range and the bandwidth is investigated in order to find the best element which suits the criteria for greater phase range and low loss performance of reflectarray elements. For ring element the outer radius= 3.97 mm and inner radius= 2.97 mm. While for dipole element,  $w = 3.74$  mm and  $8.6$  mm and rectangular patch element,  $w = 11.62$  mm and  $l = 8.5$ mm.

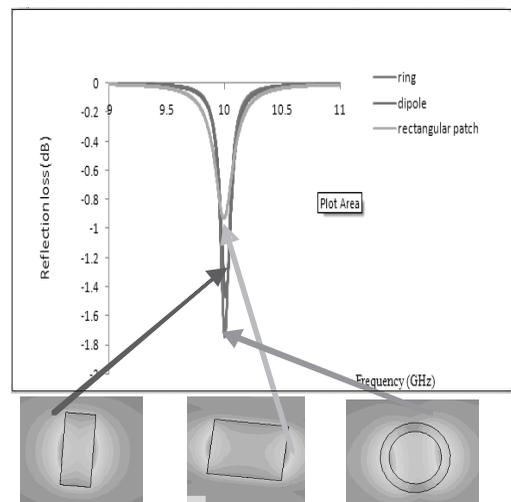


Fig. 6 Comparison of predicted surface current of ring, dipole and rectangular patch elements.

Ring element has higher loss compared to dipole element followed by rectangular patch element. Ring element has small area compared to dipole element and rectangular patch element. Because of the area of the resonant elements, ring element has a higher loss and less bandwidth compared to dipole element and rectangular patch element [1]. This is clearly shown by the surface current distribution generated from the CST computer model.

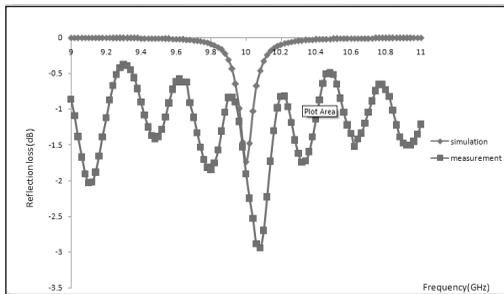


Fig. 7 Comparison between simulated and measured results of ring element

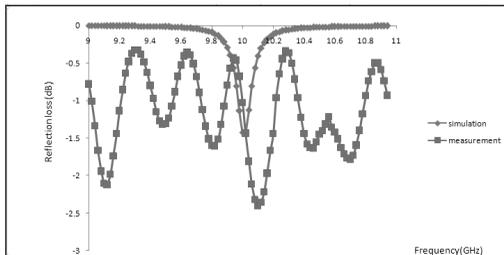


Fig. 8 Comparison between simulated and measured results of Dipole element

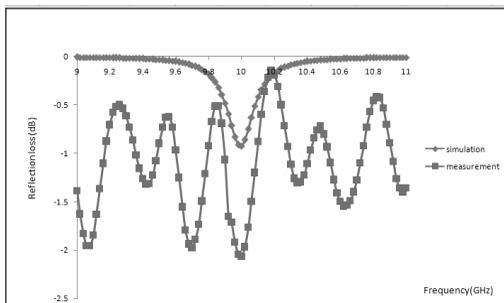


Fig. 9 Comparison between simulated and measured results of Rectangular patch element

Fig. 7,8 and 9 show the results for three different elements. As can be seen the measurement result did not match up with simulation results due to the presence of ripples and distortions.

The ripples are due to the mismatched of the calibrations. The cable conncted to the vector network anylzer should at properly to get scatering parameters of  $S_{11}$ . The dimensions of patch fabrication also has effected.

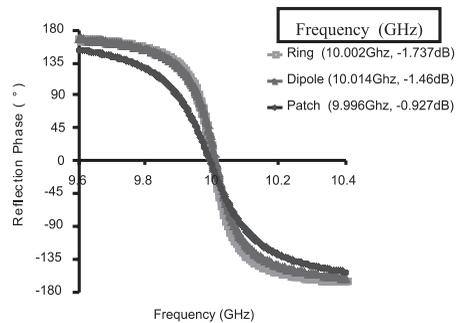


Fig. 10 Combination of ring, dipole and rectangular patch element in S-shaped phase curve.

Similar with S-shaped phase curve in previously, ring element contribute a wider phase range compared to other two elements. Dipole element nearly same as ring element has wider phase range.

Bandwidth for ring element can be increased by a suitable choice of the outer and inner radius ratio [7].

Table 1:Figure of Merit (FoM).

Case	Elements	Linear Phase Range (°)	Figure of Merit (FoM) (°/GHz)
1	Ring	177	1967
2	Dipole	171	1710
3	Rectangular Patch	150	1250

Table 1 shows linear phase range and Figure of Merit for three resonant elements. Both wider linear phase range and larger Figure of Merit contributed by ring element followed by dipole and rectangular patch elements. It is due to the trade off between narrow bandwidth and greater linear phase range.

## 5. CONCLUSIONS

In conclusions, the trend of the S-shaped phase curves of the reflectarray antenna has been investigated using different resonant elements. Analysis of the phase distribution of resonant elements carried out using CST computer model. Measurements of performance have been investigated using waveguide simulator technique. The Figure of Merit has been defined in order to give an indicator of different resonant elements of reflectarray.

## ACKNOWLEDGMENT

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