# **RADIOMETER PHASE RETARDATION PLATE EVALUATION USING PLANAR NEAR-FIELD ANTENNA MEASUREMENTS**

Jeff Guerrieri, Katie MacReynolds & Doug Tamura National Institute of Standards and Technology Radio Frequency Technology Division 325 Broadway, Boulder, CO 80305

#### Abstract

The National Institute of Standards and Technology (NIST) characterized three phase retardation plates for the National Oceanic & Atmospheric Administration (NOAA). These plates are used to produce known polarized signals needed to calibrate polarimetric radiometers.

The plates were tested at 10.7 and/or 18.7 GHz. The plates produce a phase shift between perpendicular field components of transmitted waves. The planar nearfield measurement technique was used to determine the phase shift. This paper will discuss the measurement procedure and results.

**Key Words:** phase retardation plate, phase shift, 90° rotation, polarimetric radiometer

# **1.0 Introduction**

Radiometers have become a very useful tool for atmospheric remote sensing. They are preferred over infrared and visible observation because of their ability to probe through optically opaque cloud cover and aerosols [1]. They provide data on snow and ice cover, sea surface temperature and wind, soil moisture, vegetative biomass, precipitation, cloud liquid-water content, and temperature and water-vapor profiles.

Using both linearly and circularly polarized components the polarimetric radiometer can determine the speed and direction of maritime winds [2]. A phase retardation plate is used to calibrate the polarimetric radiometer. The plate generates a predetermined phase shift ( $\sim\lambda/8$ ) between the perpendicular field components of the transmitted waves. The plate, shown in figure 1, is a lens fabricated from a slab of cross-linked polystyrene with parallel grooves machined on both sides of the lens [3].

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Verification of the phase shift is necessary to validate the radiometer calibration procedure.

NIST characterized three phase retardation plates for NOAA using the planar near-field antenna measurement technique. Plate 1 is designed to generate a phase shift of  $\sim$ 50° at 18.7 GHz, and Plates 2 and 3 introduce phase changes of  $\sim$ 50° at 10.7 GHz.



Figure 1. Phase retardation lens plate.

## **2.0 Procedure**

For measurements at 18.7 GHz the transmitting antenna was a linearly polarized Ku-band dish and the probe was an open ended waveguide. The dish was aligned at  $20\lambda$  from the scan plane and Plate 1 was placed in front of the dish at  $10\lambda$  from the scan plane, shown in figure 2 ( $\lambda$  = wavelength).



Figure 2. Planar near-field measurement setup for 18.7 GHz.

Measurements were performed for both horizontal and vertical orientations of Plate 1. The horizontal orientation is with the grooves of the plate aligned horizontally. Conversely, the vertical orientation is with the grooves aligned vertically. A 90° rotation of the plate generates the phase shift in the measured near-field.

An x-band standard gain horn and open-ended waveguide probe were used for measurements at 10.7 GHz, shown in figure 3. The distances from the horn and plate to the scan plane were respectively  $20\lambda$  and  $10\lambda$ . Measurements were performed for Plates 2 and 3 in both the horizontal and vertical orientations.



Figure 3. Planar near-field measurement setup for 10.7 GHz.

# 3.0 Results

#### Plate 1 at 18.7 GHz

Graphs of the y-axis principal plane cut of the near-field for the horizontal and vertical orientations are displayed respectively in figures 4 and 5. The 90° rotation about the z-axis of the plate introduces a phase shift but has little effect on the near-field amplitude, as expected.



Figure 4. Y-axis principal plane, near-field data for Plate 1 aligned horizontally.



Figure 5. Y-axis principal plane, near-field data for Plate 1 aligned vertically.

To determine the phase shift in the near-field, the horizontal orientation data were subtracted from the vertical orientation data. A plot of the y and x axes principal planes of the subtraction data is shown in figure 6. The average phase shift for the y-axis principal plane is 50° with an uncertainty of  $\pm$  6°, and for the x-axis principal plane is 53° with an uncertainty of  $\pm$  6°.



Figure 6. Phase shift in the near-field due to 90° rotation of Plate 1.

Another way to view the phase shift is in the far field obtained using Fourier analysis [4]. Subtraction of the far field horizontal orientation from that of the vertical orientation reveals the same phase shift in the far field, shown in figure 7 as a surface plot.



Figure 7. Phase shift in the far field due to 90° rotation of Plate 1.

## Plate 2 at 10.7 GHz

The same subtraction technique was performed for Plate 2 data at 10.7 GHz. A plot of the near-field x and y axes principal planes of the subtraction data is shown in figure 8. The average phase shift for the y-axis principal plane is 52° with an uncertainty of  $\pm$  5°, and for the x-axis principal plane is 55° with an uncertainty of  $\pm$  5°.



Figure 8. Phase shift in the near-field due to 90° rotation of Plate 2.

The far field phase shift for Plate 2 is shown in figure 9 as a surface plot, and in figure 10 as a contour plot.



Figure 9. Phase shift in the far field due to 90° rotation of Plate 2.

## Far Field Phase Change

Lens Plate 2, 10.7 GHz



Figure 10. Phase shift in the far field due to 90° rotation of Plate 2.

#### Plate 3 at 10.7 GHz

For Plate 3 at 10.7 GHz, the average phase shift for the yaxis principal plane is 47° with an uncertainty of  $\pm$  5°, and for the x-axis principal plane, it is 50° with an uncertainty of  $\pm$  5°, respectively.

## **4.0 Uncertainty Analysis**

A rigorous uncertainty analysis was not performed for the measurements, however, several components were estimated. The estimated uncertainties are a quadrature sum (RSS) of each of the uncertainty components listed in table 1.

| Table 1. | Uncertainty | in Planar | Measurements |
|----------|-------------|-----------|--------------|
|----------|-------------|-----------|--------------|

| Source of            |           | Resultant Uncertainty |         |  |
|----------------------|-----------|-----------------------|---------|--|
| Uncertainty          | in Pha    | se (deg.)             |         |  |
| -                    | Plate 1   | Plate 2               | Plate 3 |  |
| Multiple Reflections | 1         | 1                     | 1       |  |
| Repeatability        | 4         | 2                     | 2       |  |
| Alignment            | 4         | 4                     | 5       |  |
| Quadrature Su        | $m \pm 6$ | ± 5                   | ± 5     |  |

# **5.0** Conclusion

We have demonstrated how NIST used the planar near-field technique to determine the phase shift generated by the NOAA phase retardation plates. Using linearly polarized antennas and rotating the plates orthogonally the phase shift between perpendicular field components was generated and determined.

We have verified the phase shifts generated by the NOAA phase retardation plates and thus validated their polarimetric radiometer calibration procedure.

## **6.0 References**

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