Experimental Verification of The Spot of Near-field Fresnel Zone Plate With Sweeping Frequency

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Abstract. The spot of near-field Fresnel zone plate (NFFZP) is very important in electromagnetic field. In this paper, an NFFZP which has been designed to focus a spherical wave at a spot is measured, and the formula for the steered near-field spot of the NFFZP versus frequency is presented and proved. Furthermore, the $W_{3\text{dB}}$ and sidelobe level (SLL) of the spot are characterized. All the results are verified by full-wave simulations and experiments in Ku-band.

Introduction

Focused spots are of great importance to microwave wireless power transmission, remote sensing and medical imaging [2, 3, 4]. The Fresnel zone plate (FZP) is an important spot generator because it has the advantage of being lighter and more easily designed and manufactured compared to the array antennas and reflectors. Moreover, FZP lenses are thinner than traditional lens antennas especially when a large antenna aperture is needed. In this paper, we study the properties of focal spot and present experimental verification of the formulas for the steered near-field spot of the NFFZP versus frequency.

Concept and formulations

For completeness, we offer a brief conceptual overview of the formulas for the steered near-field spot of the NFFZP versus frequency, which has already been thoroughly described in [1]. The feed is located at $(0,0,F_1)$, and the focal spot is at $(0,0,F_2)$. The normalized phase of the rays can be written as follows:

$$\phi(r) = \frac{2\pi f}{c} \left( \sqrt{r^2 + F_1^2} + \sqrt{r^2 + F_2^2} - F_1 - F_2 \right)$$

(1)

where $f$ is the frequency, $c$ is the speed of light in free space, and $r(x, y, 0)$ describes the position of the secondary wavesource in the NFFZP.

Under the paraxial condition, (1) can be rewritten approximately as

$$\phi(r) \approx \frac{2\pi r^2}{c} \frac{f}{2} \left( \frac{1}{F_1} + \frac{1}{F_2} \right) - \frac{\pi}{c} \frac{f}{4} \left( \frac{r^4}{F_1^3} + \frac{r^4}{F_2^3} \right) + L$$

(2)

where the higher-order items are neglected, and the Fresnel approximation can be used [5]. For a manufactured FZP and the determined zones, while neglecting the higher-order items, the constrained relationships are formulated approximately as follows:

$$\frac{1}{F_1} + \frac{1}{F_2} \propto \frac{1}{f}$$

(3)

For the same configuration above the NFFZP and the fixed feeding position with a sweeping frequency $f'$ according to (3), the new focused spots are steered at

$$F_2' = \frac{f'}{f} \frac{F_1F_2}{F_1 + (1 - \frac{f'}{f})F_2}$$

(4)
From the nonlinear (4), we can observe that the spot is displaced in a forward direction from the original focus when the frequency is higher than the centre frequency. The formula 4 is the formula for the steered near-field spot of the NFFZP versus frequency.

**Experimental Results**

Experimental testing platform is showed in figure 1. The port 1 of an Agilent E8357A Performance Network Analyzer (PNA) drove an Ku-band feed horn, transmitting a spherical wave with the E-plane aligned in the y-direction; this wave was collimated by a NFFZP len to form a spot which is detected by a probe connecting to port 2 of the PNA. The probe is fixed on the scanning frame and is moved by controlling the scanning frame.

![Figure 1 Experimental testing platform](image)

**Figure 1 Experimental testing platform**

![Figure 2 the curve of the steered near-field spot versus frequency](image)

**Figure 2 the curve of the steered near-field spot versus frequency**

Figure 2 shows the formula for the steered near-field spot of the NFFZP versus frequency. The red dash-dotted line is getted by theoretical derivation. The blue line is getted by experiment. We can see that the theory derivation of the steered near-field spot of the NFFZP versus frequency is consistent with
the experiment. Therefore, the formula 4 correctly reflects the movement curve of the focal spot with frequency.

![Figure 3: Normalized fields for several frequency points (along the x-axis)](image)

![Figure 4: Normalized fields for several frequency points (along the y-axis)](image)

The normalized fields of the spot are measured along the xoz-axes and yoz-axes which are shown in figure 3 and figure 4. And the measured results are compared with the simulation results in figure 3 and figure 4. From figure 3 and figure 4, we can see that measured results and simulation results are coincident. The $W_{3dB}$ and the sidelobe level of the spot are obtained from figure 3 and figure 4 which are presented in table 1. The simulation results are in agreement with the measured results.
The field taper in the yoz-plane is larger than that in the xoz-plane, which is caused by the polarization performance of the FZP. As a result, SLL on the yoz-plane is reduced to a lower level, and the $W_{3\text{dB}}$ becomes larger compared to that of the xoz-plane, as shown in table 1. The beamwidth in the x-direction is narrower than in the y-direction.

**CONCLUSION**

In this paper we have experimentally demonstrated the viability of the formulas for the steered near-field spot of the Fresnel zone plate versus frequency. And the spot properties are verified again. All the measured results are coincident with the simulation results.

**REFERENCES**


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**TABLE 1**

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<th>$W_{3\text{dB}}$ <em>Y(mm)</em></th>
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