# UWB Antenna Array for Grating Lobe Reduction

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**Abstract**

*Traditional antenna array will have grating lobes if the antenna element spacing is not special arrangement. The problems of grating lobes will occur in antenna array if operating frequency is higher. In this paper, a uniformly spaced linear antenna array which composes of UWB CPW-Fed Bow-tie slot antennas, UWB cable line and UWB BFN (beam forming network) is studied. Test results in frequency domain, grating lobes for the radiation pattern are occurred. By using the Fourier transformation from frequency domain to time domain, the grating lobes are significantly reduced. The wider the frequency bandwidth, the lower the grating lobes in radiation pattern will be happened. The test results are agreed with that of simulation.*

## 1. Introduction

For the traditional antenna array, radiation pattern for main bean and grating lobes will follow the following equation,

$$\theta_{GL} = \sin^{-1}(\pm\frac{n\lambda}{d}) \qquad (1)$$

Where d is the element spacing in wavelength, $\lambda$ is the wavelength, and n is an integer. The main beam is with n=0. Grating lobes occur with n is not equal to zero. For example, $d = 1.5\lambda$, the first grating lobe occurs at $\theta = 41.8^0$.

Grating lobes of radiation pattern are typically undesirable in many communication or radar systems. There are many parameters, such as impedance, gain, polarization, pattern, grating lobes, scan angle, etc., that will limit the bandwidth of antenna array. Among these important parameters, the grating lobes will be considered as one of the most important effect in array bandwidth. The effect of inter-element spacing is an inherent problem in designing antenna arrays. It is desirable for inter-element spacing to be small for reducing the grating lobes, but the element spacing is limited by antenna element size and effects of mutual coupling. As the operating frequency is increased the inter-element spacing increases in terms of wavelength will also be increased. The pattern simulation of the four elements array with uniform element spacing of one wavelength at 3.1 GHz is shown in Fig.1. The antenna element is assumed omni-directional in broadside angle. Except for the main lobes, there are four grating lobes in the radiation pattern.

## 2. UWB Antenna Array

The UWB antenna array is composed of four UWB antenna elements, UWB BFN, and same length of coaxial cable lines for antenna array. They are discussed in the following sections.

### *a. UWB Antenna Elements*

A CPW-fed bowtie slot antenna is selected to from a uniformly spaced array as shown in Fig. 2, where the elements are placed in the x-y plane, with a spacing of d between antenna elements. Each element is excited by CPW. The size of the antenna substrate is with 47 mm (x direction) by 36mm (y direction). The parameters of RO4003 are with relative permittivity 3.38, thickness 0.508mm and loss tangent 0.002. The antenna structure is composed of a linear tapered transition slot line between the feeding CPW and the bowtie slot antenna. By using this linear tapered transition, a 120% impedance bandwidth with 10dB return loss is achieved as shown in Fig. 3.

### *b. UWB Beam Forming Network*

The performance of UWB BFN is critical for the array. The BFN is this case is a UWB power divider with equal amplitude/phase weighting. In order to realize the characteristics of UWB BFN, a five steps Chebyshev transformer as shown in Fig. 4 is designed to match the four output impedance. The BFN was fabricated in microstrip line on FR4 substrate with relative permittivity 4.4, thickness 1.6mm and loss tangent 0.0254. The size of the BFN is 44.2 mm by 31.22 mm. The measured return loss at port 1 and transmission loss S21, S31, S41, S51 is shown in Fig.5. The transmission losses from the port 1 to the four outputs are varying between -5 db and -10 db for frequency between 3.1GHz to 10.6GHz. The fractional bandwidth is 107 % with return loss with -9 db. The phase linearity for S21, S31, S41, S51 is shown in Fig.6. The maximum phase deviation from the linear phase is about 10 degrees for the whole band.

### *c. UWB RF Coaxial Cables*

In order to develop an UWB antenna array, except for the UWB antenna elements, and UWB BFN, the RF coaxial cables are also important. The four identical 60 mm coaxial cables are with ULA-316 as shown in Fig. 7. The measured maximum insertion loss for the four coaxial for the designed band is less than 3 dB as shown in Fig.8.

## 3. UWB Array and Test Results

The final assembly of the UWB antenna array is shown in Fig. 9. Four bowtie antenna elements are linear array in H-plane with element spacing 13 cm. Four identical coaxial cables are connected to the antenna elements. Other ports of the cables are connected to the UWB BFN. The phase response of the UWB antenna array and UWB antenna element is measured by impulse time domain network analyzer as shown in Fig. 10. From Fig.10, the phase deviation is small between the UWB antenna array and UWB antenna element.

For the impulse time response measurement, an Gaussian time domain signal with pulse width 30 ps is transmitted. The distance between transmit antenna and UWB array is 4 meters. Two nanosecond gate window is applied to the impulse time response. The impulse time response for the UWB array at both broadside (0 degree) and endfire directions is shown in Fig.11.

The gated impulse time response of the UWB array is transformed to the frequency domain by Fourier transformation for different aspect angle. Sixteen with frequency interval 500 MHz and seventy-six frequencies with frequency interval 100 MHz are used for the frequency band between 3.1 GHz and 10.6 GHz. Fig.12 is the power pattern at single frequency 3.1 GHz. The grating lobe is about 4 dB at 3.1 GHz. Figs.13 & 14 show the time domain pattern response with 16 & 76 frequencies respectively. The grating lobe power level for Fig.13 and Fig.14 is about 7.5 dB and 11 dB below the main lobe. Comparing Fig.13 and Fig.14, it is seen that RMS sidelobe level is smaller with 76 frequencies. From the test results of Figs.12&13&14, we can have conclusion that the UWB array will have the capability of radiation pattern without grating lobe. It is agreed with that of simulation.

## 4. Conclusion

UWB antenna element, UWB BFN, UWB cables are implemented and measurement. The test results show that they have UWB performance. UWB antenna array is fabricated by using the developed antenna elements, BFN, cables. The antenna array is measured by the impulse time domain antenna measurement system. By using the Fourier transformation, H-plane power patterns at different frequency points are calculated. The final patterns with different frequency points are analyzed. The more the patterns with different frequency points, the lower the grating lobe power level of power pattern will be.

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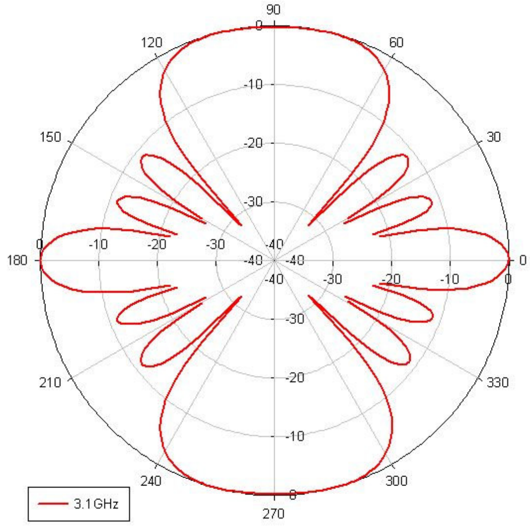


Fig. 1: Simulation pattern of 4 elements array at 3.1GHz

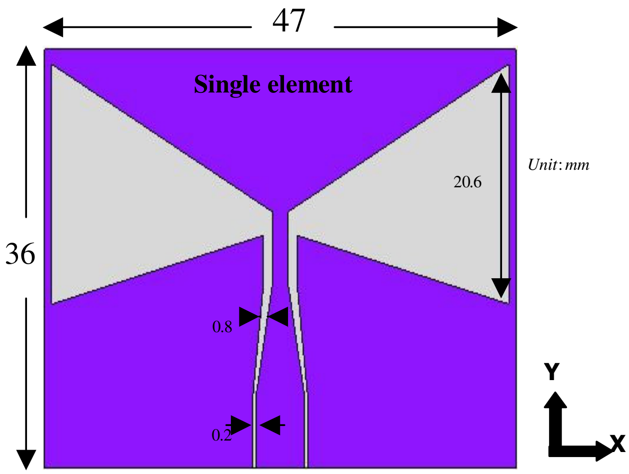


Fig. 2: CPW-Fed Bow-tie slot antenna geometry

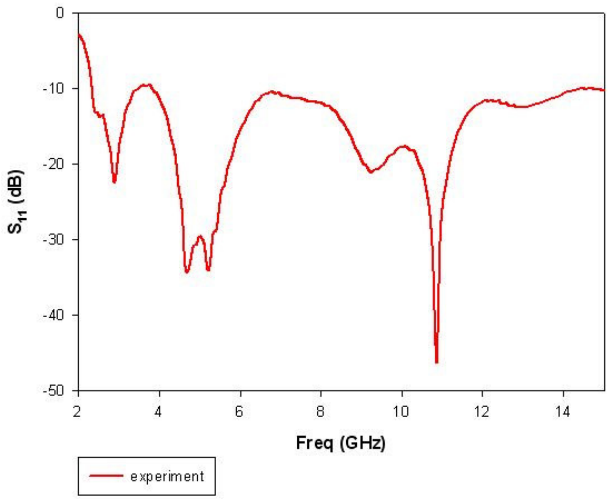


Fig. 3: Measured return loss of the antenna element

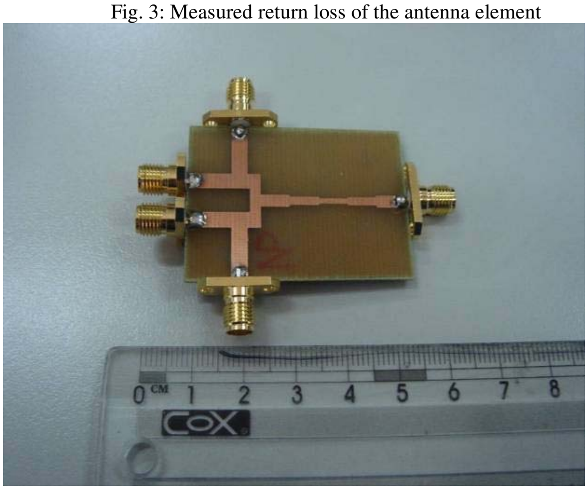

Fig. 4: Prototype of BFN

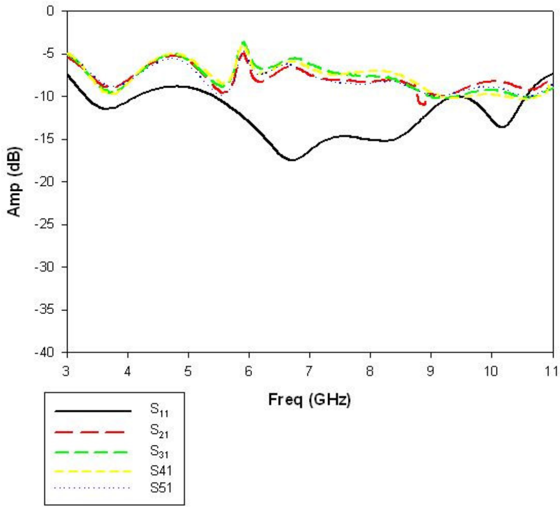


Fig. 5: Measured transmission loss and return loss of BFN

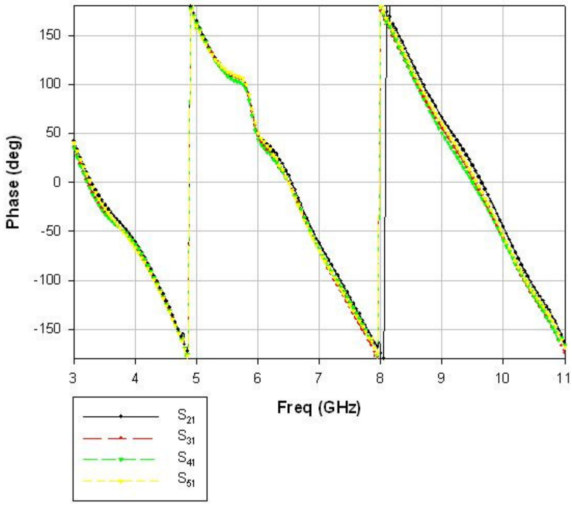


Fig. 6: Measured transmission phase information of BFN

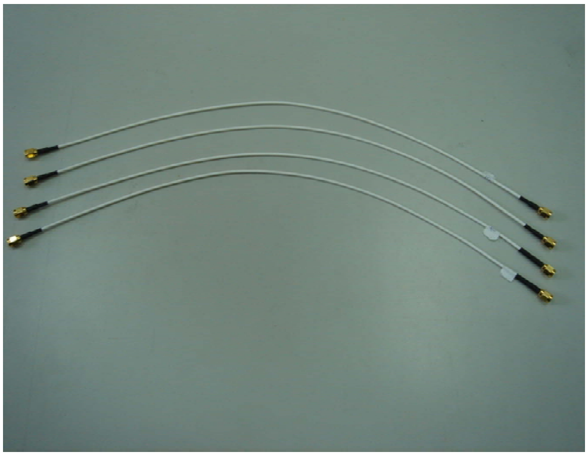

Fig. 7: UWB coaxial cable lines of ULA-316

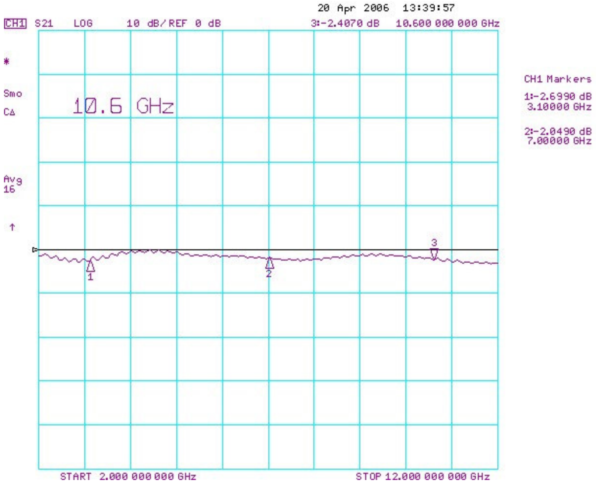


Fig. 8: Measured transmission loss of UWB coaxial cable

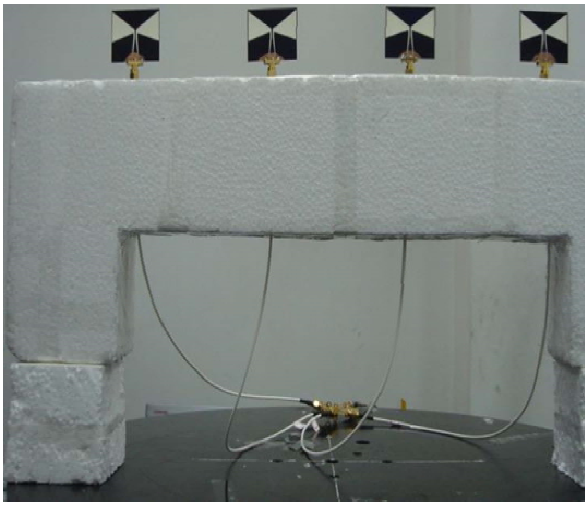

Fig. 9: Prototype of UWB antenna array

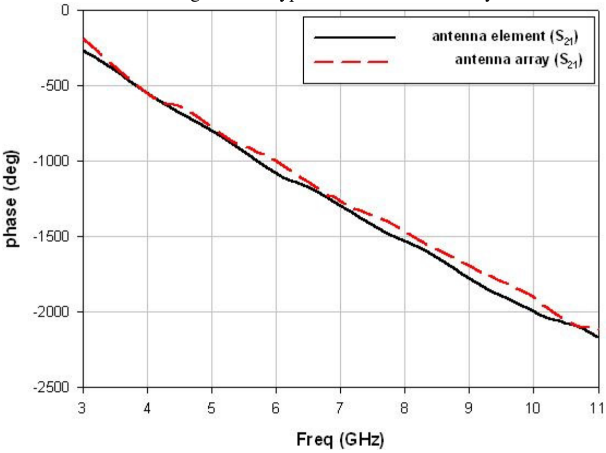


Fig. 10: Phase response of UWB antenna array and UWB antenna element

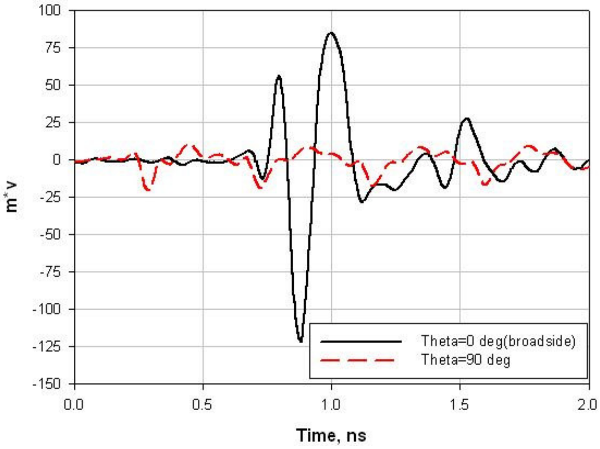


Fig. 11: Impulse time response of UWB array at broadside and endfire directions

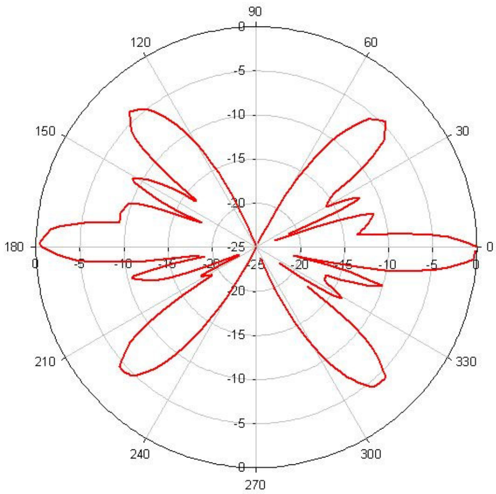

Fig. 12: Measured power pattern of UWB antenna array at 3.1 GHz

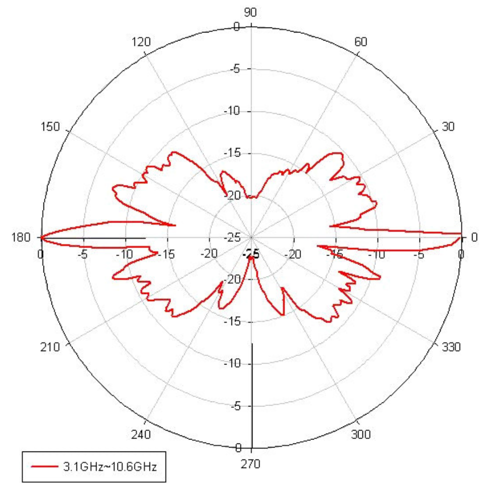


Fig. 13: Measured power pattern of UWB array with 16 frequency points

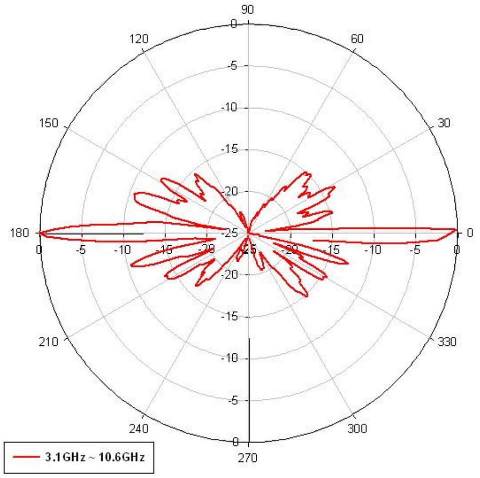


Fig. 14: Measured power pattern of UWB array with 76 frequency points