Xidian University Upgrades Existing 2-port VNA to Save Lab Set-up Cost with TMYTEK BBox™ One

BBox™ One

The Most Cost-effective and Straightforward Solution for
Antenna Radiation Pattern Validation

Background

To overcome the relatively high path loss and to increase the beam coverage, the millimeter-wave (mmWave) antenna array design is a critical circuit design in 5G NR mmWave FR2 applications. Prof. Lu-Yu Zhao's team at Xidian University (hereinafter referred to as Prof. Zhao) has developed a compact 1x4 multi-band and dual-polarization mmWave beam scanning antenna array for 5G mobile terminals. The overall size of the array antenna is small enough to fit into a mobile phone and it fully supports the 5G NR band from n258 to n261.

The antenna element in the array is a critical design that affects the overall antenna array characteristics. It is necessary to validate the array performance through the front-end system by adjusting the phase and gain. Upon completing the antenna array design, Prof. Zhao needed to fully verify the beamforming radiation patterns by setting up a beamforming test environment, which Prof. Zhao aims to build, fast and economically with existing instruments.

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◼ Challenges

Beamforming is a necessary technique in mmWave applications. However, antenna array designers must overcome a variety of test limitations before conducting beamforming measurements. To acquire the beamforming radiation patterns, antenna array post-processing is required to simulate the beamforming radiation patterns, or a beamforming front-end circuit to adjust the amplitude and phase.

Before conducting beamforming tests, Professor Zhao faces the following challenges.

• Prof. Zhao wanted to focus on the element/antenna array design and did not have the time and effort to develop beamforming post-processing algorithms or design beamforming front-end circuits.

• To measure beamforming patterns efficiently, Professor Zhao needed to invest in an 8-port (or more) vector network analyzer to test his 1x4 dual-polarized antenna but lacked the funding.

◼ Solutions

To achieve the beamforming measurement requirements, and given that Professor Zhao's antenna design is a compact 1x4 dual-polarized antenna array, TMYTEK suggested three options.

Option 1. Utilize the existing 2-port VNA: It measures the radiation patterns by manually switching each antenna element in a chamber and simulating the beamforming patterns with the post-processing method.

Option 2. An 8-port (or more) VNA: It measures the radiation patterns of each antenna element directly in a chamber, and simulates the beamforming pattern with the post-processing method.

Option 3. Utilize the existing 2-port VNA with TMYTEK's BBox™ One: This setup directly measures the radiation patterns in a chamber by adjusting the phase and gain with BBox™ One.

Of the three options, option 1 is time-consuming; option 2 is expensive to set up, requires multiple cables which are not easy to set up in a chamber, and intertwining cables may affect the measurement accuracy or damage the DUT. The above two mentioned options also shared something in common, which is that they both use the post-processing method to simulate the beamforming radiation pattern.

Figure 1. Option 3 Test System

Therefore, Prof. Zhao adopted the third option, a complete test system (Fig. 1) that consists of one Keysight N5225A VNA, one TMYTEK BBox™ One 28-GHz , one anechoic chamber, an AUT (1x4 dual-polarization antenna array designed by Prof. Zhao).
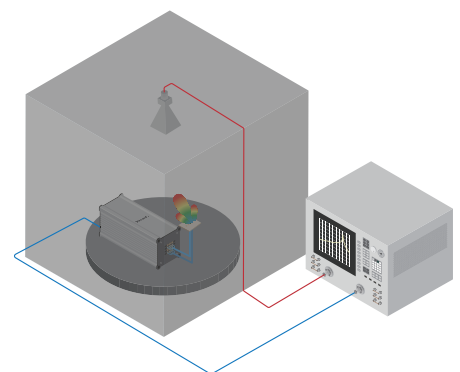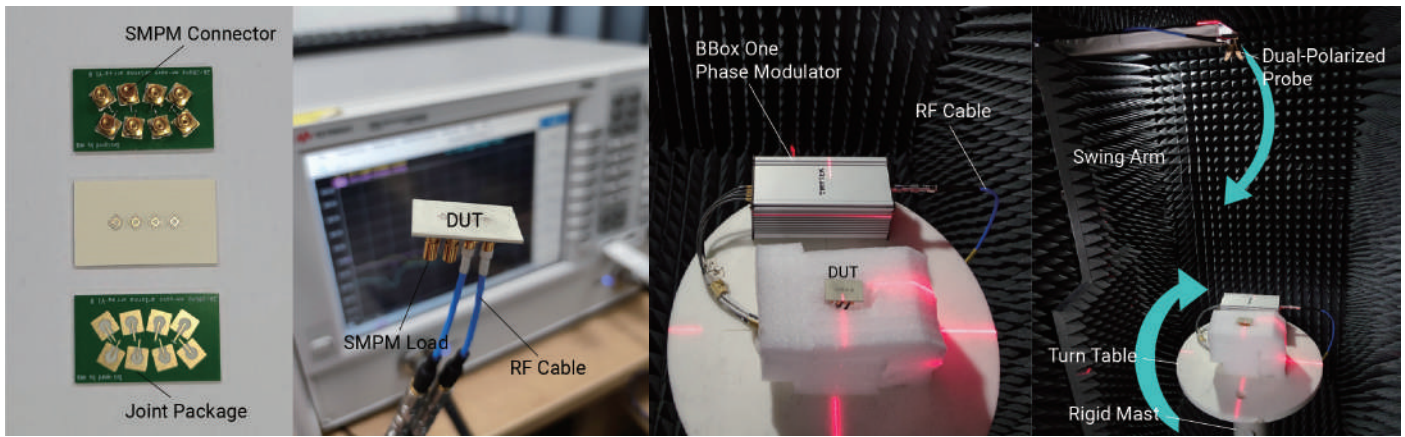
Figure 2. Prototype and measurement setup. (a) Prototype of Professor Zhao's 4-element antenna array. (b) Measurement setup of S-parameters. (c) Array under test with a BBox™ One. (d) Measurement setup of radiation patterns.

	2-port VNA + Emulation SW	8-port VNA + Emulation SW	2-port VNA + TMYTEK BBox™
Beamforming radiation patterns	Self-measure or additional support from the instrument manufacturer	Self-measure or additional support from the instrument manufacturer	BBox™ and TMYTEK GUI can directly adjust the phase, gain and control the beam angles
	Expensive and time-consuming	**Expensive and time-consuming**	**Cost-effective**
Beamforming test time (based on CATR measurement of 8 3D patterns, 15 min/3D pattern)	120 min [*1]	15 min [*2]	≒15 min [*3]
	Slowest	**Fastest**	**Fast**
Ease of setup	Manually switching the antenna elements is time-consuming	Multiple cables required for CATR and the DUT High risk of DUT and cables damage when CATR rotating	Only one cable is needed
	Hard	**High risk**	**Easiest**
Procurement costs	2-port VNA +Emulation	Multi-port VNA +Emulation	2-port VNA + TMYTEK BBox™
	Lowest	**Most expensive**	**Low**

Table 1: Comparison of Various Beamforming Radiation Patterns Testing Options

[*1] 8 (no of element)*15 min(CATR measurement time/round)=120min

[*2] 15 min (CATR measurement time/round)

[*3] 40 ms (BBox beam switching time/pattern<5ms) + 15 min (CATR measurement time/round) ≒ 15 min

TMYTEK BBox™ One helps antenna designers save test time and effort by eliminating the need to develop beamforming algorithms or additional beamforming front-end circuit design. With TMYTEK's in-house designed GUI, antenna designers can directly control phase, gain and beam direction on one panel, making beam steering and beam management easier than ever before. The combined benefits allow antenna designers to focus on antenna development and efficiently verify antenna performance without worrying about beamforming algorithms.

The TMYTEK BBox™ One has 16 independent RF channels with individual phase and amplitude control, and therefore Professor Zhao only needed to connect the BBox™ One to his existing 2-port VNA to test the antenna pattern of his 1x4 dual-polarized antenna at different angles. For Professor Zhao, who needed to measure the beamforming patterns, TMYTEK solution is the easiest, most convenient and cost-effective.

BBox™ One 5G

28 GHz／39 GHz│16 RF control channels

Spec	28 GHz	39 GHz
RF	26.5-29.5 GHz	37-40 GHz
Band	n257, n261	n260
Channels	16	
Antennas	4x4/ 8x8 Array	
	Tx/Rx Half Duplex	
	Individual Gain and Phase Control	
Size	156x82X82 mm	

Key Features

- 5G NR mmWave Beamforming Development Kit
- Beamformer with Detachable Antenna
- Build for 5G R&D
- Comprise of RF components such as T/R switch, LNA/PA and phase shifters

BBox™ Lite 5G

28 GHz／39 GHz│4 RF control channels

Spec	28 GHz	39 GHz
RF	26.5-29.5 GHz	37-40 GHz
Band	n257, n261	n260
Channels	4	
Antennas	4 Series Patch	
	Tx/Rx Half Duplex	
	Individual Gain and Phase Control	
Size	125x102x110 mm	

Users

- Antenna / Algorithm designers - verify the design by docking antenna to BBox™
- 5G protocol developers - verify the beam tracking algorithm and protocols by connecting BBox™ to the baseband instrument.

Key Results

In a 5G mobile terminal, beam scanning capability is a critical factor for mmWave antenna arrays. For comparison, Prof. Zhao measured the beam scanning angle in different directions with his proposed mmWave antenna and TMYTEK BBox™ One 28 GHz, and compared it with the simulated pattern measurement results. As shown in the figure below, Prof. Zhao measured the beam scanning capability of the antenna array at 26.6 GHz and scanning angles from 0 to 60 degrees. The difference between the final measurement and the simulation is less than 0.2 dB, which means testing using TMYTEK BBox™ One is just as accurate.
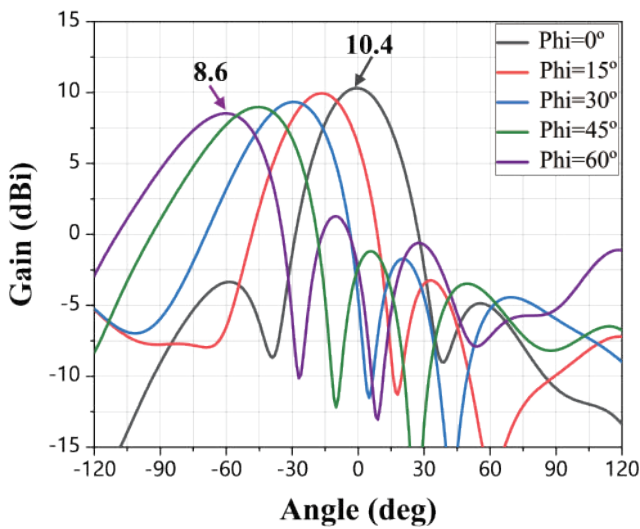

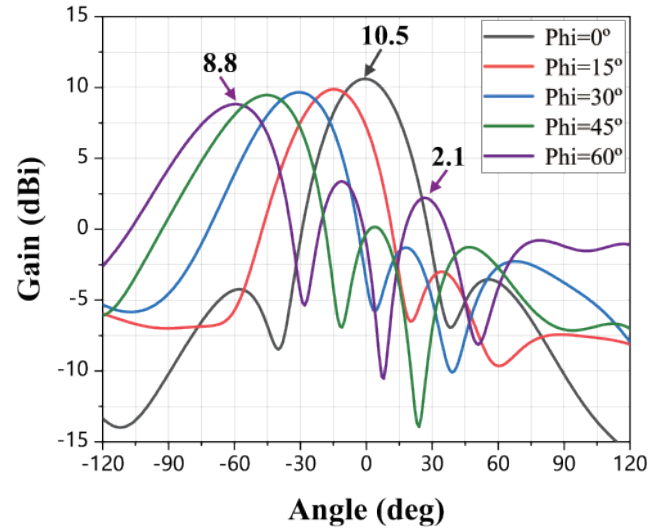Figure 3: Simulated patterns of +45° polarization.

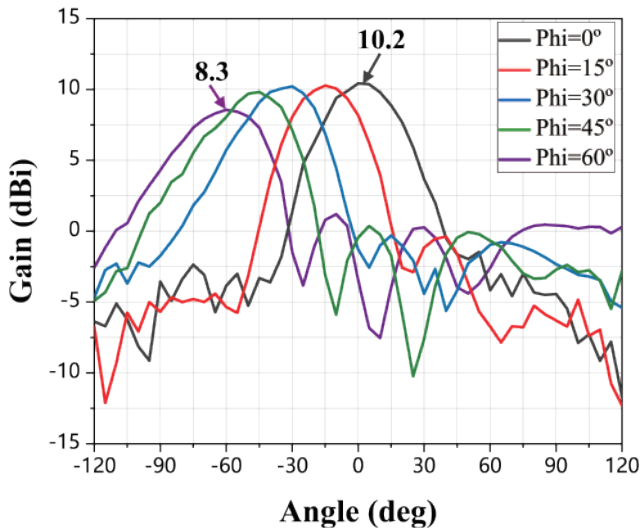

Figure 4: Simulated patterns of -45° polarization.

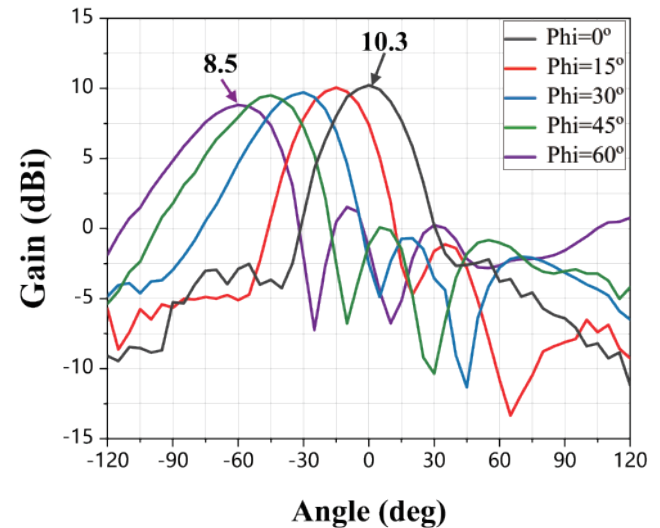Figure 5: Measured patterns of +45° polarization.

Figure 6: Measured patterns of -45° polarization.

2D beam scanning patterns of the antenna array in the plane of theta = 90° at 26.6 GHz for the proposed antenna array.

Figure 7: BBox™ One GUI developed by TMYTEK, which allows users to intuitively control the amplitude and phase of each channel.

■ Summary

Prof. Zhao incorporated TMYTEK's BBox™ One with his existing 2-port VNA and completed his 1x4 dual-polarization antenna verification experiment within his budget. With 16 independent RF channels, TMYTEK BBox™ One is applicable to the professor's various antenna configurations and is used in the OTA chamber to measure the beam patterns to verify the antenna performance. By utilizing TMYTEK's BBox™ One, the antenna testing process remains accurate but simplified, and Prof. Zhao does not have to worry about the beamforming algorithm or post-processing.

References

Y. He, et al., including Luyu Zhao, **"A Compact Dual-Band and Dual-Polarized Millimeter-Wave Beam Scanning Antenna Array for 5G Mobile Terminals,"** in IEEE Access, vol. 9, pp. 109042-109052, 2021.