



# Lab 4

## What is constructive/destructive interference in radiation?

### List of laboratories

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Please peruse the User Guide before using the developer kit.

## Introduction

The 5G (5th generation mobile network) continues to be popular in 2022. With countries releasing new licenses for the FR2 frequency band one after another, operators also bid fiercely for their target bands. The FR2 frequency band includes n258(24.25-27.5 GHz), n257(26.5-29.5 GHz), n260(37-40 GHz), and n261(27.5-28.35 GHz). The FR2 is different from FR1, it can provide wider data bandwidth to satisfy high throughput and low latency features. However, it has a weakness, and it is the short wavelength that may contribute to higher path loss. To overcome this weakness, beamforming is the key technology to solve the mmWave application. In fact, beamforming has already been adopted in many applications such as FWA, Low Earth Orbit (LEO) Satellite, ADAS, ADAS, and more.

The mmWave development is an inevitable trend in the coming years and the market size will explode in growth. The mission is obvious, to develop and train talents. For the development of mmWave, the next generation of engineers will play a key role, and it is essential that engineering graduates are prepared for the principle, practice, and advanced research of related mmWave technologies. But, the reality is that the cost of mmWave relevant components is very expensive and difficult to demonstrate practical operating applications. The TMYTEK Developer Kit is a complete and affordable mmWave training tool for lecturers, professors, and researchers. It provides complete mmWave components as well as ready-made practical classes. It is not only a great entry-level kit for mmWave teaching, but also extends to advanced research with other options like Software Defined Radio (SDR), Arduino, and Up/Down Converter.

## What's included

- 5G FR2 Beamformer - BBoard ×1
- Signal Source - PLO ×1
- Power Detector ×1
- 5G FR2 Array Antenna ×1
- 28 GHz COCO Antenna ×1
- 20 GHz-40 GHz Amplifier ×1
- 40 GHz RF Cable ×4
- 10 GHz-40 GHz Combiner/Splitter ×1



Figure 1. List of Developer Kit

## ■ Lab 4 - What is constructive and destructive interference in radiation?

### 1. Significance

Beamforming is the technique used for radiative transmission to overcome and satisfy mmWave applications. The signal is converted to electromagnetic waves to communicate. Over the air, the signal wave will be affected by different factors, for example, weather, building, various materials, etc. may cause absorption, multipath fading, reflection, and propagation effects. Therefore, understanding the effect of the environment is also an important task for wireless communication, especially for mmWave.

### 2. Aim

By replacing the cables in Lab 3 with an antenna, you are about to dive into the fundamental theories of beamforming. You will discover the radiative effects using OTA (Over-the-air) operations and analyze the difference between the two test results. After that, you will realize why most wireless communication is tested by conduction in the mass production phase.

### 3. Requirements

- 5G FR2 beamformer - BBoard × 1
- Signal source - PLO × 1
- Power detector × 1
- 5G FR2 array antenna × 1
- 28 GHz COCO antenna × 1
- 20 GHz-40 GHz amplifier × 1
- 40 GHz RF adapter × 1
- 40 GHz RF cable × 1
- A personal computer with TMXLAB kit and LTC5596 GUI installed
- DC power supply × 1
- Ruler × 1

#### 4. Procedure

- a. Connect the 5G FR2 array antenna to the BBoard using the four right-angle adapters.

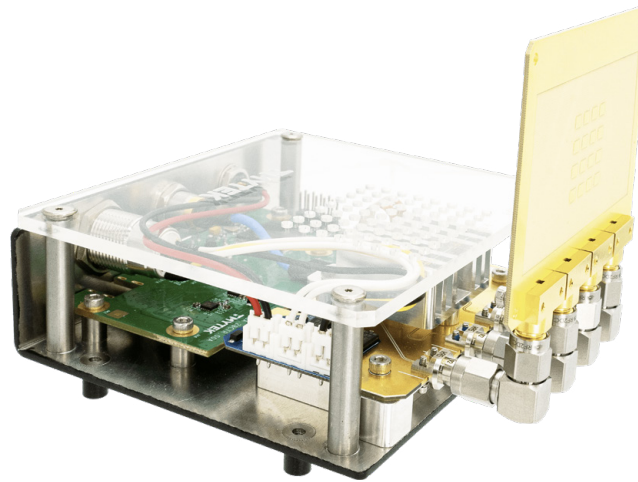


Figure 11. Connect array antenna to the BBoard

- b. Utilizing the PLO and adding an attenuator as the source and connecting it to BBoard' s RF com port via an RF cable.
- c. Connect the 28 GHz COCO antenna to the input port of the amplifier.
- d. Use the 40 GHz RF adapter to connect the output port of the amplifier and power detector.
- e. Provide a +12V DC to the amplifier from the DC power supply.
- f. Make sure there is at least a 50 cm distance between the 5G FR2 array antenna and the COCO antenna as shown in Figure 12.

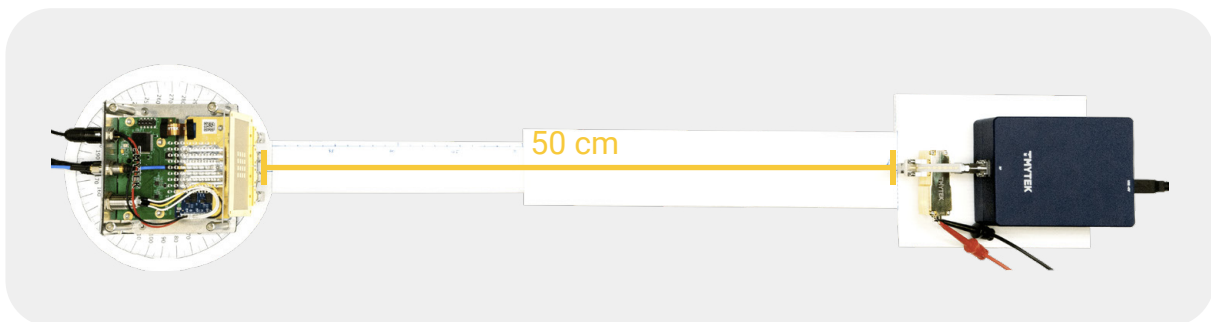


Figure 12. Configuration

- g. Execute and run the TMXLAB kit to adjust the phase step. Keep channel 1 at step 0 and just change channel 2 from 0 to 63 step by step. To ensure the result is reasonable, you must turn off channels 3 and 4 due to the array antenna connection.

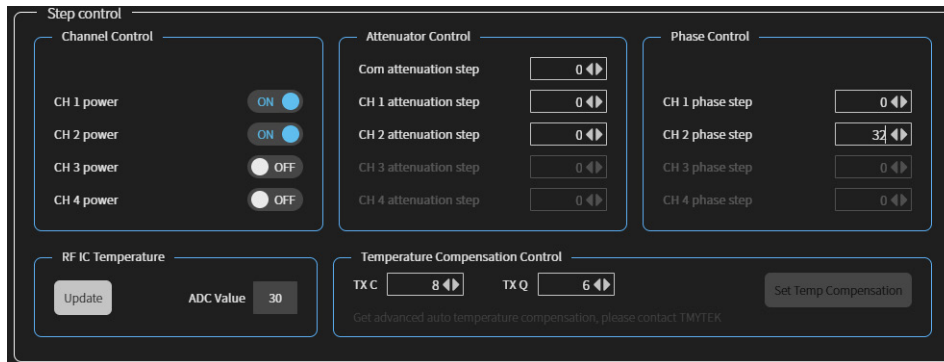


Figure 13. TMXLAB Kit

- h. Observe and record the detected power on the LTC5596 GUI after changing the phase step.

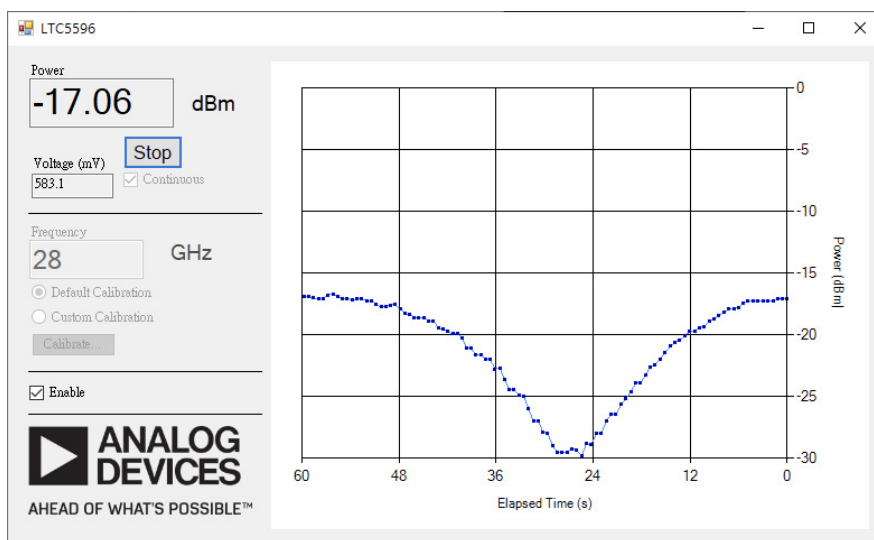


Figure 14. Measured power from LTC5596

- i. Repeat steps g. to h. on channels 1&3 and 1&4.

### 5. Results

Phase Step	Fix #1, Adj #2	Fix #1, Adj #3	Fix #1, Adj #4
0	-15.29	-13.77	-15.98
1	-15.62	-13.65	-16.01
2	-15.63	-13.72	-16.13
3	-15.46	-13.83	-16.27
4	-15.63	-13.61	-16.13
⋮	⋮	⋮	⋮
31	-29.71	-24.83	-29.11
32	-29.36	-27.31	-31.59
33	-28.53	-28.98	-32.14
34	-27.38	-31.32	-32.98
35	-27.24	-34.78	-34.07
36	-26.31	-32.66	-32.77
37	-24.93	-32.61	-30.9
⋮	⋮	⋮	⋮
62	-15.63	-14.35	-16.30
63	-15.43	-14.31	-16.13

Table 4. Test results

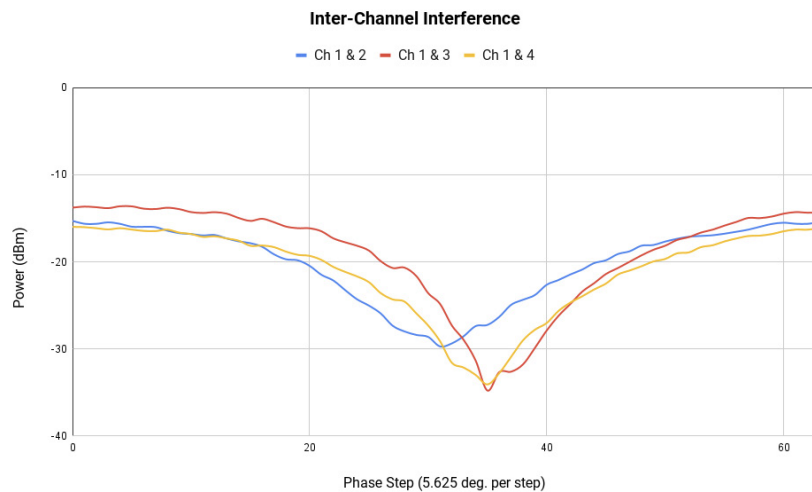


Figure 15. Inter-channel interference

	Maximum power @	Minimum power @
Ch1 & Ch2	0	31
Ch1 & Ch3	4	35
Ch1 & Ch4	0	35

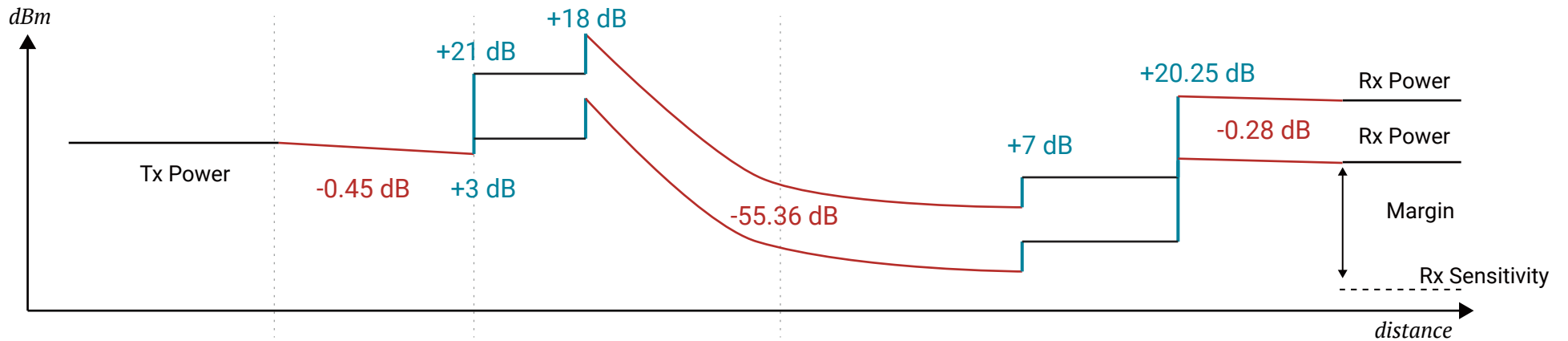
Table 5. The maximum and minimum phase step

As instructed in Lab 3, you may also locate the maximum and minimum power position as shown in Table 5. Compare to Lab 3 results, you can see that the power range and distribution are different from Lab 3. The dynamic range is significantly narrower than conduction, and the destructive interference also occurs in different phase steps. The test results may change if you perform this experiment at a different location. The main reason is the signal wave would be affected by the environment. You can also try placing various materials like glass, a mirror, metal, or plastic in the transmission path and observe the changes.

Assuming that you have already completed the in-phase calibration using the zeroing table in Table 3, calculated the link budget using results in Lab 1, and compared it against your results.



PLO w/ Attenuator    Cable #1    BBoard    AA-Kit    28 GHz Path Loss @ 50cm    COCO Antenna    Amplifier    Adapter    Power Detector



<b>Power (dBm)</b>	-22.04	-22.49	-1.49	16.51	-38.35	-31.35	-11.6	-11.88
			-19.49	-1.49	-56.85	-49.85	-29.6	-29.88

Link budget calculation