Application Brief

Optimizing TI mmWave Radar Configurations for FCC Certification

FCC Regulations at 60 GHz require customers to prioritize Bandwidth or Power

Products designed with TI Industrial mmWave radar sensors in the United States must comply with the regulations set by the Federal Communications Commision (FCC). Currently, the FCC regulates fundamental emission levels for the 60 GHz band as shown in Table 1, which can also be found in the *TI mmWave Radar Device Regulatory Compliance Guide*.

Table 1. Emission Levels for 60 GHz Band

Frequency Band (GHz)	Average Radiated TX Power	Peak Radiated TX Power	Peak Conducted TX Power
61-61.5	+40 dBm	+43 dBm	No specified limit
57-71	No specified limit	+10 dBm	-10 dBm

Notice there are two regulated bands. The narrower band of 61-61.5 GHz limits average radiated power to +40 dBm and peak radiated power to +43 dBm. The wider band of 57-71 GHz limits peak radiated power to +10 dBm and peak conducted power to -10 dBm. This leaves product designers with two options: to either operate with a wider bandwidth or with a higher transmit power. More bandwidth increases range resolution, but higher transmit power increases the detection range. TI's suggestion for balancing these tradeoffs can be see in Figure 1.

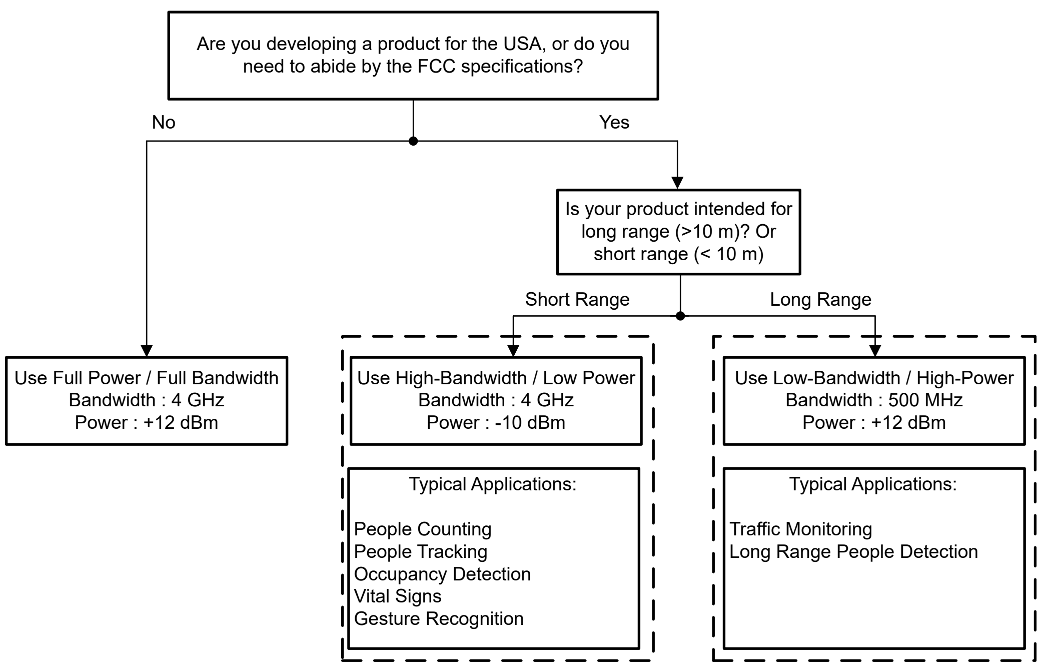

Figure 1. Power and Bandwidth Decision Flowchart

Measuring Conducted and Radiated Power

For both the high-bandwidth/low-power and low-bandwidth/high-power cases, it is crucial to measure peak conducted power and peak radiated power accurately. While peak radiated power can nearly always be measured directly, peak conducted power at 60 GHz may be infeasible to measure directly, due to constrained board layouts or because there are no conducted traces to measure on devices that use TI antenna-on-package technology. In cases where it cannot be measured directly, conducted power can be computed by measuring the overall effective isotropic radiated power (EIRP), then subtracting the antenna gain.

$$P_{conducted} = P_{radiated} - G_{antenna} \quad (1)$$

Additionally, if using multiple transmit antennas at once for *BPM-MIMO* or beamsteering, there is a factor of $10\log_{10}(N_{antennas})$ that is added to account for constructive interference.

$$G_{antenna,\ multiple\ simultaneous\ transmitters} = G_{antenna,\ single\ transmitter} + 10\log_{10}(N_{antennas}). \quad (2)$$

Option 1 : High-Bandwidth and Low-Power

The high-bandwidth/low-power configuration provides the most precise range resolution (3.75 cm) that TI radar devices offer. This enables the device to distinguish between multiple targets, even when they are spaced closely together. In use-cases like building entry and occupancy detection, maximizing range resolution unlocks the ability to distinguish between multiple people in the scene. Similarly, when using TI radar to monitor vital signs, increased range resolution allows the device to detect minute changes in position, enabling non-invasive measurement.

While the maximum bandwidth value of 4 GHz provides great range resolution, the restrictions on transmit power may result in reduced detection range in a high-bandwidth/low power configuration. Different targets require more or less transmit power to be detected. The amount of transmit power to detect a particular target may depend on factors like distance, angle, surrounding scenery and the target's radar cross-section.

Those running a high-bandwidth/low-power configuration should pay special attention to your transmit power to ensure compliance with both the peak radiated and peak conducted FCC limits. In the high-bandwidth/low-power configuration, $P_{radiated}$ must be less than +10 dBm and $P_{conducted}$ must be less than -10 dBm. Although both the conducted and radiated limits must be observed, depending on the antenna gain value, only one of the two limits will become the limiting factor, and the other limit will be met automatically as a result. Case 1 in Figure 2 demonstrates that when the antenna gain is *below* +20 dB, then keeping the peak *conducted* power below -10 dBm ensures that the peak *radiated* power stays below the +10 dBm limit, since $P_{radiated} = P_{conducted} + G$ (see Equation 1). Case 2 in Figure 2 demonstrates that when the antenna gain is *above* +20 dBm, then keeping the peak *radiated* power below +10 dBm guarantees that the peak *conducted* power stays below the -10 dBm limit, since $P_{conducted} = P_{radiated} - G$ (see Equation 1).

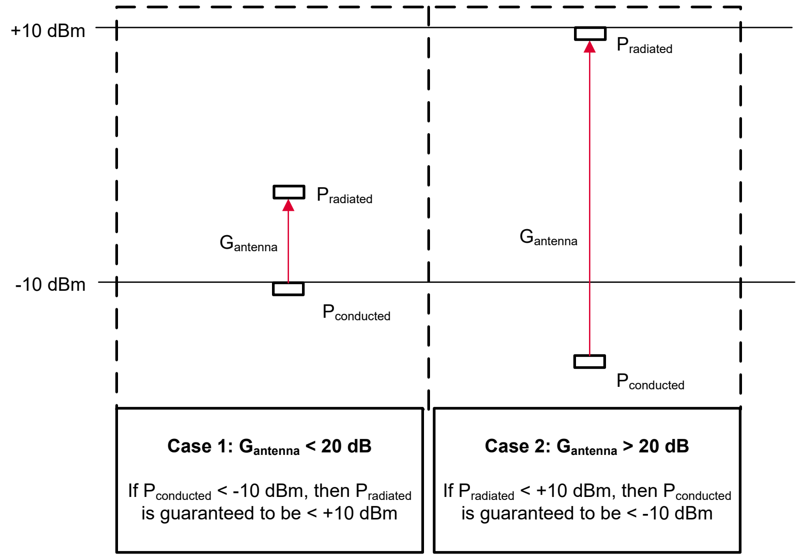

Figure 2. Radiated vs Conducted Power - Which one limits the other?

Mimicking any of the TI antenna designs (ISK, ODS or AOP) without a radome or lens should result in a maximum peak antenna gain of +7 dB. This is covered by Case 1 in Figure 2, where the peak conducted power will be the limiting factor before peak radiated power becomes relevant.

To set the bandwidth and power for a TI radar device, you must specify a profileCfg, a line used to configure chirp settings in the TI-provided demos. The profileCfg example below sets a high-bandwidth/low-power chirp configuration with the relevant bolded parameters.

profileCfg 0 60 100 10 **79** **1579032** 0 **50** 1 256 4000 0 0 30

The bandwidth set by this profileCfg is calculated by multiplying the Frequency Slope (8th value in ProfileCfg line) by the Ramp End Time (5th value in ProfileCfg line).

$$\text{Bandwidth} = \text{Frequency Slope x Ramp End Time} = 79\ \text{MHz}/\mu\text{sec x } 50\ \mu\text{sec} = 3.95\ \text{GHz} \tag{3}$$

The peak conducted power set by this profileCfg is calculated by subtracting the TX Power Backoff Value (6th value in ProfileCfg line) from the default maximum value of +12 dBm. The TX Power Backoff Value is formatted as the three backoff values (one for each transmitter) all together in hexidecimal. For example, the low power value of 1579032 can be decoded by converting it to hexidecimal, separating out the three pairs of bytes that correspond to TX0, TX1 and TX2, and subtracting them from 12 to get the TX Power of -12 dBm. Users can therefore vary the TX Power for each transmitter if they choose. Additionally, although the device will accept any value, the TXBackoff will only be modified in steps of 3 dB.

$$1579032_{10} = 0x181818.\ 0x18 = 24_{10}\ \text{dB} \tag{4}$$

$$\text{TX Power} = 12\ \text{dBm} - 24\ \text{dB} = -12\ \text{dBm} \tag{5}$$

For a more detailed explanation of the profileCfg parameters, see the profileCfg section of the mmWave SDK User's Guide.

Option 2: Low Bandwidth and High Power

The low-bandwidth/high-power option enables detection at very long ranges. When designing a traffic monitoring sensor, using the maximum amount of transmit power allows you to detect cars further away. Similarly, if you want to detect the presence of people far away from the radar, increase your detection range by increasing the transmit power.

The main drawback of a low-bandwidth/high-power configuration is that range resolution is reduced. With 500 MHz of bandwidth, the best range resolution that can be achieved is 30 cm. This is entirely appropriate for detecting large targets, such as cars or people, but it will not be able to provide the same level of detail for detecting vital signals or distinguishing between closely spaced people that the higher bandwidth configuration can.

While the high-bandwidth/low-power option requires you to keep your peak conducted power below -10 dBm, the low-bandwidth/high-power option allows for much higher conducted power values. Since the maximum conducted transmit power TI mmWave devices can provide is approximately +12 dBm, you need an antenna with at least +31 dB of gain to approach the peak radiated power limit for the 61-61.5 GHz band, and +28 dB of gain to approach the average radiated power limit. As seen in Table 2, all of the antenna patterns on 60 GHz mmWave EVMs are well below these values. Mimicking one of these patterns should ensure that you stay within certification limits. Note that radomes and lenses used to focus the radar may significantly impact the antenna gain and should be either measured or computed to ensure compliance.

Table 2. Antenna Patterns on 60 GHz mmWave EVMs

Antenna Pattern	IWR6843ISK	IWR6843ISK-ODS	IWR6843AOPEVM	IWR6843LEVM
Peak Antenna Gain (dBi)	+7	+5	+5.2	Between +5 and +6

Below is an example profileCfg that sets a low-bandwidth/high-power chirp configuration. The relevant parameters are bolded.

profileCfg 0 61 100 2 **69** **0** 0 **7** 1 256 4000 0 0 30

When calculated using the same method as the previous section, the bandwidth set by this configuration is 480 MHz, and the TX Power is +12 dBm.

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Antenna Radiation Patterns

This section discusses transmitter and receiver antenna radiation patterns in both Azimuth and Elevation planes for a specified frequency.

1 Antenna Radiation Patterns for Receiver

Figure 1 shows typical antenna radiation gain plots normalized to boresight at various frequencies for the four receivers in both Azimuth (H-Plane) and Elevation (E-Plane) planes.

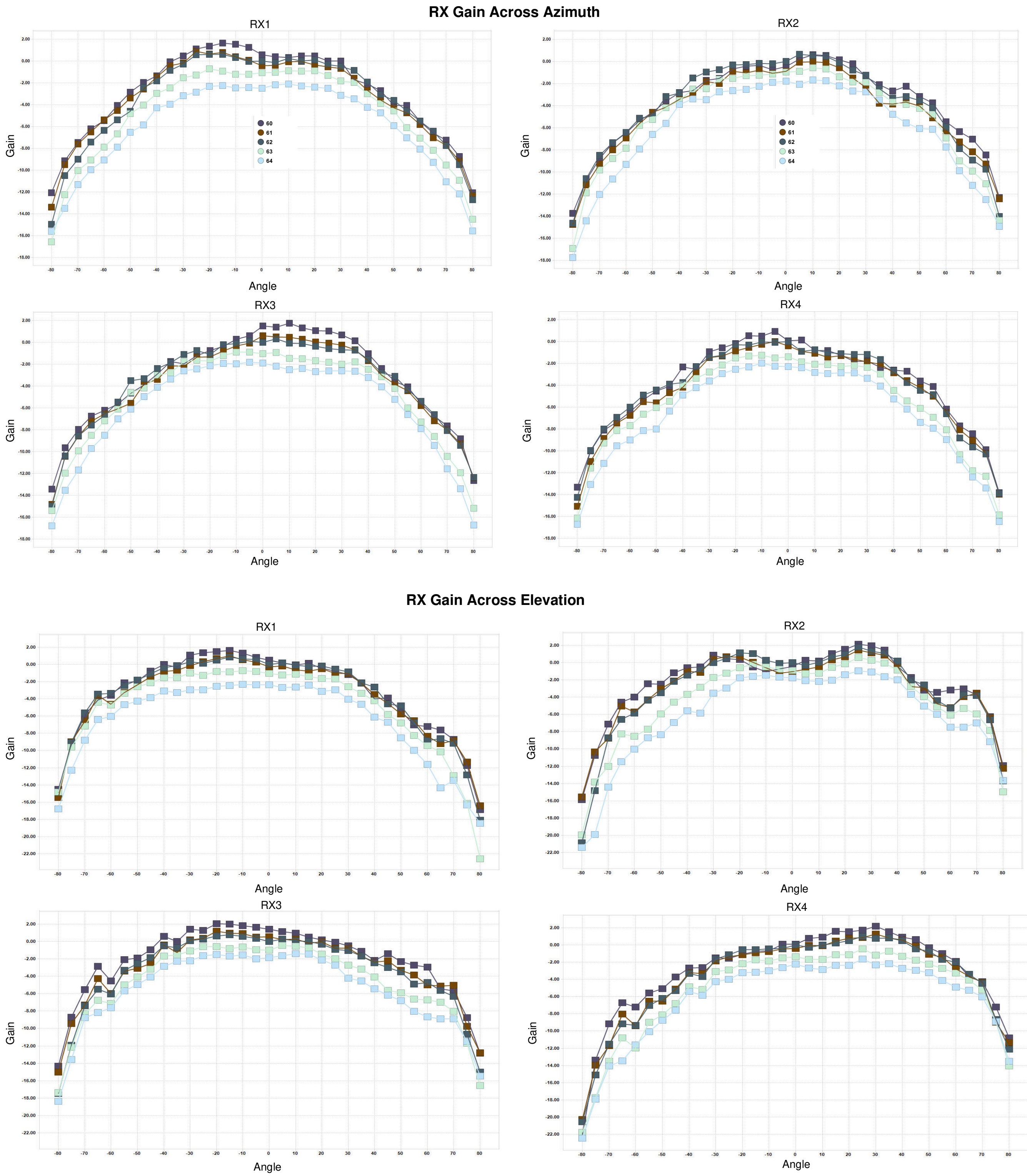

Figure 1. Receiver Antenna Radiation Pattern

2 Antenna Radiation Patterns for Transmitter

Figure 2 shows typical antenna radiation patterns for the three transmitters in both Azimuth (H-Plane) and Elevation (E-Plane) planes.

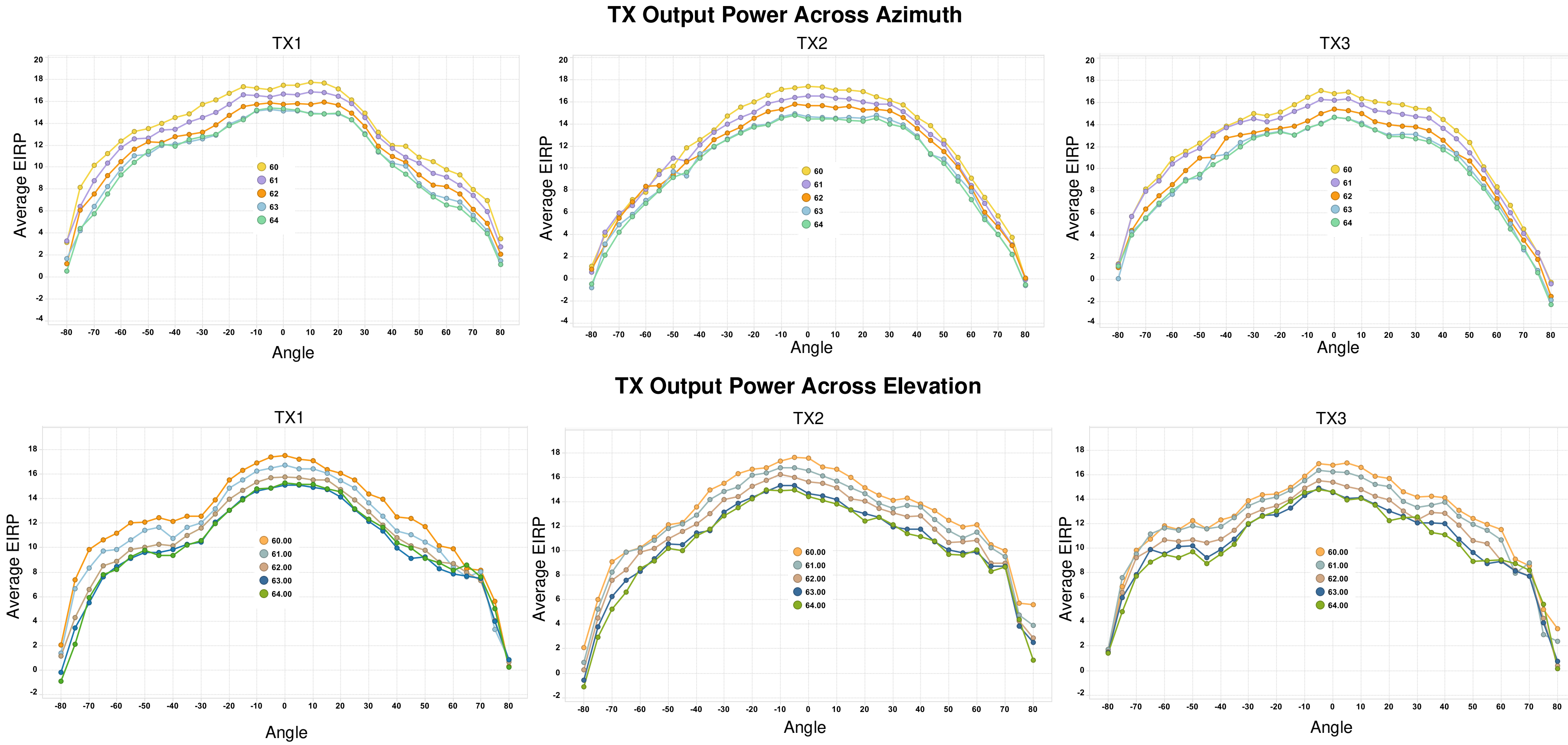

Figure 2. Transmitter Antenna Radiation Pattern