Application Note

Transmitter Back Off and Receiver Gain Recommendation for xWRL6432AOP

TEXAS INSTRUMENTS

Radar Systems and Applications

ABSTRACT

This application report provides information on how to select the transmitter power backoff and the receiver gain setting in the xWRL6432AOP radar device based on the end application and use case to avoid the increased receiver noise figure and the risk of receiver ADC saturation, and correctly program them on TI's xWRL6432AOP radar devices.

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1 Introduction

When determining overall system performance with FMCW radar sensors, many factors affect the range of detection. Range of detection is determined by chirp slope, IF bandwidth, and the signal-to-noise ratio (SNR) of the reflected energy from a detected object. The SNR in turn depends on EIRP (combination of TX power and TX antenna gain), EINF (combination of RX antenna gain and RX noise figure) and RCS of the target object. With the xWRL6432AOP device, there is limited isolation between transmit and receive antennas due to the close proximity of the antennas on the antenna-on-package (AOP) device.

This impacts the receiver performance in two ways:

- **Impact 1**: Increased receiver noise figure
  - Due to the noise riding on the TX- RX coupled signal the noise figure is increased.
- **Impact 2**: Risk of receiver ADC saturation
  - The TX - RX coupling causes a low frequency signal at the RX output which can be large enough to saturate the ADC if precautions are not taken.

2 Increased Receiver Noise Figure

The noise riding on the coupled signal can increase the noise figure of the receiver. Increased noise figure reduces the SNR of the detected object, leading to reduced detection range and accuracy. The effective isotropic noise figure therefore depends on two things:

1. TX Backoff
2. TX - RX Isolation

The TX - RX isolation depends on two factors:

- Transmit and Receive combination
- RF frequency

Figure 2-1 shows the dependencies of the effective isotropic noise figure (EINF) across different transmit and receive combinations and across different RF frequencies. The EINF is shown for two different TX backoff settings (0dB and 6dB). The change in noise figure between the two TX backoff settings show the impact of TX-RX coupling on noise figure for different RF frequencies.

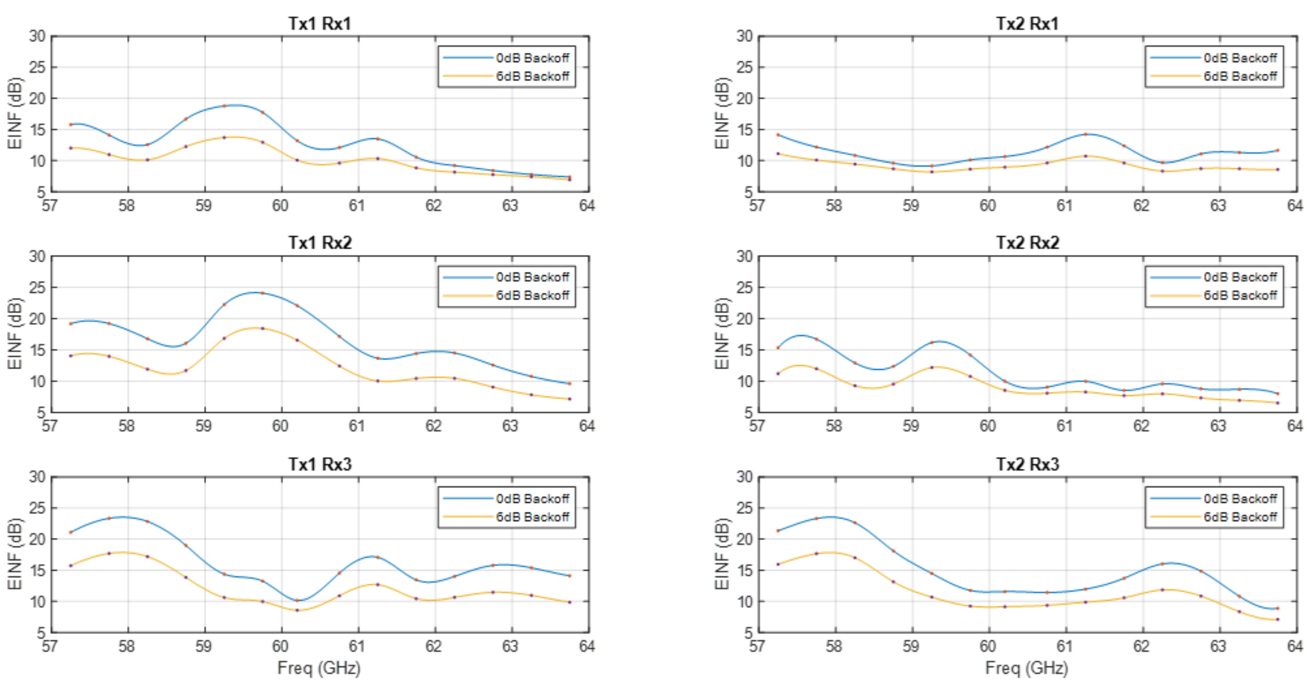

Figure 2-1. EINF With Single TX on Across Frequencies

These effects across transmit and receive pairs can be combined to show a total effect of all transmit and receive antennas across RF frequency. Figure 2-2 shows the noise figure averaged across different TX-RX combinations.

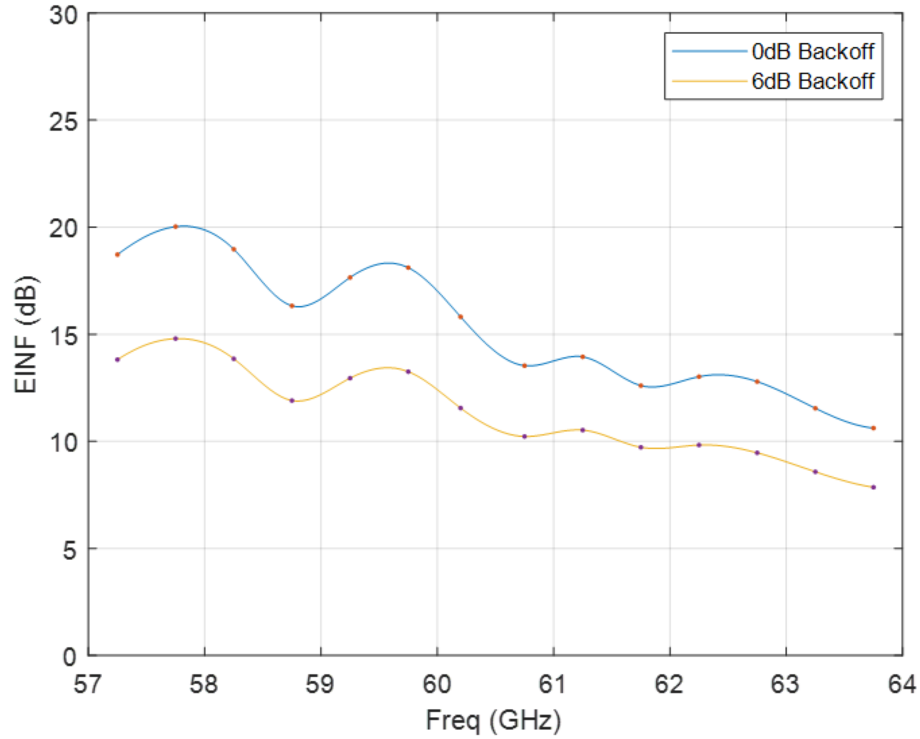

Figure 2-2. Average EINF With Single TX on Across Frequencies

Maximizing detection range (or minimizing required integration time for a particular detection distance) relies on maximizing detection SNR. Based on the previously-mentioned noise figure profiles, this can be achieved in several ways.

- Reducing TX power (increasing power backoff) lowers the noise figure by reducing the amount of coupling between TX and RX antennas. This varies between TX and RX combination and across output frequency. However, the benefit by lowered noise figure is outweighed by the reduction in transmitted power, lowering the detection range.
- Choosing start and stop frequencies (bandwidth) of the FMCW chirp can help reduce coupling and lower the noise figure. As Figure 2-2 shows, the 61 to 64GHz band has lower coupling than the 57 to 61GHz band. Designing a chirp to utilize the 61 to 64GHz portion of the frequency band can help lower the noise figure. Local regulations and other considerations can drive frequency choice of the end application, but the previous graphs can be used for expected noise figure in different frequency bands.
- For applications which do not need all 6 virtual channels (TX and RX combinations), using TX2 can help reduce noise figure. The coupling is lowest for TX2 in the 59 to 64GHz band. Single TX applications need to use TX2 over TX1 to get best performance and maximum range.

3 Risk of Receiver ADC Saturation

The TX - RX coupling causes a low-frequency signal at the RX output which can be large enough to saturate the receiver ADC if precautions are not taken. The strength of the receiver ADC saturation depends on:

1. Coupled signal level at RX input:
   - TX backoff
   - RF frequency
   - Transmit and receive combinations under consideration
2. RX Gain setting
3. HPF attenuation:
   - Chirp slope and HPF cutoff frequency configurations

To mitigate this risk, the swing at the receiver output needs to be reduced. This is achieved by the recommendations in the following section.

4 TX Backoff and RX Gain Recommendations

Figure 4-1 and Figure 4-2 give the maximum allowed RX gain setting and minimum TX back off restrictions based on chirp slope (X-axis) and HPF setting (different colors). These are recommendations which minimize the effects of increased receiver noise figure and risk of receiver ADC saturation.

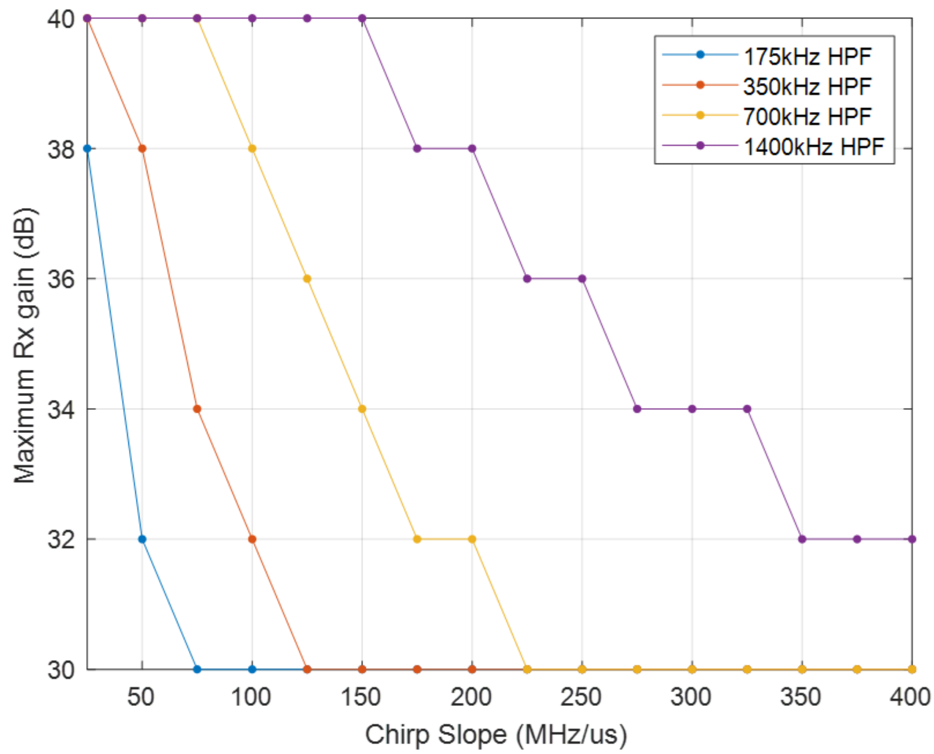

Figure 4-1. Maximum Allowed RX Gain Setting

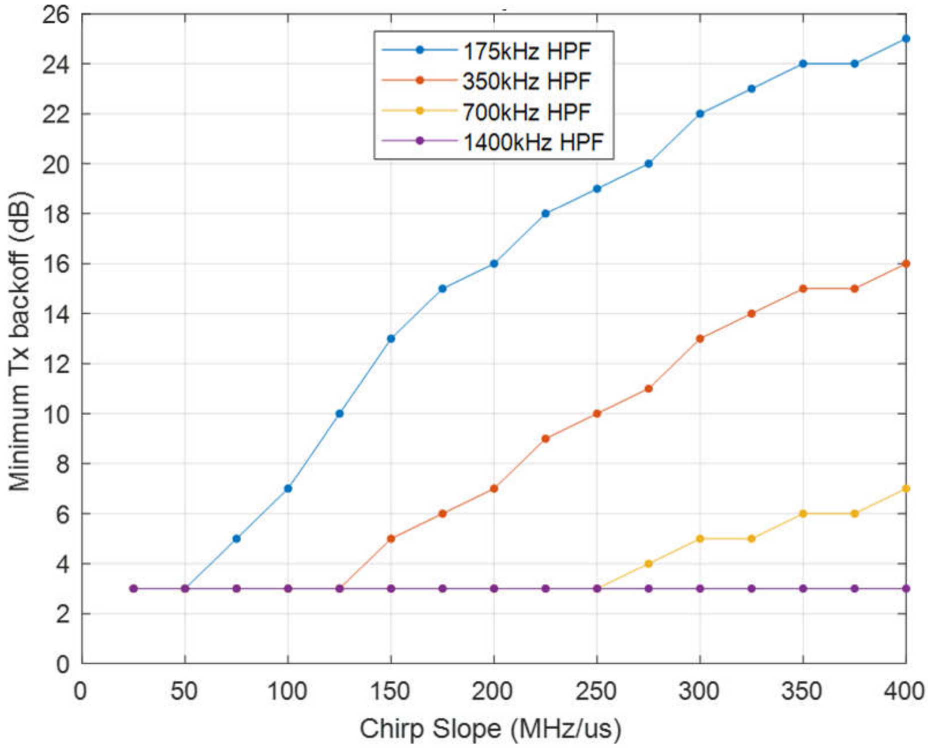

Figure 4-2. Minimum TX Backoff for 57 to 64GHz

Figure 4-3 shows that for chirps contained within 61 to 64GHz, the TX backoff restriction can be relaxed.

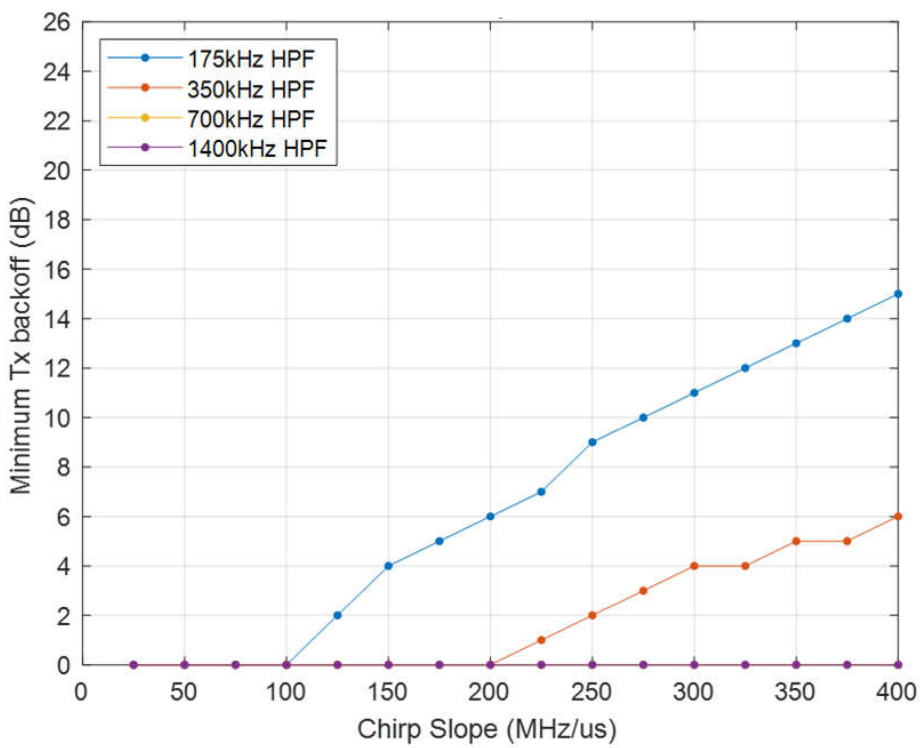

Figure 4-3. Minimum TX Backoff for 61 to 64GHz

Using the previously-shown constraints makes sure that the best possible SNR is achieved and also the receiver ADC is not saturated.

5 Chirp Configuration Recommendations Using Sensing Estimator

If there is doubt about whether the chirp configuration is following the proper recommendations mentioned in this application note, use the sensing estimator to check the chirp settings. The *Advanced Chirp Design and Tuning* tab can check a chirp configuration to see if the settings comply with the graphs the previous sections. See Figure 5-1 for an example of the warnings given in the sensing estimator.

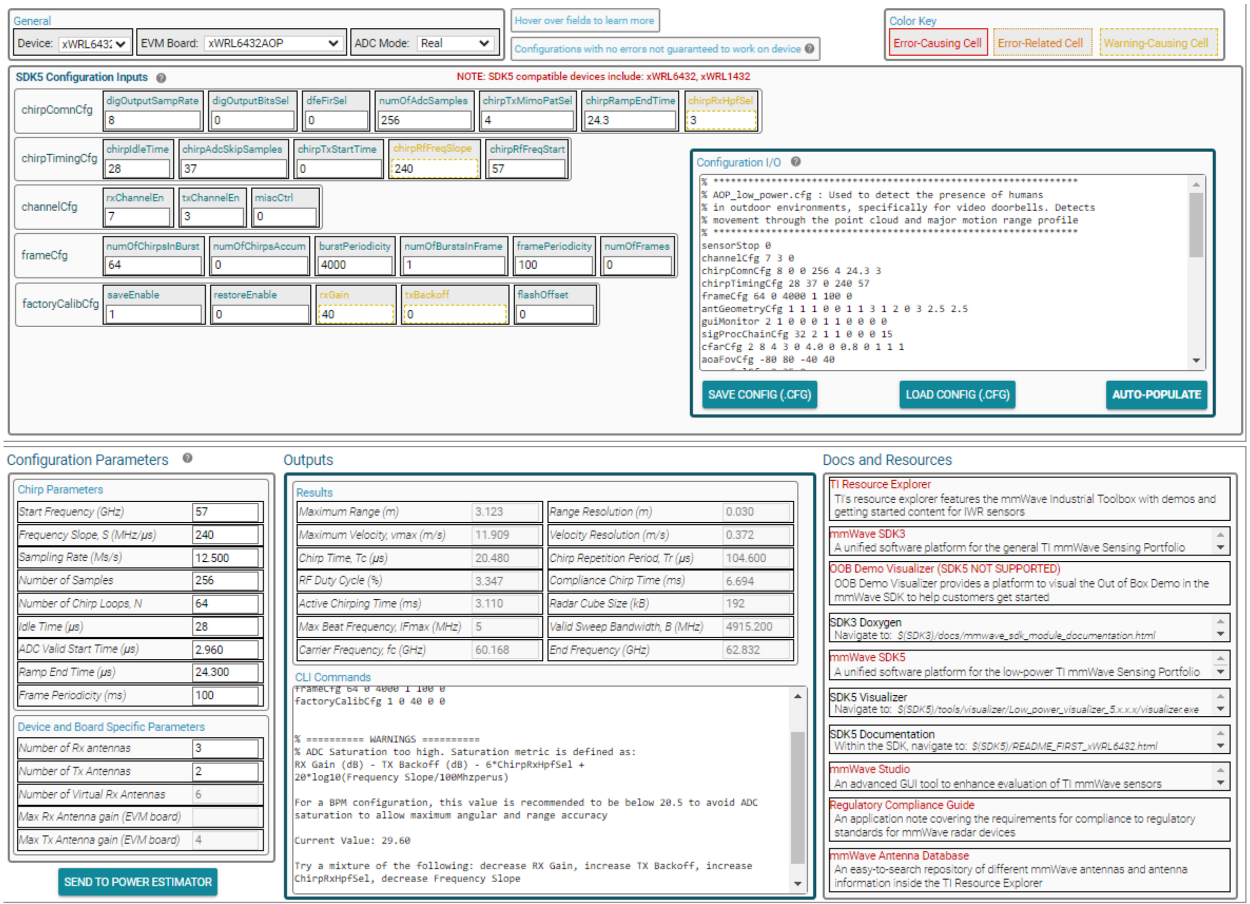

Figure 5-1. Sensing Estimator With Chirp That Causes ADC Saturation

To evaluate the chirp configuration manually, consider the following settings:

1. TX Backoff
2. RX Gain
3. HPF setting
4. Frequency Slope

First, look at the HPF setting and Frequency Slope to make sure the requirements for RX gain are met. In the example pictured in Figure 5-1, *HPF setting* = 1400kHz and *Frequency Slope, S (MHz/µs)* = 240. This means the maximum RX gain is 36 (see Figure 4-1). In this case, the decision is made to change the RX gain to 36 or below to ensure that we meet the maximum receiver gain constraint.

Next, look at the TX backoff for the frequency range. Here the frequency range is 57–63 GHz so use the data in Figure 4-2. This shows the minimum TX backoff as 3. In this case, the decision is to change the TX backoff to 3 or above to ensure we meet the minimum back off constraint.

With the changes of RX gain from 40 to 36 and the TX backoff from 0 to 3, there is little or no risk of ADC saturation and the errors in the sensing estimator are cleared.

6 Summary

The receiver ADC saturation can significantly impact radar functionality and leads to the loss of crucial information from the reflected signal of the target object. Additionally, a higher noise figure degrades the overall performance of the radar by reducing the SNR, which consequently affects both the range and angle resolution. The recommendations provided for selecting transmitter power backoff and receiver gain settings for the xWRL6432AOP radar device are intended to create the best possible performance. These guidelines address how improper settings can result in higher EINF due to noise in the TX-RX coupled signal and the risk of receiver ADC saturation from low-frequency signals at the RX output. Recommendations are provided to achieve the most favorable settings on xWRL6432AOP radar devices based on the end application, thus enhancing radar performance by managing the impact of these issues.

7 References

1. Texas Instruments, *Programming Chirp Parameters in TI Radar Devices Application Report*
2. Texas Instruments, *IWRL6432AOP Single-Chip 57 to 64GHz Industrial Radar Sensor Antenna-On-Package (AOP) Data Sheet*
3. Texas Instruments, *AWRL6432AOP Single-Chip 57- to 64GHz Automotive Radar Sensor Antenna-On-Package (AOP) Data Sheet*
4. Texas Instruments, *IWRL6432AOP Device Silicon Errata*
5. Texas Instruments, *AWRL6432AOP Device Silicon Errata*
6. Texas Instruments, *mmWave Sensing Estimator*