

Application Note

Building a 5G Compliant gNodeB with SCM and SDR

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Introduction

This application note details how the SignalCraft SC2430 Signal Conditioning Module (SCM) can complement a Software Defined Radio (SDR) to build a compliant 5G gNodeB by adding additional power, filtering, and gain control. Those implementing 5G radios using an SDR will notice that their systems are often short of the maximum transmit power that the 3GPP spec allows for, thereby impacting the coverage of their system. They also notice the spectral content generated by the SDR transmit path contains spurious products that exceed the spectrum emission limits. The SC2430 SCM addresses those typical SDR limitations with specific radio hardware designed to meet the strict radio transmission and reception requirements of the 3GPP 5G NR standard.

SDR Overview

SDR is a type of radio communication system in which the functionality typically implemented in hardware is instead implemented using software. While an RF front-end is still required, this approach offers several benefits, including flexibility, cost-effectiveness, and ease of upgrade. SDR allows for the implementation of multiple wireless communication standards using a single hardware platform, which can reduce costs and increase efficiency.

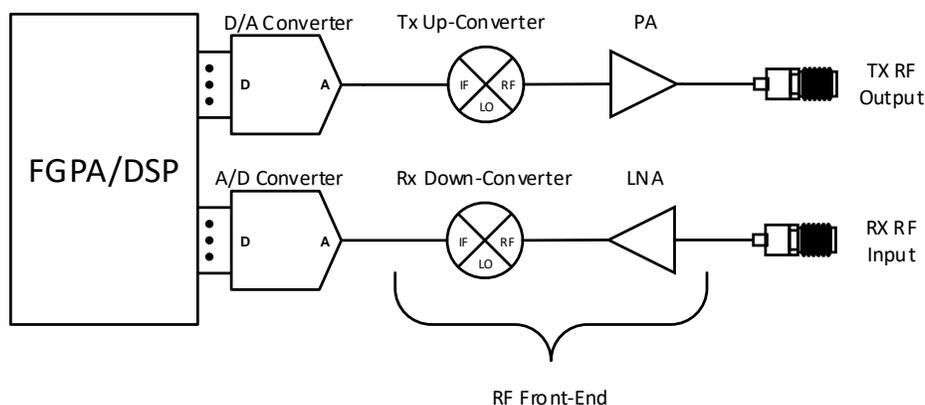


Figure 1 - Simplified Block Diagram of a Software Defined Radio (SDR) System

Additionally, because the software can be easily updated and modified, SDR systems can be adapted to new technologies and changing communication requirements.

However, the inherent flexibility of an SDR system may mean that it lacks certain radio hardware required to meet the physical layer specifications of a given communication standard. For example, in the case of 5G, an SDR system may need more transmit output power, more dynamic range, or band-specific spurious signal filtering to be compliant with the 3GPP specification.

SC2430 NR Signal Conditioning Module (SCM)

SignalCraft’s SC2430 NR Signal Conditioning Module (SCM) is a front-end solution designed to complement an SDR and provide the additional radio hardware to allow an SDR, in this example the NI Ettus-USRP X410, to be compliant with the 5G gNodeB radio requirements. The SC2430 SCM contains four independent pairs of transmit (Tx) and receive (Rx) channels in a Time Division Duplex (TDD) configuration intended to pair with the four channels of the NI Ettus-USRP X410. For FDD operation, two pairs can be combined to create a total of two FDD front-ends.



Figure 2 - SC2430 Signal Conditioning Module Front Panel

Note: Additional RF performance details are described in the document *SCT-PS0A21VC – SC2430 Product Specification*.

This block diagram depicts the functionality of a single transmit and receive channel of the SC2430.

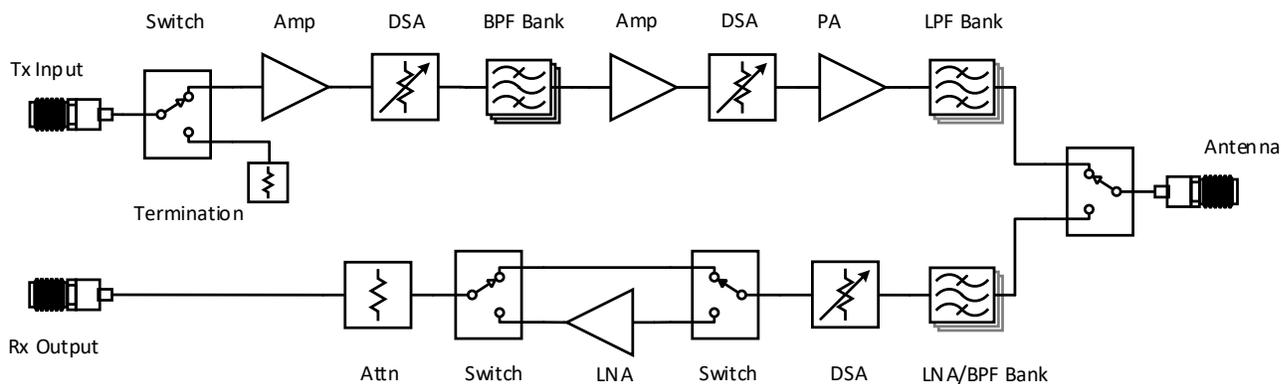


Figure 3 - SC2430 Channel Block Diagram

Using the SC2430 with the X410

Connecting the SC2430 to the X410 is simple:

- Connect the Tx outputs of the X410 to the Tx inputs of the SC2430 via SMA cables
- Connect the Rx outputs of the SC2430 to the Rx input of the X410 via SMA cables
- Connect the GPIO ports of the SX2430 to the GPIO ports of the X410 with the short HDMI cables

The SC2430 and the X410 can be controlled as a system using the Ettus USRP Hardware Driver (UHD) and the [SC2430-UHDExtension](#). Setting channel bandwidths, center frequencies configuring gain, and output power are seamless as the X410 configures the SC2430 SCM via the SPI control interface. With UHD extensions enabled, the X410 and SCM are controlled as a single instrument that also allows for the timing control necessary to meet the strict RF timing behavior necessary for TDD applications.



Figure 4 - SC2430 SCM and NI Ettus-USRP X410 Setup

How the SC2430 SCM Improves SDR Performance in 5G Applications

This section details three examples of specific performance enhancements that the SC2430 SCM will add to an SDR-based 5G radio implementation.

Tx Output Power

The RF front-end of an SDR platform typically lacks the power amplifier needed to transmit at power levels close to what the 3GPP specification allows. The following figure displays an example of the transmit output power improvements that the SC2430 SCM offers when paired with the X410.

Adding an SC2430 SCM to the RF front-end of the X410 increases the Tx output power by 8 dB, achieving an output power greater than +20 dBm, while maintaining the -29 dB EVM performance required by the 3GPP specification for 256 QAM modulation. The increased transmit output power offered by the addition of the SC2430 SCM will greatly enhance the performance of an SDR based 5G radio system.

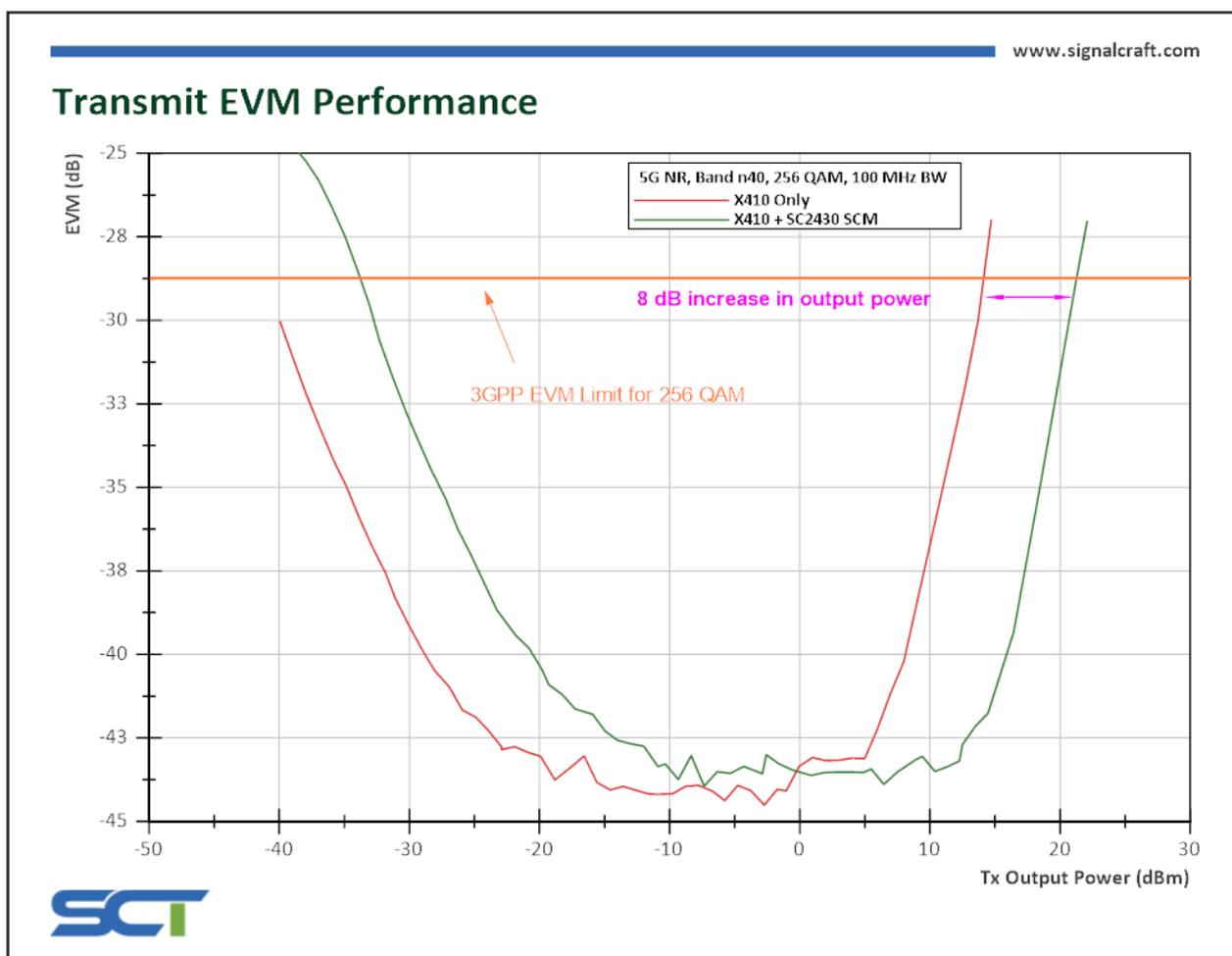


Figure 5 - Transmit EVM Performance of an SC2430 and X410 System

Tx Spurious Emissions

To maintain flexibility, an SDR often lacks filtering that would otherwise limit the frequency bands it is able to operate in. A side effect is that unwanted signals generated by the onboard D/A converters, mixers, or PLLs can make their way through the RF front-end and corrupt the transmit spectrum. These spurious signals can interfere with other users or adjacent, collocated systems

An example of this is displayed in the following output spectrum plot of the X410 when configured to transmit a 100 MHz 5G signal. Along with the desired waveform, unwanted spurious signals can be seen in the output spectrum and their level is high enough that they exceed the spurious emission limit of the 3GPP NR specification.

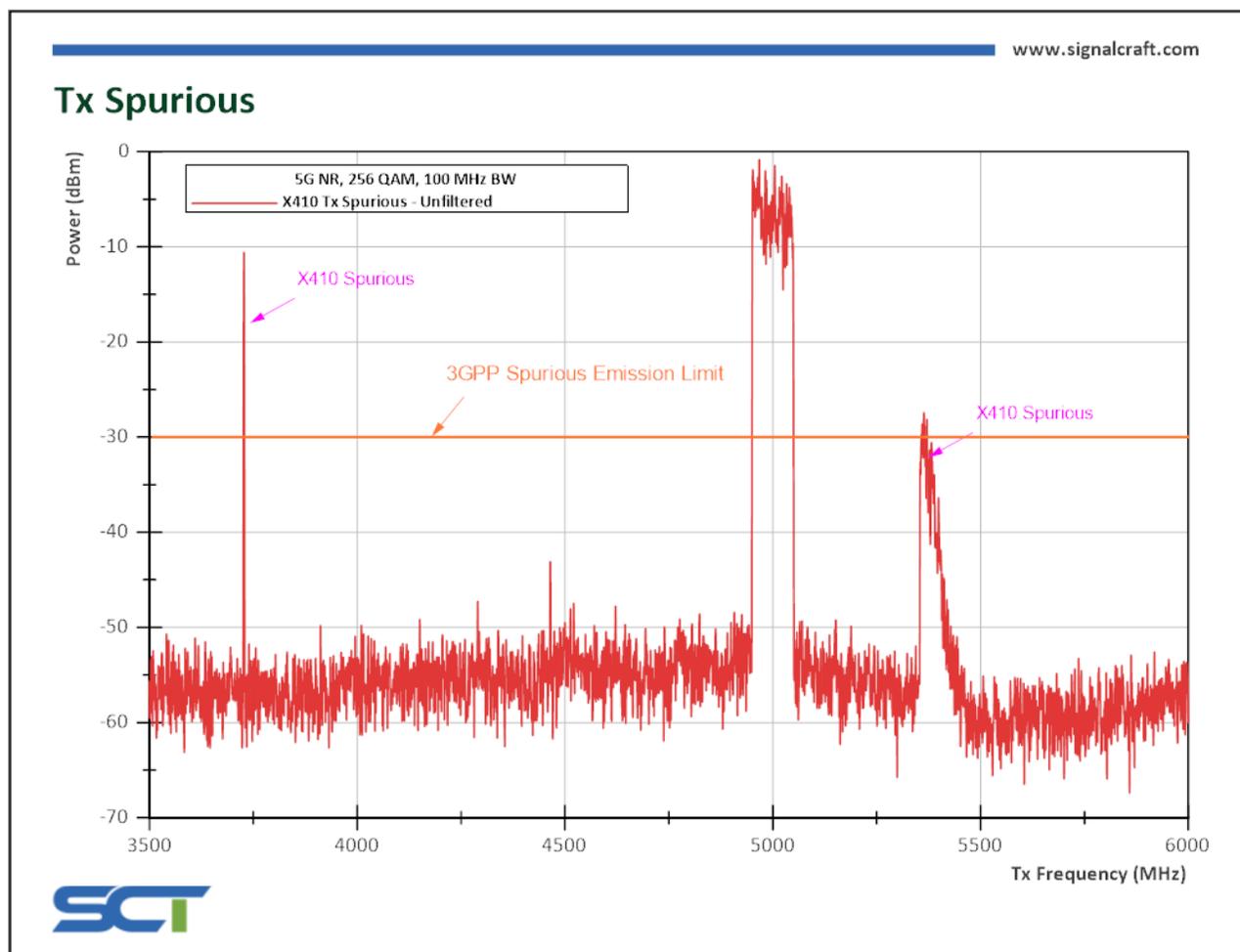


Figure 6 - X410 Unfiltered Tx Spurious

The following figure shows how enabling the filtering built into the SC2430 SCM allows for a much cleaner output spectrum that meets the spurious emission requirements of the 3GPP NR specification.

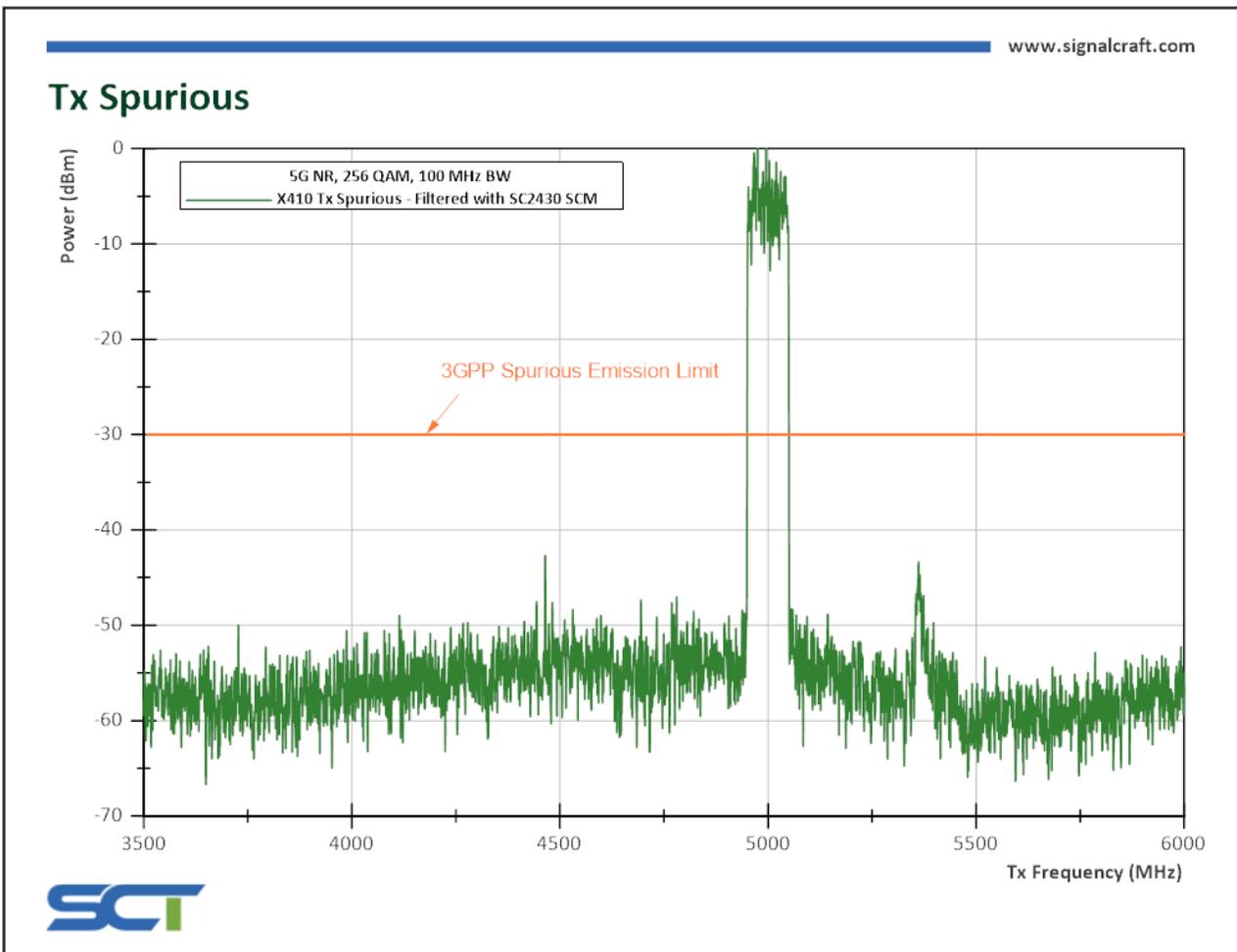
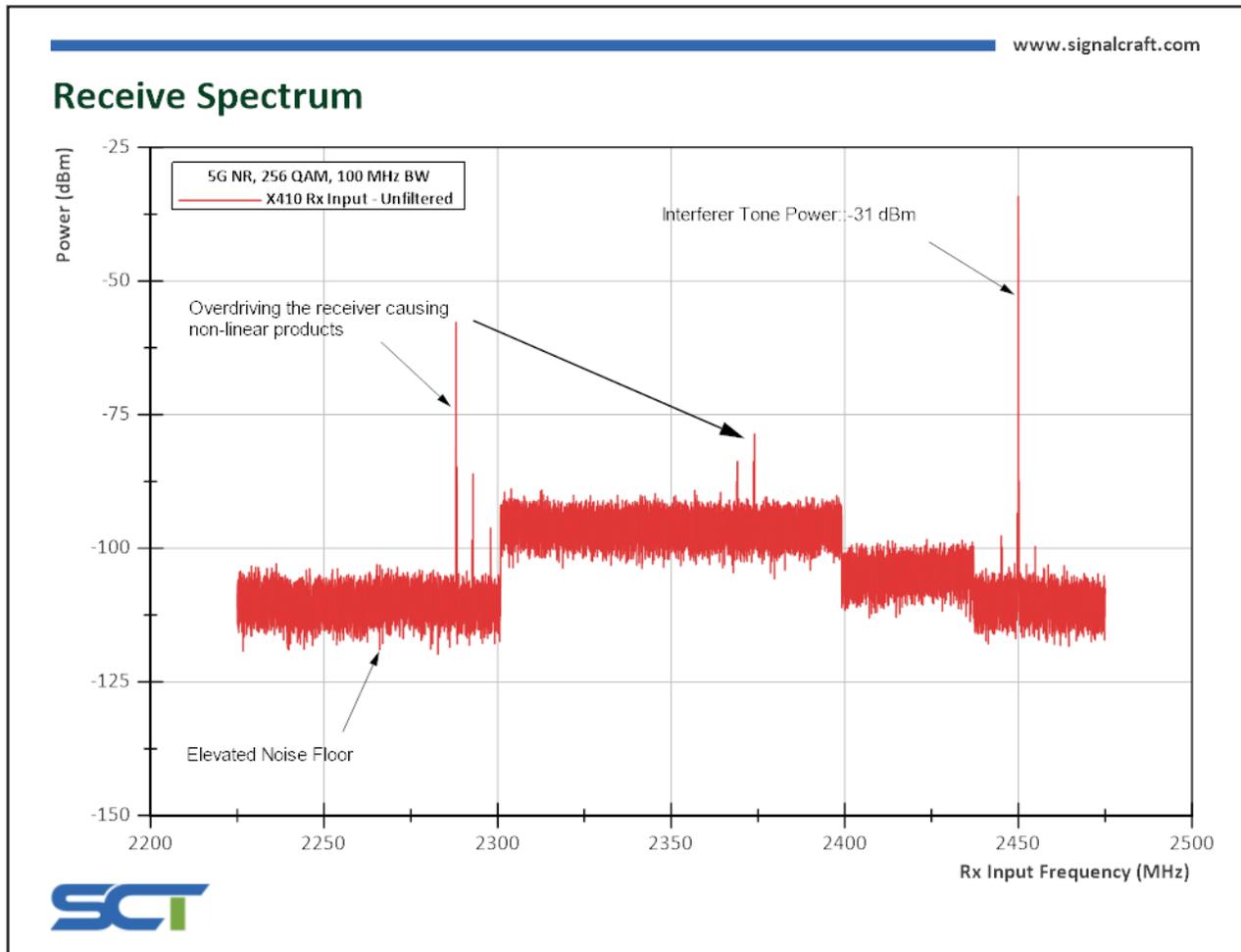


Figure 7 - X410 Tx Spurious filtered by the SC2430 SCM

Rx Blocking

Another disadvantage of having a wide-open RF front-end is that interferers can make their way into the receiver causing desense or Rx blocking. The presence of the interferer prevents the receiver from receiving a weaker intended signal than it would otherwise be able to receive if there was no interference.

For example, the following plot shows what happens to the X410 receiver, tuned to 5G band n40, when a strong interfering tone, from the adjacent 2.4 GHz ISM band, is present at the Rx input. The strong tone causes non-linearities in the receiver, thereby distorting the signal sampled by the A/D converter and drastically reducing the quality of the received signal.



When the SC2430 SCM is added as the front-end to the X410, filtering can be enabled to reject the interfering tone and prevent it from desensitizing the receiver. The intended signal can be received with no degradation.

The effect the interferer has on receiver performance can be seen in the EVM performance versus the level of the interferer. Once the level of the interferer exceeds the linear operating conditions of the receiver, either by overdriving the A/D converter or compressing the amplifiers in the receiver front-end, the EVM performance begins to suffer, as shown in the following plot.

However, optimal receiver performance, in the presence of an interferer, can be maintained by filtering out the interferer. The SC2430 SCM contains a filter bank in the receiver that covers most of the sub-6 GHz 5G bands. For a complete list of what bands are included, please see the document *SCT-PS0A21VC – SC2430 Product Specification*.

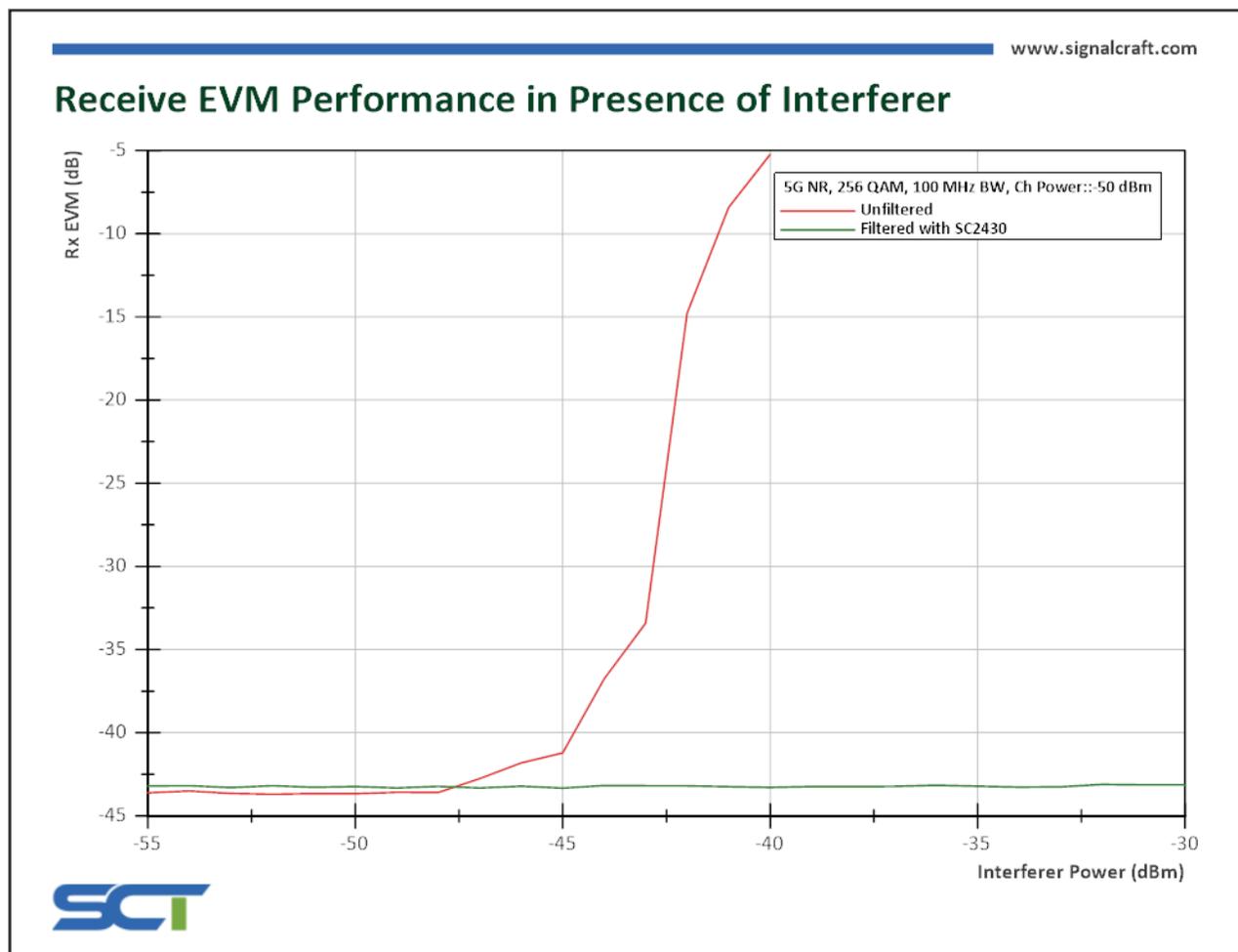


Figure 8 - X410 Receive EVM Performance in Presence of Interferer

Summary

While the flexibility and cost effectiveness of SDR platforms makes them an ideal choice for designing and experimenting with a variety of communication standards and protocols, they may lack the specific hardware required to meet many of the radio performance specifications of modern communication systems. In the case of a 5G NR radio system, pairing an SDR platform with an RF front-end, like the SC2430 SCM, allows the complete system to meet or exceed the requirements of the 3GPP specification. The added amplification and high-performance filtering offered by the SC2430 SCM allows for increased output power while keeping the spectrum free of spurious products and enabling optimum performance in real world signal conditions.

Additional Resources

SignalCraft Support

For additional documentation and resources, refer to the [SignalCraft Support Portal](#).

UHD Extension Library Source Code

See the [SC2430-UHDExtension](#) GitHub repository for the UHD Extension Library source code and supporting documentation.