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TUTORIAL 5499

Spectrum Inversion in NCDMA to Ensure Compliance with 3GPP2

Nov 27, 2013

Abstract: Unlike many other cellular standards, NCDMA is required by the 3GPP2 standard to perform spectrum inversion in the physical layer before transmission and after reception. With today's vast selection of radio frequency (RF) transceivers and baseband processors, it is easy to imagine how one could come across a set of RF transceiver and baseband processor that have mismatched spectrum in the transmit and receive paths. This simple oversight will result in noncompliance to the 3GPP2 standard and failure to demodulate. However, there are a few simple techniques that can help determine if spectrum inversion has been performed on a signal.

A similar version of this article appears on [microwaves&rf](#), October 11, 2013.

Introduction

This tutorial will help design engineers manage spectrum inversion to comply with the 3GPP2 standard. It is important for system integrators to remember that the 3GPP2 standard requires NCDMA, unlike many other cellular standards, to perform spectrum inversion in the physical layer (generally within the radio frequency (RF) IC) prior to transmission and after reception. With today's vast selection of RF transceivers and baseband processors, it is easy to imagine how one could find a set of a RF transceiver and baseband processor that has mismatched spectrum in the transmit and receive paths. This simple oversight will result in noncompliance with the 3GPP2 standard and failure to demodulate. However, there are a few simple techniques that can help determine if spectrum inversion has been performed on a signal. This tutorial presents three techniques that perform spectrum inversion on RF transceivers that do not have built-in spectrum inversion.



[Click here for an overview of the wireless components used in a typical radio transceiver.](#)

How to Detect Spectrum Inversion

In a transmitter, the easiest way to determine if the spectrum has been inverted is by comparing a single-tone continuous wave (CW) with a nominally positive frequency to the local oscillator (LO) frequency. If the RF CW output frequency is greater than the LO frequency (positive offset), then no

spectrum inversion has happened. But if the LO frequency is greater than the RF output frequency, then the spectrum *has* been inverted.

In the receive path, if a positive offset RF input frequency produces an I output that leads the Q output by 90°, then no spectrum inversion was done by the RF demodulator. Generally, the modulation format of the RF demodulator follows the modulator. To demonstrate these points, let's examine the uplink and downlink paths of a WCDMA system, as specified in the 3GPP standard TS 25.213 (**Figure 1**).

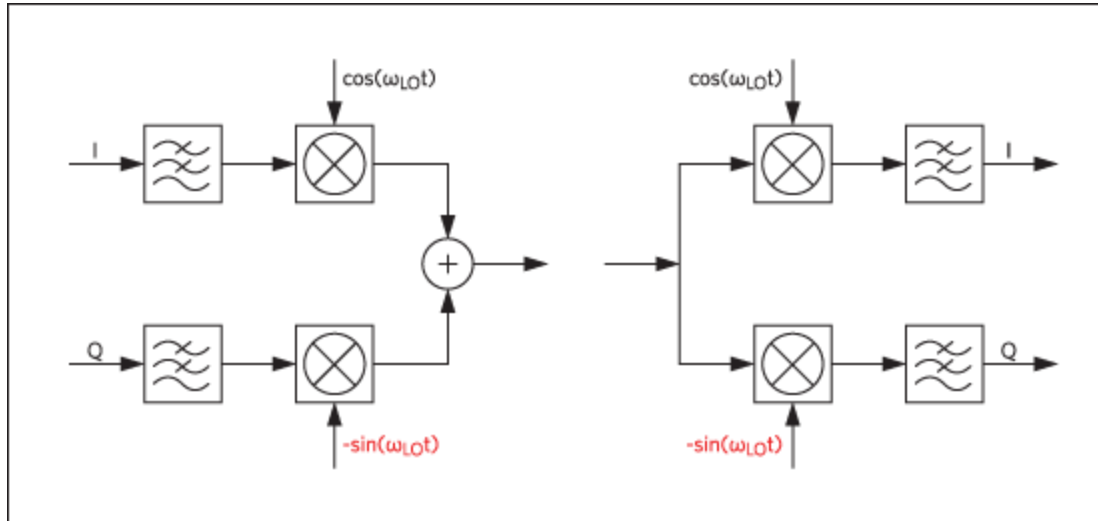


Figure 1. WCDMA I/Q modulation and demodulation format. Note that the Q channel is multiplied by a negative phase LO, i.e., $-\sin(\omega_{LO}t)$, as shown in red.

Transmitter Signals

For simplicity, assume that the transmitter baseband I and Q signals are represented by:

$$V_m = e^{j\omega_m t} = \cos(\omega_m t) + j\sin(\omega_m t)$$

(Note that this is a positive frequency, complex tone at baseband.)

The transmitter I and Q LOs are represented by:

$$LO_{ITX} = \cos(\omega_{LO}t) \text{ and } LO_{QTX} = -\sin(\omega_{LO}t)$$

Now notice the negative polarity of the Q LO:

$$V_{TX} = \cos(\omega_m t)\cos(\omega_{LO}t) - \sin(\omega_m t)\sin(\omega_{LO}t)$$

$$V_{TX} = \frac{1}{2}\cos((\omega_m - \omega_{LO})t) + \frac{1}{2}\cos((\omega_m + \omega_{LO})t) - \frac{1}{2}\cos((\omega_m - \omega_{LO})t) + \frac{1}{2}\cos((\omega_m + \omega_{LO})t)$$

$$V_{TX} = \cos((\omega_m + \omega_{LO})t)$$

As shown in the equations above, a positive modulation baseband signal, in combination with a negative phase LO frequency, produces an RF output frequency which resides above the LO frequency. The

result is no spectrum inversion.

Received Signals

On the receiving end, assume that the same transmitted RF signal is received and demodulated with the same LO format as the transmitter:

$$V_{RX} = \cos(\omega_{RX}t), \text{ with } \omega_{RX} = \omega_m + \omega_{LO}$$

$$V_{LO} = e^{-j\omega_{LO}t} = \cos(\omega_{LO}t) - j\sin(\omega_{LO}t)$$

$$V_{BB} = \cos(\omega_{RX}t)\cos(\omega_{LO}t) - j\cos(\omega_{RX}t)\sin(\omega_{LO}t)$$

After multiplying out the terms and applying lowpass filtering to remove the higher frequencies:

$$V_{BBI} = \frac{1}{2}\cos((\omega_{RX} - \omega_{LO})t) \text{ and } V_{BBQ} = \frac{1}{2}\sin((\omega_{RX} - \omega_{LO})t)$$

Substituting ω_{RX} with $\omega_m + \omega_{LO}$, the I and Q baseband outputs are the same as the I and Q of the TX baseband inputs:

$$I_m = \cos(\omega_m t) \text{ and } Q_m = \sin(\omega_m t)$$

Perform Spectrum Inversion

Now that we have a clear understanding of how to detect spectrum inversion, we turn our attention to the available methods of achieving it on purpose. As mentioned earlier, the 3GPP2 standard requires that the signal spectrum of NCDMA be inverted prior to transmission and after reception. Following are three simple methods that can be used for spectrum inversion.

Method 1

Spectrum inversion by adopting a positive phase LO. This is the modulation format recommended by the 3GPP2 standard (**Figure 2**).

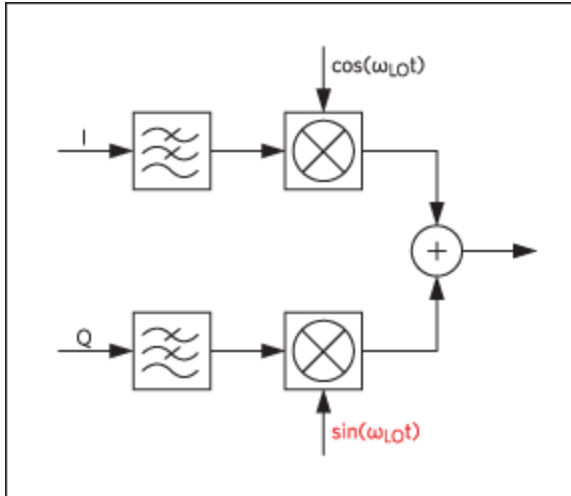


Figure 2. NCDMA I/Q modulation format. Note how the Q channel is multiplied by LO with positive phase, i.e., $\sin(\omega_{LO}t)$, as highlighted in red.

$$I_m = \cos(\omega_m t) \text{ and } Q_m = \sin(\omega_m t)$$

$$LO_{ITX} = \cos(\omega_{LO}t) \text{ and } LO_{QTX} = \sin(\omega_{LO}t)$$

$$V_{TX} = \cos(\omega_m t)\cos(\omega_{LO}t) + \sin(\omega_m t)\sin(\omega_{LO}t)$$

$$V_{TX} = \frac{1}{2}\cos((\omega_m - \omega_{LO})t) + \frac{1}{2}\cos((\omega_m + \omega_{LO})t) + \frac{1}{2}\cos((\omega_m - \omega_{LO})t) - \frac{1}{2}\cos((\omega_m + \omega_{LO})t)$$

$$V_{TX} = \cos((\omega_m - \omega_{LO})t)$$

As shown here, the RF output frequency is lower than the LO frequency. Therefore, the spectrum has been inverted.

Method 2

Spectrum inversion by inverting the polarity of the Q baseband signal.

$$I_m = \cos(\omega_m t) \text{ and } Q_m = -\sin(\omega_m t)$$

$$LO_{ITX} = \cos(\omega_{LO}t) \text{ and } LO_{QTX} = -\sin(\omega_{LO}t)$$

$$V_{TX} = \cos(\omega_m t)\cos(\omega_{LO}t) + \sin(\omega_m t)\sin(\omega_{LO}t)$$

$$V_{TX} = \cos((\omega_m - \omega_{LO})t)$$

Method 3

Spectrum inversion by swapping the I and Q transmit baseband signals.

$$I_m = \sin(\omega_m t) \text{ and } Q_m = \cos(\omega_m t)$$

$$LO_{ITX} = \cos(\omega_{LO}t) \text{ and } LO_{QTX} = -\sin(\omega_{LO}t)$$

$$V_{TX} = \sin(\omega_m t)\cos(\omega_{LO}t) - \cos(\omega_m t)\sin(\omega_{LO}t)$$

$$V_{TX} = \frac{1}{2}\sin((\omega_m + \omega_{LO})t) + \frac{1}{2}\sin((\omega_m - \omega_{LO})t) - \frac{1}{2}\sin((\omega_m + \omega_{LO})t) + \frac{1}{2}\sin((\omega_m - \omega_{LO})t)$$

$$V_{TX} = \sin((\omega_m - \omega_{LO})t)$$

Conclusion

Method 1 is the method for performing spectrum inversion recommended by the 3GPP2 standard. However, as shown above, other methods can achieve the same result and still be spec compliant. In all cases for parts derived from the [MAX2553](#) WCDMA transceivers, the baseband input and output pins are labeled so that no spectrum inversion occurs in the transceiver, neither in the transmitter path nor in the receiver path. For compliance with the 3GPP2 standard, one should be aware of this and apply one of the above methods for inverting the transmit spectrum. For the receive path, a corresponding inversion is also required in most cases, unless the baseband is already programmed to accept inverted spectrum signals.

Related Parts		
MAX2547	WCDMA/HSPA Band I RF-to-Bits Femto-Basestation Radio Receiver	
MAX2548	Quad-Band TDD-WCDMA RF-to-Bits Radio Receiver	
MAX2550	Band I, V, and VIII WCDMA Femtocell Transceiver with GSM Monitoring	Free Samples
MAX2551	Band II and V WCDMA Femtocell Transceiver with GSM Monitoring	Free Samples
MAX2553	Band Class 0, 1, and 10 cdma2000 Femtocell Transceiver	Free Samples
MAX2557	Multiband, Multimode RF-to-Bits Femto-Basestation Radio Receiver	
MAX2597	Femto-Basestation Bits-to-RF Radio Transmitter	
MAX2598	Quad-Band TDD-WCDMA Bits-to-RF Radio Transmitter	
MAX2599	Femto Basestation Bits-to-RF Radio Transmitter	

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