Phase Noise Measurements for Wireless Broadband

By Eric Hakanson

Wireless broadband has been in the news lately with January's 700 MHz spectrum auction, the announcement of Sprint's WiMAX network and the first promising trials of next generation wireless (3GPP Long Term Evolution or LTE) by a consortium of handset makers and network equipment manufacturers, including Nokia, Nortel, T-Mobile, Vodafone, France Telecom/Orange, and Alcatel-Lucent.

As the wireless communication industry moves toward higher RF frequencies and higher rates through more complex modulation and wider modulation bandwidths, the success of these emerging broadband wireless systems is based on the availability supporting measurement technology. EVM (Error Vector Magnitude) is a critical specification and is often used to describe the modulation quality of the transmitted signal. EVM is a measure of the difference between the ideal or "reference" waveform and the measured waveform. Poor EVM reduces the ability of a receiver to properly recover the transmitted signal, which increases the bit error rate at the edge of a cell, and thus reduces coverage area. One of the contributors to poor EVM is the phase noise of all of the oscillators in the transmitter and receiver.

As we can see in figure 1, phase noise on a QPSK signal looks like a rotation of the constellation. This reduces the distance between the constellation points, and thus the receiver needs a higher Signal-to-Noise Ratio (SNR) for a given Bit Error Rate (BER). Thus, the phase noise reduces the sensitivity of the receiver.

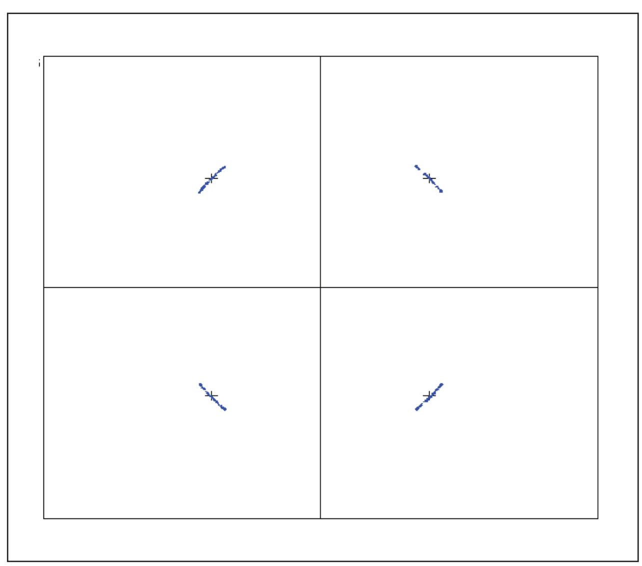

Figure 1: Phase jitter on a QPSK signal

For OFDM signals such as are used in LTE and WiMAX, phase noise from the local oscillator is superimposed on each of the N subcarriers. This phase noise has two effects:

- Random phase rotation for all subcarriers, often called Common Phase Error (CPE)

- Inter-carrier interference (ICI), which is caused by the corruption of a given subcarrier by its N-1 noisy adjacent subcarriers

OFDM symbols contain certain subcarriers, called pilots, which help the receiver track out the CPE, as well as estimate the frequency response of the transmission channel. The pilots do not help with the ICI, however, so that will still affect the EVM. This makes the effect of phase noise somewhat different from the traditional QPSK signal–the phase noise tends to look more like broadband noise than discrete jitter. Phase noise still can be a significant cause of signal degradation, however.

For a 64 QAM modulated OFDM, EVM requirements at the transmitter output are very stringent: typically 2.7% rms. This is why the LO phase noise and jitter are critical for the design of this LO PLL. To achieve the 2.7% rms EVM, a total phase jitter lower than 1 °rms has been suggested as a criteria for choosing a synthesizer.

Since phase noise can have such a significant effect on the EVM, it’s critical to verify the phase noise performance of the LO during the development process. In manufacturing, test times for low-cost devices such as user equipment or femtocells don’t allow for this kind of in-depth measurement, however this phase noise measurement capability is helpful for process monitoring and for troubleshooting manufacturing problems. You can easily see phase noise on a spectrum analyzer by looking at the signal “skirts”. If there is a fairly shallow slope with frequency, you are seeing phase noise (see figure 2). The spectrum analyzer plot doesn’t tell you how much jitter there is, however.

Measurement of phase noise with a spectrum analyzer is appropriate for moderate quality synthesizers, such as are found in commercial wireless user equipment or femtocells, and possibly even in base stations. An Anritsu MS271XB was measured to have about 0.1 degrees of jitter over the range of 10 kHz to 5 MHz on a 2.3 GHz signal, so it is clearly more than adequate for measuring the LO in our example. A spectrum analyzer is not appropriate, however, for measuring very high quality synthesizers, such as laboratory grade synthesized Signal Generators or atomic clocks. In this case, the measurement would be of the residual phase noise floor of the spectrum analyzer, rather than of the device under test. A spectrum analyzer is also of limited use when measuring drifting sources such as VCOs, because the VCO frequency drift can affect the measurement. At large offsets, such as >1 MHz, this is usually not a problem, but at small offsets such as 1 kHz, the VCO output will often drift out of the measurement span, invalidating the results.

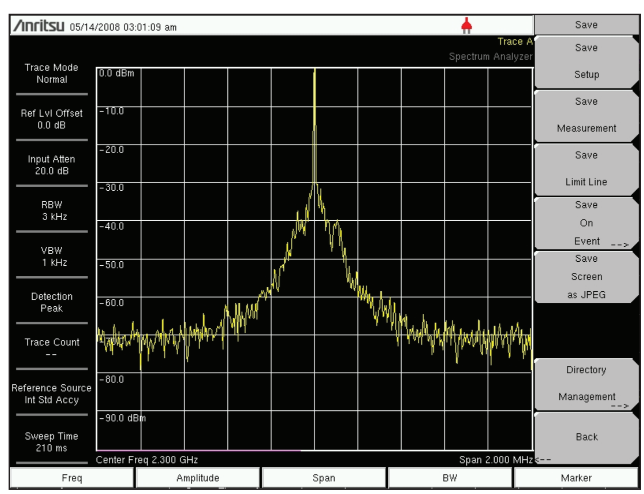

Figure 2: CW signal with phase noise

Since phase noise is measured in dBc/Hz, but the LO requirement is in degrees rms, some conversion is required. This conversion involves integrating the phase noise over many decades of offset, and conversion to the correct units—degrees, radians, or seconds. While you could do this complex process manually, it is far simpler to let the instrument do this for you. But this creates a question—over what range of offsets should the integration be done? A good rule of thumb for OFDM is pick offsets from the symbol rate out to the bandwidth of the system. The limit at the symbol rate is because the CPE is removed by the receiver, and CPE is primarily at offsets less than the symbol rate. Offsets larger than the system bandwidth are filtered by the receive filter, and again will have little influence. For WiMAX, the exact offsets will depend on the specific profile being used, but one example might use offsets from 10 kHz to 5 MHz. For LTE, the principle is the same, but the offsets would be slightly different, and again depend on the mode that the radio will use. An example for LTE might be 15 kHz to 20 MHz.

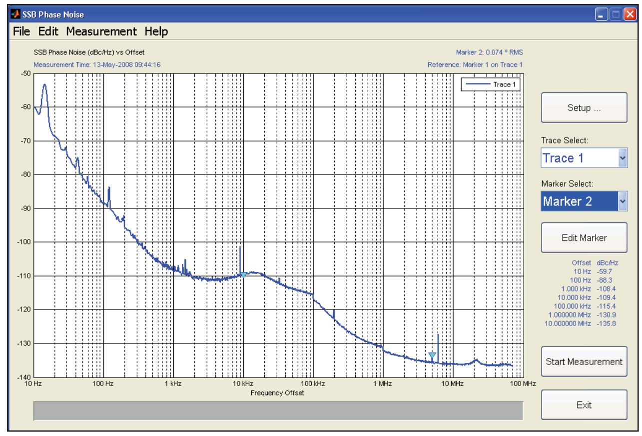

Figure 3: Example phase noise plot with jitter measurement from 10 kHz to 5 MHz offset; markers delimit the frequency offset range for the jitter measurement.

The phase noise graph provides more than just a way to get the jitter over a specific frequency offset range; it's also a tool for better understanding the PLL operation. If we examine the phase noise plot in figure 3, we see several distinct regions. For the range of offsets from 10 Hz to about 1 kHz and from about 100 kHz to 1 MHz, there is a roughly constant slope of 20 dB per decade. These are the regions where the resonant elements in the frequency reference and the VCO are dominant. From about 1 kHz to 10 kHz, we see a flat region, transitioning to the 20 dB/decade slope on either end. This is the broadband noise floor of the reference, when multiplied up to the RF frequency. The PLL loop bandwidth is also in this region, probably near the high end of the range. Depending on the loop filter, there may be a large peak in this region, which indicates an underdamped condition, and can cause instability problems. Above about 1 MHz or so offset, we see the broadband noise of the VCO.

Conclusion

Jitter is a key performance metric for local oscillators for wireless broadband transmitters and receivers. An excellent way to verify the jitter performance of these local oscillators is the Anritsu MS271XB with 2300-517 Phase Noise Measurement Software. This combination is low cost, has plenty of performance, and easily shows the jitter over the appropriate range of frequency offsets.

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