Some observations on phase noise from local oscillator strings.

K0CQ
Dr. Gerald N. Johnson, P.E. (retiring)

Recently its been proposed to add flexibility to some transverters by using a synthesizer chip out of a cell phone to replace 192 MHz range crystals and several stages of multipliers (N5AC at CSVHFS Conference in Wichita). He reports phase noise at 1.2 GHz of -87 dBc/Hz at a 10 kHz spacing. How does this compare to other oscillators?

Some 21 years ago (DUBUS 3/87 page 190) the IC 211 was considered a world standard for poor phase noise. Their measurement at 10 kHz showed -98 dBc/Hz. Adding 18 dB (20 log10 (N)) to multiply that to 1.2 GHz gives -80 dBc/Hz.

The Sirenza VCO190-1198TY a quality but narrow band VCO, running free shows -111 dBc/Hz at 1.2 GHz and 10 kHz spacing. One of the best available VCOs these days. http://www.sirenza.com look for performance plots, a .pdf file.

The HP8640B, an analog cavity oscillator, showed -133.7 dBc/Hz at 106 MHz for KE5FX (brick.htm on his web page). Multiplied to 1.2 GHz that's about -112.6 dBc/Hz at 10 kHz spacing.

The HP8662 does less than 1 dB better.

In an presentation at the 2000 WSWSS Conference at Kings Canyon National Park, California, by KD6OZH called “Low Noise Crystal Oscillators,” he showed a 92 MHz crystal oscillator multiplied up to 552 MHz had a phase noise of -146 dBc/Hz at 10 kHz spacing. Multiplied on up to 1104 MHz that's a phase noise of -140 dBc/Hz.

In the latest VHF Communications there is an article promised on the effects of phase noise on communications systems.

Compared to a good crystal, N5AC's synthesizer is a noisy beast, a quantum leap backwards in oscillator phase noise even if the stability is great.

What are the consequences of phase noise?

One effect is that in the absolute absence of signals in the RF bandpass, the phase noise of the LO mixes wide band noise (from the full phase noise sidebands) into the IF passband. This effectively raises the system noise figure. Its more significant an effect the worse the phase noise and the better the system NF. This is the hardest effect to put numbers to. Many authors including the receiver guru Ulrich Rohde tell about it without giving ways to compute the strength of the effect. Computation requires knowing the noise bandwidth and gain of the stages before and after the mixer and the leakage and termination reflections of the mixer along with the total LO phase noise spectrum from IF through all mixer input frequencies.

A second effect called “reciprocal mixing” can be more severe simply mixing phase noise to adjacent or in band signals. With MDS on the order of -142 dBm, a nearby signal at -50 dBm with -80 dBc/Hz LO phase noise at that offset results in raising the receiver background noise to -130 dBm, a loss of 12 dB of MDS. That can be disastrous on many paths. Since our 0.9, 2.3, 3.3, and 5.6 GHz bands are shared with data services these days there are always practically in band signals, more and stronger on hill tops.

The third effect is while transmitting the transmitter sidebands are generated by the phase noise and while -80 dB sidebands are acceptable to FCC rules, such a signal prevents other users of low LO noise transverters on a hill top from hearing anything but the noise from the transmitter. Which effectively prevents there being more than one QSO at a time from that hill top, no matter how many stations are present. So strong phase noise on transmit can be unfriendly and may lead to interference to other services.

Fourth, when receiving FM signals, the LO phase noise modulates the received signal so that phase noise is detected as signal and can put a minimum noise level limiting the quieting and the final S/N of the audio signal.

Fifth, if the mixer LO balance isn't perfect (and some transverters use simple diode or FET mixers with no LO balance) the LO phase noise side bands at the IF reach the IF directly and those at the RF and image frequencies get converted to the IF.

The book, "Phase Noise Analysis in Radar Systems Using Personal Computers" by Stanley J. Goldman discusses several ways for LO phase noise to affect receiver performance. First there is mixing from mixer port mismatches. Then there is "phase noise leakage to IF because of down-conversion." Computing these effects requires integrating the LO noise spectrum. They can be minimized by selecting a high IF frequency far so the LO noise level at the IF offset from the LO frequency is minimized. Which means a low IF or Zero IF receiver is hurt the most by LO noise from these leakage effects. This book also shows complex formulae and BASIC programs to compute those formulae.

With the phase noise of the N5AC/DEMI oscillator 53 dB above that of the the KD6OZH low noise crystal controlled LO, there will be all these effects at varying levels depending on the mixer, the gain stages, the IF frequency, and the local signals. There are cavity and voltage controlled oscillators that have better phase noise than the N5AC synthesizer while free running, no phase or frequency lock. Point is that the N5AC/DEMI synthesizer phase noise is significantly greater than that of a 30 year old free running signal generator like the HP8640B (that we can afford) so the synthesizer is reverse progress.

Excess LO phase noise is part of the reason that our VHF/UHF transceivers hear less well and handle strong signals less well than transverters connected to contest grade HF rigs. The simple crystal oscillator of the transverter has nearly as low phase noise as possible and the great HF rigs also have very low phase noise.

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