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High Performance Active Mixer Overcomes RF Transmitter Design Challenges

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Active mixers can solve transmitter upconversion design problems like noise and distortion tradeoffs, circuit design complexity, p.c. board layout and LO leakage—all of which save time and lower costs

Next generation cellular base station transmitter design imposes significant challenges for RF designers. These wireless systems have stringent requirements for transmission of a clean signal with a low noise floor and low intermodulation and harmonic distortion. It is particularly challenging, as higher order modulation is required while transmitting multiple carrier signals. Demand for mixer linearity performance is high. In the past, passive diode-ring type mixers have been the devices of choice to meet these requirements. Today, a new generation of active mixers offers significant advantages that save cost, power, and space, while solving some of the difficult technical problems associated with high performance transmitter designs.

Enhancing Transmitter Spurious Free Dynamic Range Performance

A primary goal for RF designers is to maximize the signal-to-noise (SNR) performance of a transmitter. This requires transmitting as much RF signal power as permitted, while pushing the noise floor as low as possible. At maximum output, the level is capped by the amount of distortion introduced by undesirable output spectral components. Spurious-free dynamic range (SFDR) is the range of signal amplitude with no discernible distortion products, i.e., they are low enough to be below the noise floor. Thus there is a fine balance between achieving high SNR and SFDR while attaining maximum output power.

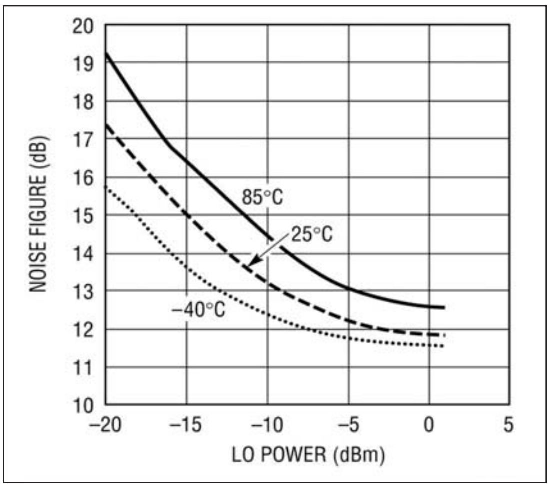

Figure 1 · Choose a lowest Noise Figure point at a reasonable LO power level.

A new generation of high performance active mixers like Linear Technology's LT5521 offers an excellent combination of high linearity, low noise, easy LO drive, and with little or no conversion loss, resulting in a cost effective, high performance solution.

Choosing the right operating point of the mixer is essential for ensuring the optimum SFDR performance, while attaining maximum output power. Referring to Figure 1, the LT5521's minimum noise figure, 11.9 dB, occurs when the LO (local oscillator) power is at 0 dBm. At this LO power level, the LT5521's IIP3 (24.1 dBm) and conversion gain (–0.5 dB) are also near their respective maxima (refer to Figure 2). Thus all three parameters are working together to enhance the dynamic range.

With the IIP3 and noise figure known, the SFDR of the mixer circuit can be computed using the following equations:

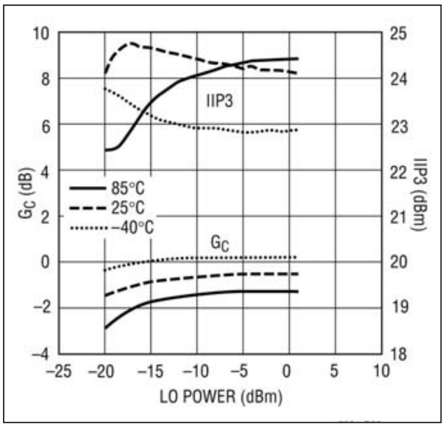

Figure 2 · Choose the maximum linearity (IIP3) and conversion gain at the optimum LO power level.

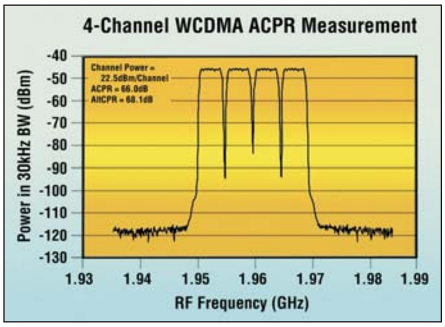

Figure 3 · Measured output spectrum of a 4-channel WCDMA modulated signal waveform, achieving very high margin for Adjacent Channel Power Ratio and Alternate Channel Power Ratio performance.

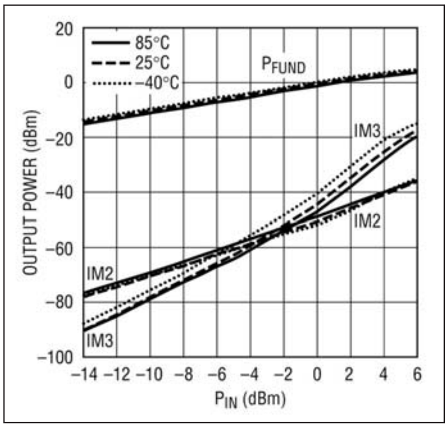

Figure 4 · The LT5521's intermodulation distortion products are low as a function of RF input power level.

$$SFDR = 2/3\ (IIP3 - \text{Noise Floor}) \quad (1)$$

where,

$$\text{Noise Floor} = NF - 174\ \text{dBm} + 10\ \text{Log BW} \quad (2)$$

For WCDMA or TD-SCDMA type signals, the BW is 3.84 MHz. Substituting the mixer IIP3 = 24.1 dBm and NF = 11.9 dB, at a LO level of 0 dBm at 1.95 GHz, thus,

$$\text{Noise Floor} = 11.9\ \text{dB} - 174\ \text{dBm} + 10\ \text{Log}\ (3.84\ \text{MHz})$$

$$= -96.3\ \text{dBm}$$

With this set of operating parameters, we can expect such a circuit's Spurious Free Dynamic Range to be

$$SFDR = 2/3\ [24.1\ \text{dBm} - (-96.3\ \text{dBm})]$$

$$= 80.3\ \text{dB}$$

Get More Signal to the Output

With the objective of maximizing the distortion-free output signal, higher conversion gain is a real advantage. This makes more signal available at the output without extra gain stages. Active mixers like the LT5521, for example, have a conversion loss of only 0.5 dB. Compared to passive mixers, which typically have much higher loss of between 6 to 10 dB, that is a net signal level improvement of 6 to 8 dB. Therefore less amplification is needed after the transmit mixer.

Managing LO Leakage

Another important advantage for an active mixer like the LT5521 is its inherently low LO drive and superior LO suppression. This new generation of high linearity active mixer requires 0 dBm (or less) signal to drive its LO port. In contrast, a similarly high IIP3 passive mixer needs at least +17 dBm LO signal. Having such a strong LO signal on a PC board is a real disadvantage.

By itself, a high power +17 dBm signal on a PC board can be a strong source of undesirable radiation. At 1 to 2 GHz frequencies, small PC board parasitic elements can couple enough LO signal to affect other sensitive circuits in the system. RF shielding may be necessary, which adds complexity. And, designing an effective RF shield may require several PC board spins and could lengthen a program's development cycle.

In contrast, an active mixer's much lower LO level greatly simplifies the LO driver circuitry, reducing many external components by eliminating one or two power amplifier stages. Considerable savings can be realized. Additionally, without the added LO drive circuitry, power consumption is much reduced. The low drive level eases the radiation and leakage problem, further reducing cost.

Active mixers are also less sensitive to LO level variations. In the case of passive mixers, 2-3 dB of LO power change can significantly degrade their linearity performance. Designing a high power LO source while holding a tight LO level tolerance can be difficult, particularly in a mass production environment. Active mixers like the LT5521 can tolerate a wider operating LO power level range without significantly degrading performance.

Better RF Isolation Simplifies Filtering

The inherently superior port-to-port isolation of active mixers helps to greatly reduce the LO leakage to the transmitter output. Typical passive mixers offer about 30 dB isolation. But with their LO signal at +17 dBm, the output will have LO output leakage in the range of –13 dBm, an unacceptably high level that will require extensive filtering to suppress. Multiple stages of filters may be necessary to control the LO leakage, and the frequency plan of the transmitter may be affected. Depending on the frequency offset, two stages of SAW filters achieve about 40dB of attenuation. The active mixers' advantage starts with its low LO drive power. Combined with superior LO isolation of more than 40 dB, it results in an LO leakage level of about –40 to –45 dBm at the RF output. This is 30 dB lower than for a passive mixer, and greatly reduces the filtering requirements that would otherwise be needed.

Having fewer filter stages not only saves cost, but also improves the signal quality. That is because sharp roll-off filters have appreciable in-band ripples. When cascaded, the ripples from each filter stage can increase in amplitude to an extent that exceeds the design limit, distorting the modulated waveform. Moreover, each filter stage contributes an appreciable insertion loss. Thus, an active mixer's relaxed output filter requirement significantly reduces the solution cost, improves signal quality and higher signal levels available at the transmitter output.

Summary

A new generation of active mixers delivers wide, spurious free dynamic range performance with clean output spectra in a high performance transmitter signal chain. We have discussed several key considerations in designing high performance cellular basestation transmitters.

Author Information

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Appendix—Device Specifications

The LT5521 features these key specifications (typical):

- 5 volt supply (3.15/5.25 V min/max)
- 82 mA typical supply current
- 10 to 3000 MHz input frequency
- 10 to 4000 MHz LO frequency
- 10 to 3700 MHz output frequency
- –5 dBm LO power
- –0.5 dB conversion gain
- 12.5 dB SSB noise figure
- +24.2 dBm 3rd order input intercept point (two-tone, 5 MHz Δf, –7 dBm per tone)