Application Note

AFE7950 Super-Heterodyne Solution for K-Band

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ABSTRACT

This application report showcases the benefit of reverting to a super-heterodyne architecture for accessing K-band applications. The approach uses the AFE7950 RF sampling transceiver to implement the first conversion stage. This device implements a high frequency IF stage that provides ample separation to any LO bleed through or images for easy filtering. This architecture provides better performance than existing direct conversion approaches for this band and more flexibility to support a variety of signal bandwidths with lower LO frequencies.

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1 Introduction

K-band operates from 18 GHz to 40 GHz. The common applications tend to fall in Ku-band from 18 – 20 GHz and a portion of Ka-band from 26 – 28 GHz. A direct conversion architecture supplanted the traditional discrete super-heterodyne architecture for these systems as new high frequency modulators and demodulators arrived on the market.

The direct conversion architecture in itself is not new. The benefits of a streamlined architecture and wide bandwidth capabilities are well documented; however, the application in very high frequencies may introduce complexities. Previously there was not a good alternative, but new RF sampling devices bring back the super-heterodyne architecture to the forefront.

2 Direct Conversion Architecture Limitations

TX modulators take complex I/Q data input and mix to the desired RF frequency. Similarly, RX demodulators mix down to quadrature baseband. In both cases imbalances within the I/Q baseband paths manifest to system level degradation. DC offset imbalance results in carrier leakage on the transmitter output or a DC component on the RX output. Amplitude and phase imbalance between the I and Q paths results in degraded sideband (i.e. image) suppression performance. Most of the imbalance comes from the modulator itself and tolerance variations in the low pass filters in the I/Q paths.

These impairments are not anything new. Typically, there are adjustment capabilities in the TX DAC or RX demodulator to minutely adjust DC offset, amplitude, and phase between the I and Q paths to improve the suppression of the unwanted components. These adjustments are valid at one temperature and at one frequency. Some kind of feedback loop is needed to monitor the performance and adjust parameters as frequency or environmental factors change. For the direct conversion K-band modulators/demodulators, the inherent balance performance is worse than in counterpart devices operating below 6 GHz. When the inherent performance starts out worse, it becomes harder to maintain optimum tuning to achieve best suppression.

Image suppression in particular is very problematic because the image is superimposed on the desired signal itself. There are no means to filter it. Even though it cannot be seen with typical RF equipment like a spectrum analyzer, it distorts the integrity of the signal. An Error Vector Magnitude (EVM%) measurement that demodulates the information of the signal reveals the degradation that the image introduces. The image performance may be responsible for up to 60% of the overall degradation that includes other impairments related to carrier feedthrough, intermodulation distortion, and thermal and phase noise. Similarly, the receiver has the same issues with the addition of a second order intermodulation distortion (IM2). Unlike third order intermodulation (IM3), the IM2 distortion comes from any wide bandwidth signal or jammer mixing with itself and falling at baseband where the desired signal resides. The article in the reference section provides more details on this phenomenon.

Figure 2-1 shows the expected impairments of the direct conversion architecture.

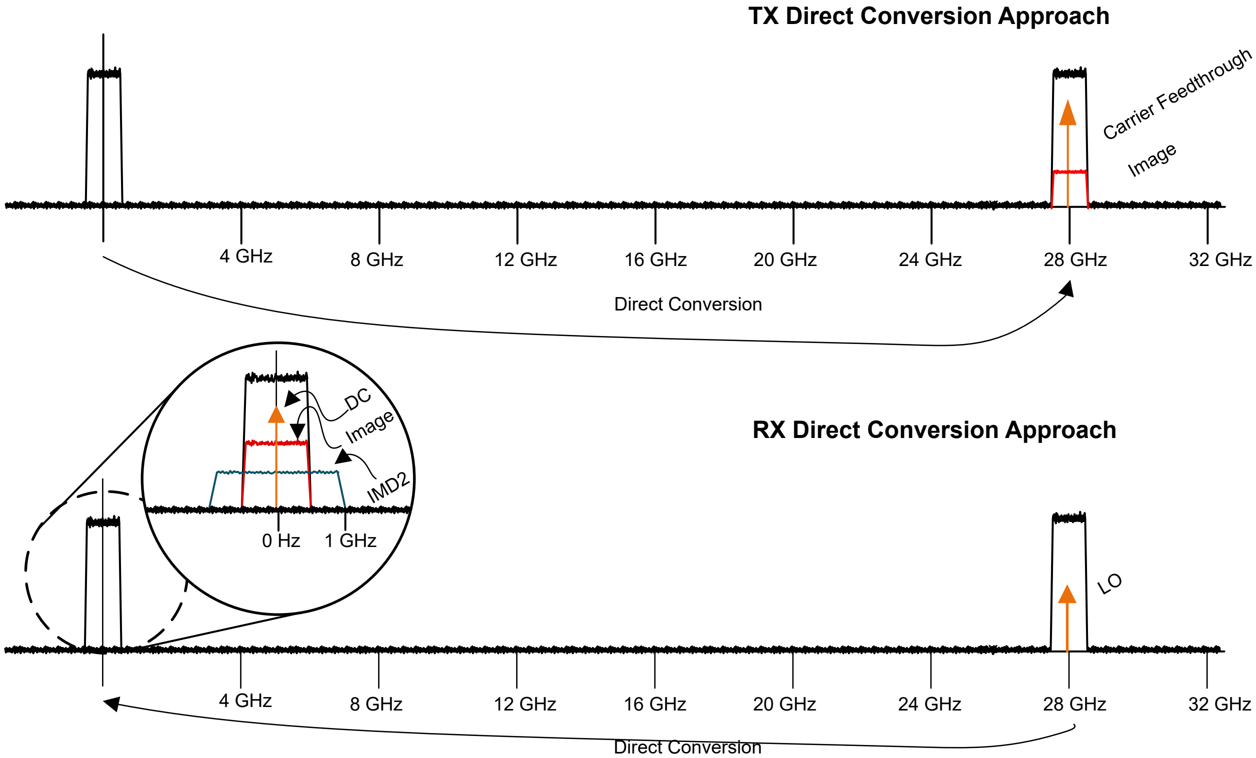

Figure 2-1. Direct Conversion Impairments

3 Super-het (back) to the Rescue

Bringing back the super-heterodyne architecture resolves many of these problems. This is not your grandfather's super-het architecture! Using the AFE7950-SP RF sampling transceiver as the first stage is a game-changer, specifically because the device supports direct RF sampling into X-band (up to 12 GHz) and is rated for space applications. With a K-band application operating at 28 GHz, a high IF frequency around 8 GHz is ideal. There are two advantages with a high IF frequency. The main one is the image separation. The image and LO bleed-through are very far away. It is very easy to filter these signals off. A similar approach with an IF below 6 GHz would yield a much tighter grouping of the LO and image and make filtering more difficult or impossible.

The second benefit is the reduction of the LO frequency. Finding good high frequency synthesizers is a challenge. While a direct conversion approach needs the LO at the center of the desired band, the super-het approach drops the frequency requirement by the IF frequency amount. Using an 8 GHz IF, the LO needed to hit 28 GHz Ka-band is 20 GHz. That is still fairly high, but is within the capabilities of the LMX2820 frequency synthesizer solution and only uses a two-times multiplier. For space qualified operation, the LMX2615-SP supports up to 15 GHz to cover the Ku-band. Figure 3-1 shows the spectrum of the super-het architecture with an IF of 8 GHz.

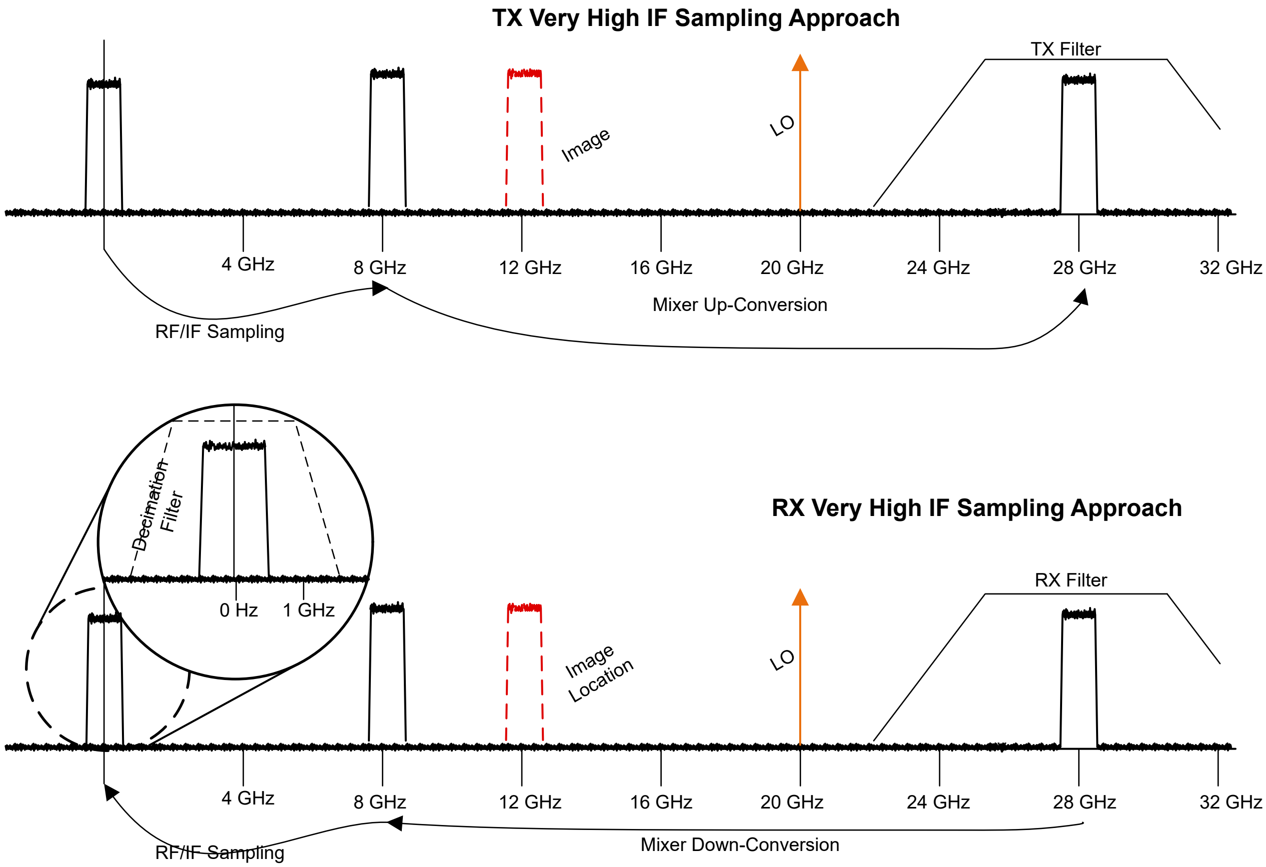

Figure 3-1. AFE7950 in Super-het Architecture

Using the RF sampling architecture of the AFE7950 in the first stage offers some additional benefits. The AFE7950 supports very wide bandwidth signals, up to 2.4 GHz bandwidth on the transmitter and up to 1.2 GHz on the receiver. The device integrates four transmitters and six receivers so it is ideal to support multi-channel applications and large antenna arrays. Integrated numerically controlled oscillators (NCOs) facilitate easy IF adjustments for frequency hopping applications. Further, the AFE7950 integrates a high frequency PLL/VCO for generating its high frequency sample clock; no need to route this signal through the board.

4 Summary

The AFE7950 (or AFE7950-SP) RF sampling transceiver and the LMX2820 (or LMX2615-SP) synthesizer is part of the super-het K-band transceiver shown in Figure 4-1. The solution if fleshed out with appropriate gain blocks, filters, low-noise amplifiers, and power amplifiers. Though the solution is a bit more discrete compared to the direct conversion approach, it offers advantages for multi-channels systems. For systems with two or more channels the integrated AFE7950 offers a smaller PCB real estate footprint, power consumption savings, and a reduction in interface connections to an FPGA or processor in addition to the system performance advantage of eliminating the co-located image.

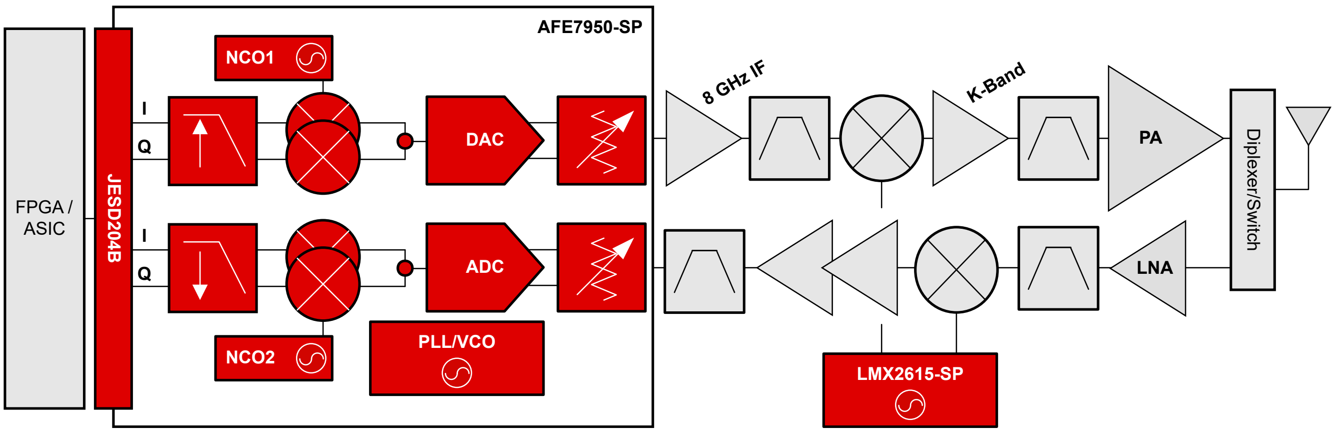

Figure 4-1. K-Band Super-het Block Diagram

5 References

- Hoppenstein, Russell, “Digital Correction Revives Direct-Conversion Receivers”, Microwaves and RF, 52. S14. 2013