Low-Cost HBT Upconverters for CDMA Transmitter ICs

To support the increasing demand for Code Division Multiple Access (CDMA), the latest digital communication technology in cellular industry, RF Micro Devices (RFMD) developed CDMA chip sets for both receiver and transmit chain. The CDMA chip sets were designed and manufactured on an advanced GaAs Heterojunction Bipolar Transistor (HBT) process from TRW. The HBT process offers several advantages over other processes such as high F_t, low noise transistors, and process consistency. The CDMA program is two-fold. The first chip set, which was designed for cellular band, consists of a receive and a transmit IF AGC amps (RF9907 and RF9909), a receive LNA/mixer (RF9906), and a transmit upconverter (RF9908). The second chip set, designed for PCS band, consists of a receive LNA/mixer (RF9936) and a transmit upconverter (RF9938). This article describes the two transmit upconverters for this CDMA program.

Design architecture is the same for both cellular and PCS designs. The PCS upconverter, RF9938, is a modified RF9908 with performance optimized for the PCS band. Both ICs operate at $3.6V_{DC}$ with 0dB conversion gain.

With -10dBm input at the IC, typical Adjacent Channel Power Rejection (ACPR) for the RF9908 is -37dB for the 880kHz offset and -58dB for the 1.98MHz offset. The typical ACPR for the RF9938 is -43dB. The nominal power supply current for the RF9908 is 18mA and 25mA for the RF9938. The overall performance is affected by less than $\pm$1dB over temperature, frequency, and the LO drive level. Both ICs are pin compatible and are packaged in a standard 8-lead plastic SOIC package.

Figure 1 is a simplified circuit topology of the mixer. As shown in the figure, the mixer is a Gilbert Cell based multiplier with an IF amplifier at the bottom and the LO switching transistors at the top. Double balanced mixers such as this offers the best port to port isolation and low LO feed-through at the output. Minimum port to port isolation is 30dB for both upconverters and the minimum spurious signal in a 60MHz bandwidth is 50dBc.

Input ports for the IF and LO are configured for differential operation. However, the LO can be driven single ended if one of the input port is AC grounded. Input impedance for the IF amplifier is 265Ω, set by the inter-

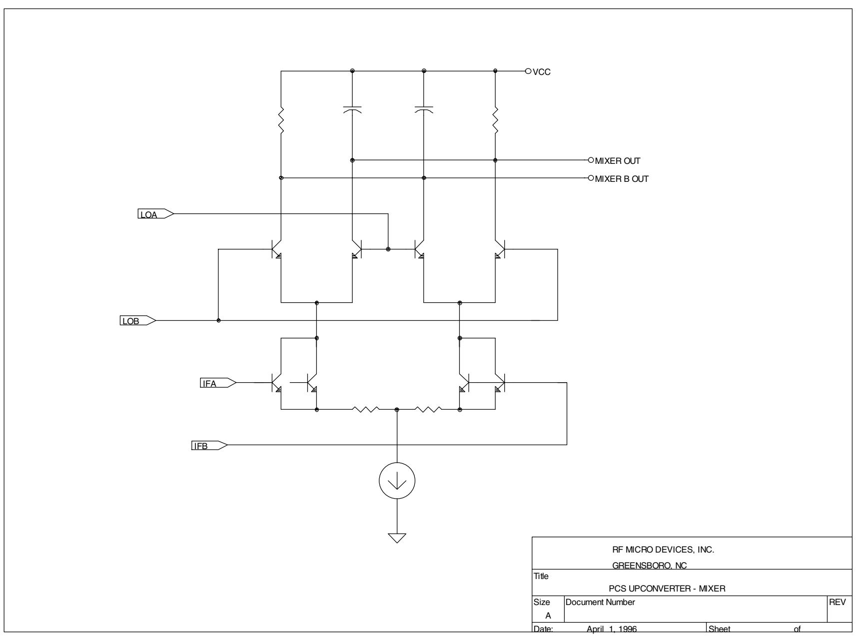

Figure 1. Simplified Circuit Topology

nal resistors. The LO input impedance is 50Ω. The IF amplifier portion of the mixer has a set of signal degeneration resistors on the transistor emitters. These resistors are designed to increase the mixer linearity by reducing the gain in the IF amplifier and keeping the signal level well below LO signals. Unfortunately, the same resistors also increase the overall noise figure. The resistor values were carefully calculated for optimal linearity and the noise figure. There are several design techniques used to improve the overall noise figure. First, the transistors in the IF amplifiers are doubled and paralleled. The paralleled transistors reduce r_b and r_e the transistors and reduces the overall noise figure. Second, a couple of capacitors are place on the collector of the mixer output transistors. These shunt capacitors act as low pass filters and reduce high frequency mixed spurious signals. Again, the values of these capacitors were carefully calculated to meet the conversion gain and linearity requirements. Third, a good bypass capacitor on the current mirror further reduces the overall noise figure.

The LO portion of the mixer contains a two sets of cross-coupled transistors to alternately turn the paired transistors on and off. Typically, an LO buffer amplifier (e.g., a limiting amplifier) is required to provide a sufficient voltage swing (ideally square waves) to drive the mixer. However, to conserve the overall current and to make the IC small, the LO buffer amplifier is omitted. The mixer is designed for an LO drive level of -6dBm or greater for best mixer performance.

The final stage of the ICs is a low noise RF amplifier. The RF amplifier takes the high impedance differential output of the mixer and converts it to a 50Ω single ended RF output. The RF amplifier is a push-pull class B amplifier where the current for each transistor flow for approximately one half of the input cycle and provides a different half of the overall signal. Since the current is only flowing one half of the time for each transistor, the required linearity can be met with about half of the current than classic “A” type amplifier.

One of the biggest advantages of CDMA technology compared to FDMA or TDMA is the capacity expansion. Unlike FDMA, where available spectrum is divided into 30kHz wide channels, or TDMA, time sharing of multiple users in 30kHz, in CDMA, multiple users share the same spectrum simultaneously. The limitation is not depended on the number of physical channels but on the channel condition. As the number of users increase, interference and the probability of higher data error rate will increase also. For this reason, the linearity requirements in CDMA is very demanding and important. The ACPR is a method of testing the IC linearity. It is a relative measurement of the energy in a 1.23MHz bandwidth CDMA waveform to the energy in the adjacent channels with a given offset (±880kHz, and ±1.98MHz for Cellular systems and 1.25MHz for PCS systems). The following graphs show the typical ACPR performance of RF9908 and RF9938. Figure 2 is the RF9908 ACPR with ±885kHz offset. Figure 3 is the RF9908 ACPR with ±1.98MHz offset. Figure 4 is the RF9938 ACPR with ±1.25MHz offset.

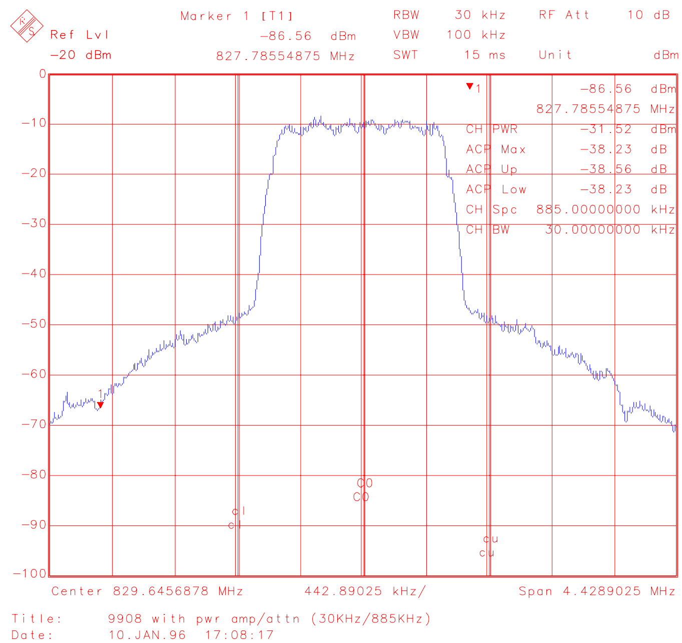

Figure 2. RF9908 ACPR at ±885 kHz Offset

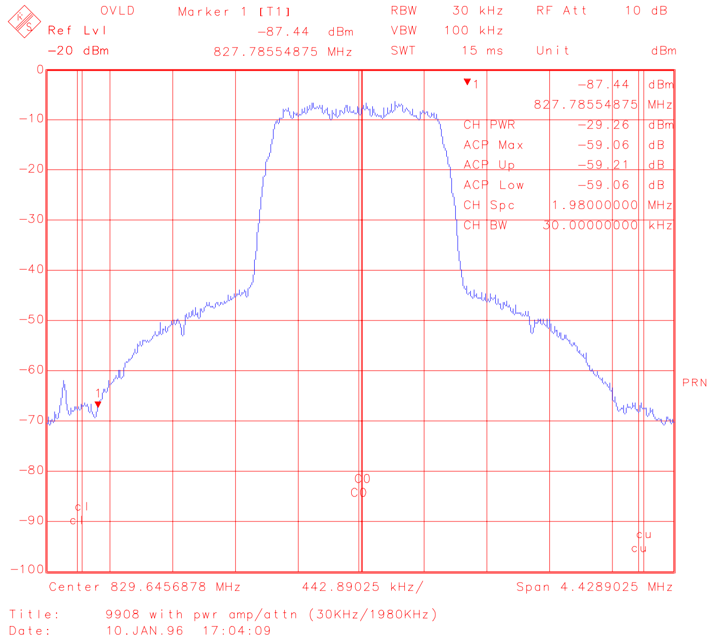

Figure 3. RF9908 ACPR at ±1.98 MHz Offset

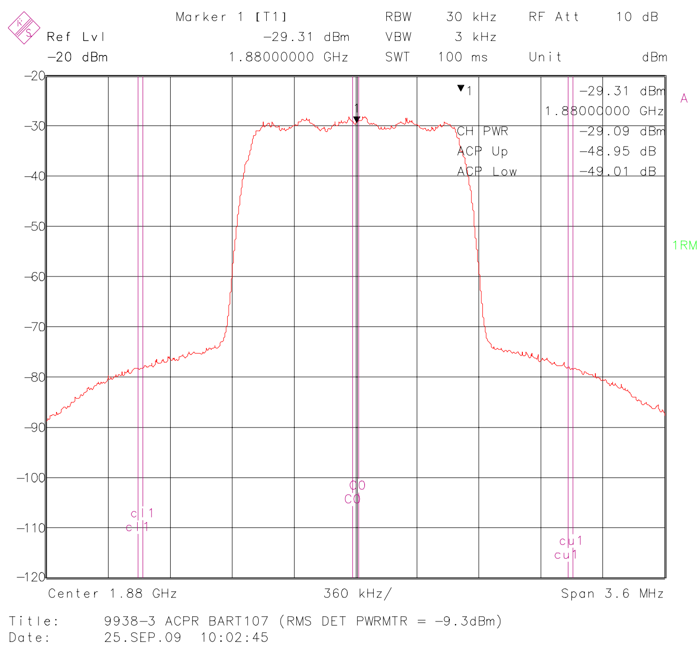

Figure 4. RF9938 ACPR at ±1.25 MHz Offset

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TECHNICAL NOTES AND ARTICLES