RF MICRO·DEVICES

Transmit and Receive AGC Amplifiers for CDMA Cellular/PCS Phones

Introduction

Cellular and Personal Communication Services (PCS) phones that are based on Code Division Multiple Access (CDMA) need careful regulation of signal levels on both the forward and reverse channels. In the reverse channel (mobile phone to base station) a transmit automatic gain control (AGC) amplifier must carefully adjust the output power of the mobile so that it does not dominate the input spectrum at the base station.

Each mobile's signal should arrive at the base station at the same power level; this helps ensure that capacity is maximized. In the forward channel (base station to mobile) a receive AGC amplifier adjusts to accommodate widely varying signal levels coming in from the base station. At a CDMA mobile phone antenna numerous signals sent from the cell base station are layered on a single frequency band and within this group of signals lays the desired data.

All of these signals (desired and undesired) pass through a low noise amplifier front end and then through a downconverting mixer. Immediately following the mixer the waveforms pass through a CDMA intermediate frequency (IF) bandpass filter. All of the aforementioned signals are in-band and are not filtered. Because of this condition the receive AGC amplifier cannot simply limit. The strongest signal would be limited and compress all other signals that were received, so if the desired data was not the strongest, it would be lost. It becomes clear that the receive AGC amplifier must provide linear amplification and attenuation to prevent limiting of undesired signals. RF Micro Devices has developed two integrated circuits (ICs) that perform both of these important functions. The RF2607 CDMA/FM Receive AGC Amplifier and the RF2609 CDMA/FM Transmit AGC Amplifier are both monolithic ICs that are fabricated in an advanced bipolar Silicon process. Both of these low cost, high performance ICs pack variable gain differential amplifier stages, gain control operational amplifiers, and temperature compensation circuitry within small QSOP16 plastic packages.

Transmit AGC

The RF2609 features a 90dB gain range from -48dB power gain to +42dB power gain and is powered from a single 3.6V supply. In a cellular system, the cellular base station sends control signals to the mobile phone

directing the RF2609 to increment or decrement its gain in 1dB steps. As the mobile strays further from the base station, the RF2609 is directed to increase its gain and hence, its output power, while the reverse occurs as the mobile approaches the base station. The gain of the IC is controlled by a single DC voltage externally supplied by a digital-to-analog (D/A) converter which is swept from 0VDC to 3VDC. Figure 1 illustrates the gain response of the RF2609 as the gain control voltage is swept.
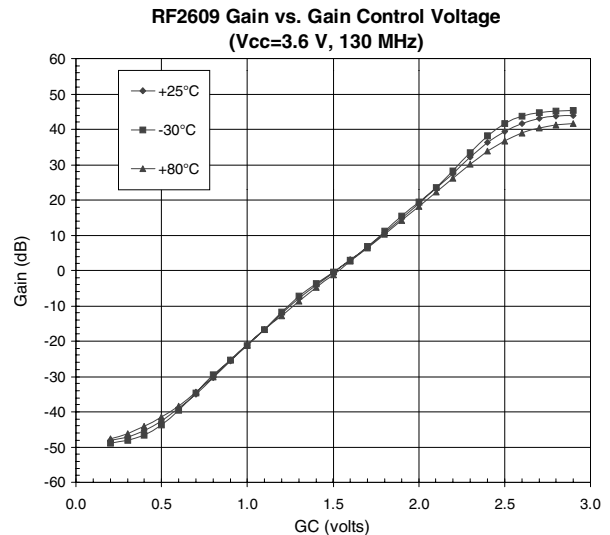

RF2609 Gain vs. Gain Control Voltage (Vcc=3.6 V, 130 MHz)

Figure 1. Gain response of the RF2609 as the gain control voltage is swept

CDMA system specifications dictate that as the gain is swept over its entire range, the transmit AGC amplifier must maintain a minimum input third order intercept point (IIP3). Another way to state this requirement is that the adjacent channel power rejection of the amplifier must remain constant regardless of the output level. This specification ensures that IS-95 transmitted spectrum requirements are met under the entire gain range of the AGC amplifier. To clarify how this affects the design, in a CDMA phone the input signal provided to the RF2609 will remain constant even while the gain is increased or decreased. Thus, the output signal will vary proportionally with the gain of the IC. Under these conditions, the third order (IM3) products must remain constant and not rise as the gain moves upward. The RF2609 uses a proprietary variable gain amplifier scheme that achieves excellent IM3 performance (see

13

Figure 2) while keeping down the noise figure of the device (see Figure 3). Although the noise requirements for the transmit AGC amplifier are not as stringent as that of the receive AGC amplifier, the challenging IIP3 requirements for the RF2609 make the noise figure more difficult to achieve. The final design, however, was able to meet both IS-95 specifications under nominal and worst-case conditions.
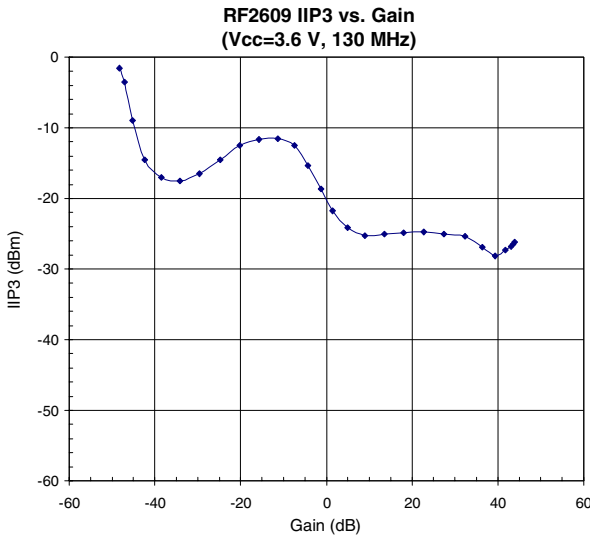

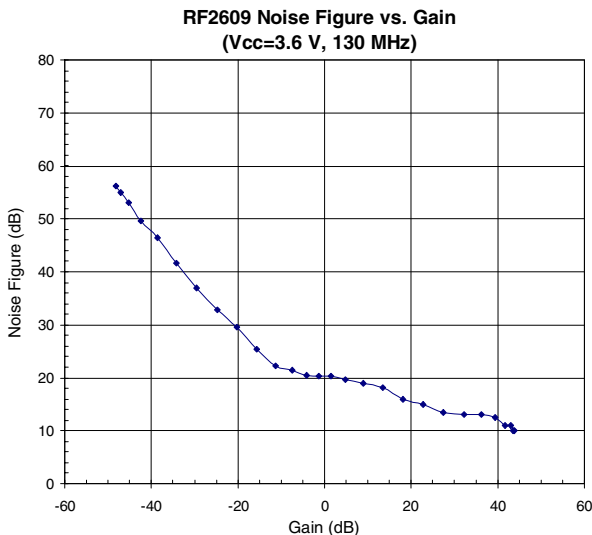**Figure 2. The RF2609 IIP3 vs. Gain**

Figure 3. The RF2609 Noise Figure vs. Gain

Understanding how to incorporate the RF2609 into a transmit chain is straightforward (see Figure 4). Pins 1 and 2 are the input port for the IC.

Source Impedance

The differential impedance of the input port is 1000Ω, so for maximum power transfer, the system designer need only provide a source impedance of 1000Ω. Typically, an intermediate frequency (IF) filter will precede the RF2609 and provide a 1000Ω source impedance. If a 1000Ω filter cannot be used, a simple L-C network can be designed to perform an impedance transformation. Since there is DC present on pins 1 and 2, the source should be AC coupled through capacitors as shown in Figure 4.

Once the IF signal is fed into the IC, it travels through four variable gain amplifier stages. Each of these amplifiers is controlled by gain control circuitry, which primarily consist of operational amplifiers. External to the part, a DC gain control voltage is fed from a D/A converter and enters the IC through pin 16. In order to achieve the correct gain curve, the DC gain control voltage must pass through a 3.3kΩ resistor. A capacitor is placed from pin 16 to ground in order to lowpass filter the signal from the D/A converter. The earlier mentioned gain control voltage range of 0VDC to 3VDC is referenced to the GAIN label on Figure 4, not at pin 16.

The output port of the RF2609 consists of pins 9 and 10. The output of the IC is open collector, which means that it looks like a high impedance. Open collector also means that the output pins must be supplied DC voltage externally for the internal output circuitry to operate.

The output is left high impedance for greater flexibility and greater precision. A system designer can choose whatever output impedance they desire and use 1% resistors to guarantee good matching. The IC was designed to drive 500Ω (1000Ω output impedance in parallel with 1000Ω load) but other impedance levels can be used if the change in power gain is taken into account. Referring back to Figure 4, a 1000Ω resistor is placed across pins 9 and 10 to set the differential output impedance of the IC.

Inductors (L1) connect the power supply to the output pins. The inductors can be used with series capacitors (C2) to form an impedance transformation network if the IF filter does not look like 1000Ω.

If the filter impedance is 1000Ω, then the values of L1 and C1 are chosen to form a parallel-resonant tank circuit at the signal frequency. In this case, C2 merely acts as a DC blocking capacitor.

Receive AGC

The RF2607 features a 96dB gain range from -48dB power gain to +48dB power gain and is powered from a single 3.6V supply. As the transmit AGC amplifier is instructed to adjust its gain, the receive AGC amplifier will track, so that they work in parallel. As the mobile strays further from the base station, the RF2607 is directed to increase its gain while the reverse occurs as the mobile approaches the base station. The gain of the IC, like the RF2609, is controlled by a single DC voltage externally supplied by a digital-to-analog (D/A) converter which is swept from 0 to 3VDC. Figure 5 illustrates the gain response of the RF2607 as the gain control voltage is swept.

With this IC, the more demanding specification to meet is noise figure. In a CDMA receiver, this component follows the downconverting mixer and must retain good noise performance at the high end of the gain range. At the same time the IIP3 must increase steadily as the gain drops from the high end of the gain range. Using a variable gain amplifier scheme similar to that used in the RF2609, both requirements are achievable. At 45 dB gain the RF2607 typically produces a noise figure of 4.5dB and an IIP3 of -41dBm. Figures 6 and 7 illustrate nominal performance of the IC over the entire gain range.

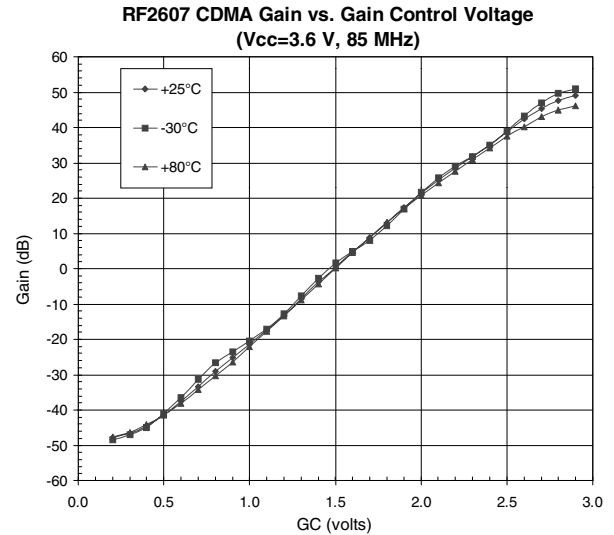Incorporating the RF2607 into a system is very simple.

RF2607 CDMA Gain vs. Gain Control Voltage (Vcc=3.6 V, 85 MHz)

Figure 5. RF2607 CDMA Gain vs. Gain Control Voltage

The RF2607 has two input ports, one for CDMA operation and one for FM operation. This feature allows the IC to be used in dual mode phones that operate in both Advanced Mobile Phone Service (AMPS) systems and IS-95 North American Digital Cellular (NADC) systems. In dual mode systems, two signal paths are required at IF in order to filter properly. The CDMA path requires a filter with a 1.26MHz bandwidth while the
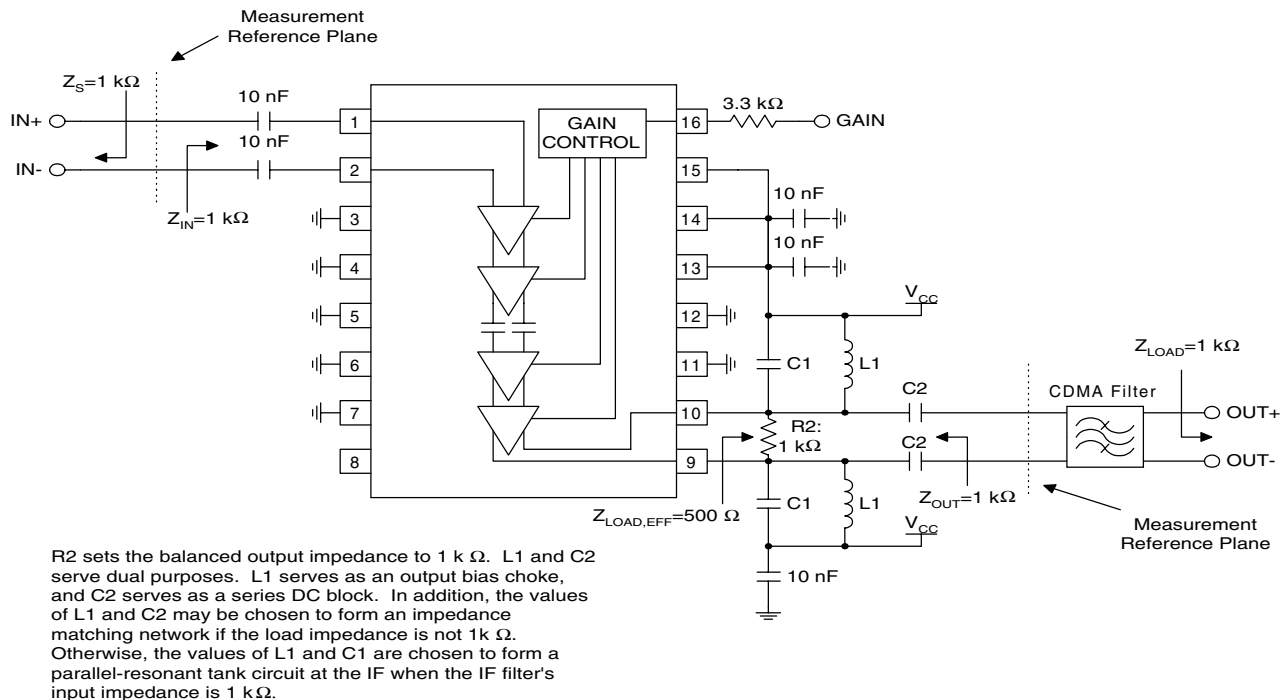

R2 sets the balanced output impedance to 1 kΩ. L1 and C2 serve dual purposes. L1 serves as an output bias choke, and C2 serves as a series DC block. In addition, the values of L1 and C2 may be chosen to form an impedance matching network if the load impedance is not 1kΩ. Otherwise, the values of L1 and C1 are chosen to form a parallel-resonant tank circuit at the IF when the IF filter's input impedance is 1 kΩ.

Figure 4. RF2609 Application Circuit

13

TECHNICAL NOTES AND ARTICLES

RF2607 CDMA IIP3 vs. Gain
(Vcc=3.6 V, 85 MHz)

Figure 6. RF2607 CDMA IIP3 vs. Gain

RF2607 CDMA Noise Figure vs. Gain
(Vcc=3.6 V, 85 MHz)

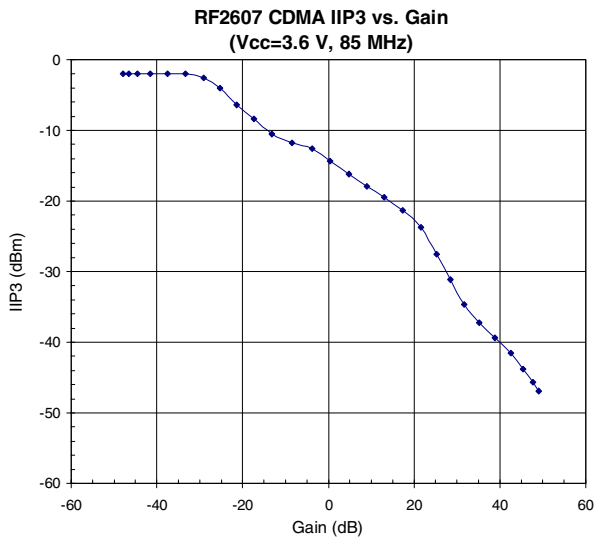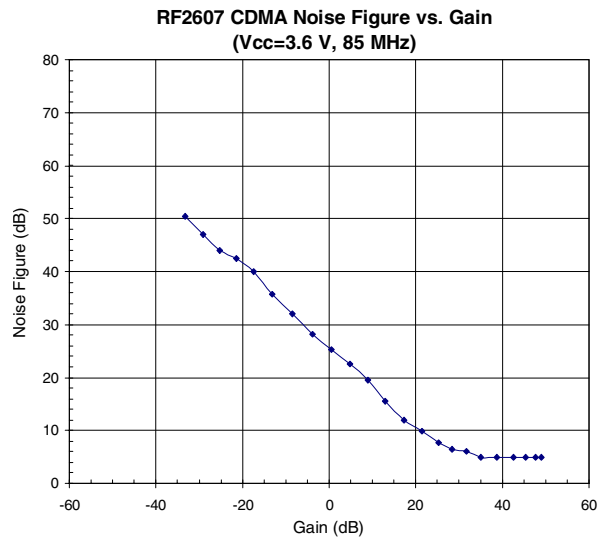**Figure 7. RF2607 CDMA Noise Figure vs. Gain**

FM path requires a filter with a 30 kHz bandwidth. The RF2607 accommodates both paths by providing two separate inputs that can be switched. Even though there are two inputs, there is virtually no difference in RF2607 performance between the two modes. The SELECT pin (pin 7) is a digital switch which determines in which mode the IC will be. Logical high corresponds with CDMA mode while logical low corresponds with FM mode.

In CDMA mode, pins 1 and 2 are the balanced input port and the differential input impedance is 1000Ω. To guarantee a good match to a 500Ω IF filter (see Figure 8), a 1000Ω 1% resistor (R1) is placed across the input port. The IC can operate with a higher or lower impedance filter by merely adjusting the external 1% resistor. The noise figure, gain, and IIP3 specifications, however, are all based upon the configuration in Figure 8. Once the IF signal is fed into the IC, it travels through four variable gain amplifier stages. Like the RF2609 each of these variable gain amplifiers is controlled by operational amplifiers. External to the part, a DC gain control voltage is fed from a D/A converter and enters the IC through pin 16. In order to achieve the correct gain curve, the DC gain control voltage must pass through a 4.7 kΩ resistor, which, together with a capacitor to ground, forms a lowpass filter to clean up the signal from the D/A converter. Like the RF2609 the gain control voltage range of 0 to 3VDC is referenced to the GAIN label on Figure 8, not at pin 16.

In FM mode, pins 4 and 5 are the balanced input port and the differential input impedance is 1000Ω. In FM mode, however, most system designers prefer to couple into the part single-endedly. In this case pin 4 or pin 5 can be used as the input port with the other pin AC coupled to ground. The single-ended input impedance is then 850Ω.

The output port of the RF2607 consists of pins 9 and 10 and is open collector. Since the output is open collector, the power supply must be fed through inductors. As with the RF2609, the output impedance and load can be varied. Typically, a 500Ω resistor is placed across pins 9 and 10 to set the differential output impedance of the IC. Referring to Figure 8, inductors (L1) connect the power supply to the output pins. The inductors can be used with series capacitors (C2) to form an impedance transformation network if the IF filter does not look like 500Ω. If the filter impedance is 500Ω, then the values of L1 and C1 are chosen to form a parallel-resonant tank circuit at the signal frequency. In this case, C2 merely acts as a DC blocking capacitor.

Alternative Architecture

An alternative CDMA phone architecture integrates additional components with both AGC amplifiers. In the transmit chain, a quadrature modulator is added in front of the AGC amplifier so that the system designer interfaces with a baseband input port. In this case, I and Q data drives the IC at baseband frequencies and is upconverted to IF where the AGC amplifier takes over. The RF9958 CDMA Transmit IC includes both the modulator and AGC amplifier as well as an RF upconverter. The upconverter can be powered down if the
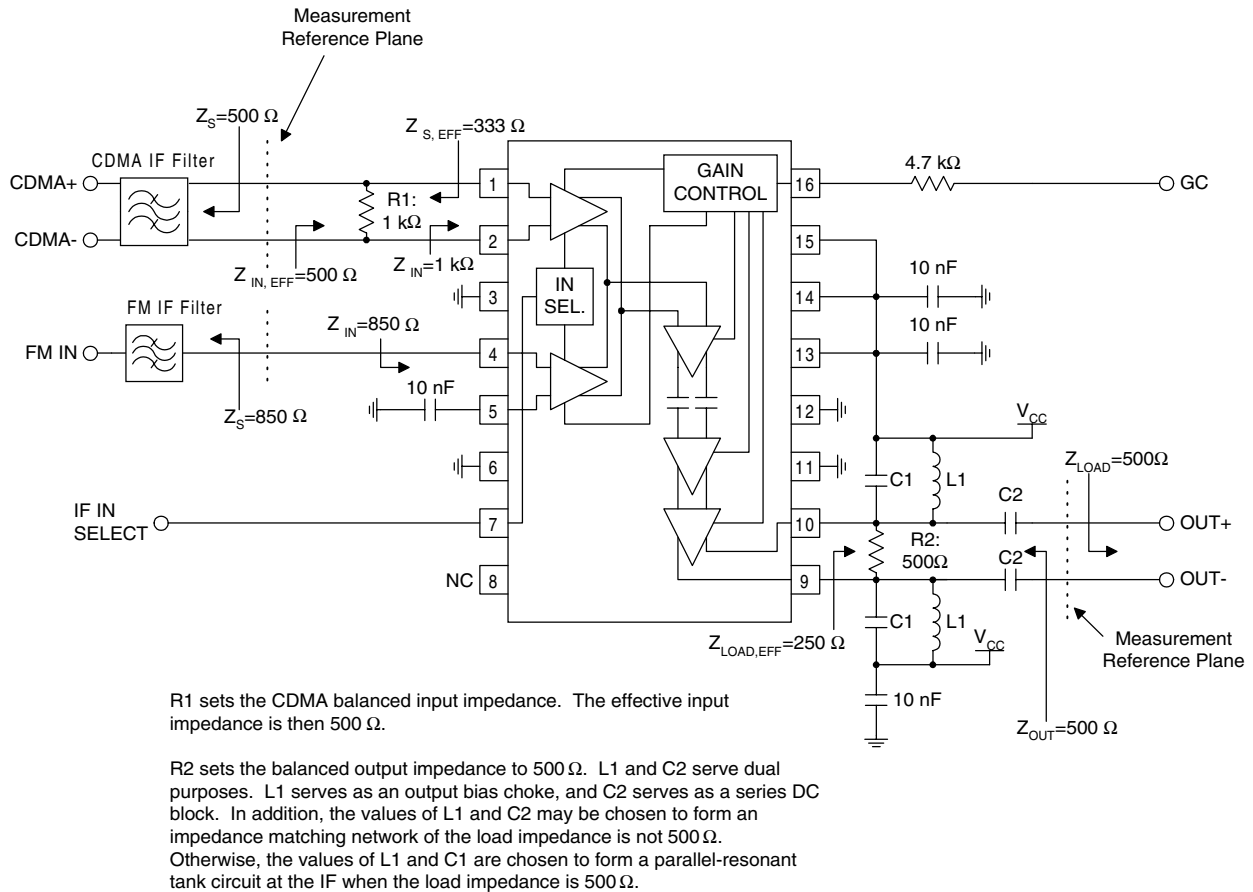
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TECHNICAL NOTES AND ARTICLES

R1 sets the CDMA balanced input impedance. The effective input impedance is then 500 Ω.

R2 sets the balanced output impedance to 500 Ω. L1 and C2 serve dual purposes. L1 serves as an output bias choke, and C2 serves as a series DC block. In addition, the values of L1 and C2 may be chosen to form an impedance matching network of the load impedance is not 500 Ω. Otherwise, the values of L1 and C1 are chosen to form a parallel-resonant tank circuit at the IF when the load impedance is 500 Ω.

Figure 8. RF2607 Application Circuit

system designer only wishes to use the modulator/ AGC section. In the receive chain, a demodulator is added to the receive AGC amplifier. In this case, the output of the part is I/Q data at baseband frequencies.

The RF9957 CDMA Receive IC includes both of these functions. Both the RF9957 and RF9958 operate from a single 3V power supply.

Summary
The RF2607 and the RF2609 are two critical components of the RF section of a CDMA phone (see Figure 9). Both of these IC's were designed to meet all of IS-95's worst-case requirements and are available in high volume at low cost. Please call RF Micro Devices' Marketing Department for additional information and details on these two products, or any others, at 910-664-1233. Also, please check our web page at www.rfmd.com.
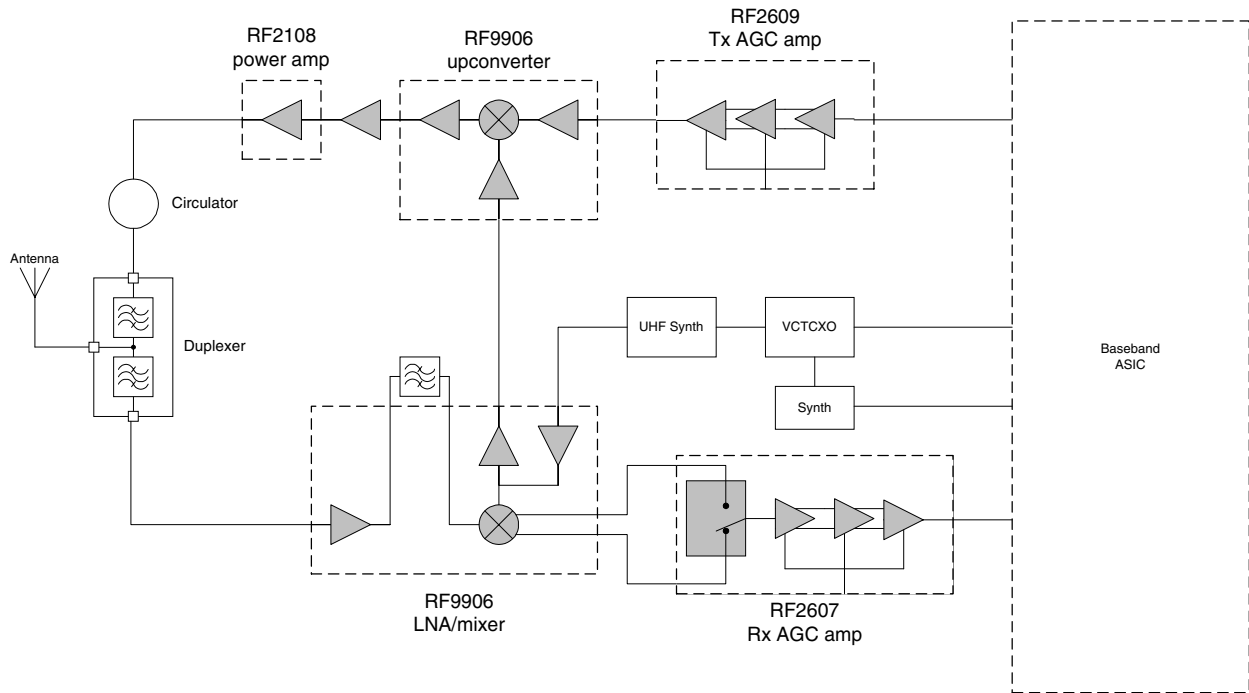
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TECHNICAL NOTES
AND ARTICLES

Figure 9. CDMA System Simplified Block Diagram