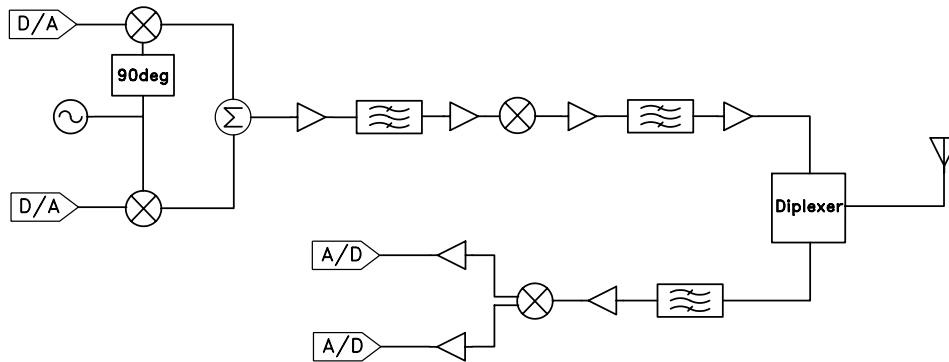


**Introduction**

The explosive growth in the Cellular market over the last few years has created a demand for ever smaller infrastructure equipment to be used for in-building applications and other space limited installations, where the traditional large multiple rack base station is not feasible. The infrastructure equipment consists of digital call processing and an analog transmitter/receiver section. The RF section of a typical cellular transceiver is shown in figure 1.



**Figure 1 – Transceiver block diagram**

Cellular communications employ many different and complex modulation schemes to transmit voice and data. Table 1 lists the characteristics of several popular cellular standards. These standards employ modulation methods that increase the peak to average power of the transmitted signal in proportion to the number of channels being transmitted. This, in turn, requires the receiver to have high linearity to minimize distortion of the channel.

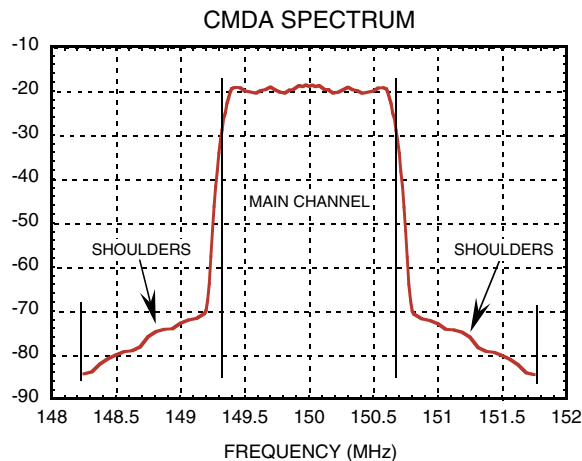
Communications Standard	Mobile Frequency (MHz)	Channel Bandwidth (MHz)	Modulation Scheme	Peak to Average Power Ratio
CDMA	Rx: 460 - 468 869 - 894 1930 - 1990 2110 - 2170 Tx: 450 - 458 824 - 849 1850 - 1910 1920 - 1980	1.25	QPSK/OQPSK	9 to 10 dB
WCDMA	(FDD) Rx: 2110 - 2170 Tx: 1920 - 1980 (TDD) 1900 - 1920 2010 - 2025 unpaired spectrum	5	QPSK	8 to 9 dB
GSM/EDGE	Rx: 460 - 468 488 - 496 869 - 894 925 - 960 1805 - 1880 1930 - 1990 Tx: 450 - 458 478 - 486 824 - 894 880 - 915 1710 - 1785 1850 - 1910	0.2	GMSK 8-PSK (EDGE only)	1 to 2 dB

Communications Standard	Mobile Frequency (MHz)	Channel Bandwidth (MHz)	Modulation Scheme	Peak to Average Power Ratio
TDMA	Rx: 869 - 894 1930 - 1990 Tx: 824 - 849 1850 - 1910	0.03	$\pi/4$ DQPSK	3 to 4 dB

**Table 1** – Popular cellular phone standards

Figure 2 shows the frequency spectrum of a single-carrier CDMA waveform. The main channel contains the desired information to be transmitted or received. The “shoulders” of the spectrum are created by intermodulation products generated within the main channel. Error Vector Magnitude (EVM) and Bit Error Rate (BER), which are parameters commonly used to quantify the quality of the digital channel, are adversely affected by distortion or interference in the main channel. Adjacent channels, which coincide in frequency with the “shoulders” of the CDMA channel, will suffer interference due to the excess energy contained in the shoulders. Adjacent Channel Power Ratio (ACPR) is a measure of the amount of power in the “shoulders” relative to the main channel power and also serves as a measure of the linearity of the channel.

The major contributors to channel distortion in a cellular receiver are the front-end Low Noise Amplifier (LNA) and mixer. This application note will discuss the performance requirements for high linearity mixers used in the cellular receiver chain.

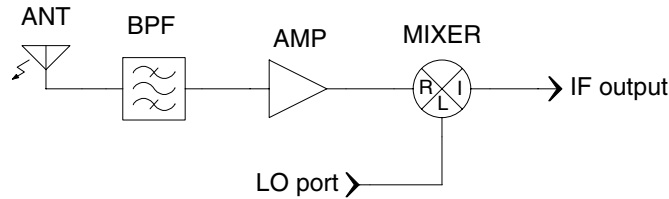


**Figure 2** – CDMA channel frequency spectrum

**Cellular Receiver Front End**

In order to understand the significance of mixer performance parameters to the cellular receive chain, a system level simulation of a receiver front end was performed using SPECTRASYS<sup>1</sup>. The system simulation allowed us to see the effects of mixer nonlinearity, spurious performance and isolation simultaneously on the received channel.

The schematic block diagram that was entered into the simulation software is shown in figure 3. The simulation was created to show the effect of an interferer landing in the frequency band of interest, once the signals are down converted in the receiver.



**Figure 3 – Receiver simulation schematic block diagram**

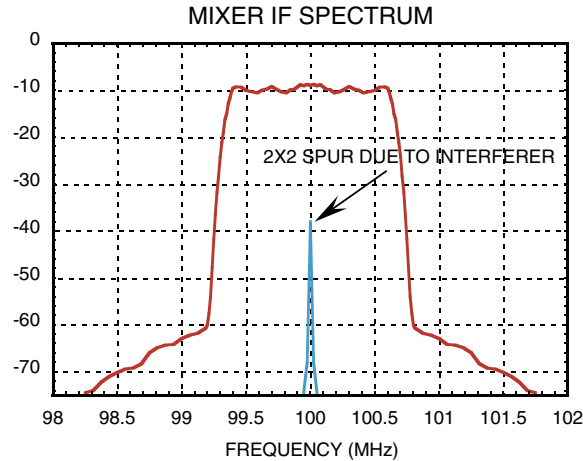
The mixer model used allowed us to enter a table containing the mixer spurious levels based on measured mixer performance. The values for the table and the other performance parameters (see figure 4) were taken directly from the datasheet of the HMC400MS8(E) mixer. Figure 5 shows the results of the simulation, as seen at the IF output of the mixer. For this simulation, the RF input frequency was 1880 MHz, the LO frequency was 1780 MHz, and an interferer was at 1830 MHz (at the RF port of the mixer). The 2x2 spur, created by the LO and the interferer, lands directly in the center of the received channel at 100 MHz. While not visible in the channel spectrum itself, the spur does degrade EVM and BER.

The screenshot shows the 'Part Properties For "MIXER\_TBL"' dialog box. It has two tabs: 'Parameters' and 'Simulation'. The 'Simulation' tab is active, showing a table of parameters. The table has columns for Name, Description, Value, Units, Default, Tune, and Show. The parameters listed are:

Name	Description	Value	Units	Default	Tune	Show
	Designator:	MIXER				<input checked="" type="checkbox"/>
CG	Conversion Gain:	-8	dB		<input type="checkbox"/>	<input checked="" type="checkbox"/>
SUM	Desired Output:0-Difference,1-Sum:	0			<input type="checkbox"/>	<input checked="" type="checkbox"/>
LO	LO Drive Level:	17	dBm	7	<input type="checkbox"/>	<input checked="" type="checkbox"/>
RTOL	RF to LO Isolation:	30	dB	30	<input type="checkbox"/>	<input type="checkbox"/>
ITOL	IF to LO Isolation:	22	dB	30	<input type="checkbox"/>	<input type="checkbox"/>
Ip1dB	Input P1dB:	21	dBm	1	<input type="checkbox"/>	<input type="checkbox"/>
lpsat	Input Saturation Power:	24	dBm	2	<input type="checkbox"/>	<input type="checkbox"/>
Z0	Reference Impedance:		ohm	50	<input type="checkbox"/>	<input type="checkbox"/>
NF	Noise Figure:		dB	CG	<input type="checkbox"/>	<input type="checkbox"/>
Rftbl	RF Input Table Variable Name:	RF_table_400			<input type="checkbox"/>	<input checked="" type="checkbox"/>
Rfpwr	RF Input Table Power:	-10	dBm		<input type="checkbox"/>	<input checked="" type="checkbox"/>
Iftbl	IF Input Table Variable Name:	IF_table		(optional)	<input type="checkbox"/>	<input type="checkbox"/>
Ifpwr	IF Input Table Power:		dBm	(optional)	<input type="checkbox"/>	<input type="checkbox"/>
Lopwr	LO Input Table Power:	10	dBm		<input type="checkbox"/>	<input checked="" type="checkbox"/>
IR	Image Rejection:		dB	0	<input type="checkbox"/>	<input type="checkbox"/>

Buttons on the right side of the dialog include: Browse..., Model..., Symbol..., Layout..., Show All, Hide All, Show Defaults, and Element Help. At the bottom are OK, Cancel, and Help buttons.

**Figure 4 – SPECTRASYS mixer parameters**



**Figure 5 – Spur inside digital channel**

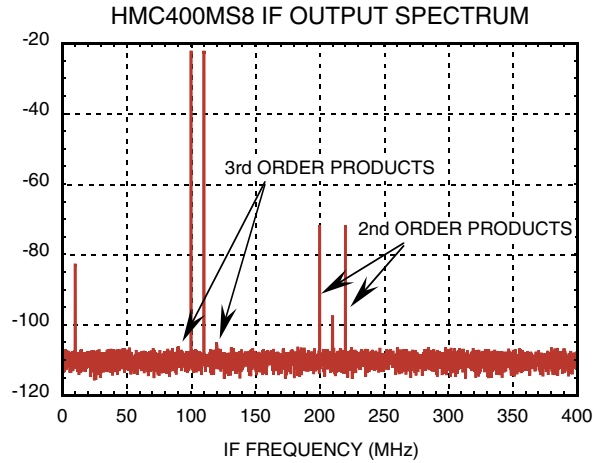
**Selecting the Right Mixer**

When selecting a high IP3 mixer, consideration must be given to other important parameters including LO drive level, isolation and spurious performance. Please visit us at [www.hittite.com](http://www.hittite.com) for a complete listing of our single-ended and double-balanced high IP3 mixers.

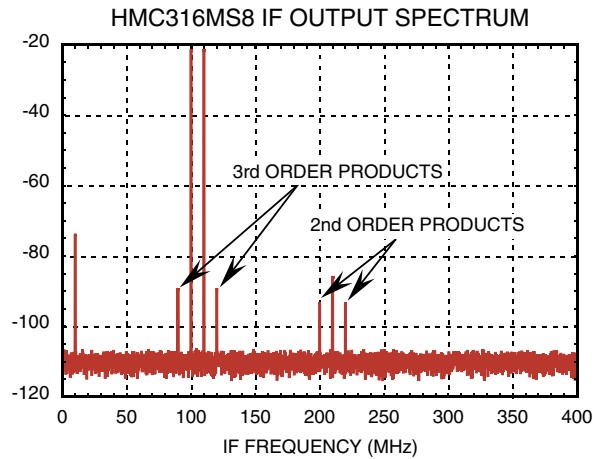
For applications where spurious and isolation performance is secondary to IP3, a single-ended mixer with the highest IP3 performance is the best choice. For applications with critical spurious issues, a double-balanced mixer with high IP3 performance is the best choice. This is often the case for a receiver that tunes over a wide IF bandwidth, where narrow IF filters cannot be used.

Figure 6 contrasts the simulated IF output spectrum for a single-ended mixer and a double-balanced mixer. For the simulation in figure 6, two tones separated by 10 MHz are injected into the RF port of the mixer and the desired 100 MHz IF signal is viewed in the spectrum analyzer output. Figure 6(a) shows the performance of the HMC400MS8(E) single-ended, high-IP3 mixer. This mixer has an input IP3 of approximately +35 dBm and 2x2 spurious suppression of -59 dBc. As expected, the excellent IP3 performance places the third-order products near the noise floor, while the second order products are clearly visible and at their expected level.

In Figure 6(b), the double-balanced HMC316MS8(E) mixer, with an input IP3 of +25 dBm and 2x2 spurious suppression of -77 dBc is shown. The tradeoff between input IP3 and spurious performance is clearly visible.



(a)

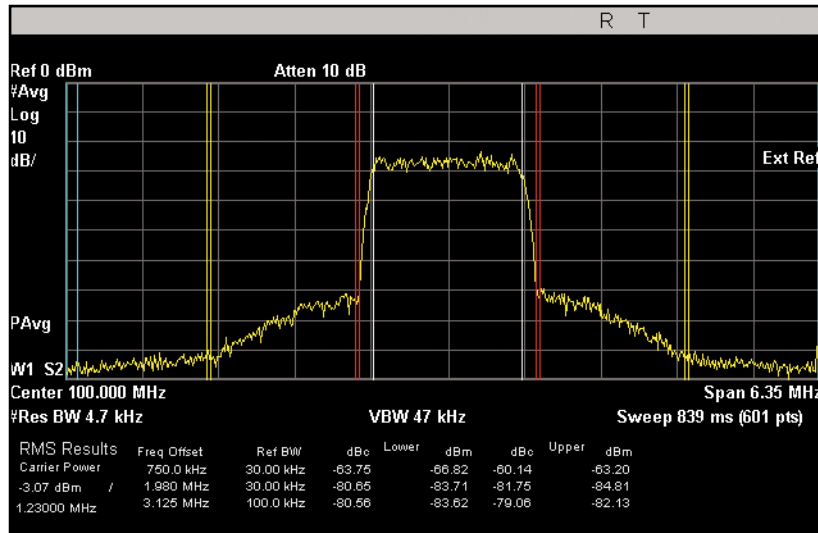


(b)

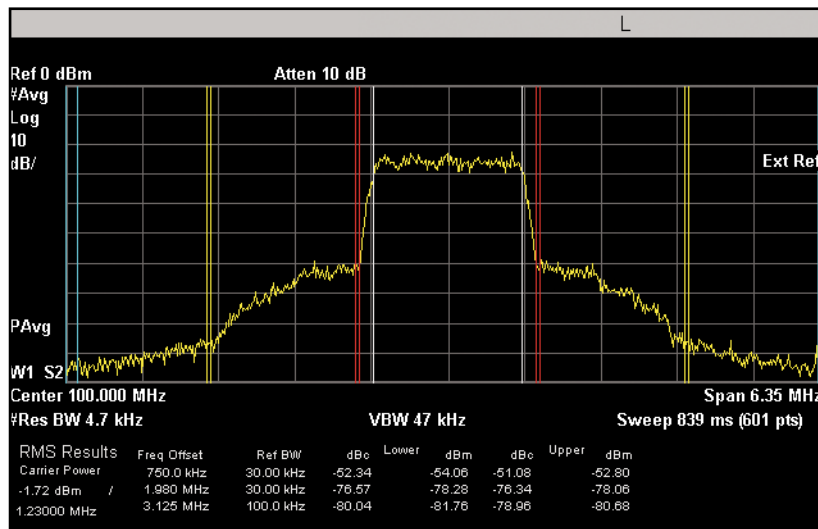
**Figure 6** – IF output spectrum for the (a) HMC400MS8(E) and (b) HMC316MS8(E) mixer

Measurements were performed to study the impact of IP3 and spurious performance on a CDMA channel. For a CDMA signal, the 3rd order products create the “shoulders” of the channel response and directly impact ACPR.

Figure 7(a) shows the IF output of the HMC400MS8(E) mixer driven with a strong CDMA signal centered at 1.85 GHz with a channel power of +6 dBm. The ACPR was measured at -64 dBc at the IF output. In Figure 7(b), the HMC316MS8(E) was driven by the same CDMA signal and the impact of the mixer IP3, in this case 10-dB lower than the HMC400MS8, can be clearly seen in the lower ACPR.



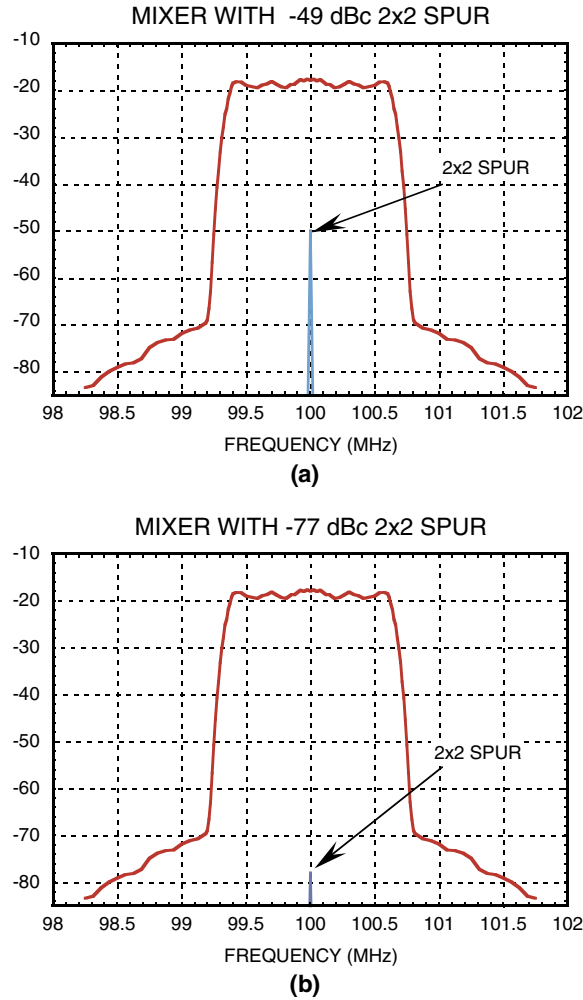
(a)



(b)

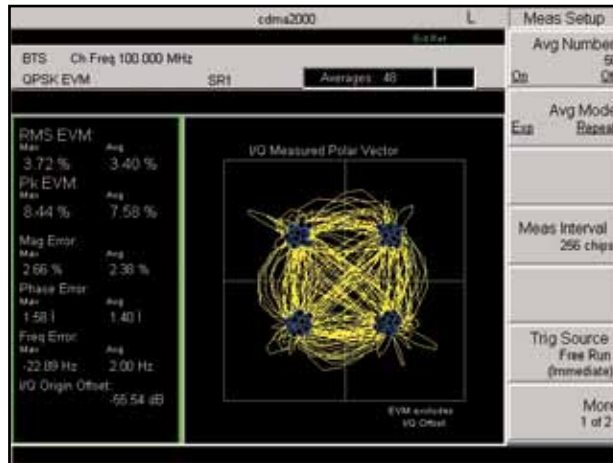
**Figure 7** – CDMA output spectrum for the (a) HMC400MS8(E) and (b) HMC316MS8(E) mixer

In order to observe the effects of spurious signals on the CDMA channel, a SPECTRASYS simulation was performed in order to view the spurious signal inside the CDMA channel. In figure 8, the same two mixers are compared for their 2x2 spurious responses. Comparing figure 8(a) and 8(b) the superior spurious performance of the HMC316MS8(E) mixer is clearly reflected in the spurious response at 100 MHz.

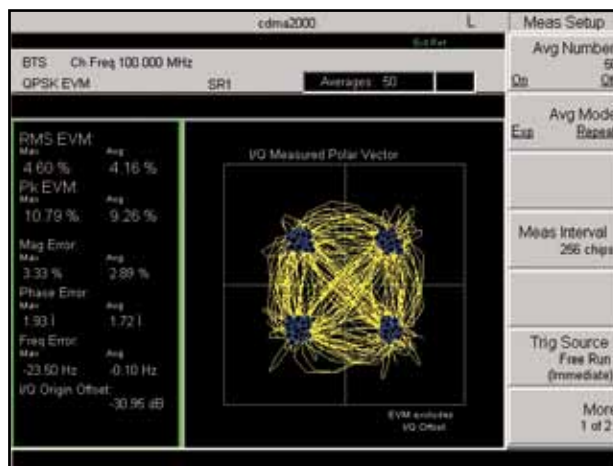


**Figure 8** – Simulated spurious performance of the (a) HMC400MS8(E) and (b) HMC316MS8(E) mixer

In order to see the effect of the spurious signal on the CDMA channel, a measurement of EVM was made on both mixers with the results shown in figure 9. For this measurement, an interferer centered at 2 GHz with +4 dBm power was injected into the RF port of the mixer along with the CDMA signal with -8.6 dBm channel power. The interferer signal was toggled on and off in order to observe the effect on measured EVM. In figure 9(a), the HMC316MS8(E) mixer EVM was measured at 3.4% with the interferer present and 3.4% with no interfering signal. In figure 9(b), the HMC400MS8(E) mixer exhibits an EVM of 3.4% with no interferer, but a noticeable degradation to 4.16% EVM with the interferer present.



(a)



(b)

**Figure 9** – Measured EVM performance of the (a) HMC316MS8(E) and (b) HMC400MS8(E) mixers in the presence of an interferer signal.

**Conclusion**

Increasing the linearity and dynamic range of a cellular receiver will lead to improved system performance, measured by decreased BER and EVM. The dynamic range of the receiver is dependent upon the linearity of the receiver front end which includes the mixer. The use of high IP3 mixers improves the ACPR, EVM, and BER of the receiver. While the IP3 performance of the mixer is critical to the linearity of the receiver, good spurious performance from the mixer is also important in maintaining the quality of the digital channel.

**Notes:**

<sup>1</sup> SPECTRASYS, RF and Microwave Linear simulation software, Eagleware Corporation, Norcross, GA