

Multi-Carrier GSM with State of the Art ADC technology

Analog Devices, October 2002 revised August 29, 2005, May 1, 2006, May 10, 2006, November 30, 2006, June 19, 2007, October 3, 2007, November 12, 2007 and July 15, 2010.

Over the last few years, a new class of BTS has been introduced that provides for a relaxed specification as outlined in the table below. This has eased the requirements for converters for some classes of basestations and this is highlighted in this document.

Frequency band	GSM 400, T-GSM 810, P-, E- and R-GSM 900								DCS 1 800 & PCS 1 900			
	other MS		small MS (Note 1)		BTS except Multicarrier BTS		Multicarrier BTS (Note 2), (Note 3)		MS		BTS including Multicarrier BTS (Note 3)	
	dBμV (emf)	dBm	dBμV (emf)	dBm	dBμV (emf)	dBm	dBμV (emf)	dBm	dBμV (emf)	dBm	dBμV (emf)	dBm
in-band												
600 kHz $\leq f-f_0 <$ 800 kHz	75	-38	70	-43	87	-26	78	-35	70	-43	78	-35
800 kHz $\leq f-f_0 <$ 1,6 MHz	80	-33	70	-43	97	-16	97	-16	70	-43	88	-25
1,6 MHz $\leq f-f_0 <$ 3 MHz	90	-23	80	-33	97	-16	97	-16	80	-33	88	-25
3 MHz $\leq f-f_0 $	90	-23	90	-23	100	-13	97	-16	87	-26	88	-25
out-of-band												
(a)	113	0	113	0	121	8	121	8	113	0	113	0
(b)	-	-	-	-	-	-	-	-	101	-12	-	-
(c)	-	-	-	-	-	-	-	-	101	-12	-	-
(d)	113	0	113	0	121	8	121	8	113	0	113	0

NOTE 1: For definition of small MS, see subclause 1.1.

NOTE 2: In case of either multicarrier BTS class with multicarrier receiver, the inband requirements for frequency offsets $800 \text{ kHz} \leq |f-f_0|$ and blocking signal levels higher than -25 dBm, the performance shall be met X dB above the reference sensitivity level or input level for reference performance, whichever applicable, as specified in subclause 6.2 where X is

- 8 dB for blocking signal levels below -20 dBm, and
- 12 dB for blocking signal levels above -20 dBm.

The relaxed values for multicarrier BTS classes are not applicable for GSM-R usage.

The requirements apply to both multicarrier BTS classes.

The requirements for Multicarrier BTS apply to multicarrier BTS with multicarrier receiver.

NOTE 3: For MSR BS multicarrier BTS requirements apply.

Sample Rate

A true multi-carrier receiver would need to process a band of up to 75 MHz. Therefore, the sample rate should ideally be at least 180 MSPS and as high as 250 MSPS. In cases where the input bandwidth is limited, it may be advantageous to use higher sampling rates to improve noise performance. Therefore, many applications may run a much higher sample rate than otherwise required, simply to improve the noise and linearity performance.

Gain based on 900 MHz Blocking

Typically ADC full-scales are between +4 and +7.5 dBm. The goal of the following analysis is to determine the best performance possible with this technology. The updated standard makes a key change that reduces the need somewhat. First the sensitivity requirements have changed for both band groups listed above. This section covers only the bands below 1 GHz. Above -25 dBm and below -20 dBm sensitivity may degrade by 5 dB. Above -20 dBm and below -16 dBm, the sensitivity is allowed to degrade another 4 dB. This potentially defines a linear degradation in performance by allowing the input signal to increase as the blocker levels increase as indicated in the table above.

Based on the ADC fullscale of +4 dBm rms and +7 dBm peak and given an in-band blocker of -25 dBm, the highest gain possible without clipping would be about 29 dB. Above -25 dBm, AGC is allowed as the level above reference sensitivity may increase. For this discussion, the focus will be prior to desensitization and therefore -25 dBm is the block level used. Given implementation margin and headroom, this could be closer to 25 dB and a NF of 3 dB will be assumed. At blocking levels above -25 dBm, the gain may be reduced. One interpretation of the standard indicates that gain may be reduced by 9 dB between -25 dBm and -16 dBm. Therefore between these levels, the gain could drop to 16 dB, a very low level but sensitivity is also allowed to degrade so it is assumed this is not a problem. Products like the AD9247 and AD6655 can be used to automate this process by taking advantage of the built in fast detect and rms power calculations subsystems.

Optimistic sensitivity at 900 MHz

Under these stated conditions, front-end noise (AFE) presented to the ADC will be -146 dBm/Hz (-174 plus 25 dB gain plus 3 dB NF). A receiver based on pipeline ADC technology should place the RF thermal noise floor about 10 dB larger than the ADC noise floor to avoid reliability issues associated with the non-white characteristics of the ADC noise. See the article titled "DNL and Some of its Effects on Data Converters"¹ for details of the reason why margin is required between the thermal noise floor and the ADC noise floor. Therefore an ideal ADC should exhibit a noise floor around -156 dBm/Hz. As noted in the table above, this is a challenge. Even though the latest specification includes considerations for MC-GSM, it is still a challenge to achieve this 10 dB margin. Therefore, slight relaxations are still necessary.

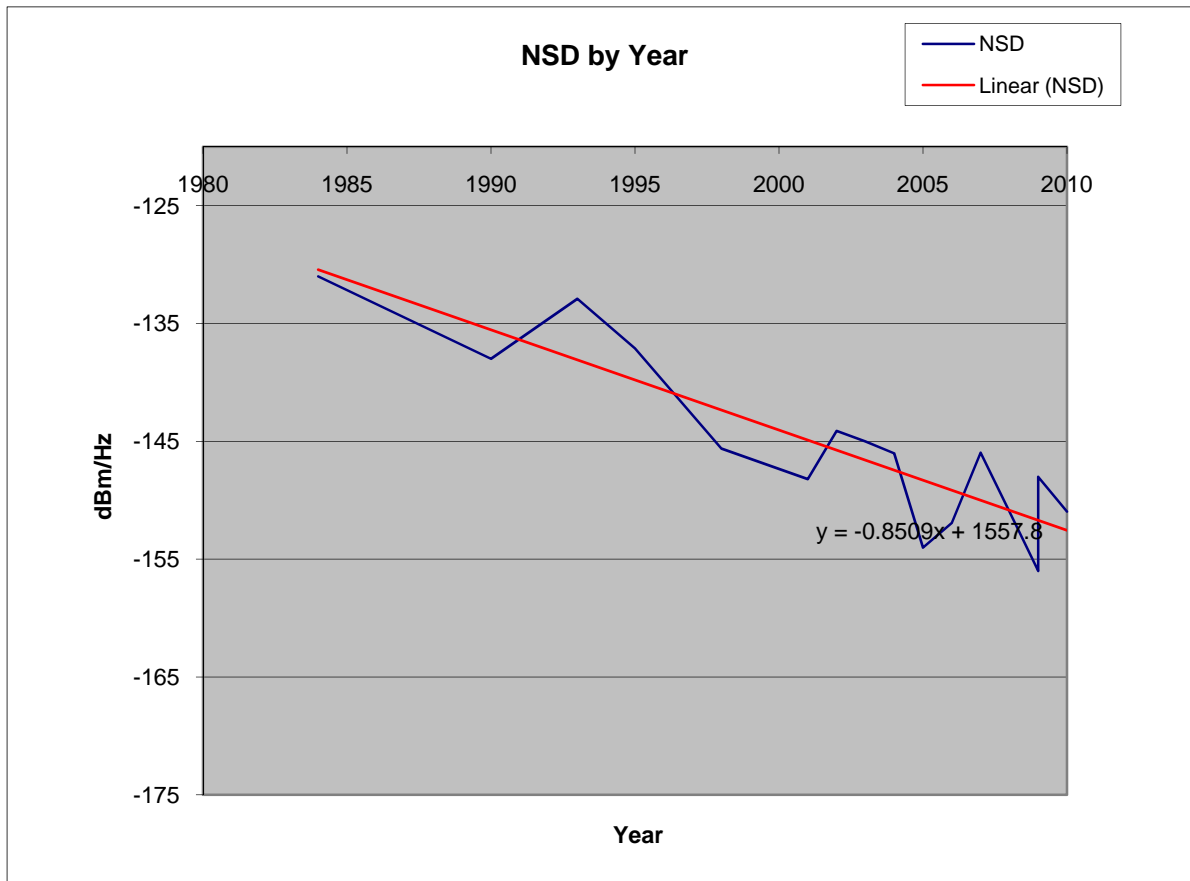
To complicate this issue, most GSM radio manufacturers exceed the reference sensitivity by 6-8 dB and that performance can be extended to MC-GSM platforms as well. For the 900 MHz band, static reference sensitivity is -104 dBm. Yet a NF of about 3 dB will allow a GSM receiver to operate as low as -113 dBm not including phase noise issues from the PLL. More realistic performance can be assumed to be between -110 and -111 dBm.

Given a noise density between -154 dBm/Hz and -156 dBm/Hz, the converter SNR can be determined assuming a specified Nyquist rate. Many converters today run at either 122.88 MSPS and 245.76 MSPS; these yield integrated noises of -77 dBm and -74 dBm respectively. If fullscale of these converters are +4 dBm, this is a required SNR of 81 dB and 78 dB respectively. There is some margin in these numbers and they can be reduced perhaps 2 dB, but reduction below these numbers would compromise integrity of the receiver too much. Therefore, the minimum SNR required would be 79 and 76 dB.

Ignoring the effects of clock and LO phase noise, a receiver based on these converters would be able to simultaneously process a signal at -25 dBm and -110 dBm². To validate this, a -25 dBm signal would be increased to 0 dBm which would provide 4 dB of margin to the converter clip point. Little distortion is expected. A -110 dBm signal would be compared to the noise floor which would be near -174 dBm/Hz + 3 dB. If this is integrated across 200 kHz total noise power of -118 dBm/200 kHz found. This is an SNR of 8 dB. Under this condition, it is expected to be received with a very low error rate.

¹ June 2001, Wireless Design and Development.

² Reference sensitivity is estimated by adding the front-end noise to the converter noise (both -159 dBm/Hz) and then integrating over a 200 kHz channel. This is a noise power of -103 dBm. It is assumed that a signal 5 dB larger than the noise could be processed -98 dBm. Referenced to the antenna this would be -110 dBm.

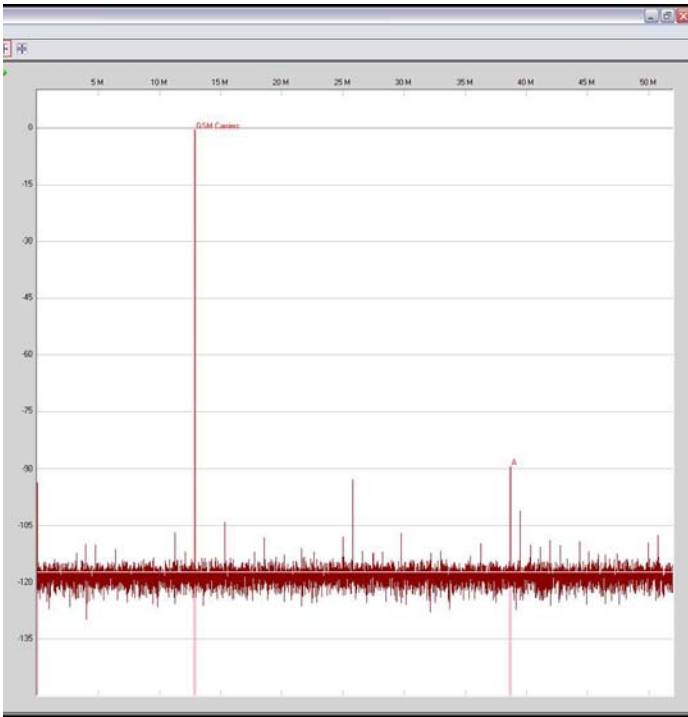


ADC Noise Spectral Density over the last few decades

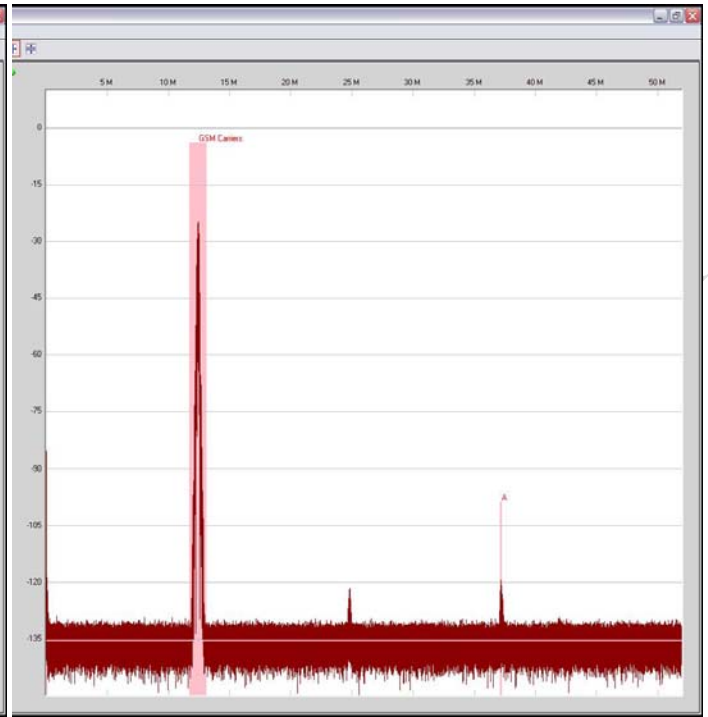
Optimistic blocking at 900 MHz

A signal at -25 dBm could produce a spurious in the ADC that behaves as a co-channel interferer. In this case, the spurious should be 9 dB lower than the desired sensitivity to prevent co-channel blocking. If the receiver were required to provide operation at this level with a signal 3 dB above reference sensitivity, this would mean that a signal of -101 dBm would need to be received in the presence of a -25 dBm blocker. The co-channel requirement is 9 dB. Therefore the generated spurious could be as high as -110 dBm. If so, this would be a minimum SFDR of 85 dBc with an input at -4 dBFS. Given the state of the art, this should not be a significant issue with converter availability.

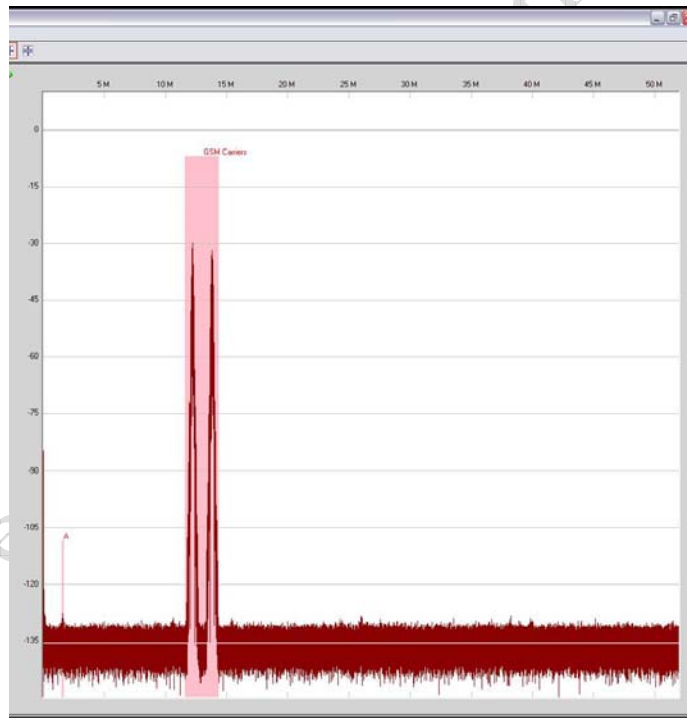
An interesting side note is that while converter performance with un-modulated tones (CW) does limit converter performance, converter performance with modulated signals is significantly better. The figure below shows performance with single and multi-carrier EDGE application. For deployment in bands where CW tones do not exist, spurious performance may well be achieved. The figures below show the same 14 bit converter with a CW tone, a single EDGE carrier and 2 EDGE carriers. In all 3 cases, the peak input drive level was about .5 dB below fullscale. In the case of the CW tone, the SFDR is about -90 dBc. In the single EDGE case, performance is now about -120 dBc remembering that the EDGE power is still fullscale even though it has been distributed across about 200 kHz. Finally for the 2 EDGE case, spurious performance is even better, limited almost entirely by the noise floor of the converter. Multi-carrier EDGE has been demonstrated to be even better. Similar performance can be achieved with WCDMA, CDMA2000 and WiMAX waveforms however, it should at all times be remembered that in the presence of CW blockers performance will be limited by those waveforms.



14 bit ADC driven with CW tone



14 bit ADC driven with 1 EDGE Carrier



14 bit ADC driven with 2 EDGE Carriers

As shown here, spurious performance with modulated waveforms is significantly better than with CW tones. As stated earlier, in applications that can avoid CW tones, performance is coming into line with the required performance. However, as with SNR, SFDR requirements for non-900 MHz applications are relaxed by 10 or more dB. Therefore, current technology exists, even for CW tone tolerance in these bands.

Operation in the 1800 & 1900 MHz Band

Operation in this band is exactly the same as the 900 MHz condition with the exception that there is no condition specified above -25 dBm. Therefore the anticipated performance will be the same as shown in the analysis above. Converter noise floor should be -155 dBm/Hz and spurious should be better than 85 dBFS.

Conclusion

Based on this overview, 900 MHz is now feasible with existing high end converters. Additionally new converters are coming to market with better performance and it is expected that given good design practices, few issues should restrict the performance of multi-carrier GSM receivers give current ADC technology.

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