**Agilent
Highly Accurate Amplifier
ACLR and ACPR Testing with
the Agilent N5182A MXG
Vector Signal Generator**

Application Note

RMS Results | Freq Offset | Ref BW | dBc Lower | dBm | dBc Upper | dBm
Carrier Power | 5.000 MHz | 3.840 MHz | -76.13 | -80.67 | -76.39 | -80.93
-4.54 dBm / | 10.00 MHz | 3.840 MHz | -77.61 | -82.15 | -77.41 | -81.95
3.84000 MHz

Agilent Technologies
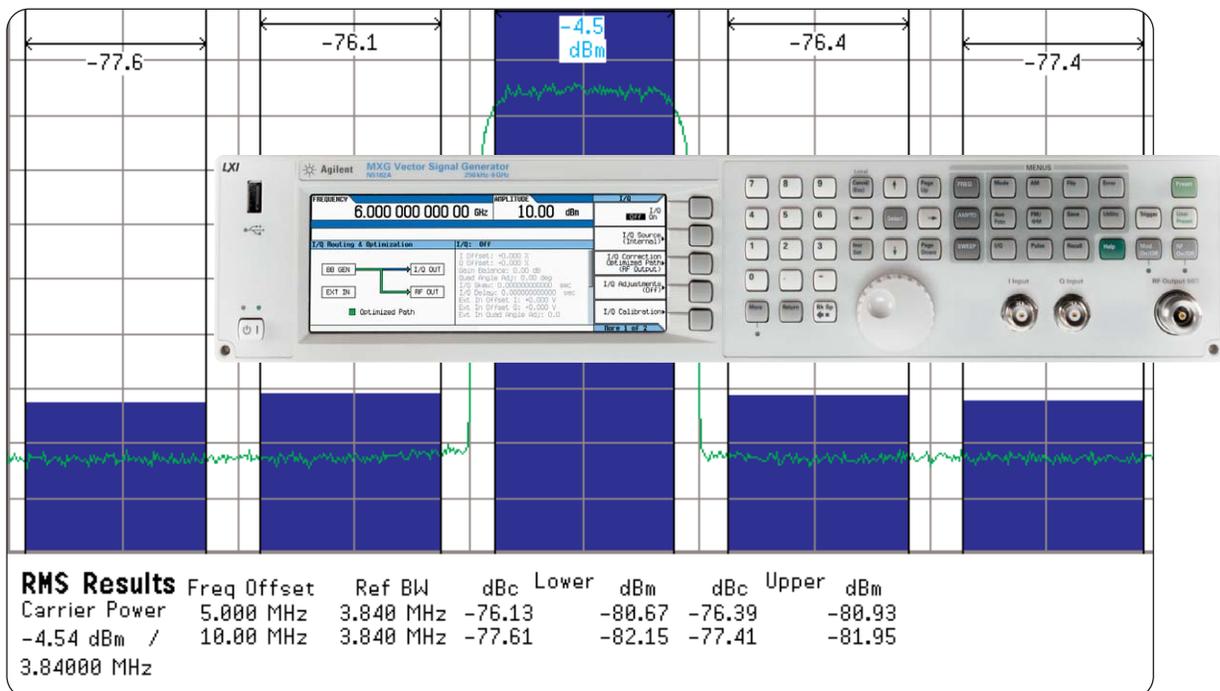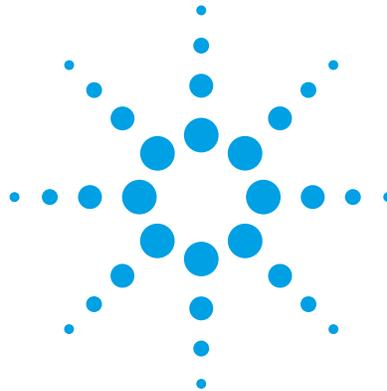
Introduction
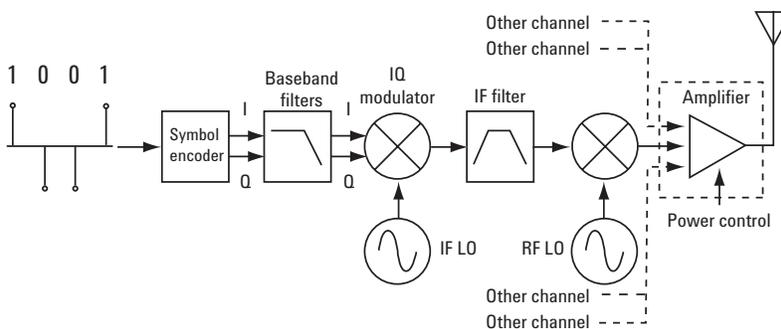
Figure 1. Wireless base station transmitter

Base station power amplifiers, amplifiers used in final transmitter stage prior to digital signal transmission, are a critical component for minimizing out-of-band transmission signals that can cause bit errors in mobile receivers. Out-of-channel signals are comprised of imperfect input IQ waveform spectrums, out-of-channel carrier noise and power amplifier intermodulation distortion. Reducing amplifier power minimizes intermodulation distortion but compromises link performance, while too much power results in compression of the transmit amplifier. This causes high levels of out-of-band signals that will interfere with other transmitted signals, causing bit errors in digital receivers. Testing the adjacent channel interference signal level in power amplifiers to ensure adequate system performance is critical.

Adjacent Channel Leakage
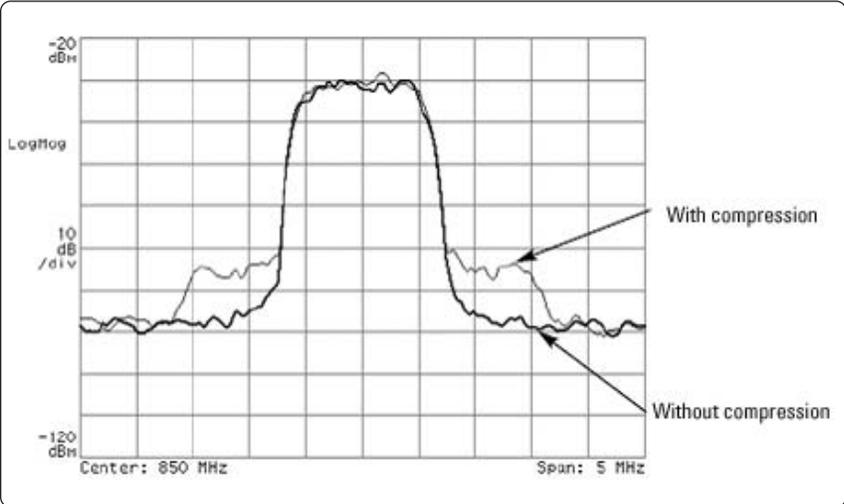
Figure 2. Adjacent channel leakage due to amplifier distortion

A key performance characteristic of transmit amplifiers is adjacent channel leakage (ACL) or adjacent channel power (ACP). The main source of adjacent channel leakage is the non-linear performance of the power amplifier. Traditional adjacent channel testing (for narrow bandwidth channels) uses two or more in-channel tones to measure the out-of-channel distortion (intermodulation distortion). This testing method does not work well for the real applications of most wide-bandwidth wireless systems. A better test is to measure the integrated, out-of-channel signal power within a specific bandwidth using actual or "real" signals, and to compare these results with the integrated in-channel signal power.

For W-CDMA systems, adjacent channel leakage ratio (ACLR) is defined as the ratio of the integrated signal power in the adjacent channel to the integrated signal power in the main channel $P(f_{1intbw})/P(f_{chbw})$ or $P(f_{2intbw})/P(f_{chbw})$ (Figure 3). ACLR is also referred to as adjacent channel power ratio (ACPR) for other waveform formats.
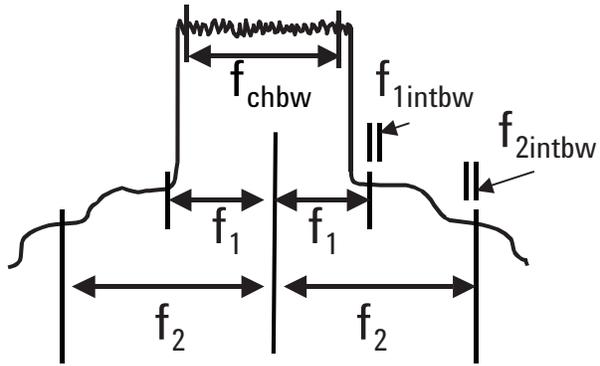

Figure 3. ACLR and ACPR channel bandwidths

For GSM systems, adjacent channel leakage is referred to as the output RF spectrum (ORFS). Each modulation standard tends to have its own method of measuring the adjacent channel signal interference (measured bandwidths, channel spacing and offset frequencies, etc).

Single-Carrier vs. Multi-Carrier Amplifiers

Single-carrier power amplifiers (SCPA) are limited to a single-carrier and require their own baseband unit to operate.

Multi-carrier power amplifiers (MCPA) replace analog interfaces with digital IQ or digital IF designs that shift carrier combining to before the amplifier. This allows one amplifier to service multiple carriers reducing the overall number of components needed in a system.
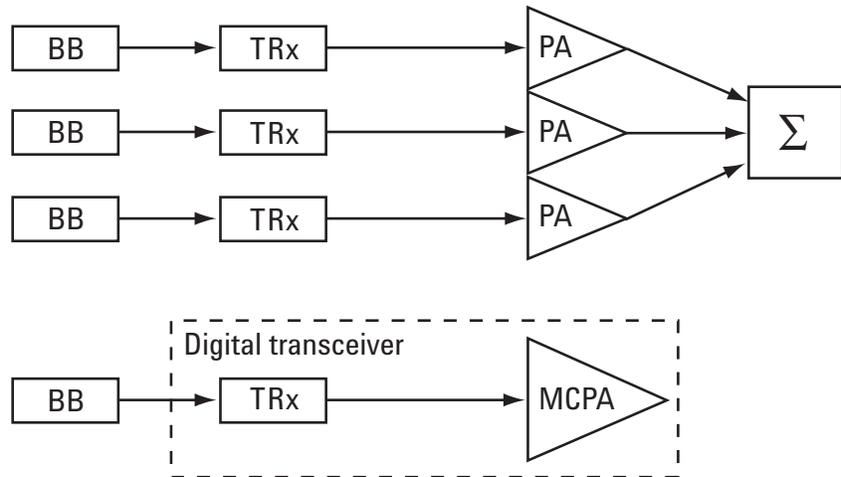

Figure 4. Single-carrier and multi-carrier amplifier transmitter configurations

Constant envelope modulation (low-peak to average signal variation or low crest factor such as in GSM waveforms) allows the amplifier to be very efficient (operate very close to its compression level). High-crest-factor waveforms (such as cdma2000® and W-CDMA) have multiple channels for a single-carrier and require ultra-wide linear range amplifiers to minimize adjacent channel distortion (resulting from high signal power peaks which drive the power amplifier briefly into its non-linear operating region).

W-CDMA implementation places strict requirements on the entire base station ACLR (–45 dBc). To provide transmitter operating margin, most power amplifier producers try to specify –50 dBc or more and it is common for amplifiers to provide ACLR performance in the –55 to –60 dBc range.

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Adjacent Channel Leakage Components

As shown in Figure 5, the amplifier spectral output (P_{out}) is comprised of the input signal (P_{in}) multiplied by the gain (G) plus the amplifier's added noise and non-linear distortion. To accurately characterize or measure the amplifier's ACL or ACP, it is important to exclude the contribution of the test signal. The only way to exclude the test signal's contribution is to use a "real" input test signal that has very low ACL performance and will not contribute to the amplifiers adjacent channel spectral output.

AUT

P_{in}

G

$P_{out} = P_{in}$ x G + Noise + Distortion

P_{in} x G

Amplifier spectral output

Margin
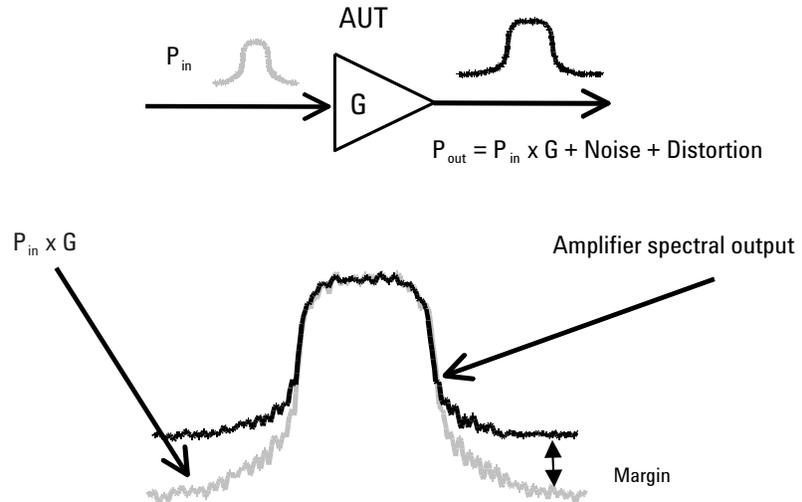
Figure 5. Test signal ACL vs amplifier ACL

If the input signal ACL characteristics are known, then the contribution of the input signal to the amplifier output ACL is also known - P_{in} x G. The total power of the amplifier spectral output in the adjacent channels can be expressed by:

P_{out} (dBm) = 10log(G x P_{in} + (output noise + output distortion))

P_{out} (dBm) = 10log(P1 + P2)

where:
P1 = G x P_{in} and P2 = (*output noise + distortion*)

For multi-channel waveforms such as cdma2000 or W-CDMA, the amplifier output distortion is "noise-like" due to the large number of adjacent channel distortions and the random nature of their phases. Since they are "noise-like", if P1 is known and Pout is known, then it is easy to determine whether or not the input signal's adjacent channel leakage is contributing to the amplifier's ACL or ACP measurement. If the input signal leakage power contribution (P1) is the same power as the amplifier's noise and distortion power (P2), the total measured output power of the amplifier will be 3 dB higher than either one of them: P_{total} (dBm) = 10 log (2 x P1) = 3 dB + 10log(P1).

To achieve accurate measurements of amplifier ACLR, it is necessary to use an input test signal whose ACL is 10 to 15 dB lower than the device being measured. Table 1 illustrates the "error" in dB that "noise-like" $P(G \times P_{in})$ contributes to the total measured output power when it is lower but within 15 dB of the amplifiers ACL power. Power margins > 15 dB provide little, if any, incremental or noticeable reduction in the error contribution.

Table 1. Input signal error contribution vs. power difference (margin)

Margin (dB)	0	1	2	3	4	5	10	15
Error contribution (dB)	3.0	2.5	2.1	1.8	1.5	1.2	0.4	0.2

Agilent MXG Vector Signal Generators

The Agilent MXG vector signal generator provides test signals ideally suited for power amplifier ACLR or other adjacent channel measurements in production. Its wide, flat bandwidth and low distortion characteristics deliver the high-dynamic-range signals (i.e. low ACLR) necessary to make accurate adjacent channel measurements. If more dynamic range is desired, adding Option UNV improves ACL or ACP performance by an additional 7 to 9 dB depending on the modulation format generated.
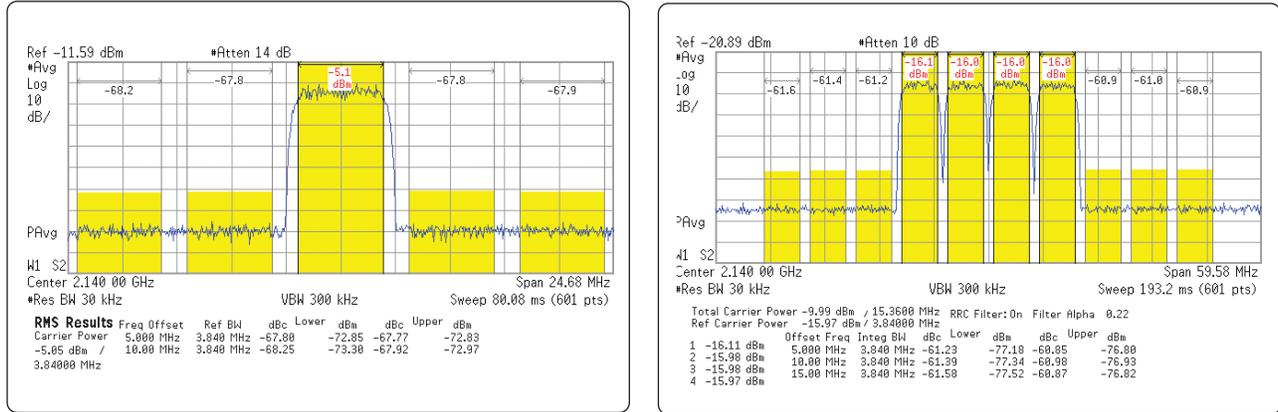
Figure 6. Typical measured ACLR for 1-carrier and 4-carrier W-CDMA for Agilent MXG vector signal generators.[1]
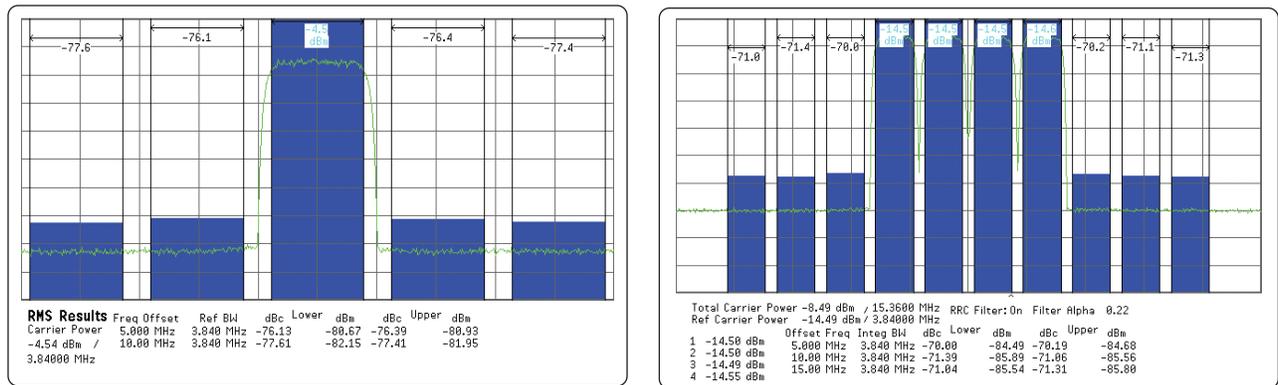
Figure 7. Typical measured ACLR for 1 and 4 carriers using Test Model 1 with 64 DPCH W-CDMA for Agilent MXG vector signal generators with Option UNV .[1]

1. All adjacent channel measurements in this note were made using the Agilent PSA series spectrum analyzers adjacent channel power measurement capability with noise correction enabled.

Simplified design minimizes adjacent channel power

To achieve low adjacent channel signal characteristics, the Agilent MXG vector signal generator starts with a synthesizer that provides low phase noise and low AM noise performance, especially for far-from-carrier offset frequencies. If no distortion is present in the adjacent and alternate channels, then the limiting factor for adjacent channel power is broadband noise (the sum of AM and PM noise).

To minimize or eliminate distortion in the adjacent and alternate channels, the Agilent MXG vector signal generator has an optimized, low distortion design and a circuit layout with few board-to-board interconnects, minimal IQ switching, and a state of the art IQ modulator. The design and layout of the generator combine to minimize out-of-channel distortion. To keep the IQ modulator operating at its optimum (i.e. low ACLR), the design includes an IQ modulator attenuator that can be automatically controlled to adjust the IQ modulator drive level.

Waveform optimization for adjacent channel performance

Waveforms created for the Agilent MXG can vary greatly in crest factor and have abrupt transitions (such as a ramp waveform). These waveform character-istics can cause significant intermodulation distortion in the adjacent channels if the internal arbitrary waveform signal is not optimized to account for them.

The Agilent MXG uses a waveform header which allows a user to provide custom waveform crest factor and scaling information. This information is used to optimize the IQ drive level and runtime scaling. Once the waveform header values are determined and saved, these parameters are automatically used whenever the waveform is recalled for playback.

Crest factor information, in the form of a computed rms value for the IQ waveform, is used to automatically adjust the IQ modulator drive level to minimize adjacent channel distortion. If the rms value of the waveform is not provided in the waveform header and the modulator attenuator setting is placed on AUTO, the Agilent MXG will internally calculate an rms value for the waveform and adjust the IQ drive level accordingly. For those signals that have a high crest factor but a low rms value, the computed rms value in the header can be replaced with a more appropriate value or the modulator drive level can be adjusted manually.

Runtime scaling information, as a percentage of full scale, can also be provided to eliminate distortion caused by over-ranging of the D-to-A converters. A runtime scaling adjustment is important for waveforms that have abrupt transitions (such as ramp waveforms). For example, the runtime-scaling factor for a CW sine-wave waveform is 99%, while the runtime-scaling factor for a triangle or ramp waveform (which has abrupt transitions) is 78%. If runtime-scaling information is not provided in the waveform header, it can be entered programmatically or from the front panel of the Agilent MXG (in real-time) without modifying the original signal.

Viewing and editing a waveform header

A waveform header can be viewed and edited from the front panel of the Agilent MXG. This allows a user to modify header information to better optimize a waveform for a specific situation. For example, if a new value for runtime scaling is preferred for a specific waveform, change the current instrument runtime scaling value and then save the current setup to the waveform header. The next time the waveform is selected, the new value for runtime scaling will be used. Refer to the Agilent MXG signal generator Users Guide for more specific instructions.
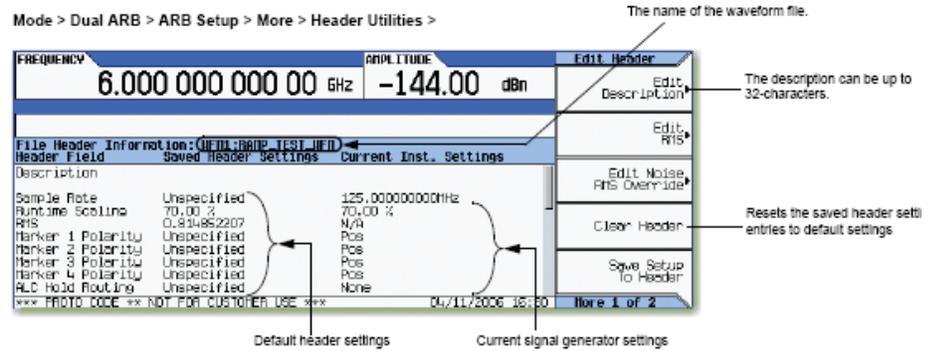
Figure 8. Viewing and editing a waveform header

Typical Agilent MXG adjacent channel characteristics for various signal formats

Figures 9 through 12 show typical adjacent channel distortion measurements for cdma2000, GSM, and WiMAX.
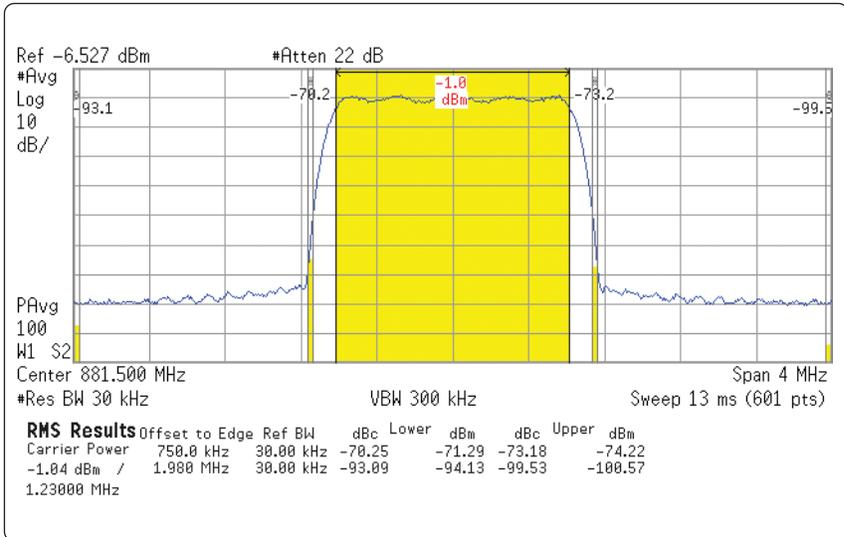
Figure 9. Typical example of ACPR of a single-carrier cdma2000 signal[1]
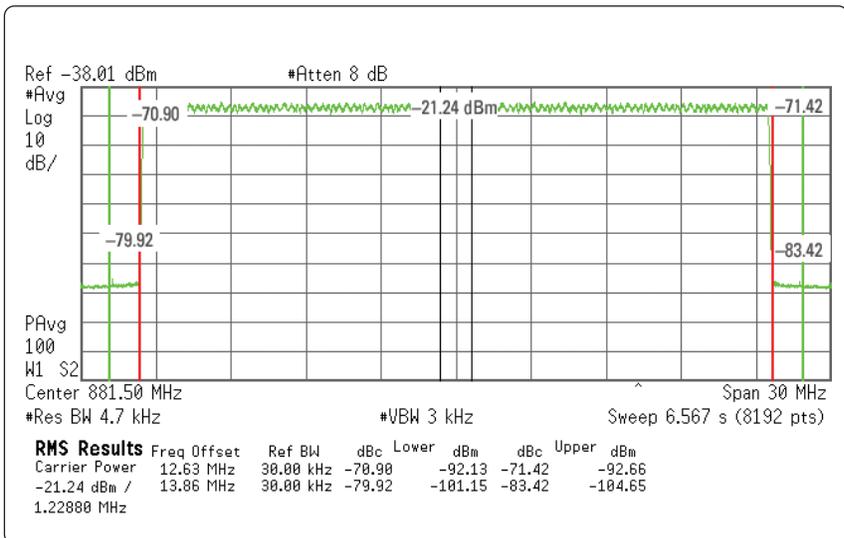
Figure 10. Typical example of ACPR for a 20-carrier cdma2000 signal[1]

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1. All adjacent channel measurements in this note were made using the Agilent PSA series spectrum analyzers adjacent channel power measurement capability with noise correction enabled.

GSM uses the output RF spectrum (ORFS) measurement to determine the adjacent channel power generated by the base station amplifier. There are two methods of measurement: 1) continuous mode and 2) burst mode. Figure 11 shows a GSM burst signal (averaged) along with its measured ORFS information. The 200 kHz and 250 kHz frequencies measure the band edge of the GSM waveform and will not benefit from the extra dynamic range offered by adding Option UNV to the standard Agilent MXG.
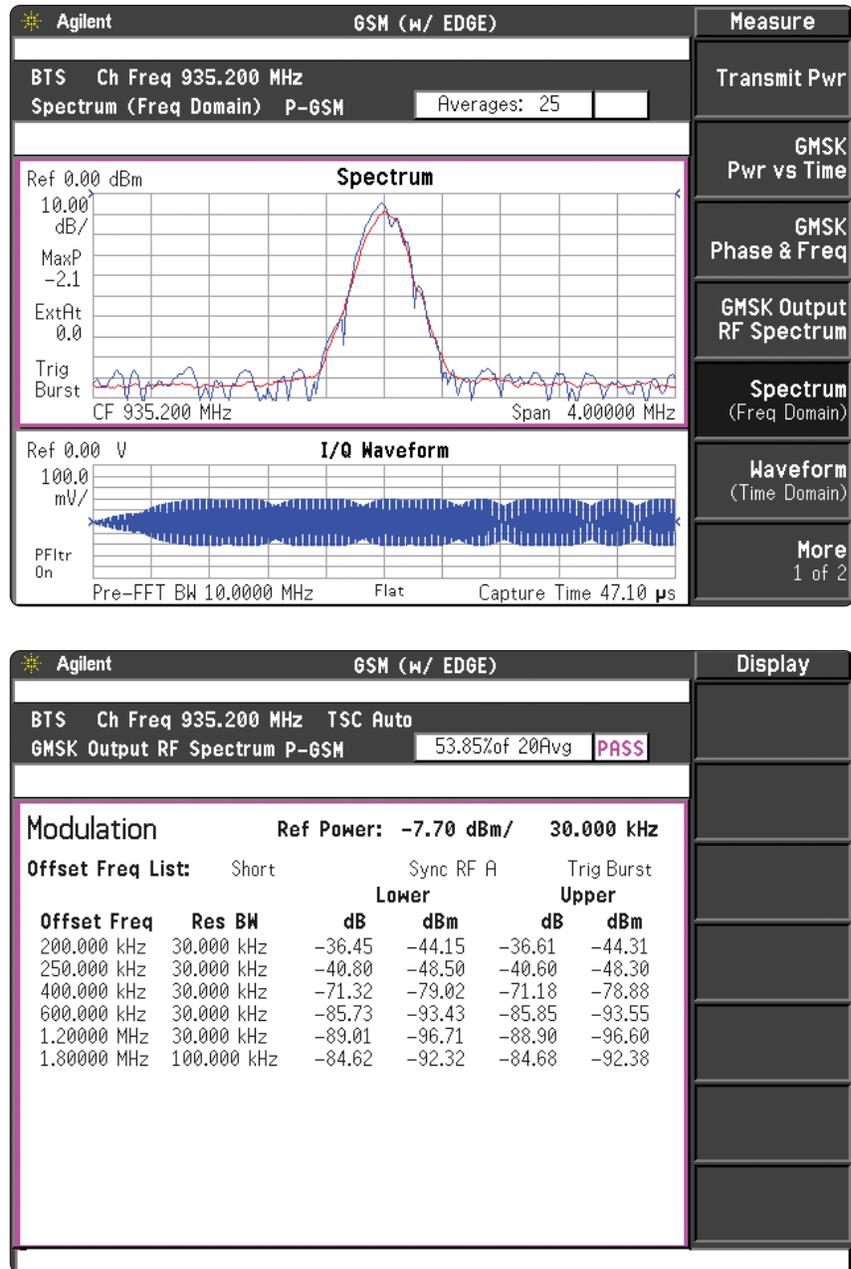
Figure 11 Typical GSM burst spectrum and ORFS performance for Agilent MXG[1]

1. All adjacent channel measurements in this note were made using the Agilent PSA series spectrum analyzers adjacent channel power measurement capability with noise correction enabled.

A WiMAX waveform adjacent channel power characteristic using a traditional ACPR measurement technique is shown in Figure 12. The exceptional ACP performance is due to the low crest factor of this WiMAX signal (some WiMAX signals have higher crest factors).
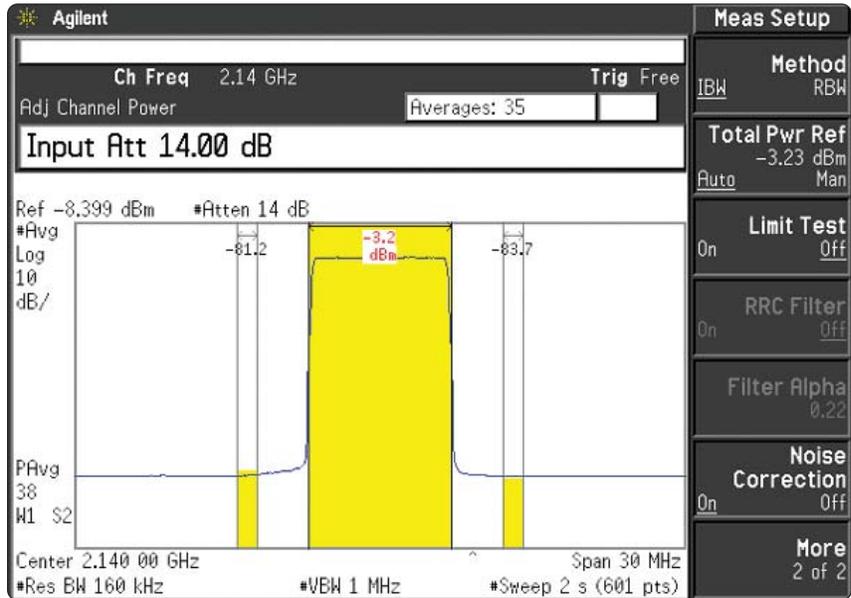
Figure 12. Typical ACPR measurement of a WiMAX signal at 2.14 GHz[1]

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1. All adjacent channel measurements in this note were made using the Agilent PSA series spectrum analyzers adjacent channel power measurement capability with noise correction enabled.

Measuring ALCR of a multi-carrier W-CDMA amplifier

Shown here is an example of a W-CDMA base station amplifier ACLR measurement. The power amplifier's output power is an average 8 watts with an RF Gain of 50 dB. The specified ACLR is –50 dBc for both the adjacent and alternate channels.

Amplifier specifications:

Frequency range: 869 to 894 MHz
Output power: 8 watts average
Input power: –11 dBm (for 8 watts), –1 dBm max
RF gain: 50 dB ±0.5 dB
Gain flatness: 0.5 dB
Input return loss: –18 dB
ACLR: –50 dBc maximum - adjacent and alternate channels
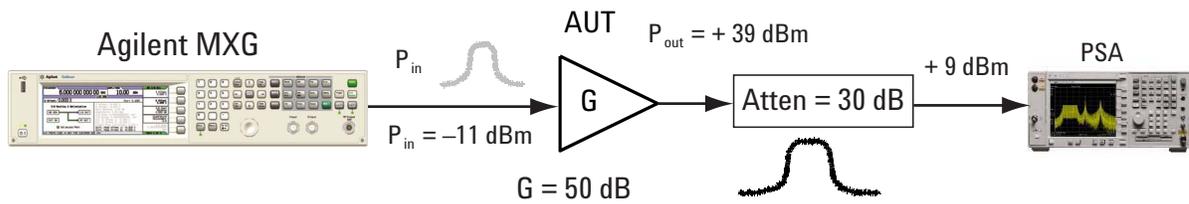
Figure 13. W-CDMA amplifier test configuration

Additional test information:

Fcenter = 881 MHz
W-CDMA = 4-carrier TM1 64 DPCH , –11 dBm total carrier power
Attenuation = 30 dB, air cooled attenuator
Signal generator = Agilent N5182A MXG vector signal generator
Vector signal analyzer = Agilent PSA series spectrum analyzer

The measured ACLR of the input test signal (provided by the Agilent MXG vector signal generator) is approximately –70 dB and –70 dB for the alternate and adjacent channels (Figure 14).
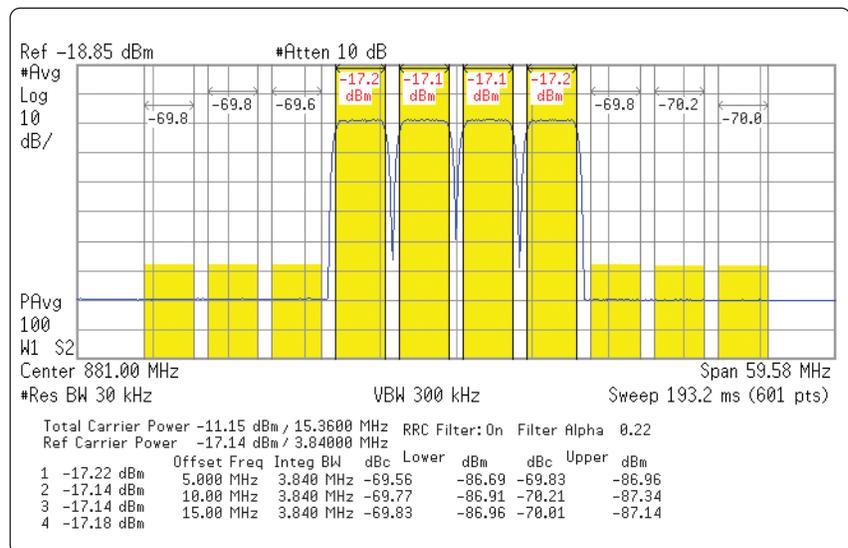
Figure 14 Measured ACLR of the Agilent MXG vector signal generator @ –11.15 dBm total carrier power.

The measured total carrier output power is 8.55 dBm, (approximately –11.15 dBm plus 50 dB gain minus the 30 dB of attenuation) and the measured output ACLR for the adjacent channels is –57 and –52 dBc (Figure 15).
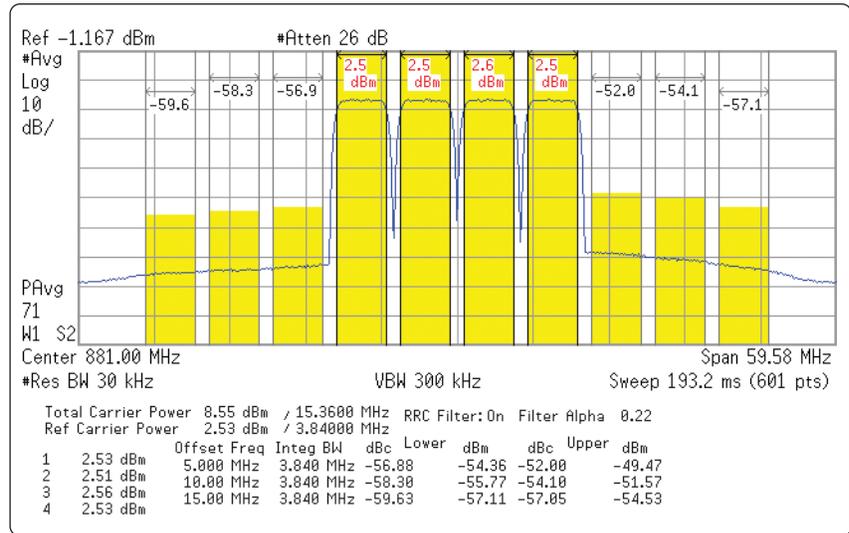
Figure 15 Measured ACLR of amplifier output spectrum

Since the minimum power difference between the input signal (plus the amplifier gain) and the measured output signal in the adjacent channels is 13 dB, the test signal contribution to the amplifier's output adjacent channel power is less than 0.3 dB resulting in a very accurate measurement. The measured ACLR of the amplifiers output spectrum is 2 to 7 dB better than minimum specified performance.

Summary

Characterizing a high power amplifier's adjacent channel distortion requires an input test signal with low distortion that will not mask the amplifier's true performance. The Agilent MXG vector signal generator provides modulated test signals with the low adjacent channel distortion necessary (typically more than a 10 dB margin) to allow accurate amplifier ACLR or ACPR measurements for all waveforms, including those with high crest factors, making it the ideal choice for production applications and challenging R&D waveform development situations.

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