

---

# ADJACENT CHANNEL REJECTION MEASUREMENTS FOR 802.15.4 RADIOS

---

(Formerly document 120-5059-000)

This application note describes the methods used by Silicon Labs to characterize adjacent channel rejection (ACR) on its chips. It also compares different methods used by other manufacturers when quoting ACR performance.

## New in This Revision

Reformat to Silicon Labs standards.

## Contents

1	Introduction.....	2
2	Requirements.....	2
3	Interferer Waveforms.....	2
4	Silicon ACR Results .....	4
5	CoChannel measurements.....	5
6	Conclusion .....	5

## 1 Introduction

Adjacent channel rejection (ACR) is an important parameter for any radio receiver. It is a measure of how well a receiver performs on its frequency channel when there is an interfering system in the vicinity operating on a nearby channel.

ACR is generally one of the parameters that is used to compare the performance of different RF ICs. However, different silicon vendors use different methods for measuring ACR, which may distort performance figures.

This application note presents the method Silicon Labs uses to measure ACR on its IEEE 802.15.4-2003 compliant ICs, and compares it against other methods.

## 2 Requirements

The IEEE 802.15.4-2003 standard specifies a minimum level of ACR that chips must meet. It is defined as follows:

### “6.5.3.4 Receiver jamming resistance

The minimum jamming resistance levels are given in Table22. The adjacent channel is one on either side of the desired channel that is closest in frequency to the desired channel, and the alternate channel is one more removed from the adjacent channel. For example, when channel 13 is the desired channel, channel12 and channel14 are the adjacent channels, and channel11 and channel15 are the alternate channels.

**Table 22—Minimum receiver jamming resistance requirements for 2450 MHz PHY**

Adjacent channel rejection	Alternate channel rejection
0 dB	30dB

The adjacent channel rejection shall be measured as follows. The desired signal shall be a compliant 2450MHz IEEE 802.15.4 signal of pseudo-random data. The desired signal is input to the receiver at a level 3 dB above the maximum allowed receiver sensitivity given in 6.5.3.3. In either the adjacent or the alternate channel, an IEEE 802.15.4 signal is input at the relative level specified in Table22. The test shall be performed for only one interfering signal at a time. The receiver shall meet the error rate criteria defined in 6.1.6 under these conditions.”

Most 802.15.4 ICs exceed the standard's requirements by a long way.

The standard does not specify the filtering of the interferer signal, it only states that it should be 802.15.4 compliant, which means it must meet the spectral mask and error vector magnitude (EVM) specifications.

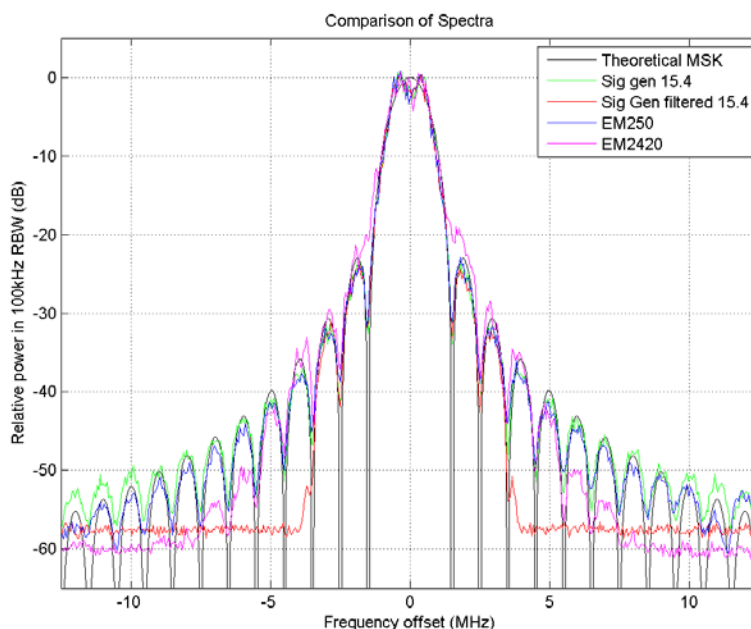
## 3 Interferer Waveforms

For the ACR figures quoted in Ember data sheets, the interferer signal is generated by using the arbitrary waveform generator mode of a signal generator, and constructing a near ideal 802.15.4 O-QPSK waveform containing pseudo-random symbols.

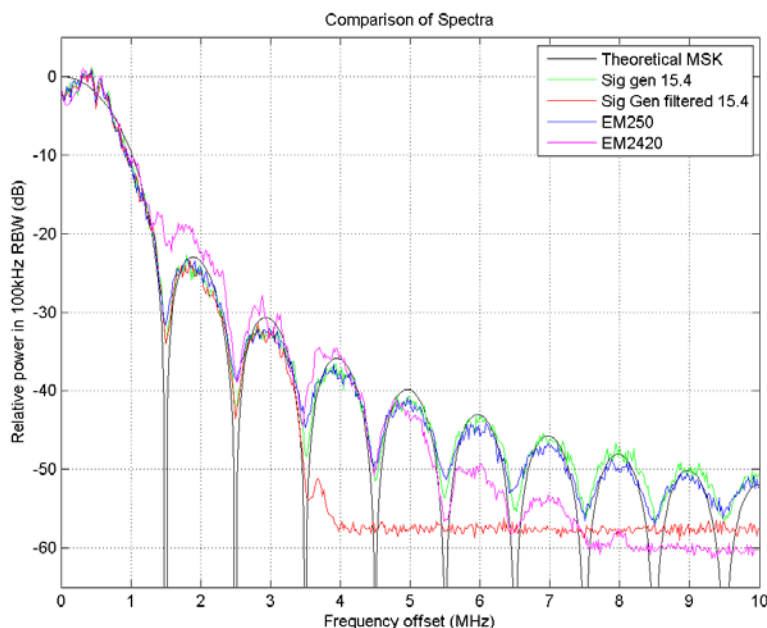
Other manufacturers use a heavily filtered IEEE 802.15.4-2003 signal to measure ACR. This has the result of removing all energy from the interferer's sidelobes that would fall in-band. Silicon Labs has also created such a signal by filtering the ideal signal prior to loading into a signal generator. The filter used was a 100 tap FIR with cutoff frequency at 3.5 MHz so that the 2nd (3MHz) sidelobe is not attenuated, but the 3rd one (4 MHz) is almost completely removed. Whilst this signal is IEEE 802.15.4-2003 compliant (it meets the EVM specified in the standard), it is not representative of any real implementation since this degree of filtering is not practical in real silicon.

Figure 1 and Figure 2 show a comparison of 802.15.4 spectra produced by signal generators and 802.15.4 silicon. Using an ideal signal source, ACR performance is ultimately limited by energy from an interfering signal that falls into the wanted channel bandwidth. Figure 2 shows that at 5 MHz offset, the ideal and real silicon spectra are 42dB below the wanted signal level in a 100 kHz bandwidth. A good receiver will have a 1.1 MHz bandwidth, and the integrated power in this bandwidth is -38 dBc at 5 MHz (1.1 MHz is the bandwidth of the matched filter for optimum signal reception, different receivers may have wider bandwidths than this). Therefore, if a receiver has an SNR requirement of 3 dB, then it cannot achieve an ACR of better than 35 dB. Any data sheet that quotes more than 35 dB for ACR is not using an ideal or even a representative 802.15.4 interferer signal. Whilst some chips may be capable of higher rejection of the main signal lobe at 5MHz, this is of little value since the in-band sidelobe level limits real system performance.

At 10 MHz, the receiver cannot achieve a rejection of better than 48 dB for an ideal 15.4 signal.



**Figure 1. Comparison of Spectra, 25 MHz span**



**Figure 2. Comparison of Spectra, 10 MHz span**

The EM250 modulates the synthesizer loop to generate the modulation, whereas the EM2420 uses a vector modulator with a reconstruction filter. It is this filter that causes the EM2420 signal to roll off beyond 5MHz.

It can be seen that the heavily filtered 15.4 signal generated by the signal generator is not representative of either type of modulation technique, and therefore does not give a useful measure of real performance.

At 10 MHz there is a difference between the two modulation methods of about 10 dB. This means that the vector-modulated signal could show a better ACR if the receiver's own rejection is high enough. However, quoted alternate channel measurements should still use an ideal signal since a system designer cannot know what type of transmitter is used in the interfering node(s).

Note that the standard specifies using an 802.15.4 signal of pseudo-random data for the interferer. This is not the same as using a signal generator to generate an MSK signal with pseudo-random chips, although the effect on ACR is small. The difference between random MSK chips and random 15.4 symbols is the dip in the spectrum at 0 Hz offset.

## 4 Silicon ACR Results

In future data\_sheet revisions Silicon Labs will quote three figures for ACR :

- Ideal 802.15.4 interferer
- Heavily filtered 802.15.4 interferer
- Continuous waveform (CW) interferer (a tone)

The following table shows a comparison of the three methods on Ember silicon (EM250):

**Table 1. Comparison of ACR results**

Channel	Theoretical maximum rejection of ideal signal (dB)	Ideal 802.15.4 signal rejection (dB)	Filtered 802.15.4 rejection (dB)	CW rejection (dB)
-10MHz	48	43	43	43
-5MHz	35	35	47	47
+5MHz	35	35	39	46
+10MHz	48	43	45	45

Theoretical maximum calculation assumes –

- In band signal integrated over 1.1 MHz bandwidth (with flat filter)
- Receiver requires a 3 dB SNR

Measurement conditions are –

- Chips on Ember ceramic balun reference design
- Wanted signal at -82 dBm
- Rejection is the highest interferer level for 1% packet error rate

The CW measurement allows comparison of the actual rejection of a receiver at the channel centre and removes any effect of signal filters used. However, it is still not particularly relevant to real systems.

## 5 CoChannel measurements

It should also be noted that CoChannel interference measurements should be made using a properly modulated IEEE 802.15.4-2003 signal, and not with an MSK signal with random chips. The MSK signal will look like noise to the receiver, whereas a CoChannel IEEE 802.15.4-2003 signal may give worse performance as the receiver sees it as a valid signal.

## 6 Conclusion

Care must be taken when measuring adjacent and alternate channel rejection since the interferer signal characteristics greatly affect results. The only unambiguous interferer signal waveforms to use for IC comparison are an ideal 802.15.4 signal and a CW tone.

The use of a filtered 15.4 signal is not representative of a real world scenario, and is not well enough specified to ensure consistency between manufacturers.

## CONTACT INFORMATION

### Silicon Laboratories Inc.

400 West Cesar Chavez  
Austin, TX 78701  
Tel: 1+(512) 416-8500  
Fax: 1+(512) 416-9669  
Toll Free: 1+(877) 444-3032

Please visit the Silicon Labs Technical Support web page for ZigBee products:  
[www.silabs.com/zigbee-support](http://www.silabs.com/zigbee-support) and register to submit a technical support request

### Patent Notice

Silicon Labs invests in research and development to help our customers differentiate in the market with innovative low-power, small size, analog-intensive mixed-signal solutions. Silicon Labs' extensive patent portfolio is a testament to our unique approach and world-class engineering team.

The information in this document is believed to be accurate in all respects at the time of publication but is subject to change without notice. Silicon Laboratories assumes no responsibility for errors and omissions, and disclaims responsibility for any consequences resulting from the use of information included herein. Additionally, Silicon Laboratories assumes no responsibility for the functioning of undescribed features or parameters. Silicon Laboratories reserves the right to make changes without further notice. Silicon Laboratories makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Silicon Laboratories assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. Silicon Laboratories products are not designed, intended, or authorized for use in applications intended to support or sustain life, or for any other application in which the failure of the Silicon Laboratories product could create a situation where personal injury or death may occur. Should Buyer purchase or use Silicon Laboratories products for any such unintended or unauthorized application, Buyer shall indemnify and hold Silicon Laboratories harmless against all claims and damages.

Silicon Laboratories, Silicon Labs, and Ember are registered trademarks of Silicon Laboratories Inc.

Other products or brandnames mentioned herein are trademarks or registered trademarks of their respective holders.