Application Note
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Adjacent Channel Rejection Measurements

For 802.15.4 radios

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

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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 Ember uses to measure ACR on its IEEE 802.15.4-2003 compliant ICs, and compares it against other methods.

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.

Interferer waveforms

For the ACR figures quoted in Ember datasheets, 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. Ember 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 3.5MHz so that the 2nd (3MHz) sidelobe is not attenuated, but the 3rd one (4MHz) 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 5MHz offset, the ideal and real silicon spectra are 42dB below the wanted signal level in a 100kHz bandwidth. A good receiver will have a 1.1MHz bandwidth, and the integrated power in this bandwidth is -38dBc at 5MHz (1.1MHz 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 3dB, then it cannot achieve an ACR of better than 35dB. Any datasheet that quotes more than 35dB 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 10MHz, the receiver cannot achieve a rejection of better than 48dB for an ideal 15.4 signal.

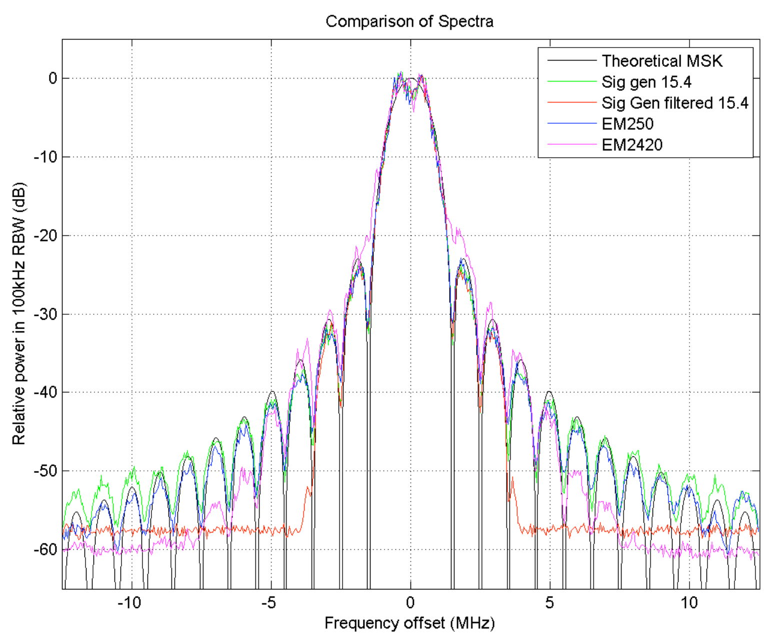

Figure 1 - Comparison of spectra, 25MHz span

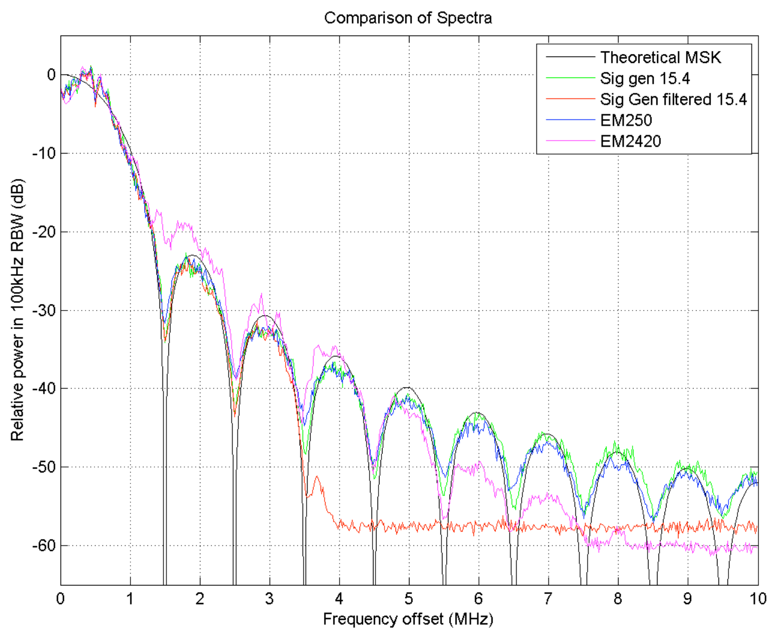

Figure 2 - Comparison of spectra, 10MHz span

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 10MHz there is a difference between the two modulation methods of about 10dB. 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 0Hz offset.

Silicon ACR Results

In future datasheet revisions Ember will quote 3 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 3 methods on Ember silicon (EM250):

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

Table 1 Comparison of ACR results

Theoretical maximum calculation assumes –

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

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.

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.

After Reading This Document

If you have questions or require assistance with the procedures described in this document, please contact an Ember support representative at support@ember.com.

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