SDR-IQ Spurs And Intermod

Dallas Lankford, 1/29/08, rev. 2/5/08

If you listen above 5 MHz, especially above 15 MHz, and do not like spurious responses, you may not like the SDR-IQ.

Shortly after my IQ arrived last June I noticed what seemed to be a few weak international SW broadcast signals between 21 and 23 MHz which should not be there. At first I thought my IQ might have a unique defect. After all, no one had mentioned such spurs. But when I asked another owner about his, I learned that he had similar AM signals which should not be there. Later when man made noise was lower and conditions were more favorable for producing the spurs, I found that these weak signals were indeed off-frequency international SW broadcasters, that they were much more numerous than I had previously thought, and that they could be found over a much wider frequency range. These spurious signals, when they could be heard clearly, almost always sounded (somewhat) like intermodulation distortion, with two (but possibly more) spurious signals occupying the same frequency to which the IQ was tuned.

At first I did not know what caused these spurs. Later I concluded that the only reasonable hypothesis was that they were spurious mixing products. To determine if that was the case, a single HP 8640B signal generator with 400 Hz modulation was connected to the IQ antenna input and set to about -50 dBm output, the IQ was tuned to a fixed frequency, and the 8640B was tuned slowly from 1 to 30 MHz. Multiple mixing spurs were found when the IQ was tuned to virtually any fixed frequency above 5 MHz. My initial discovery of them between 21 and 23 MHz was coincidental... I just happened to be listening to SW broadcasters above 21.45 MHz at the time. Since then I have heard similar spurs down to at least 15 MHz. I have spent little time searching for them between 5 to 15 MHz. Only a few very weak mixing spurs have been found with the 8640B when the IQ is tuned below 5 MHz. I have not heard and it is unlikely that mixing products will be heard below 5 MHz when DXing with an antenna connected to the IQ because of the higher levels of man made noise.

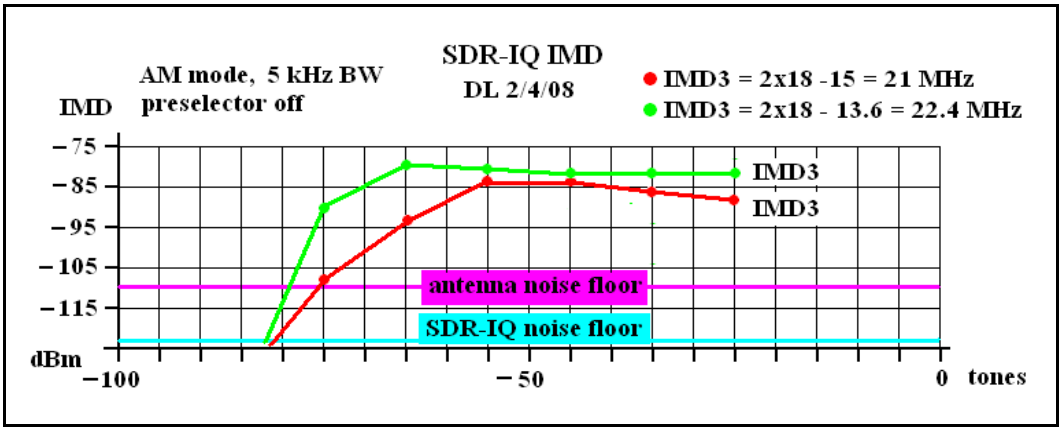
The amplitudes of the mixing products seem to depend in an unusual manner on the amplitudes of the signals which cause them. Weak signals do not cause spurs in the sense that they are too weak to hear. As the causative signals amplitudes increase, the spurs amplitudes increase, up to a point... namely, about -50 dBm at the IQ antenna input. Curiously, as the causative signals amplitudes increase above -50 dBm, the spurs decrease back to inaudibility. And there is not a linear relationship between the causative signals amplitudes and the spurs amplitudes. The spurs amplitudes vary more quickly than the causative signals amplitudes. This causes the spurs amplitudes to fade up and down by substantially larger amounts than the causative signals amplitudes.

Some of the mixing spurs appear to be offset by 6.666 and 3.333 MHz from the signals which cause the spurs. It will be noticed that those two frequencies are 1/10 and 1/20 of the 66.666 MHz clock. But there are other offsets which do not seem to be associated with the 66.666 MHz clock. It not known if the SDR-IQ will keep getting better with regard to its mixing spurs without hardware changes. I would guess not. I bought my IQ for MW listening, so I will keep it, especially after modifying its preamp in mine for improved 2nd order intercepts (to +55 dBm) and improved sensitivity (to 1.25 μV).

After the above was written, Pieter of RF Space emailed me the following. “Most of the spurs that you call mixing spurs are non linearities in the ADC that end up folding every 33.333 MHz. That why they end up at odd frequencies. The main way to get rid of these is by adding half octave filter banks so that you only let the frequency band of interest in. That is why the more filter banks you have the better. There are some spurs that are caused by the choice of digital decimation filters and those can be improved in software.”

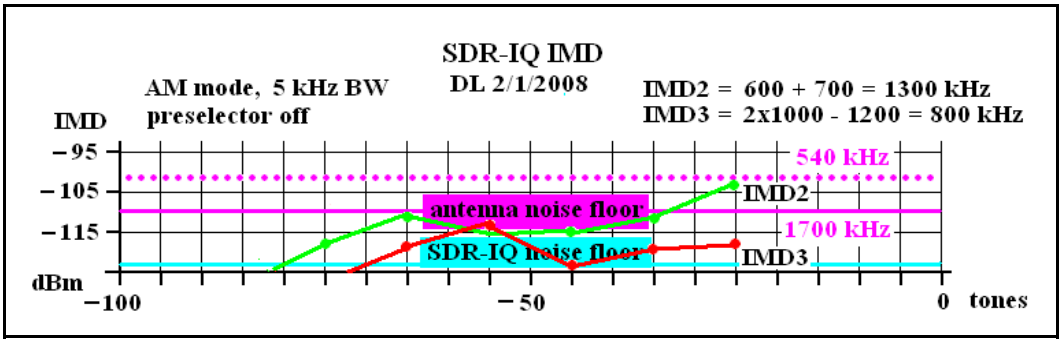
I did not intend to imply that most of the frequencies of the off frequency SW signals were odd. But I suppose that I could have given that impression. In fact, many of the frequencies of the spurious signals end in 5 or 0 kHz. And as I said originally (above), “These spurious signals, when they could be heard clearly, almost always sounded (somewhat) like intermodulation distortion, with two (but possibly more) spurious signals occupying

the same frequency to which the IQ was tuned." At the time I wrote that it did not seem possible that the the spurious signals could be intermod. But after some detailed measurements like those in the graph below, it was determined that many of the off frequency signals were (and are) intermod.



It is well known that intermod in DDC SDR receivers does not obey the usual slope 2 (IMD2) and slope 3 (IMD3) laws which analog receivers obey. The intercepts of DDC SDR receivers depend on the tones levels. For an analog receiver the 3rd order intermod would drop off quickly from the right hand points and not be audible for tones weaker than about -35 dBm, which are quite strong signals. But for the SDR-IQ, the graph above shows that 3rd order intermod around 21 and 22 MHz due to signals at 13.6, 15, and 18 MHz would be audible with my antenna for signals as low as -75 or -80 dBm. This is, in fact, the case, as I verified by listening. Later I heard closer spaced intermod in the 16 meter band, such as 2x17.435 – 17.595 = 17.275 MHz , 2x17.775 – 17.595 = 17.955 MHz, and in the 19 meter band, such as 2x15.590 – 15.130 = 16.050 MHz. I have also heard a few weak occurrences of relatively close spaced 3rd order intermod around the 31 and 25 meter bands. Suitable filters may eliminate the spurious signals around 21 and 22 MHz. However, there are no filters sharp enough to eliminate close spaced 3rd order intermod.

Thus, there are at least 3 potential causes of spurious signals in an SDR-IQ at higher SW frequencies, namely mixing spurs, non linearities in the ADC that end up folding every 33.333 MHz, and intermodulation distortion products. It is often not trivial to determine which type of spur one is listening to.



Fortunately for MW DXers, the SDR-IQ MW intermod is substantially lower than its SW intermod. The 2nd order intermod in the graph above is for my SDR-IQ which has a modified preamp that is about 15 dB lower than 2nd order intermod in an unmodified SDR-IQ. The 3rd order intermod is the same for both a modified and an unmodified SDR-IQ, and so should not be a problem in the MW band. A description of my SDR-IQ preamp mod is contained in an article in The Dallas Files.

For weak signal listening above about 5 MHz (just to be sure), and certainly above 15 MHz, I use some other receiver. For example, I have been using a Perseus for a few weeks now, and it seems to be a much better

receiver than the IQ with respect to spurs (the Perseus has few of the garden variety spurs which are so weak that they will not be heard in normal listening situations, and no mixing spurs), intercepts (the Perseus IIP2 and IIP3 are more than 15 dB greater than the IQ even after my IQ preamp mod), and intermodulation distortion due to lower signal levels.