Dynamic Range tests of WSJT X and WSPR on 630m using AGC with IC-7300

Executive summary:

The dynamic range of the system, which consisted of an Icom IC-7300, a Monitor Sensors 160m to 630m transverter, and an HP Elite 8300 i7 computer, is approximately 75 dB when running AGC. Impulse noise capturing AGC may be more of a problem with shorter cycle times, such as with FT8's 15 second cycle time, than with JT9's 60 second or WSPR's 120 cycle times.

Impulse noise capturing AGC is a design flaw in most radios with DSP that have shipped in the past 10 years, exclusive of the Elecraft K3 or K3S, late Apache SDR software, and some Ten-Tec products.

Test signals:

Stable WSPR signals over a two hour period from K5DNL in Oklahoma and KC3OL in Kansas from 1910Z to 2112Z (1210 to 1412 PM MST) were used for the desired decoded signals. Those two stations are 540 and 528 miles away from my QTH in Colorado. The decoded signal levels from K5DNL were -10 dB +/- 1 dB over that entire time, and KC3OL a constant at -24 dB until peaking at -21 dB for the last decode at 2112Z. These decode levels held constant until an injected interfering signal degraded reception by 3 dB.

With the normal WSPR audio range of 1400 to 1600 Hz, transmissions from K5DNL were on 1506 Hz and KC3OL on 1558 Hz. An interfering RF signal was injected producing a third signal at 2500 Hz, and that interfering signal level was varied over an 80 dB range. Receiver bandwidth was 2800 Hz. When the interfering signal was set at -80 dBm, it equaled K5DNL's signal on the WSJT X spectrum scope. When the interfering signal was -95 dBm, it displayed approximately the same as the signal from KC3OL on both the spectrum and waterfall displays. The test signal absolute level is explained in the test equipment setup section.

Unknown weak constant-carrier signals and band noise read S2 on the IC-7300 S meter, regardless whether the WSPR signals were transmitting. K5DNL at a -10 dB decode level did not affect the S meter reading, nor did KC3OL at -24 dB decode level. The only other amateur signals observed on the band while these tests were in progress, were KA7OEI in Utah at -27 to -29 dB, and W7IUV in Washington state at -30 dB. Those two decoded stations transmitted less frequently, or were decoded less frequently, possibly due to QSB. Since neither the -10 dB nor the -24 dB decoded signal was ever degraded until all in-band signals were degraded, the dynamic range of the system may be as high as 80 dB if the -30 dB decoded signal from W7IUV is included.

When the interfering signal was increased from -80 dBm to -20 dBm in 10 and later 5 dB steps, there was no degradation in decode of either WSPR signal. Additionally, there was no change in the color or width of the waterfall graphic. When the interfering signal was at -20 dBm, the S meter on the 7300 read S9+20 dB, compared to a reading of S2 for the band noise, extraneous carriers and the desired WSPR signals. As a frame of reference, K0KE who is 78 miles away decodes a JT9 transmission at a +18 and reads S9 on the IC-7300 S meter. The WSJT manual explains the meaning of the decode strength numbers.

"Signal reports are specified as signal-to-noise ratio (S/N) in dB, using a standard reference noise bandwidth of 2500 Hz. JT65 reports are constrained to lie in the range –30 to –1 dB, and values are significantly compressed above about -10 dB. JT9 supports the extended range –50 to +49 dB". I have never seen a WSPR decode lower than -30 dB, or a JT9 decode lower than -28 dB.

Only when the interfering signal was increased to -15 dBm was decode copy affected. At that point the 7300 S meter read S9+25 dB. The decode level of K5DNL dropped 4 dB and the decode level of KC3OL dropped 3 dB. Additionally, the waterfall display showed similarly degraded signal levels, weakening in width and density. The other extraneous carriers also showed changes in signal level on both the spectrum display and the waterfall display on the WSJT X console.

Radio equipment and test equipment setup:

To operate on 630m I use a Monitor Sensors transverter between 160m and 630m. The transverter only needs 5 watts of drive to output its nominal 50 watts on 475 kHz. A 100-watt exciter, however, has increased phase and broadband noise reference the desired signal when operated at such a low level. To solve this issue I insert a 10-dB 75-watt Bird in-line attenuator between the transverter and the antenna jack of the IC-7300. This improves the broadband noise emissions of the 630m signal by 9 dB. The transverter itself does not degrade broadband noise any significant amount. The 7300 has its 20 dB attenuator enabled all the time. The transverter has a net gain of 6 dB on receive, thus total attenuation of the 630m band is 24 dB, resulting in a band noise of S2 when no signals are in the 2.8 kHz passband. Note: Icom S units are about 3 dB from S5 to S9, and about 2 dB per S unit from S1 to S5.

A Mini-Circuits hybrid combiner rated from 100 kHz to 400 MHz was used to inject the interfering signal. This added 3.1 dB of additional insertion loss, and has a nominal 28 dB of isolation between ports. This combiner was inserted before the 10-dB 75-watt attenuator, providing an excellent return loss to the combiner. An HP 8642A synthesized generator was used to inject the interfering signal into one port, and the output of the transverter fed the other port.

The actual signal level going into the 7300 is 10 dB lower than the values listed above due to the 10-dB in-line attenuator. Note: There is no point in band noise reading significantly up-scale on an S meter.

Conclusion:

While anyone can adjust receiver gain manually with AGC OFF if they desire, these tests imply that there is little reason to do so. If a desired signal can be consistently decoded that is 75 dB, and possibly 80 dB weaker than an undesired signal in the same passband, I fail to see why the receiver's AGC shouldn't determine net receiver gain. With a legacy receiver there are few ways to know how to set attenuation, be it with an RF gain control or with the receiver's attenuators. Some direct-sampling receivers have an overload enunciator, while others do not. If the OVF (overflow) indicator of an IC-7610 or IC-7300 is all an operator has to go on, that isn't extremely helpful if one is manually setting receiver gain.

Rev C