Icom IC-7300 and the OVF display

The maximum level of a digital, direct-scan receiver is determined by the clipping (saturation) of its ADC. For visual indication of overflow, the Icom IC-7300 and IC-7610 have an "OVF indicator" in the display, which lights up whenever the receiver is overdriven. Analog superheterodyne receivers do not have such a display, the overflow of the 1st mixer starts slowly and relatively early and is usually not noticed by the user (Fig. 1).

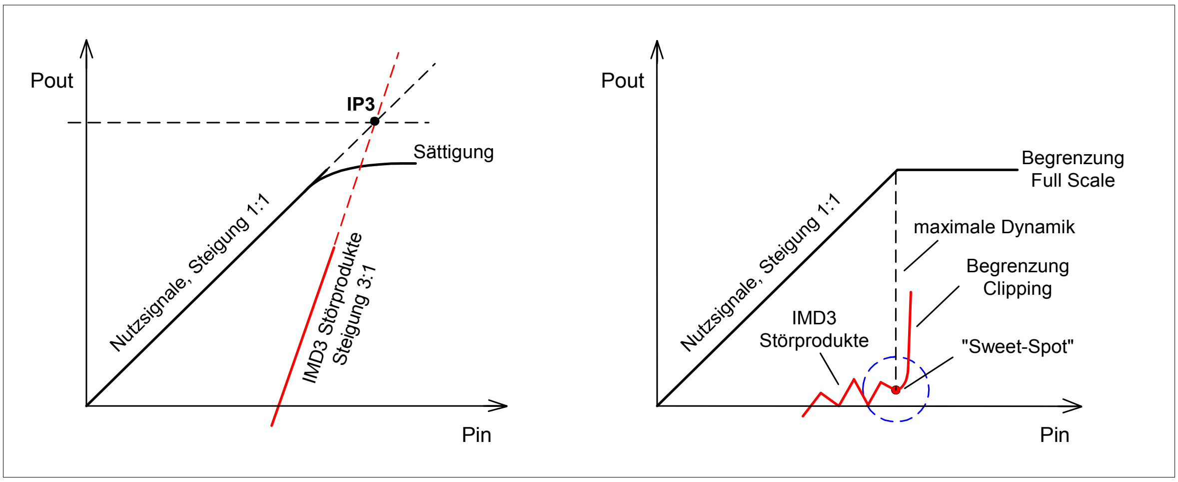

Figure 1: IM curve of an analog (left) and digital receiver (right)

On the other hand, a ADC can be driven up to just before its limit and - in contrast to a mixer - only feels really "comfortable" at high levels and only then delivers its greatest IM-free dynamics, e.g. of 100 dB (sweet spot). However, if the ADC is then only slightly overdriven, it produces almost suddenly strong intermodulation and further reception becomes impossible. Another problem can arise with small signals, because an ADC - again unlike analog receivers - generates undesirable IM products even at low levels, which can be visible as spikes in the background noise. The dither and random function provides a remedy. The many fundamental differences between analogue and digital receivers should be noted and known, and then many "phenomena" will explain themselves.

OVF (ACD clip display)

In this test, the receiver is set 10 kHz above or below the transmitter signal and the level of an injected CW signal is increased until the OVF (Overload) indicator lights up (Table 1) (Fig. 3). The receiver can only be overdriven by signals that are outside the receive frequency; otherwise the automatic gain control (AGC) will attenuate the signal. Therefore fs=7.100MHz and fe=7.110MHz.

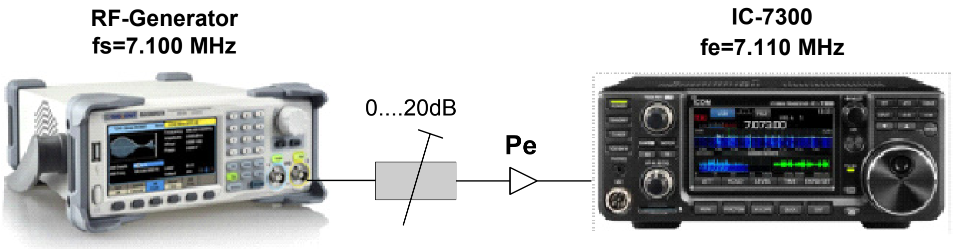

Figure 2 Clipping the IC-7300 by a CW signal

Result: The IC-7300 is driven by a sine signal (CW-Signal) on all bands with a level of Pe=-8dBm (0.16mW = 90mVeff = S9+65dB) in limitation (saturation) (Table 1) (Fig. 3). If the level is reduced from -8 dBm to -9dBm, so only by 1dB, the OFV display goes out and the receiver is back in the linear operating range. This is proven by the previously mentioned abrupt limitation of an ADC in case of overload.

Frequenz	1,8 MHz	3,6 MHz	7,1 MHz	14,1MHz	21,1MHz	28,3MHz
OVF, Clipping-Level	-8 dBm	-8 dBm	-8 dBm	-8 dBm	-8 dBm	-8 dBm

Table 1: Clipping of the IC-7800 in dependence of the frequency

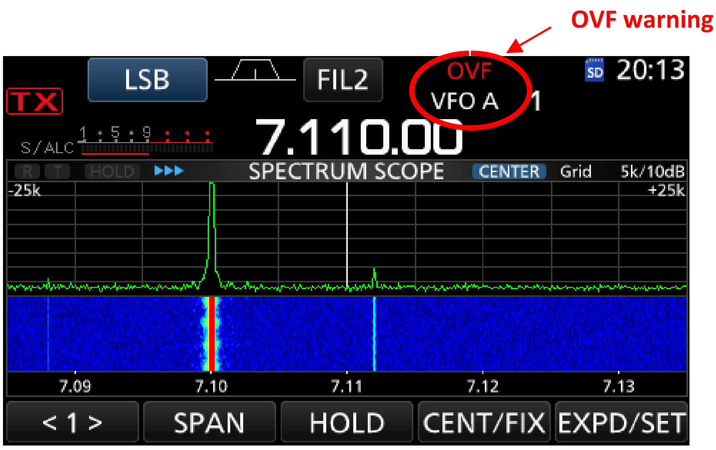

Figure 3: Overflow (OVF) at Pe = -8dBm

OVF-indication via a noise signal
However, determining ADC clipping with only a single sinus signal, as shown in Figure 3, is not practice-oriented. Via an antenna, the IC-7300 simultaneously receives many signals of different frequency and power, which as a sum can exceed the limit of the ADC. For this reason, the clipping should be measured either with very many individual CW signals or with a constant white noise signal.
Note: Determining the large signal strength (clipping) of a receiver using a noise signal is a "hard" measurement method, similar to an NPR measurement. If the receiver has a preselector in the RF input of e.g. 2 MHz bandwidth, a 2MHz wide constant white noise band is fed to the ADC, which corresponds to approx. 4000 equally large 500Hz wide signals. The result of such a measurement therefore always corresponds to the "worst" that can happen to a receiver. But this is exactly what we want to find out.

For this we connect the input of the IC-7300 to a noise generator, which produces a constant white noise band of 0-30MHz, with a noise power of P_{Noise} = 0dBm (224mV into 50 Ohm). Starting at a level -20dBm, the noise is increased until the OVF display starts just to flicker (Fig. 5).

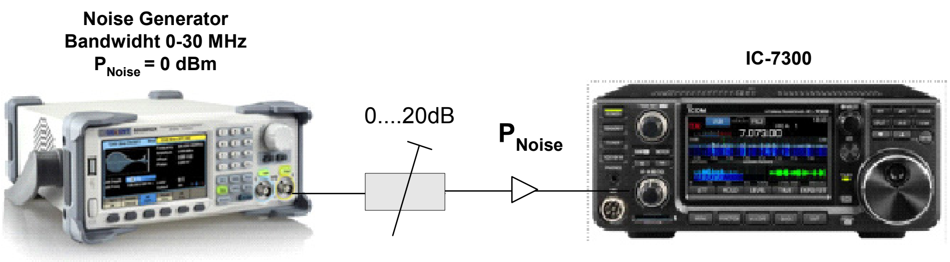

Figure 4: Determining the limitation with a noise signal

Frequenz	1.8 MHz	3.6 MHz	7.1 MHz	14.1 MHz	21.1 MHz	28.3 MHz
Preselektor (BPF)	1.6 - 2 MHz	3 - 4.5 MHz	6.5 - 8 MHz	10 - 15 MHz	15 - 22 MHz	22 - 30 MHz
Bandbreite	400 kHz	1.5 MHz	1.5MHz	5.0MHz	7 MHz	8 MHz
OVF, Clipping-Level	**-5 dBm**	**-8 dBm**	**-11 dBm**	**-14 dBm**	**-17 dBm**	**-17 dBm**

Table 2: OFV as a function of a noise signal

In contrast to the measurement with a CW signal, the clipping level now decreases with increasing frequency (Table 2). This is due to the different bandwidths of the preselectors in the front-end of the IC-7300, depending upon his receiving frequency. At e.g. fe =1.8 MHz (160m-band) the IC-7300 uses a bandpass filter with a bandwidth of only 400 kHz and at 28.3 MHz (10m-band) a bandpass filter of 8 MHz bandwidth is used. According to that, the bandwidths of the preselectors alone determine the noise level at which the ADC moves into limiting mode (Fig. 5).

The results are shown in Table 2: The smaller the bandwidth of the preselector in the input of the receiver, the greater the large signal immunity of the receiver, and vice versa.

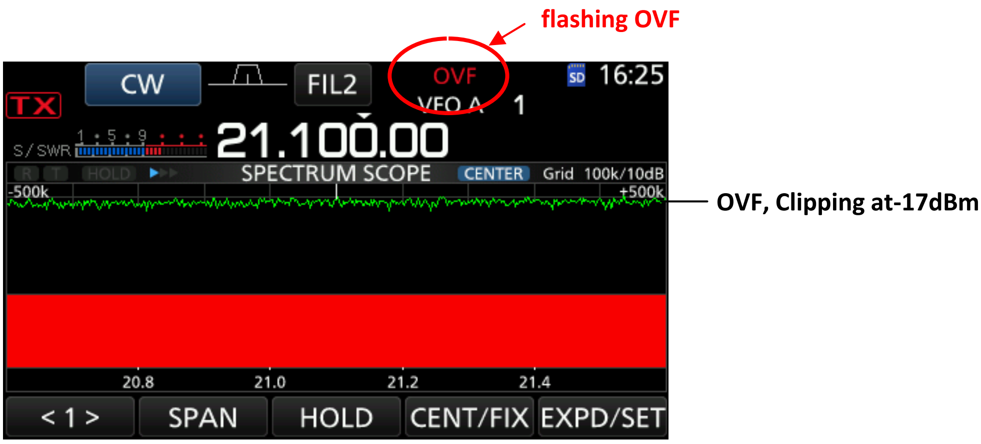

Fig. 5: OVF indication in the 15m band at a noise power line of -17dBm

OVF and NPR

However, the OFV display offers further advantages, you can also use it to determine the NPR (Noise Power Ratio) of the IC-7300 on all bands! Normally a noise generator and a sharp notch filter are required for NPR measurements (Fig. 6). The noise is increased until the ground noise in the base of the notch filter is minimally increased, which is a sign of the beginning overdriving of the ADC. The maximum NPR of the receiver is reached at this moment and corresponds to the difference between the maximum input noise power (P_{TOT}) and the sensitivity (MDS). Figure 7 shows the NPR result of the IC-7300, measured by a notch filter at fe =2.4MHz. At a noise level of P_{TOT} = -8dBm the max. NPR of 76dB is reached.

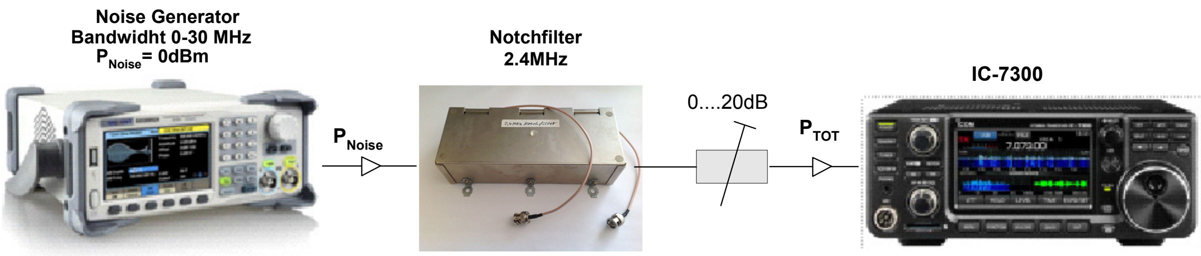

Figure 6: NPR measuring station with notch filter

It is important to note here: At exact the same level, however, the OFV display also lights up! This gave me the idea to determine the NPR of the IC-7300 even without a notch filter by using the OVF display as an indicator for P_{TOT}! The IC-7300 acts as the measuring instrument.

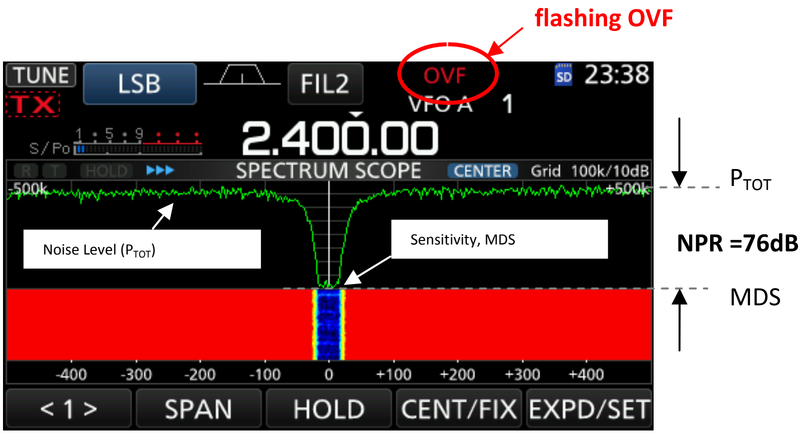

Figure 7: NPR measurement via a notch filter at 2.4MHz

The measurement in Figure 8 shows my experiment. I removed the notch filter and increased the noise level until the OVF just started blinking. For this I needed the same noise level (P_{TOT}) as before with the notch filter, namely -8dBm! The resulting NPR can also be determined directly from the spectra, it corresponds to the difference between the generator noise line (P_{TOT}) (Fig. 8, left) and the sensitivity noise line (MDS) (Fig. 8, right). Result: The determined NPR is identical with and without notch filter!

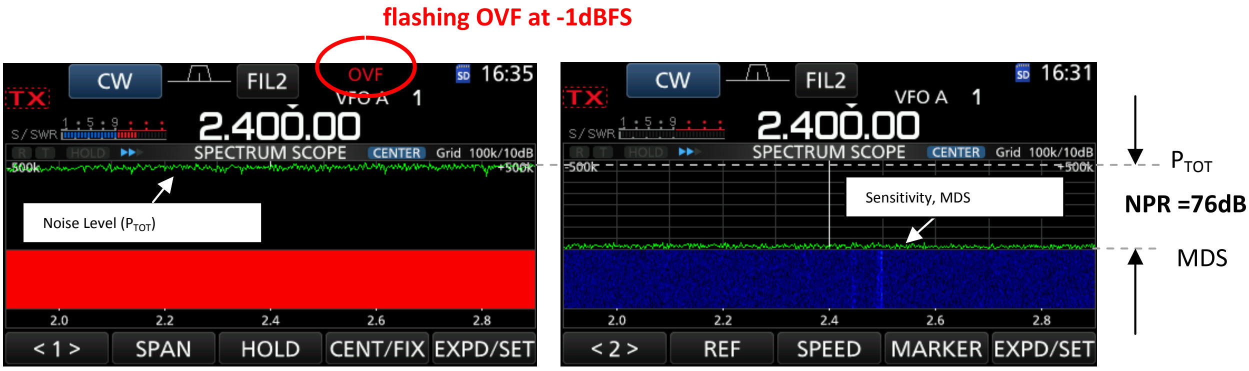

Figure 8: Noise line for clipping (left) and MDS line (right), difference between both lines: NPR

As the screen resolution of the IC-7300 is not so good, the NPR should be calculated. For calculation we still need the sensitivity of the IC-7300 on all bands. How to measure the sensitivity I already described in (1).

Outgoing from the determined clipping levels and sensitivity on all bands the NPR of the IC-7300 can be calculated by the following formula

NPR = PNoise - 10log (noise bandwidth/resolution bandwidth) - sensitivity

Example for the NPR calculation at fe =21.1 MHz (15m band):

At a noise level of P_{TOT} = -17dBm the OVF display starts flashing and the maximum ADC output level is reached. This results in a NPR of

NPR = -17dBm - 10lg (30MHz/500Hz) - (-133dBm) = -17dBm - 48dBm + 133dBm = 68dB

Table 3 shows the determined NPR values from 1.8 to 28.3MHz (160-10m band).

Frequenz fe	Empfindlichkeit (MDS) B=500Hz	Preselektor	Preselektor Bandbreite	OVF Clipping	S-Meter	NPR
1.8 MHz	**-131 dBm**	1.6 - 2MHz	400 kHz	**-5 dBm**	S9+68	**78 dB**
3.6 MHz	**-132 dBm**	3 - 4.5 MHz	1.5 MHz	**-8 dBm**	S9+65	**76 dB**
7.1 MHz	**-134 dBm**	6.5 - 8 MHz	1.5 MHz	**-11 dBm**	S9+62	**75 dB**
14.1 MHz	**-134 dBm**	10 - 15 MHz	5 MHz	**-14 dBm**	S9+59	**72 dB**
21.1 MHz	**-133 dBm**	15 - 22 MHz	7 MHz	**-17 dBm**	S9+56	**68 dB**
28.3 MHz	**-132 dBm**	22 - 30 MHz	8 MHz	**-17 dBm**	S9+56	**67 dB**

Table 3: IC-7300, NPR from 1.8MHz to 28.3MHz, calculated from OFV clipping (P_{TOT}) and sensitivity

The bar chart in Fig. 9 clearly shows that the NPR (the large signal handling capability) of the IC-7300 decreases with increasing frequency. NPR ranking of receivers: 65 to 70dB sufficient, 70 to 75dB satisfactory, 75 to 80dB good, >80dB very good

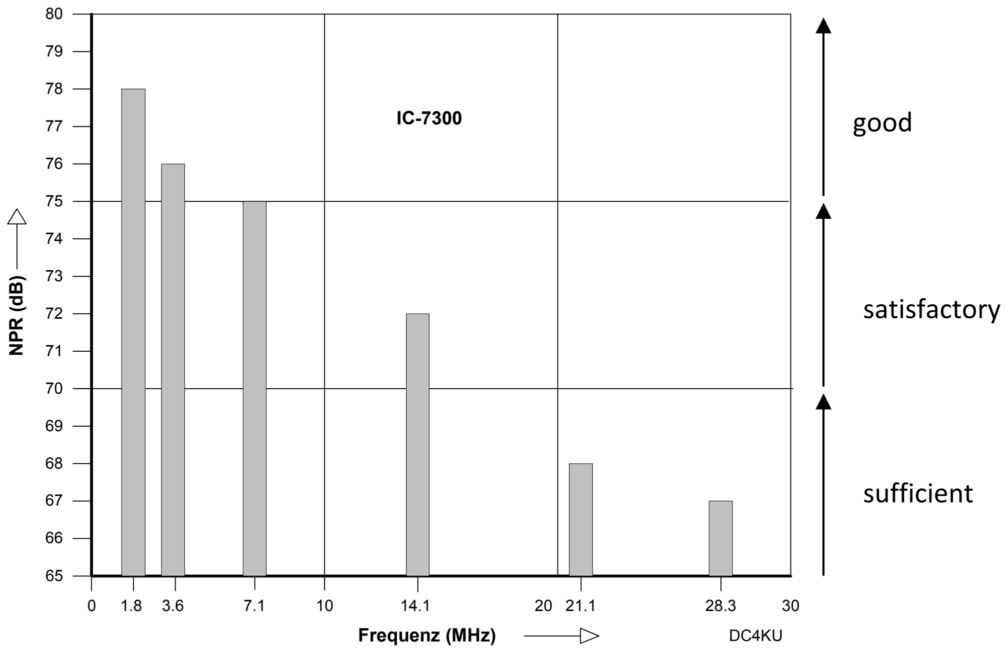

Figure 9: IC-7300, NPR as a function of frequency

Example of NPR calculation at 7.1 MHz:
At a noise level of P_{Noise} = -11 dBm, the OVF display starts to flash and the maximum ADC output level is reached. With B=500Hz (CW) an NPR results of

NPR = -11dBm - 10log (30MHz/500Hz) - (-134dBm) = -11dBm -48dBm + 134dBm = 75dB

The NPR can also be calculated via the bandwidths of the front-end preselector. At fe=7.1 MHz the IC-7300 works with a preselector (bandpass filter) of 6.5-8MHz, i.e. with an effective bandwidth of 1.5MHz. The injected noise power of 0-30MHz is reduced by 10log (30MHz/1.5MHz) = 13dB to P_{Noise} = - 13dBm. With a clipping level of -11dBm the NPR is then calculated as

NPR = (-11dBm -13dBm) - 10log (1.5MHz/500Hz) - (-134dBm) = 75dB

If the resolution bandwidth of the receiver is changed from 500Hz (CW) to 2.4kHz (SSB), the NPR does not change either, because the sensitivity of the receiver changes from -134dBm/500Hz to -126dBm/2.4kHz The NPR is then calculated to

NPR = -11dBm - 10log (30MHz/2.4kHz) -127dBm = 75dB

No matter how you set the receiver, the NPR result remains the same. Theory and practice match.

Notes

The determination of the NPR via the OVF display of an SDR cannot keep up with the classical measurement via notch filter regarding accuracy. When using notch filters, the limitation of the ADC can be set exactly to -1dBFS, with the OVF display I have to rely on the flashing LED warning display. I would estimate the accuracy of the NPR measurement via OVF at +/- 1.5dB.

Summary

The OVF display of the IC-7300 and IC-7610 is a very practical and useful feature and should not be missing on any direct scanning SDR receiver.

If the overflow indicator on the IC-7300 lights up, you should reduce the "RF-Gain" by turning the potentiometer "RF/SQL" a few millimeters to the left. This activates a pin diode attenuator in the RF input and the message "RFG" (Reduced RF-Gain) appears on the screen and the OVF display disappears again.

The selectable preamplifiers (Preamp. 1 and 2) should of course be switched off. The IC-7300 is already very sensitive with -133dBm/500Hz. In order to see whether the sensitivity of the receiver is sufficient on any band (e.g. 20m) even without a preamplifier, you should briefly remove the antenna from the receiver and observe the noise line. If the noise decreases by a few dB, you do not need a preamplifier, because then the antenna determines the sensitivity and not the receiver.

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04.09.2020

Literature:

(1) Noise Power Ratio, DC4KU
FUNKAMATEUR 12-2017, 01-2018
http://www.dc4ku.darc.de/Noise-Power-Ratio.pdf

(2) Website of OE3HKL
http://www.oe3hkl.com/hf-measurements/npr-messplatz-rauschgenerator/rx-messungen.html