USING ORION's RECEIVER

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Overview

Perform the steps in this order:
* initial adjustments,
* start an audio analysis program (optional but very useful),
* set the optimum RX sensitivity for the given environment,
* set AGC to avoid it causing distortion to weak signals,
* adjust filters according to band conditions.

Initial Adjustments

1. Connect and select the desired antenna.

2. Use studio quality stereo headphones (my choice: Beyerdynamic DT-770 Pro or DT-109 headset). Good isolation from room noise is essential.

3. AUDIO menu:
   * set LEFT, RIGHT and SPEAKER to MAIN or BOTH;
   * turn off BinRX;
   * set both RX EQ values to 0 dB.

4. RX menu:
   * main AGC hang = 0.30 s (for fast contest operation decrease it later to 0.00 s)
   * main AGC decay = 5 dB/s (for fast contest operation increase it later to 10-15 dB/s)
   * PBT/BW STEP = 10 Hz.

5. OTHER menu:
   * all five rates to FAST.

6. FILTR menu:
   * XTAL FILTER = AUTO (for CW operation 1 kHz filter provides best dynamic range)
   * enable optional filters that are present
   * DSP FILTER LENGTH = 199 taps.

7. Set controls:
   * MAIN RX = ON
   * LCK = OFF
   * select desired frequency
   * ATTN = OFF
   * AGC = PROG
   * SWEEP = OFF
   * STEP = 10
   * SPOT = desired value (my choice is 600 - 700 Hz; with wide CW filters use 800-1000 Hz)
   * RF GAIN = 100
   * PREAMP = ON
   * MODE = desired mode
   * NB = OFF
   * NR = OFF
   * NOTCH = OFF
   * AN = OFF
   * RIT and XIT = OFF
   * MAIN AF GAIN to a comfortable listening level (disable sub RX AF GAIN)
   * select CUT L, rotate the knob to set PBT = 0 Hz for CW and PBT = 150 Hz for SSB; later in operation: use the knob to cut low-pitched interference on SSB;
   * select BW, rotate the knob to set BW = 500 Hz for CW and 2100 Hz for SSB later in operation: use the knob to adjust CW filter bandwidth or to cut high-pitched interference on SSB.

Audio Analysis Program

A PC with a sound card and an audio analysis program (such as SpectraLab, Spectrogram, Sound Forge, Cool Edit or K6STI's DSP Blaster) is strongly recommended. Audio spectrum display makes sensitivity, AGC and DSP filter adjustments both fast and accurate.

Connect the rear panel LINE OUT to your PC's LINE IN.
Start the program.
Adjust volume levels accordingly.
Activate the spectrum display.

Sensitivity

Theory

The ultimate limiting factor in receiving weak signals is noise, and not receiver's "gain".
The total noise power audible from headphones is a sum of:
* internal receiver's noise, and
* external noise coming from the antenna and being received just like any other signal.

Receiver's noise must be weaker than external noise if the receiver is not to degrade reception.
It is recommended the internal noise level to be 10-12 dB below the external noise level.
This way the internal noise will cause negligible increase in the total noise power.
The audible signal-to-noise ratio will be determined solely by external noise.

However, there is no point in making receiver's noise weaker than external noise by more than 10-12 dB.
Signal-to-noise ratio cannot be improved that way, and the receiver would become more susceptible to overload.

The optimum sensitivity level clearly depends on the environment - location, frequency, antenna and propagation.
Therefore, a new adjustment is needed whenever the environment is changed.

A common mistake is to use the as much gain as available, regardless of actual conditions.
This is wrong - too much gain seriously impairs receiver's ability to receive weak signals
in the presence of interfering strong signals, thus degrading the effective sensitivity.

Adjustment

The following procedure is specifically tailored to Orion's controls, but the method is the same with any receiver.

Connecting and disconnecting the antenna should result in noise level difference of 10-12 dB (~2 S units).
If RX AUX connector is not used, one can simply press MAIN RX/TX RX ANT key.
Strictly speaking, the antenna shall be replaced by a 50 Ohm termination (on RX AUX connector).

Anything more than 10-12 dB overloads the receiver unnecessarily.
Anything less than 10-12 dB reduces the signal to noise ratio.

Start with full sensitivity and reduce it until the above condition is satisfied.
Orion has 3 sensitivity controls which should be reduced in the following order:
* PREAMP turned off;
* ATTN increased to 6, 12 or 18 dB;
* RF GAIN reduced.

If the external noise moves the S meter sufficiently, one can use its indication which is reasonably accurate and does not depend on AGC THRESHOLD setting.

If the test is done by external instrumentation or by ear, AGC THRESHOLD must be increased slightly above the point where the external noise volume starts to decrease. This ensures that AGC will stay inactive, and what is heard (and measured) will reflects actual power ratios. The exact point is not critical and may be much higher than the minimum one. Of course, the selected setting must not be changed during the test.

Additional information

Orion's sensitivity is exceptional, even with preamp off, so don't be suprised if the optimal adjustment asks for far more attenuation than you ever imagined. With full sized antennas on lower bands it is normal to have both the preamp off and attenuator heavily on. Always follow the adjustment procedure strictly.

Don't waste Orion's good, but necessarily limited IM dynamic range on noise.
By keeping the sensitivity at the optimum level one is actually maximizing the effective IM dynamic range.
Please see the table given below under "Roofing Filters".

Orion's phase noise performance is exceptional.

Preamp gain is 12 dB.

Minimum copyable CW signal

Conditions: 7010 kHz, Main RX to ANT 1, Sub RX to ANT 2, ATTN OFF
LCW mode, 1 kHz roofing filter, 250 Hz DSP CW filter

with PREAMP OFF: -128 dBm = S9 - 55 dB = 89 nV
with PREAMP ON: -137 dBm = S9 - 64 dB = 32 nV

AGC

The Purpose

The purpose of AGC [Automatic Gain Control] is to avoid overload of ears by reducing the gain for strong signals.

Unfortunately, as implemented in Orion and most other receivers, AGC can degrade weak signal reception.
AGC essentially divides the signal by a rectified and filtered version of it, creating intermodulation which is particularly bad with a weak signal near the noise level. The signal and the noise get intermodulated, significantly reducing readability.

Therefore, the AGC action is undesirable with weak signals.
However, AGC must stay on in order to protect ears from unexpected strong signals.

The purpose of AGC adjustment is to provide the optimum tradeoff between readability and protection.

Orion's AGC Controls

Orion has four sets of AGC settings: SLOW, MED, FAST and PROG.
Each set is independently adjustable with PROG providing the widest range of adjustment.

Within RX menu there are three AGC settings (with separate values for each of the sets):
* AGC HANG time,
* AGC DECAY rate,
* AGC THRESHOLD level.

AGC is inactive for a HANG time long period after a signal peak that determined the latest gain reduction.
During that period the gain is held at a fixed level, resulting in two benefits (until the "hang" period ends):
* the job of our aural system is made easier, in part by not raising noise level between characters/words;
* the usual AGC-induced intermodulation is avoided.

When the "hang" period expires, AGC starts increasing the gain at AGC DECAY rate.
Faster rate enables the receiver to recover gain in shorter time, but too fast a rate will reduce readability due to disproportionate increase of noise and interference volume.

AGC THRESHOLD

AGC THRESHOLD determines the signal level above which the AGC starts to reduce the gain.

On "usual" receivers, RG GAIN control can be used to superimpose DC control voltage (and move S meter) making AGC loop inoperative for signals that do not move S meter anymore. This is a very effective weak signal technique. There is an Inrad flyer recommending its use on FT1000MP. One simply turns RF GAIN counter-clockwise until the S meter stops responding to noise peaks.
Contrary to popular belief, no sensitivity is lost by reducing RF GAIN control in this way, because the actual gain would have been reduced by AGC anyway.

Orion's RF GAIN does not control the AGC threshold directly. Orion users have to activate menus and then select and change the clumsy AGC THRESHOLD setting (which does not move the S meter), instead of simply turning a knob counter-clockwise as on "less modern" receivers. Therefore, speaking ergonomically, Orion's AGC THRESHOLD control is less adequate for the purpose due to:

* lack of correlation between AGC THRESHOLD values and S meter noise readings;
* lack of dedicated knob.

Both disadvantages can be overcome, but the price in time and effort may simply be too high in contests.

Particularly cumbersome is to know "how much of it" to apply, compared to RF GAIN method where one simply looks for a non-moving S meter.

Menu readings are given in microvolts. The manual is not explicit where are these microvolts measured. One is tempted to <u>assume</u> that they are measured at the antenna connector and can therefore be correlated with S meter indication on the basis of S9 = 50 uV and +1 S unit = doubling the voltage.

However, such an assumption is <u>wrong</u>. Despite 0.01 uV resolution, indicated AGC THRESHOLD levels are <u>grossly inaccurate</u>. On my Orion measured AGC threshold levels are ~21 dB below set values with preamp on, and ~9 dB below set values with preamp off.

Correlation with S meter indication (on my Orion) was found to be as follows:

AGC THRESHOLD	S meter
191.48 uV	8.8
95.74 uV	7.9
47.87 uV	6.8
23.94 uV	5.6
11.97 uV	4.3
5.98 uV	2.9

The table above was valid independent of the preamp and attenuator settings.

TenTec would have done a much better job by displaying AGC THRESHOLD values in S meter units, with some care taken to ensure good tracking between them, which I guess is easy, as both S meter and AGC are DSP functions.

<u>Adjustments</u>

Sensitivity adjustment must be performed first, as desribed above.

If the external noise is kept at the same level on various bands (S 3 level is recommended), then AGC settings may also stay the same.

Adjusting AGC THRESHOLD by instrumentation or by ear:

* ensure that sensitivity is correctly adjusted, avoiding noise readings above S 8;
* starting with a low value, increase AGC THRESHOLD until the external noise volume is reduced by ~15 dB (~2.5 S units); external noise will remain comfortably audible, but not as strong as usable signals;
* adjust AF GAIN for comfortable volume.

Adjusting AGC THRESHOLD by S meter:

* ensure that sensitivity is correctly adjusted, avoiding noise readings above S 8;
* adjust AGC THRESHOLD ~2 S units above the S meter noise readings, according to the table above; external noise will remain comfortably audible, but not as strong as usable signals;
* adjust AF GAIN for comfortable volume.

AGC DECAY can be kept at 5 dB/s (slightly faster in contests), with AGC HANG time at 0.30 - 1.00 seconds.

Filters

Roofing Filters

The purpose of roofing filters is to protect stages after the first mixer from strong adjacent signals.

Orion repeats the mistake of earlier receivers by overloading the weak stages after the first mixer and then attempting to escape from IM problems by putting in narrow roofing filters, which works down to 1 kHz, but then breaks up after amplification is added with 500 Hz and 250 Hz filters.

The filters work very well, in spite of not being shielded.

Both 500 Hz and 250 Hz filters should be centered. The procedure given in the manual suggests positioning the peak gain point on the spot frequency. This will not work with slightly asymmetric passbands. It is better to use an audio analysis program and position -3 dB or -6 dB points symmetrically around spot frequency.

Measured Roofing Filter Performance

using 200 Ohm termination

nominal bandwidth [Hz]	standard / option	order [xtals]	insertion loss [dB]	bandwidth -3 dB [Hz]	bandwidth -60 dB [Hz]	group delay [ms]
6000	standard	4	1.02	5521	24570	0.18 - 0.34
2400	standard	4	0.96	2174	10250	0.43 - 0.75
1800	option	8	2.85	1768	3171	1.10 - 3.15
1000	standard	4	2.12	920	4672	0.98 - 1.68
500	option	8	6.86	454	1178	3.30 - 5.50
250	option	6	10.09	225	796	4.90 - 7.00

Interested parties should email me for bandwidth and group delay sweeps in JPG format.

Two-tone IM performance

Conditions: 7 MHz band, Main RX to ANT 1, Sub RX to ANT 2, PREAMP OFF, ATTN OFF, LCW mode, 250 Hz DSP CW filter.

This table gives the maximum IM-free input level (not producing audible IM3 products).
Actual level is given first, with S meter indication in parentheses
Both are in dB's over S 9 with S 9 = -73 dBm (50 uV into 50 Ohms).

roofing filter	signal separation 0.7	2.0	4.0	10.0
6000 Hz	+15 (+21)	+16 (+22)	+21 (+27)	+33 (+38)
2400 Hz	+4 (+7)	+11 (+16)	+18 (+23)	+27 (+31)
1800 Hz	+15 (+18)	+34 (+38)	+37 (+39)	+38 (+40)
1000 Hz	+27 (+31)	+35 (+39)	+39 (+40)	+41 (+40)
500 Hz	+0 (+8)	+25 (+32)	+28 (+35)	+28 (+35)
250 Hz	+23 (+30)	+23 (+30)	+28 (+36)	+27 (+34)

Notes:
* for the best close-in IM performance on CW use the 1000 Hz roofing filter;
* 500 Hz and 250 Hz filters are useless as IM-fighting devices; IM performance is degraded in or around the amplifier stage preceeding them - exact cause not known;
* actual levels are 12 dB lower with PREAMP ON, and 6, 12 or 18 dB higher with ATTN ON, with S meter indication the same as above;
* IM performance was found to be temperature sensitive;
* readers should be aware of possible unit-to-unit variations in both the actual IM performance and S meter calibration - therefore the table should only be used as a rough guide.

DSP Filters

DSP filters provide Orion's ultimate selectivity.

Recommended use of filters knobs is described at the end of "Initial Adjustments" section.

Particularly valuable is the ability to change filter bandwidth and to shift the passband
without causing any disturbance to received audio, unlike so many other receivers.

It is a widespread myth that a narrow CW filter enables the operator to hear weak signals buried in white noise and not audible with wider filters. This simply doesn't happen, at least not before the bandwith is reduced very much below ~50 Hz (with slow telegraphy). This comes from the fact that our aural system performs a very good signal processing, effectively narrowing the bandwidth around a CW signal to about 50 Hz.

But when the reception is limited by adjacent transmissions (not by white noise), a narrow CW filter can help a lot.
When using a narrow CW filter, it is most important to center the signal inside the filter passband.
Simply switching to a narrow filter may not help, and the desired signal may actually disappear if it is not centered.

The centering is usually done using a VFO knob or RIT, aiming for the signal tone equal to the keying sidetone.
The SPOT key may be pressed to produce a beat note, but that will disturb the reception.

A much better method is to use an audio analysis program and center the signal visually using the audio spectrum display. The spectrum display is also very useful for selecting an optimum filter bandwith according to current conditions, and for adjusting low and high cutoff frequencies during SSB operation in order to optimally separate the signal from interference. It is also useful with the manual notch filter. A useful article by Roger Rehr W3SZ is available on Elecraft's site: http://www.elecraft.com/TechNotes/w3sz_dsp/w3szdspnew.htm.

Audio outputs

There are three DACs (digital-to-analog converters) called Left DAC, Right DAC and Speaker DAC.
They generate three audio voltages which are then fed to headphone and speaker amplifiers,
and LINE OUT, LEFT AUX and RIGHT AUX outputs.

Left DAC feeds the line-level LEFT AUX OUT (pin 4 of the rear panel AUX I/O DIN connector)
and the left headphone channel.

Right DAC feeds the line-level RIGHT AUX OUT (pin 6 of the rear panel AUX I/O DIN connector)
and the right headphone channel.

Speaker DAC feeds the line-level LINE OUT (rear panel CINCH connector) and the speaker.

The source for each DAC is independently selectable (from the AUDIO menu) as Main RX, Sub RX or Both.
When BinRX is active, source selection is automatic, overriding user settings.

Strangely enough, when headphones are <u>not</u> engaged, Left or Right DAC will <u>not</u> use a source that is not simultaneously used for Speaker DAC, <u>even</u> if the source <u>is</u> selected for the Left/Right DAC.
This prevents independent source selection for the speaker and AUX outputs.
TenTec must have had some reason for playing such tricks, but I consider it dirty.

Advancing MAIN AF control will increase the Main RX source level, <u>and</u> simultaneously decrease the Sub RX source level. Decreasing MAIN AF control to minimum or muting it will reduce Main RX source level to zero, <u>and</u> simultaneously increase Sub RX source level to maximum, unless SUB AF is at minimum or muted.
All of this applies to SUB AF control too, mutatis mutandis.

Please note that we are talking about <u>source</u> levels here, before any of them is actually applied to a DAC.
In other words - the mutual influence is there at all times, it does <u>not</u> depend on DAC source selections at all.

Therefore, Main RX and Sub RX levels available from a DAC will <u>always</u> reflect the <u>relative</u> ratio of MAIN AF position to SUB AF position.

Line-level outputs have full scale voltages of 1 V rms.
Driving impedance is low as they are driven directly by TL082 op amps.

The speaker and headphone amplifiers get the same signal mix as corresponding line-level outputs (as described above), with additional <u>absolute</u> volume control applied.

Unfortunately, Orion doesn't have plain and simple line-level outputs with levels completely independent of front panel volume settings, as most prior rigs had. This was sacrified in order to save a few dollars - cost of an additional stereo DAC.

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