G0ETP SDR HF Receiver – User Guide

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This document describes the controls and functions of the G0ETP HF receiver, along with some useful operating procedures and tips.

Initial Power On

The radio uses battery backed-up SRAM to store various parameters when the power is off. If corrupt values are detected in the NV-SRAM (or if the VFO button is held in while the radio is turned on) the SRAM will be initialised with default values.

Primary Radio Controls

Push Buttons

- **VFO** Press this to toggle between VFO A and B
  Hold this to copy the current VFO into the other one.
- **Mode** Press this to cycle through the modes USB, LSB, CW and DATA or AM and FM modes.
  Hold this button to switch between SSB/CW and AM/FM groups.
- **Display** Press this to cycle through display modes that are appropriate to the current mode. In SSB, AM and FM this will be the FFT display and the waterfall display. In CW and DATA modes a text decode screen is also available.
  Hold this button in CW mode to view the amplitude slicer or in DATA mode to view the raw demodulator output.
- **Step** Press this to cycle through the tuning step sizes from 10Hz to 10kHz. If Auto Step is enabled then this gets set to a suitable value on certain mode changes.
  Hold this to enter 100kHz tuning mode to move quickly between HF bands.

Push/Rotate Menu Knob

Pressing the menu knob will first bring up the menu display if it is hidden.

Pressing this while the menu is visible will toggle between menu item selection and menu item adjustment.

When a menu item is selected for adjustment, the rotation of the menu knob remains associated with that value, even after the menu display has disappeared.

Menu Items

The following items are stored on a per-VFO basis:

- **Max AGC Gain** This limits the maximum gain that will be applied to weak signals. It is used to control the volume of the *channel background noise*.
This controls the CW slice threshold in CW mode and the squelch in FM mode.
- **Bandwidth** Select Normal, Wide or Narrow bandwidth (widths available are mode dependent).
- **Notch filters** These allow the notch filters to be turned on and off. When it is on the notch freq is displayed. Notch tuning if performed by the main tuning knob but *only* when the menu is visible.
- **IF Shift** Shifts the filter passband to help avoid adjacent channel interference.
- **Data mode** Select between RTTY45, BPSK31, 63 and 125 modes.
- **DDS ref mult** This changes the multiple of the 26MHz TCXO that is used as the internal DDS reference. This can be used to avoid spurious signals that are caused by DDS spurs (but most of them are not).
- **Auto step** When this is on the tuning step size is (re)set to a convenient value when certain mode changes occur.
- **Waterfall bias** This offsets the waterfall level (colours) *relative* to the current signal levels being received and the Max AGC setting.
- **FFT peak hold** FFT peak hold enables a line of dots that track the envelope of the FFT display.

The following items are global:

- **Pre-sel filter** If you have an RF pre-selection filter you must select the correct type here.
There is a bypass option for all filter types, regardless of whether your particular filter hardware supports it.
- **Ref freq adjust** Used to calibrate the internal TCXO (see calibration procedure below).
- **W/fall Hscroll** When this is on the waterfall history will scroll sideways when the radio is tuned.
- **AGC spk thresh** Adjusts the *relative* level above which a signal is considered a noise spike.
- **AGC spk delay** Changes the hold time before the 'normal' AGC level is restored.

- **Code version** Display only.

Tuning

The main tuning knob is self explanatory. The tunable frequency range is 4kHz to 30MHz in 10Hz (or greater) steps.

FFT and Waterfall displays

These show signals in the range ±12.5kHz with 0 at the centre of the screen.

In FFT mode, the Y axis is logarithmic with a scale of 1dB per pixel, so it can display a range of 128dB.

The waterfall display uses a colour palette similar to that used in FLDIGI; this goes from black to blue to yellow to white to red. There is a blue 'plateau' just before yellow which can be used to separate stuff above (active signals) and stuff below (band noise). The Max AGC gain control is linked to the waterfall colour offset so that Max AGC gain can be adjusted to accommodate the current band noise conditions, both for the AGC and the waterfall in one operation. If you need to offset the *relationship* between these two functions then adjust the 'Waterfall bias' in the menu.

Pre-Selector Filter Selection

If you have fitted a pre-selector filter to your radio then you will need to select the correct filter within the radio menu. Failure to select the correct filter can result in little or no signal reception.

Check http://www.themadhowes.org.uk/g0etp/sdr_rx/filters.html for an up to date list.

Distunguishing Real Signals from Images and Spurs

Signals that are 'really there' will move across the FFT and waterfall displays at the expected tuning rate, i.e. on the waterfall they will remain as vertical traces (when waterfall Hscroll is enabled).

Signals that result from harmonic mixing in the radio QSD mixer will move at a multiple of the tuning rate or in a different direction; these will *not* stay still on the waterfall display and can therefore be recognised. To help avoid those that are caused by images of real signals, a bandpass pre-selection filter can be applied at the antenna input (e.g. the HA8LFK filter). An ATU can help a lot here too. If you are unlucky and have a persistent in-channel interferer then the notch filters can help.

Signals that result from DDS spurs often (but don't always) occur in symmetric sets about the centre of the waterfall display and can therefore be recognised. These can often be avoided by changing the DDS reference multiplier.

Other spurs, such as those coming from the ADC sample clock and the ARM board will tend to stay still as they are 'real signals'. (Some reduction in these spurious signals can be achieved by employing careful grounding, shielding and signal routing when you build the radio. Some of these signals are coming from the STLINK processor, so you could look into ways to stop this when it is not in use.)

TCXO Frequency Calibration

The suggested method for calibrating the radio's internal TCXO frequency reference is to use an accurate off-air frequency standard, such as the Russian time and frequency reference RWM on 9996kHz (also 4996kHz and 14996kHz) Calibrate as follows:

- Select USB mode, 500Hz step size.
- Set IF shift to -700Hz (so we can hear 500Hz either side of 0).
- Tune to 9995.5kHz and set the tuning step to 1kHz.
- Flip between 9995.5 and 9996.5 and alter the 'Ref freq adjust' menu option until you get the same 500Hz tone either side of 9996kHz.

You can of course use an accurate RF signal generator if you have one.

S-Meter (RSSI) Calibration

The gain of the receiver board should not vary drastically from one build to the next, so adjustment of the S meter is not essential. If for any reason you want to check this calibration the procedure is as follows:

Put the radio in CW-W mode and inject a calibrated signal from an RF generator at, for example -60dBm at 14MHz. Using the RSSI calibration in the menu, find the min and max calibration point where the RSSI reads -60dBm. Set the RSSI calibration to the mid point of these 2 values.

Useful Operating Procedures

Max AGC Gain Setting

This menu setting limits the maximum gain that the AGC can apply. This will have a large impact on the background channel noise and will have no effect on the volume of signals unless this gain is reduced *too far*.

I aim to set the gain so that the channel background noise is at least 10dB lower than that of active signals; this makes for a pleasant listening experience and reduces fatigue.

When you are familiar with this control, this is easy. Otherwise, one way to do this is to tune to an empty channel and increase the gain from low to high. Remember the step at which the noise becomes no louder then back off by 9-12dB.

The default waterfall 'bias' has been set so that this setting coincides with the channel noise on the waterfall being a mid blue colour and not quite causing yellow to appear.

CW Decoder Slicer Level Adjustment

Like the colours in the waterfall, the threshold level used in the CW decoder key up/down decision is linked to the Max AGC gain control, so altering the Max AGC gain setting will adjust the CW decoder sensitivity.

The threshold needs to be set so that between transmissions, channel noise is just below the CW threshold and no 'crumbs' appear on the ticker-tape at the bottom of the CW decode screen. This threshold setting can limit sensitivity, however, particularly when there is a lot of channel fading. If more CW sensitivity is required, increase the Max AGC gain but accept the fact that noise will now cause false characters to appear.

RTTY Reception

The RTTY demodulator is configured for 2-FSK signals with a frequency shift of 170Hz. The MARK tone (logic 1) is the higher of the 2 RF frequencies and is indicated exactly by the VFO frequency display. The MARK tone has been set in this design to generate a 1000Hz audio tone. The SPACE tone (logic 0) is the lower of the 2 RF frequencies and produces an 830Hz audio tone. Tune the signal so that the signal energy shown in the data tuning indicator is centred. (You should be able to hear *both* tones of the RTTY signal.)

The RTTY decoder operates using the 5-bit Baudot / ITA-2 character set at 45.45 BAUD (22ms bit duration). There is an operating convention known as Un-shift On Space (UOS); this is enabled in this receiver.

PSK Reception

PSK reception is currently achieved using a single bandpass filter followed by a differential PSK demodulator. The current implementation is adequate for a casual look at PSK traffic but it should be noted that:

1. The Amateur PSK design is such that a *matched* filter cannot be used in the receiver, so any filter that is used will be sub-optimum in some way.
2. Differential demodulation is simple but provides sub-optimal performance at low signal to noise ratios.
3. There is no AFC, so very accurate manual tuning is required.

A signal must be tuned to the nearest 10Hz step so that the energy in the data tuning indicator is centred. PSK31 is the most critical.

AM Reception

A feature of this zero-IF radio design and the particular ADC used means that there is a narrow notch at the 0 IF centre. If an AM station is tuned exactly, the AM carrier can fall into this notch and result in distorted AM demodulation.

In AM mode, the workaround for this (for the time being) is to tune slightly to one side. E.g. set the VFO frequency 100Hz higher than the nominal AM carrier.

Whilst there is no synchronous AM detector, the accuracy of the VFO in this radio is so good that you can asynchronously decode AM in SSB mode. If the VFO error is < 5Hz this is even good enough for music.

When demodulating AM in SSB mode, the presence of the AM carrier can force the AGC up and lead to low audio output. If this is causing you grief, set the IF shift to +100Hz and this will bring the audio back to the expected volume but at the expense of a reduced bass response.

During AM reception I find that the FFT display is more useful than the waterfall display.

Notch Filter Tuning

Sometimes you have to wait until a wanted signal goes away so that you can optimise the notch filter tuning. Tuning the notch filter back-and-forth slightly can be used as a trick to hold the display in 'notch tuning mode' for longer, until you get a chance to make the best adjustment.

Specifications

Tuning Range

4kHz to 30MHz in 10Hz (or greater) steps. (Note that additional pre-selection filtering becomes increasingly important as you go down in frequency.)

IF Filter Bandwidths

- SSB -6dB 2766Hz, -60dB 3314Hz (shape factor 1.2)
- SSB-W -6dB 4253Hz, -60dB 5066Hz (shape factor 1.2)
- SSB-N -6dB 2238Hz, -60dB 2685Hz (shape factor 1.2)
- CW -6dB 255Hz, -60dB 559Hz (shape factor 2.2)
- CW-W -6dB 508Hz, -60dB 1116Hz (shape factor 2.2)
- CW-N -6dB 86.3Hz, -60dB 188Hz (shape factor 2.2)
- AM -6dB 6510Hz
- AM-W -6dB 8650Hz
- FM -6dB 12880

In SSB mode the default BFO position (IF shift set to 0) is at the -6dB point on the filter skirt.

Sensitivity and Maximum Signal Handling

The receiver analogue gain is fixed to deliver a compromise between receiver sensitivity and strong signal handling. The 24bit ADC reaches saturation at an input signal level of around -23dBm, which is equivalent to S9+50dB. The noise figure (NF) of this receiver is around 27dB. This may seem poor by commercial receiver standards which can be as good as 7dB, however, a NF this good is *excessive* on all HF bands below 28MHz: On lower bands, the man-made and atmospheric band noise can be above the thermal noise of the receiver by more than 40dB and the use of an attenuator is commonplace.

The 27dB NF of this receiver is equivalent to a NF of 7dB with a 20dB attenuator on its input. With this configuration, the band noise at my (urban) home location is at least 20dB greater than the receiver noise floor on bands below 15MHz and this margin steadily reduces as you head up towards 30MHz.

If more *sensitivity* is required, an external low-noise preamp may be used but be aware that this will reduce the strong signal handling of the receiver and upset the S-meter calibration.

If more strong signal handling is required then an external attenuator can be used. This will further reduce the NF and will upset the S-meter calibration.

TODO: Calculate the IP3 of the receiver.

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