Ultimate3: QRSS Labs Multi-mode QRSS Beacon Kit

v3.00

1. Introduction

This is the operation manual for the third generation "Ultimate3" Multi-mode QRSS beacon kit. Please read it in conjunction with the assembly manual for building the kit. This version supports modes: QRSS, FSKCW, DFCW, Hell, DX Hell, Slow Hell, FSK, CW, CW ID, WSPR, WSPR-15, TX and customisable patterns.

2. Operating instructions

The microcontroller has a 512-byte Electically Erasable Programmable Read Only Memory (EEPROM). This is used for storing your individual settings such as mode, keyer speed, and message. When the kit is first switched on, it automatically enters the "run" mode, in which the message is being transmitted in the selected mode. This is so that in the event of power interruption, the kit recommences the message transmission as soon as power is restored, without user intervention.

When you have just built the kit, the memory will contain only certain default settings, and an empty message. An error will be displayed, saying "Error: Message", which indicates that the message is empty:

It is now necessary for you to configure the message and settings for your use.

2.1 Menu system

The user interface consists of the 24-character LCD and two push-buttons. There are 20 user-configurable settings available. The menu system allows all of the settings to be edited. The use of only two buttons to edit so many settings necessarily means that you must scroll through various options by many button presses. Clearly, there is no full computer keyboard in the kit with which to edit your alphanumeric message. However, the use of these two buttons to control the kit is fairly intuitive.

The menu is a list of items, and the LEFT button is used to scroll through these items. When you see the item which you want to edit, press the RIGHT button to start editing it. The list of menu items shown (right) has example settings for sending WSPR followed by the message "73 DE G0UPL" in FSKCW with 6-second dit symbols.

```
Mode 0
Mode 1
Mode 2
Freq. 0
Freq. 1
Freq. 2
Speed
Callsign
Message
Frame
Start
Locator
Power
GPS Mode
GPS Baud
FSK (Hz)
Fine FSK
Sys. Frq.
Ref. Frq.
ParkMode
ParkFreq
Set Time
```

After cycling through the list of menu items using the LEFT button, the system is returned to the "Run" mode, transmitting the configured message.

Note the final item "Right button to start!". When this final item is reached, you must press the RIGHT button, which then resumes the "Run" mode. The reason for this is that if, for example, you only wanted to change the mode, which is the first setting. It would be tiresome to have to scroll carefully though the remaining items until the "Run" mode was resumed. There are many configurations and you could easily miss the run mode, re-entering the menu system again at the first item. With the right button start feature, you can simply keep the LEFT button pressed, relying on the key autorepeat to quickly cycle through all the remaining menu items and stop at the end. It is also useful for when you want to start the system at an exact time.

Note that if one of the modes is WSPR, it should always be the FIRST transmission. This is because WSPR needs to start at a precise time (the 2nd second of even minutes past the hour). If you had WSPR as the second transmission it would not start at the correct time and you would get no WSPR hits (unless you had timed your first message very carefully to take the right time).

2.2 Editing a menu item

There are three types of menu item: alphanumeric (e.g. callsign), numeric (e.g. frequency), and list (e.g. mode). Editing a configuration is slightly different depending on the type. When scrolling through the list of menu items using the LEFT button, you enter editing mode by pressing the RIGHT button.

2.2.1 List editing

If the menu item is a list menu, such as the Mode menu, use the RIGHT button to cycle through the list to find the setting you want. An On/Off menu such as Use GPS is also a list, having only two settings (On and Off). When you have chosen the setting you want, press the LEFT button. This saves the setting into memory and returns to the menu list.

2.2.2 Number editing

When editing a numeric setting, the RIGHT button is used to cycle through the numbers 0..9 until you find the number you want. The LEFT button moves rightwards one position to the next character to be edited. The current character being edited flashes. When the final (rightmost) digit has been chosen, a LEFT button press saves the setting into memory and returns you to the menu list.

Note that in some cases, there are restrictions on the value which may be chosen. For example, when editing the 10's of minutes digit, the RIGHT button only cycles 0..5 then returns to 0.

2.2.3 Alphanumeric editing

The most complex editing is alphanumeric, which also includes certain punctuation characters supported by the Hellshreiber character set. The principle is the same as for Number editing: the LEFT button moves the cursor one character to the right, and the RIGHT button cycles through the letters, punctuation and digits. However facilities are also provided to delete one character, or the whole message.

The order of the letters, punctuation and numbers is as follows:

The following characters have special function:

Backspace (delete): If you select this character as the current flashing character using the RIGHT button, then when you press the LEFT button, the current character is deleted and the flashing cursor moves back left one position.

Delete all: If selected as the current character, pressing the LEFT button has the effect of deleting the entire message, starting again at the left of the screen. There is no "undo", so use with caution!

Enter (finished): If selected as the current flashing character, pressing the LEFT button is used to finish editing the setting. The setting is saved, and you return to the main menu list. Note that the text that is saved is only the text to the left of the Enter symbol. If you select this symbol and press the LEFT button when you are not at the furthest right position of the message, then everything right of your position is deleted.

Note that when you continue to press the RIGHT button, there is an automatic key-repeat feature so that you can cycle quickly though the characters without having to press the RIGHT button many times. When pressing the RIGHT button continuously, the character will stop cycling at the 'Z', '9' and 'Enter' characters. To resume cycling through the characters, release the button, then start pressing again. This makes editing easier and faster because you are not so likely to go too far past the character you are looking for, and have to cycle through them all again.
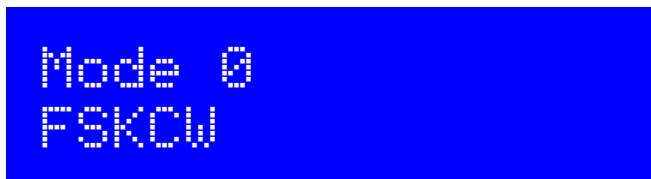
2.2.4 Configuration validation

In some cases, the configuration setting is validated at the time of entry. For example, the system does not allow the entry of an invalid time setting, or entering letters where numbers are required.

Additionally, there are many cases where particular combinations of settings produce an invalid situation for the transmission mode being used. In these cases, the configuration validation is done when the "Run" mode is entered, i.e. transmission started. If there is any reason why the configuration is invalid, an appropriate error message will be displayed, prompting you to return to the configuration setting to correct it.

2.3 Menu configuration settings

There are 20 user-configurable settings available in this kit. Not all of them are going to be relevant to the mode you wish to use, or to your hardware configuration. The following sections explain each setting in detail.

The Mode 0 setting selects the mode for the first message transmission. The available modes are: None, FSKCW, QRSS, DFCW, Slow Hell, Hell, DX Hell, CW, CW ID, WSPR, WSPR-15, TX.

The Mode 0 setting must always contain a valid mode (not "None"). If you wish to send WSPR, please choose WSPR as the first transmission, so that the timing of the start of the WSPR message is correct.

Similarly, there are parameters called "Mode 1" and "Mode 2" which specify the modes of the second and third transmissions to be sent in the sequence.

Mode 1 and Mode 2 settings can be left at "None" if you do not want to send a second transmission. Please do not choose WSPR or WSPR-15 as the Mode 1 or 2 setting, because the timing of the start of the transmission is critical and will not be correct if it is transmitted second.

```
Freq. 0
10,140,050
```

This frequency sets the baseline RF output frequency of the first transmission (at zero FSK).

Similarly, there are parameters called "Freq. 1" and "Freq. 2" which specify the frequencies of the second and third transmissions to be sent in the sequence.

Freq. 1 and 2 set the baseline RF output frequency of the next transmissions in the sequence (at zero FSK). If a setting is left at 0, that mode/frequency pair will just be ignored.

These settings can be used to send the Callsign Identifier automatically, by using the "CW ID" mode (see CW ID mode section below). For example, Mode 0 could be WSPR, Mode 1 could be CW ID.

```
Speed
003
```

The Speed setting selects the dit speed, in seconds, for the following modes: FSKCW, QRSS, DFCW. In CW and FSK modes, the Speed setting means Words Per Minute. In Slow-Hell mode, the setting is the number of seconds duration of one character (see later section for explanation). The setting has no effect at all, in CW ID, Hell, DX Hell, WSPR or WSPR-15 modes; these modes all have a defined timing which cannot be changed. It also has no effect in the TX mode. The default setting is "006" (6 seconds).

```
Callsign
G0UPL
```

The callsign setting is an alphanumeric setting, which may be up to 14 characters long. It can theoretically include punctuation but clearly that isn't normally used in a callsign. The callsign is NOT used for the normal message transmission in most modes.

The callsign is used only for TWO purposes:

1) The Callsign is used for generating the WSPR message encoding

2) The Callsign is sent at 12wpm in the CW ID mode, which can be used to send your callsign in standard 12wpm CW at pre-programmed intervals, as a station identifier (read your license conditions)

Note that when using the WSPR mode, the callsign must satisfy certain rules. Firstly, it can only be a 5 or 6 characters long. The callsign must consist of the following:

1) One or two characters consisting of A-Z or 0-9

2) One character which must be a number, 0-9

3) Three characters which must be A-Z or space

These restrictions are placed on the callsign in order to satisfy the requirements of the WSPR encoding algorithm.

Note that if your callsign is a 4-character callsign then you need to add spaces at the right, to comply with condition 3 above. If your callsign is of the form AB0CD then you need to add one space at the right, e.g. "AB0CD ".

```
Message
73 DE G0UPL
```

The message setting is an alphanumeric parameter which may be up to 250 characters long. For FSKCW, DFCW, CW, QRSS modes, it must be in the range A – Z, 0 – 9, / or a space character. Hell modes can use punctuation characters as well, but not the * character.

Any message may be entered, but if the message is invalid for the mode being used, an error will be displayed.

The * character has a special purpose, it is used to signify the start and end of user-customisable pattern generation specification (see description below).

IMPORTANT: remember to add a space character at the beginning or end of your message! G0UPLG0UPLG0UPL... etc. is not easy to read, because it has no spaces. G0UPL G0UPL G0UPL is how you want your message sent, with a space between the messages.

```
Frame
00
```

This parameter is used to define the message frame length. A technique called "stacking" has been developed by QRSS'ers to improve signal-to-noise ratio even further. The transmitting station transmits messages defined into a frame of a precise length. The receiving station overlays multiple message reception frames on top of each other on the display. Any message which is repeating at that precise frame length gets re-enforced by the averaging of multiple message receptions; any other non-repeating message or QRM gets reduced.

As an example, consider a message which in the chosen QRSS mode and speed happens to take 8 minutes to transmit. You could set the "Frame" setting to 10. This means that after the message transmission has completed, the microcontroller will wait until 10 minutes after the message start, before starting the next transmission. Receiving stations who have are using QRSS decoding software with the stacking feature, and have it set to 10 minutes frame length, will be able to collect six (say) transmissions over one hour and average them together to improve the signal-to-noise ratio.

This parameter is also used for the WSPR mode. In the WSPR mode, the Frame parameter defines how often the WSPR transmission packet is transmitted. WSPR transmissions take just under 2 minutes and are always aligned to the start of an even minute. Therefore in WSPR mode, the Frame parameter must be an even number (a multiple of 2), e.g. 10 minutes (9 minutes is not possible).

Typically, Frame should be set to 10 minutes for WSPR. 10 minutes is also a popular frame length for "stacking" QRSS reception, as long as your message transmission fits within 10 minutes. If it does not, the controller will wait until the next 10 minutes have elapsed.

In WSPR-15, Frame should be a non-zero multiple of 15 minutes, typically 15 minutes.

When using GPS frequency stabilisation, you must choose a non-zero Frame parameter. This is because the frequency stabilisation must take place when there is no transmission from the kit, i.e. during a pause between transmissions. The frequency stabilisation takes 13 seconds and occurs just after the end of a transmission. Therefore you need to ensure that the Frame parameter is sufficiently large that there is a minimum gap of 13 seconds between the completion of your message transmission and the start of the next one.

Default: the default value is 00 which means no frame size is defined, and the stacking feature is not used. All mode/frequency combinations are sent repeatedly in sequence. Frame must be set to a non-zero value for WSPR and WSPR-15.

```
Start
00
```

This parameter is used in conjunction with the Frame parameter described previously. It defines when the transmission cycle starts. For example if Start is set to 03, and Frame is set to 10, then the message transmission will start on the when time reaches 00:03 (or 3 minutes past any hour), and will repeat at exactly 10 minute intervals.

Again for WSPR, the Start parameter must be even (a multiple of two). For WSPR-15, a multiple of 15.

Default: the default value is 00 which means the Start parameter is not used

```
Locator
IO90
```

The locator setting is only used in WSPR mode, and is one of the inputs to the WSPR encoding algorithm. It is four characters, the first two are always A – R and the second two are numbers in the range 0 – 9. Editing this parameter automatically prevents incorrect entries. The locator is not needed for any other mode than WSPR and may be left blank.

If a GPS module is connected with a correctly configured serial data stream, then the locator is set automatically from the GPS data.
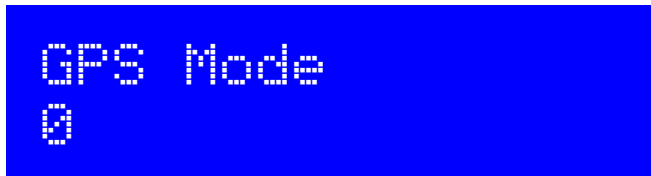
```
Power
23
```

The power setting is another input to the WSPR message. This setting is not needed for any other mode than WSPR. Although the parameter will accept any 2-digit value, only certain values are valid for the WSPR encoding scheme. The power is the transmitter output in dBm. It must be in the range 0 – 60, and the least significant digit must be 0, 3 or 7.

The allowable values, with their corresponding power in watts, are listed here:

00 dBm	=	1mW
03 dBm	=	2mW
07 dBm	=	5mW
10 dBm	=	10mW
13 dBm	=	20mW
17 dBm	=	50mW
20 dBm	=	100mW
23 dBm	=	200mW
27 dBm	=	500mW
30 dBm	=	1W
33 dBm	=	2W
37 dBm	=	5W
40 dBm	=	10W
43 dBm	=	20W
47 dBm	=	50W
50 dBm	=	100W
53 dBm	=	200W
57 dBm	=	500W
60 dBm	=	1000W

The default value in this kit is 23dBm (200mW) which is closest to the measured prototype output power of 180mW.

An illegal value will result in a runtime error display.

This controls how and whether GPS is used. If set to a non-zero value, and a GPS module is connected with a valid 1pps signal, then the accurate time pulses from the GPS unit will be used to lock the frequency, and to keep precise time. In the event of a GPS signal outage (for example, poor reception), the kit can continue to use the onboard 20MHz crystal oscillator for time-keeping.

If additionally the serial data connection from the GPS unit is valid, the Maidenhead locator will be computed from the latitude and longitude received from the GPS module, and the internal realtime clock will be set using the time from the GPS module.

When using the connected GPS module for frequency stabilisation, you must choose a non-zero Frame parameter. This is because the frequency stabilisation must take place when there is no transmission from the kit, i.e. during a pause between transmissions. The frequency stabilisation takes immediately after the transmission has completed. You need to ensure that the Frame parameter is sufficiently large that there is a minimum gap of about 15 seconds between the completion of your message transmission and the start of the next one.

Frequency stabilisation can also be provided by a 1pps signal derived from an accurate frequency reference. In this case, connect the 1pps signal to the 1pps connection, and set Use GPS to "On". With no serial data, the kit will not decode the Maidenhead locator or time, however the 1pps signal **will** be sufficient for frequency stabilisation.

When GPS is enabled, a heart symbol will appear on the display. When a GPS frequency calibration has been successfully completed, the symbol will beat in sync with the 1pps signal input. The heartbeat will go to a solid (non-flashing) display during the 15 seconds following a transmission, while calibration is in progress. Please see the website for more details on the GPS frequency calibration algorithm.

GPS Mode settings:

0   GPS is not used at all. The kit is in free-running mode, it will run from it's 20MHz crystal oscillator.

1   For backward compatibility, this is how the kit worked in v2.03. The kit triggers on a <u>change</u> in the voltage level on the 1pps input. A timer is included to prevent it triggering on both rising and falling edges and to correctly detect the right edge, theoretically. This mode would probably be useful if the pulse width from the GPS is very short.

2   The kit triggers on the rising (positive) edge of the 1pps signal. This is appropriate for most GPS modules, where the pulse width is 100ms for example.

3   The kit triggers on the falling (negative) edge of the 1pps signal.

```
GPS Baud
009,600
```

This setting determines the baud rate for receiving serial data input from the GPS module. It must be set to match the data output from the GPS module otherwise no data can be decoded. You will need to refer to your GPS module documentation to determine the correct speed.

Any baud rate can be entered here. 9,600 is common. The kit should be able to support 115kbps but higher than this may be subject to inaccuracies and not function properly.

The kit uses no parity, 1 stop bit, and 8-bit data. I have never encountered a GPS module that does not use the same settings, which appear to be very standard.

```
FSK (Hz)
004
```

FSK size is determined by this parameter, and may be in the range 0 to 999Hz. For FSKCW and DFCW modes, the specified FSK is the height of the symbol shift. For Slow-Hell mode, it is the height of the text. The parameter does not apply for the other modes. Generally, you will want a shift of 4 or 5 Hz for the slow-speed modes. For the fast-speed FSK mode used for beaconing on the 10m band, a few hundred Hz is typically used.

When Fine FSK is switched On (see below), the FSK (Hz) parameter's meaning is changed. In this case, the parameter specifies the number of minimum steps of the DDS. The DDS resolution is 0.029Hz using the supplied module with 125MHz reference oscillator. For more details see below description of the "Fine FSK" parameter.

```
Fine FSK
Off
```

When Fine FSK is "On", the FSK (Hz) parameter's meaning is changed. The FSK (Hz) parameter then specifies the number of DDS frequency steps, using the maximum fine resolution available in the DDS module. With the supplied module having a 125MHz reference oscillator, the step size is 0.029Hz. So for example, if "Fine FSK" is "On" and "FSK (Hz)" is 010, the actual frequency shift will be 0.29Hz.

This setting therefore gives very fine control over the frequency shift, which can be useful for the very slow modes sometimes being used on LF and MF bands.

Note that when using WSPR modes, the correct frequency shifts for WSPR are calculated by the kit; the "Fine FSK" and "FSK (Hz)" settings have no effect in the WSPR mode. They also have no effect on CW, CW ID, QRSS or the Hellschreiber modes.

```
Sys. Frq.
20,000.00
```

The system clock frequency is the crystal oscillator frequency which clocks the microcontroller. In this kit, a 20MHz crystal is used, and there is no facility for adjusting its frequency – the trimmer capacitor sometimes used in such circuits is omitted here in order to keep the kit as simple and inexpensive as possible.

The system clock is used for timing purposes when there is no GPS module connected to lock the frequency. Where the frequency is slightly different to 20.000000MHz the time-keeping of the real-time clock will become inaccurate. Ordinarily this will not matter for most modes, the exception may be WSPR where the frames must coincide with the start of even minutes, within a second or two. Over some days, an inaccuracy of a second or two per day in the real-time clock can cause the WSPR signal decoding to become impossible.

Accordingly this parameter has been provided so that if you wish, you can set the frequency to the actual exact frequency of your 20MHz crystal. This will ensure that time-keeping is precise. The best way to measure the oscillation frequency will be to use a general coverage receiver having an accurate digital display, and listen for the 20MHz signal on the receiver, then tune the receiver to zero-beat, i.e. until the tone of the audio decreases to 0Hz. Then enter this frequency into the Sys. Frq. configuration setting.

An alternative method may be to measure the time gain or loss over a period of several days, and work backwards to determine the required value to use for the Sys. Frq. Parameter to correct it.

```
Ref. Frq.
125,000,000
```

The Reference Frequency setting is the actual frequency of the on-board 125MHz canned crystal oscillator module on the pre-assembled DDS module board. It is important to set it accurately, otherwise the actual output frequency of the kit transmission will not match the value set in the Frequency parameter (see above). Calibration of this parameter is discussed in section 9, see below.

```
ParkMode
0
```

The "ParkMode" and "ParkFreq" parameters are used to control the behaviour of the kit during key-up. This was intended to prevent the -30dB (or so) leakage of carrier to the antenna, even when transistor Q1 was switched off. The meaning of this parameter is as follows:

0   Same behaviour as v2.03. The DDS is left on the same frequency during key-up. The problem with this is that there is signal leakage through Q1 during key-up.

1   During key-up, the DDS frequency is shifted up by however many Hz "ParkFreq" specifies (maximum is 65,535Hz)

2   During key-up, the DDS frequency is set at the "ParkFreq" frequency which can be zero, or whatever you want. A zero park frequency is the same behaviour as in v2.04. However please note that it appears that on some DDS modules, this causes a frequency drift during the next key-down. This will be worse on higher transmission frequencies than lower. It can be bad enough to prevent WSPR decodes.

3   The DDS output is switched off using bit 34 of the control word ("power down")

```
ParkFreq
00,000,000
```

See above description in the "ParkMode" parameter.

```
Set Time
00:53
```

The kit has an internal real time clock which is used for the Frame (QRSS stacking) and for timing WSPR messages. This configuration allows you to set the real time clock. The clock setting takes effect, and the seconds (internally counted but not displayed) are set to zero, when the LEFT button is pressed after setting the minutes. **Accurate timing is critical for the WSPR modes.** With careful adjustment of the "Sys. Frq." parameter, the 20MHz oscillator will keep accurate enough time for WSPR for up to a week, even without GPS.

Note that if using a GPS module with "Use GPS" switched on, and if there is a valid serial data stream properly decoded (by correct choice of "GPS Baud" parameters), then there is no need to set the time, because it is automatically decoded from the GPS data.

An accurate real time clock is not required other than for the WSPR modes. Even if the real time clock is not set, it will start from 00:00 when the system is powered up. This is sufficient for stacking if enabled (i.e. if Frame is non-zero).

2.4 Understanding error messages, and how to fix them

In the event of inconsistent parameter setting, an error message may be displayed on the LCD. The cause of these messages is well-defined. The following lists the possible error messages and their causes.

```
Error:
Mode  0
```

This error occurs if Mode 0 is set to "None". Mode 1 can be "None" if you want to send only one message transmission, but Mode 0 must be set to a valid transmission mode.

```
Error:
Freq.  0
```

The Freq. 0 parameter cannot be set to 0. You should enter a valid value.

```
Error:
Speed
```

This error results from having a zero Speed parameter, or Speed > 200 seconds, in any mode other than Hell, DX Hell, CW ID, WSPR, WSPR-15 and TX. These modes have specific defined speeds which are not adjustable, and so the Speed setting is ignored for them.

```
Error:
Callsign
```

For the WSPR mode, you have not entered your callsign, or it is invalid for the WSPR encoding algorithm. Please check the description of the callsign parameter setting, see above.

```
Error:
Message
```

This error concerning the transmission message can occur for two reasons:

1) The message is empty, and the mode is set to anything except a WSPR mode. In the WSPR modes, the message encoding is generated automatically from the callsign, locator and power settings. In all other cases, the message must be set, otherwise the kit has nothing to transmit.

2) In modes QRSS, CW, CW ID, FSKCW, DFCW, there is an invalid character in the message. Valid characters are A – Z, 0 – 9, space and /. in the case of FSKCW the message may also contain an asterisk * which enables the user-customised pattern mode.

Note that the "Message" setting is not used in the "Transmit" mode but you still need to enter something. Anything will be fine.

```
Error:
Frame
```

In WSPR mode, Frame (number of minutes between transmissions) must be even (a multiple of two), and it must be non-zero. 10 [minutes] is the recommended value. In the WSPR-15 mode, Frame must be a non-zero multiple of 15, with 15 [minutes] being the recommended value.


```
Error:
Start
```

In WSPR mode, the Start parameter must be an even minute (power of two), and in WSPR-15, a multiple of 15 minutes. In all modes, the Start parameter must be less than 60 (as there are only 60 minutes in an hour).


```
Error:
Power
```

This error can only arise during WSPR mode. The Power setting must be in the range 00 – 60 and the last digit must end in 0, 3 or 7. i.e. 00, 03, 07. 10, 13, 17 are all Ok.


```
Error:
Locator
```

Again, an error which can only arise in WSPR mode. The locator must be a standard 4-digit Maidenhead locator (e.g. IO90). If you are getting this error, it means you have not properly set the Locator configuration parameter – it should consist of two letters in the range A – R followed by two digits in the range 0 – 9.

3. QRSS Modes

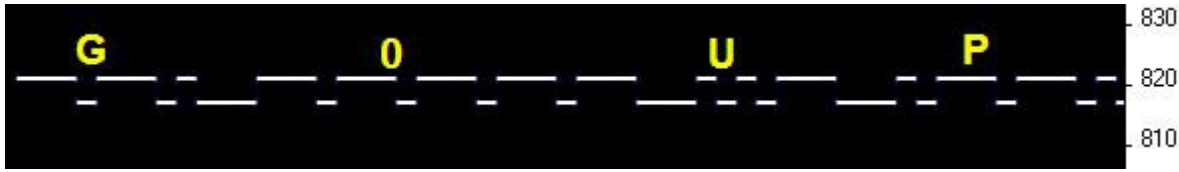The following is a short description of each kind of QRSS mode, and what to expect.

3.1 FSK/CW


```
FSKCW6 800+4   --
G0UPL G0UPL G0UP
```

The display will show FSKCW followed by the symbol length – in this example 6 seconds. Next comes the base frequency. In AF Output mode, that is Hz. In RF Output mode, it is the last three digits of the

frequency – e.g. if the Frequency parameter is set to 10,140,050 then the display will show 050. The FSK shift in this case, from the "FSK (Hz)" setting, is 4Hz – indicated by the +4. Finally the message will show. The leftmost character is the one currently being sent, and the – before it indicates a dash is being sent. As the message is sent, the message will scroll to the left.

In the following image, the decoded letters have been drawn above the received signal in yellow, to show clearly how the mode is to be decoded.
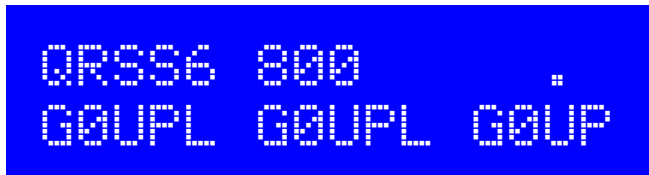

In Frequency Shift Keyed CW (FSK/CW) the dahs and dits have the same timing as traditional (slow) morse i.e. QRSS, but the carrier is always on and "key down" is indicated by a slight upwards shift of a few Hz. FSK/CW is the most popular of the slow-signal modes.

Good for: The transmitter being continuously on, avoids any "chirp" (frequency pulling) of the oscillator, that can be a problem, particularly in more simple circuits. The signal is very readable in the presence of QRM or in weak conditions, because of the continuously present carrier. Decoding the signal is intuitive, just by reading the top line like ordinary CW.

Bad for: Because the carrier is continuously on, it will take more battery power (if that's a concern), than an on/off keyed mode like plain CW. It also takes more bandwidth than the single sub-Hz bandwidth of plain QRSS.

3.2 QRSS

Here the display shows the scrolling message, with a – or a . (for dah and dit), to show which character and symbol is currently being transmitted. The dit speed follows the mode (QRSS), in this example 6 second dits. The frequency is as for FSK/CW (see above) – in this case 800Hz audio output.

The original plain QRSS mode is simply plain CW, but massively slowed down, typically with dit speeds from 3 seconds or slower, even all the way to 120 seconds in some cases.

Good for: Simple to decode by eye, since it is the same was what we can imagine hearing. Very narrow bandwidth and band occupancy, sub-1Hz.

Bad for: In weak signal conditions or where there is a lot of QRM, an interfering weak carrier may also look like an intermittent horizontal line, so the wanted signal can be hard to distinguish from the QRM. Fading (QSB) can cause interfering carriers to look like QRSS too. In simpler circuits, "chirp" (oscillator pulling) can be a problem.

3.3 DFCW

The display will show DFCW followed by the symbol length – in this example 6 seconds. This is followed by the base frequency (see FSK/CW section above) and the FSK size. The scrolling message is shown as usual, with the – or . to show the current symbol of the current character.
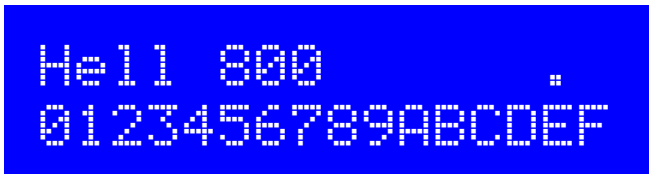

DFCW means dual-frequency CW. The dits and dahs are the same length, but dahs are shifted upwards by the FSK amount. A 1/3 dit-length gap inserted between symbols improves the readability.

Good for: The mode is faster than QRSS, with the same signal-to-noise ratio improvement, because the dah's are the same length as the dits. In QRSS dah's are three times longer. So the message transmission is faster.
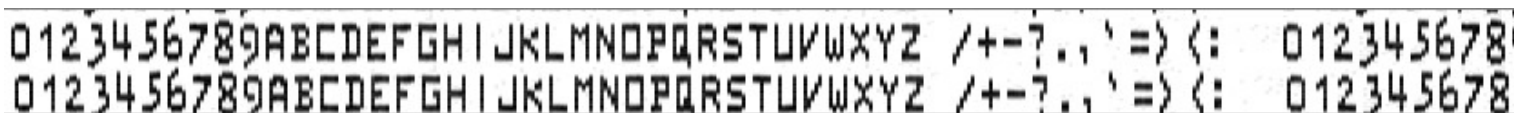
Bad for: Not very intuitively easy to read as QRSS is. If the signal is a bit weak and hard to decode, the eye/brain may have more trouble "filling in the gaps", because it is not so intuitive.

3.4 Hellschreiber (also called FeldHell).

As usual, the display shows the mode, frequency and the message scrolls to the left as it is sent.

The screenshot fragment below is from IZ8BLY's excellent Hellschreiber receiving (and sending) software.

Hellschreiber is a fax-like mode designed in the 1920's by Rudolf Hell in Germany. It was later used in WWII. The literal translation into English would be "Light Writer" and of course rhymes with its inventor's name. Each character is made up of a 7-row, 5-column grid. Technically there are 14 half-rows, but there are no lonely half-pixels in the characters, half-pixels are only ever seen in groups of at least two. This was an ingenious idea to minimise transmission bandwidth yet improve readability. The baud rate of a standard Hell transmission is 122.5. Most of the characters fit into a 10-half-row, 5-column grid, but the numbers are extended above and below this in some cases.

Good for: Fun, history, and easy readability.

Bad for: Bandwidth. Hell is not a slow-signal mode; the bandwidth is said to be around 400Hz.

I am proud to be using the original Hell font in this kit as carefully designed by Rudolf Hell. I know this because Pierre ON5SL, who owns a real antique FeldHell machine, kindly sent me a scan of one page of the operator's manual. This page shows the drum pattern of the machine.

Various software is freely available that can send and receive Hellschreiber, using any Windows font. Specially designed fonts are available. One called "FeldReal.fon" claims to use the original Hellschreiber character design but I am not convinced – if you are interested, look for example, at the K. FeldReal.fon's K actually looks nicer, but it doesn't quite match the one in the machine, look at the top right of the K.
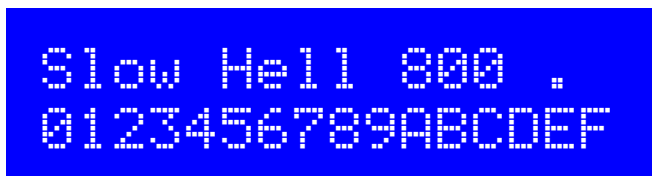
3.5 DX Hellshreiber

As usual, the display shows the mode, frequency and the message scrolls to the left as it is sent.

The screenshot fragment below is from IZ8BLY's excellent Hellschreiber receiving (and sending) software.

 So-called DX Hellschreiber is the same as ordinary Hellschreiber described above, except that every column is sent twice. The characters are therefore twice as wide, the message takes twice as long to send, but it has the advantage of potentially being more readable in weak conditions.
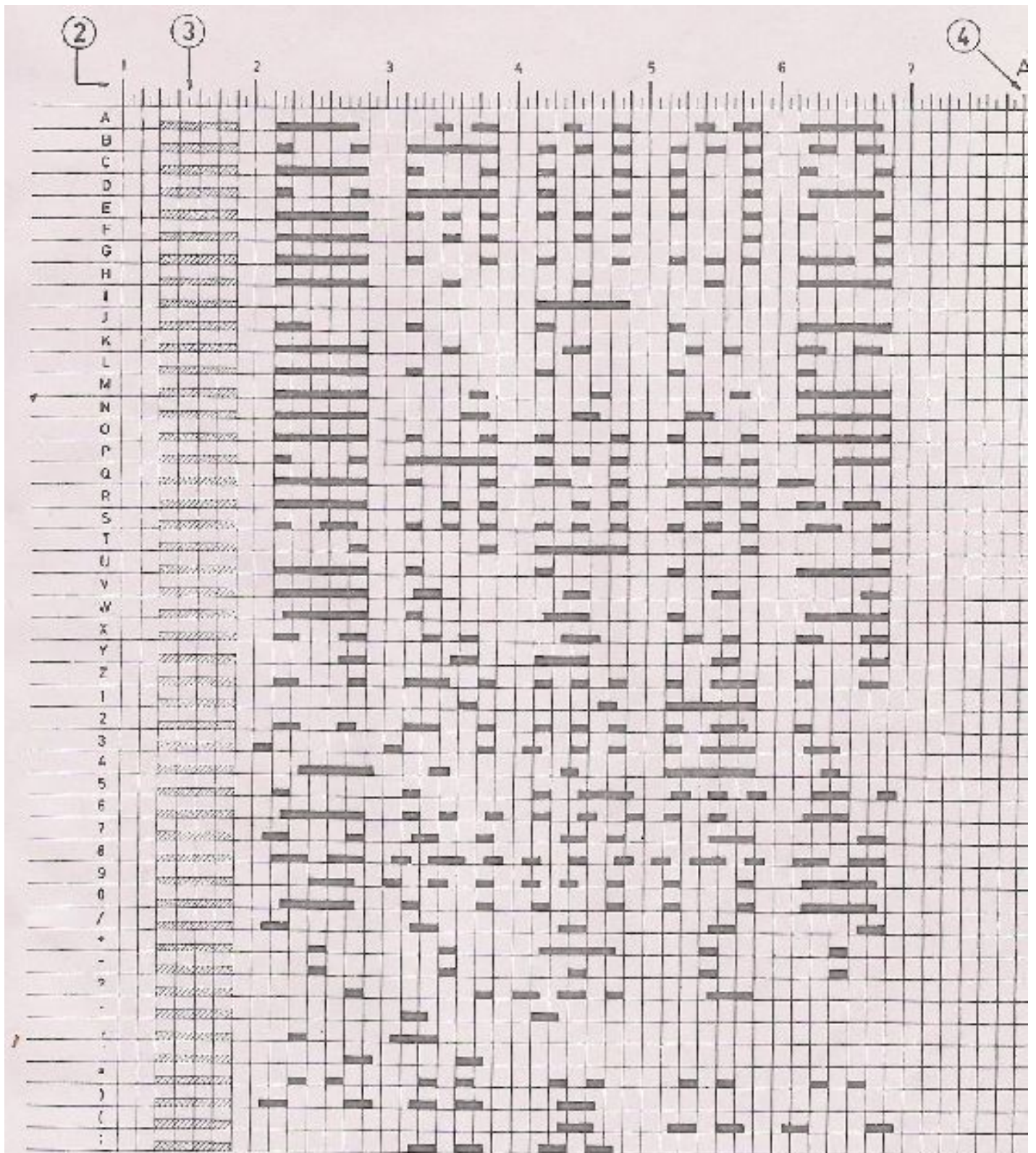
3.6 Slow Hellshreiber

As usual, the display shows the mode, frequency and the message scrolls to the left as it is sent.

Slow Hellschreiber is the slow-signal Hellschreiber equivalent. Each Hellschreiber letter row is shifted slightly in frequency. Typically the single pixel rate is very slow, for example 1 second per pixel (0.5 seconds per half-pixel). The character pattern is "scanned" one column at a time from bottom to top, shifting the frequency as the row increases up the character. In this way an image of the character is built up at the receiving station.

In Slow Hellshreiber mode, certain configuration settings in the kit require special attention:

Speed: The speed setting is the number of seconds required to transmit one whole character. Recall that a Hell character is composed of 7 rows (14 half-rows) and 5 columns; there is also one empty column as an inter-character space. Therefore each character is composed of 42 "pixels". Therefore if you want the transmission time to be 1 second per pixel, set Speed to 042. If you wanted 1.5 seconds per pixel, you would set Speed to 063, and so on.
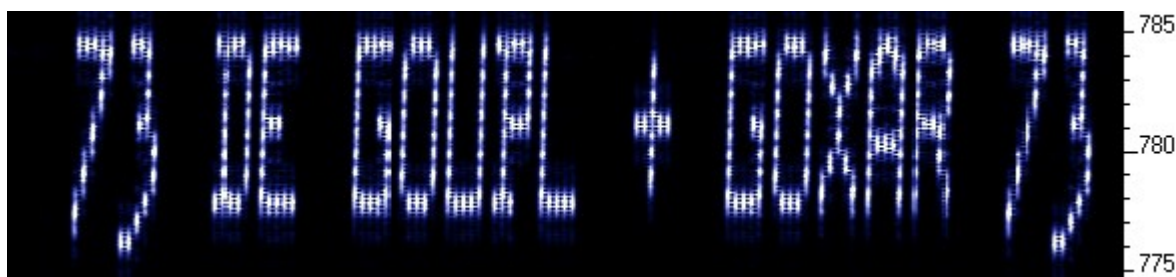
Page from a real Hellschreiber machine owned by Pierre ON5SL, showing the character drum.

15

① Abwicklung der Sendenocken
② Einteilung der Meßscheibe
③ Anlaufschritt
④ Nullstellung der Senderachse

FSK (Hz): The FSK size configuration specifies the height of each character, it is the number of Hz for 5 rows of the character. Recall that most Hell characters, such as the letters, fit on a 7-column, 5-row grid. FSK (Hz) specifies the size of that grid; some of the numbers extend above or below the grid. For example an FSK (Hz) setting of 05 would result in characters 5Hz high, i.e. 1Hz per row (pixel).

Be aware of fundamental limitations of information theory. If the pixel rate is 1 second (Speed = 042), the minimum theoretical bandwidth is 1Hz. Therefore choosing a pixel size of less than 1Hz, i.e. FSK (Hz) = 05, does not make any sense. Faster transmissions require larger bandwidth, and you will have to set the FSK size higher to match. If you do not, the image at the receiving end will be blurred.

This example image was taken in Argo, in its 10 second "slow" mode. The message is "73 DE G0UPL + G0XAR", the Speed is 042, and FSK (Hz) is 08. Note that even here, the characters start to look slightly blurred – a consequence of the fourier transform and minimum bandwidth, because the bucket size in Argo's 10 second mode is well under 1Hz so the 1Hz.

The following image shows part of the same thing in Argo's 3 second "slow" mode. The larger fourier transform bucket size means the image is more clear, but the faster scroll rate makes the letter's height to width ratio somewhat less attractive. Other slow-speed fourier transform software present more configuration options and may be more suited for slow-Hellshreiber reception than Argo.

3.7 CW

CW mode is just plain, ordinary on/off keyed CW (morse code) at ordinary speeds. The display will show CW followed by the speed – in this example, 12 words-per-minute (wpm), followed by the message which scrolls to the left as it is sent. The character position right before the message shows – or . depending on whether a dah or dit is being sent.

In CW mode, the Speed setting is the words-per-minute speed, e.g. 012 for 12 wpm.

Have you ever spent a lazy Sunday afternoon calling CQ on 80m CW with QRP power, with no luck? Why not use the kit as a CQ machine, and take the hard work out of calling CQ! In AF output mode, the AF output could be rectified and used to key a CW transmitter, with the Frame setting used to control how often the CQ message would be transmitted.

3.8 CW ID

```
CW ID 800        .
G0UPL
```

The CW ID mode can be used for transmitting your callsign identification periodically if you wish, if you think that it helps you to comply with licensing conditions.

This mode is similar to "CW", it is just ordinary on/off keyed CW. However, instead of transmitting the contents of the "Message" setting, it simply transmits the "Callsign" configuration parameter. Additionally, the speed is always 12 wpm, it ignores the "Speed" setting.

A typical use of the CW ID mode would be to transmit your desired slow-speed modes in the Mode 0/1 and Frequency 0/1 settings, with something like a 10-minute frame. Then set Mode 2 to CW ID and the frequency to match your frequency 0 (or 1) setting. Your callsign would accordingly be sent at 10 minute intervals in plain 12 wpm CW.

Note that if you do not enter anything in the Callsign field, then the CW ID Mode setting will simply be ignored. There is no validation for this, so please be careful to enter your callsign in the "Callsign" parameter if you wish to use the CW ID mode.

3.9 FSK

```
FSK 800+400    —
CQ DE G0UPL K
```

This mode is designed for wideband fast FSK. It is in common use for 10m beacons using FSK shifts of several hundred Hz. The speed setting is interpreted as a words-per-minute speed, e.g. enter 012 for 12 words-per-minute.

3.10 Transmit

```
TX 14,060,000
```

Here the kit can be used as a basic CW transmitter. The frequency is set by "Freq. 0". You can connect a straight morse key across the right button, for keying the transmitter.

3.11 Tune

In any mode when in the "waiting" state, waiting for the next transmission frame to begin (i.e. the "Frame" parameter is non-zero), pressing the right button keys the transmitter. This can be used for antenna tuning.

3.12 WSPR

The WSPR mode display is composed of several elements. Given the example display above:

WSPR   The mode being used!
800   Baseline output frequency (last few digits only)
137   Symbol number currently being sent; WSPR messages are made of 162 symbols
2   Tone currently being sent – WSPR messages are made of four tones, 0 – 3.
IO90   Maidenhead locator setting coded into the WSPR message

WSPR stands for Weak Signal Propagation Reporter. The message consists of three parts: the operator's callsign, Maidenhead locator (4-character, e.g. IO90) and two digits specifying the power. At the receiving station, messages are decoded and uploaded to a central internet database.

The WSPR message is encoded into a set of 162 symbols, each may be 0, 1, 2 or 3, using a compressed data format with forward error correction. The symbols are transmitted as tones, each tone separated by 12,000 / 8,192 Hz i.e. approximately 1.46Hz. The duration of each symbol is the reciprocal of the tone spacing, which is approximately 0.683 seconds. WSPR messages take about 110.6 seconds to transmit, and always start at even minutes past the hour.

In WSPR, timing is critical, so when using WSPR you must set the time configuration parameter as exactly as possible. Be sure to keep the rightmost flashing 1-minute digit, watch your clock until the seconds turn over to 00, and then press the left button. This will ensure the seconds are in sync with your real clock time. If careful attention is given to setting the frequency and the real time clock, then successful WSPR reports will be obtained. Of course these things are easier if you are using a GPS module: the Maidenhead locator will be calculated from the received latitude and longitude, and the time decoded nicely from the GPS serial data stream.

The microcontroller in this kit takes care of the WSPR message encoding algorithm, without any assistance from a PC host computer. It also calculates the tone spacing and symbol duration.

In between message transmissions, the display will show instead just a clock (see below), while we wait patiently for the next WSPR transmission to begin, according to the settings of the configuration parameters Frame and Start. This is useful for checking that the time on your kit is accurately set. The display also shows the minute at which the next frame will start transmitting. In the example below, the time is 13:04:53 and the next frame will start at 13:10:00.
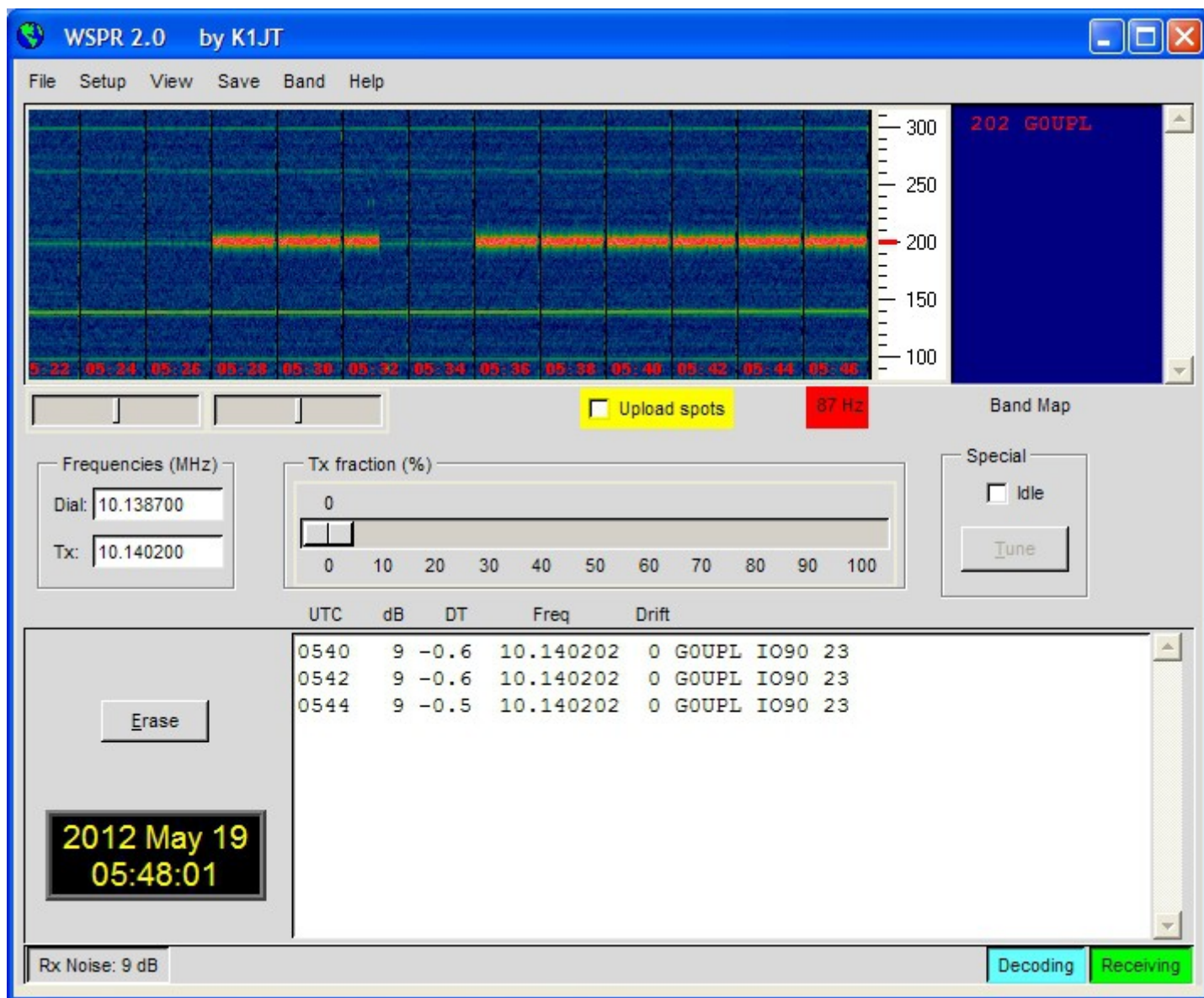

On Argo, WSPR messages look ugly, like this:

WSPR decoding takes place in the WSPR program by K1JT (see http://physics.princeton.edu/pulsar/K1JT/wspr.html). Below is a screenshot showing the WSPR 2.0 screen following reception of a few transmissions (output frequency = 1,500Hz, Frame = 02, Start = 00).

Choose a transmission frequency somewhere in the 200Hz-wide standard HF WSPR bands:

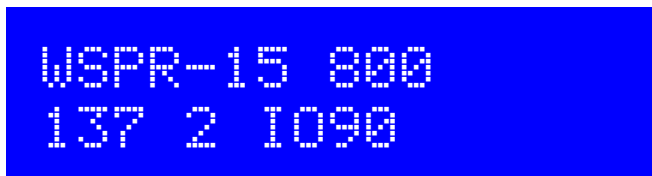|		
160m: 1.838000 – 1.838200		20m: 14.097000 – 14.097200
80m: 3.594000 – 3.594200		17m: 18.106000 – 18.106200
60m: 5.288600 – 5.288800		15m: 21.096000 – 21.096200
40m: 7.040000 – 7.040200		12m: 24.926000 – 24.926200
30m: 10.140100 – 10.140300		10m: 28.126000 – 28.126200

3.13 WSPR-15

WSPR-15 is a relatively new experimental mode that is a variation of the common WSPR mode. It is used on the LF bands where the higher signal-to-noise ratio it offers is advantageous. WSPR-15 uses the same

encoding algorithms as WPSR, but the tone spacing is 8 times closer (approximately 0.18Hz) and the speed is also 8 times slower.

In WSPR-15, the Frame parameter must be a non-zero multiple of 15 minutes, and the Start parameter must be zero (usually) or a multiple of 15 minutes.

4. Customised message patterns

The kit has the ability to produce customised message patterns in the FSKCW mode. To enter or leave custom mode, a * character is inserted in the message. The first two characters after the * character specify the symbol duration of each symbol, in seconds. Subsequent characters specify the frequency shift of each symbol one by one, in units of 0.5Hz. For example, 5 means a shift of 2.5Hz. After the numbers, you can continue with letters. So A would mean a shift of 5Hz, B a shift of 5.5Hz, C a shift of 6Hz, and so on. For example consider the following message:

The callsign G0UPL is sent in ordinary FSK/CW with height and speed according to the configuration settings. Next comes a custom message, the duration of each symbol is 03 seconds. The shifts are 1, 2, 3, 4Hz respectively. On Argo, this message produces (with kit configuration FSK (Hz) = 04, Speed = 003):

As an example of what kinds of patterns can be produced, the pattern below is created using message *01ACDFGIJJKKKJJIGFDCA87542110001124578*

5. Factory Reset

On powering up the kit, a message is shown for a few seconds on the LCD, which indicates the version number. If the Right button is pressed during the display of this splash screen message, then the chip EEPROM contents are erased and returned to the original factory settings.

The effect of this feature is to entirely return the microcontroller chip to its original settings, it is the same as buying a new chip and inserting it. All calibration settings, message, frequency, etc. are erased and returned to the default settings.

6. Signal-generator mode

Another use of this kit, is as an accurate, stable signal generator. If you set the kit in the FSKCW mode, and set the FSK to 0 Hz, then whatever message you've entered, the output will always just be a single un-modulated signal at the chosen frequency.

7. Resources

Please see the kit page http://www.hanssummers.com/qrssultimate3 for any information on latest updates and issues.

Use the QRSS Knights mailing list: http://cnts.be/mailman/listinfo/knightsqrss_cnts.be to announce your operation.

You should get reception reports by email and see your signals on the various online "grabbers" (see http://digilander.libero.it/i2ndt/grabber/grabber-compendium.htm for a set of links to "grabbers" worldwide).

Please join the Yahoo group http://groups.yahoo.com/group/qrplabs/ to for new kit announcements, to discuss any problems with the kit, enhancements you've made, or just to tell everyone how much fun you're having.

For general information and more QRSS projects, links to other QRSS resources etc., see http://www.hanssummers.com.

Argo QRSS decoding software by Alberto I2PHD: http://www.weaksignals.com/

WSPR network home page: http://wsprnet.org

Analog Devices DDS information: http://www.analog.com/en/rfif-components/direct-digital-synthesis-dds/products/index.html

8 Version History

1	14-Oct-2013

Initial draft version, for firmware version v3.00