Ultimate3/3S: QRSS Labs Multi-mode QRSS Beacon Kit

v3.09/v3.09a

1. Introduction

This is the operation manual for the third generation "Ultimate 3S" and "Ultimate 3" Multi-mode QRSS/WSPR beacon kits. 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, Opera, PI4, JT9, TX CW, TX FSK and customisable patterns.

Ultimate 3S vs **Ultimate 3**

Kits supplied since January 2015 are U3S PCB's with a Si5351A module. The earlier U3 used an AD9850 DDS module. When you apply power to your kit, the microcontroller will automatically detect whether you have an Si5351A module plugged in, or the older AD9850 DDS module. During the first few seconds the screen shows the "Ultimate3" and the firmware version number. If you have the Si5351A module, the screen shows "Ultimate3S" (note the S, stands for Si5351A).

Some sections of this manual differ depending on whether you are using the Si5351A module or the DDS module. These sections are clearly labelled: **Ultimate 3S** for Si5351A, and **Ultimate 3** for DDS. Please read the section according to your module.

Important note: You can plug an Si5351A module or a DDS module into the old U3 PCB (revisions 1 to 4). However you must NOT plug an AD9850 DDS module into a U3S PCB.

2. Operating instructions

The microcontroller has a 1024-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 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.

However, when you have just built the kit and have not yet configured it, upon power-up the kit will enter "Diagnostic Mode". If you can see this message on the screen, all is well. Press the Left button to continue. If you do not see this message or any writing on the LCD, please refer to the troubleshooting web page.

The memory initially contains only certain default settings. An error will be displayed, saying "Error: No Transmissions", which indicates that you have not configured anything to transmit.

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 16-character 2-row LCD and two push-buttons. There are 31 user-configurable settings available. Many of the menu items have multiple settings grouped into one item. 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.

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 contents of the first mode 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 automatic button press repeat 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.

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 list of mode types, use the RIGHT button to cycle through the list to find the setting you want. When you have chosen the setting you want, press the LEFT button. This saves the setting into memory and the list setting leaves editing mode.

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 insert/modify/delete one character, or the whole message.

The order of the letters, punctuation and numbers is as follows:
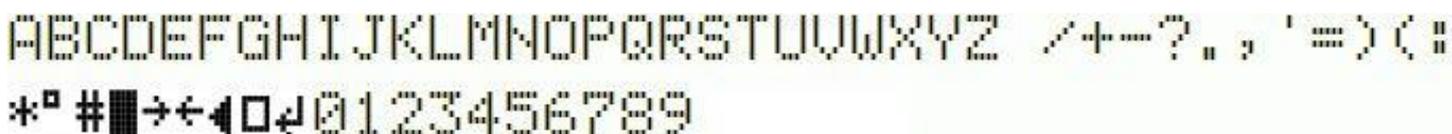
The following characters/symbols have special function:

Delimiter: This character is used to delimit sub-text inside the text entry.

Insert: Use this symbol to insert a character in the text. Find this character using the RIGHT button, then press the LEFT button to activate it. All the characters to the right of the cursor position are shifted right one position, including the character which was originally in the current position.

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.

Enter Right (finished): The behaviour of this symbol is the same as Enter, except that it preserves all the text, including the text to the right of the cursor. It simply saves the whole line.

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. When you have cycled through the menu and made any necessary amendments, upon pressing the right button to start, a validation is performed. 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. Potential error messages and solutions are described in a section below.

2.3 Menu configuration settings

Not all of the user-configurable settings 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.

```
0] 1  010,140,200
WSPR            23 3
```

This is an example of a Mode setting menu. The first set of configuration screens are all Mode settings. By default 3 mode settings screens are shown. Up to 16 mode setting screens are available. The number shown in the menu listing is controlled by a configuration parameter (see later section).

They facilitate the selection of band, frequency and mode combinations. When the system is placed into the Run mode, it will sequence through all enabled mode configurations in turn. This allows you to program sequences of bands, if you have connected the optional relay-switched Low Pass Filter (LPF) kit. Even if you are not using the relay-switched LPF extension kit, you may still use different modes and frequencies, and the mode settings enable a rich set of control signals that you can use to extend the functionality of the kit.

The screen contains multiple elements which are explained here in turn with reference to the example shown.

0] is the mode index. It cannot be edited, it simply shows you which mode setting you are editing. The 16 mode menus are labelled 0 to 9 then A to F.

1 is the band. This value can be from 0 to 5, and selects one of the six LPF band-switching relays, when you are using the extension kit. During transmission, one of the six control lines "BAND 0" to "BAND 5" in the circuit diagram (see Assembly document) are activated. The control lines are active-low and can be used for your own modifications, if not using the relay-switched LPF extension kit. When using the relay-switched kit, you should ensure that the low pass filter board plugged into the selected slot is appropriate to the chosen transmission frequency.

010,140,200 is an **example** transmission frequency: the centre frequency in WSPR mode; Frequency Shift Keying (FSK) is added to this in FSK modes.

WSPR is the transmission mode. The available modes are: None, FSKCW, QRSS, DFCW, Slow Hell, Hell, DX Hell, CW, CW ID, WSPR, WSPR-15, TX CW, TX FSK, Opera05, Opera1, Opera2, Opera4, Opera8, Opera32, Opera65, Opera2H and PI4.

23 is the Power output, in dBm. In WSPR the allowed values for power are 00, 03, 07, 10, 13, 17… etc. dBm. Any other value produces an error.

The power setting is part of the Mode configuration screen because you may wish to transmit at stepped power levels, using a relay-switched attenuator. In this case you would require the WSPR message to be re-encoded for each transmit frame, and this configuration allows that possibility. You may naturally find that the power output varies on different bands, and this setting allows you to accurately transmit your measured power in the message.

In transmission modes other than WSPR, that transmit a message read from the "Message" configuration parameter, this setting is used to indicate the number of the sub-message within the main message. This allows different message transmissions on different bands and/or modes to send different messages. See discussion in the "Message" setting below.

3 is an auxiliary output. This appears on the LCD data lines D4-D7 when not being used for writing to the LCD or DDS. These additional control lines can be used to control other relays or circuits in your application. For example you may wish to control relay-switched attenuators, or switch between different antennas for side-by-side comparison purposes. Some examples will be given in a different document.

The allowable power values according to the WSPR protocol, with their corresponding power in watts, are listed below (60 dBm, i.e. 1,000W, is omitted from the kit. This is a QRP kit, after all...)

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

A good recommended value for this kit would be 23dBm (200mW) which is close to the measured prototype output power. If possible, you should measure the power output on the band(s) you are operating, and set the nearest dBm value.

Enabling/Disabling Mode settings:

Each mode setting screen can be enabled or disabled. The default situation at the start, is for ALL mode settings to be disabled. When a mode setting is disabled, it appears "crossed out".

In order to toggle a mode setting between enabled and disabled state: cycle through the menu items with the Left button until you find the mode setting screen you want to enable or disable. Then press the right button twice, to toggle the enable/disabled state.

To EDIT the mode setting contents, e.g. the band, frequency or mode, press the Right button once, followed by the Left button to move the cursor onto the Band setting (1 in the above example). Then press the Left button to move along to the Frequency, then Mode, Power and Aux settings.

Note: Error checks

Any of the mode setting screens can be enabled or disabled. This feature can be used to program your favourite band, frequency and mode combinations, then to quickly be able to enable/disable which ones you want to use. Of course, at least one of the mode settings must be enabled and correctly set up, in order for any transmission to occur. When you have finished setting up the configurations (mode setting screens, message, callsign etc), an error check is performed to make sure that all the configurations are correct and consistent. This check validates the configuration of all enabled mode setting screens only. Disabled mode setting screens are ignored by the error check.

It is important to realise that some configuration parameters are actually shared by multiple different modes, and can be used in slightly different ways.

The following example shows the appearance of an enabled and disabled mode screen.

Enabled mode setting:

```
0] 1 010,140,200
WSPR         23 3
```

Disabled mode setting:

```
0]-1-010,140,200
WSPR----------23--3
```
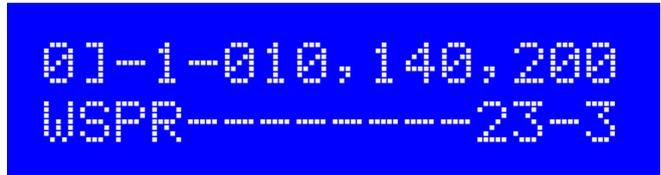
Error checking examples:

Example 1: the message setting contains the message that is transmitted in the QRSS, FSKCW, CW, FSK and DFCW modes. But the message setting is also transmitted by the Hellschreiber modes. Now the Hellschreiber message can contain characters such as + and = which the QRSS modes do not allow. The QRSS modes can only contain 0-9, A-Z, / and Space characters. Therefore in a situation where one of the mode settings transmits FSKCW, and another transmits Slow-Hell, the message must contain only characters which are allowable in both modes – which is to say, no +, = etc.

Example 2: the Frame setting has restrictions in the WSPR modes. It must be an even number of minutes, for WSPR. But for WSPR15, the Frame setting must be a multiple of 15. Now if you happen to be sending WSPR in one of the mode settings, but another enabled mode setting screen is sending WSPR15, the Frame configuration parameter must be a value which is valid for both WSPR and WSPR15. Furthermore the general restriction that Frame must be less than 60 applies always. The only valid Frame value in this case would be 30.

```
CW Dit Hel  Speed
12 006 001
```

The Speed settings selects the transmission speed for various modes. The default is 00 000 000, at power up.

CW: this is the speed in Words Per Minute, for the following modes: CW, FSK.

Dit: this is the duration of a CW dit, in seconds. It applies to the modes FSKCW, QRSS and DFCW. 6 seconds ("006") is quite appropriate for FSKCW on HF bands.

Hel: This is the duration in seconds, of each half-pixel, in the SHELL (Slow HELL) mode, only

All other modes e.g. CW ID, Hell, DX Hell, WSPR, WSPR-15, Opera, Pi4 and JT9 have timing defined by their protocols that cannot be changed; the speed settings have no effect on these modes.

```
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. However, if a character cannot be transmitted by the active transmission mode, then a space character will be substituted.

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.

Multiple sub-messages can be entered. If you wish to enter sub-messages, use the delimiter character (inverse square block, see above section 2.2.3 discussion) to separate and define the sub-messages. When using the sub-message functionality, each of the mode transmission screens can send a different sub-message.

You define which sub-message to send for each mode transmission screen, using the numeric setting to the right-middle of the bottom line of the mode screen display. This is the number that is used for entering the power, in the WSPR mode. In modes that send your operator-defined string from the "Message" parameter, this number determines which sub-message to send. 00 is the first sub-message, 01 the second sub-message, etc. There can be up to 100 sub-messages, in theory (numbered 00-99).

In the event that you specify transmission of a sub-message that does not exist in the message configuration parameter, the system will just send the 0th message.

Another feature of the Message configuration parameter is that you can include #-tags. At transmission time, these tags are replaced by dynamically supplied data. An example is the #LT tag. If you include "#LT" in a message, then when the message is transmitted, "#LT" will be replaced by the latitude read from the GPS receiver module.

The available #-tags are described in a later section of this operating manual.

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 three purposes:

1) The Callsign is used for generating the message encoding in WSPR, Opera and PI4 modes

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)

3) The Callsign can also be inserted automatically into the standard Message transmission, if you include the "#CS" tag in the message.

Note that when using the WSPR and Opera modes, the callsign must satisfy certain rules. Firstly, it can only be 4 – 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) Two or three characters which must be A-Z

These restrictions are placed on the callsign in order to satisfy the requirements of the WSPR and Opera encoding algorithms. PI4 callsigns are 8 characters, any of A-Z, 0-9, space or '/'. **Be sure to finish your 4, 5 or 6 character callsign with a string terminator, using the "Enter" symbol (see page 2). Do not be tempted to pad the remaining string size with spaces!**

Note: from firmware v3.05, the callsign must not contain any spaces. Any necessary padding with spaces will be carried out automatically by the system when encoding the WSPR message.

On occasions where you need to use a callsign prefix or suffix in your WSPR message, this is supported; please read the "Ext. WSPR" configuration parameter setting below. Opera modes do not support this.

The locator setting is only used in WSPR and PI4 modes, and is one of the inputs to the WSPR encoding algorithm. It is six characters, the first two are always A – R, the second two are numbers in the range 0 – 9, and the final pair are always A – X. Editing this parameter automatically prevents incorrect entries. The locator is not needed for any other mode than WSPR and PI4, and may be left blank if not using these.

If a GPS module is connected with a correctly configured serial data stream, then the locator is set automatically from the GPS data and does not need to be entered manually. However, in this case the system will skip past transmission of any WSPR mode until the locator has been decoded from GPS data.

WSPR messages ordinarily just encode 4-character Maidenhead locators such as IO90 in this example. The 5th and 6th fine detail location specifiers ("AB" in this example) are ignored. On occasions where you need to send the full 6-character locator in your WSPR message, this is supported; please read the "Ext. WSPR" configuration parameter setting below.

The 4-character or 6-character locator can also be dynamically inserted into the Message (for transmission modes that read the Message string) if you use the "#M4" or "#M6" tags, respectively.

This is a set of configuration parameters that control the Ultimate3/3S functionality. There are FIVE configuration parameters in one configuration screen; this is to save space and to save time when scrolling through the menu items; since in general these configuration options are not likely to be changed often (if at all). The five settings are described below.

XW This parameter enables the extended WSPR mode when set to 1. In extended WSPR mode, you may use a callsign containing a prefix or a suffix (not both). Furthermore, the full 6-character locator is transmitted providing more accuracy than the usual four. However, extended WSPR mode does have some disadvantages:

1) Two transmissions are required in order to transfer all the information, and the U3 sends them in alternate transmission cycles. The receiving station must receive both transmissions in order to fully copy all information, or in some cases, even your callsign (which is only sent in one of the two message types). In weak signal conditions a station may not receive more than one decode from you; and you will therefore lose reception reports compared to ordinary WSPR which only takes one transmission (one 2-minute slot).

2) The two transmission types are linked by transmission of a 15-bit hash code. This is sent in the second message instead of the full callsign. It is like a lossy-compression of the callsign. Multiple callsigns would produce the same hash code because there are only 32,768 possible values (15 binary bits). There is therefore a risk of false decodes. If many people switch on extended mode, there is an increased risk of false decodes.

These are limitations of the WSPR protocol, not the U3 kit. The same limitations apply to WSPR sent using a PC and the WSPR program.

For the above reasons, **enabling extended WSPR is not recommended unless you really need to send a long callsign or the full 6-character Maidenhead locator.**

When sending a callsign in extended WSPR mode with a prefix or suffix, three types of extended callsign are allowed, as follows:

1) A single character suffix in the range 0-Z, e.g. G0UPL/P

2) A double digit suffix, numeric only, e.g. G0UPL/26

3) A prefix consisting of between 1 and 3 letters or numbers, e.g. MM/G0UPL

The extended WSPR protocol does not allow both a prefix and a suffix, and it does not allow callsign extensions other than the three types listed above. The U3/U3S kit validates the entered callsign to ensure that it meets the requirements.

X2 This setting is intended to allow the U3/U3S to drive certain LF power amps which require a double-frequency input (for push-pull purposes).

Ultimate 3S	Ultimate 3
When X2 Freq is set to 1, the output frequency is 2x the actual configured transmission frequency on transmission frequencies below 1MHz. There is no effect on frequencies of 1MHz and above.	When X2 Freq is set to 1, the output frequency is 2x the actual configured transmission frequency.

Tn When set to 1, potentiometer frequency tuning is enabled. This is useful for people wishing to use the U3S kit as a CW transmitter. See http://www.hanssummers.com/ultimate3/u3mods.html#tuning

Iv When set to 1, this setting enables an Inverted output (180-degree phase shifted) output on the Si5351A's Clk1 output. This has potential uses for Push-pull output stages. When set to 2, the Clk1 output is on the same frequency as Clk0 (as for Iv = 1) but the Clk1 output is always on (unkeyed).

This setting is IGNORED on the U3; it only applies to the U3S with the Si5351A module kits.

When Iv (Inverted Clk1 output) is enabled in the U3S, the Park Modes are disabled. The "Iv" setting overrides the Park mode settings. This is because the park modes also use the Si5351A Clk1 output.

TxS The TxS setting specifies the number of mode transmission screens to show in the configuration menu. It is actually the ID of the last mode transmission screen to be displayed when scrolling through the configuration menu. The default is "02". This means that three mode transmission screens will be shown: 0], 1] and 2].

When mode transmission screens are hidden because their ID is higher than the TxS configuration parameter, their settings are still stored. However they do not appear in the listing when scrolling through the configuration menu items, and they are not transmitted, even if they were enabled before being hidden.

```
FSK (Fine Hz)
0 004
```

This configuration screens containing TWO settings relating to the way Frequency Shift Keying (FSK) is applied.

`0`

The first setting switches Fine FSK on (1) or off (0). This is the old "Fine FSK" parameter (pre v3.02).

Ultimate 3S	Ultimate 3
When Fine FSK is 1, the second FSK (Hz) parameter's meaning is changed. The FSK (Hz) parameter then specifies the FSK in units of $1/16^{th}$ Hz, when transmitting on frequencies below 1MHz (i.e. 2200m and 600m bands). The setting has no effect on transmission frequencies of 1MHz and above. For example, if "Fine FSK" is 1 (on), and "FSK (Hz)" is 010, the actual frequency shift will be 0.625Hz (i.e. 10 x $1/16^{th}$ Hz), on transmission frequencies below 1MHz. Otherwise 10Hz as normal.	When Fine FSK is 1, the second 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. For example, if "Fine FSK" is 1 (on) and "FSK (Hz)" is 010, the actual frequency shift will be 0.29Hz (i.e. 10 x 0.029Hz).

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.

The second setting determines the FSK size, 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. Any more than that, will be considered anti-social by other operators. For the fast-speed FSK mode used for beaconing on the 10m band, a few hundred Hz is typically used.

Note that when using WSPR modes, the correct frequency shifts for WSPR are calculated by the kit; the Fine and FSK settings have no effect in the WSPR mode. They also have no effect on CW, CW ID, QRSS, Opera, PI4, JT9 or the Hellschreiber modes: these all have frequency shifts defined already by the mode protocol.

```
(Frame Start)
10 00
```

The first parameter is "Frame" and 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, PI4 and JT9 modes. In these modes, the Frame parameter defines how often the encoded transmission data 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 14 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 14 seconds between the completion of your message transmission and the start of the next one. The duration and type of the frequency stabilisation is determined by the "Cal" parameter, described later.

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, WSPR-15, PI4 and JT9 modes.

`00`

This second parameter is "Start" and is used in conjunction with the Frame parameter. 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.

```
GPS (Mode Baud)
0 009,600
```

`0`
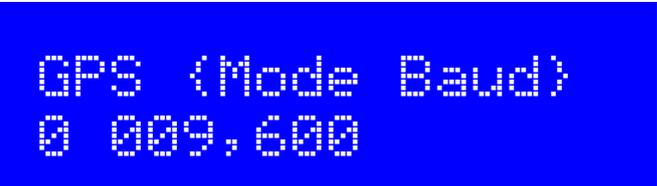
The first setting is the GPS mode. This controls how and whether GPS is used. If set to a non-zero value, and a GPS module is connected and producing a valid 1pps signal, then the accurate time pulses from the GPS unit will be used to lock the frequency, and to keep precise time. In the event of a GPS signal outage (for example, poor reception), the kit can continue to use the on-board 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 begins 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 14 seconds between the completion of your message transmission and the start of the next one. (See also the "Cal" setting described below, which controls the step and duration of the frequency stabilisation – **step size default is 00 which means NO calibration! Please set it!**).

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, and a 1pps signal is present from the GPS receiver module, a heart symbol will appear on the display. The heart beats in sync with the 1pps signal input.

While the system is calibrating, the bottom row of the LCD shows the text "Cal" followed by a status bar animation. The status bar fills as the calibration progresses.

When the calibration is completed, the bottom row will display the new calibrated reference frequency, and the change from the previous value. After 20 seconds, the bottom row is blanked again. Note that in the event of loss of 1pps signal, the status bar will pause, and calibration resumes when the 1pps signal is regained.

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

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.

```
 009,600
```

This second setting on the GPS screen 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 most common and is the default. The kit should be able to support 115kbps but higher than this may be subject to inaccuracies and may 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.

```
GPS Info
0
```

During the wait period between transmissions, the lower half of the screen displays GPS information in realtime. This information is displayed when the calibration has completed and 10 seconds of showing the calibrated reference frequency have elapsed. The "GPS Info" setting controls what information is displayed.

By default (GPS Info = 0), the display cycles through 4 pieces of information, showing each for 4 seconds: Latitude, Longitude, Altitude and Info. The first three are self-explanatory. Note that latitude/longitude are in degrees and decimal minutes (not seconds). This is straight from the GPS $GPRMC string. The info line shows five pieces of information about the quality of the GPS reception.

An example:

A 3D f06 t10 s31

a) A or V, validity flag. A means valid GPS fix. V means void.
b) Type of fix. No or 2D or 3D. ("No" means "None").
c) Number of satellites in fix (solution). f is for "fix". Here, 6 satellites are used in the fix.
d) Number of satellites being tracked. t is for "tracked". Here, 10 satellites are being tracked.

e) Average signal strength of tracked satellites. s is for "Signal". In this example, it is 31.

This information is updated with freshly decoded data from the GPS every second. It comes from the following NMEA sentences.

$GPRMC: Latitude, Longitude, Validity flag
$GPGSA: Type of fix, None, 2D, 3D
$GPGGA: Number of satellites in fix, Altitude
$GPGSV: Number of satellites being tracked, signal strength

All of these four NMEA sentences are active by default on the SKM52 GPS module, and most other GPS modules. In the event that any information is missing because the data hasn't been received from the GPS, or because the GPS doesn't send that NMEA sentence containing the data: then the data is replaced by a "-" or in the case of latitude/longitude, just shows as blank.

E.g. "A 3D f-- t10 s31" means no $GPGGA string is present.

The value of the "GPS Info" setting is from 0 to 3, and has the following meaning:

0: (default): Cycles through Info, Longitude, Latitude and altitude, for 4 seconds each

1: Info display only

2: Cycles through latitude, longitude and altitude for 4 seconds each

3: Off (no display on bottom line, like in v3.05 and earlier)

```
Cal (Step Time)
01 010
```

```
01
```

This setting determines the frequency step applied at each 1 second interval, by the "Huff-Puff"-like calibration method in the U3/U3S.

For a full discussion of the Huff Puff frequency calibration please read
http://www.hanssummers.com/ultimate3/u3info/u3hp.html

From firmware v3.08 onwards, ALL calibration uses the Huff Puff method. Previous firmware versions supported a non-Huff Puff method also (measure frequency for 10 seconds, calculate correction). The Huff Puff method was originally introduced in order to overcome inaccuracies in the 1pps specification of Sirf III-based GPS receiver modules such as the VK16E. The Huff-Puff method is more robust and accurate, so to save code space and simplify the situation, it is now the ONLY calibration method since firmware v3.08.

The default Cal Step value of 00 means that NO adjustment will be made – NO calibration at all occurs. So make sure you understand the effects of the Cal Step parameter and choose an appropriate value.

Ultimate 3S	Ultimate 3
When using the Huff Puff mode, the frequency is set to 6.75MHz and measured during the 1 second interval between incoming 1pps pulses. If the measured frequency is higher than 6.75MHz, it means that the reference oscillator calibration frequency must be too low, so the Cal Step amount (in units of 0.1Hz) is added to the 27,000,000 reference oscillator frequency. Conversely, if the measured frequency is lower than 6.75MHz, it means the reference oscillator calibration is higher than the real world value, so the parameter is decreased by the Cal Step amount (1/10th Hz). The optimum setting for Cal Step will depend on how much drift is to be compensated, since a limited correction is applied during each calibration. For example, if Cal Time is 10 seconds and Cal Step is 20 (means 2Hz), then the maximum correctable error on the 27MHz setting is 20Hz per calibration. For this reason, it is a good idea to increase the Cal Time setting.	The frequency is set to 6.25MHz and measured during the 1 second interval between incoming 1pps pulses. If the measured frequency is higher than 6.25MHz, it means that the reference oscillator calibration frequency must be too low, so the Cal Step amount (in Hz) is added to the 125,000,000 reference oscillator frequency. Conversely, if the measured frequency is lower than 6.25MHz, it means the reference oscillator calibration is higher than the real world value, so the parameter is decreased by the Cal Step amount. The optimum setting for Cal Step will depend on how much drift is to be compensated, since a limited correction is applied during each calibration. For example, if Cal Time is 10 seconds and Cal Step is 20Hz, then the maximum correctable error on the 125MHz setting is 200Hz per calibration. For this reason, it is a good idea to increase the Cal Time setting.

`010`

The second setting determines the length of time to spend doing the reference frequency calibration using a GPS 1pps signal. The default is 10 seconds, A longer interval is preferable.

A suggested approach is: for example, if transmitting WSPR once every 10 minutes, set Cal Time to 240 and choose a Park Mode. In this case the 2 minute WSPR frame would be followed by 4 minutes (240 seconds) of calibration, then 4 minutes of "Park" in which the DDS frequency could be set to near the transmission frequency, to allow the DDS temperature to stabilise.

The maximum possible Cal Time is 250 seconds. This is because the internal representation is an 8-bit integer value (maximum value 255), and it also has 4 seconds added before the calibration starts. If you try to enter a value higher than 250, the system will automatically set Cal Time to the maximum value of 250 seconds.

The initial calibration of your U3/U3S may be very slow if you use a Cal Step size of 01. The unit will gradually adjust the reference frequency setting by a limited amount at each calibration cycle. The process can be sped up considerably, by using a larger step size e.g. 10, or even more. Then the calibration will quickly find the correct reference frequency. However with large step sizes, there will be a significant variation from calibration cycle to calibration cycle. For most accuracy, small step size should be used e.g. 01.

A good strategy is to use large step size for the initial calibration, then when the correct reference frequency has been determined, change it to a small size e.g. 01, for very accurate calibration.
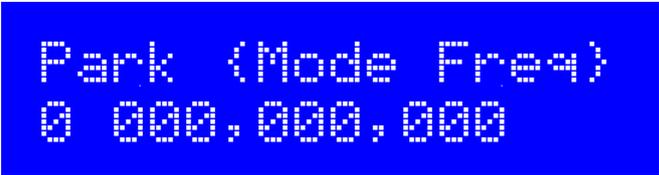
```
Park (Mode Freq)
0 000,000,000
```

The "ParkMode" and "ParkFreq" parameters are used to control the behaviour of the kit during key-up. Originally with the AD9850 DDS (U3), this was intended to prevent the -30dB (or so) leakage of carrier to the antenna, even when transistor Q1 was switched off. The setting is also useful for reducing frequency drift, both with the AD9850 DDS and with the Si5351A module kit (non-OCXO version).

In the U3S, the Si5351A Clk1 output can be switched on permanently on any frequency from 1 to 150MHz, using Park Mode 4.

Ultimate3S behaviour (Si5351A module kit):

Park modes are only possible in the U3S when the "Iv" configuration bit is set to 0 (see above section for description). When "Iv" is set to 1, Park modes are disabled.

In the U3S, the Park Mode sets a frequency on the Si5351A Clk1 output during the gaps between transmissions. It can be used to significantly reduce the frequency drift, when using the non-OCXO version of the Si5351A module kit.

```
0
```

The first parameter is the Park Mode, which has the following meaning:

0   Si5351A Clk1 output is set to the next mode screen's frequency, between transmissions

1   Si5351A Clk1 output is set to the frequency of the next mode screen's transmission, plus an offset defined by the "Park Freq", specified in Hz (the second setting on this screen). The sum must be between 1MHz and 150MHz.

2   Si5351A is set to the specified "Park Freq" frequency between transmissions. The frequency must be between 1MHz and 150MHz.

3   Si5351A Clk1 output is Off between transmissions.

4   Si5351A Clk1 output is permanently ON, and set to the frequency defined by "Park Freq"

5   Si5351A Clk1 output is permanently ON, and set to the frequency determined by the formula: 4 * (current output frequency – park frequency).

```
000,000,000
```

The second setting is the Park Frequency. The above description explains how this setting is used, depending on the Park Mode.

When using the OCXO version of the Si5351A module kit, drift should be negligible and the Park feature does not need to be used.

When using the non-OCXO version, it has been found to reduce drift considerably, if you enable the Park feature on a frequency much higher than the transmission frequency. As an example, when using Park

Mode 2 with Park Freq 150,000,000, I can routinely obtain zero Hz drift reports on 10m WSPR (28MHz output frequency).

Ultimate3 behaviour (AD9850 DDS):

`0`

The first parameter is the Park Mode, which has the following meaning:

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 depending on "Park Freq" (the second setting on this screen). The number of Hz of shift is the setting multiplied by 0.93. Do not enter a value higher than 65,535! The maximum shift is therefore 65,535 * 0.93 which is 61,034Hz.

2   During key-up, the DDS frequency is set at the "Park Freq" 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")

`000,000,000`

The second setting is the Park Frequency. The above description explains how this setting is used, depending on the Park Mode.

`Sys. Frq.`
`20,000,000`

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.
27,000.000
```

Ultimate 3S	Ultimate 3
The Reference Frequency setting is the actual frequency of the 27MHz crystal on the Si5351A module	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 the Assembly manual.

```
Backlight
9
```

This setting allows the LCD screen's blue LED backlight brightness to be adjusted. The default value is 9 (maximum brightness). 0 corresponds to minimum brightness – the backlight is switched off.

Use of the backlight parameter requires a hardware modification that is described on the modifications page on the website! Without this modification, the parameter is just ignored.

You should also note that the backlight brightness control is achieved by 8-bit pulse width modulation of the LED voltage. The frequency is 610Hz and the duty cycle is varied. Pulsing the 30mA LED could introduce noise onto the power supply so if you are also using a receiver you should check that interference is not caused.

```
Set Time
00:53
```

The kit has an internal real time clock which is used for the Frame (QRSS stacking) and for timing WSPR, PI4 and JT9 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 the time is set automatically.

An accurate real time clock is not required other than for the WSPR, PI4 and JT9 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).

```
Right button
to start!
```

Finally at the end of scrolling through all the configuration menu items, this screen is displayed. Now simply press the Right button, to start the kit in its transmission sequence.

You can always reach this screen quickly by keeping the left button pressed to cycle rapidly though the configuration menu items which you do not wish to change.

If you have made any errors in the configuration, then an error message will now be displayed (if the kit is unable to start transmitting). The error messages are explained in the following section.

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. If there is a number in square brackets, it indicates the mode setting screen where the error first occurs (but the error may apply to multiple mode setting screens).

The following lists the possible error messages and their causes.

```
Error:
No transmissions
```

There are no enabled mode setting screens. At least one of the 16 mode setting screens 0] to F] must be enabled. To toggle a mode setting screen between enabled/disabled state, scroll through to the mode setting screen to be changed, and press the Right button twice. See also the description in the mode setting screen paragraph above.

```
Error: 0
Mode
```

This error occurs if the mode setting indicated (mode screen 0 in this example) is set to "None", or you selected a mode which is not supported by this firmware version (certain modes have been coded but are not enabled at compilation time, because they do not fit into the ATmega328 chip's program memory).

Ultimate 3S: this error can also occur when using the Si5351A module, if you have selected WSPR15 and the frequency is 1MHz or above – which is not allowed.

```
Error: 7
Frequency
```

This error occurs if the frequency setting indicated (mode screen 7 in this example) is zero.
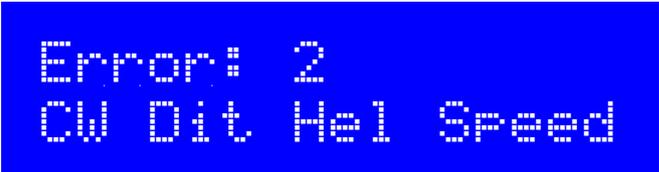
```
Error: 2
CW Dit Hel Speed
```

This error results from having an invalid Speed parameter for the mode in use. For QRSS, FSKCW and DFCW, "Dit" must be non-zero and not more than 200 seconds. For Slow Hell mode, "Hel" must be non-zero and not more than 200 seconds. For CW and FSK modes, "CW" must be non-zero. The other modes have specific defined speeds which are not adjustable, and so the Speed setting is ignored for them. In this example, the error is in mode setting screen 2.

```
Error: 0
Callsign
```

For a setting (screen 0 in this example) sending a WSPR or Opera mode, you have not entered your callsign, or it is invalid for the encoding algorithm. Please check the description of the callsign parameter setting, see Callsign parameter description above.

For a setting (0 in this example) sending the CW ID mode, you have not entered your callsign, or it contains an invalid character for the CW transmission. Valid characters are A – Z, 0 – 9, space and /. Please enter a correct value in the Callsign parameter.

Please also note that if you have enabled Ext WSPR then additional restrictions apply, see the Ext WSPR section for details of valid prefix or suffix.
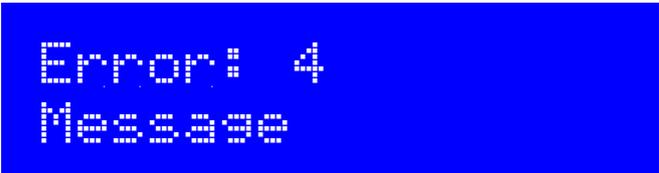
```
Error: 4
Message
```

This error (in this example, mode screen setting 4) concerning the transmission message occurs because the message is empty, and the mode is set to anything except a WSPR, Opera or PI4 mode, JT9 modes or CW ID mode. In these 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.

Note that the "Message" setting is not used in the "Transmit" mode but you still need to enter something. Anything at all, will be fine.
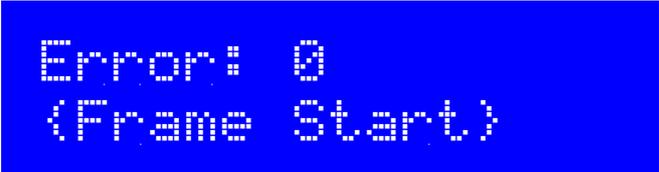
```
Error: 0
(Frame Start)
```

This error message (the example here, shows the mode setting 0 is causing the error) can have two possible causes.

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.

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).

In PI4 mode, the Frame (number of minutes between transmissions) must not be zero.

Note that if you have enabled a WSPR mode setting, as well as a WSPR15 mode setting, then the restrictions of BOTH modes apply. In this case, the only Frame setting which will work for both WSPR and WSPR15 is 30. The only Start settings which are valid, are 00 and 30.
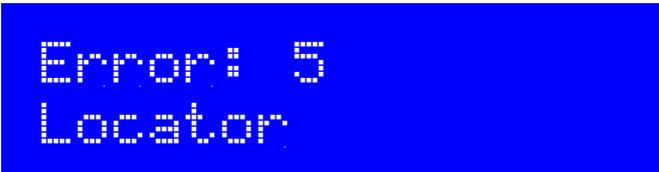
```
Error: 5
Locator
```

Again, an error which can only arise in WSPR mode, in mode screen setting 5 in this example. The locator must be a standard 6-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, followed by two letters in the range A – X.

```
Error: Si5351A
```

This error means the U3S was unable to communicate with your Si5351A module. If you have no module at all plugged in, the kit will assume that you have an Si5351A and will show this error. If the bottom row says "No Clk" this indicates the U3S was unable to correctly configure the Si5351A chip. These errors probably indicate an issue with your Si5351A module kit.

2.5 Understanding the automatic frequency calibration using GPS

When using a GPS with 1pps signal, the kit can calibrate the reference oscillator (27MHz for the Ultimate 3S Si5351A, 125MHz for the Ultimate 3 AD9850 DDS). When a 1pps signal is present and GPS enabled, a "heart" symbol is shown on the display, and "beats" In time with the incoming applied 1pps signal.

The automatic frequency calibration takes place immediately after a transmission sequence (mode settings 0 to F). In order for an automatic calibration to take place, Frame must be set to a non-zero value and there must be a sufficient gap to do the calibration.

If you leave insufficient time between transmissions for the calibration (Cal Time setting you have configured) then the calibration will not be completed correctly. **Also ensure that the Cal Step parameter is non-zero: the default 00 means NO CALIBRATION will occur!**

During the first 4 seconds after the transmission sequence, the serial data stream from the GPS is parsed to extract location and time information; then disabled and the 1pps monitoring stabilised. Next, the calibration starts. The calibration time is determined by the Cal Time parameter in the Cal {HP Time} screen. The gap following the transmission sequence must be larger than Cal Time + 4 seconds.

The waiting screen, showing wait for the following transmission sequence to begin looks like this:

In this example, the time is 15:36:30 and the system is waiting until 40 minutes (time 15:40:00) to start the next message transmission. Additionally the heartbeat will flash, in the space on the top row. When a calibration is about to take place (GPS mode is non-zero) , there will be an additional second line display:

Once the actual frequency calibration starts, the Cal text is followed by a status bar which indicates the progress of the calibration. When calibration has completed, the new reference frequency value for 10 seconds (or whatever Cal Time is set to), as well as the change that was made since the previous calibration. For example:

In this example, the calibration just completed has increased the reference clock value by +4Hz to 125,002,432Hz (Ultimate 3 in this example; Ultimate 3S will show a frequency near 27MHz).

After 10 seconds, the bottom row will show GPS information for the rest of the interval until the next transmission frame starts. The type of information shown depends on the "GPS Info" setting described above. In the default mode 0, the bottom row cycles through Longitude, Latitude, Altitude and GPS information, spending 4 seconds on each.

An example showing the info line is:

```
>40        15:38:23
A 3D f10 t12 s30
```

Here:

A means valid GPS Data (V would mean invalid data)
3D means a 3D fix (could be None, 2D or 3D)
f10 means the GPS solution fix uses 10 satellites
t12 means the GPS receiver is tracking 12 satellites
s30 means the average signal strength of the 12 tracked satellites is 30.

For more details please see the description in the "GPS Info" menu setting described above.

Ultimate3S	Ultimate3
During calibration, the DDS output frequency is set to 6.75MHz which is measured by the microcontroller, using the 1pps signal as the timing gate. If using the old U3 PCB the keying signal is Off so the PA is switched off during the calibration, although some low level leakage on 6.75MHz is normal. Once the calibration is completed, the Si5351A output is switched off.	During calibration, the DDS output frequency is set to 6.25MHz which is measured by the microcontroller, using the 1pps signal as the timing gate. Of course the keying signal is Off so the PA is switched off during the calibration, although some low level leakage on 6.25MHz is normal. Once the calibration is completed, the DDS is configured according to the "Park {Mode Freq}" screen settings.

Additional points to note, concerning the frequency calibration:

1) The calibrated frequency value is stored automatically in the Ref Freq. setting in EEPROM. Therefore when you next power up the kit, the previous frequency calibration is automatically used so the frequency should be close to the correct calibrated value. The calibrated value is ONLY stored in EEPROM if it has changed by more than a certain threshold compared to the currently stored value. The threshold is 10Hz for the Ultimate 3S (27MHz crystal), or 50Hz for the Ultimate 3 (125MHz DDS reference oscillator).

2) When first switched on, a GPS unit powered from the same power supply may not yet have achieved 3D lock. In this situation the time will likely be wrong (starting at 00:00:00). If GPS Mode is non-zero, the transmission sequence does not start until a valid time decode from the GPS. If there is no valid time decode by the time "Frame" minutes have elapsed, the system will give up waiting for a valid decode and start transmitting regardless.

3) At power-up, the system does not do a calibration. It waits until after the first transmission sequence. This is because the stored Ref Freq value in EEPROM is probably more accurate than the first calibration would be, until a few minutes have passed allowing the reference oscillator time to warm up, therefore waiting for initial warm-up drift to cease.

4) Pressing the right button during a calibration cancels the calibration, and returns the Ref Freq to the previously stored setting.

2.6 Message tags

Certain 2-character tags can be inserted in the transmission message, these will be substituted with dynamic data during the transmission.

For example, if the callsign setting is "G0UPL" and the Maidenhead locator setting is "IO91AB", and the message setting is "#CS #M4 " then the actual transmitted message will be "G0UPL IO91 ". GPS parameters and analogue channel data tags can also be used. The following list describes the available tags. Any tag not recognised is just sent as a single blank space. If you try to send longitude or latitude when the GPS does not have a satellite lock, you also get a single blank space.

#A0   Analogue channel 0 [Note 1, 2]
#A1   Analogue channel 1 [Note 1, 2]
#A2   Analogue channel 2 [Note 1, 2]
#A3   Analogue channel 3 [Note 1, 2]
#A4   Analogue channel 4 [Note 1, 2]
#A5   Analogue channel 8 (internal temperature sensor) [Note 1, 2, 3]
#AT   Altitude - all the characters from the GPS string
#GS   Groundspeed – all the characters from the GPS string – groundspeed is in knots
#LT   Latitude – degrees and decimal minutes: all the characters from the GPS string, plus N/S suffix
#LN   Longitude – degrees and decimal minutes: all the characters from the GPS string, plus E/W suffix
#M4   4-character Maidenhead locator e.g. "IO91"
#M6   6-character Maidenhead locator e.g. "IO91AB"
#CS   Callsign configuration entry (just inserts whatever is in the Callsign parameter)
#T1   Message #1 of 26-character JT9 telemetry format used by VK3YT balloons [Note 4]
#T2   Message #2 of 26-character JT9 telemetry format used by VK3YT balloons [Note 4]

Notes:

1) Analogue channels have the value 0000 to 1023, but are actually sent as three characters. In the event the left two characters are "10", i.e. the value is in the range 1000-1023, then the first of the three characters is 'A', so that for example, a value of 1005 will show as "A05".

2) In order to use and read the analogue channels 0 to 4, nothing else must be connected to the processor pin that would interfere with the analogue measurement. So don't connect relays to the pins if you want to use Channel 0 and 3. The switches S1 and S2 should be fine as long as whatever you connected to the pin doesn't mind being shorted to ground (e.g. use a small series resistor). For reference:

    Channel 0: Pin 23; Band 1 relay control
    Channel 1: Pin 24: Switch S2
    Channel 2: Pin 25: Switch S1
    Channel 3: Pin 26: Band 5 relay control
    Channel 4: Pin 27: Unused

3) The internal temperature sensor in the ATmega328 is linear but inaccurate. To improve the accuracy it would be necessary to calibrate the reported temperature values against a known accurate thermometer. The temperature reading used by the #A5 tag is not centigrade, it is just the 10-bit reading from the ADC for channel 8.

4) The #T1 and #T2 tags create two 13-character, base-42 encoded message strings for transmission using JT9 mode. This telemetry can be decoded by a special version of WSJT-X. Please see http://www.picospace.net for further information.

3. QRSS Modes

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

3.1 FSK/CW

The display's top line shows the sequence number, band and frequency, exactly as in the editing screen. In this example, it is sequence 0, band 0 and 10,140,050Hz. The bottom line shows FSKCW followed by the symbol length – in this example 6 seconds. Finally the message will be shown. The leftmost character is the one currently being sent. "–" after the sequence number, in the 4'th character of the top row, indicates a dash is being sent. Naturally a "." will appear if a dit is being sent. As the transmission 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

```
01.0 010,140,050
QRSS6 G0UPL G0UP
```

The display's top line shows the sequence number, band and frequency, exactly as in the editing screen. In this example, it is sequence 0, band 0 and 10,140,050Hz. The bottom line shows QRSS followed by the symbol length – in this example 6 seconds. Finally the message will be shown. The leftmost character is the one currently being sent. ".“ after the sequence number, in the 4'th character of the top row, indicates a dit is being sent. Naturally a “-” will appear if a dash is being sent. As the transmission is sent, the
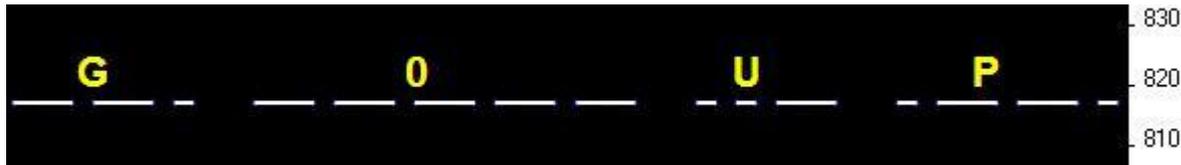
message will scroll to the left.

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

```
1]-0 010,140,050
DFCW6 UPL G0UPL
```

The display's top line shows the sequence number, band and frequency, exactly as in the editing screen. In this example, it is sequence 0, band 0 and 10,140,050Hz. The bottom line shows DFCW followed by the symbol length – in this example 6 seconds. Finally the message will be shown. The leftmost character is the one currently being sent. “–“ after the sequence number, in the 4'th character of the top row, indicates a dash is being sent. Naturally a “.” will appear if a dit is being sent. As the transmission is sent, the message will scroll to the left.

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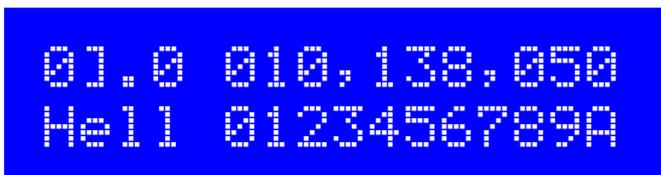
As usual, the display shows the band, mode, frequency and the message scrolls to the left as it is sent.

The screenshot fragment below is from IZ8BLY's excellent Hellschreiber receiving (and sending) software.
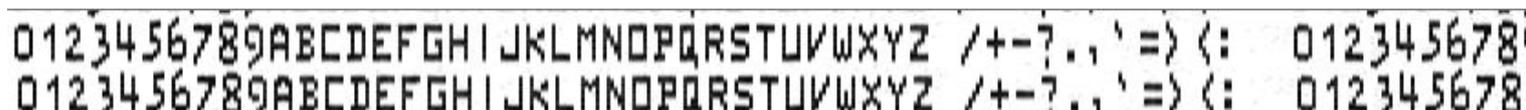
Hellschreiber is a fax-like mode designed in the 1920's by Rudolf Hell in Germany. It was later used in WWII. The literal translation into English would be "Light Writer" and of course rhymes with its inventor's name. Each character is made up of a 7-row, 5-column grid. Technically there are 14 half-rows, 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. The following 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

```
01.0 010,138,050
DX Hell 01234567
```

As usual, the display shows the band, 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.

```
0123456789ABCDEFGHIJKLMNOPQRS1
0123456789ABCDEFGHIJKLMNOPQRS1
```

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

```
01.0 010,140,050
Slow Hell 012345
```

As usual, the display shows the band, 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.

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.

Manual page from a real Hellschreiber machine owned by Pierre ON5SL, shows character drum.
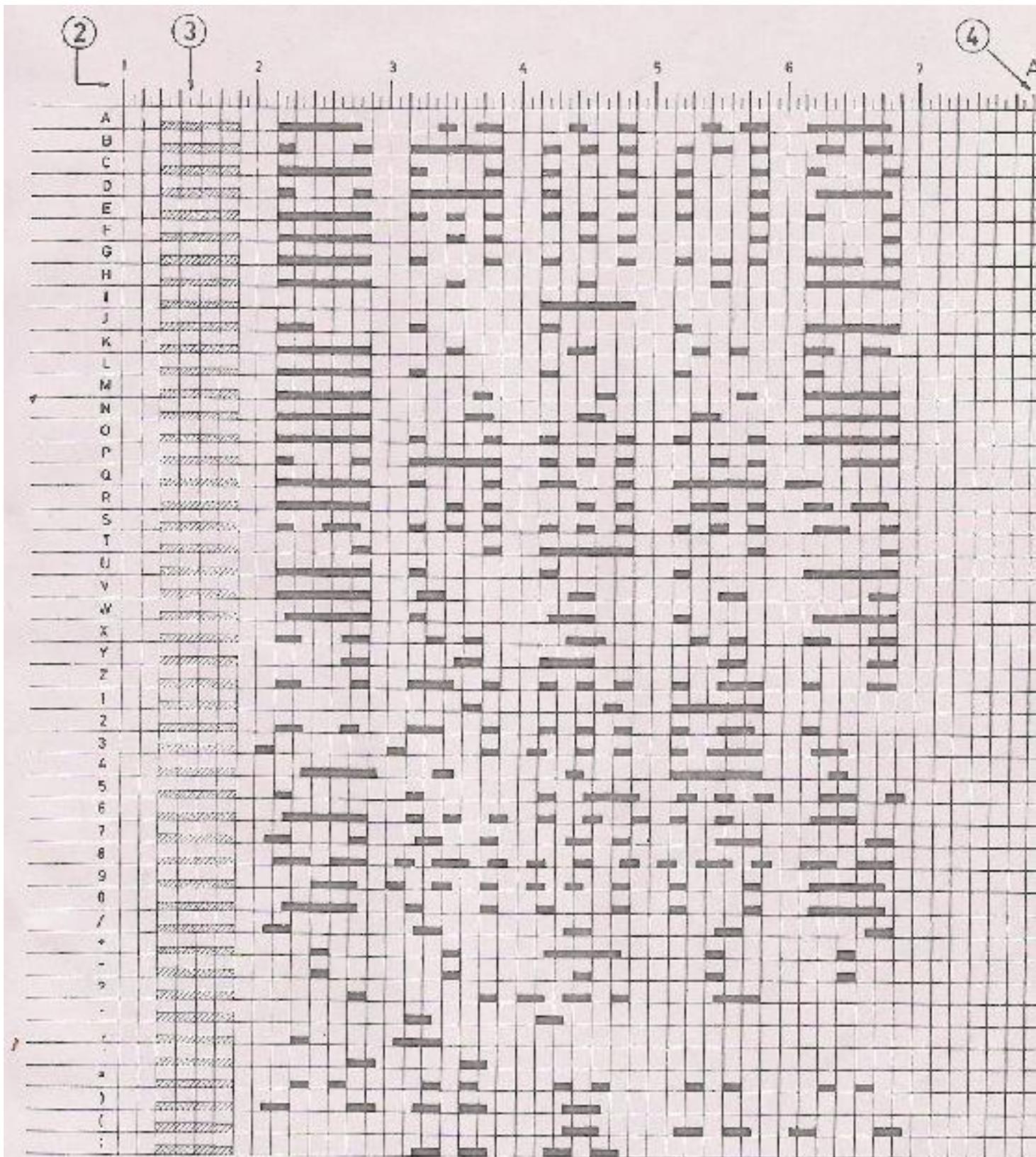
① Abwicklung der Sendenocken
② Einteilung der Meßscheibe
③ Anlaufschritt
④ Nullstellung der Senderachse

15

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.
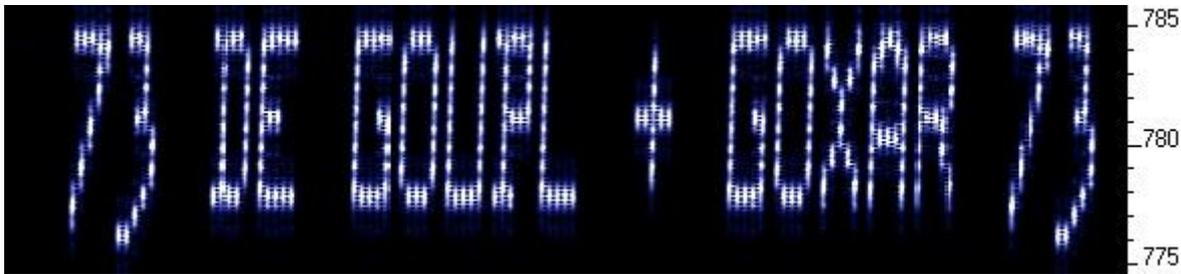
The following image shows part of the same thing in Argo's 3 second "slow" mode. The larger fourier transform bucket size means the image is more clear, but the faster scroll rate makes the letter's height to width ratio somewhat less attractive. Other slow-speed fourier transform software present more 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's top line shows the sequence number, band and frequency, exactly as in the editing screen. In this example, it is sequence 0, band 0 and 10,140,050Hz. The bottom line shows CW followed by the speed – in this example 12 wpm. Finally the message is shown. The leftmost character is the one currently being sent. "–" after the sequence number, in the 4'th character of the top row, indicates a dash is being sent. Naturally a "." will appear if a dit is being sent. As the transmission is sent, the message will scroll to the left. At 25wpm and above, there is no message or character display, because it would interfere with the precise timing of the message.

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! A keying output is available at pin 19 of the processor, which in recent PCB revisions is also a pad near the board edge. It could be 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

```
01.0 010,140,050
CW ID 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 space character (actual duration is 8 dit-lengths) i.e. a pause or key-up, is automatically added before sending the CW callsign ID.

Note that if a mode setting is set to CW ID, the Callsign parameter must not be left empty, and you must enter a valid Callsign parameter for CW, containing only characters A-Z, 0-9, Space or /. An empty Callsign or invalid character in the Callsign will result in an error message.

3.9 FSK

```
01-0 028,132,000
FSK12 CQ DE G0UP
```

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 CW

```
01 0 014,060,000
TX CW
```

Here the kit can be used as a basic CW transmitter. The frequency is set in the mode screen where this mode is set. You can connect a straight morse key across the right button, for keying the transmitter. A keying signal could also be connected to the right button, and would key the transmitter when low. For example, an external paddle and keyer could be used.

3.11 Transmit FSK

```
01 0 014,060,000
TX FSK
```

Here the kit can be used as a basic FSK transmitter. The frequency is set in the mode screen where this mode is set and the FSK amount is in the FSK configuration parameter. A keying signal can be used to apply the FSK, connected to the right button input.

3.12 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.

Note that if the right button is pressed during calibration (when using a GPS for frequency calibration, and the GPS mode is therefore set to a non-zero value), then the calibration will be cancelled. The reference frequency setting will be restored to the previously stored value in the EEPROM.

3.12 WSPR

```
0] 0 010,140,200
WSPR    23  137 2
```

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

0	The transmission sequence number
0	The band number (when the relay-switched LPF kit is used)
10,140,200	Example transmission frequency: this is the WSPR centre frequency, not base.
WSPR	The mode being used! During operation, this will alternate with the locator.
23	Transmission power setting, in dBm
137	Symbol number currently being sent; WSPR messages are 162 symbols
2	Tone currently being sent – WSPR messages are made of four tones, 0 – 3.

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.

While a WSPR transmission is in progress, the "WSPR" text shown in the above example screenshot will change intermittently to the 4-character Maidenhead locator being transmitted. This can be useful during mobile operation if a GPS receiver is used, since the WSPR message is dynamically encoded with the fresh location data from the GPS unit, and the display will show the actual transmitted locator for the current location.

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.

The U3 kit also suppports encoding of the extended WSPR message protocol, which can send a callsign with a prefix or suffix, and sends the Maidenhead locator in full 6-character accuracy. This is controlled by the "Ext. WSPR" parameter and described more fully in that section, see above.

Note that the WSPR message is re-calculated at every transmission frame in the sequence, since each frame contains its own power setting. This allows the kit to be used to transmit a series of different powers, if external attenuators are connected, for comparison purposes.

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. During calibration, the bottom line will additionally show a status bar indicating the progress of the calibration.

On Argo, WSPR messages look ugly, like this local reception copy (or worse, because you probably are over-driving your receiver when receiving your own signal!):


WSPR transmission standard frequencies:

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

2200m:	0.137400 – 0.137600	17m:	18.106000 – 18.106200
600m:	0.475600 – 0.475800	15m:	21.096000 – 21.096200
160m:	1.838000 – 1.838200	12m:	24.926000 – 24.926200
80m:	3.594000 – 3.594200	10m:	28.126000 – 28.126200
60m:	5.288600 – 5.288800	6m:	50.294400 – 50.294600
40m:	7.040000 – 7.040200	4m:	70.092400 – 70.092600
30m:	10.140100 – 10.140300	2m:	144.490400 – 144.490600
20m:	14.097000 – 14.097200		

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).
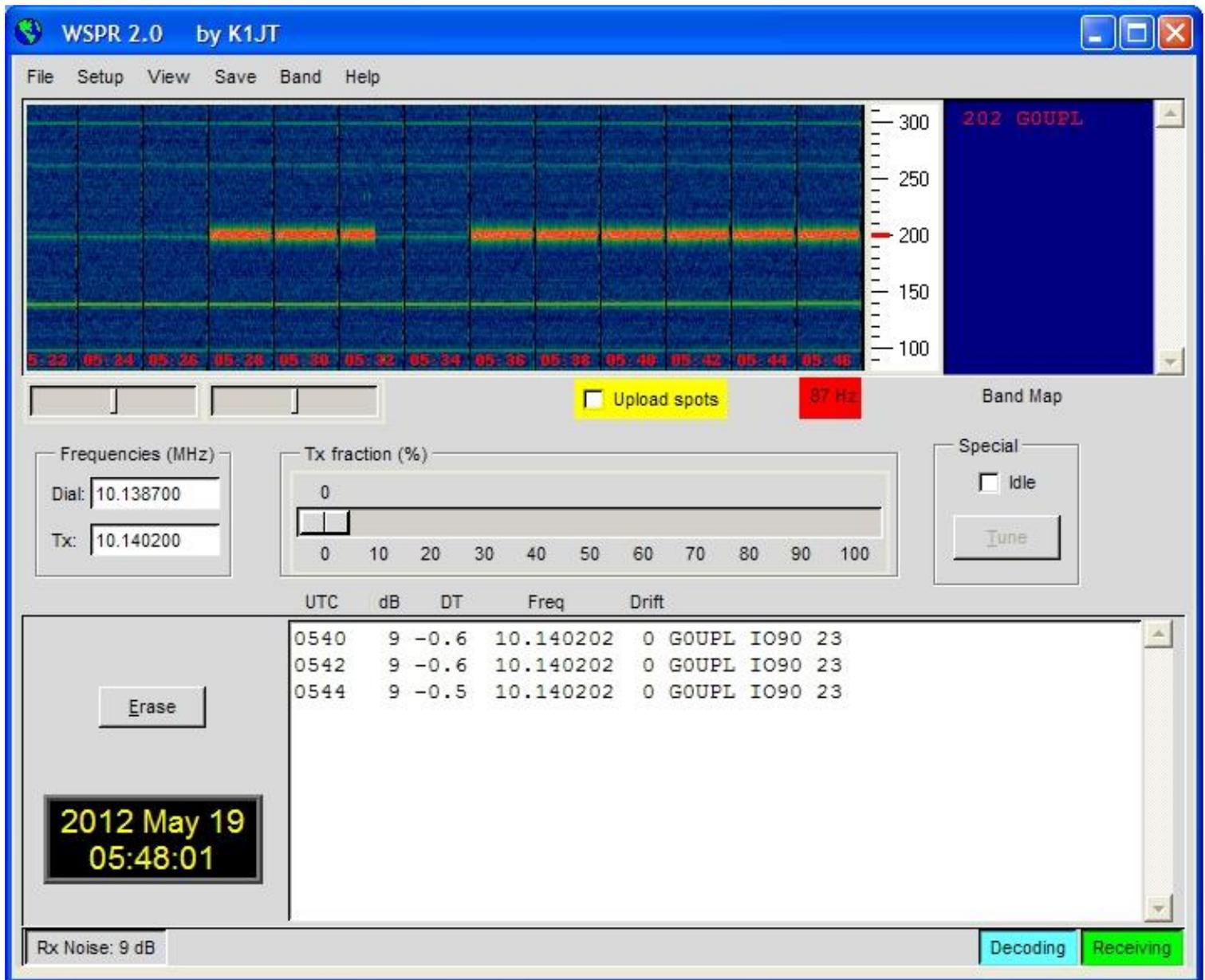
3.13 WSPR-15

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.

Ultimate 3S: WSPR-15 mode is only possible on frequencies below 1MHz (which is anyway the only place you'd want WSPR-15).

3.14 Opera modes

Opera encodes the callsign (from the callsign parameter field) into a forward error corrected on/off keyed carrier with 239 symbols. There are eight Opera modes, Opera05, Opera1, Opera2, Opera4, Opera8, Opera32, Opera65, Opera2H. The suffix indicates the approximate number of minutes required for the message transmission, with Opera05 meaning 0.5 minutes (30 seconds); Opera2H takes 2 hours to send the callsign. The speed may be chosen to suit the band in use. Slower Opera modes e.g. Opera8, Opera32 are more suited for MF and LF bands.

Opera does not require any time synchronisation, transmissions are successfully decoded regardless of the start time.

More details on Opera can be found here: http://rosmodem.wordpress.com/

The table below gives standard Opera modes and transmission frequencies (centres of activity). (Note: reception dial frequencies will be 1.5kHz below these for USB with 1500Hz audio).

Carrier Frequency	Mode	Carrier Frequency	Mode
137,500	Opera32	18,106,500	Opera2
478,500	Opera8	21,075,500	Opera1
1,837,500	Opera4	24,926,500	Opera1
3,548,500	Opera2	28,071,500	Opera1
5,290,500	Opera2	50,071,500	Opera1
7.039,500	Opera2	70,094,500	Opera05
10,136,500	Opera2	144,181,500	Opera05
14,063,500	Opera2		

3.15 PI4


```
0] 0 028,140,200
PI4  MGM  108  2
```

PI4 is a beacon mode with a 1-minute sequence. The transmission consists of:

– Callsign encoded forward-error corrected data transmission, lasting 25 seconds. It has 146 symbols of four tones and is similar in concept to WSPR, but the tone spacing is much wider and the symbol duration is much shorter. Unlike WSPR, it encodes only the callsign, not the locator or power.

– Callsign and Locator are sent in 12wpm FSK CW with 250Hz FSK

– The remainder of the minute is filled with a plain unmodulated carrier

The mode is quite wideband and therefore intended/suited only for beacons for 10m and above.

During the data transmission (also called "MGM"), the screen looks like the image above. Here "108" indicates the 108'th tone is being sent, and "2" indicates the tone being sent (0, 1, 2 or 3).

During the callsign and locator transmission, the display bottom line shows the transmitted text, in the same way as a QRSS or FSKCW transmission. The text scrolls left as the transmission progresses, the leftmost character is the currently transmitted one. A – or . is displayed to indicate a dah or dit being sent, respectively.

During the plain carrier transmission the display bottom line simply shows "PI4 Carrier".

The screenshot below shows the PI4 receiver screen and a typical 1 minute transmission. More details on PI4 can be found here: http://rudius.net/oz2m/ngnb/index.htm
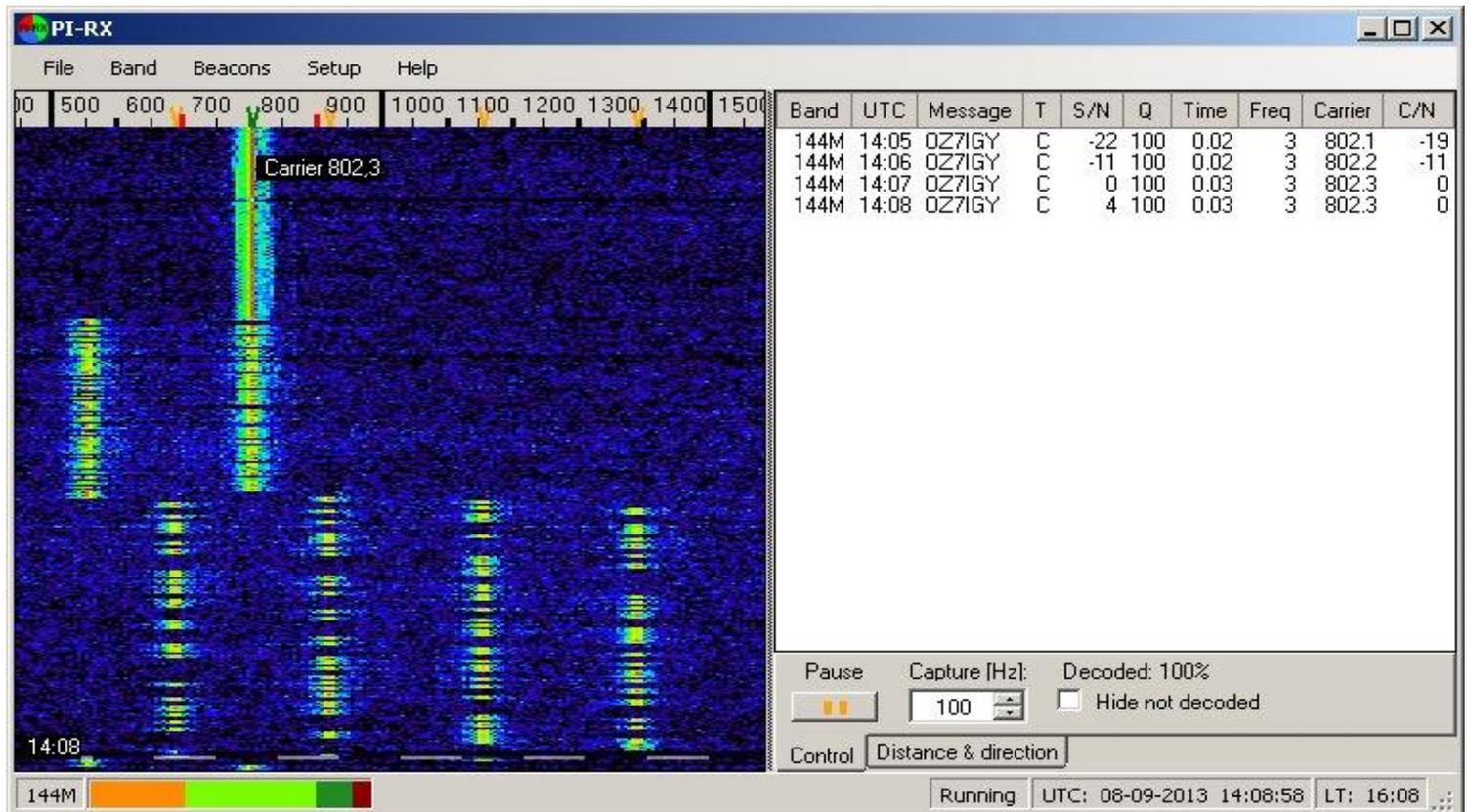
3.16 JT9

The JT9 mode is mainly used for short live QSOs. It has been included as a U3S kit feature starting in firmware v3.08, following several requests. JT9 is not available for the U3 (AD9850 DDS version).

A JT9 message consists of a 13 character message, containing the characters A-Z, 0-9, space, and + - . / ? characters. The message encoding uses forward error correction (etc.) and produces 85 tone symbols, which are transmitted on one of 9 tone frequencies in a narrow band.

In the U3S kit the JT9 modes transmit the message from the usual "Message" configuration parameter, and you can select sub-messages as described previously. You can also insert #-tags to substitute parameters dynamic at transmit time.

Of particular note are the two tags #T1 and #T2 which were specifically created for the JT9 "beacon" mode. These tags each produce a 13-character encoded string, that together contain longitude, latitude, height, battery voltage, temperature, GPS state, etc. This telemetry format has been successfully used by Andy VK3YT for a pico-balloon global circumnavigation, tracked using JT9 telemetry in this format. A special version of the WSJT-X software is used for this purpose. See http://www.picospace.net for more information.

Five sub-types of JT9 are supported: JT9-1, JT9-2, JT9-5, JT9-10, JT9-30. In each case the sub-type (following the hyphen) indicates the approximate number of minutes taken to transmit the message.

Note that this also imposes limitations on the Frame parameter, since JT9 is synchronised to the start of the minute, and Frame must be set to a multiple of the number of JT9 minutes in the transmission. Similar discussions apply to JT9 as to WSPR – the need for accurate time-keeping, in particular.

4. Additional notes

4.1 Non-standard AD9850 DDS reference frequency (Ultimate3 only)

The firmware contains stored frequency steps, used for shifting the AD9850 DDS frequency by 1Hz or by 1.46Hz (for WSPR). The number of DDS steps with the standard 125MHz reference oscillator is 34 (for 1Hz) or 50 for WSPR (1.46Hz). However, this will only work properly when the reference crystal oscillator for the DDS module is the standard 125Mhz type.

In order to accommodate people who wish to use a DDS with a different reference oscillator frequency, this step size has been moved to EEPROM from firmware v3.08 onwards.

The byte at EEPROM address 0x001 is decimal 32 (hex 0x22), this is the 1Hz shift

The byte at EEPROM address 0x002 is decimal 50 (hex 0x32), this is the 1.46Hz WSPR shift

In order to use a different DDS reference frequency, you would need to calculate the number of DDS steps to achieve as close as possible to 1Hz and 1.46Hz shifts, and manually edit the EEPROM file, replacing the default values with your new calculated values. Then you need to re-program the EEPROM using the amended file.

Note that some other features of the U3 will not work, such as PI4 – the frequency shifts for these are still defined in the code, not in EEPROM.

Note also that none of this applies to the U3S (Si5351A module) – in the Si5351A module all step sizes are calculated dynamically, this means that you can use any reference crystal oscillator (within the Si5351A spec), and just enter the correct value in the configuration menu item.

4.2 Manually generated DFCW

Another button (or transistor, etc.) called "S3" can be connected from pin 27 of the processor to ground. When using the "TX CW" mode, when the button S3 is pressed (or transistor switched on, etc.), the transmitter keys down but at a shifted frequency, determined by the FSK parameter.

In this way, the Ultimate3/3S transmitter can be used to generate manually (or externally) keyed DFCW mode transmissions.

5. 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 up to Z. A space character can be used, in order to cause a key-up (no transmission). Note also that when "Fine FSK" is enabled, the shift is reduced (1/16Hz steps for the U3S, or 0.029Hz steps for U3).

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*

6. 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 a confirmation message appears saying "Reset? Sure? Press left btn". Now if you press the left button, 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.

7. 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.

8. Resources

Please see the kit page http://www.qrp-labs.com/ultimate3 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 QRP Labs projects, links to other QRSS resources etc., see http://www.qrp-labs.com.

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

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

9 Version History

1   14-Oct-2013

- Initial draft version, for firmware version v3.00

2   07-Dec-2013

- Firmware version v3.01
- Introduces new Cal Time and Cal HP settings, with a new "Huff Puff" GPS calibration mode
- Offset in Park Mode 1 is now in multiples of 32x the minimum frequency step of the DDS

3   14-Jan-2014

- Firmware version v3.02
- Introduces 16 transmission settings, each with their own mode, frequency, power, band
- Support for the relay-switched low pass filter board kit
- Support for "auxiliary" output, to control other relays or external circuits e.g. switched attenuators
- Several pairs of related configuration parameters are now shared into one screen
- Added new animation that is displayed during frequency calibration
- Bug fix: factory reset had moved to the left button. It is now correctly back on the right button.
- Bug fix: factory reset left all mode settings blank, rather than "None"

4   14-Jan-2014

- Change example WSPR tx freq from 10,140,150 to 10,140,200.

5   05-Mar-2014

- Firmware version v3.03
- New enable/disable for each of the transmission mode settings. When disabled, looks "crossed out"
- Mode 0 no longer needs to be populated with valid data – any mode settings can be empty if they are disabled
- Heartbeat always flashes on for 0.25s in sync with the detected 1pps event, even during calibration
- Calibration progress is now indicated by a status bar animation
- The error check now checks all of the enabled mode settings [0] to [F]
- The Aux setting is now re-enabled
- Bug fix: No Hell mode message error, if Hell modes are used in mode settings other than [0]

6   02-June-2014

- Firmware version v3.04
- Improve accuracy of wspr tone spacing: was 1.43, now 1.46Hz
- Toggle back and forth between "WSPR" and locator, in WSPR mode run display; show each for 3 tones' duration
- Forces CalTime to 10 if in non-HP calibrate mode
- Limits CalTime at 250 seconds maximum
- WSPR freq is now the centre freq, not baseline (i.e. base frequency is 2.2Hz lower than U3 set/displayed frequency)
- Put back "relay chatter", i.e. don't lock relay closed, on "Tune" (leave lock-on feature for TX to stop relay chatter)
- Factory reset check, "Reset? Sure? Press left btn!" to prevent accidental reset
- Allow blank locator when GPS enabled; the sytem waits indefinitely for a valid locator to be set
- Bug fix: pressing left button in message edit, on the first blank character, entered a Null not a space
- Bug fix: if the callsign was incorrect for WSPR, it reported it as a frequency error

7   27-August-2014

- Firmware version v3.05
- Support for Extended WSPR (callsign prefix/suffix, 6-char locator)
- Change TX mode to TX CW and add new TX FSK mode
- Locator display in WSPR15 as well as WSPR
- Facility to tune the U3 using a potentiometer (requires hardware modification)
- Backlight control from configuration menu (requires simple hardware modification)
- Display the new calibrated reference frequency, and change from the old one, after a calibration
- Diagnostic mode on first startup, to help troubleshooting (1Hz and 2Hz signals on alternating pins)
- Bug fix: in some cases, time setting could allow incorrect characters e.g. letters etc
- Bug fix: aux functionality did not work; also, now allows setting Aux to full hex range i.e. 0-F

8   27-October-2014

- Firmware version v3.06
- Support for Opera modes (8 standard speeds, Opera 05 to Opera2H)
- Support for PI4 mode
- GPS information display (satellites tracked, signal strength fix type etc.) during wait display
- DDS tuning word calculation improved by using 64-bit integer calculation, removing floating point rounding error of up to 2Hz on 10m band.
- Bug fix: Huff Puff mode calibration mode locked the reference frequency 10Hz too high i.e. 125,000,010 rather than 125,000,000.

9   19-January-2015

- Firmware version v3.07
- Support for the Si5351A module, which is the Ultimate 3S kit
- Frequency fields have 9 digits, to allow 2m band operation (Si5351A)
- "X2 Freq" parameter for double-frequency output, for driving some LF amps
- "EEPROM-saver": only save calibrated frequency value if it has changed by more than a threshold (10Hz for 27MHz Si5351A, or 50Hz for 125MHz AD9850 DDS)

9   15-February-2015

- Added page numbering
- Added table of standard Opera frequencies/modes

10   24-April-2015

- Firmware version v3.08
- Added support for JT9 modes (Si5351A only, not AD9850 DDS)
- Message parameter can now be divided into sub-messages using delimiter character
- Support various #-tags embedded in messages
- Added Park modes support for Si5351A, can significantly reduce frequency drift
- Speed parameter split into three, for CW, Slow modes (QRSS) and Slow-Hell
- All invalid message characters for a given mode, are now simply sent as a space
- Support for non-HP calibration method is discontinued
- Move x2 and Ext WSPR settings to a combined 5-setting configuration screen
- Configurable number of Mode screens appear in the menu now (default 3)
- Potentiometer tuning mod now needs to be enabled in configuration, if used

- Park mode 4, in Si5351A, now leaves the Park Freq permanently on Clk1 output
- Additional digit for Park Frequency, which in Si5351A can be 1-150MHz
- New flag "Invert" output, produces a 180-degree (inverse) output on Clk1 output
- Switch "S3" on pin 27 can now be used to create a shifted dah in CW mode, kind of manual DFCW
- Editing of messages improved, can now insert a character, and enter without going to end of msg
- Bug fix: PI4 mode was shifted 250Hz when using Si5351A, starting in v3.07
- 1Hz and WSPR DDS shifts now held in EEPROM, so non-125MHz DDS could be used
- An "Off" relay output is now tri-stated, not put into high (+5V) state – so 11-band mod works
- Added "Altitude" to GPS Info display

11   21-Oct-2015

- Firmware version v3.09
- Clarified the manual, about latitude/longitude display format: it is degrees and decimal minutes, not seconds.
- Clarified the section on custom message formats; the shift specification goes up to Z only, and the shift size is reduced if Fine FSK is enabled (1/16Hz for U3S, 0.029Hz for U3).
- Remove crystal frequency dependency, so now U3 should work on any crystal (within reason)
- Improve the speed of writing to the LCD
- Allow setting Iv flag to 2, which means Clk1 frequency = Clk0, but do not key Clk1 in sync with Clk0
- Park mode 5 added: Clk1 frequency in park is 4 * (f - parkFreq)
- Add key-up pause at the start of CW ID (8 dit-lengths)
- Add #GS tag for GPS groundspeed in knots
- Removed GPS Mode 1. Now 1 means negative edge, 2 means positive edge PPS. There's no 3.
- Bug fix: Clk1 when using INV Output (Iv = 1) did not work until after first frame transmitted
- Bug fix: In park mode 4, did not switch on Clk1 for first transmit cycle (and other cases)
- Bug fix: S3 button press was not being detected
- Bug fix: first symbol of first CW character in message was being deleted
- Bug fix: first symbol of every CW character was a little shortened
- Bug fix: When GPS mode active, CW timing was slightly garbled
- Bug fix: custom FSK in messages wasn't working
- Bug fix: Hellshreiber mode timing is now correct (both fast and slow Hell)
- Bug fix: Long message strings, overwrite the top LCD line when looping through menu
- Bug fix: Incorrect 6th Maidenhead character in 10% of QTHs
- Bug fix: When Iv flag set to 1, it did not key Clk1 output in sync with Clk0
- Bug fix: Setting Cal Time to 000 caused strange behaviour. Now causes error message
- Bug fix: Left button press did not escape from TX_CW or TX_FSK manually keyed modes

12   26-Oct-2015

- Clarified in several sections, that JT9 only works with the U3S (Si5351A synth) not the U3 (AD9850 DDS)

13   13-November-2015

- Clarify the single reason for "Error: Message" detailed on page 20

14   17-November-2015

- Removed obsolete reference to "AF Output" mode (page 30)
- Added sentence to explain that the message is not displayed on screen in CW mode when the speed is 25wpm or greater (page 30)

15   26-November-2015

- Just an update to this version history, for the contents of release v3.09a
- Bug fix: Custom messages: state variable not properly cleared on entering menu, could be stuck in custom etc
- Bug fix: Custom messages: after space (key-up) the next custom symbol does not key-down again
- Bug fix: Custom messages: the timing of the first custom symbol was wrong
- Bug fix: Message display in slow CW modes e.g. FSKCW does not display if Fast CW speed is 25wpm or more
- Bug fix: GPS mode 3 was still selectable when editing GPS mode(only 0, 1, 2 are valid)
- Bug fix: Manual TX could mistakenly transmit as another mode, because an internal state variable wasn't reset
- Bug fix: display during carrier part of PI4 kept the last character of the locator subsquare e.g. the G in "PI4 GCarrier"
- Bug fix: Factory reset did not properly reset the contents of the EEPROM in some cases
- Bug fix: Hell modes sent all punctuation messages as a space

16   05-January-2016

- Removed incorrect reference to calibration section of the assembly manual.