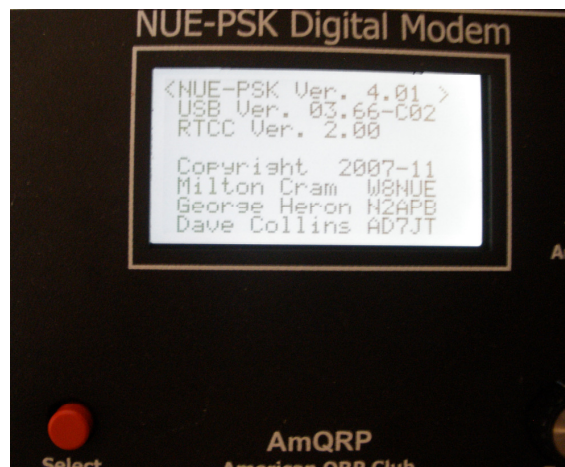# CW Operating Mode

for

NUE-PSK Modem

Version 4.02

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1.0 INTRODUCTION

This specification defines the Version 4.01 firmware release for the NUE-PSK modem which includes a CW operating mode. This added operating mode is implemented in firmware and is available with all hardware versions and options. Adding the CW operating mode to an existing NUE-PSK modem will only require a firmware update. Before getting into the details, some definitions are in order.

Throughout this specification the term "SPACE" refers to a key-up condition and the term "MARK" refers to a key-down condition. The term "DIT" refers to the MARK duration of a Morse code dot and the term "DAH refers to the MARK duration of a Morse code dash. DITs and DAHs are referred to as "Morse elements". Morse elements are combined to form characters. Characters can be letters, numbers, punctuation marks, and prosigns. A prosign is a combination of elements representing something other than the characters and, in this context, something unique to amateur radio. Throughout this specification, prosigns are represented by two, lower-case, boldface letters the Morse code characters for which are sent, run together, with no inter-character space between them. Familiar prosigns include **bk** (BreaK and **sk** (Silent Key). Normal, alpha Morse characters are represented as upper-case, boldface letters.

The terms "intra-character SPACE" and "inter-element SPACE" refer to the duration of the SPACE between DITs and DAHs within a character. The term "inter-character SPACE" refers to the SPACE duration between characters. The term "inter-word SPACE" refers to the SPACE duration between words.

A basic time unit (Tcw) is used to quantify time durations of Morse code elements and SPACEs. Standard Morse code durations for Morse elements and SPACEs are as follows:

DIT..1 x Tcw ("short MARK")
DAH ....3 x Tcw ("longer MARK")
Inter-element SPACE............1 x Tcw (between DITs and DAHs within a character)
Inter-character SPACE ....3 x Tcw (between characters)
Inter-word SPACE.................7 x Tcw (minimum, between words)

Since all timing is derived from Tcw, its duration determines the transmission rate commonly stated in "words per minute" or "wpm". A standard "word" has been defined for computing wpm. That word is "PARIS " which, in Morse code, has ten DITs and four DAHs and contains exactly 50 Tcw including the ending inter-word SPACE. Using this standard word, the relationship between Tcw and wpm is: wpm = 1200 / Tcw, where Tcw is expressed in milliseconds and all element and SPACE durations are standard as listed above.

2.0 GENERAL DESCRIPTION

While receiving CW, the modem will copy and display standard Morse code characters received through an audio output from a transceiver. While transmitting, the modem will transmit standard

Morse code characters as entered by the operator or contained in macros via the audio input to a transceiver. The transceiver shall be in DATA, PACKET, or SSB mode, **not CW mode**. CW mode is selected for the modem using the MODE entry in the configuration menu system. Once CW mode is activated, the modem will be in the receive state until transmission is activated. The transmit state may be activated or deactivated in a number of ways as described below.

2.1   TUNING

Normally, the transceiver translates received RF to baseband audio referenced to the frequency displayed on the transceiver dial. The modem uses DSP techniques to analyze and demodulate the audio signal and extract the desired information according to the mode the modem is operating in. The modem can process signals in a 2 KHz spectrum of audio frequencies ranging from 500 Hz to 2500 Hz; however, in CW mode, the tuning range is limited to 1500 Hz at the top end. Tuning is aided with a spectrum display representing the energy detected in each of 128 frequency slices or "buckets". Each bucket represents a 15.625 Hz slice of the spectrum and is displayed as a vertical bar chart or histogram. The length of each of the 128 bars represents the amount of energy detected in the associated bucket. The histogram data is generated by a 512 term, Fast Fourier Transform with a sampling rate of 8,000 samples per second.

The spectrum display includes a cursor representing the current frequency of interest. The cursor may be moved in a couple of ways by the operator. During normal operation, the operator sets the transceiver frequency dial to a base frequency and can then tune the modem to cover a range of between 500 Hz and 1500 Hz above the base frequency. Tuning can also be done by leaving the modem cursor at a fixed position (e.g., at 800 Hz) and tuning the transceiver to move displayed bars to the cursor. Generally it is more convenient to do gross tuning (1 KHz increments) with the transceiver and fine tuning with the modem

The normal modem tuning features are available in CW mode; however, the tuning range is limited to a maximum of 1500 Hz and confined to the left half of the display. During operation, the transceiver is tuned to get the desired signal's bucket on the display. This is done by listening to the transceiver audio and watching the modem display as the transceiver is tuned. Fine tuning is then done by moving the cursor to the bucket. The modem tuning controls allow tuning in steps of 10, 5, 2, or 1 bucket from the keyboard. The modem also provides a tuning dial that can be rotated left or right to move the cursor down or up the spectrum display. In receive mode, pressing the End key on the keyboard will activate the Acquire function and the cursor will automatically be moved to the bucket with the most energy within two buckets of the current bucket. The Acquire function is automatically activated after a short timeout following any tuning of the modem.

It will not be apparent to the operator but the dial frequencies on the two transceivers will be off by the modem tuning frequency when the remote transceiver is operating in CW mode. For example, if the local transceiver is tuned to 14,060.00 KHz and the modem is tuned to 800 Hz, the remote transceiver will be tuned to 14,060.80 when its tuning indicator indicates "on frequency".

Note that the FFT generation is much too slow to be used for demodulating the CW signal. It is only intended as an aid to tuning. Instead, a specialized DFT algorithm called a "Goertzel filter" is used

to process the raw ADC output. The Goertzel algorithm is very fast to compute and very efficient when the application only requires analysis of a small number of frequencies when only energy levels are needed and phase information is not needed. The most common use for Goertzel filters is to decode the DTMF tones generated by telephone keypads.

2.2 CW RECEPTION

In order to receive CW accurately, the signal must have certain characteristics often attributed to an operator with, what is commonly referred to as, a "good fist". Best results will be obtained by the modem when the signal is generated by a computer (or a microcontroller) and strictly follows normal Morse code standards (e.g., a DAH is three times a DIT, inter-word SPACEs are at least 7 DITs, etc.). This case includes modem-to-modem CW communication. The most probable causes of errors will be received signal fading (QSB), interference from other stations operating near our operating frequency (QRM), or excessive noise (low Signal-to-Noise ratio) in the receive channel. Some of these sources can be handled through filtering, adjusting the gain of the input amplifier, or adjusting the MARK-SPACE threshold level. There are limits, however, and solid CW copy by the modem will require a fairly strong, distinct, and clear tone from the receiver audio channel with the receiver tuned to produce a CW side tone within the 1 KHz audio spectrum processed by the modem in CW mode.

The second-best choice would be an electronic keyer operating in fully automatic mode so that it will strictly control the duration of DITs and DAHs and the SPACE between them. In this mode, the transmitting operator is responsible for inter-character and inter-word SPACE duration. The receive algorithm will try to accommodate variations in this timing but there are limits. (Some of the parameters used to define various CW elements can be tweaked manually by the operator.) The following are some of the problems that will occur when these limits are exceeded:

> Inter-word SPACE too short .... words run together
> Inter-character SPACE too long .... extra spaces between characters
> Inter-character SPACE too short .... characters run together

The third-best choice would be an electronic keyer operating in semi-automatic ("bug") mode where the keyer controls the DOT duration and the SPACE between consecutive DOTs and but the operator is responsible for DASH durations, the SPACES before and after DASHES, and those items listed above for an electronic keyer in fully automatic mode. Exceeding limits in these areas adds the following to our list of problems:

> DASH duration too short .... DASHs interpreted as DOTs
> Inter-DASH SPACE too long .... characters split into two or more false characters
> Inter-element SPACE too short .... missed DOTs (combined into long DASHs)
> Inter-DASH SPACE too short .... missed DASHs (combined into very long DAHs)

These conditions can also cause the modem to recalculate an inaccurate Tcw which will affect the accuracy of decoding following characters.

2.3   CW TRANSMISSION

During CW transmission, the operator selects a transmission speed (words per minute or "wpm") and all Morse elements, inter element, and inter character durations are determined by that selection. A minimum inter-word duration is determined by the modem but this duration may be extended by keying additional spaces between words or by pauses in the keyed input. The minimum, transmitted inter-word SPACE duration is set at seven Tcw. Transmitted inter-element SPACE durations are set at one Tcw; inter-character SPACE durations are set at three Tcw. The primary objective in transmit mode is to send perfect Morse code according to the standards described in the INTRODUCTION above.

3.0   <u>FUNCTIONAL DESCRIPTION</u>

The heartbeat of CW mode is a timer that generates an interrupt every millisecond. The interrupt service routine (ISR) increments three counters: space_msec, mark_msec, and last_trans. The first two are used to time SPACEs and MARKs, respectively, during CW receive operations. The third is used to time how long it has been since the last transition between a SPACE and MARK levels and is used to filter out short noise bursts in the receive channel. The general firmware structure is such that the time spent in the ISR is minimized. All the processing functions are called from the main control loop, outside of any ISR. The CW control loop has two function calls. A state variable (cw_state) determines which of two CW receive functions is called. One receive function runs during key-up (SPACE) and the other during key-down (MARK).

3.1   CW TRANSMISSION

The modem always starts CW mode in receive state. Transmit state is activated when one of the following occurs:

- The operator presses and releases F10
- A macro is played containing a <TXON> tag at the start of the macro.

The modem will return to receive state when one of the following occurs:

- The operator presses and releases F10
- A macro is played containing a <TXOFF> tag

The same display area is used to display received and transmitted text, one at a time. The transceiver is always in transmit mode when the modem is in CW transmit state. The transceiver will not go into receive mode until the modem state is changed to receive which releases PTT. Because of this, it is not possible to "hear" received characters between transmitted characters and true QSK operation cannot be supported.

3.1.1   Status Display

At this point, the spectrum display is cleared and replaced by the following status information displayed on the second and third lines of the LCD display:

```
   "TX CW WPM: WW
    SIDE TONE: SSSS Hz"
```

Where "WW" is a two-digit representation of the current wpm (words per minute) setting. The wpm setting may be varied between 5 wpm and 50 wpm by turning the tuning knob when the above status is displayed (modem in the CW transmit state).

3.1.2   Transmit Side Tone

As an added feature, the modem's beeper may be used to generate a side tone so the operator can listen to the Morse code being transmitted. The transmit side tone generator is toggled on and off by pressing and releasing the ESC key while in CW transmit state. The side tone frequency can be adjusted by holding the CONTROL key down while turning the tuning knob. The frequency can be adjusted to any of nine frequencies between 400 and 2,000 Hz. There is no volume control; however, the frequency response of the "speaker" is such that some frequencies sound much louder than others. Changing the side tone frequency offers some control of the side tone apparent volume. (My preferred side tone frequency is 1333 Hz.)

The three or four digit display "SSSS" is the current side tone frequency in Hertz. Note that side tone frequency is only displayed and can only be changed in transmit state when the transmit side tone is turned on. The side tone frequency selection applies to both the transmit and the receive side tones. The on-off state of the side tone, the side tone frequency, and the wpm will be saved with a saved configuration and automatically restored each time the modem is powered up. They are also included in the CONFIG.TXT file.

3.1.3   Keyboard Input

In CW mode, the keyboard is forced into Caps Lock mode where all keyed alpha characters will be entered as upper-case letters unless a SHIFT key is pressed. All alpha characters keyed while the SHIFT key is depressed will be entered as lower-case letters. Lower-case letters are transmitted as prosigns by following the last CW element with a single (one Tcw) inter-element SPACE instead of the normal (three Tcw) inter-character SPACE. For example, keying Shift-B, K, and Space will result in the prosign **bk** being transmitted as "−...−.−".

During CW transmission, keystrokes are queued as ASCII characters in a first-in-first-out (FIFO) buffer until a code representing a space code is buffered. At this point, characters are read, one at a time, from the FIFO, translated to Morse characters, and transmitted up to and including the space character which is transmitted as an inter-word SPACE. Sending words as a contiguous block of Morse characters avoids pauses in the input keying causing the insertion of unwanted, inter-word SPACEs in the transmitted text. The inter-word SPACE duration is only specified as minimum so longer pauses between words generally do not cause a problem (assuming the delay does not exceed the receiving operator's level of patience). This approach also allows error correction and editing within words. When the operator continues keying during transmission, space characters are counted as they are entered into the FIFO. This count is decremented each time a space character is removed from the FIFO. As long as the space count is greater than zero, transmission will continue.

Note that Prosigns follow the same rules as other characters and will not be transmitted until they are followed by a space character in the FIFO.

The transmit FIFO is 256 characters deep and is a circular or "ring" buffer. That means that after the last character position in the buffer is loaded, the next character will be loaded in the first character position of the buffer. There is no overrun check, if buffer input gets 256 characters ahead of the transmitted data stream, the 256-character contents of the buffer will be lost and will not be transmitted. It is recommended that the operator not have more text queued for transmit than will fit in the transmit text area of the LCD display. This corresponds to about 80-character type-ahead. (The full 256 character FIFO capacity is required for queuing macros for transmission.)

3.1.4   Transmit Text Display

Keyed CW text characters are displayed on the lower four lines of the graphic LCD display as they are entered even though there will usually be a time delay until they are transmitted. Keyed characters are displayed on the LCD with a continuous over line. For example:

`AD7JT`

If this is all that is keyed, nothing will be transmitted. The first character is only transmitted after a space code is keyed and entered in the buffer. As each character is transmitted, the over line is removed to indicate to the operator what has been transmitted and what remains queued to be transmitted. The modem maintains a count of the number of un-transmitted space codes in the transmit buffer. This count is incremented each time a space code is inserted into the transmit buffer and is decremented each time a space code is read from the buffer. Transmission will continue as long as the space count is greater than zero. When the space count is decremented to zero, transmission will pause until another space code is inserted in the buffer.

Since CW text is essentially transmitted in words, it is not possible to backspace in (or into) a word that has started to be transmitted. In other words, the backspace key will not work when the space count is equal to one. It will work when the space count is equal to zero indicating there is only one word to be transmitted in the buffer and a trailing space has not been entered. It will work when the space count is greater than one indicating there are at least two words in the buffer and the last one has not started to be transmitted. It is not possible to backspace into a word on the display that has already been transmitted (no over line). Backspacing is also limited to the bottom two lines of the text display.

The hot-keys Alt-M, Alt-T, and Alt-S may be used to insert "My Call", "Their Call" and a serial number (see Section 5.3) in the transmit buffer. In these cases, the characters are entered as if the operator keyed them and they are displayed with the over line. They will not be transmitted until a following space code is keyed. The call signs must be entered (Ctrl+M and Ctrl+T) with upper-case letters to avoid generating unwanted prosigns. Spaces in a call sign are not allowed and may cause erratic behavior.

3.1.5 CW Macros

When macros are played, the characters are displayed as they are transmitted so over lines are not used. They also do not require an ending space code to transmit the last word in the macro. If a macro does not end in a space code or <TXOFF>, a space code will be automatically added to the end of the macro as it is buffered for transmission. The CW macros are a different set of macros than the ones used by the other, digital modem modes. They are accessed normally (F1 – F7) but only when the modem is in CW mode. The normal Ctrl-key combinations may be used to insert <TXON>, <TXOFF>, <MYCALL>, <THEIRCALL> and <SERIALNO> (see Section 5.3) codes in macros. Note that the data is case sensitive. Normal alpha text must be entered as upper case letters. Lower-case letters will generate prosigns as described above. Each of the seven CW macro buffers can hold up to 255 characters.

3.2 CW RECEPTION

As previously described, during CW reception, the transceiver audio is monitored over a specific frequency spectrum and shown in the spectrum display in the top three lines of the LCD display. A Goertzel filter is used to detect the MARK-SPACE signals being received in a pass band centered on the selected bin of the FFT process. The output of the Goertzel filter is processed by one of two functions. Which is used depends on the last noted state of the received signal. These functions time the duration of the received MARKs and SPACEs and determine the type of elements and SPACEs received. The MARK types (DOT and DASH) are buffered until an inter-character SPACE is received. The buffered MARK types are interpreted and translated to a Morse character or a prosign and displayed on the lower half of the graphics display as described above.

3.2.1 SPACE Processing

When CW mode is first entered, it is assumed the receive state is SPACE. The SPACE processor first checks the state of the received signal to determine if it is still SPACE. If it is, it then determines the duration of the current SPACE. This is done by testing the value of the space_msec counter. This counter is cleared when the received signal transitions from MARK to SPACE so it will contain the duration of the current SPACE code in milliseconds.

When the received signal changes back to MARK in less than 5 milliseconds, the SPACE is assumed to be the result of noise in the input and is ignored. In this case, the modem goes back to MARK processing as if the transition to SPACE had not occurred. Note that the mark_msec timer is still running so no time information is lost.

When the SPACE duration is greater than the Tcw count limit for inter-character SPACE, the accumulated MARKs are translated to ASCII per the table in Appendix A and displayed. After each character is displayed, the current wpm is calculated and displayed at the center of the top line of the graphic LCD display. Note that the wpm will not be displayed until at least one character has been received and Tcw can be calculated.

When the SPACE duration exceeds the Tcw count threshold for inter-word SPACE, a space character is displayed on the graphic display. At this point, the received signal is only monitored to determine when it transitions from SPACE to MARK. At that point, the receive state is changed to

MARK, the mark_msec timer is reset to zero, and the next call from the main control loop will be to the MARK processing function.

During SPACE processing, two thresholds or fences are computed and used to detect inter-character and inter-word SPACEs in the received signal. The durations of the last ten spaces that are shorter than the current inter-word SPACE are saved and their average computed each time a new SPACE is added to the buffer. The character SPACE fence is set to twice this average. (Remember that intra-character SPACE durations are nominally one Tcw and inter-character SPACE durations are nominally three Tcw, giving an average of two Tcw durations.) The second fence is used to detect inter-word spaces. It is nominally set to 2.5 times the character SPACE fence. Both of these fences can be adjusted by the operator in increments of tenths of one Tcw duration as described in later sections.

3.2.2   MARK Processing

MARK processing consists of measuring and buffering the duration of each MARK received and the recalculation of Tcw to adapt to changes in received data rates. All MARK processing is done when the function detects the received signal has transitioned from MARK to SPACE. The first check is to make sure the MARK duration is greater than 5 milliseconds. If it is not, it is ignored and the receive state is changed back to SPACE. Note that the space_msec counter has not been reset and is still measuring the SPACE duration. It is assumed that any MARK shorter than this is the result of signal interference. (At 99 wpm, the shortest MARK is about 12 milliseconds long.) This action constitutes a noise filter.

After the MARK to SPACE transition has been validated, the MARK duration is noted and compared with a "fence" that is computed by analyzing the last 32 elements received. When the duration is greater than the fence, it is recorded as a DASH; otherwise it is recorded as a DOT. After a MARK is classified as a DOT or a DASH, it is buffered in a MARK buffer. Each entry consists of a code identifying it as a DOT or a DASH.

The MARK buffer can contain up to 8 MARKs. When this limit is exceeded (buffer overflow), the buffer is cleared and a pound sign ('#') is displayed. The average duration and the average mean deviation of the last 32 MARKs received and saved are calculated. The results of these calculations are used to generate new values for Tcw and the DOT-DASH fence. To avoid skewing these results when long strings of DOTs or DASHs are received, all repeated Morse elements after a specific number (the zkew limit) are left out of the average calculations. An element is considered to be repeated when its duration is within +/- 12.5% of the duration of the last element received and saved. An exception is made if four times the absolute value of the mean deviation average is greater than the current MARK average. In this case, the current MARK is accepted regardless of the value of the proceeding MARK duration. This algorithm decreases the amount of time required to adapt to rapid changes in received wpm which may occur, for example, when changing frequencies.

The fence (used to differentiate between DOTs and DASHs) is calculated as the average of all the values in the MARK buffer plus the average mean deviation. Ideally, the buffer will contain an

equal number of DOTs (1 x Tcw) and DASHs (3 x Tcw) and the average mean deviation will be zero resulting in a fence value of 2 Tcw.

Making these calculations at the end of each MARK received enables the receive function to adapt to changes in received wpm. The number of samples used by these calculations determines the speed and accuracy of the results. The lower the number, the faster it will adapt. The higher the number, the more accurate the results will be. The number of samples currently used for these calculations is 32. If desirable, in a future release, this number may be adjusted somewhat by the operator to better suit requirements and band conditions. [The mechanism for this is TBD].

Note that similar analysis is done on SPACE time durations but not as thorough (or as complex) as is done on MARK time durations. This is because MARK durations are generally determined by a keyer or a computer and are, therefore, much more accurate than spaces which can depend on the skill of the sending operator. The Tcw calculated from MARKs is used as a time base for SPACE duration fences.

3.2.3   Receive Text Display
In receive state, received and decoded CW text is displayed on the bottom four lines of the graphic LCD display. Each line displays up to 20 characters. As in other modes, lines are scrolled up when the end of the bottom (eighth) line is reached. Characters are displayed as they are decoded. Normal text is displayed as upper-case letters; recognized prosigns are displayed as pairs of lower-case letters. Recognized prosigns are listed in Appendix C.

Unrecognized (invalid) Morse characters are displayed as a single asterisk ('*'). When a character overflows the 8-entry MARK buffer the buffer is cleared and a pound sign ('#') is displayed.

3.2.4   Spectrum Display
The standard FFT display covering the range of 0.5 to 2.5 KHz (above the frequency the receiver is set to) is displayed on the top half of the graphic LCD display along with the optional RTCC date and time information. In receive state, the current, computed receive wpm is displayed in the center of the top line.

In receive mode, the right half of the spectrum display can used to display and/or modify/edit one of a number of parameters as described in following subsections. In all cases, pressing Enter will clear this portion of the display. Switching to transmit mode will also clear this portion of the display but it will be refreshed after switching back to receive mode. The refreshed screen will be displaying the same parameter(s) that was (were) displayed when the modem last switched to transmit mode.

3.2.5   Receive Decode Parameters
There are four parameters affecting the decode operation which may be adjusted within limits by the operator. Two of the parameters define the thresholds for recognizing a SPACE as being inter-character or inter-word. These thresholds are expressed in Tcws. The third parameter specifies the number of (near) equal, consecutive MARK durations that will be accepted and used for timing

calculations. The fourth parameter is the Goertzel filter threshold level or fence between MARK and SPACE levels.   These parameters and their range limits are as follows:

- Inter-character SPACE (Char): .... 1.6 to 6.0 Tcw with 0.1 Tcw precision
- Inter-word SPACE (Word): .... (Char + 0.5) to 12.0 Tcw with 0.1 Tcw precision
- Skew Limit (Zkew):............................ 2 to 6 MARKs
- Goertzel threshold (Th): .... 200 to 250,000 in steps of 200 (Th <=10,000) or 1000 (Th >10,000)
- Bandwidth (BW) .... 100 to 1000 Hz, nine selections

These parameters may be displayed in CW receive state by the operator depressing any one of the first letters in the parameter name ('C', 'W', 'Z', 'T' (or 'G'), or 'B'). When one of these characters is depressed, the right half of the spectrum display area is used to display the parameter name abbreviation, the allowed range, and the current value. Received data continues to be displayed on the lower four lines of the LCD display.

The Char display is as follows:

```
"2011-09-14 13.5 V. 26 WPM 17:48:16"
"            Char:  1.8"
"           (1.6-  6.0)"
" |_^_|                "
```

The Word display is as follows:

```
"2011-09-14 13.5 V. 26 WPM 17:48:16"
 "            Word:  5.1"
"           (2.1-12.0)"
" |_^_|                "
```

The Zkew display is as follows:

```
"2011-09-14 13.5 V. 26 WPM 17:48:16"
"            Zkew:   02"
"              (02-06)"
" |_^_|                "
```

The Th display is as follows:

```
"2011-09-14 13.5 V. 26 WPM 17:48:16"
"             Th:   3326"
"            (64K-200)"
" |_^_|                "
```

The BW display is as follows:

```
"2011-09-14 13.5 V. 26 WPM 17:48:16"
"                 CW BW: "
"                  400 Hz"
" |_^_|                     "
```

The lower four lines of the display continue to display received CW text and the FFT spectrum display continues to operate.

Changes to the displayed parameter are made with the '+' and '-' keys. The plus will add 0.1 to Char or Word, 1 to Zkew, or 200 to Th. The minus key will subtract 0.1 from Char or Word, 1 from Zkew, and 200 from Th. The range allowed for the parameter is displayed on line three below the parameter name. The minimum for Word is computed to be 0.5 greater than the current value of Char. When the operator tries to change a parameter to a value outside the displayed range, the parameter is restrained to the displayed limit. When Char is changed, the minimum limit for Word will be changed accordingly and if the changed Char value is less than 0.5 below the current Word value, the current Word value (and minimum) will be changed to the Char value plus 0.5.

The significance of Char, Word, and Zkew should be obvious from the above discussion. The significance of Th is a little more obscure. The Goertzel filter a fence used to determine whether the received signal is a MARK or a SPACE is computed as previously described. The units used are not standardized so only relative values are used. The energy level computations tend to range between 100 and over 250,000 units and are affected by the gain of both the transceiver and the modem. Normally, the Goertzel function calculates the fence value based on two running averages, one for high levels (above the current fence) and one for low levels (below the current fence).

When the operator presses a 'T', the current threshold fence value is displayed. Since the display is constantly updated, the operator can watch how the threshold is changing with incoming signal strength. When the operator presses a '+' or '-' key, the fence value calculation is suspended (is locked) and the fence value comes under control of the operator until the Enter key is pressed. When the operator presses the Enter key in receive state, the fence value is unlocked and is again calculated by the Goertzel filter function.

The Char and Word values are also continuously calculated by the modem. When one of these is selected, the displayed value will be updated continuously. When the operator presses a '+' or '-' key, the value is locked and comes under control of the operator until the Enter key is pressed. Note that any or all three (Char, Word, and Th) may be locked at the same time. Zkew and CW BW are always locked and under control of the operator.

The CW BW display allows selection of one of nine bandwidths for the Goertzel filter. When the operator presses a 'B', the current bandwidth is displayed. Pressing the '+' or '–' key will move up or down through the available bandwidths. The following options are available:

```
 100 Hz
 125 Hz
 160 Hz
 200 Hz(Default)
 250 Hz
 400 Hz
 500 Hz
 800 Hz
1000 Hz
```

Note that the narrower bandwidths may reduce the top keying speed (wpm) the modem can copy. The bandwidth is not saved in the EEPROM nor is it saved or restored with the writing or reading of the CONFIG.TXT file. Each time the modem is turned on, the bandwidth is set to the default value. The current pass band is shown graphically as a box around the cursor.

Pressing the Enter key will return the upper portion of the LCD display to the normal FFT spectrum display. At this point, any locked parameters will be unlocked and will again come under control of the modem. Note that none of the keys listed in this section are case (or shift) sensitive and the shift key is ignored. This includes the '+' (or '=') and '–' (or '_') keys.

4.0   CONFIGURATION

A number of modem configuration parameters have been added to support the CW mode of operation. These parameters can be saved in the EEPROM so they will be reloaded each time the modem is powered up. When the USB option is installed, the contents of the EEPROM may be saved to or loaded from a USB thumb drive.

4.1   EEPROM MAP

The current contents of the EEPROM are shown in Appendix D. The new entries supporting CW operation are shown in bold face type.

4.2   CONFIG.TXT FILE

The CONFIG.TXT file format has been extended to include several CW-specific entries. The new file format is shown in Appendix E. The added items are on lines 16 through 29. Most of the items should be self-explanatory. Line 17 configures the side tone frequency for both the RX and TX side tones. The parameter value for this line may have any integer value between 2 and 10. The side tone frequency is equal to 4000/N Hz, where N is the parameter. This gives the following frequency options:

N	FREQ
10	400 Hz
9	444 Hz
8	500 Hz
7	571 Hz
6	666 Hz
5	800 Hz
4	1000 Hz
3	1333 Hz
2	2000 Hz

5.0   OTHER V4.00 CHANGES

The following features are not strictly CW features but were added to the same release introducing CW mode.

5.1   DATE FORMATS

Version 3.01 changed the date format from "MM/DD/CCYY" to "CCYY-MM-DD". This version adds a configuration option to select one of three date formats. A "Save Config" operation will save the current date configuration in the EEPROM. Each time the modem is powered up, the saved date format will be initialized to the value in the EEPROM. The date format is not, however, saved with an "Upload Config" operation nor is it changed by a "Download Config" operation.

The user may select any one of the following date formats:

"CCYY-MM-DD"   (default)
"MM/DD/CCYY"
"DD/MM/CCYY"

Where:

"CC" is the century number (00 through 84)
"YY" is the year number (00 through 99)
"MM" is the month number (01 through 12)
"DD" is the day of the month(01 through 27, 28, 30, or 31 depending on the month and leap year status)

The selected date format will be used to display the date on the LCD screen and to format the dates in timestamps when logging transmitted and received data. The selected date format is also used when manually entering a new date (Ctrl-D).

5.2 ENTERING THEIR CALL AND MY CALL

Previous versions cleared the LCD screen and paused the receive operation while the user entered "Their Call" and "My Call". This version allows the entering of "Their Call" and "My Call" and the incrementing and decrementing of a three-digit serial number (see Section 5.3) without interrupting the receive operation. This change applies to all modes of operation, the old, full-screen method is no longer provided for entering Their Call and My Call. The new method uses the second and third lines of the right side of the LCD display while the received characters continue to be displayed on the last four lines of the display. This is especially convenient for entering Their Call since it leaves the received call sign displayed while it is being entered. The modem continues to receive and display characters so Their Call can be entered during the initial exchange without waiting for the end of the received transmission.

The enter My Call (Ctrl-M) display is as follows:

```
"2011-09-14 13.5 V. 26 WPM 17:48:16"
"          My Call:   "
"          AD7JT       "
"  |_^_|               "
```

The enter Their Call (Ctrl-T) display is as follows:

```
"2011-09-14 13.5 V. 26 WPM 17:48:16"
"          Their Call:"
"          N2APB       "
"  |_^_|               "
```

In both cases, the current call letters will be displayed when the Ctrl-M or Ctrl-T key is pressed and the cursor positioned just to the right of the last character displayed. There is no visual cursor.

The displayed call sign can be edited by using the backspace key to delete characters and move the cursor to the left. Pressing the home key will clear the current call sign and position the cursor in the first character position. Since Space characters are not allowed in call signs, any Space character keyed by the operator while entering a call sign will be ignored.

After My Call has been entered or edited, pressing Enter (or Ctrl-Z) will save it to EEPROM and it will be persisted when modem power is turned off. Their Call is maintained in RAM and is updated in-place and will not be persisted when modem power is turned off. Their Call can be used immediately, it is not necessary to press Enter (or Ctrl-Z) to save it. Both call signs are limited to 11 characters (previous firmware versions allowed up to 12 characters).

The information is displayed as an overlay. That is, it is ORed with the spectrum display so that the spectrum information can still be seen when entering call signs. The ORing is done in such a way as to display this information in reverse video when it overlaps bars in the spectrum display.

Note that displays that include call signs may be cleared using either of two key sequences Enter or Ctrl-Z. They both clear the current display but Enter will also unlock the Word, Char, and Th parameters if they are locked when Enter is pressed. Ctrl-Z will not unlock these parameters. Note also that pressing Enter at any time while in receive mode will unlock these three parameters whether or not any of them are displayed when Enter is pressed.

5.3 SERIAL NUMBERS

Many amateur radio contests require each QSO exchange to include a serial number that usually starts at 001 and is incremented by one for each QSO logged. This release includes a new tag "<SERIALNO>" for macros to insert a three-digit serial number in the transmit data stream. It also includes hot-keys for incrementing, decrementing, and resetting the serial number. The serial number value is stored in the EEPROM but is not included in the CONFIG.TXT file. This allows the serial number to be preserved when modem power is turned off and to not be disturbed when downloading CONFIG.TXT to, for example, update macros. There are actually two different displays associated with serial numbers.

The basic Serial Number display is activated when in receive state by pressing 'S' or 's'. The display is as follows:

```
"2011-09-14 13.5 V. 26 WPM 17:48:16"
"              S/N: 123     "
"                _ _ _ _ _ _"
"  |_^_|                    "
```

Pressing the '+' (or '=') key will increment the serial number by one. Pressing the '-' (or '_') key will decrement the serial number by one. Pressing the Home key will reset the serial number to 001. The allowed range is 001 through 999. Attempting to change the value to less than 001 or more than 999 will cause an audible Beep and the number will not change. This display can be closed by pressing Enter or any of the other recognized receive state hot keys.

The second display containing the serial number also displays Their Call. This allows the operator to manage both the serial number and Their Call while in receive state. As is the case for all displays using the upper-right portion of the display, the receive operation continues and received characters will be displayed on the last four lines of the display.

The combined Serial Number and Their Call display is activated when in receive state by pressing 'X' or 'x' while in receive state. The display is as follows:

```
"2011-09-14 13.5 V. 26 WPM 17:48:16"
"              S/N: 123     "
"              N2APB        "
"  |_^_|                    "
```

When this display is shown, the keyboard control functions for both the Serial Number and Their Call are available to the operator with one exception. The exception is the Home key. In the basic Serial Number display, pressing the Home key will reset the serial number to 001. Here, pressing the Home key will clear Their Call. This has the advantage of protecting the operator from inadvertently clearing the Serial Number in the heat of a contest. The displayed call sign can be edited as described above for the Their Call display. Both the serial number and Their Call are updated immediately so it is not necessary to exit the display before using new values.

Since all the letter and number keys are available for editing Their Call, this display can only be closed by pressing the Enter key (or Ctrl-Z). This is the recommended display for actual contesting because of the protection against resetting the serial number. If the operator is not using Their Call (e.g., when only answering CQs in "seek and pounce" mode), just press Home to clear the Their Call line making the spectrum display more visible.

When serial numbers are transmitted in CW mode, each leading zero is replaced with a single DASH ('T'). For example, a serial number of 005 will be transmitted as "TT5". This is a common convention followed by most CW contest participants. In all other modes, leading zeroes are transmitted as zeroes ('0').

When recording a macro, pressing Alt-X or Alt-S will enter the serial number tag into the macro text. When the macro is played back, the then-current serial number will replace the tag in the transmitted text. When keying transmit data in transmit state, pressing Alt-X or Alt-S will insert the then-current serial number in the transmit buffer. In CW mode, the serial number will be displayed with an over line indicating the text has not been transmitted. Transmission of the serial number will not start until at least one space character is entered following the serial number. At any time before the modem has started to transmit the serial number, the serial number may be edited or deleted by the operator using the Back Space key.

5.4   KEYER INPUT
This change is related to CW mode but is not required for CW operation. Expansion pad b on the main modem board is used as an input to allow and external keyer to be used as input to the CW decode logic. This input is ORed with the Goertzel filter output. To use this feature, add a wire to expansion pad b and 2-pin connector. The second pin is to be grounded. Shorting the two pins together will present a key-down (MARK) to the decode logic. This feature was added primarily as a test and debug aid for developing the CW decode logic but it would have some value as a CW training and / or demonstration aid.

5.5   DEFAULT RECORD (LOG) FILE NAME
Previous versions required a valid Log File name in the EEPROM for RECording mode to work properly. If the EEPROM did not contain a file name, a no-name file would be created on the flash drive which results in Illegal Path errors when attempting to read the file on a PC. This can happen, for example, when a CONFIG.TXT file is downloaded with a blank Log Fname field. When this happened, the only way to clear the error was to reformat the flash drive. This version added a

check of the saved file name and if none, uses a default file name. The default file name is
"REC.TXT".

5.6   BATTERY VOLTAGE DISPLAY

A constant display of the current battery voltage was added to the top line of the display. The
battery voltage display was removed from the splash screen and the configuration menu.

```
"2011-09-14 13.5 V. 26 WPM 17:48:16"
"                                   "
"                                   "
"  |_^_|                            "
```

When the voltage drops below 9 volts or rises above 40 volts, the battery voltage will be displayed in
reverse video. This is the input voltage range specified for the modem's five volt regulator.

```
"2011-09-14 8.8 V. 26 WPM  7:48:16"
"                                 "
"                                 "
"  |_^_|                          "
```

APPENDIX A.   CW CODE/CHARACTER CONVERSION TABLE

CHAR	DEC	HEX	MORSE	PROSIGN
	32	0x20	SPACE	
!	33	0x21		
"	34	0x22	.-..-.	
#	35	0x23		
$	36	0x24		
%	37	0x25		
&	38	0x26		
'	39	0x27		
(	40	0x28	-.--.	KN
)	41	0x29		
*	42	0x2A	...-.-	SK
+	43	0x2B	.-.-.	AR
,	44	0x2C	--..--	
–	45	0x2D	-.--.-	
.	46	0x2E	.-.-.-	
/	47	0x2F	-..-.	
0	48	0x30	-----	
1	49	0x31	.----	
2	50	0x32	..---	
3	51	0x33	...--	
4	52	0x34	....-	
5	53	0x35	.....	
6	54	0x36	-....	
7	55	0x37	--...	
8	56	0x38	---..	
9	57	0x39	----.	
:	58	0x3A	---...	
;	59	0x3B	-.-.-.	
<	60	0x3C		
=	61	0x3D	-...-	BT
>	62	0x3E		
?	63	0x3F	..--..	

CHAR	DEC	HEX	MORSE
@	64	0x40	
A	65	0x41	.-
B	66	0x42	-...
C	67	0x43	-.-.
D	68	0x44	-..
E	69	0x45	.
F	70	0x46	..-.
G	71	0x47	--.
H	72	0x48	....
I	73	0x49	..
J	74	0x4A	.---
K	75	0x4B	-.-
L	76	0x4C	.-..
M	77	0x4D	--
N	78	0x4E	-.
O	79	0x4F	---
P	80	0x50	.--.
Q	81	0x51	--.-
R	82	0x52	.-.
S	83	0x53	...
T	84	0x54	–
U	85	0x55	..-
V	86	0x56	...-
W	87	0x57	.--
X	88	0x58	-..-
Y	89	0x59	-.--
Z	90	0x5A	--..

APPENDIX B. NEW CONFIGURATION OPTIONS AND HOT-KEYS

In CW mode:

F10:   Toggles between receive (RX) and transmit (TX) modes.

In CW Receive mode:

C or **c**:   Inter-character SPACE (char): .... 1.6 to 6.0 Tcw with 0.1 Tcw precision

Determines the threshold between received intra-character SPACEs and inter-character SPACEs.

Z or **z**:   Skew Limit (Zkew):......................... 2 to 6 MARKs

Number of MARKs of equal duration that will be used to calculate thresholds. Consecutive MARKs are considered equal when their durations are within +/- 12.5 % of each other.

W or **w**:   Inter-word SPACE (word):............. (char + 0.5) to 12.0 Tcw with 0.1 Tcw precision

Determines the threshold between received inter-character SPACEs and inter-word SPACEs. Will be automatically incremented when the Inter-char SPACE parameter is incremented to within 0.5 Tcw.

T or **t:**   MARK-SPACE threshold .... 64,000 to 200 with 200 unit precision

Displays or sets the threshold/fence used by the Goertzel filter to distinguish between MARK and SPACE levels.

F or **f:**   FFT CW Spectrum display

Displays a numerical representation of FFT buckets 18, 19, and 20.

+ or **=**:   Increment selected parameter .... +1

− or **_:**   Decrement selected parameter ...... -1

Enter: Clears parameter display.

Esc: Toggles RX side tone on and off.

In CW Transmit mode:

F1 – F7 Transmit the selected CW macro.

If not in transmit mode when the function key is pressed, the macro must start with `<TXON>` or the macro will not be processed. Note, the CW macros are separate from the macros used in other modes.

TUNE: Adjusts the transmit rate............... 5 to 99 wpm

Ctrl–TUNE: Adjusts the side tone freq.............. 400 to 2000 Hz

Nine discreet frequencies are available: 400, 444, 500, 571, 666, 800, 1000, 1333, and 2000 Hz (4000/N where N is an integer between 10 and 2, inclusive).

Esc: Toggles TX side tone and TX side tone display on and off.

APPENDIX C.   RECOGNIZED PROSIGNS

MORSE	PROSIGN	MEANING	DESCRIPTION
.-.-..	al		???
.-.-.	ar	All Right	end of message
.-...	as	wait A Sec	stand by
-...-.-	bk	BacK-to-you/let me in	BreaK
-...-	bt		Separator
-.-..-..	cl	CLear	CLosing down
-.-.--.-	cq		Calling
-.-.-	ct	Commence Transmission	start of message
....	hh	error	HuH?
..--.-	iq		???
-.--.	kn	oK, Named-station	Kalled statioN only
...-.-	sk	Silent Key	end of contact
...-.	sn	Sho' 'Nuff	understood

APPENDIX D.   EEPROM CONTENTS

Note: Entries new with Version 4.00 are shown in bold-face italics.

ADDRESS (HEX)	CONTENT	TO ENTER or EDIT	MAX # CHARS
00000	's' (indicates saved config is valid)	-	1
00001	CFG1 (PGA + mMode)		1
00002	CFG2 (BL + SQTH + AFC + CWID)		1
00003	CFG3 (*CW side tone enables* RTCC display enable flags)	*Esc*	1
00004	*CW TX Speed (WPM)*	*CW Mode + Tuning*	*1*
00005	*CW Side-Tone Period*	*CW Mode + Ctrl-Tuning*	*1*
00006	*CW RX inter-char Tcw x 10*	*'C' +/-*	*1*
00007	*CW RX inter-word Tcw x10*	*'W' +/-*	*1*
00008	*CW RX skew limit*	*S' +/-*	*1*
00009	*Date Display Format (see below)*	*Config option*	*1*
0000A-0000B	*Serial Number (high, low)*	*'N'/'X' +/-/Home*	*2*
0000C-0001F	Reserved		20
00020	'd'	-	1
00021	'e'	-	1
00022	' '	-	1
00023-0002F	My Call Sign *(11 char max, null terminated)*	Ctrl+M	12
00030-0003F	Saved Frequency	Ctrl+F	4
00040 - 0004F	(unassigned)	-	16
00050	' '	-	1
00051-00059	Log File Name (8.3)	Ctrl+N	12
0005A-0005F	(unassigned)	-	6
0005A-000FF	(unassigned)	-	166
00100-001FF	Macro 1	Ctrl+F1	255
00200-002FF	Macro 2	Ctrl+F2	255
00300-003FF	Macro 3	Ctrl+F3	255
00400-004FF	Macro 4	Ctrl+F4	255
00500-005FF	Macro 5	Ctrl+F5	255
00600-006FF	Macro 6	Ctrl+F6	255
00700-007FF	Macro 7	Ctrl+F7	255
00800-03FFF	(unassigned)	-	

NUE-PSK MODEM EEPROM (25AA1025) CONTENTS

04000-040FF	(unassigned)	-	256
04100-041FF	*CW Macro 1*	*Ctrl+F1*	*255*
04200-042FF	*CW Macro 2*	*Ctrl+F2*	*255*
04300-043FF	*CW Macro 3*	*Ctrl+F3*	*255*
04400-043FF	*CW Macro 4*	*Ctrl+F4*	*255*
04500-045FF	*CW Macro 5*	*Ctrl+F5*	*255*
04600-046FF	*CW Macro 6*	*Ctrl+F6*	*255*
04700-047FF	*CW Macro 7*	*Ctrl+F7*	*255*
04800-07FFF	(unassigned)	-	30720
08000-0BFFF	(unassigned)	-	32768
0C000-0FFFF	(unassigned)	-	30720
10000-1FFFF	(unassigned)	-	32768

CFG Byte Formats:

BIT:	7	6	5	4	3	2	1	0
CFG1:	X	PGA			mMode			
CFG2:	X	X	BL	X	SQTH		AFC	CWID
CFG3:	X	X	**CW RX ST**	**CW TX ST**	X	time	date	RTCC

Date Display Formats:

> 00 – "CCYY-MM-DD"
> 01 – "MM/DD/CCYY"
> 02 – "DD/MM/CCYY"

APPENDIX E.   CONFIG.TXT

```
===========================================================================================
                              NUE-PSK CONFIG
                              ==============
 Configuration file for the NUE-PSK Digital Modem for device settings and macro strings.

 DESCRIPTION ... This file is generated by the 'Upload Config' selection in the
     modem's CONFIGURE menu, and is written to a USB flash drive inserted into the modem.

 CONFIG.TXT ... This file reflects all the current settings of the modem, and may be
     modified as desired on a PC by using a simple text editor like Microsoft WordPad.

 EDITING ... Editing this text file must be done very carefully by changing characters after
     the colon and space.  The options available for each field are listed in parentheses
     for each field and must be entered exactly as shown. Special control characters are
     entered into macro strings as <TXON>, <TXOFF>, <MYCALL> <THEIRCALL> and <SERIALNO>.
     For example ...<TXON>Thanks <THEIRCALL>. QTH HERE IS BALTIMORE, de <MYCALL><TXOFF>

 LOADING INTO MODEM ... The settings and strings contained in the CONFIG.TXT file may loaded
     into the modem by placing the file onto the flash drive, inserting it into the modem,
     and then selecting 'Download Config' in the modem's CONFIGURE menu.

 RESULTS ... If the modem is able to successfully read and transfer all the settings to the modem,
     'Exit' will be displayed and pressing the Select pushbutton will bring you back to the
     normal operating mode of the mode with the new settings in effect.  Otherwise, the modem
     will beep will beep and the Download Config operation will terminate.
===========================================================================================

 1)   My Call: AD7JT

 2)   Log Fname: NUE-PSK.txt

 3)   PGA (x1,x5,x16,x32): x32

 4)   Mode (BPSK,QPSK,QPSK/R,RTTY,CW): BPSK

 5)   BackLight (ON,OFF): ON

 6)   SQLCH (25, 50): 50

 7)   AFC (ON,OFF): ON

 8)   CWID (ON,OFF): OFF

9)   Macro 1: <TXON>CQ CQ CQ DE <MYCALL> <MYCALL> <MYCALL> PSE K<TXOFF>|

 10) Macro 2: <TXON><THEIRCALL> <THEIRCALL> <THEIRCALL> DE <MYCALL> <MYCALL> <MYCALL> PSE K <TXOFF>|

 11) Macro 3: |

12) Macro 4:  HERE IN SUN CITY WEST, AZ (NW SUBURB OF PHOENIX) NAME HERE IS DAVE DAVE. HOW COPY?
<THEIRCALL> DE <MYCALL> K<TXOFF>|
```

13) Macro 5: RIG HERE IS YAESU FT-897D RUNNING ABOUT 40 WATTS CONTROLLED BY A NUE-PSK DIGITAL MODEM
WITH NO PC. MY ANT IS A 20M VERTICAL ATTACHED TO THE SIDE OF THE HOUSE. THE ANT IS DISGUISED BECAUSE
OUR HOA EXPLICITLY FORBIDS HAM ANTENNAS|

 14) Macro 6: I WAS FIRST LICENSED IN MN AS W0LSH IN 1952 AT THE AGE OF 13 BUT LET MY LICENSE LAPSE IN
THE 70S DUE TO THE DEMANDS OF STARTING A CAREER AND A FAMILY. I RETIRED IN 2005, MOVED FROM SO CA TO
AZ AND GOT RELICENSED IN THE FALL OF 2006.|

 15) Macro 7: |

 16) CW TX WPM (5 – 99): 20

 17) CW Side Tone Frequency (10 => 400 Hz, 2 => 2000 Hz): 03

 18) CW TX Side Tone (ON, OFF): OFF

 19) CW RX Side Tone (ON, OFF): OFF

 20) CW RX Inter-Char Tcw (2.0 – 4.0):2.0

 21) CW RX Inter-Word Tcw (2.5 – 7.0):2.5

 22) CW RX Max Skew Count (2 – 6):2

 23) CW Macro 1: <TXON>CQ TEST CQ TEST DE <MYCALL> <MYCALL> TEST K<TXOFF>|

 24) CW Macro 2: <TXON><THEIRCALL> 5NN <SERIALNO> <TXOFF>|

 25) CW Macro 3: <TXON>TU QRZ TEST DE <MYCALL> TEST K<TXOFF>|

 26) CW Macro 4: <TXON><MYCALL><TXOFF>|

 27) CW Macro 5: <TXON><THEIRCALL> <THEIRCALL> <THEIRCALL> DE <MYCALL> <MYCALL> <MYCALL> kn<TXOFF>|

 28) CW Macro 6: <TXON><THEIRCALL> DE <MYCALL> RIG HERE IS FT2000 RUNNING 100W TO A 20M VERTICAL.
ALSO USING A NUE PSK MODEM WITH NEW CW MODE I AM TESTING. HOW DOES IT SOUND? <THEIRCALL> DE <MYCALL>
kn <TXOFF>|

 29) CW Macro 7: |

APPENDIX F.   HOT KEY MAP

Note: **Boldface** entries are new to Version 4.00.

KEY	- - -	Ctrl-	Alt-
A		Enable AFC	Disable AFC
B	**CW Groetzel Bandwidth**	Clear internal buffers	
C	**CW Char SPACE fence**	Toggle RTTY FIGS	
D		Enter date (MM/DD/CCYY)	Enter Time (hh:mm:ss)
E			
F	**CW FFT bucket counts**	Save freq in EEPROM	Retreve saved freq
G			
H			
I		Enter text to be RECed (toggle)	
J			
K		Clear keyboard buffer	Add counter in beacon mode
L		Clear text display	
M		Enter My Call (MC)	Insert My Call in macro or Tx queue
N		Enter REC file name	
O		Toggle back light	
P		*Keyboard to Tx buffer*	
Q		Insert Tx OFF in macro	
R		Reverse RTTY Mark & Space	
S	**Serial Number**	Insert Tx ON in macro	**Insert Serial Number in macro or Tx queue**
T	**CW Groetzel threshold**	Enter Their Call (TC)	Insert Their Call in macro or Tx queue

U		Toggle REC (record) mode	
V			
W	**CW Word SPACE fence**		
X	**Serial Number/TC**		**Insert Serial Number in macro or Tx queue**
Y			
Z	**CW Skew count**	Input string terminator	
F1	Play macro 1	Record macro 1	Delete macro 1
F2	Play macro 2	Record macro 2	Delete macro 2
F3	Play macro 3	Record macro 3	Delete macro 3
F4	Play macro 4	Record macro 4	Delete macro 4
F5	Play macro 5	Record macro 5	Delete macro 5
F6	Play macro 6	Record macro 6	Delete macro 6
F7	Play macro 7	Record macro 7	Delete macro 7
F8	Toggle TUNE mode		
F9	*Save_Macro*		Beacon OFF
F10	Toggle Rx & Tx		
F11	Display My Call		
F12	Toggle settings display		
Tab	Dummy Function	Display current freq	
Pg-Up	Increase PGA gain		
Pg-Dn	Decrease PGA gain		
L-Arrow	Tune down x 1		Tune down x 5
R-Arrow	Tune up x 1		Tune up x 5
D-Arrow	Tune down x 2		Tune down x 10
U-Arrow	Tune up x 2		Tune up x 10