Using DSP filtering techniques to isolate and process Morse code for both receive and transmit in the Amateur Radio bands ... without a PC!

by Dave Collins, AD7JT
and
George Heron, N2APB
CW Mode for the NUE-PSK Digital Modem

Agenda

• Session I
  – Introduction
  – Transmit Channel
  – Q & A

• Session II
  – Receive Channel
  – Results/Conclusions
  – Q & A
NUE-PSK Modem = Standalone digital mode operation ... no PC required!

Introduced ~ 4 years ago ... PSK31, then other modes

Users clamored for CW support, but ...

Classic performance problems with “CW Readers”

NUE-PSK Modem has a “leg up”:
  - DSP processing
  - Nice spectral Display
CW Mode for the NUE-PSK Digital Modem

System Configuration

- Modem interfaces to transceiver with modulated, base-band audio signals.
- CW is transmitted and received as SSB signals.
- Transceiver operates in SSB or Digital mode, NOT CW MODE.

- Modulation is done with on-off delivery of an audio tone.
- Received audio is digitized at 8,000 samples per second.
- A Goertzel filter reconstructs the On-Off Keying signal.
- Characters are translated to ASCII and displayed.
• Keyboard-to-Morse conversion
  – Simple speed (wpm) control
  – “Perfect” DIT-DAH and SPACE timing
• Tone generation with existing PSK modulator
• Goertzel filter to detect the tone
• Morse-to-ASCII conversion
  – Automatic speed detection & tracking
  – Automatic DIT-DAH weighting adjustments
  – Manual tweaking to accommodate imperfect “fists”
• Tuning algorithm and indication
  – Tune with AFC (simplifies tuning and tracks drifters)
  – Bandwidth control
• MARK = Key down, SPACE = Key up
• $T_{cw}$ is the basic unit of timing for CW
• Inter-word SPACE = $7 \times T_{cw}$ (minimum)
Words Per Minute (wpm) calculations

- Standard word = “PARIS ”
- Contains exactly 50 \( T_{cw} \) including the ending Inter-word SPACE
- Therefore, \( wpm = \frac{1200}{T_{cw}} \) where \( T_{cw} \) is expressed in milliseconds
**CW Mode for the NUE-PSK Digital Modem**

**Transmit Channel**

- Keyboard
- EEPROM
- Scan Code Processing
- Macro Playback
  - ASCII to Morse
  - LCD Graphic Display
    - Phase Modulator
      - Audio to Transceiver
  - USB Option Card
  - Flash Drive
• Standard PS/2 keyboard interface
• Forced Caps Lock mode
• Upper-case letters for normal text
• Lower-case letters for prosigns
• Hot-keys for entering <My Call> and <Their Call>
• Support for Serial Numbers
• Seven, separate CW macros
• Up to 255 Characters each
• Tags for <TXON>, <MYCALL>, <THEIRCALL>, <TXOFF>, and <SERIALNO>
• Flexible save, restore, and edit functions
Four lines of text are displayed with line-scrolling.
Operator controls wpm (Tune) and side tone (Ctrl-Tune).
Displayed characters are over lined until transmitted.
Text is transmitted only as full words.
Prosigns are displayed as lower-case letters.
- ASCII to Morse Look Up Table
- Each element followed by 1 $T_{cw}$ SPACE
- Uses PSK CWID feature
- 8,000 output samples per second
CW Mode for the NUE-PSK Digital Modem

Questions?
End of Session I
Session II

- Receive Channel
- Results/Conclusions
- Q & A
CW Mode for the NUE-PSK Digital Modem

Receive Channel

Audio from Transceiver → PGA and ADC → Goertzel Filter → Mark Grouping

AGC ➔

Goertzel Tweaking ➔

Level ➔

Tune ➔

Bandpass ➔

Fence Tweaking ➔

Character ➔

Word ➔

Morse to ASCII → LCD Graphic Display

USB Option Card ➔

Flash Drive ➔
- Specialized DFT algorithm
- Used for DTMF decoding
- Very simple to implement
- Very fast to execute

\[
g_{\text{coef}} = 2 \times \cos(2 \times \pi \times \text{center\_frequency} / 8000)
\]

\[
g_{\text{sample}} = \left(\frac{\text{double}\ f_{\text{sample}}}{32768.0}\right);
\]

\[
q_0 = g_{\text{coef}} \times q_1 - q_2 + g_{\text{sample}};
\]

\[
q_2 = q_1;
\]

\[
q_1 = q_0;
\]

\[
\text{if}(++g_{\text{sample\_count}} \geq \text{cw\_n})\{
\]
\[
g_{\text{sample\_count}} = 0;
\]
\[
\text{cw\_n} = \text{cw\_bwa[cw\_bwa\_index]};
\]
\[
g_{\text{current}} = q_1 \times q_1 + q_2 \times q_2 - q_1 \times q_2 \times g_{\text{coef}};
\]
\[
q_2 = 0;
\]
\[
q_1 = 0;
\]

\[
\text{f\_sample}\ is\ the\ raw,\ digitized\ input\ signal
\]

\[
g_{\text{coef}}\ determines\ the\ pass\ band\ center\ frequency
\]

\[
The\ band\ pass\ is\ the\ sampling\ frequency\ (8000)\ divided\ by\ the\ block\ length\ (\text{cw\_n})
\]

\[
g_{\text{current}}\ is\ the\ filter\ output
\]
**CW Mode for the NUE-PSK Digital Modem**

**Level (Threshold)**
- Threshold defines MARK/SPACE “fence”
- Normally calculated as average between recognized MARKs and SPACEs
- Operator can override the calculations

**Bandwidth**
- Operator can select between 100 Hz and 1000 Hz in eight steps
- Narrower the pass band, the longer the Goertzel calculation takes
• Block length (cw_n) must be an integral factor of the sampling rate
• The modem’s bandwidth is bound by the transceiver’s bandwidth
• $T_{cw}$ should be at least 4 times the Time per Block
• Therefore:
  Maximum wpm = $\frac{1200}{(4 \times \text{Time/Block})} [300 – 30 \text{ wpm}]$
**CW Mode for the NUE-PSK Digital Modem**

Audio from Transceiver → PGA and ADC → **Goertzel Filter** → Mark Grouping → Morse to ASCII → LCD Graphic Display

\[
g_{coef} = 2 \times \cos\left(2 \times \pi \times \text{center_frequency} / 8000\right)
\]

- \(g_{coef} = 1.600102\)
- \(g_{coef} = 1.614280\)
• CW modulates time – not waveforms
• MARK and SPACE lengths are averaged
• Fences are calculated
• MARKs are grouped
- MARKs only come in two flavors
- $T_{cw} = (\text{MARK average}) / 2$
- Duplicate MARK lengths are limited
- The DIT-DAH fence is the average MARK length plus the average mean deviation
• SPACEs come in three flavors
• Any SPACE ends a MARK
• When a SPACE length exceeds the character fence, the MARK group is processed
• When a SPACE duration exceeds the word fence, a space code is inserted in the text.
CW Mode for the NUE-PSK Digital Modem

- The MARK $T_{cw}$ is the basis for SPACE fences
- Character SPACE lengths are averaged
- Character fence = 2 x inter-element average
- Word fence = 2.5 x character fence
Operator can override SPACE fence calculations
Can vary $T_{cw}$ multipliers by tenths
Will lock until Enter is pressed
Receive continues during tweaking
CW Mode for the NUE-PSK Digital Modem

Audio from Transceiver → PGA and ADC → Goertzel Filter → Mark Grouping → Morse to ASCII → LCD Graphic Display

<table>
<thead>
<tr>
<th>Index</th>
<th>Factor</th>
<th>‘C’</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>64</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>128</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

00000000001111111111222222222222 0123456789012345678901234567890
*ETIANMSURWDKGOHVF*L*PJBXCYZQ**

- Sum of products for ‘C’ = 25
- This works for 1, 2, 3, and 4 Morse elements
- Mark groups with 5, 6, 7, and 8 Morse elements are translated with brute-force
- Prosings are translated to two, lower-case letters
- Group overflow generates a ‘#’
CW Mode for the NUE-PSK Digital Modem

Audio from Transceiver → PGA and ADC → Goertzel Filter → Mark Grouping

AGC ↓ Level Tune Bandpass

Morse to ASCII → LCD Graphic Display

USB Option Card → Flash Drive

Questions?
Conclusions

- Goertzel filter outperforms expectations
- Tuning at the modem is a must
- Word SPACE multiple most useful tweak
- Zkew least useful tweak
- A good aid for CW contesting
- Using it to check your “fist” can be humbling
Future Project Candidates

- Keyboard-less configuration
  ... Paddle input to built-in keyer:
    - ORed with keyboard and macro input
    - ORed with Goertzel filter output
- Display-less configuration (Morse audio)
- Logging to flash drive in a standard format
- Incorporate modem functions in SDR Cube ... in progress!
- More?

*The ultimate “Portable Digital Station”*  
(The original “Portable PSK” vision from 2001)
CW Mode for the NUE-PSK Digital Modem

Summary

Transmit

Keyboard → Scan Code Processing

EEPROM → Macro Playback

ASCII to Morse → Phase Modulator

LCD Graphic Display → Audio to Transceiver

USB Option Card → Flash Drive

Receive

Audio from Transceiver → PGA and ADC

AGC → Goertzel Filter

Goertzel Tweeping Bandpass → Fence Tweeping Character Word

Morse to ASCII → LCD Graphic Display

USB Option Card → Flash Drive
Thank you!

Dave Collins, AD7JT
22111 N San Ramon Drive
Sun City West, AZ 85375
dmc@dnbrealty.com

George Heron, N2APB
2419 Feather Mae Ct
Forest Hill, MD 21050
n2apb@MidnightDesignSolutions.com