CW Mode for the NUE-PSK Digital Modem

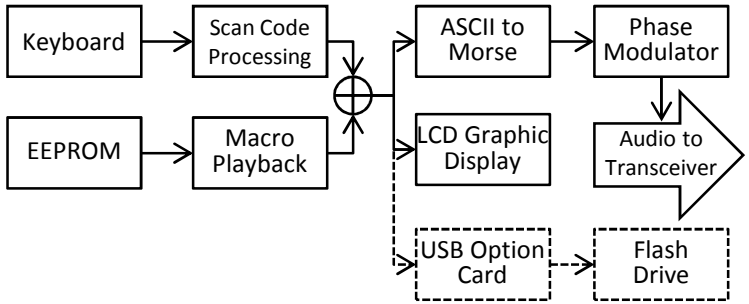
Using DSP filtering techniques to isolate and process Morse code for both receive and transmit in the Amateur Radio bands … without a PC!

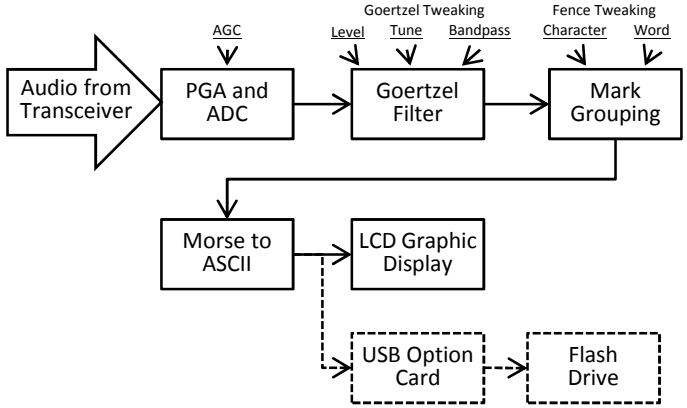
by Dave Collins, AD7JT
and
George Heron, N2APB

CW Mode for the NUE-PSK Digital Modem

Agenda

- Session I
  - Introduction
  - Transmit Channel
  - Q & A
- Session II
  - Receive Channel
  - Results/Conclusions
  - Q & A





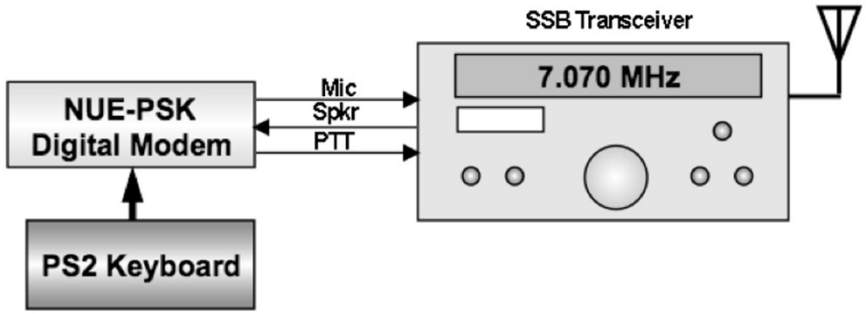
CW Mode for the NUE-PSK Digital Modem

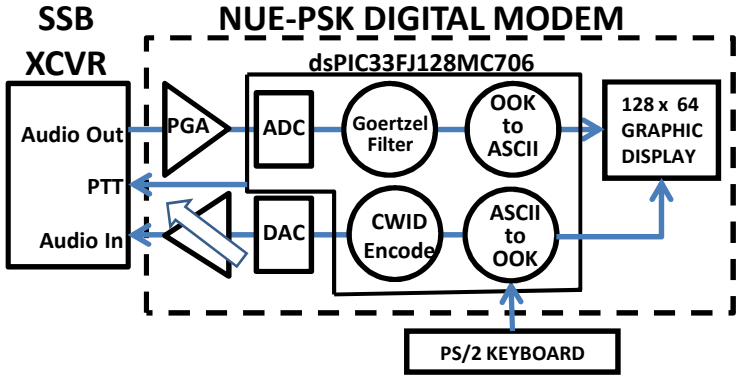
WHY?

- 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



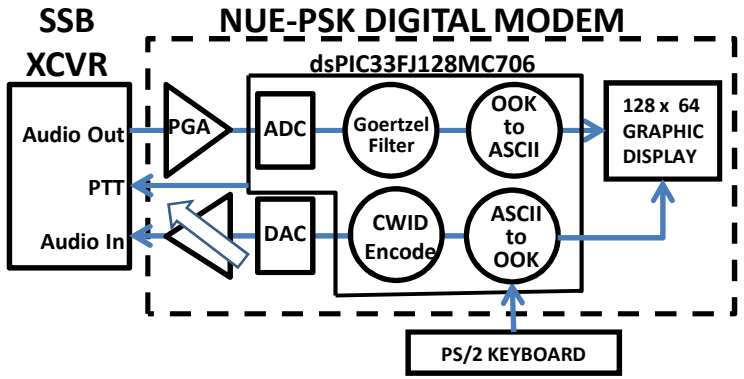


- Modem interfaces to transceiver with modulated, base-band audio signals.
- CW is transmitted and received as SSB signals.
- Transceiver operates in SSB or Digital mode, **NOT CW MODE**.

- 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 **O**n-**O**ff **K**eying signal.
- Characters are translated to ASCII and displayed

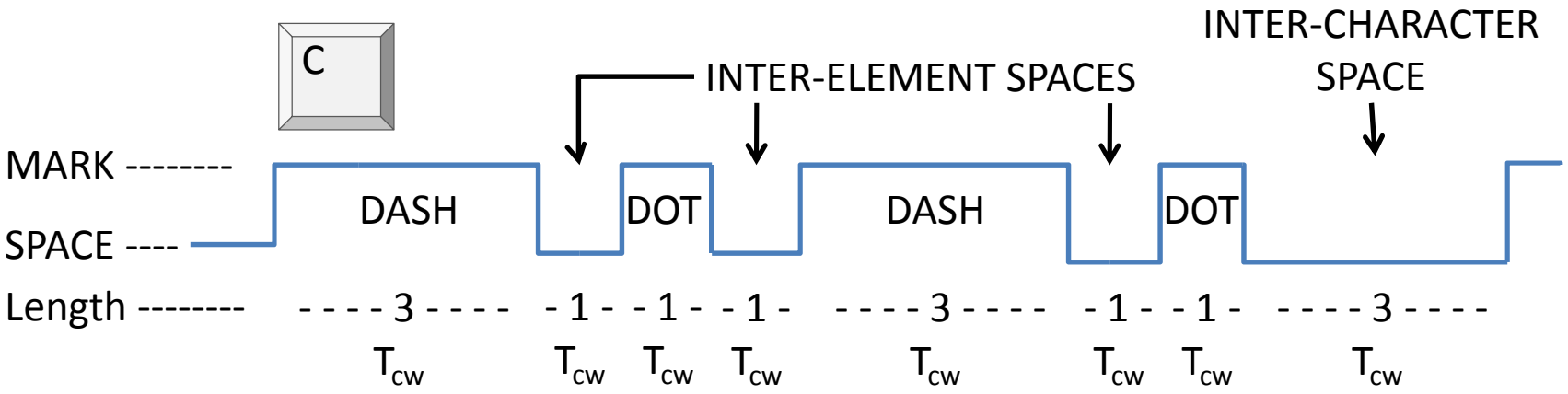
CW Mode for the NUE-PSK Digital Modem

- Keyboard-to-Morse conversion
  - Simple speed (wpm) control
  - "Perfect" DIT-DAH and SPACE timing
- Tone generation with existing PSK modulator



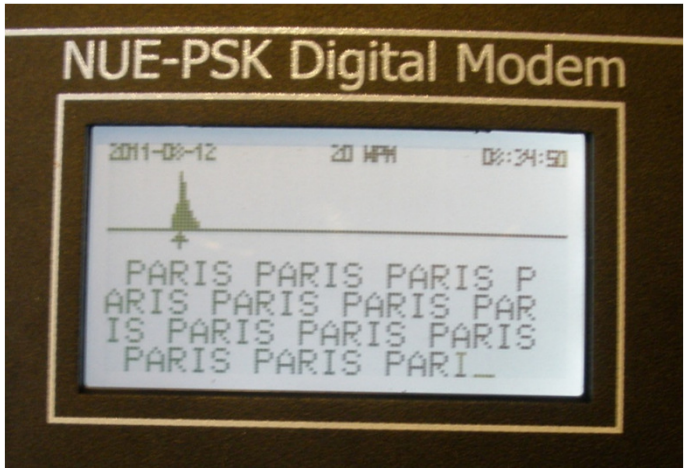
- Goertzel filter to detect the tone
- Morse-to-ASCII conversion
  - Automatic speed detection & tracking
  - Automatic DIT-DAH weighting adjustments
  - Manual tweaking to accommodate imperfect "fists"
- Tuning algorithm and indication
  - Tune with AFC (simplifies tuning and tracks drifters)
  - Bandwidth control

CW Mode for the NUE-PSK Digital Modem



- MARK = Key down, SPACE = Key up
- T_{cw} is the basic unit of timing for CW
- Inter-word SPACE = 7 x T_{cw} (minimum)

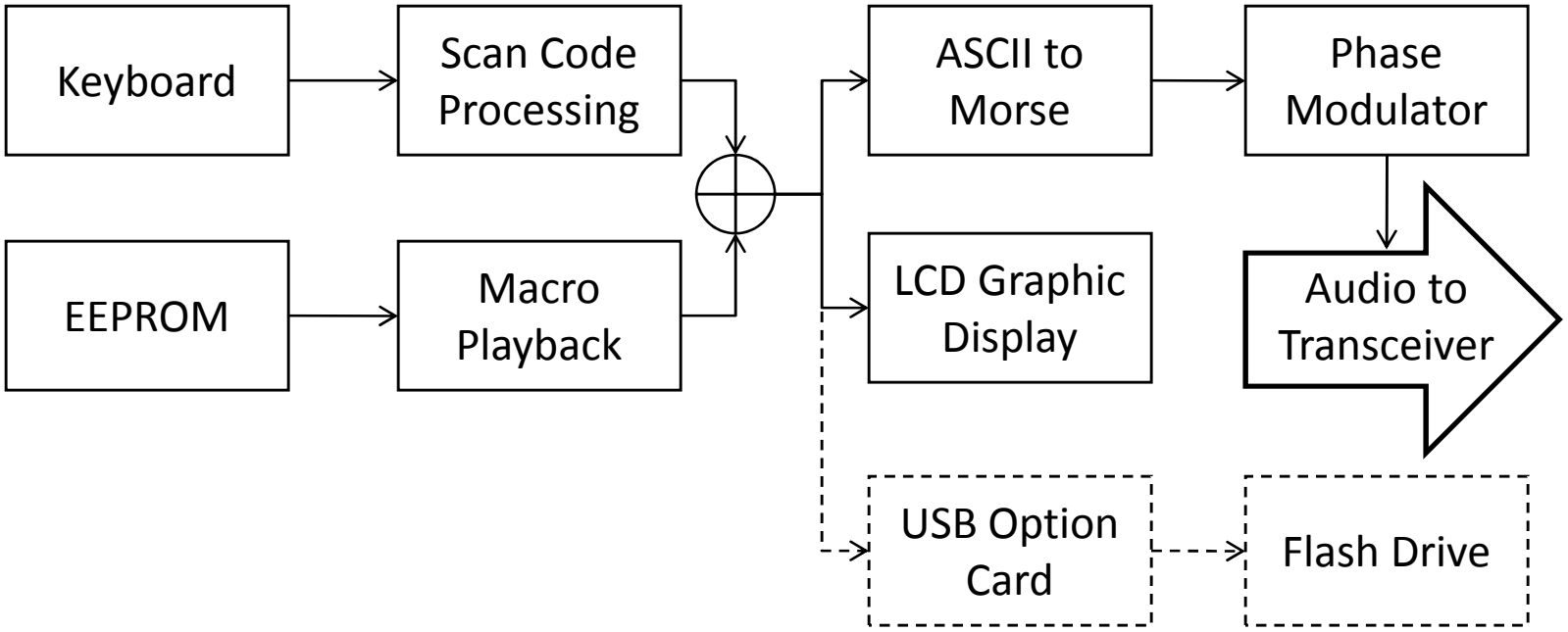
CW Mode for the NUE-PSK Digital Modem



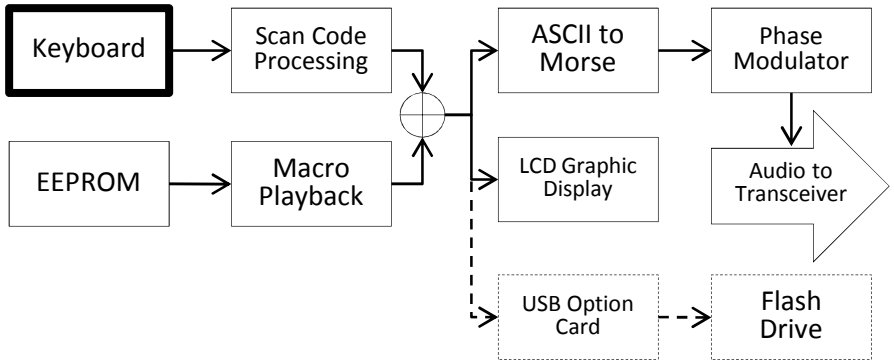
- Words Per Minute (wpm) calculations
  - Standard word = “PARIS ”
  - Contains exactly 50 T_{cw} including the ending Inter-word SPACE
  - Therefore, wpm = 1200 / T_{cw} where T_{cw} is expressed in milliseconds

CW Mode for the NUE-PSK Digital Modem

Transmit Channel

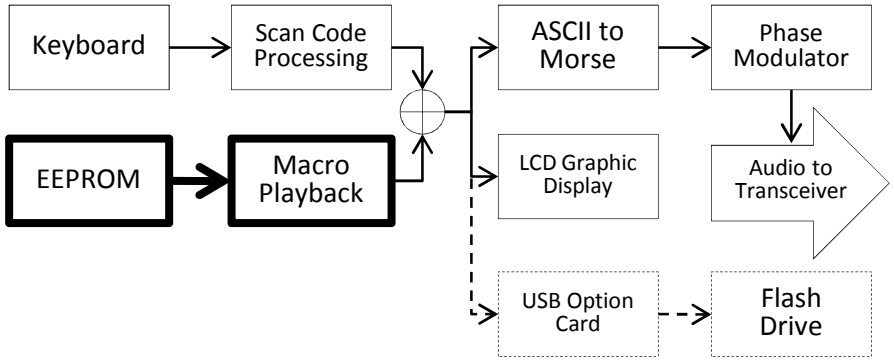


CW Mode for the NUE-PSK Digital Modem



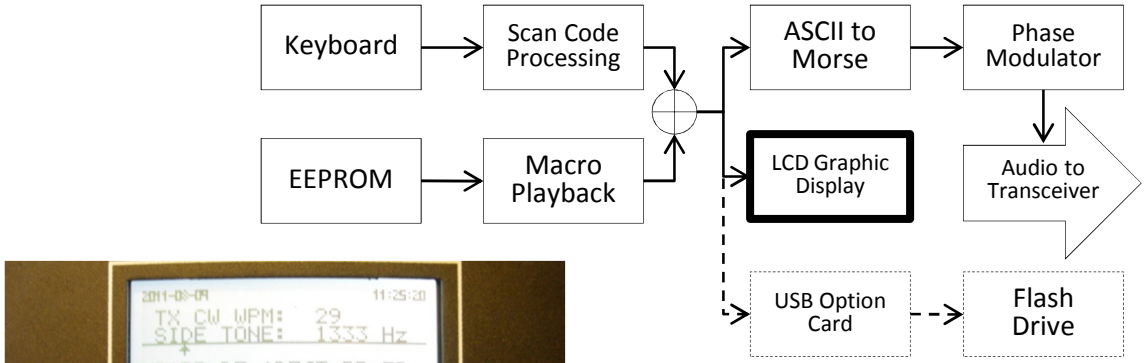
- Standard PS/2 keyboard interface
- Forced Caps Lock mode
- Upper-case letters for normal text
- Lower-case letters for prosigns
- Hot-keys for entering <My Call> and <Their Call>
- Support for Serial Numbers

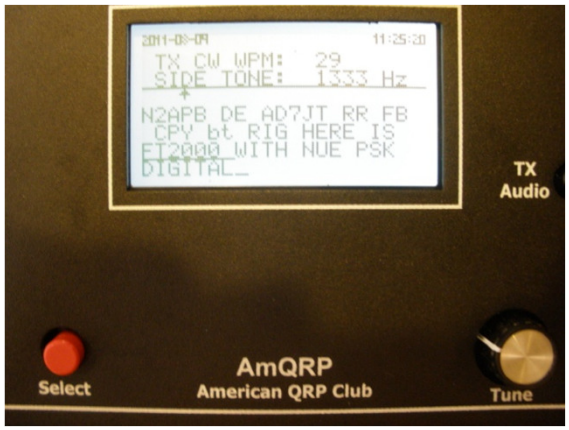
CW Mode for the NUE-PSK Digital Modem



- Seven, separate CW macros
- Up to 255 Characters each
- Tags for <TXON>, <MYCALL>, <THEIRCALL>, <TXOFF>, and <SERIALNO>
- Flexible save, restore, and edit functions

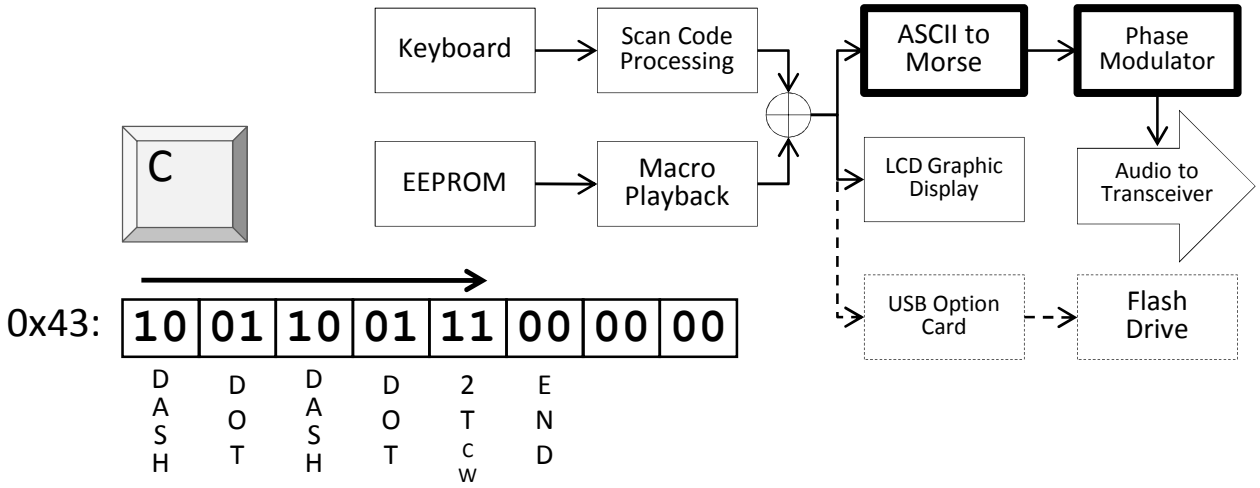
CW Mode for the NUE-PSK Digital Modem





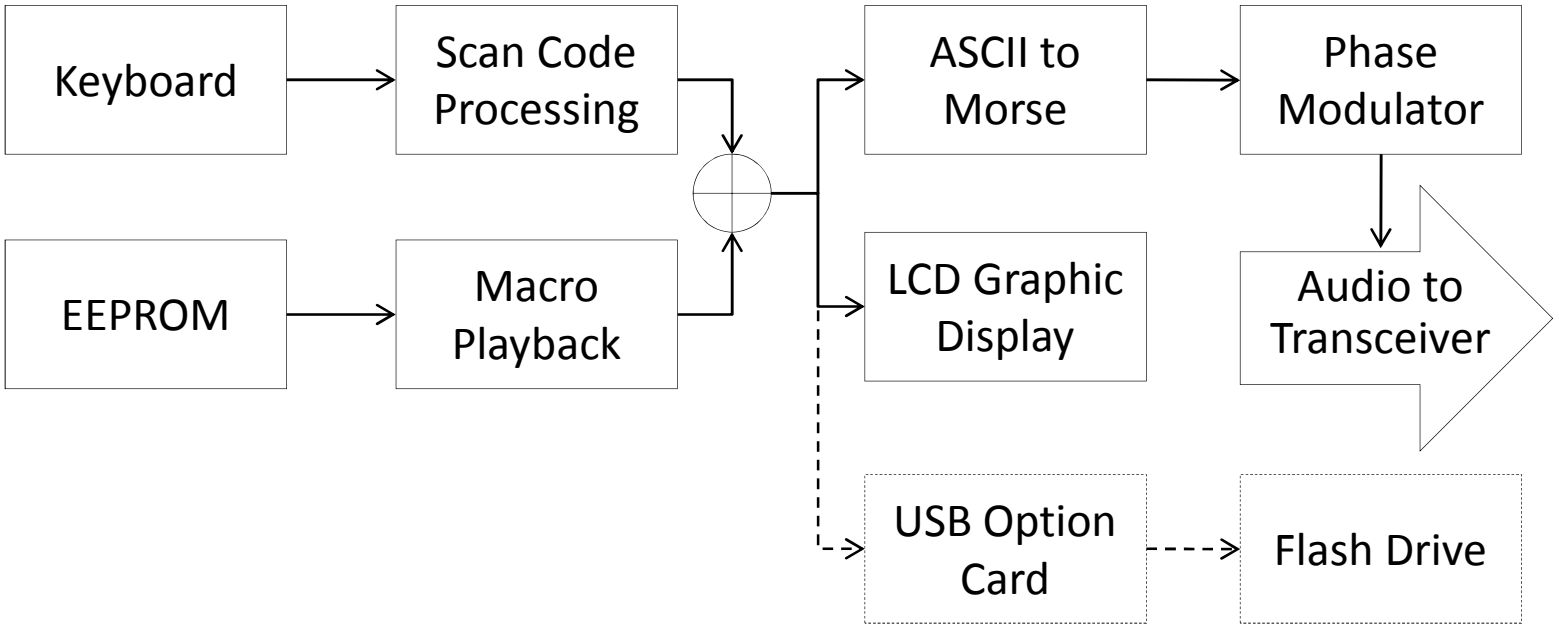
- Four lines of text are displayed with line-scrolling.
- Operator controls wpm (Tune) and side tone (Ctrl-Tune).
- Displayed characters are over lined until transmitted.
- Text is transmitted only as full words.
- Prosigns are displayed as lower-case letters.

CW Mode for the NUE-PSK Digital Modem



- 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

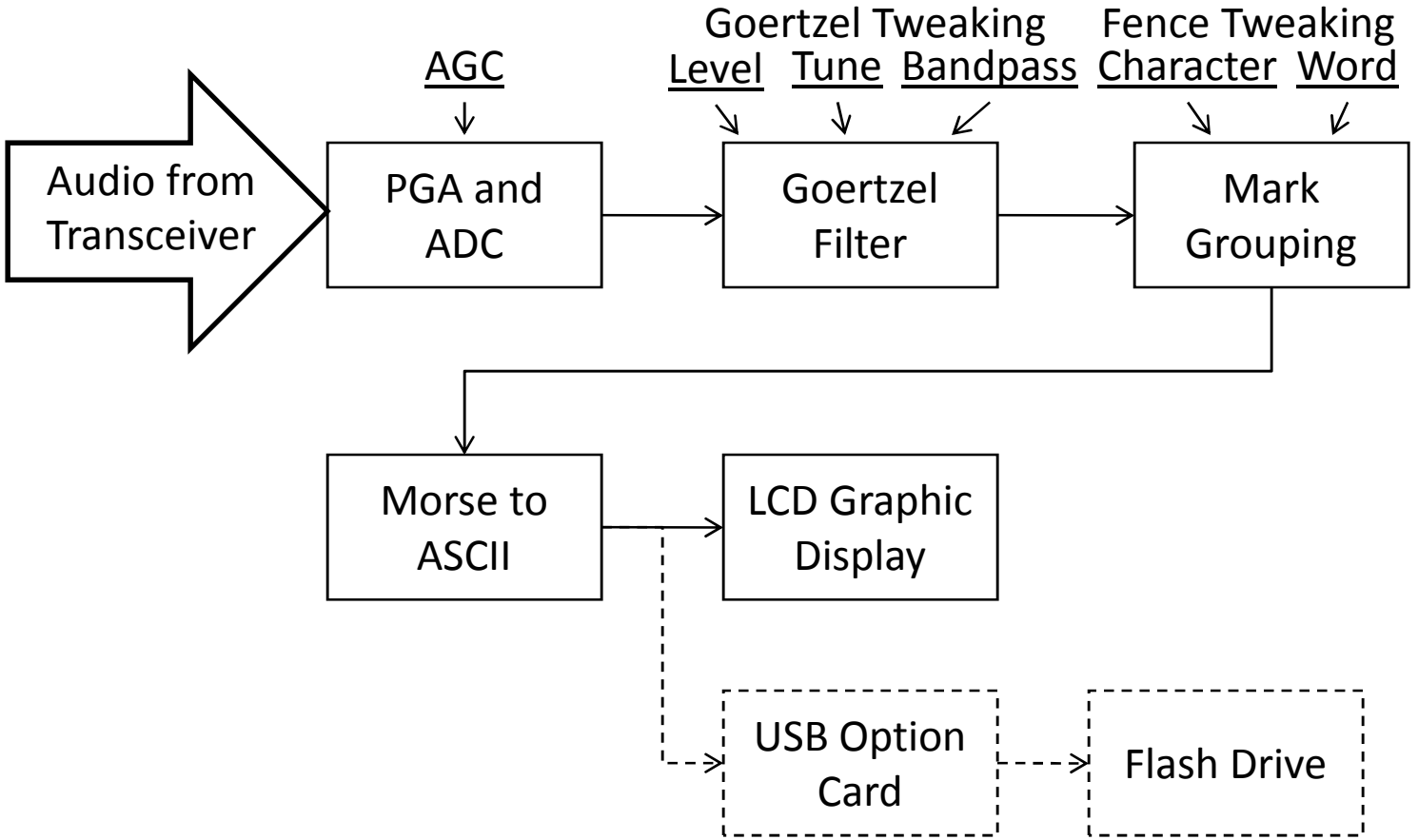
CW Mode for the NUE-PSK Digital Modem

Session II

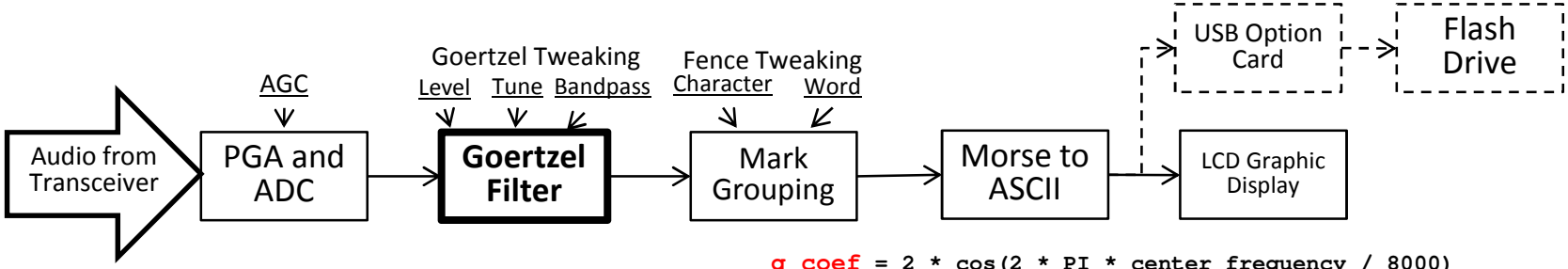
- Receive Channel
- Results/Conclusions
- Q & A

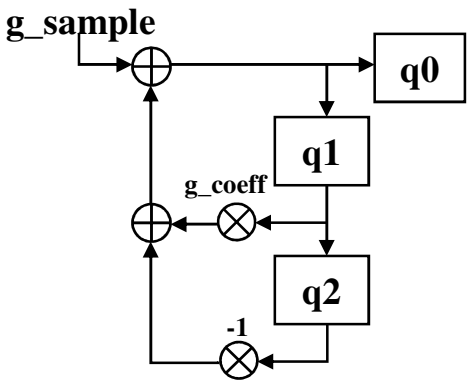
CW Mode for the NUE-PSK Digital Modem

Receive Channel



CW Mode for the NUE-PSK Digital Modem





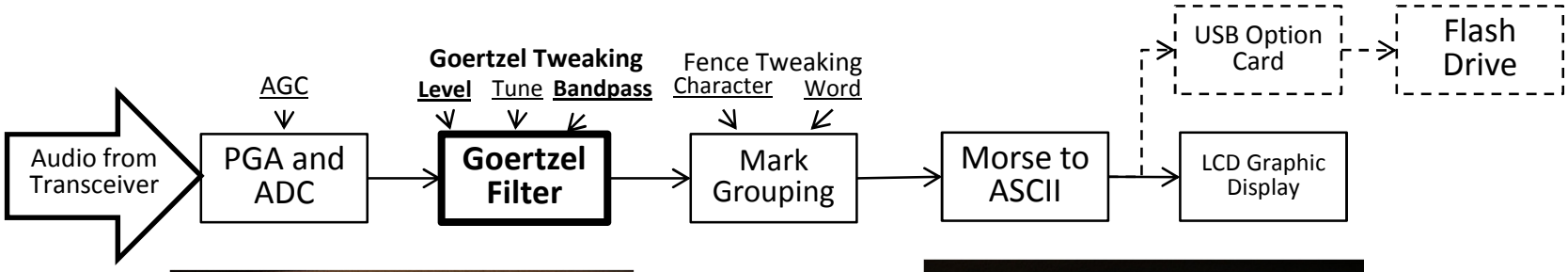

```
g_coef = 2 * cos(2 * PI * center_frequency / 8000)
     . . . . . .
g_sample = (((double) f_samp)/32768.0);
q0 = g_coef*q1 - q2 + g_sample;
q2 = q1;
q1 = q0;

if(++g_sample_count >= cw_n){
     g_sample_count = 0;
     cw_n = cw_bwa[cw_bwa_index];
     g_current = q1*q1 + q2*q2 - q1*q2*g_coef;
     q2 = 0;
     q1 = 0;
     . . . . . .
```

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

- **`f_sample`** is the raw, digitized input signal
- **`g_coef`** determines the pass band center frequency
- The band pass is the sampling frequency (8000) divided by the block length (**`cw_n`**)
- **`g_current`** is the filter output

CW Mode for the NUE-PSK Digital Modem



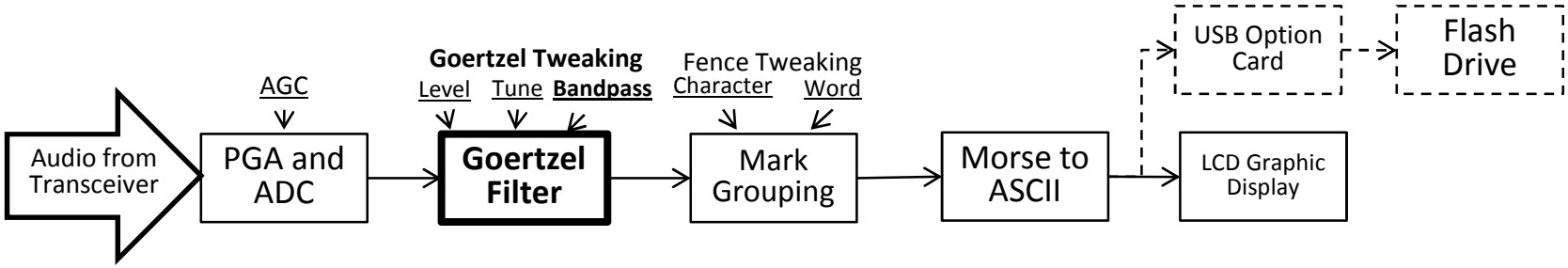
Level (Threshold)

- 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

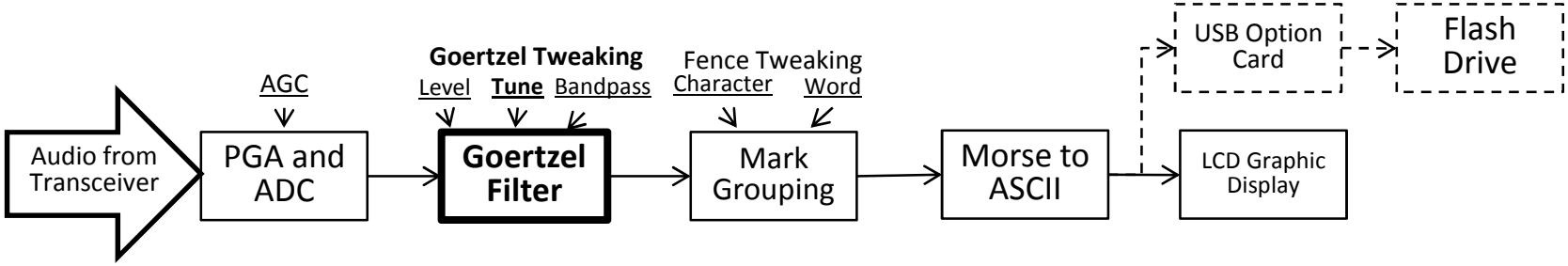
CW Mode for the NUE-PSK Digital Modem

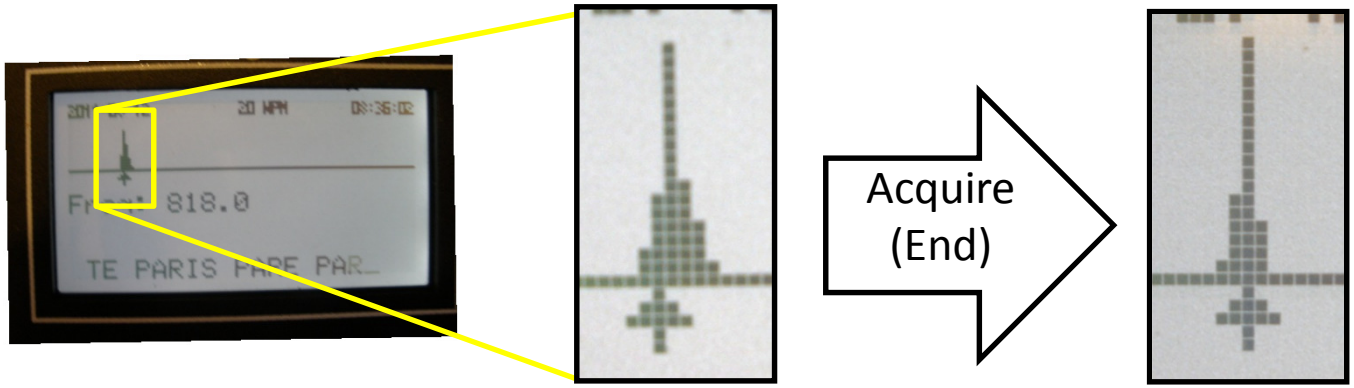


Block Length (cw_n)	Bandwidth (Hz)	Time/Block (ms)
8	1000	1.00
10	800	1.25
16	500	2.00
20	400	2.50
32	250	4.00
40	200	5.00
50	160	1.25
64	125	8.00
80	100	10.00

- 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 = 1200 / (4 x Time/Block) [300 – 30 wpm]

CW Mode for the NUE-PSK Digital Modem



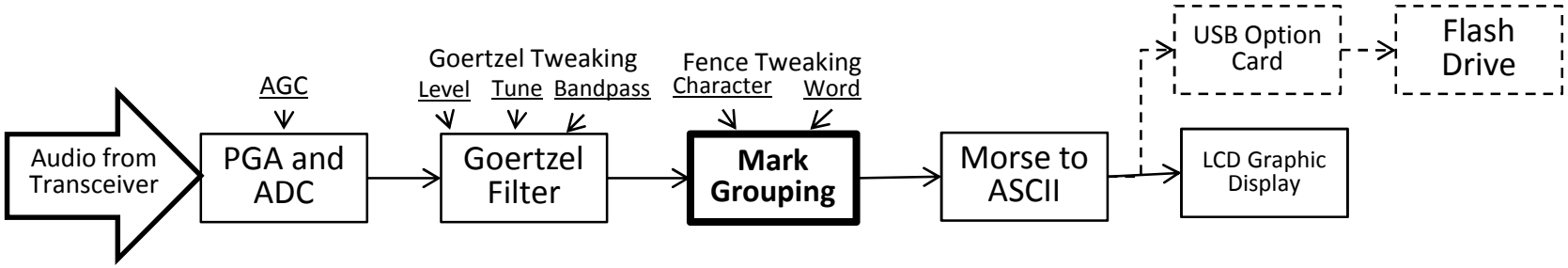


g_coef = 1.600102

g_coef = 1.614280

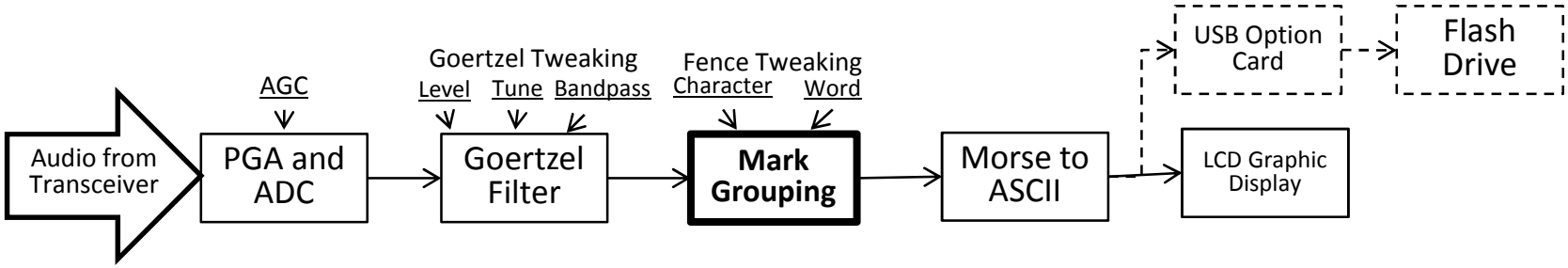
```
g_coef = 2 * cos(2 * PI * center_frequency / 8000)
```

CW Mode for the NUE-PSK Digital Modem



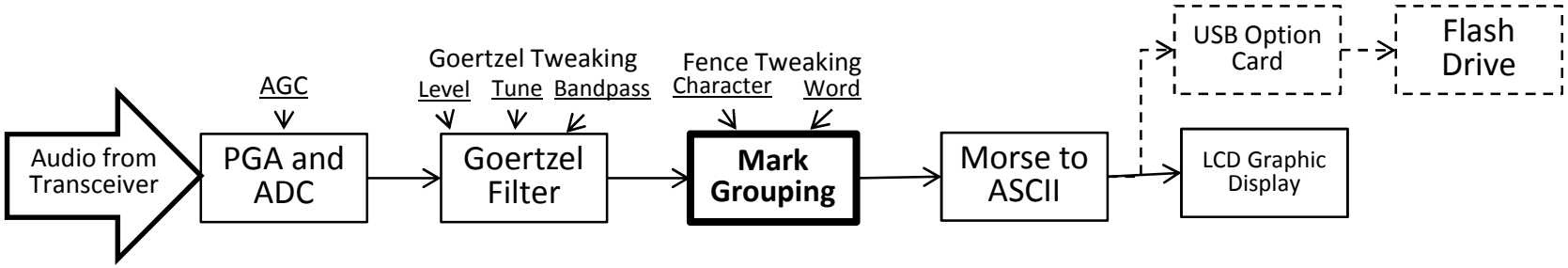
- CW modulates time – not waveforms
- MARK and SPACE lengths are averaged
- Fences are calculated
- MARKs are grouped

CW Mode for the NUE-PSK Digital Modem



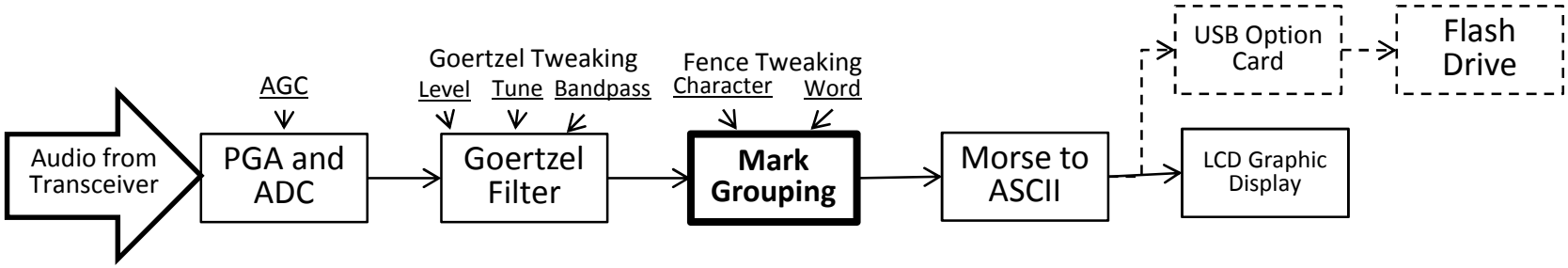
- MARKs only come in two flavors
- T_{cw} = (MARK average) / 2
- Duplicate MARK lengths are limited
- The DIT-DAH fence is the average MARK length plus the average mean deviation

CW Mode for the NUE-PSK Digital Modem



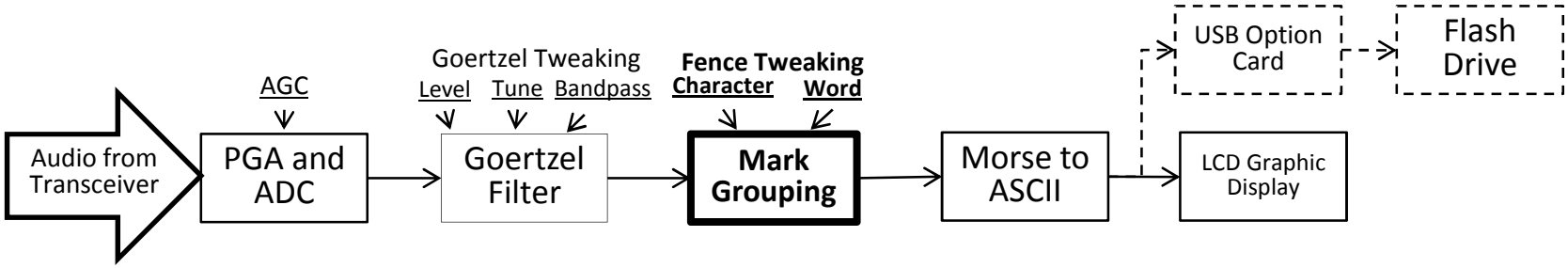
- SPACEs come in three flavors
- Any SPACE ends a MARK
- When a SPACE length exceeds the character fence, the MARK group is processed
- When a SPACE duration exceeds the word fence, a space code is inserted in the text.

CW Mode for the NUE-PSK Digital Modem



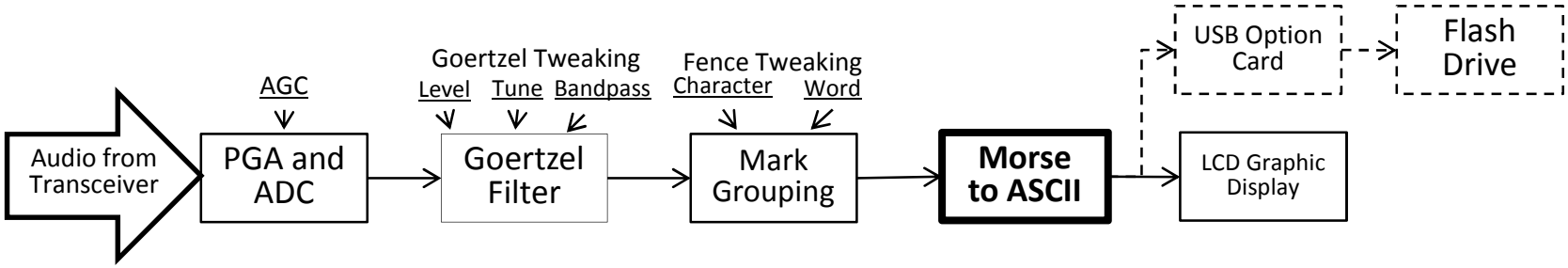
- The MARK T_{cw} is the basis for SPACE fences
- Character SPACE lengths are averaged
- Character fence = 2 x inter- element average
- Word fence = 2.5 x character fence

CW Mode for the NUE-PSK Digital Modem



- 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

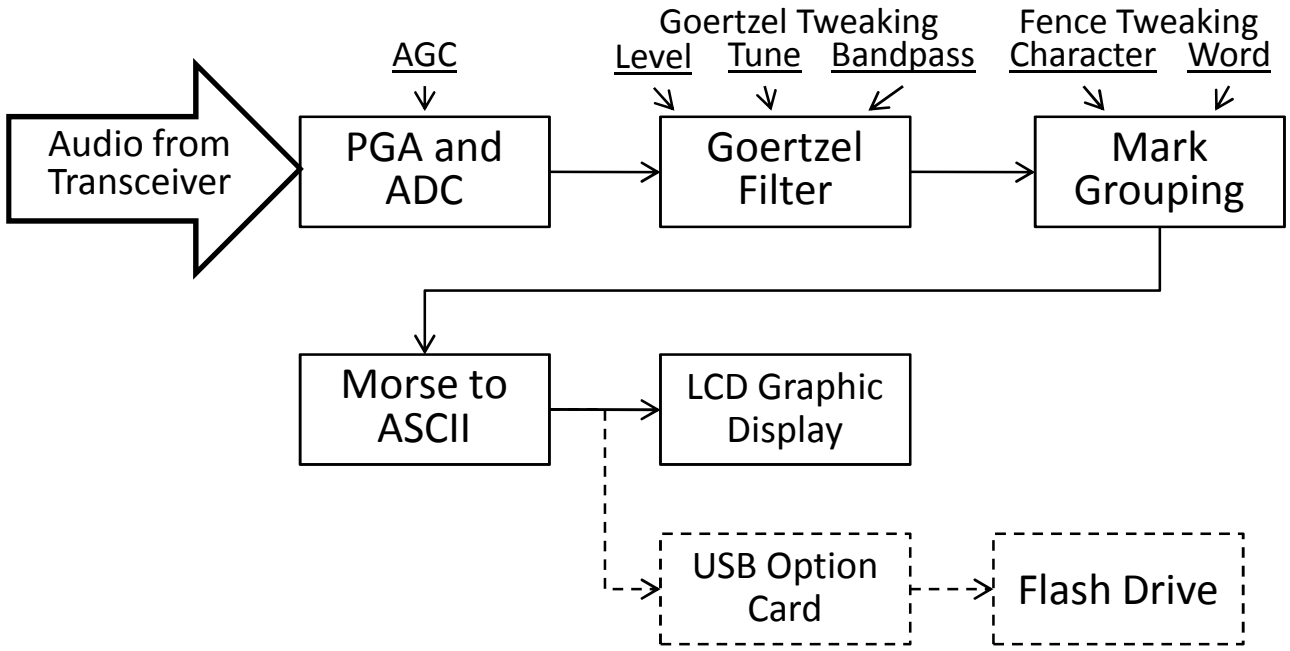


Index	Factor	'C'	Value
0	1	1	1
1	2	2	4
2	4	1	4
3	8	2	16
4	16	0	0
5	32	0	0
6	64	0	0
7	128	0	0

```
00000000001111111112222222222223
01234567890123456789012345678890
*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
- Prosigns are translated to two, lower-case letters
- Group overflow generates a '#'

CW Mode for the NUE-PSK Digital Modem



Questions?

CW Mode for the NUE-PSK Digital Modem

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

CW Mode for the NUE-PSK Digital Modem

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?

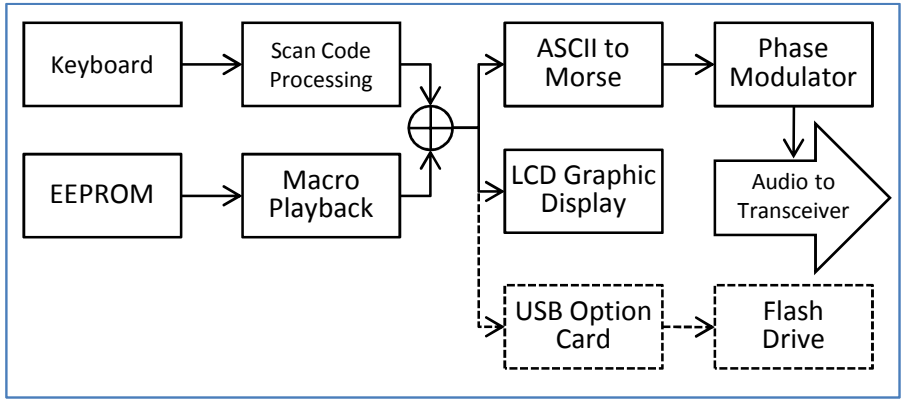
The ultimate "Portable Digital Station"

(The original "Portable PSK" vision from 2001)

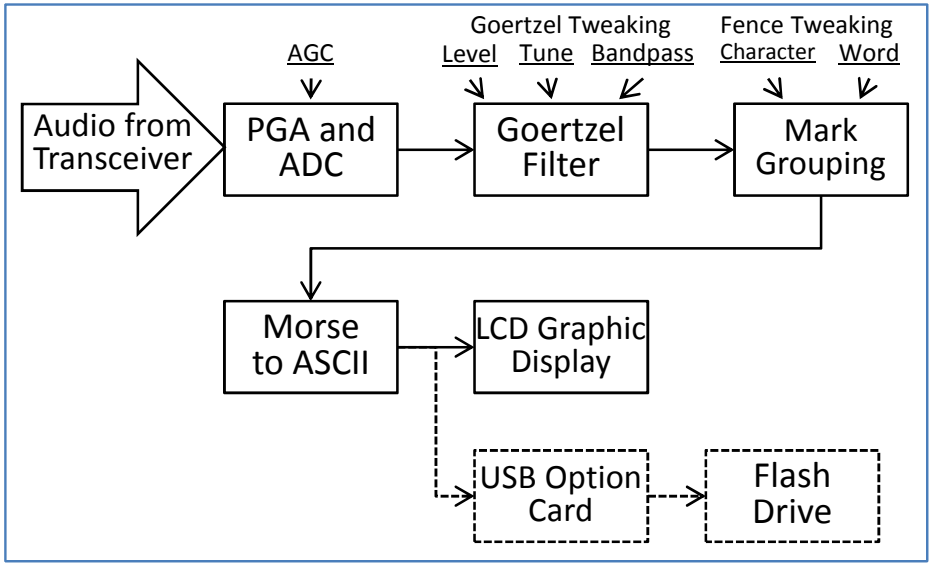
CW Mode for the NUE-PSK Digital Modem

Summary

Transmit



Receive



CW Mode for the NUE-PSK Digital Modem

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