Amateur Digital Voice
Dayton 2002

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Technical Challenges of H.F Digital Voice

- Symbol Alignment
- Frequency Alignment
- S/N and fading performance
- Multipath performance
- PMR problem
- Late Entry

Solutions

- Serial Tone Modems
- Parallel Tone Modems

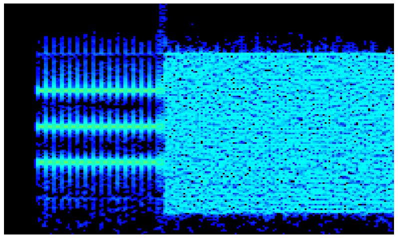
Serial tone modem

- 2400 baud, uses channel equalisation, coherent detection.
- Good for data not so good for voice.
- When fails, fails catastrophically due to equaliser failure.

Parallel tone

- Fails gradually, better for digital voice.
- Simple to implement
- Normally uses differential encoding and a guard period therefore requires no equalisation.
- High PMR

Current Modem



- 3 Tone BPSK Preamble
- Reference phase on all tones
- Start of Message BPSK sequence
- Voice Data
- End of Message BPSK sequence
- Clipping of TX waveform

Voice Frame Format

- 160 samples per frame, 72 bits, 50Hz
- 3600 bitrate, 2400 Voice, 1200 FEC
- 8000 samples per sec
- 128 point IFFT/FFT
- 32 samples used for guard period
- Modulation DQPSK
- Phase error used for fine frequency error correction.

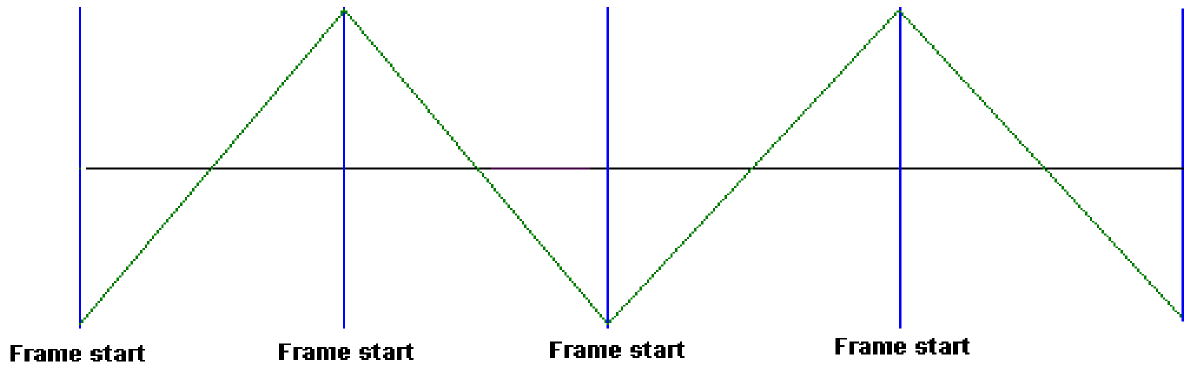
Main Problems

- Frequency error estimation critical.
- Modem has no late entry mode.
- S/N performance could be improved.
- Cannot be used with adaptive notch filters in IF DSP based radios.

Time Alignment

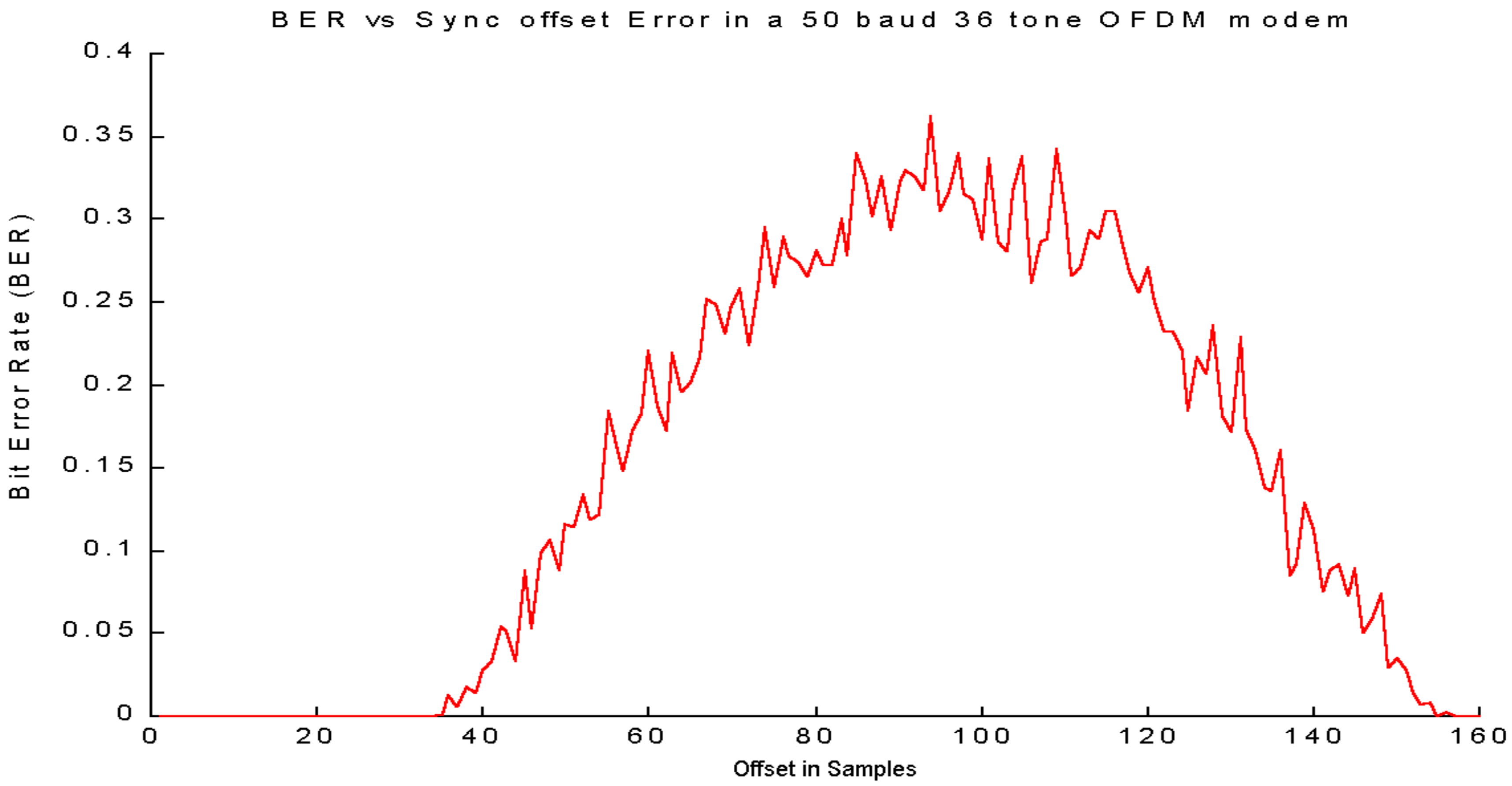
- Preamble
- Guard Period
- FFT Bin
- Re-inserted sync sequences

Time Sync From Preamble



Differentially decode BPSK preamble, accumulate the result and search for max to find sync.

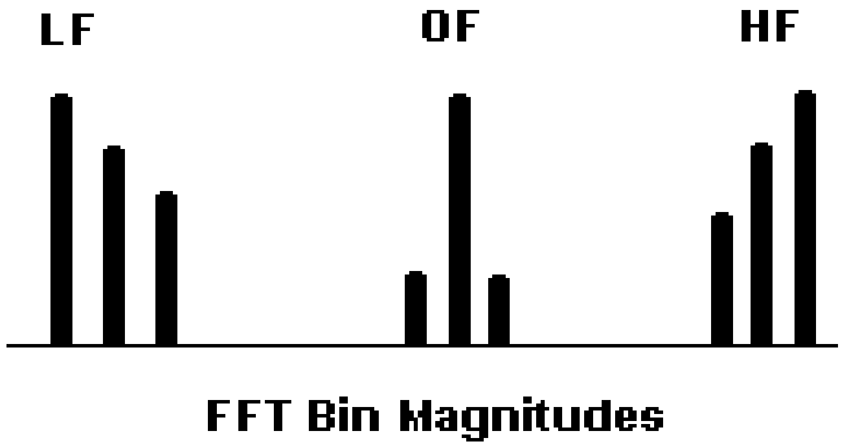
Effects of time misalignment



Frequency Alignment

- Preamble
- Phase error
- Guard period
- FFT Bins
- Re-inserted sync sequence

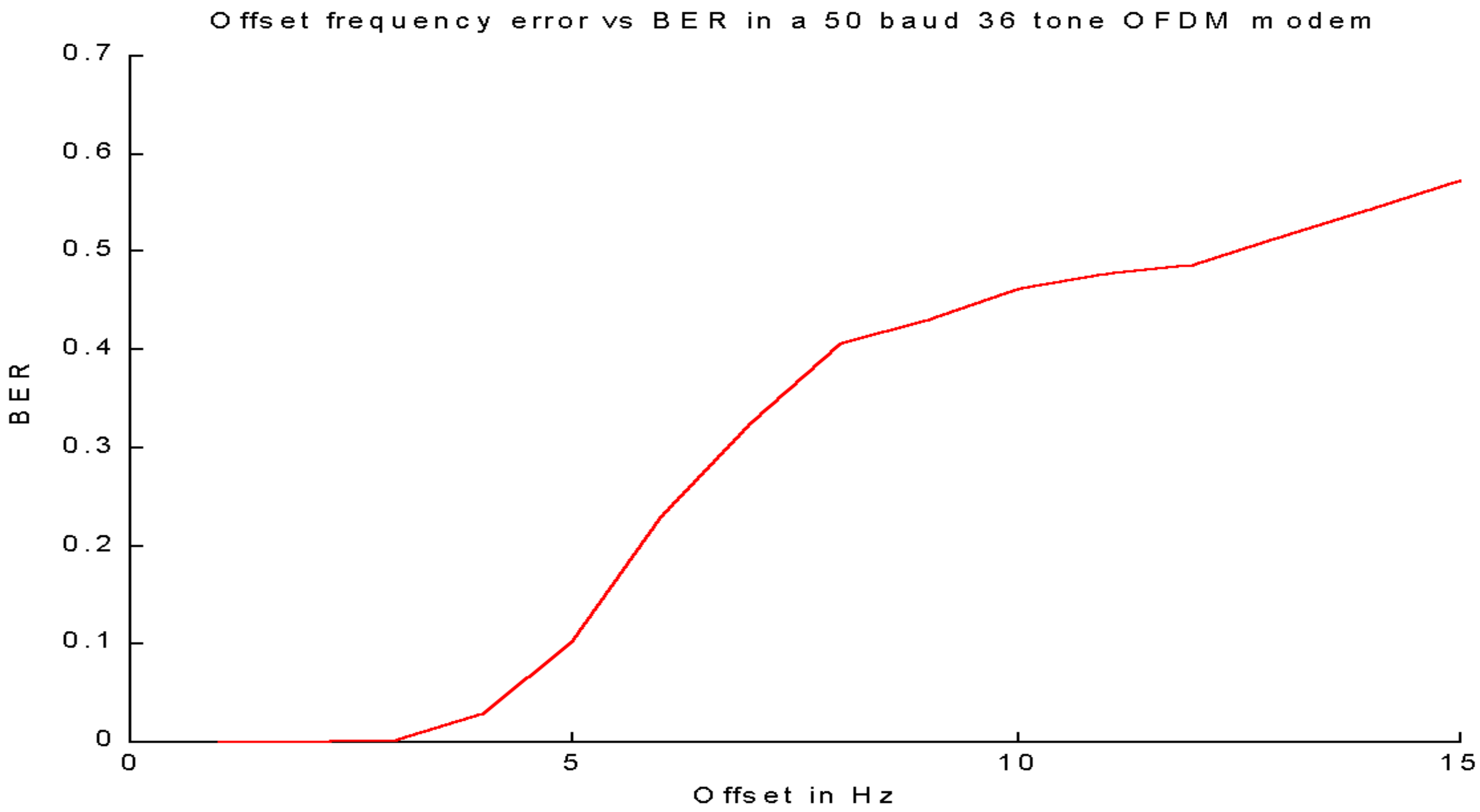
Frequency error from Preamble



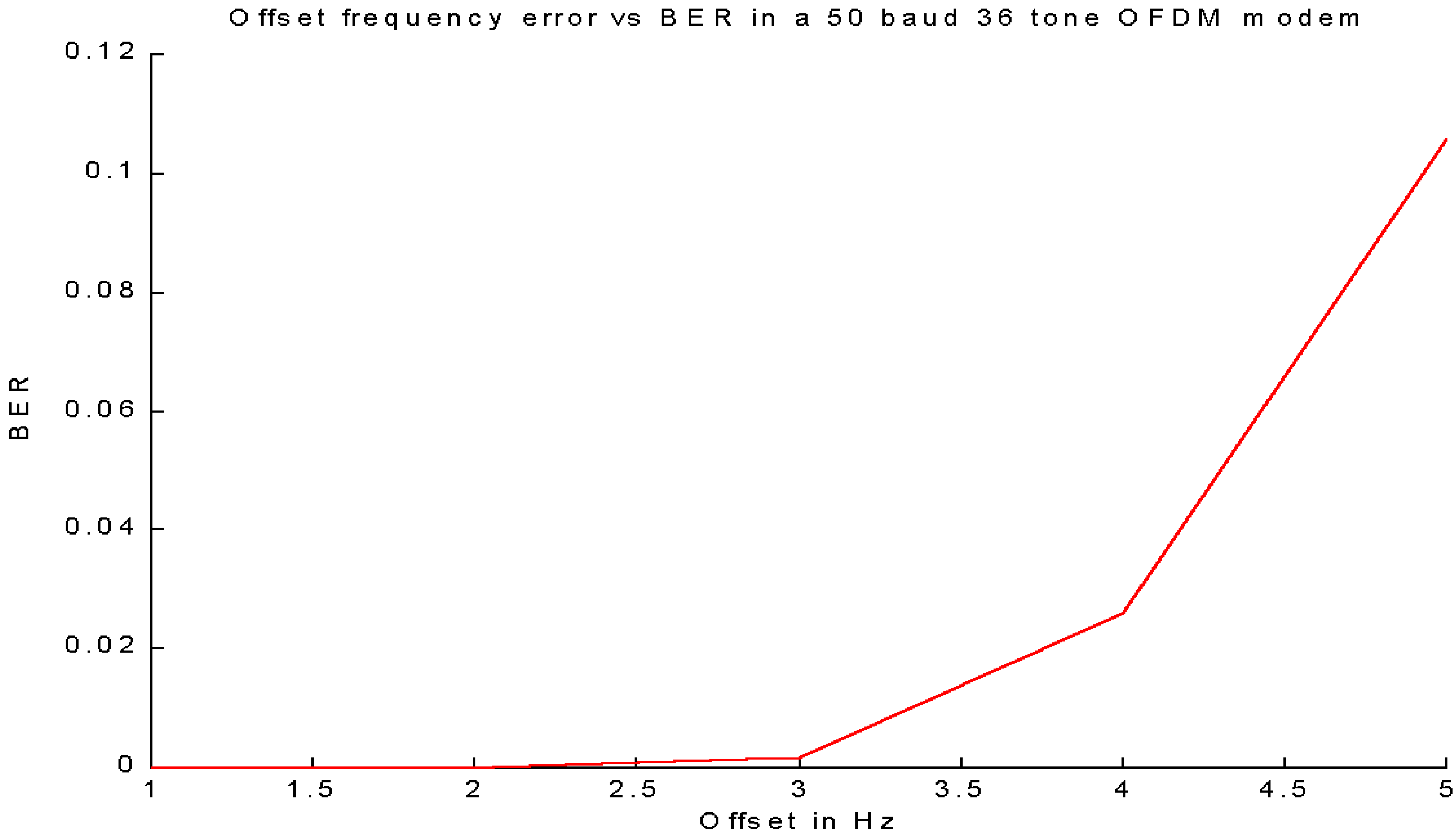
frequency error calculated from FFT bin spillover.

Ratio of preamble / non preamble tone magintudes indicates presence of the preamble sequence.
Correction not done when preamble absent.
SOM indicates start of voice data and end of preamble.

Effects of Frequency Misalignment



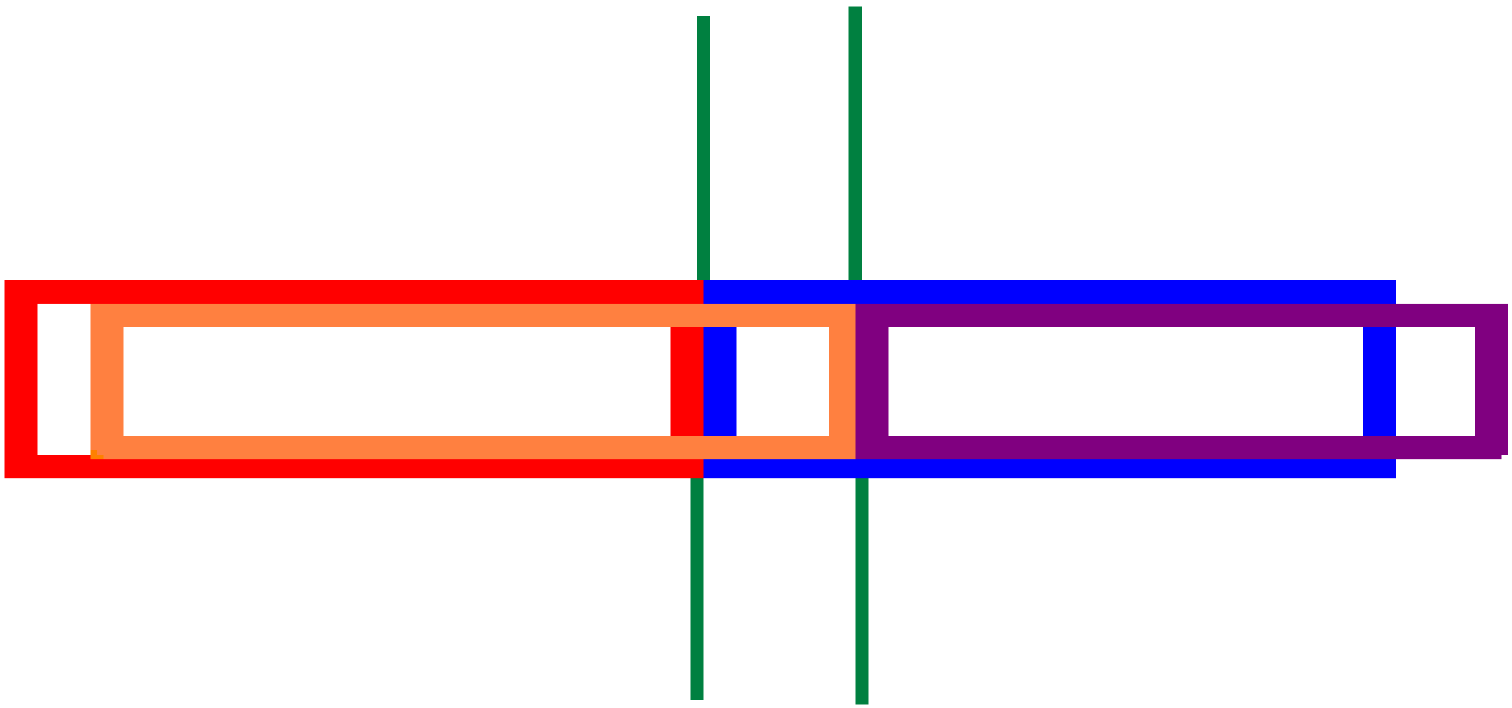
Effects of Frequency misalignment



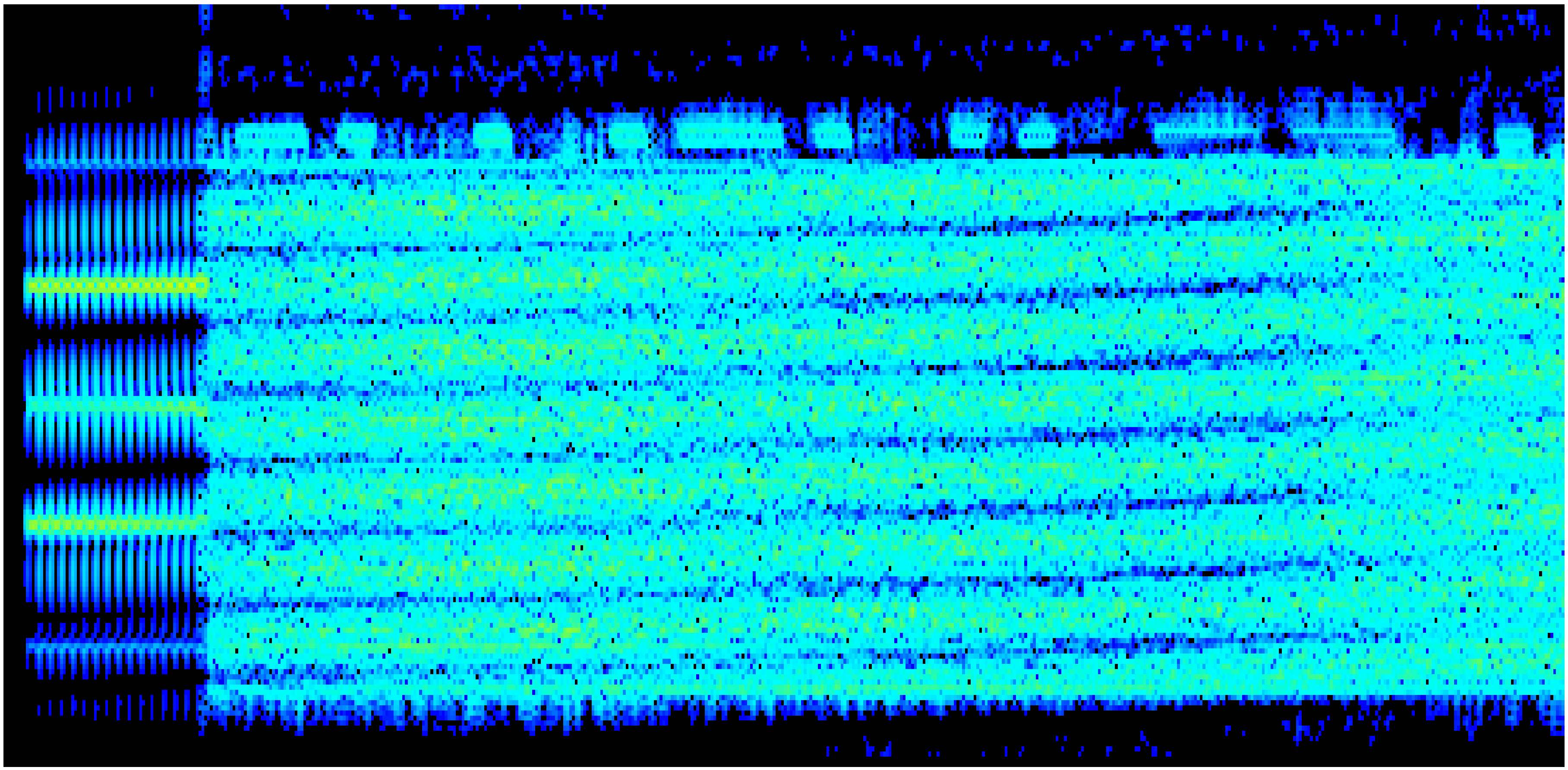
Effects of Multipath

- Inter Symbol Interference
  - Guard Period
- Selective fading
  - FEC

Guard Period



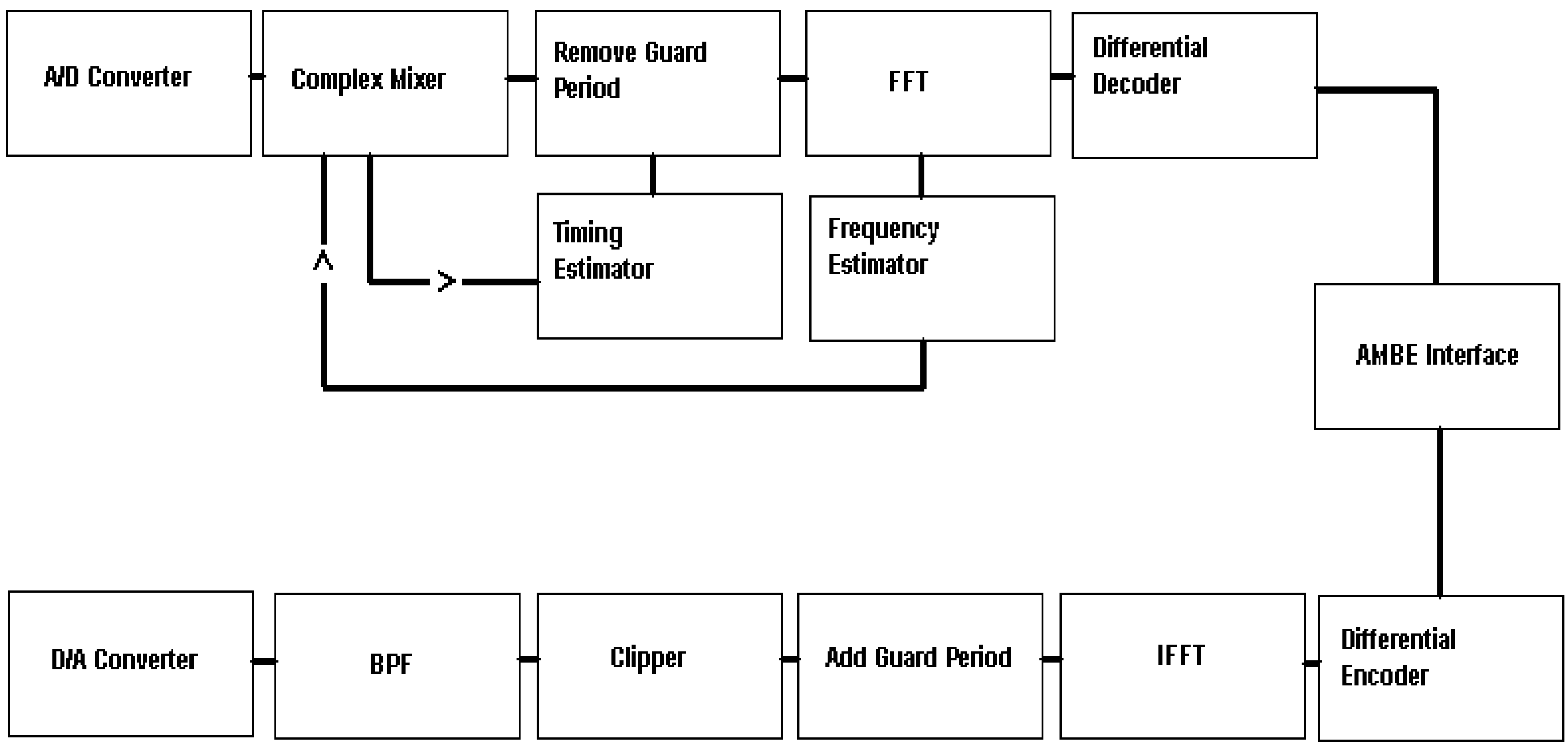
Selective Fading



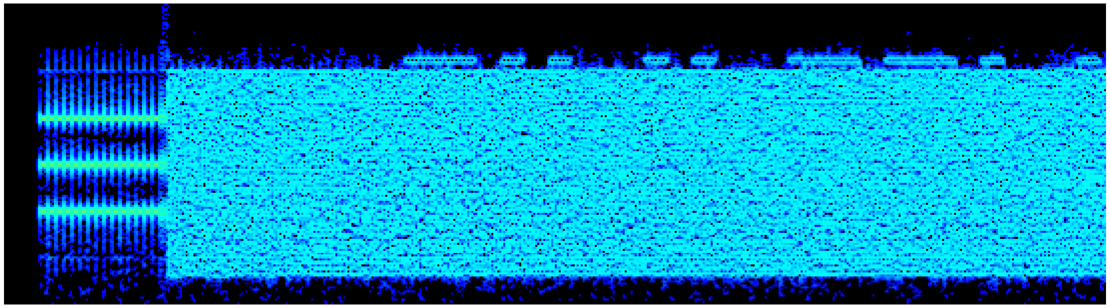
PMR Problem

- High peak to mean ratio in parallel tone modems.
- An Impulse in the time domain equates to a flat response in the frequency domain.
- Addition of multiple tones produces a sharp pulse in the time domain.
- Clipping used to overcome this.

36 Tone Modem



20 dB S/N Gaussian Channel

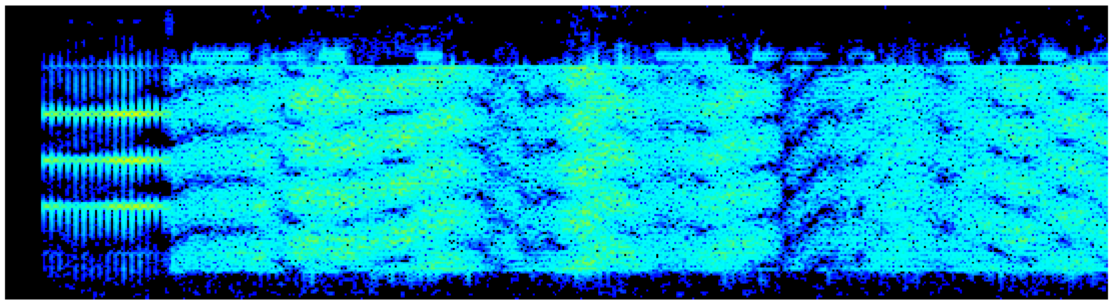


- Modem Sound
- Vocoder Output

ITU-R Channels

- Poor - 2ms multipath 1 Hz spread
- Good - 0.1ms multipath 0.5Hz spread
- Channel simulation done using Johan’s KC7WW channel simulator. See 1999 DCC conference notes.

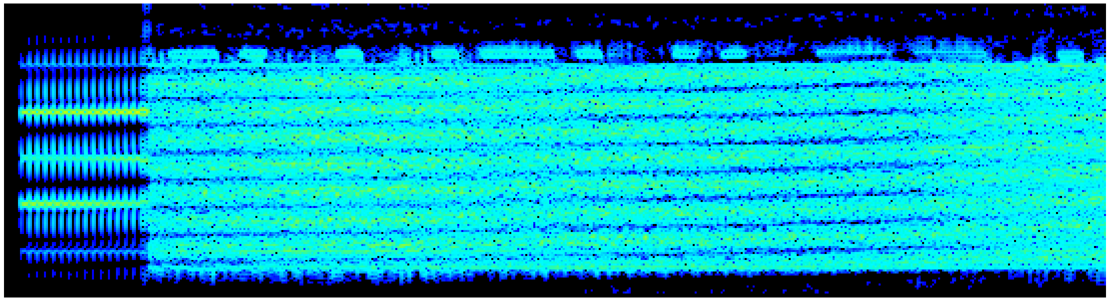
20 dB S/N ITU-R Poor



Modem Sound

Vocoder Output

20 dB S/N ITU-R Good



Modem Sound

Vocoder Output

Various other channels

10 dB Gaussian

10 dB Good

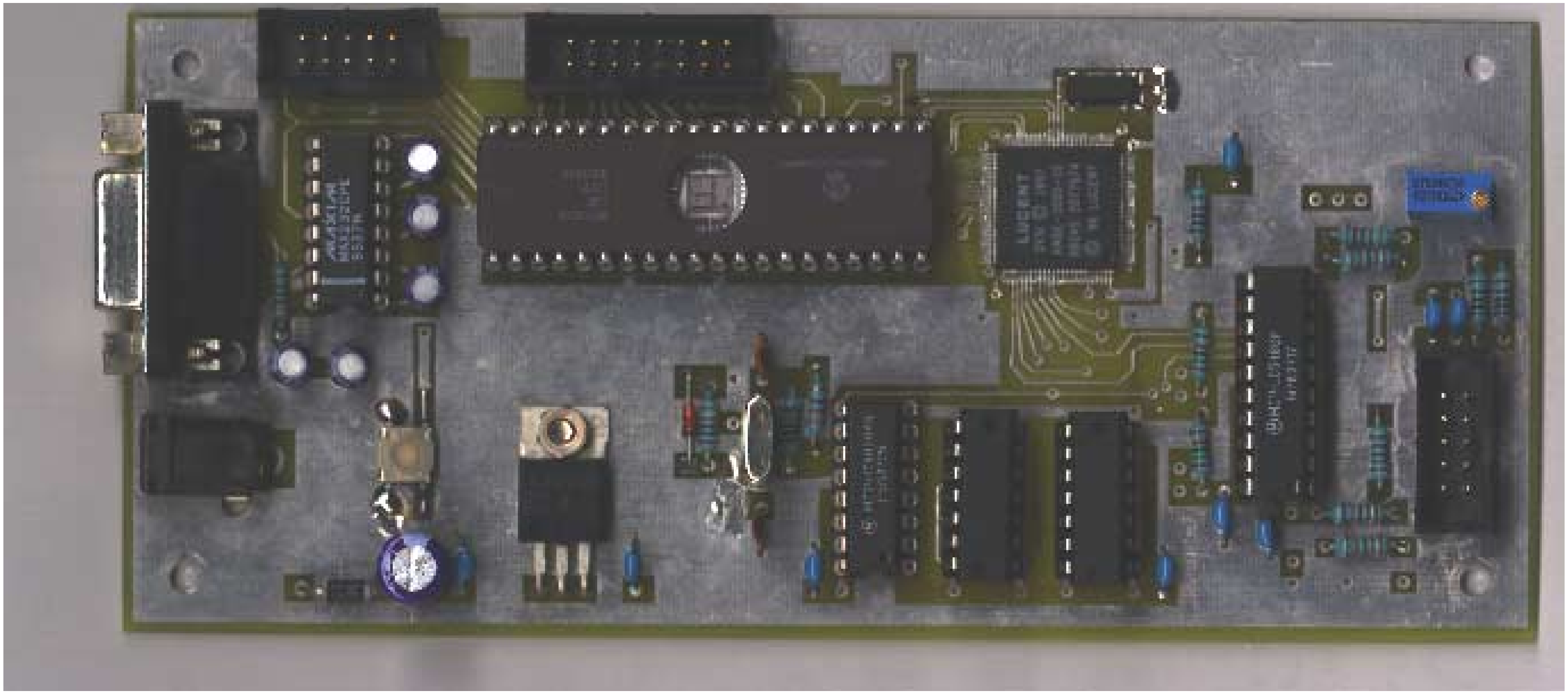
10 dB Poor

5 dB Gaussian

5 dB Poor

0 dB Gaussian

Vocoder board



Future Research

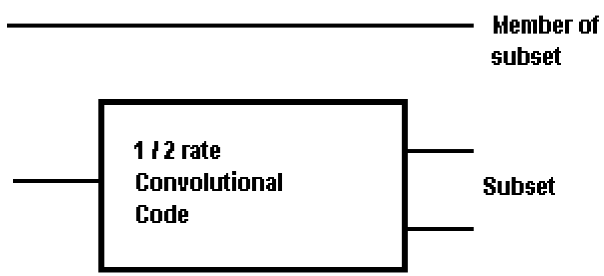
New Preamble

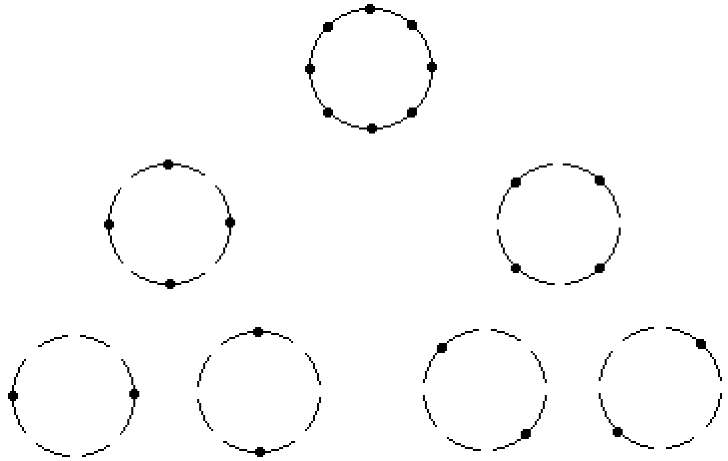
- Use of modulated PN sequence
  - Allows IF notch filters
  - Accurate frequency error estimate

Better FEC

- Trellis Code Modulation with Full Tail Biting.
  - FEC matched to transmitted symbols.
  - Better performance for given bandwidth.
- Disadvantages
  - More Complex
  - More sensitive to frequency errors.

Simple TCM





Constellation Partitioning

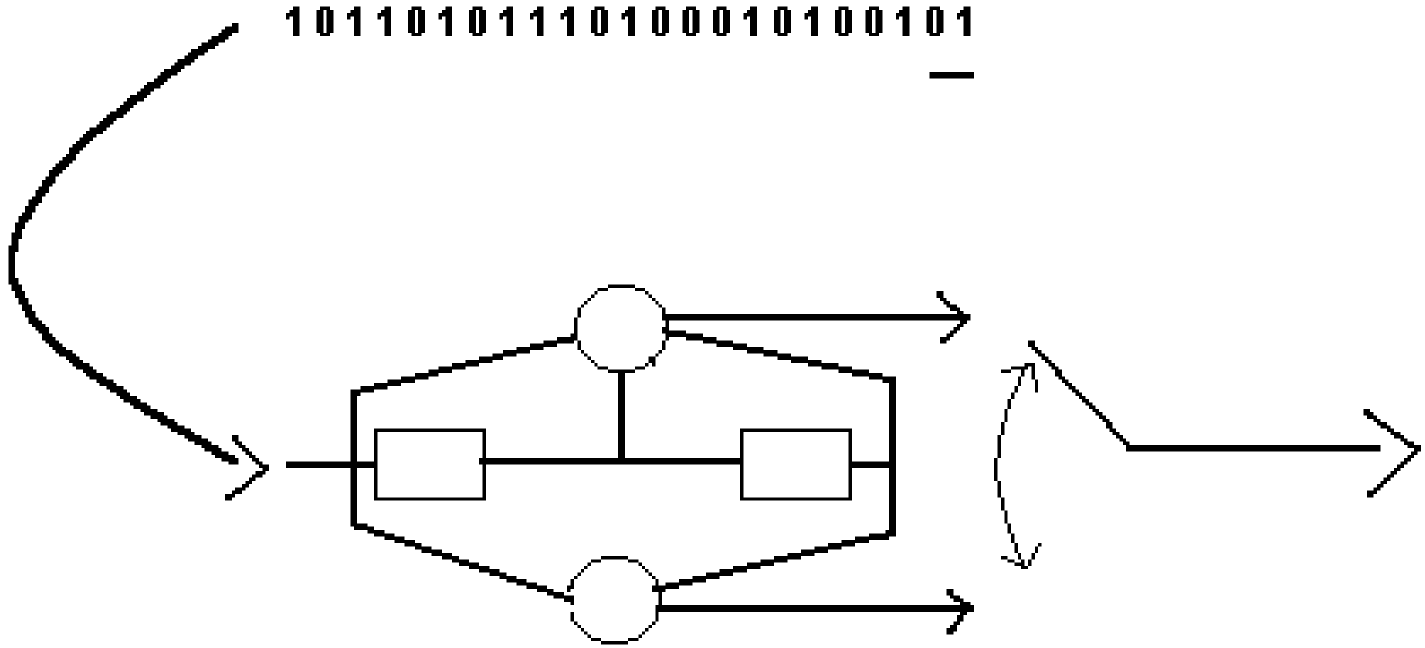
Coding Gain of Ungerboeck 8-PSK Codes, WRT Uncoded 4-PSK

Number of states	4	8	16	32	64	128	256	512
Coding Gain (dB)	3	3.6	4.1	4.6	4.8	5	5.4	5.7

Full Tail Biting

- Normal Convolutional code starts and ends in state zero, when used as a block code.
- Overhead of flush 0's
- Tail biting codes only have to start and end in the same state.
- Start in end state, (load shift register with final bits). No flush bits!

Full Tail Biting Transmit



Re-inserted preambles

- Insertion of Preambles during Voice inactivity periods.
  - Allows late entry
  - Can be used to mark data/voice sequences.

Diversity Reception

- Development of Dual Channel modem
- Polarisation Diversity
- Active Loop Antennas

End of Part 1

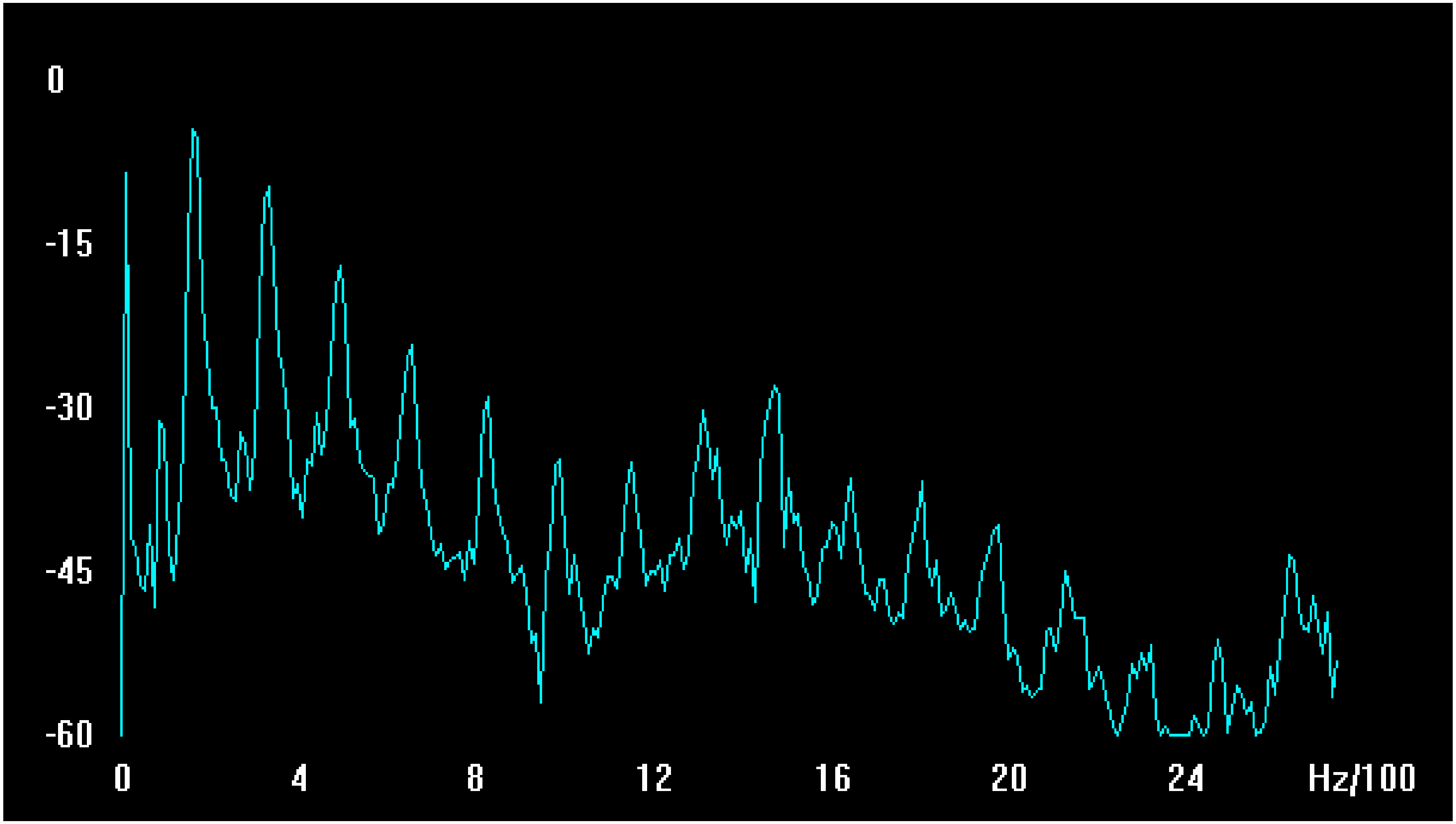
AMBE

Advanced Multiband Excitation

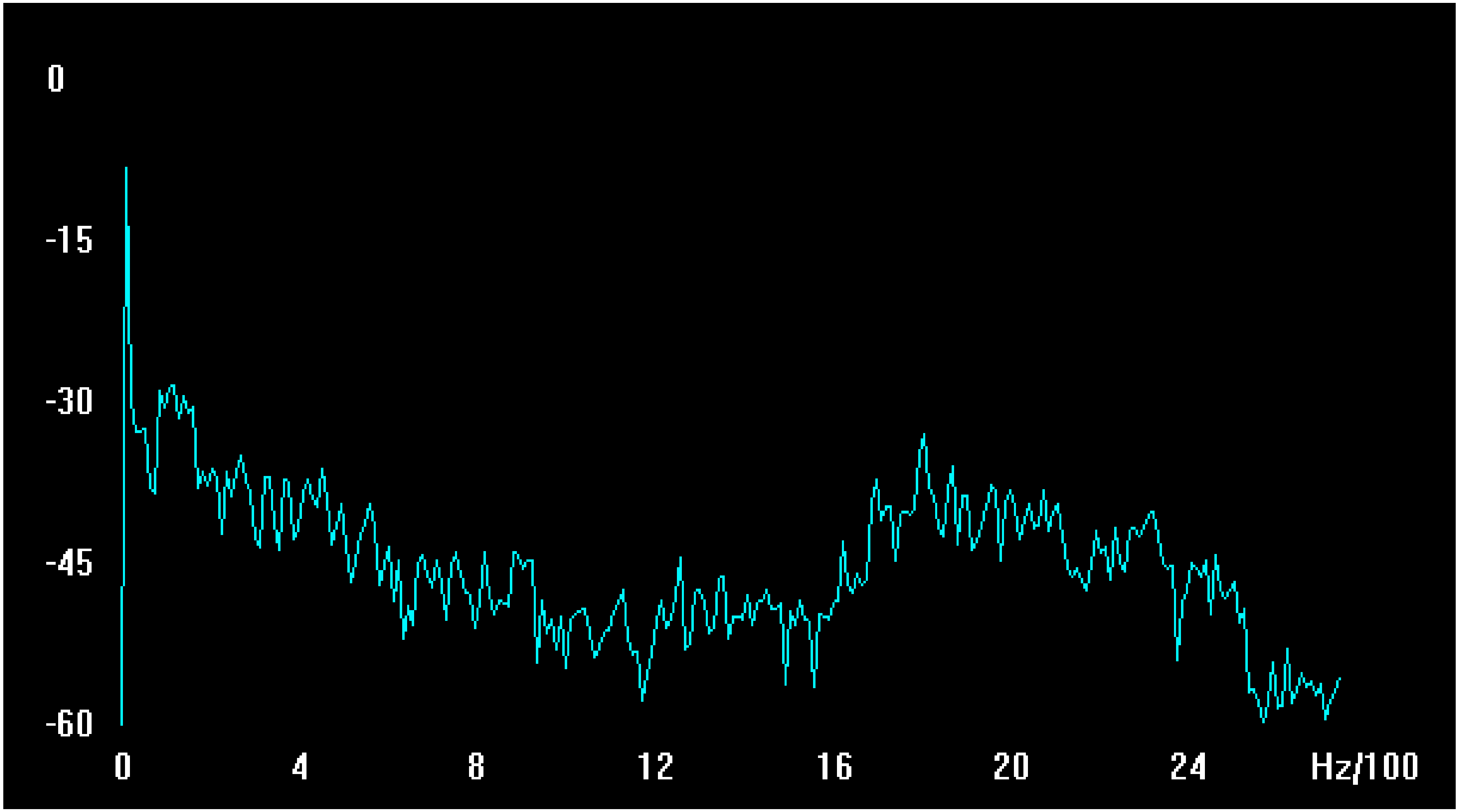
Speech Classification

- Voiced Speech
- Unvoiced Speech
- Mixture of Voiced and unvoiced
- Silence

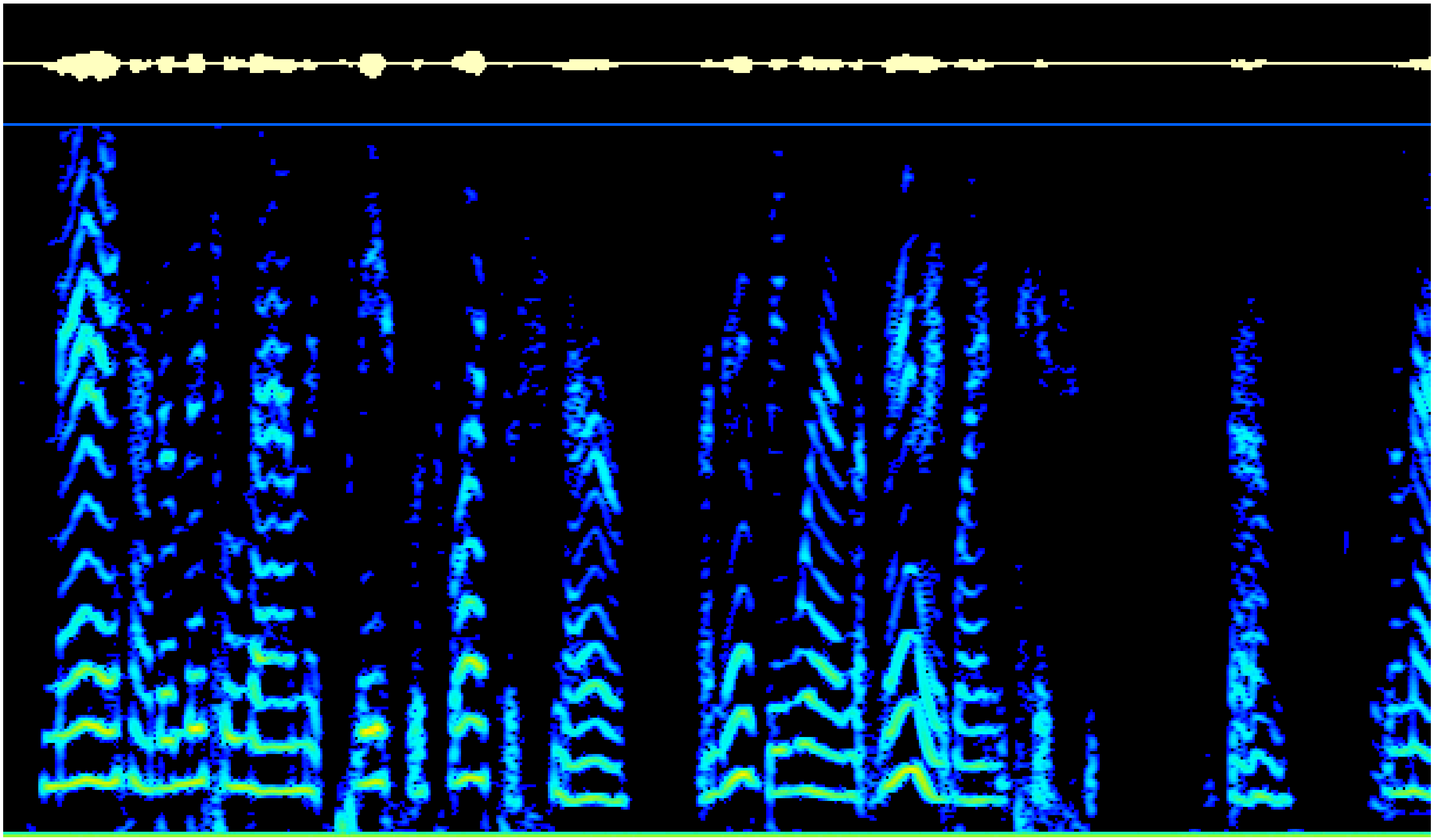
Voiced Speech



Unvoiced Speech



Speech Spectrum



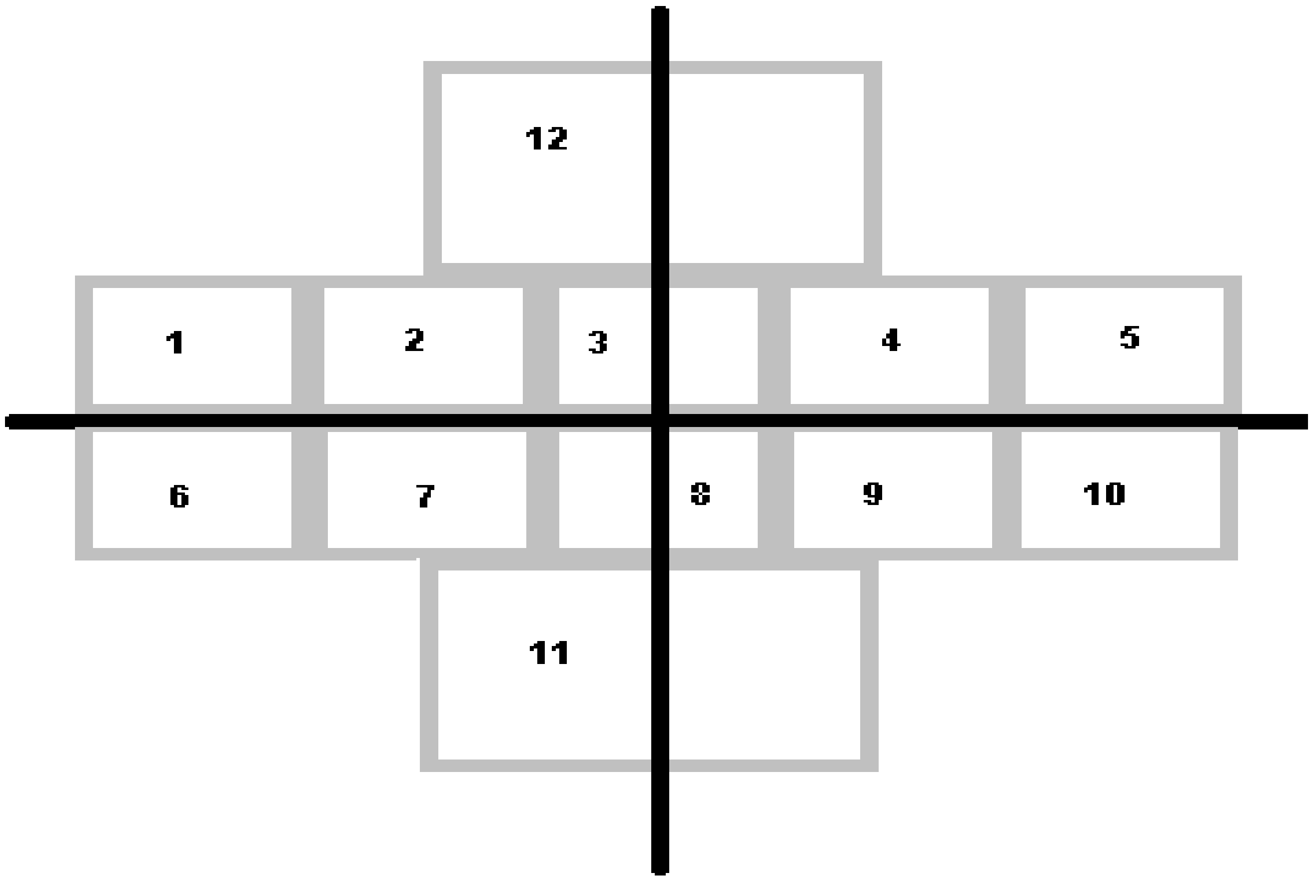
Find pitch frequency

Split pitch harmonics into frequency bands

Make Voiced / Unvoiced decisions on each band

Calculate Band Magnitudes

Vector Quantize



Add FEC

Transmit!

Receive!

Remove errors using FEC

Decode Vectors

Remove errors

Produce voiced / unvoiced spectrum using FFT, apply band magnitudes.

Spectrum may look nothing like original.

G4GUO Vocoder

- LPC 10 based
- Pitch detection uses inverse filtering followed by autocorrelation and median filtering.
- Filter coefficients encoded as Line Spectral Frequencies.
- Scaler quantized (at present)

The End

Thank you !

Any Questions ?