Decoding of Alternating Codes using Fast Fourier Transforms

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- Alternating codes
  - Powerful and robust
- Decoding
  - Classical
  - FFTs
- Implementations
  - Wide band (plasma line)
  - Narrow band (multi region)
- Speed improvements
- Summary

Alternating codes

- Used in all EISCAT Common Programs
- Powerful
  - Side lobe free
  - Same code for all altitudes
    - All transmitter power used at all altitudes
- Robust
  - Background removed in the decoding process
    - Taken at target ranges
- Need stable target over the cycle time

Alternating codes

- Oversampling relative the bit length
  - Fractional lags
  - Reduces code cycle
  - Improved height resolution
    - Lower ranges
  - Wider frequency band
    - Higher ranges
  - Increased computations

Classical decoding

Make all lagged products

Keep different codes apart

Convolve lag profiles with decoding array

Sum codes together

All fractional lags kept apart

- Enables higher resolution than bit length

Decoding matrix

16 bit AC, Fractionality 3
Gating 3

FFT decoding (1)

- Gate samples according to the bit length
- Apply decoding window
  - Same as the code
- Do the transform
  - Zero padding
    - Code length ≤ Number points ≤ 2*Code length
- Sum power spectra
- Make inverse transforms
  - ACFs

Decoding matrix (FFT

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16 bit AC, Fractionality 3

FFT decoding (2)

- Divide samples into bit lengths
- Make transforms
  - 2*Bit length
- Sum power spectra depending on code
- Sum all codes + number of bit ranges
- Make inverse transform
  - ACF
- Subtract the short ACF from the long ACF
  - Contribution only from bit length ranges

Decoding matrix (FFT

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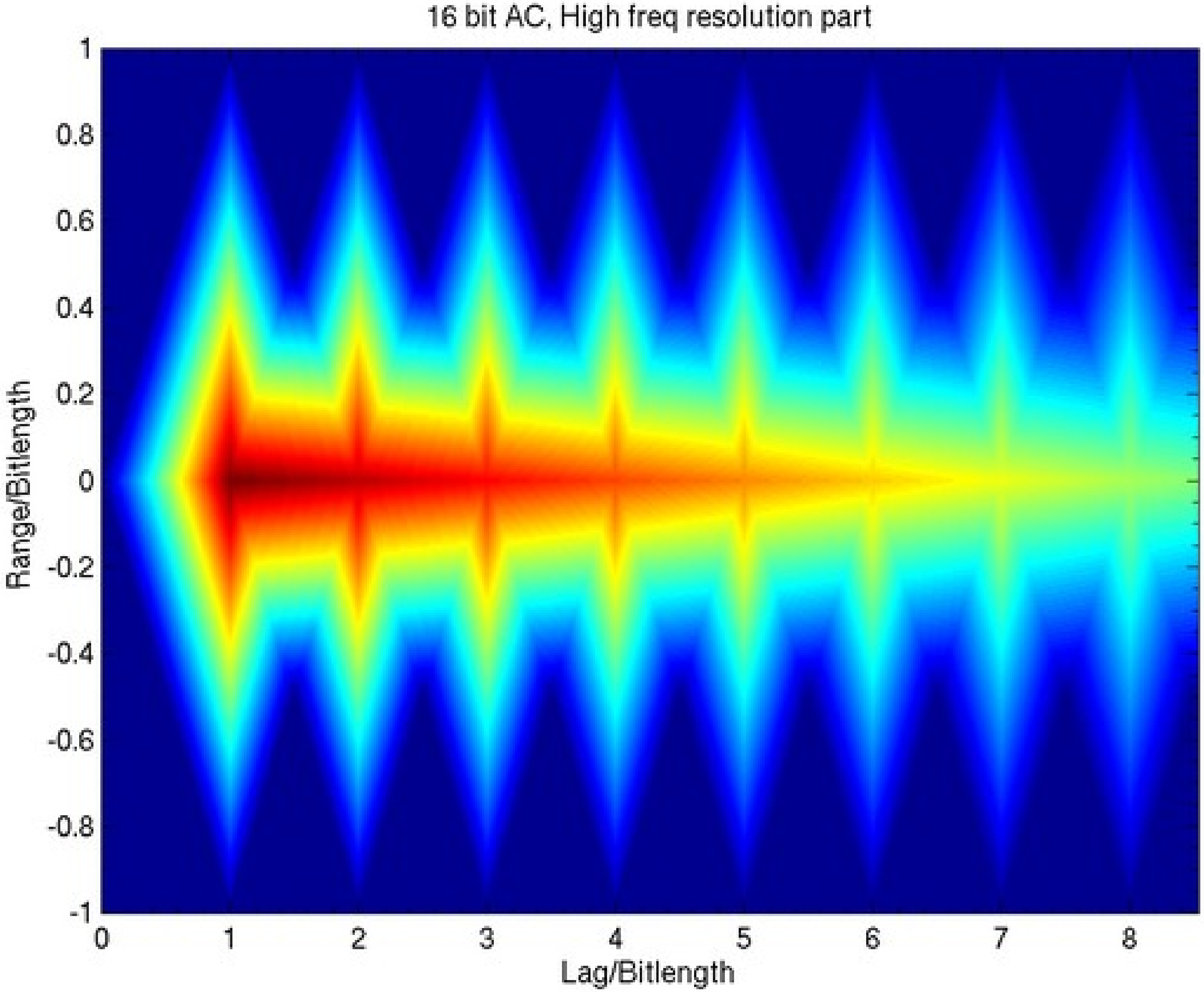
```

16 bit AC, Fractionality 3
Low res removed
64 point FFT

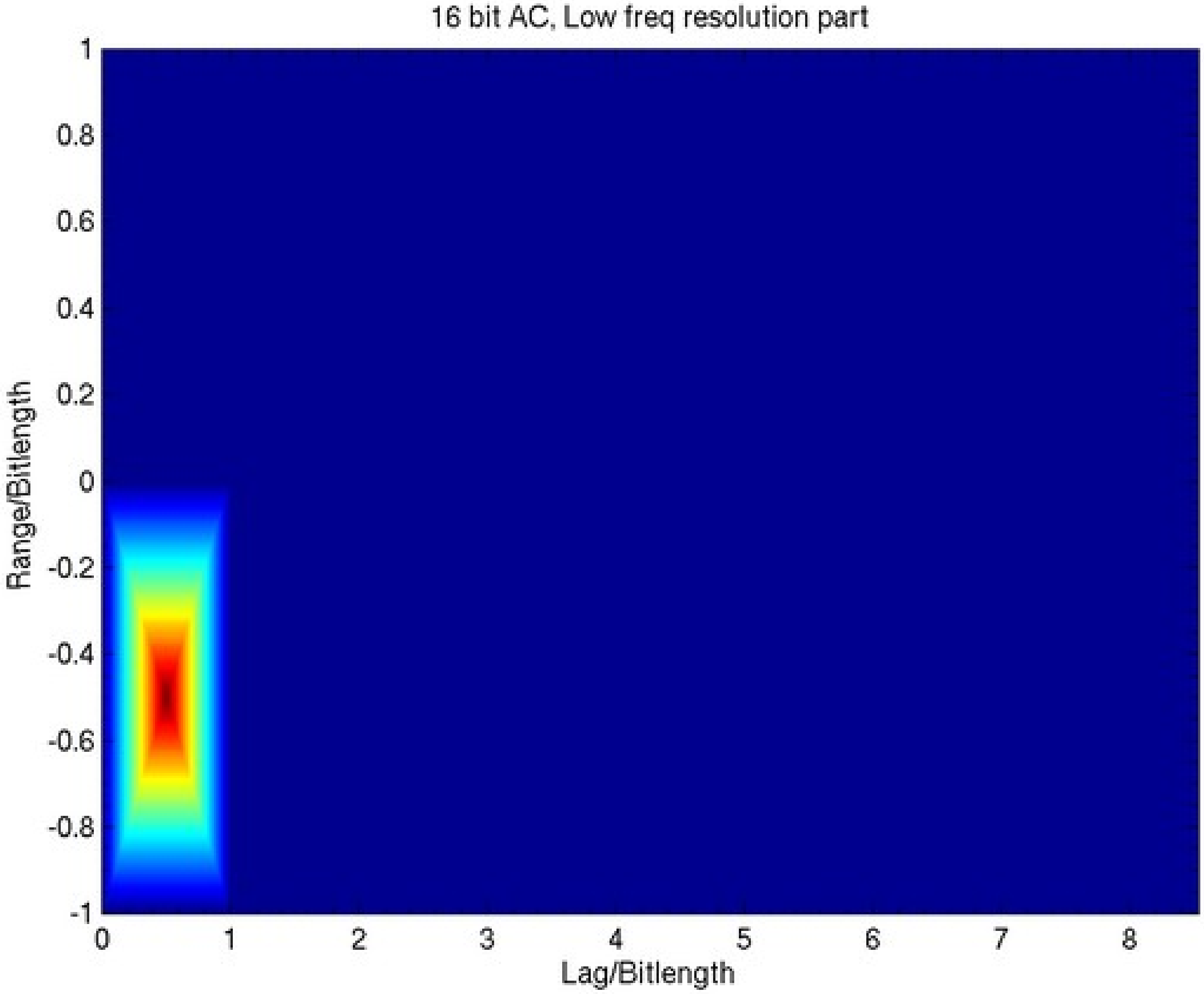
16 bit AC, Fractionality 240
Low res removed, 4096 point FFT



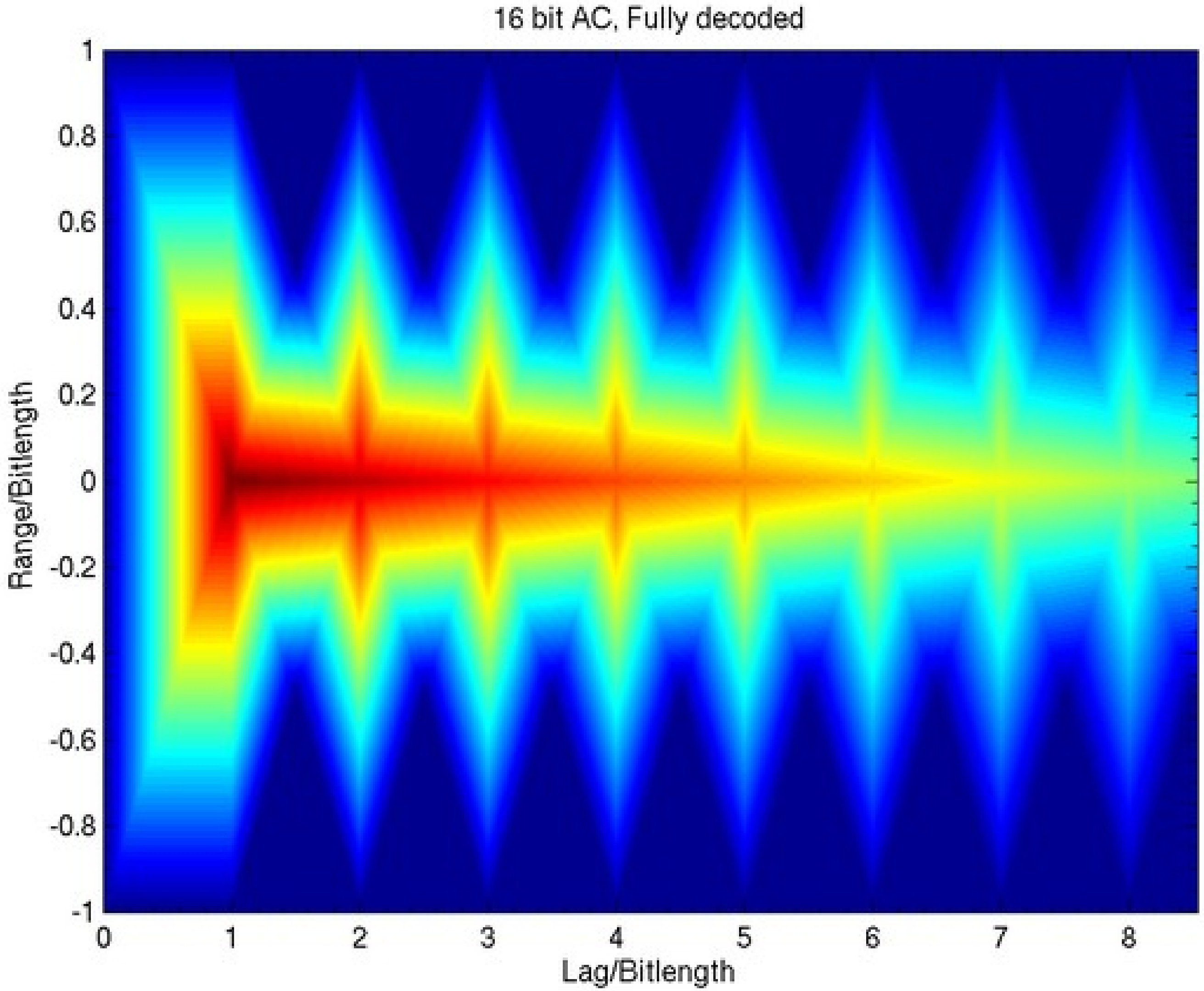
FFT decoding (3)

- Decode sorted short power spectra
  - Use (main) lag 1 decoding
  - Gives 1 gate more than the long ACF
- Make inverse transform
  - ACF
- May add the two short ACFs to the long ACF

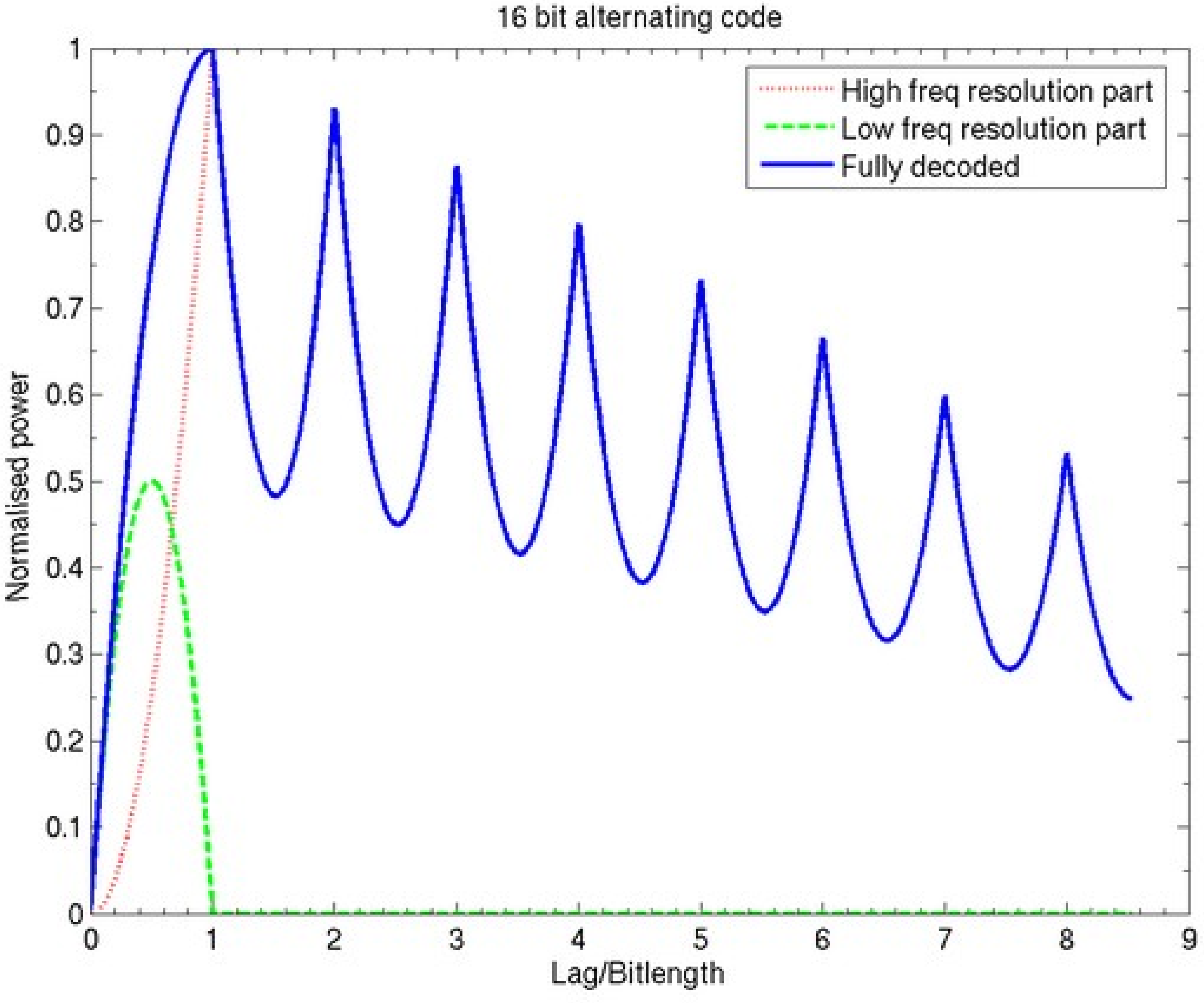
16 bit AC, Fractionality 240
Low res decoded, 480 point FFT



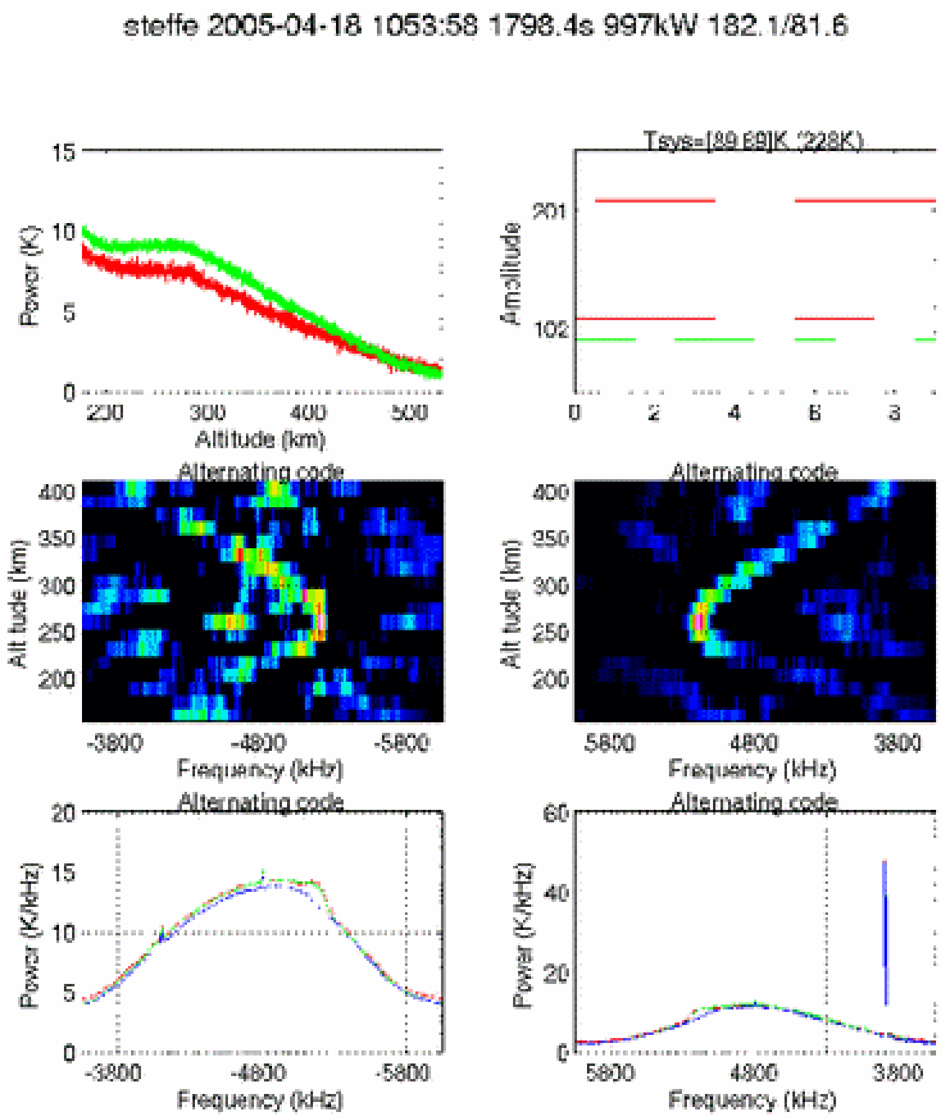
16 bit AC, Fractionality 240
Fully decoded, 4096+480 point FFT



16 bit AC, Fractionality 240
4096+480 point FFT

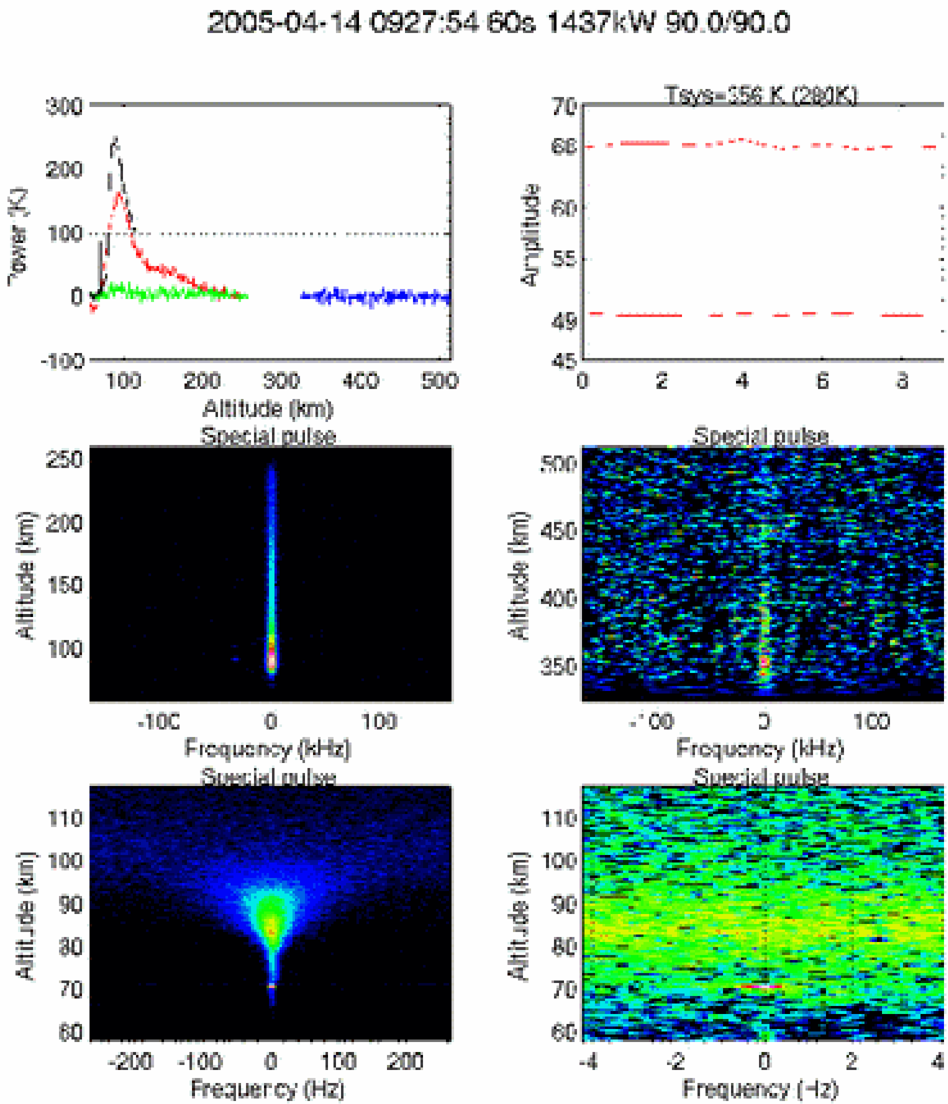


ESR Plasma line (steffe)



Pulse length=16*96 μs
Sampling interval=0.4 μs
Fractionality=240
Freq span=±1.25 MHz
Freq resolution=610 Hz
Range resolution=15 km
Number gates=18

VHF Ion line (manda)



Pulse length=64*3 μs
Sampling interval=3 μs

FFT decoding
- Fractionality=1
- E-region
  - 128 pt FFT
  - 450 gates
- F-region
  - remote pulse
  - 128 pt FFT
  - 418 gates

FIR filtering
- D-region
  - 2048 pt FFT
  - 132 gates

Speed improvements

(Preliminary tests)

FFT (fftw) vs EISCAT lagprofiling

manda (64 lags) 4 times faster

steffe (2048 lags) 2500 times faster

? At about 30 lags the speeds are the same ?

Combining of methods

- Fractionality higher than 1
  - Low altitudes
    - Classic decoding
      - improved range resolution
  - Higher up
    - Range resolution given by bit length is acceptable
    - FFT decoding
      - improved calculation speed
      - may also use remote pulse

Conclusions

FFT decoding is faster for most normal experiments

A combination of methods is best

Improved speed

- extended ranges
- higher resolution
- comparison preliminar

Statistics

- equal for fractionality=1
- else probably also (need to be checked)