A new method for decoding phase codes

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Outline

- Recording the amplitude data
- Short introduction to lag profile inversion
- Comparison to alternating code decoding
- First results of a code pair experiment

Data recording

- The attenuated transmitter signals and ionospheric echoes are recorded in amplitude domain
- The digitizer is connected to the second IF stage of the radars
- Sampling frequency usually 1 MHz
- Raw samples saved in hard disk for later analysis

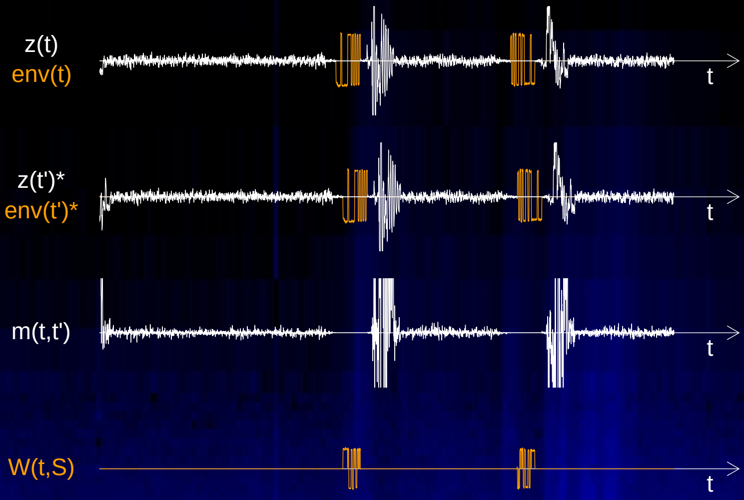
Lagged products and range ambiguity functions

- Transmission envelopes $env(t)$ and the echoes $z(t)$ in the same data stream
- A data vector contains one integration period of data
- Lagged products of the data vector and its complex conjugate
  - Ambiguous lagged products from the echo part

$$m_\tau(t) = z(t)\overline{z(t-\tau)}$$

  - Range ambiguity functions from the transmission part

$$W_\tau(t,S) = env(t-S)\overline{env(t-\tau-S)}$$



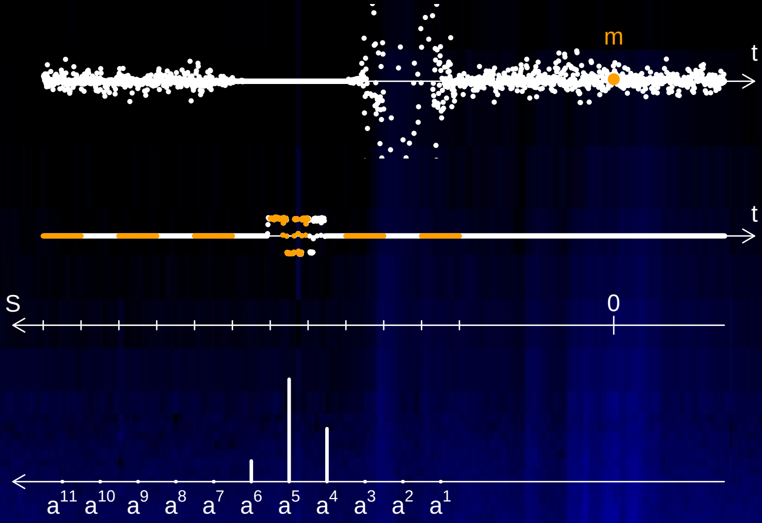
z(t)
env(t)
t
z(t')*
env(t')*
t
m(t,t')
t
W(t,S)
t

Lag profile inversion

- The radar beam is divided into range gates
- x_τ^k is the unknown lag value in gate k
- Each $m_\tau(t)$ is a weighted sum of the unknowns x_τ^k

$$m_\tau(t) = \sum_{k=1}^{N} a_\tau^k(t) x_\tau^k + \varepsilon_\tau(t),$$

- Coefficient $a_\tau^k(t)$ is the integral of $W_\tau(t, S)$ over range gate k



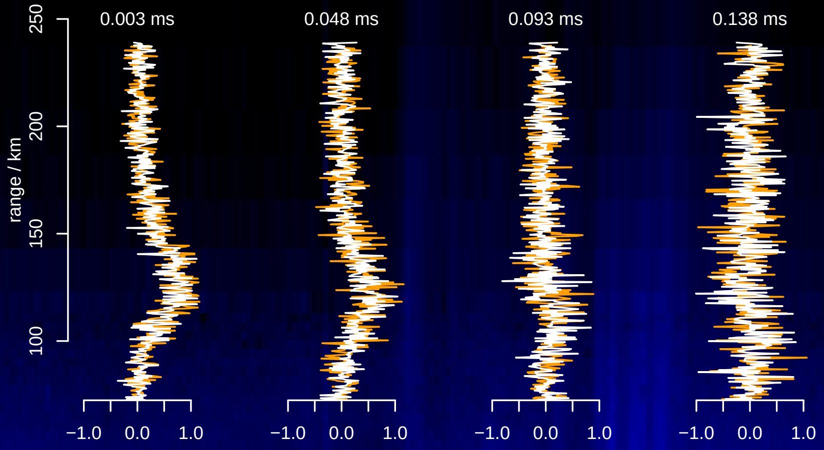
$$m = a^1x^1 + a^2x^2 + \ldots + a^Nx^N$$

- All lagged products from one integration period are collected in a large set of linear equations

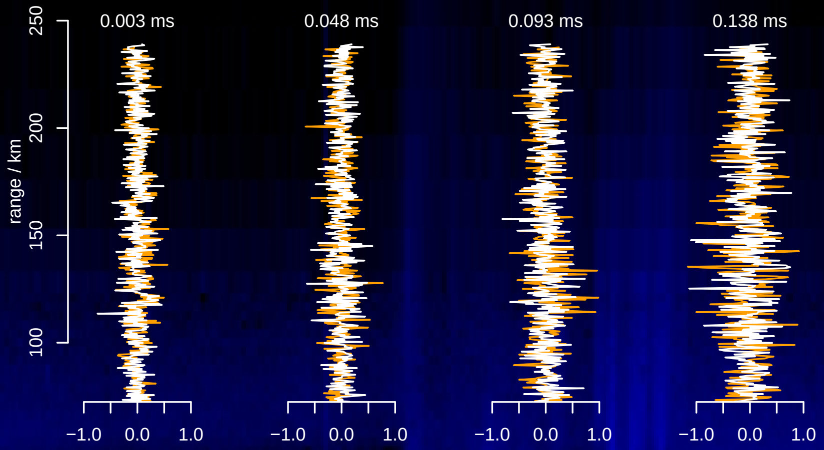
$$\mathbf{m}_\tau = \mathbf{A}_\tau \mathbf{x}_\tau + \varepsilon_\tau$$

- The most probable lag profile and its variance can be solved with FLIPS
- The same procedure for all lag profiles $\Rightarrow$ ACF
- Parameter fit to the ACF using iterative methods

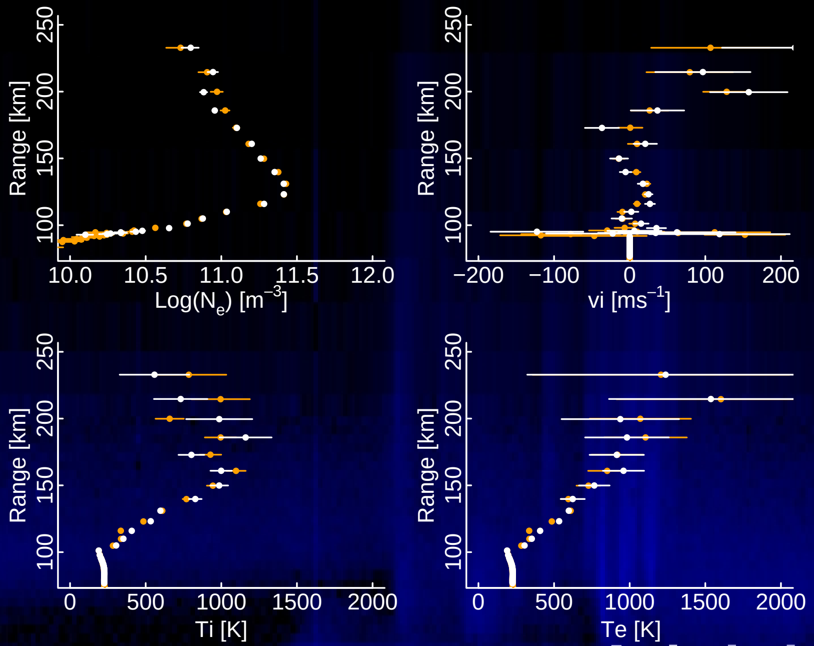
MANDA, Nov. 25th 2006, 22:05 UT, 6s integration time, real part



MANDA, Nov. 25th 2006, 22:05 UT, 6s integration time, imaginary part

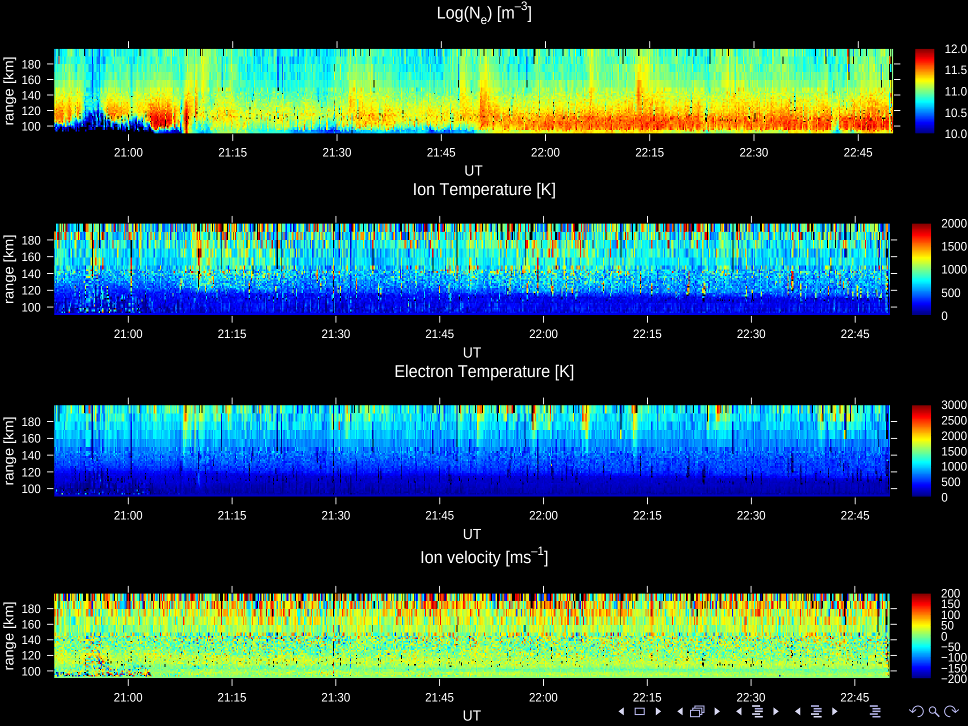


MANDA, Nov. 25th 2006, 22:05 UT, 1 min integration time



Binary code pair experiment

- Nov. 26th 2006
- 21-bit binary code pair
- Bit length 10 μs
- In this example:
  - Full lags 1,2,...,17,18
  - In each full lag $\pm$ 2 μs fractional lags included
  - Time resolution 10 seconds
  - Range resolution 2 km



Log(Ne) [m−3]
Ion Temperature [K]
Electron Temperature [K]
Ion velocity [ms−1]
range [km]
UT
21:00
21:15
21:30
21:45
22:00
22:15
22:30
22:45

Summary

- Lag profile inversion was introduced as an analysis method for any phase and / or amplitude modulated ISR experiment
- Lag profile inversion was successfully used for analysing alternating code experiment
- A new experiment with a phase code pair was designed
- Amplitude data from the new experiment was successfully analysed with lag profile inversion