EE123
Digital Signal Processing

Lecture 24
Lab 4
Minimum Phase

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* Beautiful handwritten figures by Prof. Murat Arcak

Project

- **Select a project by Friday, April 1st**
  - Can be in teams
  - Submit 2 paragraphs project proposal (More info later)
  - Happy to discuss!
- There will be Weekly 5-10min project followups
  - Period I 04/15, Period II 04/22, Period III 04/29
- Projects are Due during deadweek.
- **Project Deliverables**
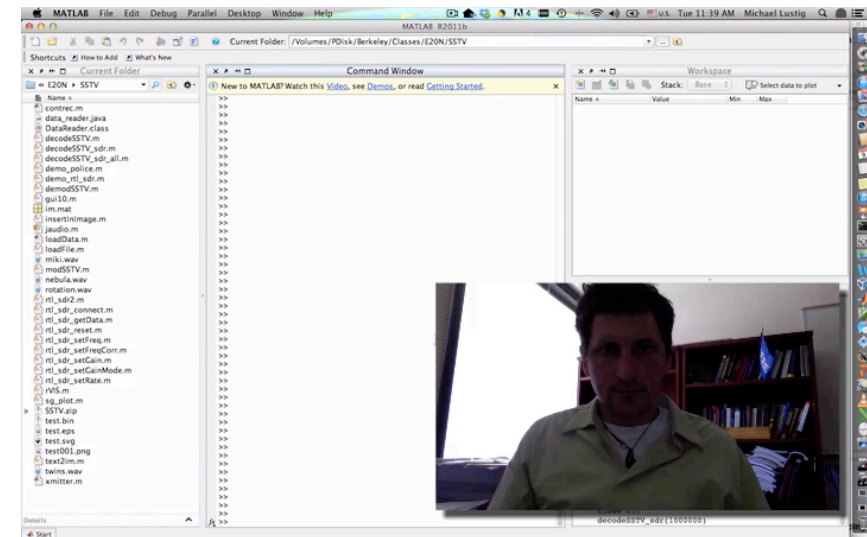 - Software
  - Demo
  - A few slides / Poster

Competition Project

- ## Image communication
  - We will give you and image
  - You will need to transmit it with the best quallity over a limited amount of time (1min)
  - Evaluation is based on PICSNR and visual quality score

- ## You can use ANY method you write yourself
  - Compression
  - Filtering, image recovery....
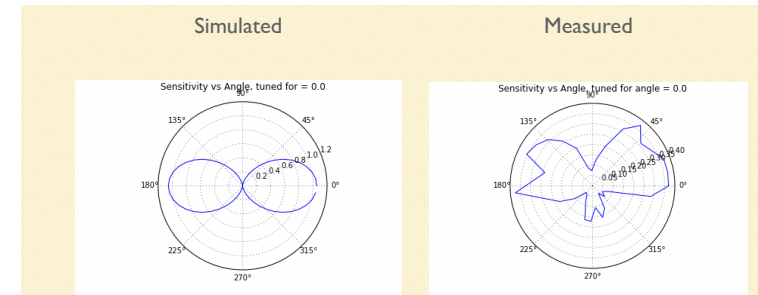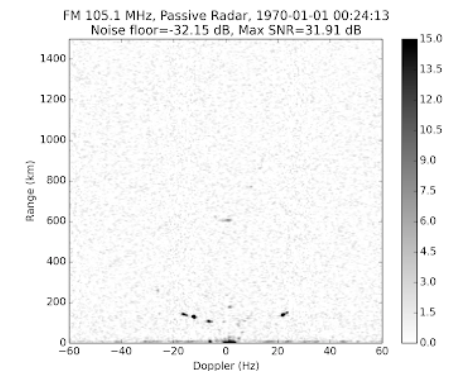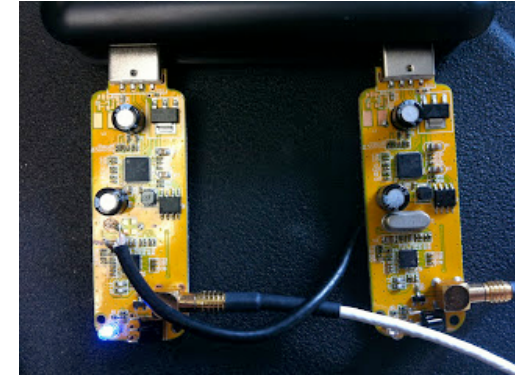 - Modulation (digital or analog), detection, ...

Competition project

- ## Evaluation based on

  - – Comparison to a baseline implementation with packet APRS -- slow and low res

  - – Scope

  - – Creativity

  - – Presentation

- ## Winners gets a prize: radio

Other projects

- If you REALLY want to do something else...

- Phased array passive radar

  – http://kaira.sgo.fi/2013/09/passive-radar-with-16-dual-coherent.html

  – https://www.youtube.com/watch?v=6Wiv8Dwi-kA

- Electronically steerable antenna

  – (Gabe Buckmater EE123 2014)

FM 105.1 MHz, Passive Radar, 1970-01-01 00:24:13
Noise floor=-32.15 dB, Max SNR=31.91 dB

Simulated   Measured

Other projects

- ## Weak Signal communications with OOK and incoherent codes

  - Inspired by JT65

  - Used for telemetry low-rate

- ## http://physics.princeton.edu/pulsar/K1JT/JT65.pdf

```
1,0,0,1,1,0,0,0,1,1,1,1,1,1,0,1,0,1,0,0,0,1,0,1,1,0,0,1,0,0,
0,1,1,1,0,0,1,1,1,1,0,1,1,0,1,1,1,1,0,0,0,1,1,0,1,0,1,0,1,1,
0,0,1,1,0,1,0,1,0,1,0,0,1,0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,1,1,
0,1,0,0,1,0,1,1,0,1,0,1,0,1,0,0,1,1,0,0,1,0,0,1,0,0,0,0,1,1,
1,1,1,1,1,1
```
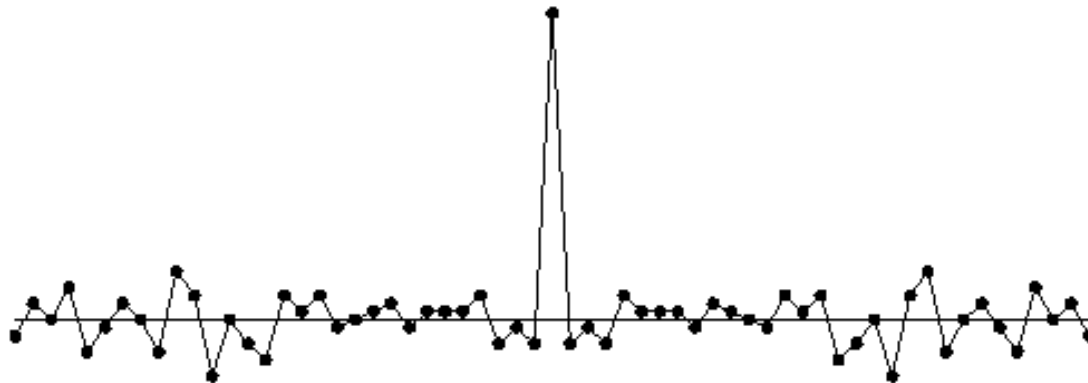
Fig. 3. – The pseudo-random sequence used in JT65 as a "synchronizing vector," and a graphical representation of its autocorrelation function. The isolated central correlation spike serves to synchronize time and frequency between transmitting and receiving stations
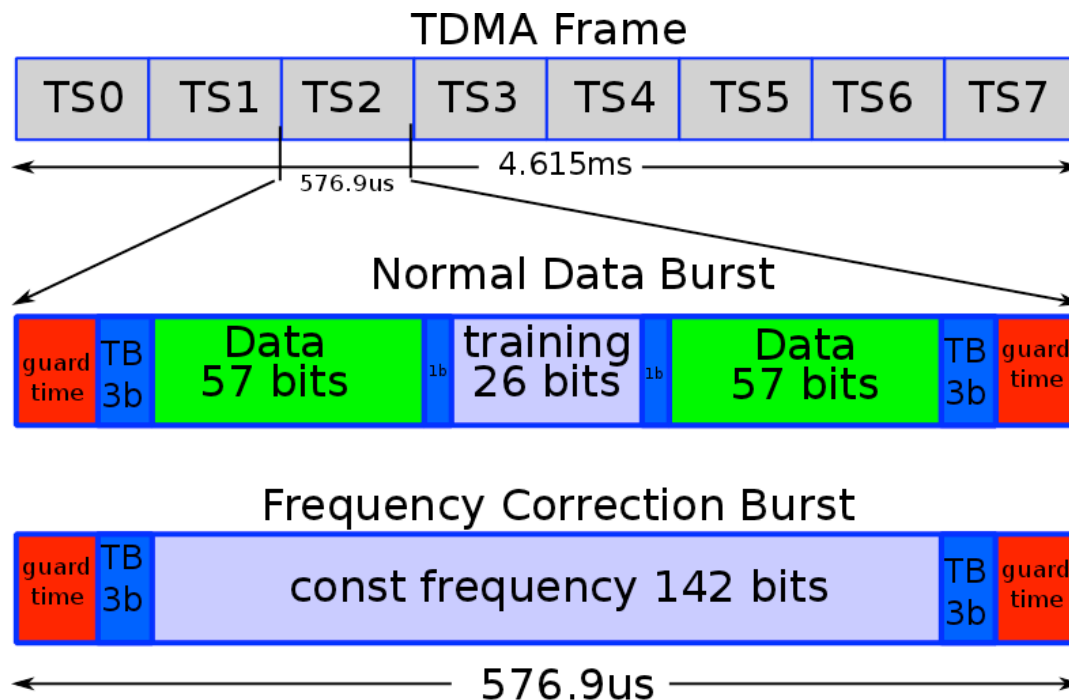
- SDR crystal oscillator often has offset

- Also drifts with temperature

- Cellphones do the same!

- GSM protocol has built in synchronizations

http://sdrformariners.blogspot.com/2013/12/cooling.html
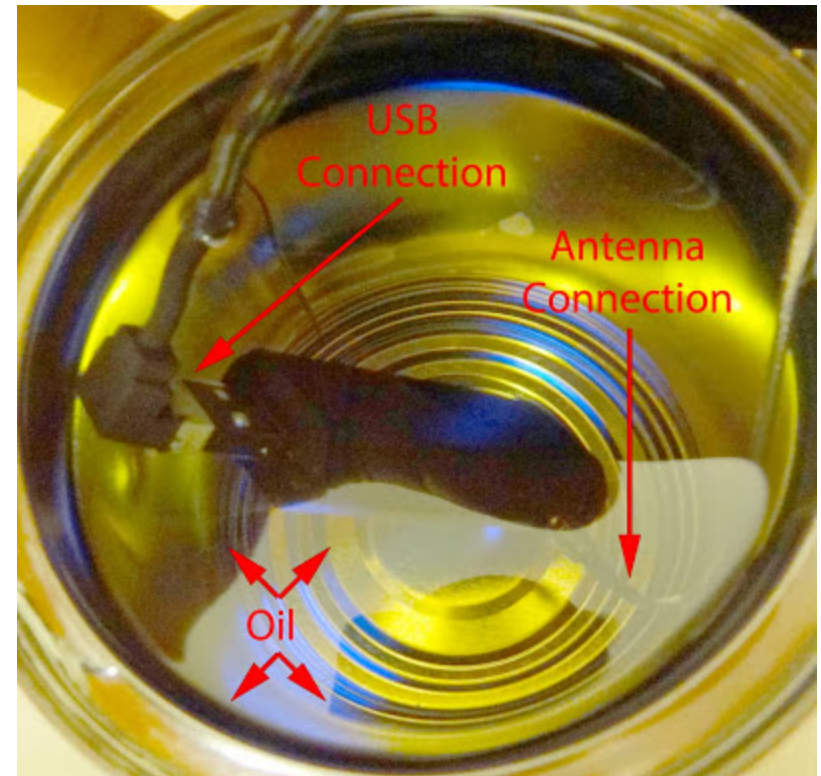
GSM-850

- ## Frequencies 200KHz channels
  - –Uplink 824-849
  - –Downlink 869-849
- ## TDMA: Time division multiple access

TDMA Frame
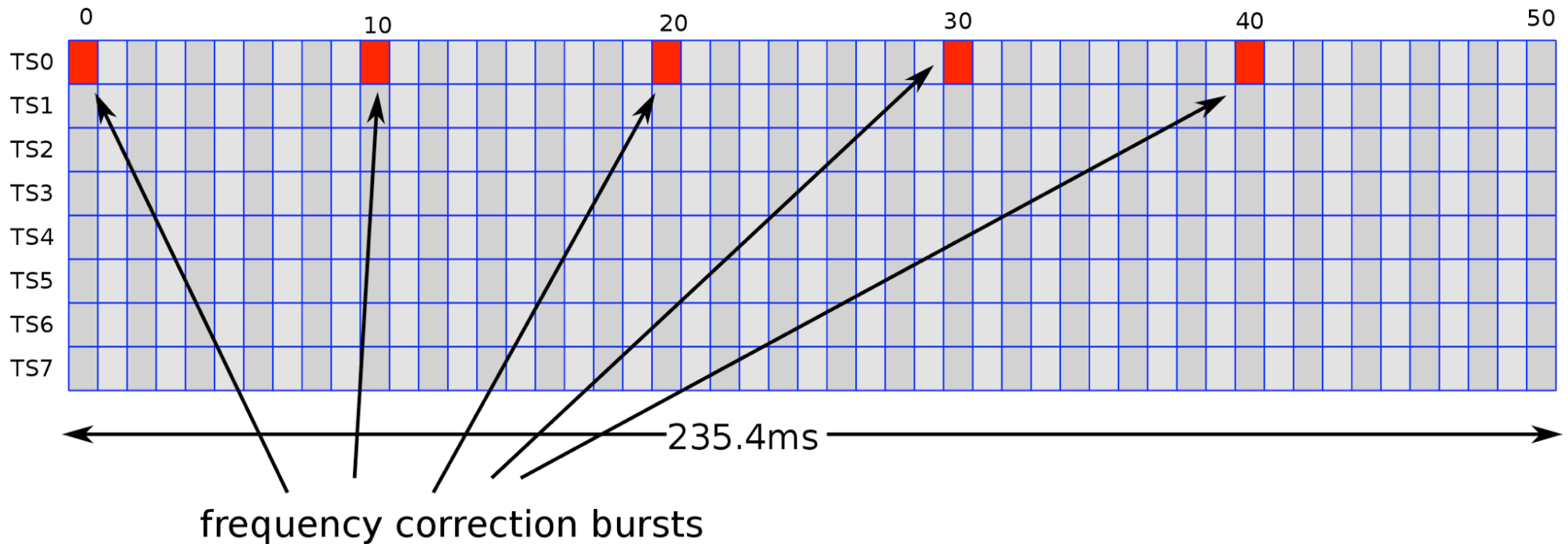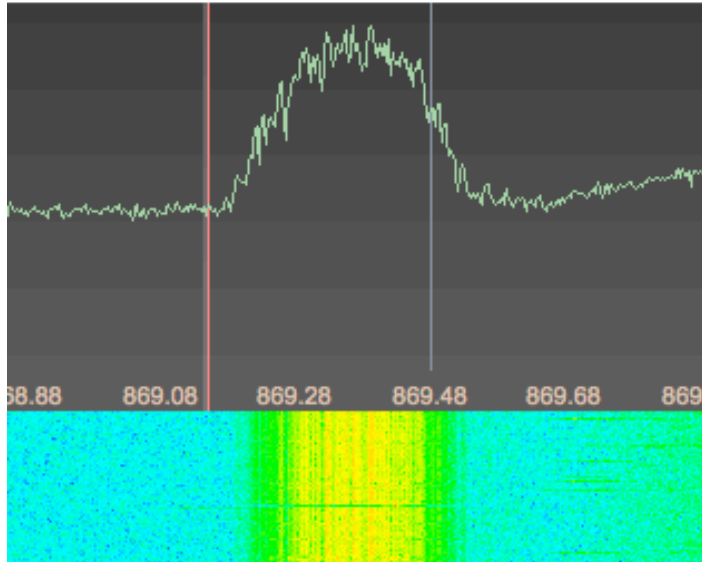
TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7

576.9us ◄————— 4.615ms —————►

Normal Data Burst

| guard time | TB 3b | Data 57 bits | 1b | training 26 bits | 1b | Data 57 bits | TB 3b | guard time |

Frequency Correction Burst

| guard time | TB 3b | const frequency 142 bits | TB 3b | guard time |

◄————— 576.9us —————►

GSM Frequency Correction Channel

- Pure frequency bursts @67.7083KHz

Control Channel Multi-Frame

frequency correction bursts

235.4ms

How to find GSM Base Stations

GSM

spread spectrum

average power spectrum of GSM

Magnitude GSM signal, showing TDMA frames
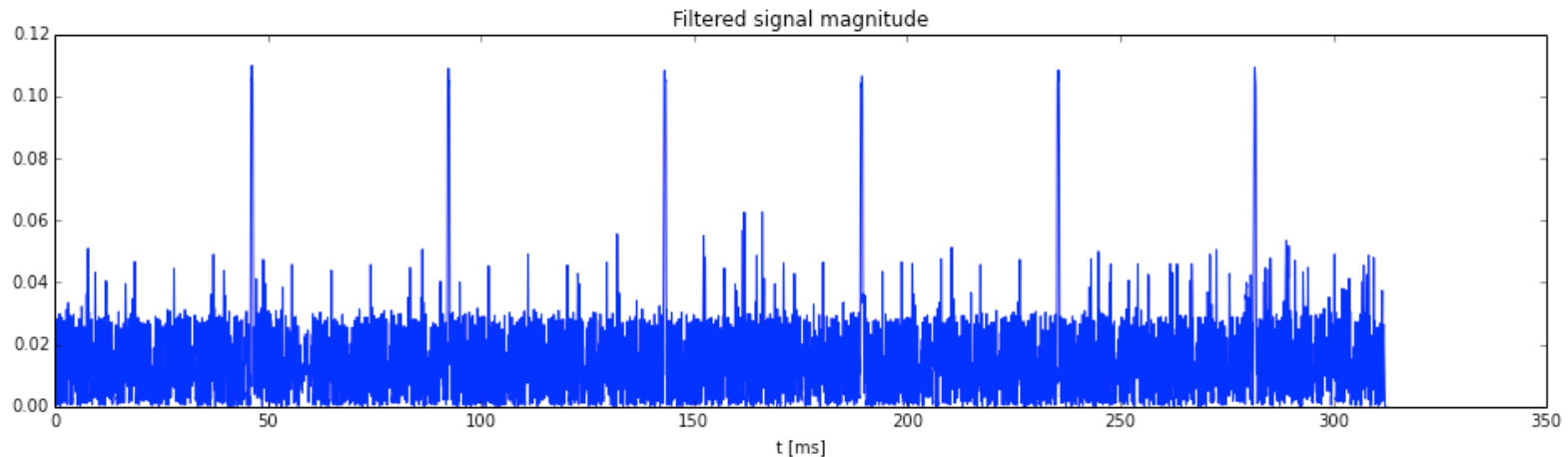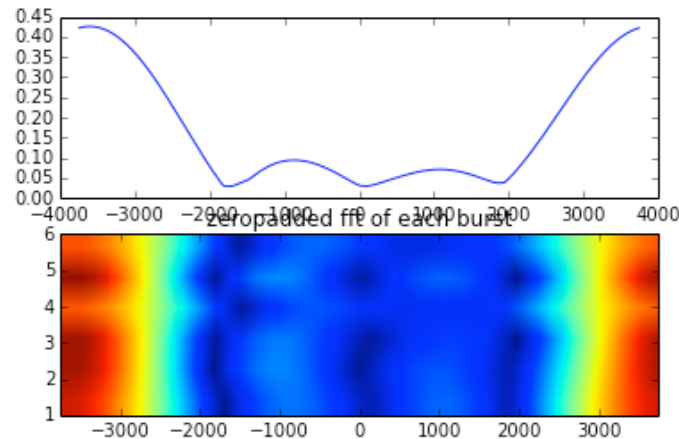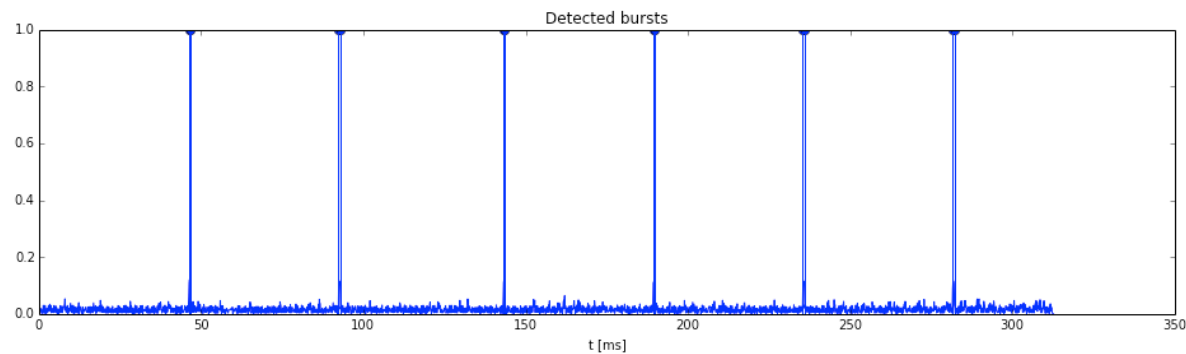
Spectrogram of GSM

Spectrogram of a GSM base-station signal
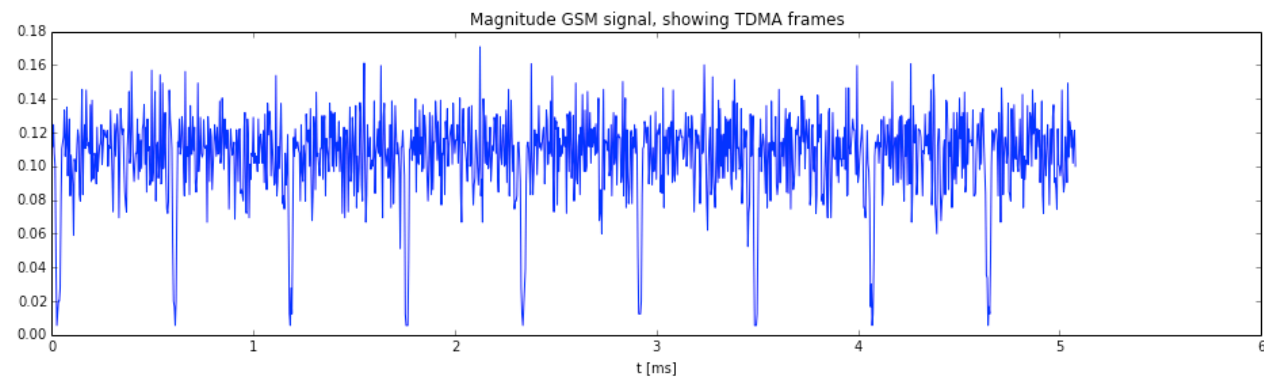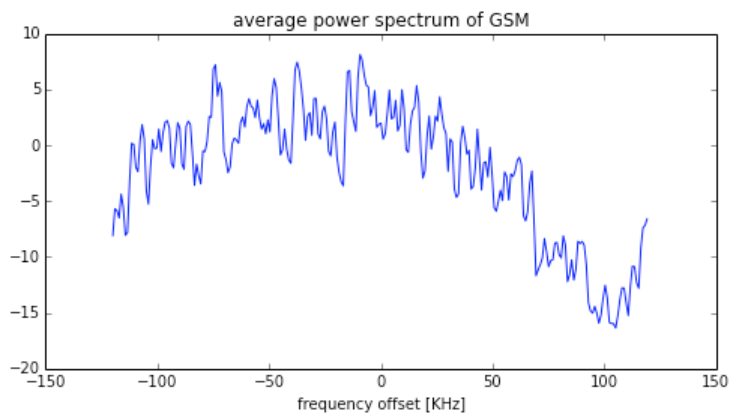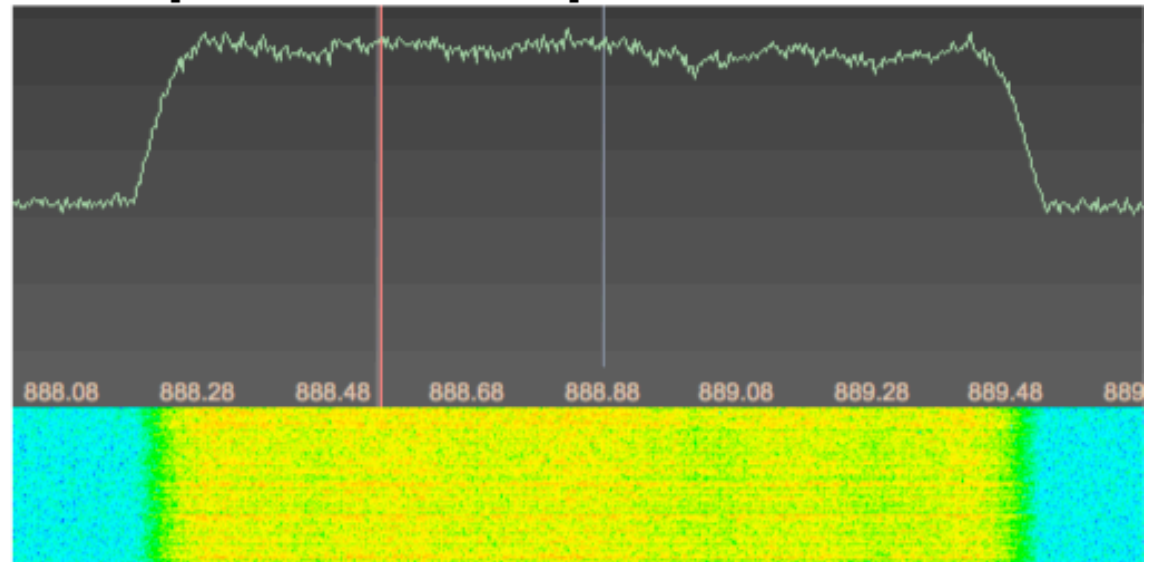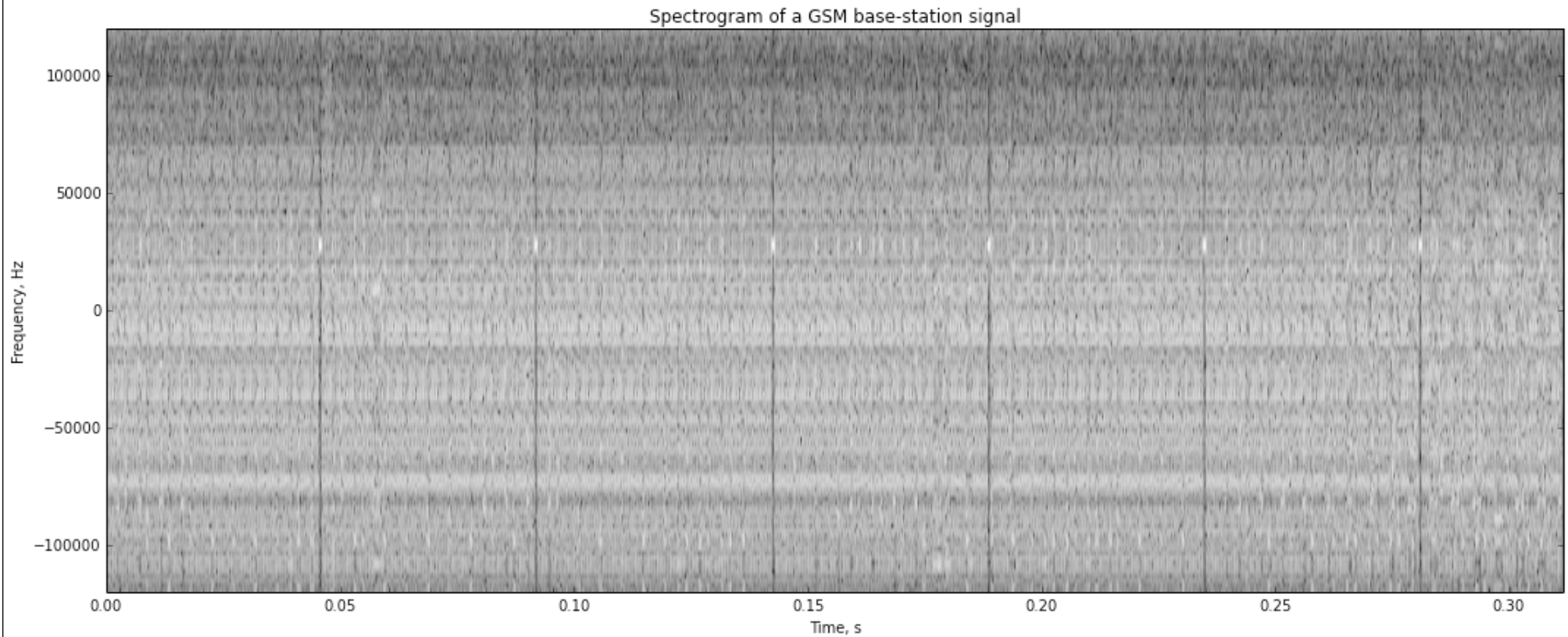
How to find Bursts?

- ## Use a translating, decimating filter and compute magnitude of result

Detect Bursts and Compute Frequency

- Detect bursts at low rate sampling
- Compute frequency
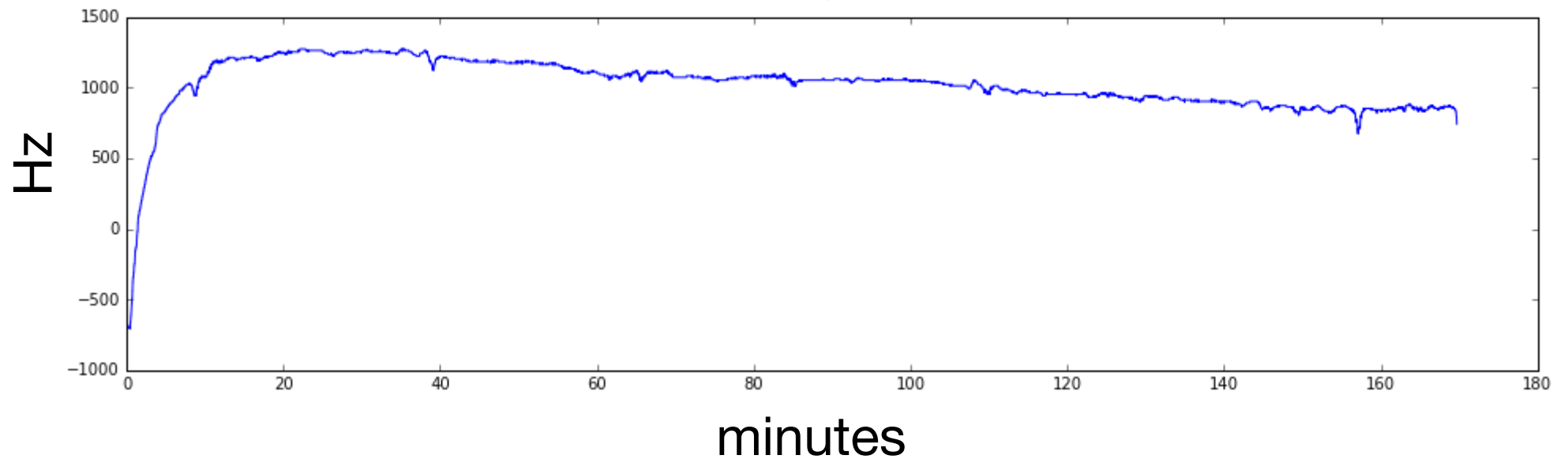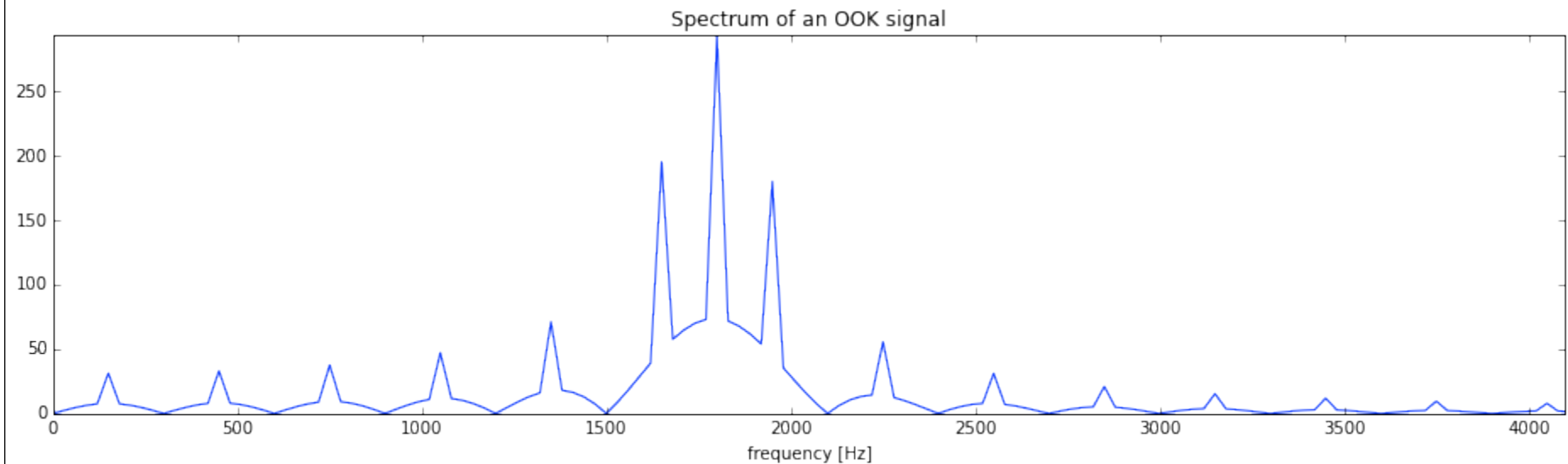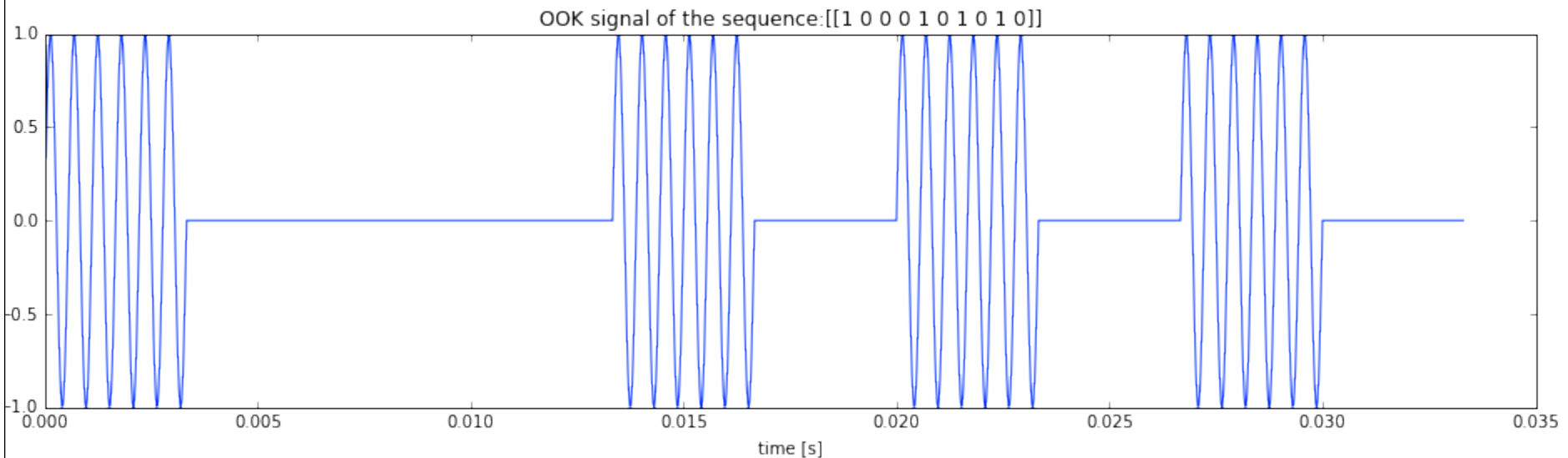- Calculate the original frequency!

Frequency Drift
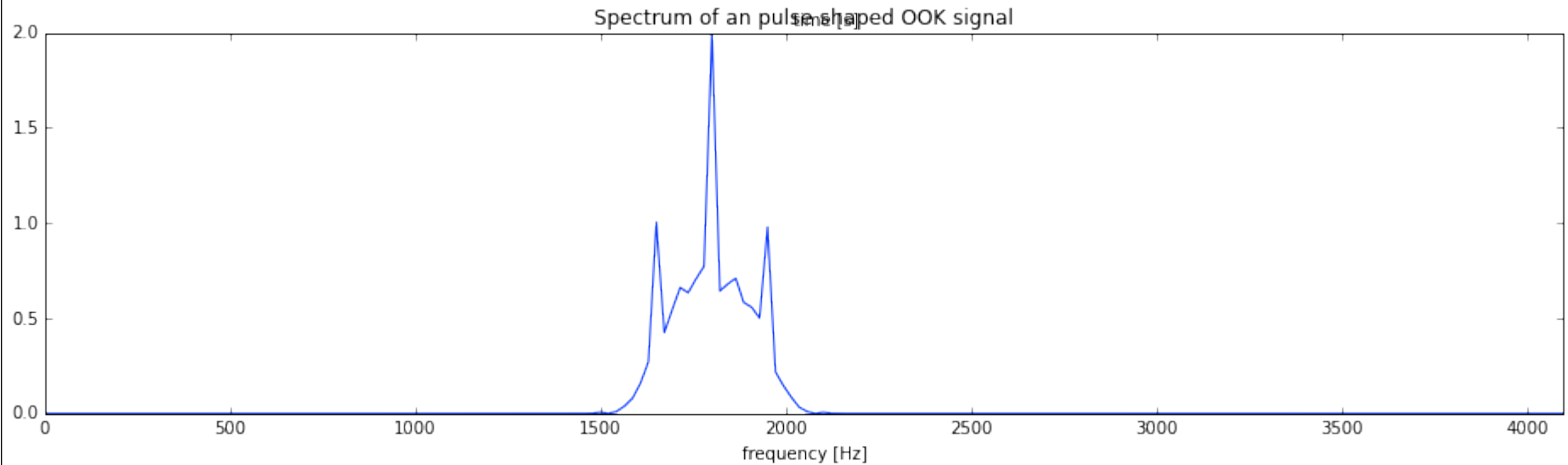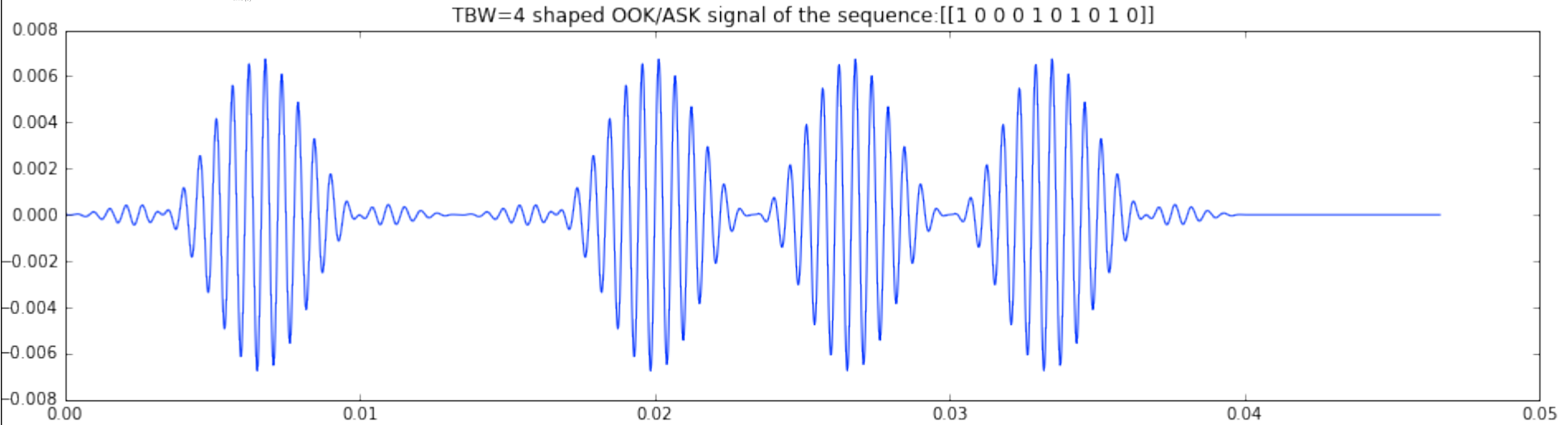
- ## Track frequency over time

frequency over time

minutes

Hz

Lab4 - Digital Communication Methods

- ## Amplitude Shift Keying

OOK signal of the sequence:[[1 0 0 0 1 0 1 0 1 0]]

Spectrum of an OOK signal

Pulse Shaping to Reduce Sidebands

OOK signal of the sequence:[[1 0 0 0 1 0 1 0 1 0]]

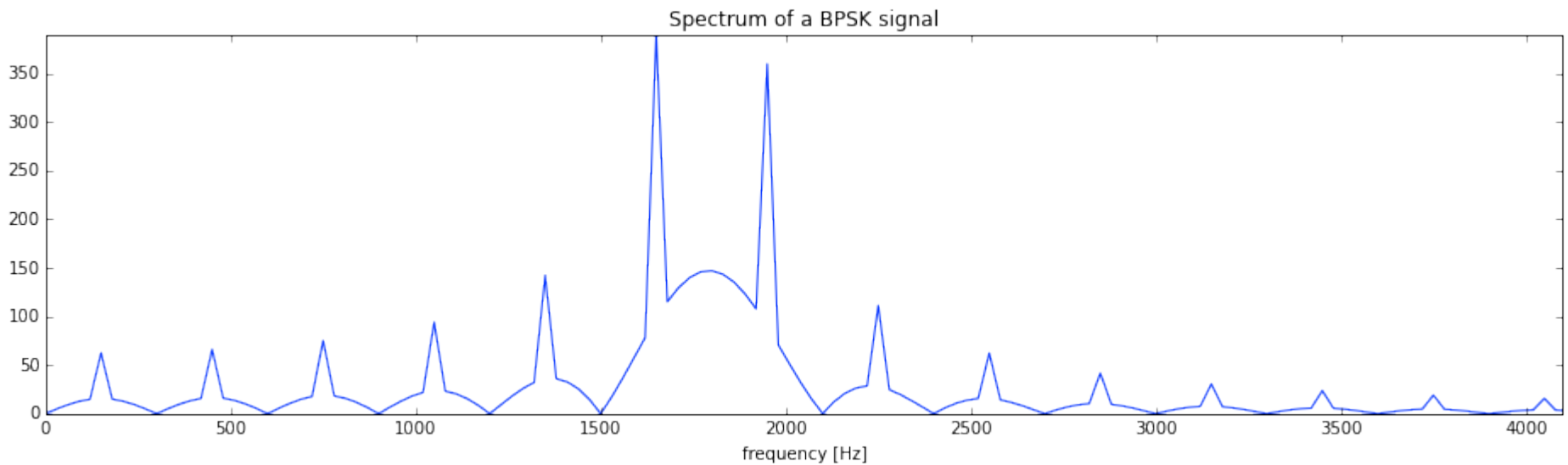TBW=4 shaped OOK/ASK signal of the sequence:[[1 0 0 0 1 0 1 0 1 0]]

Spectrum of an pulse shaped OOK signal
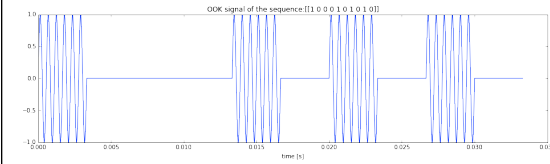
- Narrow band, but inter-symbol interference!

Phase Shift Keying

BPSK signal of the sequence:[[1 0 0 0 1 0 1 0 1 0]]

Spectrum of a BPSK signal
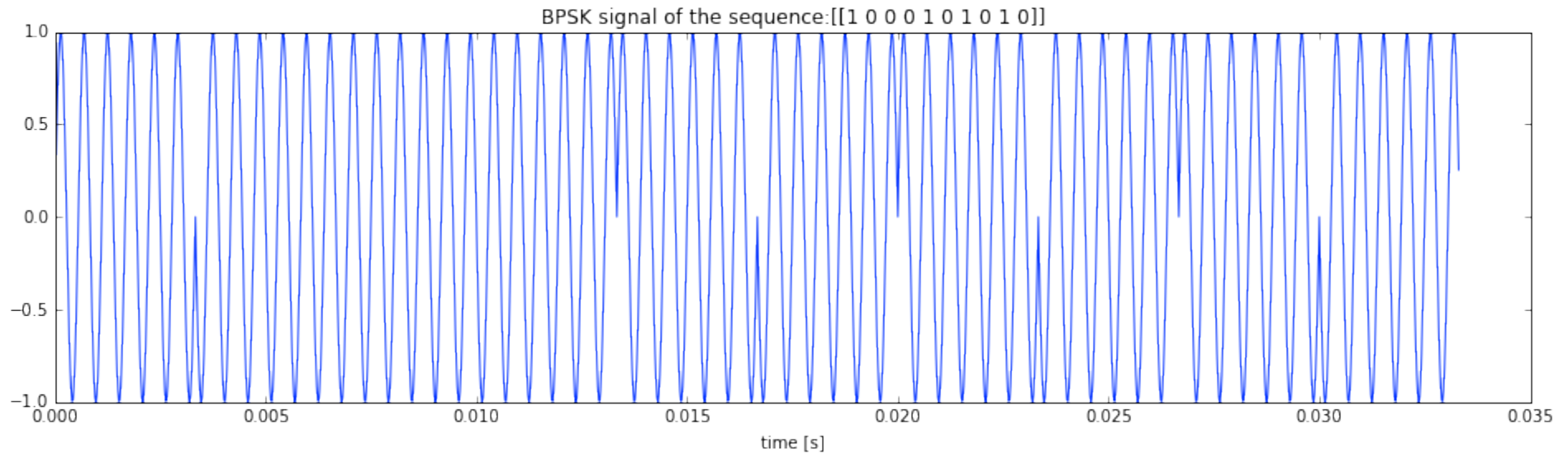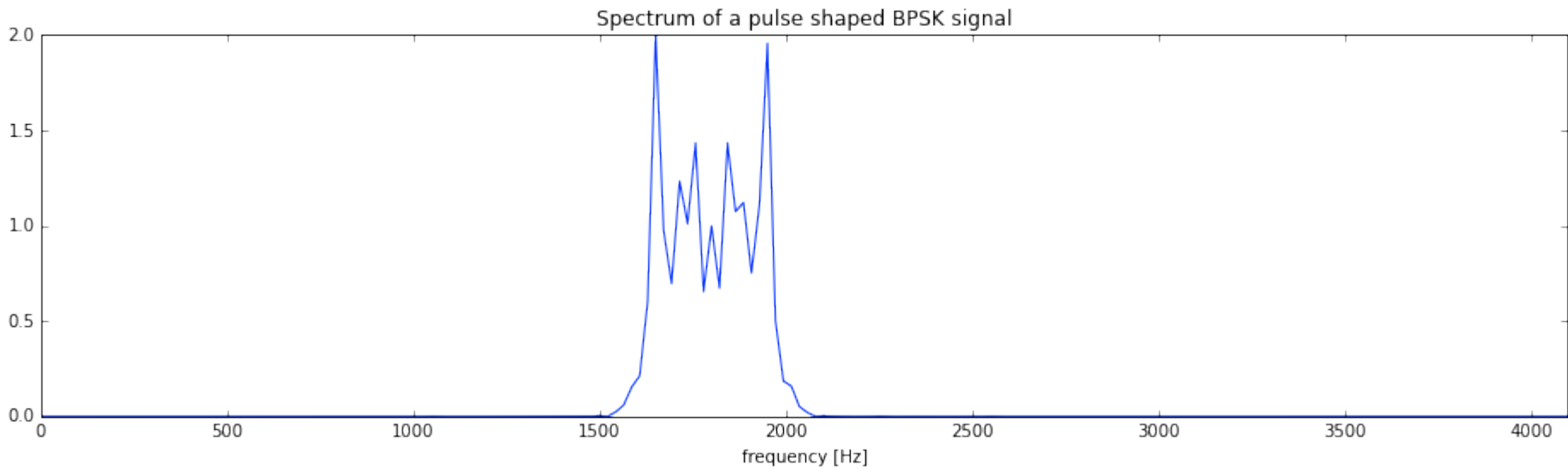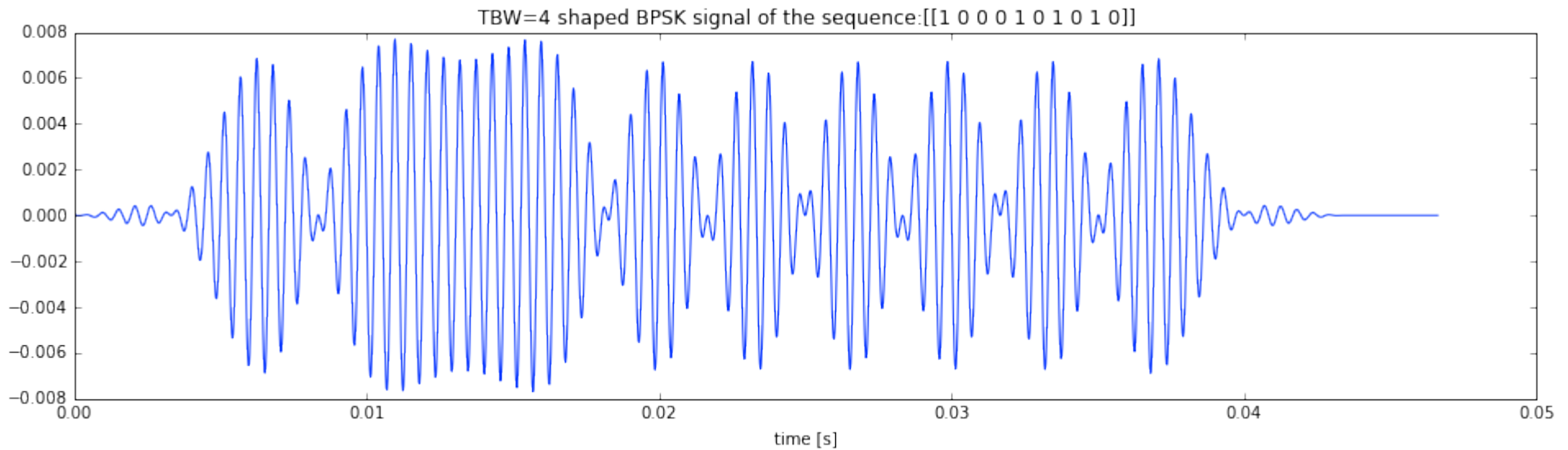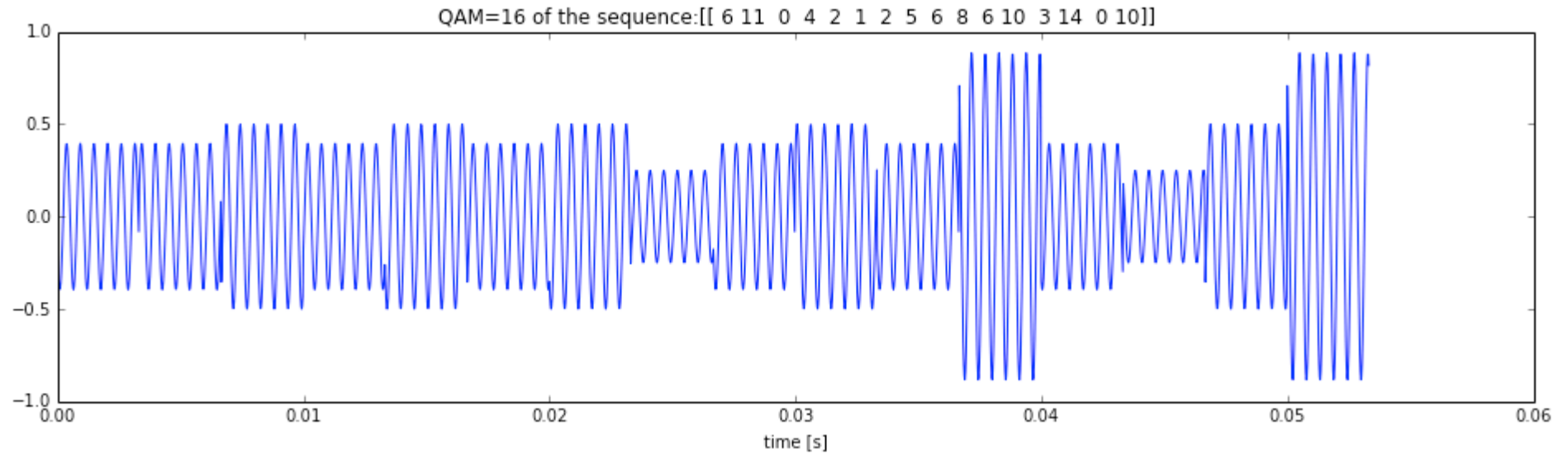
- Lots of sidelobes, but constant envelope!

Pulse Shaping

TBW=4 shaped BPSK signal of the sequence:[[1 0 0 0 1 0 1 0 1 0]]
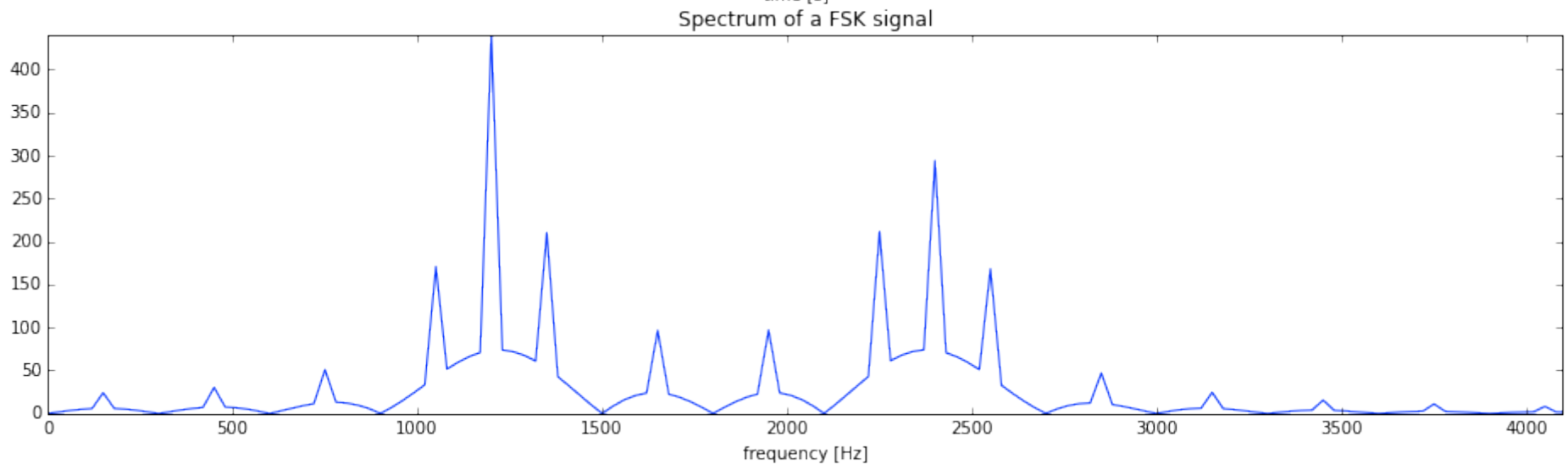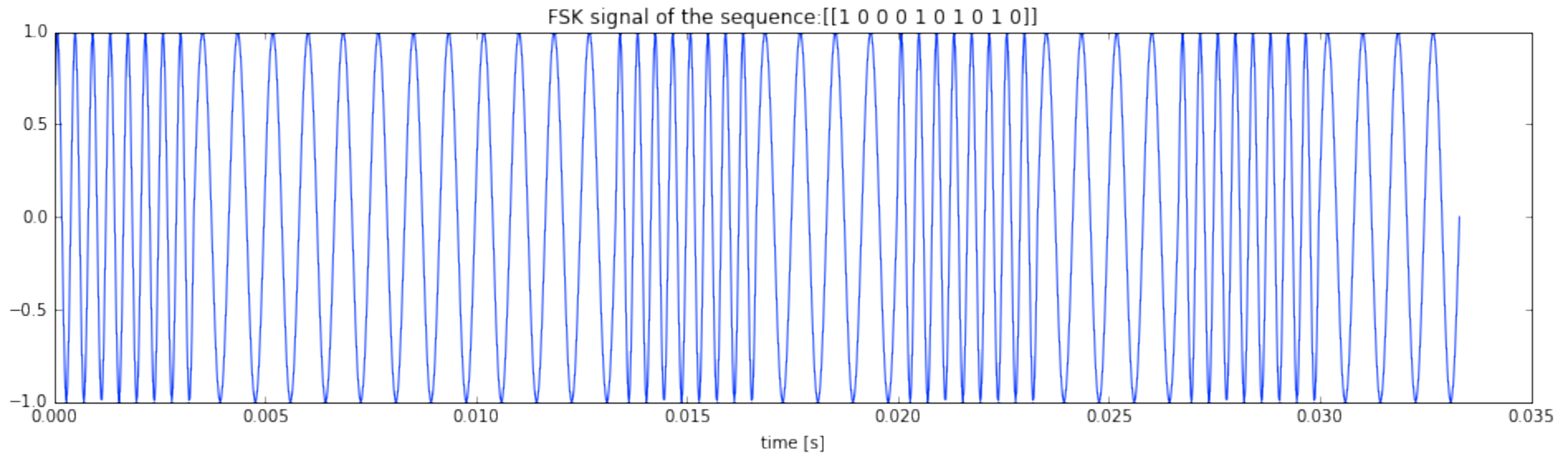
Spectrum of a pulse shaped BPSK signal

- Lost the sidelobes, but not constant envelope!

Quadrature Amplitude Modulation(QAM)

QAM=16 of the sequence:[[6 11 0 4 2 1 2 5 6 8 6 10 3 14 0 10]]

Frequency Shift Keying

FSK signal of the sequence:[[1 0 0 0 1 0 1 0 1 0]]

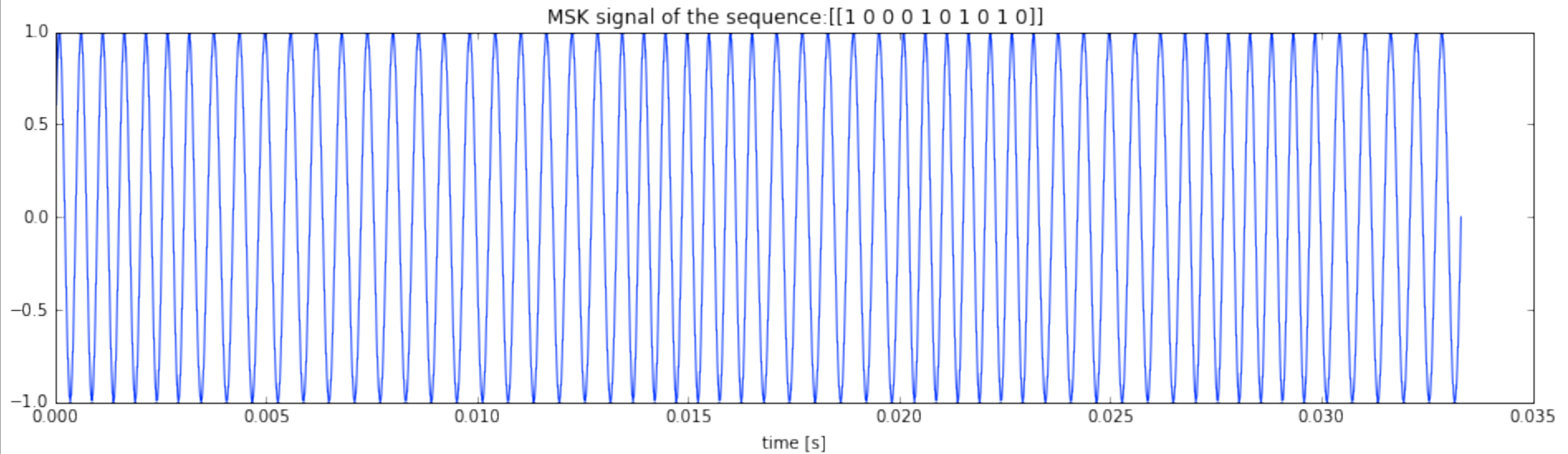Spectrum of a FSK signal
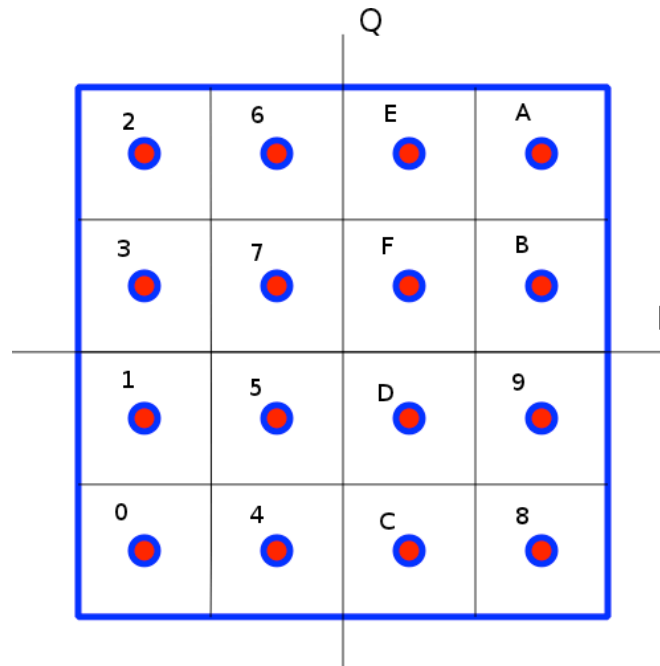
- 1200Hz/2400Hz 300 baud. 4/8 cycles/bit

- Constant envelope, wide band

Minimum Shift Keying (MSK)

MSK signal of the sequence:[[1 0 0 0 1 0 1 0 1 0]]

Spectrum of a MSK signal
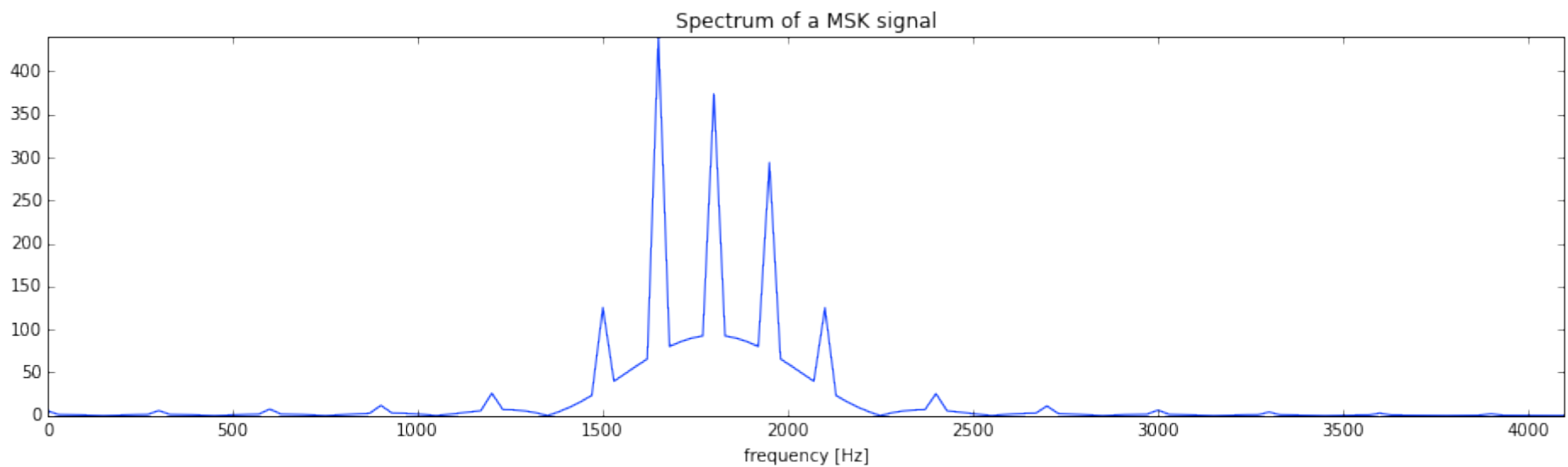
- 1200Hz/2400Hz 2400 baud.   0.5/1 cycles/bit

- Much more narrow-band