eCULTS: energy autarctic Configuration-free Ultrasonic Tracking System

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Summary
Aim of the eCULTS project is to localize mobile objects by ultrasonic communication. This require a robust communication system without medium access control. The communication model is derived and the hardware design is shown. The simulation results demonstrate the performance of the communication system.

Communication
- Chirp Spread Spectrum (CSS) with constant slope
- Frequency Range 38 – 42 kHz
- 8 Bit Transmission
- Binary coding of the chirp slope:
  - Positive slope → binary 1
  - Negative slope → binary 0

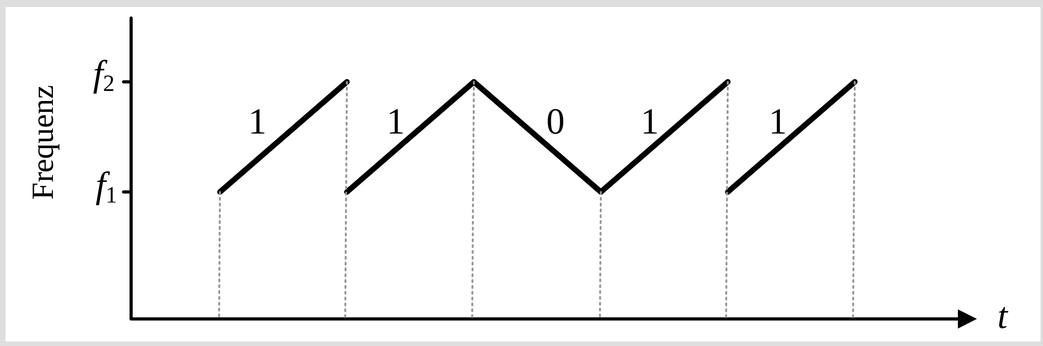

Figure 1: Chirp Spread Spectrum for binary coding of 5 bits.

Design of Transmitter
- Simple Low Power µC with PWM Output
- Chirp sequence stored in Flash/EEPROM in µC
- Low cost design
- Energy autarctic operation possible
- No need of synchronization between receivers

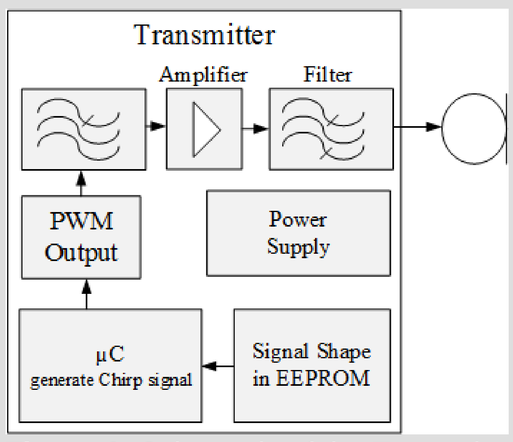

Figure 2: Schematic of the Transmitter.

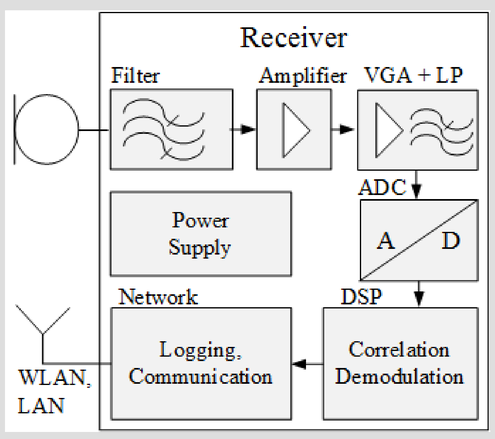

Figure 3: Schematic of the Receiver.

Design of Receiver
- Wide Dynamic range
  - o variable gain amplifier (VGA) → 0 - 46 dB
  - o Analog-to-Digital-Converter (ADC) → 70 dB SINAD
- Digital Signal processing on dual-core ARM Cortex-A9
- ADC with 12 Bit and up to 3 MSps → Oversampling
- Network interface for data forwarding
- Free resources on DSP for user applications

Discrete Transmission Model
- Quantization noise w_{DAC}, w_{ADC}
- Linear no fading channel
- Additive white Gaussian noise $w_w \sim N(0,\ {\sigma_w}^2)$
- Modulation by $f_{Mod} := f_{Start}$ and decimation
- Matching Filter correlation
- Correlation shape for up slope
  $|\rho_{Up}(t_c)| = \frac{\sqrt{2}}{16\pi s|t_c|}\sqrt{1-\cos(4\pi t_c f_\Delta)}$
- Chirp $s_{ChirpU} = \cos\left(2\pi n f_{Abtast}\left(f_{Start} + f_\Delta n f_{Abtast}/\tau\right)\right)$

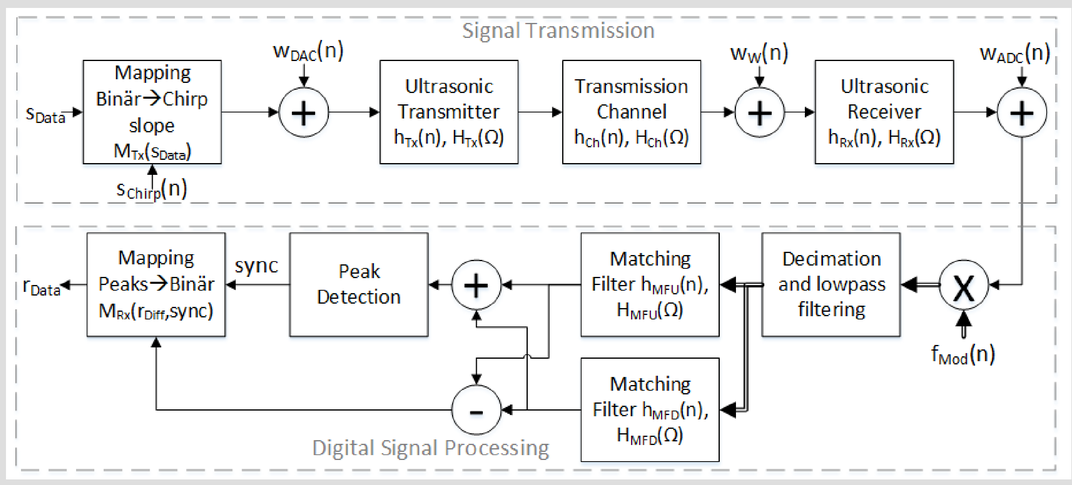

Figure 4: Discrete Transmission model.

Simulation results
- Envelope of correlation for different frequency modulation

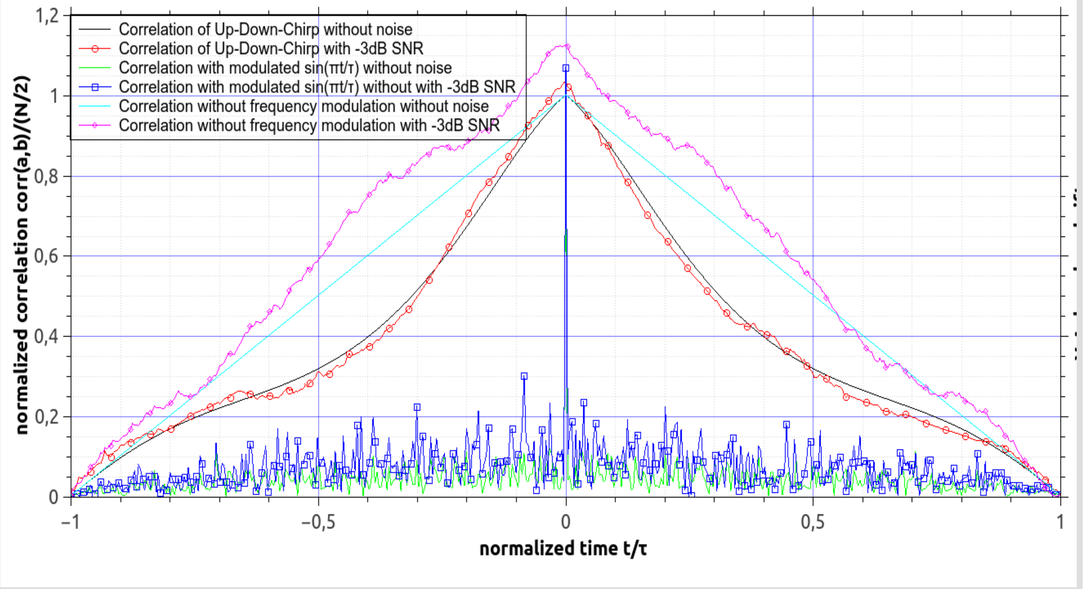

Figure 4: Simulation for different frequency modulation

Future Work
- Analyze logarithmic amplifier
- Implement algorithms in C++ on ARM
- Measurements in noisy environment

Acknowledgement
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