Wireless Congress 2007
Systems & Applications

Chirp Spread Spectrum: The Latest Advances

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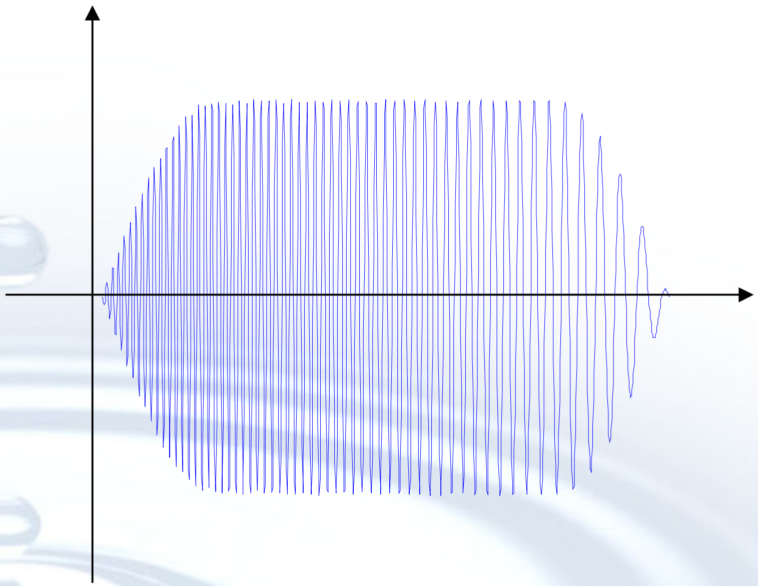
Basic definitions

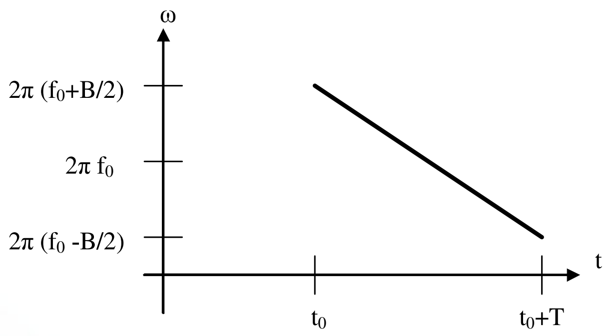
- Let‘s call linear frequency modulates pulses **chirp pulses**
- Let‘s call it up-chirp if the frequency is linearly increasing
- Let‘s call it down-chirp if the frequency is linearly decreasing

Down chirp pulse in band-pass domain

Signal plot

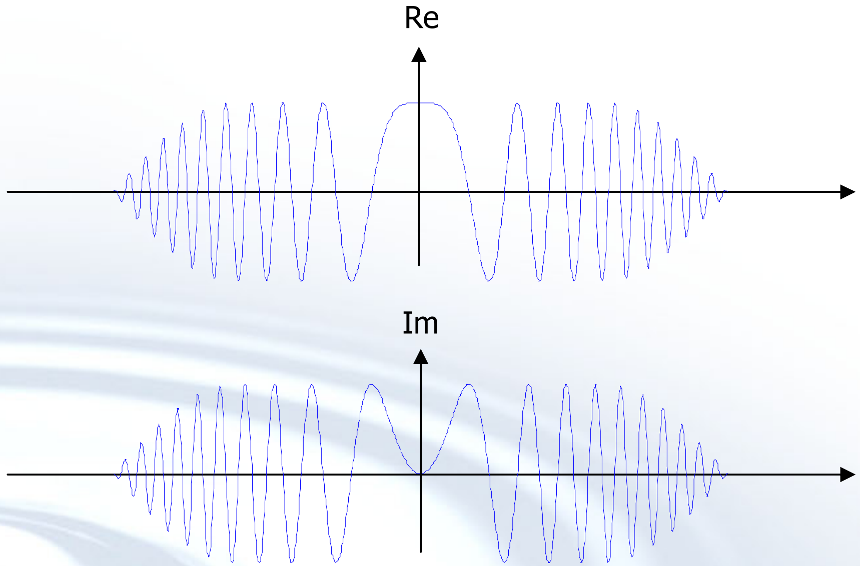


Time frequency diagram

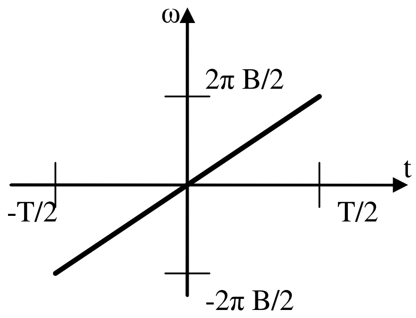


Up chirp pulse in low-pass domain

Signal plot

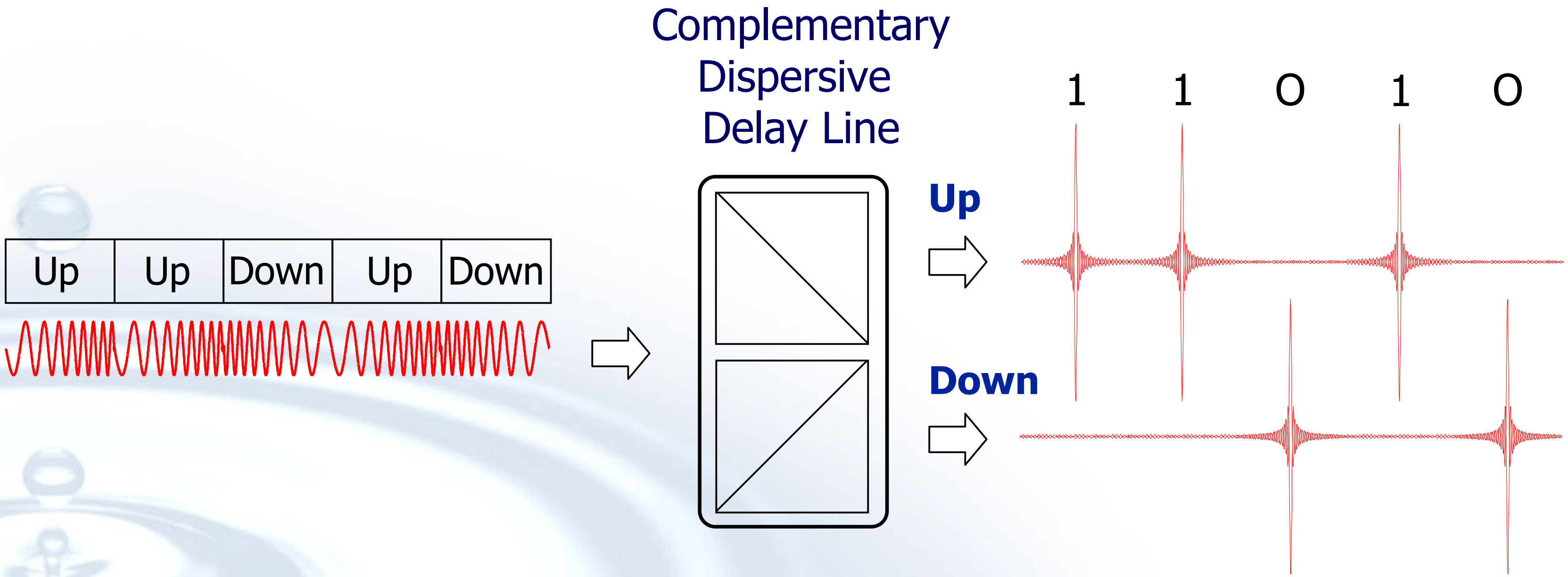


Time frequency diagram



Up-Chirp / Down-Chirp

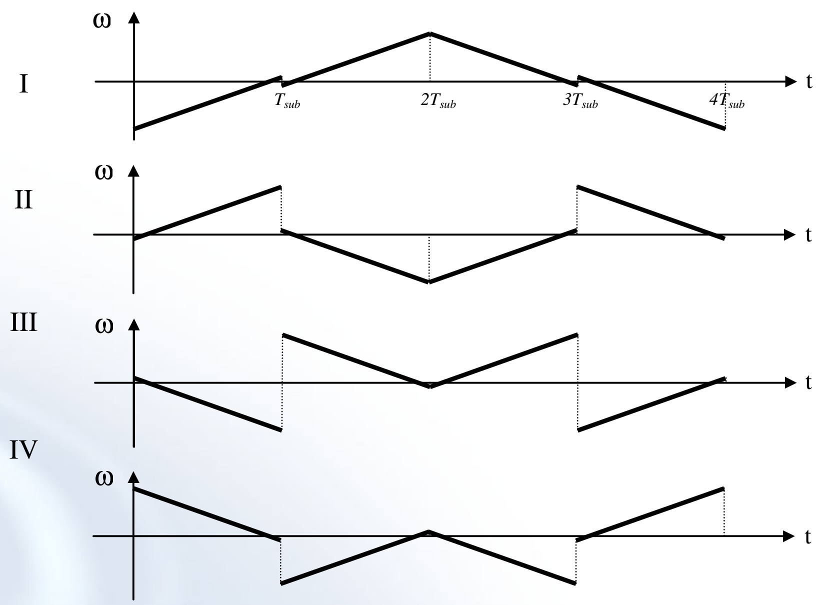
- Up-Chirp and Down-Chirp are orthogonal and easy to separate



- 2 ary orthogonal
- No chip synchronization needed
- Ranging: Simple TOA (Time of Arrival) evaluation

CSS in IEEE 802.15.4a

- Sequences of sub chirps
- DQPSK on each subchirp
- Two data rates realized by different code rates
- Bandplan corresponds with 802.11b



15.4a is available since 2007

CSS in IEEE 802.15.4c

- Standardization project to harmonize with national Chinese WPAN standard
- Chirp sequence over M-PSK
- 15.4c has just moved from study group level to task grup level

CSS in ISO 24730

- 24730 defines components of RTLS systems
  - 24730-1 defines the Application Program Interface (API)
  - 24730-2 is a draft standard which defines a blink only tag
  - 24730-5 is a draft standard which defines a tag with CSS based ranging and communication abilities

Ranging: Theoretical limits 1

Radar theory states the relationship between
standard deviation of time delay,
effective bandwidth and
signal to noise ratio as:

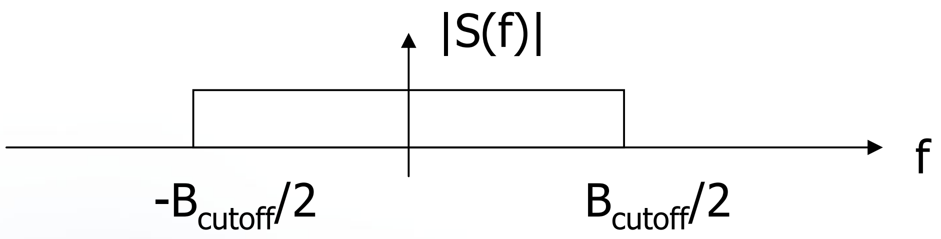
$$std(T_R) = \frac{1}{B_{eff}\sqrt{2\frac{E_s}{N_0}}}$$

With the effective bandwidth being:

$$B_{eff}^{\ \ 2} = \frac{1}{E_s}\int_{-\infty}^{\infty}(2\pi f)^2 \,|\, S(f)\,|^2 \, df$$

Ranging: Theoretical limits 2

For a signal with a flat spectrum (chirp) the following numbers are obtained:



$$\rightarrow \quad B_{eff} = \frac{\pi \cdot B_{cutoff}}{\sqrt{3}}$$

B_{cutoff}	B_{eff}	E_s/N_0=20 dB	E_s/N_0=25 dB
14 MHz	25.4 Mrad/s	2.785 ns (0.835 m)	1.566 ns (0.470 m)
20 MHz	36.3 Mrad/s	1.949 ns (0.585 m)	1.096 ns (0.328 m)
80 MHz	145.1 Mrad/s	0.487 ns (0.146 m)	0.274 ns (0.082 m)
500 MHz	906.9 Mrad/s	0.077 ns (0.023 m)	0.044 ns (0.013 m)

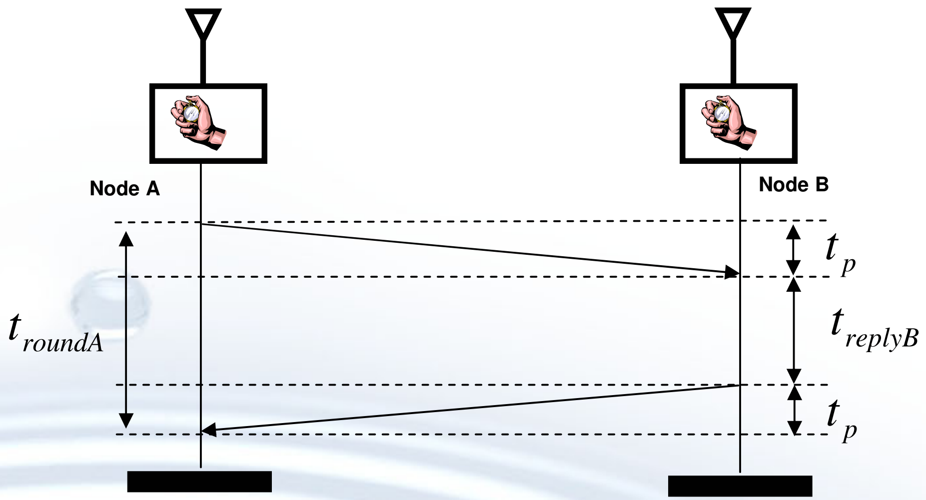
Ranging: Theoretical limits 3

- What about effects multipath reflections?
  - No expression for performance bound known
  - Broad field of research
  - Chirp pulses allow transform the problem from time domain to frequency domain where techniques like super resolution algorithms can be applied
  - Experience from communication theory: Theoretical capacity of AWGN channel can (with some additional effort) also be approached also on multipath channels

Point to point ranging

- Errors introduced by time base differences…

Two Way Ranging (TWR)



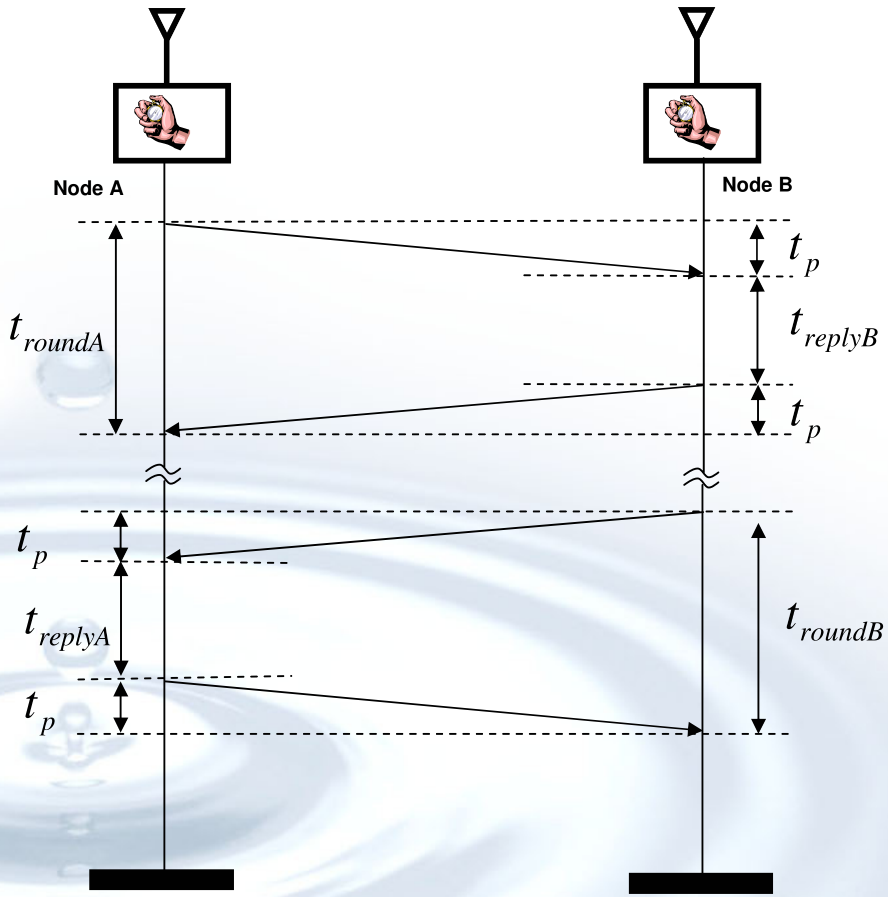
- Estimate of propagation time:

$$\hat{t}_p = \frac{T_{roundA} - T_{replyB}}{2}$$

- Estimation error cause by differences in time bases:

$$\hat{t}_p - t_p \approx t_{replyB} \frac{1}{2}(e_A - e_B)$$

Symetric Double Sided Two Way Ranging (SDS-TWR)



- Estimate of propagation time:

$$\hat{t}_p = \frac{t_{roundA} - t_{replyA} + t_{roundB} - t_{replyB}}{4}$$

- Estimation error cause by differences in time bases:

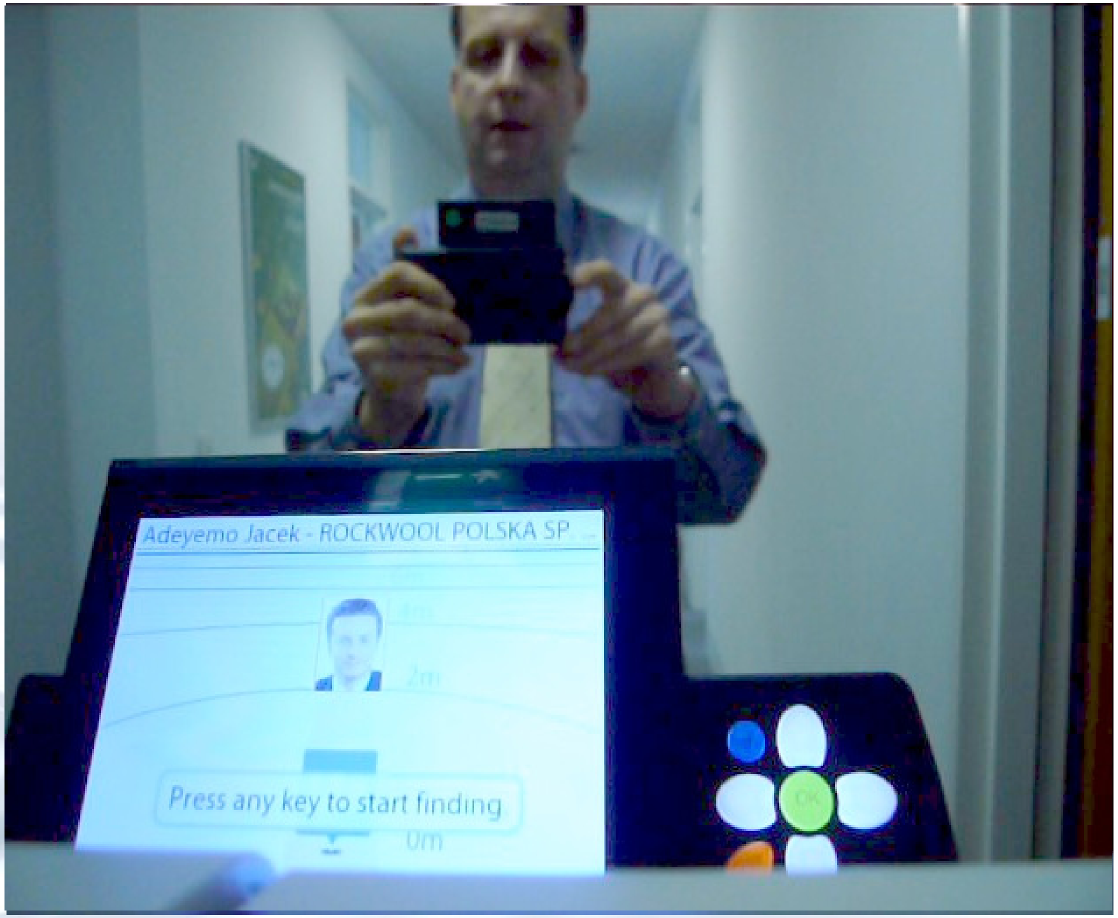
$$(\hat{t}_p - t_p) \approx \frac{1}{4} \Delta_{reply} (e_A - e_B)$$

nanoLOC TRX – Indoor Ranging

Indoor ranging test

nanoLOC TRX – Indoor Ranging

Indoor Ranging Tests with PDA handhelds with **nanoLOC TRX** ranging technology ins



Range

→65m←

→40m←

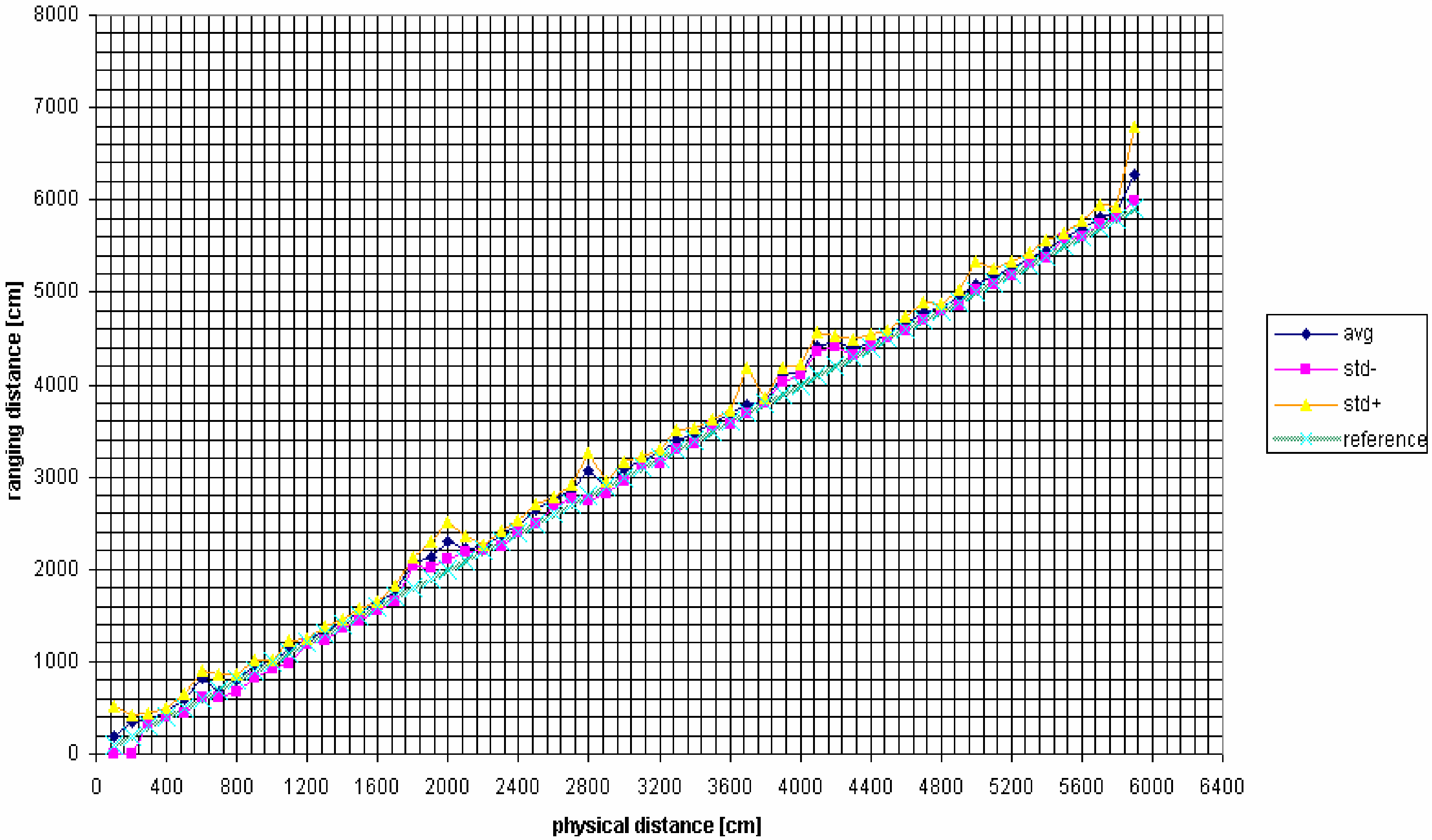
→30m←

→10m←

→ 0m←

nanoLOC TRX – Indoor Ranging

Verification of measured ranging distance vs. physical distance



Chirp it.

Conclusion

- CSS has been adopted by an international IEEE standard
- More standards will adopt CSS
- The theory proves that ranging with CSS pulses of 20 to 80 MHz bandwidth is possible.
- Practical measurements confirm the usability of CSS and SDS-TWR

For more information..

Please check the proceeding papers!

Thank you for your attention!

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