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Submission Title: [**Two Hopeful Technologies for TG4a --- DS-UWB and CS-UWB**]

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Abstract [This document has been prepared for an official proposal in January 2005. Two possible technologies of direct-sequence UWB(DS-UWB) and chirp-signal UWB(CS-UWB) are investigated in performance on BER, ranging resolution, complexity, power consumption, SOP and so on. The performance comparison is concluded by a few differences in performance but we need to modify these primitive technologies so as to match with requirements.]

Purpose: [Providing technical contributions to IEEE 802.15.4a.]

Two Hopeful Technologies for TG4a --- DS-UWB and CS-UWB

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Outline of presentation

- Requirements of TG4a
- DS-UWB and CS-UWB (Chirp signal UWB)
  - ✓ Advantages of using DS-UWB and CS-UWB
  - ✓ Correlation characteristics
  - ✓ Coexistence
  - ✓ Frequency bandwidth
  - ✓ Link budget
  - ✓ Performance examples
  - ✓ Ranging issue
  - ✓ Summary and comparison
- Conclusion

Technical Requirements

- Low complexity, low cost, and low power consumption.
- Precision ranging by PHY --- tens of centimeters.
- Communication distance is ~30m (can be extended)
- Better robustness and mobility than 802.15.4
- Low bit rate (individual link) >= 1 kbps.
- High bit rate (aggregated) >= 1 Mbps.

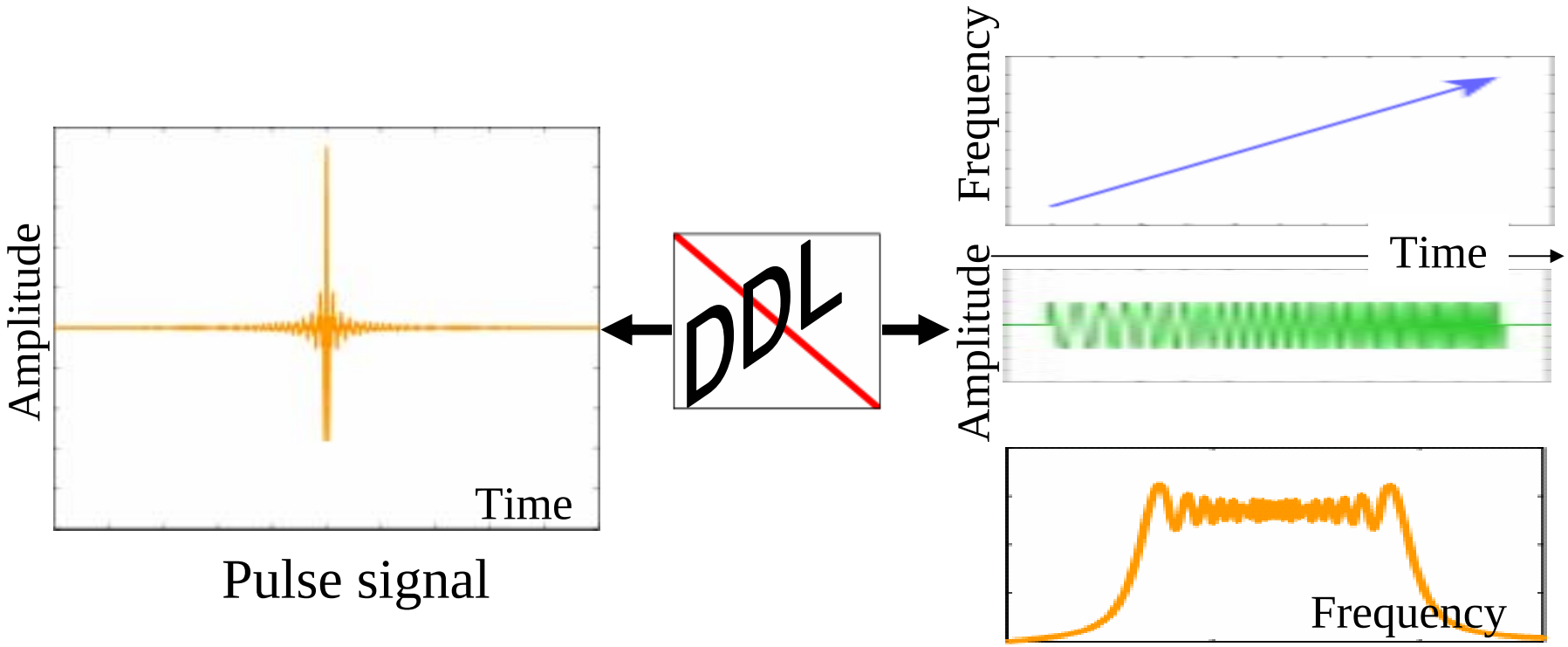
Advantages

Both DS-UWB and CS-UWB are available for

- **High precision ranging**
  - Be up to tens of centimeters
  - Depend on pulse width (bandwidth)
- **Low complexity**
  - Simple ADC (2 or 3-bit)
- **High frequency efficiency**
  - Uniform use of frequency within the band.
- **High robustness against noise and multipath**
  - Correlated processing
- **Low power consumption**
  -

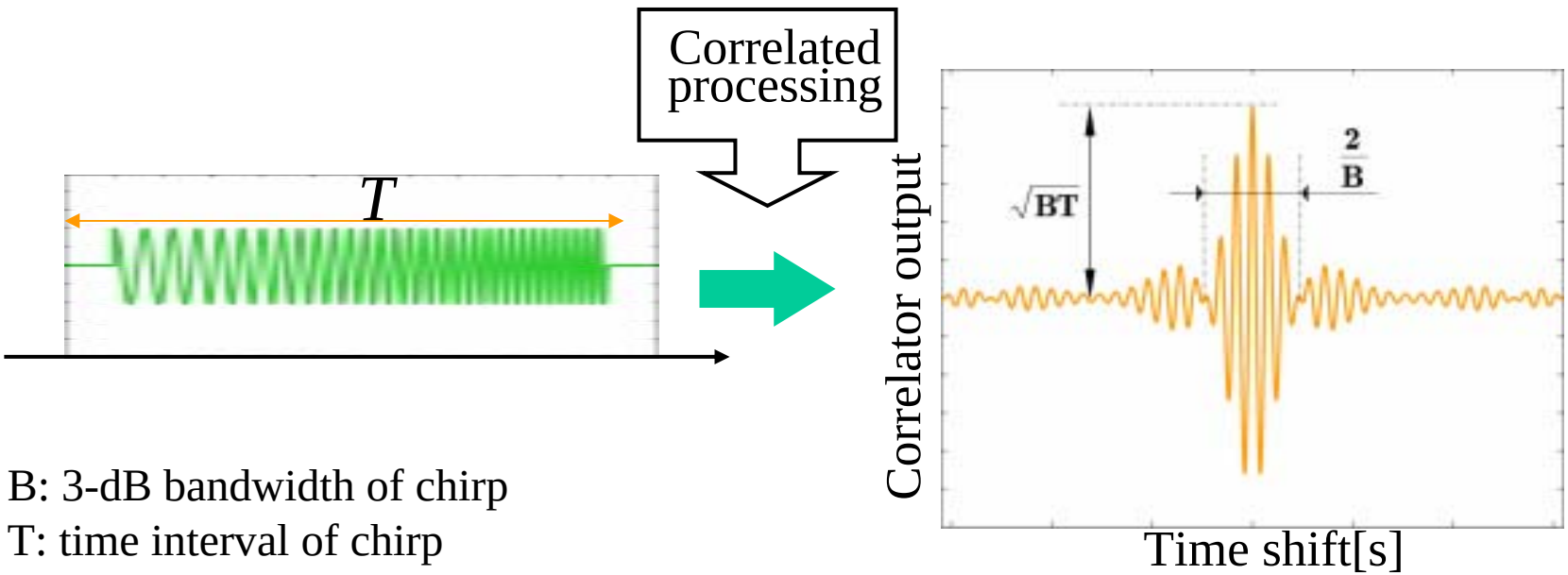
Generation of CS-UWB

- CS-UWB can be generated by passing a pulse signal through a distributed delay line (DDL) such as a SAW DDL.



Correlated processing

- Correlated processing produces not only high precision ranging but also robustness against noise and multipath.

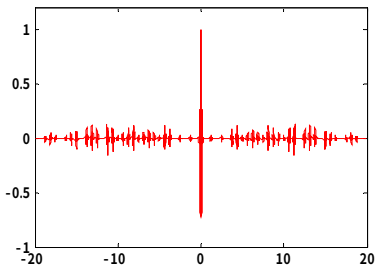


B: 3-dB bandwidth of chirp
T: time interval of chirp

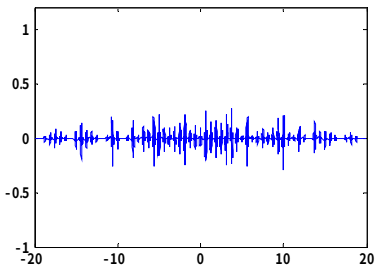
The wide the bandwidth, the sharp the peak.

Characteristics of correlation

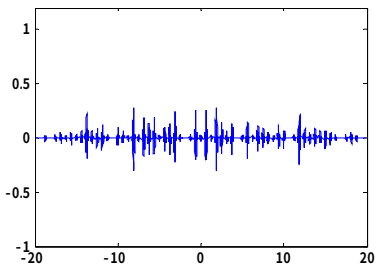
DS-UWB



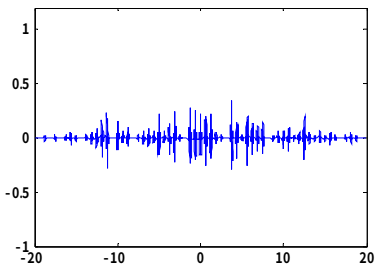
autocorrelation



cross correlation

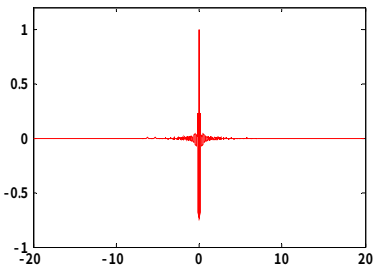


cross correlation

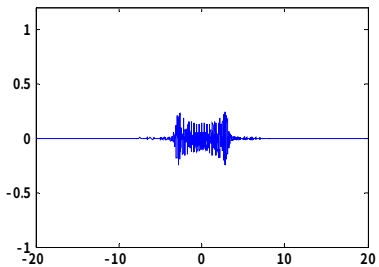


cross correlation

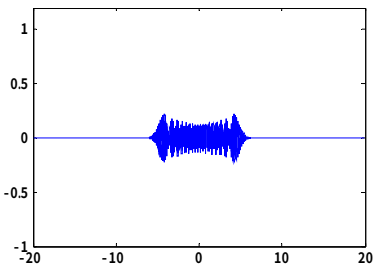
CS-UWB



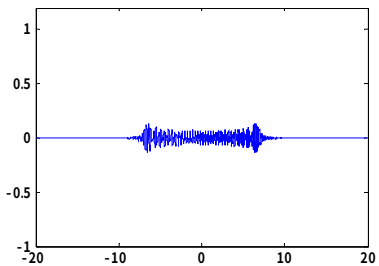
autocorrelation



cross correlation

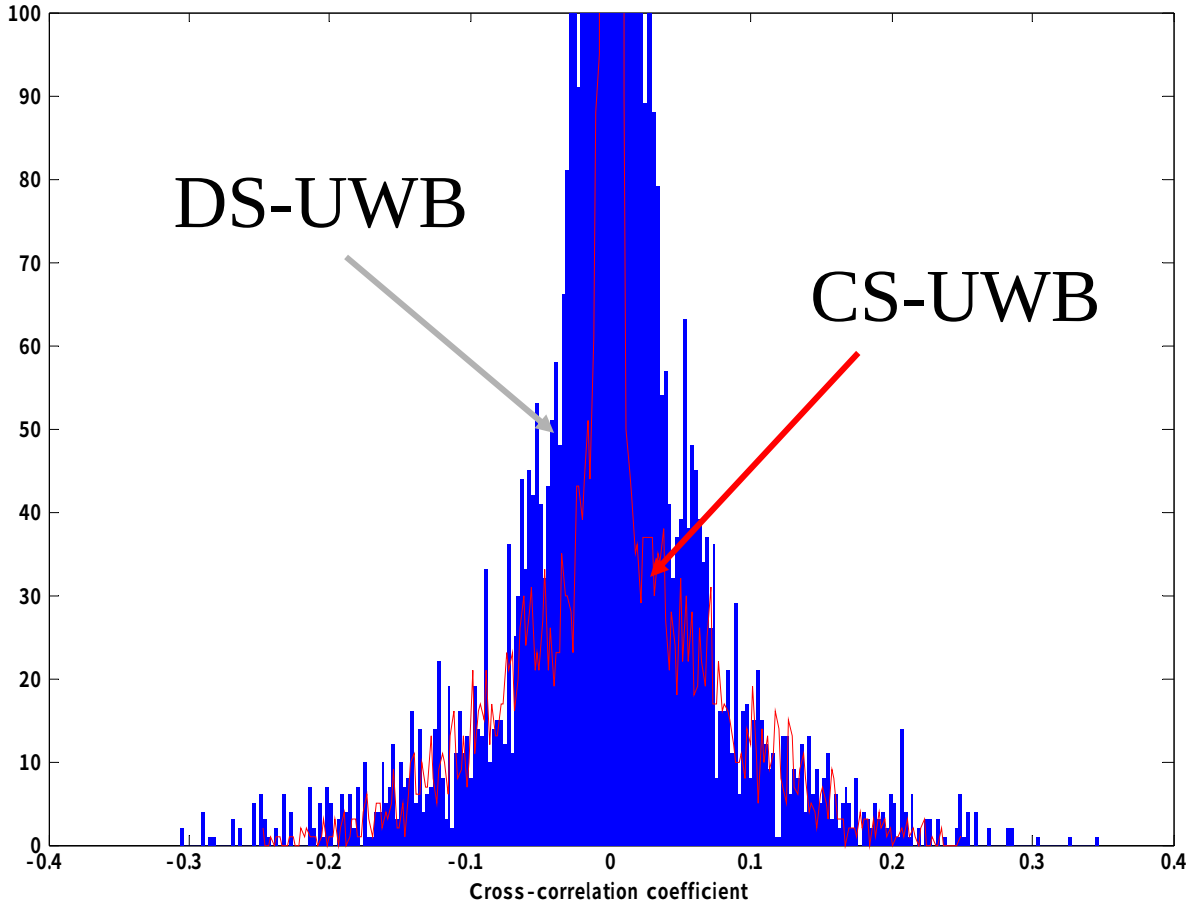


cross correlation



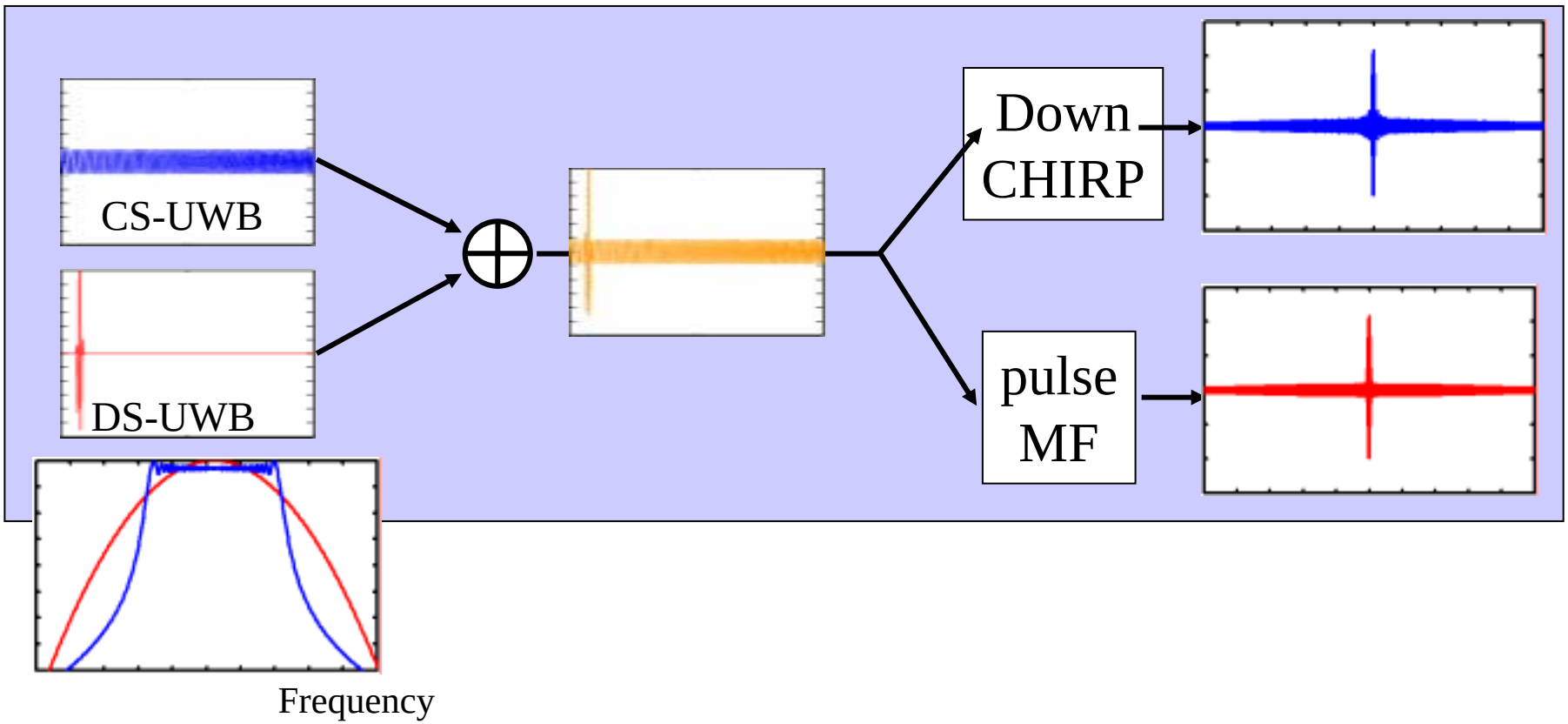
cross correlation

Cross correlation coefficient

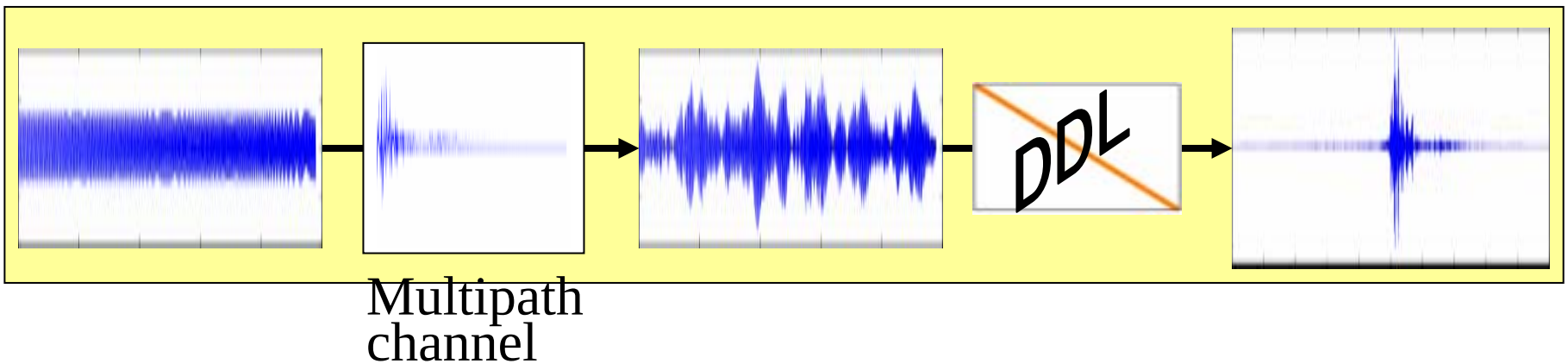


Coexistence

- Coexistence between DS-UWB and CS-UWB



Robustness against multipath



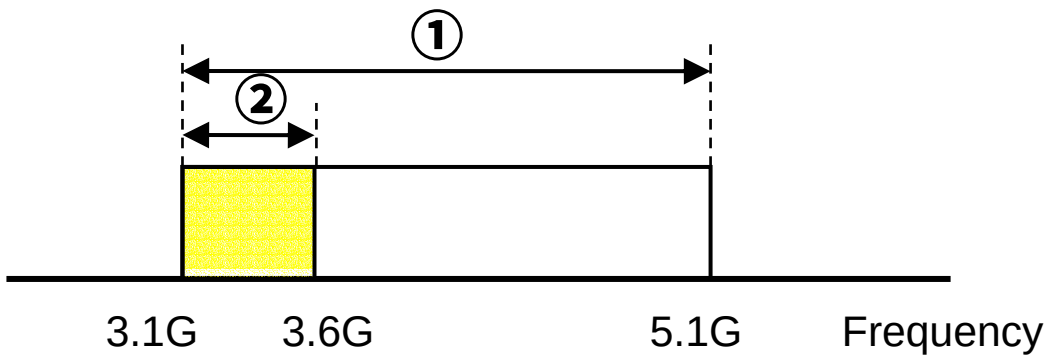
Due to the good correlation characteristics, correlator can detect a signal even under heavy multipath channel.

Frequency Band

- We consider the use of UWB band here, and give examples of link budgets for use of the following two bandwidth.

① BW=2 GHz (3.1GHz – 5.1GHz)

② BW=500 MHz (3.1GHz – 3.6GHz)



DS-UWB Link Budget (BW=2GHz)

Parameter	Value	Value	Notes
Data rate (Rb)	1	1024	(kbps)
Modulation	BPSK		Coherent detection
Coding rate (R)	½		(24,12)-Extended Golay Hard-decision decoding
Raw Symbol rate (Rs)	2	2048	Rs=Rb/R (ksymbol/second)
Pulse duration (Tp)	0.662		(ns)
Spreading code length (Ns)	1024	64	
Chip rate (Rc)	2.048	131.072	=Rs*Ns (MHz)
Chip duration	488.3	7.63	=1/Rc (nsec)

Parameter	Value	Value	Unit
Distance (d)	30	10	m
Peak payload bit rate (Rb)	1	1024	kbps
Average Tx power (Pt)	-10.5		dBm
Tx antenna gain (Gt)	-3.00		dBi
Frequency Band	3.1 - 5.1		GHz
Geometric center frequency (fc)	3.98		GHz
Path loss @ 1m (L1)	44.43		dB
Path loss @ d m (Ld)	29.54	20.00	dB
Rx antenna gain (Gr)	-3.00		dBi
Rx power (Pr)	-90.47	-80.93	dBm
Average noise power per bit (N)	-144.00	-113.90	dBm
Rx Noise Figure (Nf)	7.00		dB
Average noise power per bit (Pn)	-137.00	-106.90	dBm
Minimum required Eb/N0 (S)	6.25		dB
Implementation loss (I)	3.00		dB
Link Margin	37.28	16.72	dB
Min. Rx Sensitivity Level	-127.75	-97.65	dBm

DS-UWB Link Budget (BW=500MHz)

Parameter	Value	Value	Notes
Data rate (Rb)	1	1024	(kbps)
Modulation	BPSK		Coherent detection
Coding rate (R)	½		(24,12)-Extended Golay Hard-decision decoding
Raw Symbol rate (Rs)	2	2048	Rs=Rb/R (ksymbol/second)
Pulse duration (Tp)	2.649	2.649	(ns)
Spreading code length (Ns)	1024	64	
Chip rate (Rc)	2.048	131.072	=Rs*Ns (MHz)
Chip duration	488.3	7.63	=1/Rc (nsec)

Parameter	Value	Value	Unit
Distance (d)	30	10	m
Peak payload bit rate (Rb)	1	1024	kbps
Average Tx power (Pt)	-16.9		dBm
Tx antenna gain (Gt)	-3.00		dBi
Frequency band	3.1 - 3.6		GHz
Geometric center frequency (fc)	3.34		GHz
Path loss @ 1m (L1)	42.92		dB
Path loss @ d m (Ld)	29.54	20.00	dB
Rx antenna gain (Gr)	-3.00		dBi
Rx power (Pr)	-95.36	-85.82	dBm
Average noise power per bit (N)	-144.00	-113.90	dBm
Rx Noise figure (Nf)	7.00		dB
Average noise power per bit (Pn)	-137.00	-106.90	dBm
Minimum required Eb/N0 (S)	6.25		dB
Implementation loss (I)	3.00		dB
Link Margin	32.39	11.83	dB
Min. Rx Sensitivity Level	-127.75	-97.65	dBm

CS-UWB Link Budget (BW=2GHz)

Parameter	Value	Value	Notes
Data rate (Rb)	1	1024	(kbps)
Modulation	BPSK		Coherent detection
Coding rate (R)	½		(24,12)-Extended Golay Hard-decision decoding
Raw Symbol rate (Rs)	2	2048	Rs=Rb/R (ksymbol/s)
Chirp signal duration (Tc)	100		(ns)
Spreading code length (Ns)	1024	4	
Chip rate (Rc)	2.048	8.192	=Rs*Ns (MHz)
Chip duration	488.3	122.1	=1/Rc (nsec)

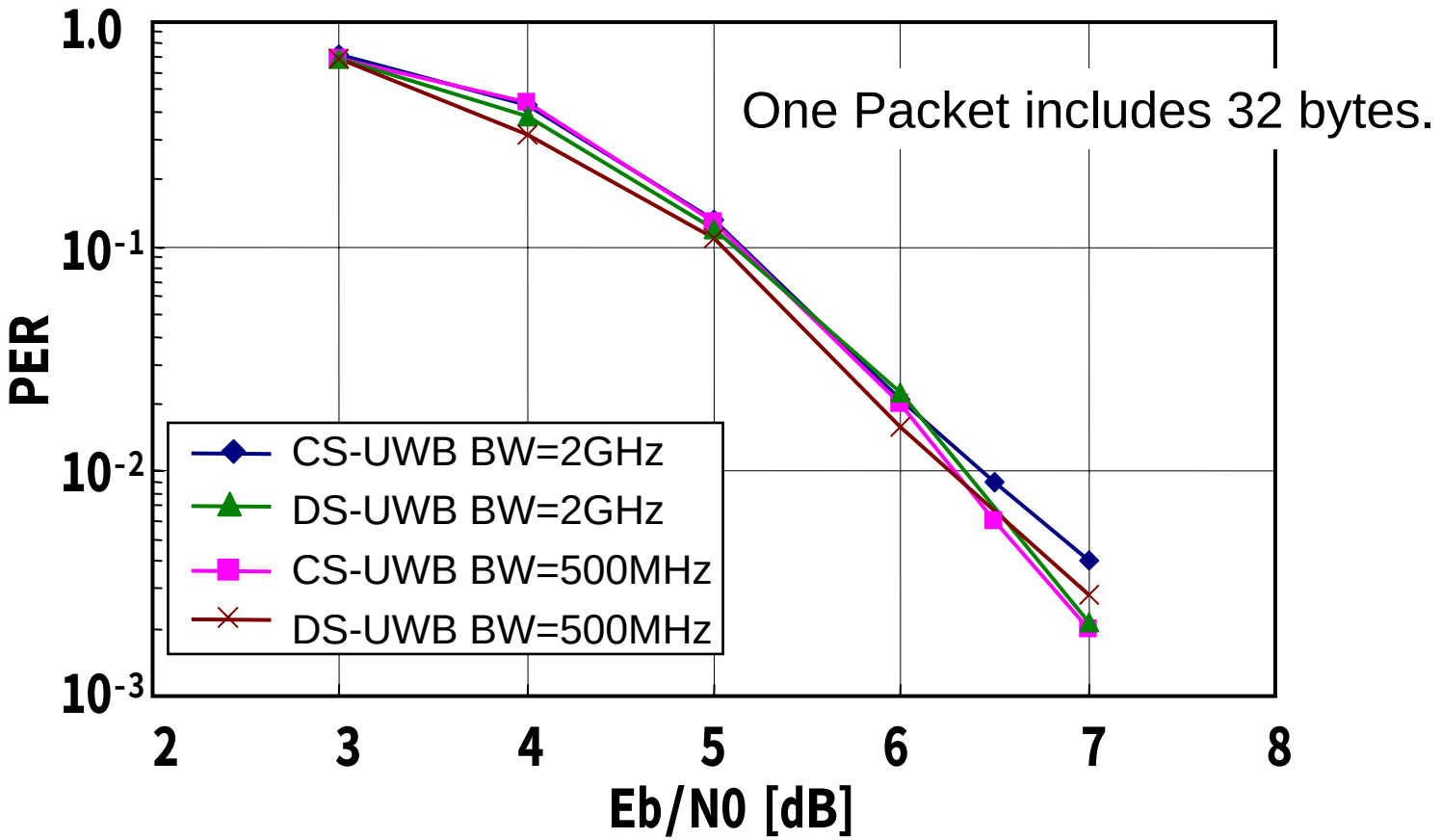
Parameter	Value	Value	Unit
Distance (d)	30	10	m
Peak payload bit rate (Rb)	1	1024	kbps
Average Tx power (Pt)	-10.5		dBm
Tx antenna gain (Gt)	-3.00		dBi
Frequency band	3.1 - 5.1		GHz
Geometric center frequency (fc)	3.98		GHz
Path loss @ 1m (L1)	44.43		dB
Path loss @ d m (Ld)	29.54	20.00	dB
Rx antenna gain (Gr)	-3.00		dBi
Rx power (Pr)	-90.47	-80.93	dBm
Average noise power per bit (N)	-144.00	-113.90	dBm
Rx Noise figure (Nf)	7.00		dB
Average noise power per bit (Pn)	-137.00	-106.90	dBm
Minimum required Eb/N0 (S)	6.25		dB
Implementation loss (I)	3.50		dB
Link Margin	36.78	16.22	dB
Min. Rx Sensitivity Level	-127.25	-97.15	dBm

CS-UWB Link Budget (BW=500MHz)

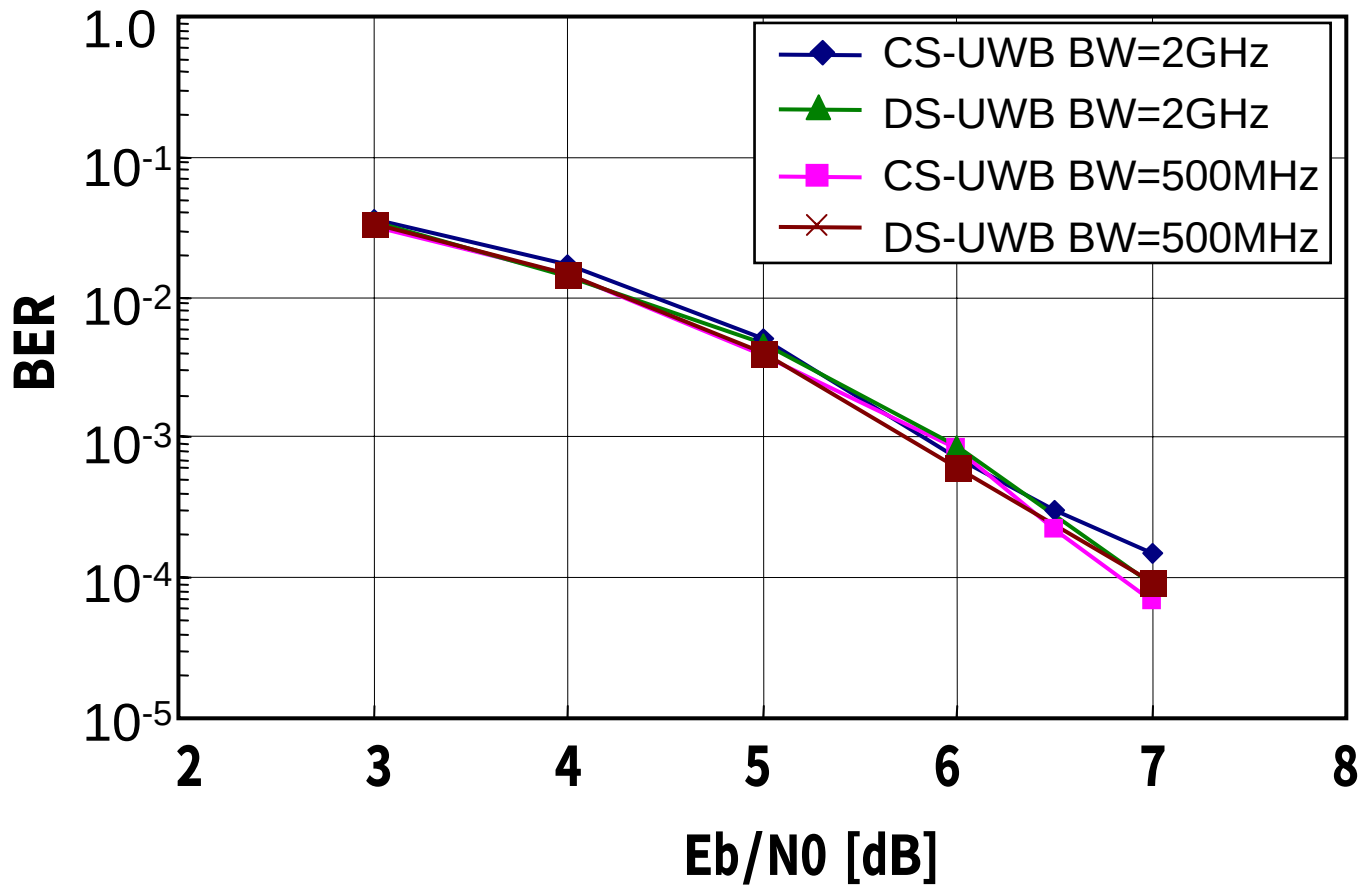
Parameter	Value	Value	Notes
Data rate (Rb)	1	1024	(kbps)
Modulation	BPSK		Coherent detection
Coding rate (R)	½		(24,12)-Extended Golay Hard-decision decoding
Raw Symbol rate (Rs)	2	2048	Rs=Rb/R (ksymbol/s)
Chirp signal duration (Tc)	25		(ns)
Spreading code length (Ns)	1024	16	
Chip rate (Rc)	2.048	32.768	=Rs*Ns (MHz)
Chip duration	488.3	30.5	=1/Rc (nsec)

Parameter	Value	Value	Unit
Distance (d)	30	10	m
Peak payload bit rate (Rb)	1	1024	kbps
Average Tx power (Pt)	-16.9		dBm
Tx antenna gain (Gt)	-3.00		dBi
Frequency band	3.1 - 3.6		GHz
Geometric center frequency (fc)	3.34		GHz
Path loss @ 1m (L1)	42.92		dB
Path loss @ d m (Ld)	29.54	20.00	dB
Rx antenna gain (Gr)	-3.00		dBi
Rx power (Pr)	-95.36	-85.82	dBm
Average noise power per bit (N)	-144.00	-113.90	dBm
Rx Noise figure (Nf)	7.00		dB
Average noise power per bit (Pn)	-137.00	-106.90	dBm
Minimum required Eb/N0 (S)	6.25		dB
Implementation loss (I)	3.50		dB
Link Margin	31.89	11.33	dB
Min. Rx Sensitivity Level	-127.25	-97.15	dBm

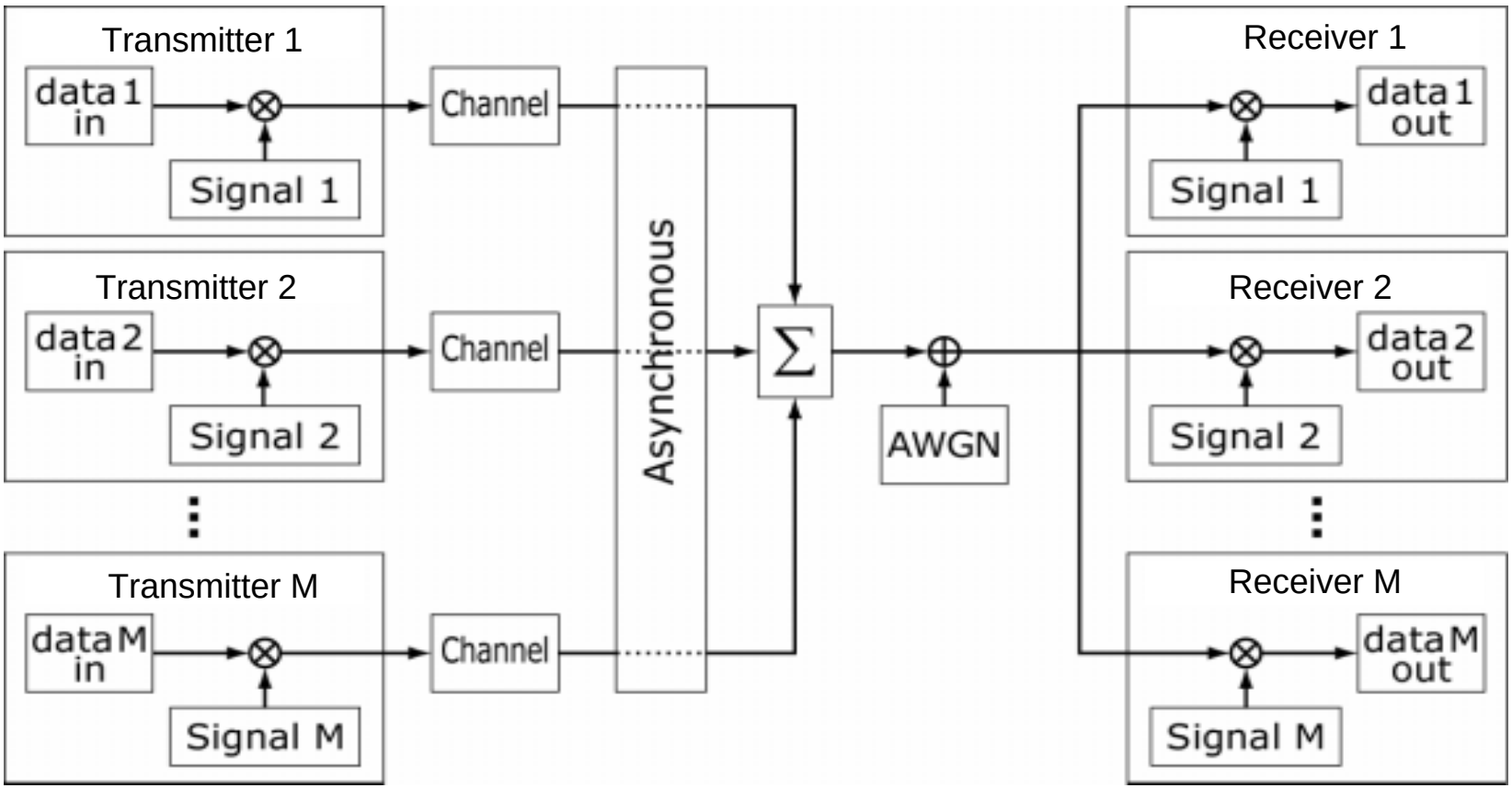
Simulation results (Single link)



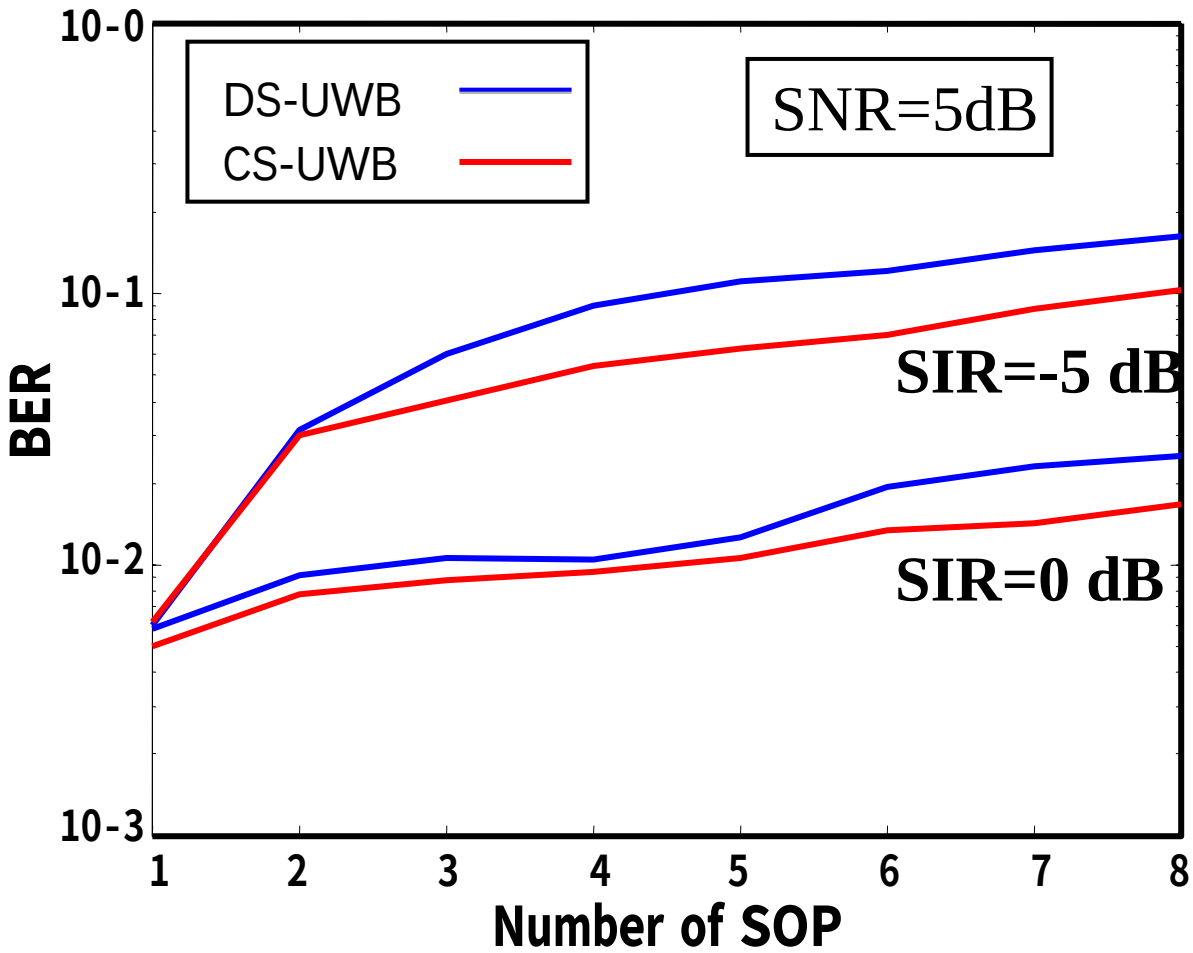
Simulation results (Single link)



Simulation block diagram for SOP



Simulation results for SOP



Ranging issue

- Ranging precision depends on the frequency bandwidth used.
- Using a simple TOA, DS-UWB provides better precision than CS-UWB in principle.

DS-UWB and CS-UWB Summary

++ good, + fair

	DS-UWB	CS-UWB
Low complexity	++	+
Peak-to-average ratio	+	++
Effect of SOP	+	++
Ranging precision	++	+

Conclusions

- DS-UWB and CS-UWB are good candidates for 15.4a.
  - Have similar characteristics and advantages.
  - Present similar performances but have own strength at different aspects.
  - Can be further improved
- Both can meet the Technical Requirements.
  - Low complexity, low cost, low power consumption.
  - Precision ranging.
  - Robustness.
- More studies are on going and will be presented at January meeting.