Influence of Delay-close Multi Path Components on FTM-RTT

Date: 2020-01-14

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Abstract

[1], [2] present results on RTT ranging performance for 11bd NGV 10 and 20 MHz modes in 5.9 GHz band

➔ Optimistic performance results due to selected channel models

This contribution:

- **Influence of delay-close Multi Path Components (MPCs) on FTM-RTT ranging due to ground reflection (GR)**
- **For safety critical applications requirements on ranging accuracy cannot be met with high probability**

➔ Larger bandwidth for improved ranging accuracy needed

Influencing Factors for RTT Ranging

- **Bandwidth ➔ Resolution in distance and delay**

Bandwidth / [MHz]	Distance Resolution / [m]	Delay Resolution/ [ns]
10	30	100
20	15	50
1000	0.3	1

- **Operation frequency *f* and distance *d* ➔ Signal to Noise Ration (SNR) [1]**

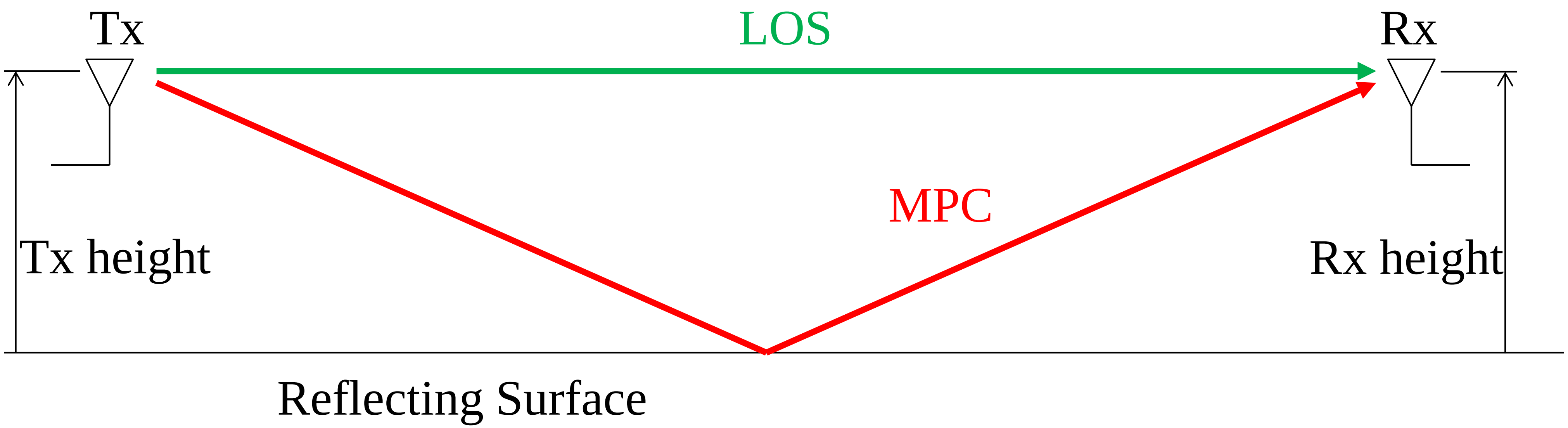
$$P_{Rx} = P_{Tx}\left(\frac{c}{4\pi df}\right)^2 \Rightarrow SNR(d) = \frac{P_{Tx}G_{Tx}G_{Rx}}{N_F k_B T_N BW}\left(\frac{c}{4\pi df}\right)^2$$

One-Path Model

Tx …Transmitter
Rx … Receiver

LOS … Line of Sight

Two-Path Model



Depending on phase of MPC constructive or destructive interference

➔ Worst case scenario MPC out-of-phase to LOS

Tx …Transmitter
Rx … Receiver

LOS … Line of Sight
MPC … Multi Path Component

Simulation Settings (1)

- **Single range simulations with [3]: 10 000 packets simulated**
- **Tx, Rx height = 1.5 m or 4 m**
- **Tx-Rx distance random between 10 to 100 m**
- **Channel models**
  - LOS, AWGN
  - UA-LOS [4]
  - Ground reflection on LOS with -3 or -10 dB relative path power
- **Path delay estimation:**
  - Packet detection and coarse synchronization
  - Fine synchronization
  - SAGE (space-alternating generalized expectation-maximization) algorithm

Simulation Settings (2)

Label	LOS model	MPC			SNR / [dB]	Path estimation	BW / [MHz]
		Presence	Noise	Power / [dB]			
Channel 1	AWGN	No			10/20	1-5 paths	10/20
Channel 2	UA-LOS	No					
Channel 3	AWGN	Yes	AWGN	-3, -10			
Channel 4	UA-LOS	Yes	AWGN	-3, -10			

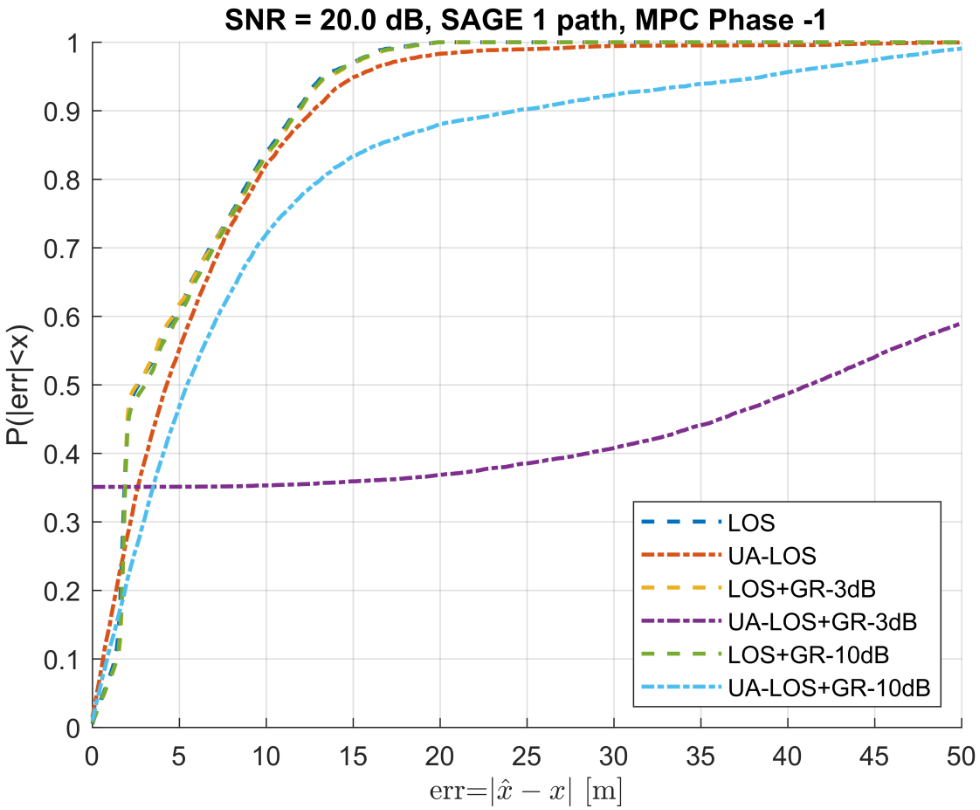
Table 2: Urban Approaching (UA) LOS Parameters [4]

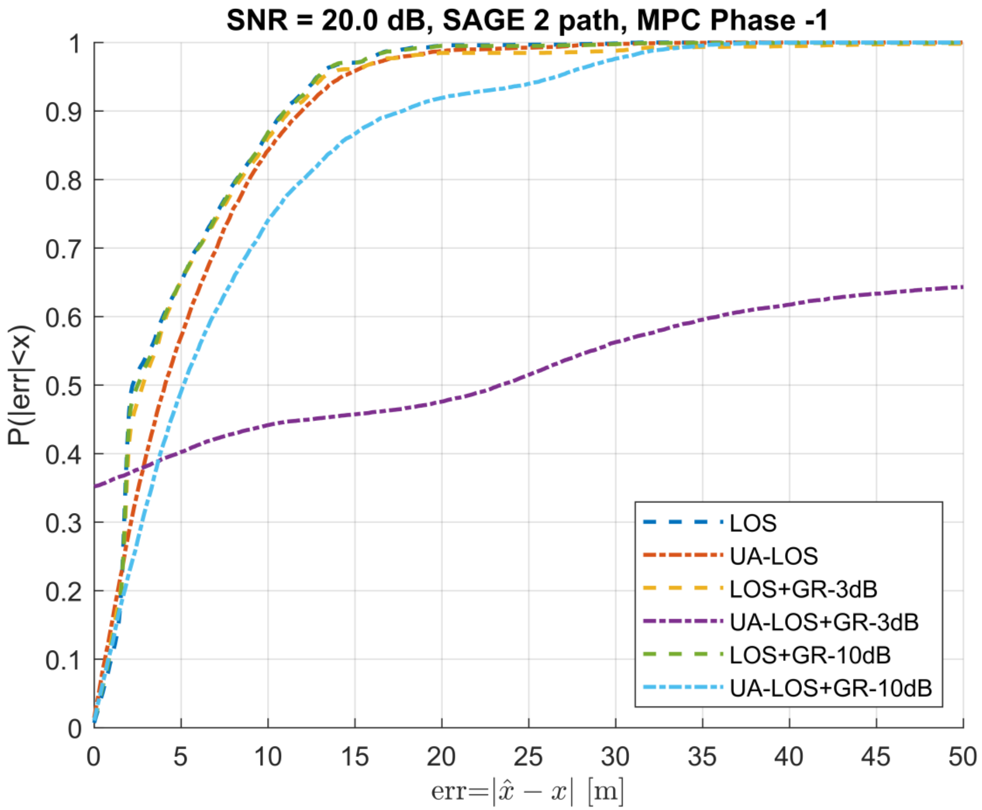
	Tap1	Tap2	Tap3	Tap4	Units
Power	0	-8	-10	-15	dB
Delay	0	117	183	333	ns
Doppler	0	43	-29	90	Km/h
Profile	Static	HalfBT	HalfBT	HalfBT	

Simulation Results

- **Take into account non detected packets (coarse sync on STF failed)**
- **Compare LOS, LOS + ground reflection (GR), UA-LOS and UA-LOS + GR with different relative path powers**
- **Ranging method:**
  1. **Packet detection and coarse estimation**
  2. **Fine estimation**
  3. **SAGE (space-alternating generalized expectation-maximization)**
- **Cumulative distribution function (CDF) of absolute distance error**
  P(|err|< x) = y %

BW=10MHz, Out-of-Phase MPC, Antenna Height 1.5 m, SNR 20 dB





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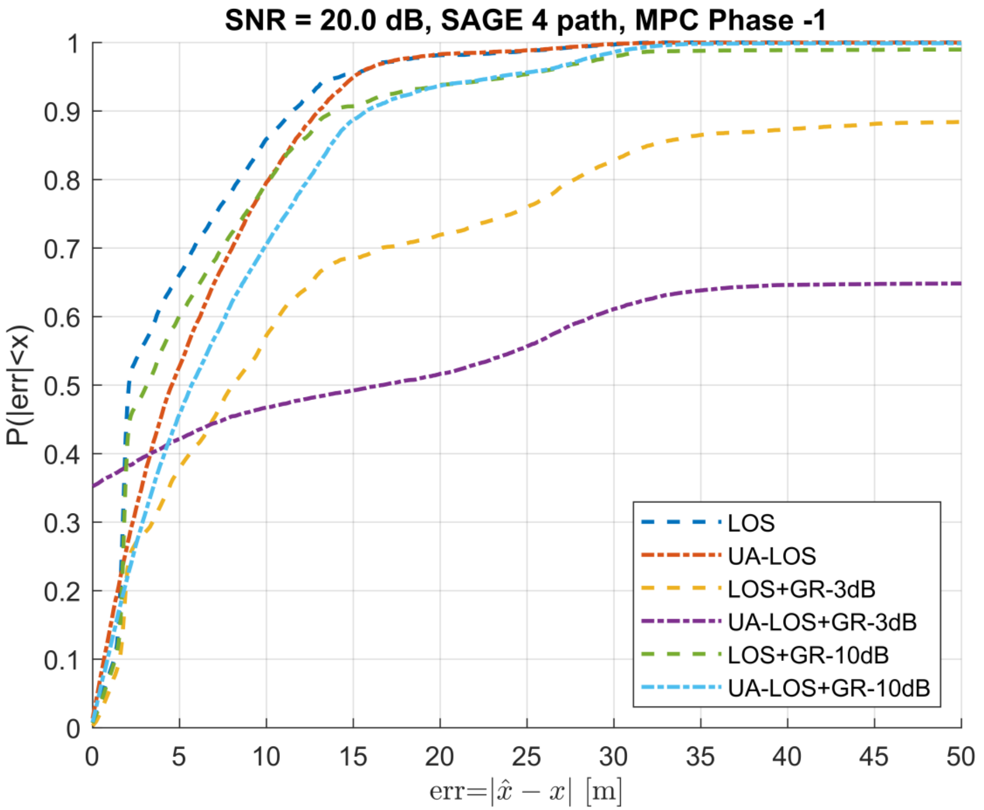
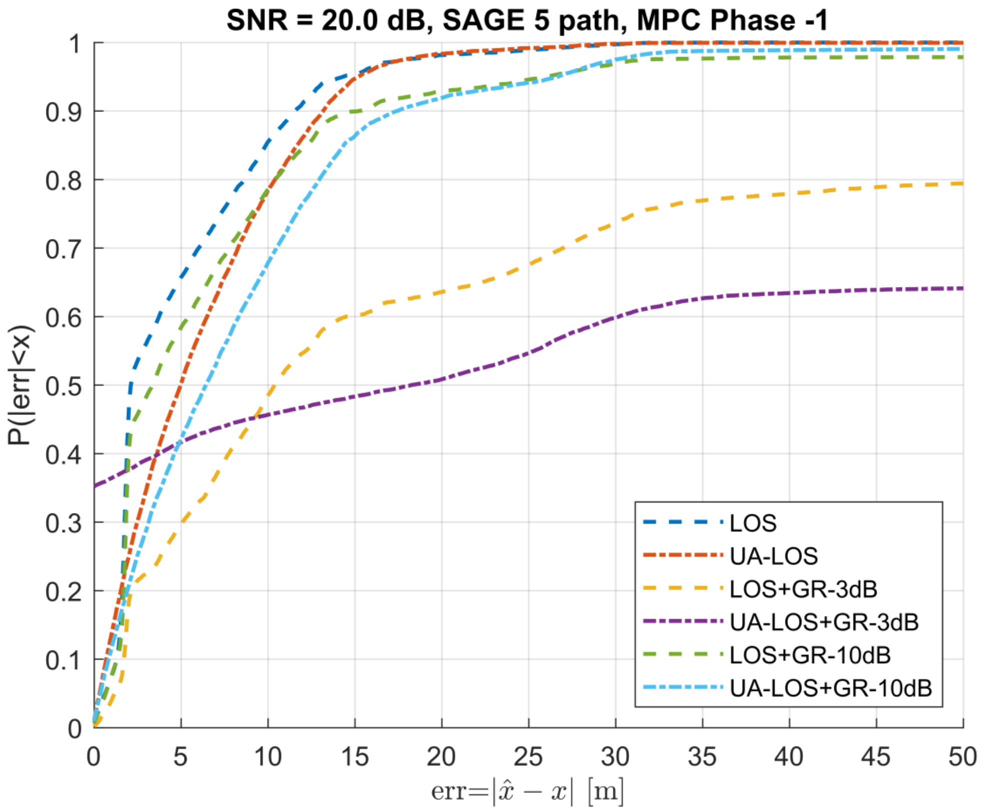
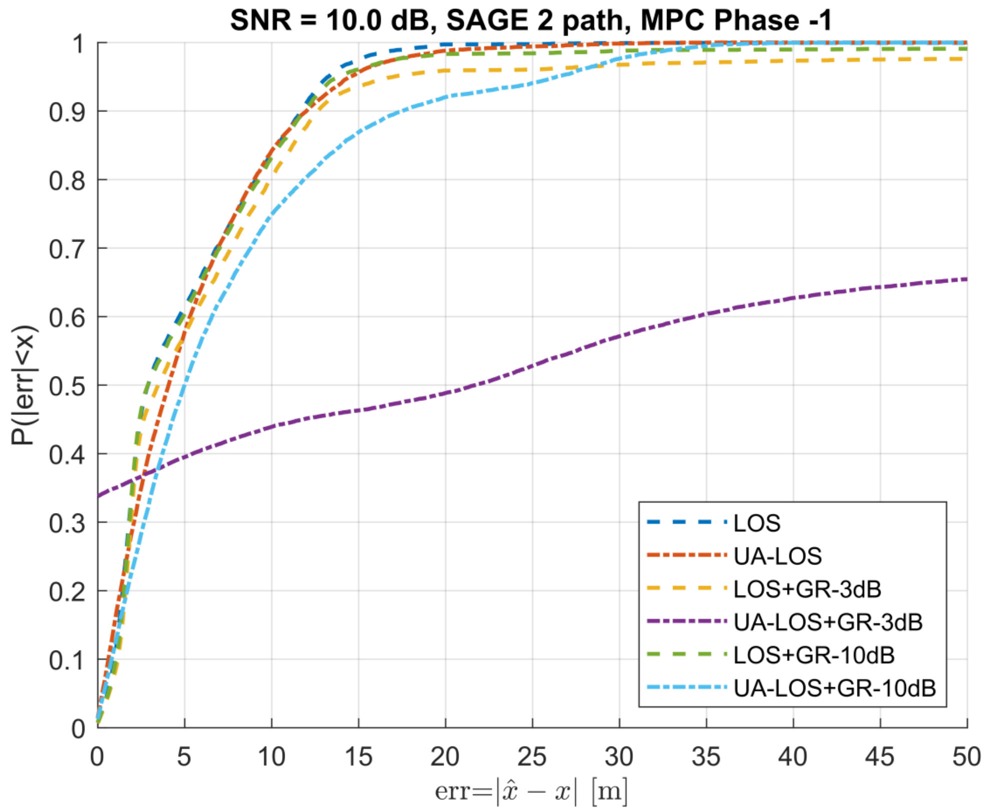
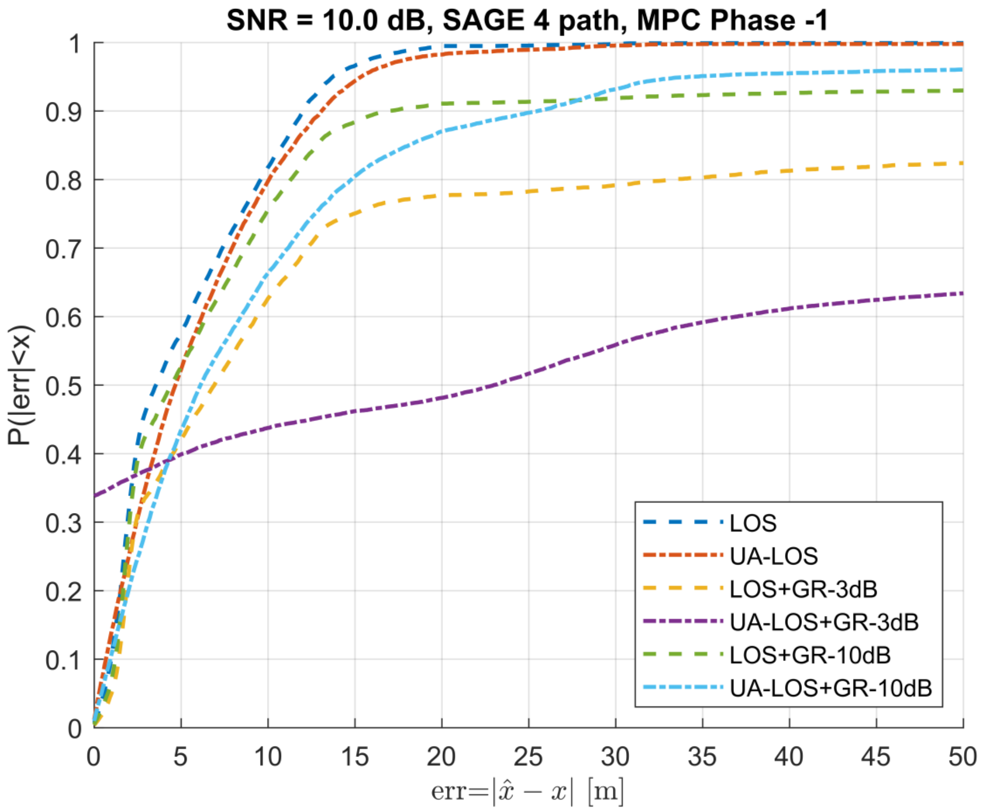




BW=10MHz, Out-of-Phase MPC, Antenna Height 1.5 m, SNR 10 dB





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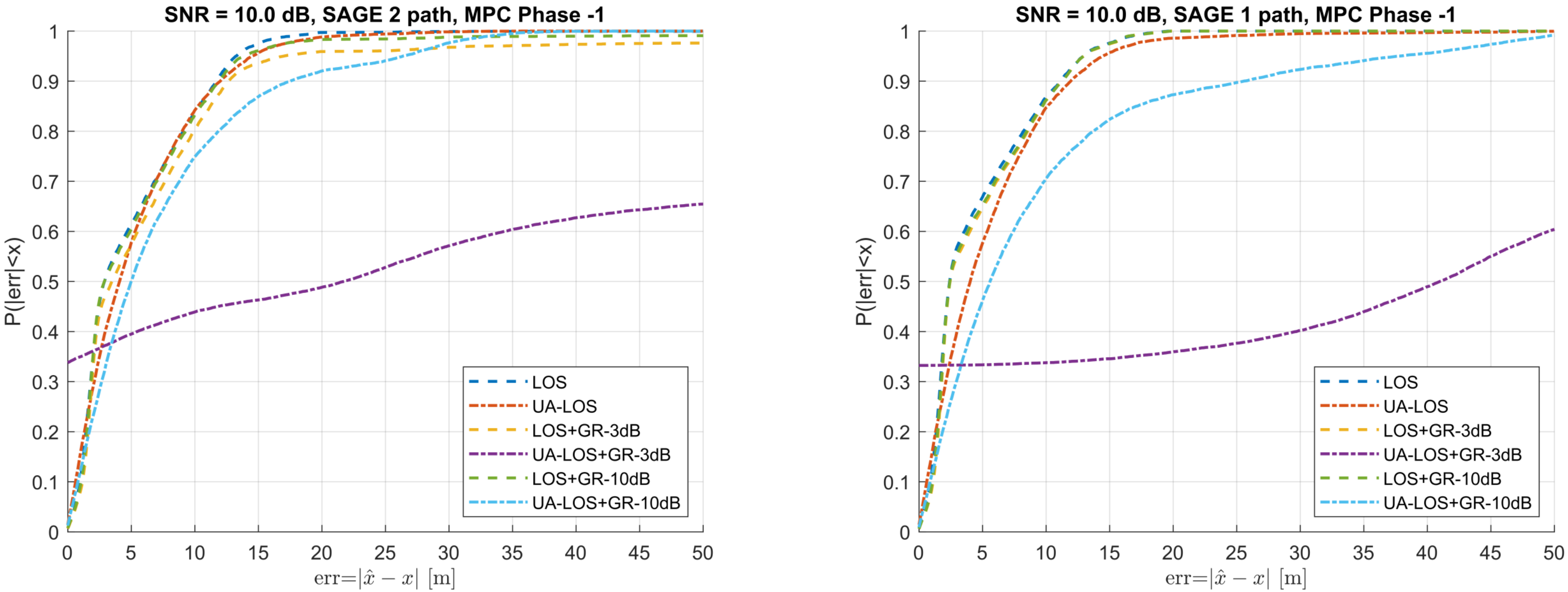
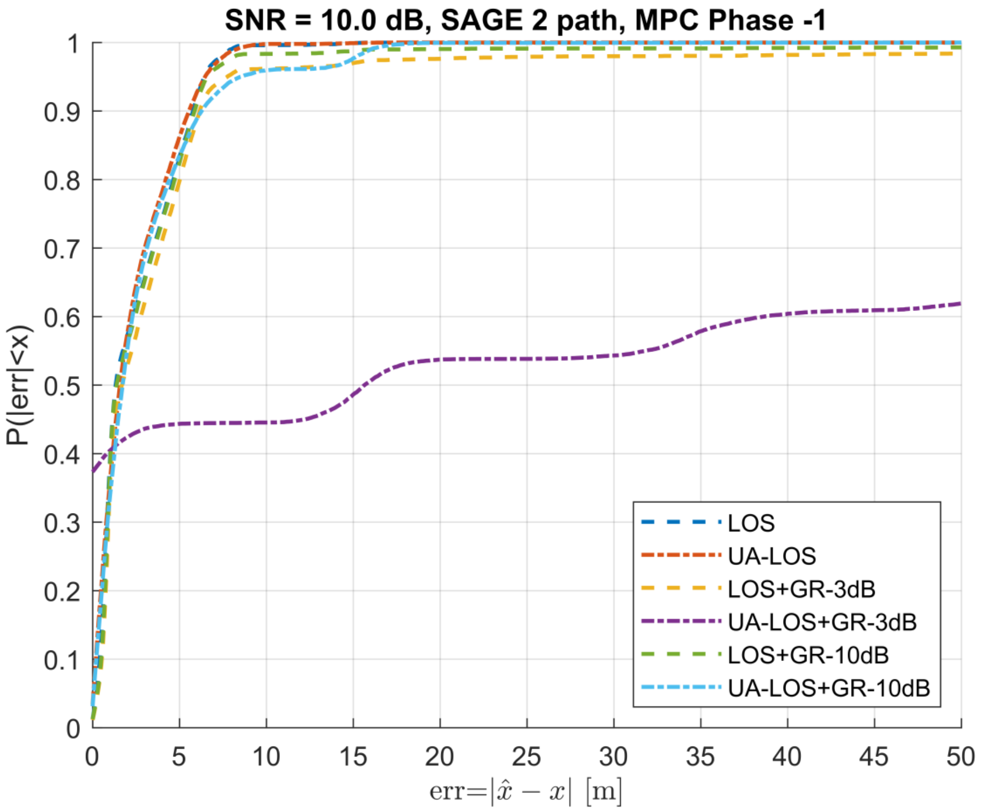
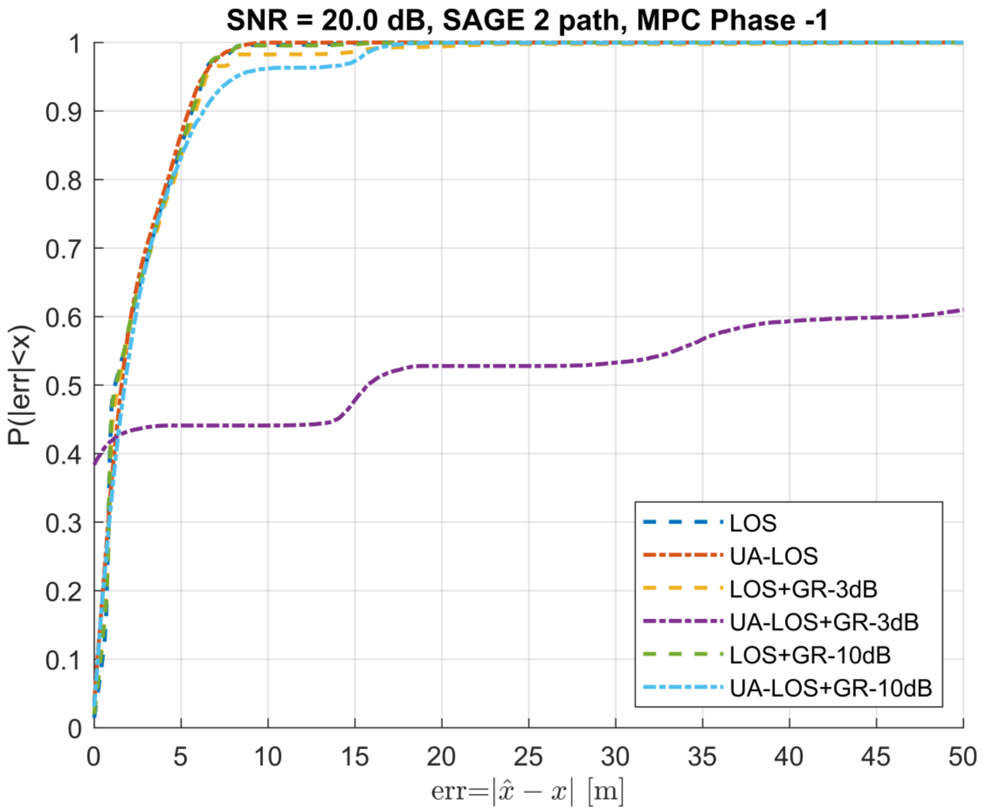
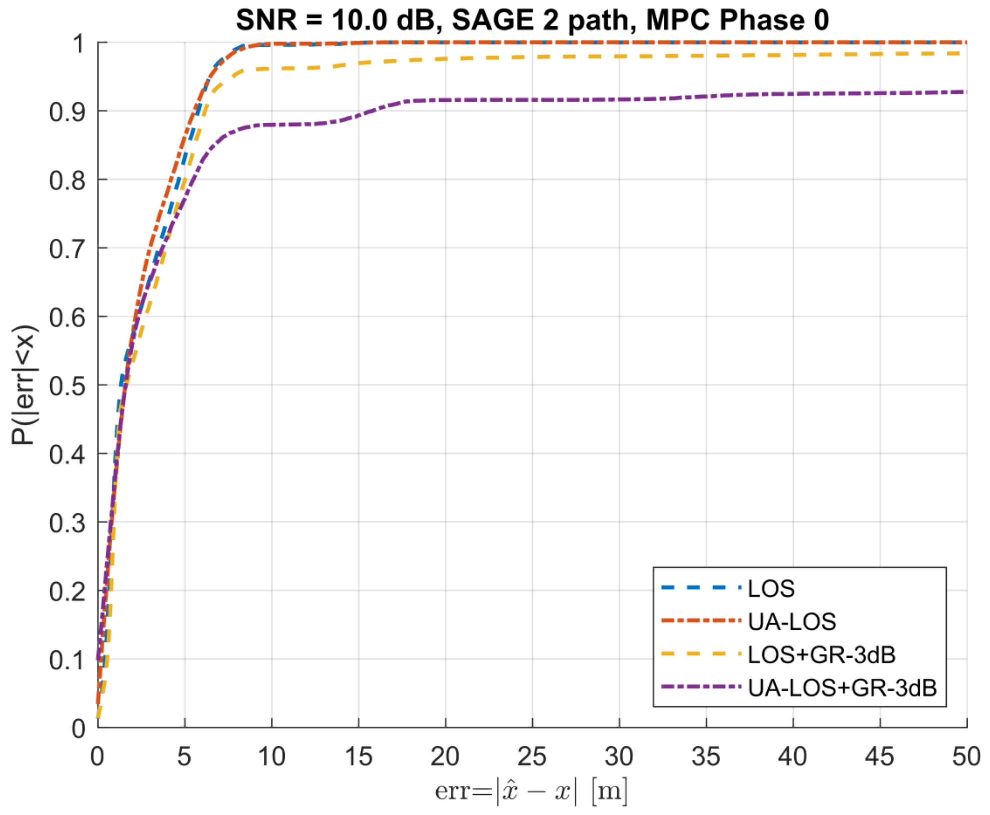


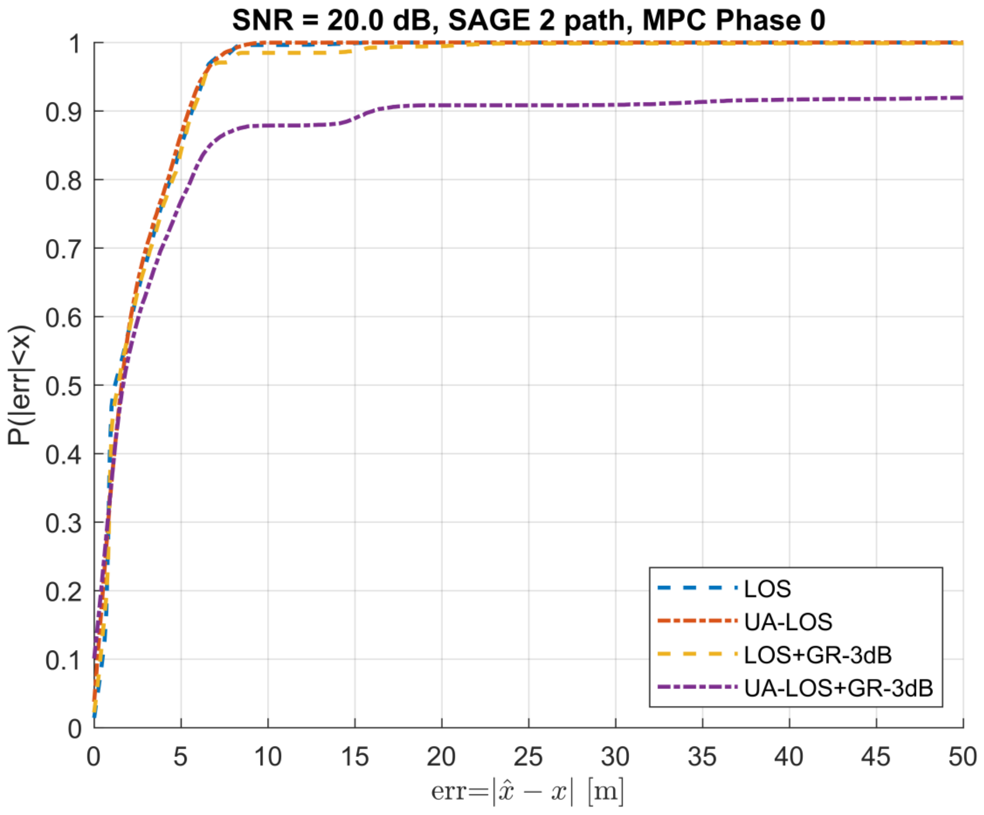
BW=20MHz, Out-of-Phase MPC, Antenna Height 1.5 m, SNR 10 dB, 20 dB



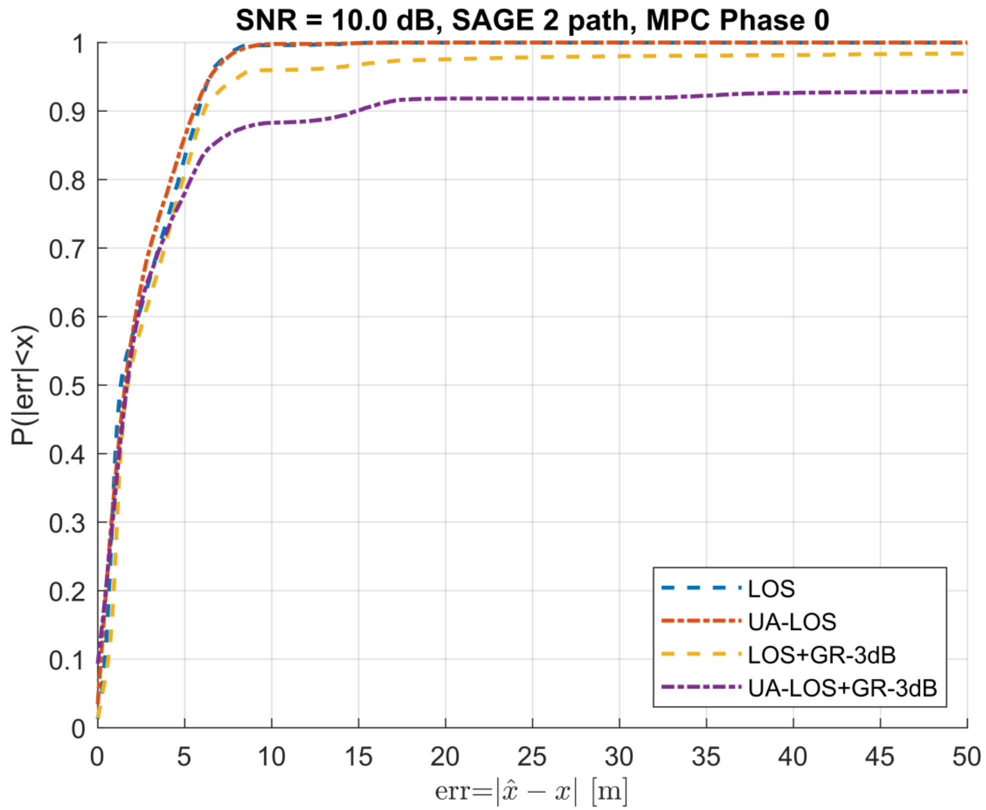


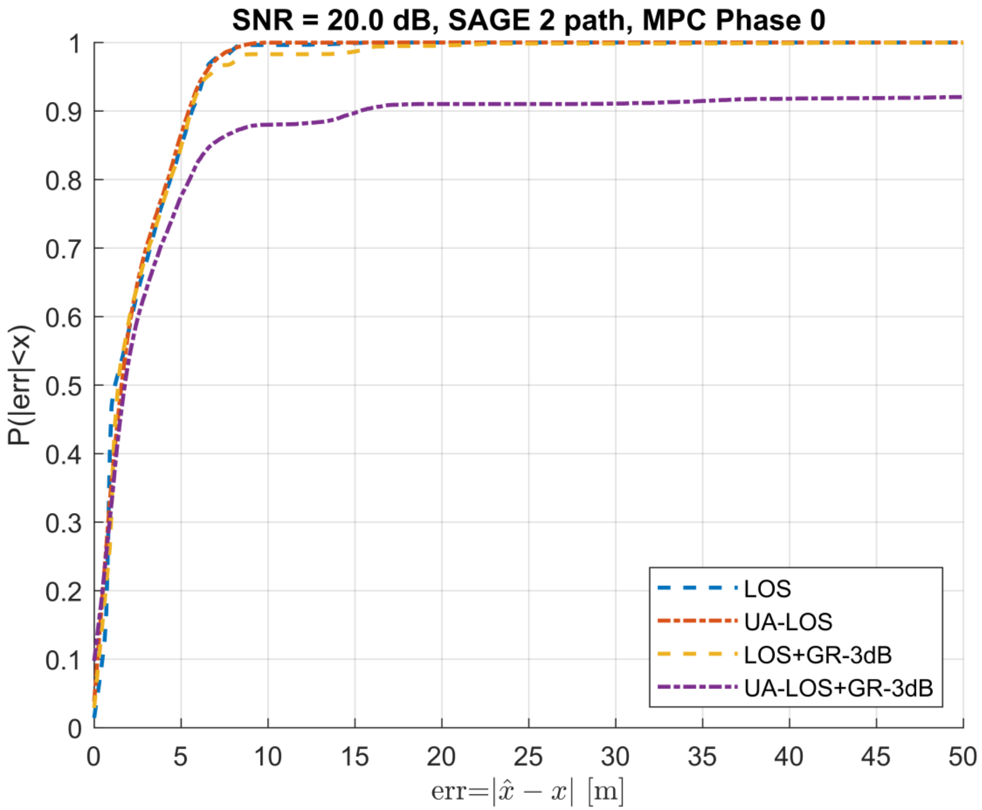
BW=20MHz, Random Phase MPC, Antenna Height 1.5m, SNR 10 dB, 20 dB





BW=20MHz, Random Phase MPC, Antenna Height 4 m, SNR 10 dB, 20 dB





Conclusion

- **Influence of BW = 10 MHz or 20 MHz to resolve delay-close MPCs**
  - Significant improvement by doubling the BW
- **Influence of channel models with delay-close MPCs (ground reflection)**
  - Significant decrease of ranging accuracy
  - Optimistic results with standard tapped-delay line models [2]
  - Geometric stochastic channel models would give more realistic results [5]
- **Saftey critical applications [6] require 1% ranging accuracy**
  ➔ 1m accuracy at 100 m ➔ P(|err|<1 m)< 40%

➔Larger bandwidth needed for improved ranging accuracy:
11bd 60 GHz mode with BW > 1 GHz

References

[1] IEEE 802.11-19/0788 Considerations on Ranging in NGV

[2] IEEE 802.11-19/0859 Ranging Performance in 11bd

[3] IEEE 802.11-18/1480 V2X Simulation Model

[4] IEEE 802.11-18/0858 C2C Channel Model Overview

[5] IEEE 802.11-19/0034 Considerations on Vehicular Channel Models

[6] IEEE 802.11-19/1342-r1 11bd Use Cases