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 $\Rightarrow$ Resolution in distance and delay

<table>
<thead>
<tr>
<th>Bandwidth / [MHz]</th>
<th>Distance Resolution / [m]</th>
<th>Delay Resolution/ [ns]</th>
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<tbody>
<tr>
<td>10</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>15</td>
<td>50</td>
</tr>
<tr>
<td>1000</td>
<td>0.3</td>
<td>1</td>
</tr>
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</table>

- Operation frequency $f$ and distance $d$ $\Rightarrow$ 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
LOS … Line of Sight
Rx … Receiver
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

Tx height
LOS
MPC
Rx height
Reflecting Surface
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)

<table>
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<tr>
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<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Channel 1</td>
<td>AWGN</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Channel 2</td>
<td>UA-LOS</td>
<td>No</td>
<td></td>
<td></td>
<td>10/20</td>
<td>1-5 paths</td>
<td>10/20</td>
</tr>
<tr>
<td>Channel 3</td>
<td>AWGN</td>
<td>Yes</td>
<td>AWGN</td>
<td>-3, -10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel 4</td>
<td>UA-LOS</td>
<td>Yes</td>
<td>AWGN</td>
<td>-3, -10</td>
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Table 2: Urban Approaching (UA) LOS Parameters [4]

<table>
<thead>
<tr>
<th>Tap</th>
<th>Power</th>
<th>Delay</th>
<th>Doppler</th>
<th>Profile</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Static</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-8</td>
<td>117</td>
<td>43</td>
<td>HalfBT</td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>183</td>
<td>-29</td>
<td>HalfBT</td>
</tr>
<tr>
<td></td>
<td>-15 dB</td>
<td>333 ns</td>
<td>90Km/h</td>
<td>HalfBT</td>
</tr>
</tbody>
</table>
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
  \[ P(|\text{err}| < x) = y \% \]
BW=10MHz, Out-of-Phase MPC, Antenna Height 1.5 m, SNR 20 dB
BW=10MHz, Out-of-Phase MPC, Antenna Height 1.5 m, SNR 20 dB

SNR = 20.0 dB, SAGE 4 path, MPC Phase -1

SNR = 20.0 dB, SAGE 5 path, MPC Phase -1
BW=10MHz, Out-of-Phase MPC, Antenna Height 1.5 m, SNR 10 dB
BW=10MHz, Out-of-Phase MPC, Antenna Height 1.5 m, SNR 10 dB
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]

- **Safety critical applications [6] require 1% ranging accuracy**
  - 1m accuracy at 100 m \( \Rightarrow P(|err|<1 \text{ m})< 40\% \)

  \( \Rightarrow \text{Larger bandwidth needed for improved ranging accuracy:} \)
  - 11bd 60 GHz mode with BW > 1 GHz
References

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