Experimental analysis of multipath effects on GNSS positioning in urban canyon

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INTRODUCTION

Global navigation satellite system (GNSS) can provide us with three-dimensional coordinates information of anyplace on the earth. However, in densely populated urban areas, the obstruction and reflection of signals from high-rise buildings lead to bad geometries and multipath effects, which will cause the decline of GNSS positioning accuracy.

The reason why the multipath effects can affect GNSS positioning is that it produces time-varying deviation of GNSS signal and leads to an error of pseudo-range (PRE). Therefore, it is meaningful to study the influence of the multipath effects on PRE in urban canyon scenarios.

Based on channel measurements in an urban canyon scenario at both 1.575 GHz and 1.207 GHz, we analyze and model the root mean square (RMS) delay spread (DS) characteristics in multipath channels and study the effect of the transmitter-receiver (Tx-Rx) elevation angle on PRE and the dependence of PRE on RMS DS, respectively.

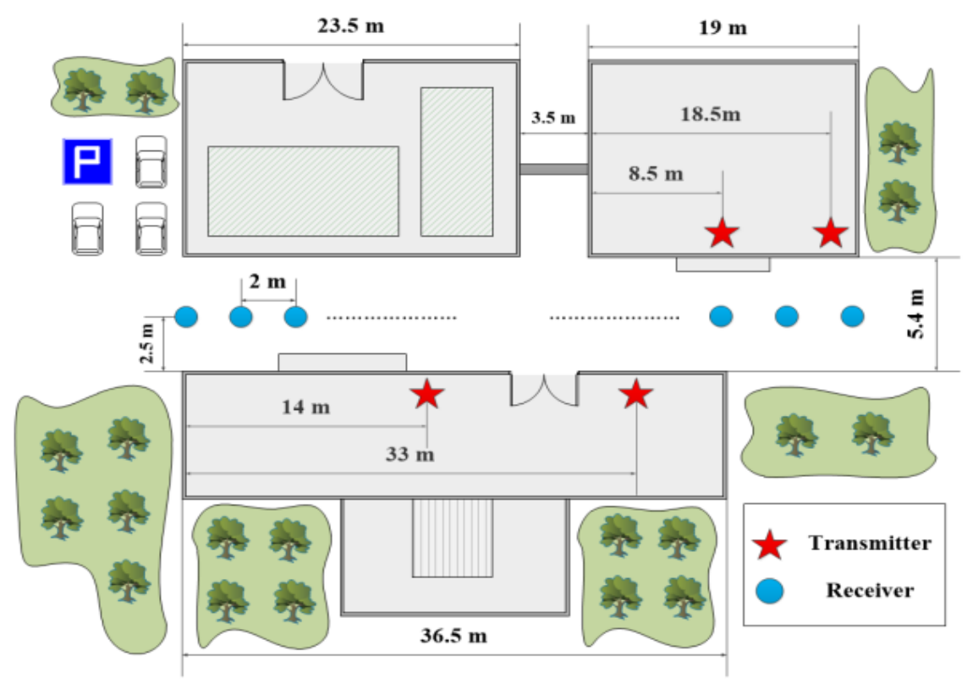
MEASUREMENT SETTING AND ENVIRONMENT

The channel measurement was carried out in a urban street canyon which has a narrow structure with a dimension of 5.4 m (width) by 17 m (height) by 46 m (length).

MEASUREMENT SYSTEM PARAMETER.

Scenario	Urban canyon
CF	1.207/1.575 GHz
Symbol rate	100 Mbps
Bandwidth	200 MHz
Tx/Rx antenna type	Omnidirectional/ Omnidirectional
Tx1/Tx2/Tx3/Tx4/Rx height	16.4/16.4/13.2/17.5/1.5 m
Modulation	BPSK

A vector signal generator (R&S SMW 200A) is used as the transmitter to generate a pseudo-random code with a length of 511 while the receiver uses the spectrum analyzer (R&S FSW 43) to record and capture channel information.

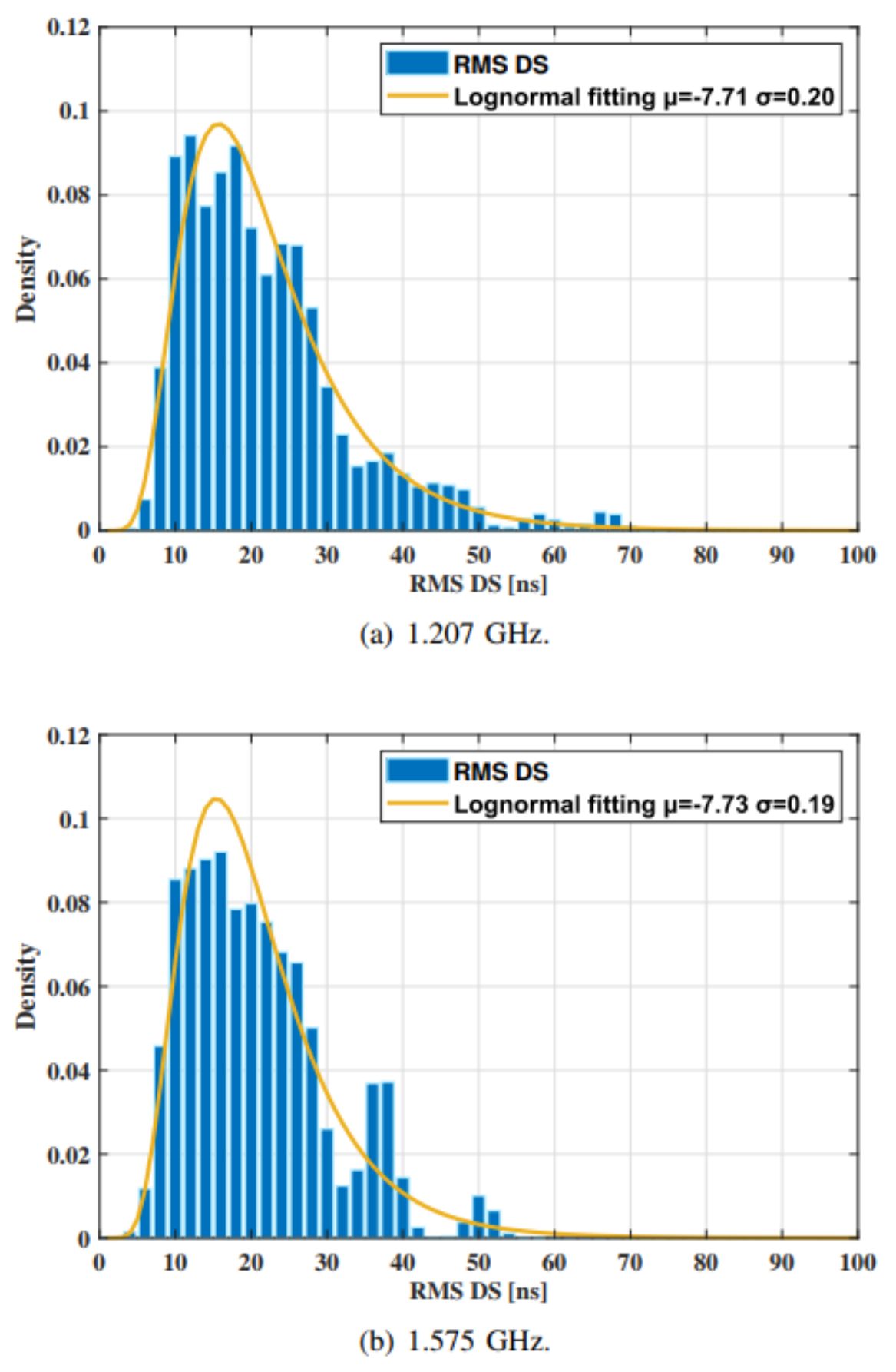


DATA PROCESSING

Main formulas used in data processing and their definitions.

Formulas	Definitions
$h(t,\tau)=\sum_{n=1}^{N}\alpha_n e^{j\theta_n(t)}\delta(\tau-\tau_n)$	Impulse response of the channel (CIR)
$P(t_m,\tau_n)=\lvert h(t_m,\tau_n)\rvert^2$	Power delay profile (PDP)
$\tau_{rms}=\sqrt{\frac{\sum_{n=1}^{N}(\tau_n-\tau_{mean})^2P(\tau_n)}{\sum_{n=1}^{N}P(\tau_n)}}$ $\tau_{mean}=\frac{\sum_{n=1}^{N}P(\tau_n)\tau_n}{\sum_{n=1}^{N}P(\tau_n)}$	Root mean square delay spread (RMS DS)
$S_{mp}(t,\tau)=h(t,\tau)\otimes C(\tau)$	Simulated GNSS multipath signal
$E=\frac{\overline{S_{mp}(t,\tau)C(\tau-\tau_1+d/2)}}{\overline{S_{mp}(t,\tau)C(\tau-\tau_1)}}$ $L=\frac{\overline{S_{mp}(t,\tau)C(\tau-\tau_1-d/2)}}{\overline{S_{mp}(t,\tau)C(\tau-\tau_1)}}$ $\delta=\frac{1}{2}(E-L)$	Early minus late (E-L) model of GNSS software receiver
$\rho_{mp}=c\tau_{mp}$ $\tau_{mp}=\delta/fc$	Error of pseudo-range (PRE)

MEASUREMENT RESULTS AND ANALYSIS



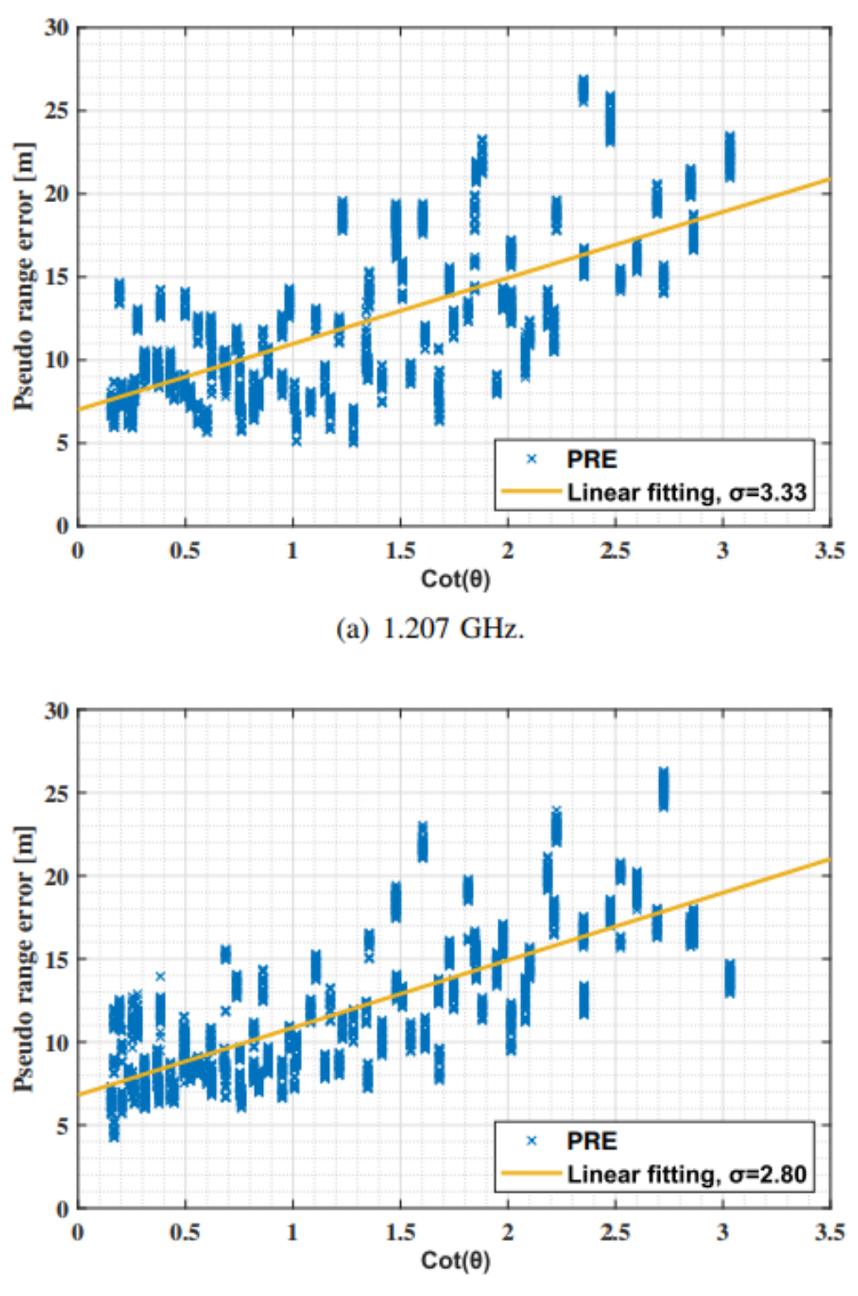
(a) 1.207 GHz.

(b) 1.575 GHz.

Fig.3 shows the probability density function (PDF) of RMS DS at 1.207 GHz and 1.575 GHz in the urban canyon scenario. Compare with the urban micro-cells scenario (UMi) in ITU-R, the μ_{lgDS} and σ_{lgDS} in the urban canyon scenario are smaller than those in UMi. The reason for this difference may be that the structure of urban canyons is narrower and smaller than that of UMi, which leads to more intensive multipath effect and shorter delay.

RMS DELAY SPREAD

Fre (GHz)	scenario	μ_{lgDS}	σ_{lgDS}
1.207	Measured	-7.71	0.20
	ITU-UMi	-7.19	0.40
1.575	Measured	-7.73	0.19
	ITU-UMi	-7.19	0.40



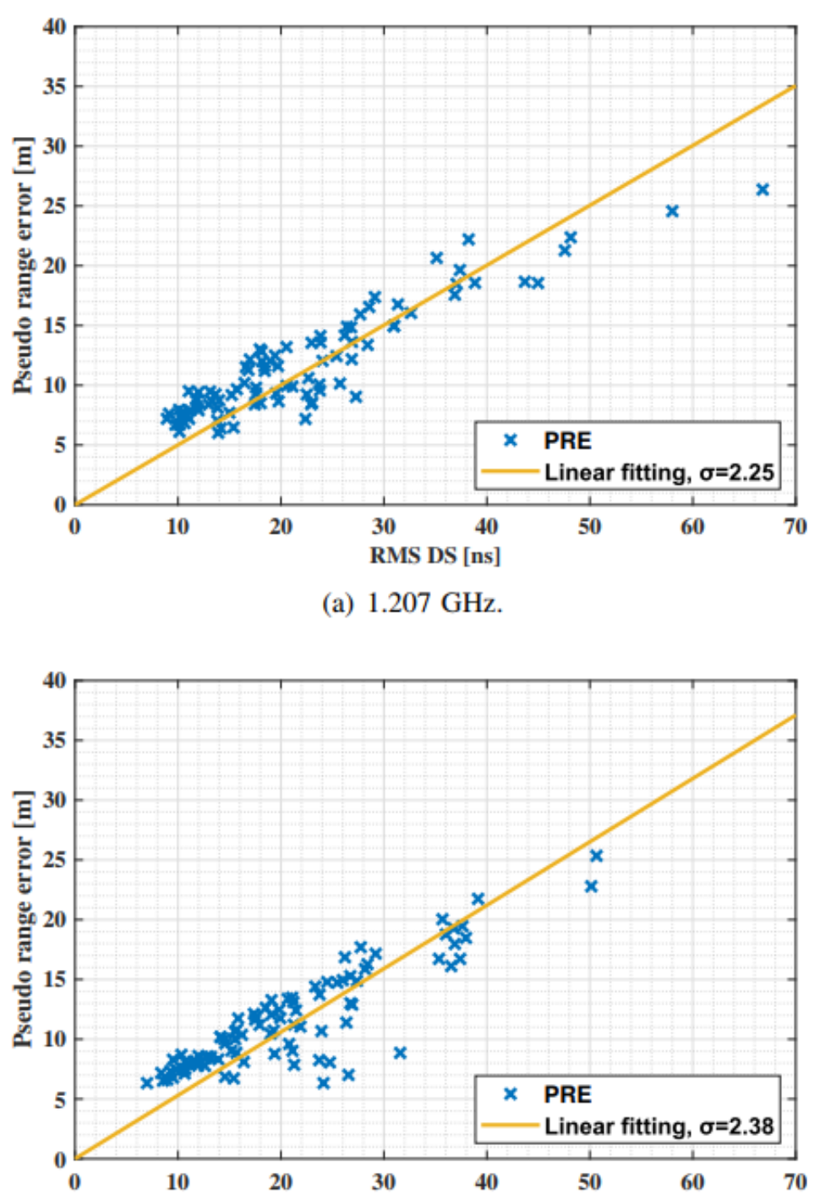
(a) 1.207 GHz.

(b) 1.575 GHz.

$$PRE_{1.207}=7.01+3.97cot(\theta)$$

$$PRE_{1.575}=6.81+4.06cot(\theta)$$

Fig.4 shows that PRE increase with the increase of the cot(θ) at both 1.207 GHz and 1.575 GHz. The slope and intercept at 1.575 GHz are similar to those at 1.207 GHz, but the standard deviation at 1.575 GHz is 0.53 less than that at 1.207 GHz. This is mainly because the signal at 1.207 GHz has experienced smaller attenuation, and more multipath components could reach Rx, which results in a stronger multipath effect.



(a) 1.207 GHz.

(b) 1.575 GHz.

Fig.5 shows that the PRE increases linearly with the increase of RMS DS. When RMS DS increases by 1 ns, PRE increases by 0.50 meters at 1.207 GHz and 0.53 meters at 1.575 GHz. It can be seen that there is a good and similar linear relationship between PRE and RMS DS at two frequencies. Based on this, we may use the known multipath delay characteristics of the channel to predict the error of pseudo-range and improve the accuracy of GNSS positioning.

$$PRE_{1.207}=0.50\tau_{rms}$$

$$PRE_{1.575}=0.53\tau_{rms}$$

CONCLUSION

- ✓ The fitting parameters of RMS DS at 1.575 GHz and 1.207 GHz in the urban canyon scenario is 0.5 dB and 0.2 dB smaller than that in UMi respectively.
- ✓ The multipath effects on GNSS positioning of low-frequency signals are more abundant and complex in the scenario.
- ✓ There is a linear relationship between PRE and RMS DS. that is, when RMS DS increases by 1 ns, PRE increases by 0.50 meters at 1.207 GHz and 0.53 meters at 1.575 GHz.

ACKNOWLEDGEMENT

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