Test of Covid-19 Bluetooth LE Localization Precision
Interim Measurement Report

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1 Introduction

The goal of the DCAITI student project *Test of Covid-19 Bluetooth LE localization precision* at TU Berlin is to measure and evaluate how and how precise Bluetooth distance estimation works in real world scenarios. Our first measurements have shown that both, transmitting and receiving smartphone models influence the measured RSSI value and therefore the calculated distance between them. As this might be interesting for the development of contact tracing apps, we want to share this report and the underlying data.

2 Measurement Setup

We measured the RSSI level of BLE advertisements with different smartphones at distances between 0 and 20 meters. Experiments were done in in a public park without obstacles between or around the smartphones. Between 0 and 12 meters every 0.5 m one phone transmitted while the other recorded incoming advertisements for a period of 10 seconds. Between 12 and 20 meters the distance interval was increased to 2 m.

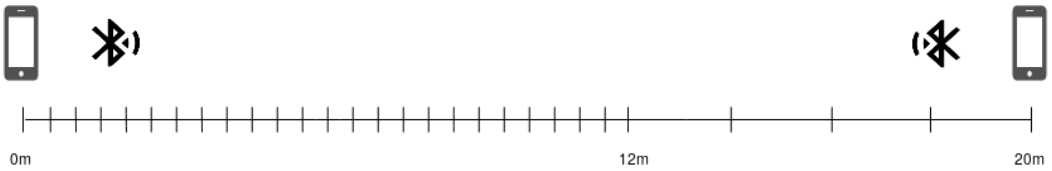

Figure 1: Measurement setup

Transmitting and receiving advertisements was realized by using Apple's and Google's BLE APIs in a self-built app.

3 Transmission Power

To compare and evaluate the following results it is necessary to keep the transmission power of each smartphone in mind.

Model	TX Power
iPhone 11 Pro	7 dBm
iPhone 7	12 dBm
Galaxy S7	1 dBm

Table 1: Transmission power of test devices

4 Results

For each pair of smartphones median (orange line), mean (blue line) and variance (blue area) was measured. Additionally the theoretical ideal relationship between RSSI level and distance is shown (green line) as well as the best fit of that curve to the measured values (dotted black line). The transmission power level was subtracted in graphs that are marked as normalized for better comparability. Two measurements were performed at the same place but on different days with different weather.
The path loss is calculated with the assumption that the path loss exponent equals two (free space propagation):

$$L_{\mathrm{dB}} = 20 \log_{10} \left(\frac{4\pi f}{c} \right) + 20 \log_{10} d \tag{1}$$

An ideal RSSI value for a given distance is calculated using:

$$P_{\mathrm{RX,dBm}} = P_{\mathrm{TX,dBm}} - 20 \log_{10} \left(\frac{4\pi f}{c} \right) + 20 \log_{10} d \tag{2}$$

4.1 Day 1

Measurements performed on 02.06.2020 (sunny, 28% humidity).

4.1.1 iPhone 7 - iPhone 11 Pro

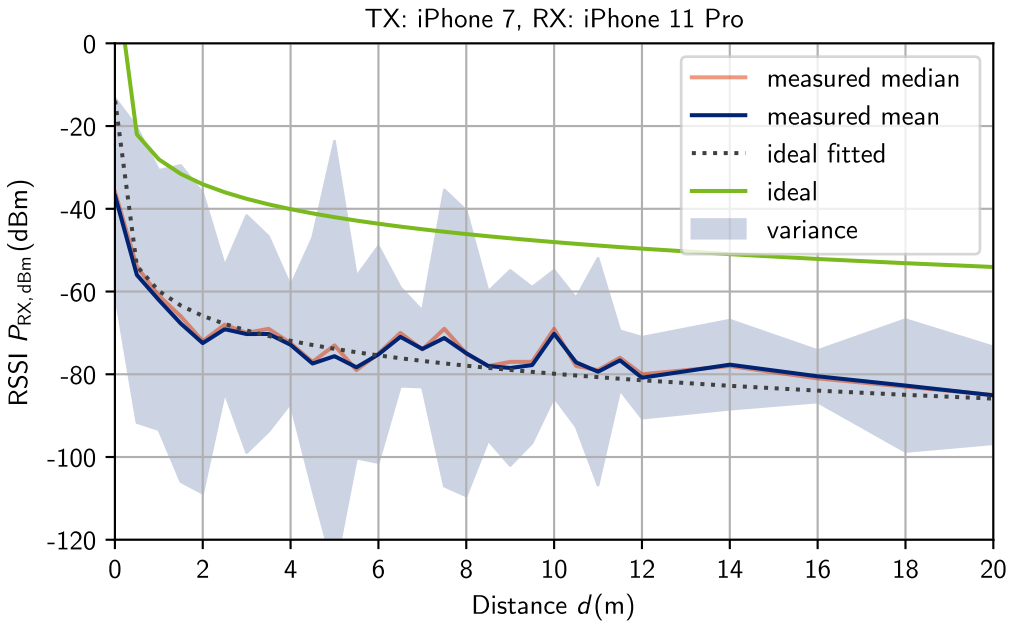

Figure 2: RSSI vs distance, transmitter: iPhone 7, receiver: iPhone 11 Pro

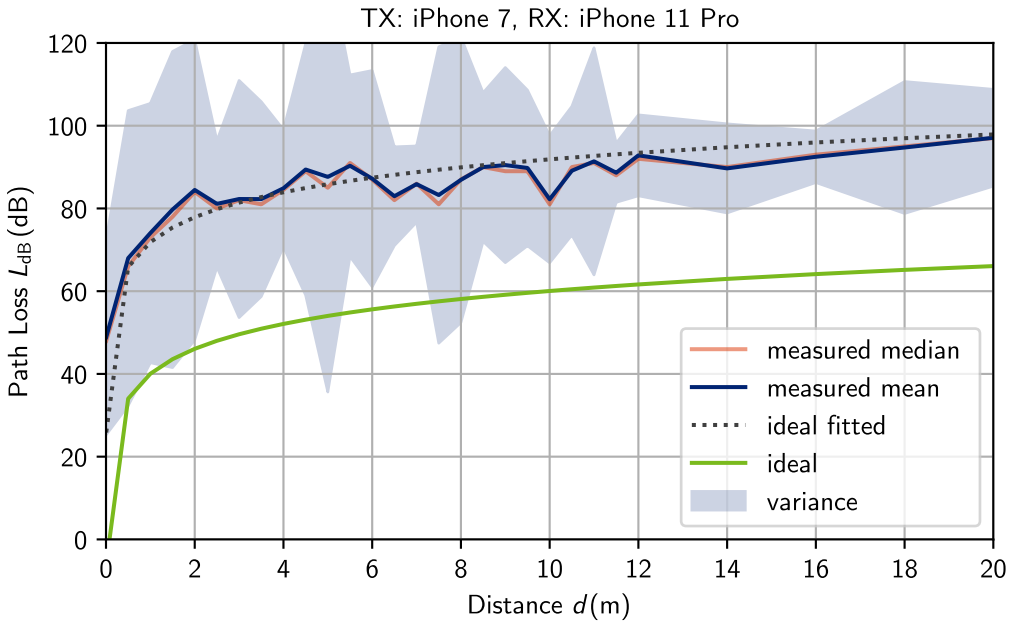

Figure 3: Path loss vs distance, transmitter: iPhone 7, receiver: iPhone 11 Pro

4.1.2 iPhone 11 Pro - iPhone 7

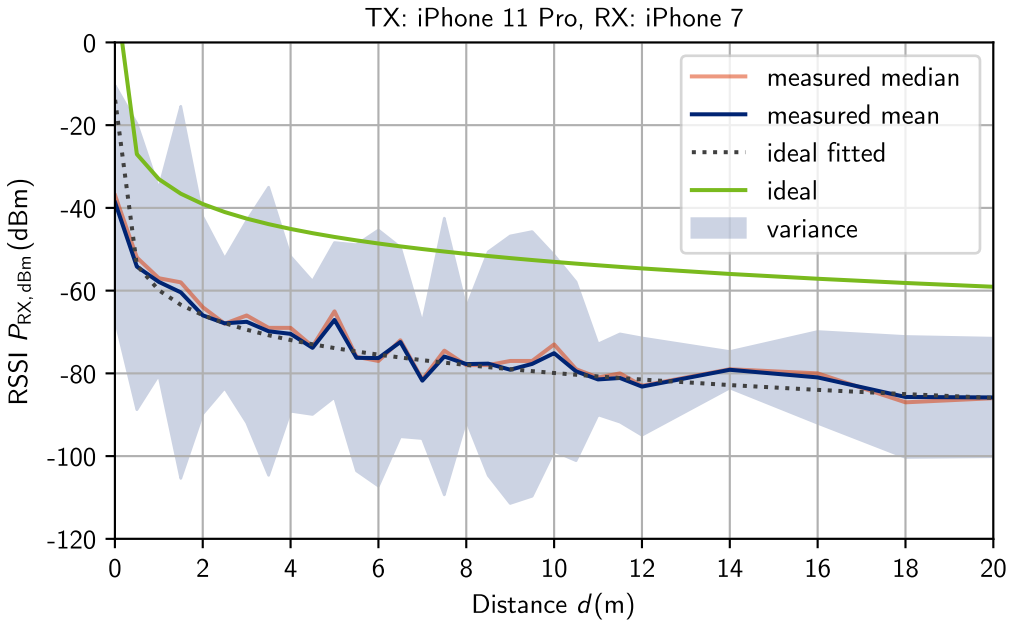

Figure 4: RSSI vs distance, transmitter: iPhone 11 Pro, receiver: iPhone 7

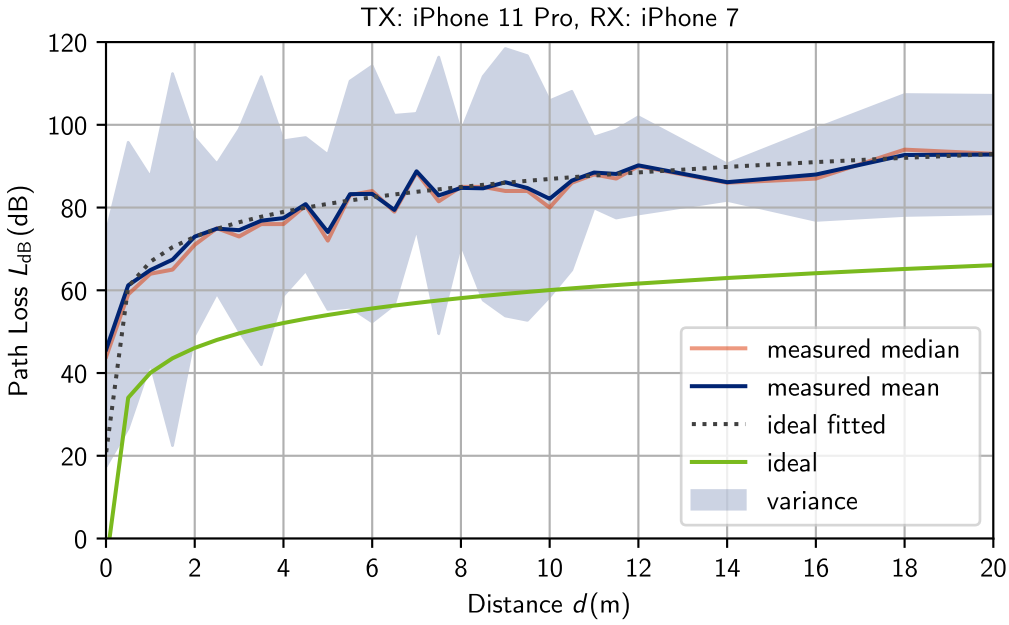

Figure 5: Path loss vs distance, transmitter: iPhone 11 Pro, receiver: iPhone 7

4.1.3 iPhone 7 - Samsung Galaxy S7

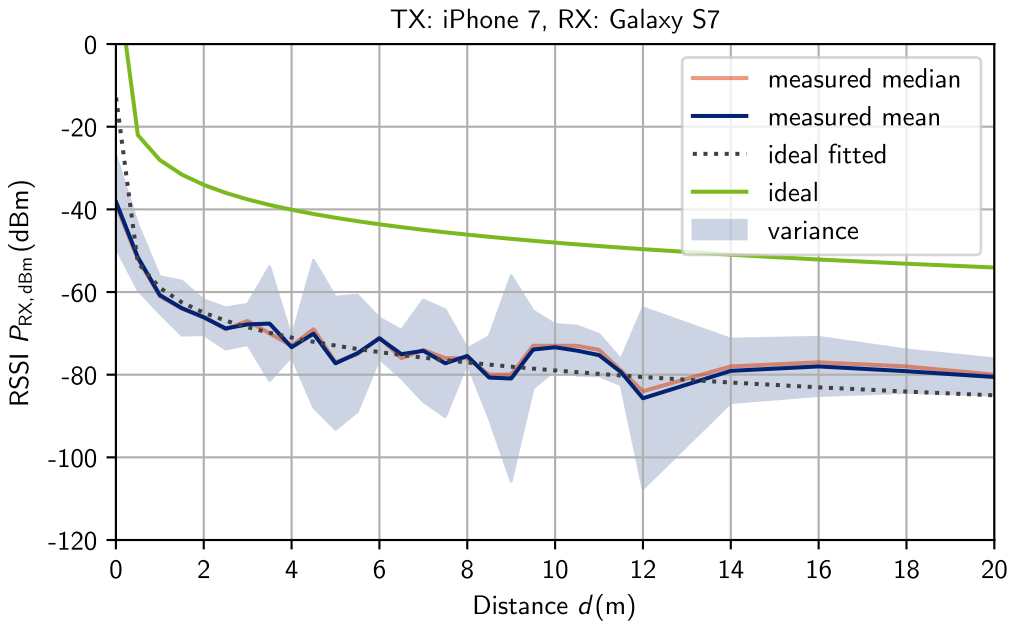

Figure 6: RSSI vs distance, transmitter: iPhone 7, receiver: Galaxy S7

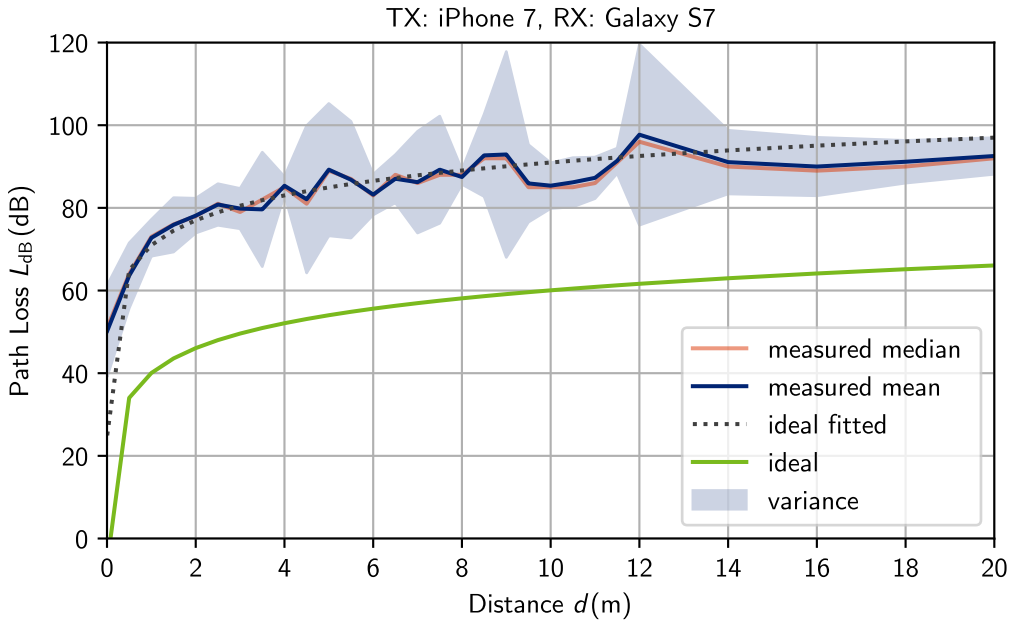

Figure 7: Path loss vs distance, transmitter: iPhone 7, receiver: Galaxy S7

4.1.4 Samsung Galaxy S7 - iPhone 7

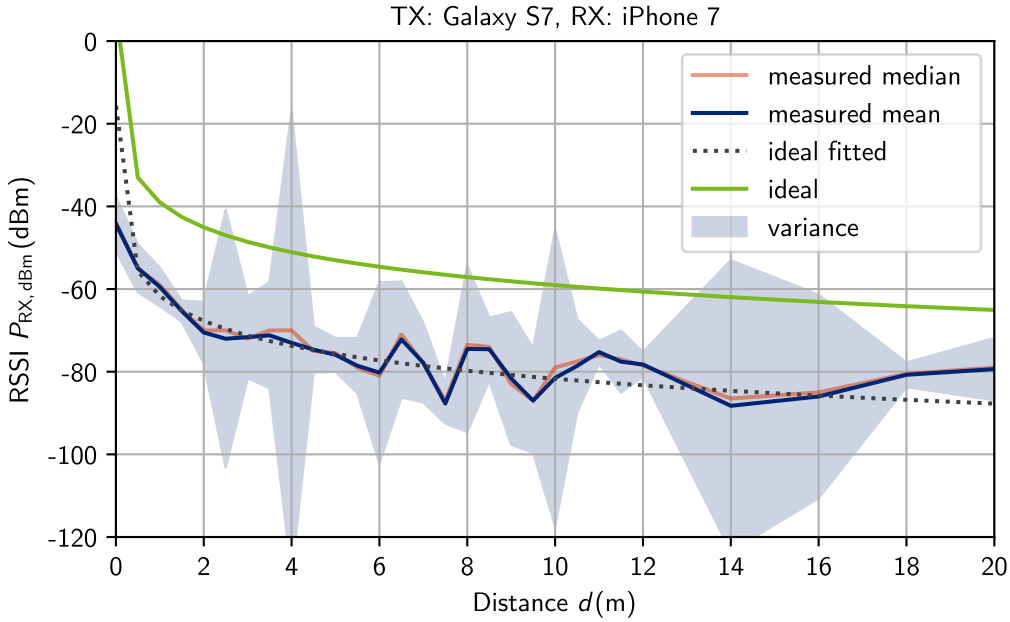

Figure 8: RSSI vs distance, transmitter: Galaxy S7, receiver: iPhone 7

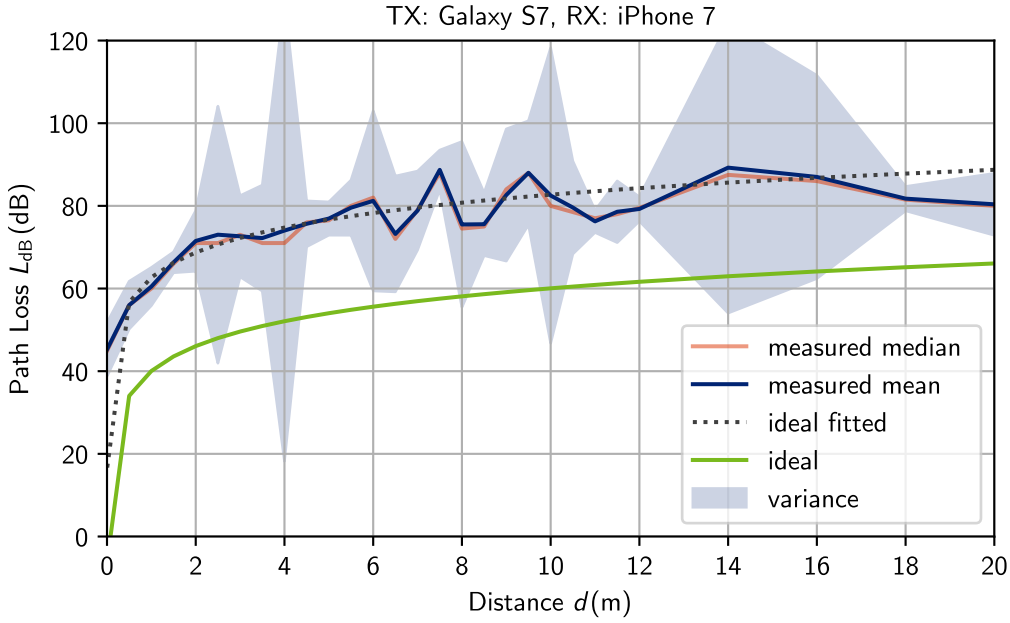

Figure 9: Path loss vs distance, transmitter: Galaxy S7, receiver: iPhone 7

4.1.5 iPhone 11 Pro - Samsung Galaxy S7

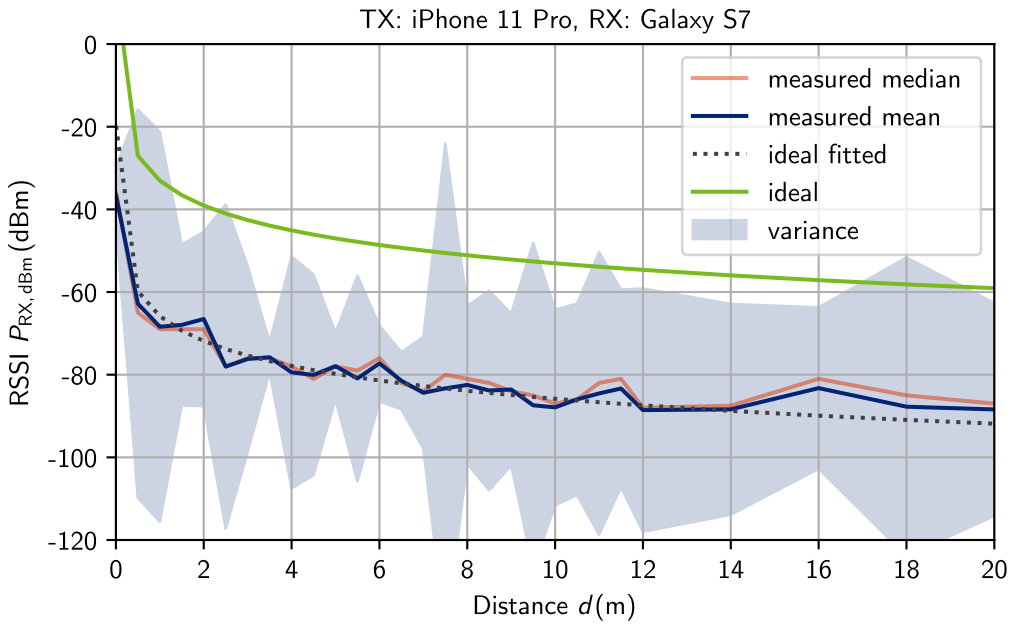

Figure 10: RSSI vs distance, transmitter: iPhone 11 Pro, receiver: Galaxy S7

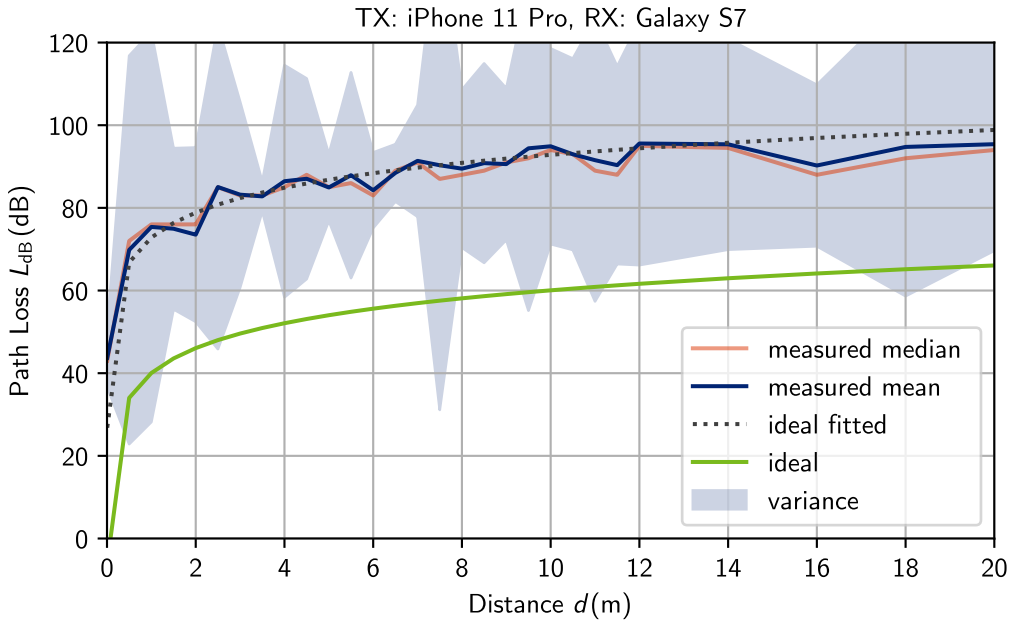

Figure 11: Path loss vs distance, transmitter: iPhone 11 Pro, receiver: Galaxy S7

4.1.6 Samsung Galaxy S7 - iPhone 11 Pro

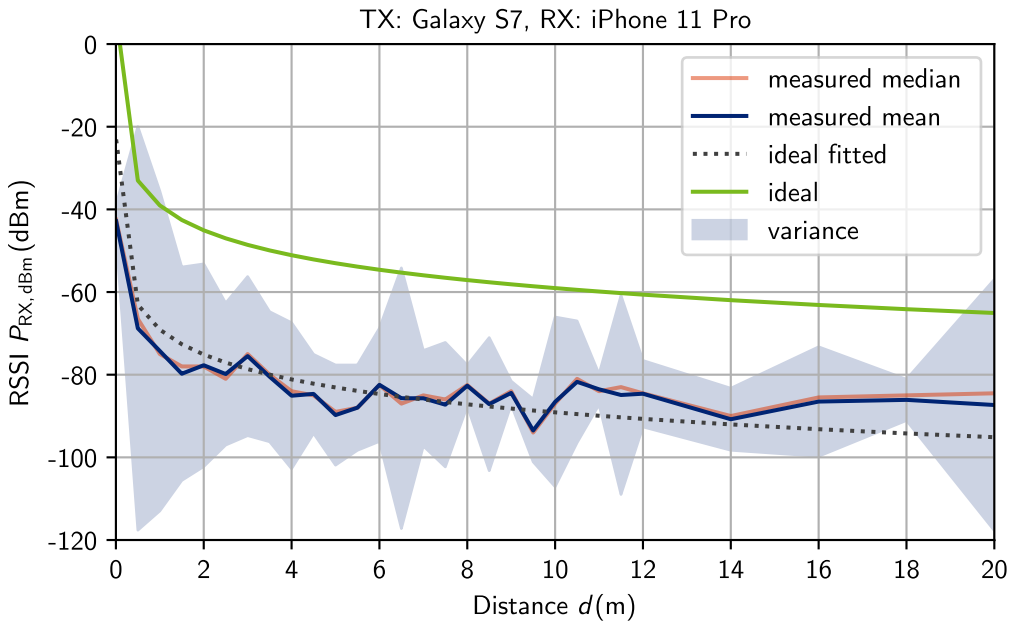

Figure 12: RSSI vs distance, transmitter: Galaxy S7, receiver: iPhone 11 Pro

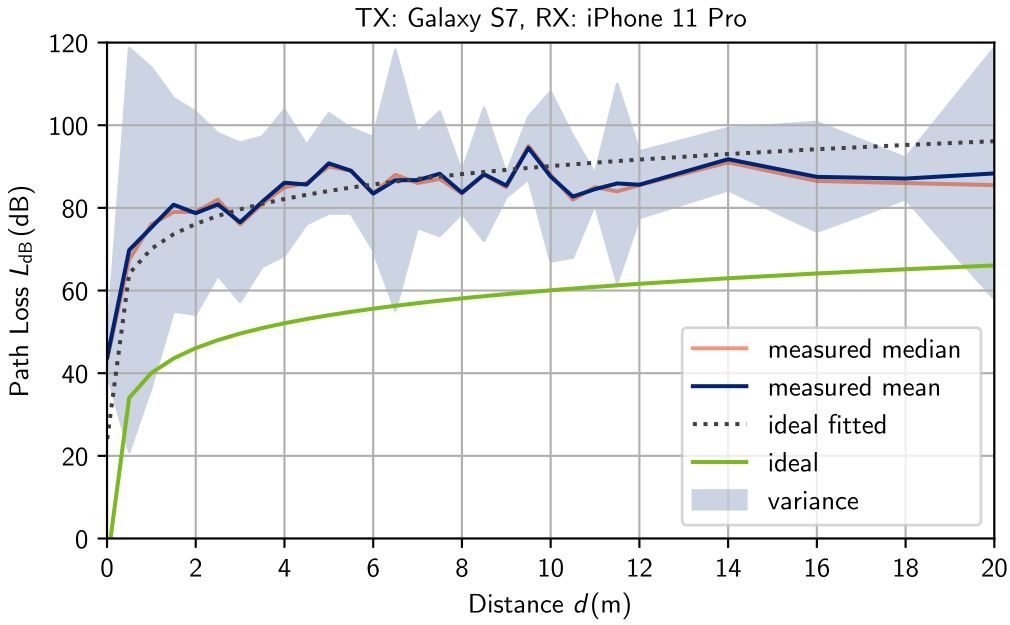

Figure 13: Path loss vs distance, transmitter: Galaxy S7, receiver: iPhone 11 Pro

4.2 Comparison of results

4.2.1 RSSI mean of all devices

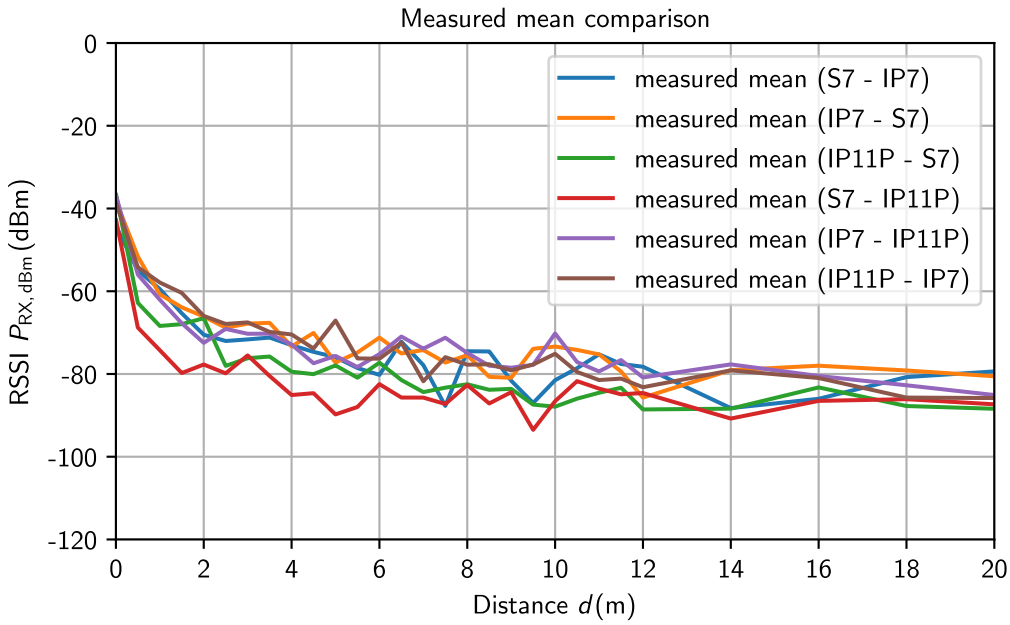

Figure 14: Comparison of mean RSSI to distance graphs

4.2.2 Ideal fitted RSSI of all devices

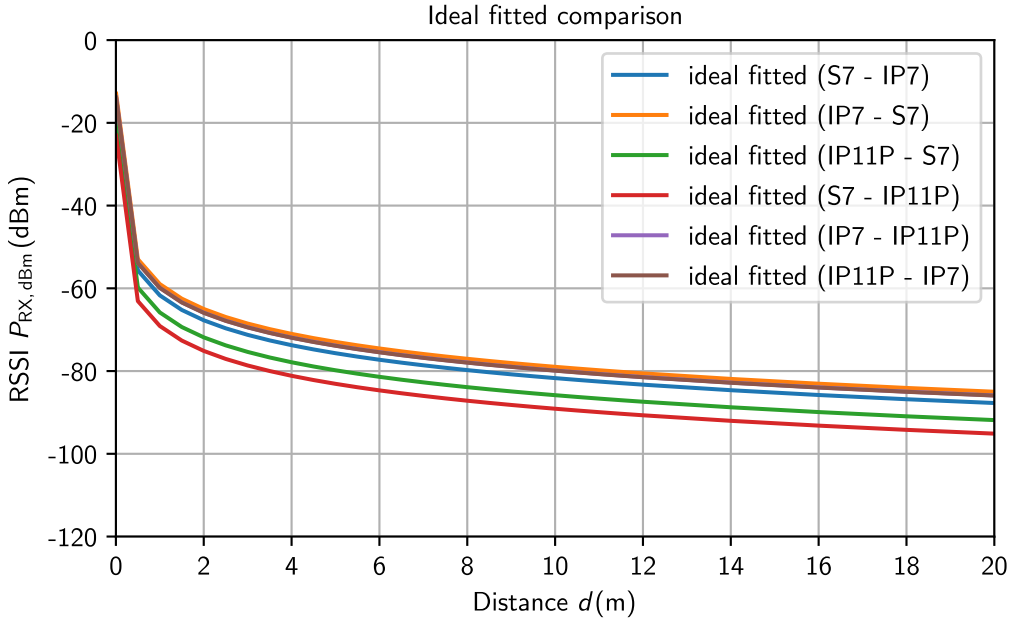

Figure 15: Comparison of fitted ideal RSSI to distance graphs

4.2.3 RSSI mean of all devices (normalized)

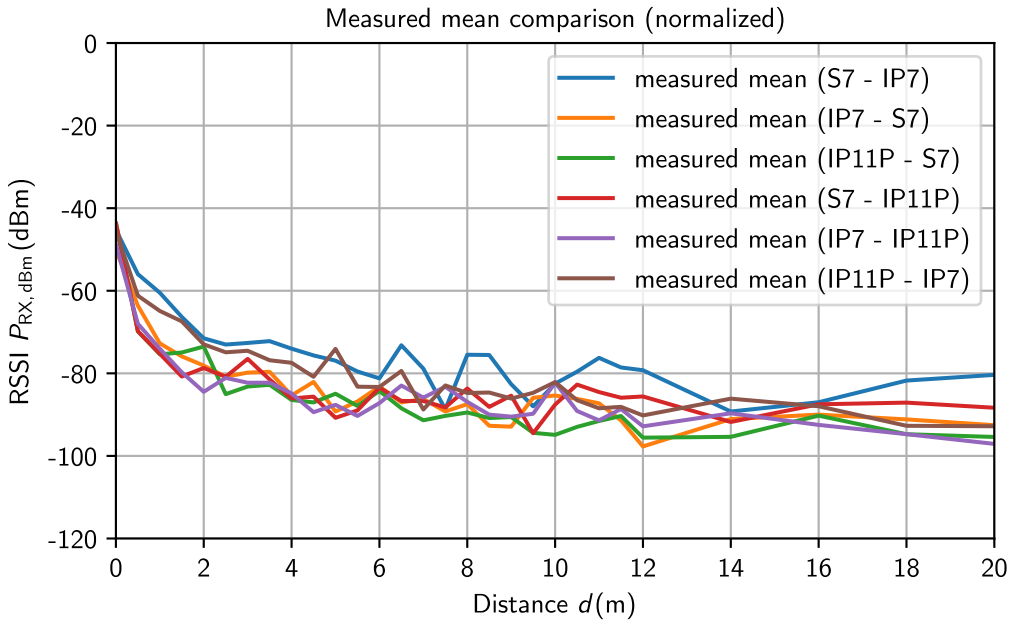

Figure 16: Comparison of mean RSSI to distance graphs (normalized)

4.2.4 Ideal fitted RSSI of all devices (normalized)

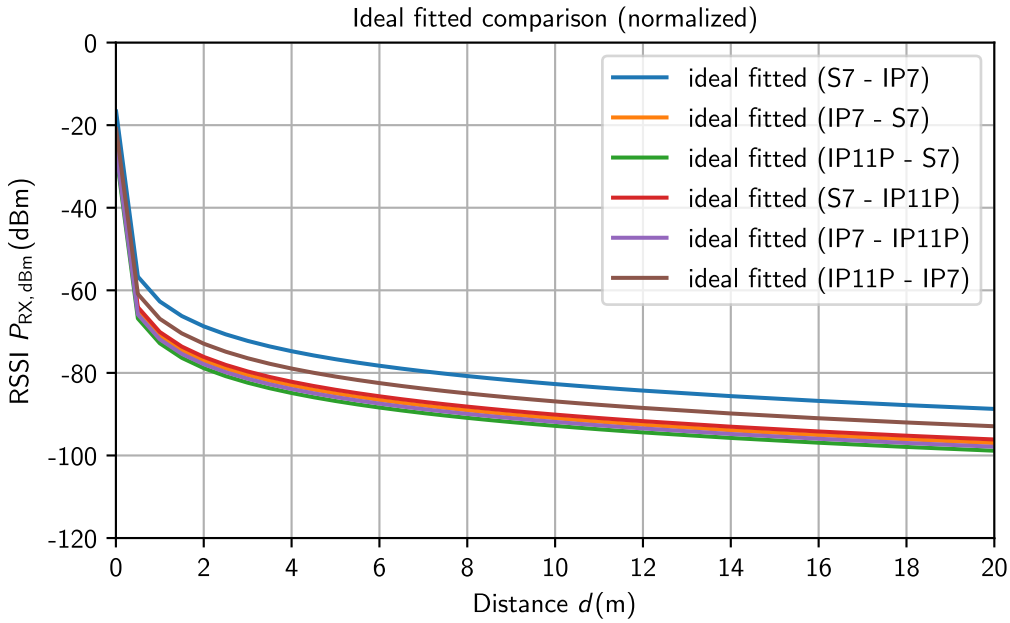

Figure 17: Comparison of fitted ideal RSSI to distance graphs (noprmalized)

4.3 Day 2

Measurements performed on 04.06.2020 (rainy, 68% humidity).

4.3.1 iPhone 7 - iPhone 11 Pro

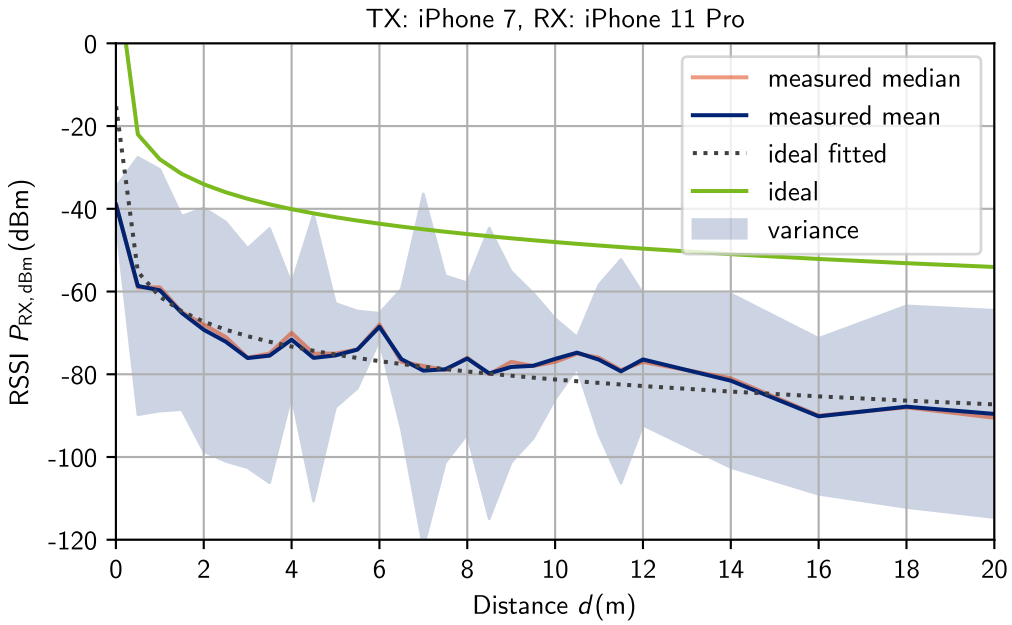

Figure 18: RSSI vs distance, transmitter: iPhone 7, receiver: iPhone 11 Pro

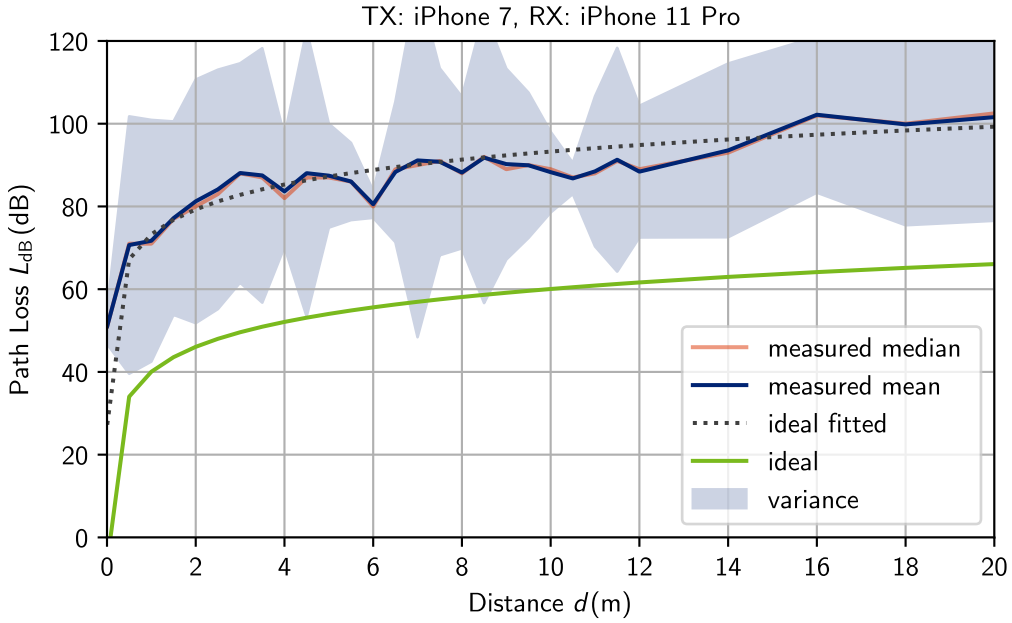

Figure 19: Path loss vs distance, transmitter: iPhone 7, receiver: iPhone 11 Pro

4.3.2 iPhone 11 Pro - iPhone 7

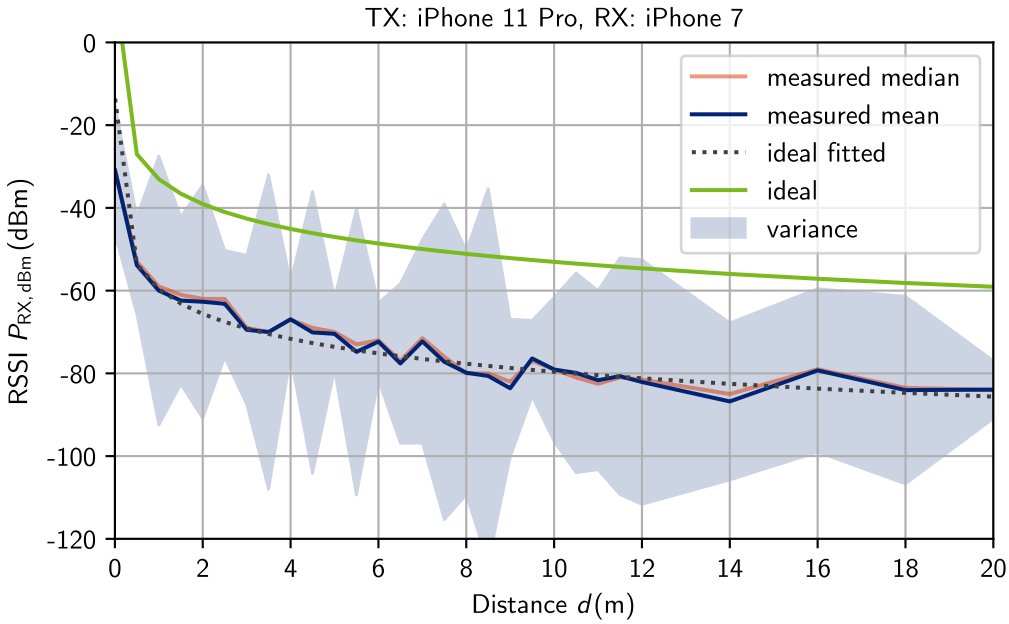

Figure 20: RSSI vs distance, transmitter: iPhone 11 Pro, receiver: iPhone 7

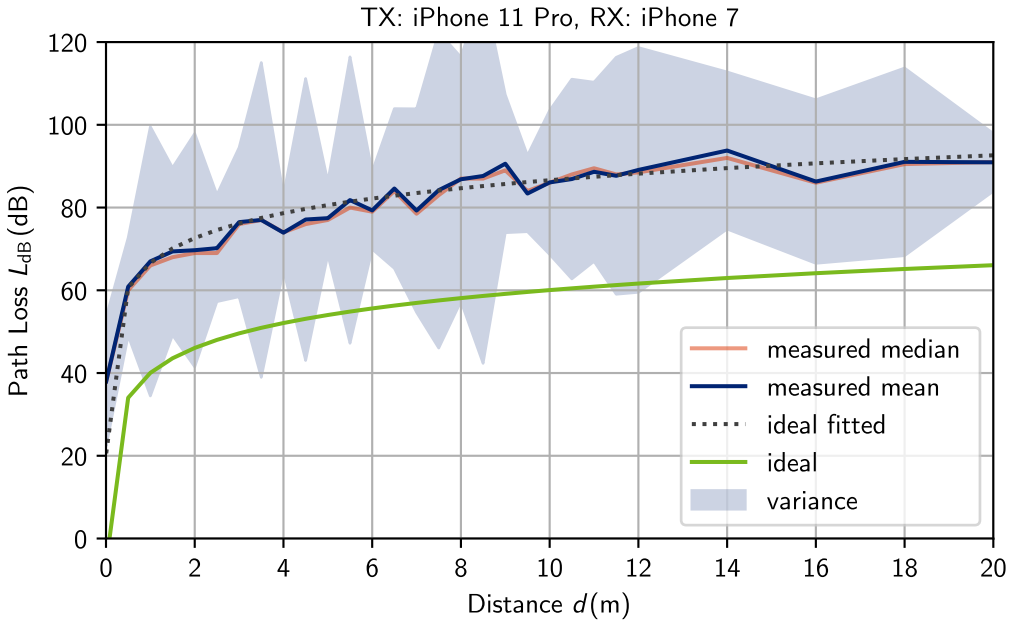

Figure 21: Path loss vs distance, transmitter: iPhone 11 Pro, receiver: iPhone 7

4.3.3 iPhone 7 - Samsung Galaxy S7

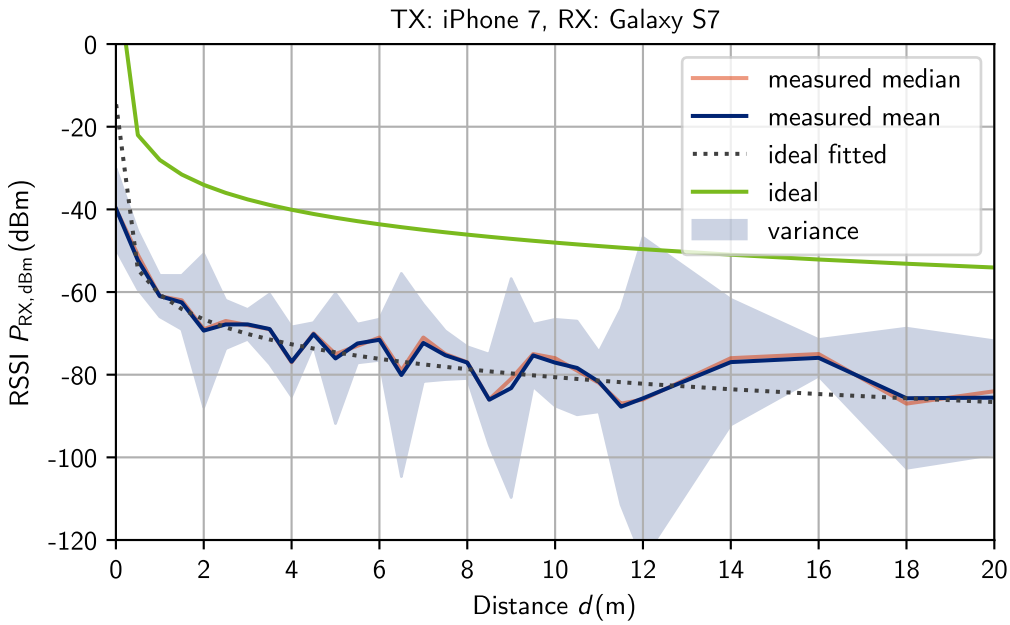

Figure 22: RSSI vs distance, transmitter: iPhone 7, receiver: Galaxy S7

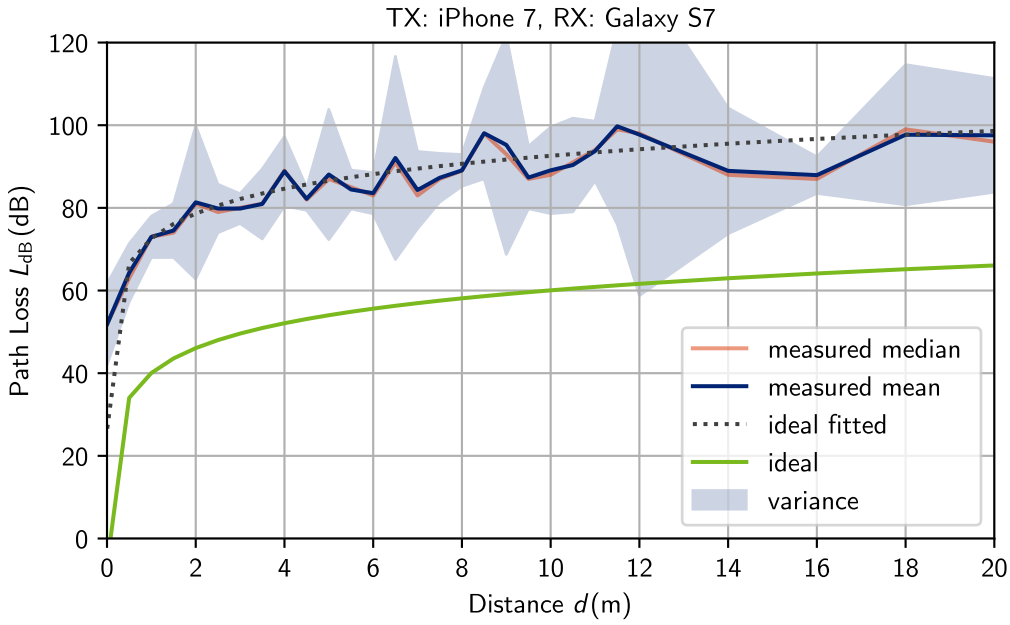

Figure 23: Path loss vs distance, transmitter: iPhone 7, receiver: Galaxy S7

4.3.4 Samsung Galaxy S7 - iPhone 7

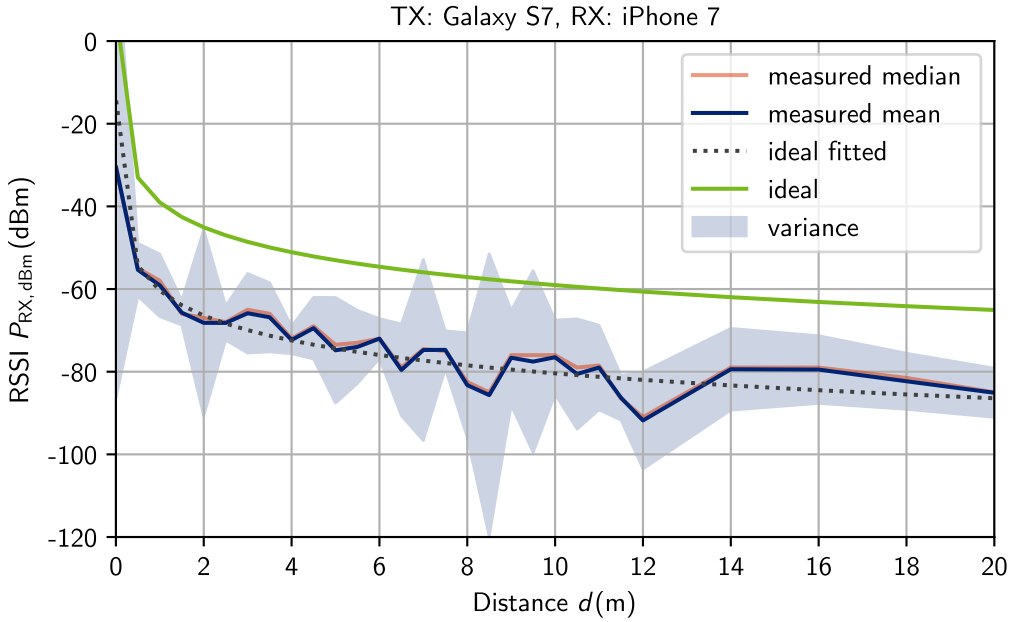

Figure 24: RSSI vs distance, transmitter: Galaxy S7, receiver: iPhone 7

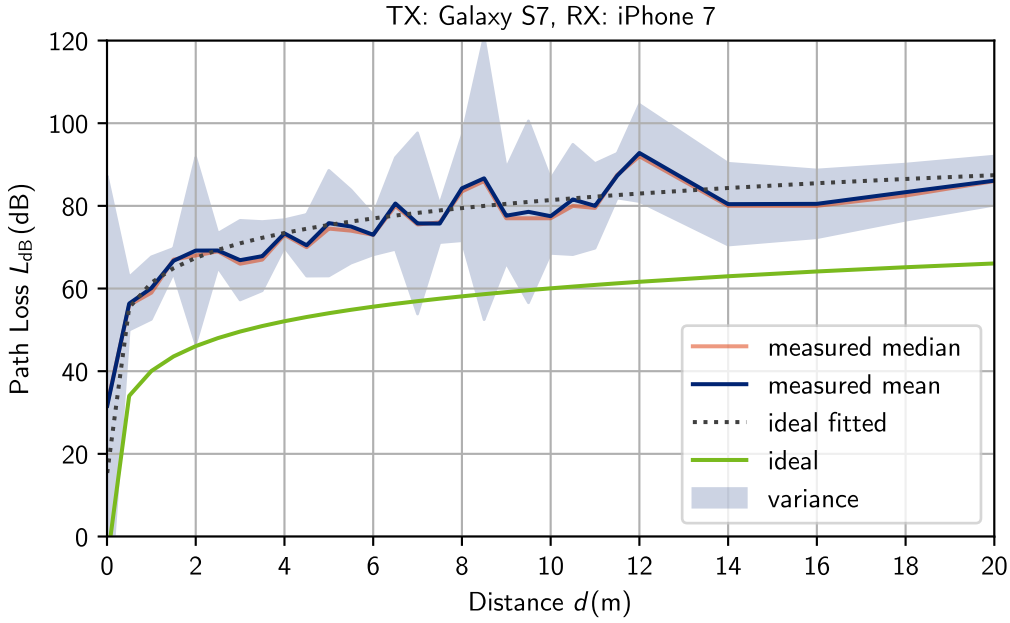

Figure 25: Path loss vs distance, transmitter: Galaxy S7, receiver: iPhone 7

4.3.5 iPhone 11 Pro - Samsung Galaxy S7

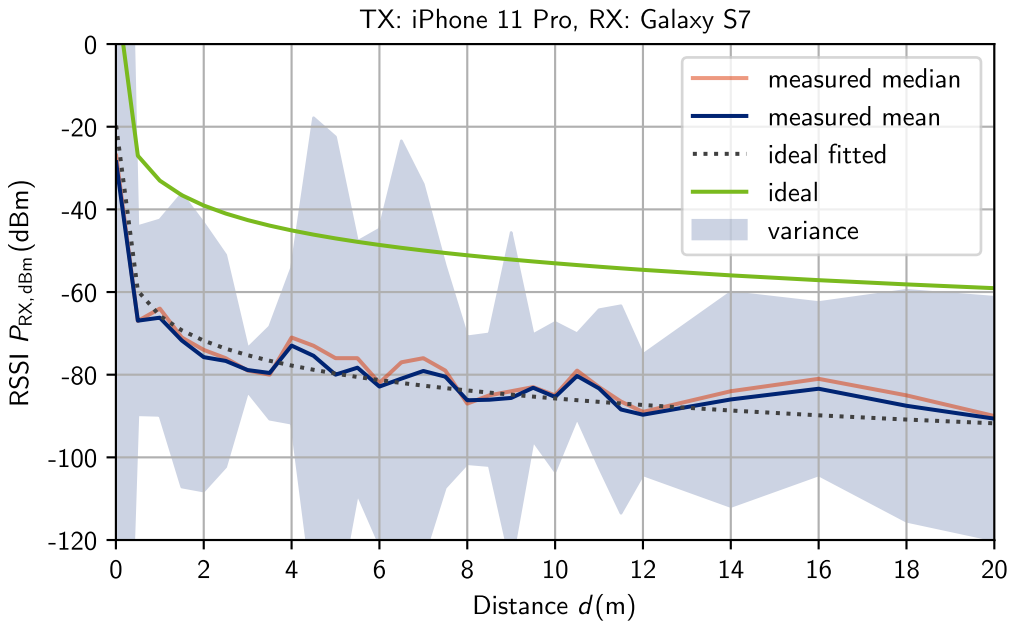

Figure 26: RSSI vs distance, transmitter: iPhone 11 Pro, receiver: Galaxy S7

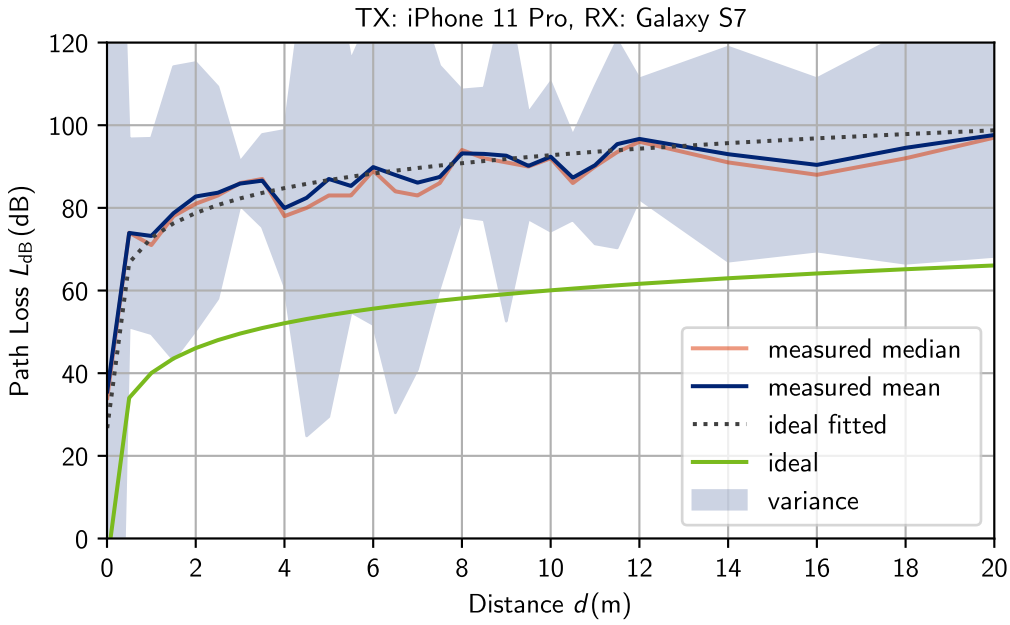

Figure 27: Path loss vs distance, transmitter: iPhone 11 Pro, receiver: Galaxy S7

4.3.6 Samsung Galaxy S7 - iPhone 11 Pro

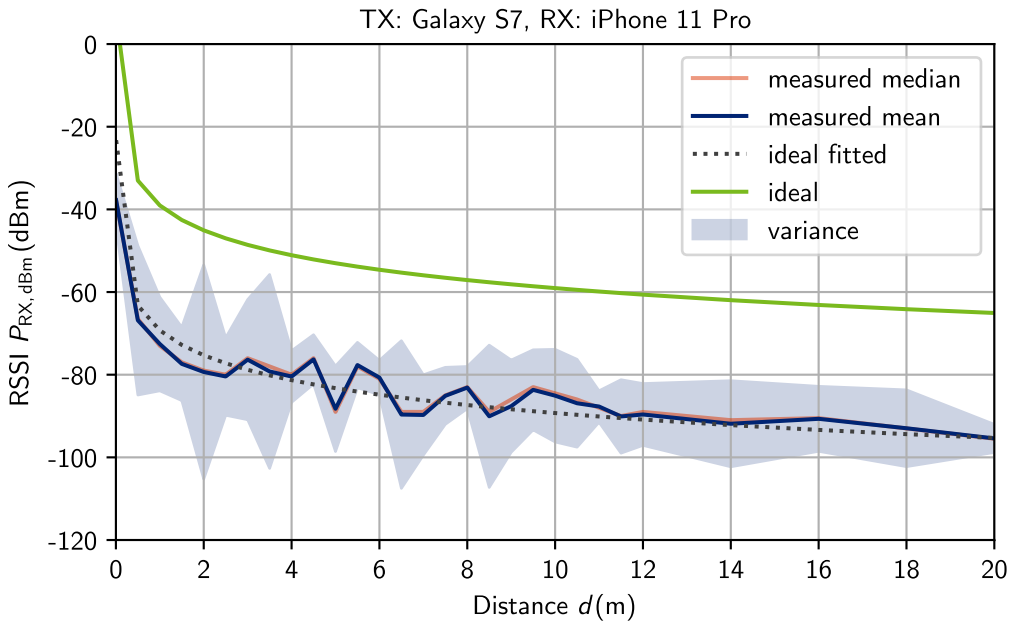

Figure 28: RSSI vs distance, transmitter: Galaxy S7, receiver: iPhone 11 Pro

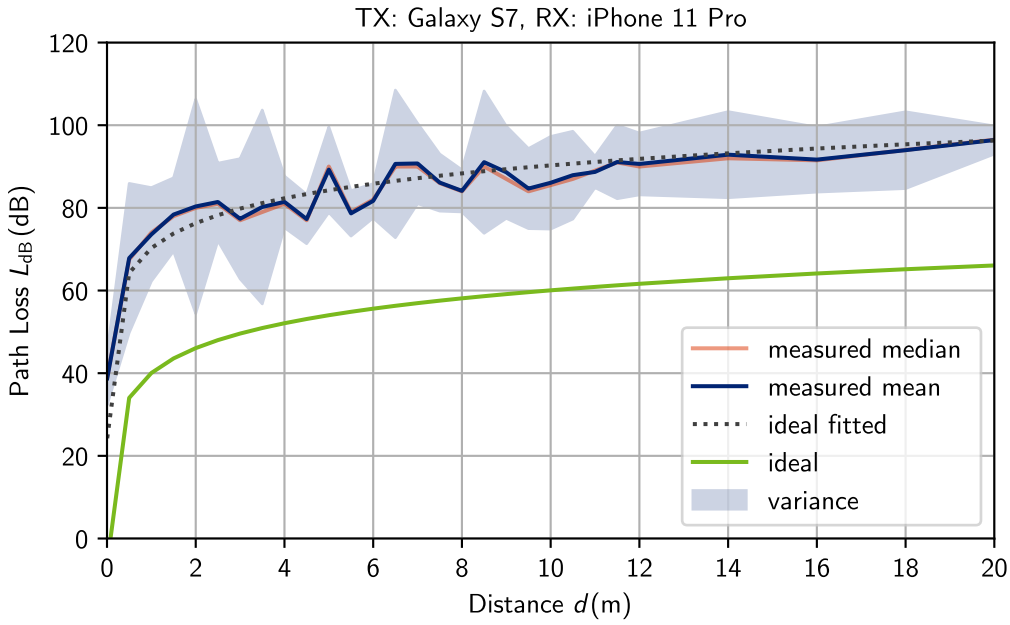

Figure 29: Path loss vs distance, transmitter: Galaxy S7, receiver: iPhone 11 Pro

4.4 Comparison of results

4.4.1 RSSI mean of all devices

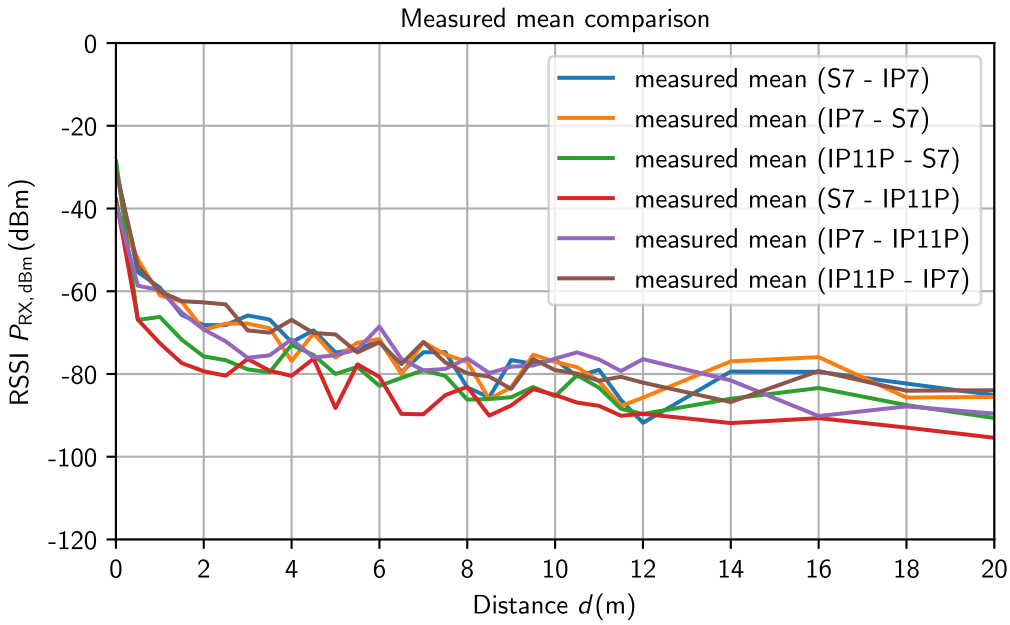

Figure 30: Comparison of mean RSSI to distance graphs

4.4.2 Ideal fitted RSSI of all devices

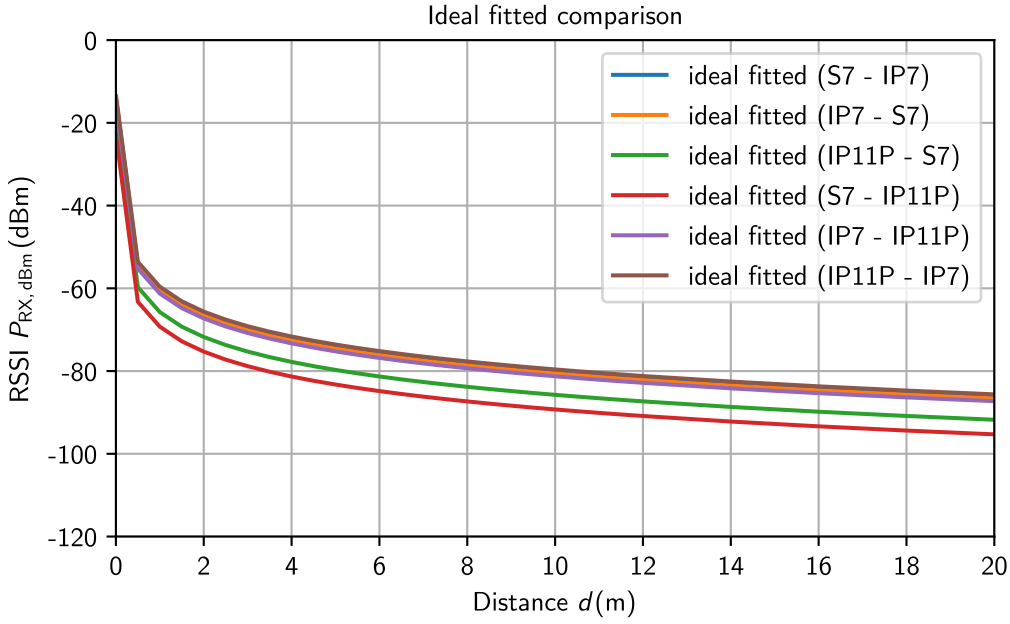

Figure 31: Comparison of fitted ideal RSSI to distance graphs

4.4.3 RSSI mean of all devices (normalized)

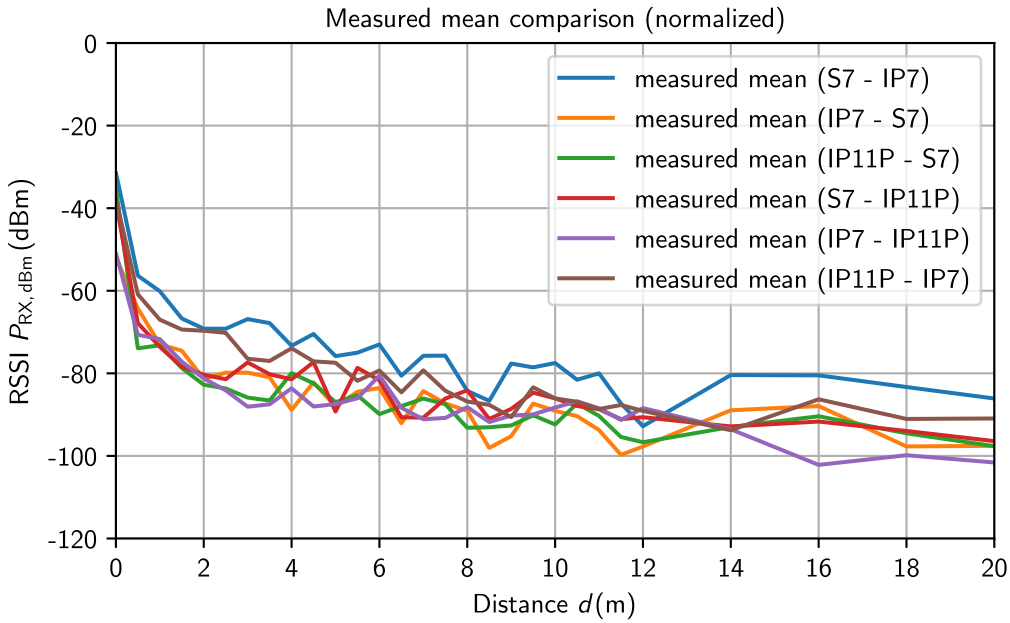

Figure 32: Comparison of mean RSSI to distance graphs (normalized)

4.4.4 Ideal fitted RSSI of all devices (normalized)

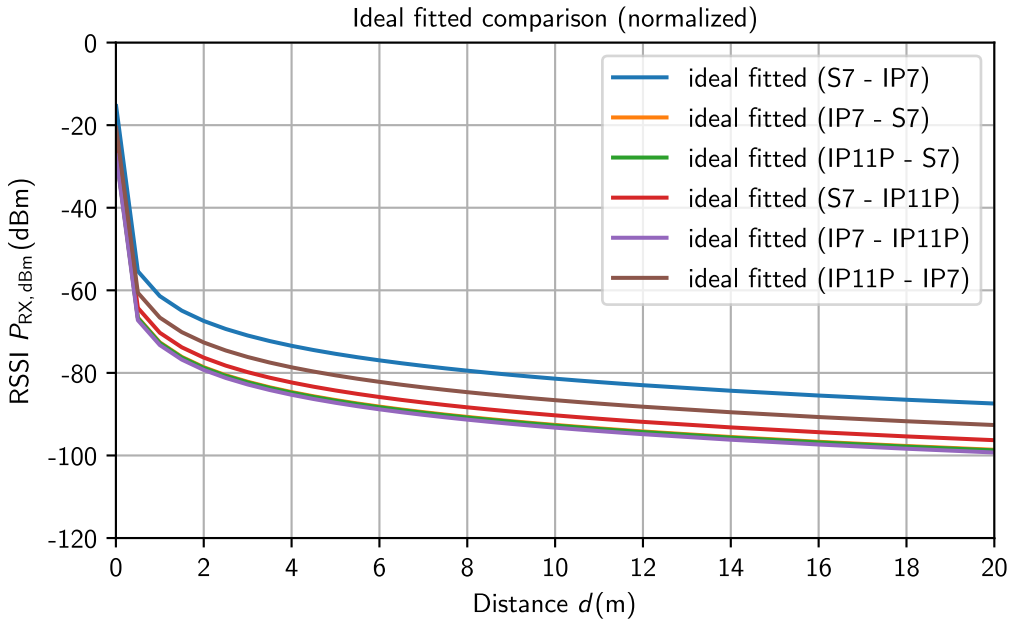

Figure 33: Comparison of fitted ideal RSSI to distance graphs (noprmalized)

4.5 Comparison of both measurement days

4.5.1 iPhone 7 - iPhone 11 Pro

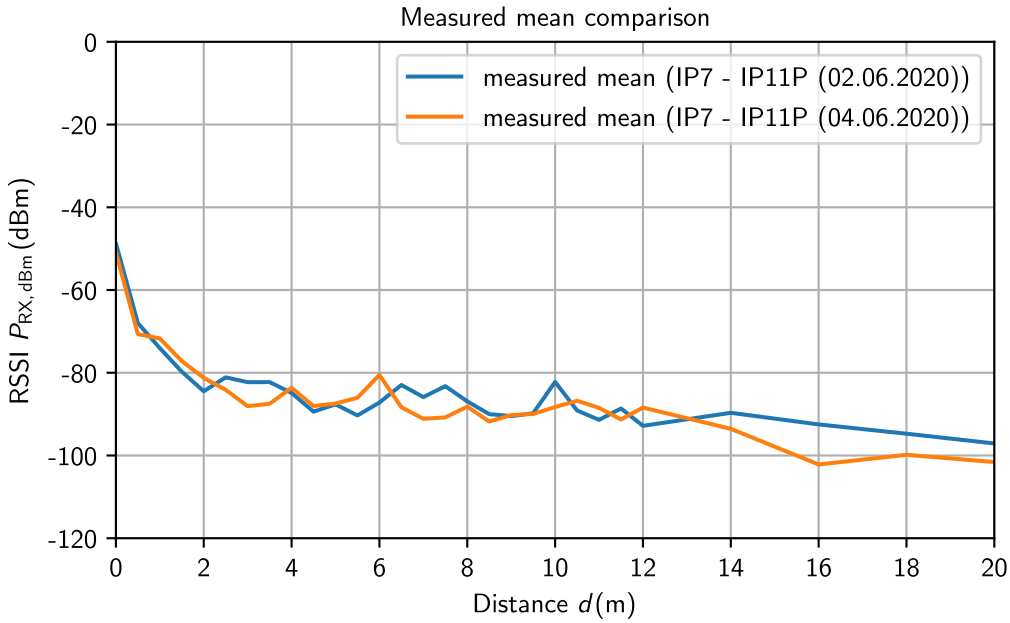

Figure 34: RSSI vs distance comparison, transmitter: iPhone 7, receiver: iPhone 11 Pro, normalized

4.5.2 iPhone 11 Pro - iPhone 7

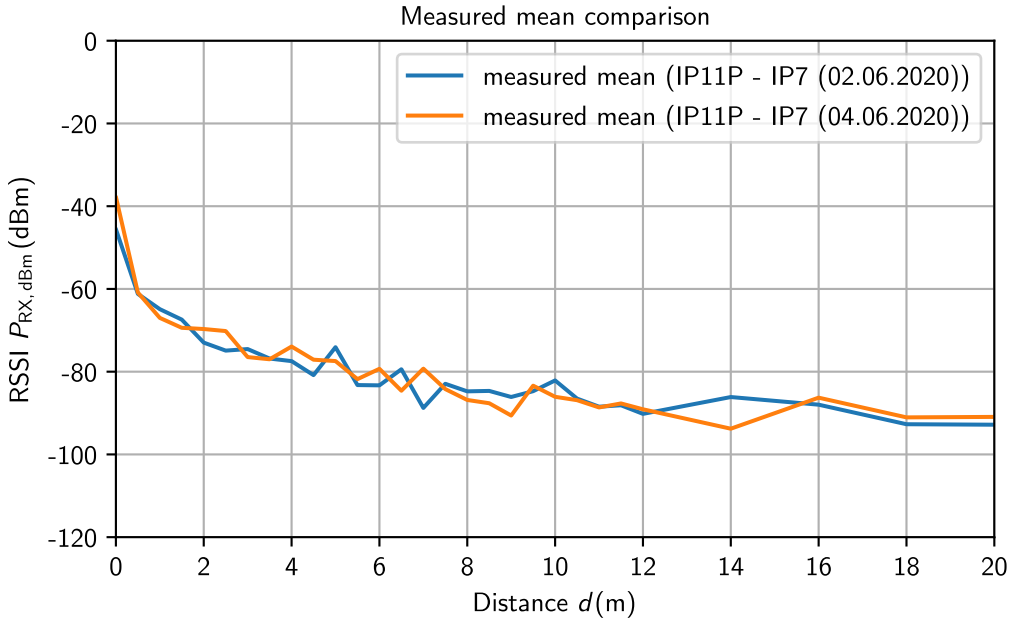

Figure 35: RSSI vs distance comparison, transmitter: iPhone 11 Pro, receiver: iPhone 7, normalized