

# Proximity Tracing App

## Distance Measurements and Classification Test Report

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### Executive Summary

This document presents the results of first measurements of close contacts between smartphones. The measurement approach is based on evaluating Bluetooth Low Energy (BLE) signals between smartphones. Received Signal Strength (RSS) is used for distance estimation as this can be obtained on a wide number of smartphones. Two approaches have been tested. One for distance measurements and the other approach is a classification method distances above/below 1.5/2/2.5 meters.

The results show that distance estimation and classification is possible on a wide range of phones. The accuracy is also influenced by the holding position of the phone. For all these cases, the results show that classification rates >80% for a classification within or without a 2m circle over a 2 minute time interval is possible.

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## Introduction

Smartphones are capable of sending and receiving Bluetooth Low Energy (BLE) advertising signals. Received Signal Strength (RSS) of BLE advertising signals is a well-known indicator for the distance between a BLE sender and receiver. BLE beacons are widely spread low cost modules that send out BLE advertising signals. Smartphones receive BLE advertising signals and trigger events when they are close enough to the BLE beacon.

In the scope of this project a peer-to-peer approach is tested where smartphones send out BLE advertising signals and also receive advertising signals of other smartphones.

Estimating proximity by measuring RSS can be influenced by a number of parameters, including phone model (antennas, BLE chip), usage pattern (in hand, at ear, in pocket), environment (indoor/outdoor, open space / crowded rooms), phone orientation and others. However, RSS-based positioning is widely spread and has to cope with the same effects.

To evaluate the fluctuation of the RSS values and the effect on proximity estimation, various tests have been performed.

## Test protocol

Task:	
Validate distance classification for detection of close contacts using Bluetooth Low Energy.	
Number of persons	2
Phone types used for the test	Samsung Galaxy S7/S8/A6, Motorola Moto X Play, LG Nexus 5x
Number of tests	50
Location	All tests in this report have been conducted at the LINK testing facility at Fraunhofer IIS in Nuremberg, Germany

## Measurement Setup

A circular setup with one person carrying a smartphone in the center and another person with another phone were performing distance tests for distances of 0.5m to 5m. The test persons were equipped with protective clothing and masks. The Test persons were moving the devices slightly (several cm) to emulate usual human behavior.

A testing app on both smartphones triggers BLE advertising signals and scans for BLE advertising signals of the other smartphone. The tests have been performed with five different smartphone models and with varying holding positions (ear, hand, front pocket,

back pocket). All data was recorded locally for evaluation. Two types of tests have been performed:

1. Fixed position tests at various distances (test persons not moving)
2. Ring tests at various distances (test person moving circular in a fixed distance around the person in the center)

Ring test measurements:

For this type of measurements, one person was standing in the center and a second person was carrying two phones at different holding positions and moves for 5min within distance intervals:  $< 2\text{m}$  (contact): red circle,  $>2\text{m} \sim < 5\text{m}$  blue circle,  $\sim > 5\text{m}$  (see Fig. 1).

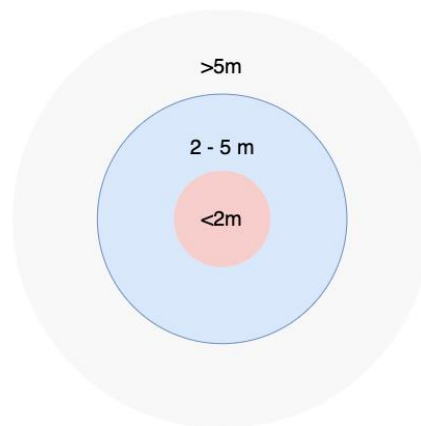


Fig. 1: Circular Distances

## Distance Estimation Approach

RSS decreases over distance in free space with a well-known formula. The formula has two parameters: transmission power (TP) and path loss exponent (PLE). PLE is known for free space and has to be adapted for Indoors. TP is either known or can be easily measured.

The approaches that have been chosen can be categorized as follows:

1. Assume free space conditions: fix PLE and only adjust TP by using a calibration measurement at 1m distance (orange)
2. Curve fit for PLE (green, red) using different methods
3. Curve fit for real RSS measurements (blue)

These curves are depicted for an example in Fig. 1 for fits of pathloss functions onto measurement data. The mean of the recorded data is shown as a blue line, while the blue area indicates the variance of the data. The different model optimization types are indicated by orange, green and red lines.

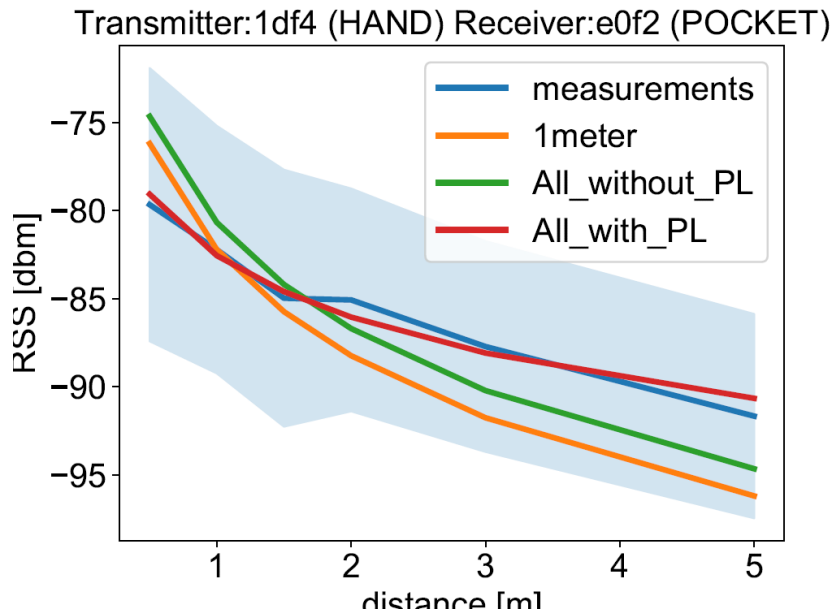


Fig. 2: Curve fitting for various approaches

The measurements are labelled with test details as follows: Transmitter 1df4 (HAND) Receiver e0f2 (POCKET) means device 1df4 was held in hand and transmitting while device e0f2 was in the pocket and receiving.

As the blue line shows the real distances at all RSS values, errors of the different models can easily be obtained by comparing the distances at a given RSS value.

All errors depend on the distance as the curves become flatter.

## Distance Classification

Classification whether two persons have been in contact is a classification problem. This relies on the fact, that measurements over a given distance threshold (e.g. 2m) differ from measurements below that distance. Training models with known values from outside and inside this circle will form a classification model.

Fig. 3 shows an example for a histogram computed over RSS for values recorded at a distance smaller and greater than 2.5 meters. They indicate how well these distance bins can be separated based on raw RSS data. This was refined by introducing four distance classes and performing the ring type measurements (see above):

1. 0m - 1.5m
2. 1.5m - 2.5m
3. 2.5m - 3.5m
4. 3.5m - xm

The performance of this type of algorithms increases with the amount of training data. Therefore, measurements with different types of smartphones and various holding positions have been taken. Moreover, the time interval for collecting values for classification (range window) was varied.

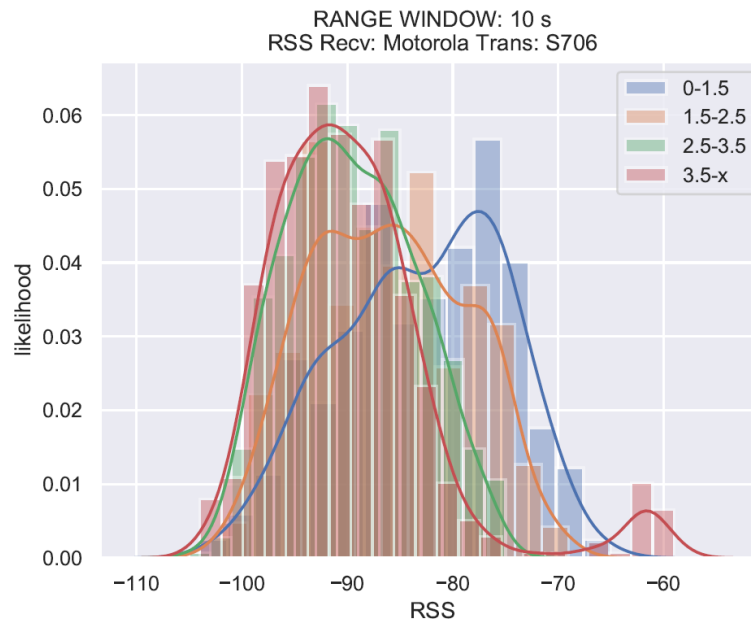


Fig. 3: Histogram of received RSS values

The histogram that has been computed over estimated distances for values recorded at a distance smaller and larger than 1.5m. It indicates, how well these distance bins can be separated based on RSS data processed relative to an inverse pathloss model.

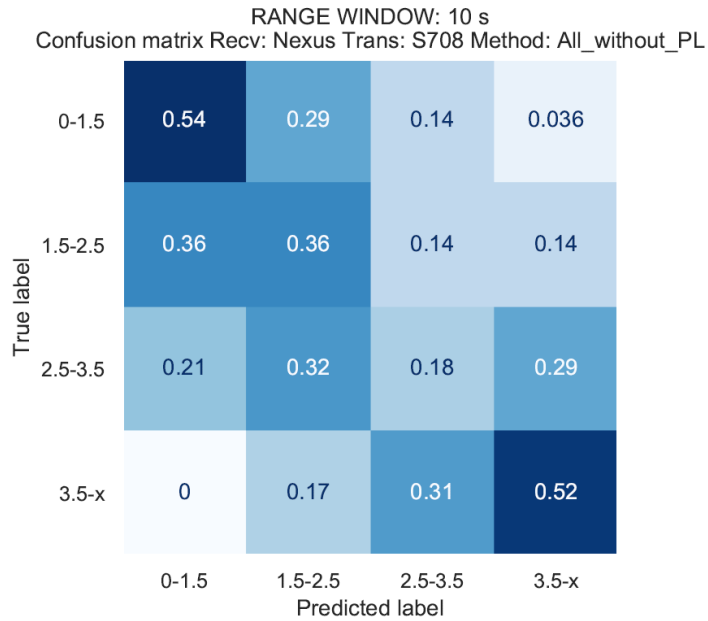
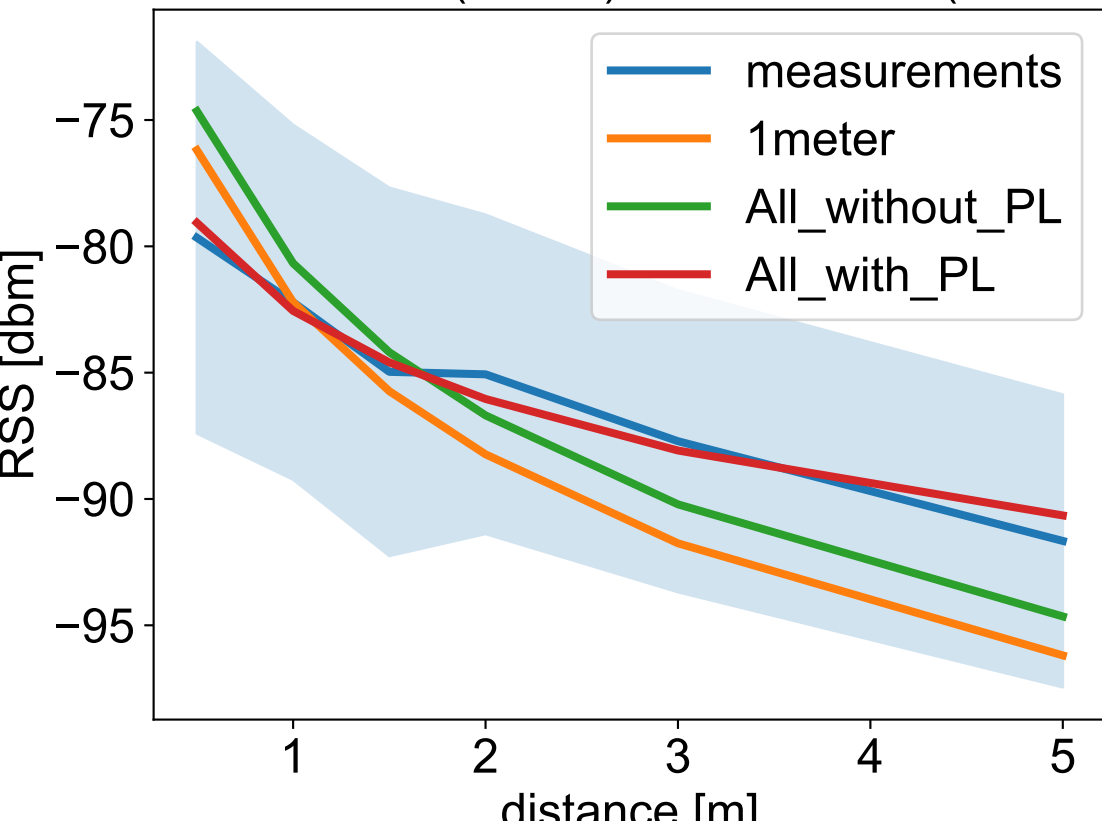


Fig. 4: Matrix of joint probabilities between true labels and predicted labels

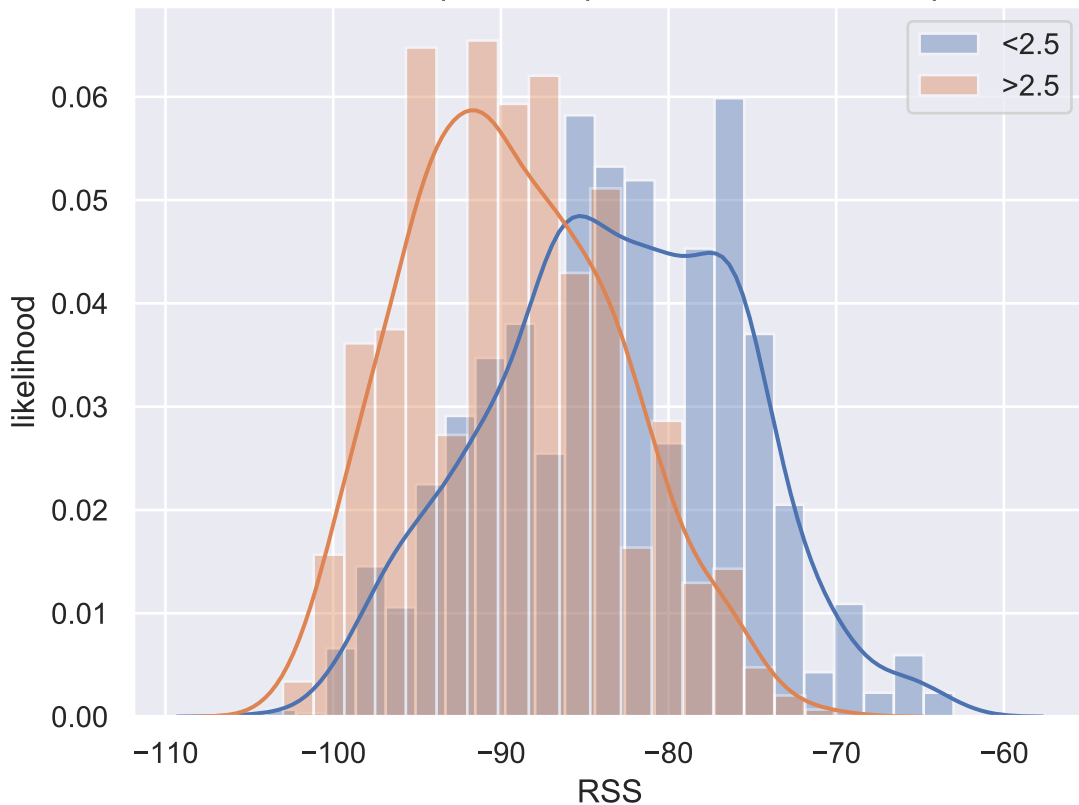
For each setup, a matrix was created that shows joint probabilities between true labels and predicted labels. An example is shown in Fig. 4. As distance classes 1 and 2 (0-2,5m) form the contact radius, they can be seen as one resulting in 83% of all values below 1.5 meters classified correctly and 72% of the values between 1.5 and 2.5. The evaluation has been done for different smartphone models and range windows.

Further technical details and visualizations are presented in the attached measurement details.

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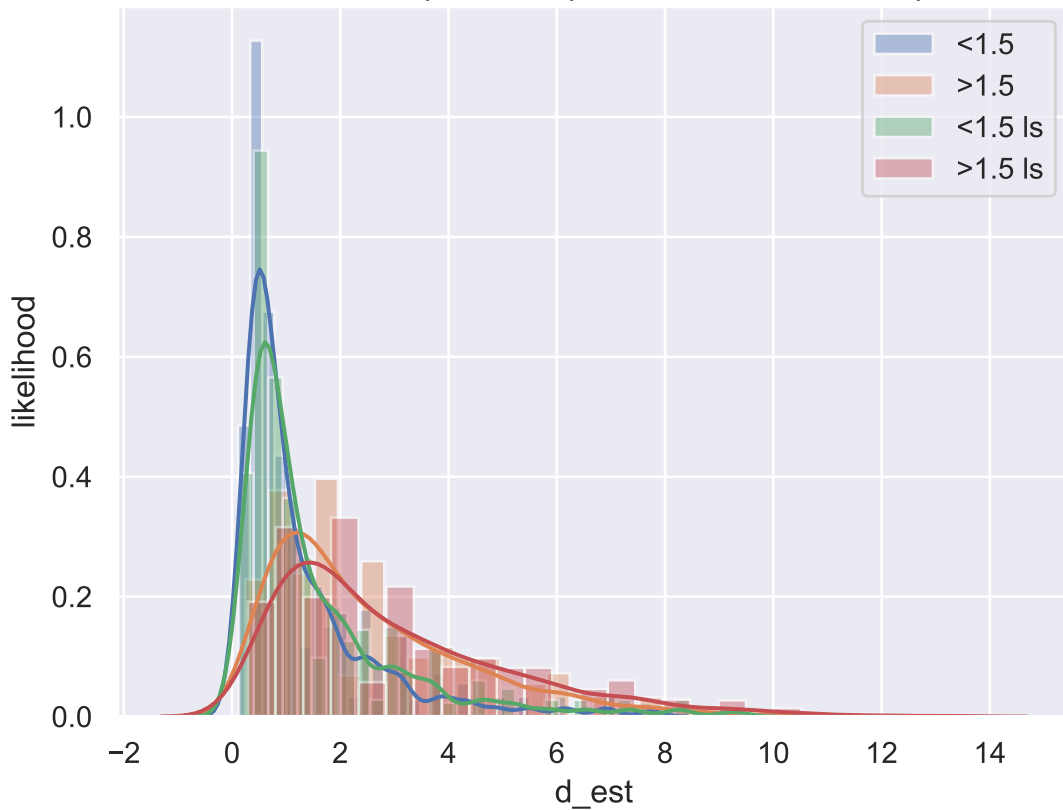


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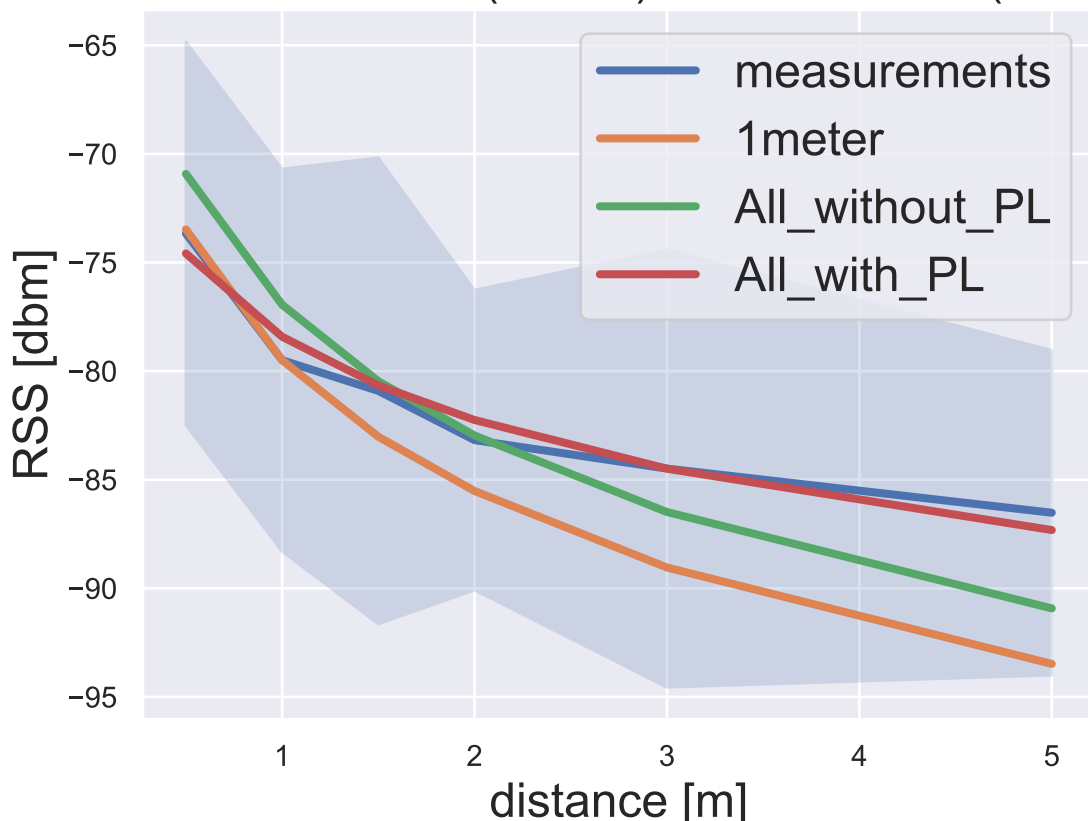




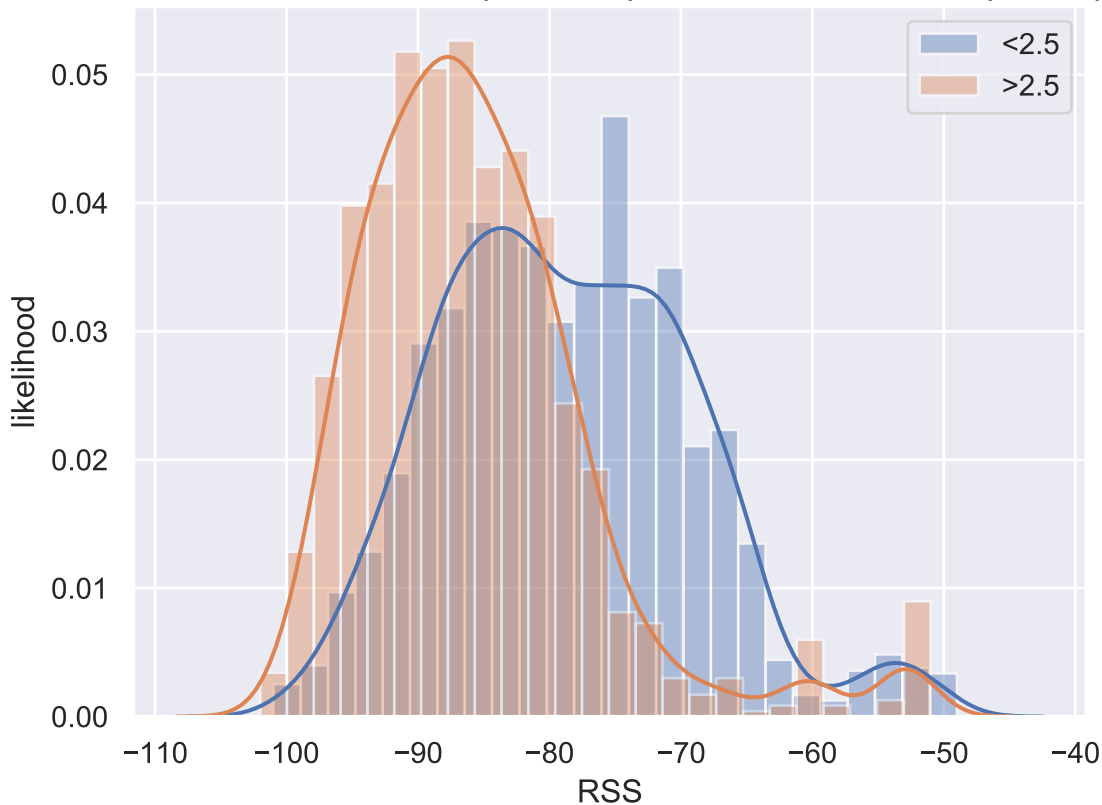
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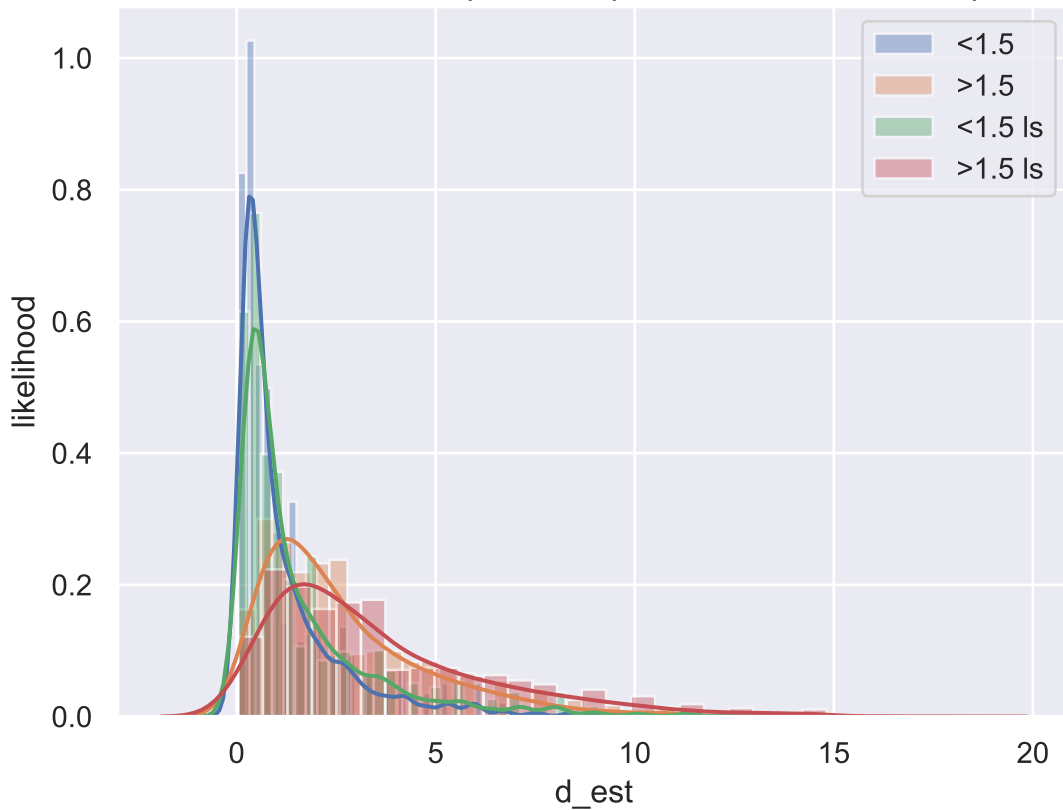
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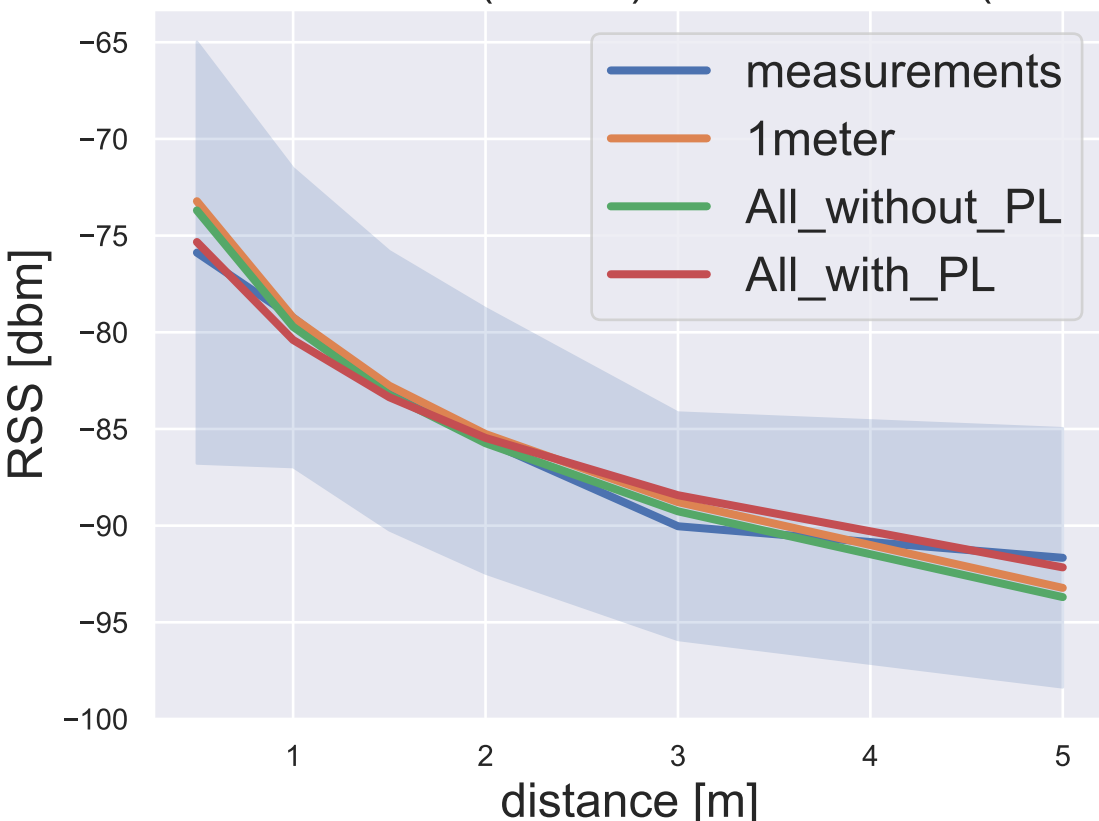
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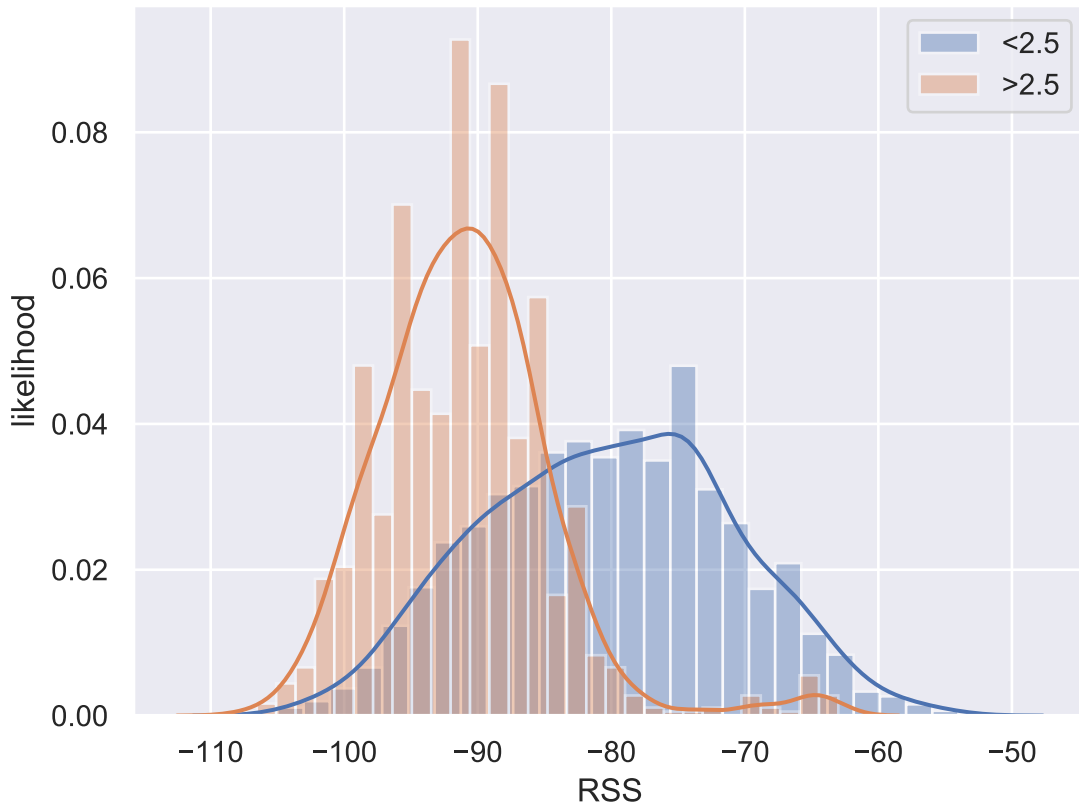
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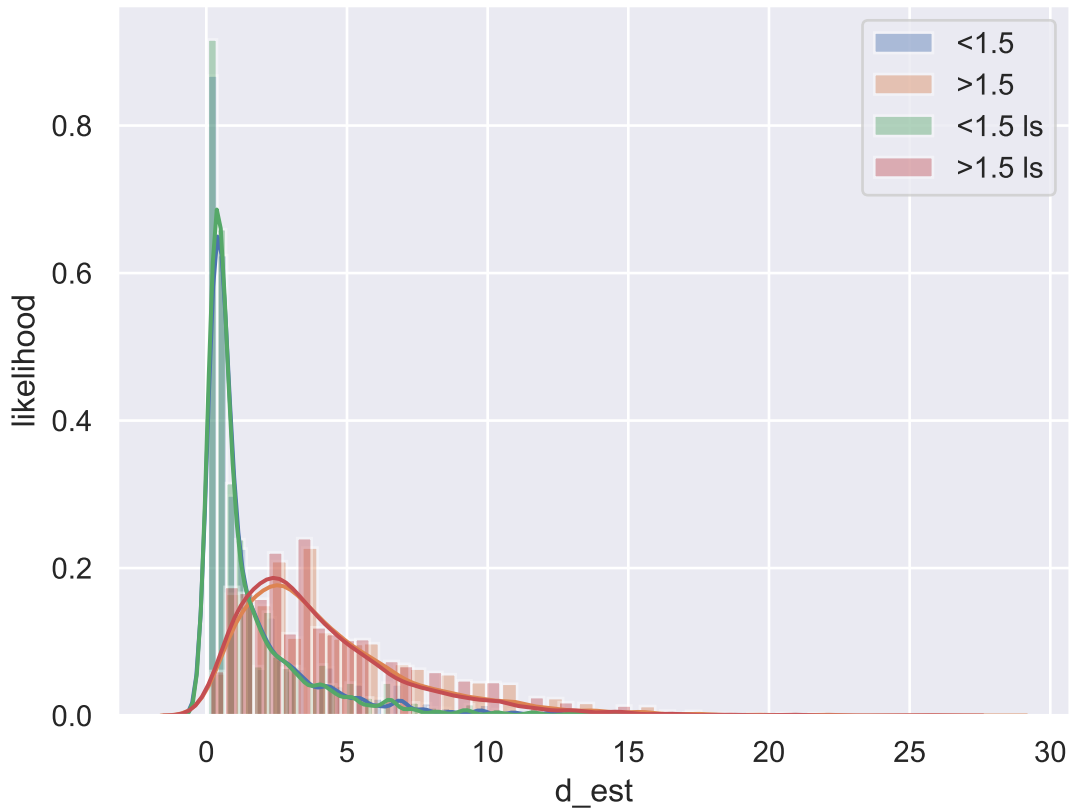
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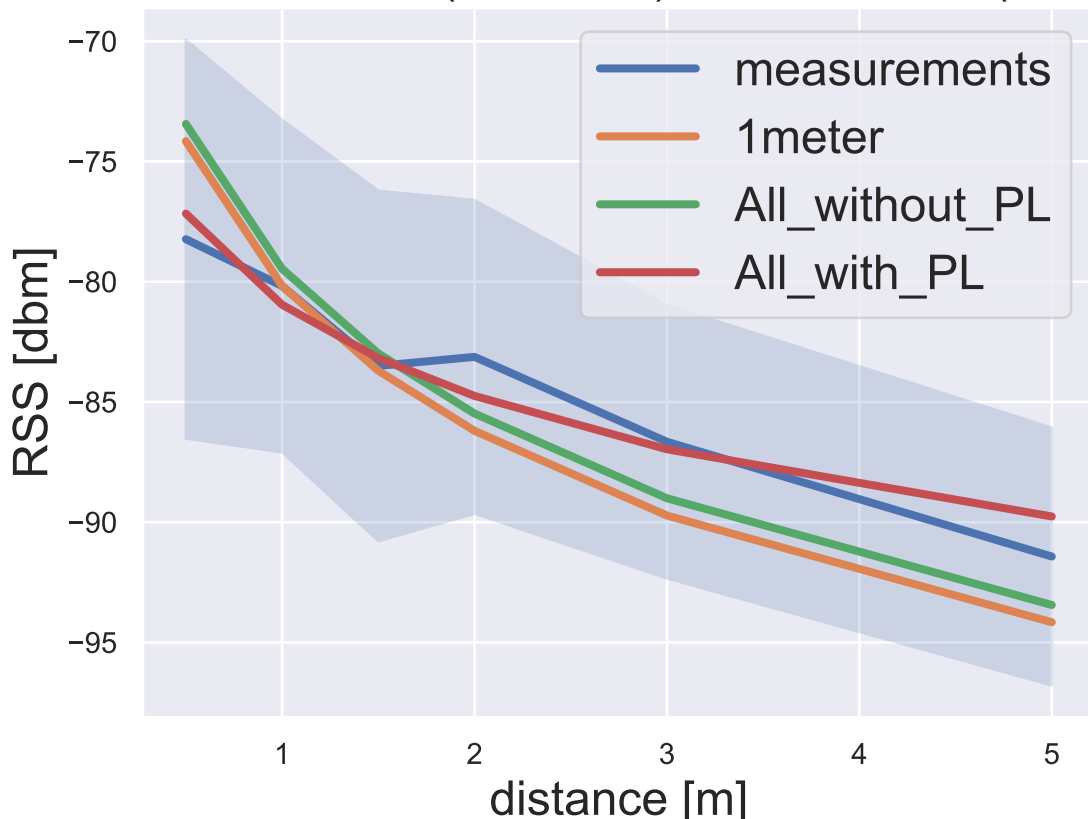
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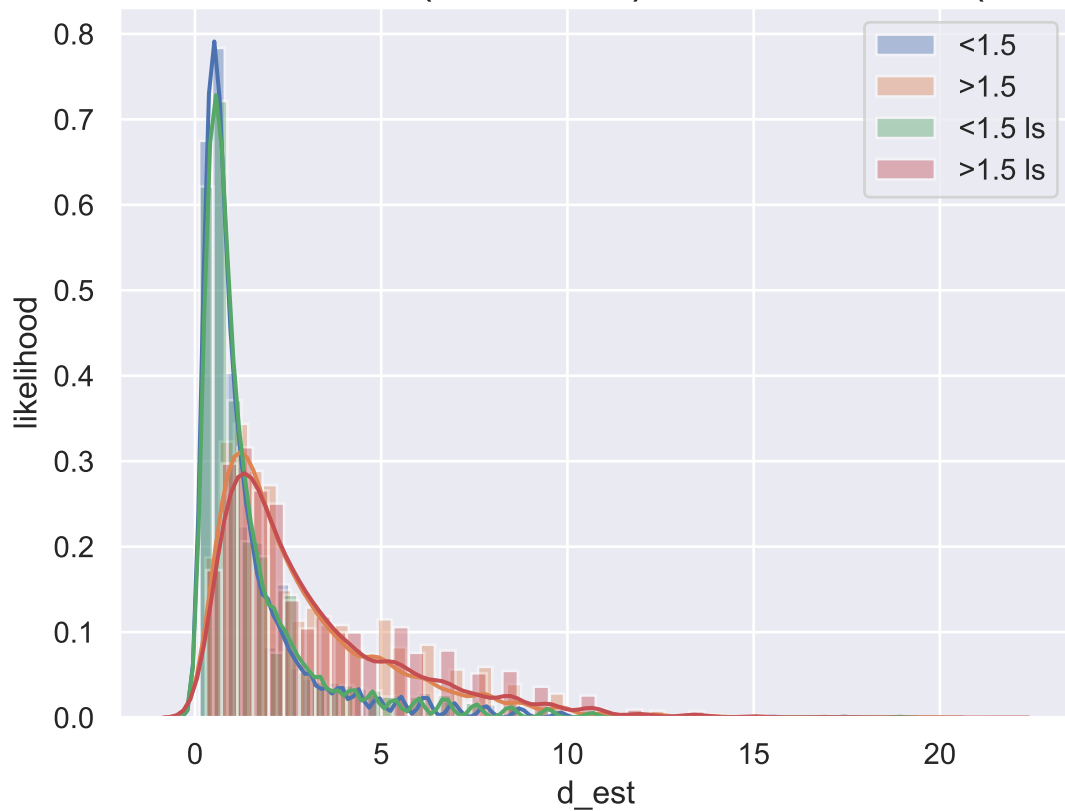




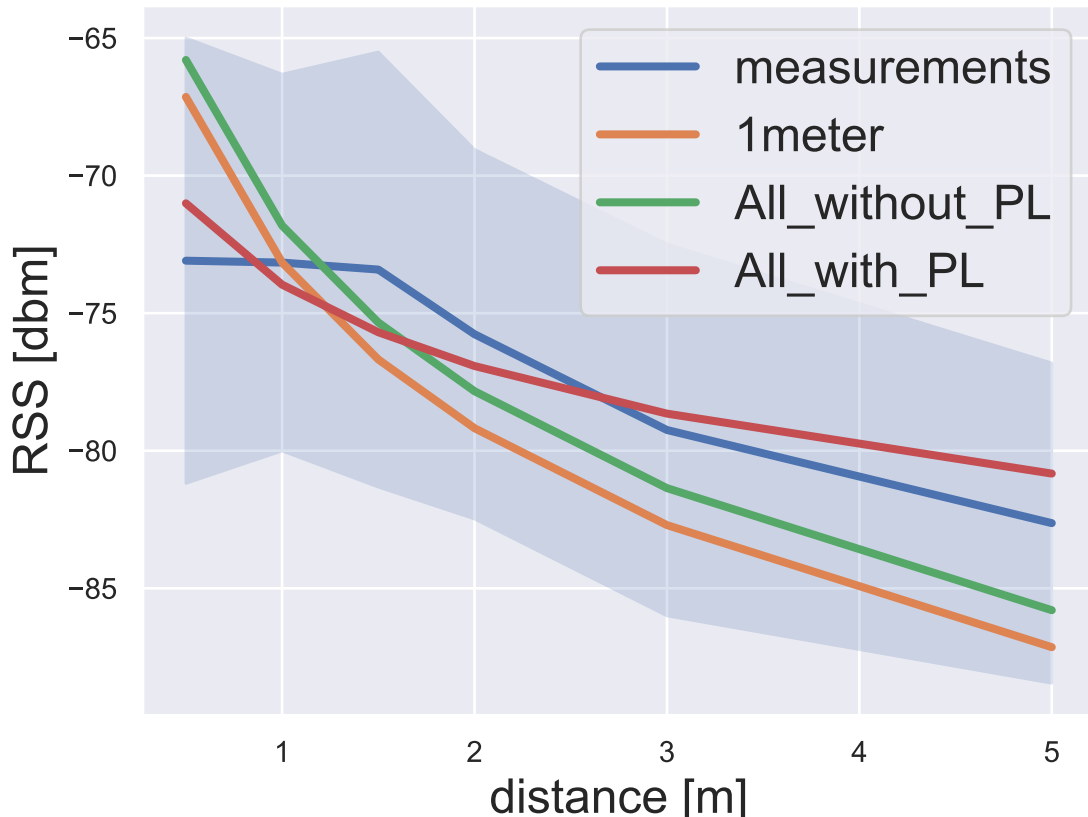
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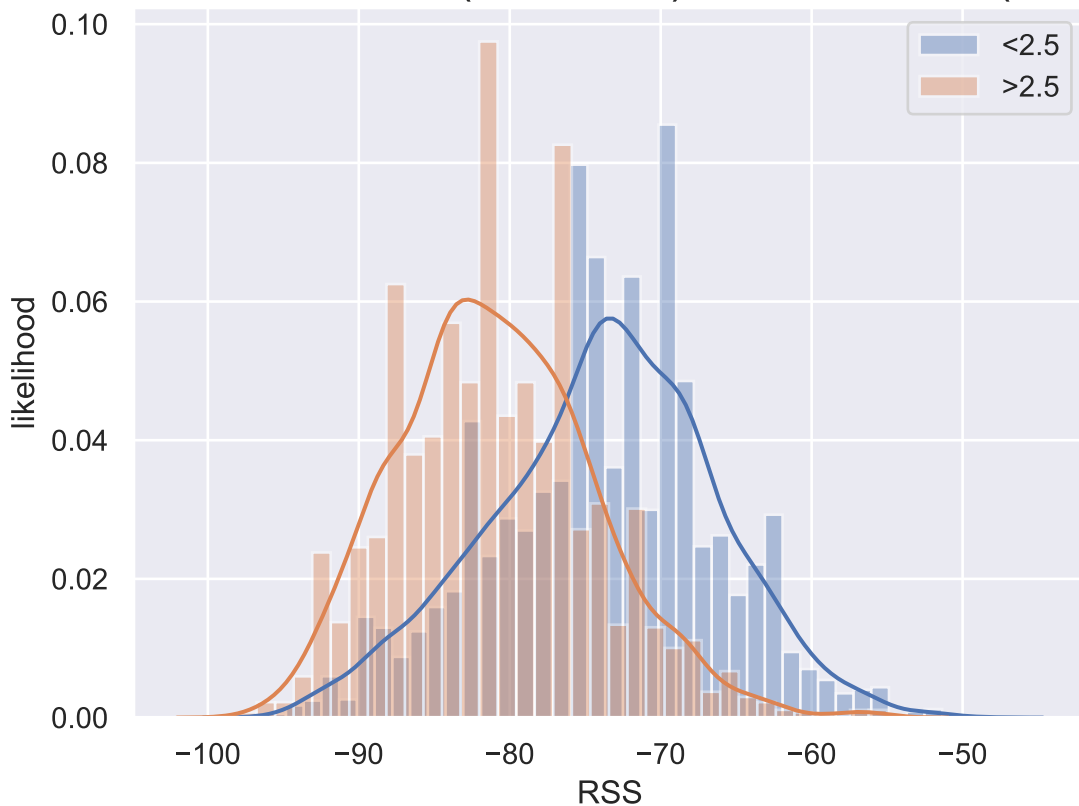
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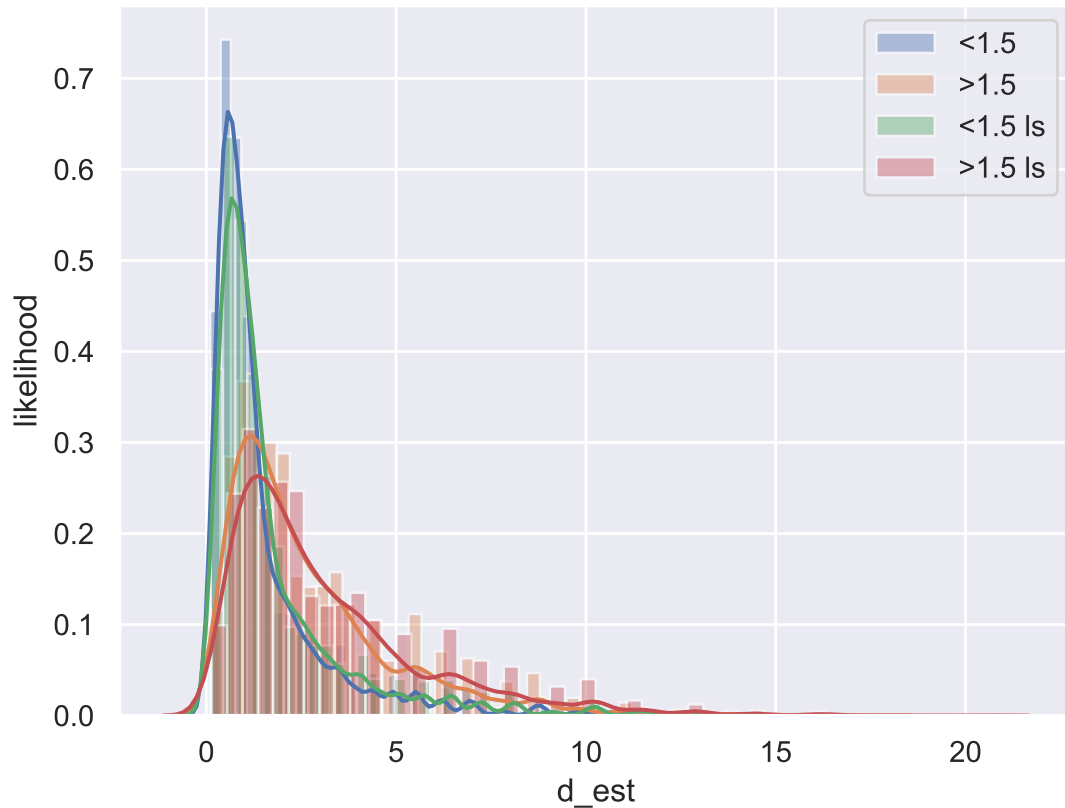
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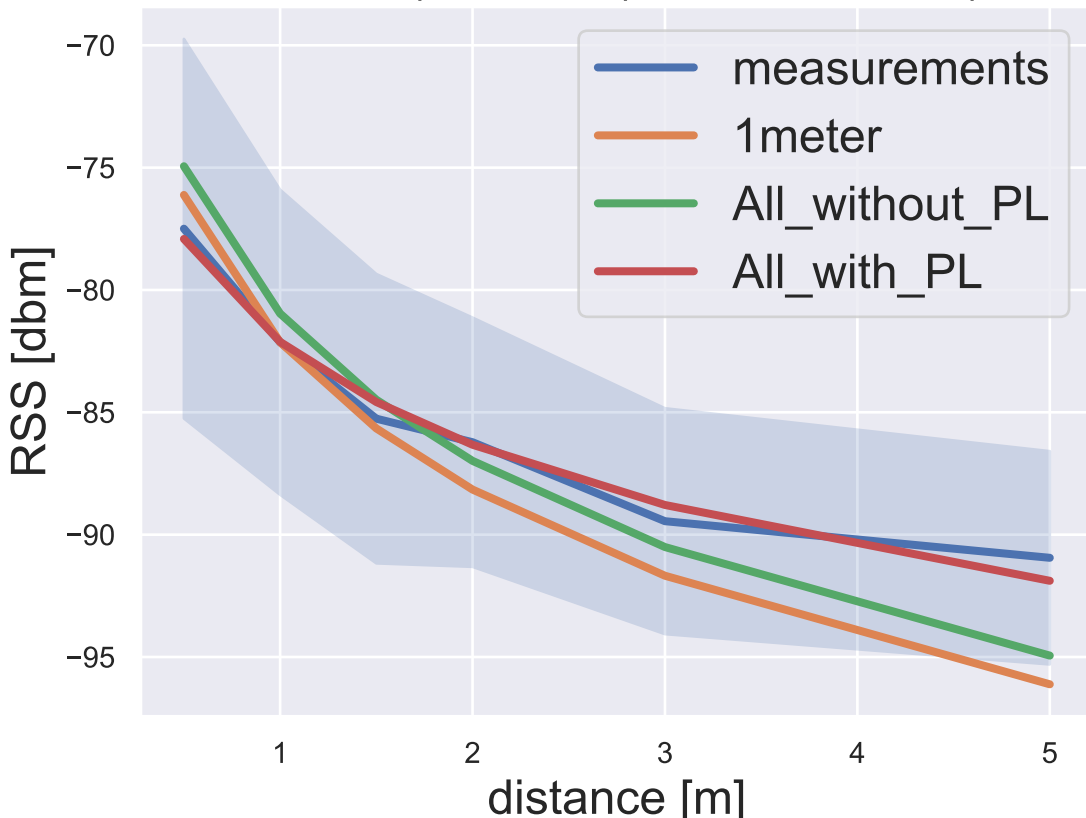
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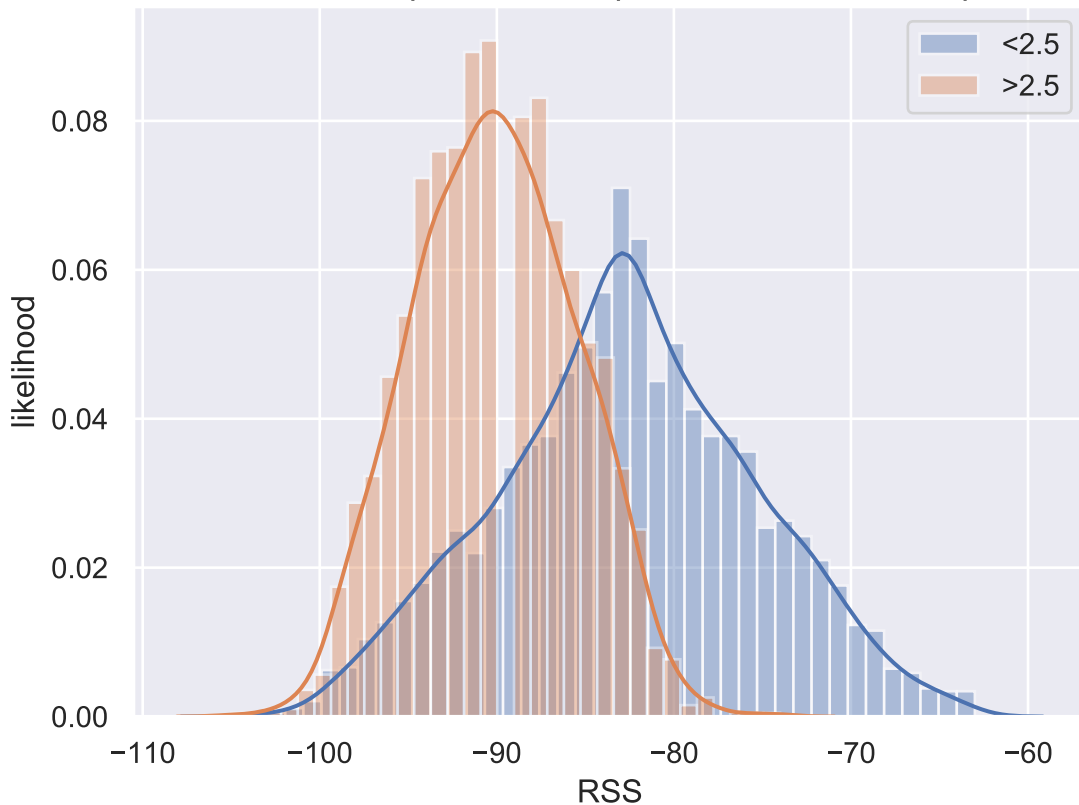
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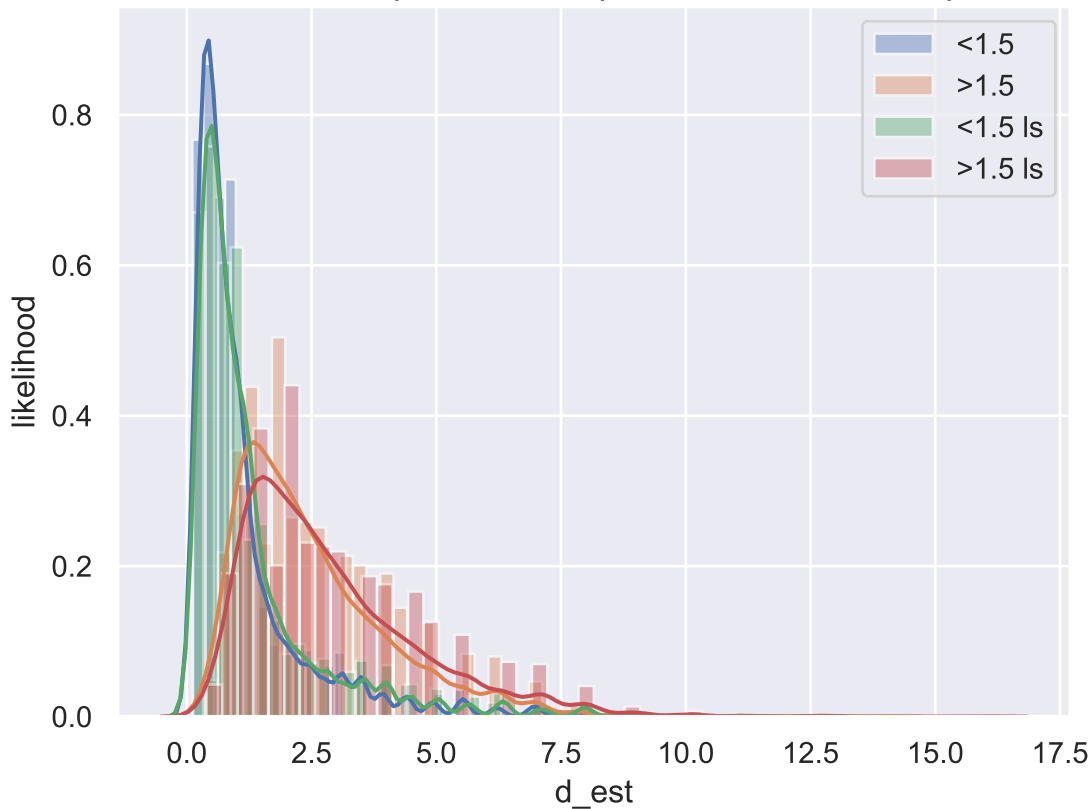
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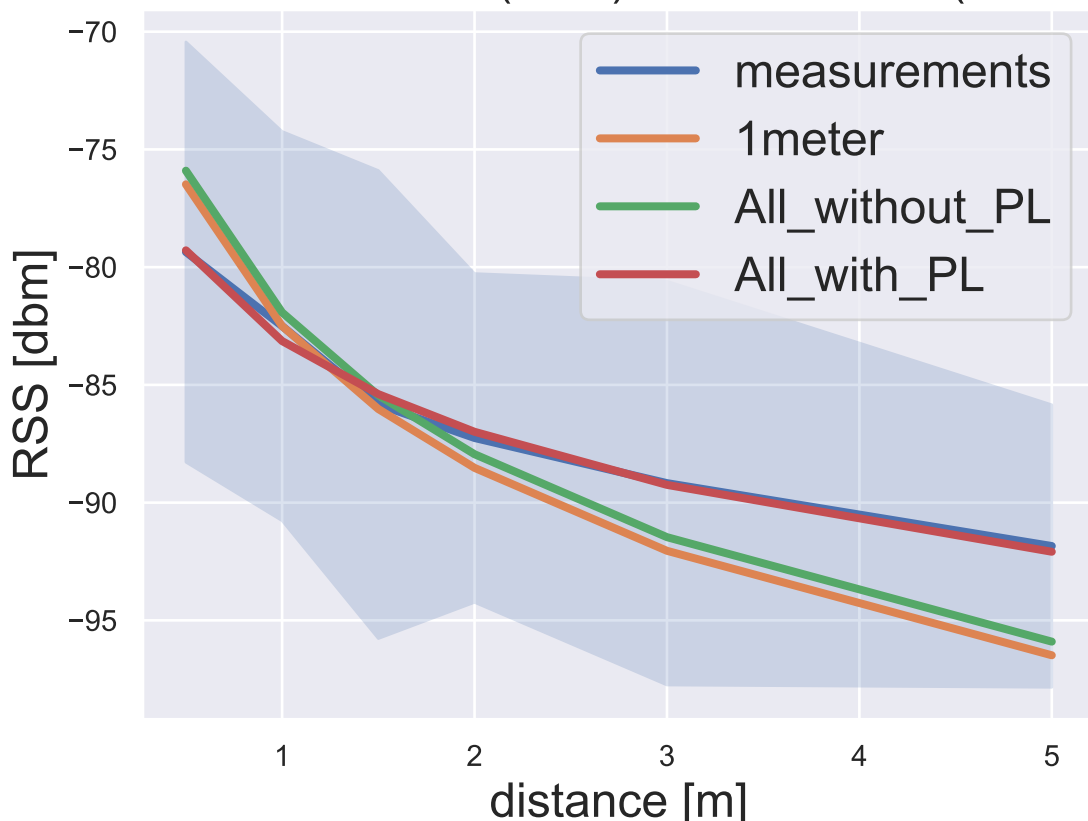


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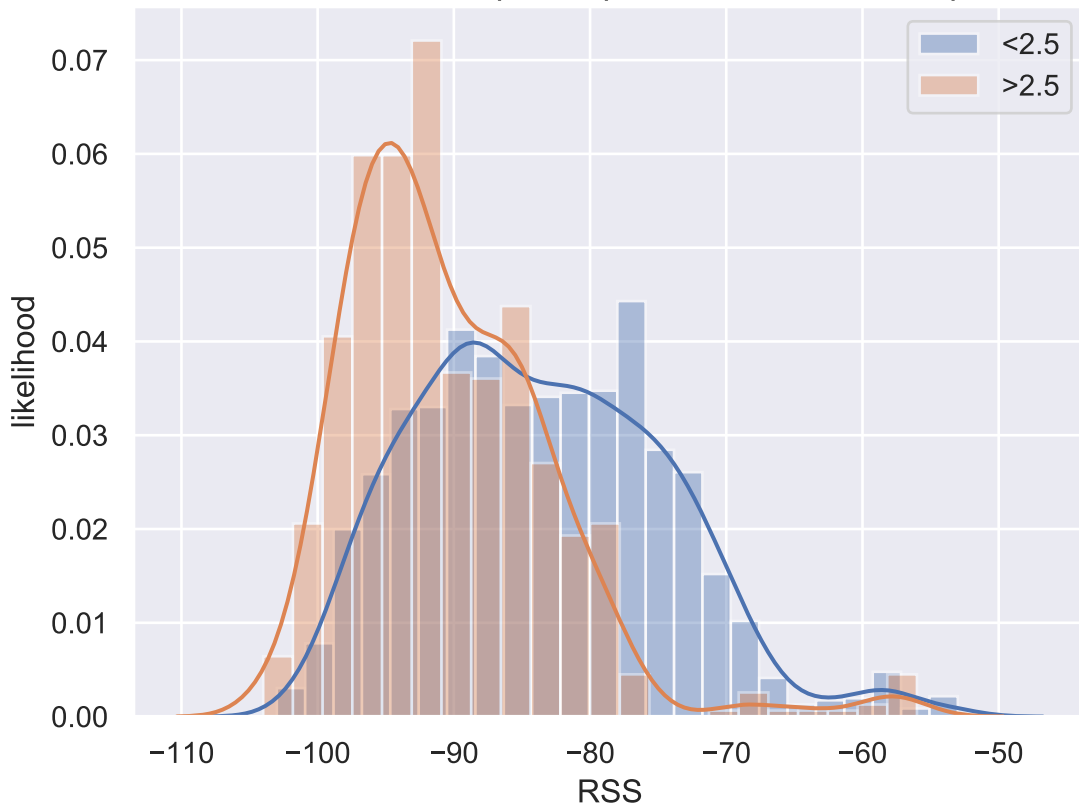




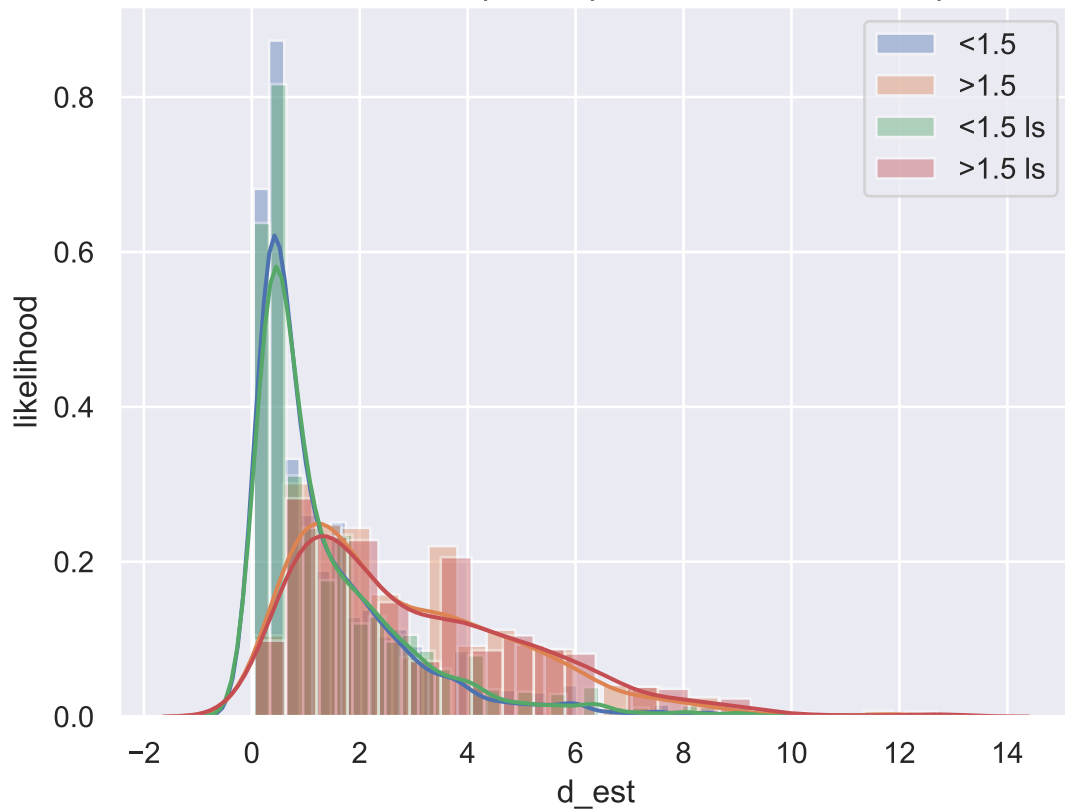
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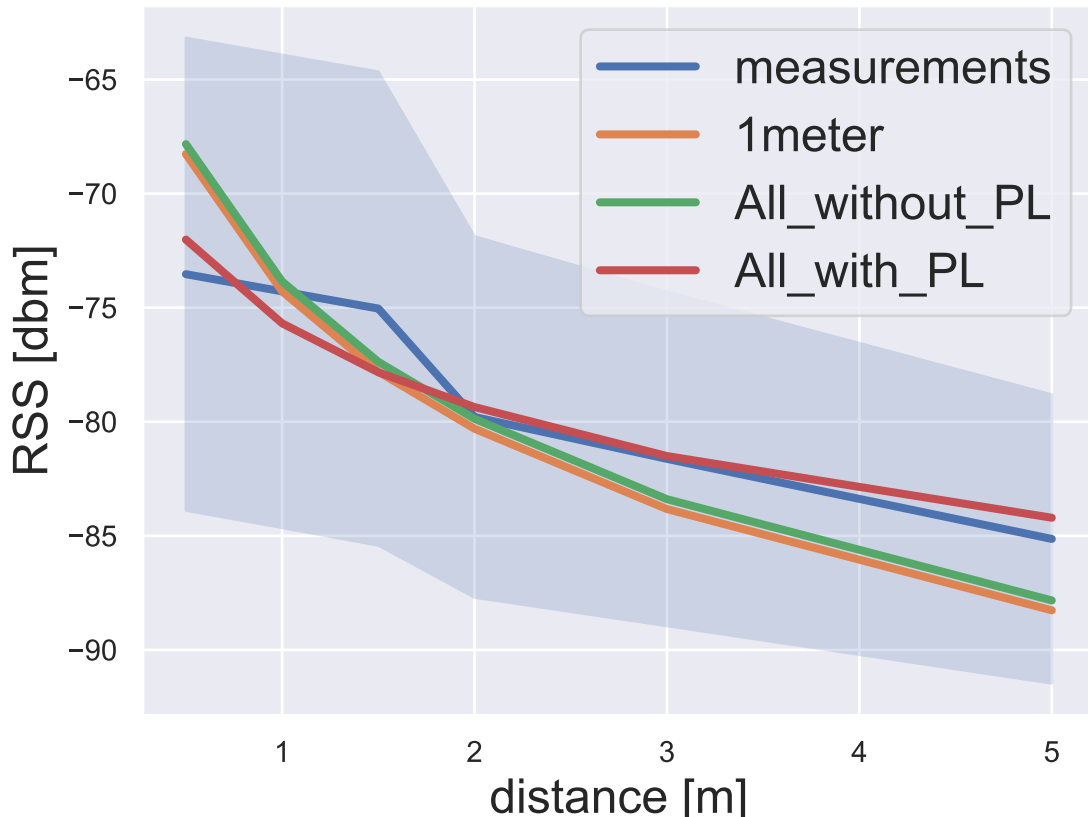
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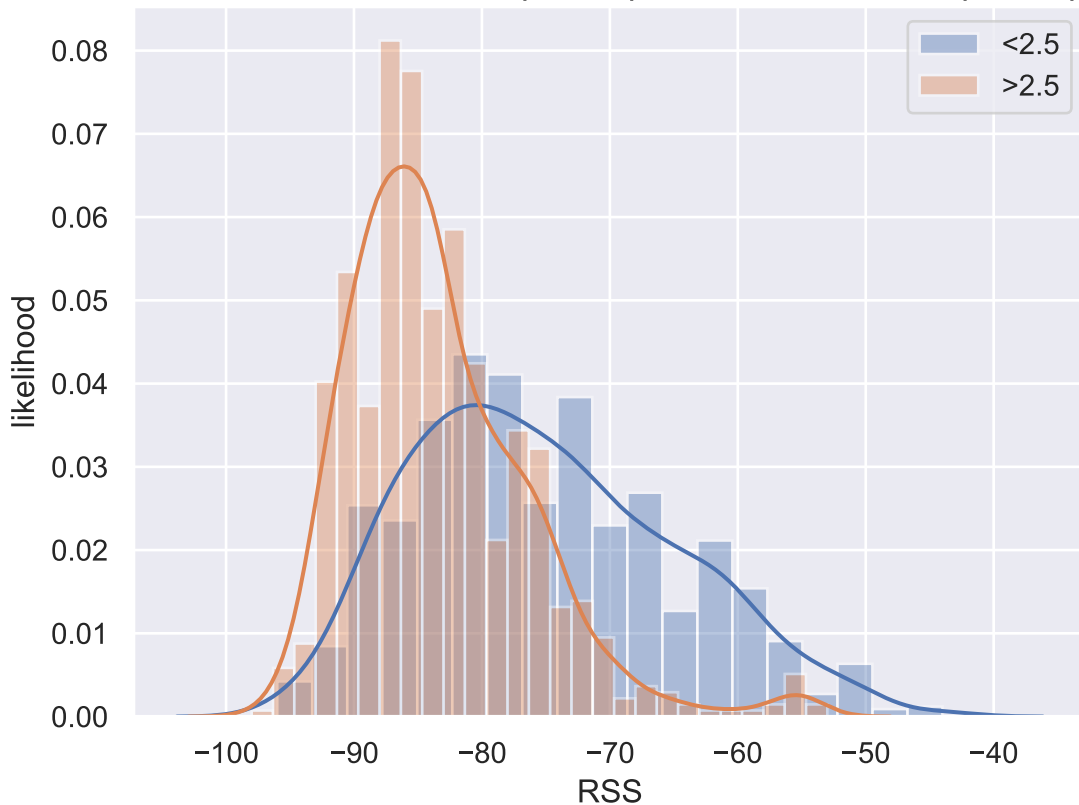
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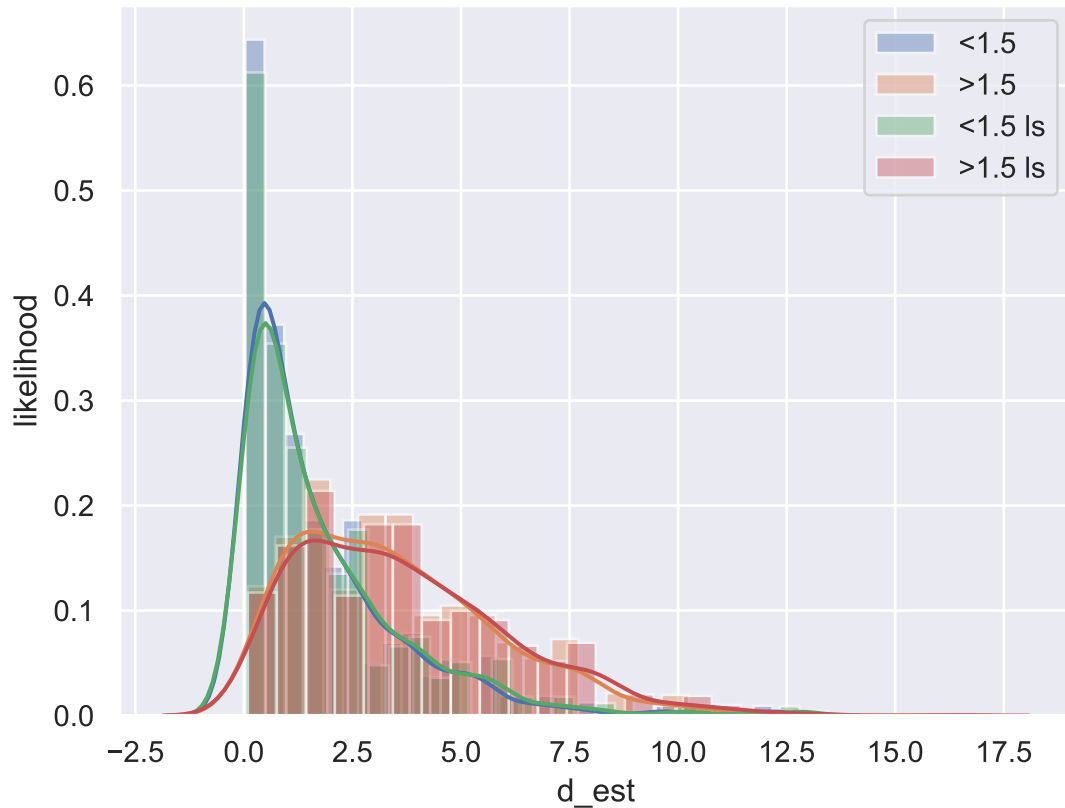
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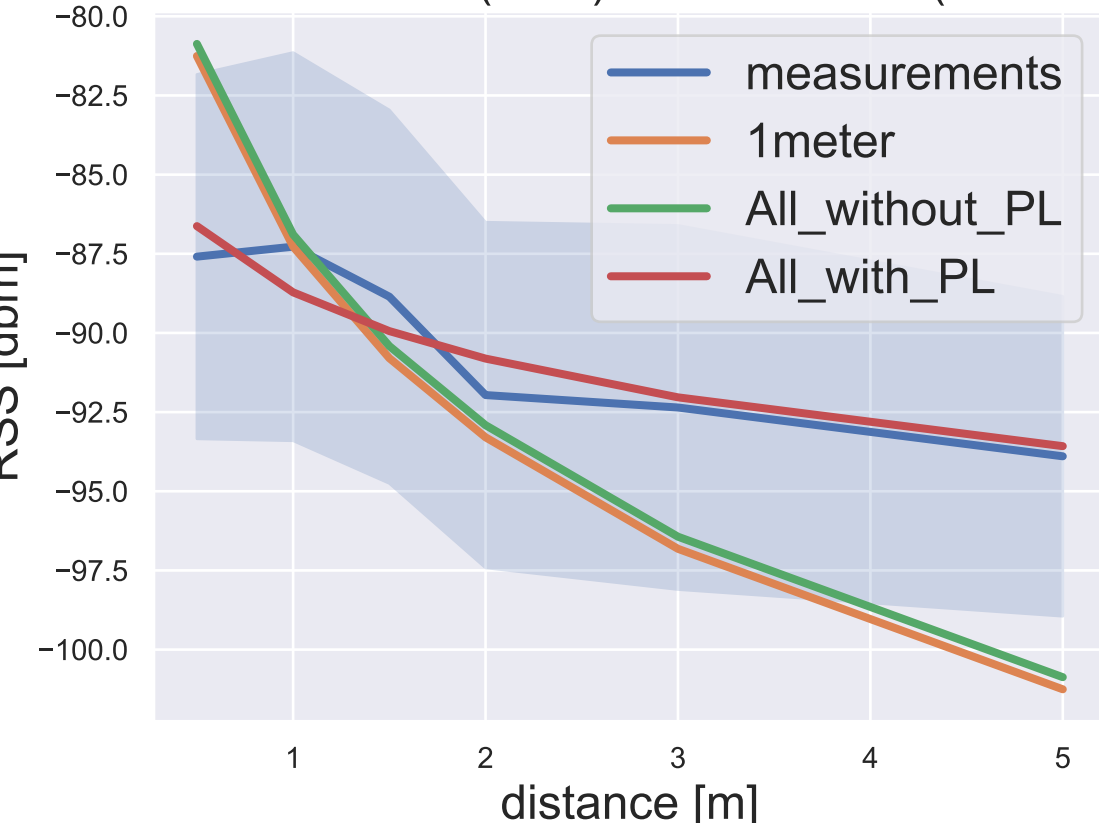
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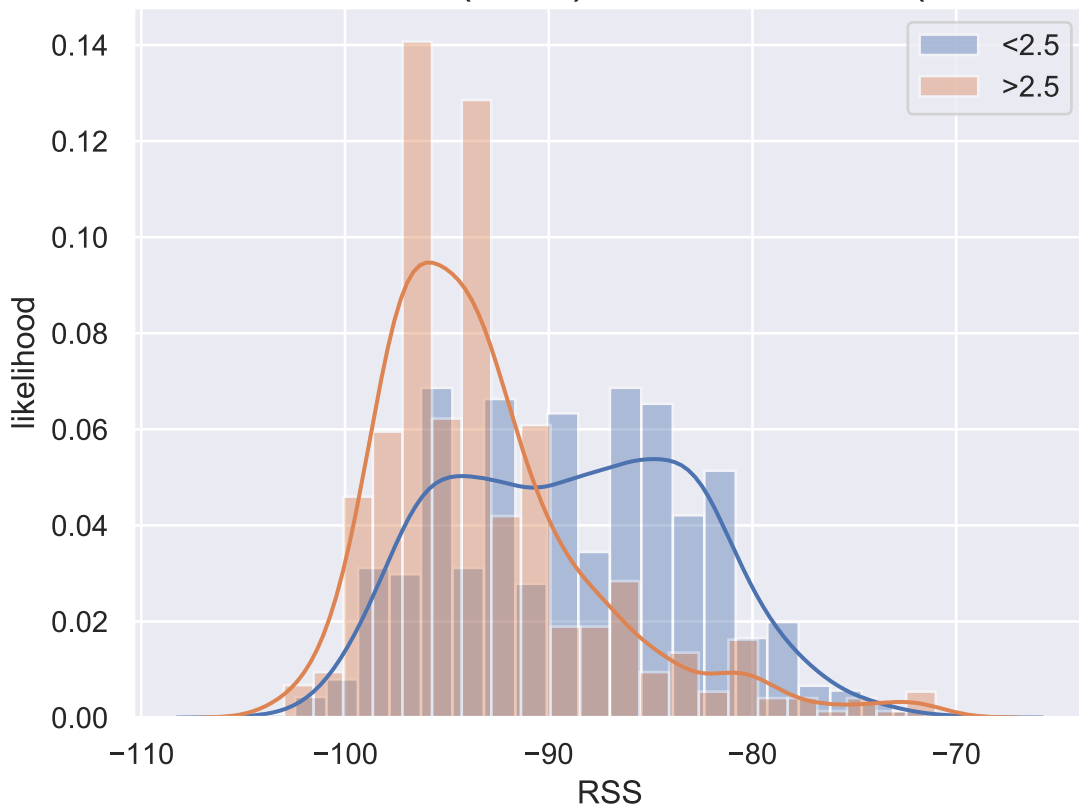
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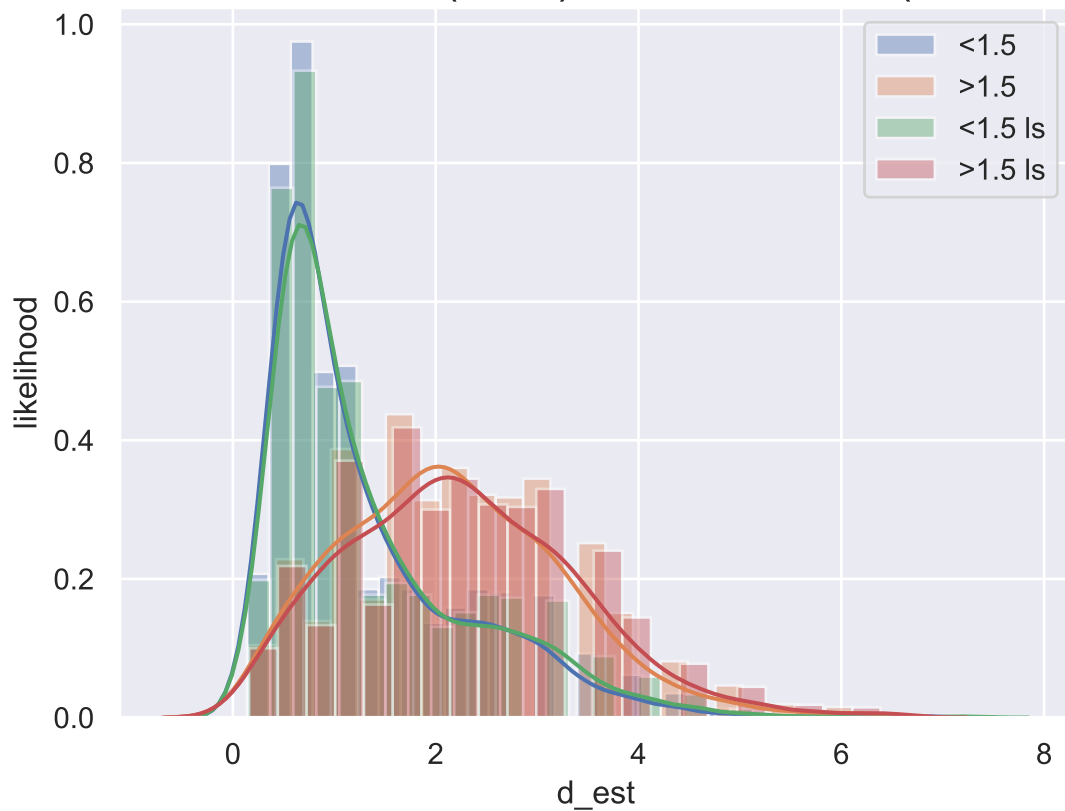


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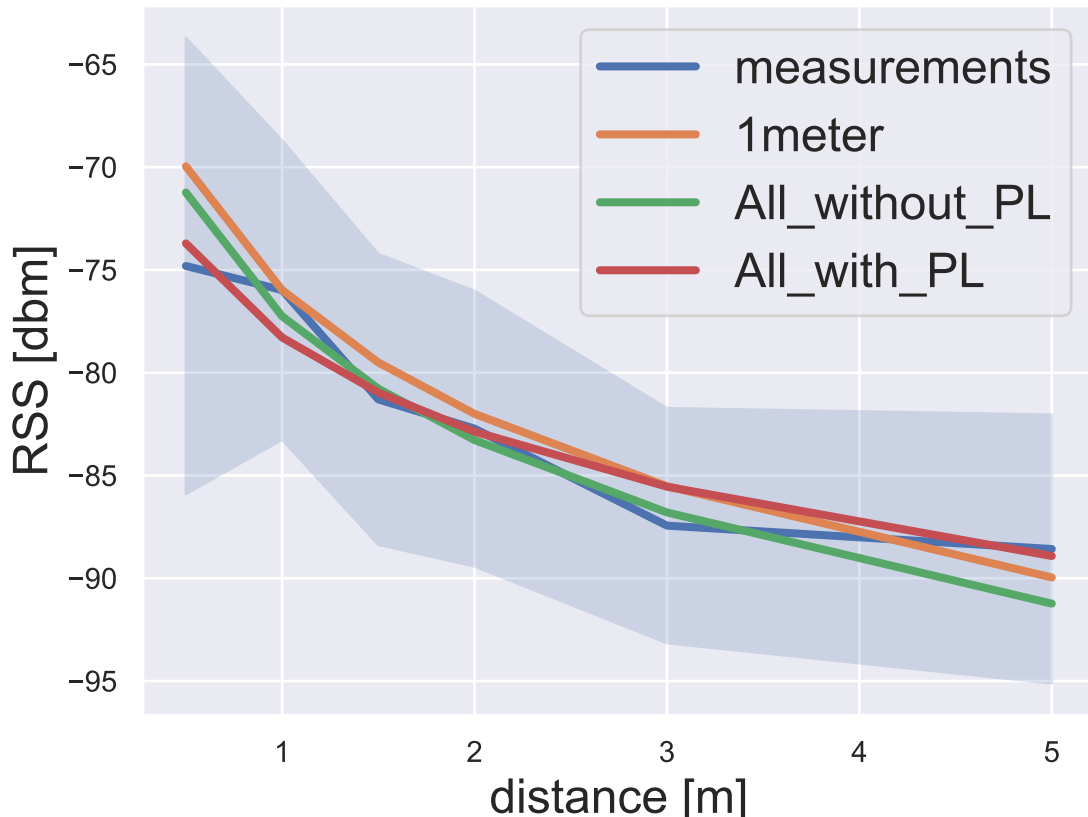




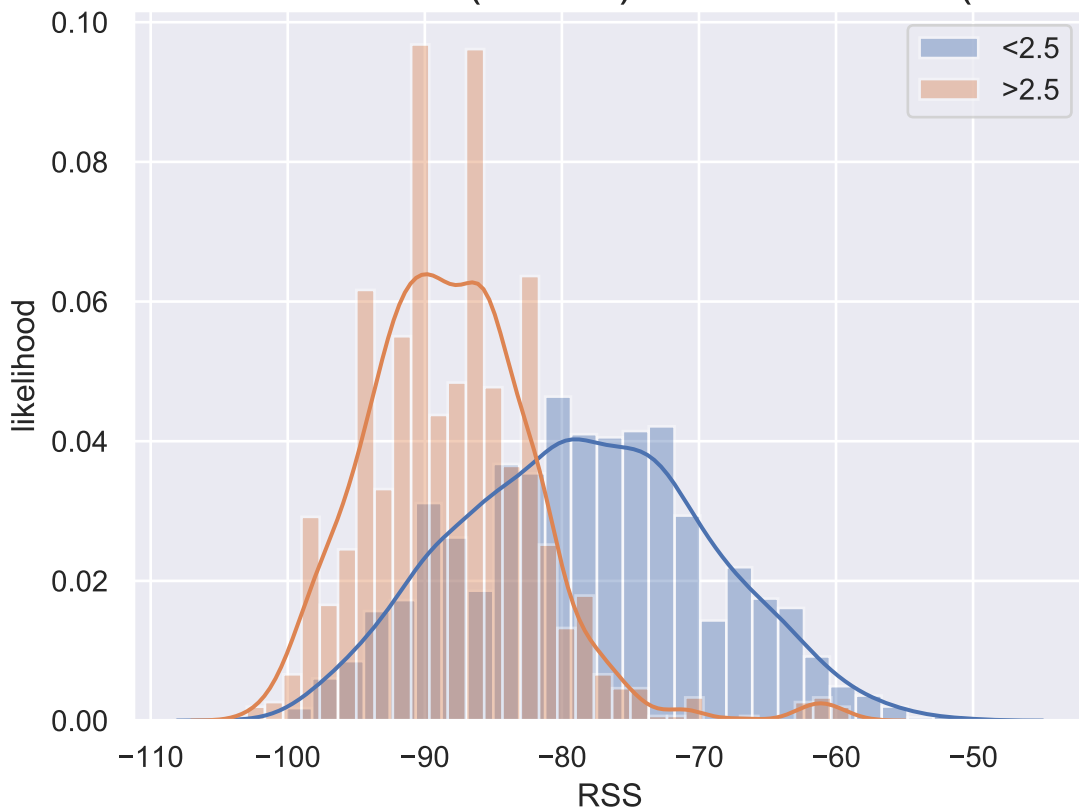
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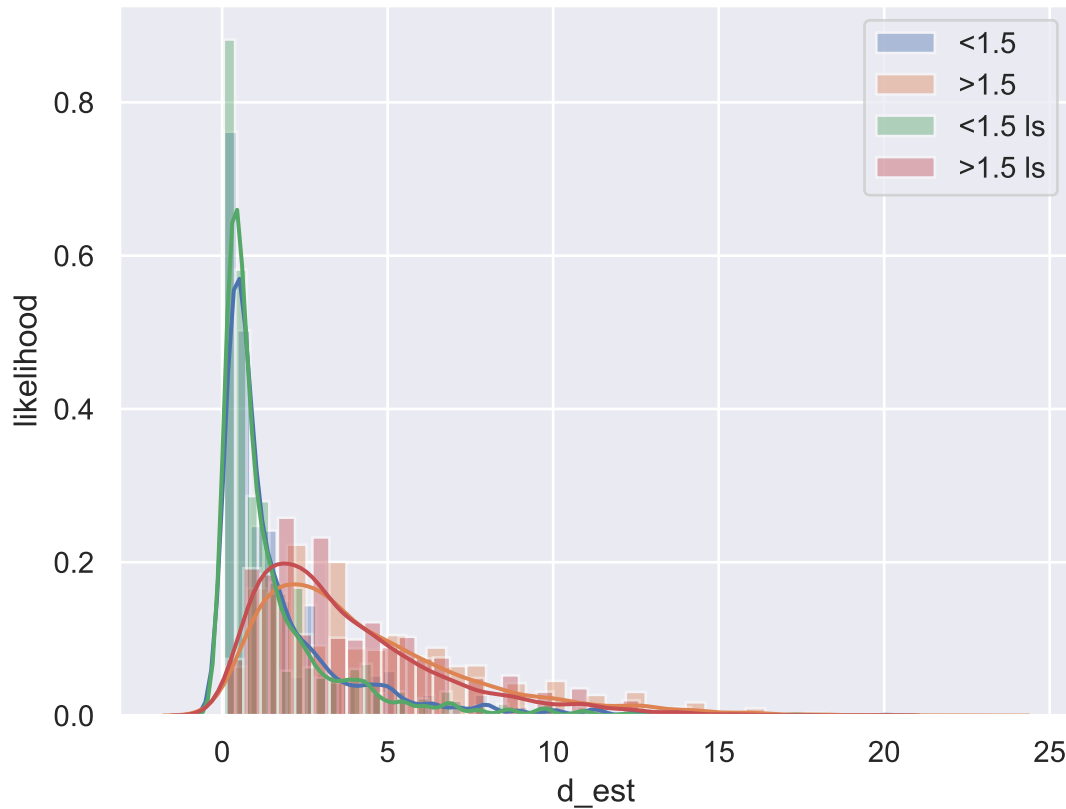
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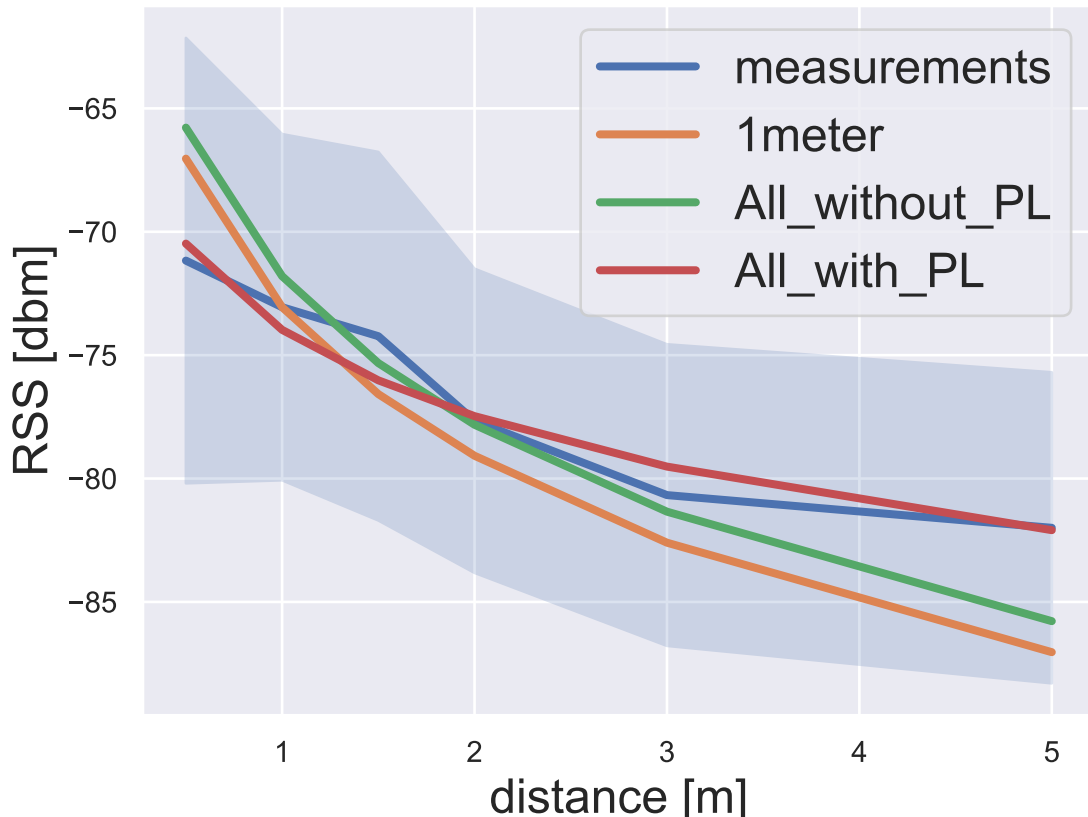
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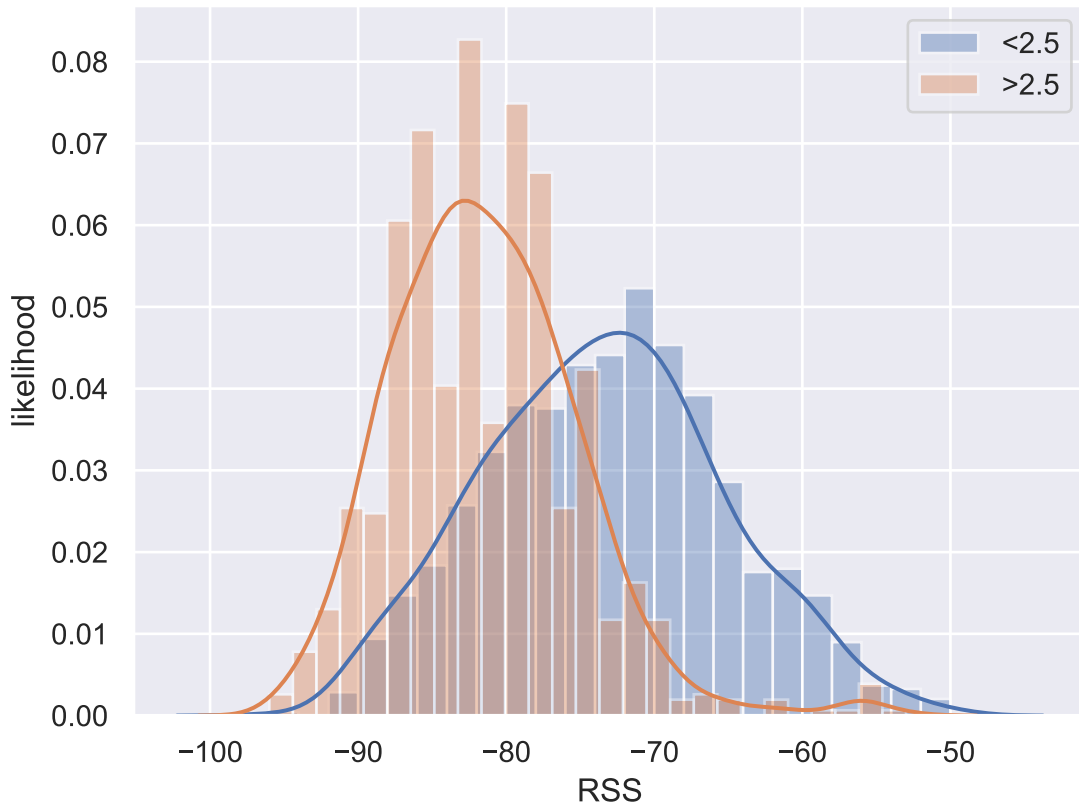
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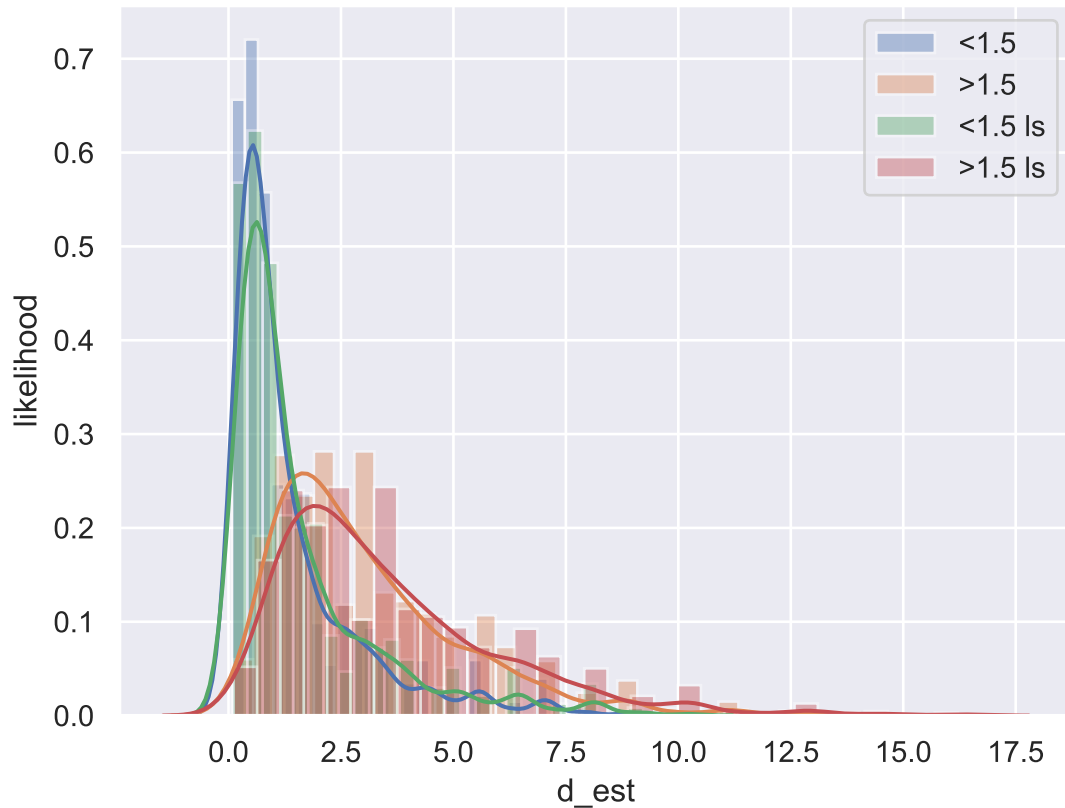
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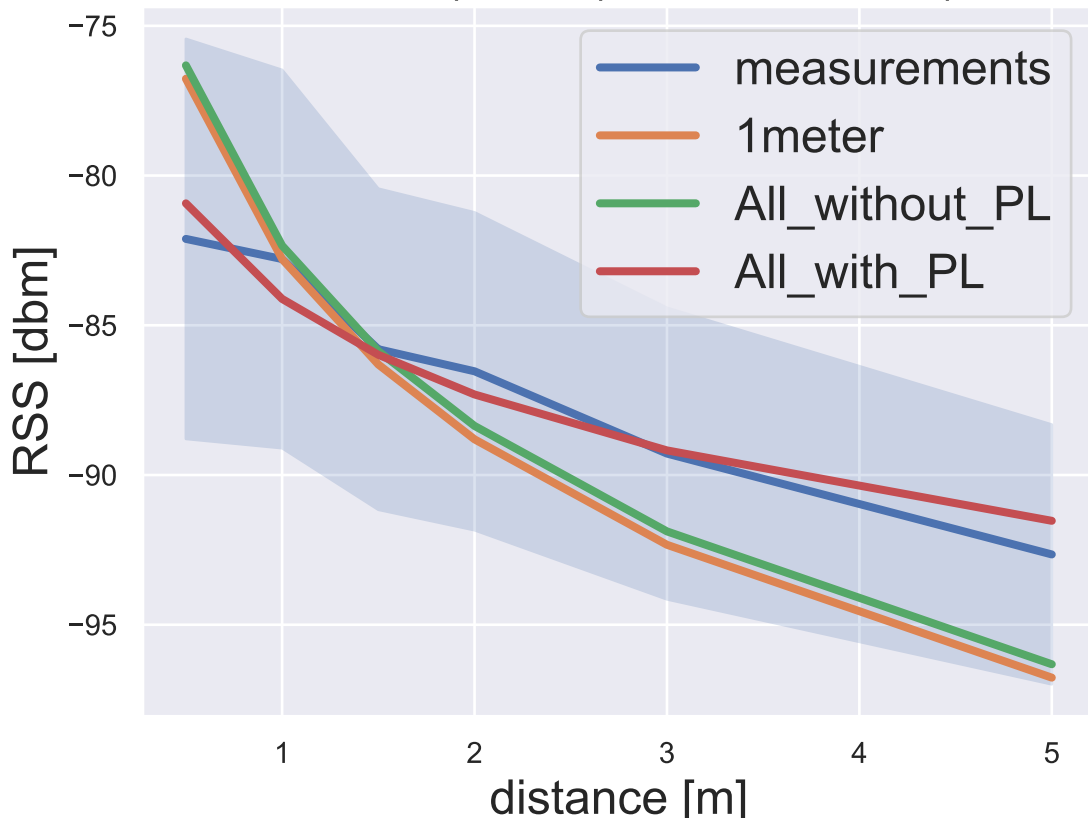
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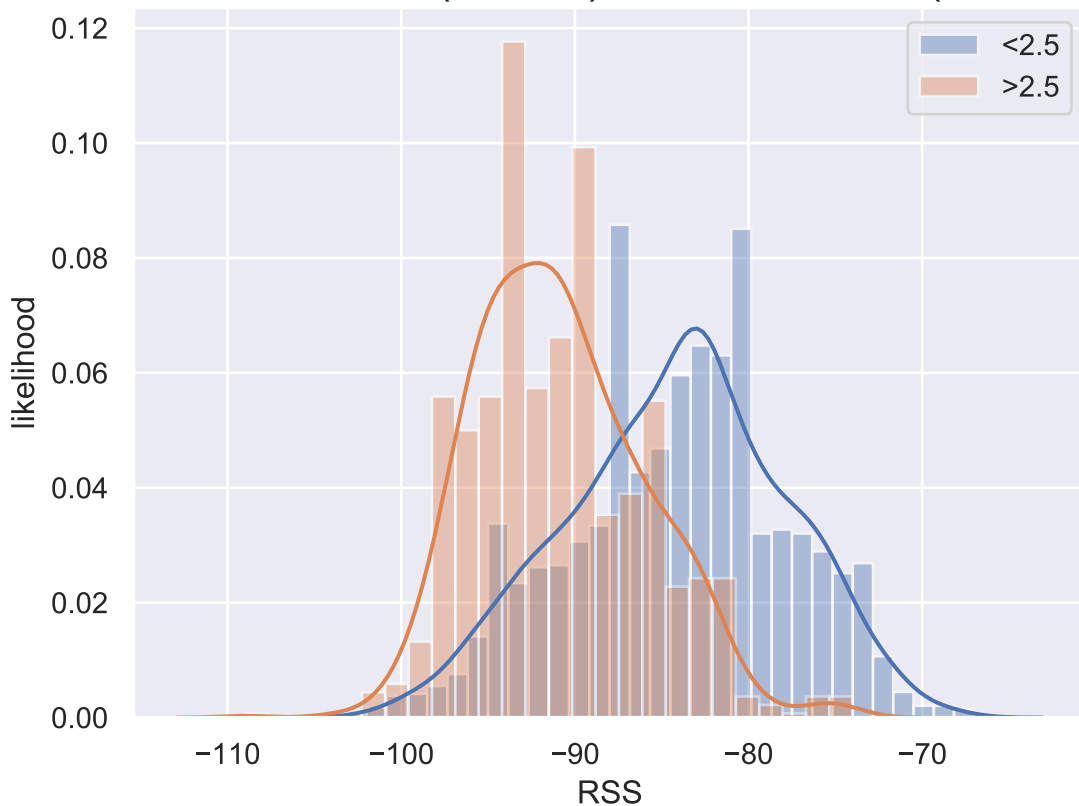


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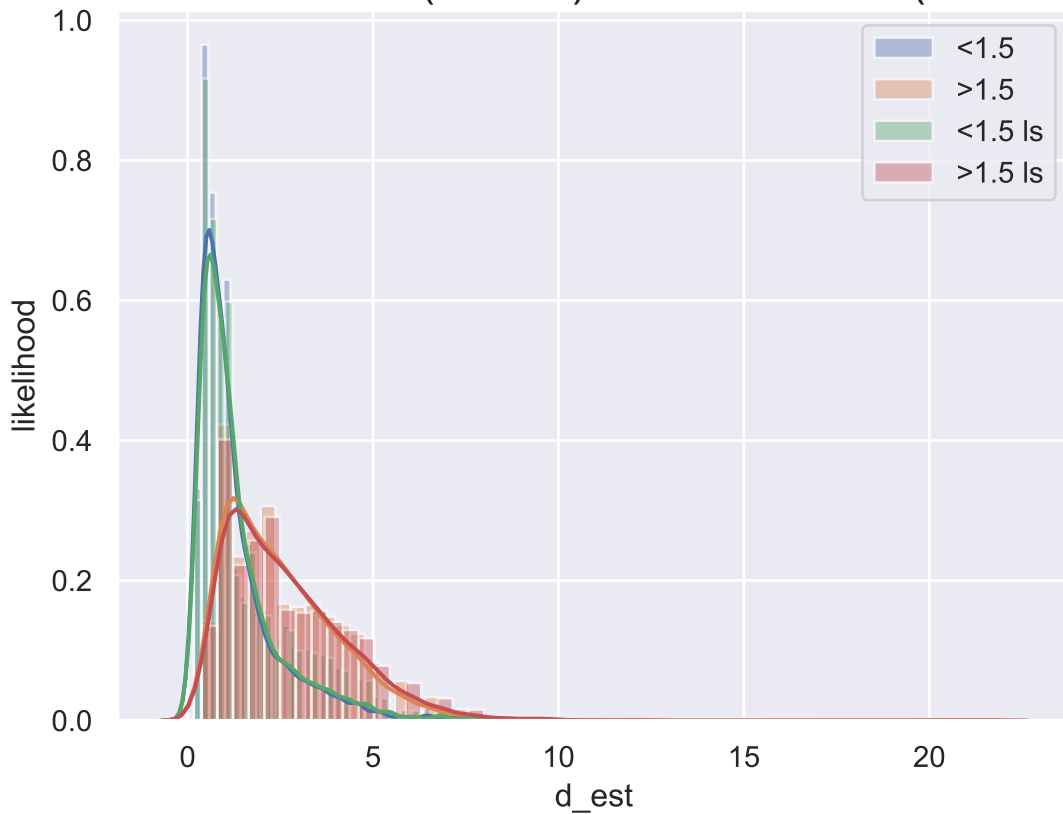




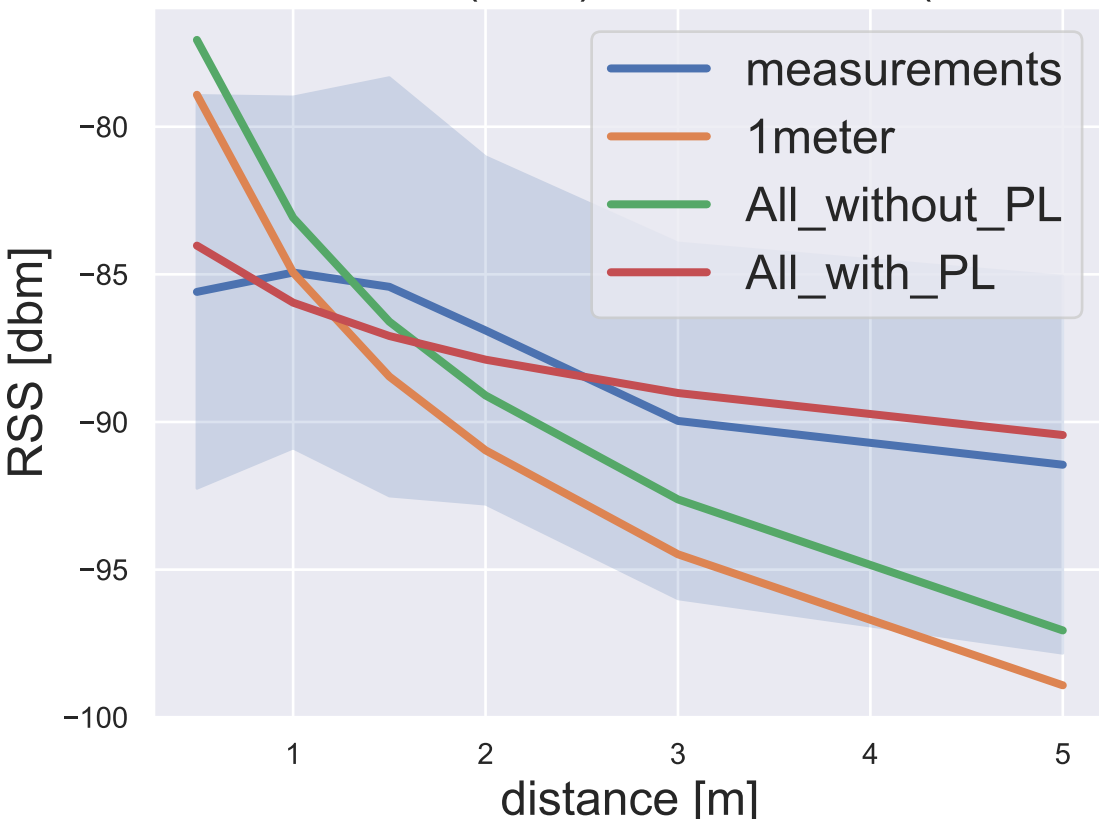
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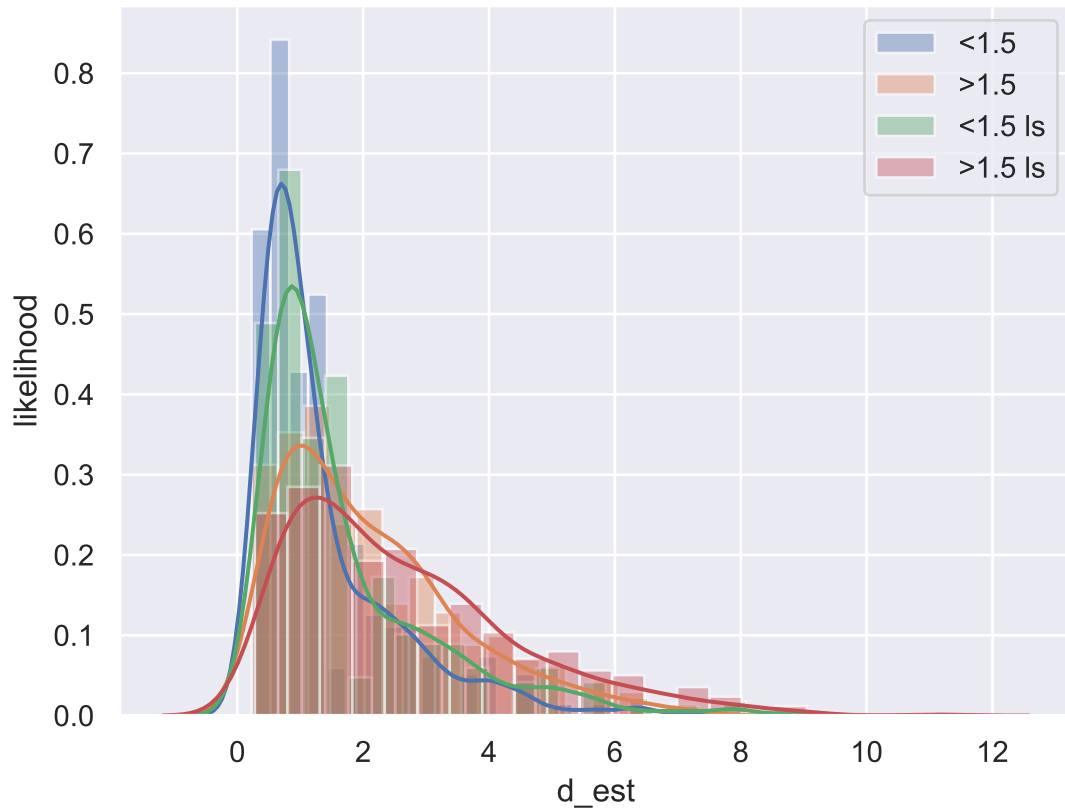
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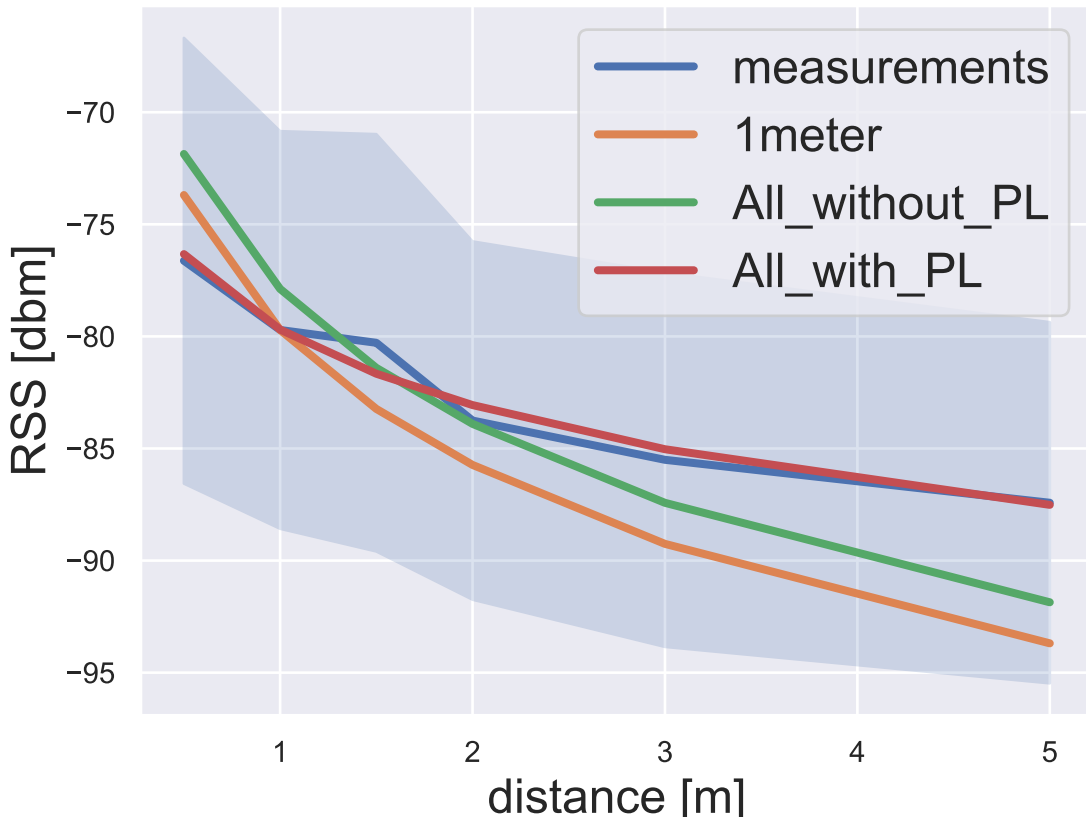
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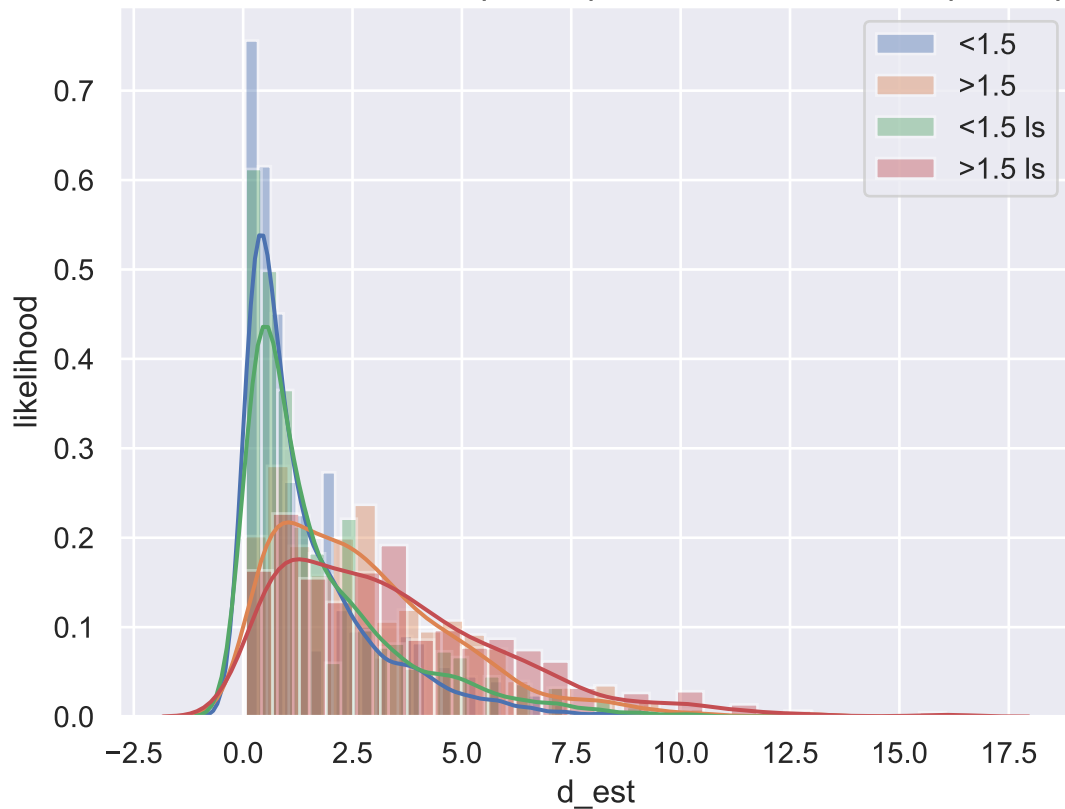
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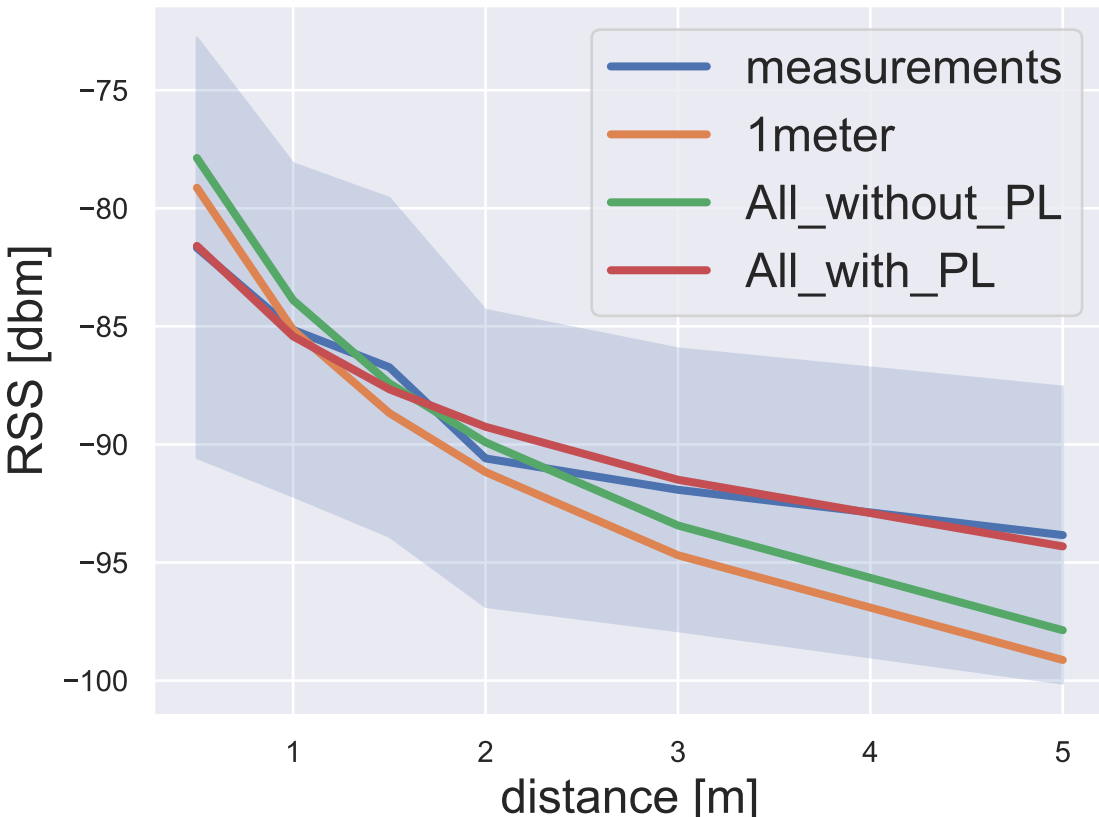


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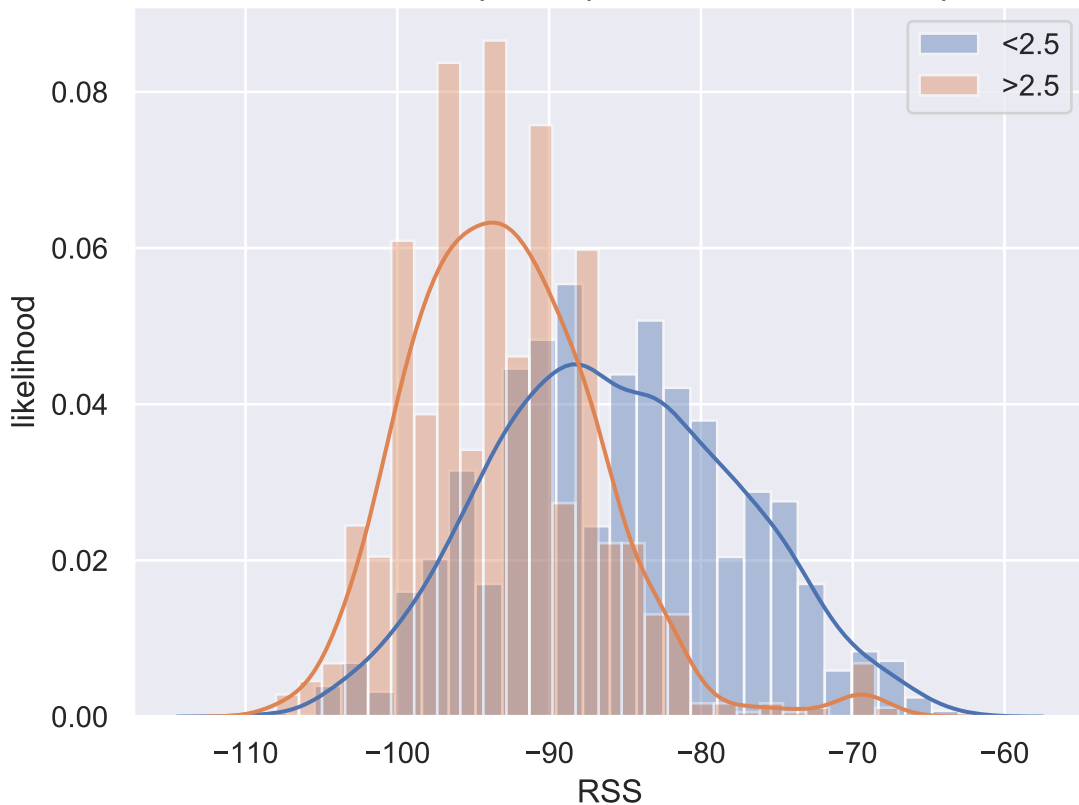




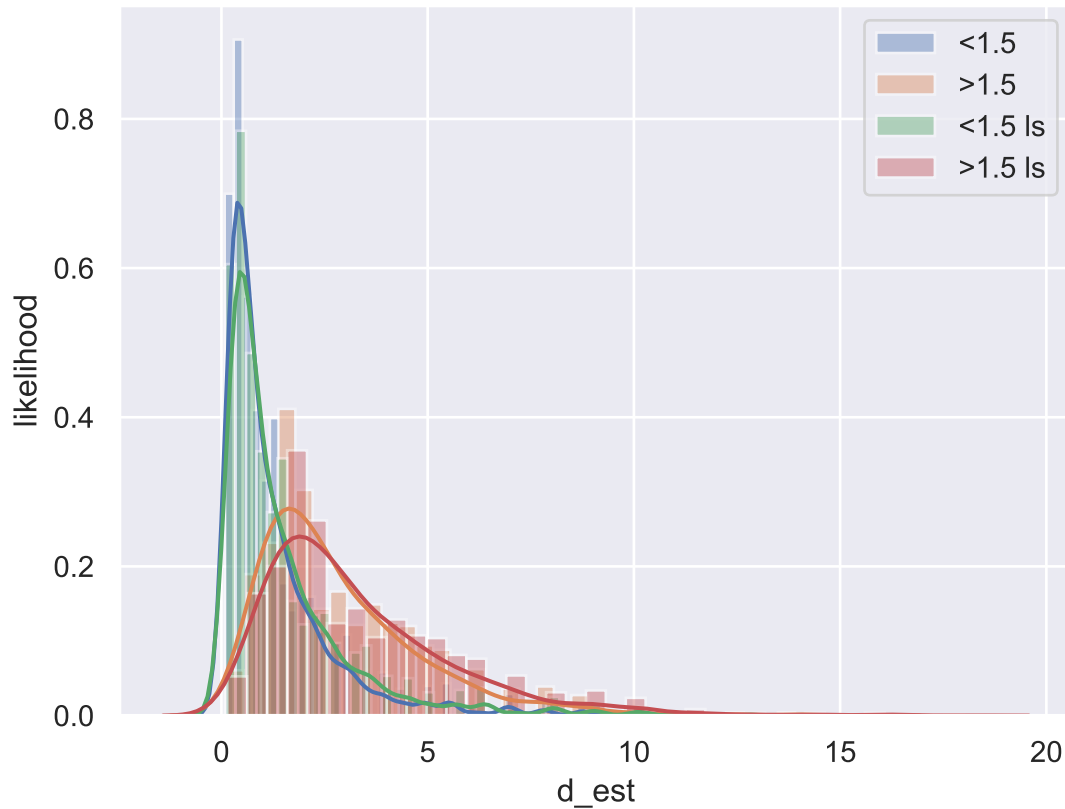
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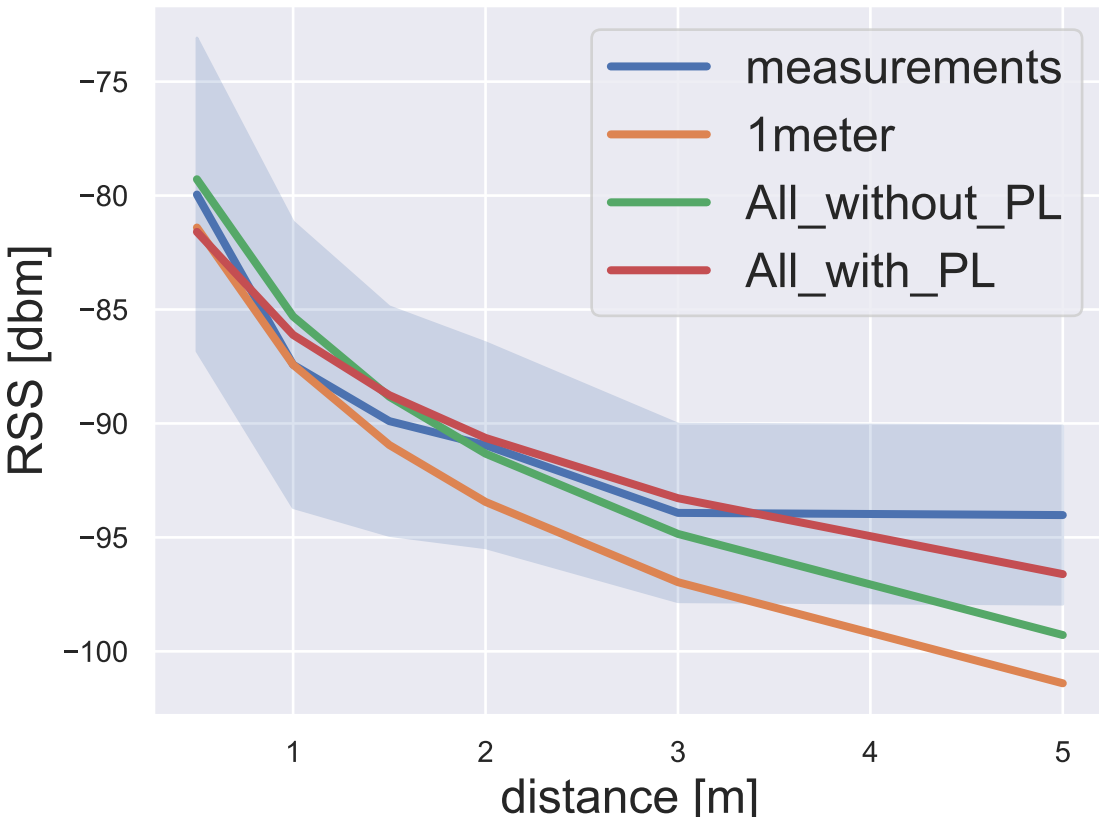
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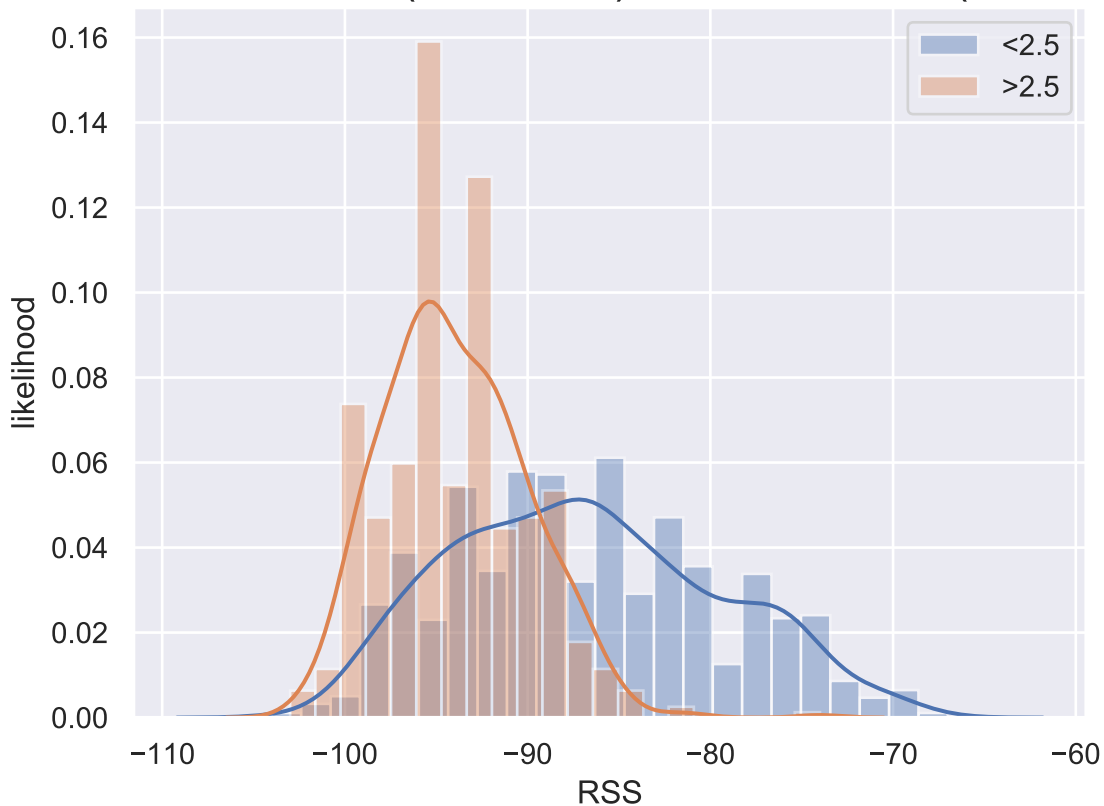
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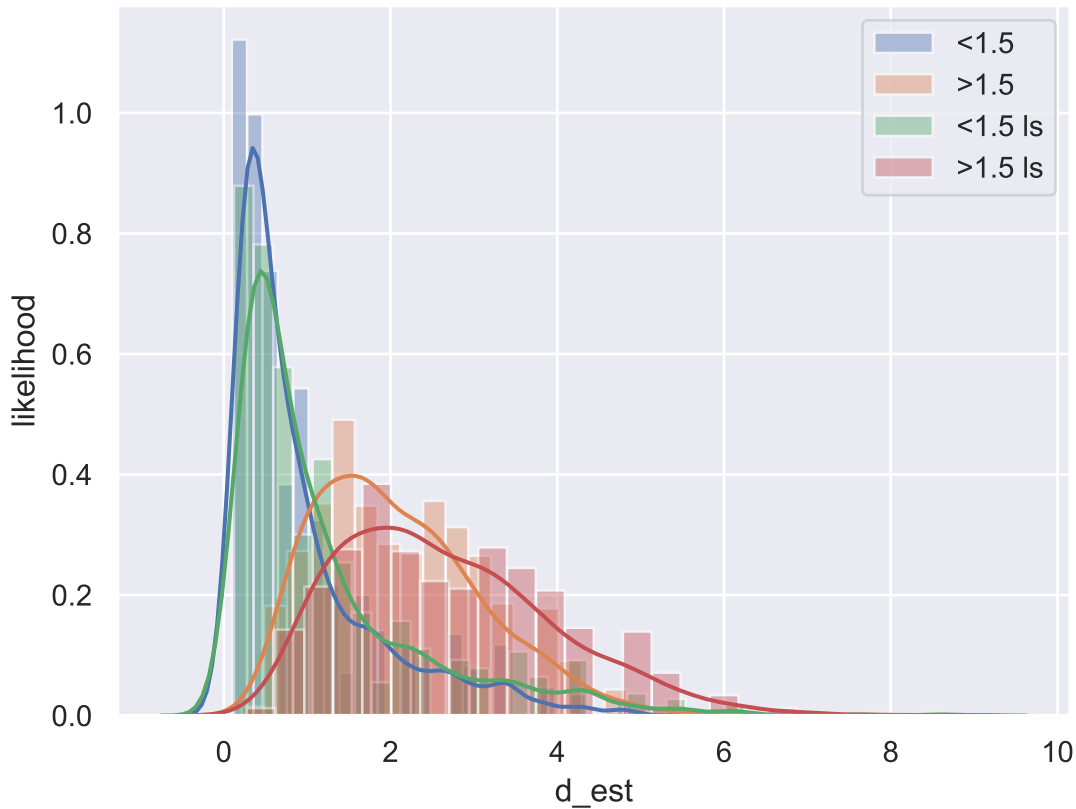
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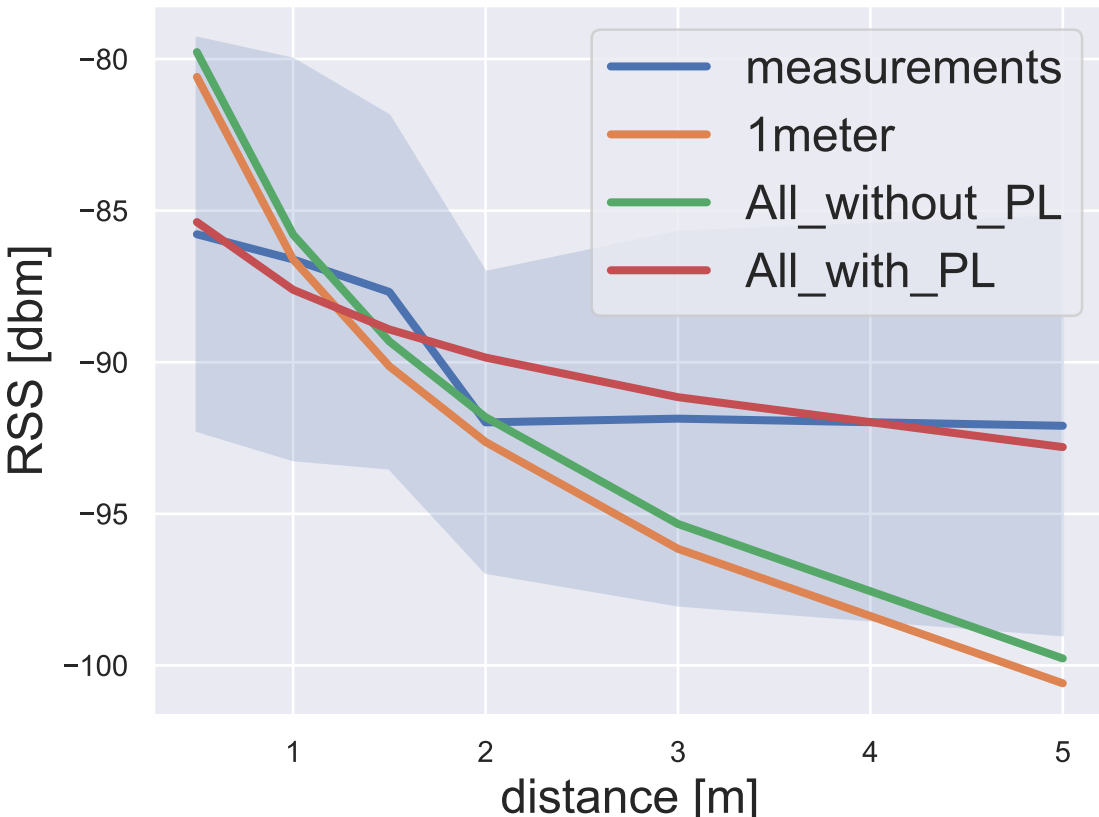
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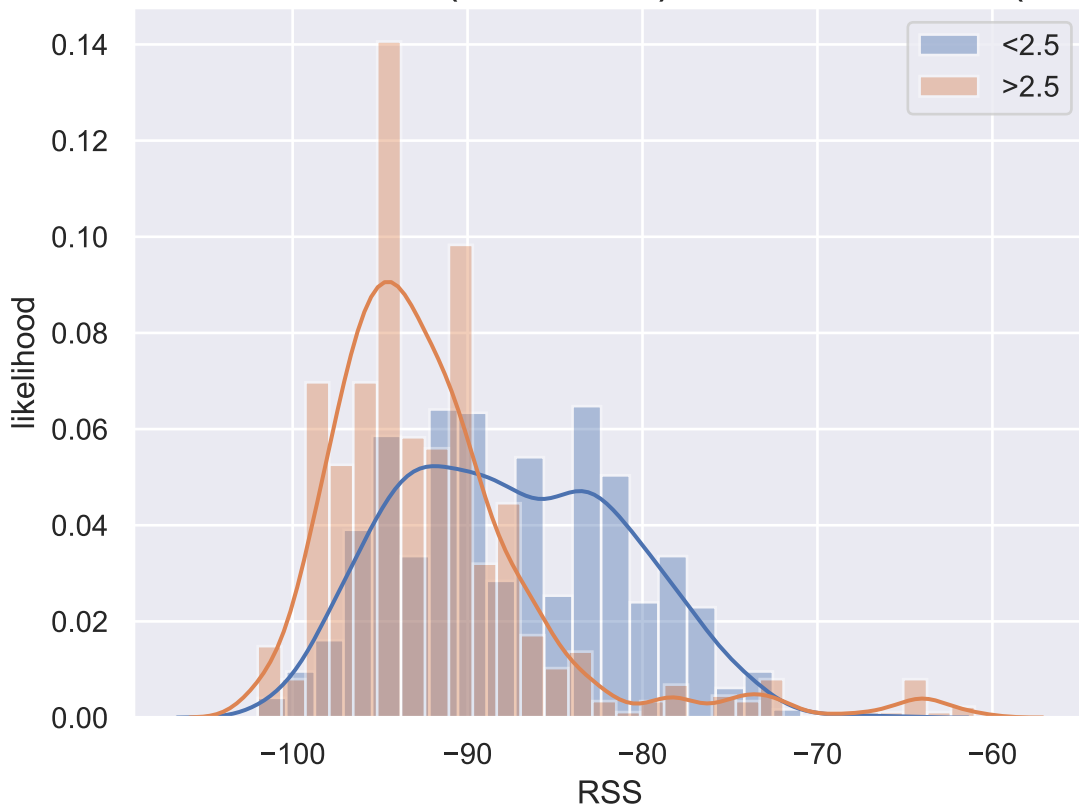
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Transmitter:f761 (POCKET) Receiver:45d9 (EAR)

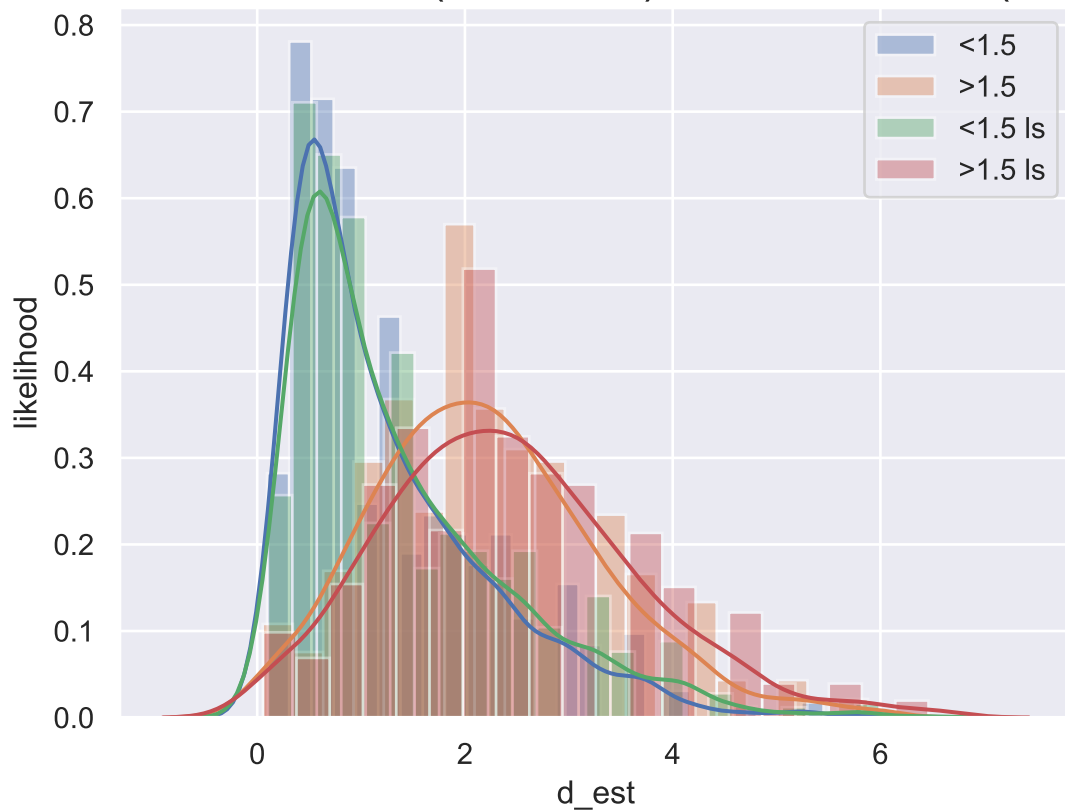


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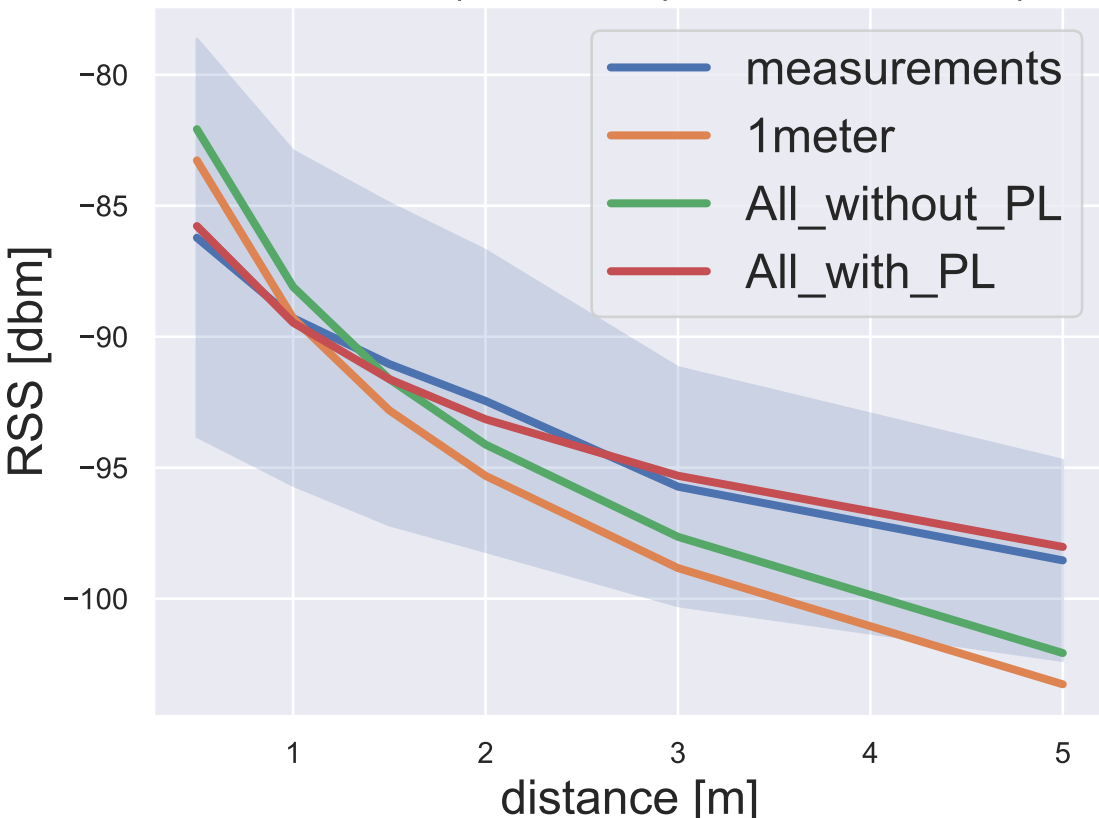




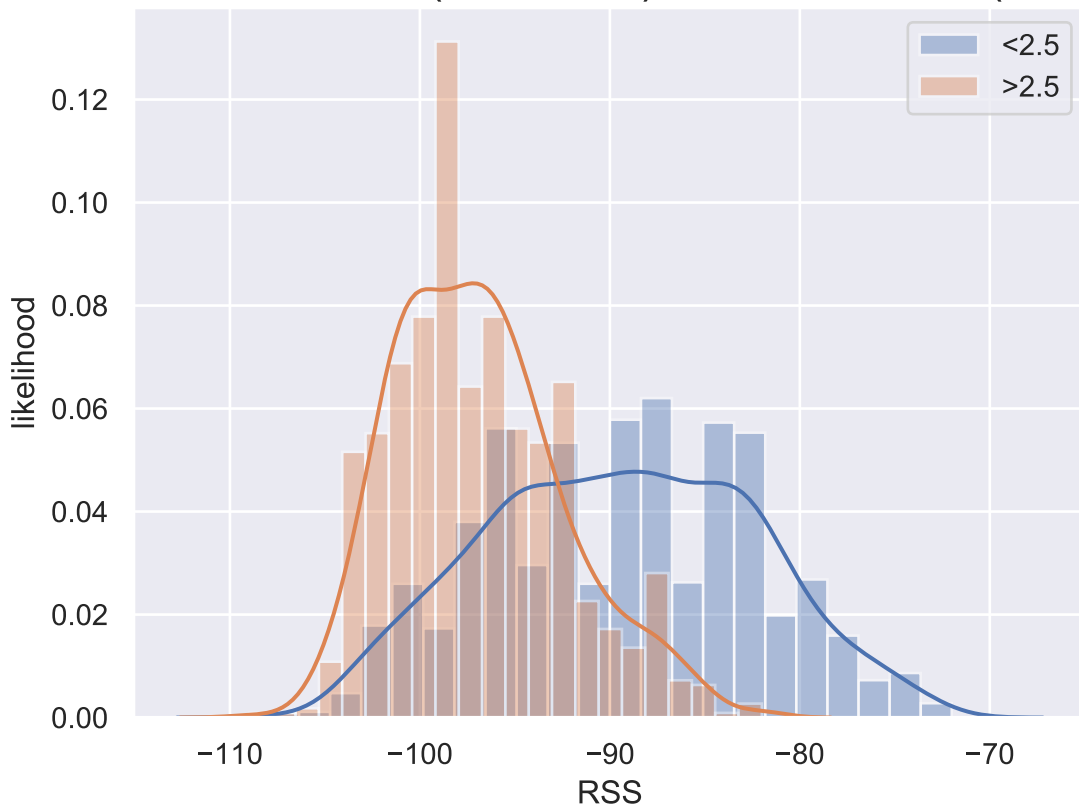
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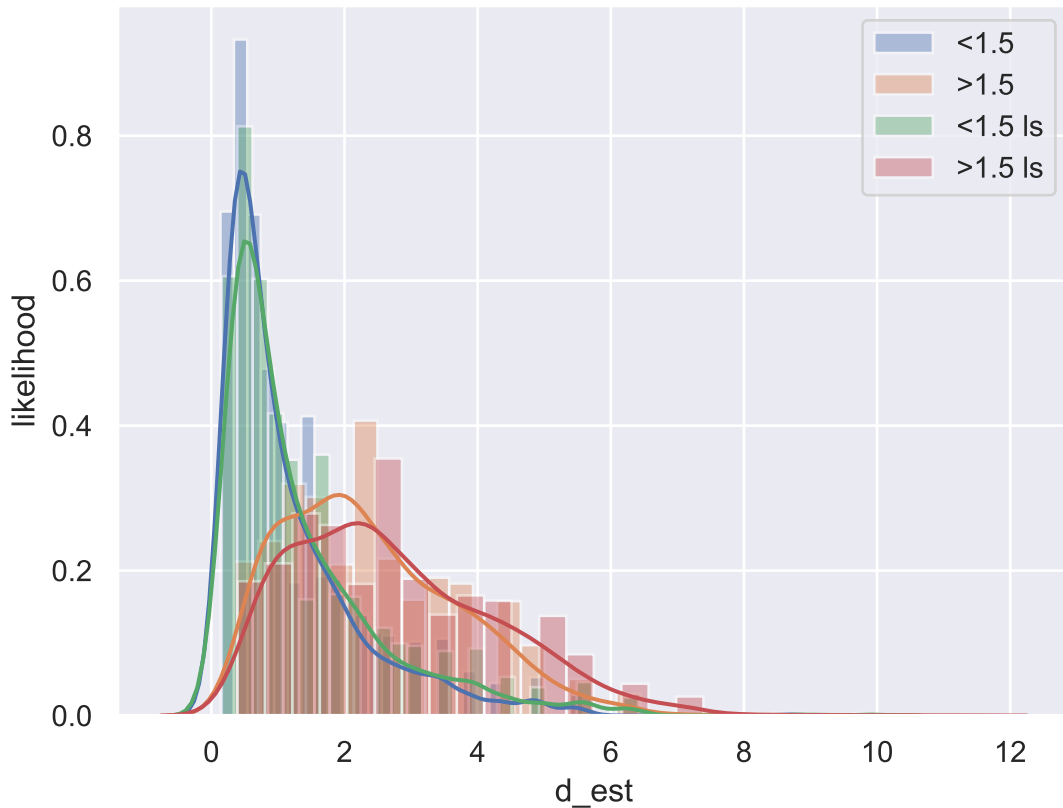
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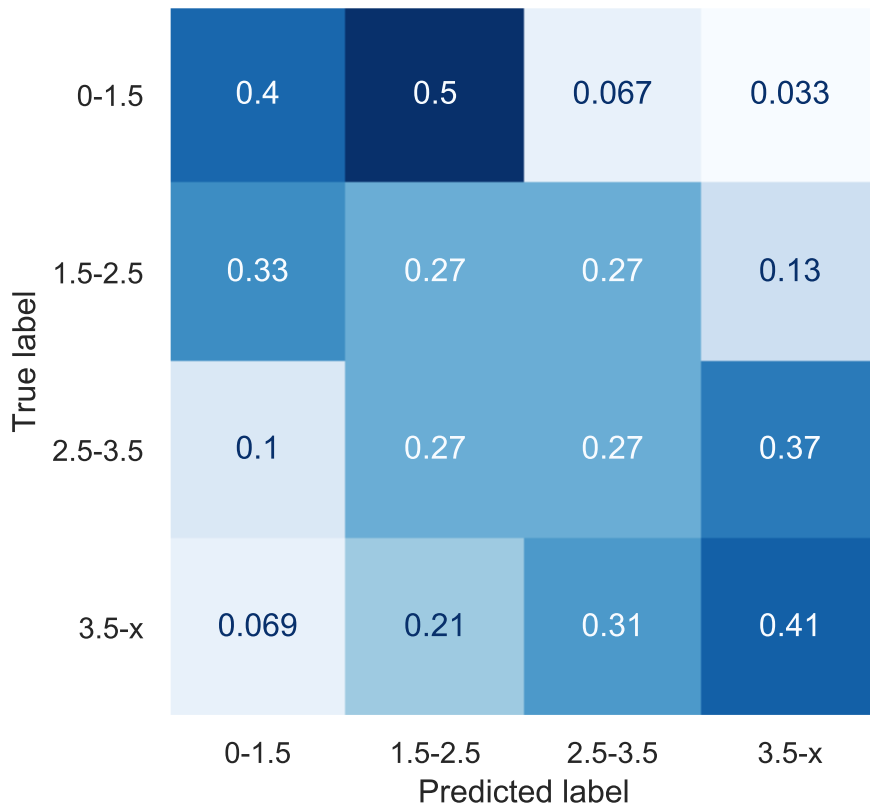
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RANGE WINDOW: 10 s  
RSS Recv: Motorola Trans: S706

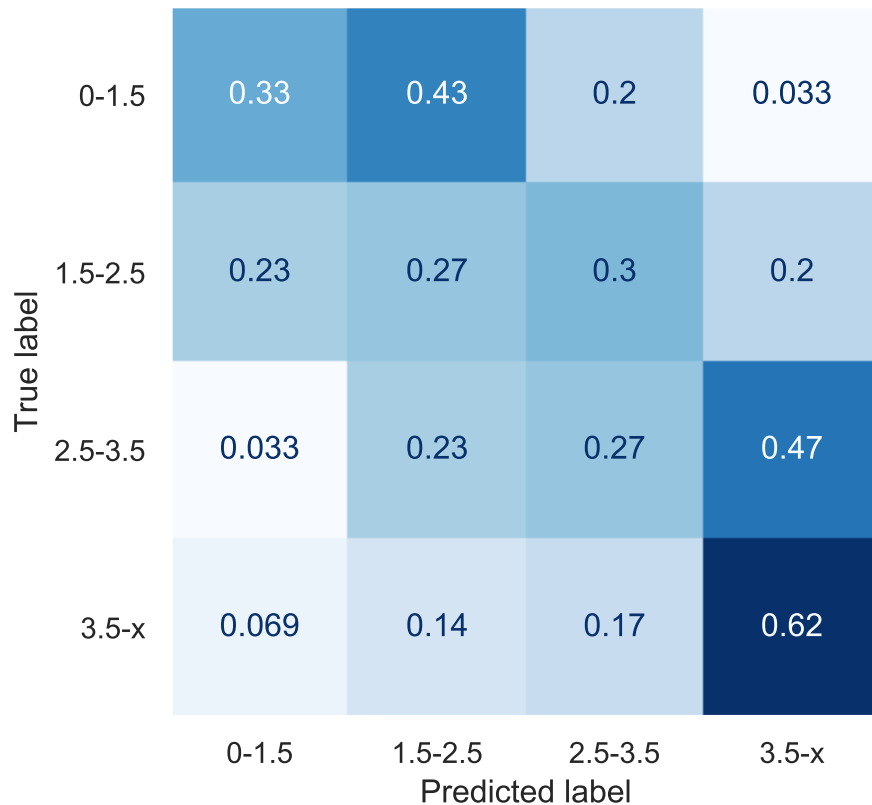


RANGE WINDOW: 10 s  
Confusion matrix Recv: Motorola Trans: S706 Method: 1meter



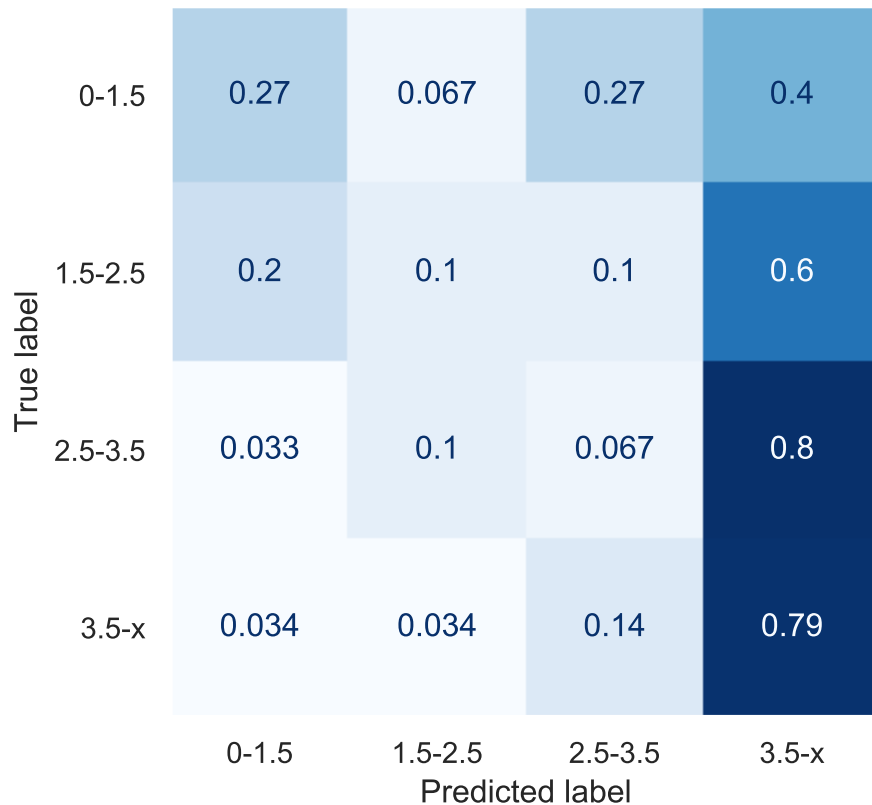
RANGE WINDOW: 10 s

Confusion matrix Recv: Motorola Trans: S706 Method: All\_without\_PL



RANGE WINDOW: 10 s

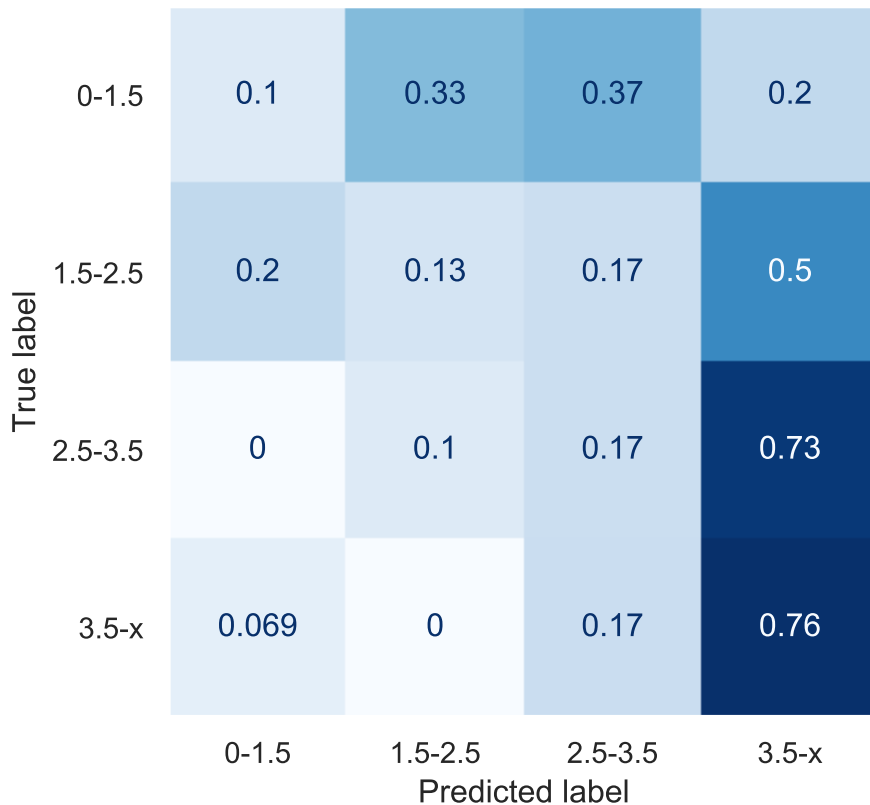
Confusion matrix Recv: Motorola Trans: S706 Method: All\_with\_PL





RANGE WINDOW: 10 s

Confusion matrix Recv: Motorola Trans: S706 Method: method 4

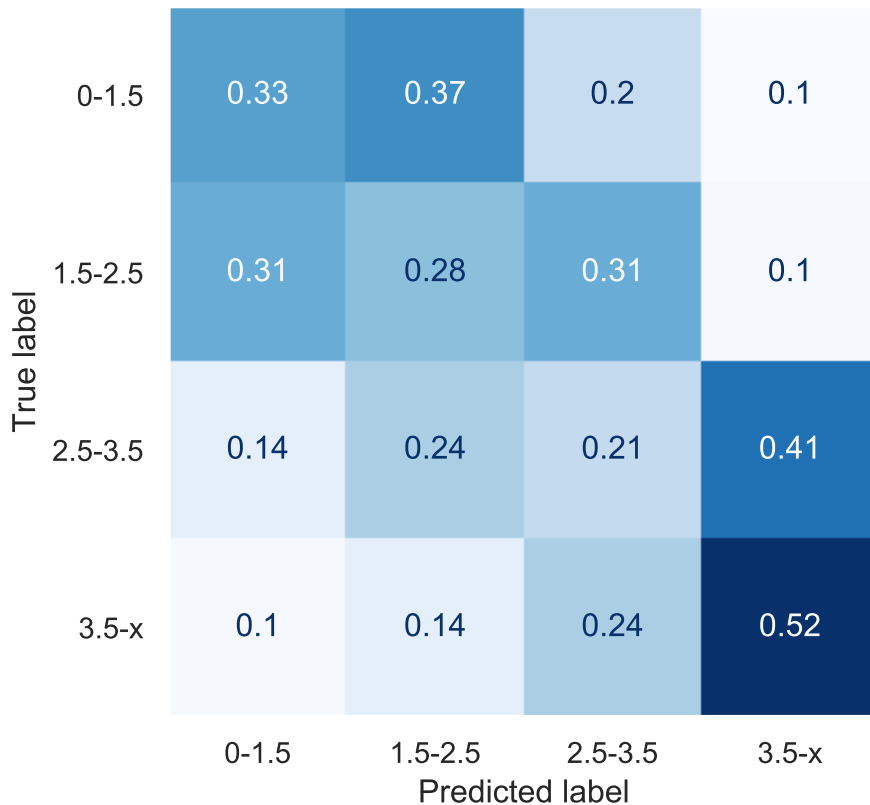


RANGE WINDOW: 10 s  
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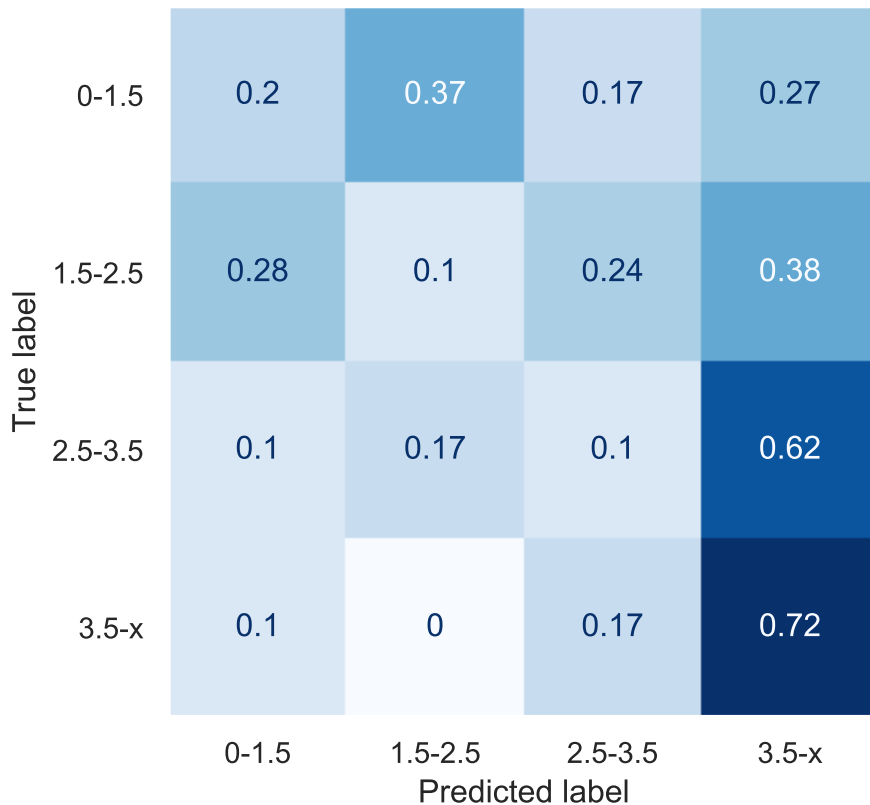
RANGE WINDOW: 10 s

Confusion matrix Recv: SamsungA6 Trans: S706 Method: 1meter



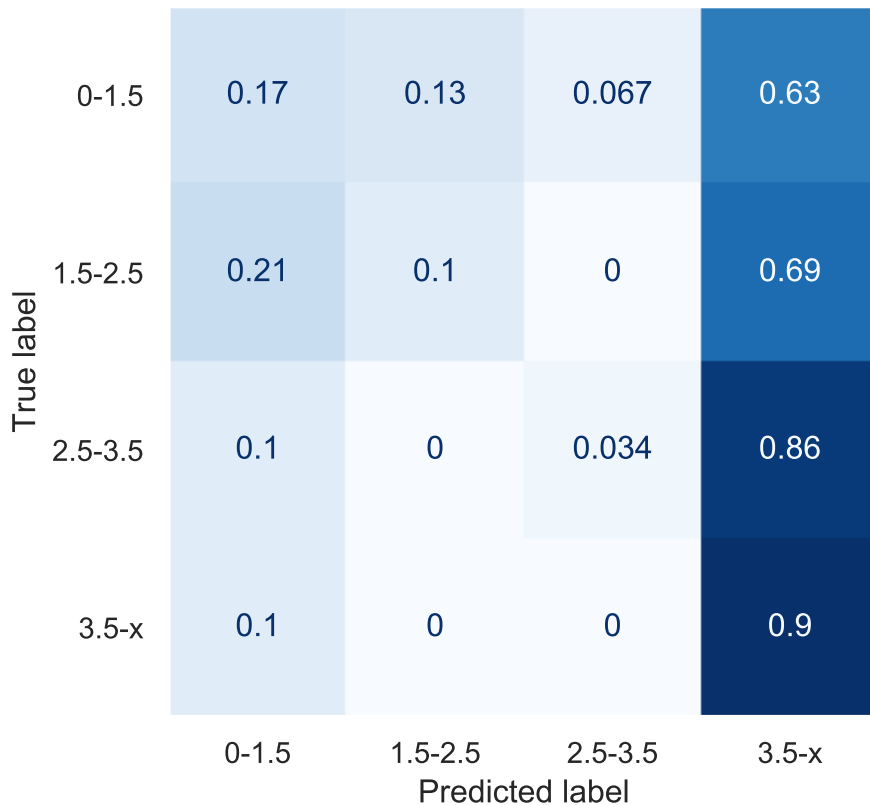
RANGE WINDOW: 10 s

Confusion matrix Recv: SamsungA6 Trans: S706 Method: All\_without\_PL



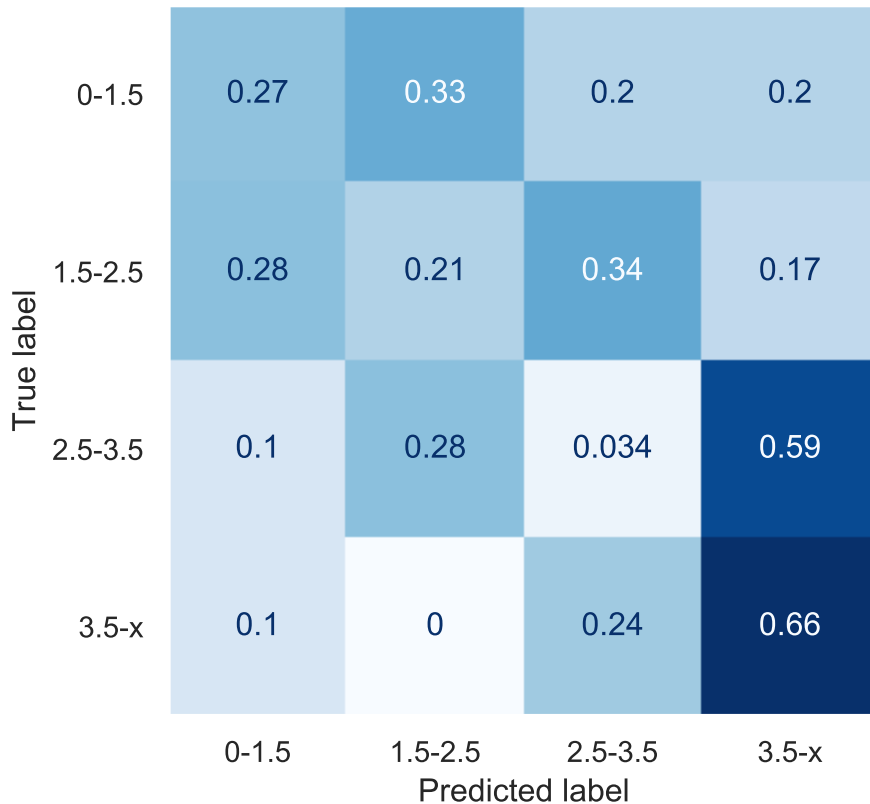
RANGE WINDOW: 10 s

Confusion matrix Recv: SamsungA6 Trans: S706 Method: All\_with\_PL



RANGE WINDOW: 10 s

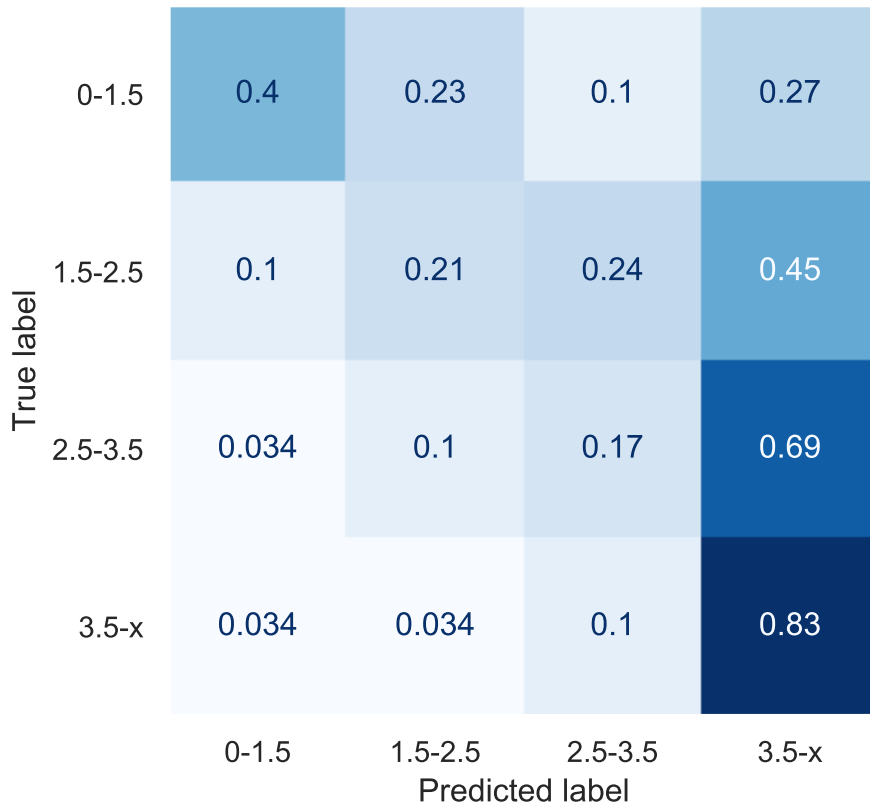
Confusion matrix Recv: SamsungA6 Trans: S706 Method: method 4



RANGE WINDOW: 10 s  
RSS Recv: S708 Trans: S706



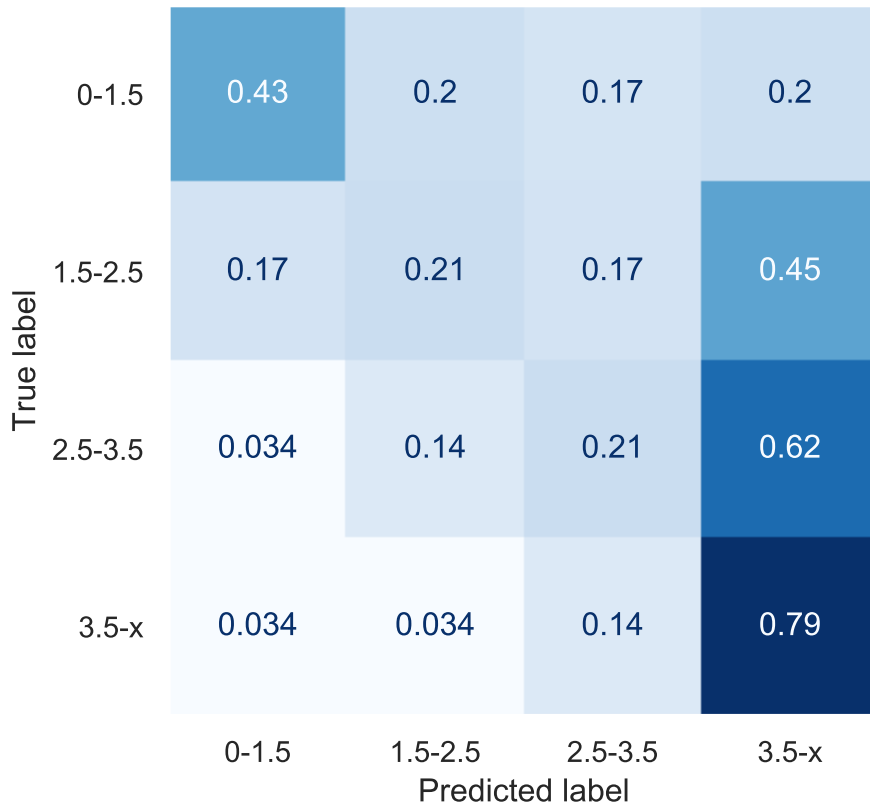
RANGE WINDOW: 10 s  
Confusion matrix Recv: S708 Trans: S706 Method: 1meter





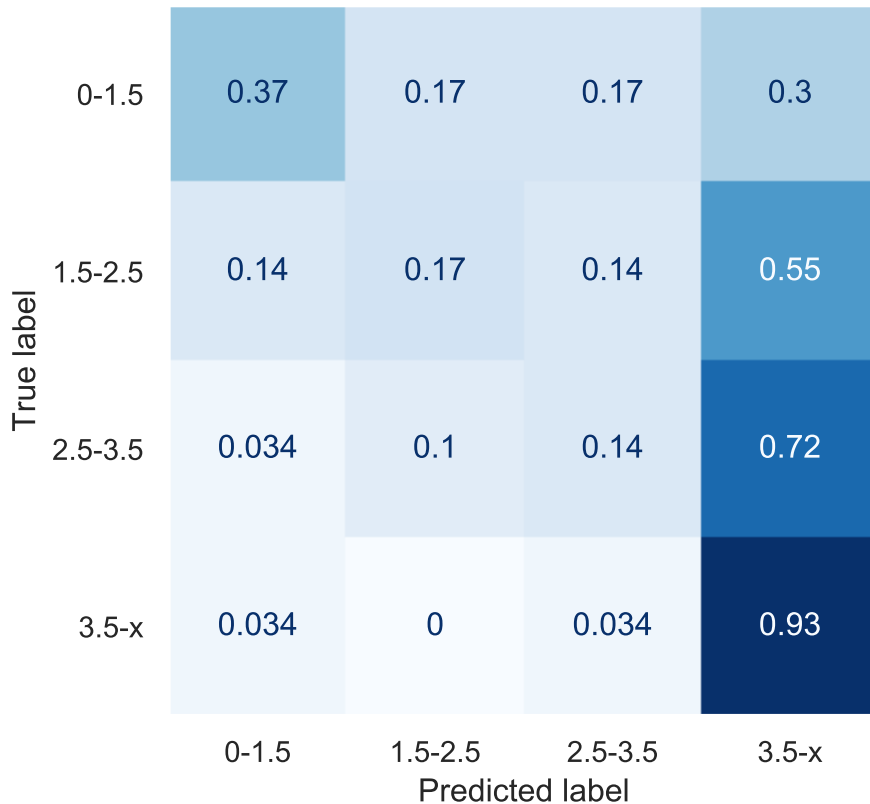
RANGE WINDOW: 10 s

Confusion matrix Recv: S708 Trans: S706 Method: All\_without\_PL

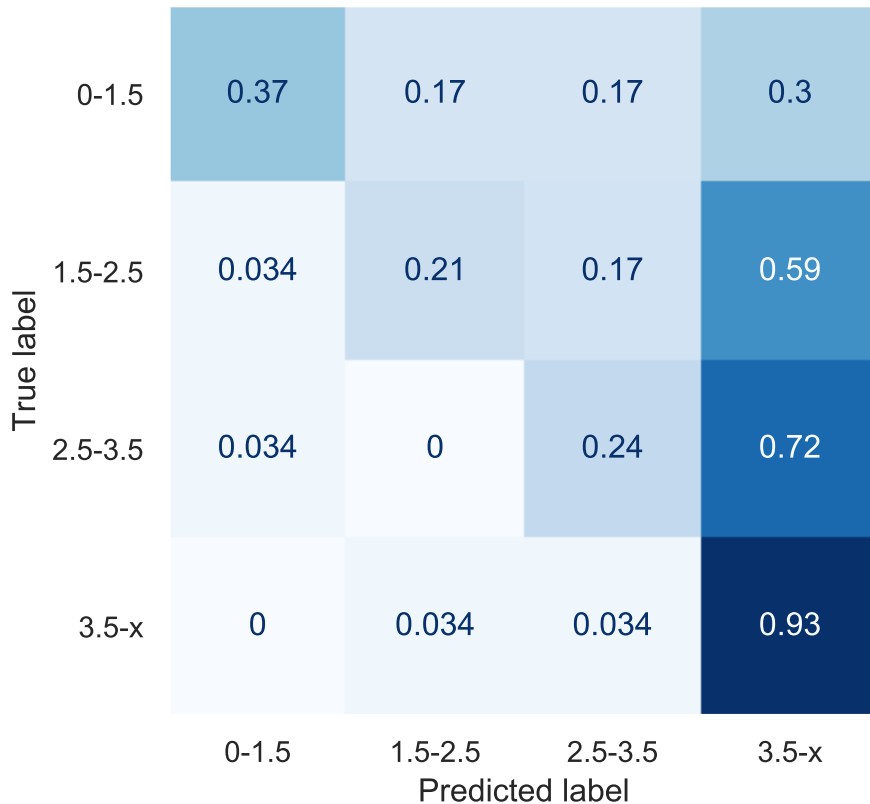


RANGE WINDOW: 10 s

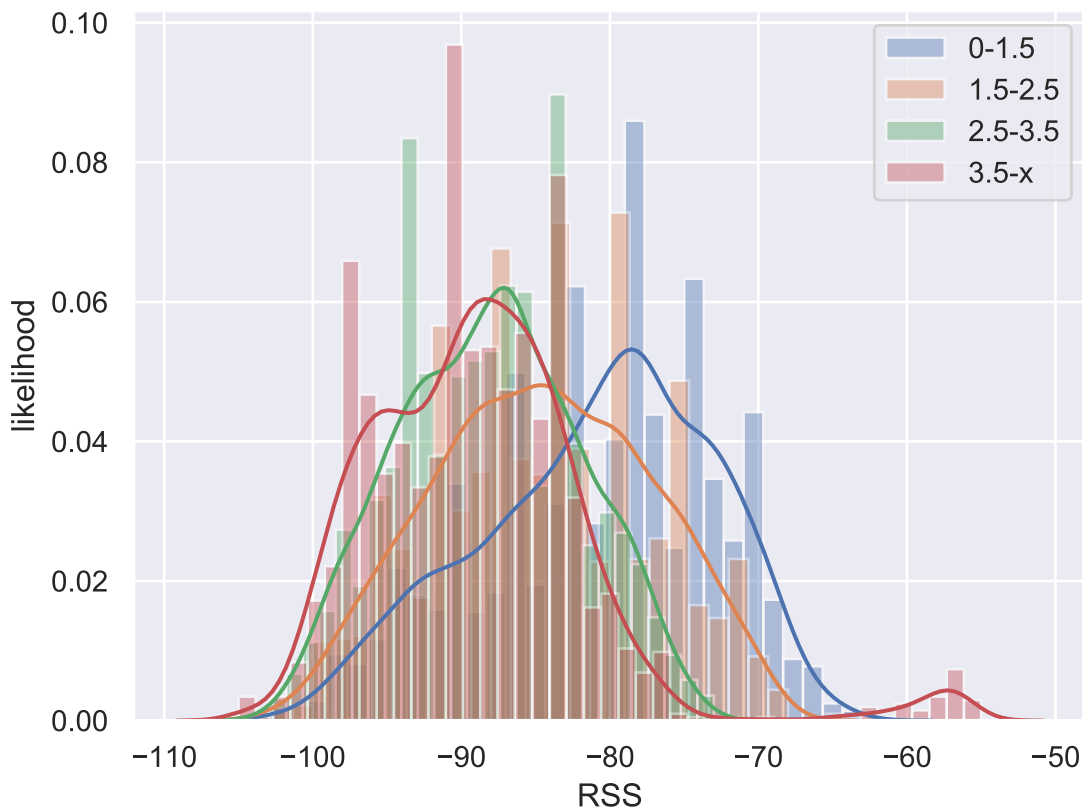
Confusion matrix Recv: S708 Trans: S706 Method: All\_with\_PL



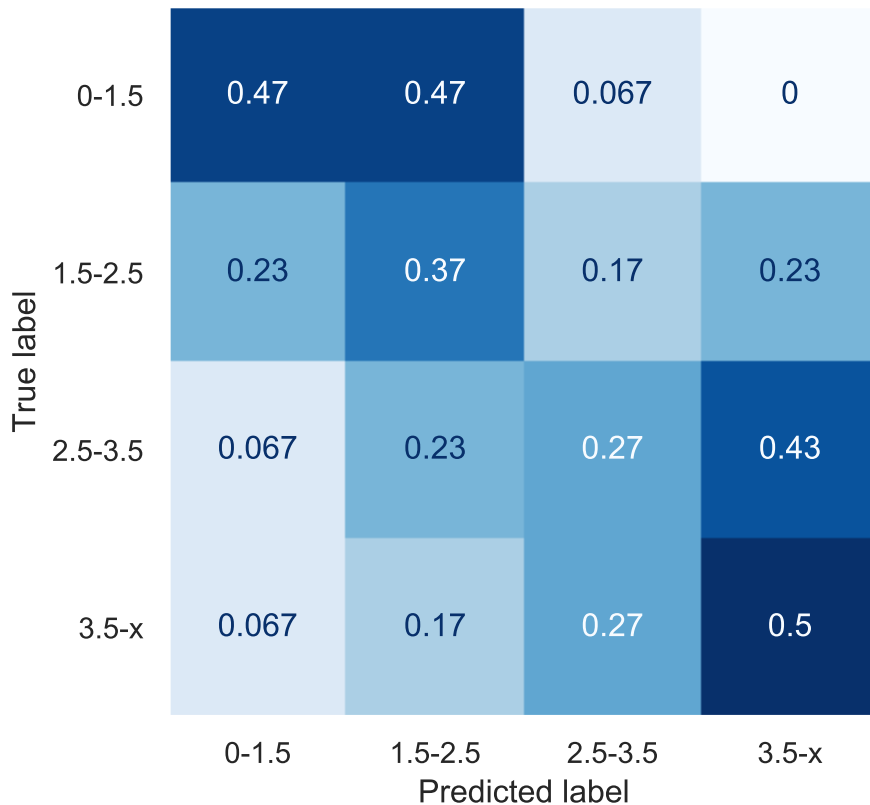
RANGE WINDOW: 10 s  
Confusion matrix Recv: S708 Trans: S706 Method: method 4



RANGE WINDOW: 10 s  
RSS Recv: S706 Trans: Motorola

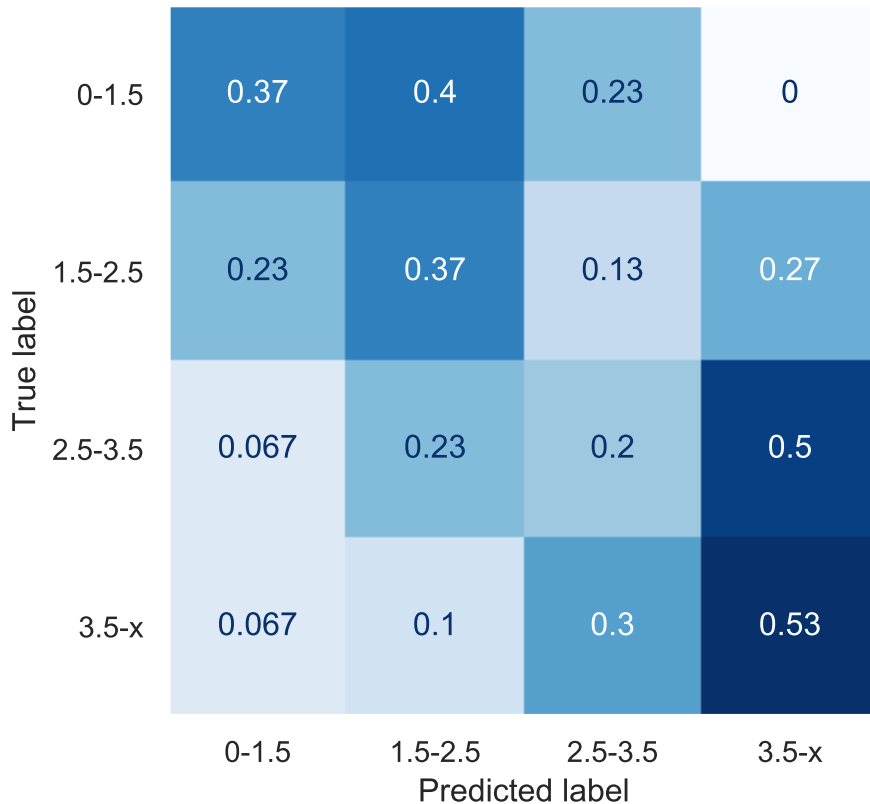


RANGE WINDOW: 10 s  
Confusion matrix Recv: S706 Trans: Motorola Method: 1meter



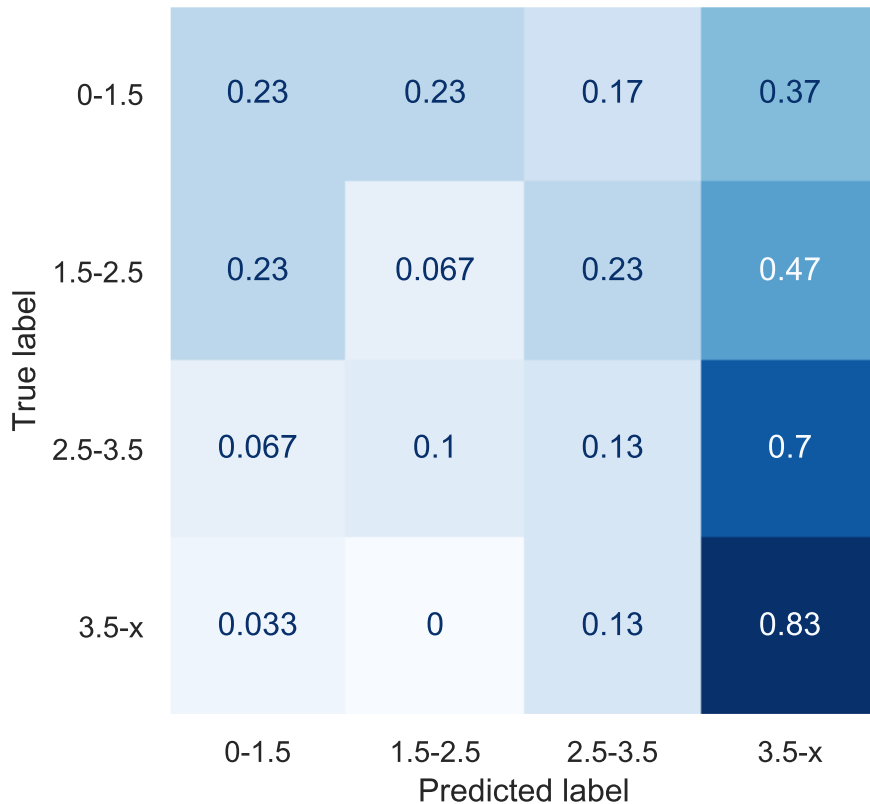
RANGE WINDOW: 10 s

Confusion matrix Recv: S706 Trans: Motorola Method: All\_without\_PL



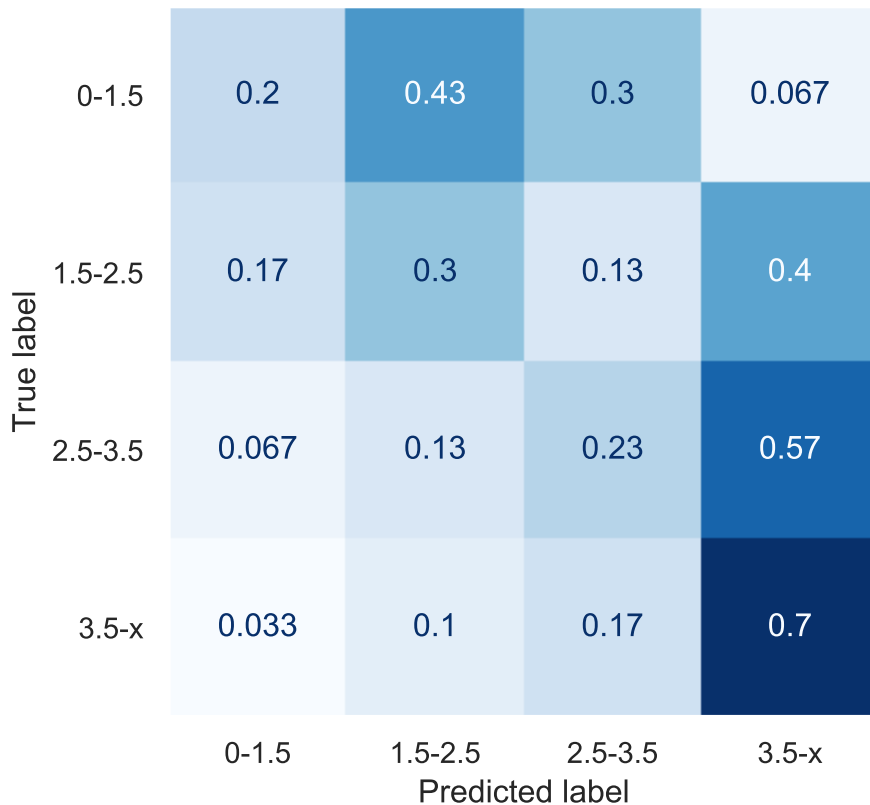
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Confusion matrix Recv: S706 Trans: Motorola Method: All\_with\_PL



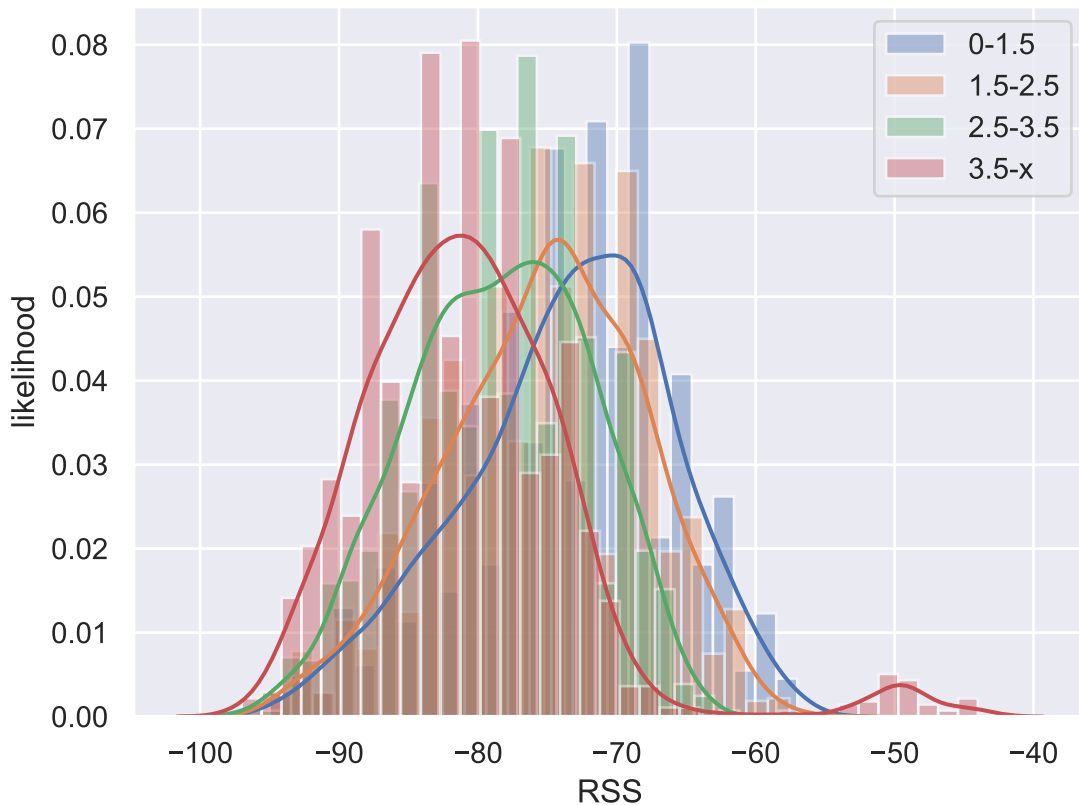
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Confusion matrix Recv: S706 Trans: Motorola Method: method 4



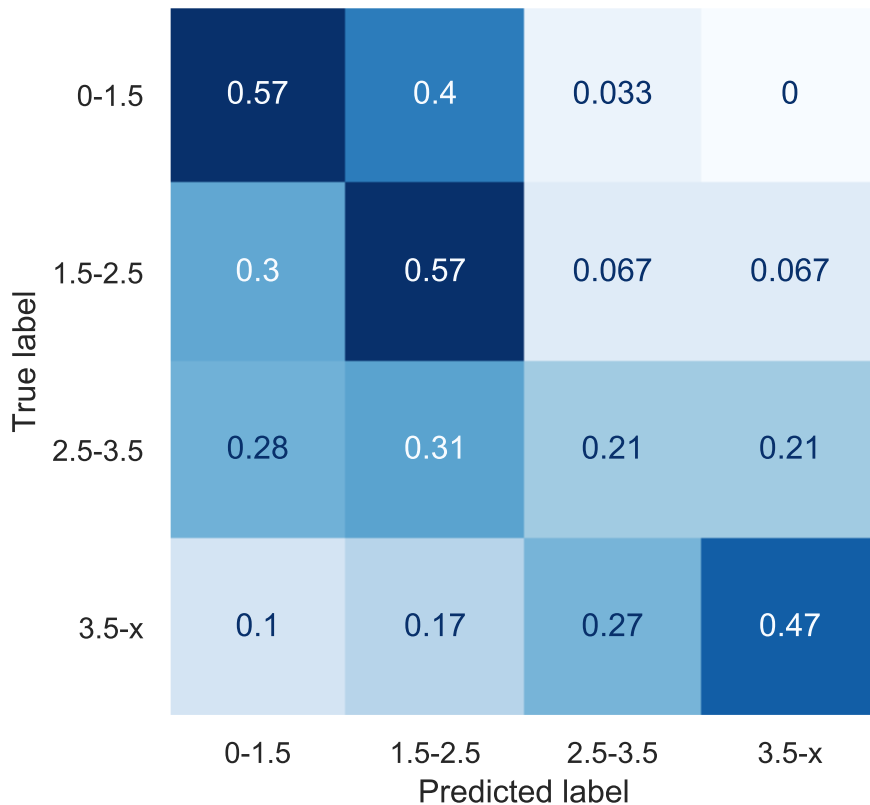


RANGE WINDOW: 10 s  
RSS Recv: Nexus Trans: Motorola



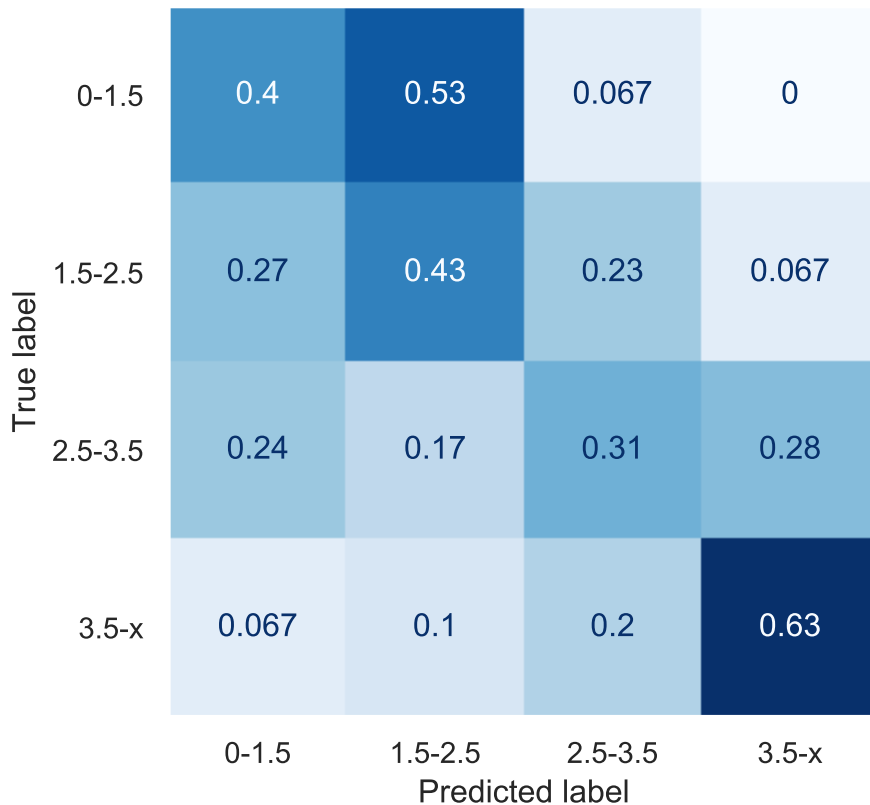
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Confusion matrix Recv: Nexus Trans: Motorola Method: 1meter



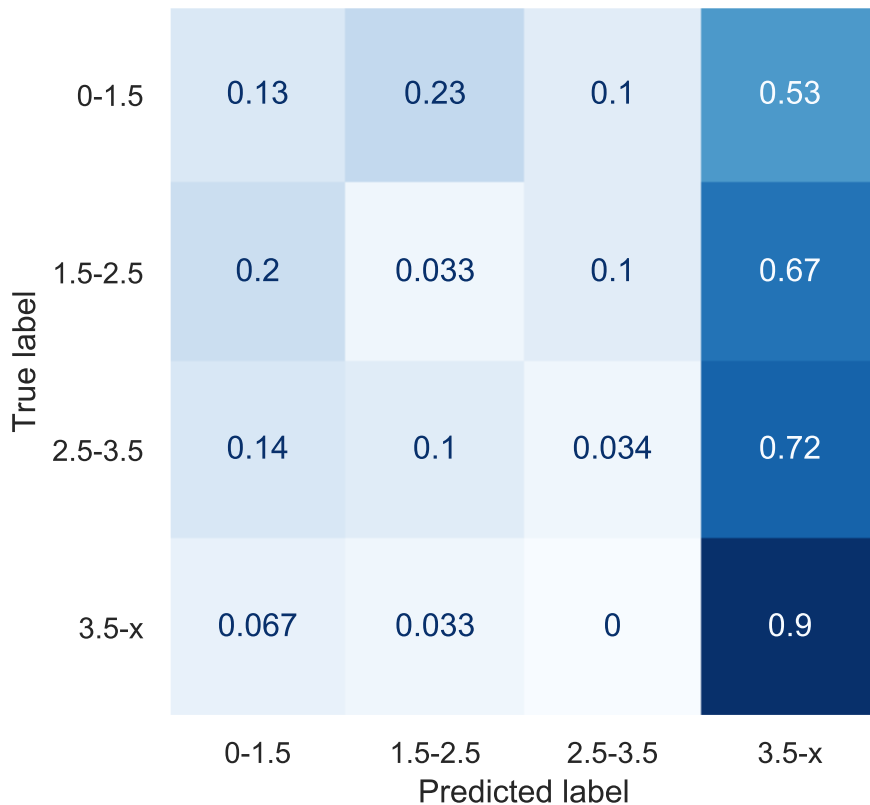
RANGE WINDOW: 10 s

Confusion matrix Recv: Nexus Trans: Motorola Method: All\_without\_PL



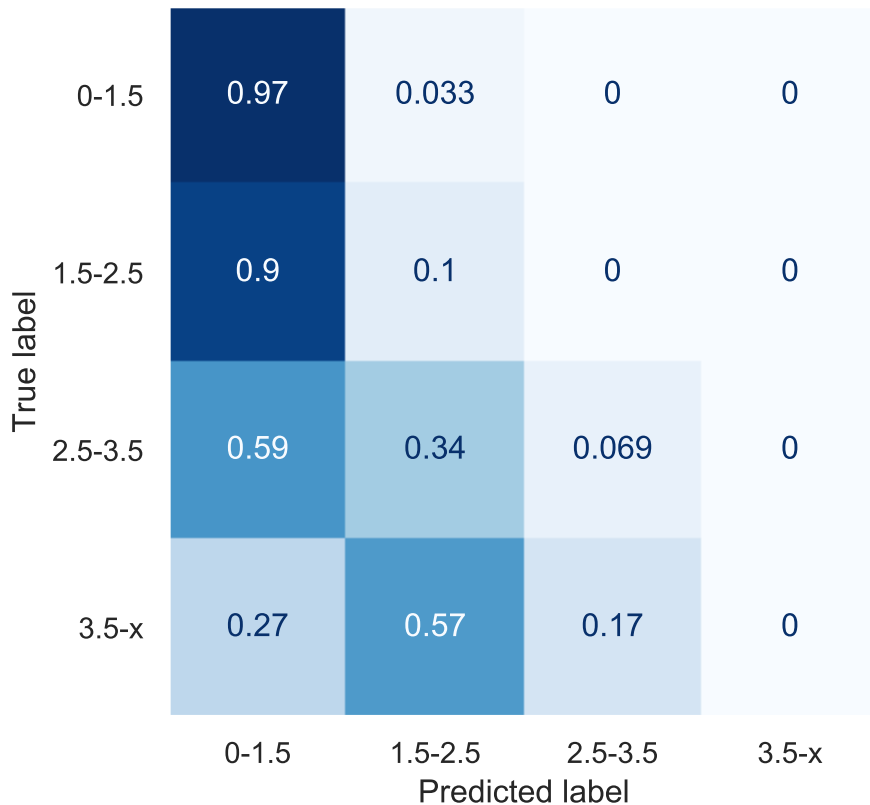
RANGE WINDOW: 10 s

Confusion matrix Recv: Nexus Trans: Motorola Method: All\_with\_PL

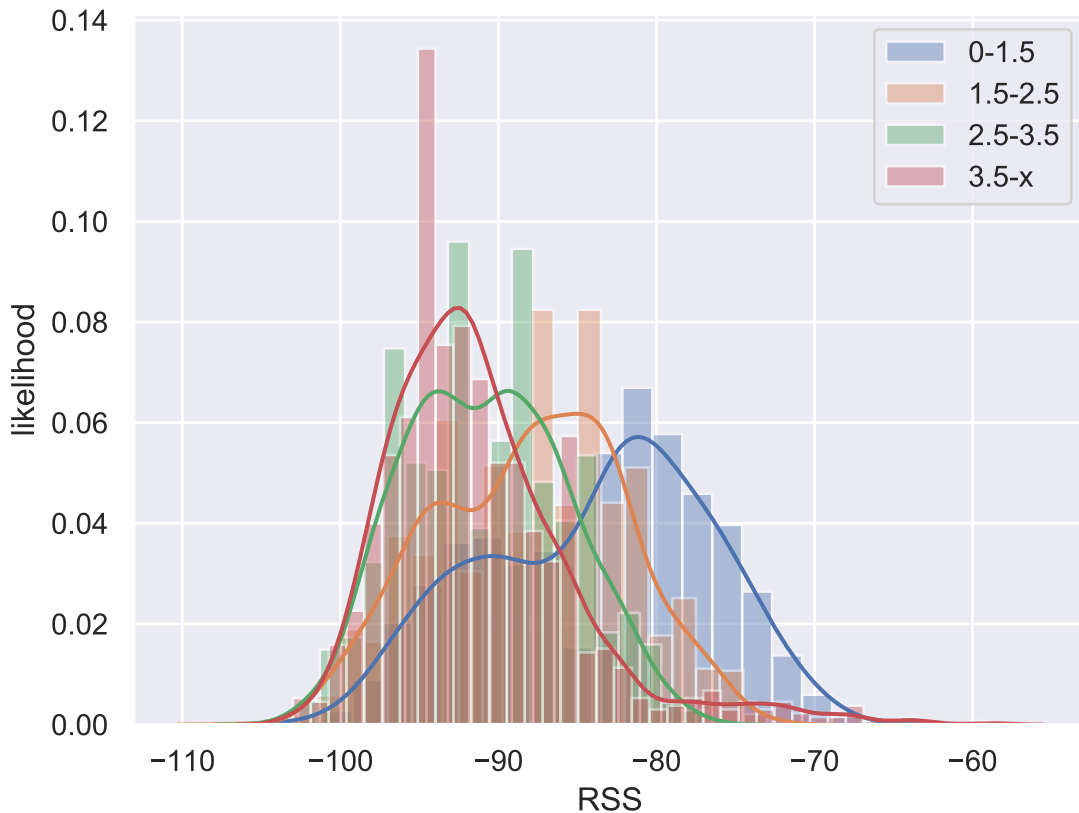


RANGE WINDOW: 10 s

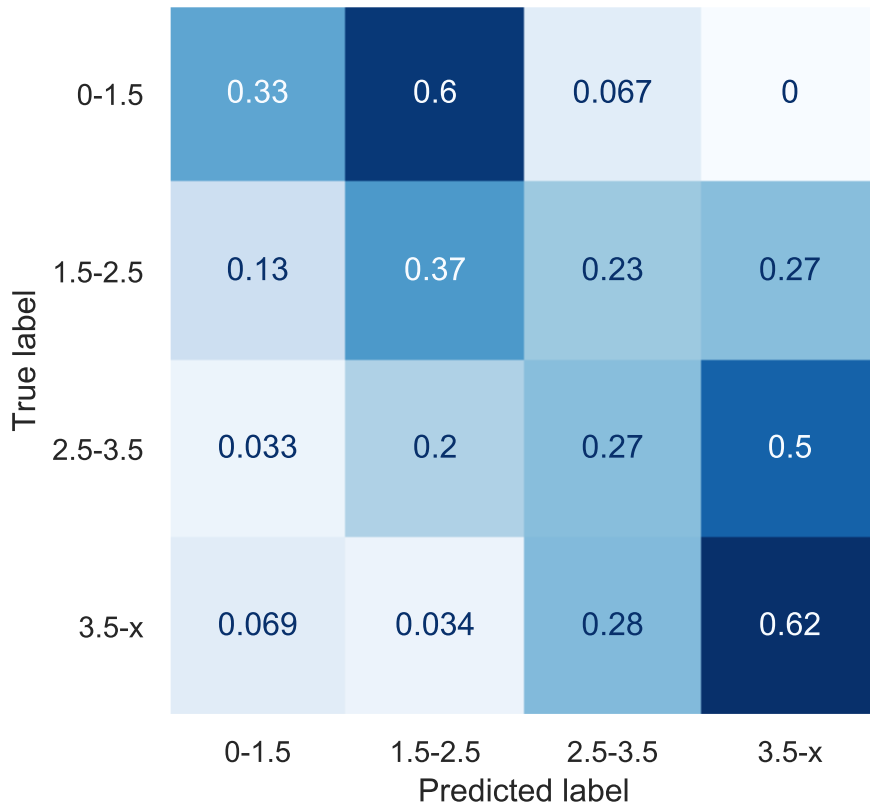
Confusion matrix Recv: Nexus Trans: Motorola Method: method 4



RANGE WINDOW: 10 s  
RSS Recv: S8 Trans: Motorola

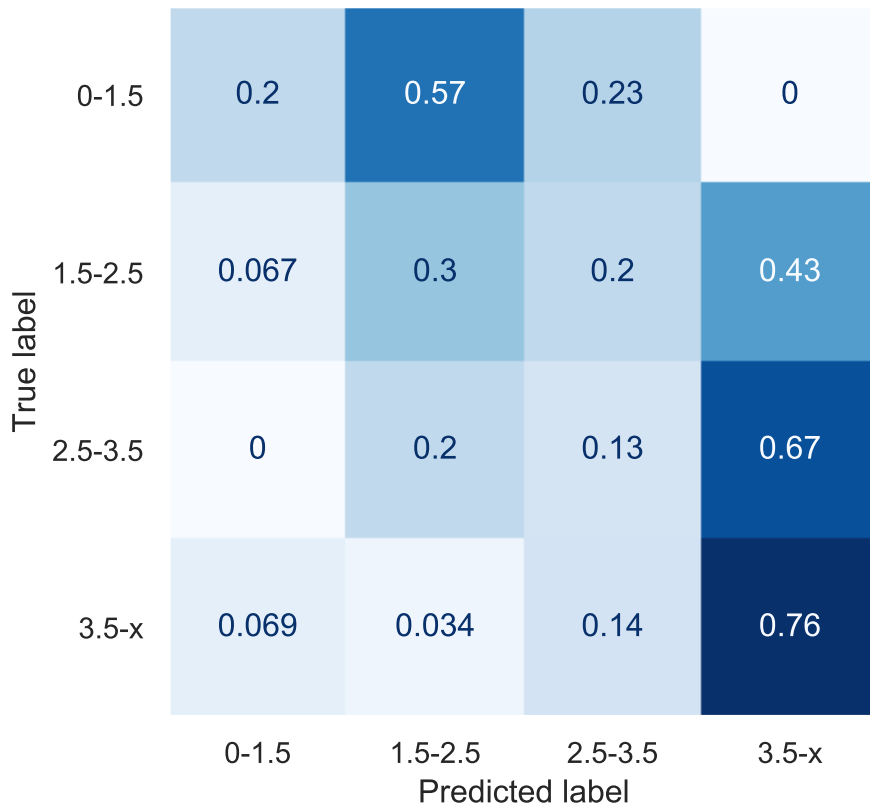


RANGE WINDOW: 10 s  
Confusion matrix Recv: S8 Trans: Motorola Method: 1meter



RANGE WINDOW: 10 s

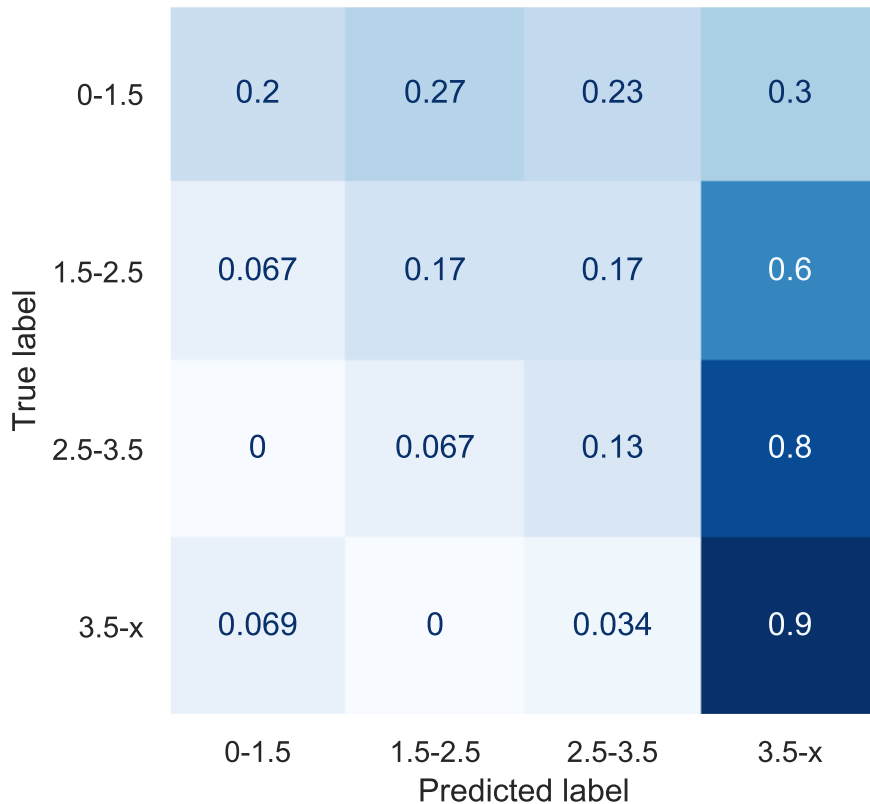
Confusion matrix Recv: S8 Trans: Motorola Method: All\_without\_PL



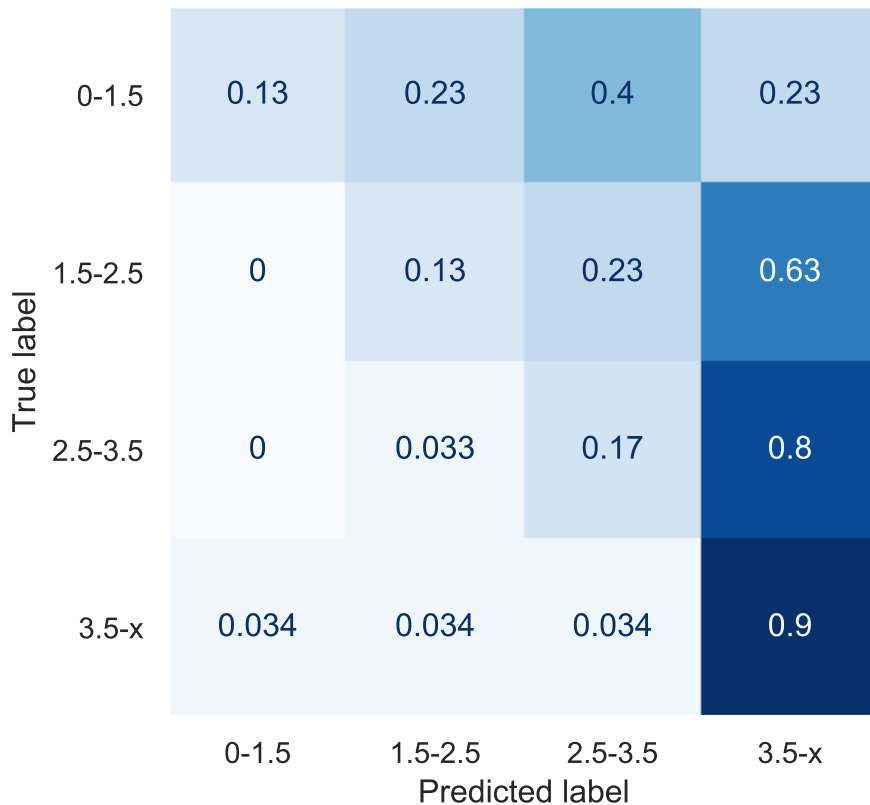


RANGE WINDOW: 10 s

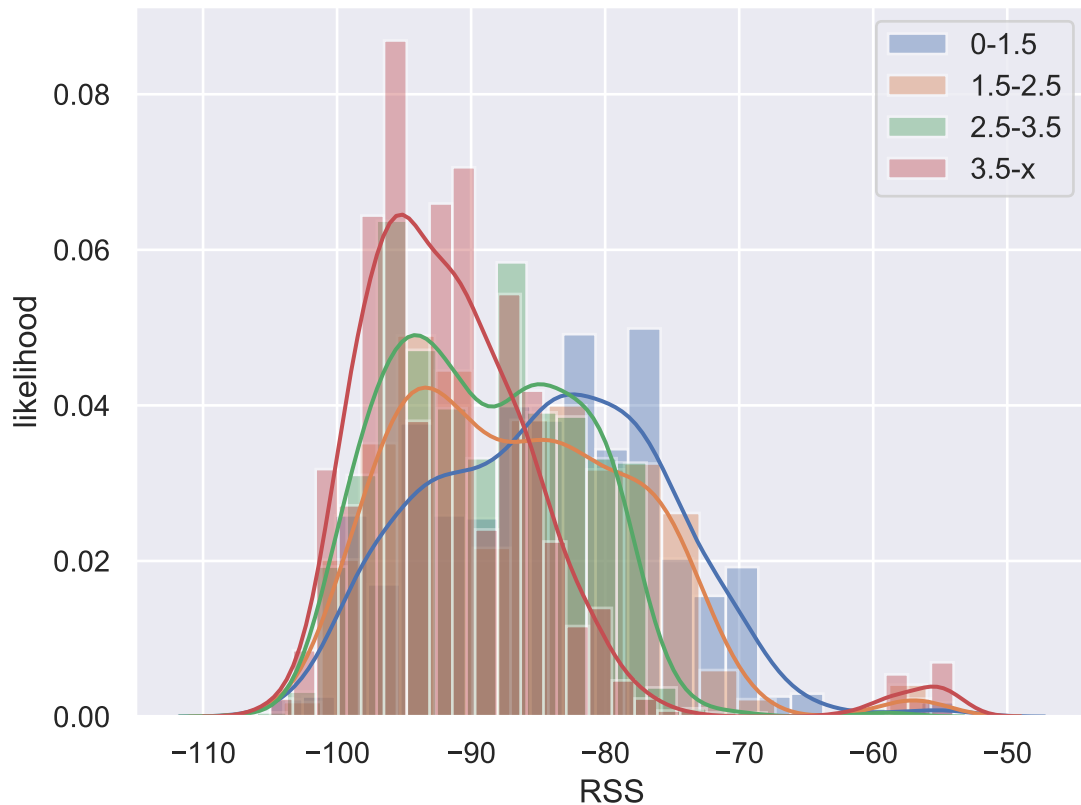
Confusion matrix Recv: S8 Trans: Motorola Method: All\_with\_PL



RANGE WINDOW: 10 s  
Confusion matrix Recv: S8 Trans: Motorola Method: method 4

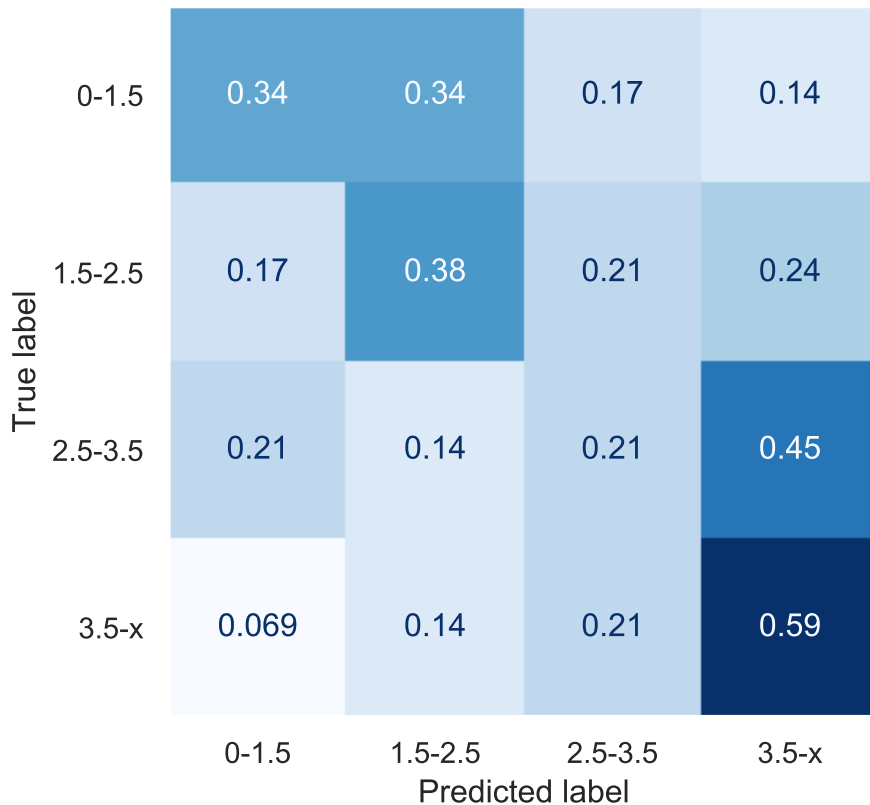


RANGE WINDOW: 10 s  
RSS Recv: S706 Trans: SamsungA6



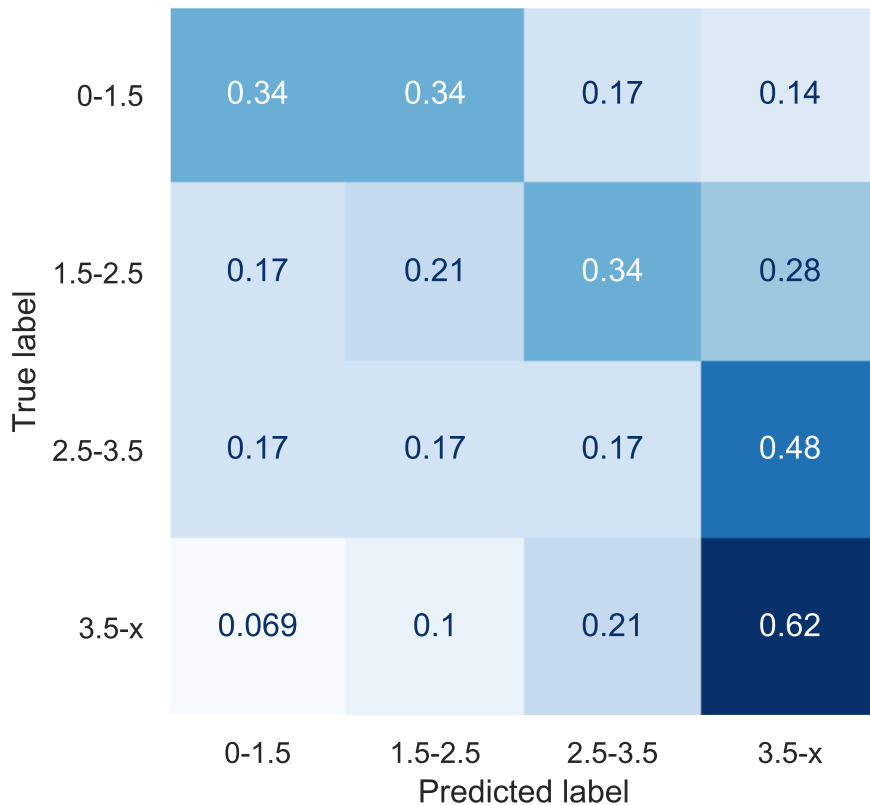
RANGE WINDOW: 10 s

Confusion matrix Recv: S706 Trans: SamsungA6 Method: 1meter



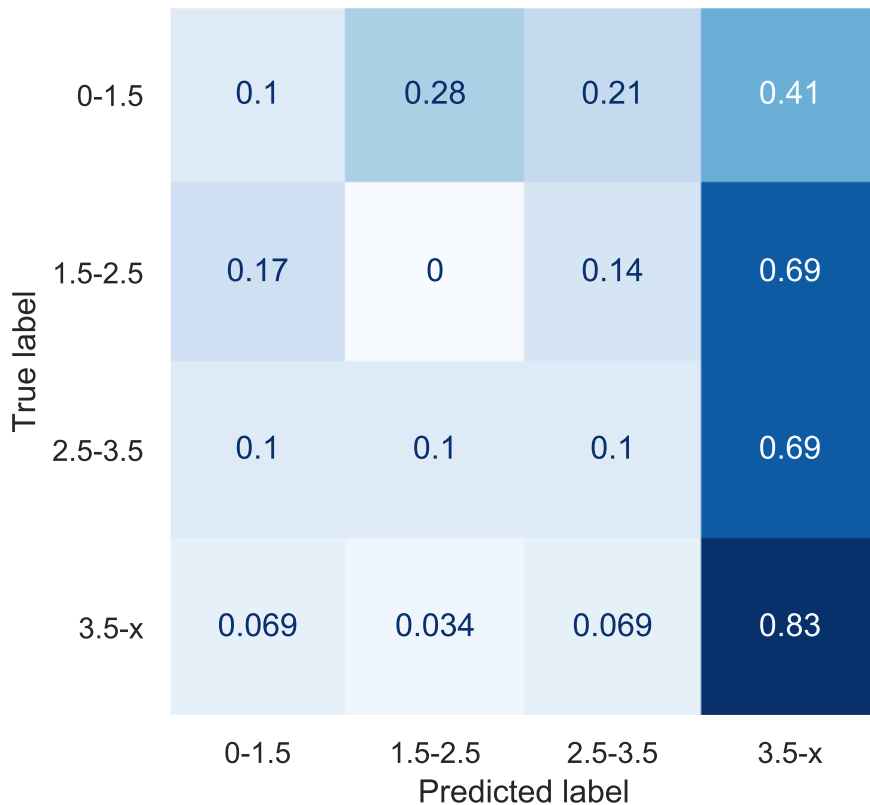
RANGE WINDOW: 10 s

Confusion matrix Recv: S706 Trans: SamsungA6 Method: All\_without\_PL



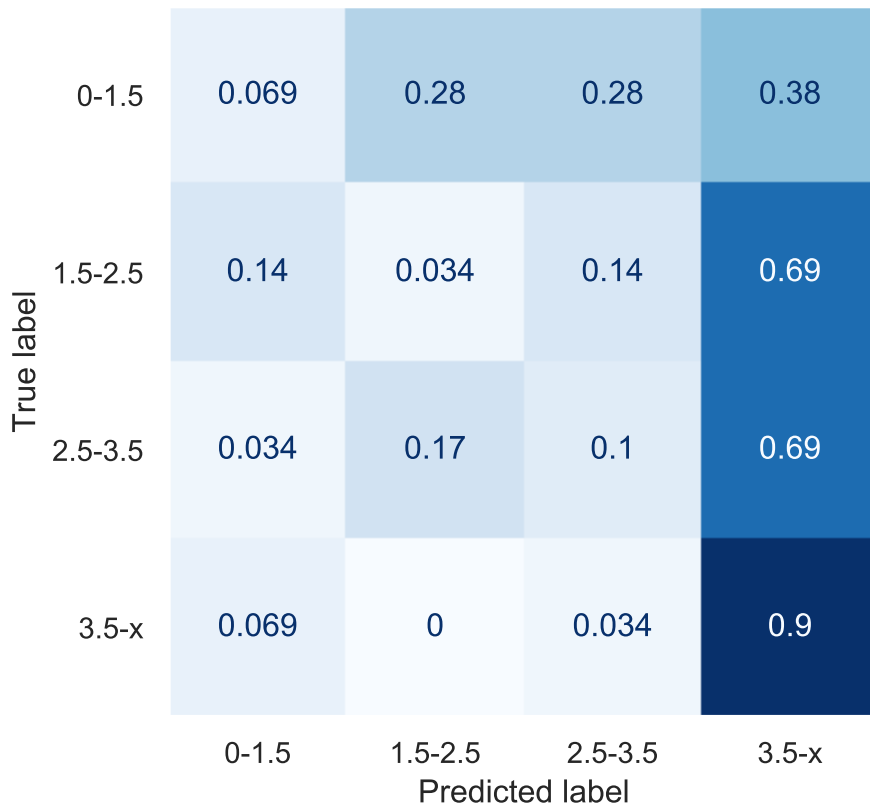
RANGE WINDOW: 10 s

Confusion matrix Recv: S706 Trans: SamsungA6 Method: All\_with\_PL

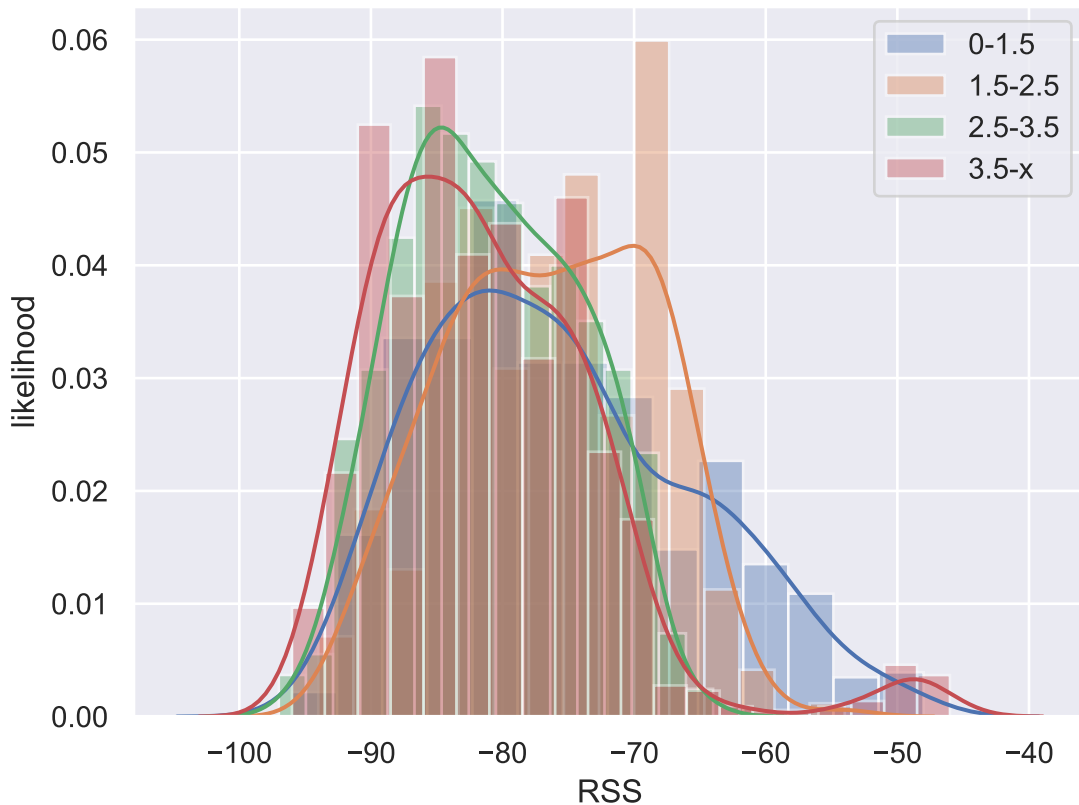


RANGE WINDOW: 10 s

Confusion matrix Recv: S706 Trans: SamsungA6 Method: method 4



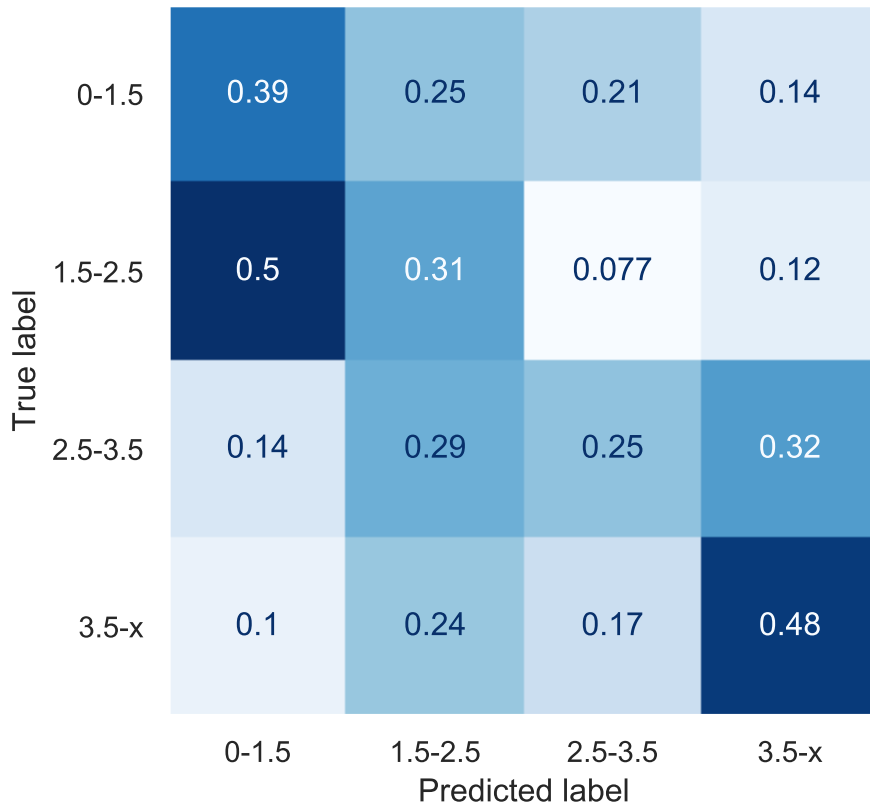
RANGE WINDOW: 10 s  
RSS Recv: Nexus Trans: SamsungA6





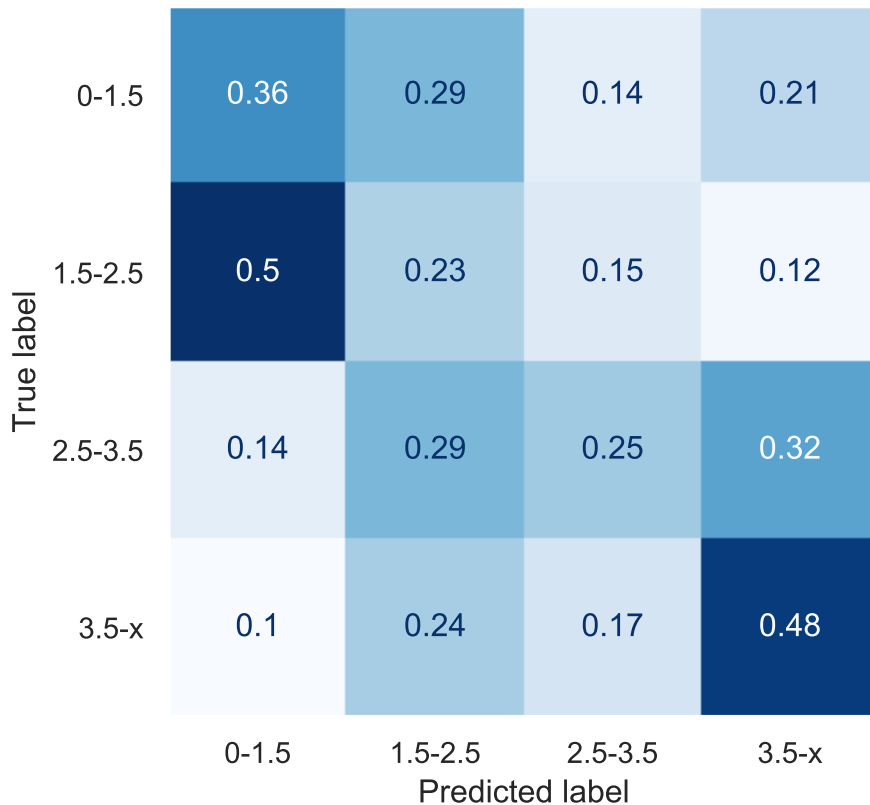
RANGE WINDOW: 10 s

Confusion matrix Recv: Nexus Trans: SamsungA6 Method: 1meter



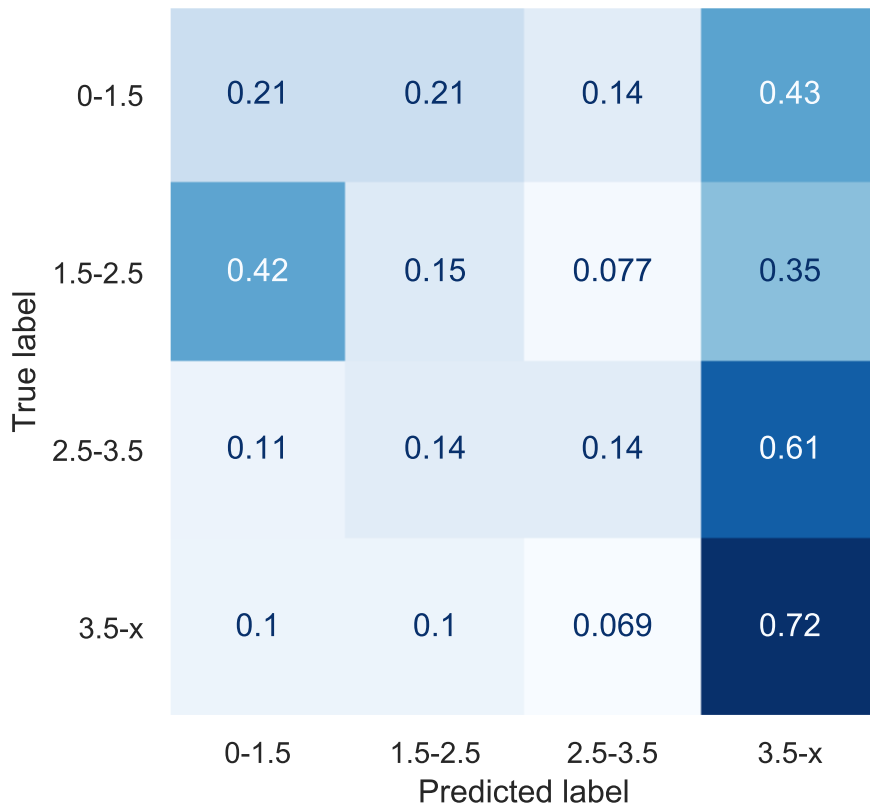
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Confusion matrix Recv: Nexus Trans: SamsungA6 Method: All\_without\_PL



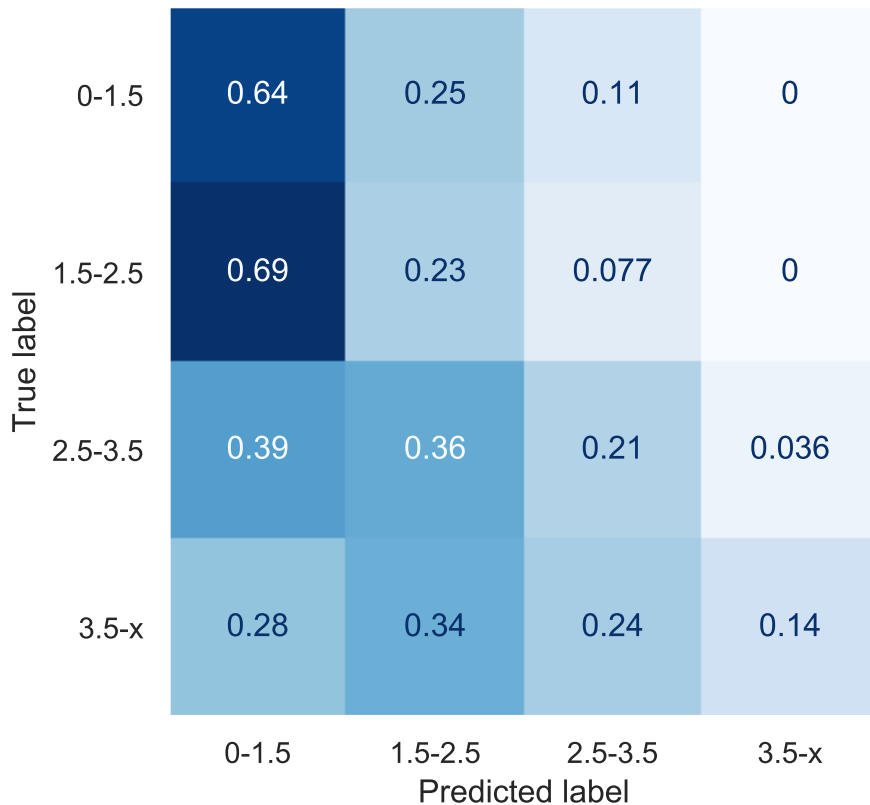
RANGE WINDOW: 10 s

Confusion matrix Recv: Nexus Trans: SamsungA6 Method: All\_with\_PL

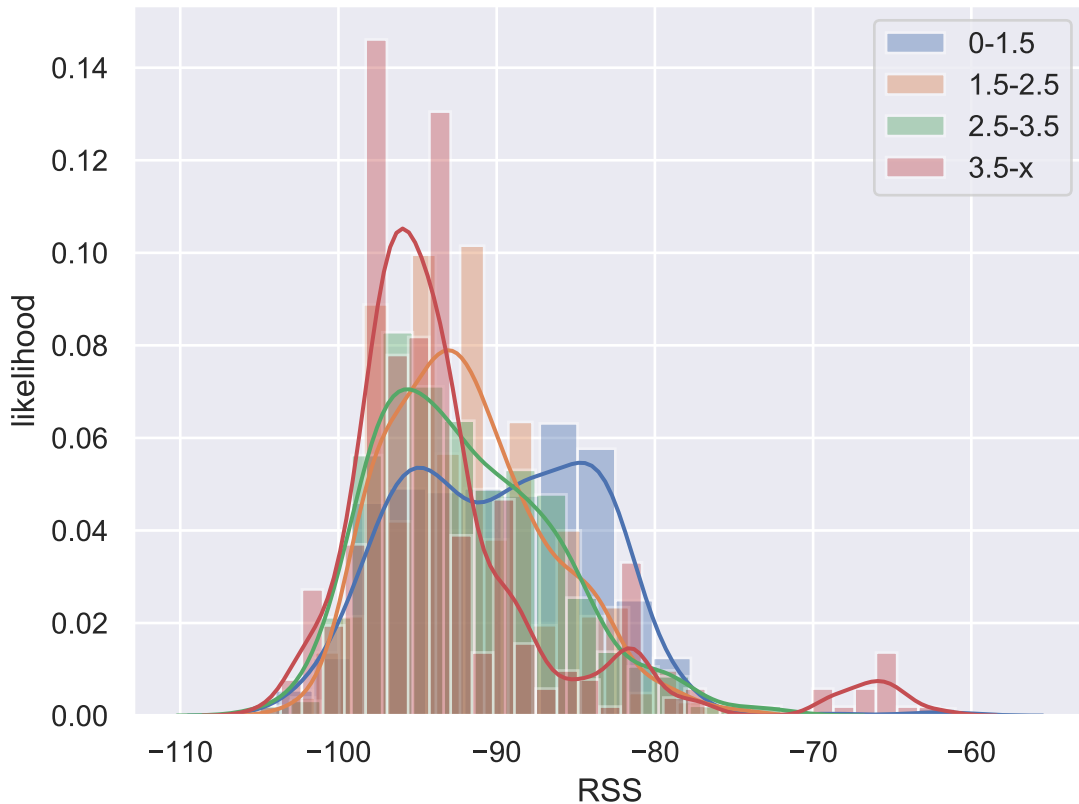


RANGE WINDOW: 10 s

Confusion matrix Recv: Nexus Trans: SamsungA6 Method: method 4

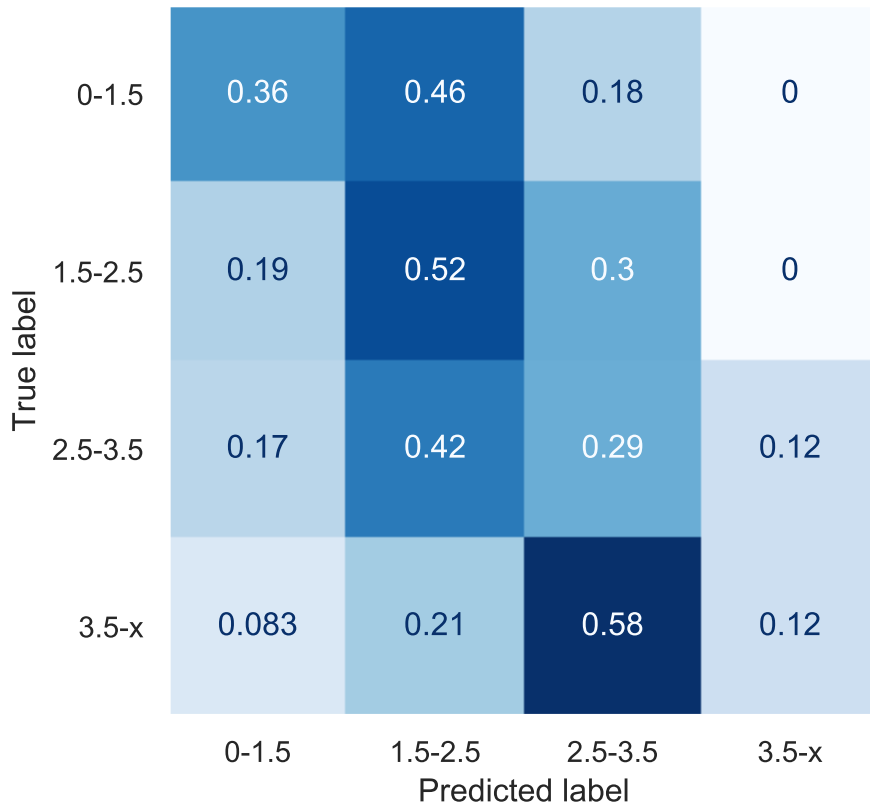


RANGE WINDOW: 10 s  
RSS Recv: S8 Trans: SamsungA6



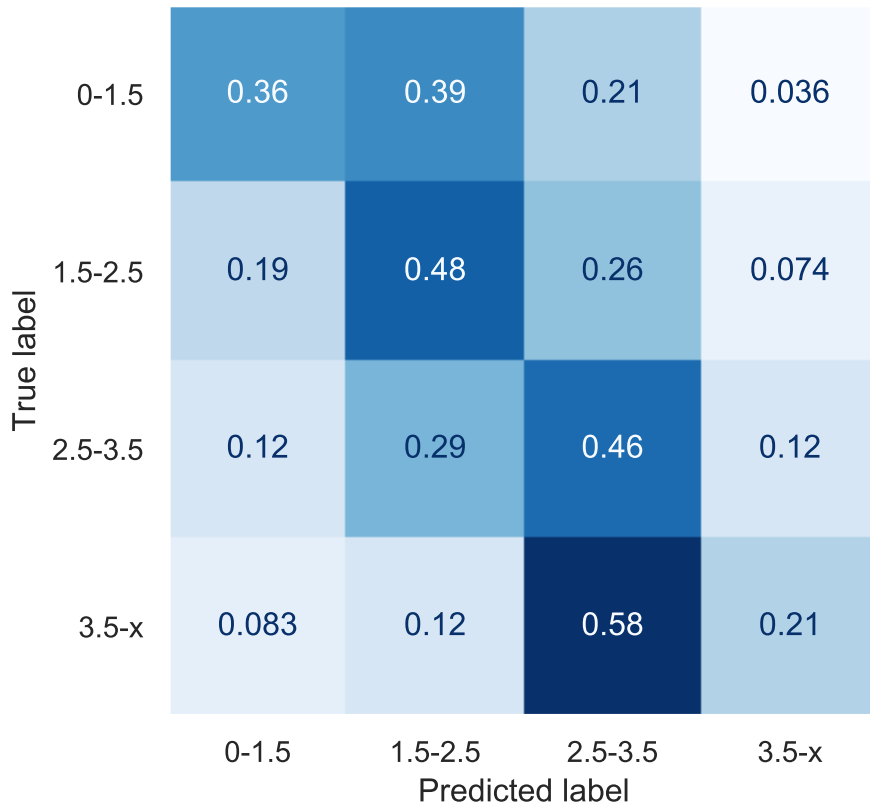
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Confusion matrix Recv: S8 Trans: SamsungA6 Method: 1meter



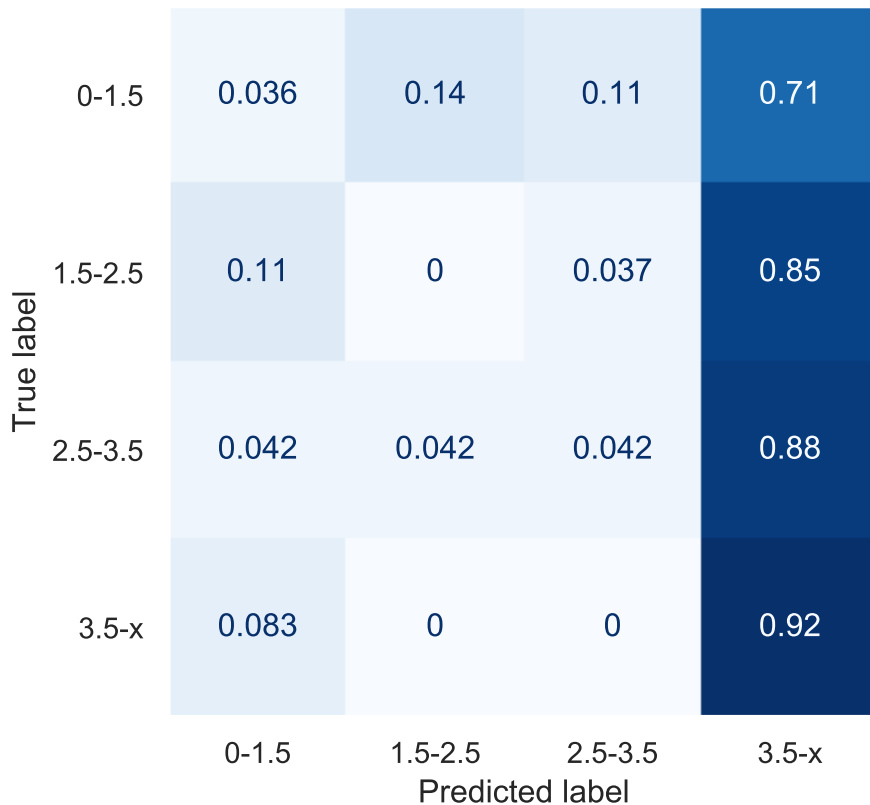
RANGE WINDOW: 10 s

Confusion matrix Recv: S8 Trans: SamsungA6 Method: All\_without\_PL



RANGE WINDOW: 10 s

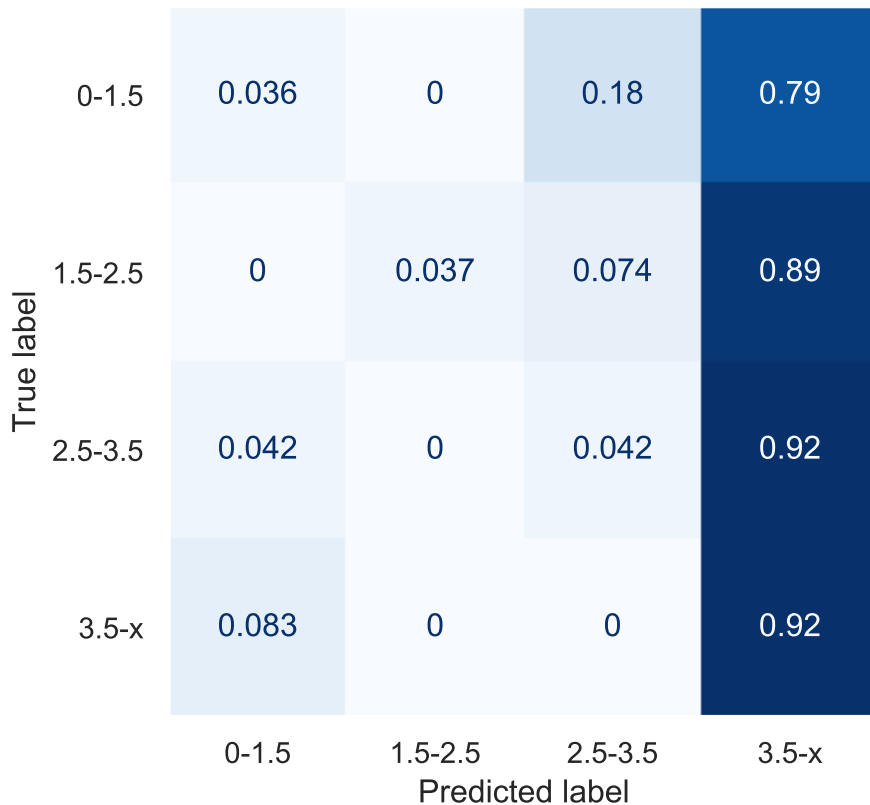
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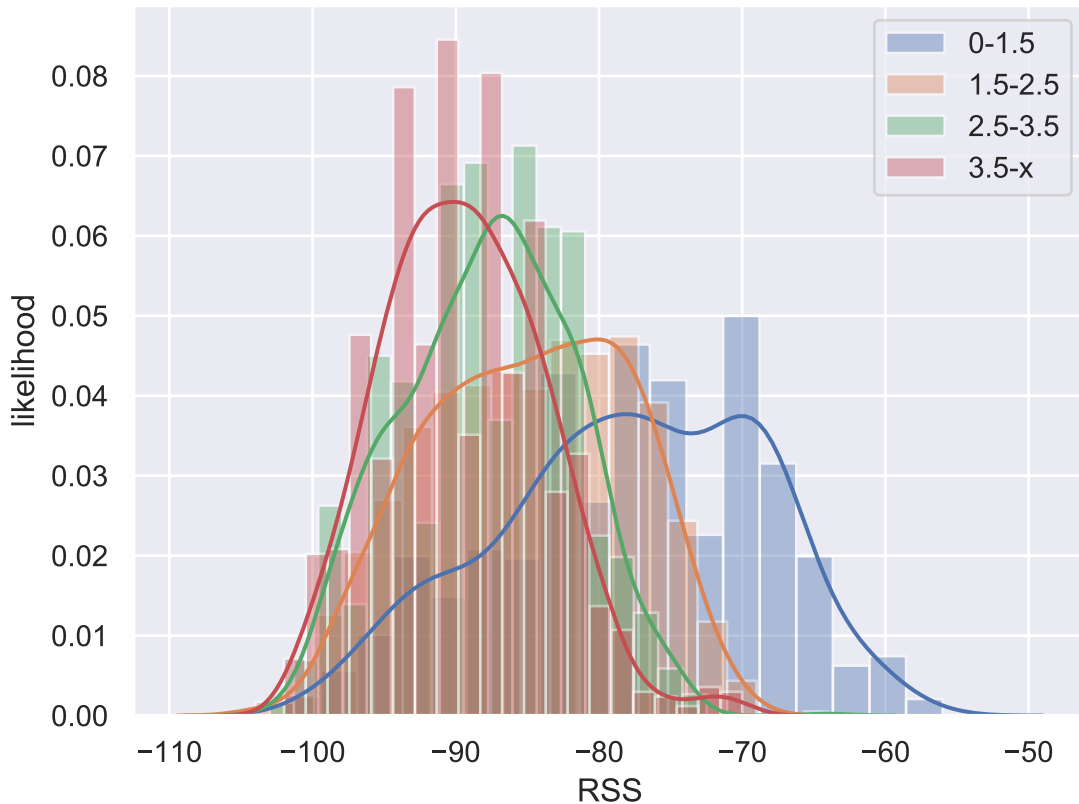


RANGE WINDOW: 10 s

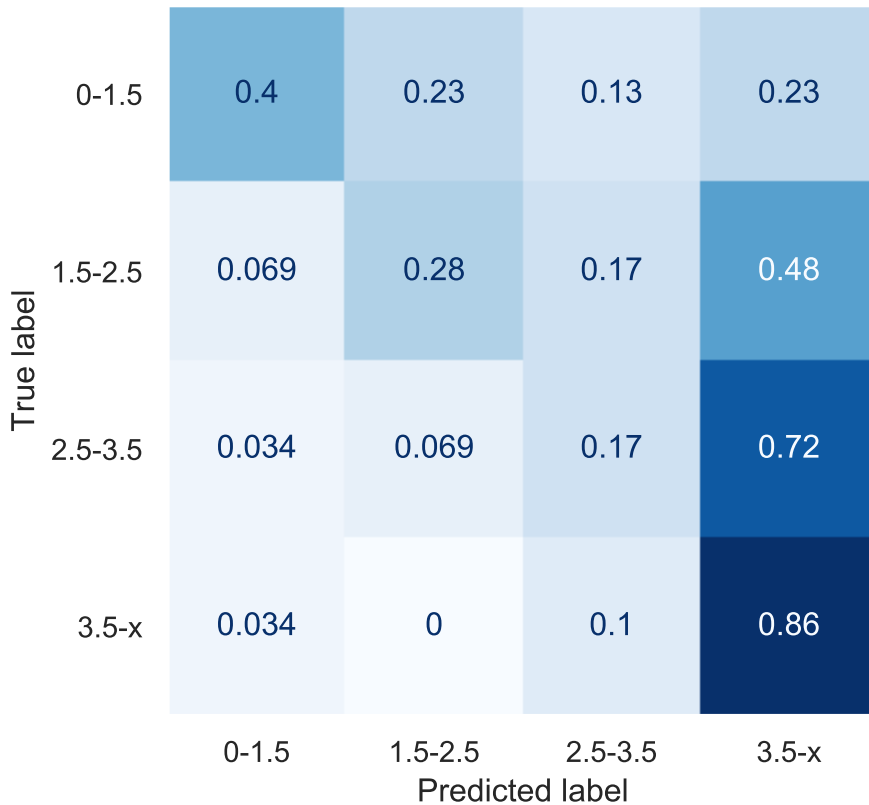
Confusion matrix Recv: S8 Trans: SamsungA6 Method: method 4



RANGE WINDOW: 10 s  
RSS Recv: S706 Trans: S708

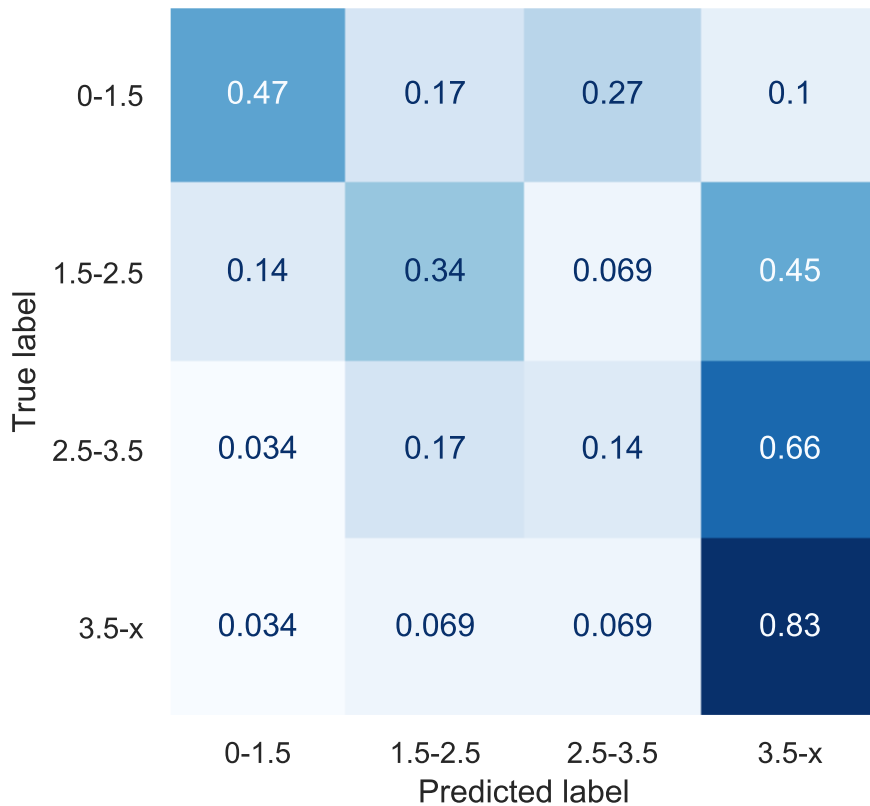


RANGE WINDOW: 10 s  
Confusion matrix Recv: S706 Trans: S708 Method: 1meter



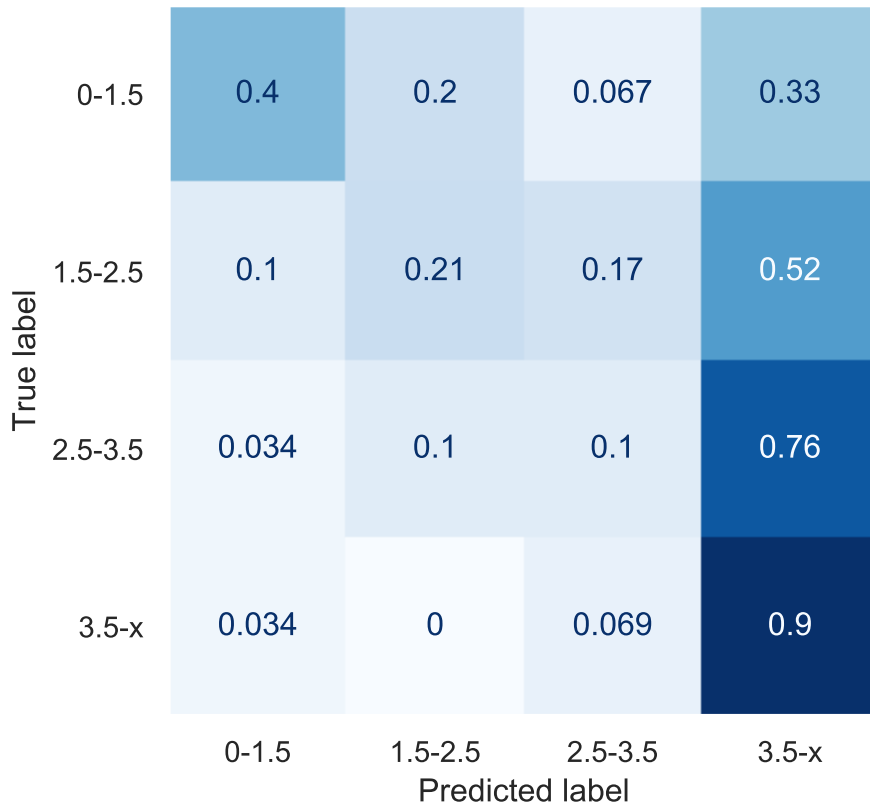
RANGE WINDOW: 10 s

Confusion matrix Recv: S706 Trans: S708 Method: All\_without\_PL



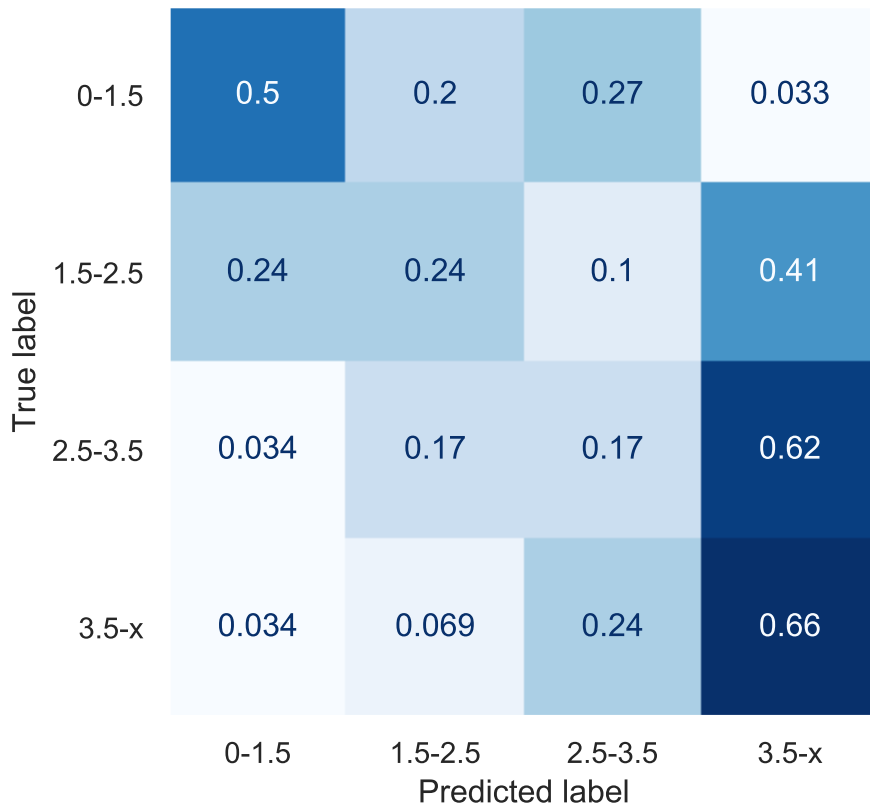
RANGE WINDOW: 10 s

Confusion matrix Recv: S706 Trans: S708 Method: All\_with\_PL

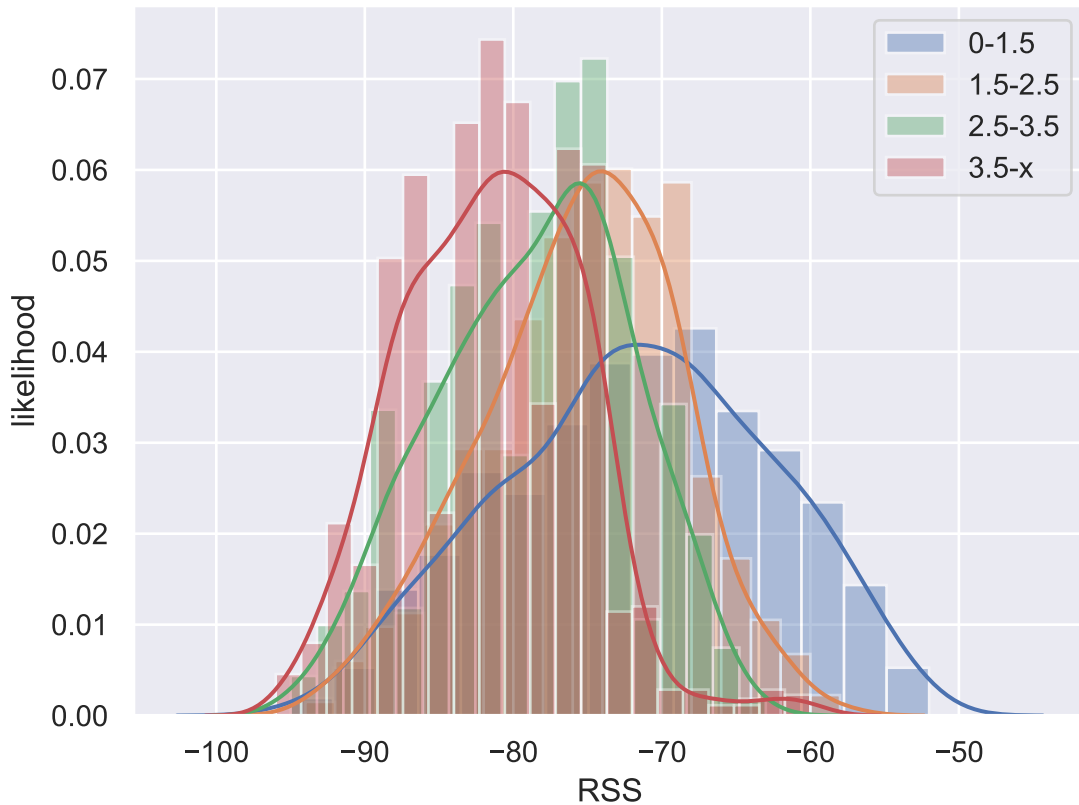


RANGE WINDOW: 10 s

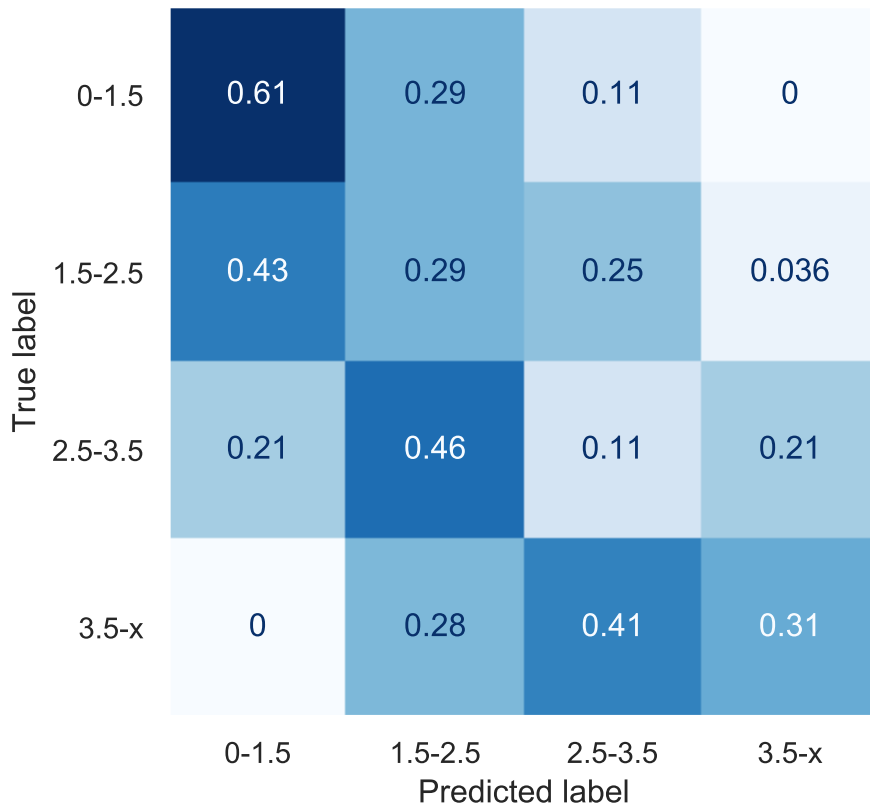
Confusion matrix Recv: S706 Trans: S708 Method: method 4



RANGE WINDOW: 10 s  
RSS Recv: Nexus Trans: S708



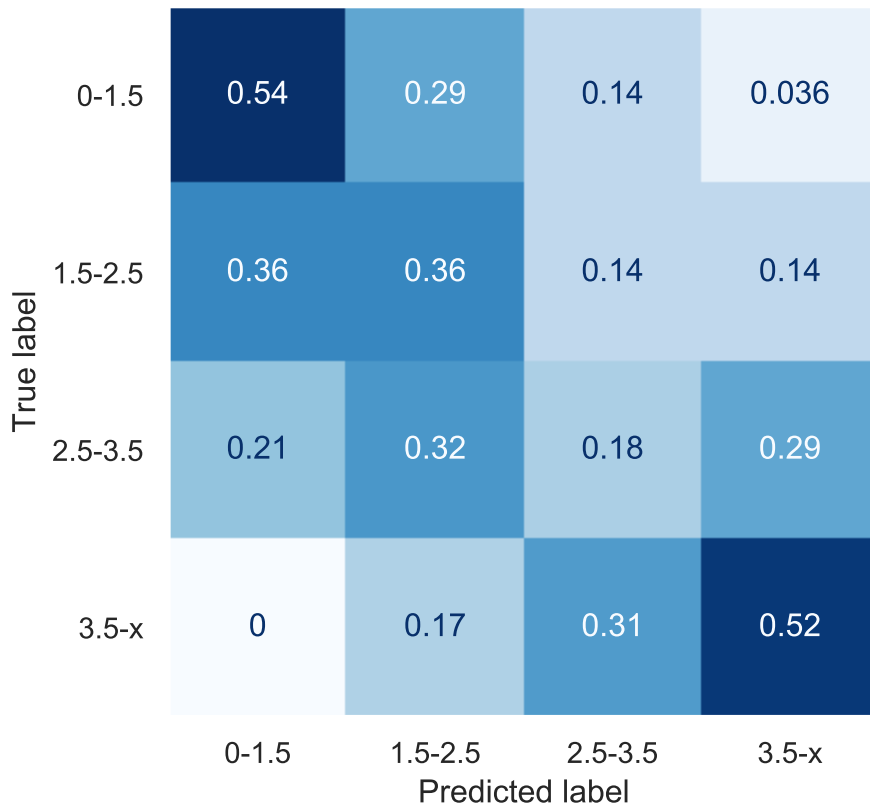
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Confusion matrix Recv: Nexus Trans: S708 Method: 1meter





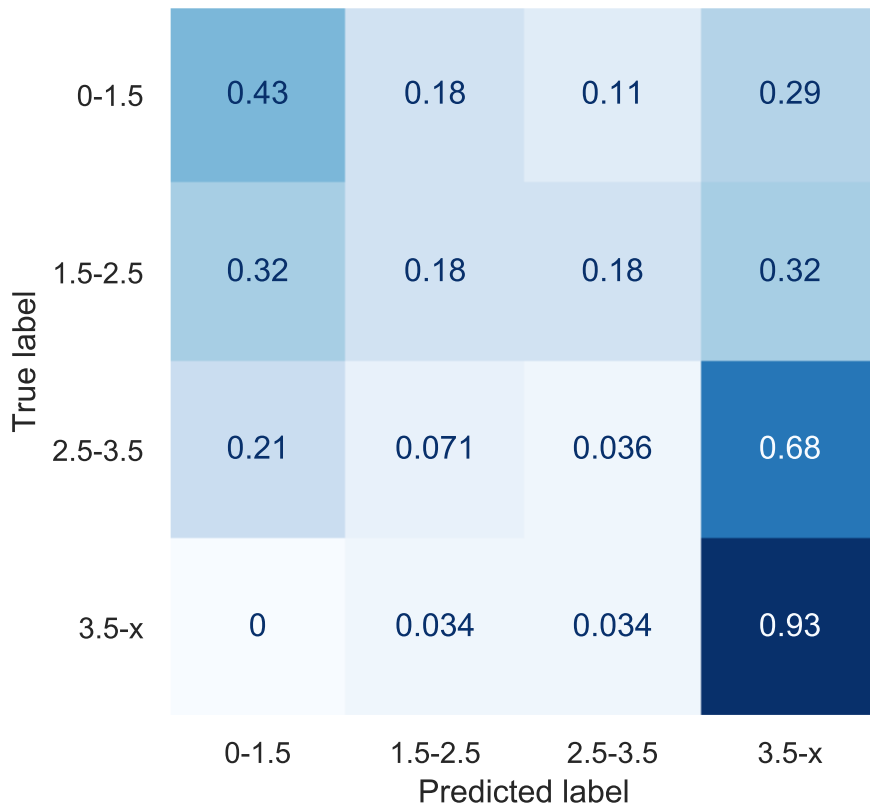
RANGE WINDOW: 10 s

Confusion matrix Recv: Nexus Trans: S708 Method: All\_without\_PL



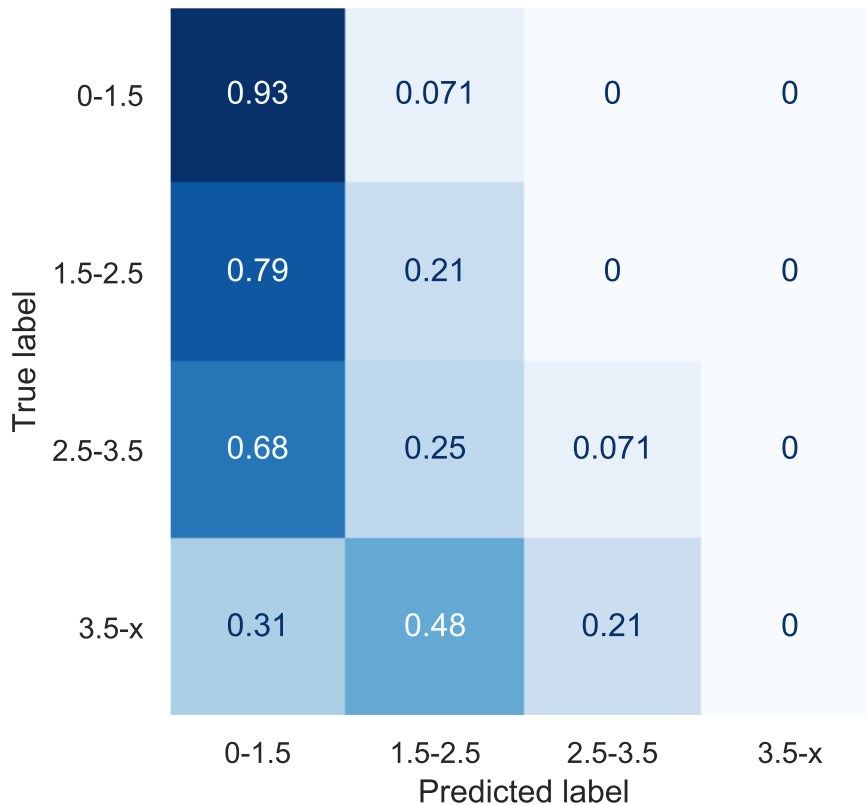
RANGE WINDOW: 10 s

Confusion matrix Recv: Nexus Trans: S708 Method: All\_with\_PL

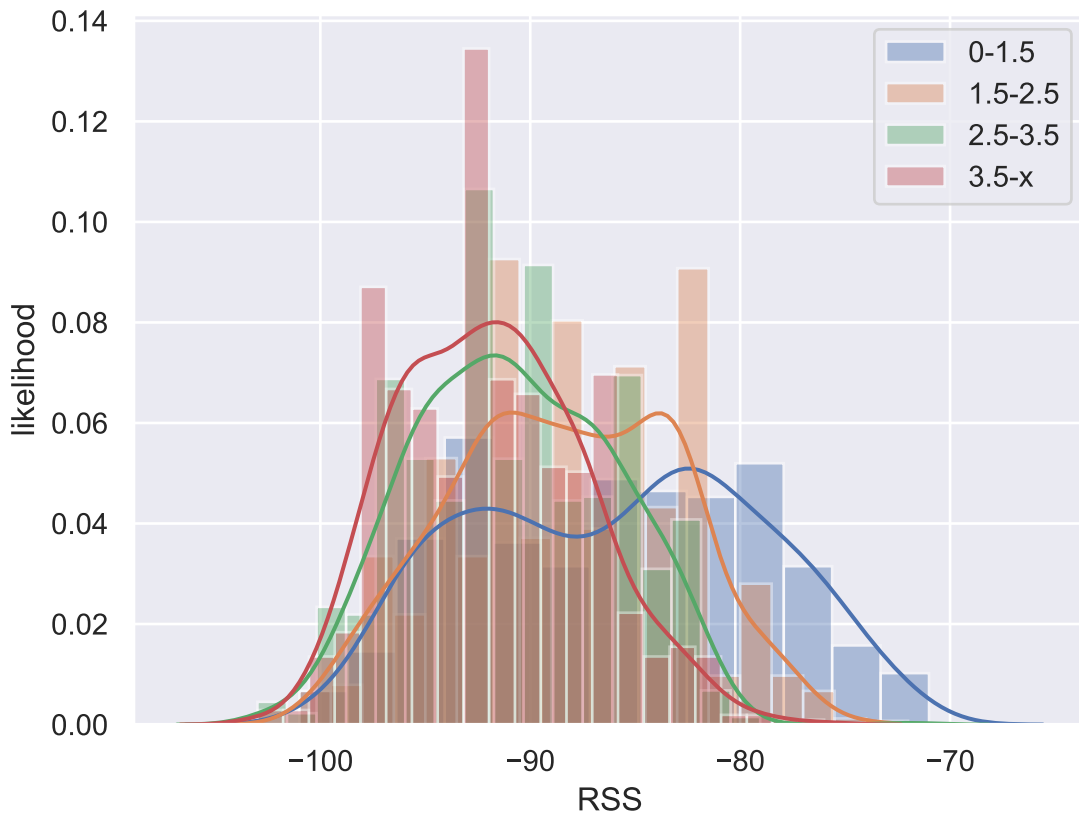


RANGE WINDOW: 10 s

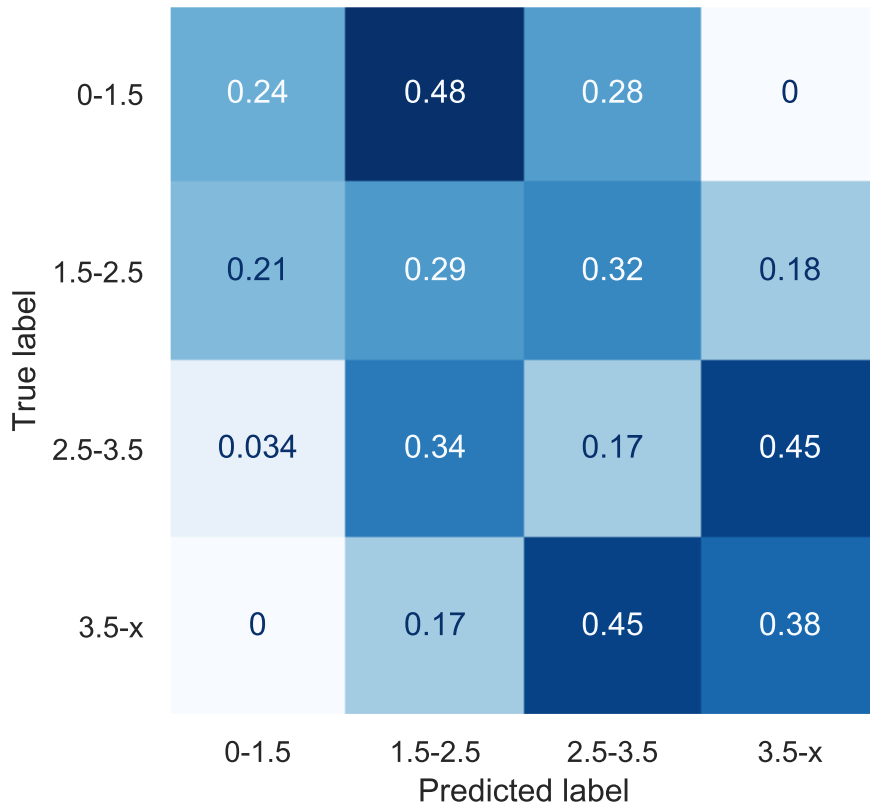
Confusion matrix Recv: Nexus Trans: S708 Method: method 4



RANGE WINDOW: 10 s  
RSS Recv: S8 Trans: S708

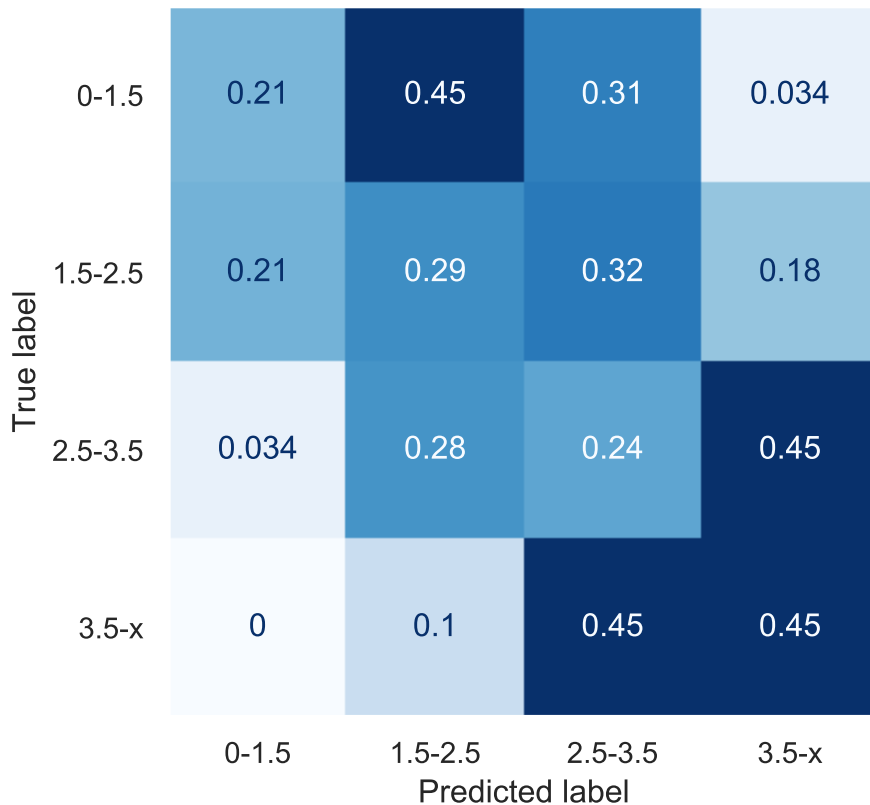


RANGE WINDOW: 10 s  
Confusion matrix Recv: S8 Trans: S708 Method: 1meter



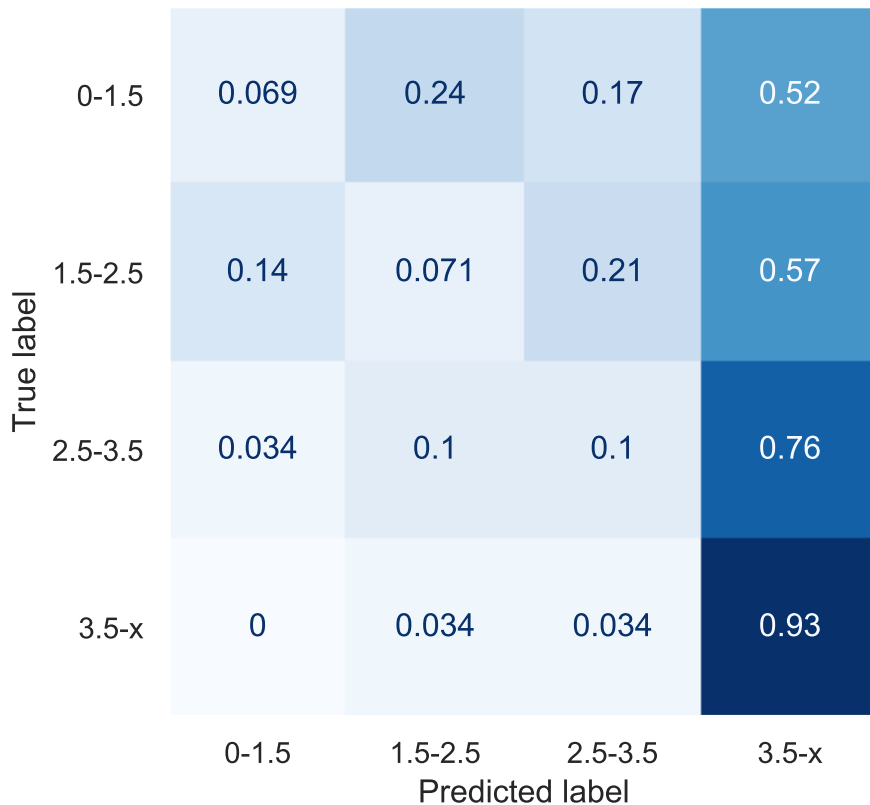
RANGE WINDOW: 10 s

Confusion matrix Recv: S8 Trans: S708 Method: All\_without\_PL

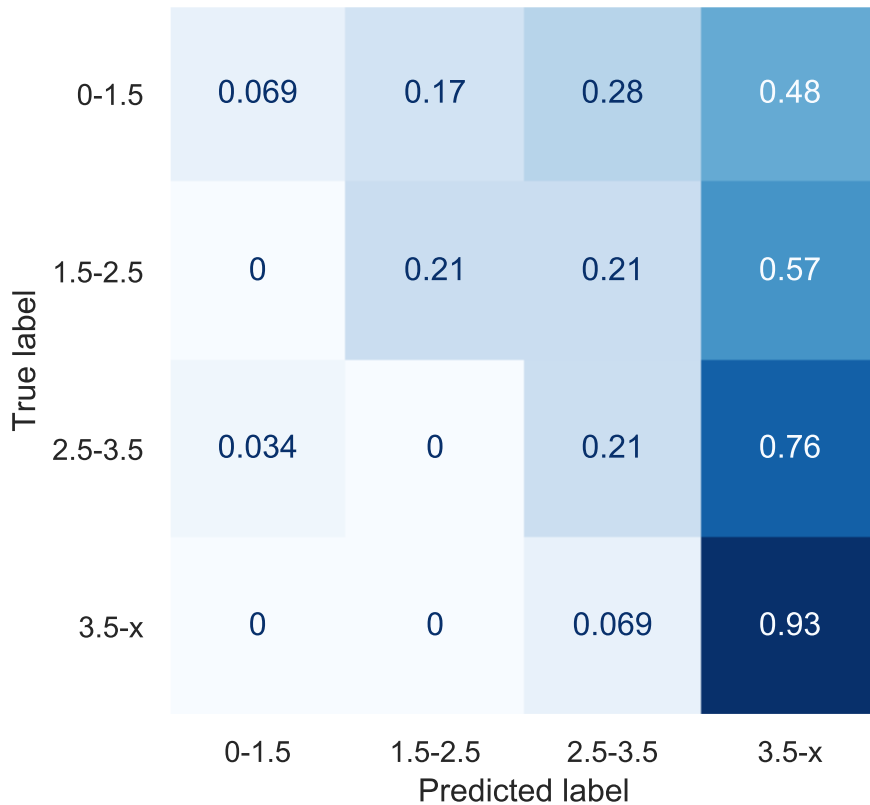


RANGE WINDOW: 10 s

Confusion matrix Recv: S8 Trans: S708 Method: All\_with\_PL

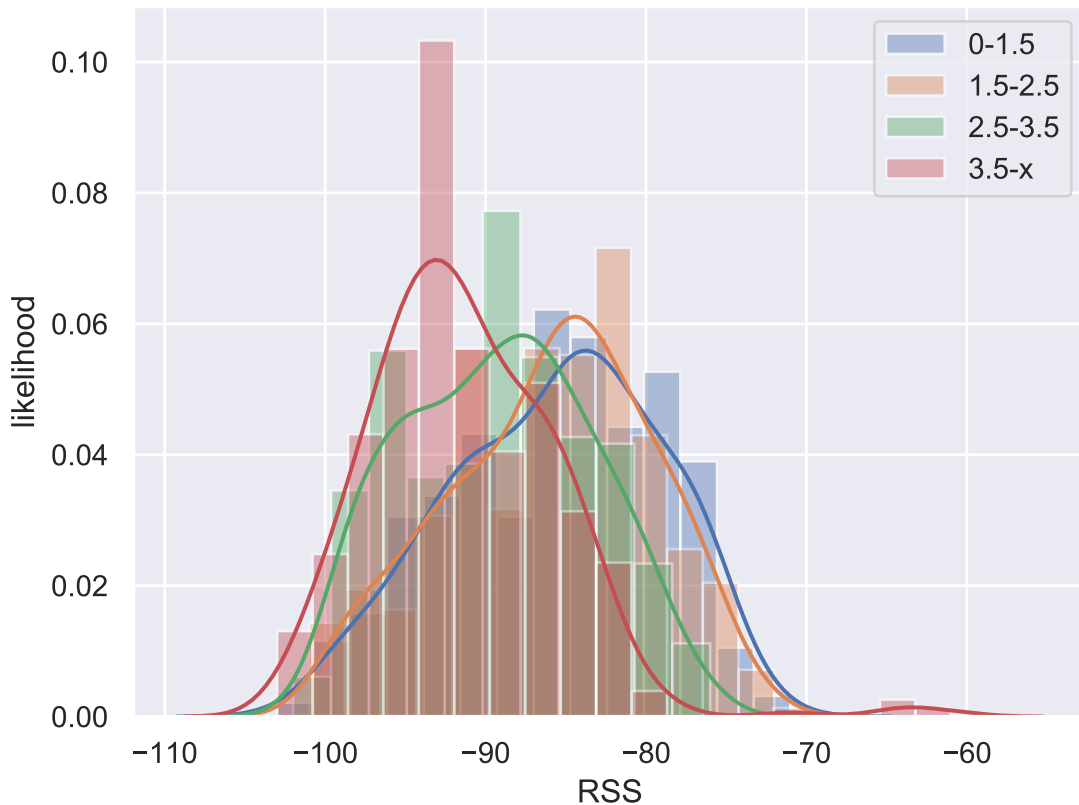


RANGE WINDOW: 10 s  
Confusion matrix Recv: S8 Trans: S708 Method: method 4



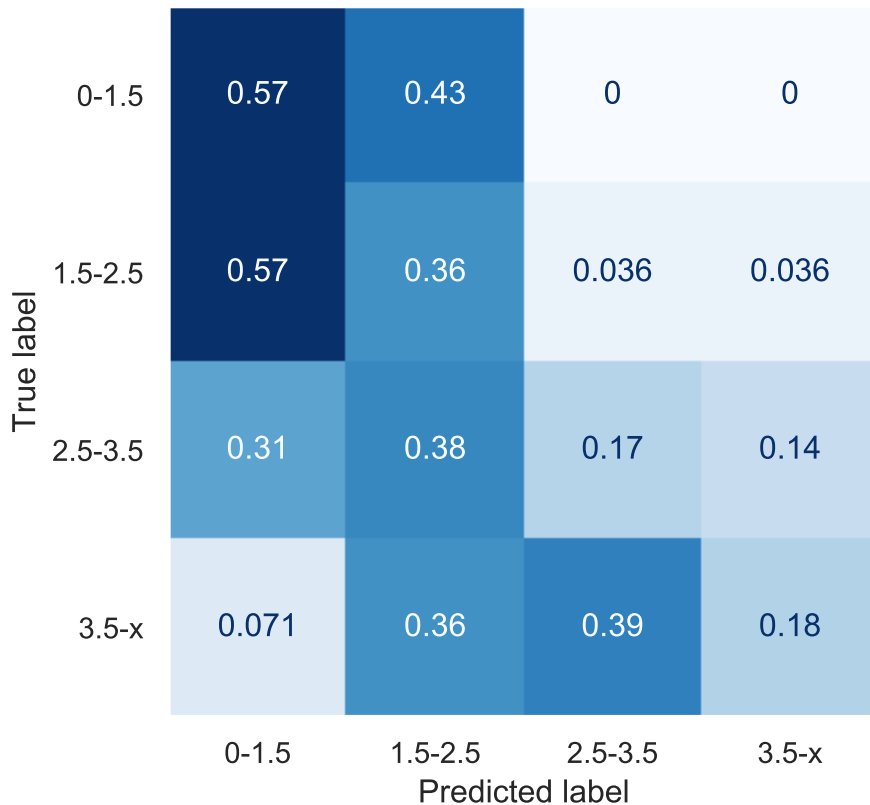


RANGE WINDOW: 10 s  
RSS Recv: Motorola Trans: Nexus



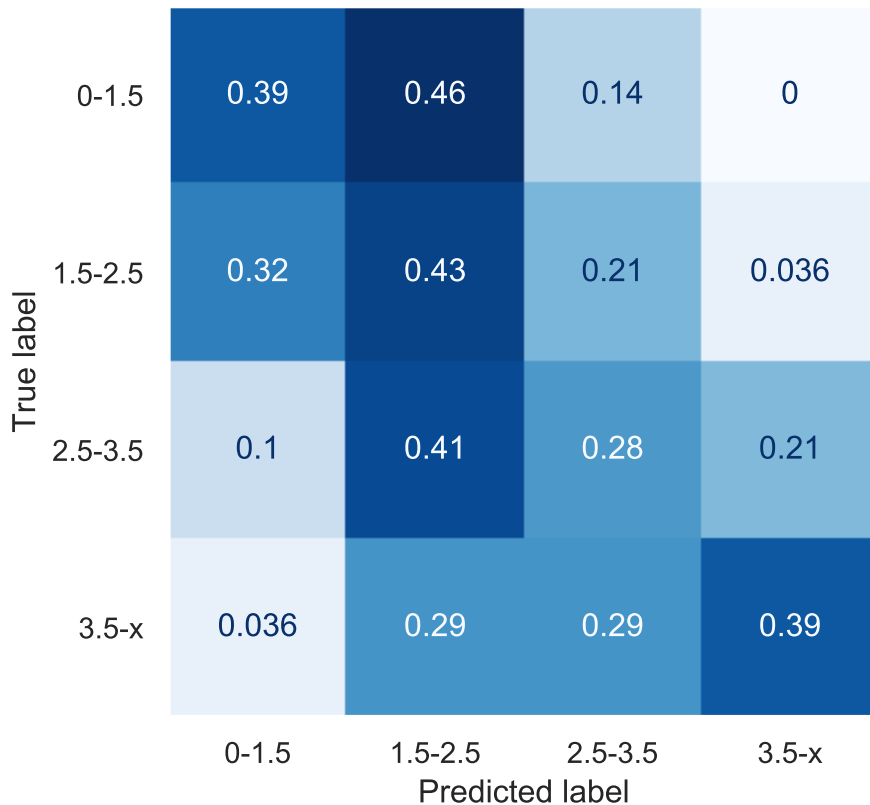
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Confusion matrix Recv: Motorola Trans: Nexus Method: 1meter



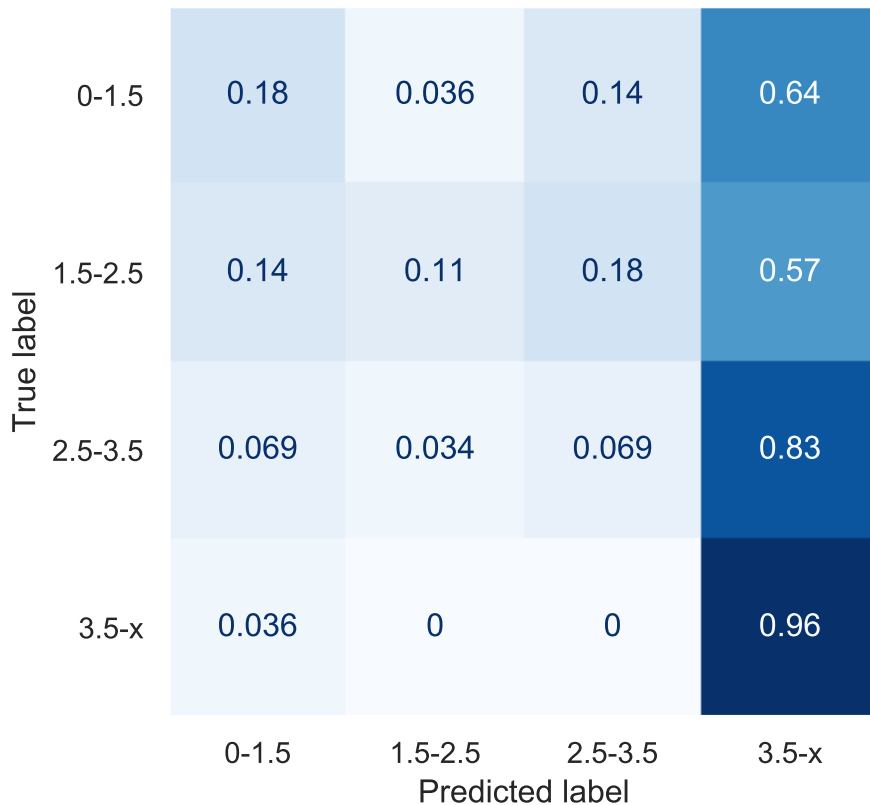
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Confusion matrix Recv: Motorola Trans: Nexus Method: All\_without\_PL



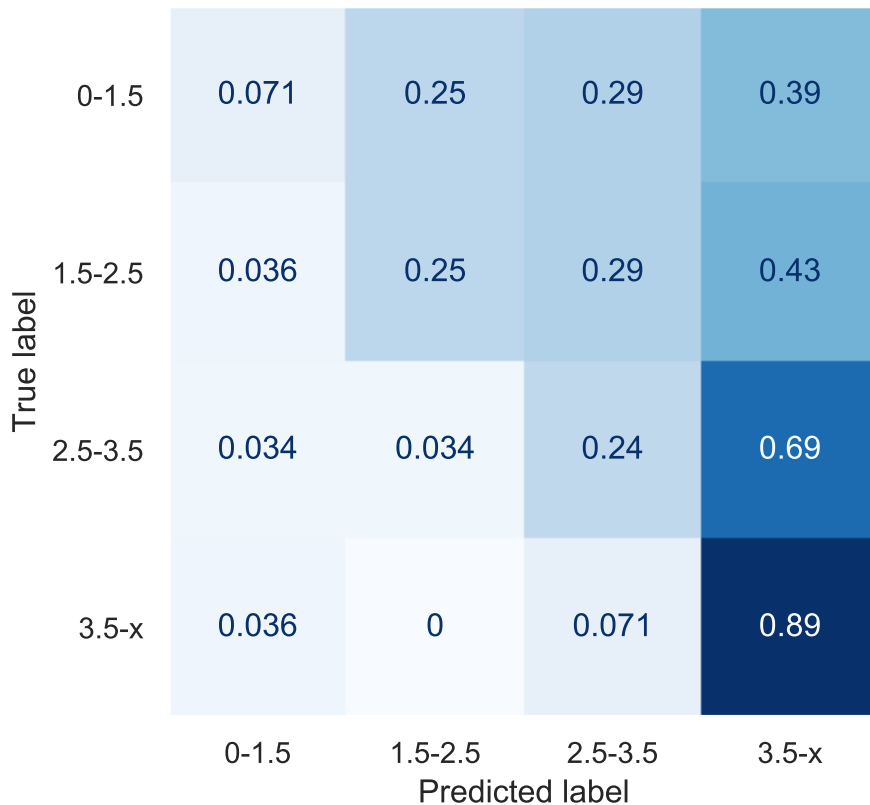
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Confusion matrix Recv: Motorola Trans: Nexus Method: All\_with\_PL

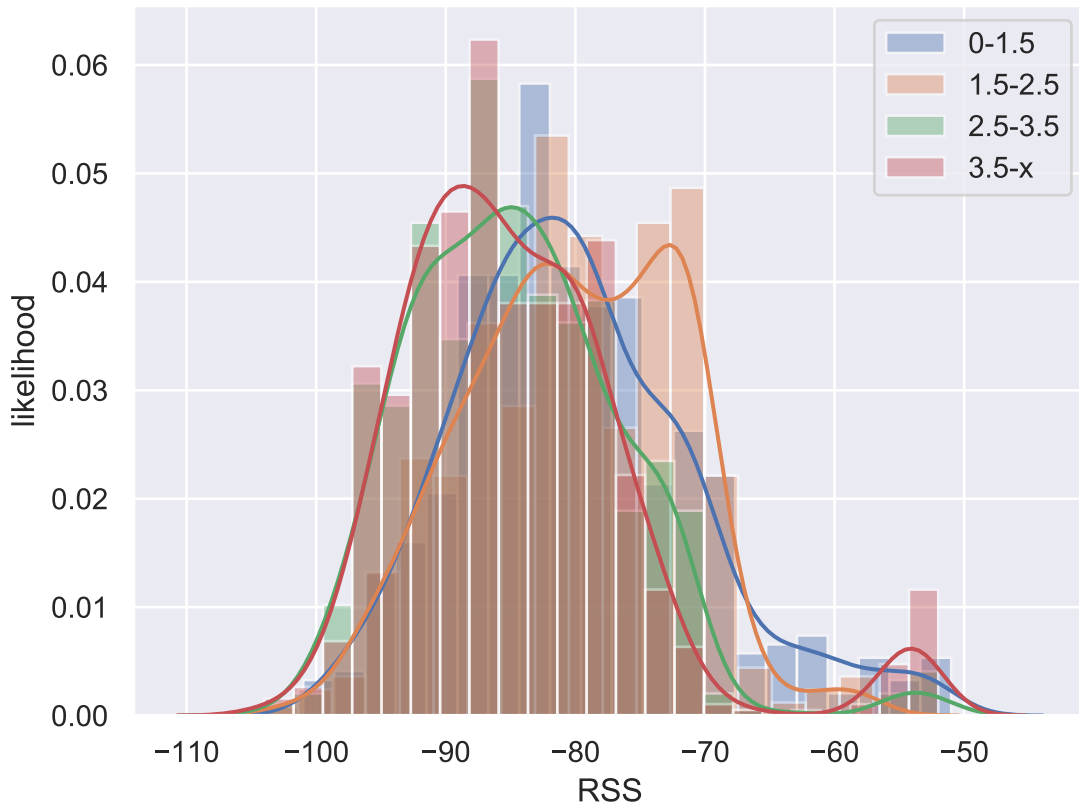


RANGE WINDOW: 10 s

Confusion matrix Recv: Motorola Trans: Nexus Method: method 4

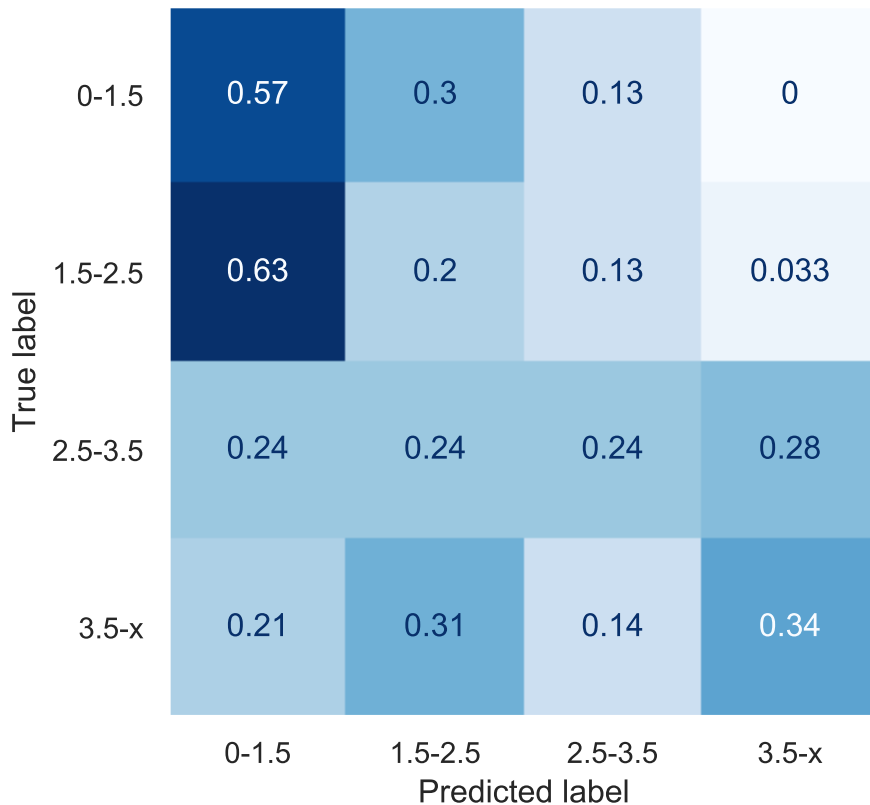


RANGE WINDOW: 10 s  
RSS Recv: SamsungA6 Trans: Nexus



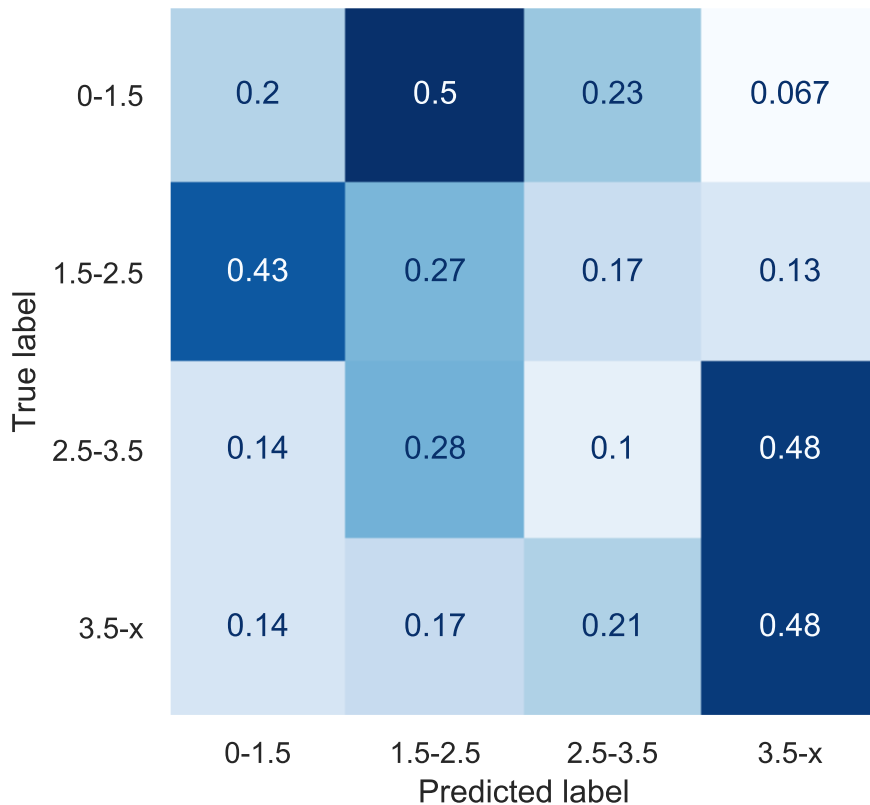
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Confusion matrix Recv: SamsungA6 Trans: Nexus Method: 1meter



RANGE WINDOW: 10 s

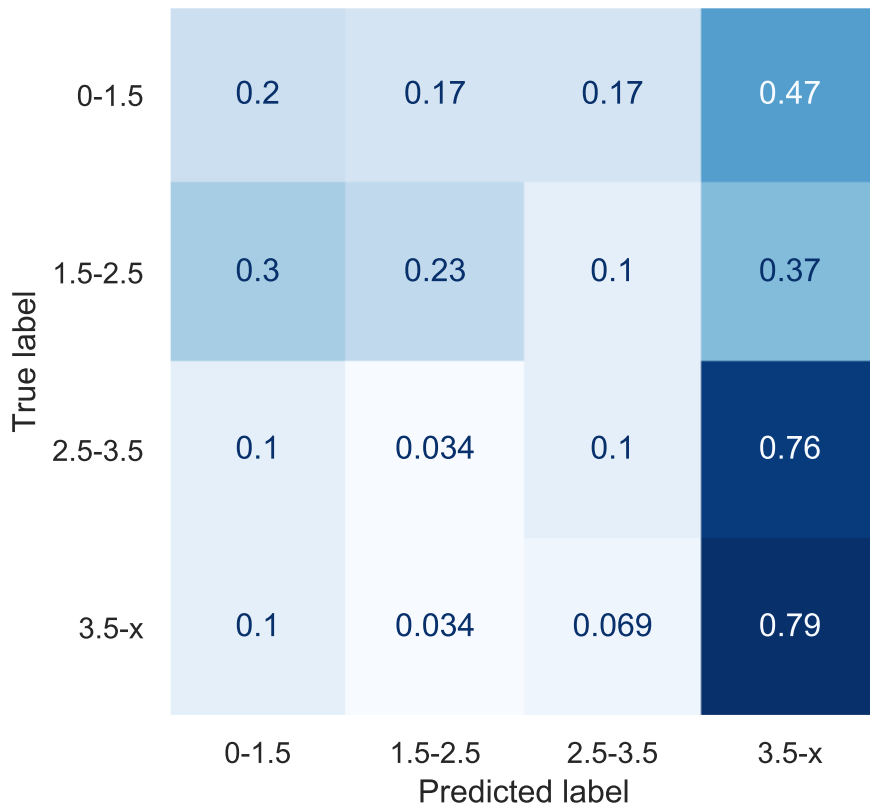
Confusion matrix Recv: SamsungA6 Trans: Nexus Method: All\_without\_PL





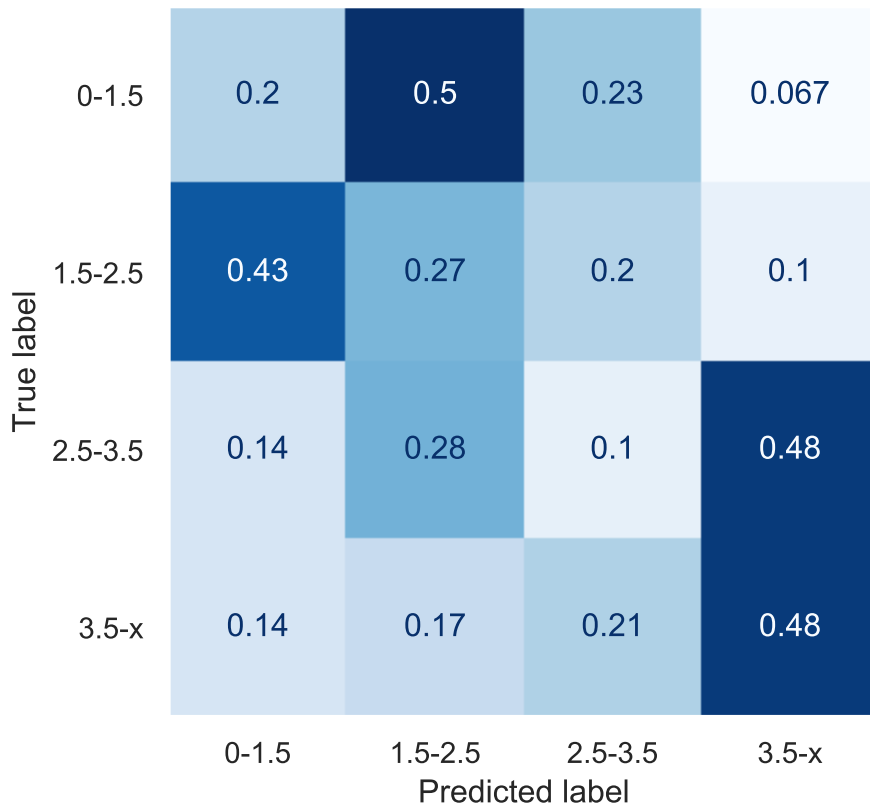
RANGE WINDOW: 10 s

Confusion matrix Recv: SamsungA6 Trans: Nexus Method: All\_with\_PL

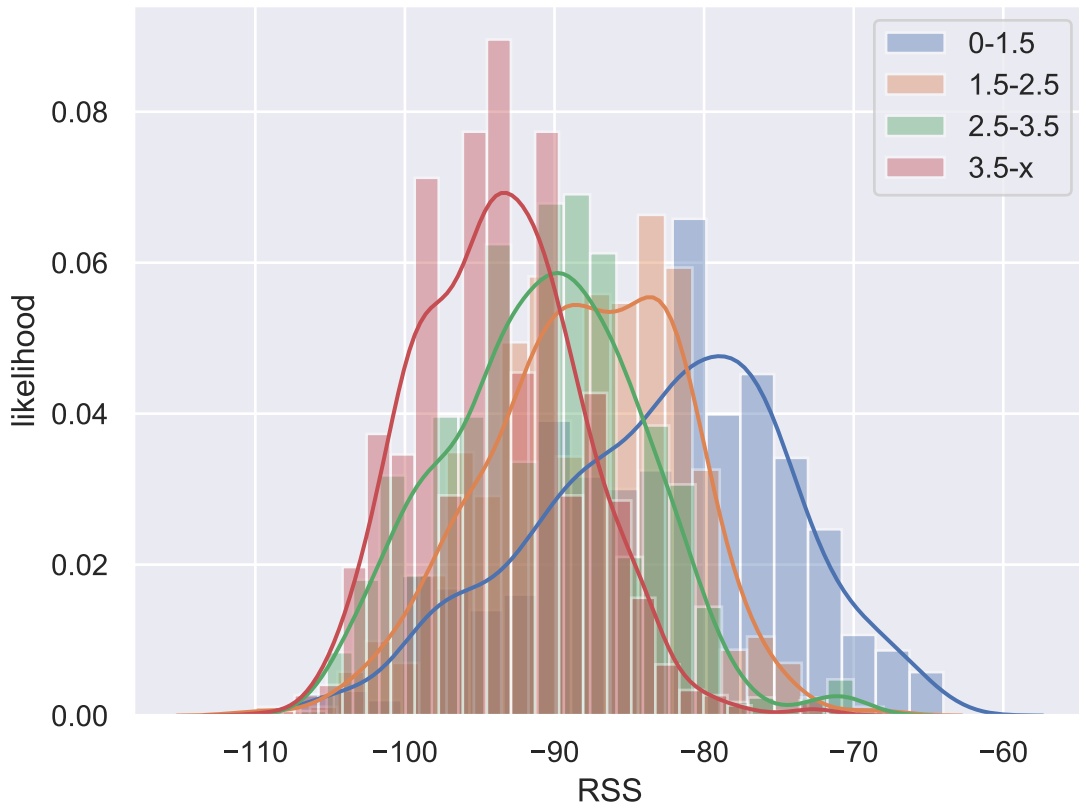


RANGE WINDOW: 10 s

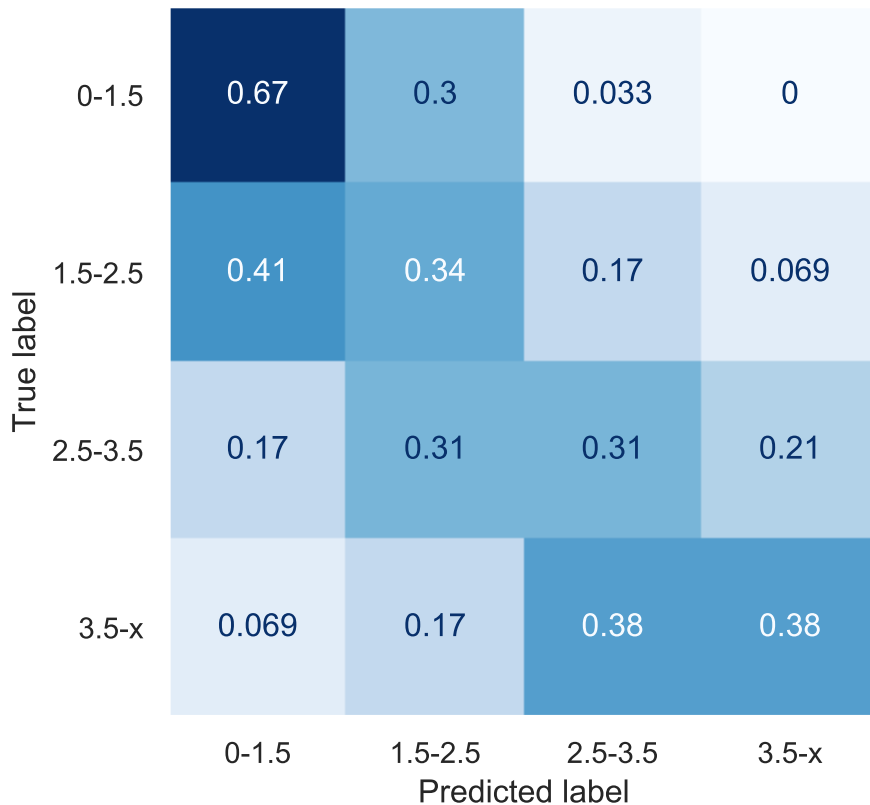
Confusion matrix Recv: SamsungA6 Trans: Nexus Method: method 4



RANGE WINDOW: 10 s  
RSS Recv: S708 Trans: Nexus

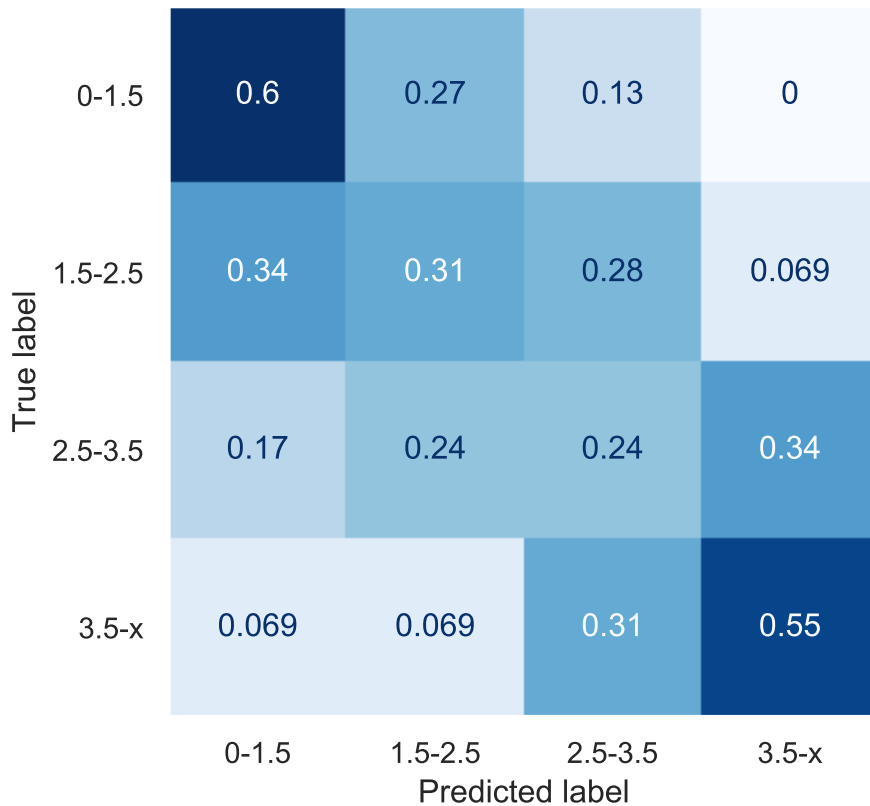


RANGE WINDOW: 10 s  
Confusion matrix Recv: S708 Trans: Nexus Method: 1meter



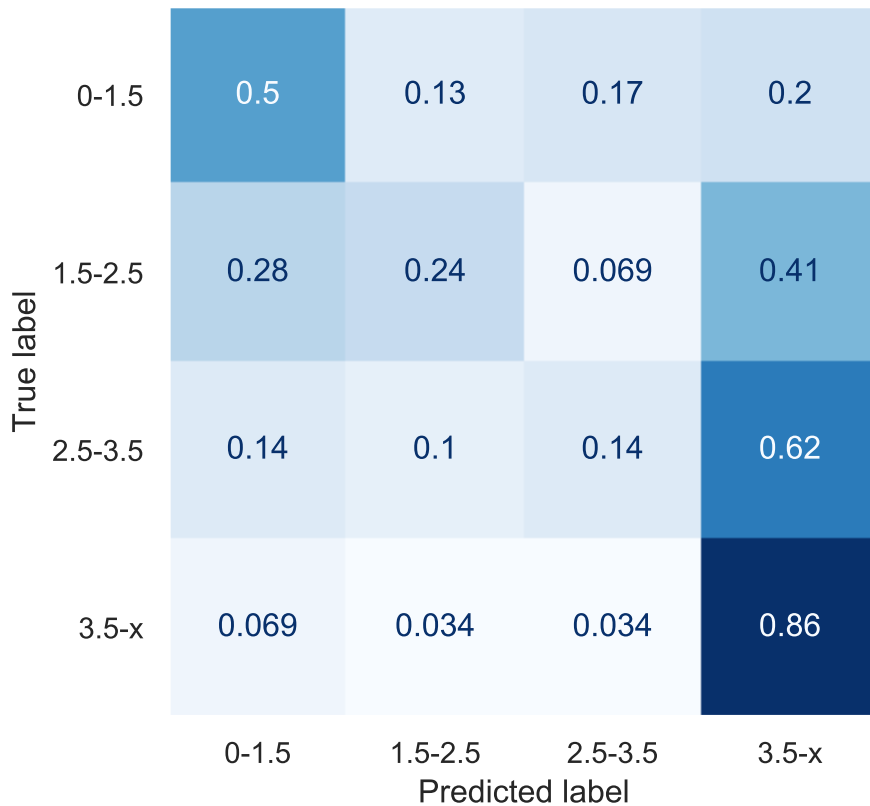
RANGE WINDOW: 10 s

Confusion matrix Recv: S708 Trans: Nexus Method: All\_without\_PL



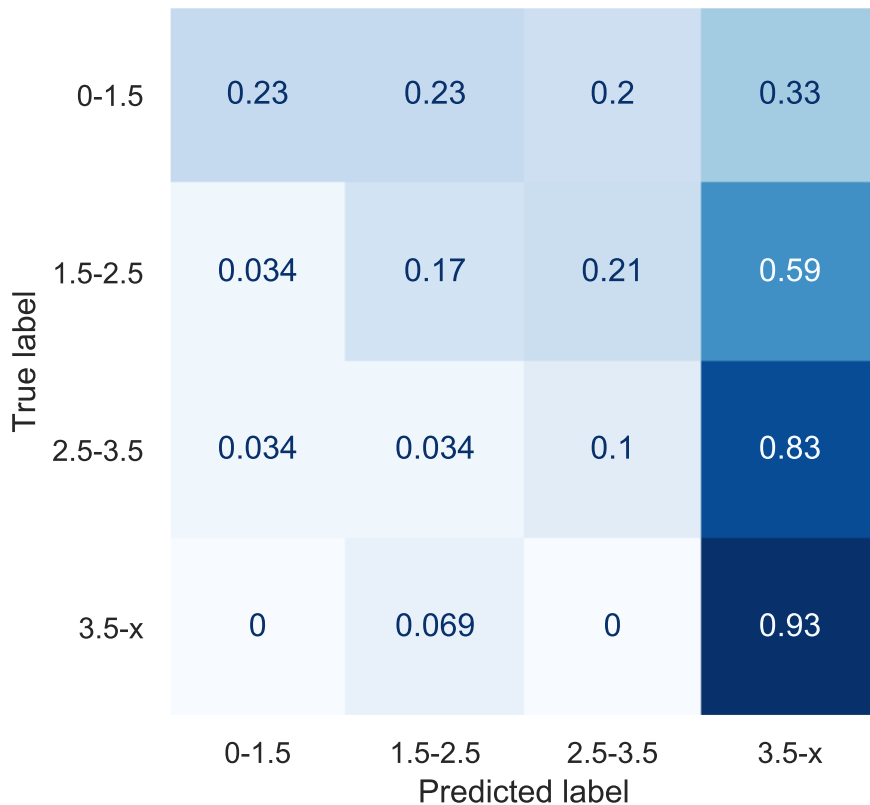
RANGE WINDOW: 10 s

Confusion matrix Recv: S708 Trans: Nexus Method: All\_with\_PL

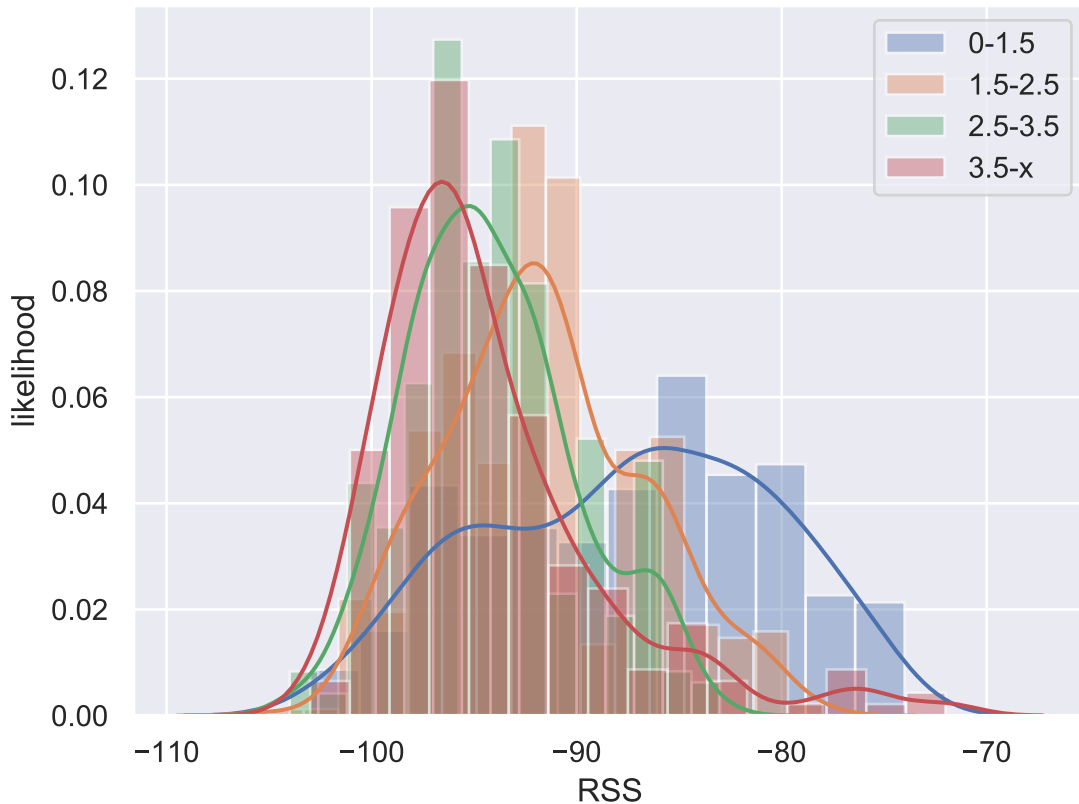


RANGE WINDOW: 10 s

Confusion matrix Recv: S708 Trans: Nexus Method: method 4

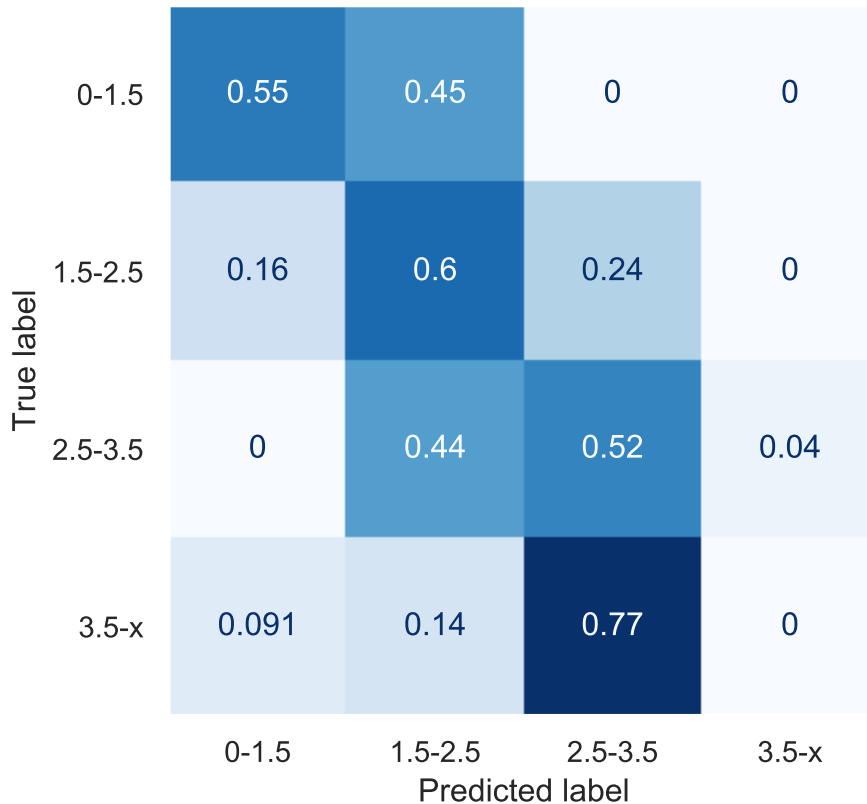


RANGE WINDOW: 10 s  
RSS Recv: Motorola Trans: S8



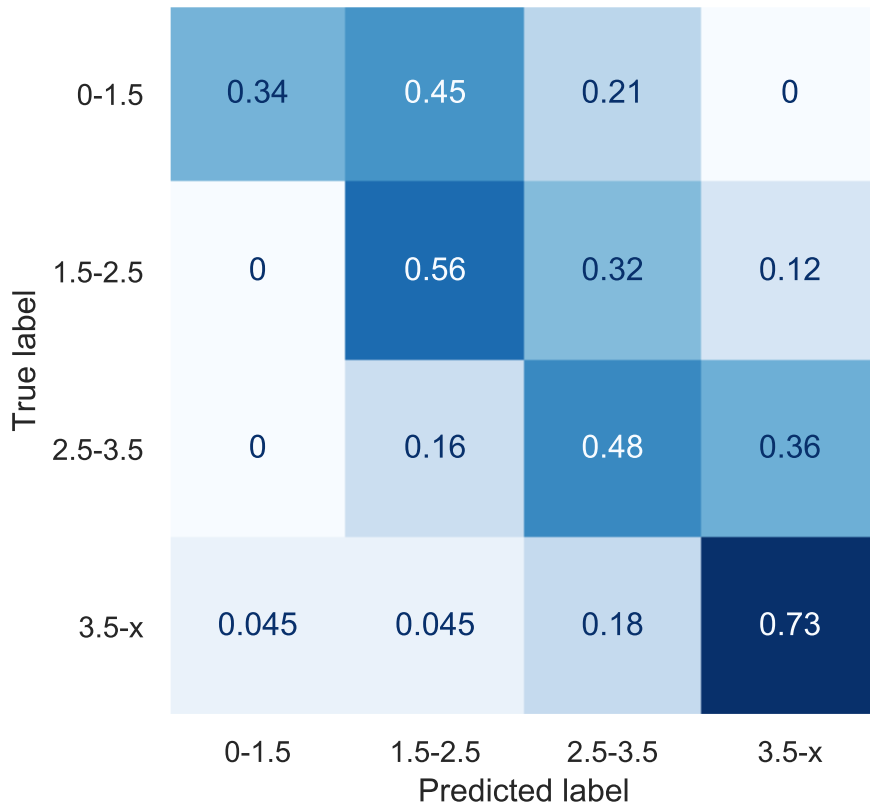


RANGE WINDOW: 10 s  
Confusion matrix Recv: Motorola Trans: S8 Method: 1meter



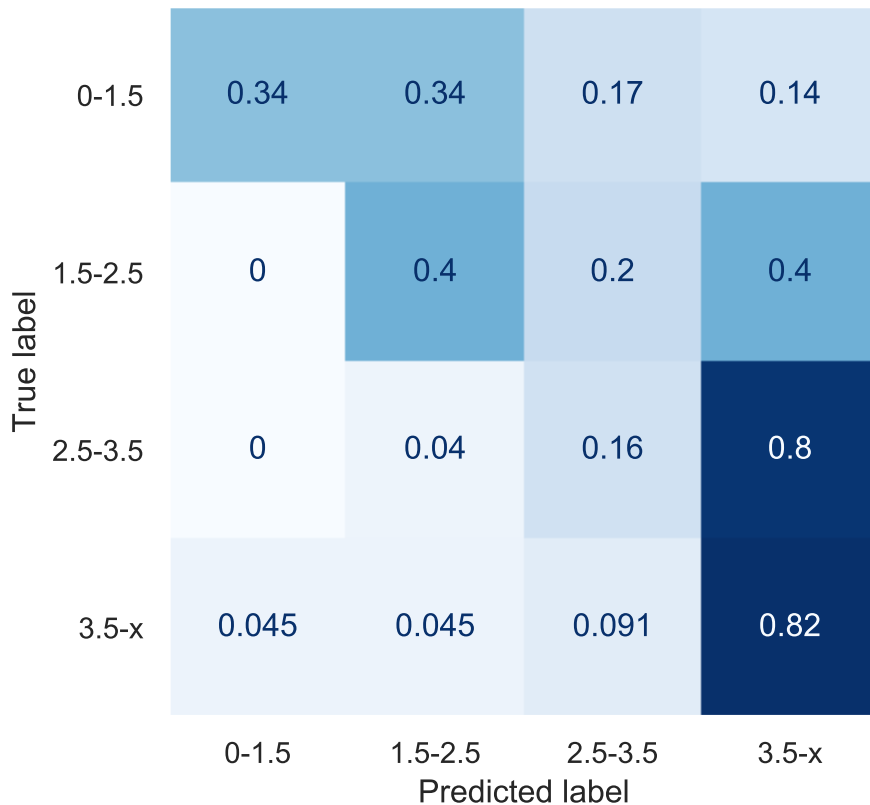
RANGE WINDOW: 10 s

Confusion matrix Recv: Motorola Trans: S8 Method: All\_without\_PL

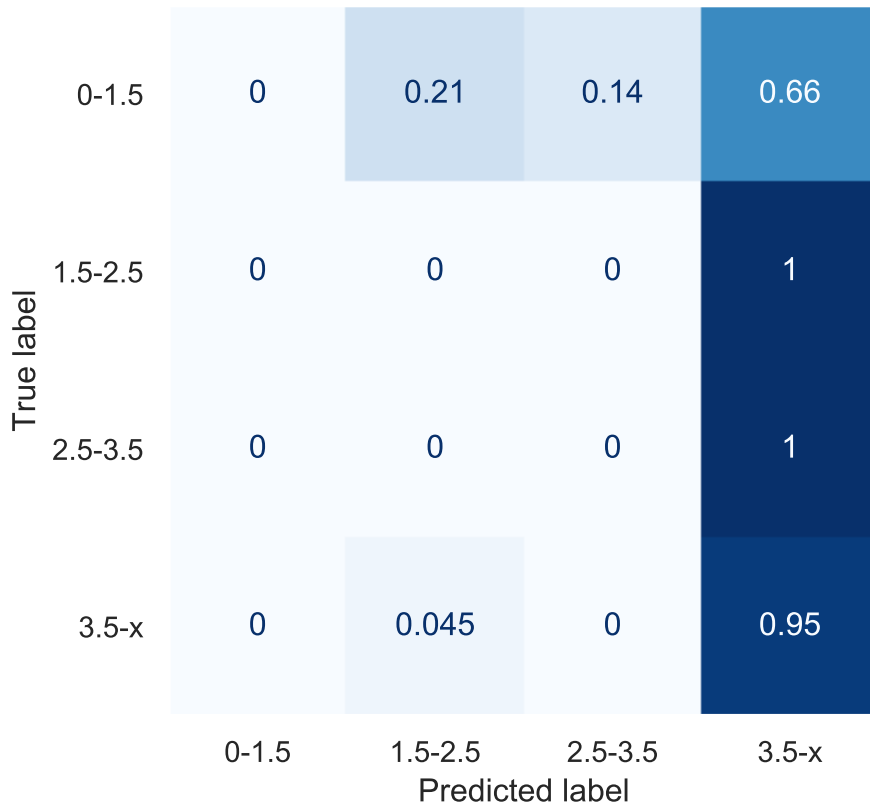


RANGE WINDOW: 10 s

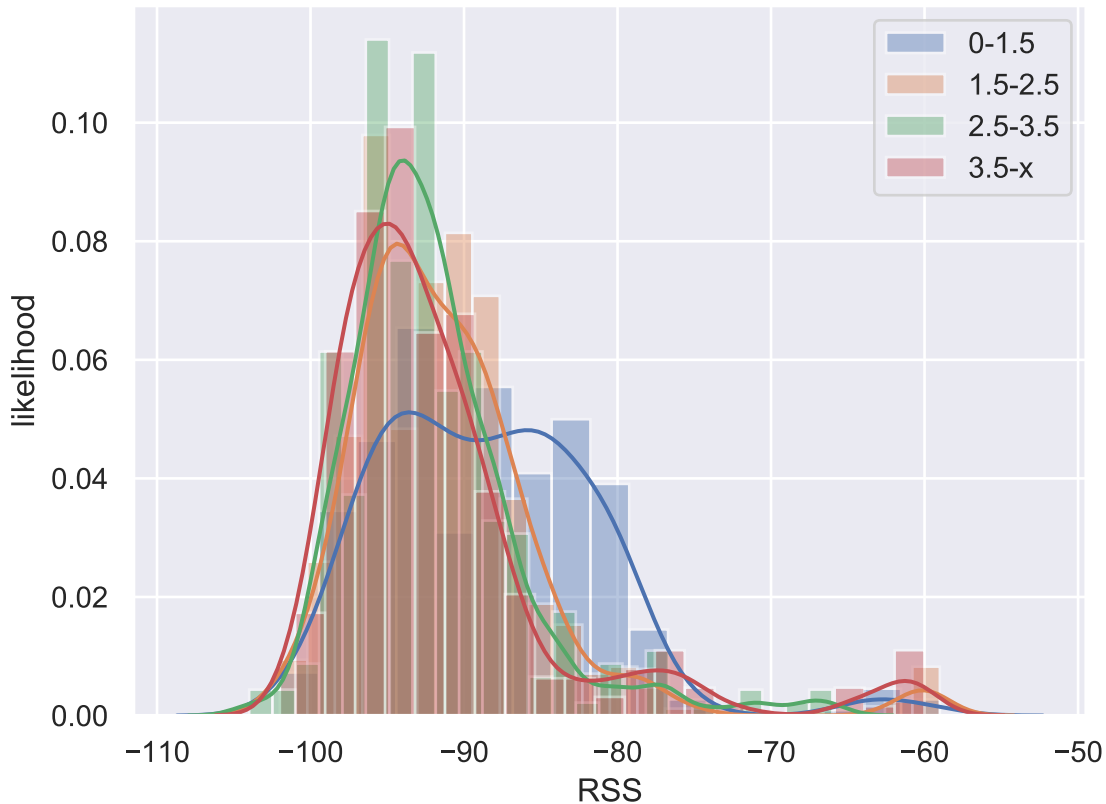
Confusion matrix Recv: Motorola Trans: S8 Method: All\_with\_PL



RANGE WINDOW: 10 s  
Confusion matrix Recv: Motorola Trans: S8 Method: method 4

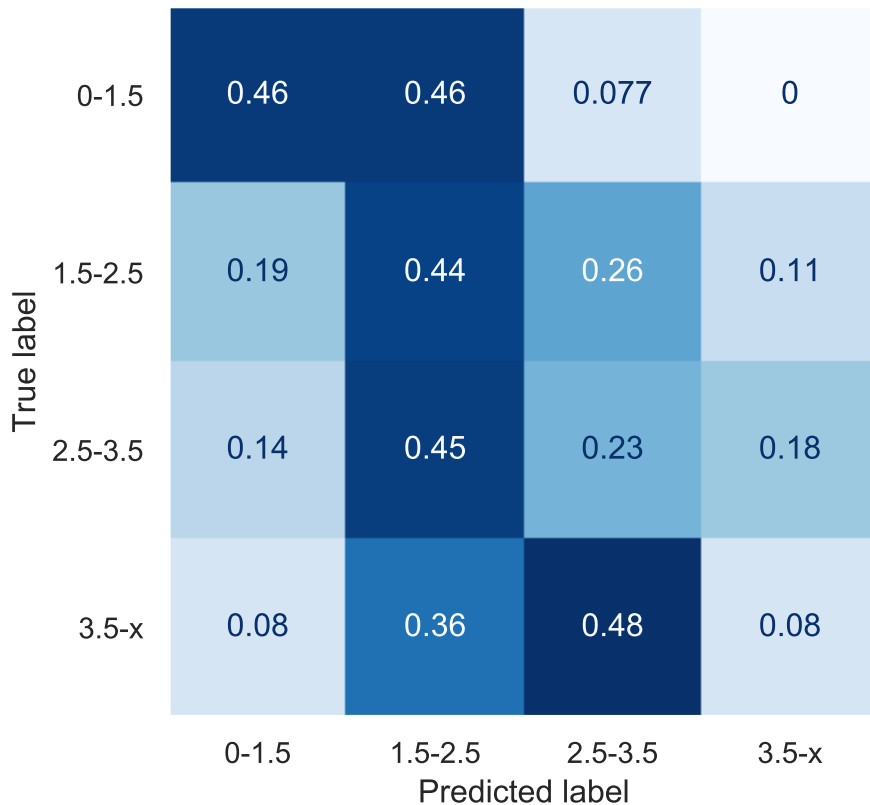


RANGE WINDOW: 10 s  
RSS Recv: SamsungA6 Trans: S8



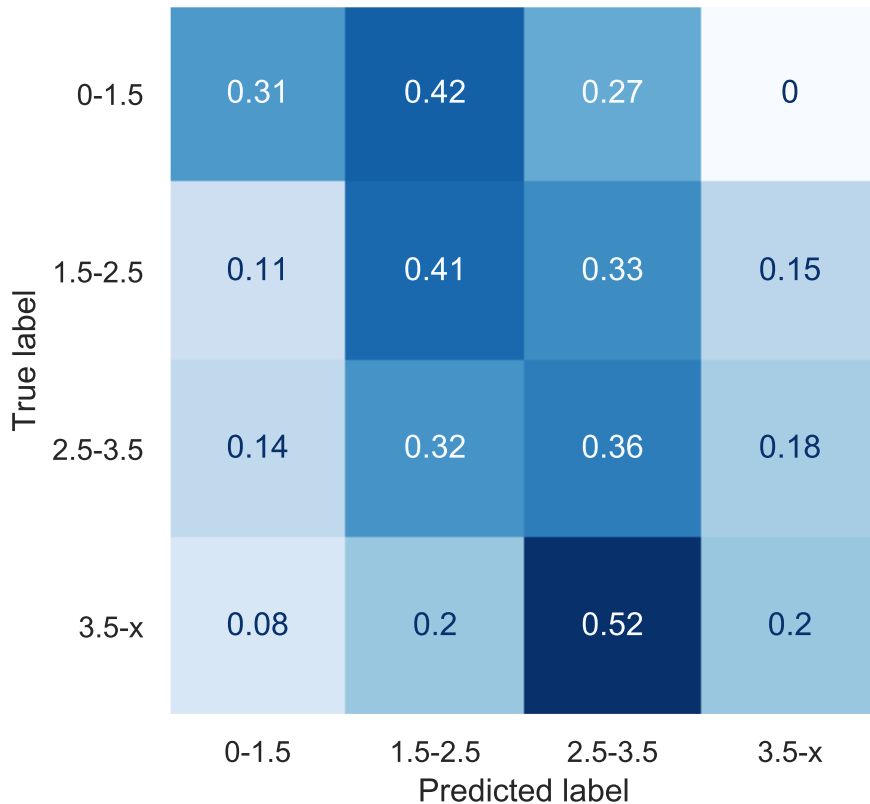
RANGE WINDOW: 10 s

Confusion matrix Recv: SamsungA6 Trans: S8 Method: 1meter



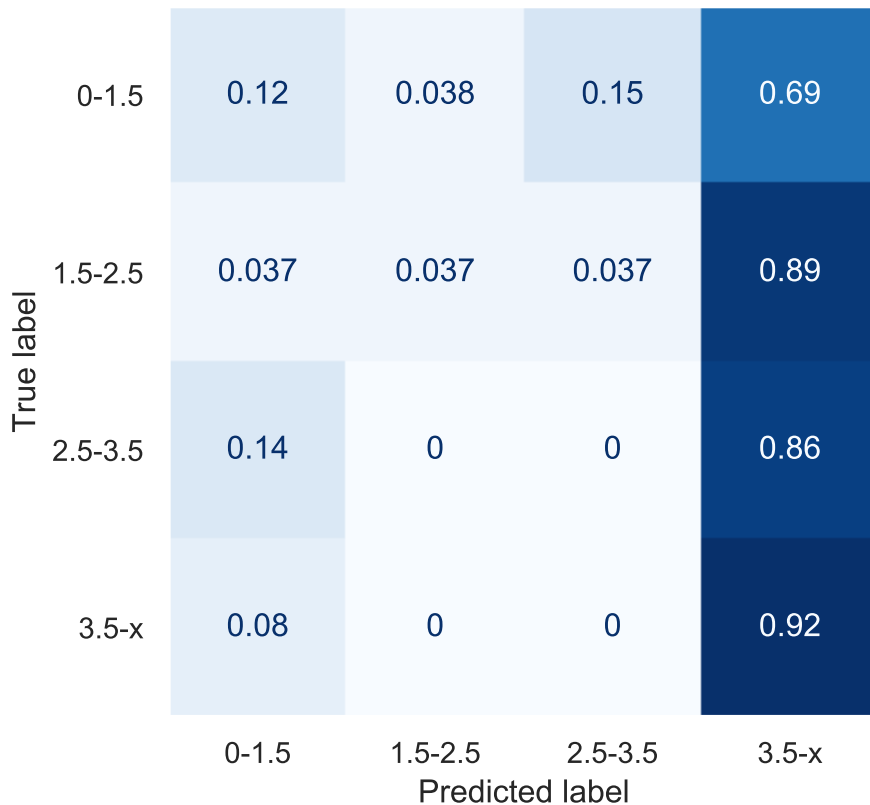
RANGE WINDOW: 10 s

Confusion matrix Recv: SamsungA6 Trans: S8 Method: All\_without\_PL



RANGE WINDOW: 10 s

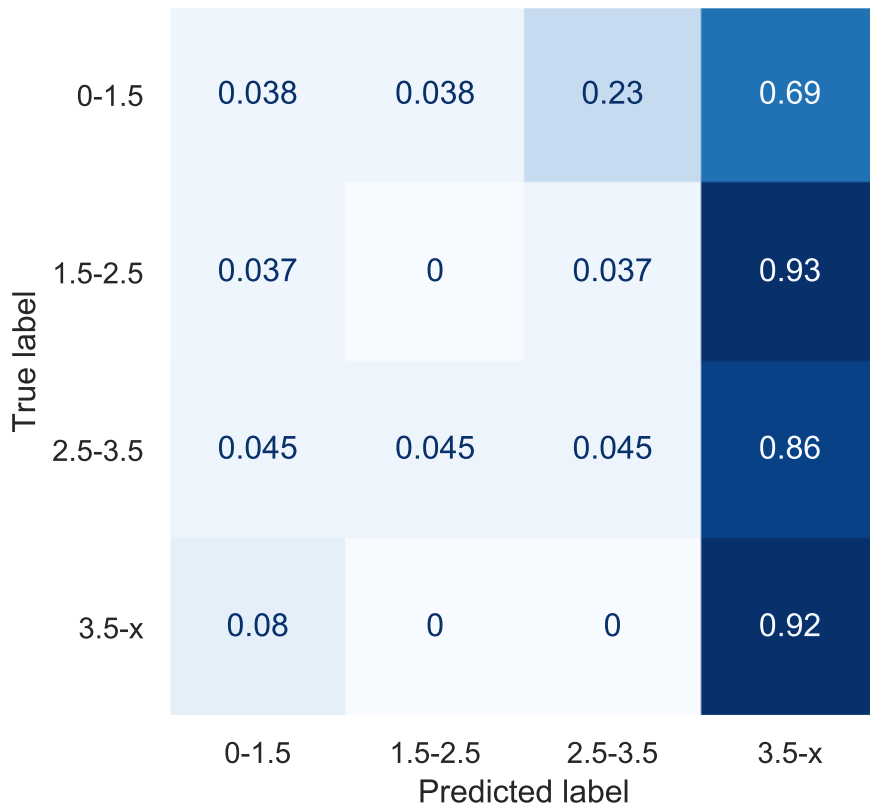
Confusion matrix Recv: SamsungA6 Trans: S8 Method: All\_with\_PL



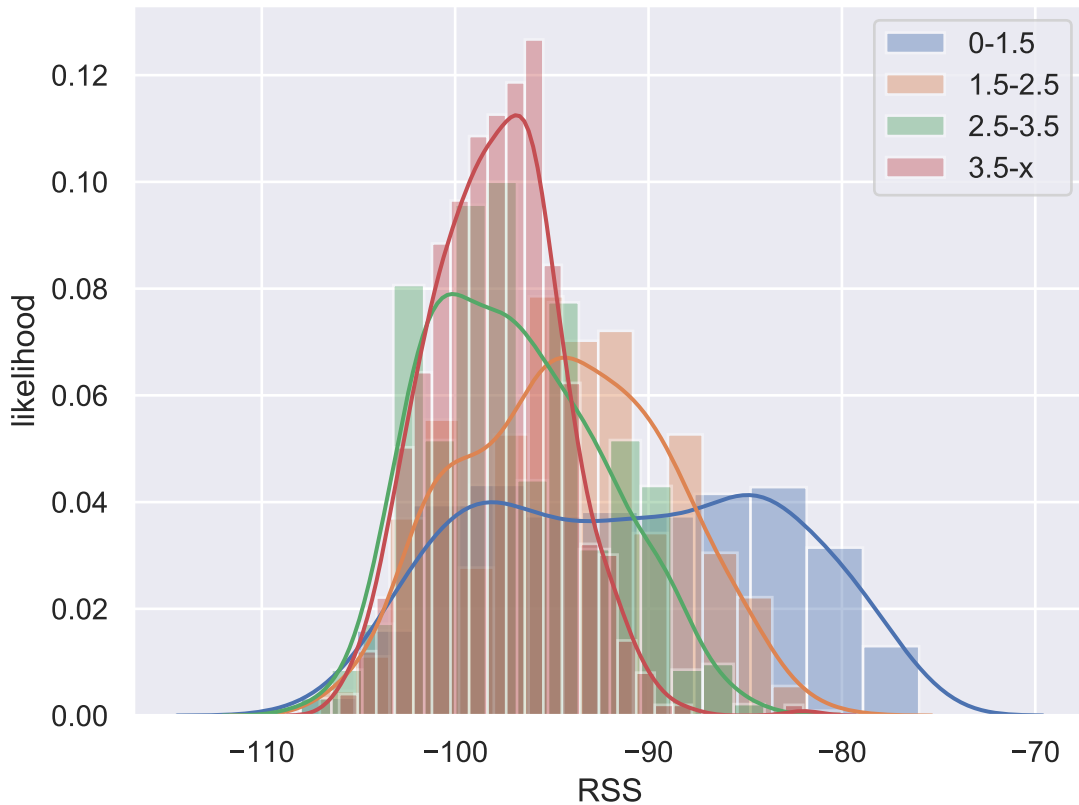


RANGE WINDOW: 10 s

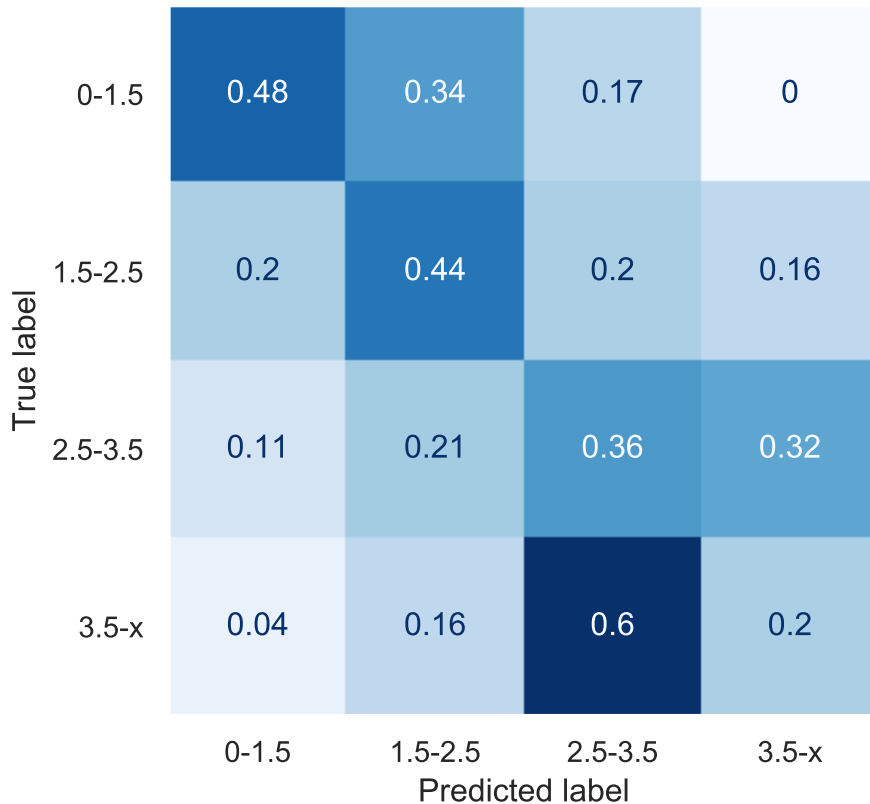
Confusion matrix Recv: SamsungA6 Trans: S8 Method: method 4



RANGE WINDOW: 10 s  
RSS Recv: S708 Trans: S8

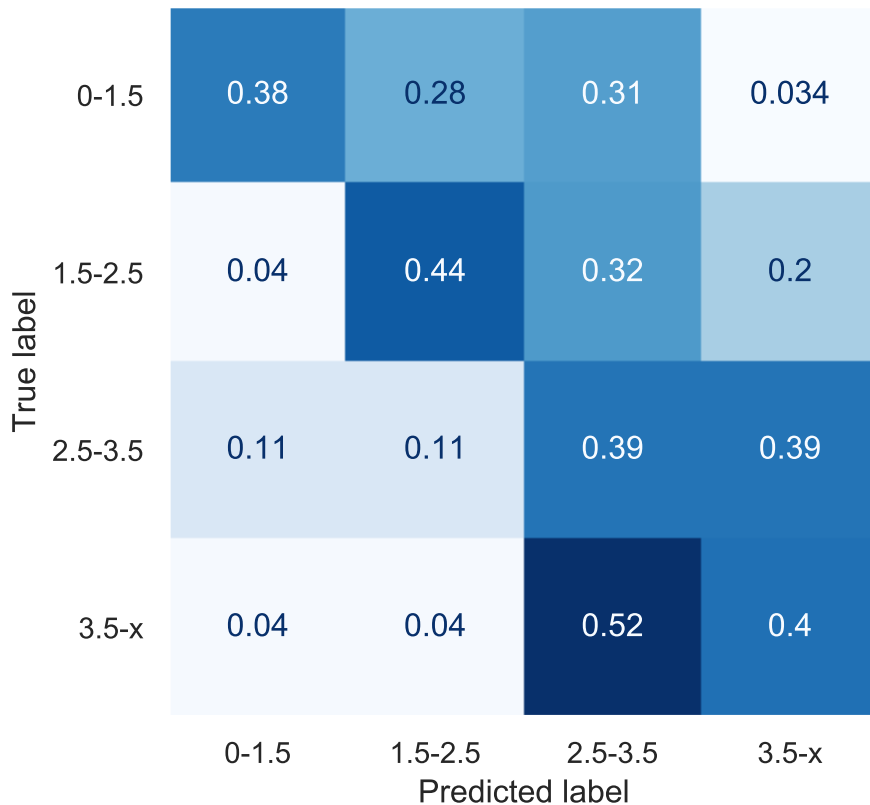


RANGE WINDOW: 10 s  
Confusion matrix Recv: S708 Trans: S8 Method: 1meter



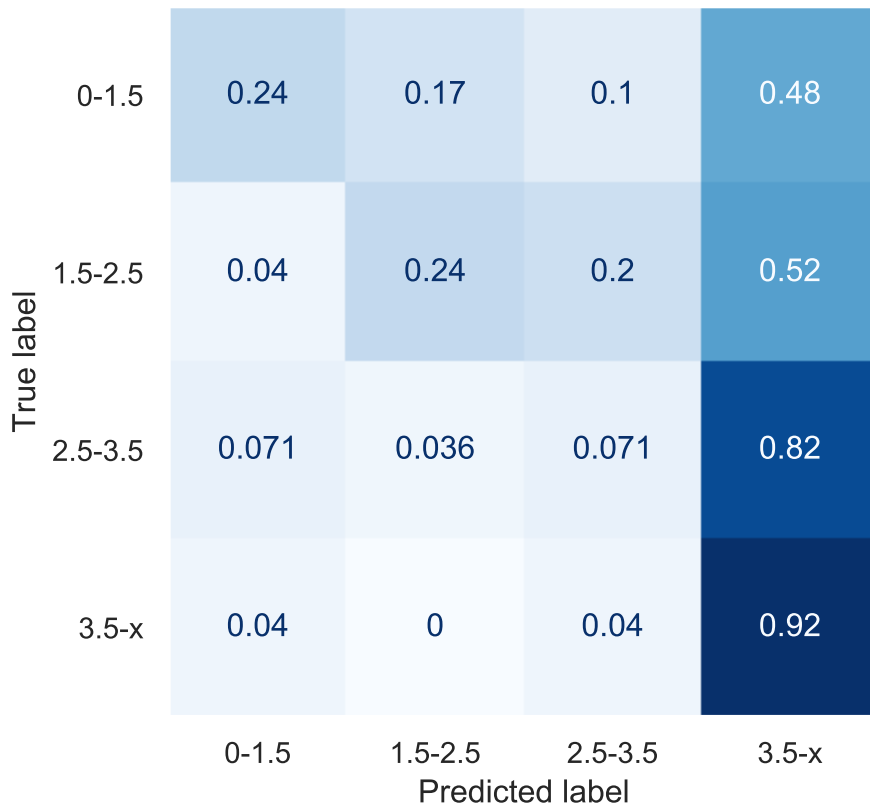
RANGE WINDOW: 10 s

Confusion matrix Recv: S708 Trans: S8 Method: All\_without\_PL



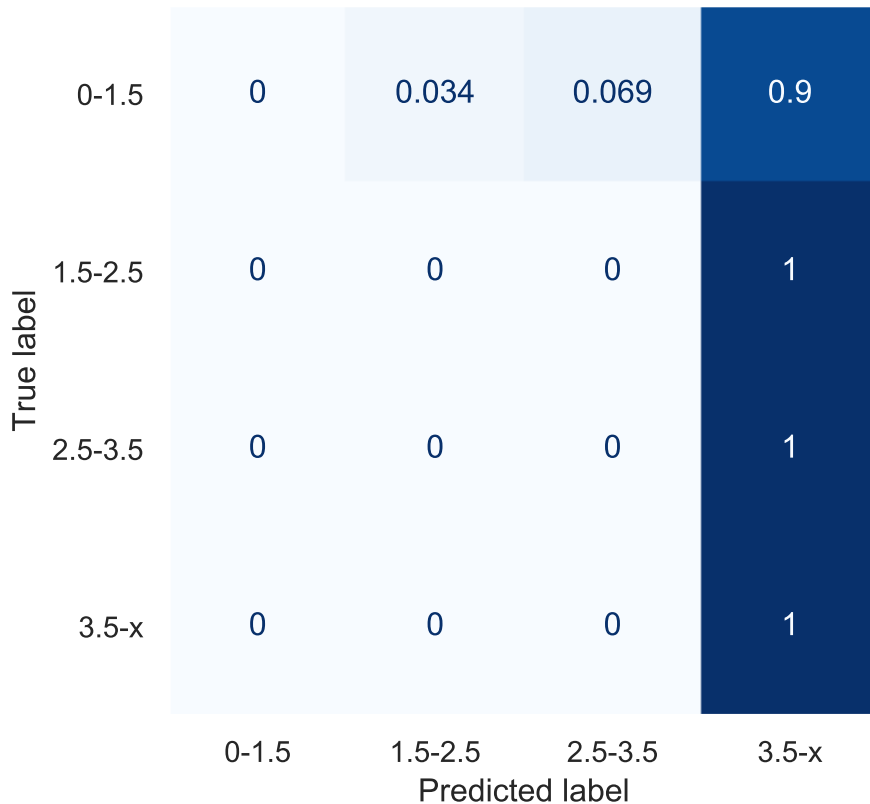
RANGE WINDOW: 10 s

Confusion matrix Recv: S708 Trans: S8 Method: All\_with\_PL

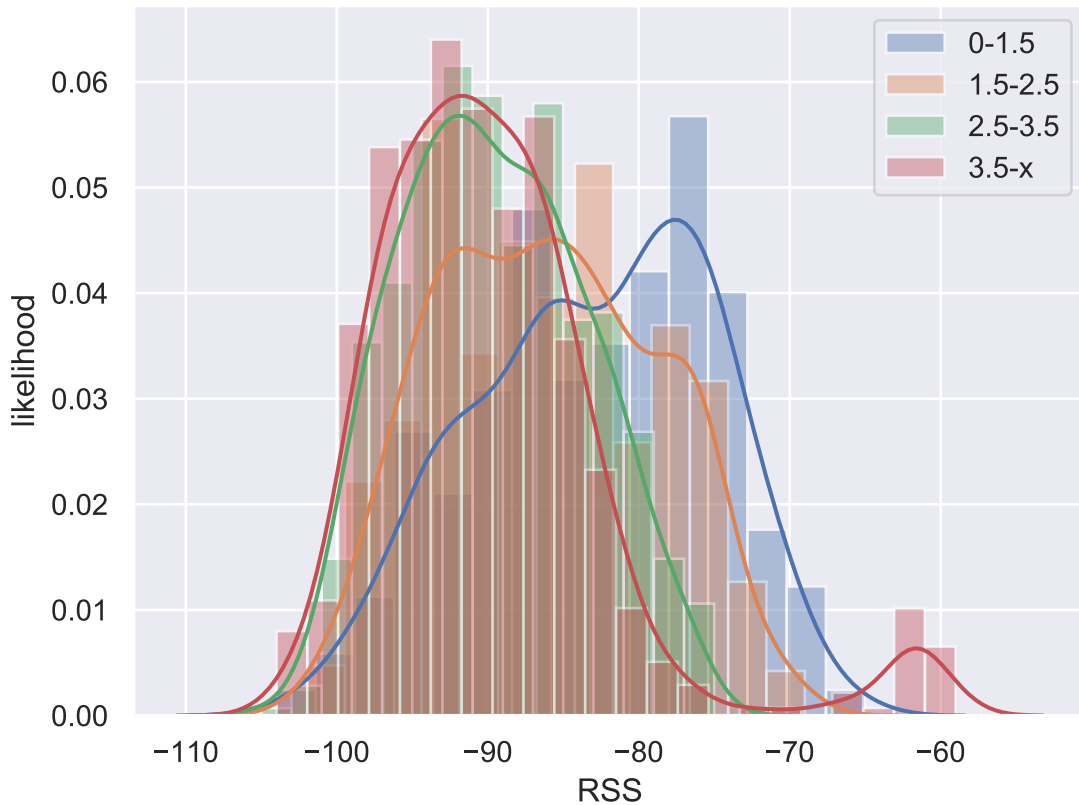


RANGE WINDOW: 10 s

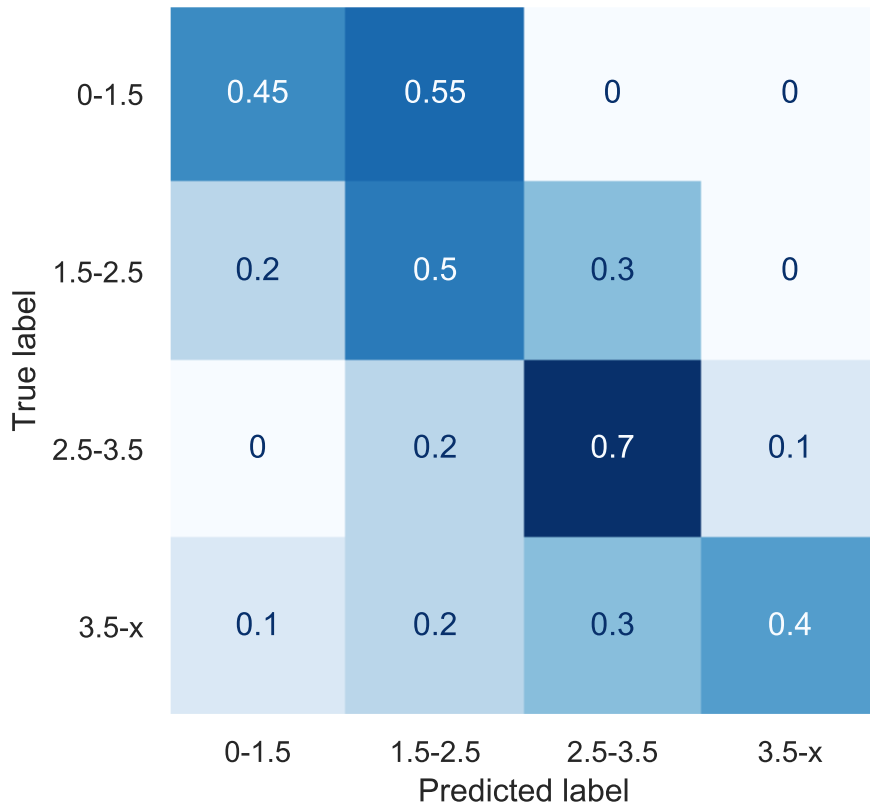
Confusion matrix Recv: S708 Trans: S8 Method: method 4



RANGE WINDOW: 30 s  
RSS Recv: Motorola Trans: S706



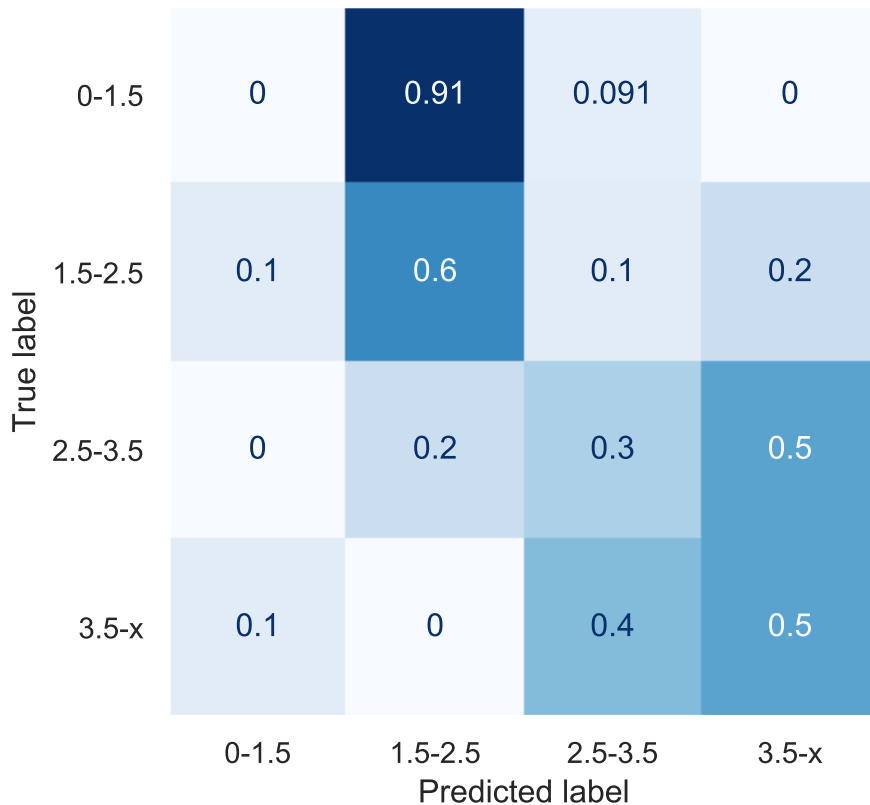
RANGE WINDOW: 30 s  
Confusion matrix Recv: Motorola Trans: S706 Method: 1meter





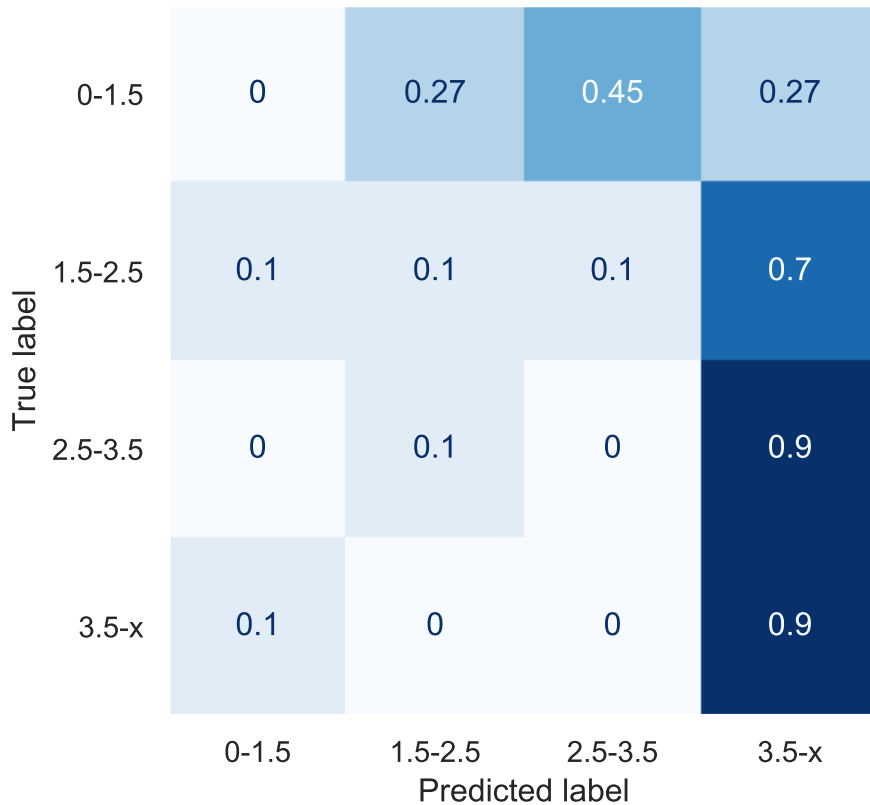
RANGE WINDOW: 30 s

Confusion matrix Recv: Motorola Trans: S706 Method: All\_without\_PL



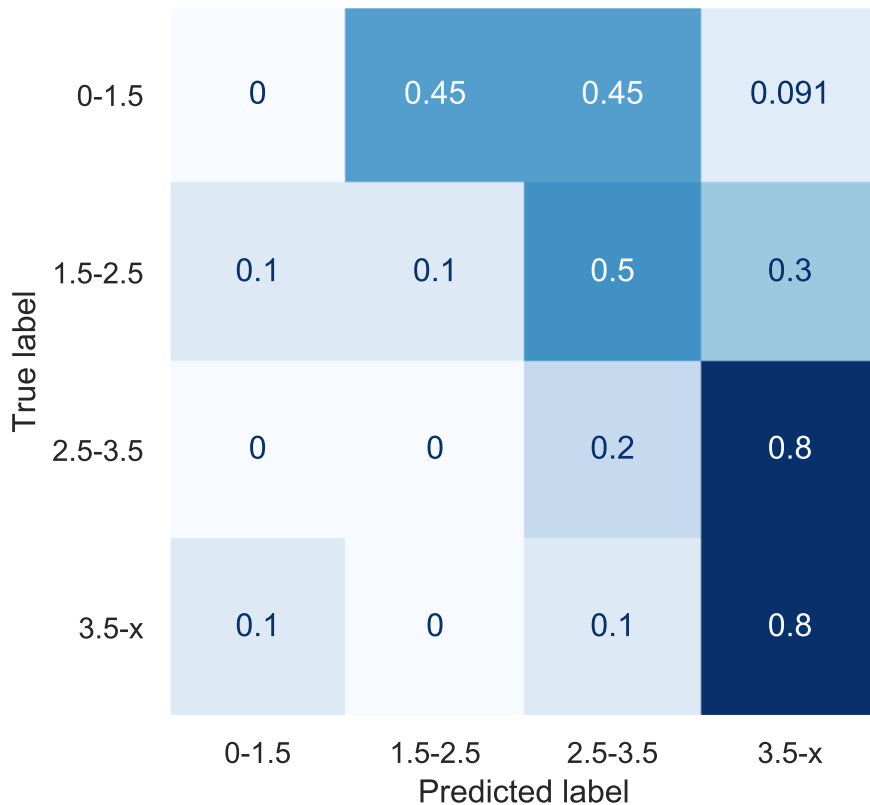
RANGE WINDOW: 30 s

Confusion matrix Recv: Motorola Trans: S706 Method: All\_with\_PL



RANGE WINDOW: 30 s

Confusion matrix Recv: Motorola Trans: S706 Method: method 4

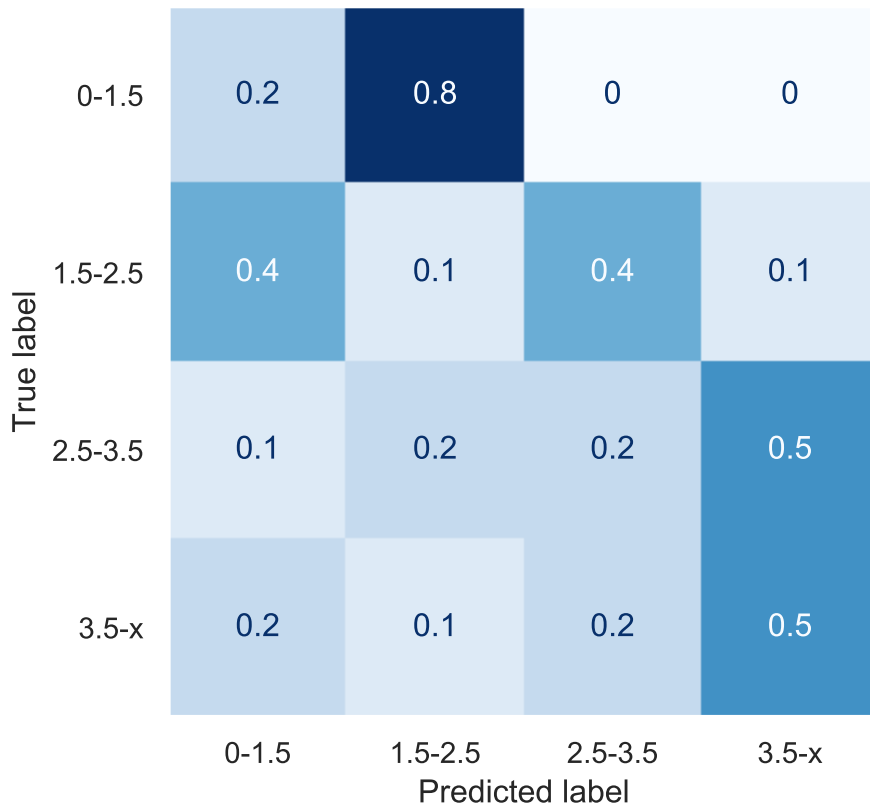


RANGE WINDOW: 30 s  
RSS Recv: SamsungA6 Trans: S706



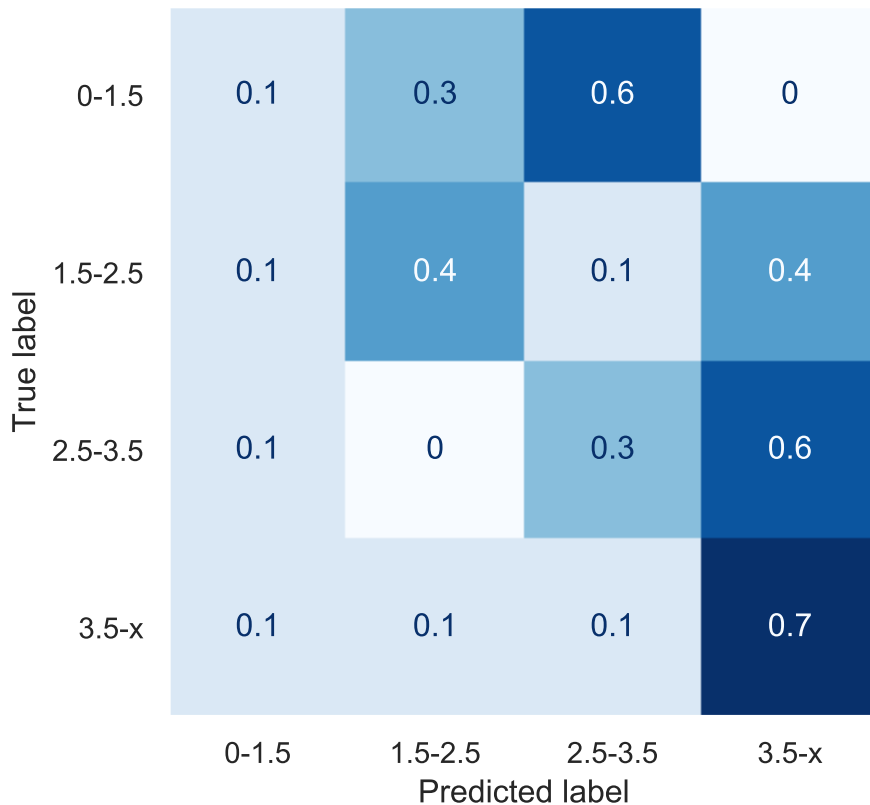
RANGE WINDOW: 30 s

Confusion matrix Recv: SamsungA6 Trans: S706 Method: 1meter



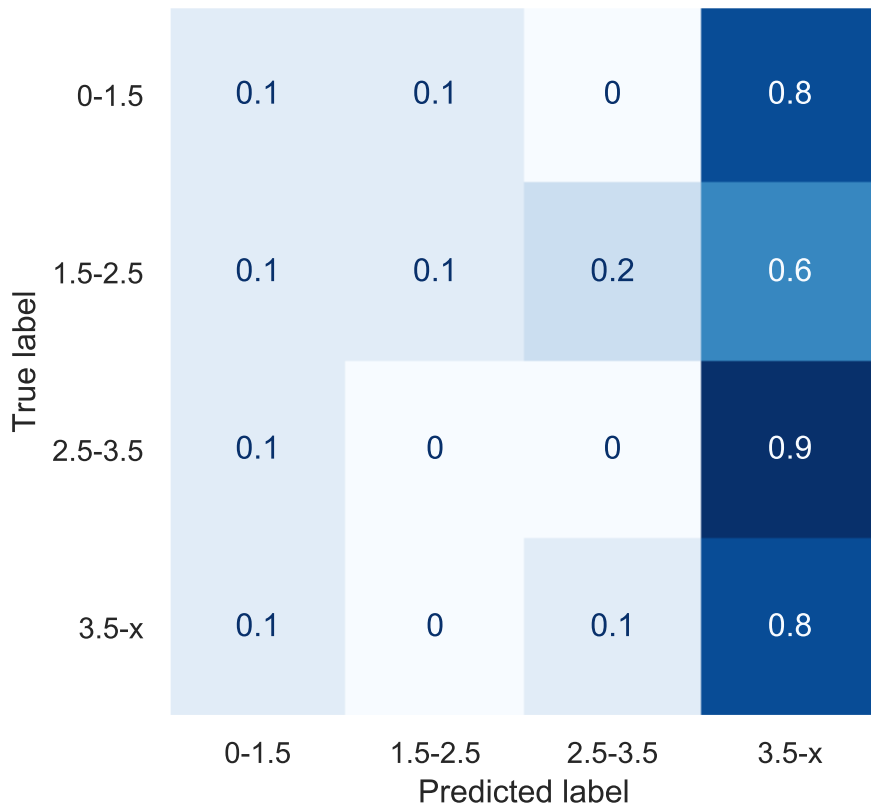
RANGE WINDOW: 30 s

Confusion matrix Recv: SamsungA6 Trans: S706 Method: All\_without\_PL



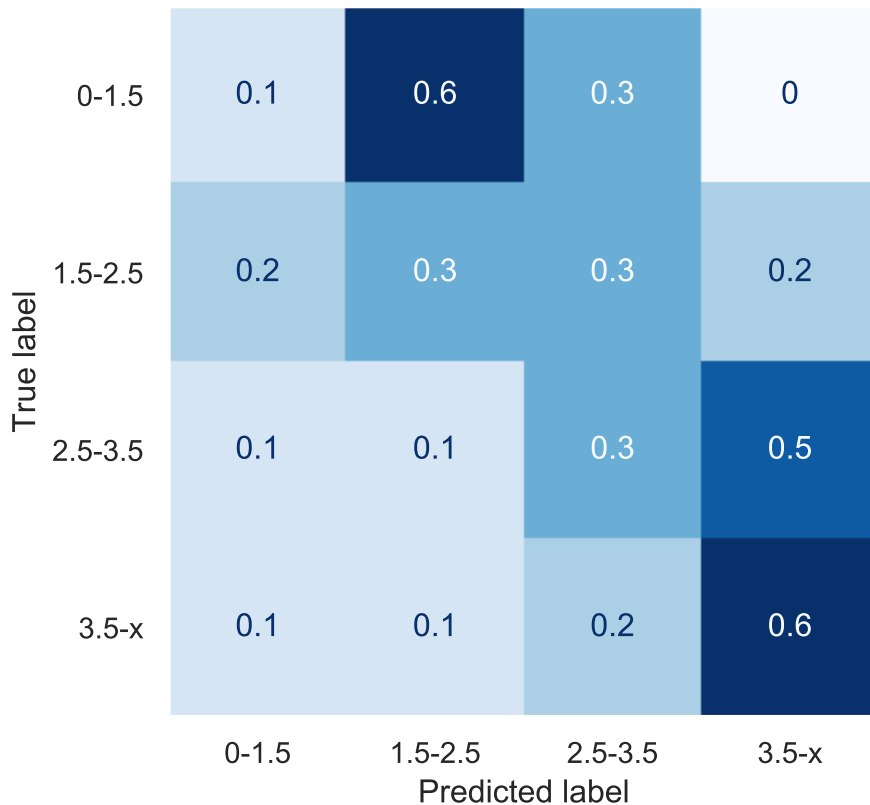
RANGE WINDOW: 30 s

Confusion matrix Recv: SamsungA6 Trans: S706 Method: All\_with\_PL



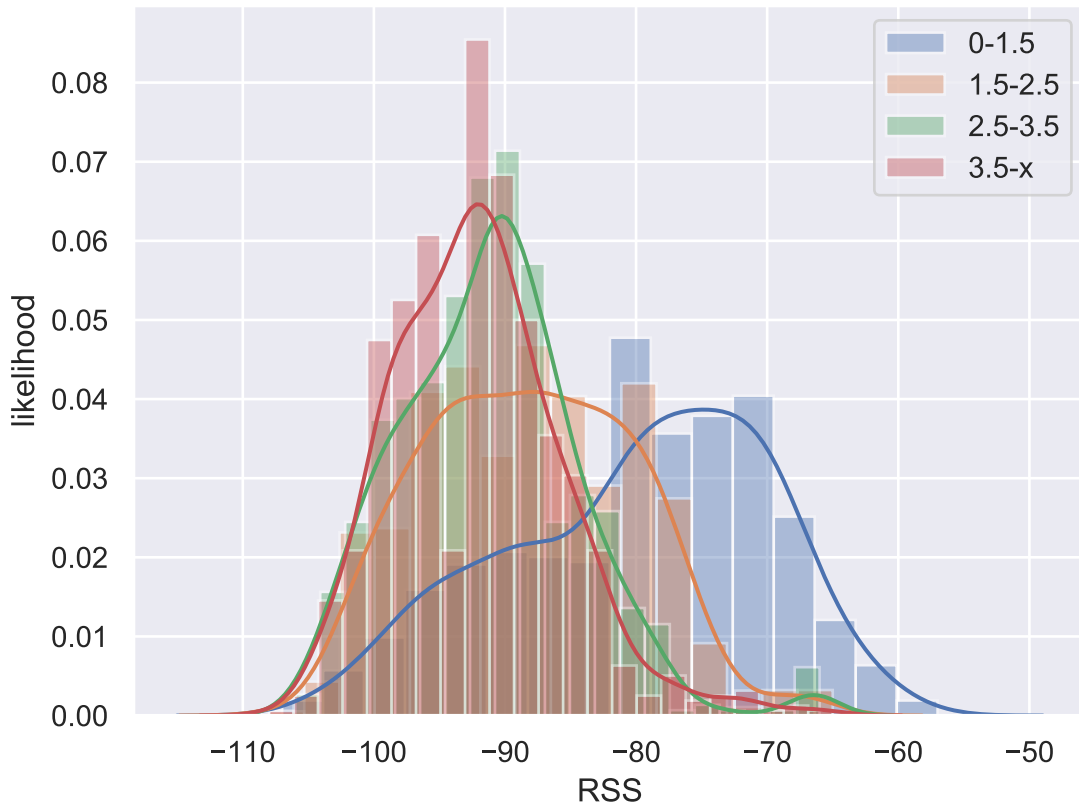
RANGE WINDOW: 30 s

Confusion matrix Recv: SamsungA6 Trans: S706 Method: method 4

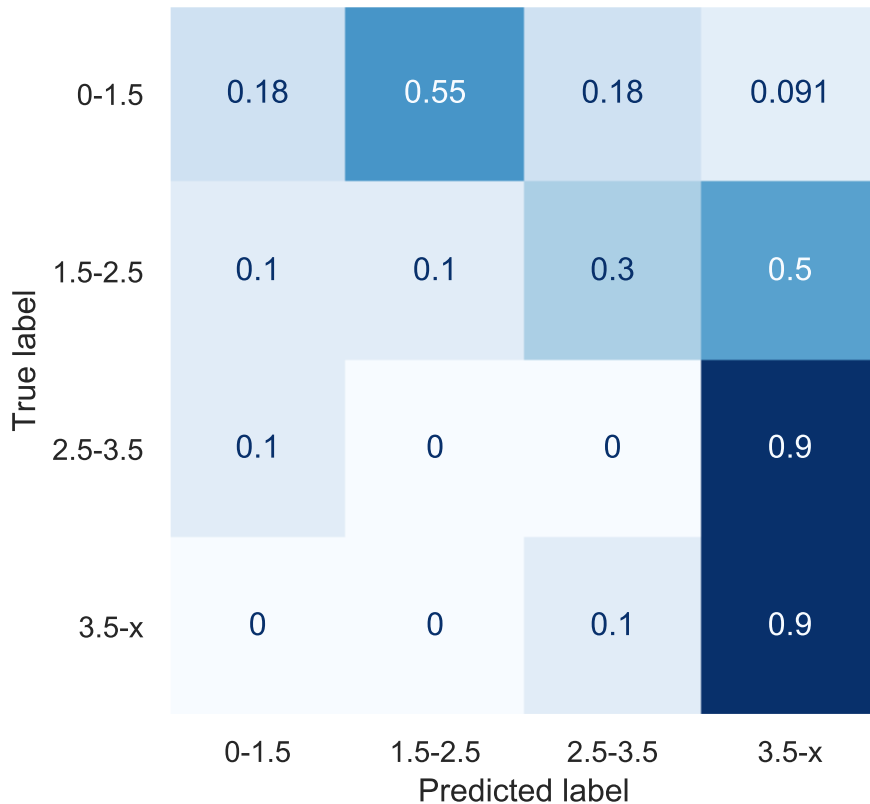




RANGE WINDOW: 30 s  
RSS Recv: S708 Trans: S706

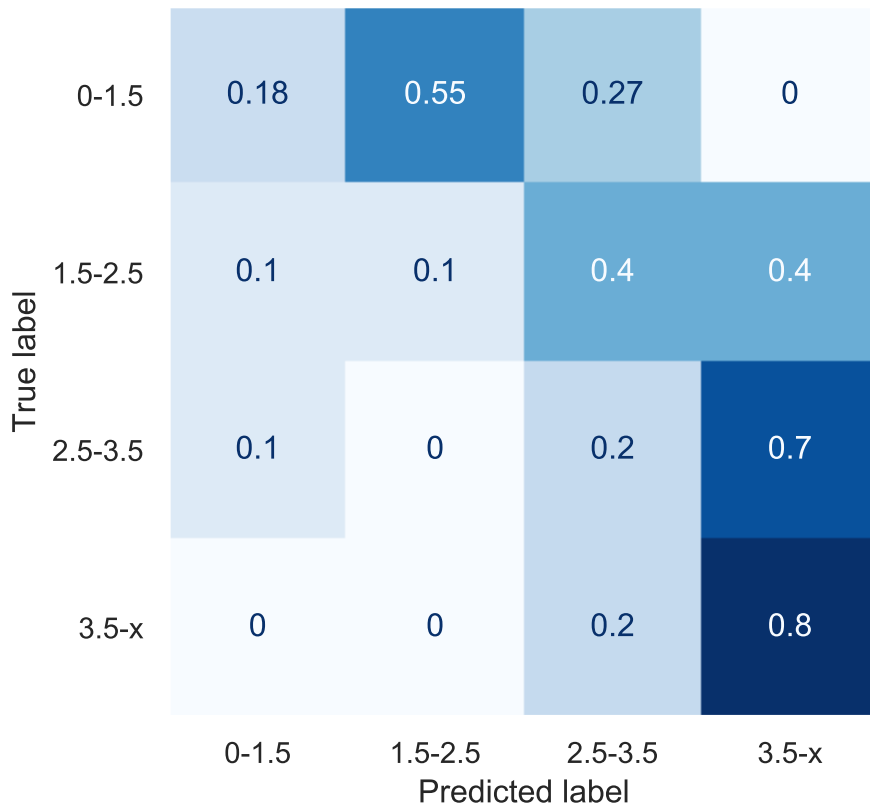


RANGE WINDOW: 30 s  
Confusion matrix Recv: S708 Trans: S706 Method: 1meter



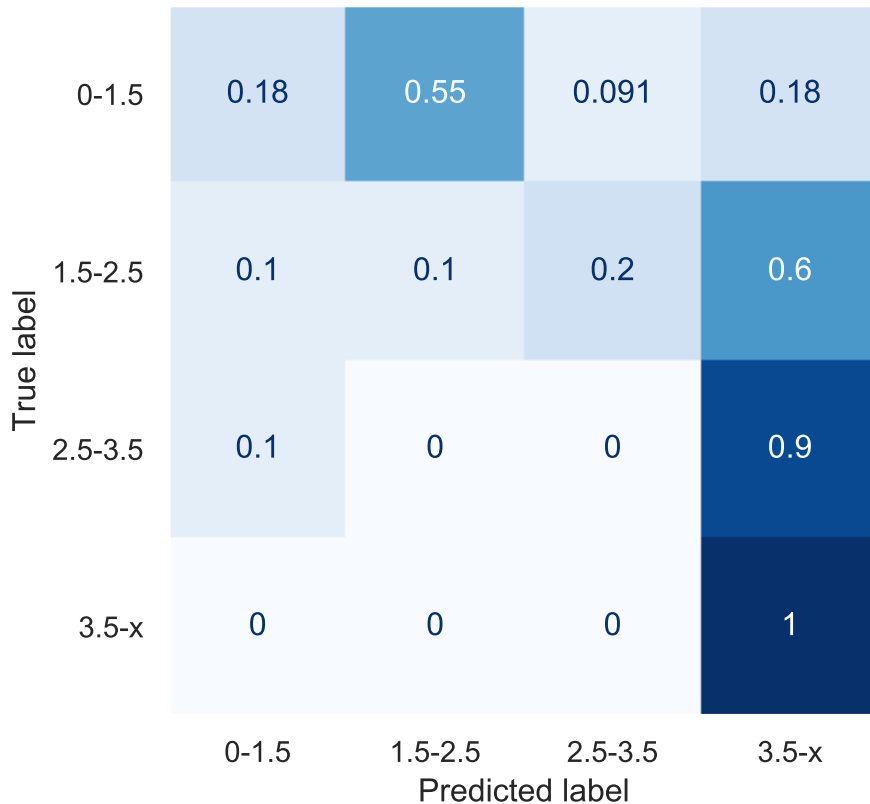
RANGE WINDOW: 30 s

Confusion matrix Recv: S708 Trans: S706 Method: All\_without\_PL

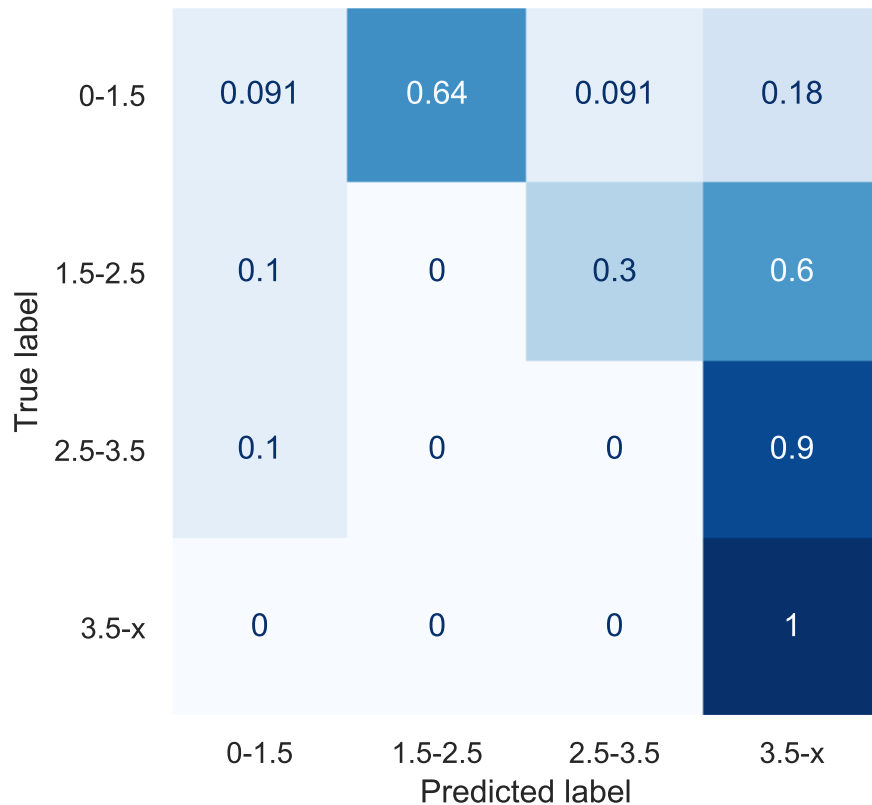


RANGE WINDOW: 30 s

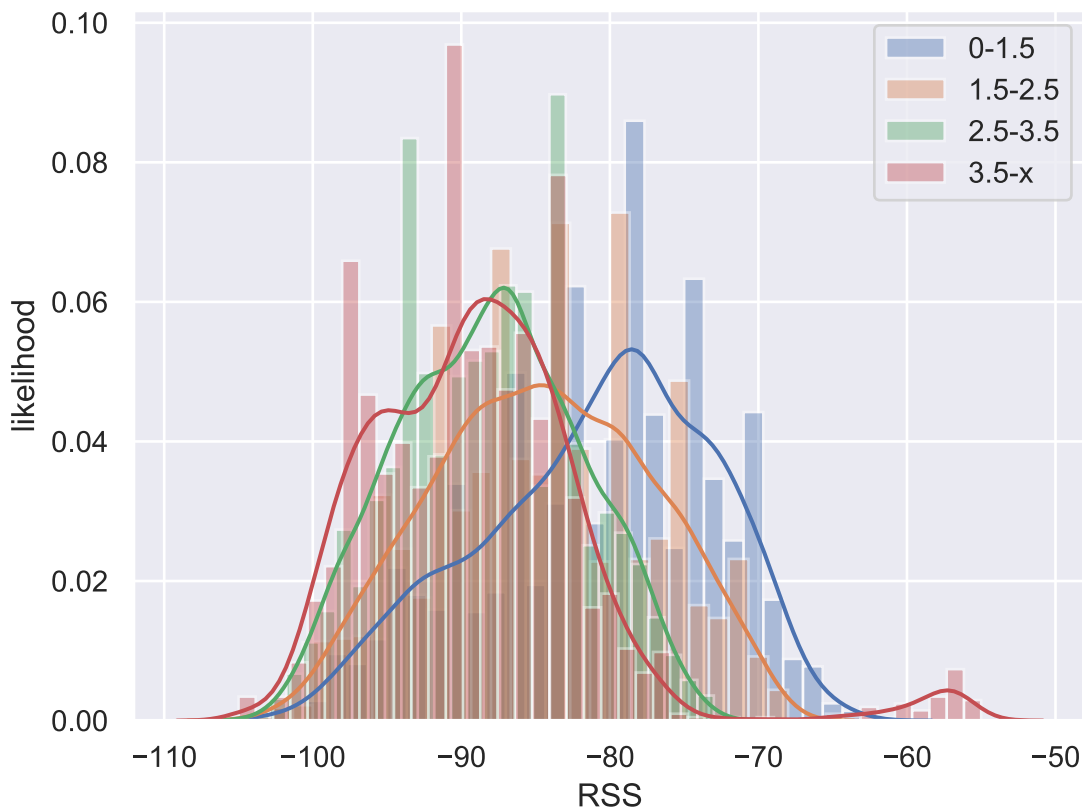
Confusion matrix Recv: S708 Trans: S706 Method: All\_with\_PL



RANGE WINDOW: 30 s  
Confusion matrix Recv: S708 Trans: S706 Method: method 4

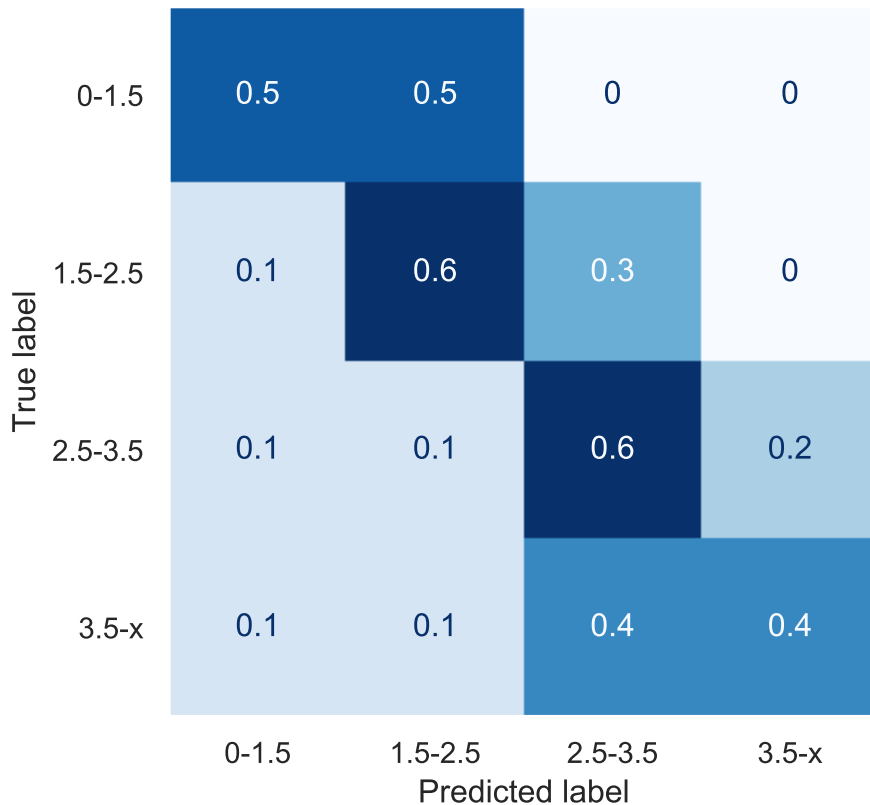


RANGE WINDOW: 30 s  
RSS Recv: S706 Trans: Motorola



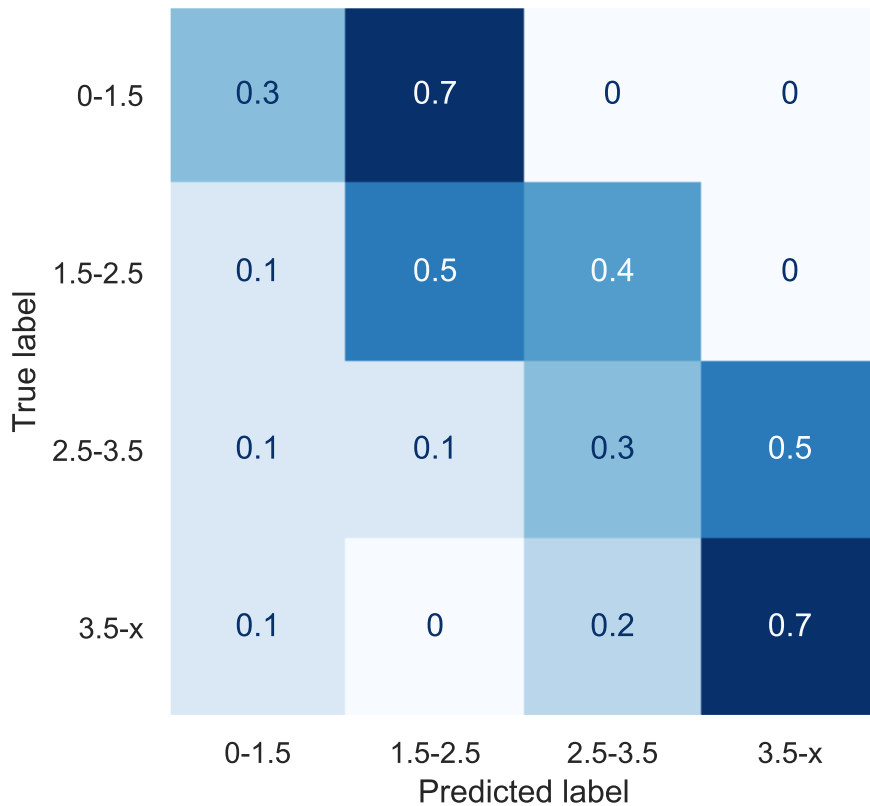
RANGE WINDOW: 30 s

Confusion matrix Recv: S706 Trans: Motorola Method: 1meter



RANGE WINDOW: 30 s

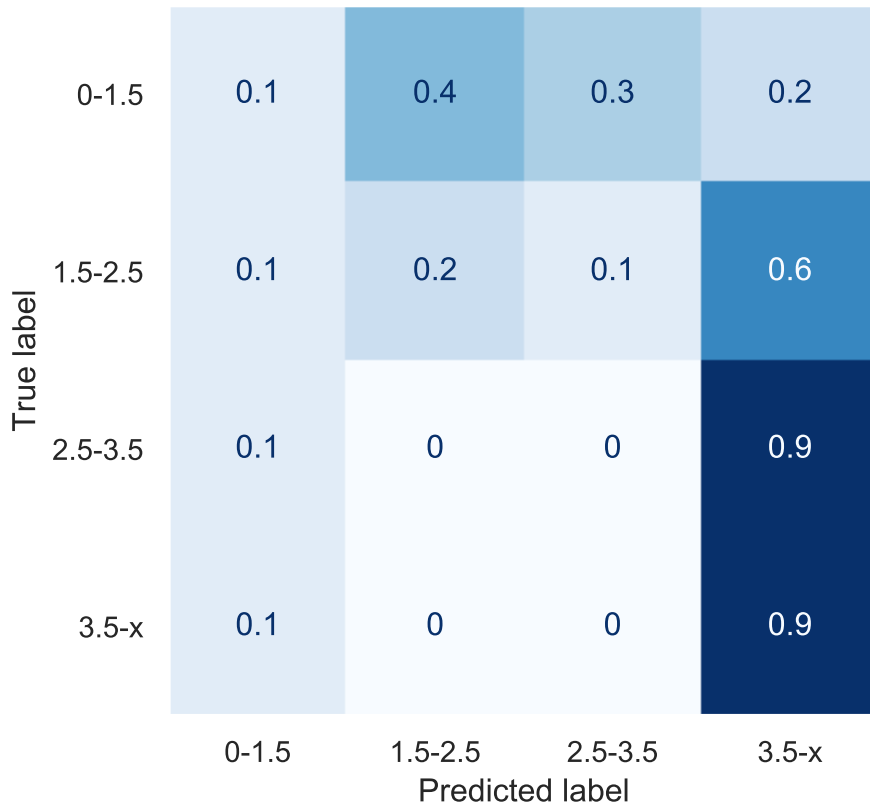
Confusion matrix Recv: S706 Trans: Motorola Method: All\_without\_PL





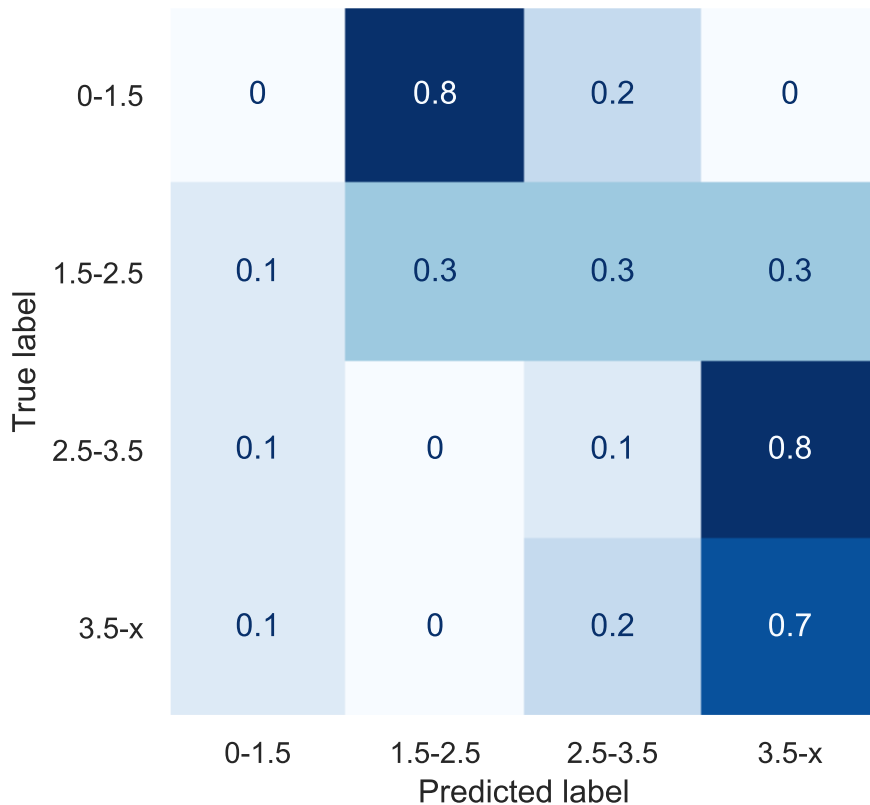
RANGE WINDOW: 30 s

Confusion matrix Recv: S706 Trans: Motorola Method: All\_with\_PL

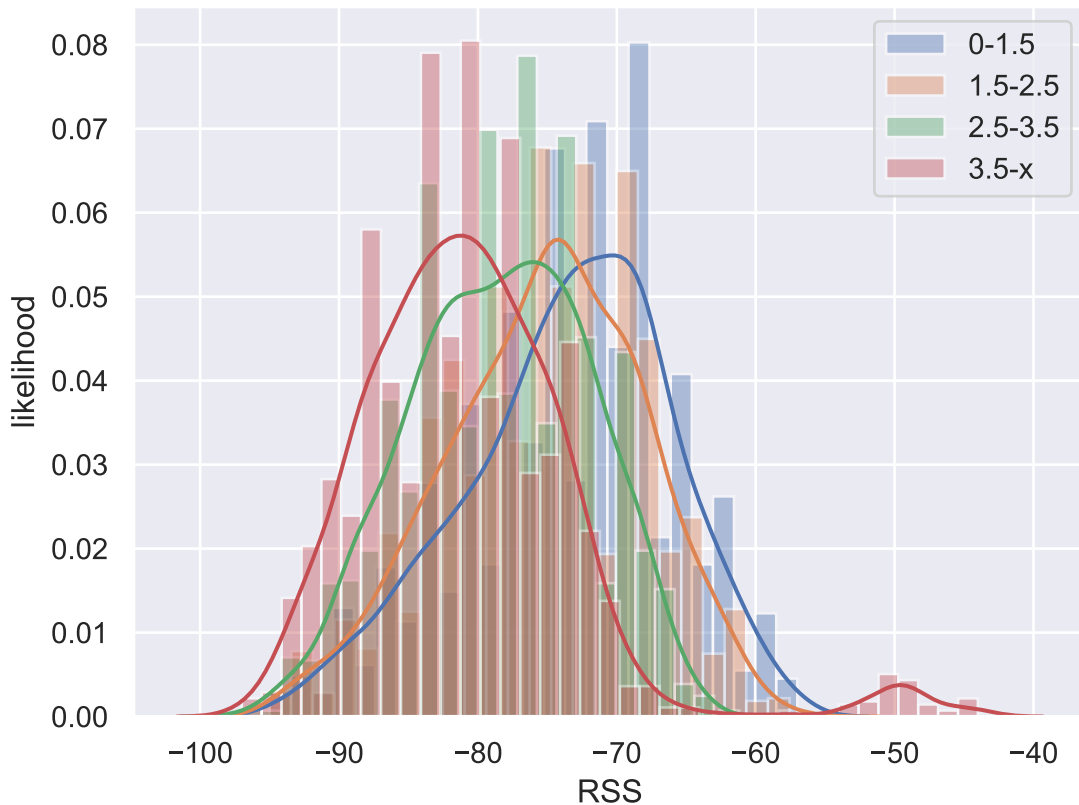


RANGE WINDOW: 30 s

Confusion matrix Recv: S706 Trans: Motorola Method: method 4

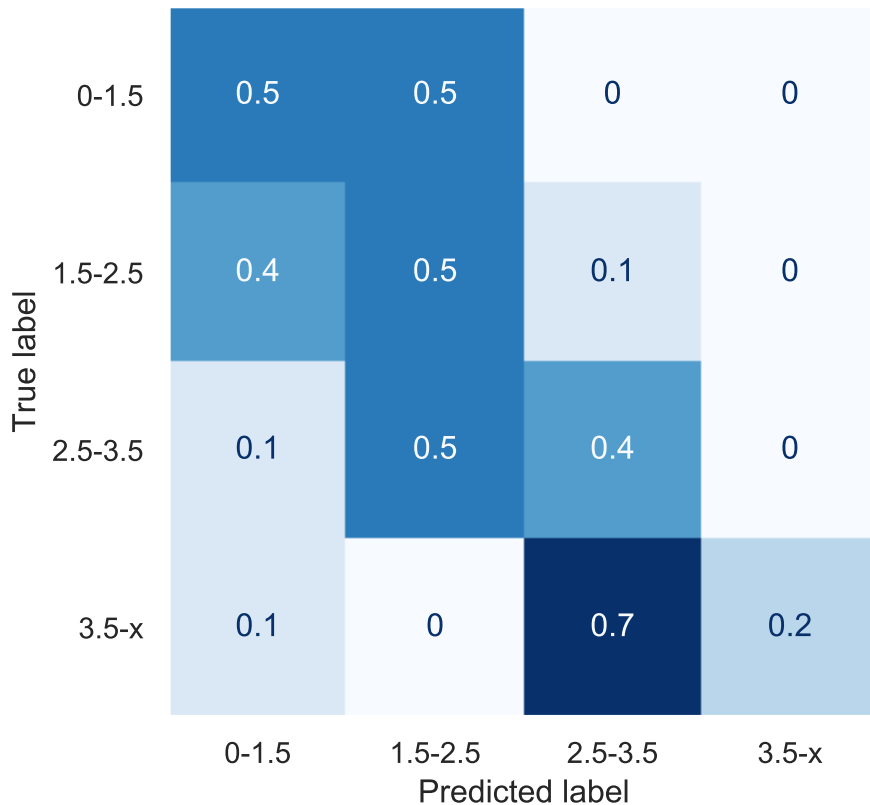


RANGE WINDOW: 30 s  
RSS Recv: Nexus Trans: Motorola



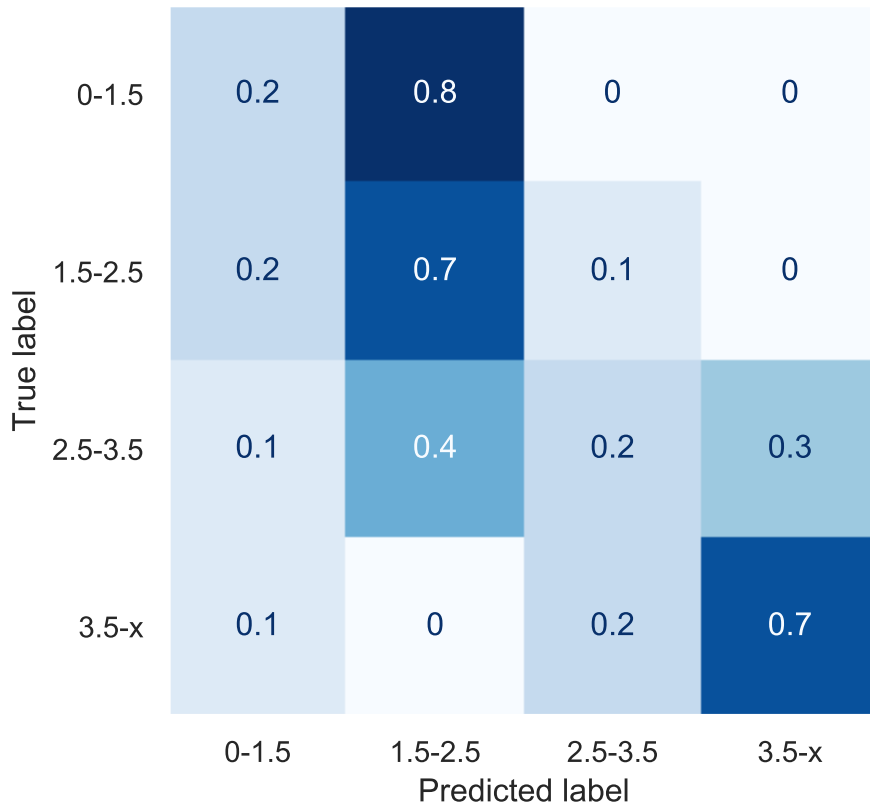
RANGE WINDOW: 30 s

Confusion matrix Recv: Nexus Trans: Motorola Method: 1meter



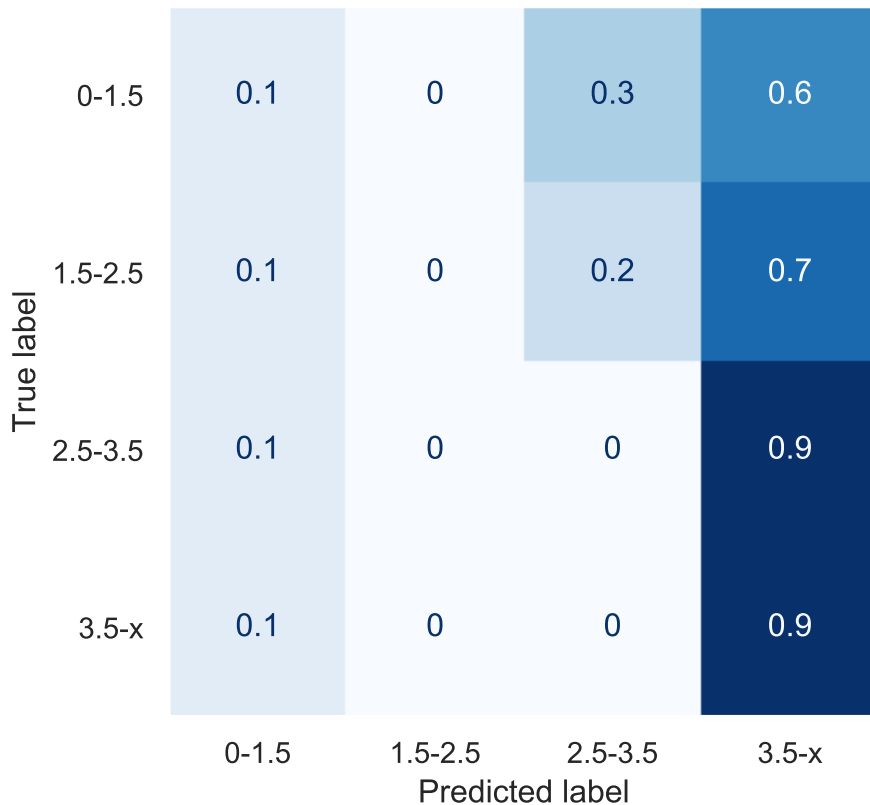
RANGE WINDOW: 30 s

Confusion matrix Recv: Nexus Trans: Motorola Method: All\_without\_PL



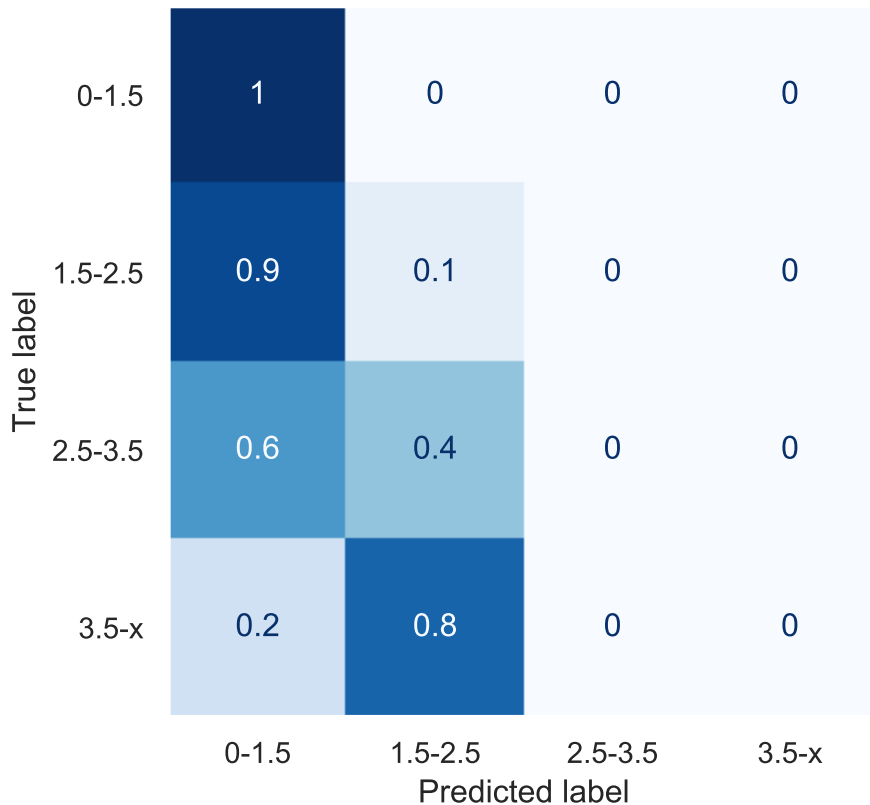
RANGE WINDOW: 30 s

Confusion matrix Recv: Nexus Trans: Motorola Method: All\_with\_PL

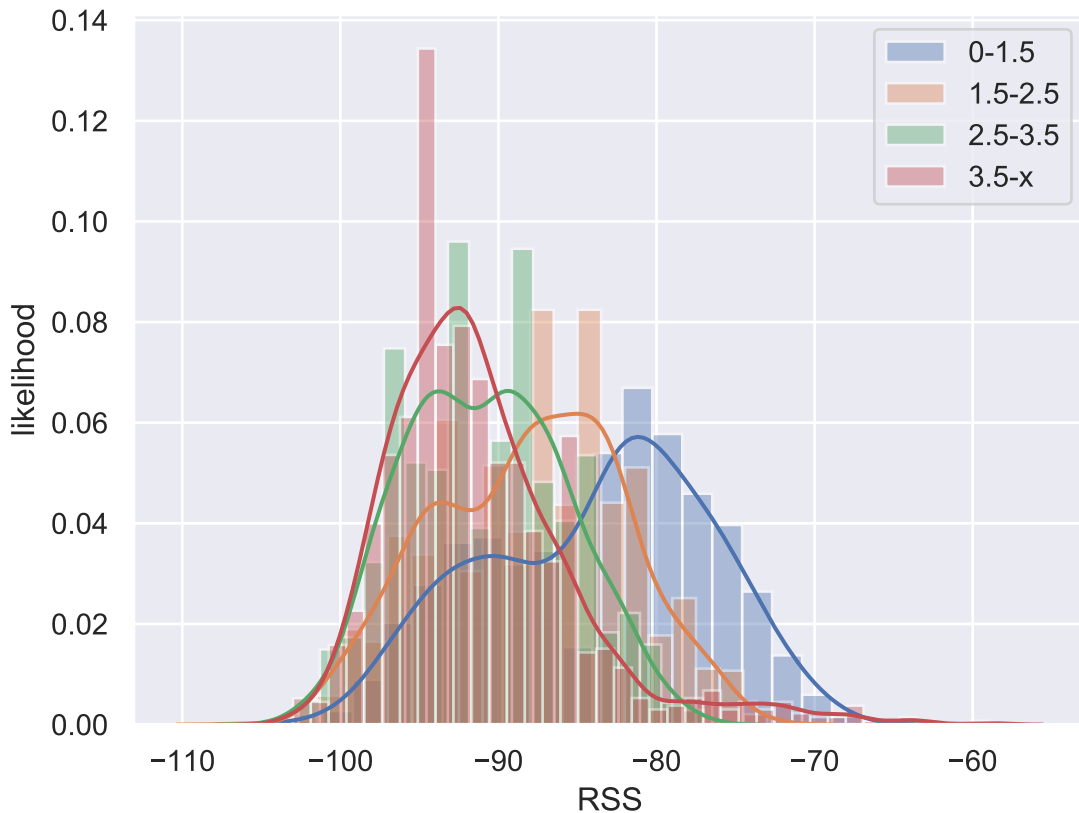


RANGE WINDOW: 30 s

Confusion matrix Recv: Nexus Trans: Motorola Method: method 4

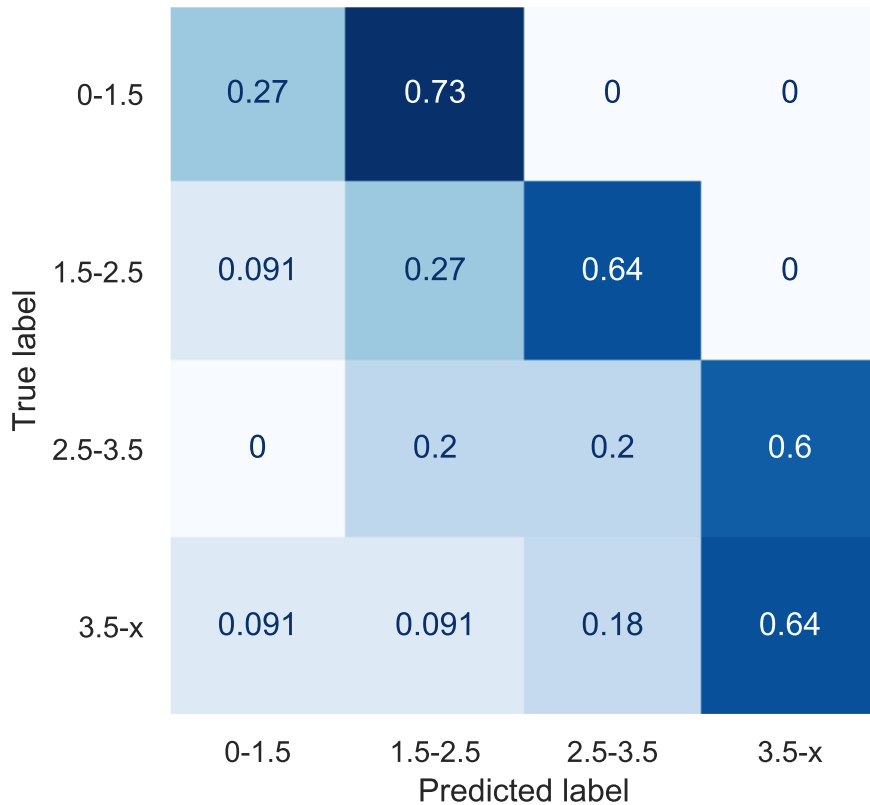


RANGE WINDOW: 30 s  
RSS Recv: S8 Trans: Motorola



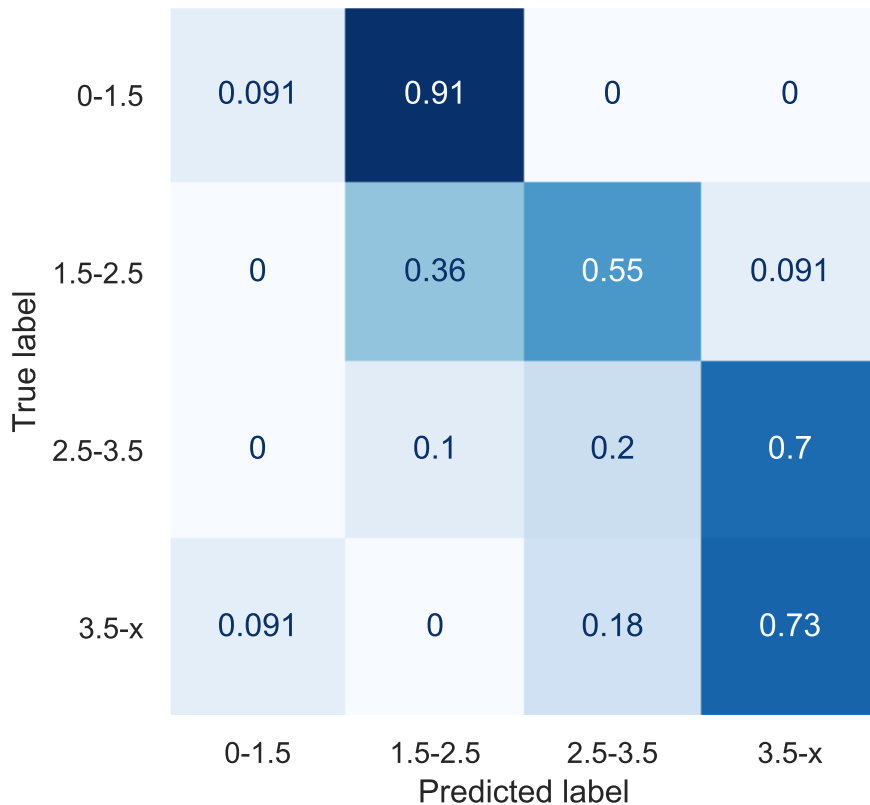


RANGE WINDOW: 30 s  
Confusion matrix Recv: S8 Trans: Motorola Method: 1meter



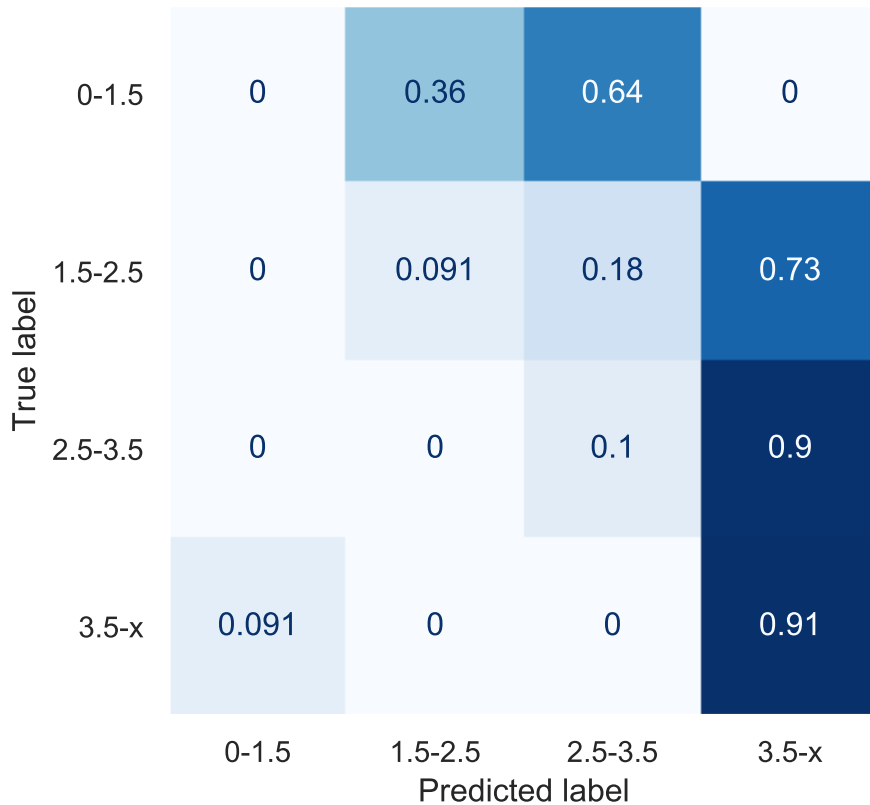
RANGE WINDOW: 30 s

Confusion matrix Recv: S8 Trans: Motorola Method: All\_without\_PL

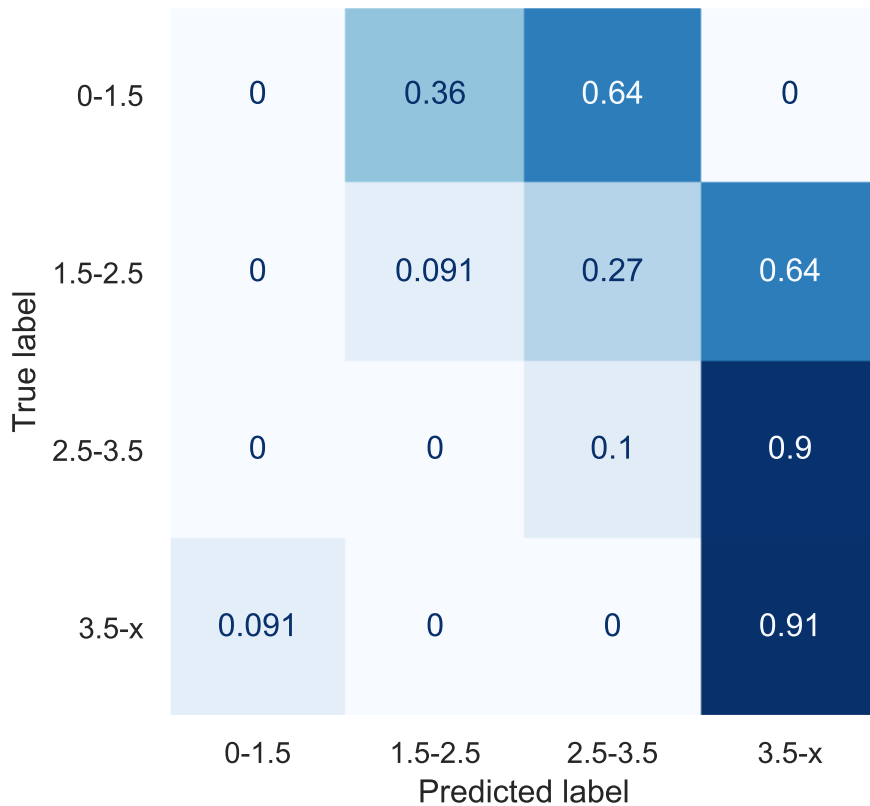


RANGE WINDOW: 30 s

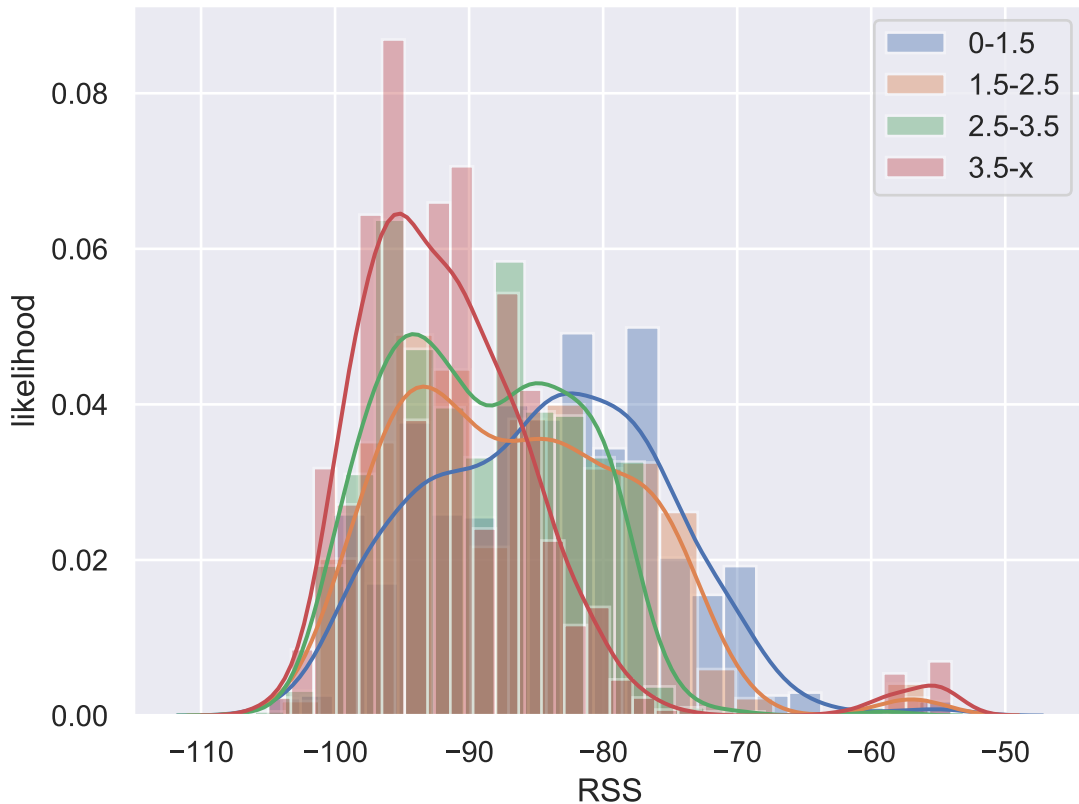
Confusion matrix Recv: S8 Trans: Motorola Method: All\_with\_PL



RANGE WINDOW: 30 s  
Confusion matrix Recv: S8 Trans: Motorola Method: method 4

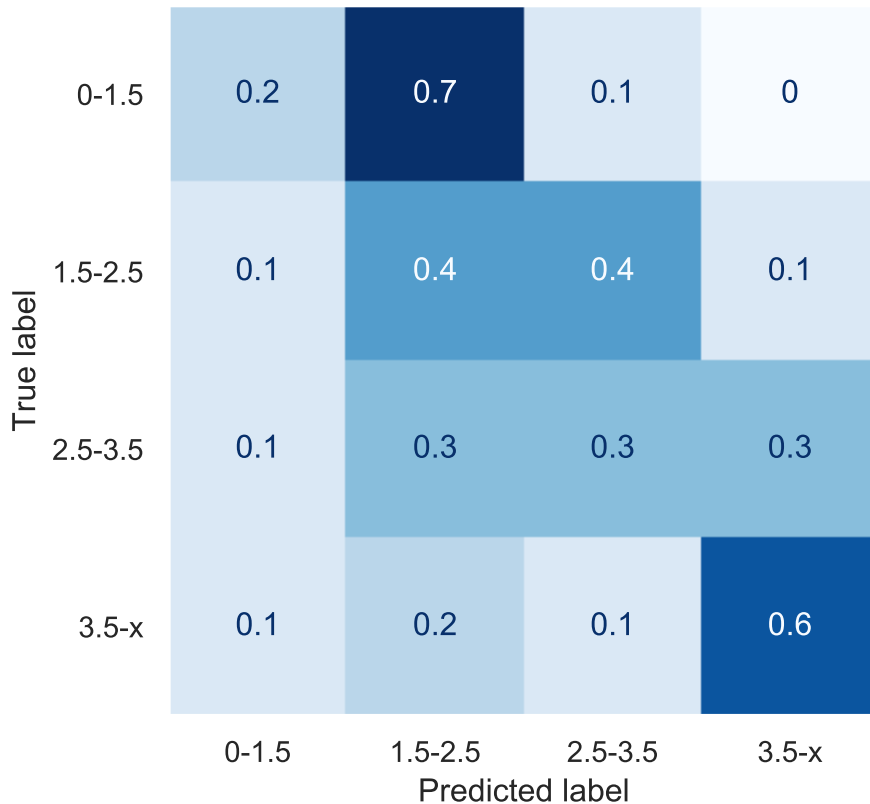


RANGE WINDOW: 30 s  
RSS Recv: S706 Trans: SamsungA6



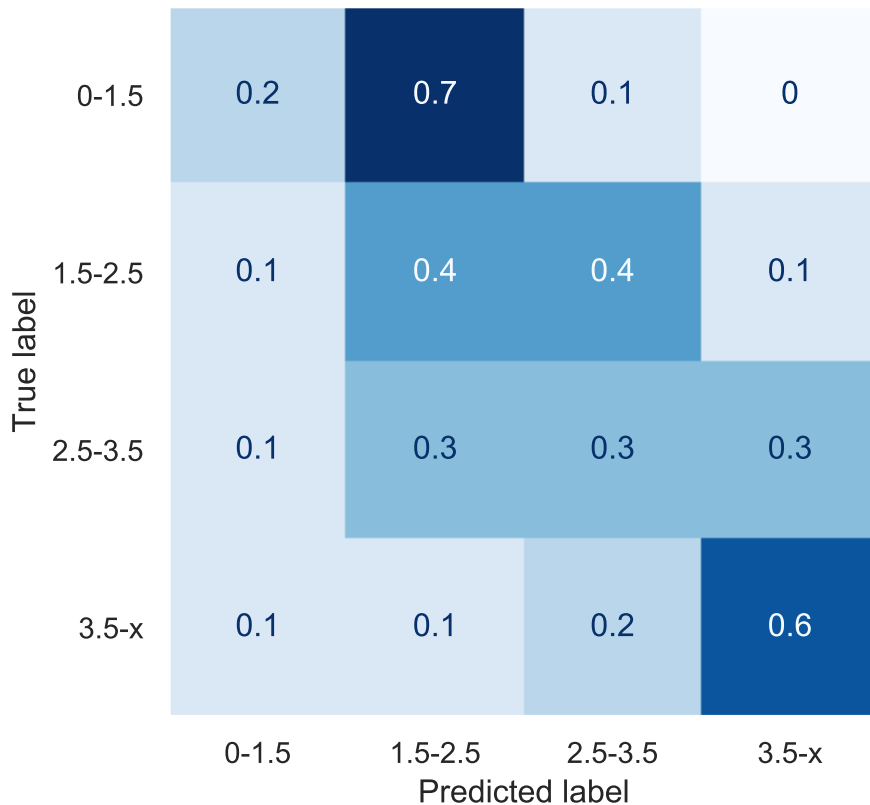
RANGE WINDOW: 30 s

Confusion matrix Recv: S706 Trans: SamsungA6 Method: 1meter



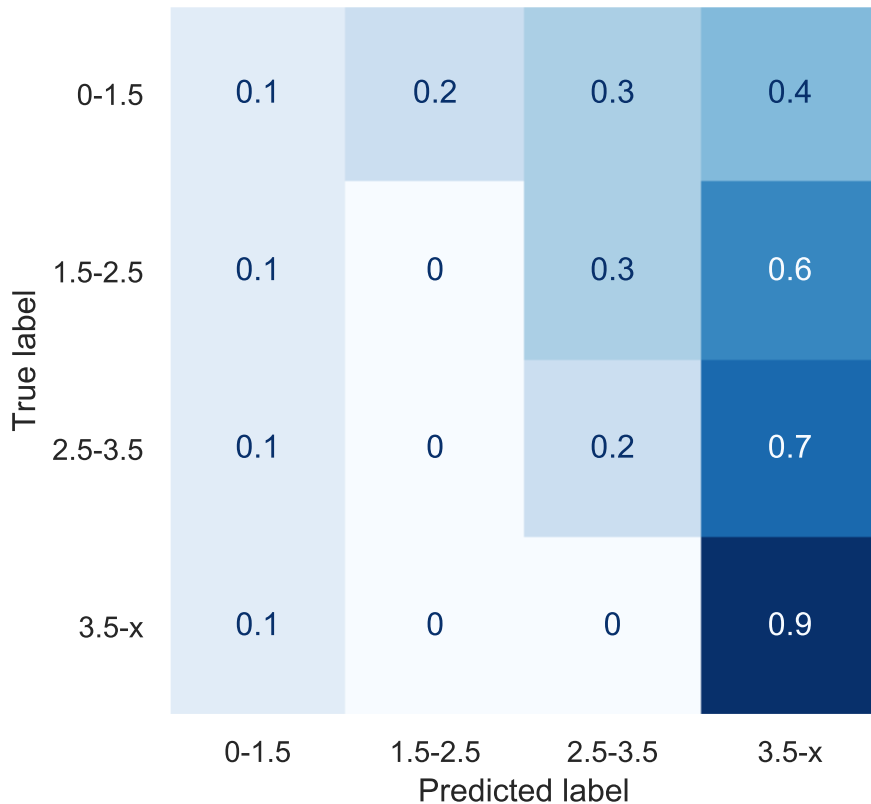
RANGE WINDOW: 30 s

Confusion matrix Recv: S706 Trans: SamsungA6 Method: All\_without\_PL



RANGE WINDOW: 30 s

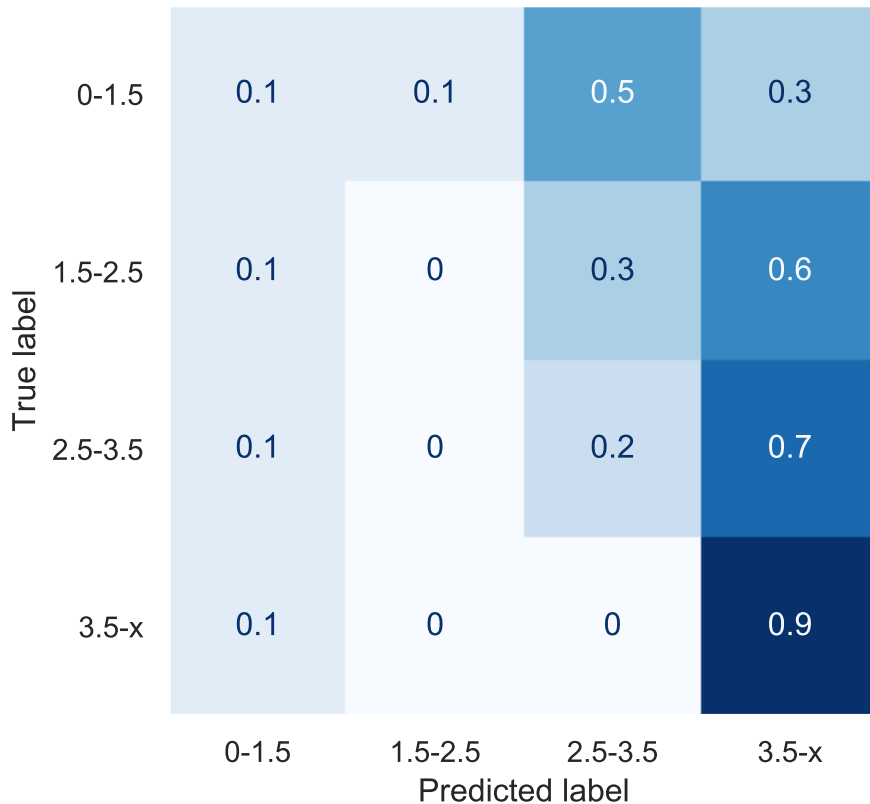
Confusion matrix Recv: S706 Trans: SamsungA6 Method: All\_with\_PL



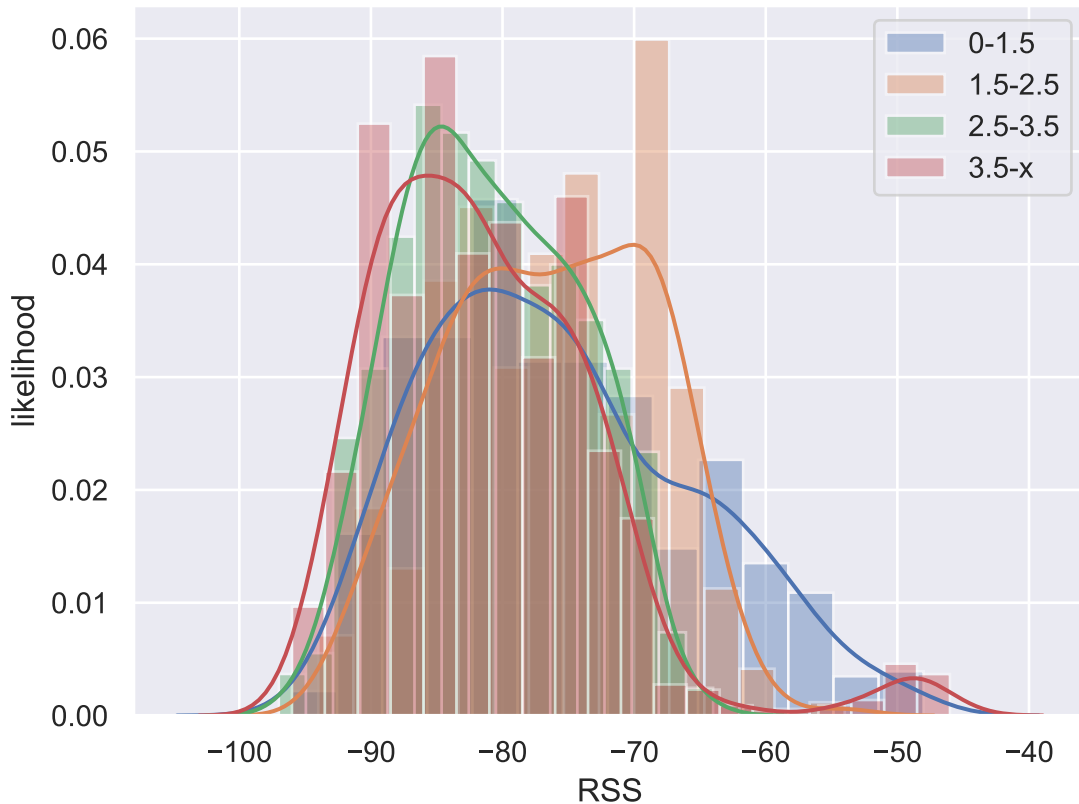


RANGE WINDOW: 30 s

Confusion matrix Recv: S706 Trans: SamsungA6 Method: method 4

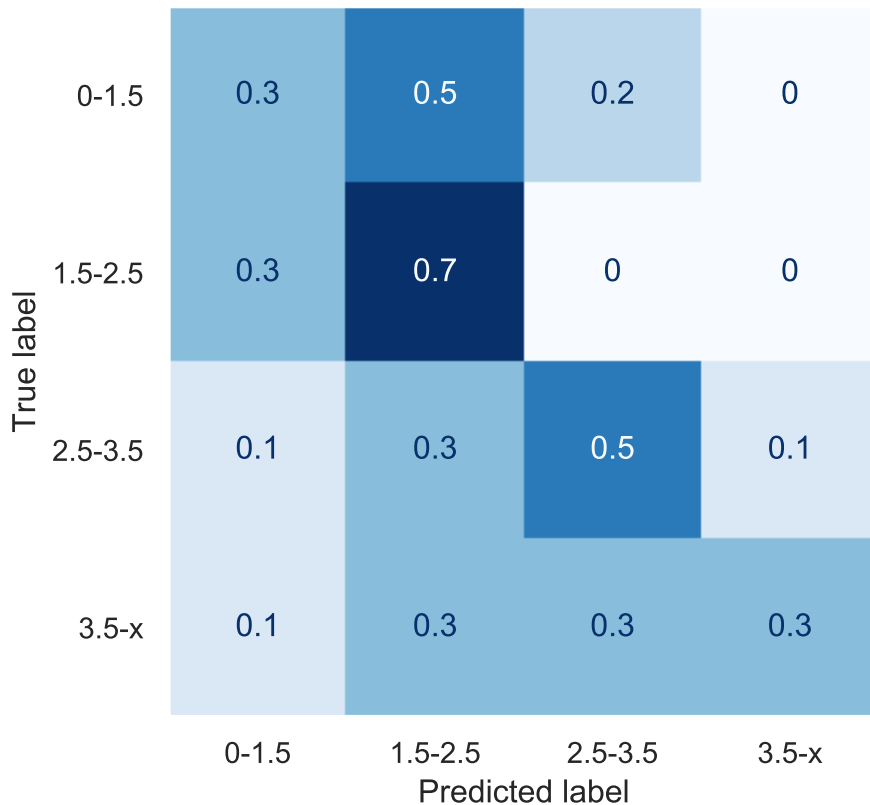


RANGE WINDOW: 30 s  
RSS Recv: Nexus Trans: SamsungA6



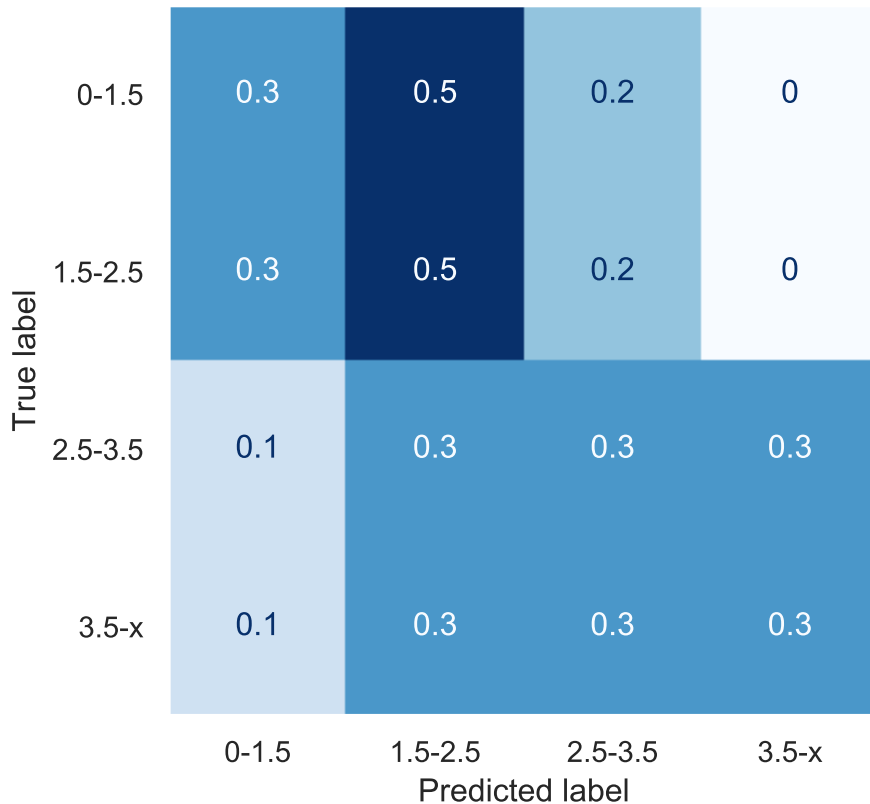
RANGE WINDOW: 30 s

Confusion matrix Recv: Nexus Trans: SamsungA6 Method: 1meter



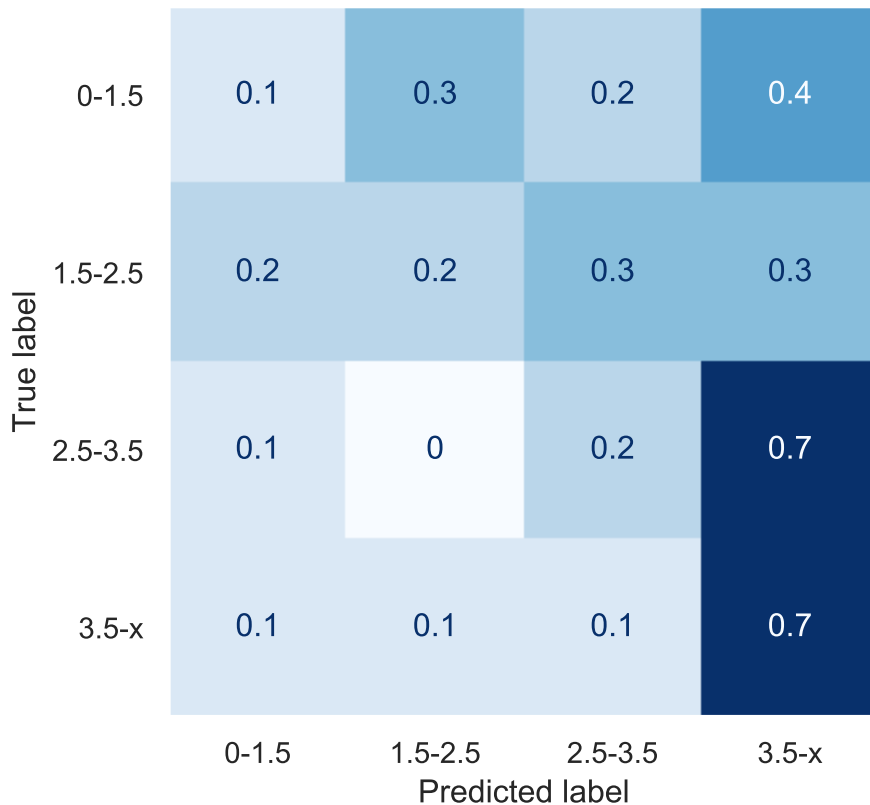
RANGE WINDOW: 30 s

Confusion matrix Recv: Nexus Trans: SamsungA6 Method: All\_without\_PL



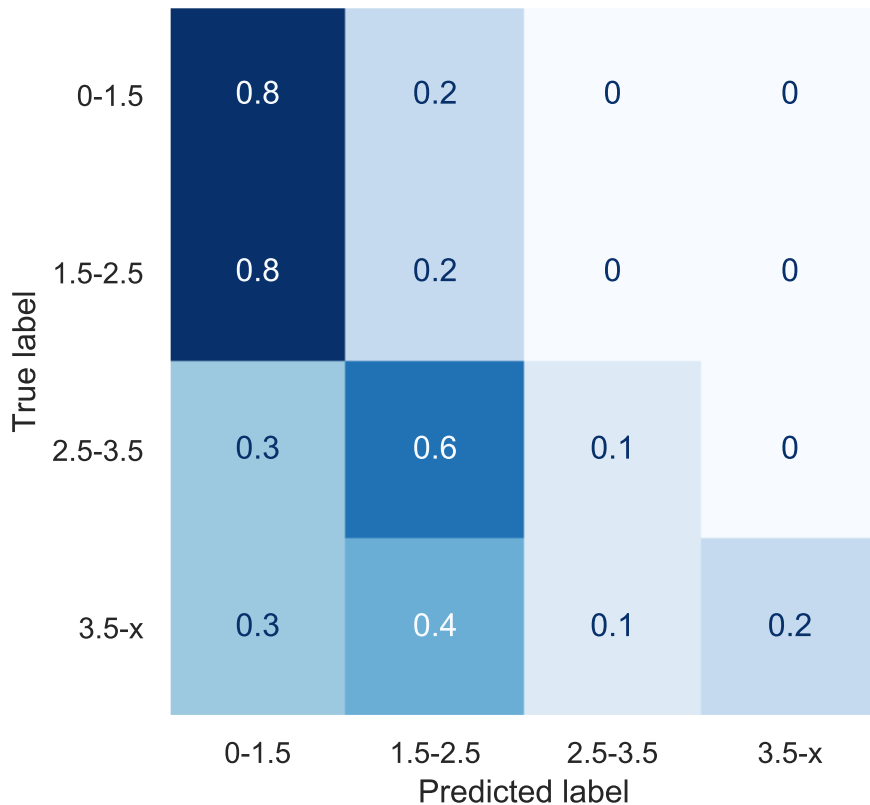
RANGE WINDOW: 30 s

Confusion matrix Recv: Nexus Trans: SamsungA6 Method: All\_with\_PL

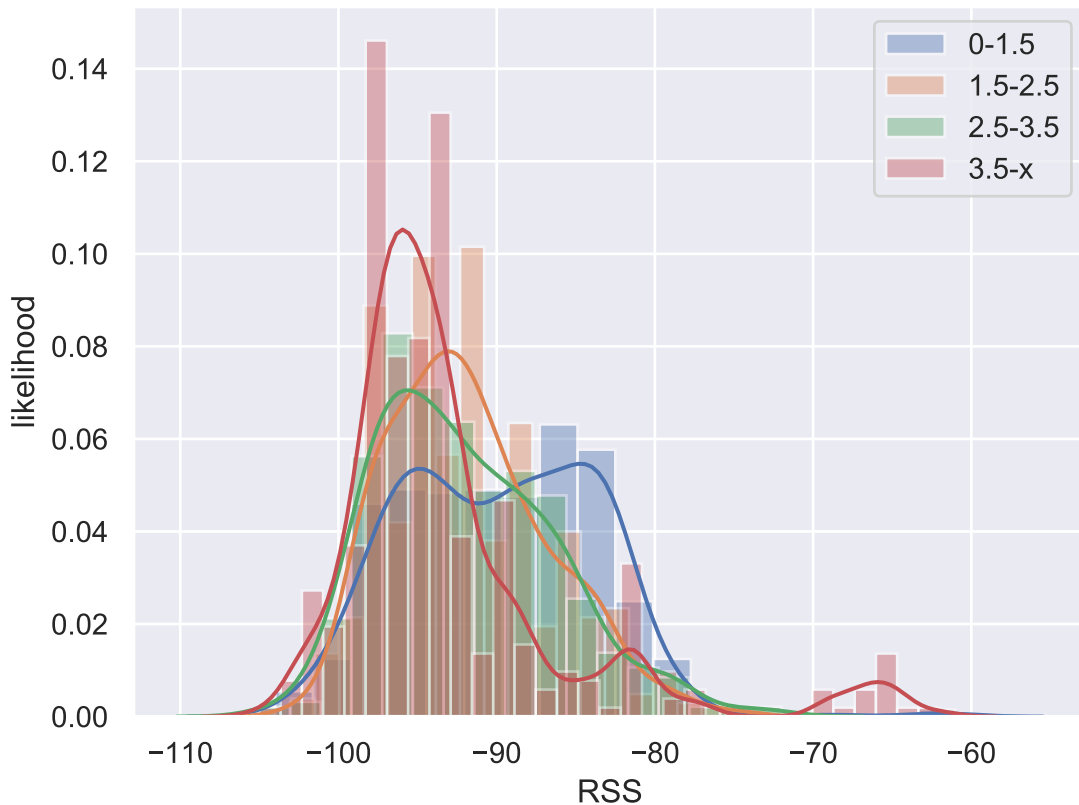


RANGE WINDOW: 30 s

Confusion matrix Recv: Nexus Trans: SamsungA6 Method: method 4

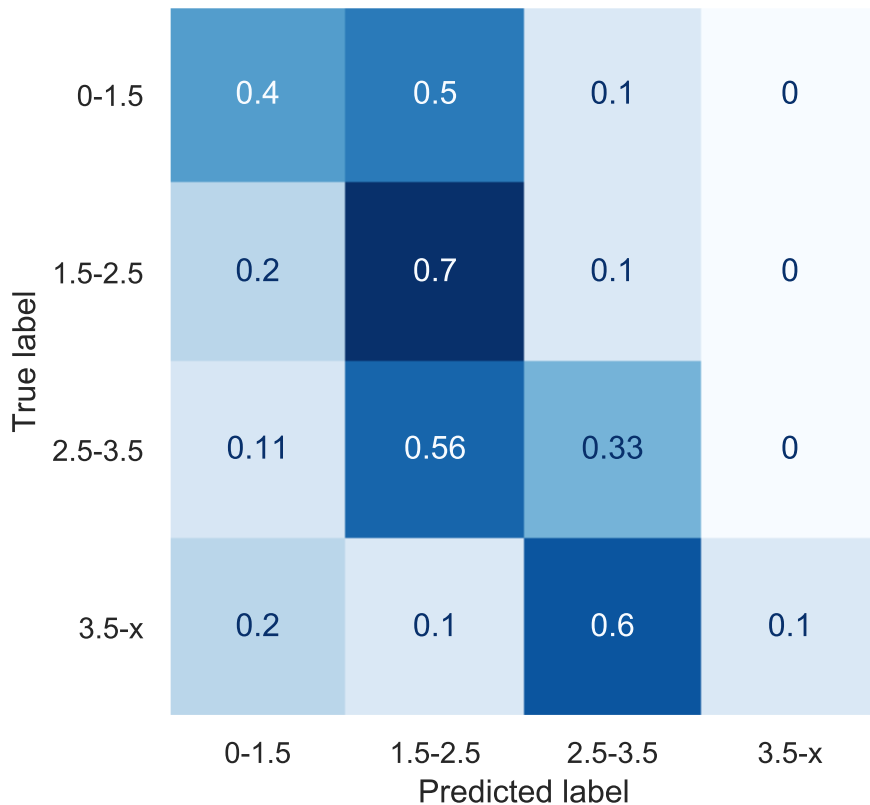


RANGE WINDOW: 30 s  
RSS Recv: S8 Trans: SamsungA6



RANGE WINDOW: 30 s

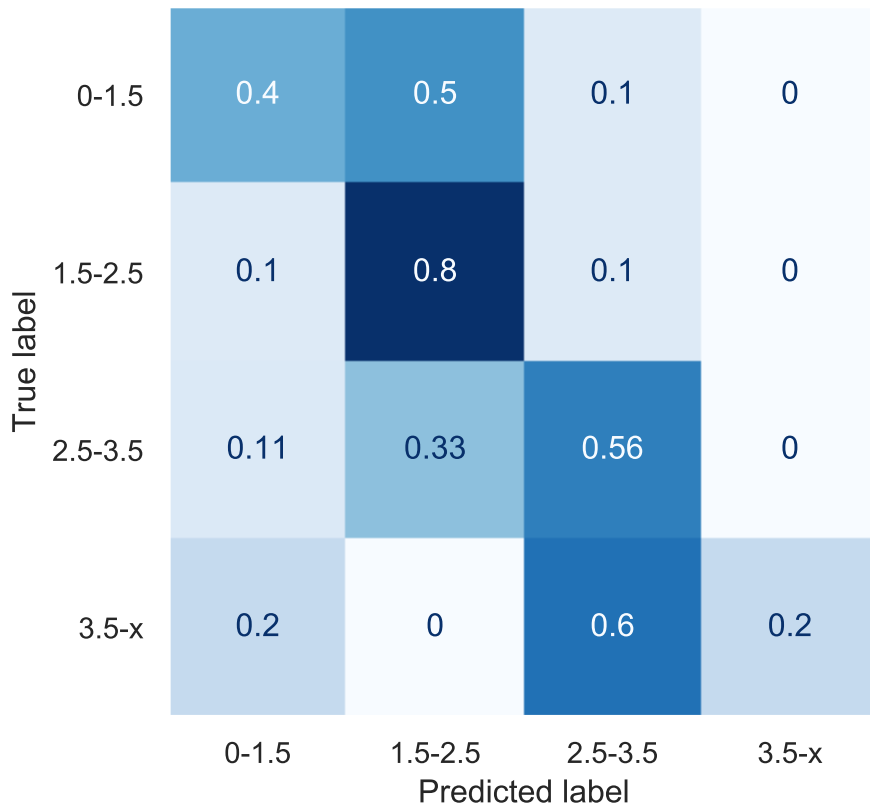
Confusion matrix Recv: S8 Trans: SamsungA6 Method: 1meter





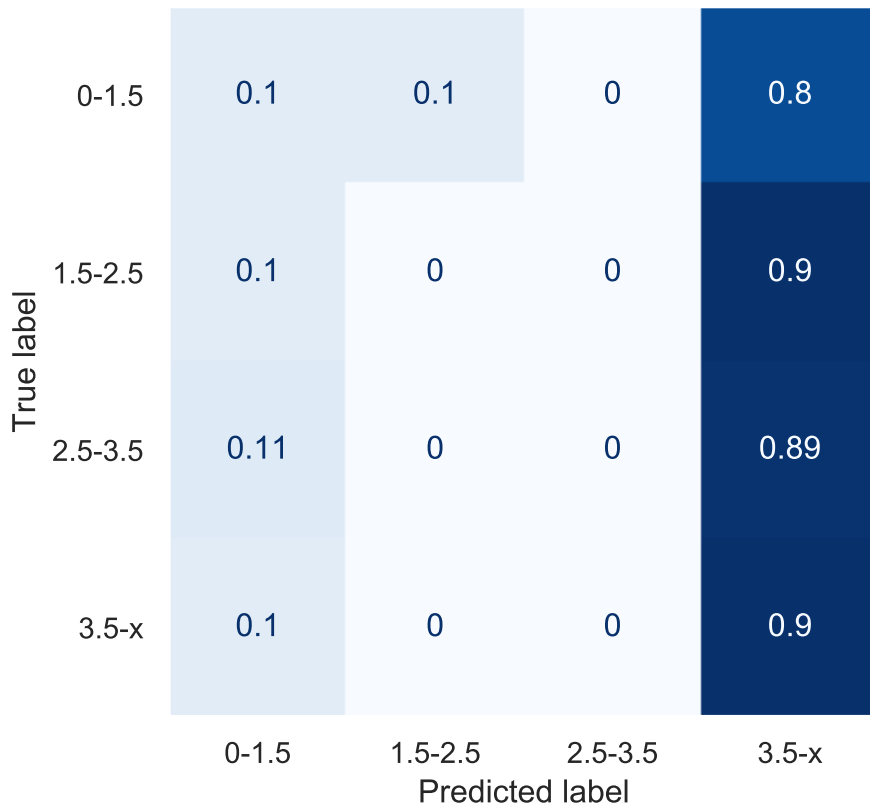
RANGE WINDOW: 30 s

Confusion matrix Recv: S8 Trans: SamsungA6 Method: All\_without\_PL



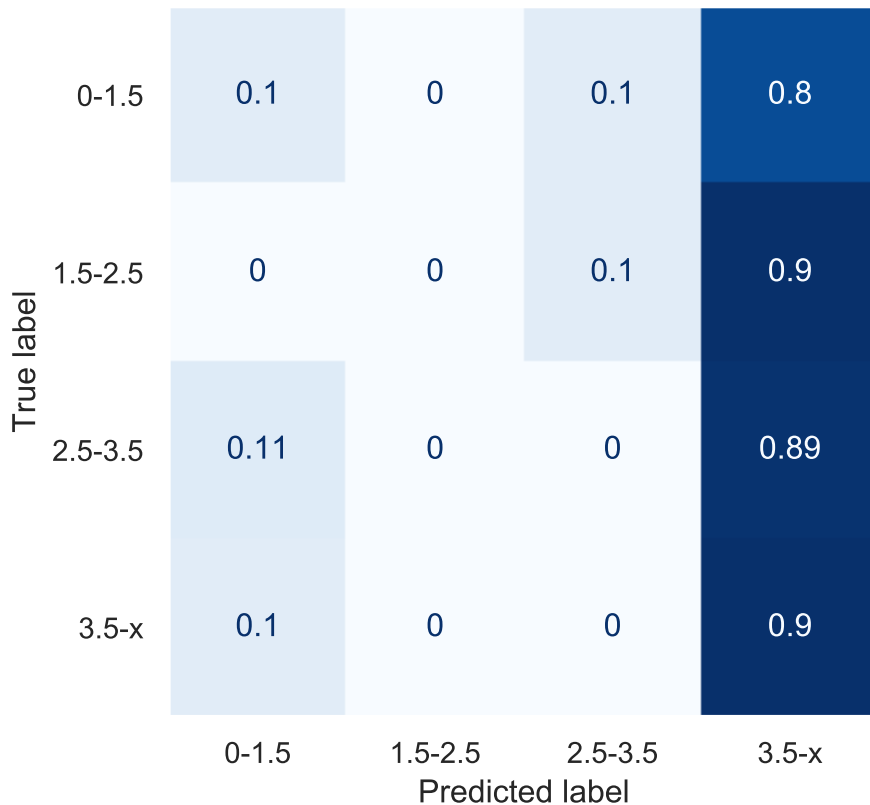
RANGE WINDOW: 30 s

Confusion matrix Recv: S8 Trans: SamsungA6 Method: All\_with\_PL

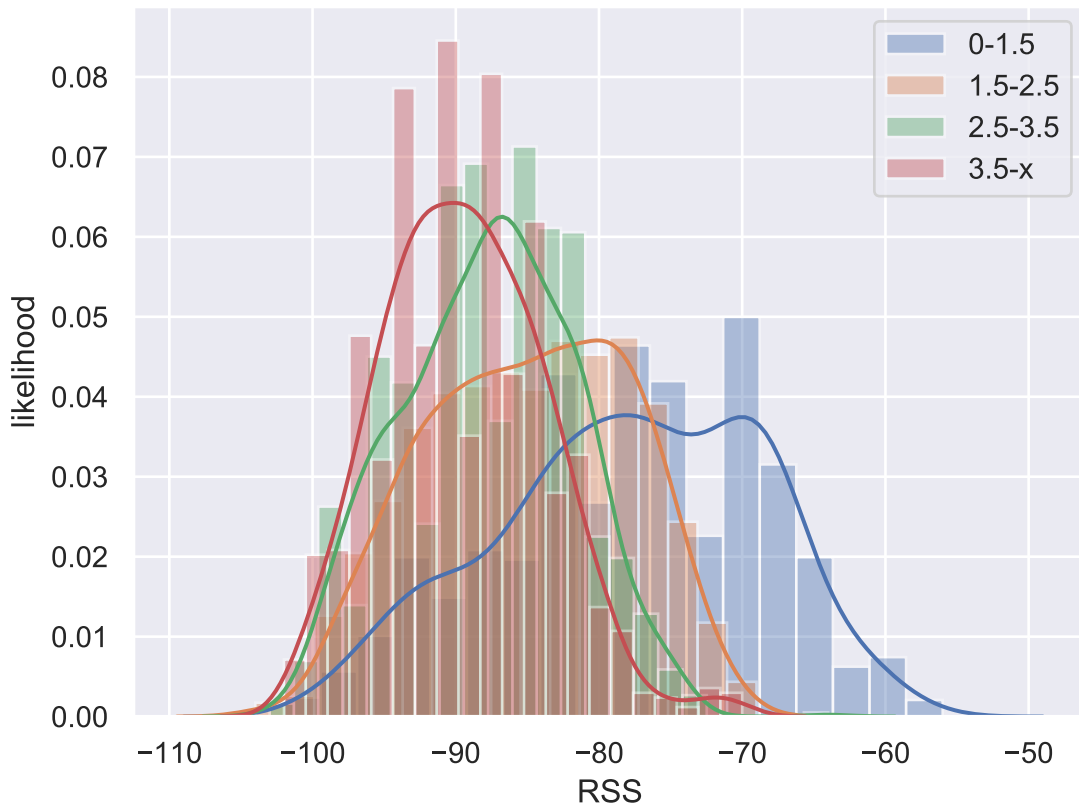


RANGE WINDOW: 30 s

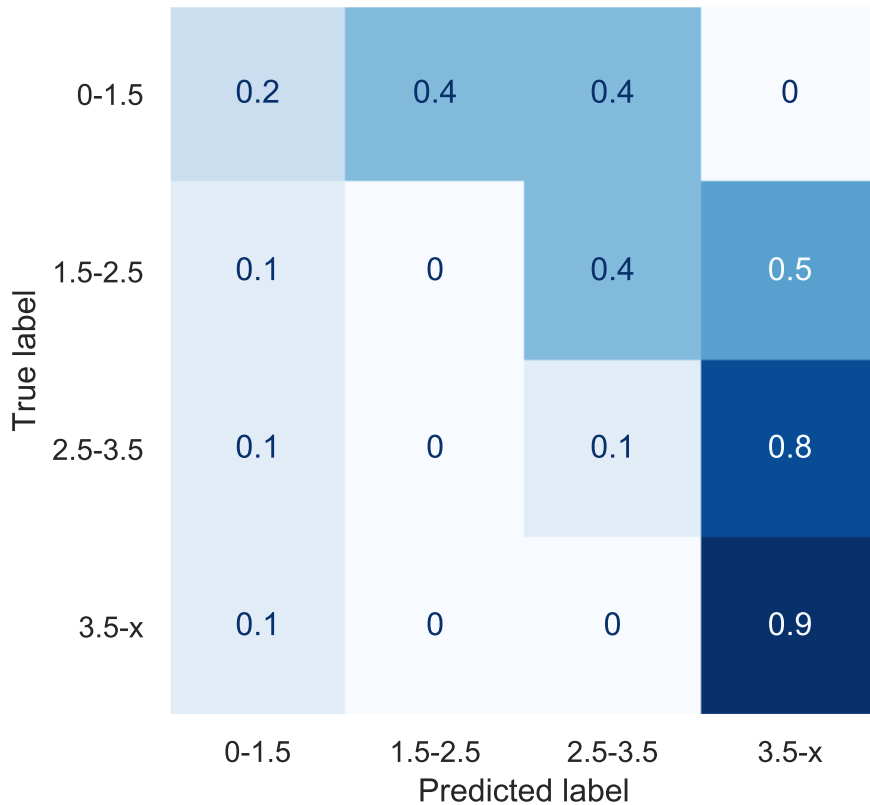
Confusion matrix Recv: S8 Trans: SamsungA6 Method: method 4



RANGE WINDOW: 30 s  
RSS Recv: S706 Trans: S708

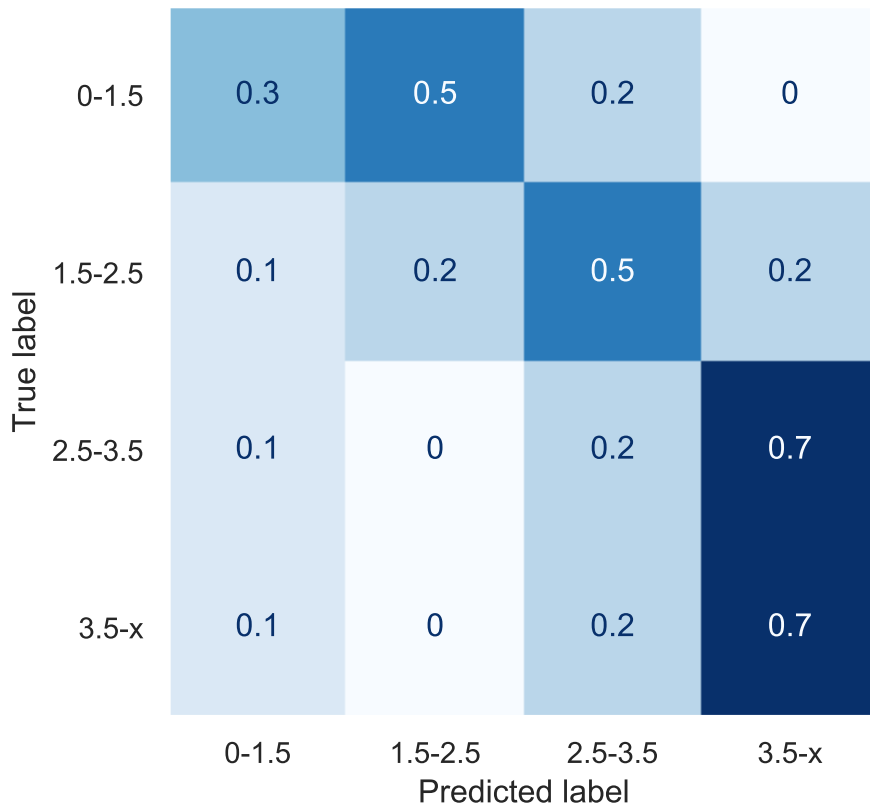


RANGE WINDOW: 30 s  
Confusion matrix Recv: S706 Trans: S708 Method: 1meter



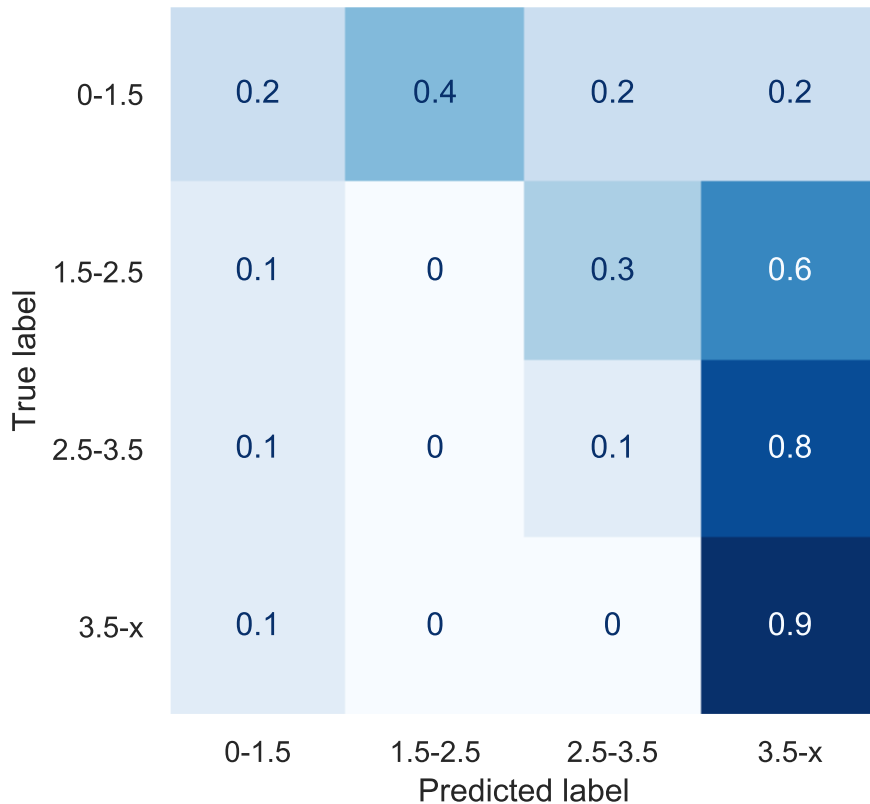
RANGE WINDOW: 30 s

Confusion matrix Recv: S706 Trans: S708 Method: All\_without\_PL



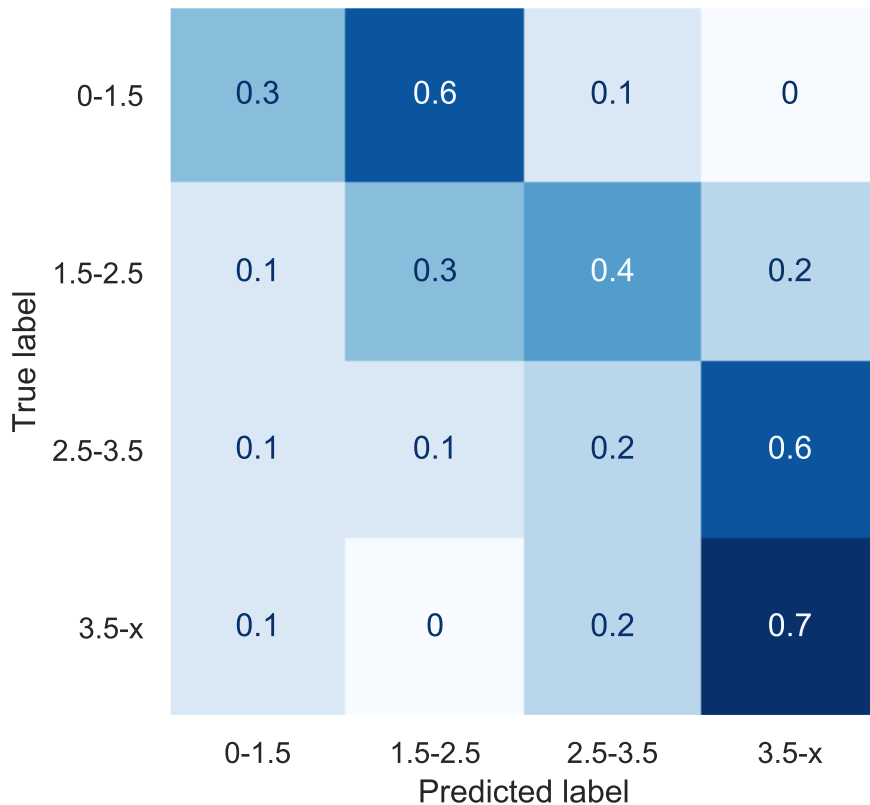
RANGE WINDOW: 30 s

Confusion matrix Recv: S706 Trans: S708 Method: All\_with\_PL



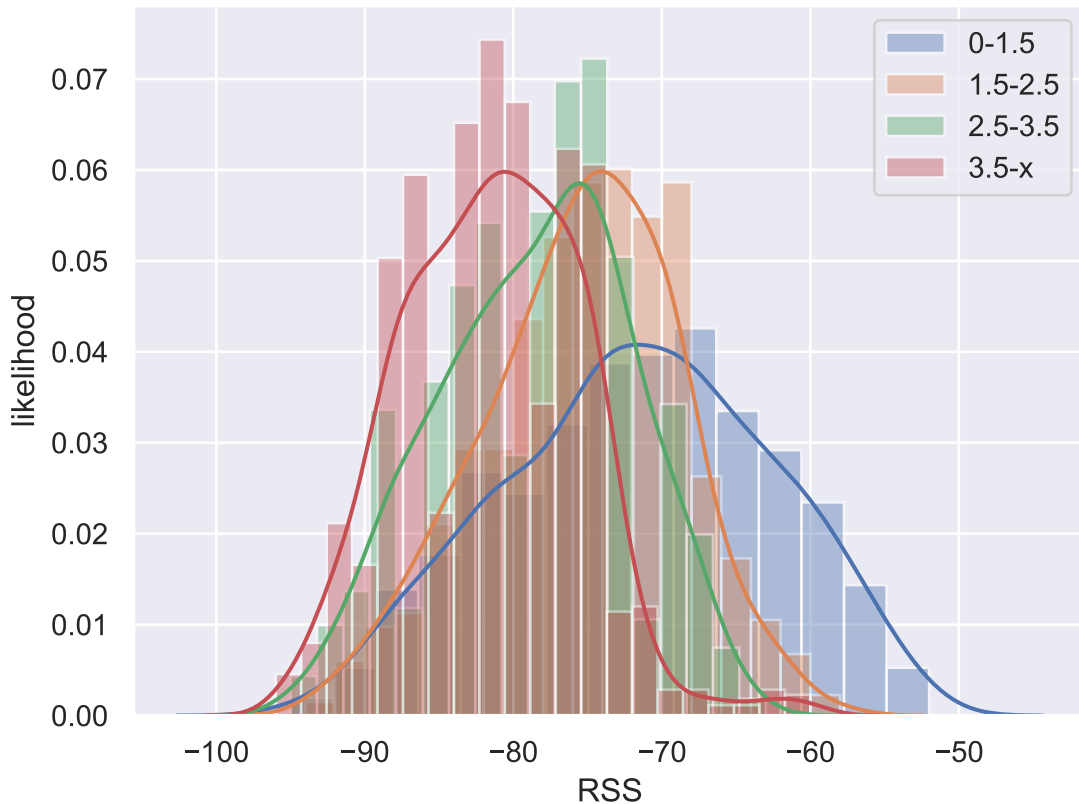
RANGE WINDOW: 30 s

Confusion matrix Recv: S706 Trans: S708 Method: method 4

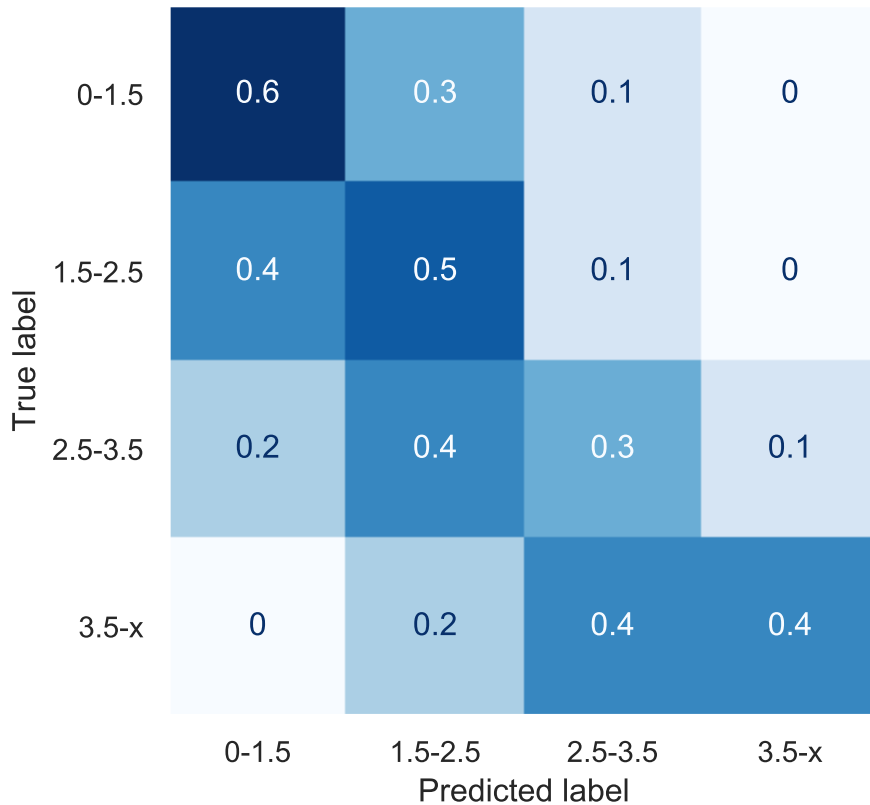




RANGE WINDOW: 30 s  
RSS Recv: Nexus Trans: S708

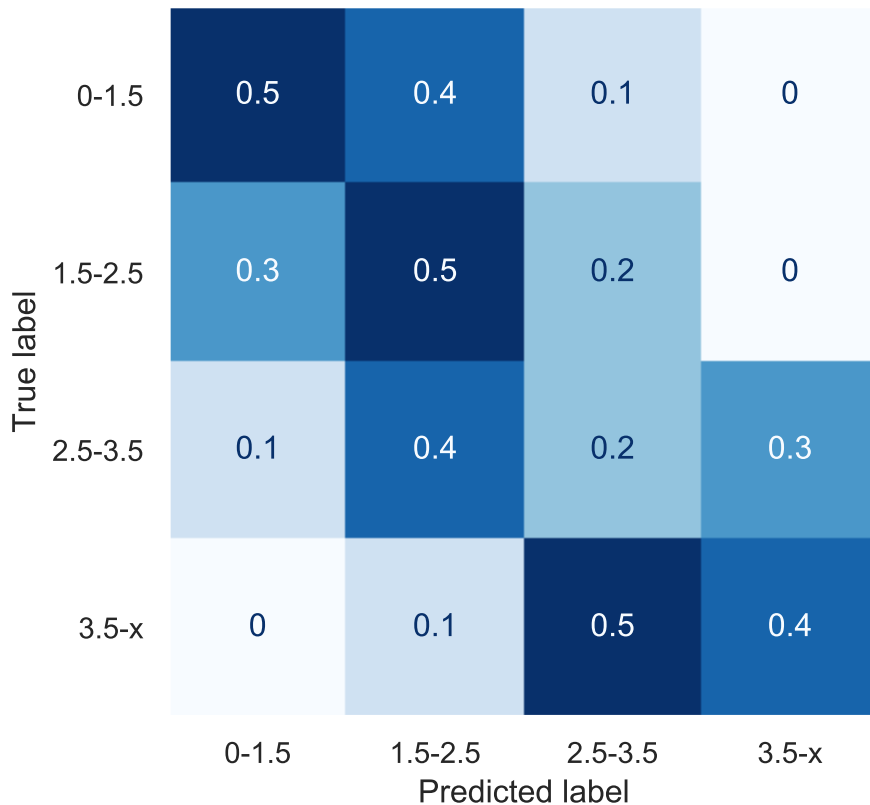


RANGE WINDOW: 30 s  
Confusion matrix Recv: Nexus Trans: S708 Method: 1meter



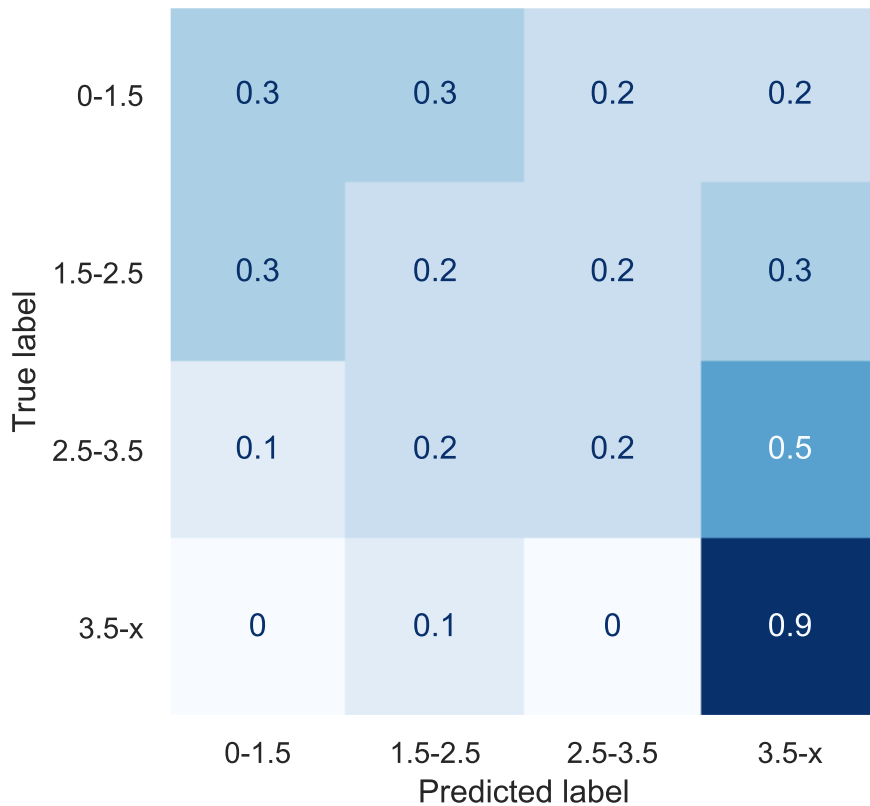
RANGE WINDOW: 30 s

Confusion matrix Recv: Nexus Trans: S708 Method: All\_without\_PL



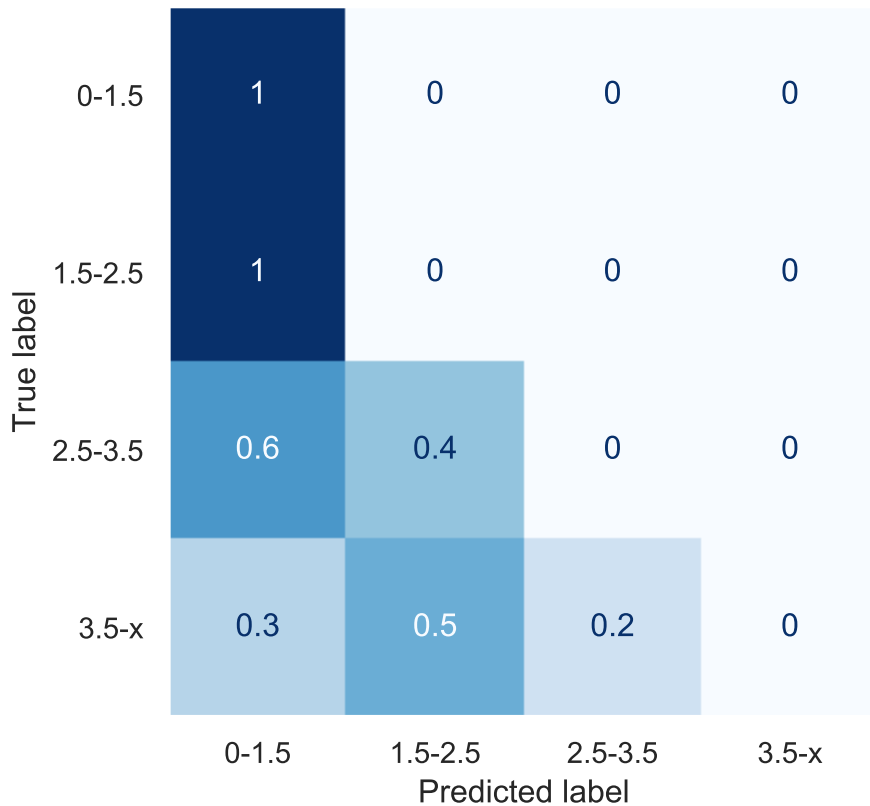
RANGE WINDOW: 30 s

Confusion matrix Recv: Nexus Trans: S708 Method: All\_with\_PL

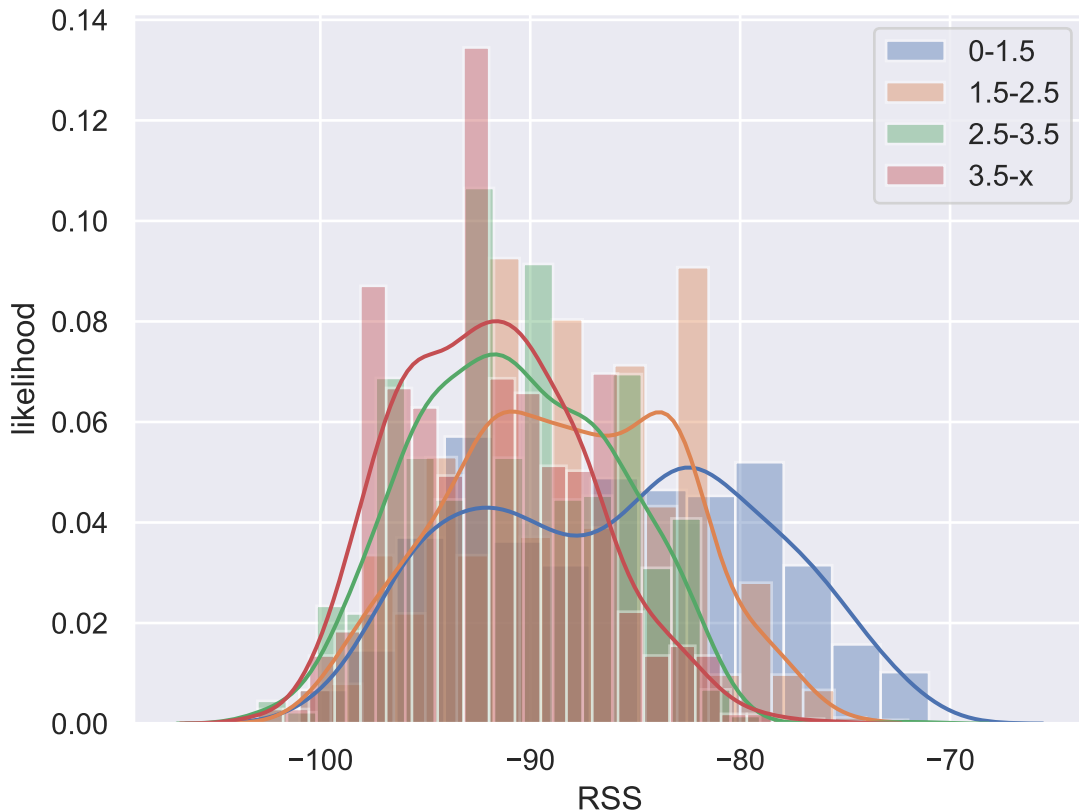


RANGE WINDOW: 30 s

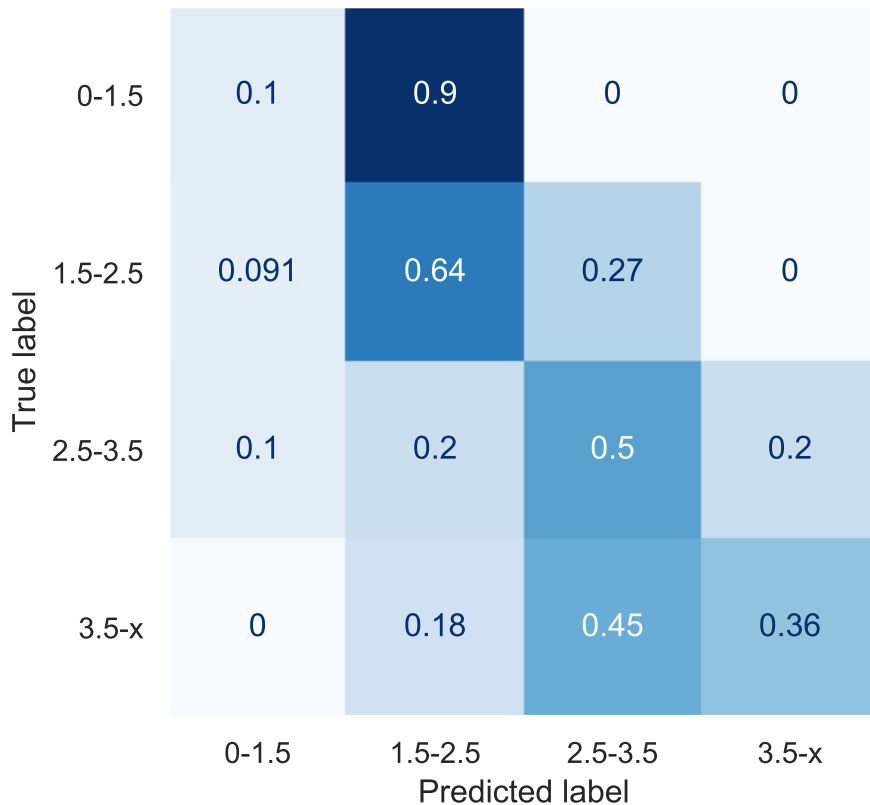
Confusion matrix Recv: Nexus Trans: S708 Method: method 4



RANGE WINDOW: 30 s  
RSS Recv: S8 Trans: S708

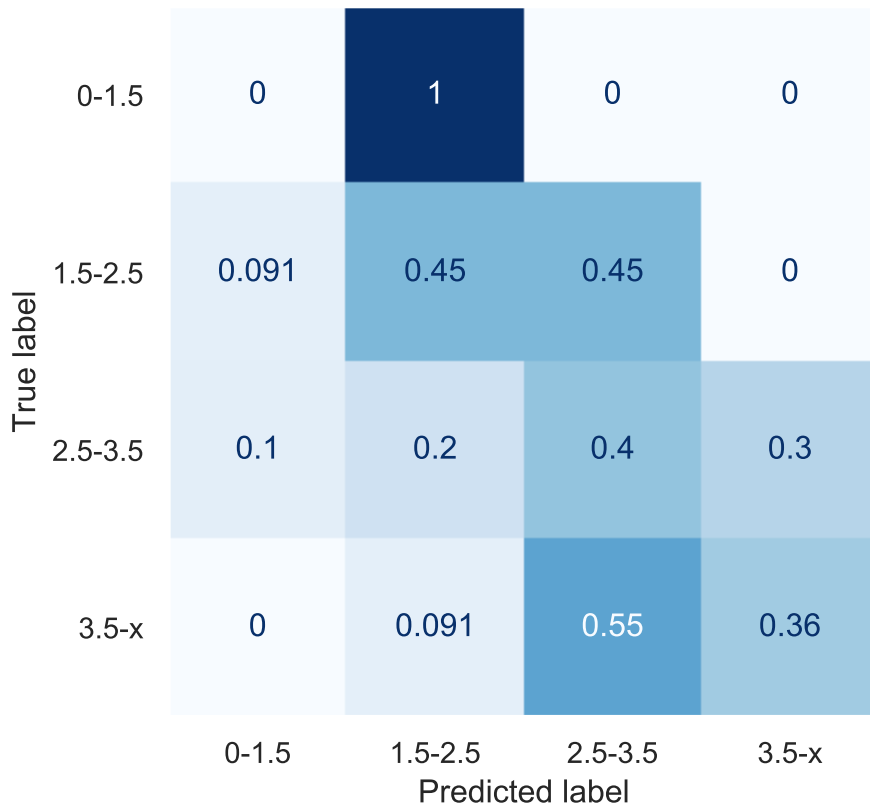


RANGE WINDOW: 30 s  
Confusion matrix Recv: S8 Trans: S708 Method: 1meter



RANGE WINDOW: 30 s

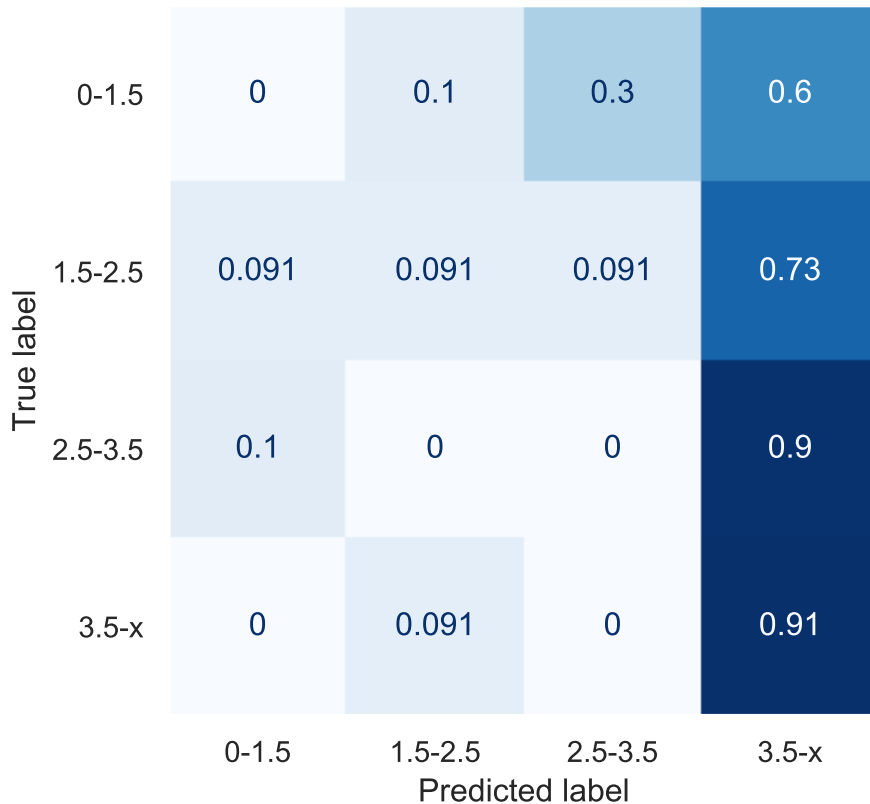
Confusion matrix Recv: S8 Trans: S708 Method: All\_without\_PL





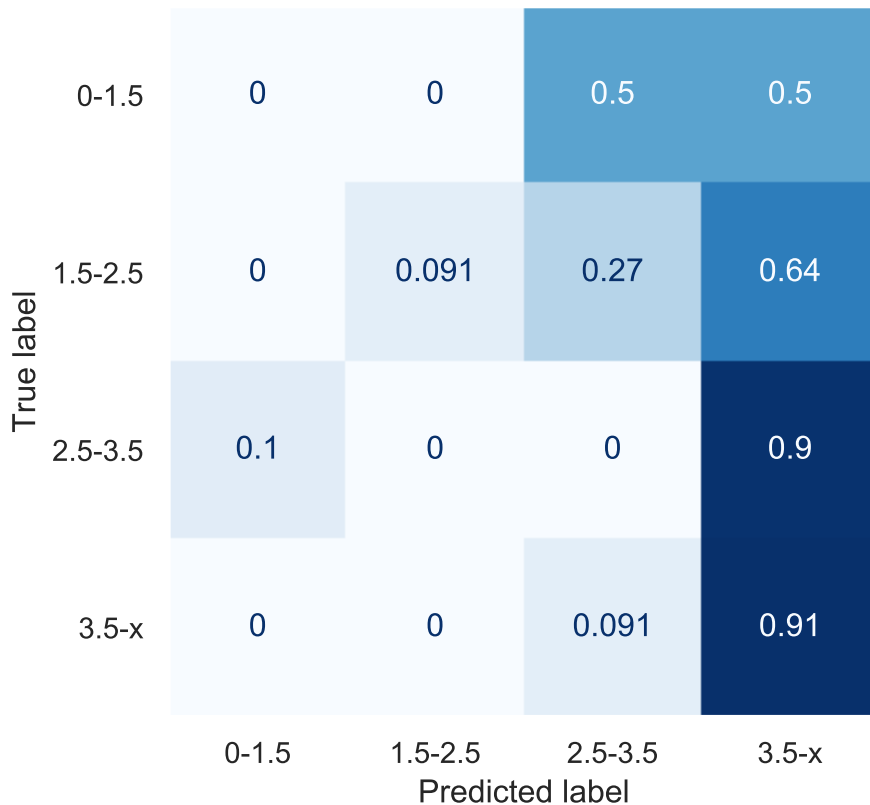
RANGE WINDOW: 30 s

Confusion matrix Recv: S8 Trans: S708 Method: All\_with\_PL

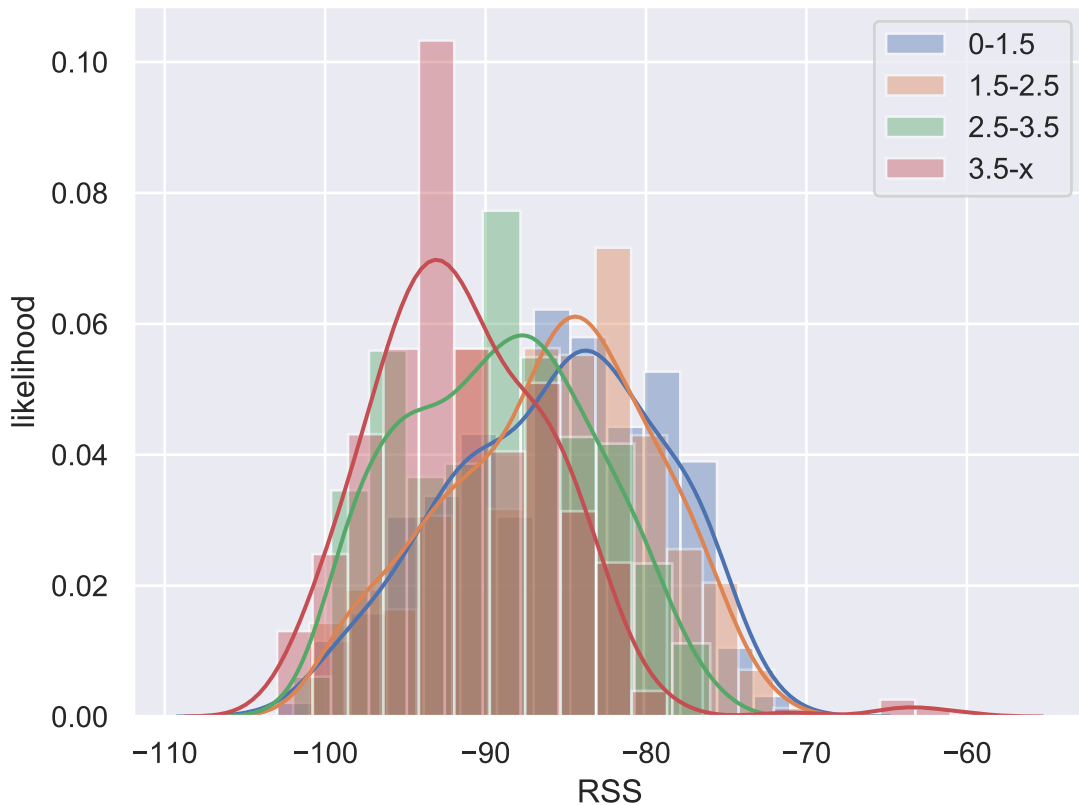


RANGE WINDOW: 30 s

Confusion matrix Recv: S8 Trans: S708 Method: method 4

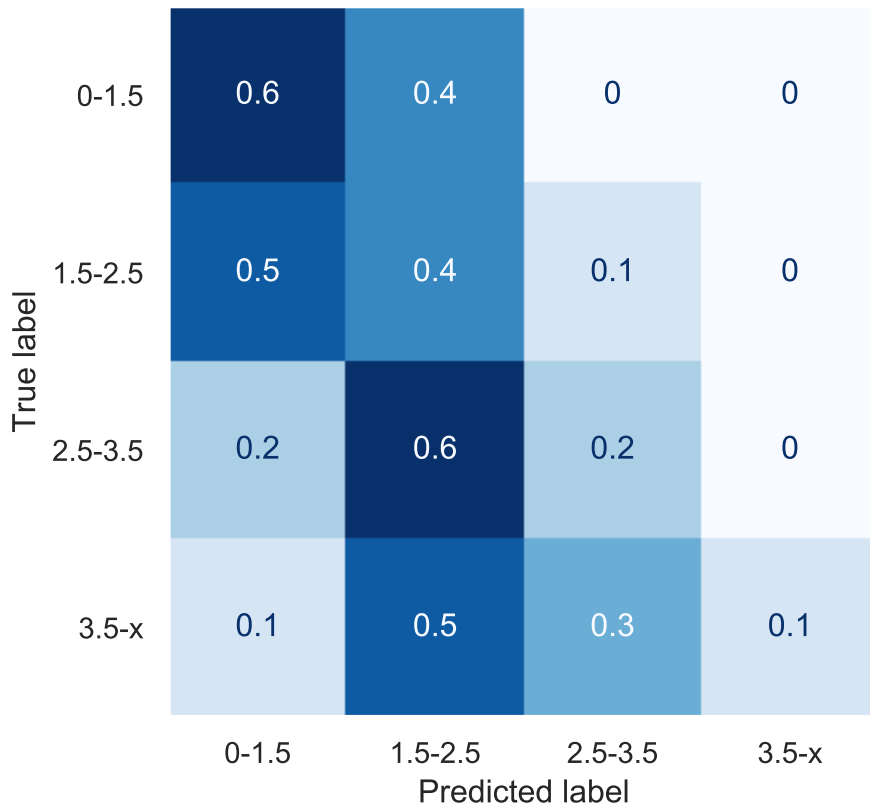


RANGE WINDOW: 30 s  
RSS Recv: Motorola Trans: Nexus



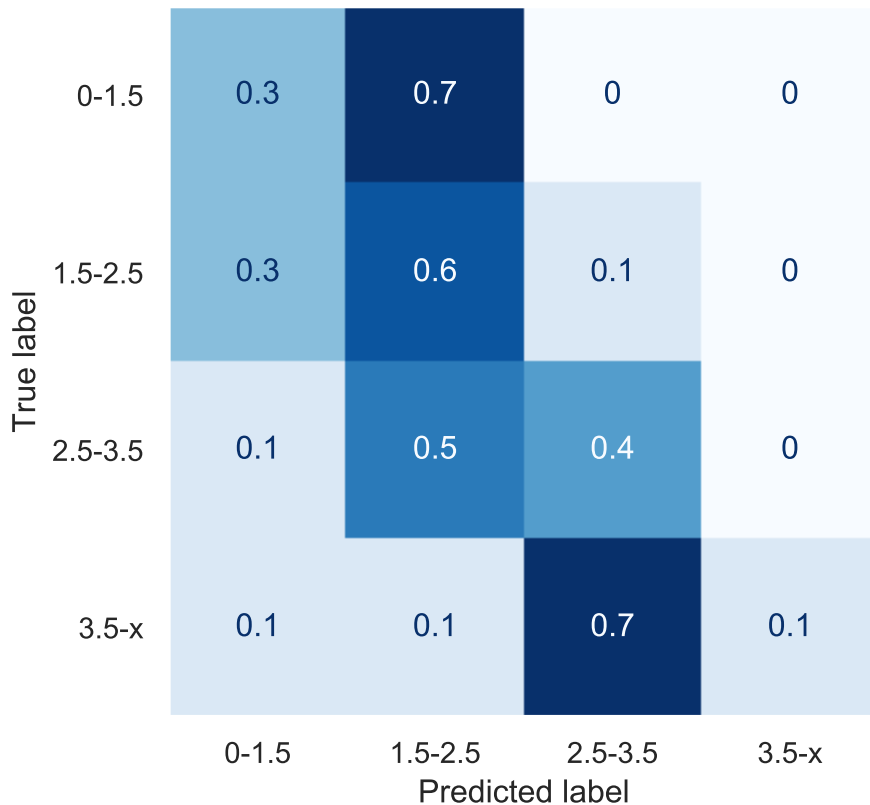
RANGE WINDOW: 30 s

Confusion matrix Recv: Motorola Trans: Nexus Method: 1meter



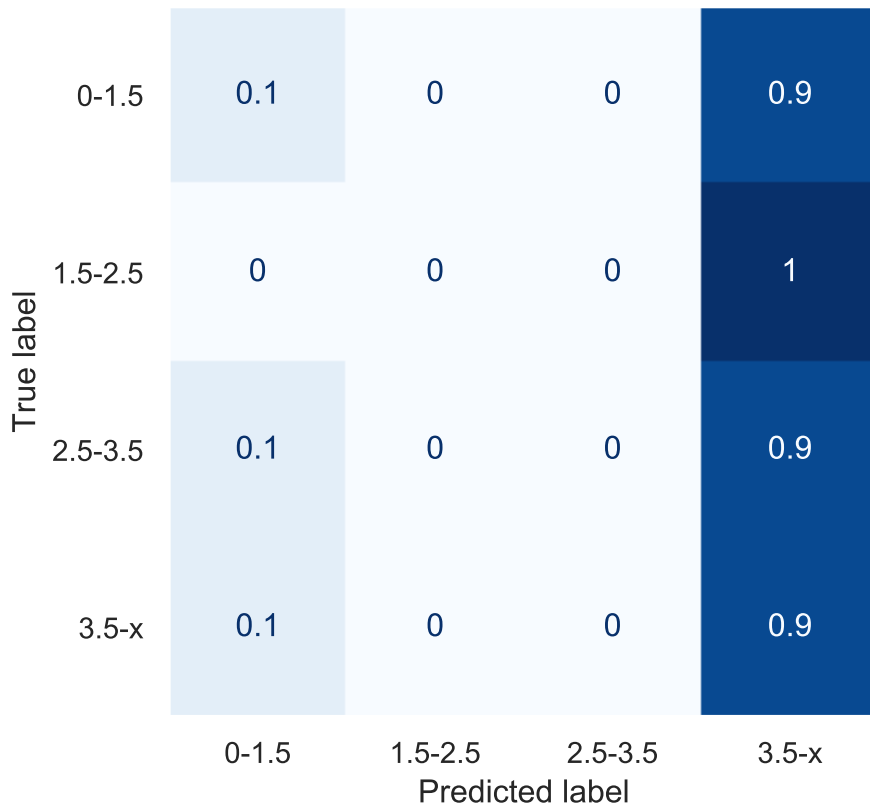
RANGE WINDOW: 30 s

Confusion matrix Recv: Motorola Trans: Nexus Method: All\_without\_PL



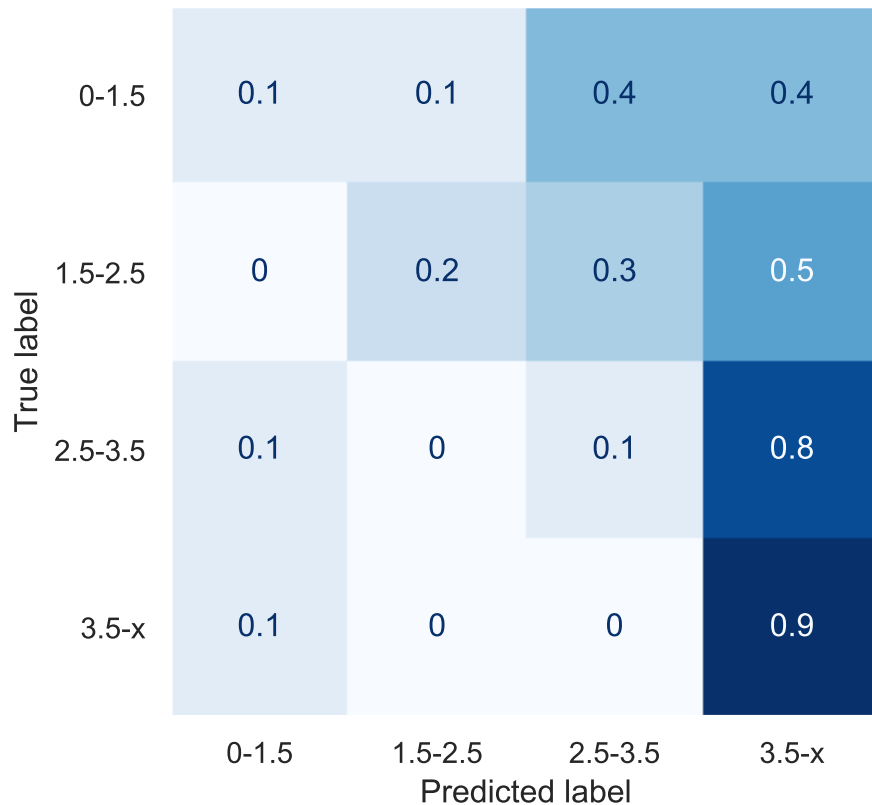
RANGE WINDOW: 30 s

Confusion matrix Recv: Motorola Trans: Nexus Method: All\_with\_PL

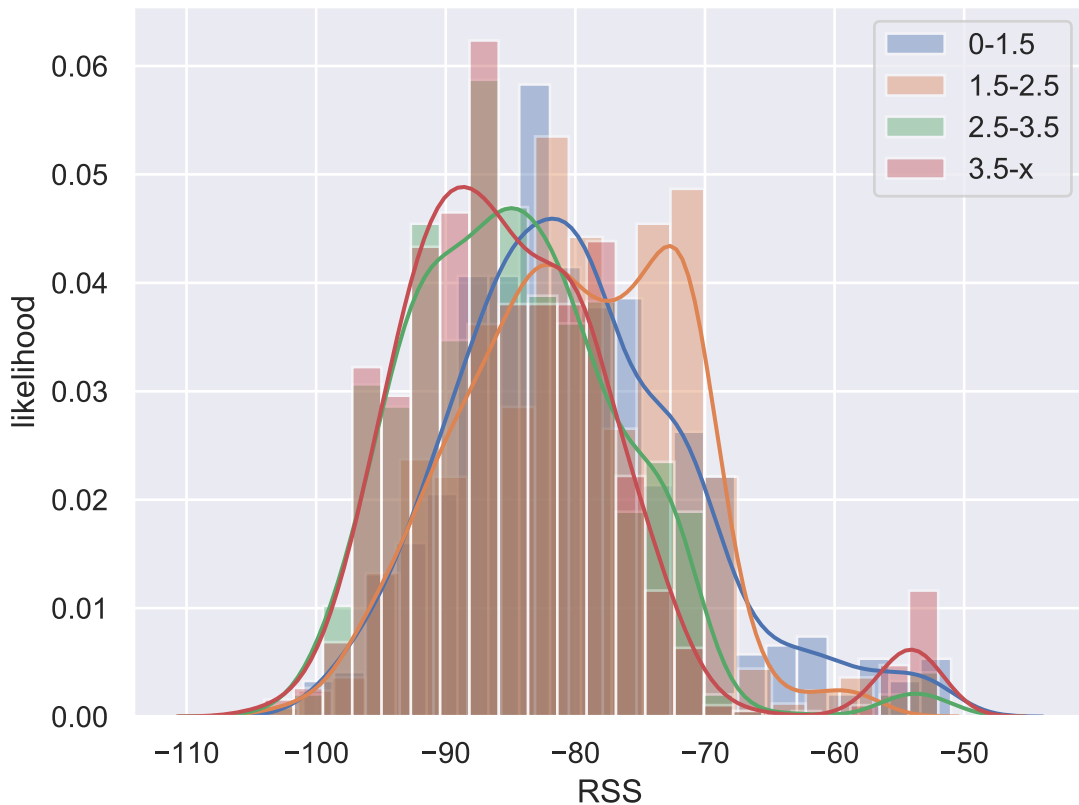


RANGE WINDOW: 30 s

Confusion matrix Recv: Motorola Trans: Nexus Method: method 4



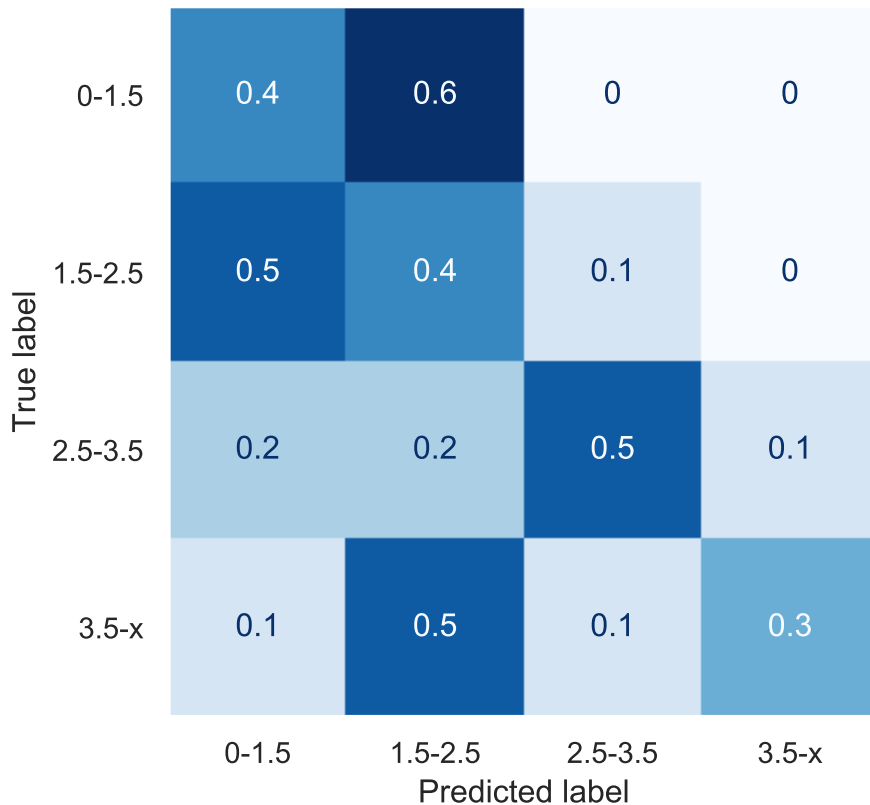
RANGE WINDOW: 30 s  
RSS Recv: SamsungA6 Trans: Nexus





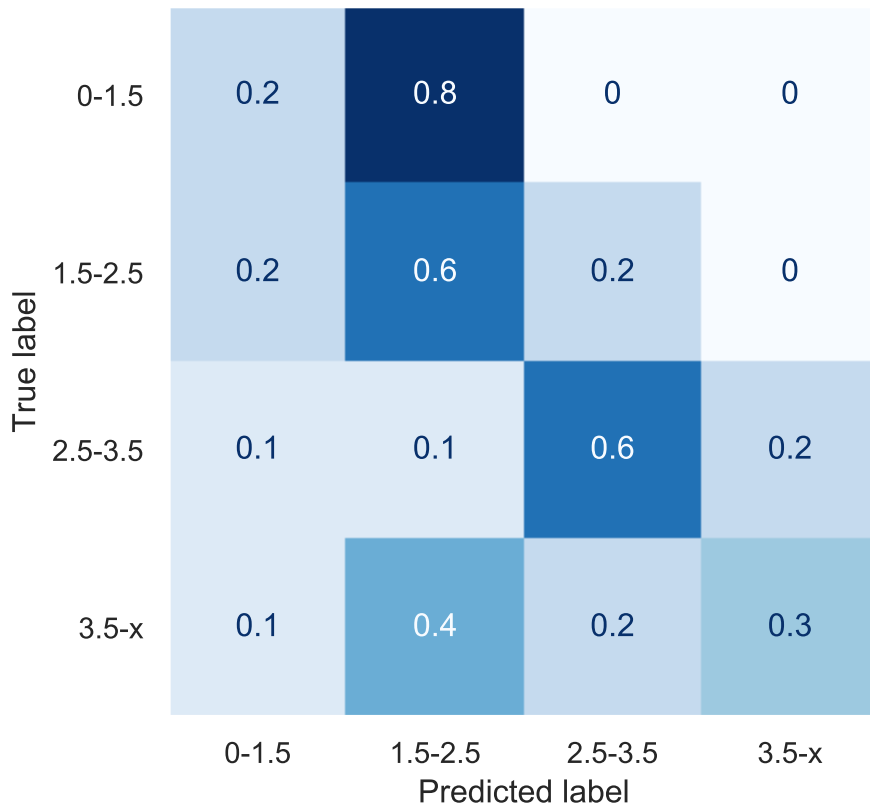
RANGE WINDOW: 30 s

Confusion matrix Recv: SamsungA6 Trans: Nexus Method: 1meter



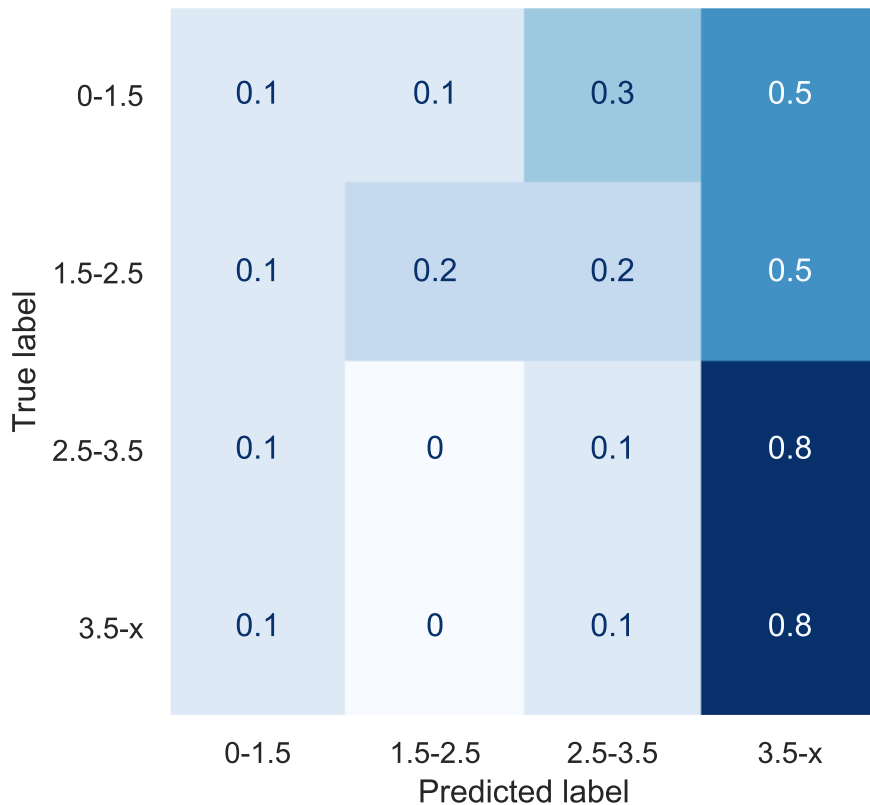
RANGE WINDOW: 30 s

Confusion matrix Recv: SamsungA6 Trans: Nexus Method: All\_without\_PL



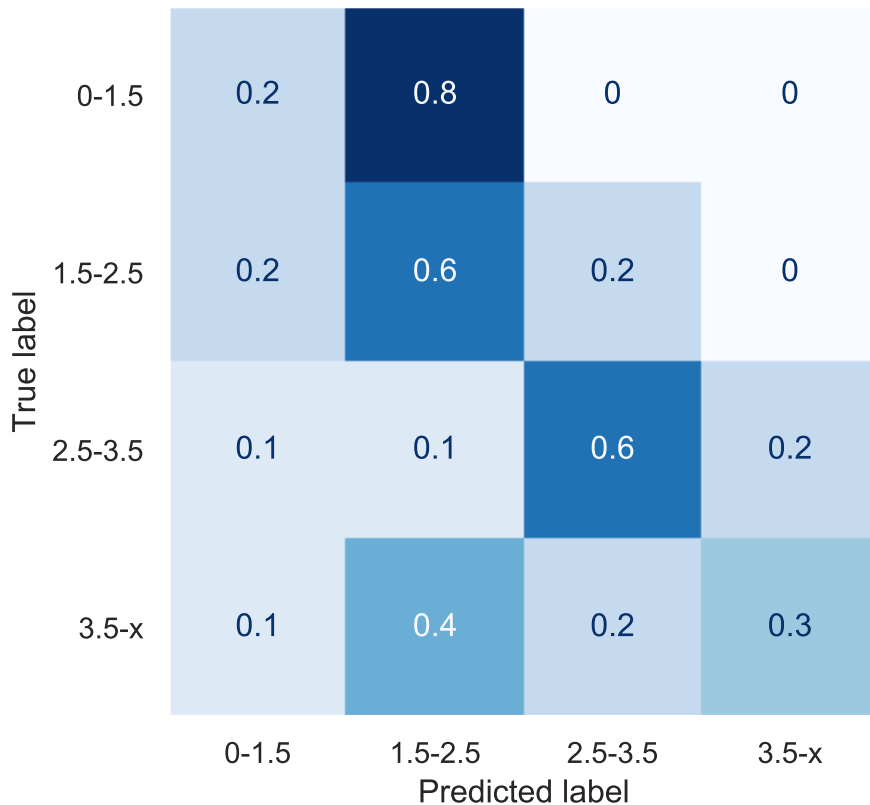
RANGE WINDOW: 30 s

Confusion matrix Recv: SamsungA6 Trans: Nexus Method: All\_with\_PL

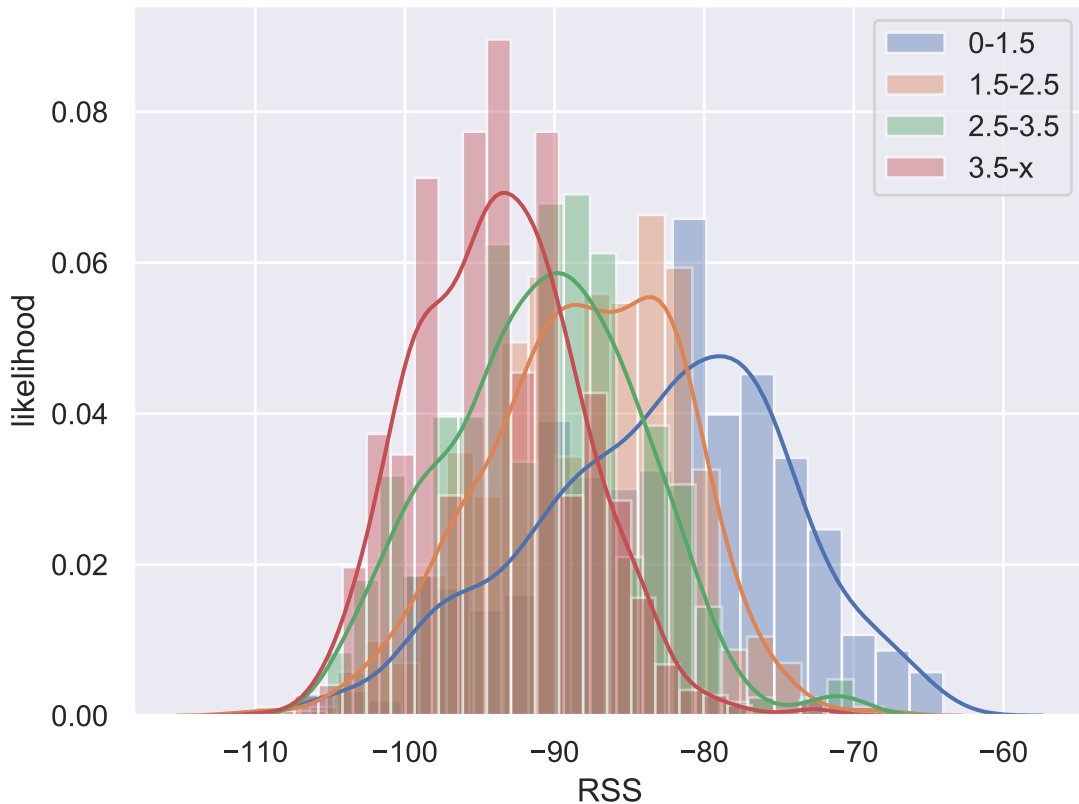


RANGE WINDOW: 30 s

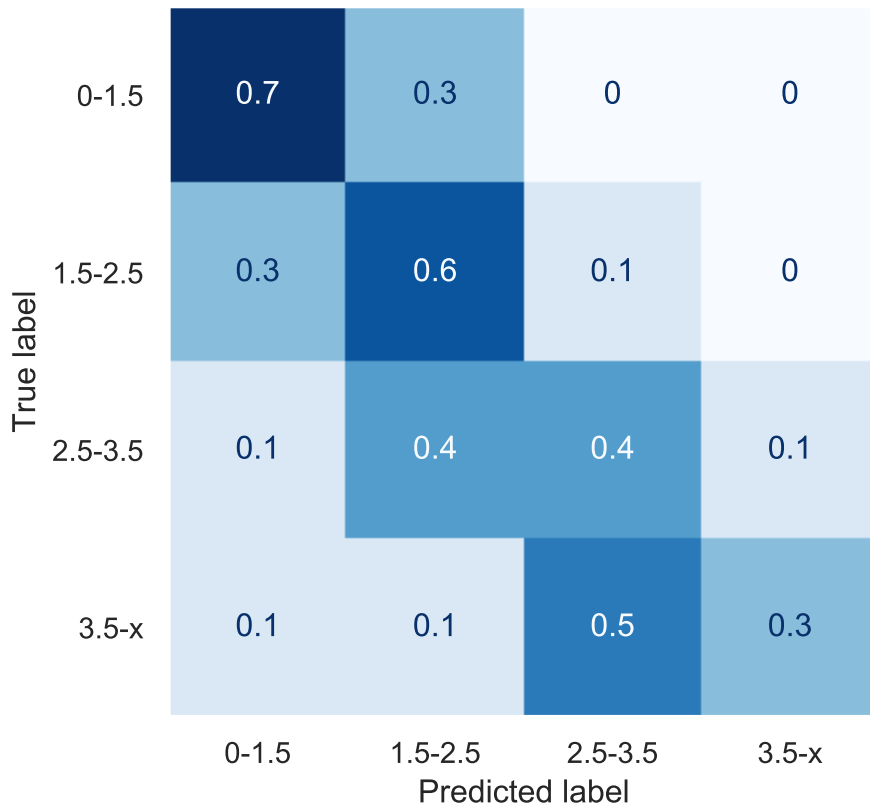
Confusion matrix Recv: SamsungA6 Trans: Nexus Method: method 4



RANGE WINDOW: 30 s  
RSS Recv: S708 Trans: Nexus

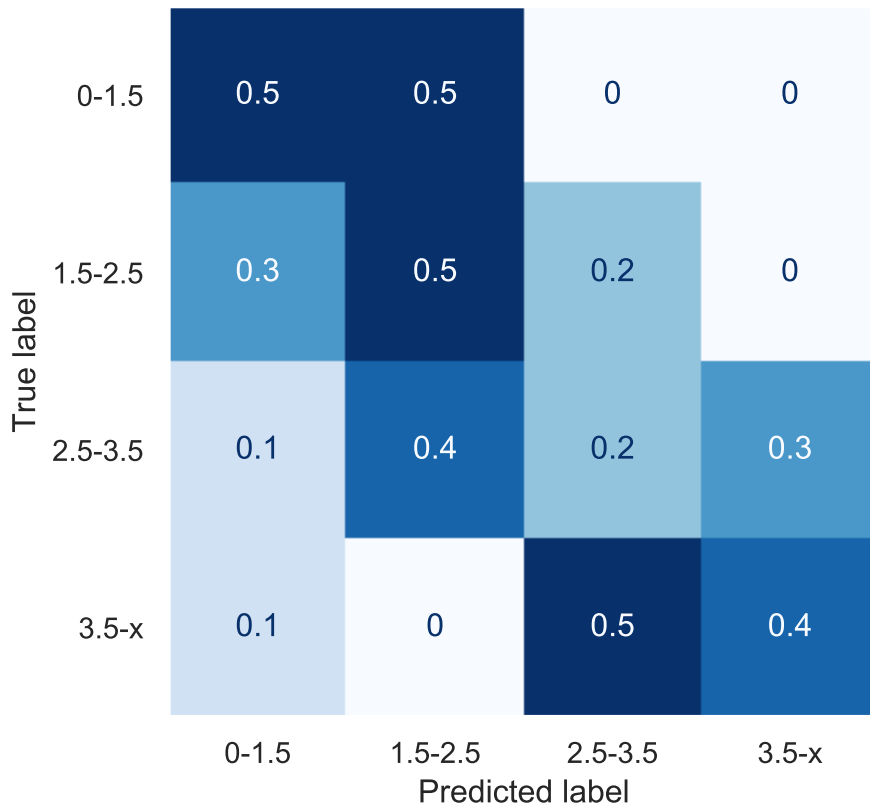


RANGE WINDOW: 30 s  
Confusion matrix Recv: S708 Trans: Nexus Method: 1meter



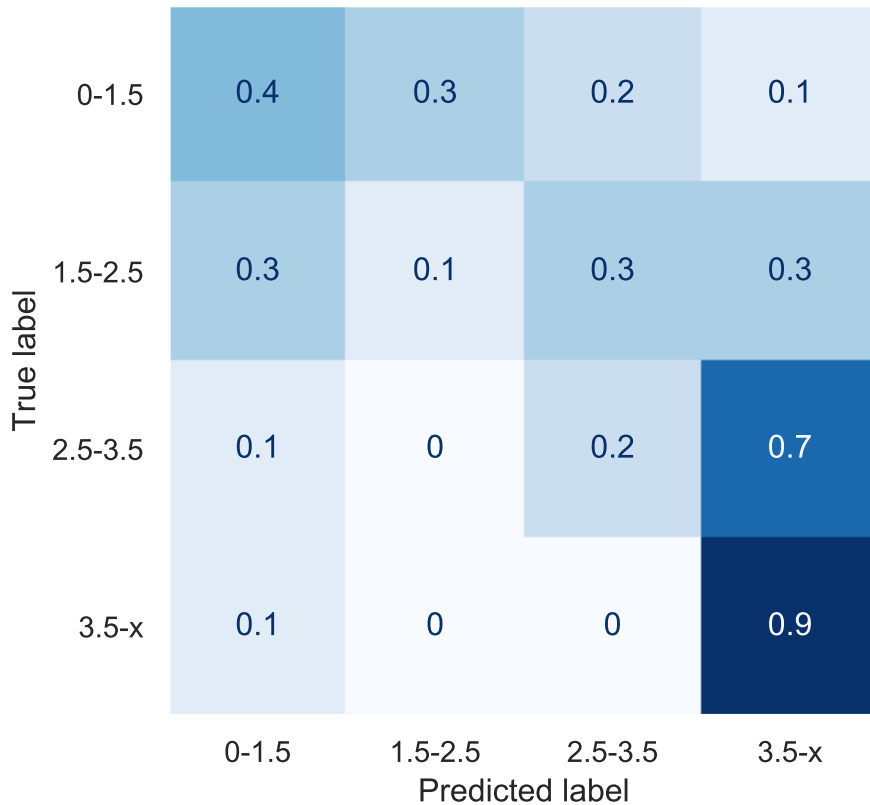
RANGE WINDOW: 30 s

Confusion matrix Recv: S708 Trans: Nexus Method: All\_without\_PL



RANGE WINDOW: 30 s

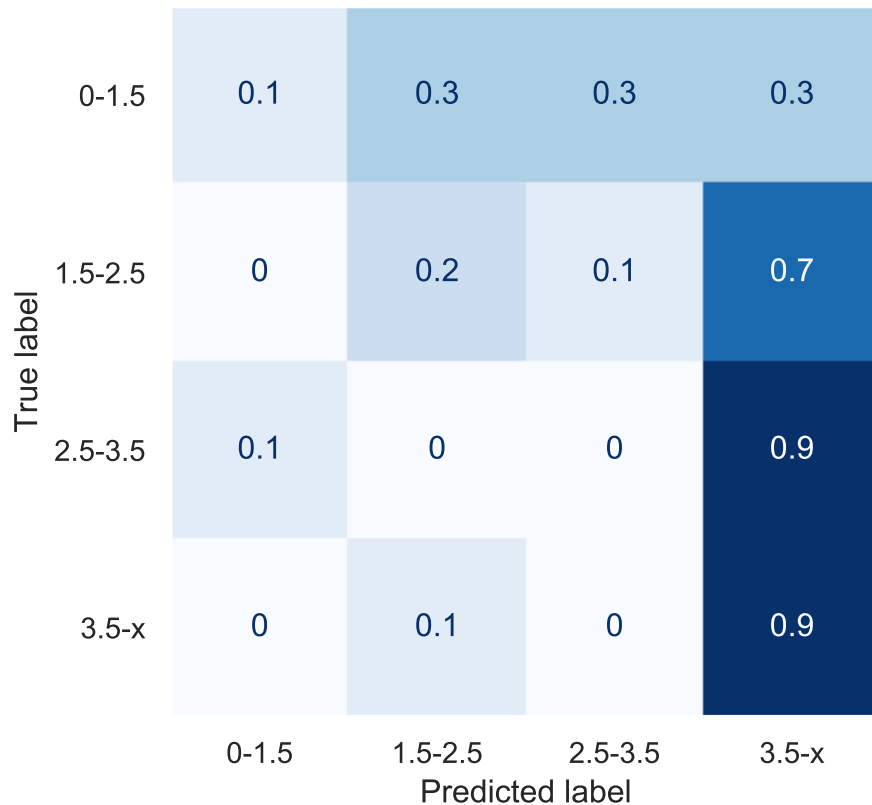
Confusion matrix Recv: S708 Trans: Nexus Method: All\_with\_PL



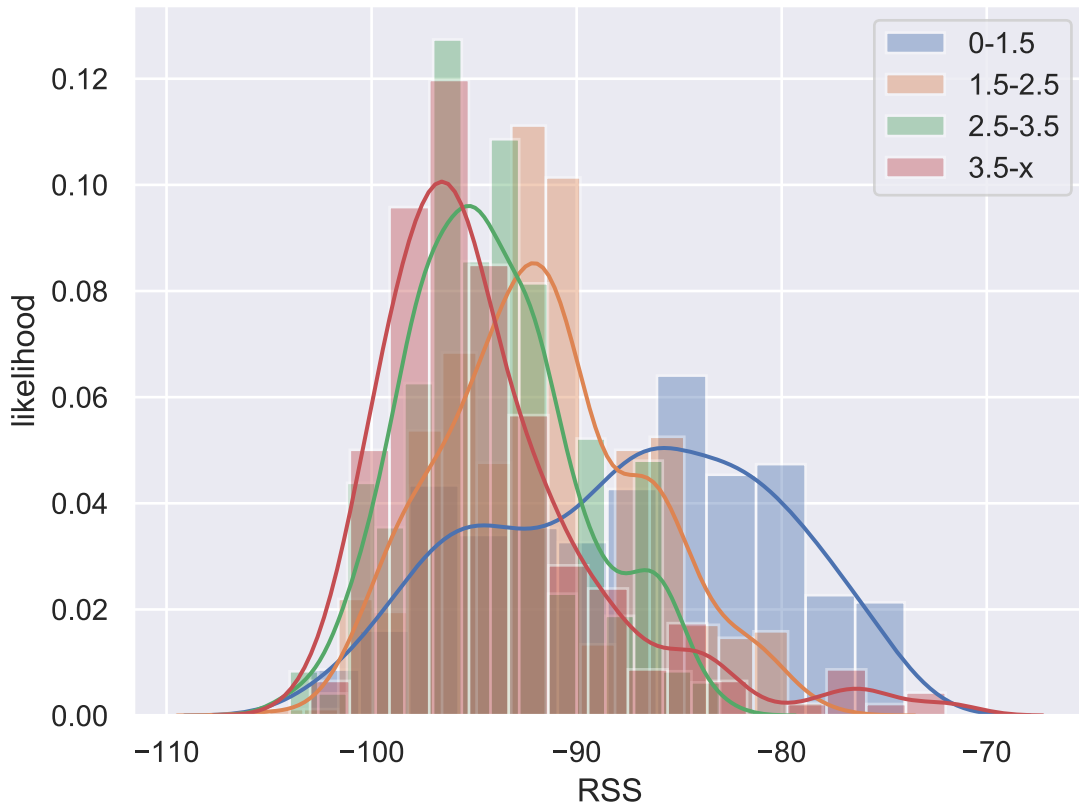


RANGE WINDOW: 30 s

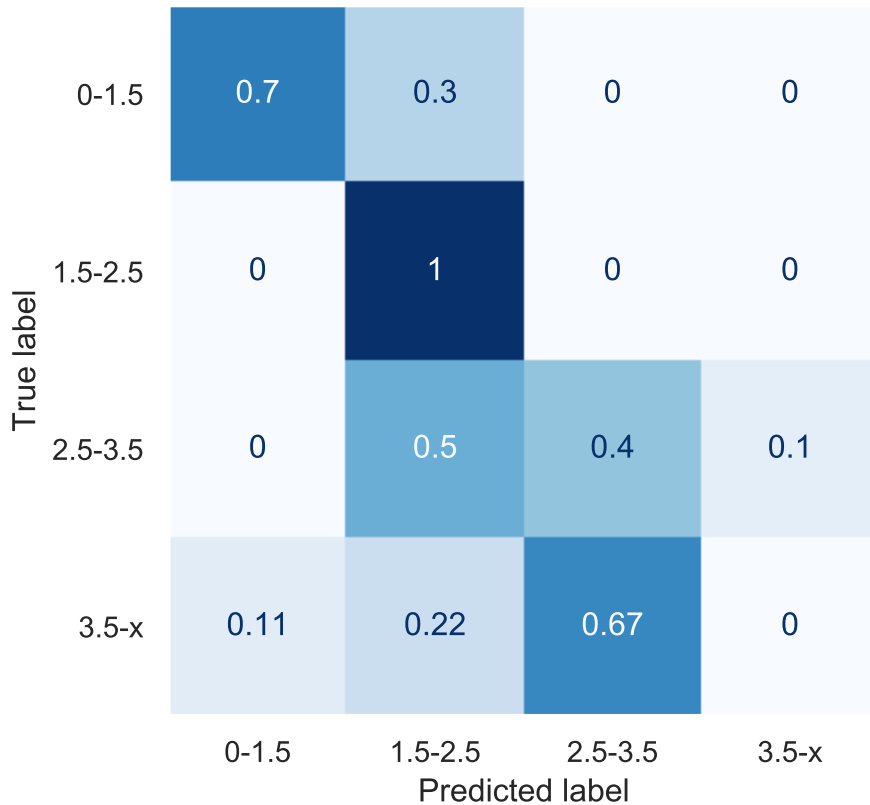
Confusion matrix Recv: S708 Trans: Nexus Method: method 4



RANGE WINDOW: 30 s  
RSS Recv: Motorola Trans: S8

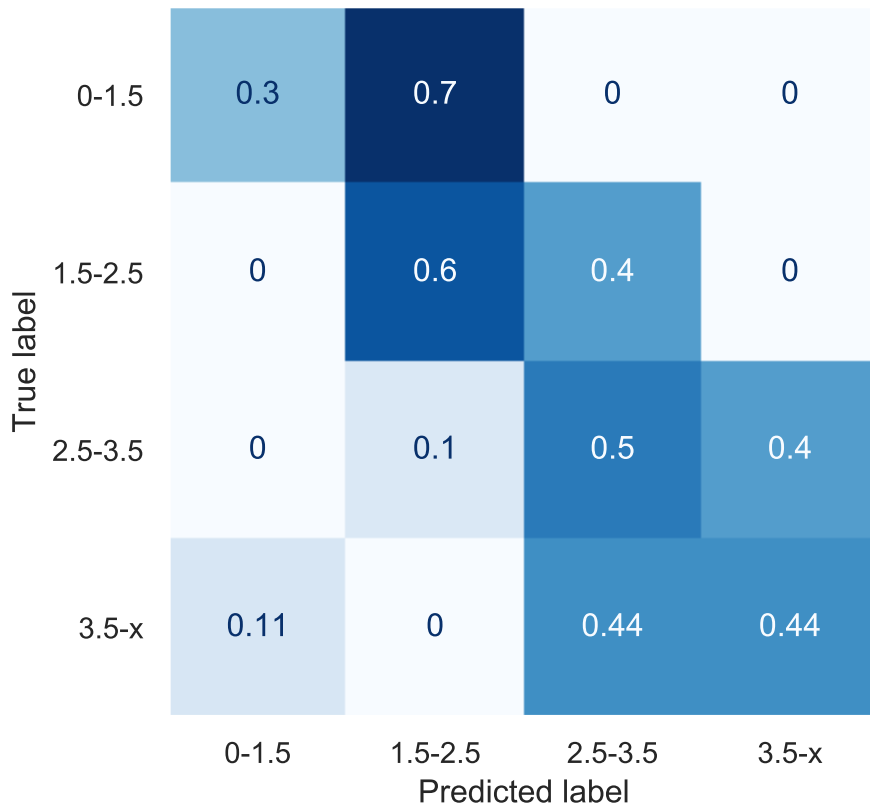


RANGE WINDOW: 30 s  
Confusion matrix Recv: Motorola Trans: S8 Method: 1meter



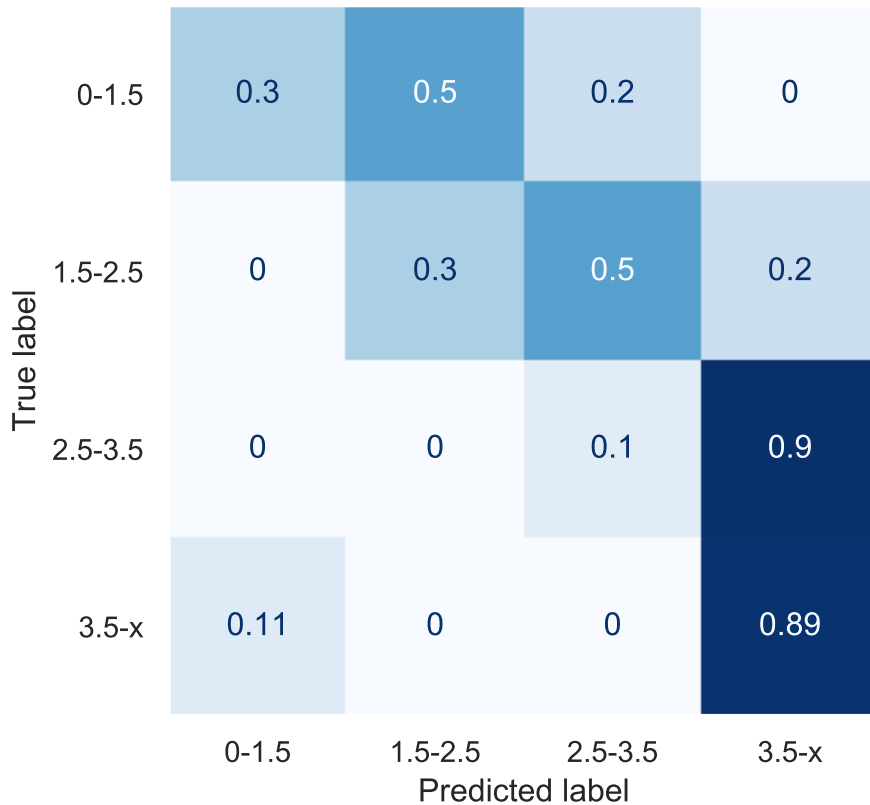
RANGE WINDOW: 30 s

Confusion matrix Recv: Motorola Trans: S8 Method: All\_without\_PL

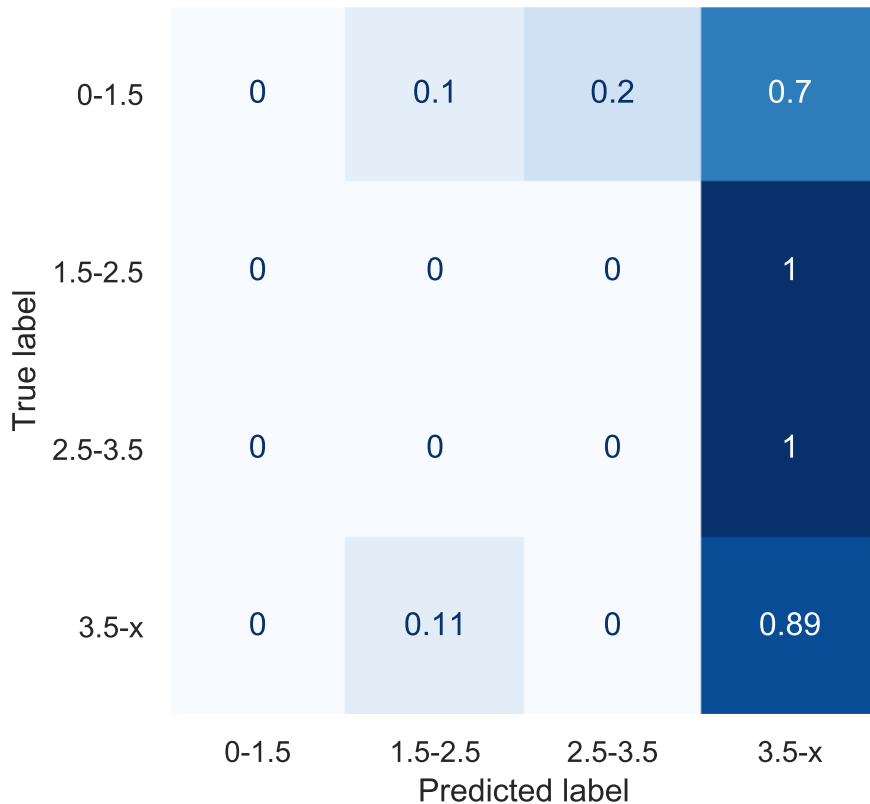


RANGE WINDOW: 30 s

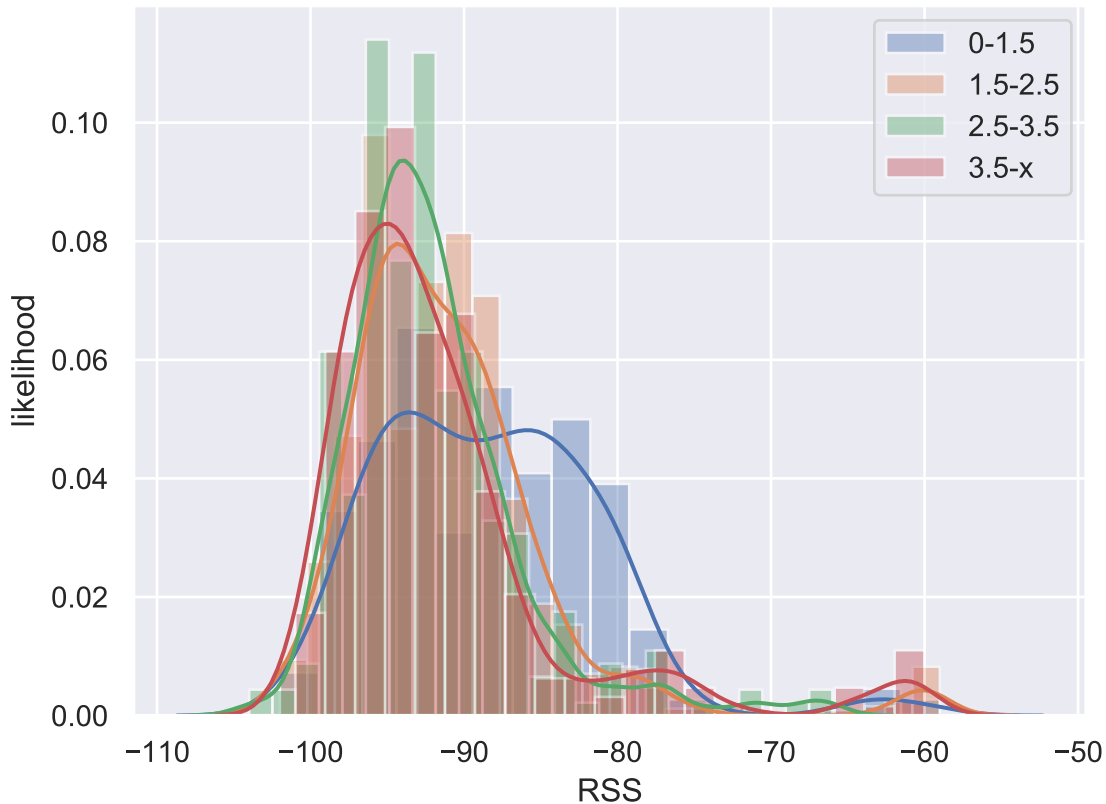
Confusion matrix Recv: Motorola Trans: S8 Method: All\_with\_PL



RANGE WINDOW: 30 s  
Confusion matrix Recv: Motorola Trans: S8 Method: method 4

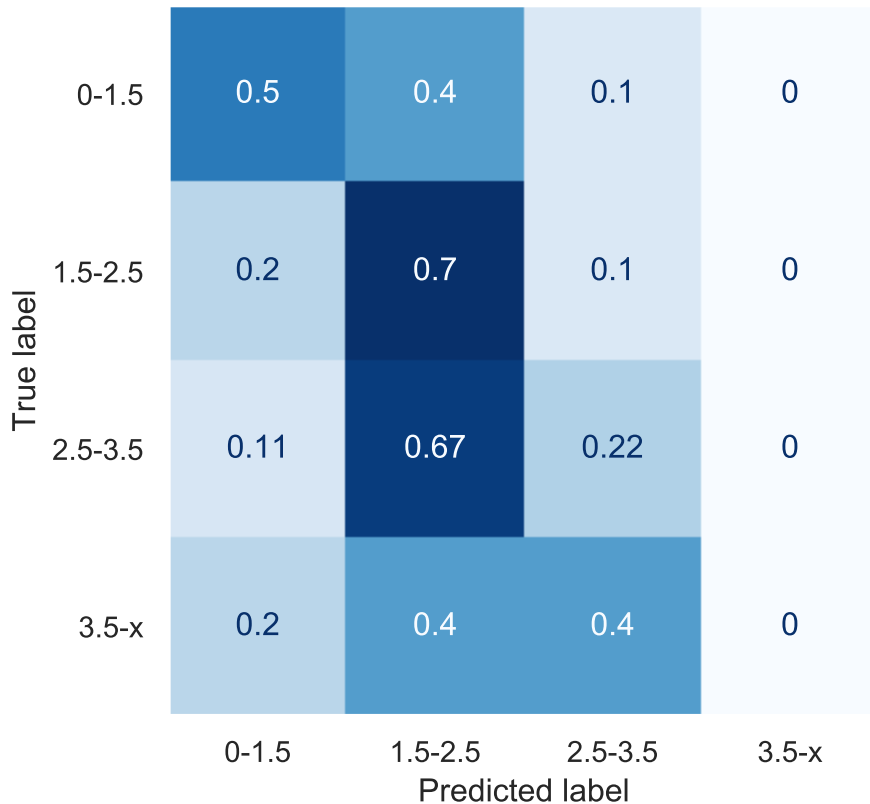


RANGE WINDOW: 30 s  
RSS Recv: SamsungA6 Trans: S8



RANGE WINDOW: 30 s

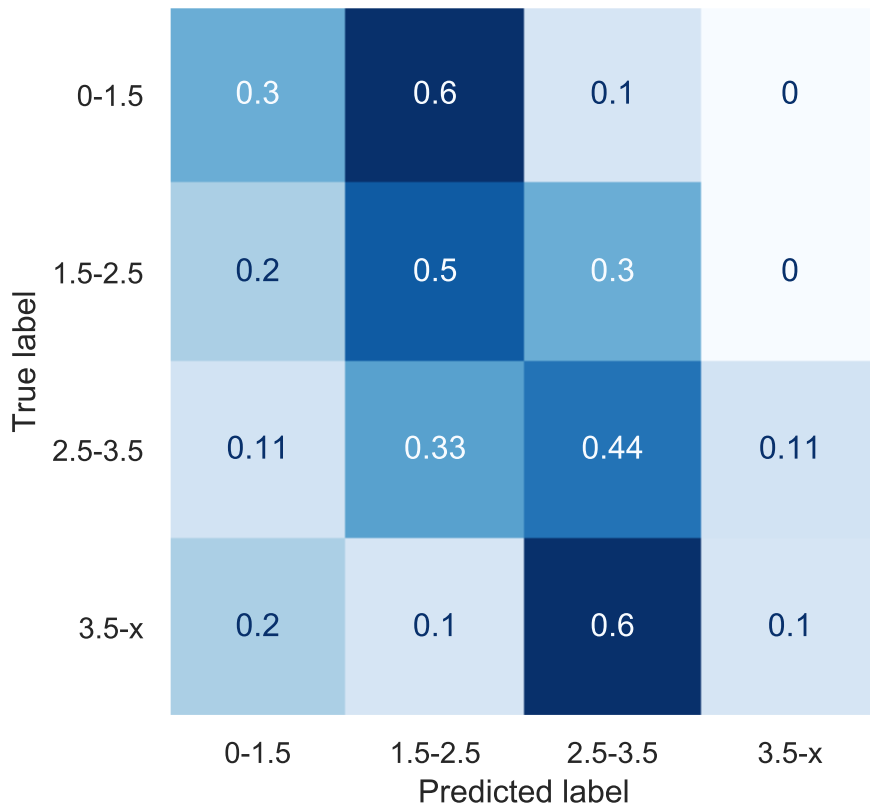
Confusion matrix Recv: SamsungA6 Trans: S8 Method: 1meter





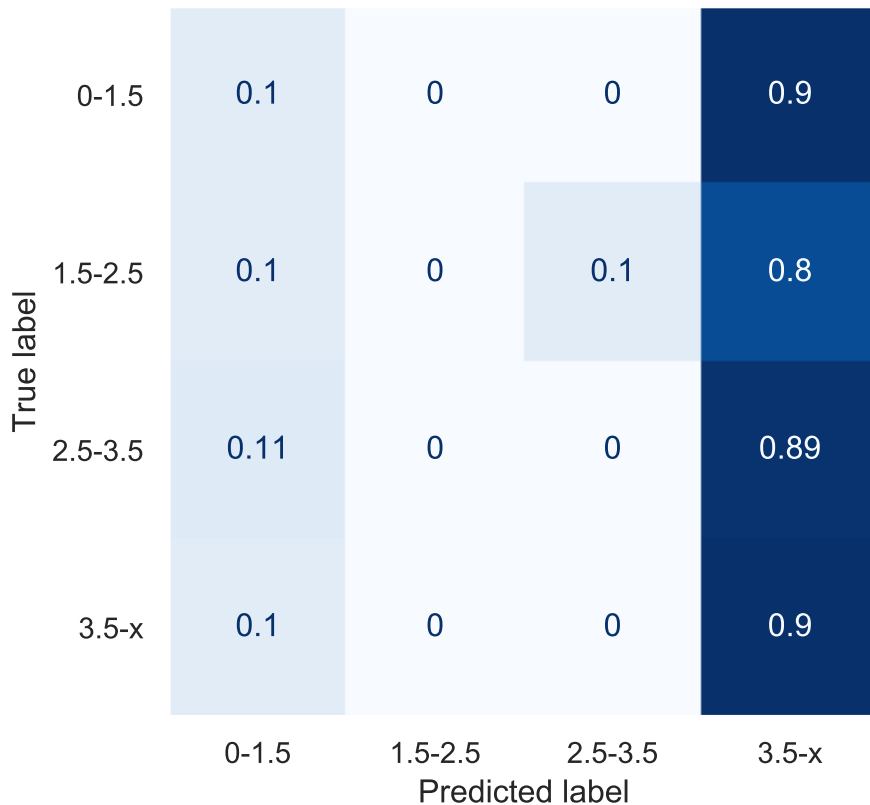
RANGE WINDOW: 30 s

Confusion matrix Recv: SamsungA6 Trans: S8 Method: All\_without\_PL



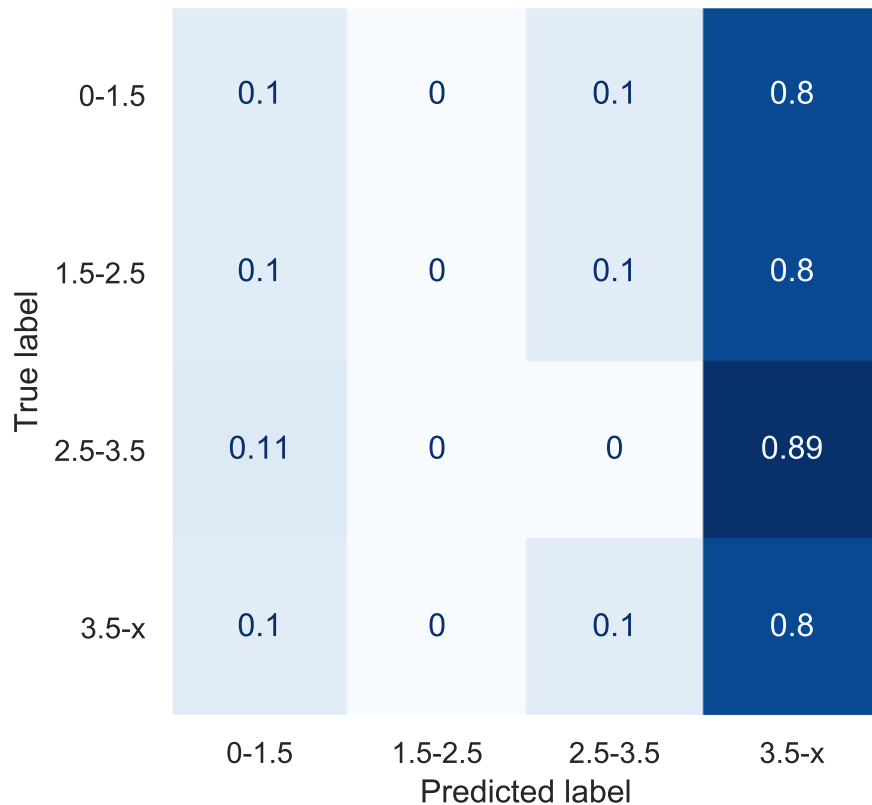
RANGE WINDOW: 30 s

Confusion matrix Recv: SamsungA6 Trans: S8 Method: All\_with\_PL

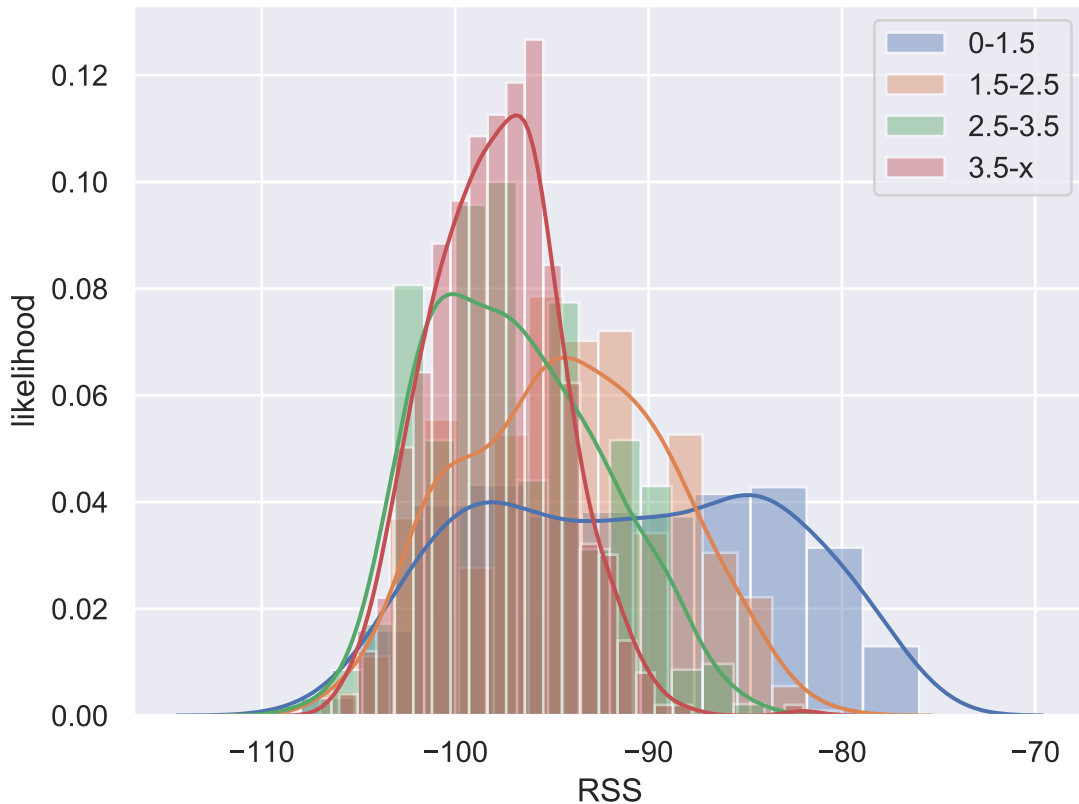


RANGE WINDOW: 30 s

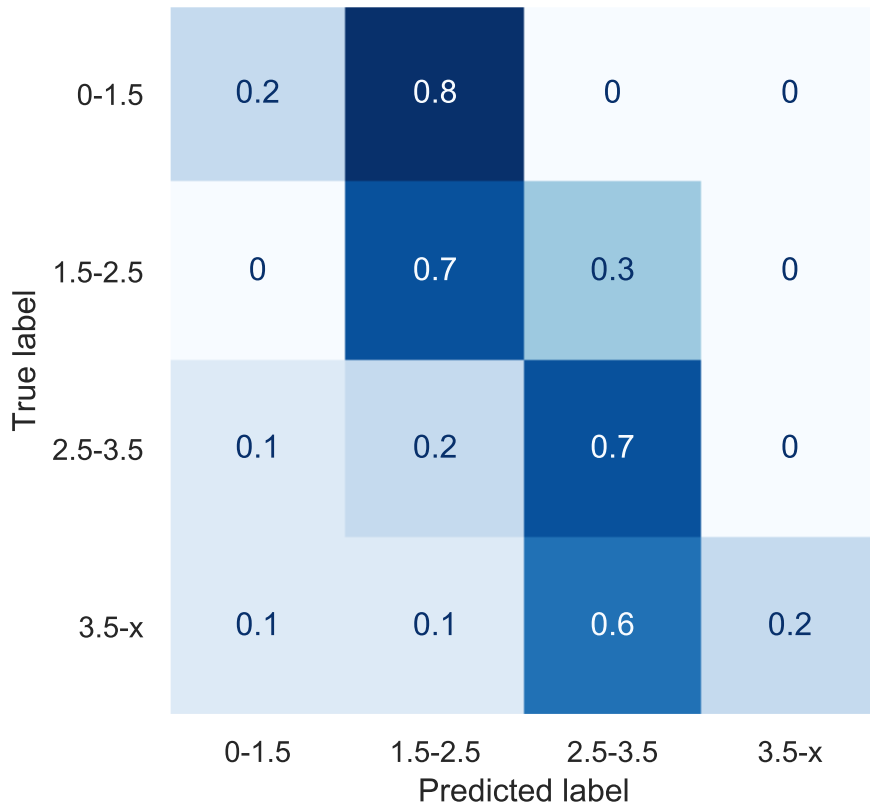
Confusion matrix Recv: SamsungA6 Trans: S8 Method: method 4



RANGE WINDOW: 30 s  
RSS Recv: S708 Trans: S8

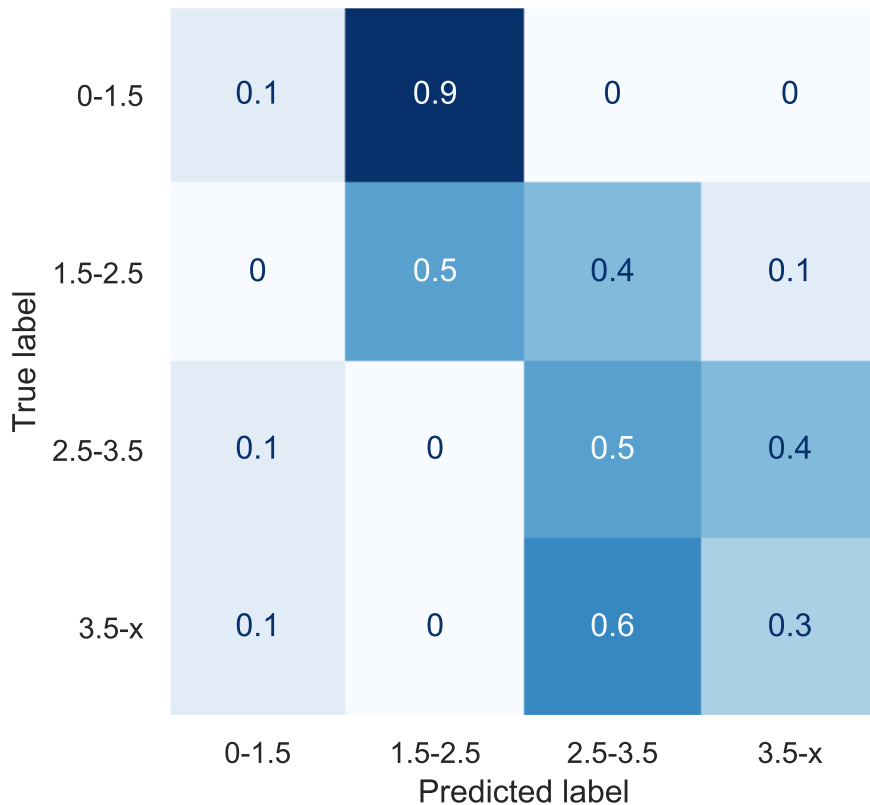


RANGE WINDOW: 30 s  
Confusion matrix Recv: S708 Trans: S8 Method: 1meter



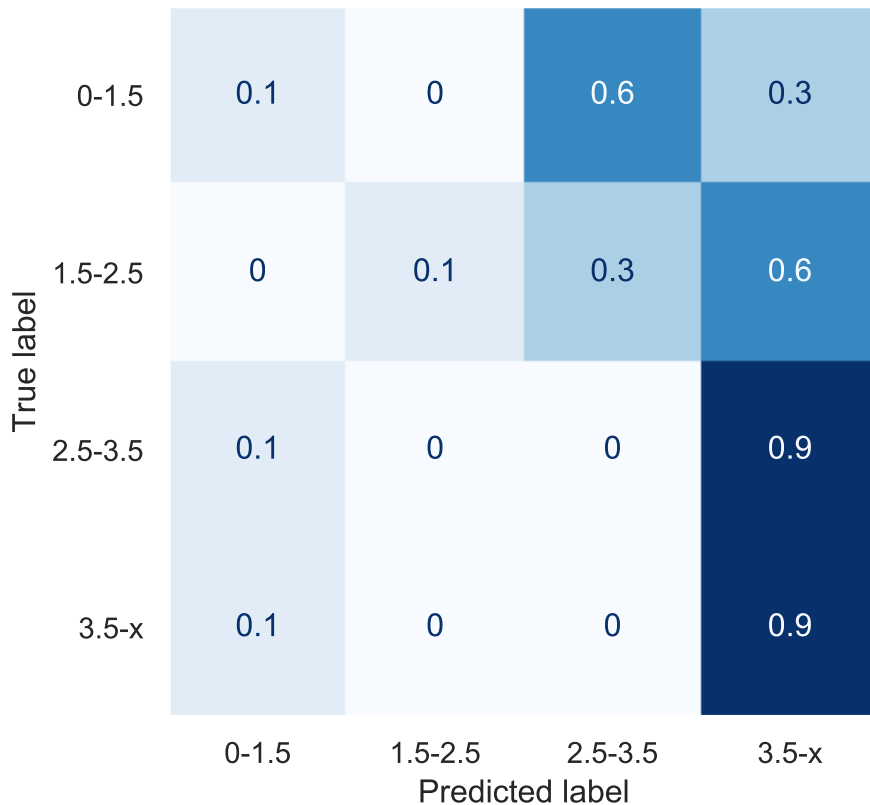
RANGE WINDOW: 30 s

Confusion matrix Recv: S708 Trans: S8 Method: All\_without\_PL



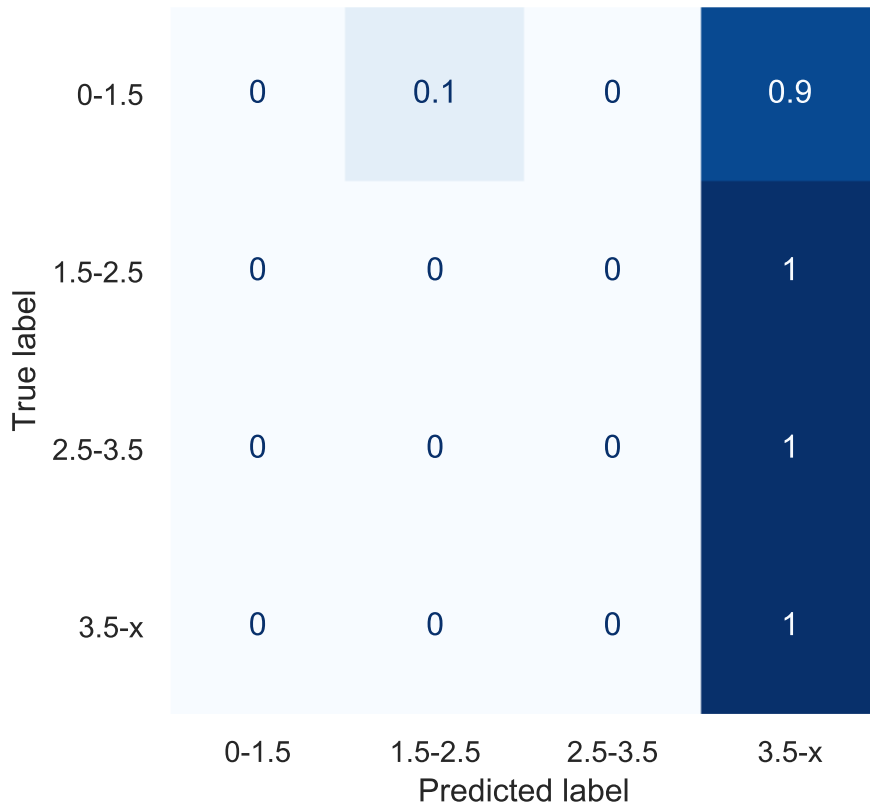
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Confusion matrix Recv: S708 Trans: S8 Method: All\_with\_PL



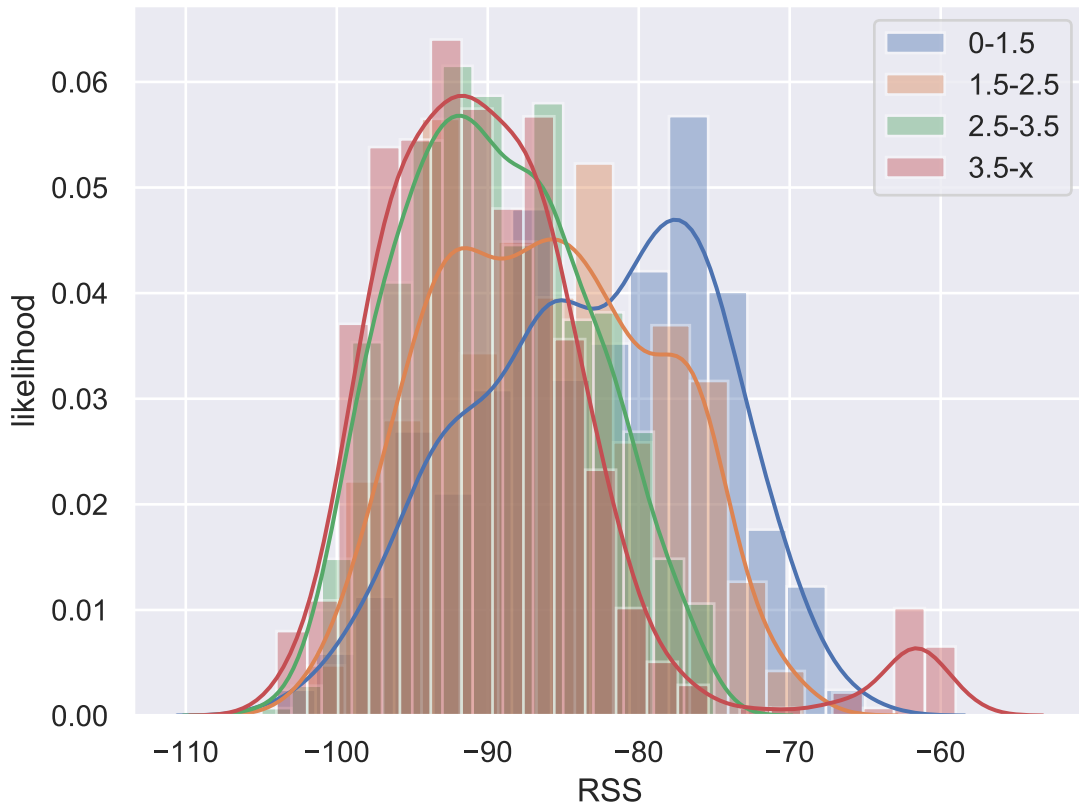
RANGE WINDOW: 30 s

Confusion matrix Recv: S708 Trans: S8 Method: method 4

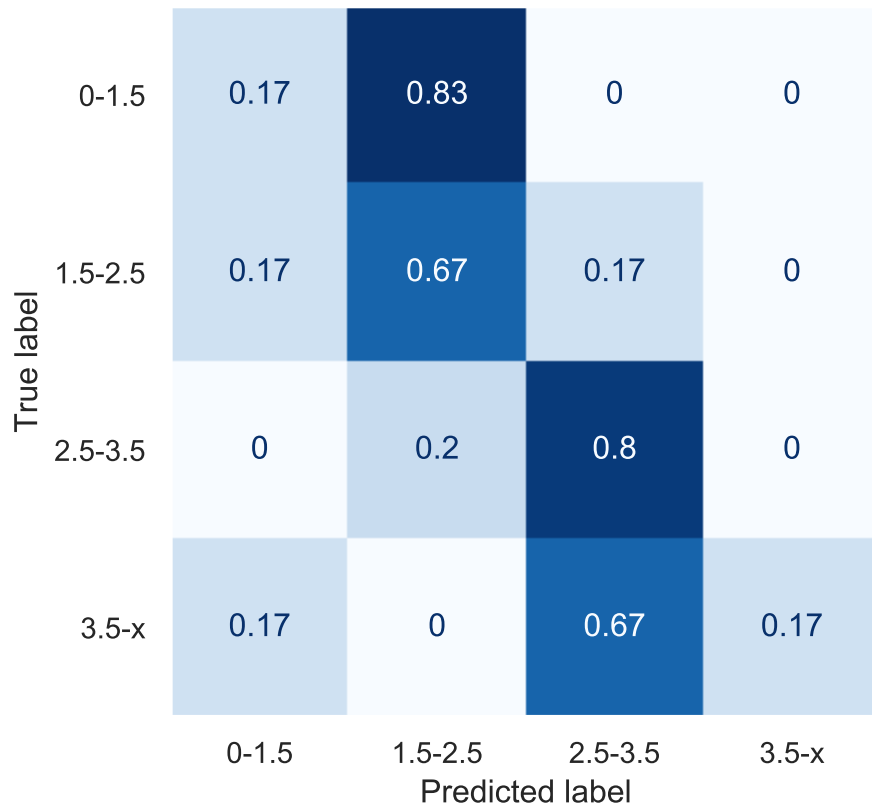




RANGE WINDOW: 60 s  
RSS Recv: Motorola Trans: S706

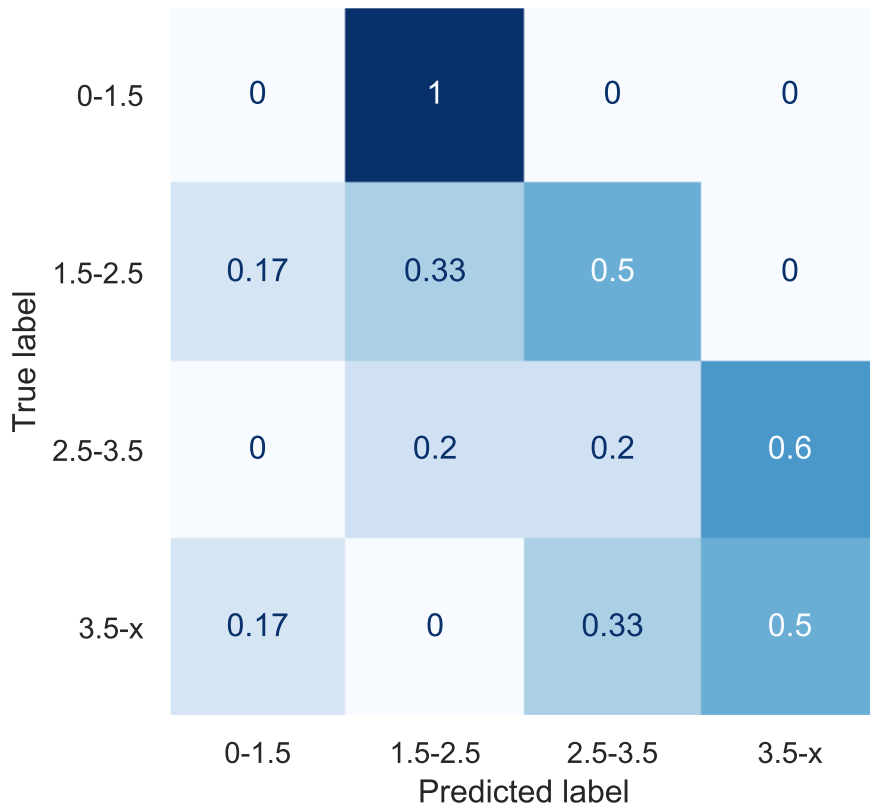


RANGE WINDOW: 60 s  
Confusion matrix Recv: Motorola Trans: S706 Method: 1meter



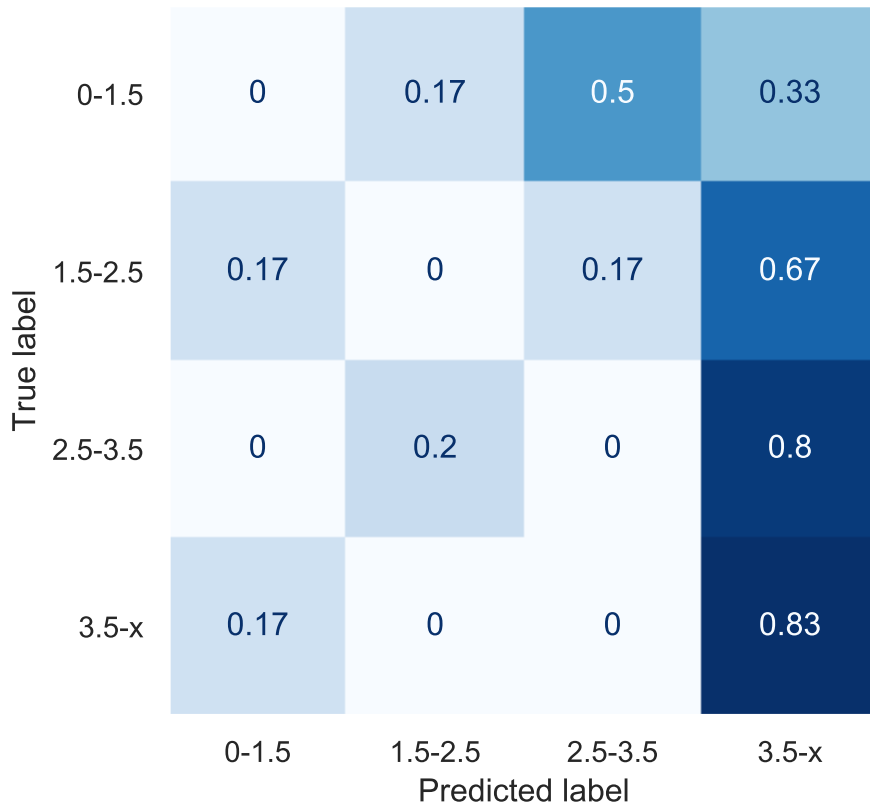
RANGE WINDOW: 60 s

Confusion matrix Recv: Motorola Trans: S706 Method: All\_without\_PL



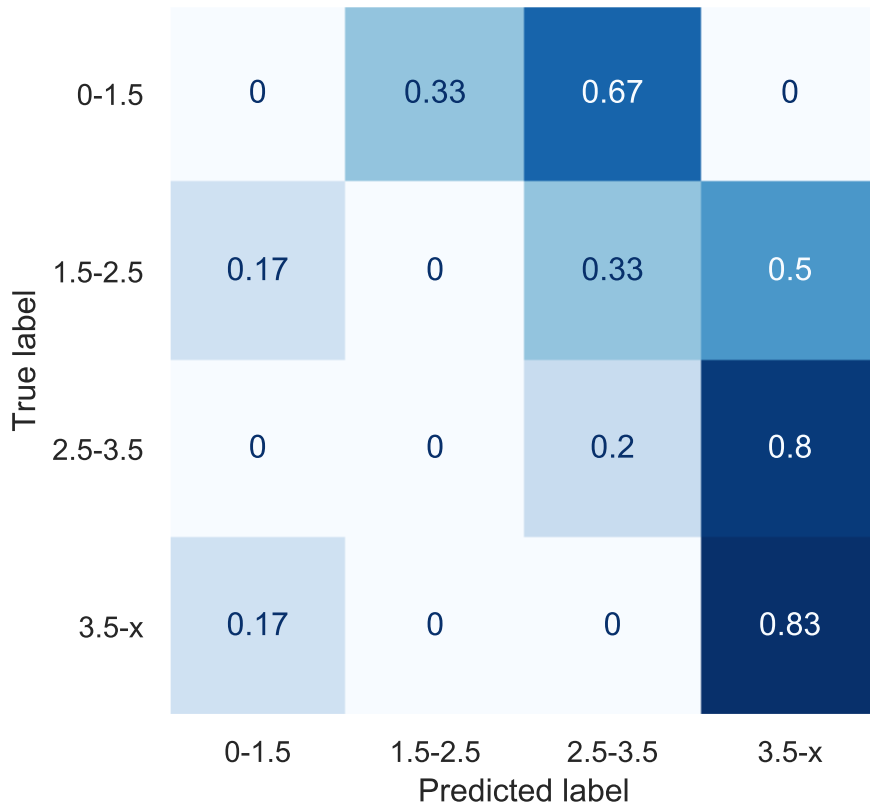
RANGE WINDOW: 60 s

Confusion matrix Recv: Motorola Trans: S706 Method: All\_with\_PL



RANGE WINDOW: 60 s

Confusion matrix Recv: Motorola Trans: S706 Method: method 4

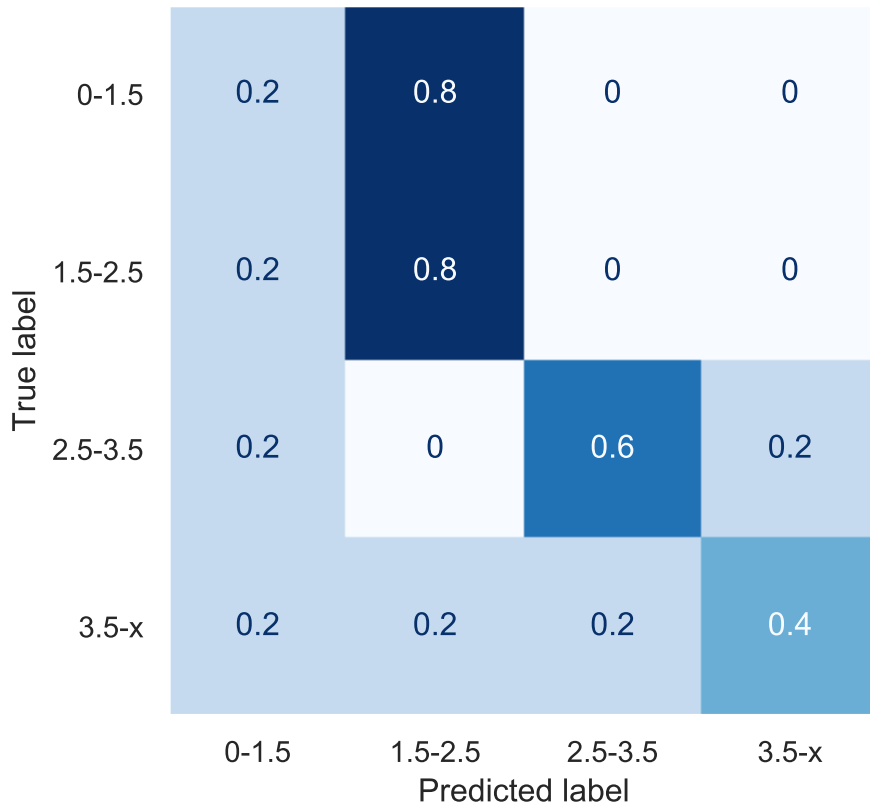


RANGE WINDOW: 60 s  
RSS Recv: SamsungA6 Trans: S706



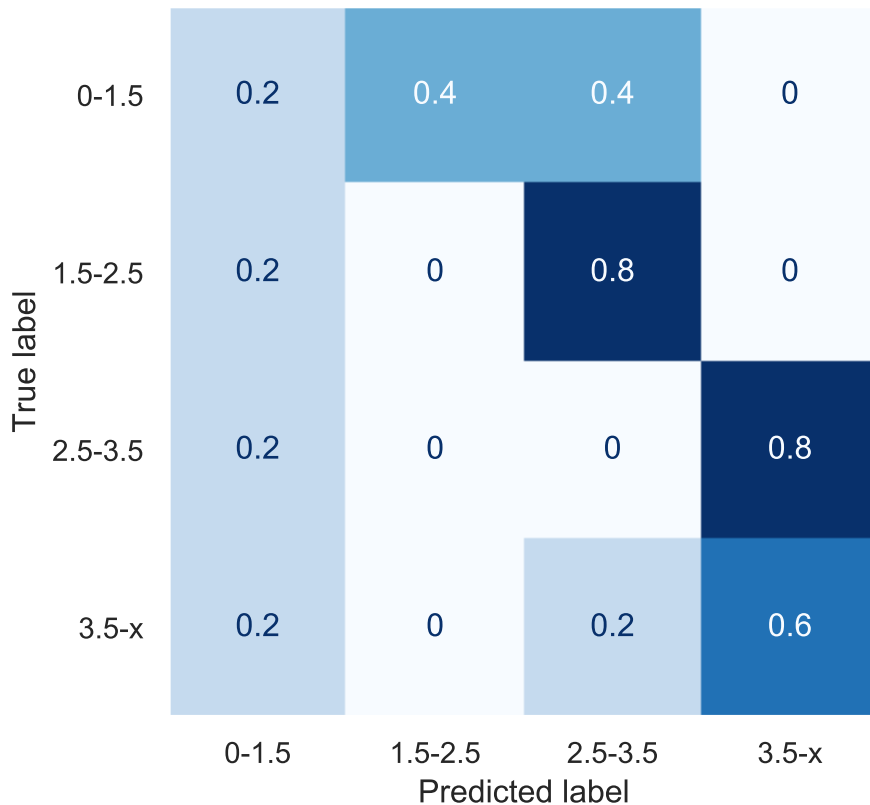
RANGE WINDOW: 60 s

Confusion matrix Recv: SamsungA6 Trans: S706 Method: 1meter



RANGE WINDOW: 60 s

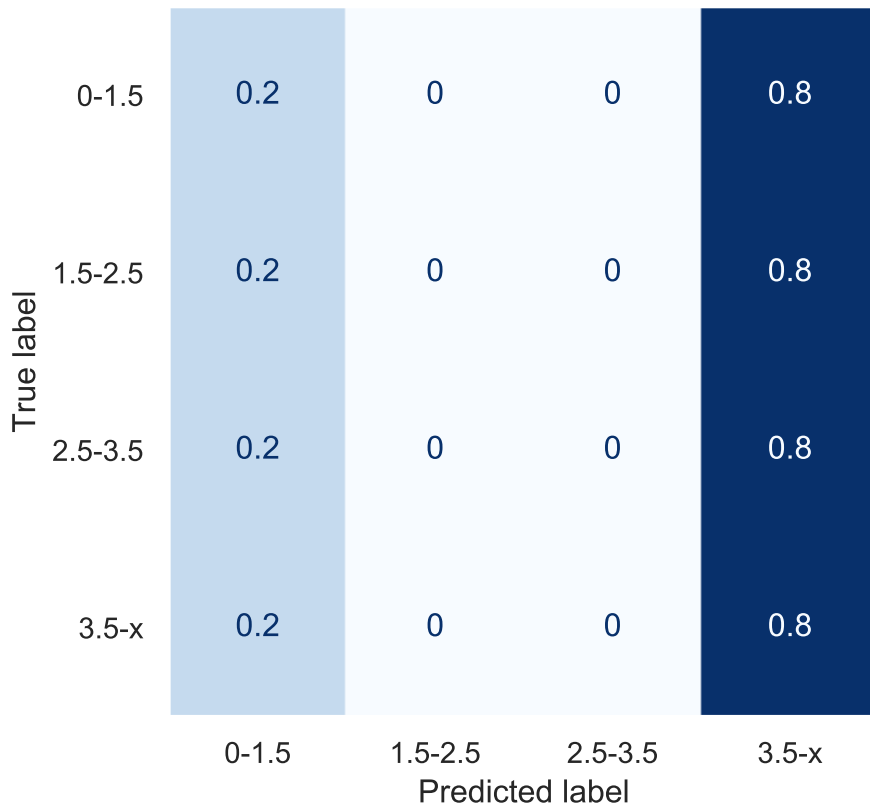
Confusion matrix Recv: SamsungA6 Trans: S706 Method: All\_without\_PL





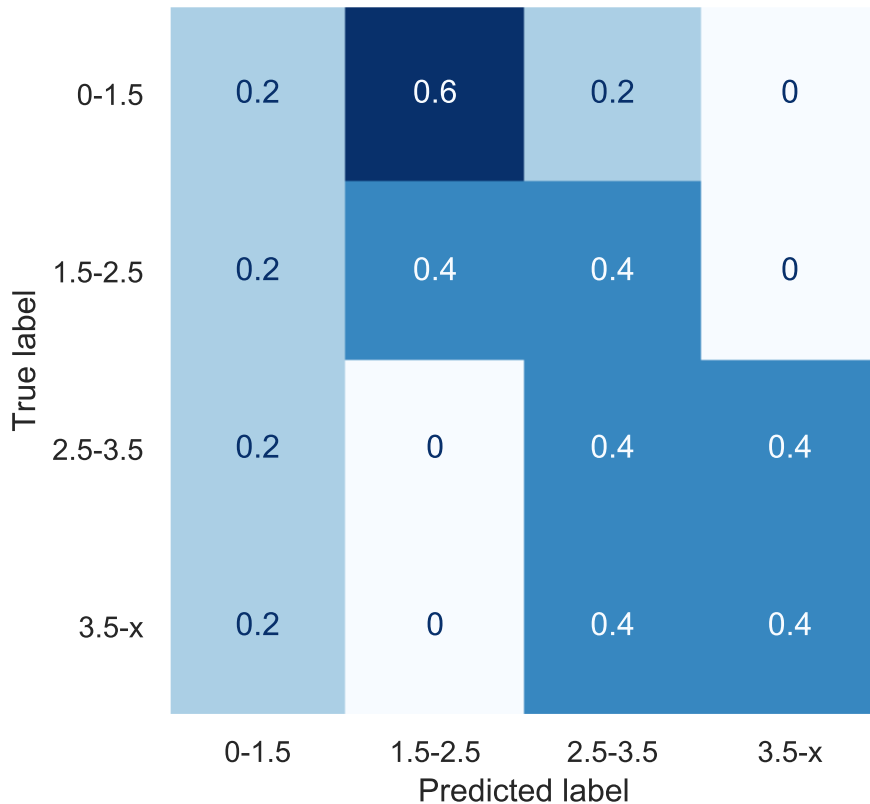
RANGE WINDOW: 60 s

Confusion matrix Recv: SamsungA6 Trans: S706 Method: All\_with\_PL

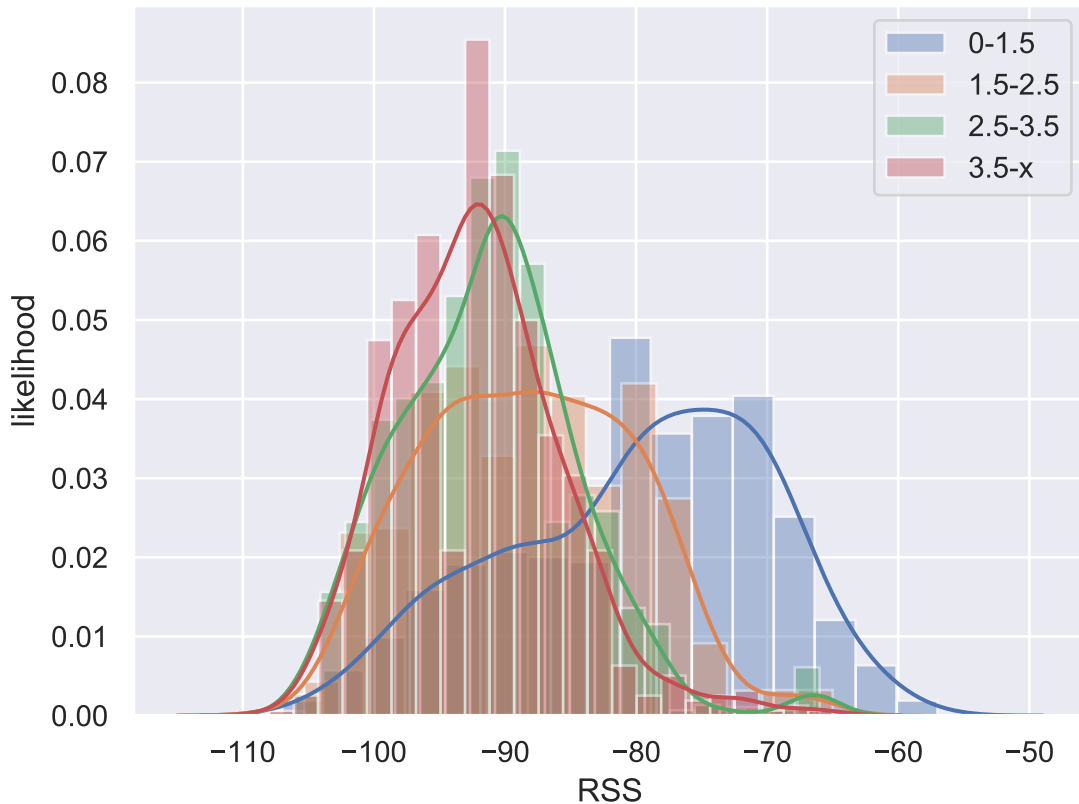


RANGE WINDOW: 60 s

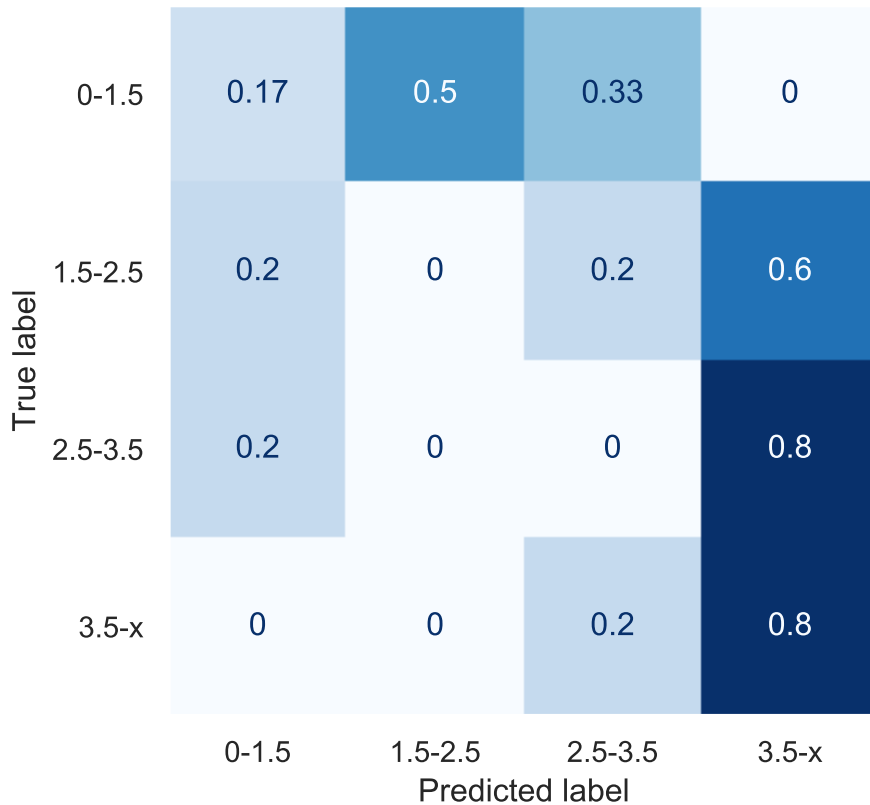
Confusion matrix Recv: SamsungA6 Trans: S706 Method: method 4



RANGE WINDOW: 60 s  
RSS Recv: S708 Trans: S706

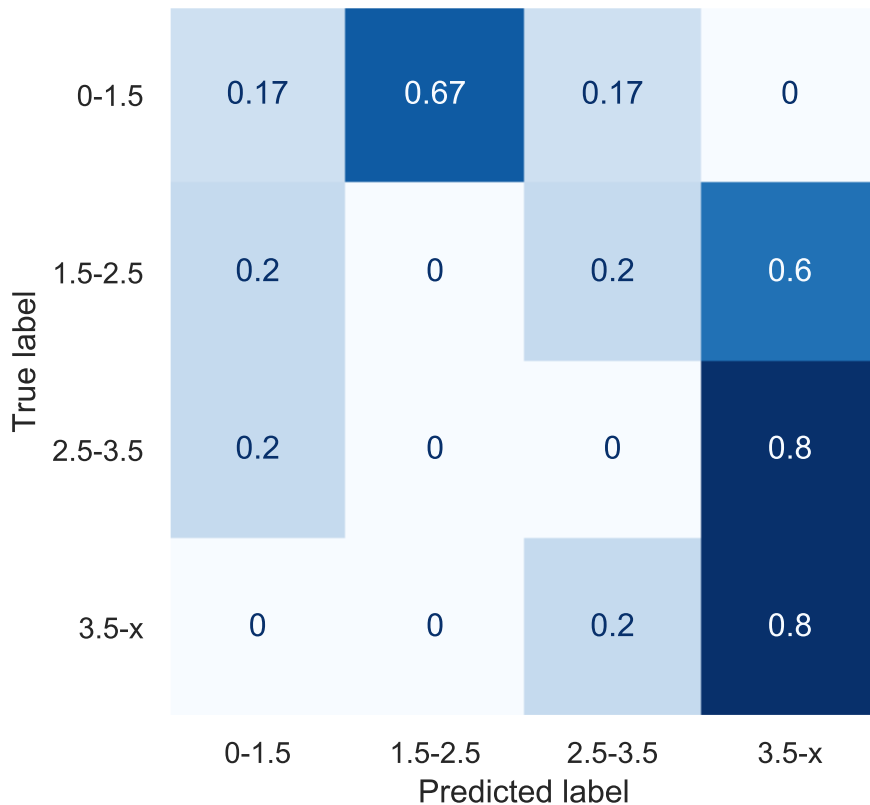


RANGE WINDOW: 60 s  
Confusion matrix Recv: S708 Trans: S706 Method: 1meter



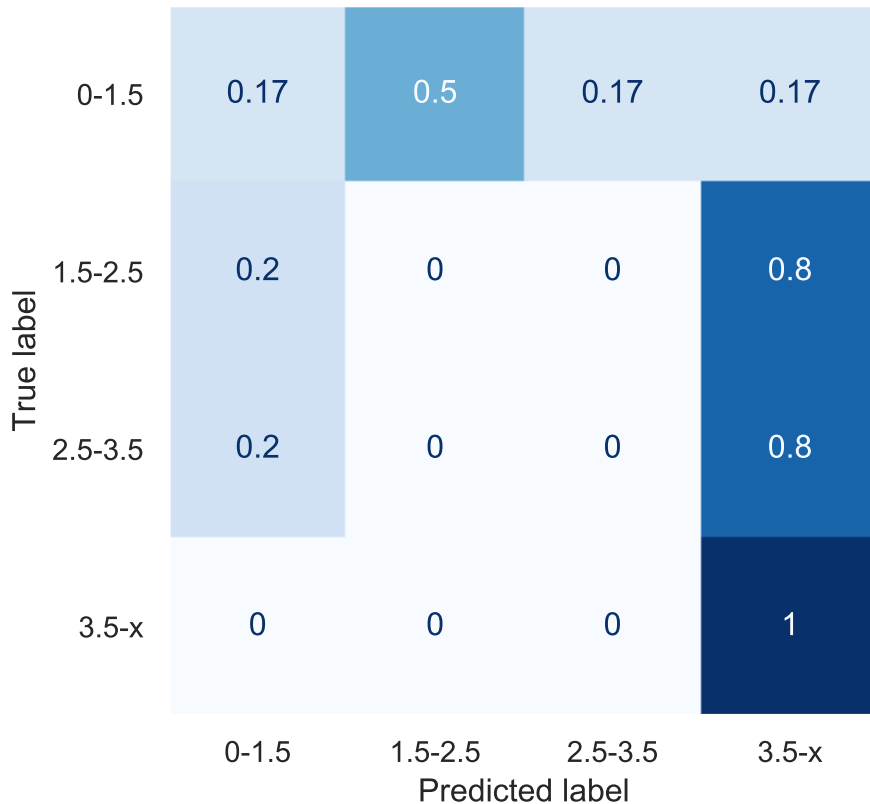
RANGE WINDOW: 60 s

Confusion matrix Recv: S708 Trans: S706 Method: All\_without\_PL



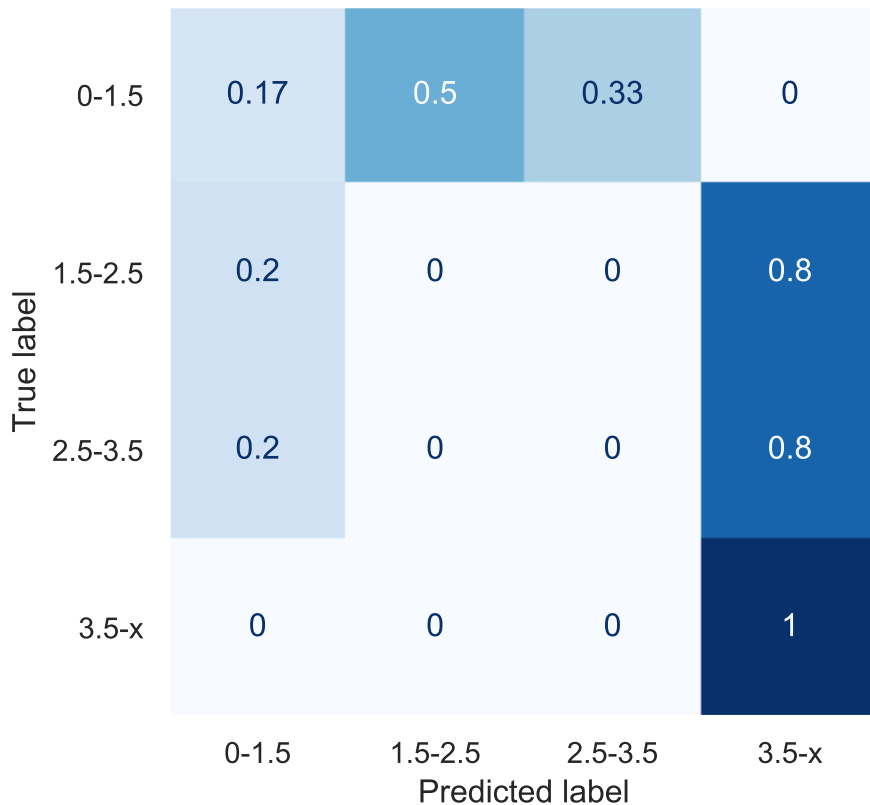
RANGE WINDOW: 60 s

Confusion matrix Recv: S708 Trans: S706 Method: All\_with\_PL

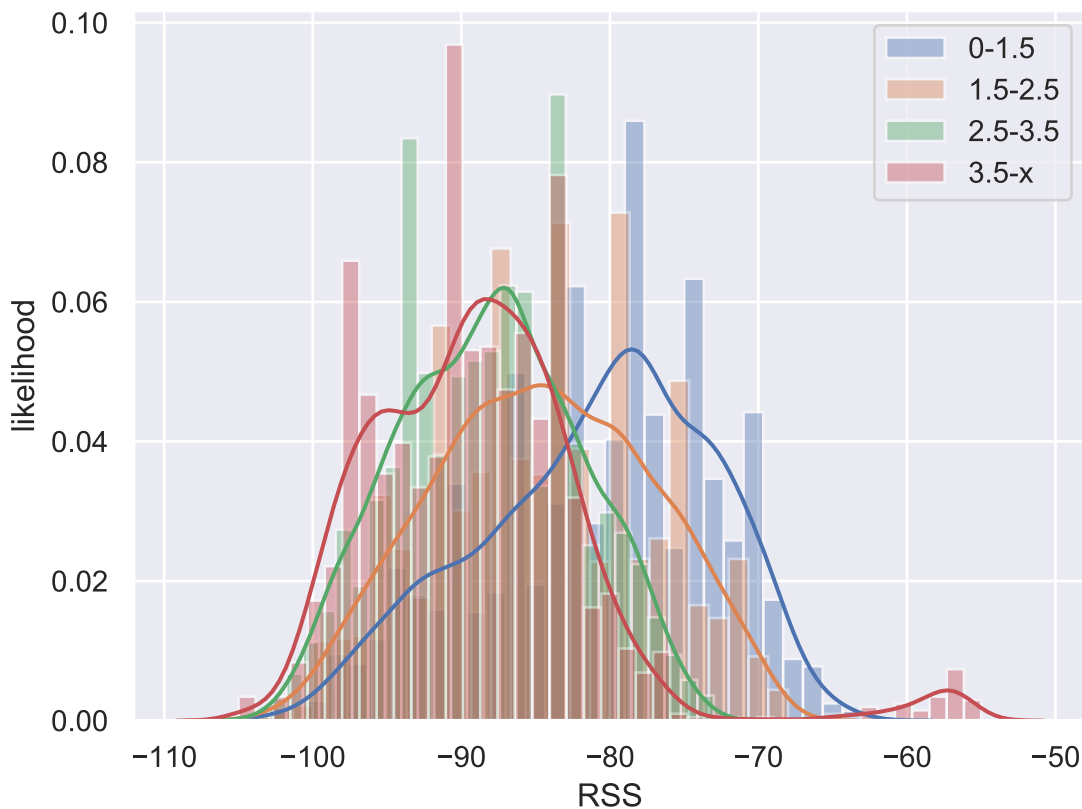


RANGE WINDOW: 60 s

Confusion matrix Recv: S708 Trans: S706 Method: method 4



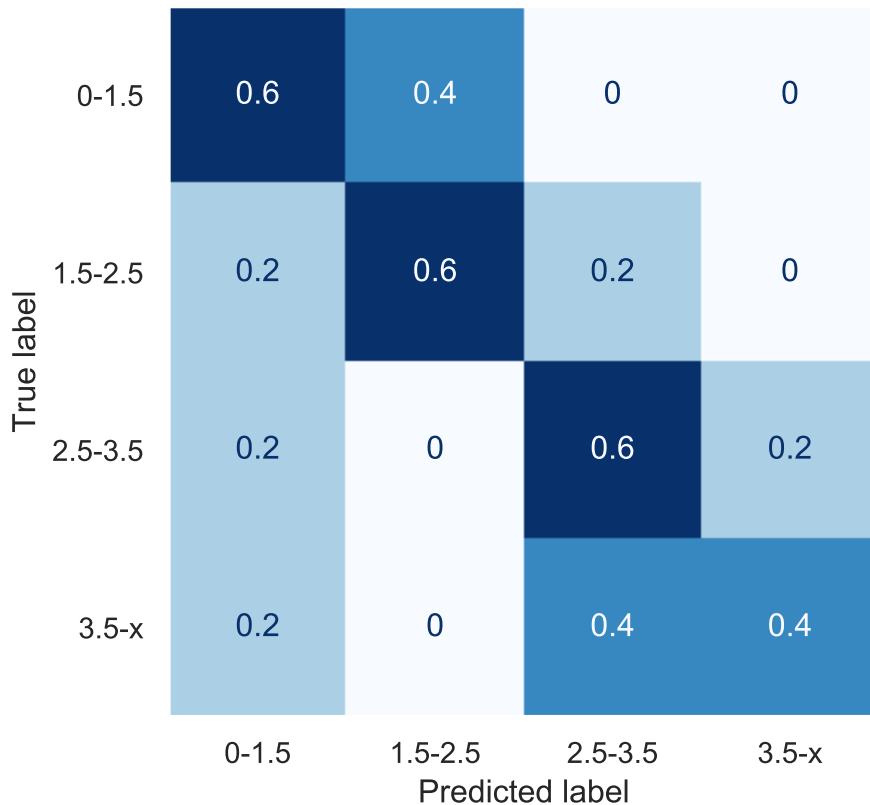
RANGE WINDOW: 60 s  
RSS Recv: S706 Trans: Motorola





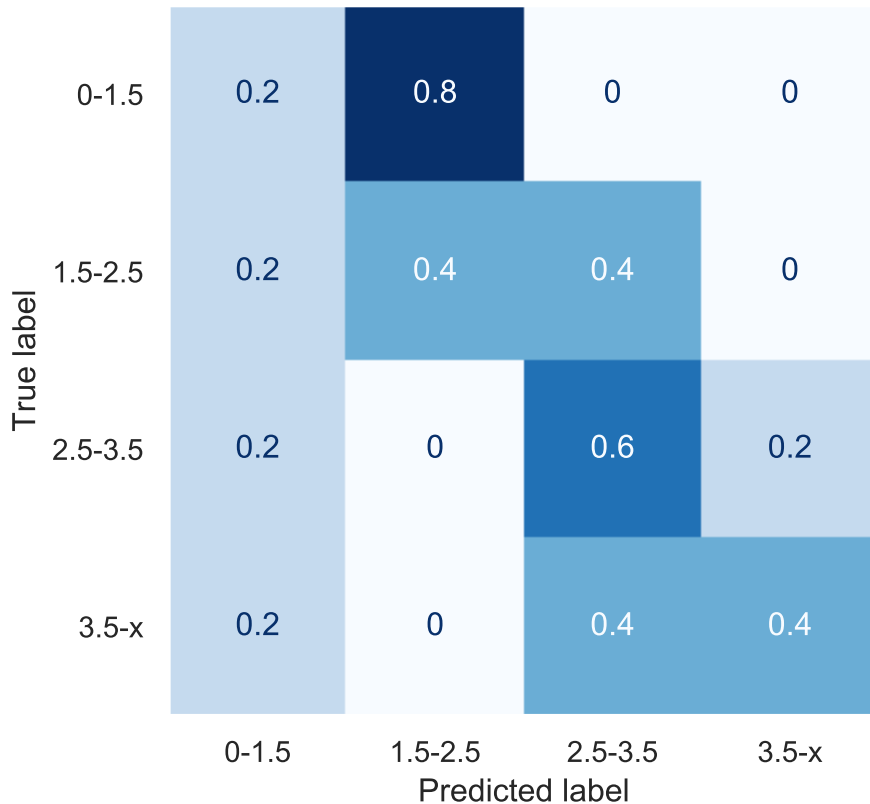
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Confusion matrix Recv: S706 Trans: Motorola Method: 1meter



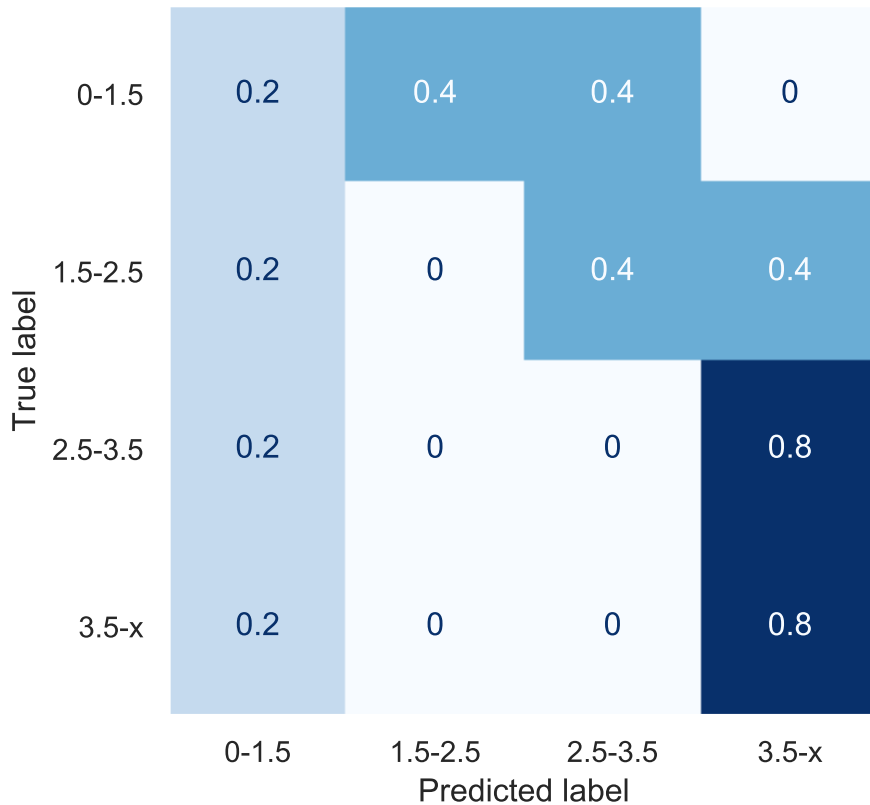
RANGE WINDOW: 60 s

Confusion matrix Recv: S706 Trans: Motorola Method: All\_without\_PL



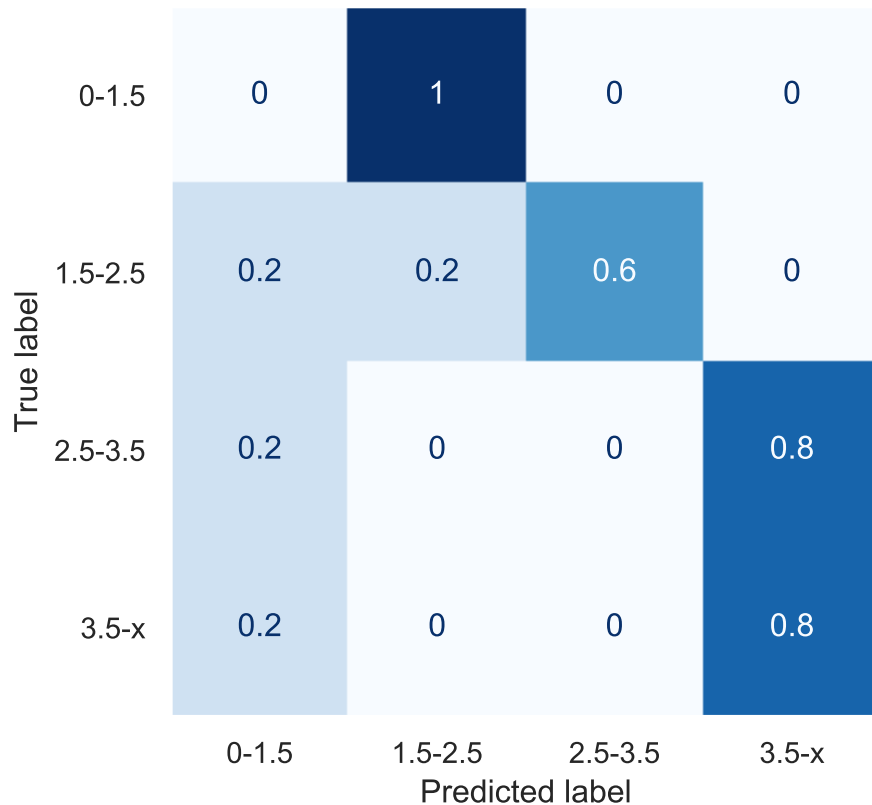
RANGE WINDOW: 60 s

Confusion matrix Recv: S706 Trans: Motorola Method: All\_with\_PL

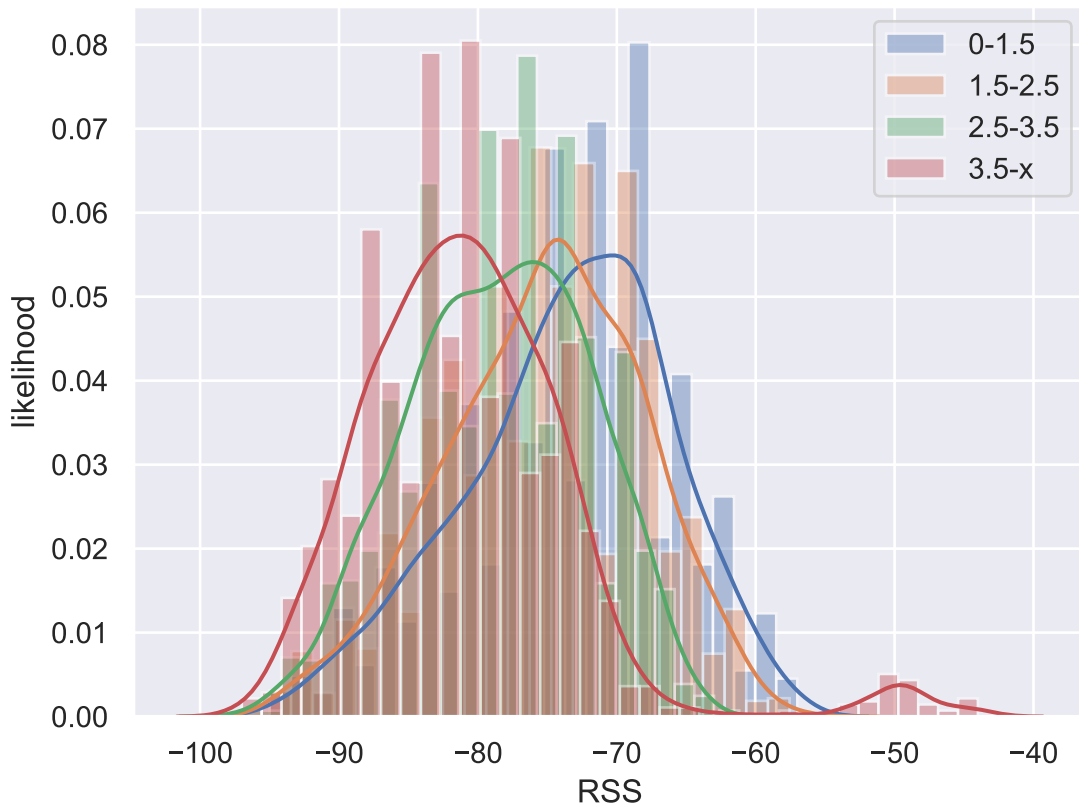


RANGE WINDOW: 60 s

Confusion matrix Recv: S706 Trans: Motorola Method: method 4

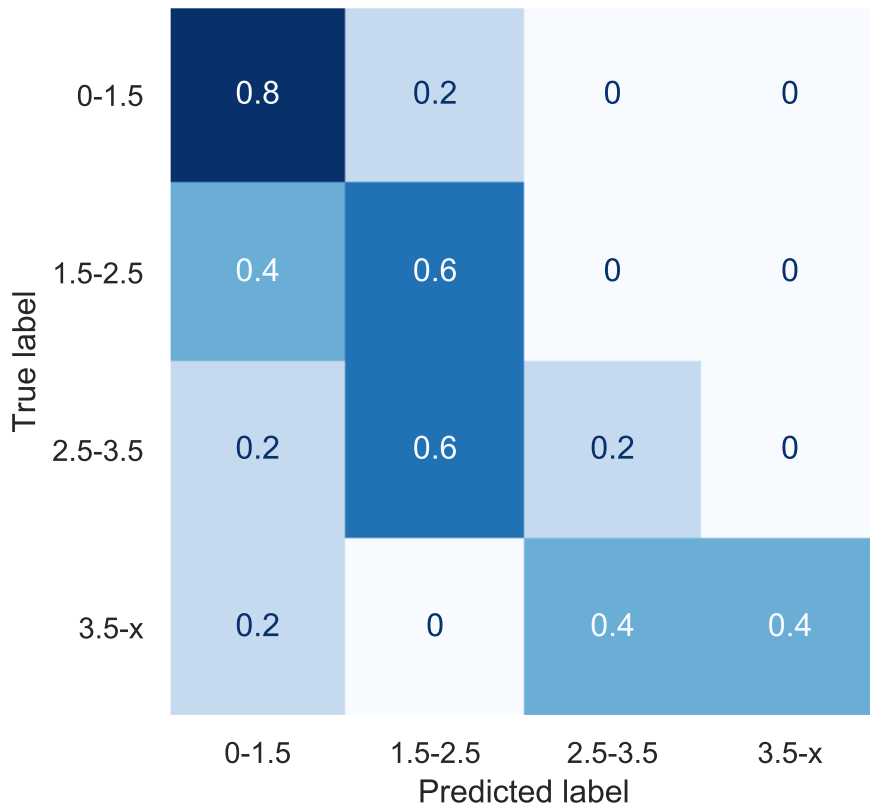


RANGE WINDOW: 60 s  
RSS Recv: Nexus Trans: Motorola



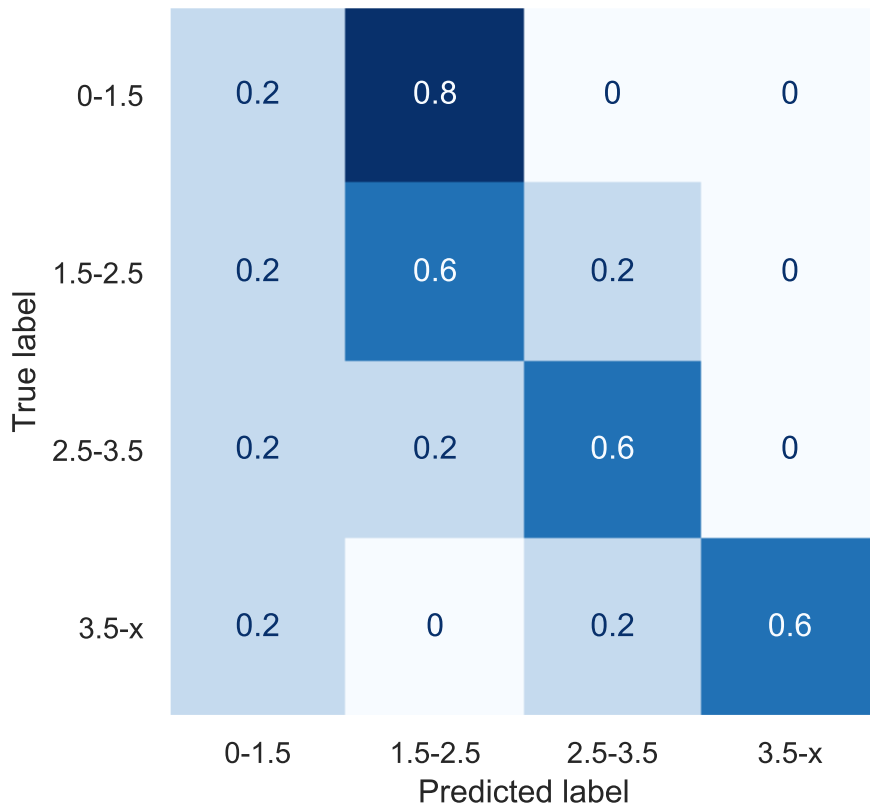
RANGE WINDOW: 60 s

Confusion matrix Recv: Nexus Trans: Motorola Method: 1meter



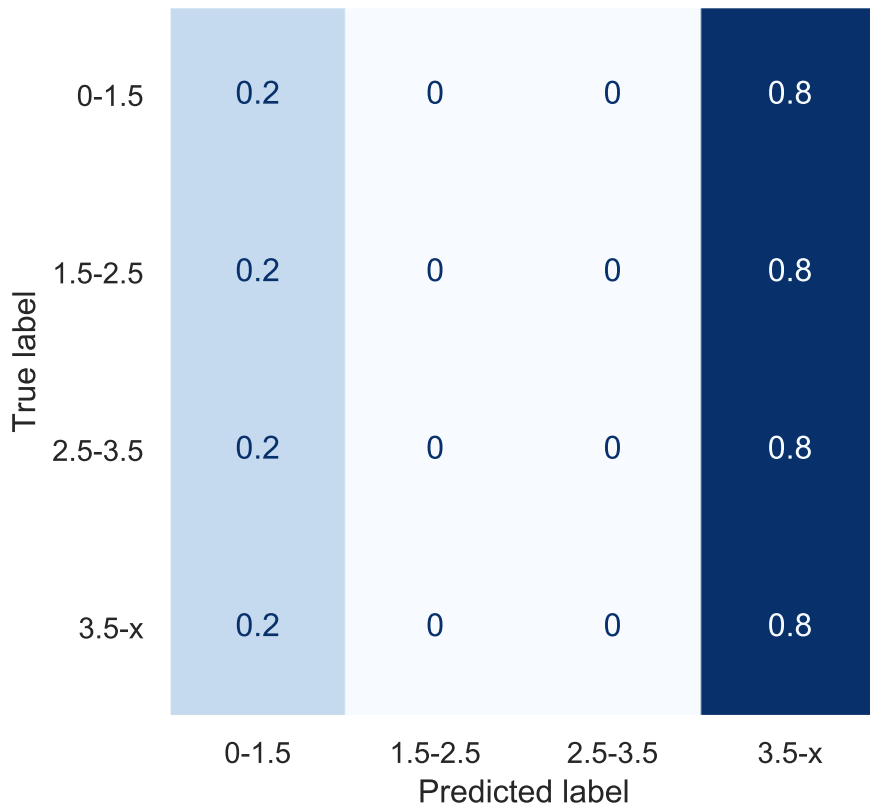
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Confusion matrix Recv: Nexus Trans: Motorola Method: All\_without\_PL



RANGE WINDOW: 60 s

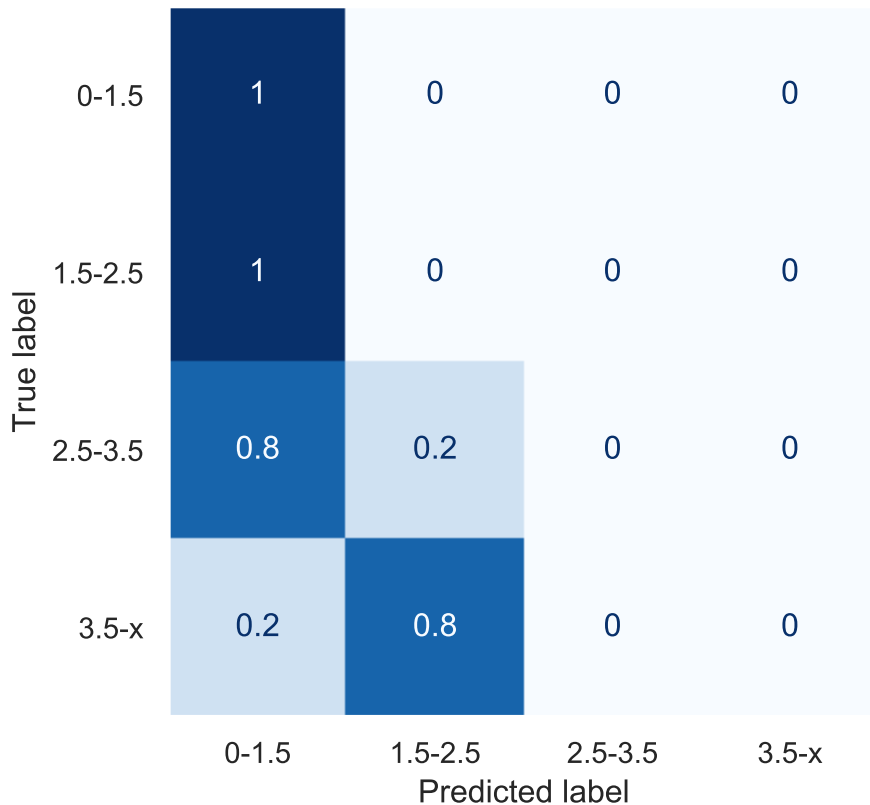
Confusion matrix Recv: Nexus Trans: Motorola Method: All\_with\_PL



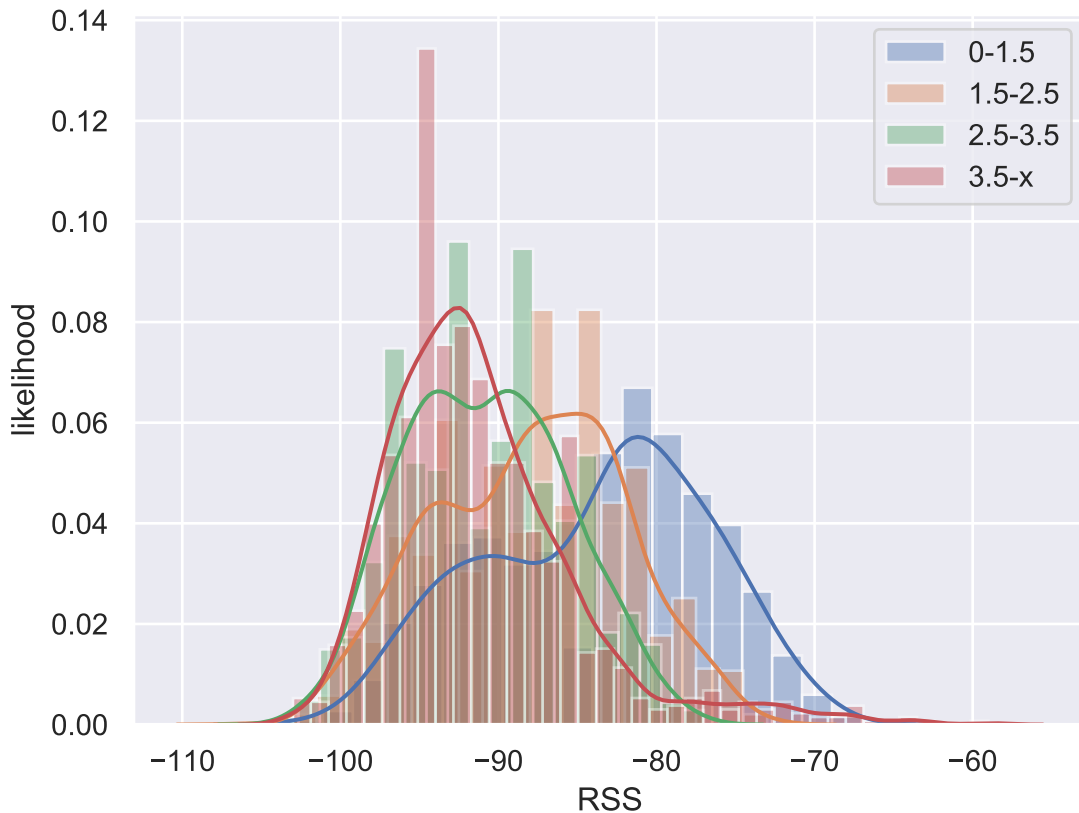


RANGE WINDOW: 60 s

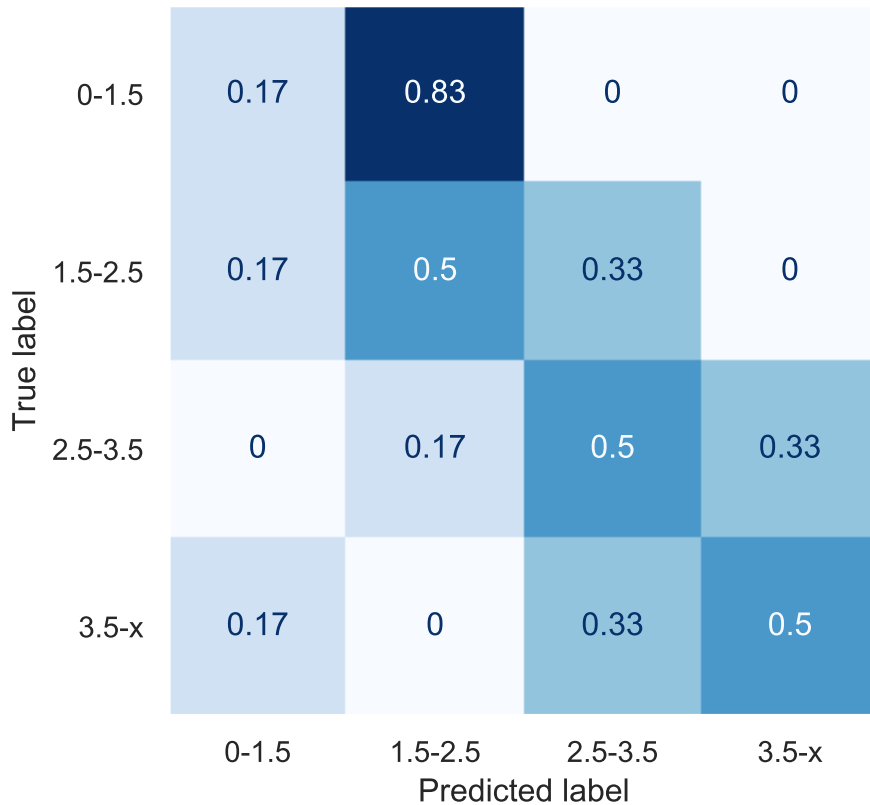
Confusion matrix Recv: Nexus Trans: Motorola Method: method 4



RANGE WINDOW: 60 s  
RSS Recv: S8 Trans: Motorola

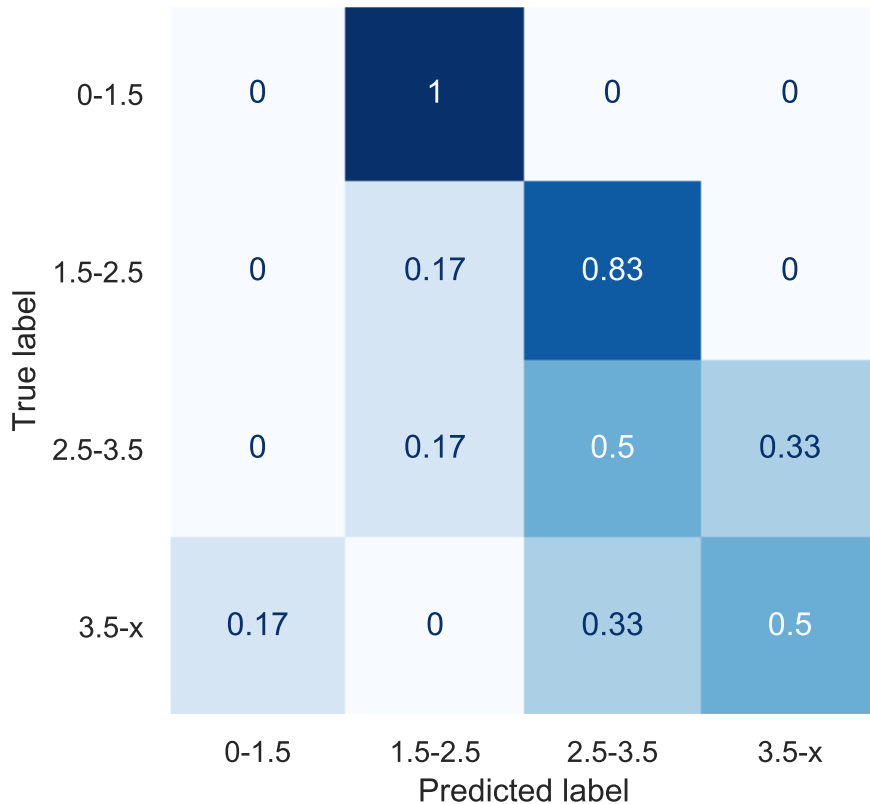


RANGE WINDOW: 60 s  
Confusion matrix Recv: S8 Trans: Motorola Method: 1meter



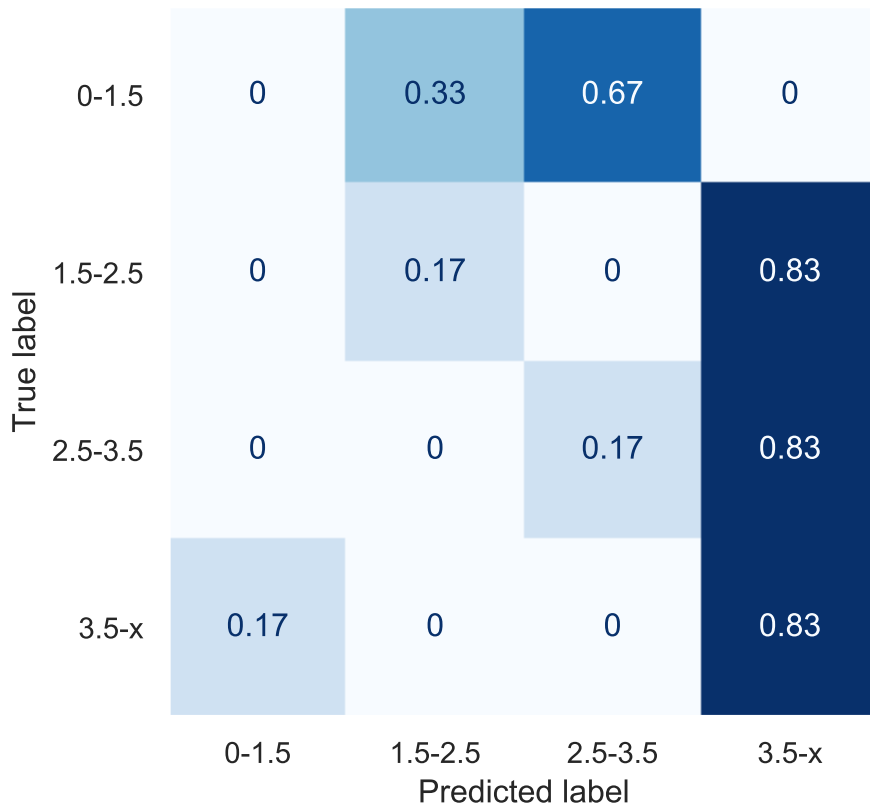
RANGE WINDOW: 60 s

Confusion matrix Recv: S8 Trans: Motorola Method: All\_without\_PL

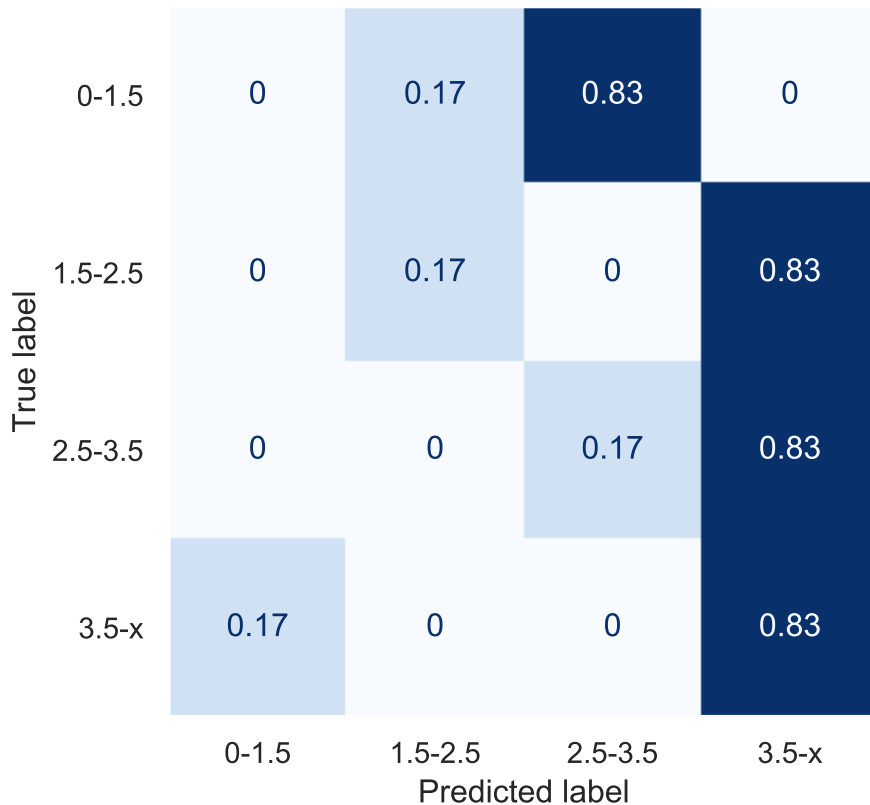


RANGE WINDOW: 60 s

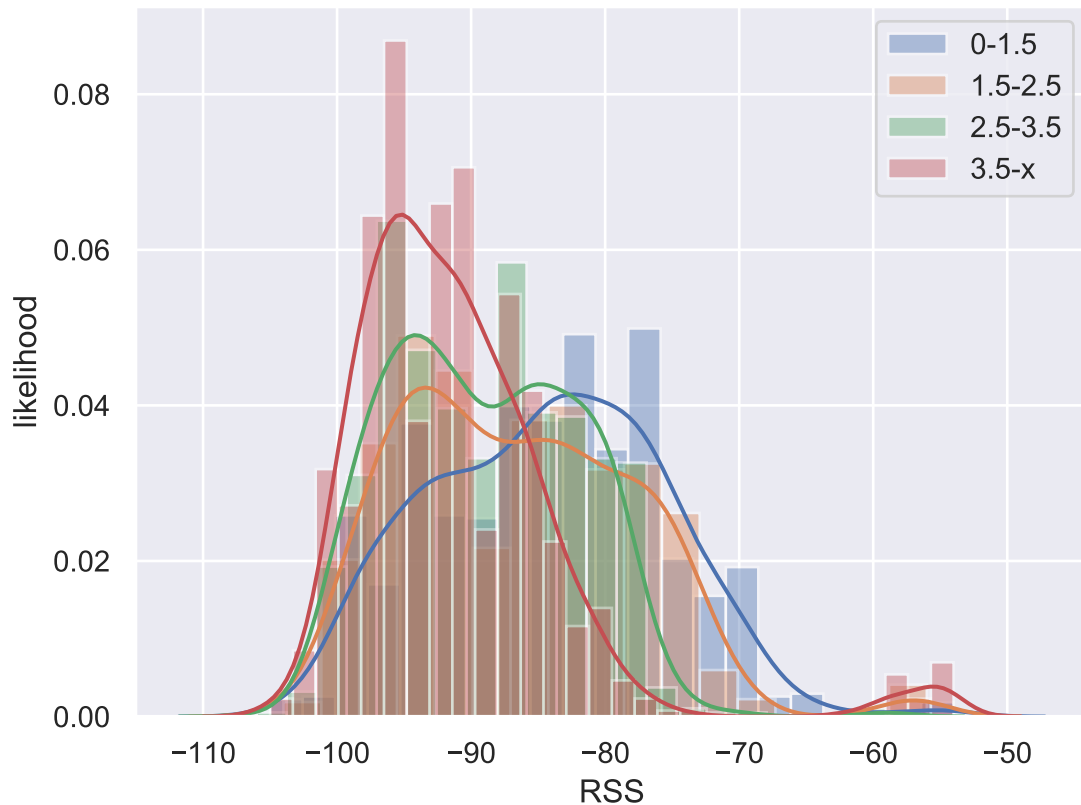
Confusion matrix Recv: S8 Trans: Motorola Method: All\_with\_PL



RANGE WINDOW: 60 s  
Confusion matrix Recv: S8 Trans: Motorola Method: method 4

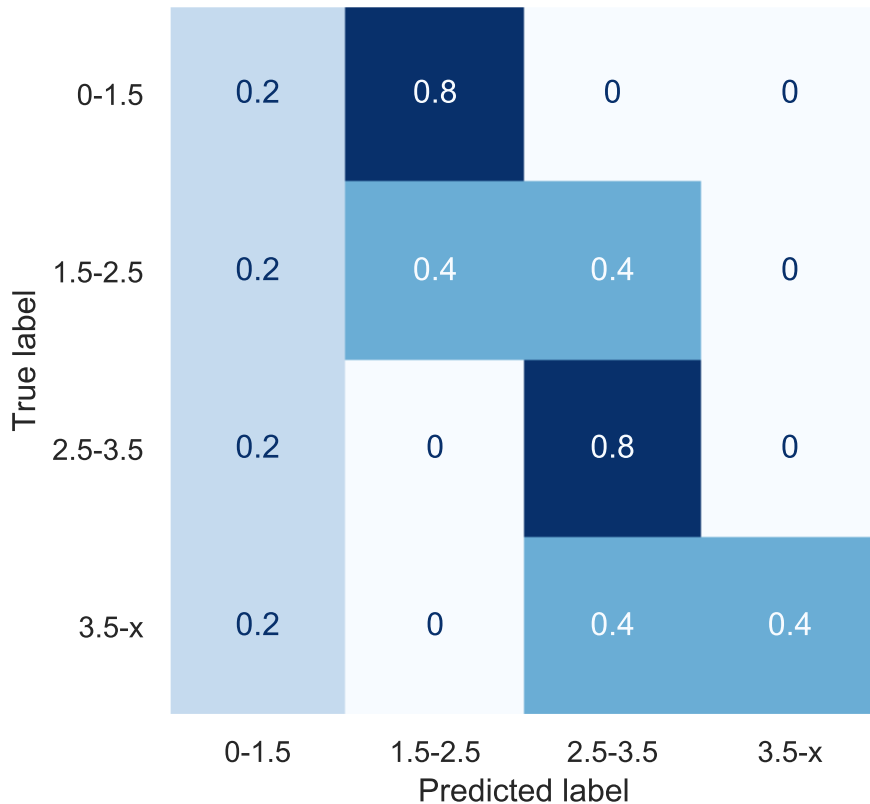


RANGE WINDOW: 60 s  
RSS Recv: S706 Trans: SamsungA6



RANGE WINDOW: 60 s

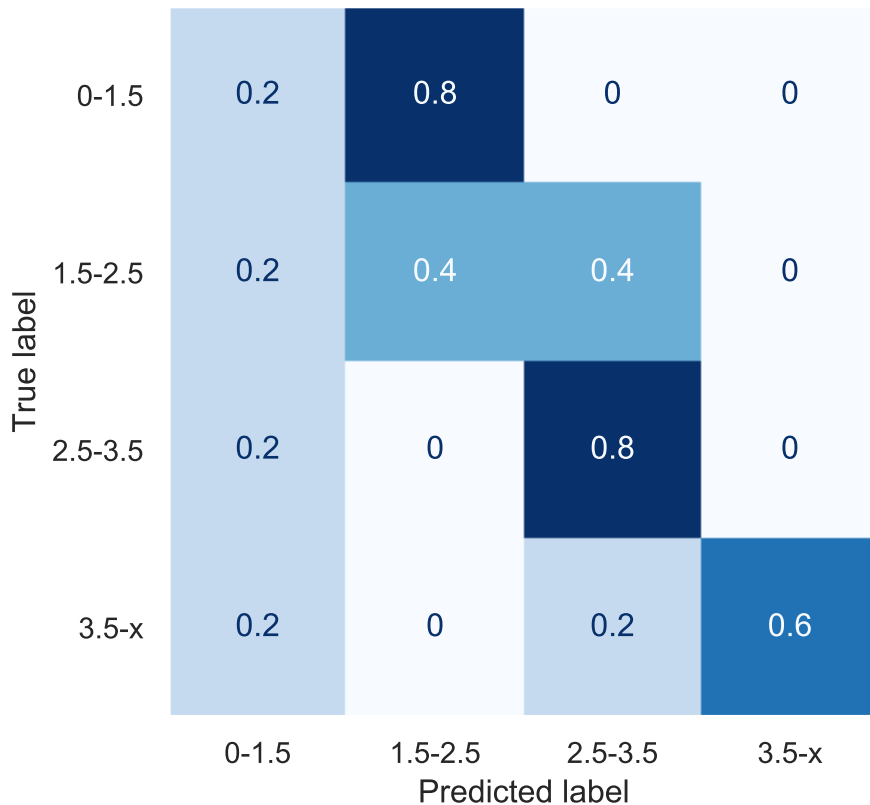
Confusion matrix Recv: S706 Trans: SamsungA6 Method: 1meter





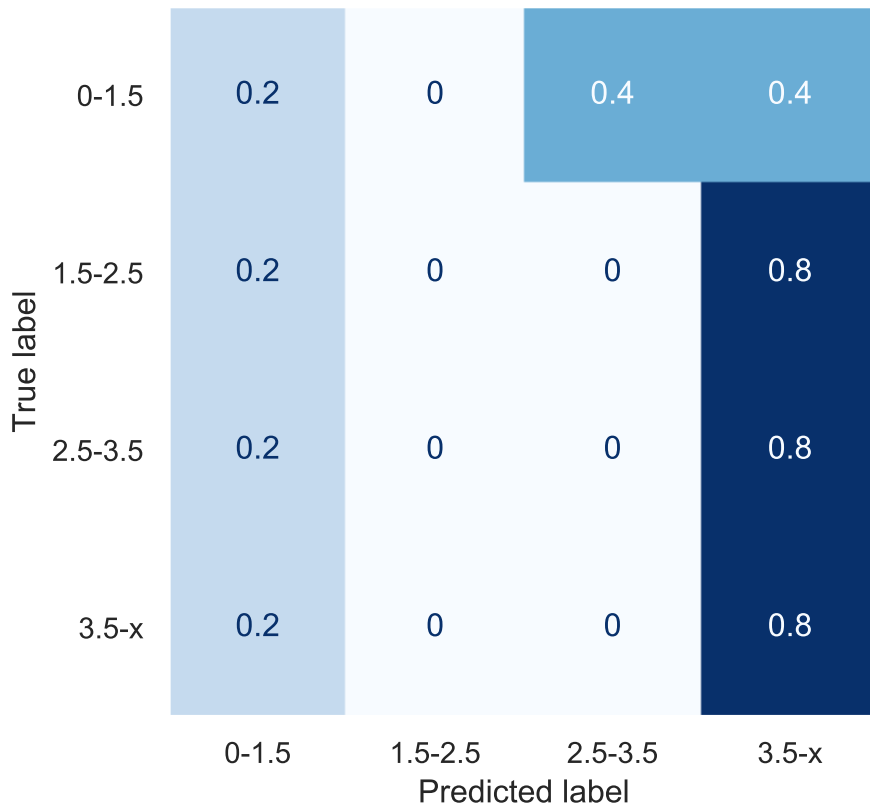
RANGE WINDOW: 60 s

Confusion matrix Recv: S706 Trans: SamsungA6 Method: All\_without\_PL



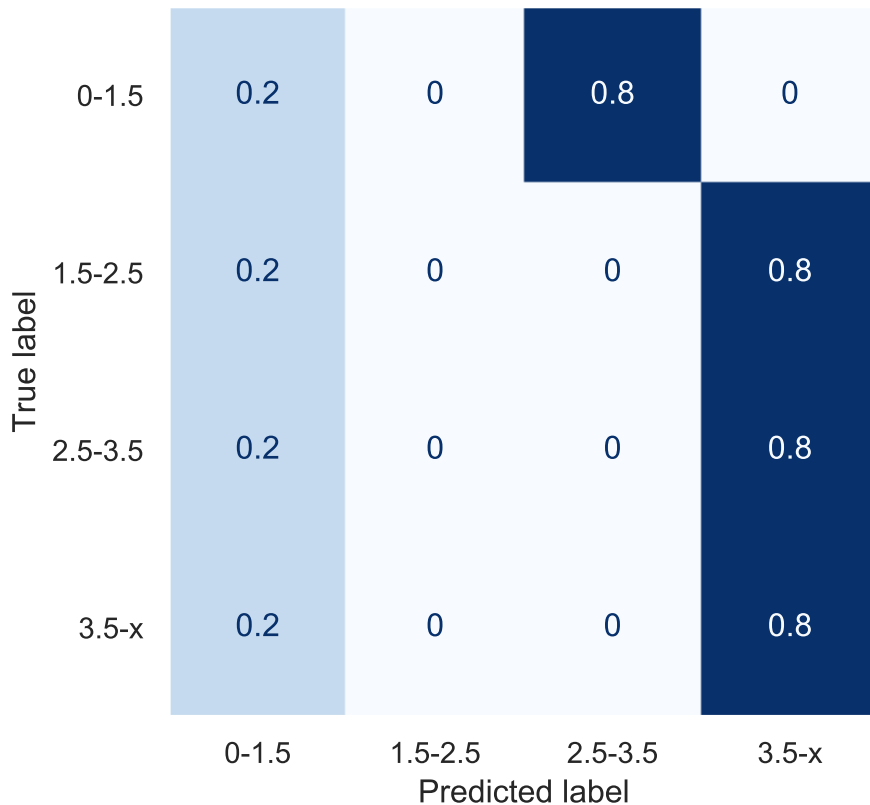
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Confusion matrix Recv: S706 Trans: SamsungA6 Method: All\_with\_PL

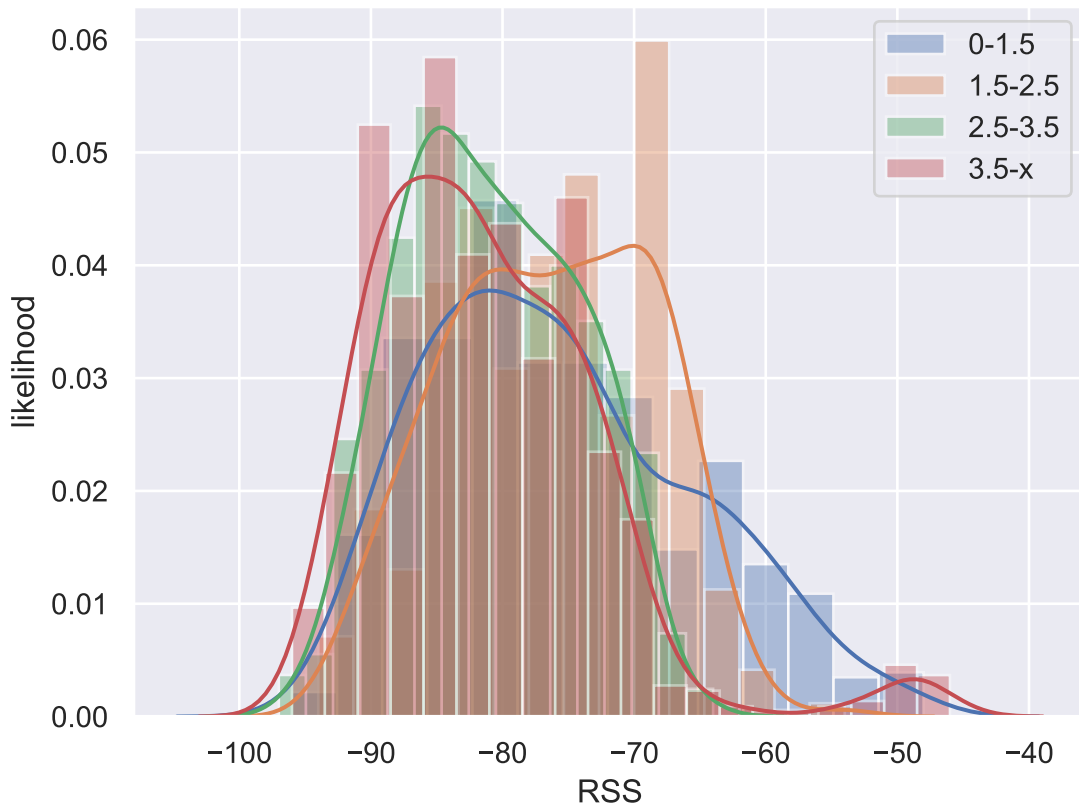


RANGE WINDOW: 60 s

Confusion matrix Recv: S706 Trans: SamsungA6 Method: method 4

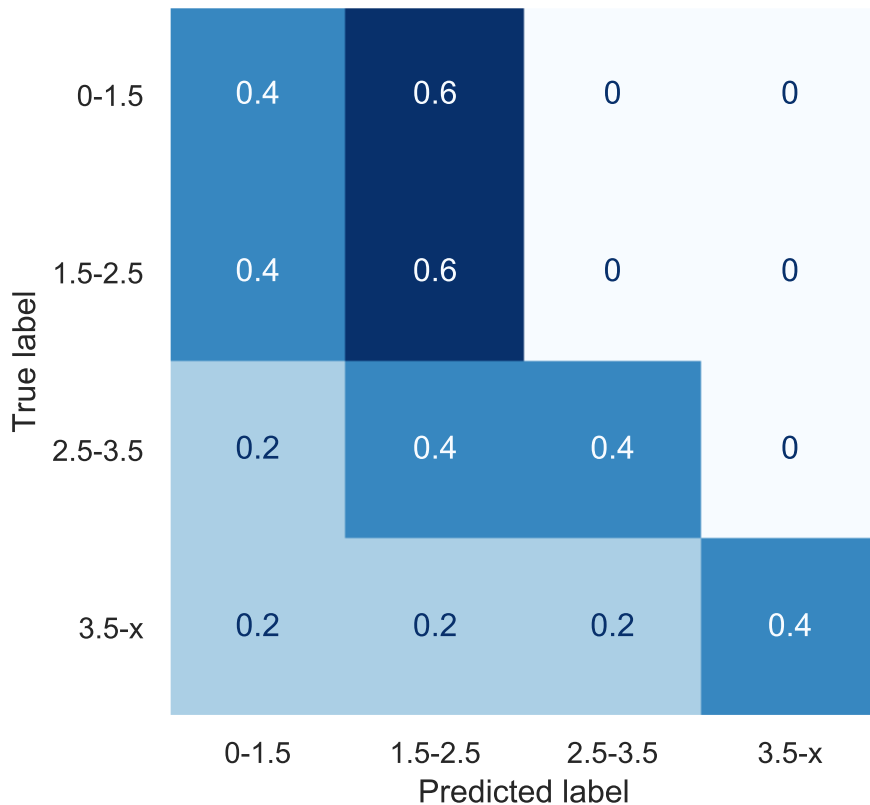


RANGE WINDOW: 60 s  
RSS Recv: Nexus Trans: SamsungA6



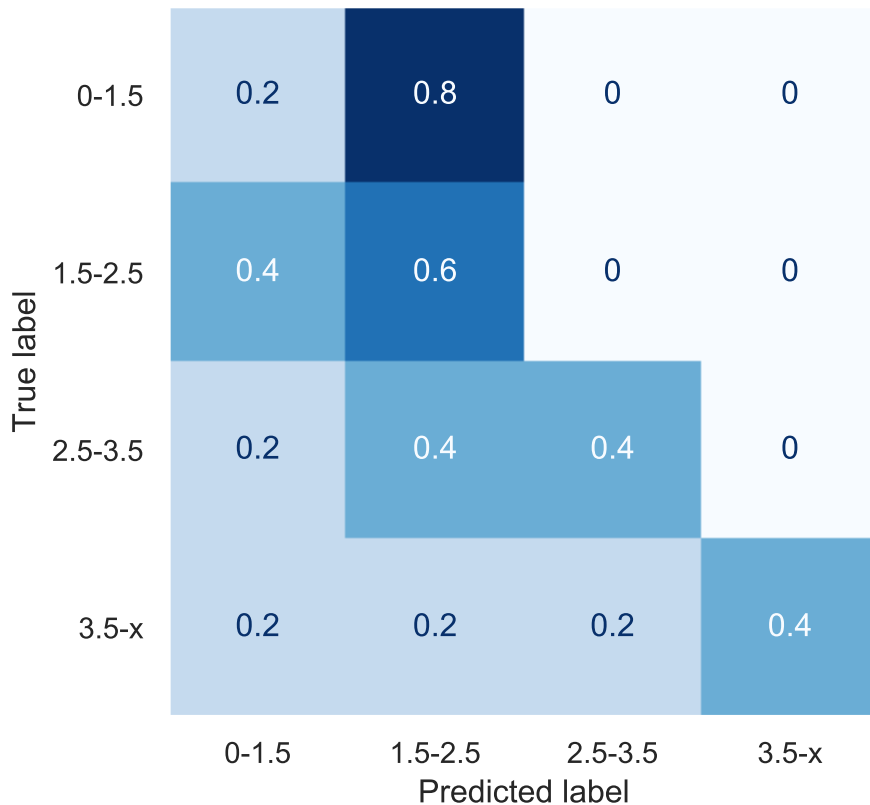
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Confusion matrix Recv: Nexus Trans: SamsungA6 Method: 1meter



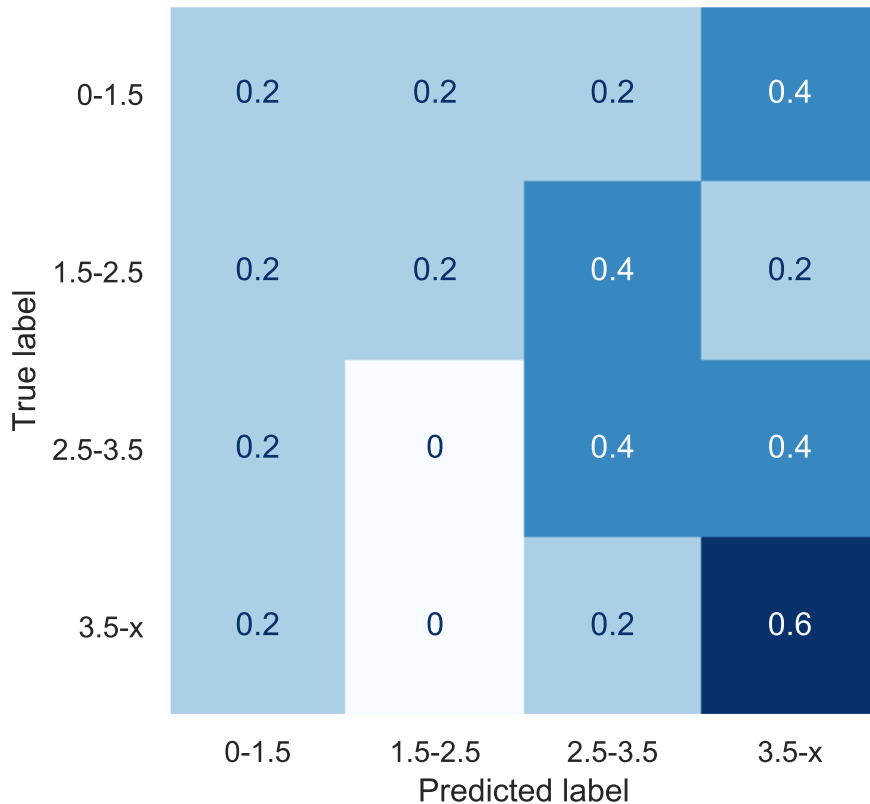
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Confusion matrix Recv: Nexus Trans: SamsungA6 Method: All\_without\_PL



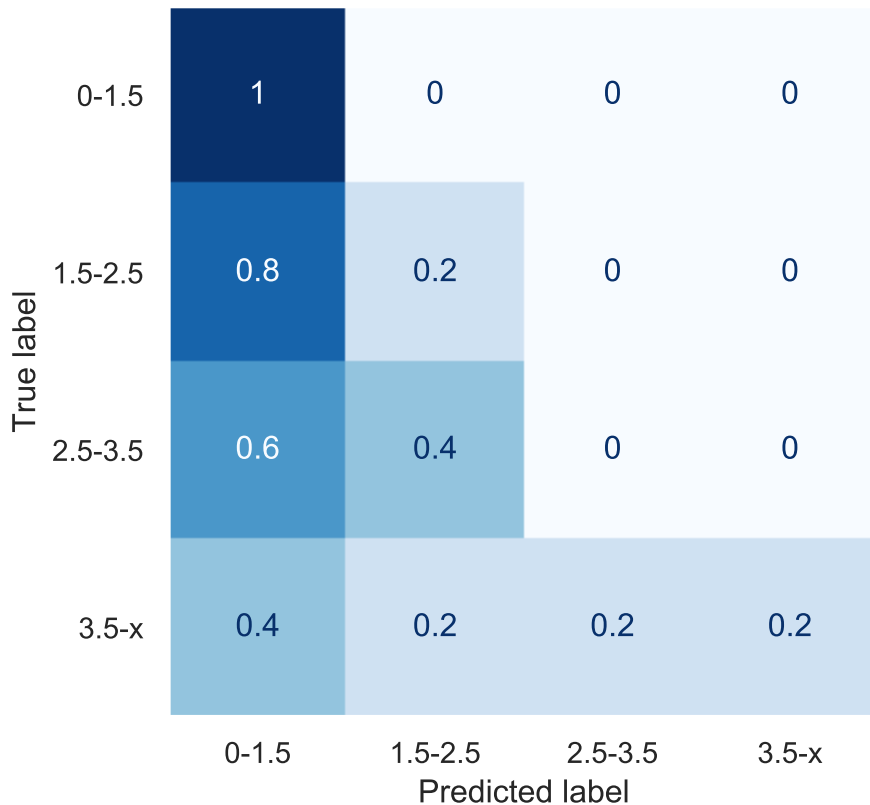
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Confusion matrix Recv: Nexus Trans: SamsungA6 Method: All\_with\_PL



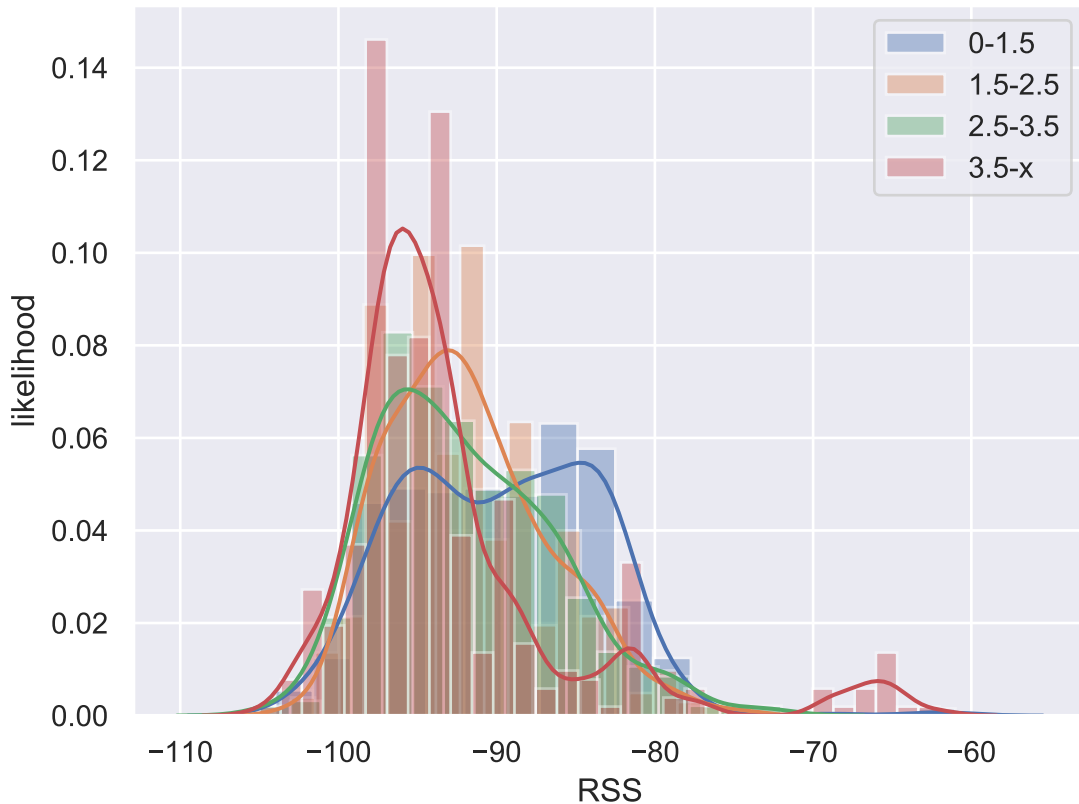
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Confusion matrix Recv: Nexus Trans: SamsungA6 Method: method 4



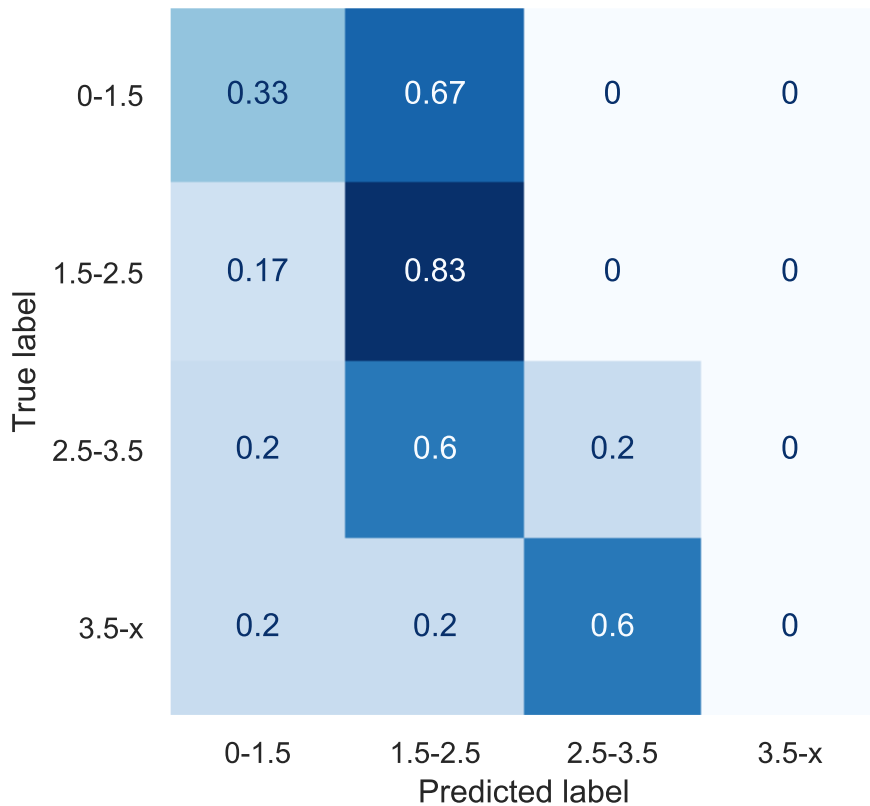


RANGE WINDOW: 60 s  
RSS Recv: S8 Trans: SamsungA6



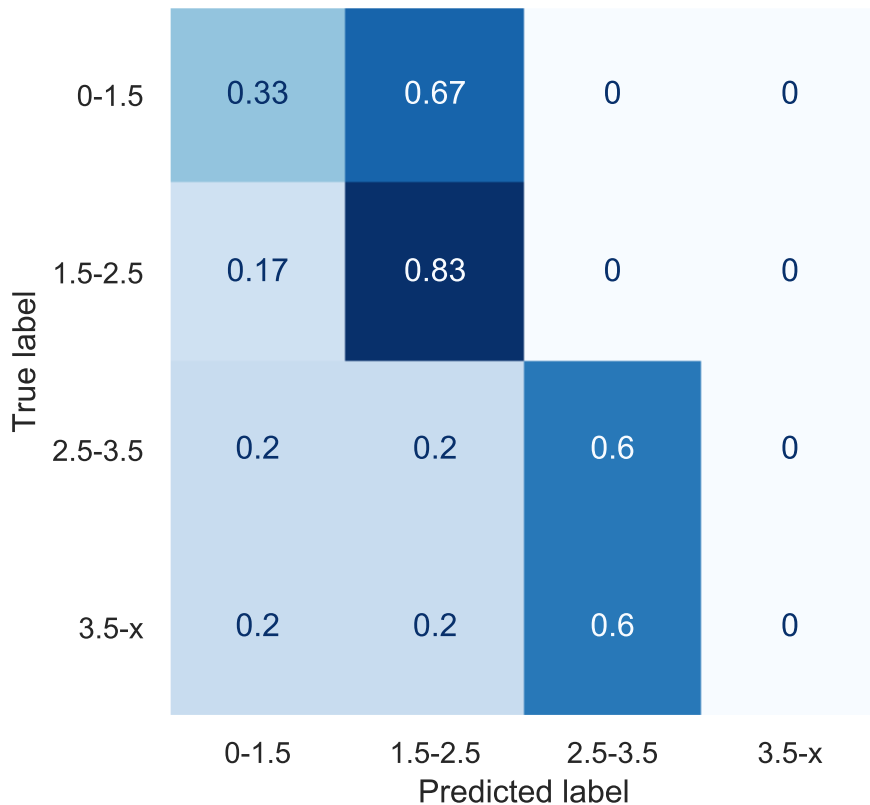
RANGE WINDOW: 60 s

Confusion matrix Recv: S8 Trans: SamsungA6 Method: 1meter



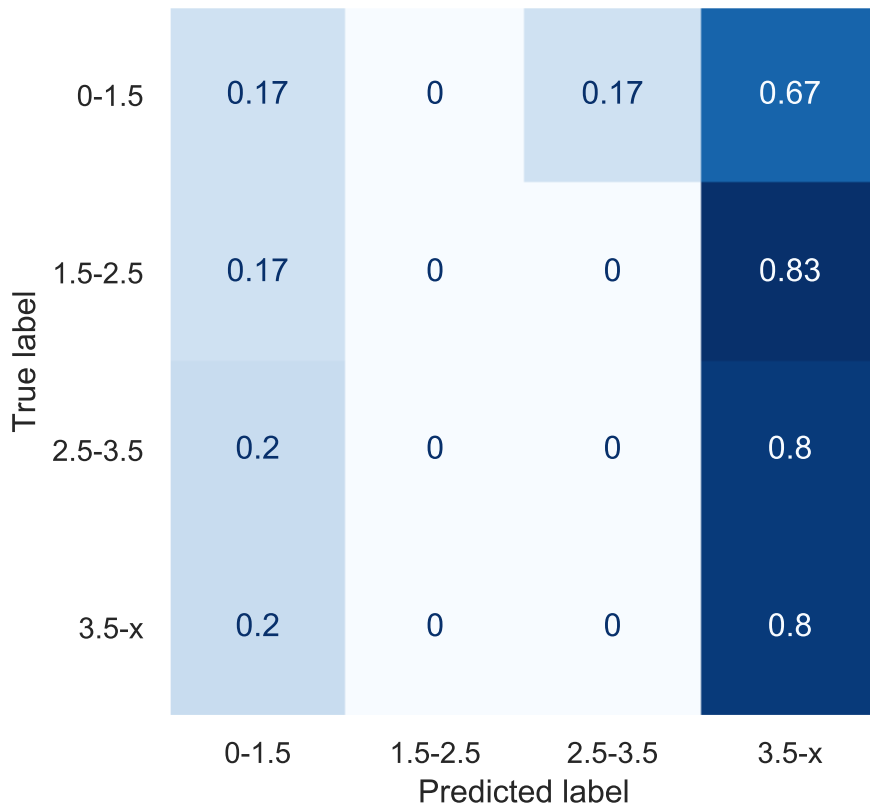
RANGE WINDOW: 60 s

Confusion matrix Recv: S8 Trans: SamsungA6 Method: All\_without\_PL



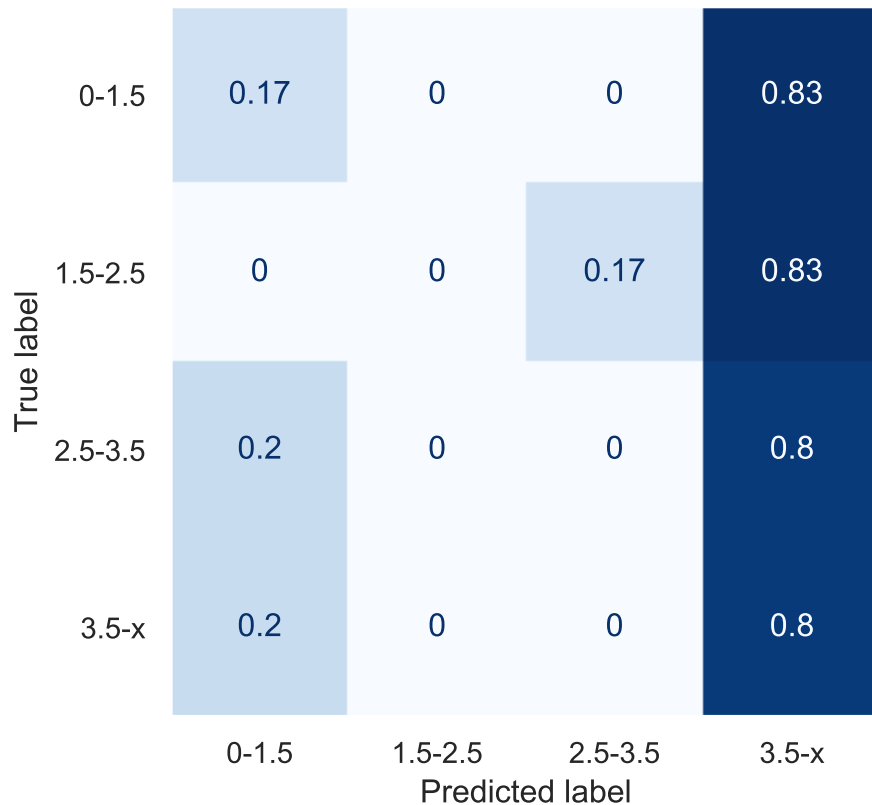
RANGE WINDOW: 60 s

Confusion matrix Recv: S8 Trans: SamsungA6 Method: All\_with\_PL

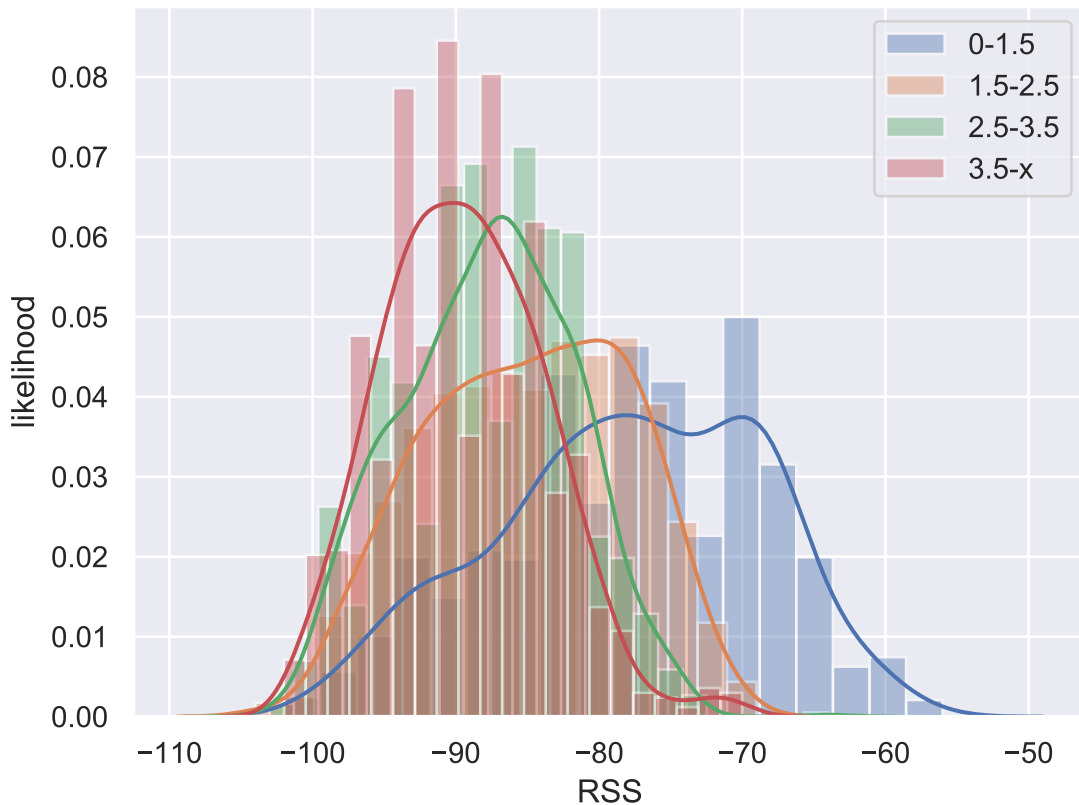


RANGE WINDOW: 60 s

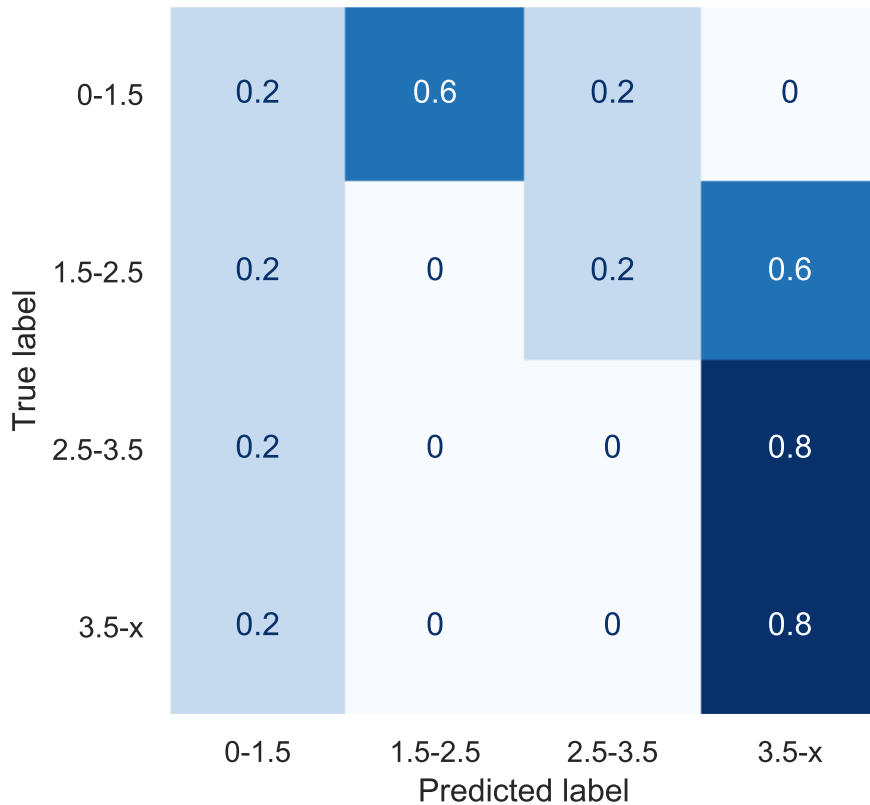
Confusion matrix Recv: S8 Trans: SamsungA6 Method: method 4



RANGE WINDOW: 60 s  
RSS Recv: S706 Trans: S708

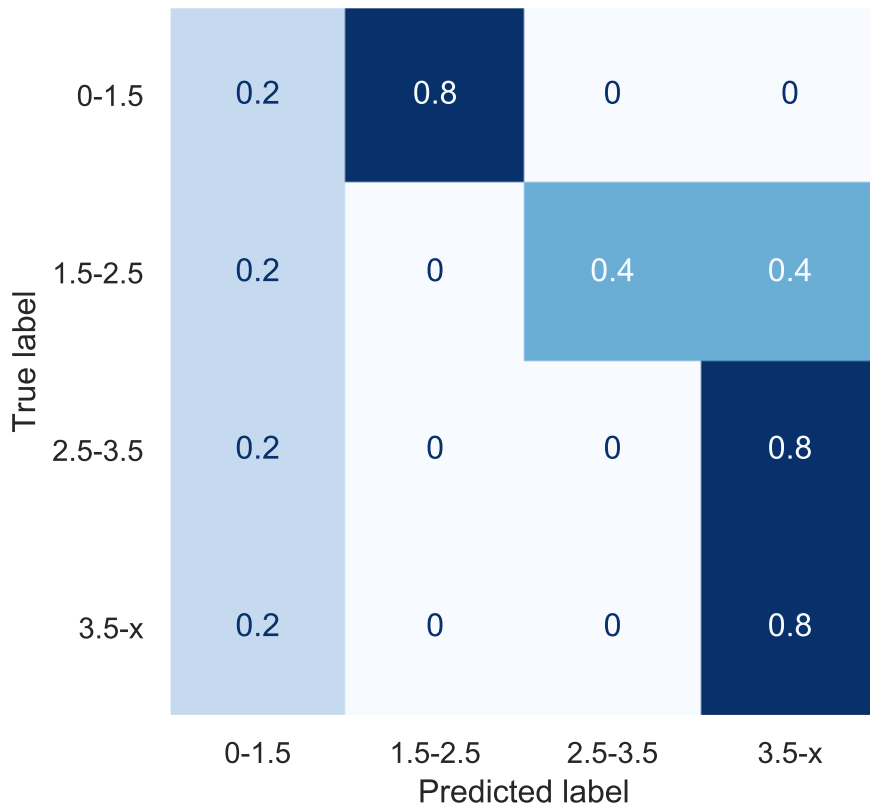


RANGE WINDOW: 60 s  
Confusion matrix Recv: S706 Trans: S708 Method: 1meter



RANGE WINDOW: 60 s

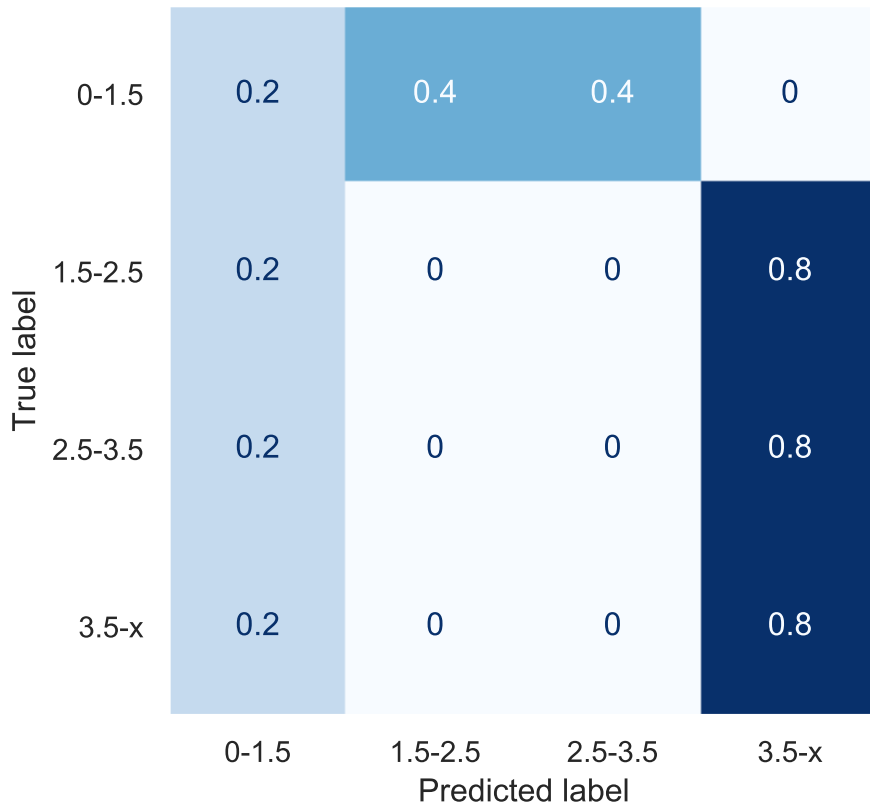
Confusion matrix Recv: S706 Trans: S708 Method: All\_without\_PL





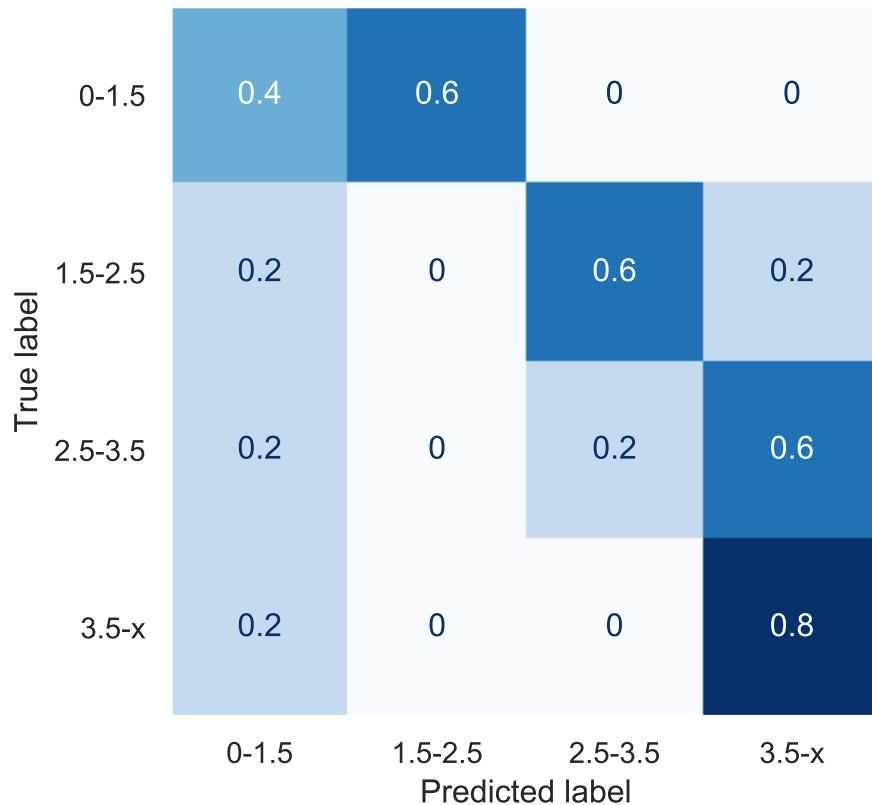
RANGE WINDOW: 60 s

Confusion matrix Recv: S706 Trans: S708 Method: All\_with\_PL

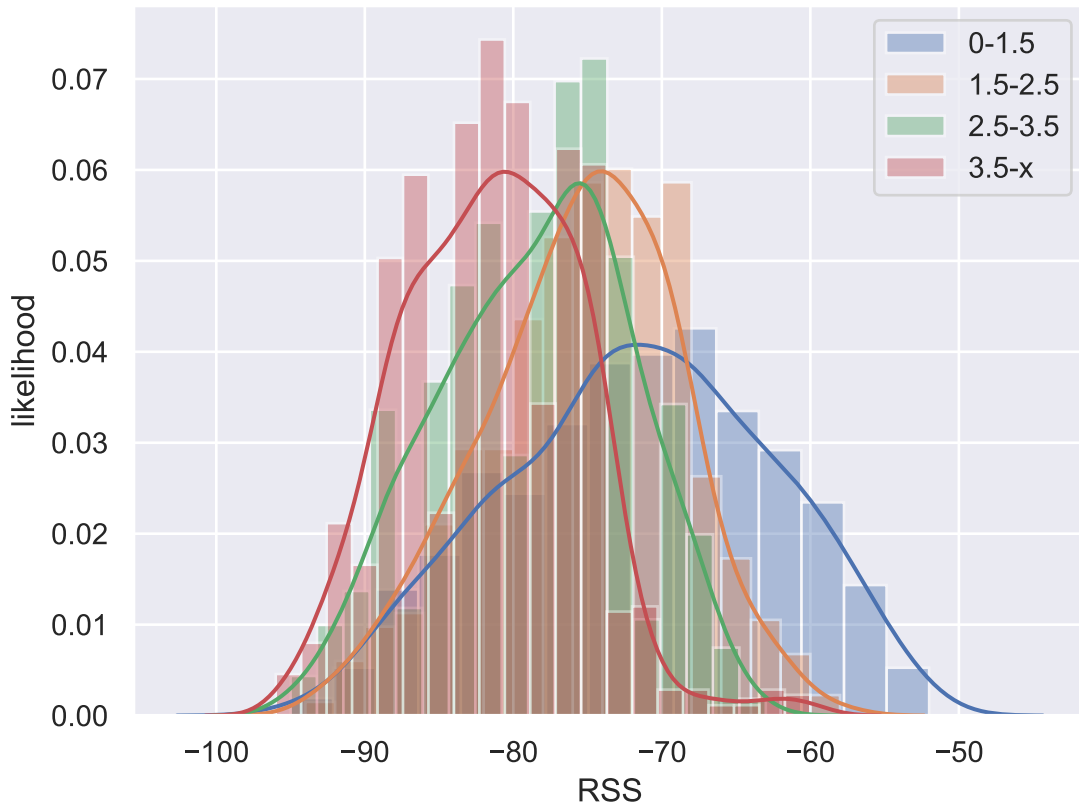


RANGE WINDOW: 60 s

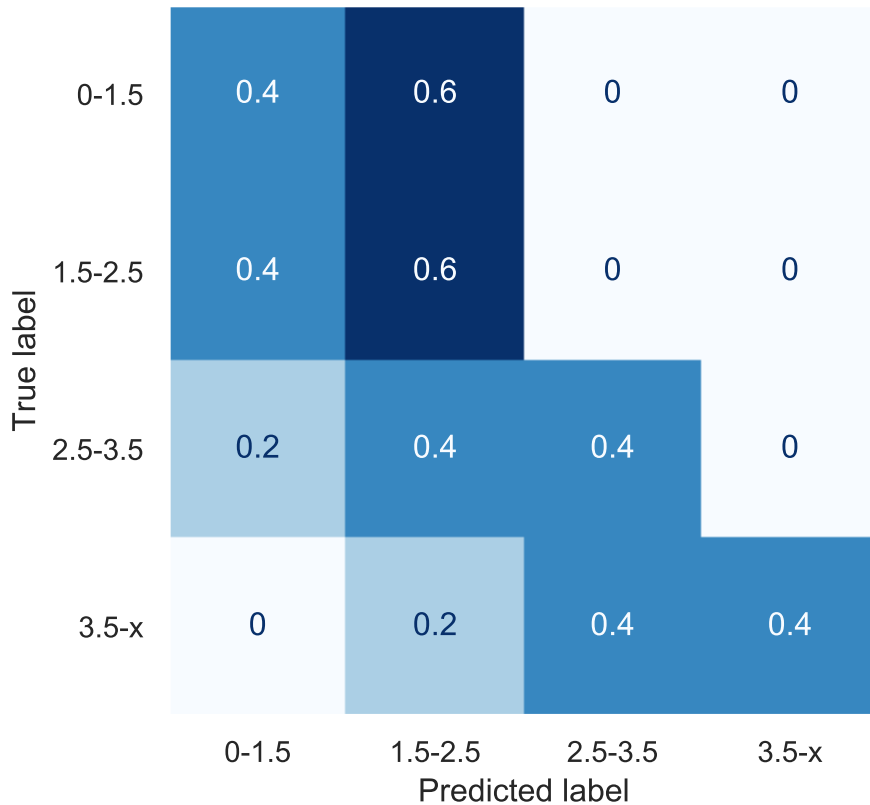
Confusion matrix Recv: S706 Trans: S708 Method: method 4



RANGE WINDOW: 60 s  
RSS Recv: Nexus Trans: S708

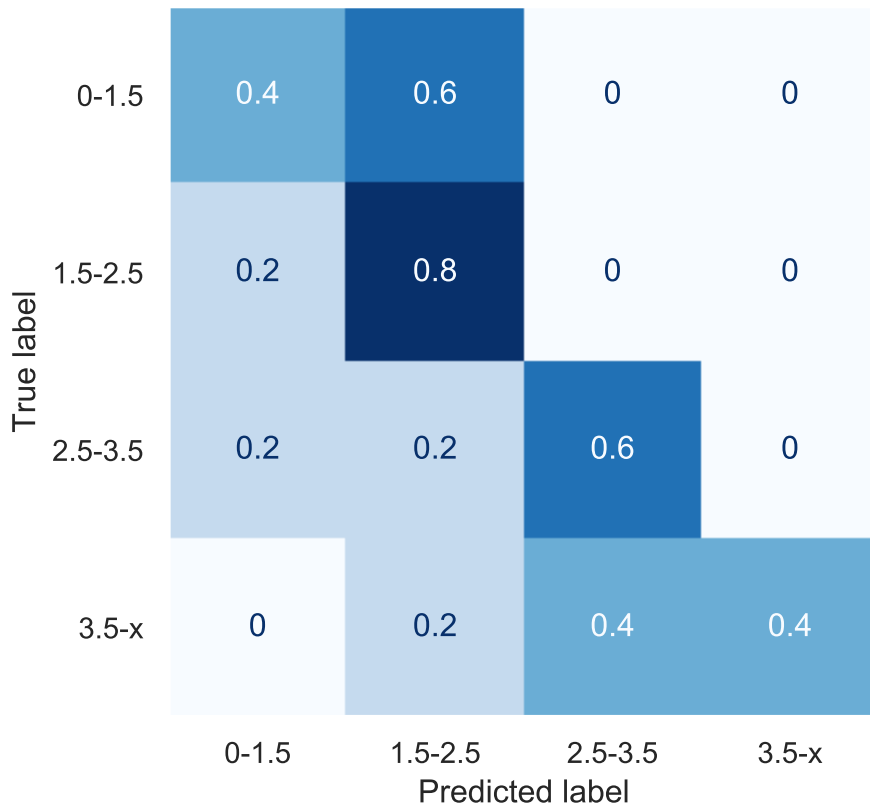


RANGE WINDOW: 60 s  
Confusion matrix Recv: Nexus Trans: S708 Method: 1meter



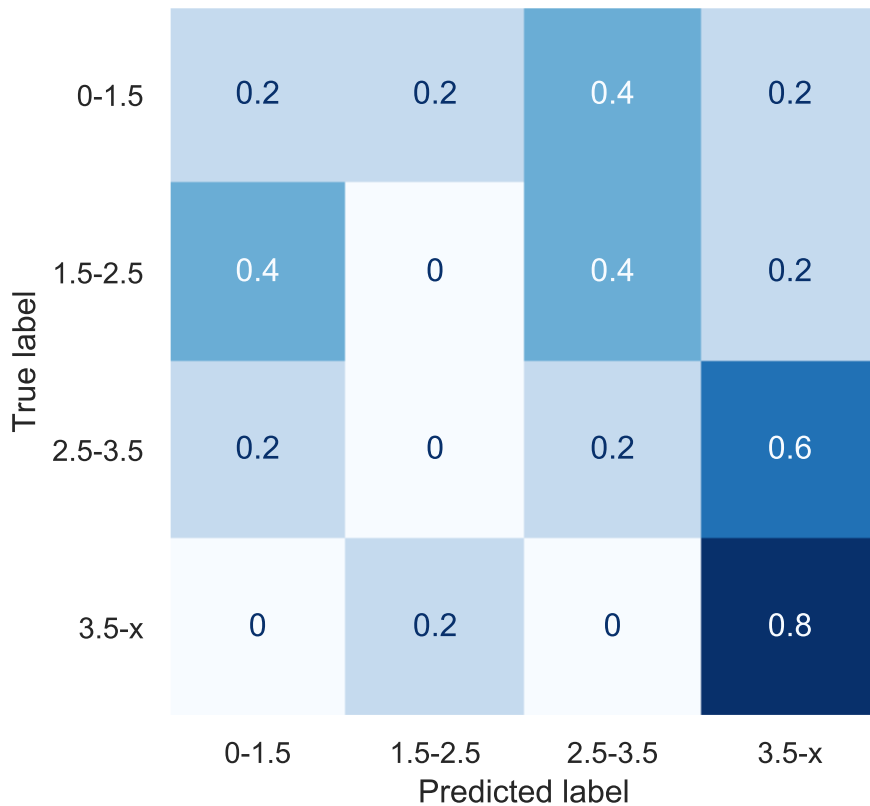
RANGE WINDOW: 60 s

Confusion matrix Recv: Nexus Trans: S708 Method: All\_without\_PL



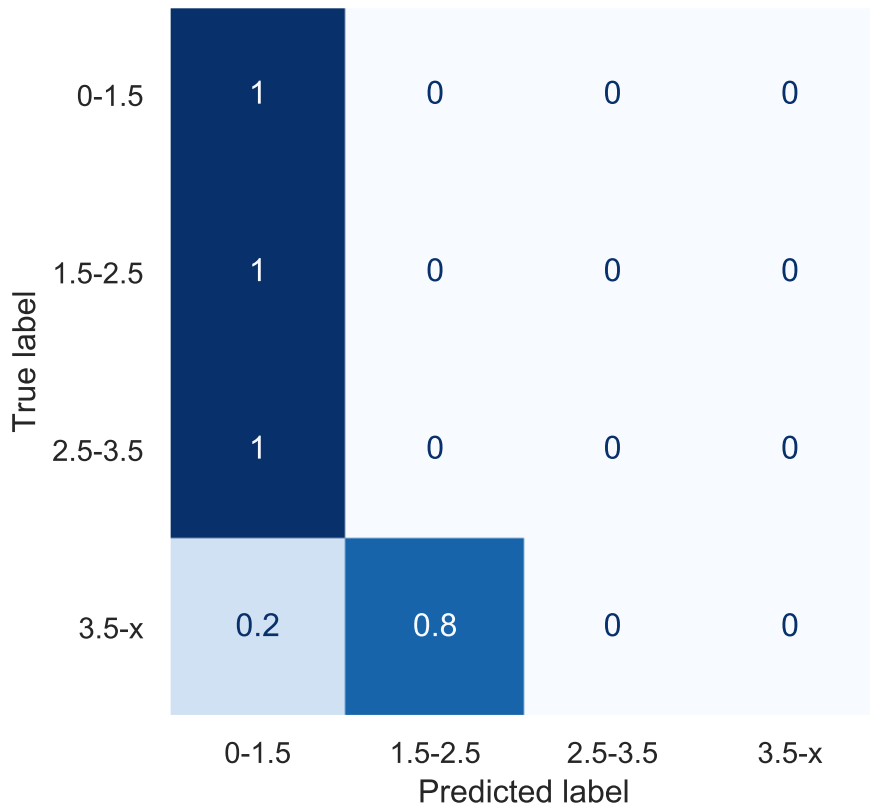
RANGE WINDOW: 60 s

Confusion matrix Recv: Nexus Trans: S708 Method: All\_with\_PL

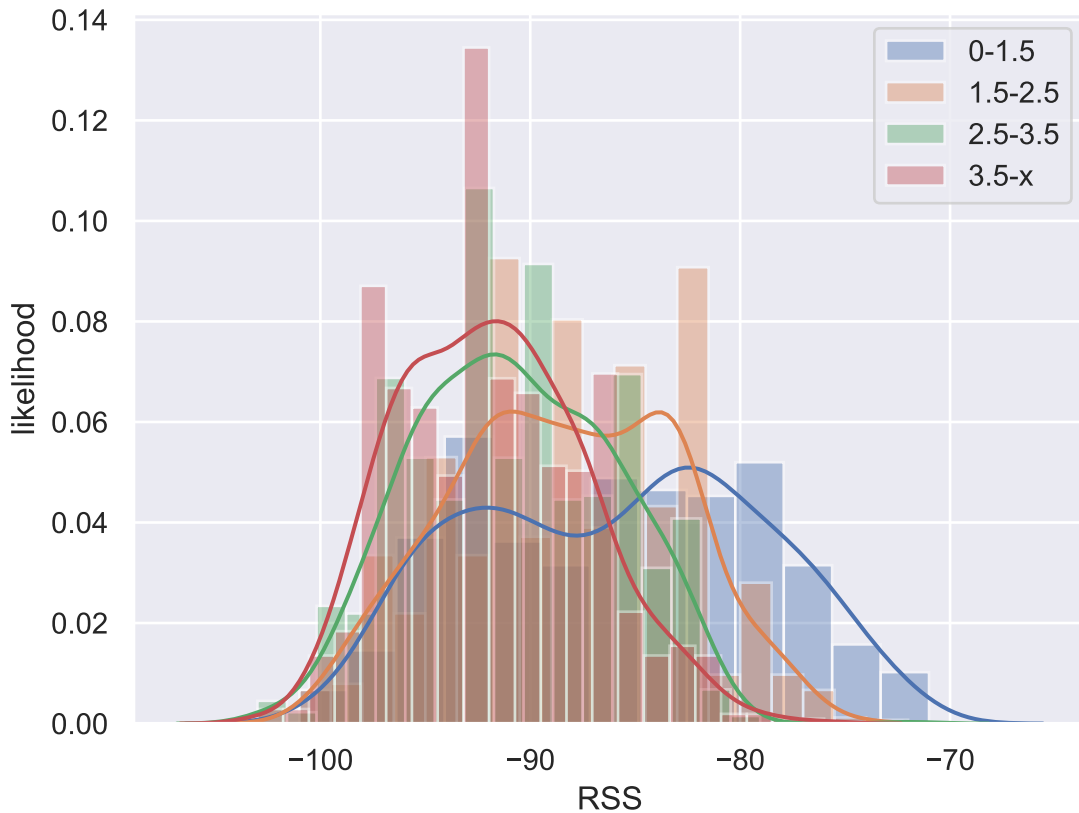


RANGE WINDOW: 60 s

Confusion matrix Recv: Nexus Trans: S708 Method: method 4

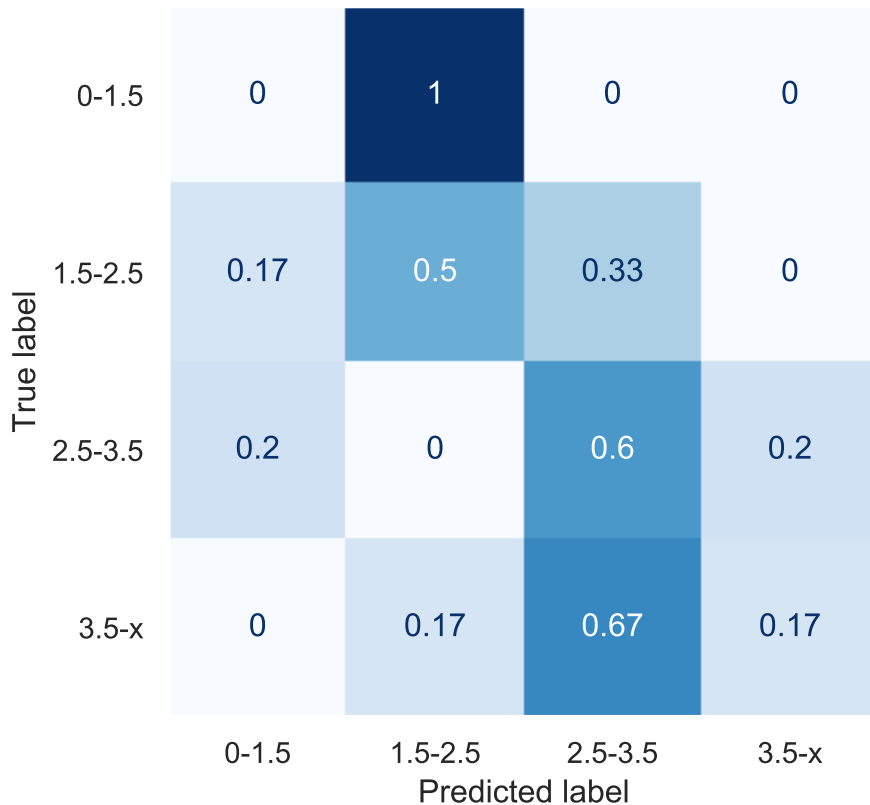


RANGE WINDOW: 60 s  
RSS Recv: S8 Trans: S708



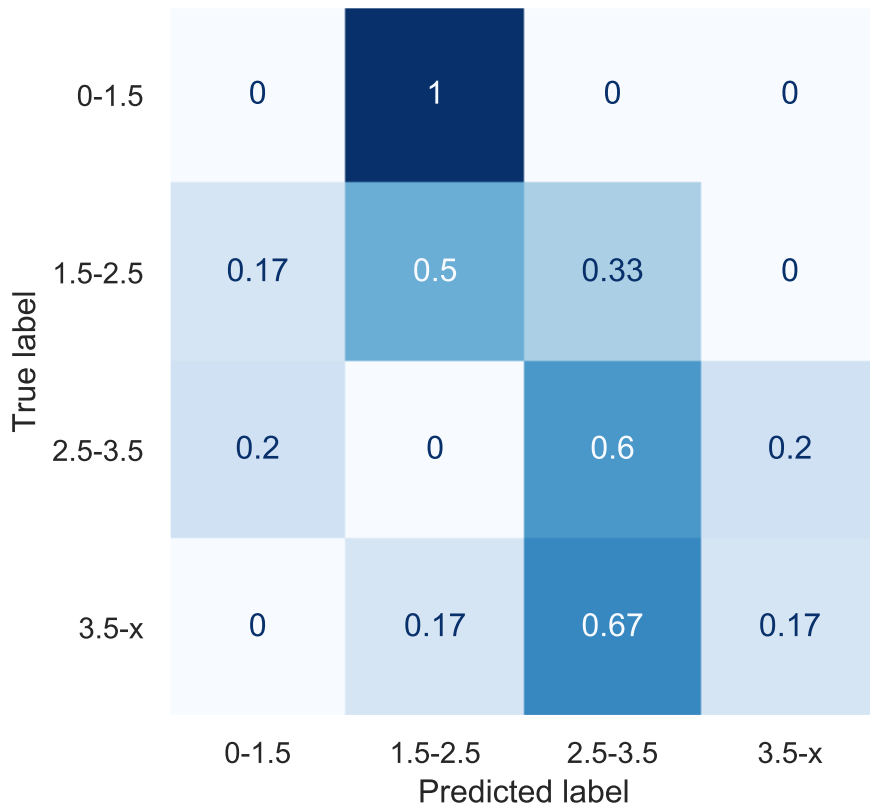


RANGE WINDOW: 60 s  
Confusion matrix Recv: S8 Trans: S708 Method: 1meter



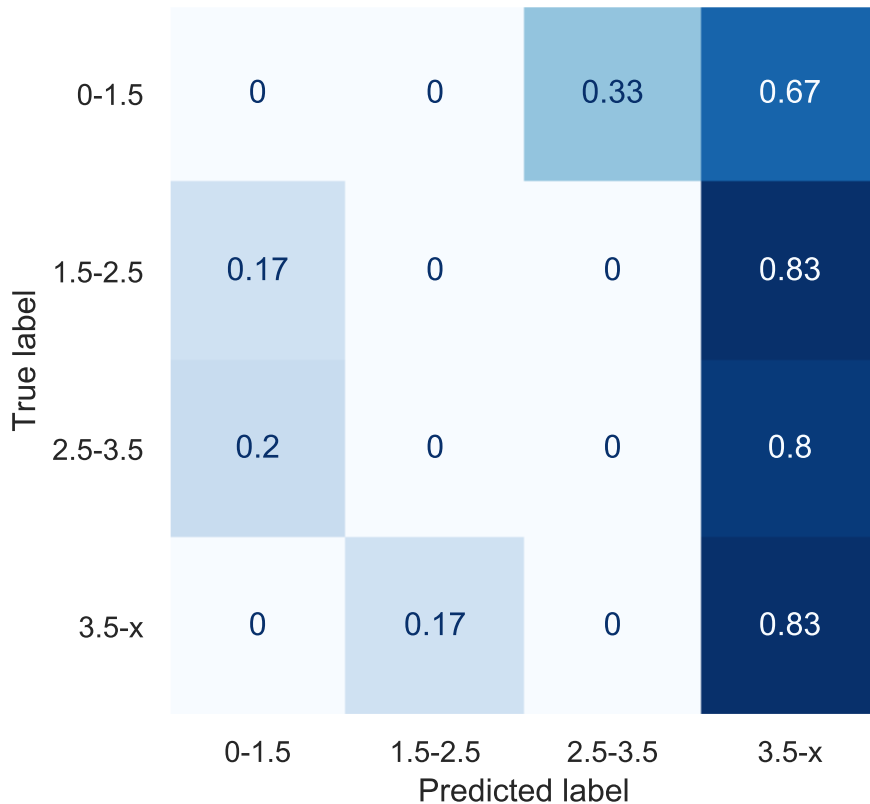
RANGE WINDOW: 60 s

Confusion matrix Recv: S8 Trans: S708 Method: All\_without\_PL

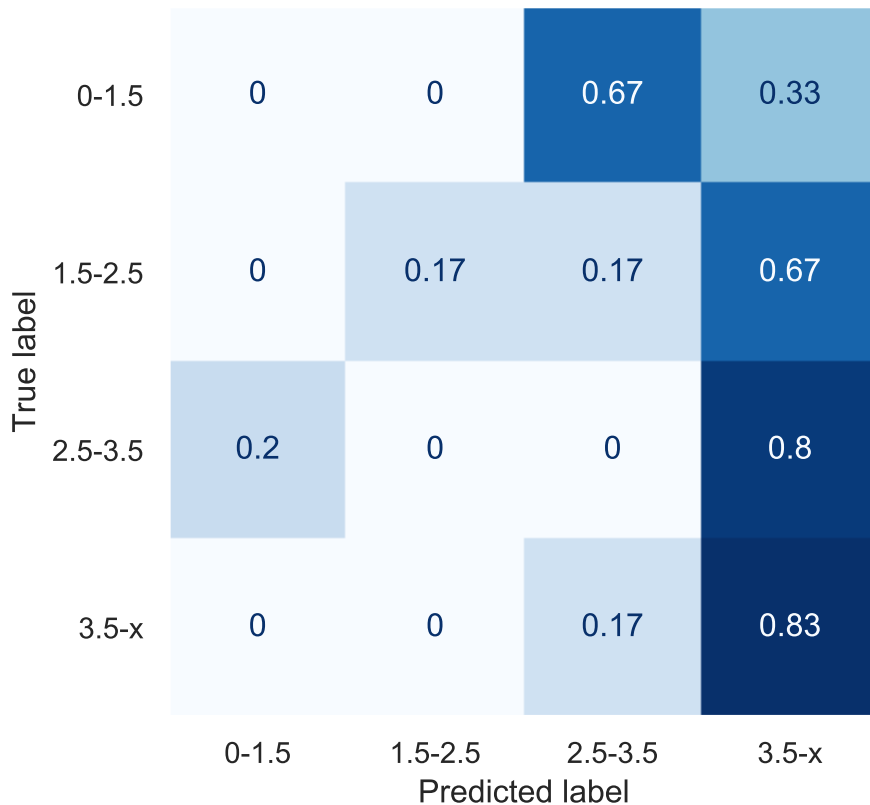


RANGE WINDOW: 60 s

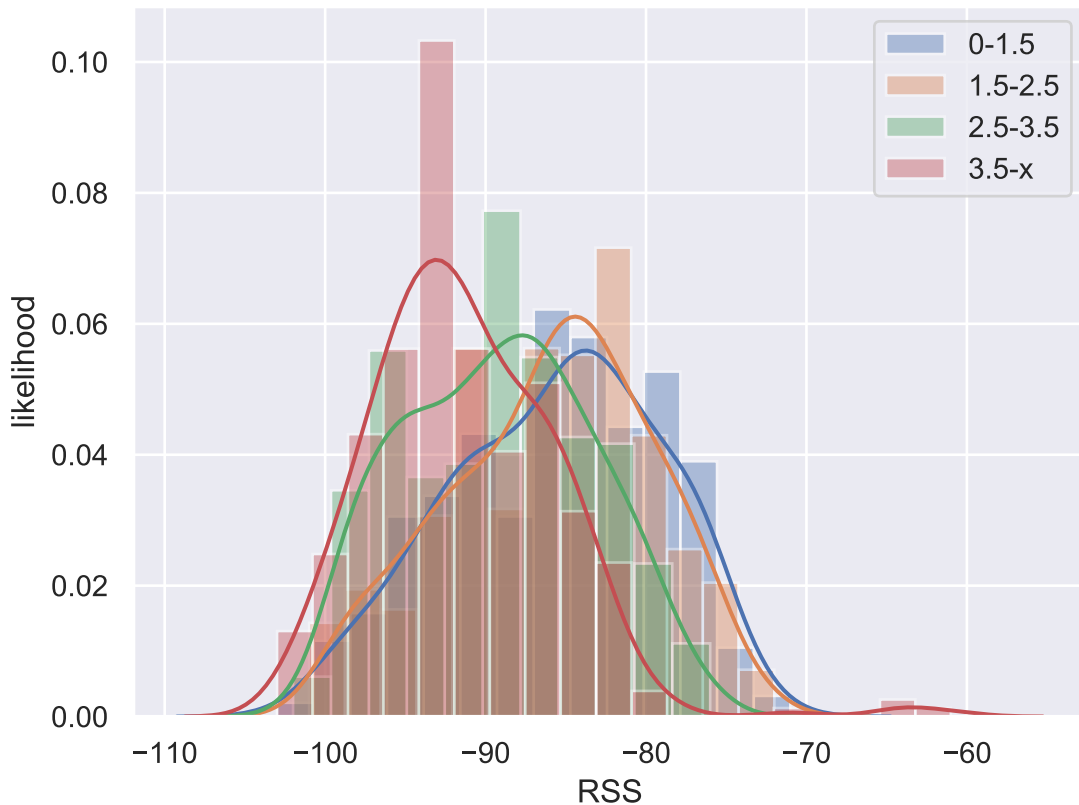
Confusion matrix Recv: S8 Trans: S708 Method: All\_with\_PL



RANGE WINDOW: 60 s  
Confusion matrix Recv: S8 Trans: S708 Method: method 4

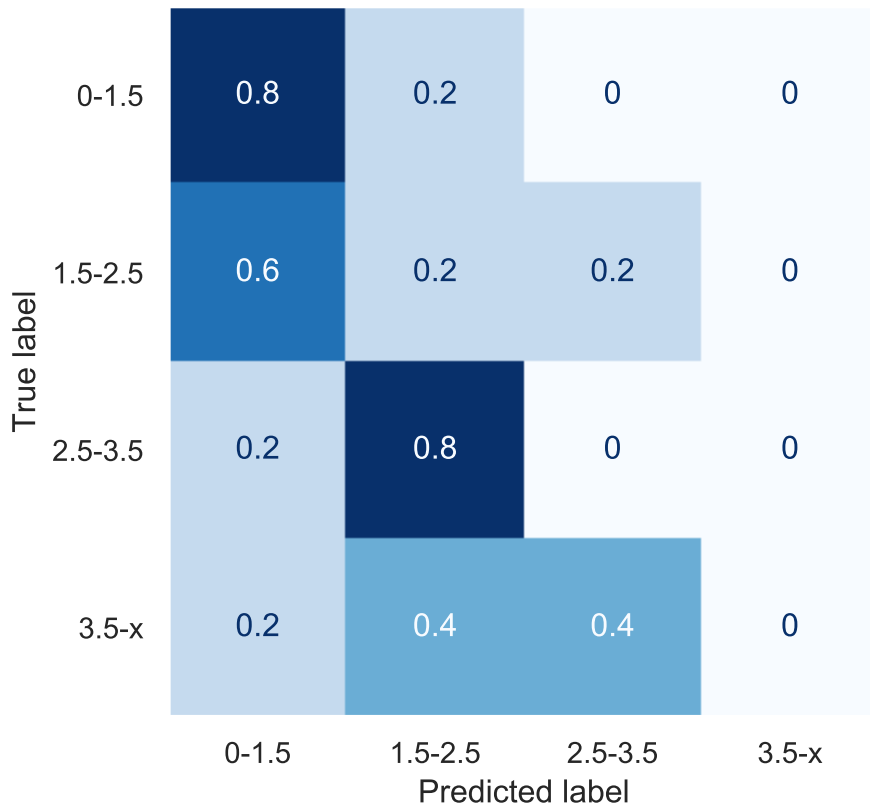


RANGE WINDOW: 60 s  
RSS Recv: Motorola Trans: Nexus



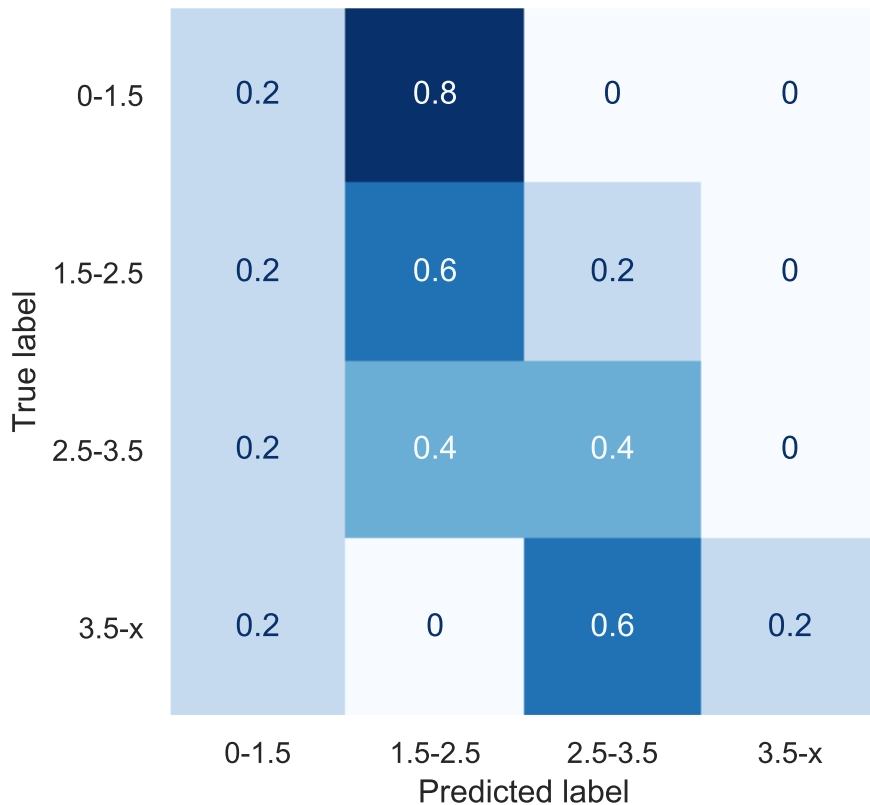
RANGE WINDOW: 60 s

Confusion matrix Recv: Motorola Trans: Nexus Method: 1meter



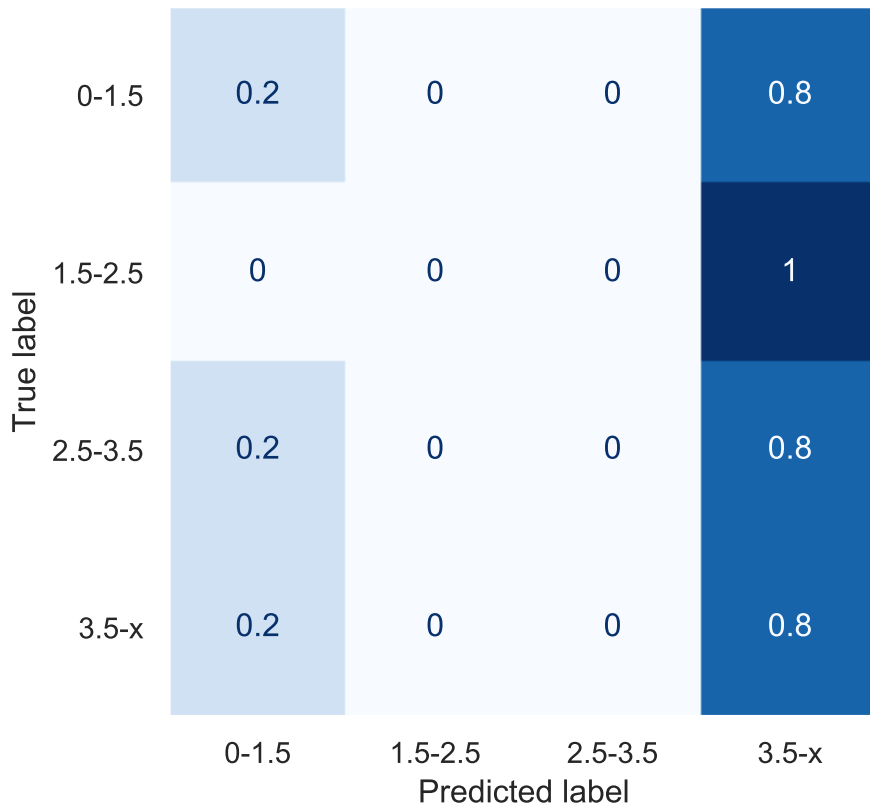
RANGE WINDOW: 60 s

Confusion matrix Recv: Motorola Trans: Nexus Method: All\_without\_PL



RANGE WINDOW: 60 s

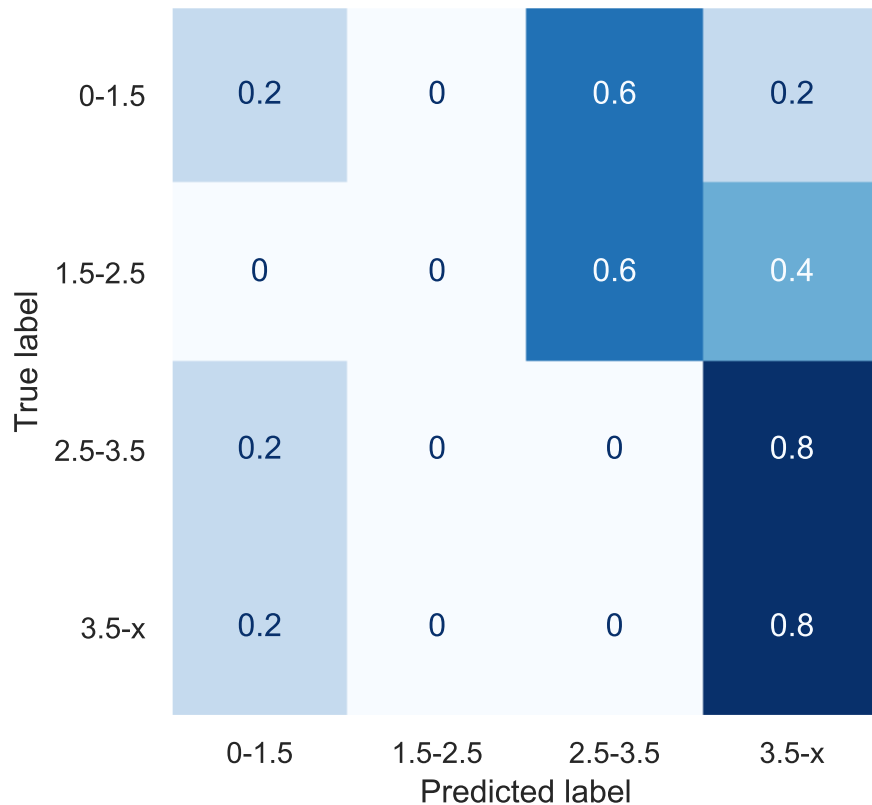
Confusion matrix Recv: Motorola Trans: Nexus Method: All\_with\_PL



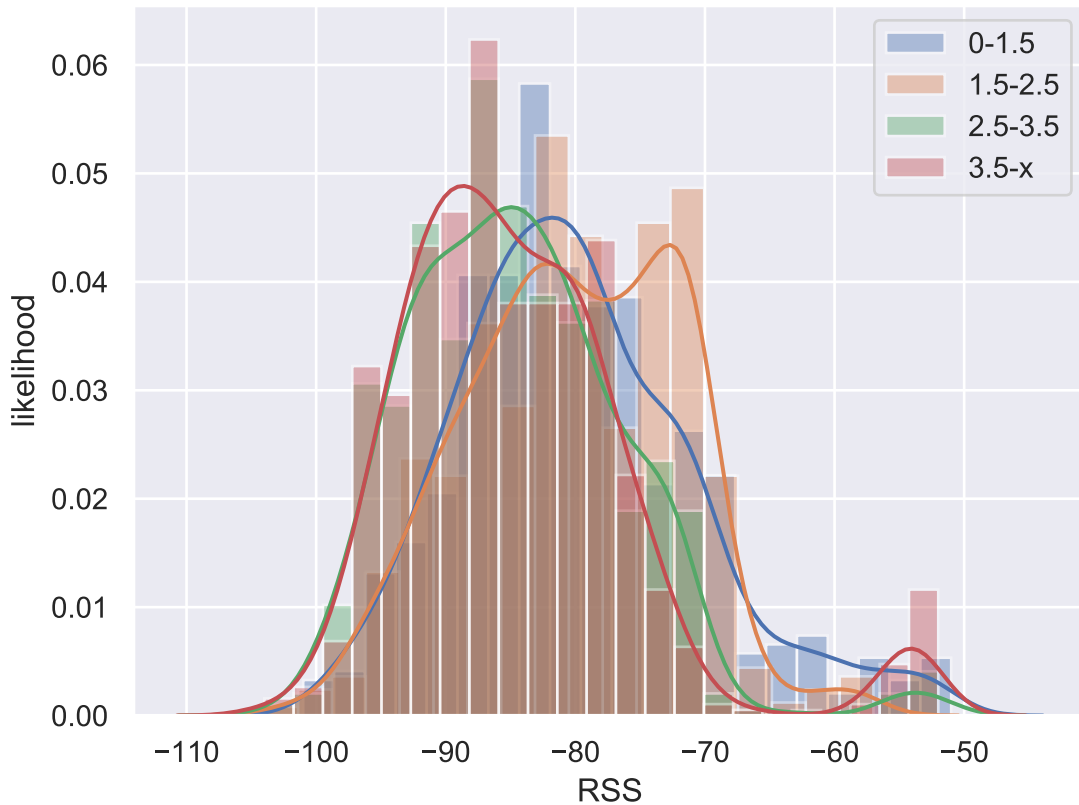


RANGE WINDOW: 60 s

Confusion matrix Recv: Motorola Trans: Nexus Method: method 4

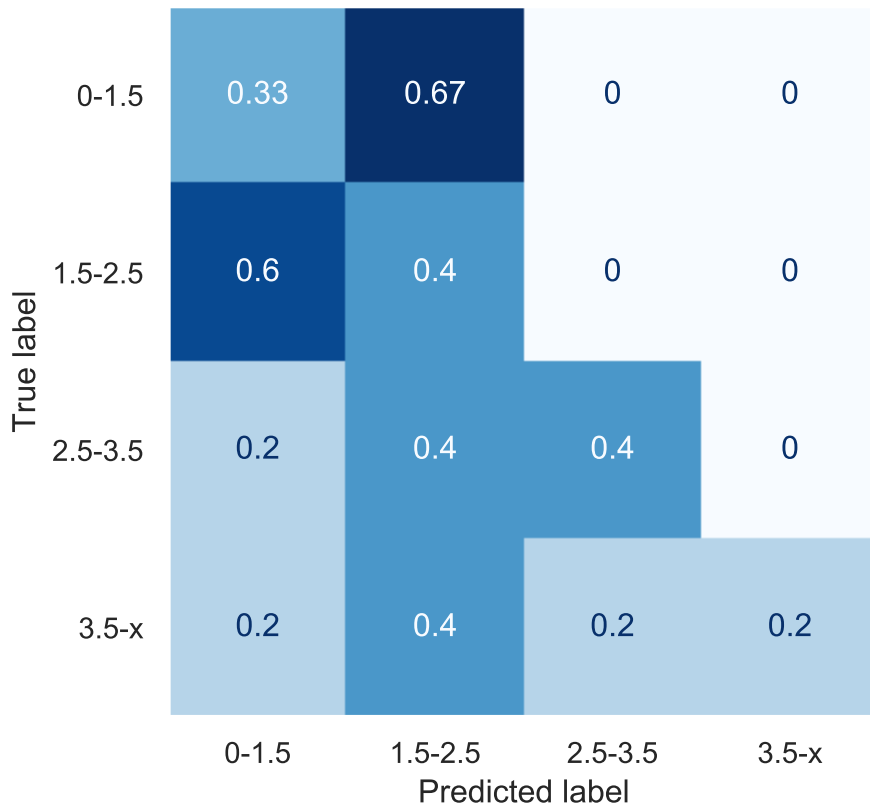


RANGE WINDOW: 60 s  
RSS Recv: SamsungA6 Trans: Nexus



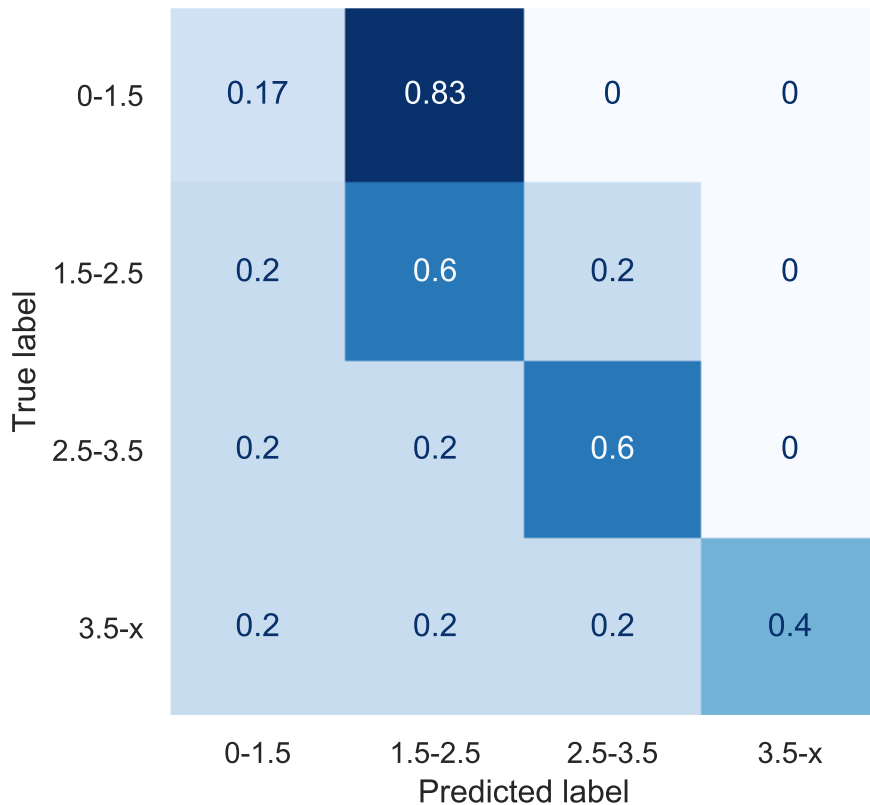
RANGE WINDOW: 60 s

Confusion matrix Recv: SamsungA6 Trans: Nexus Method: 1meter



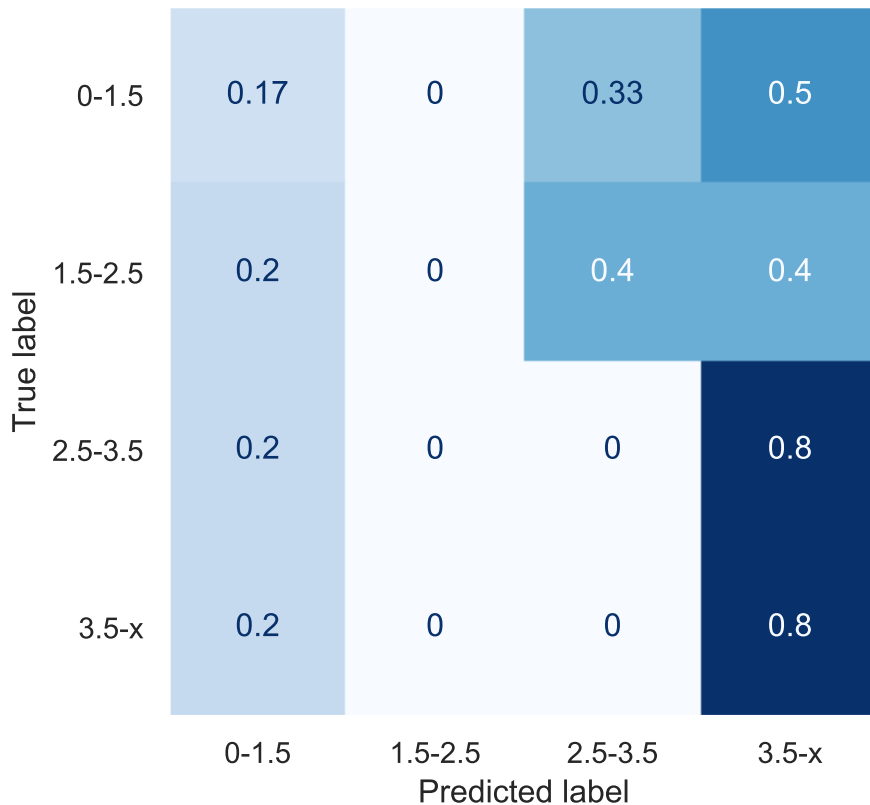
RANGE WINDOW: 60 s

Confusion matrix Recv: SamsungA6 Trans: Nexus Method: All\_without\_PL



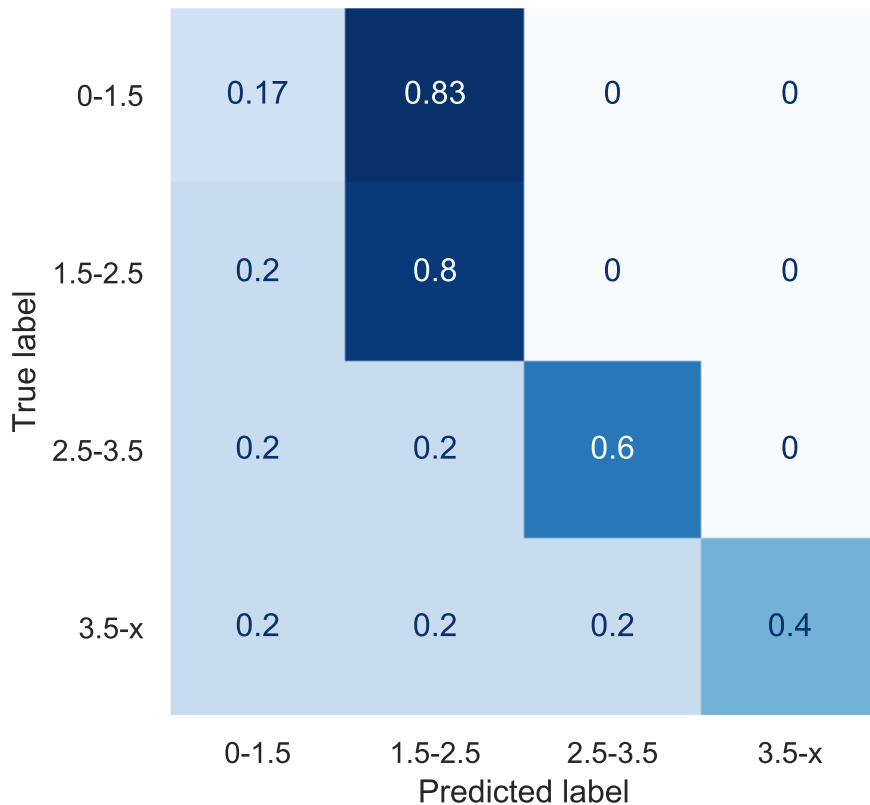
RANGE WINDOW: 60 s

Confusion matrix Recv: SamsungA6 Trans: Nexus Method: All\_with\_PL

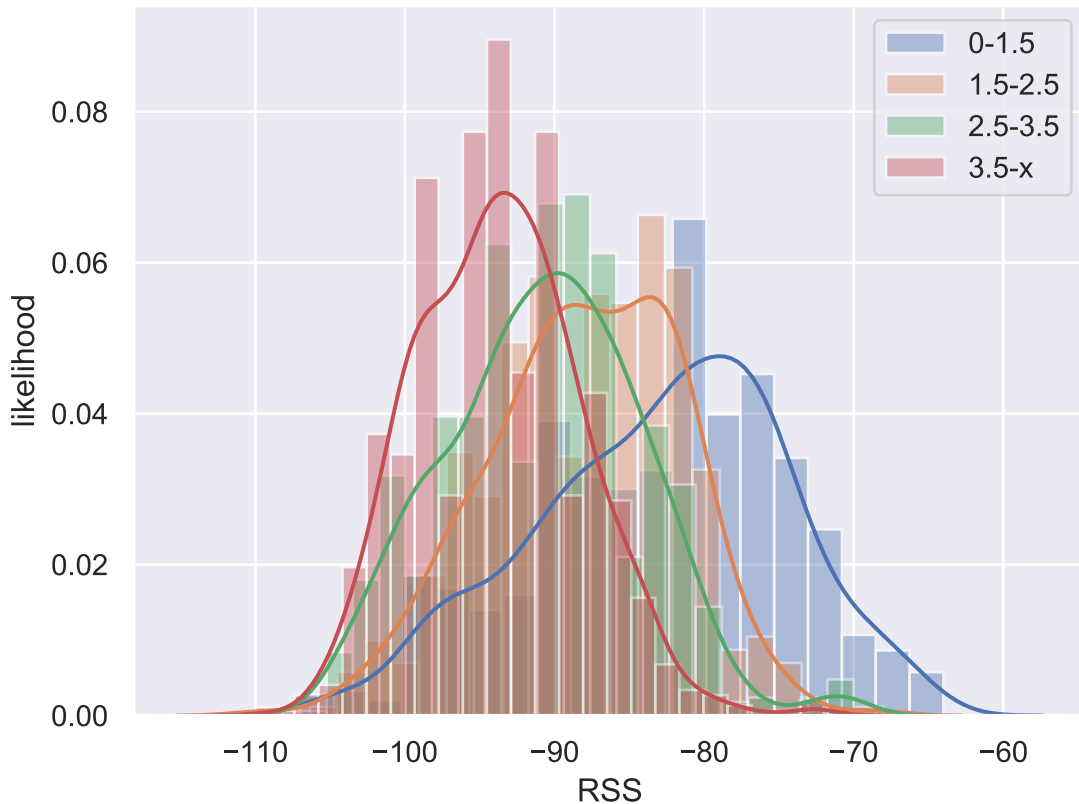


RANGE WINDOW: 60 s

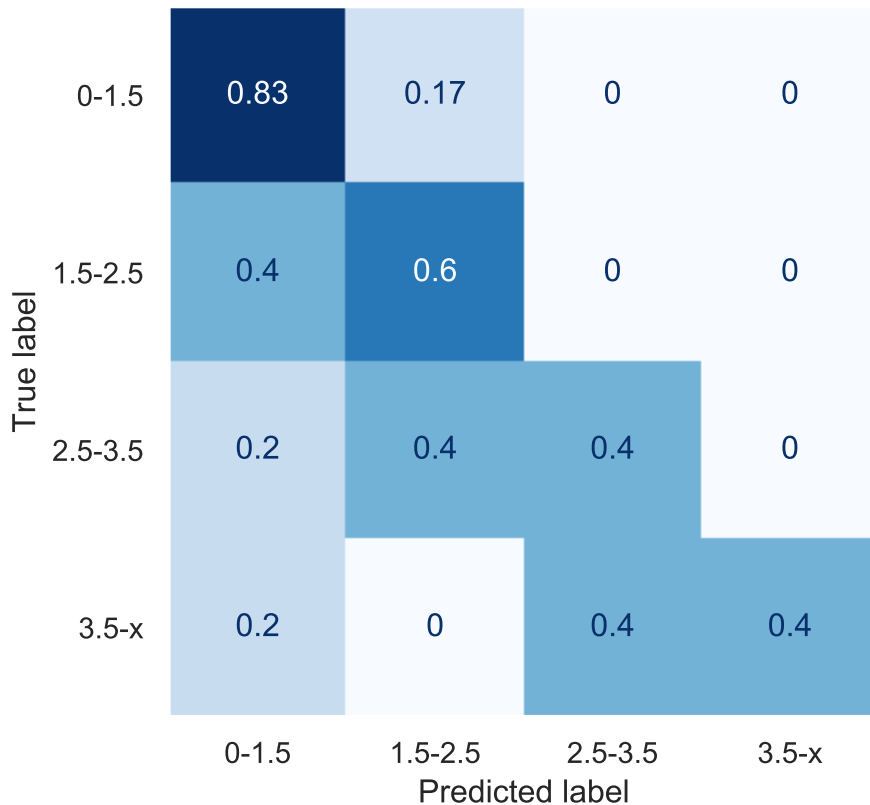
Confusion matrix Recv: SamsungA6 Trans: Nexus Method: method 4



RANGE WINDOW: 60 s  
RSS Recv: S708 Trans: Nexus



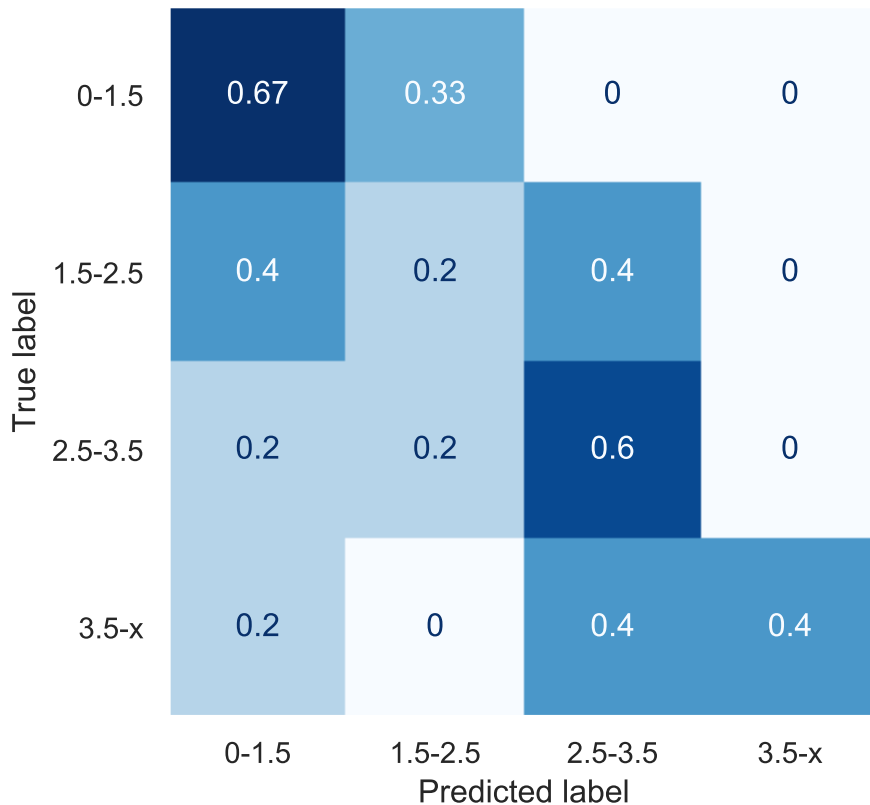
RANGE WINDOW: 60 s  
Confusion matrix Recv: S708 Trans: Nexus Method: 1meter





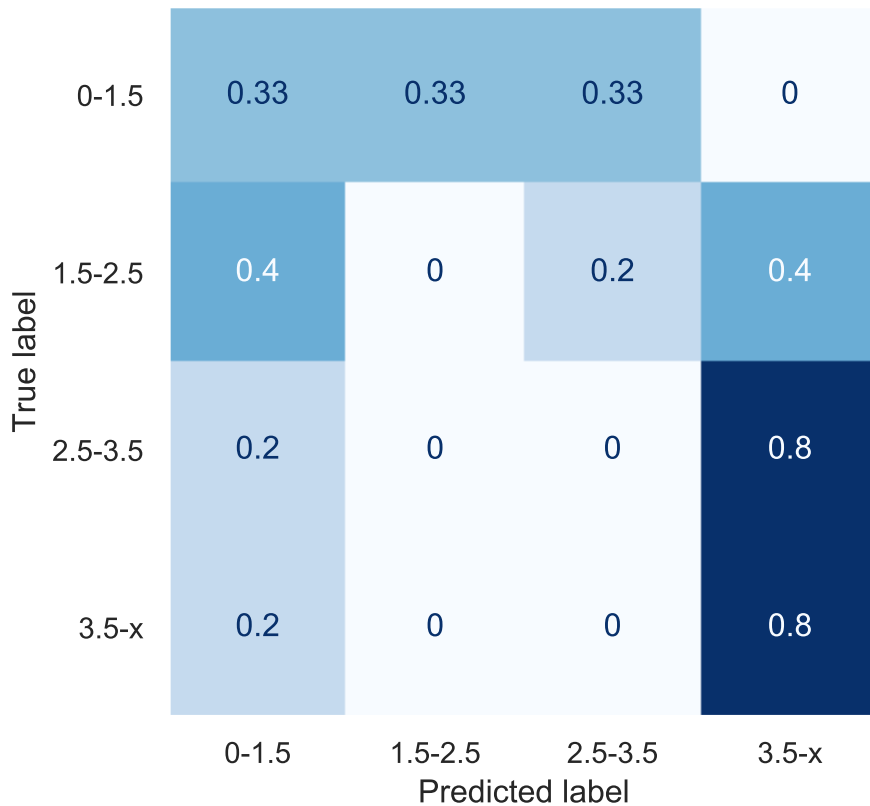
RANGE WINDOW: 60 s

Confusion matrix Recv: S708 Trans: Nexus Method: All\_without\_PL

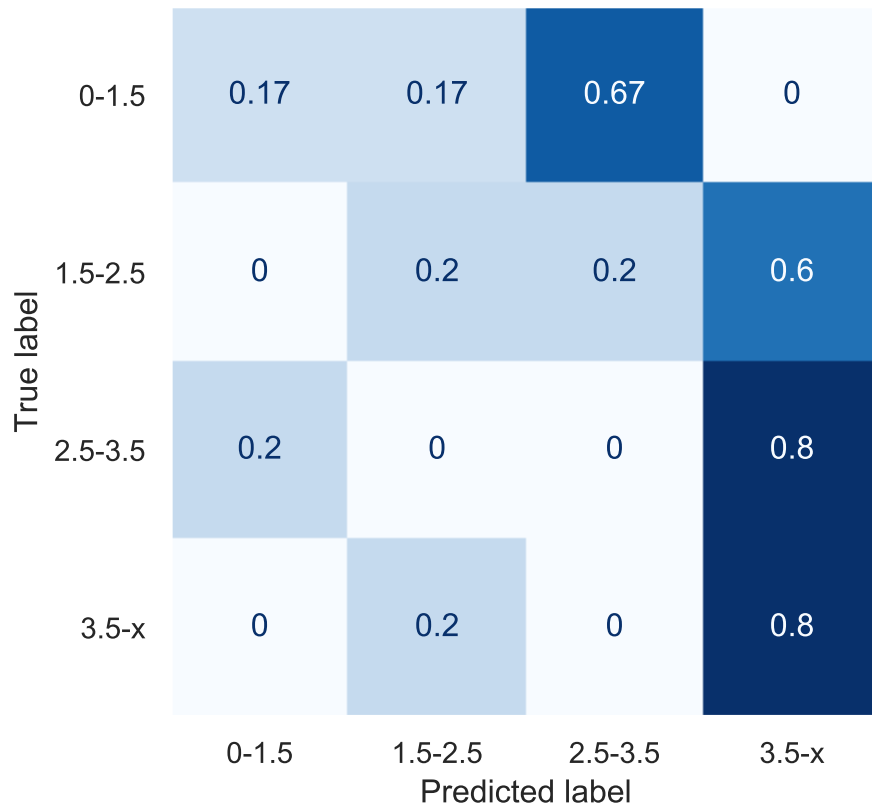


RANGE WINDOW: 60 s

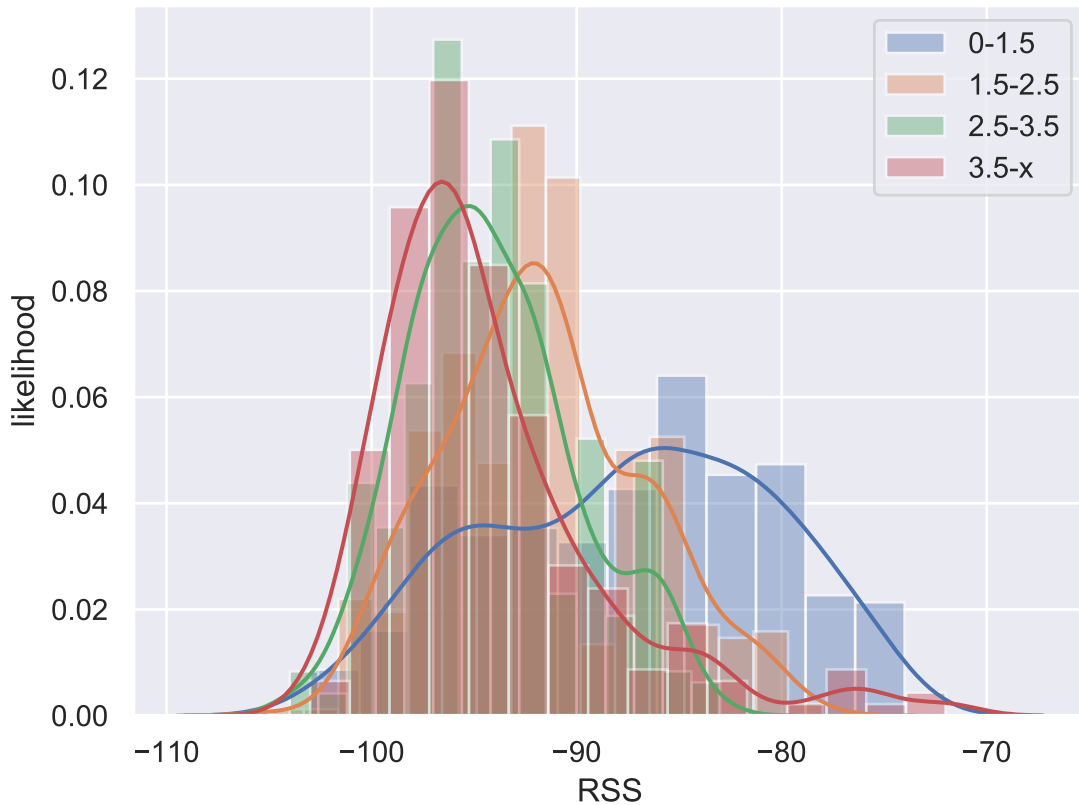
Confusion matrix Recv: S708 Trans: Nexus Method: All\_with\_PL



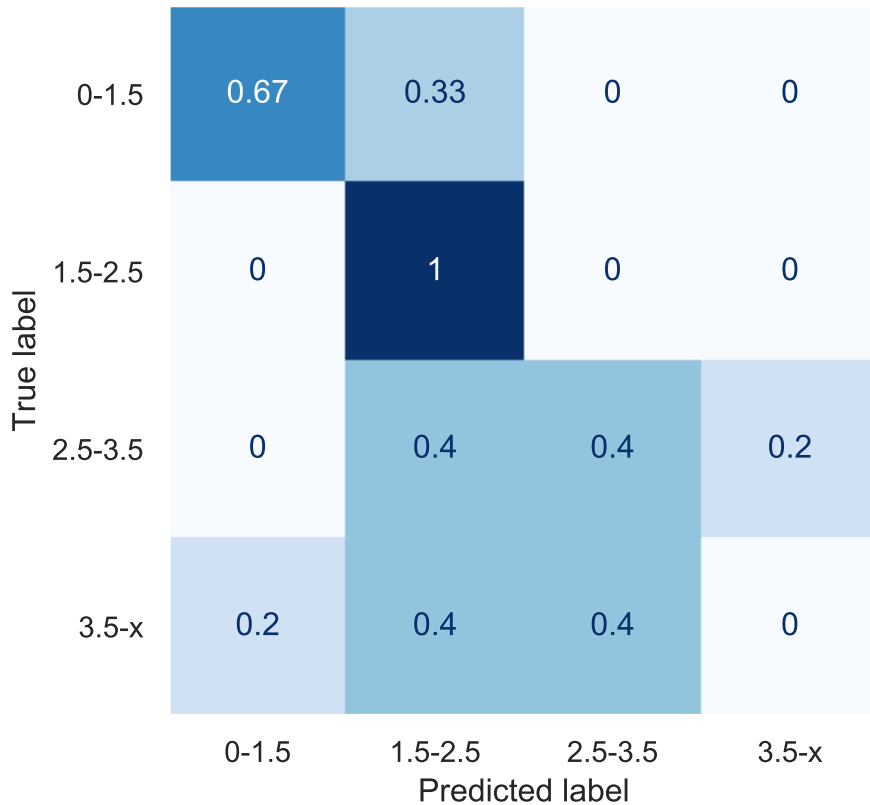
RANGE WINDOW: 60 s  
Confusion matrix Recv: S708 Trans: Nexus Method: method 4



RANGE WINDOW: 60 s  
RSS Recv: Motorola Trans: S8

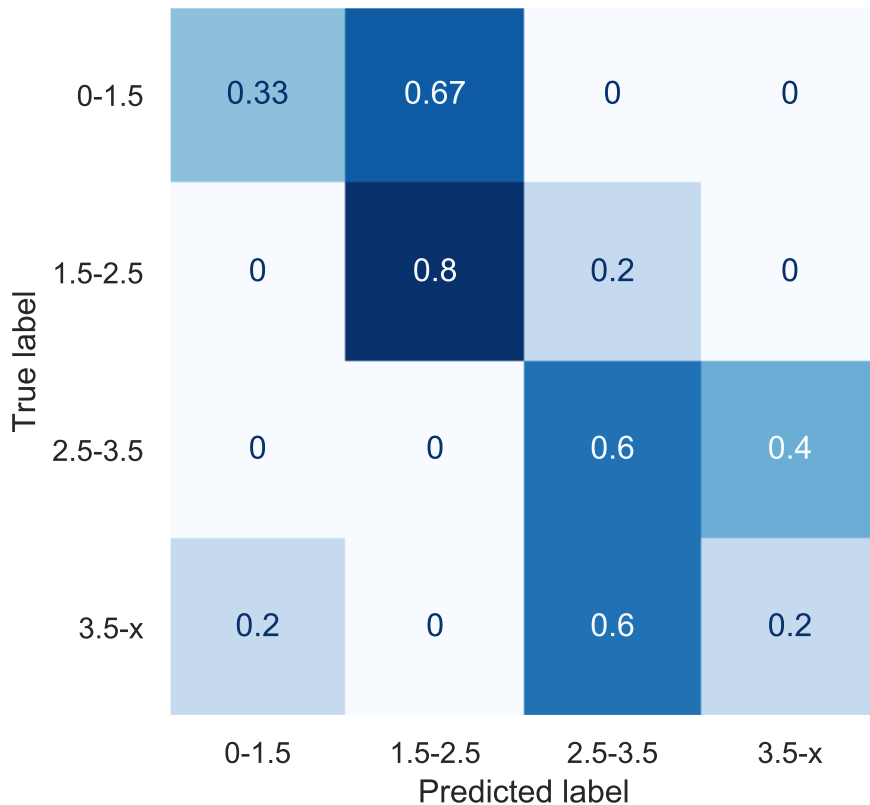


RANGE WINDOW: 60 s  
Confusion matrix Recv: Motorola Trans: S8 Method: 1meter



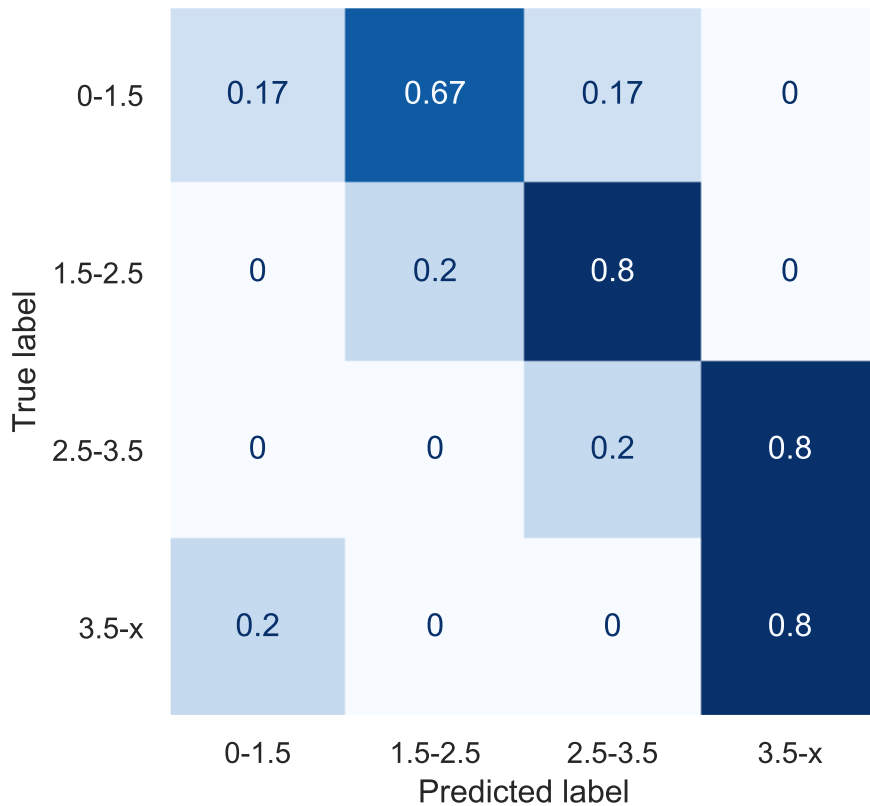
RANGE WINDOW: 60 s

Confusion matrix Recv: Motorola Trans: S8 Method: All\_without\_PL

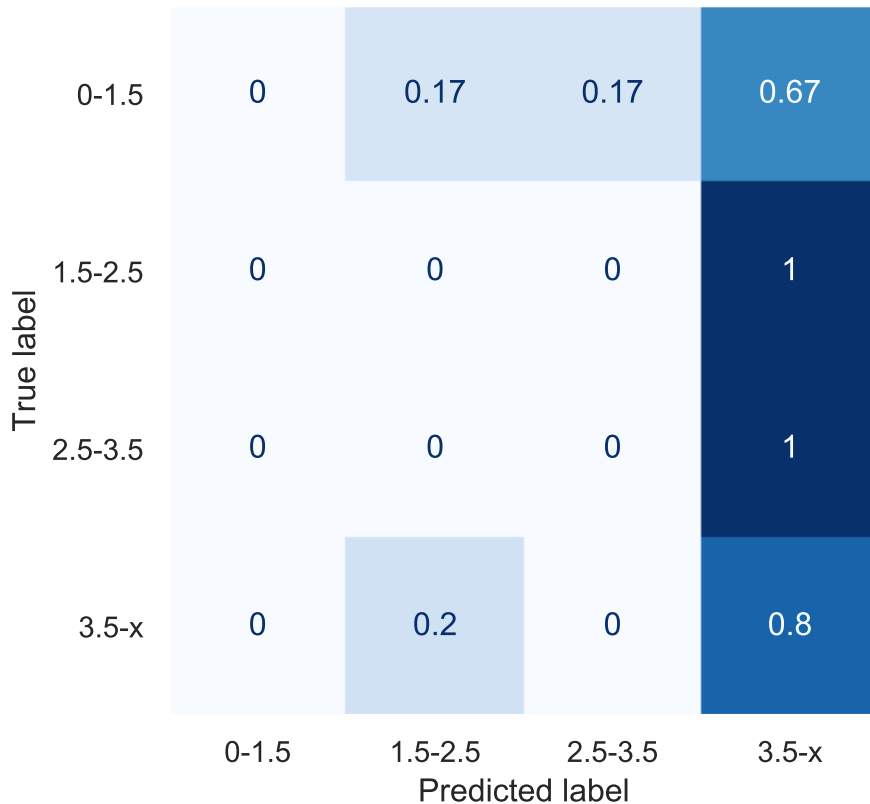


RANGE WINDOW: 60 s

Confusion matrix Recv: Motorola Trans: S8 Method: All\_with\_PL

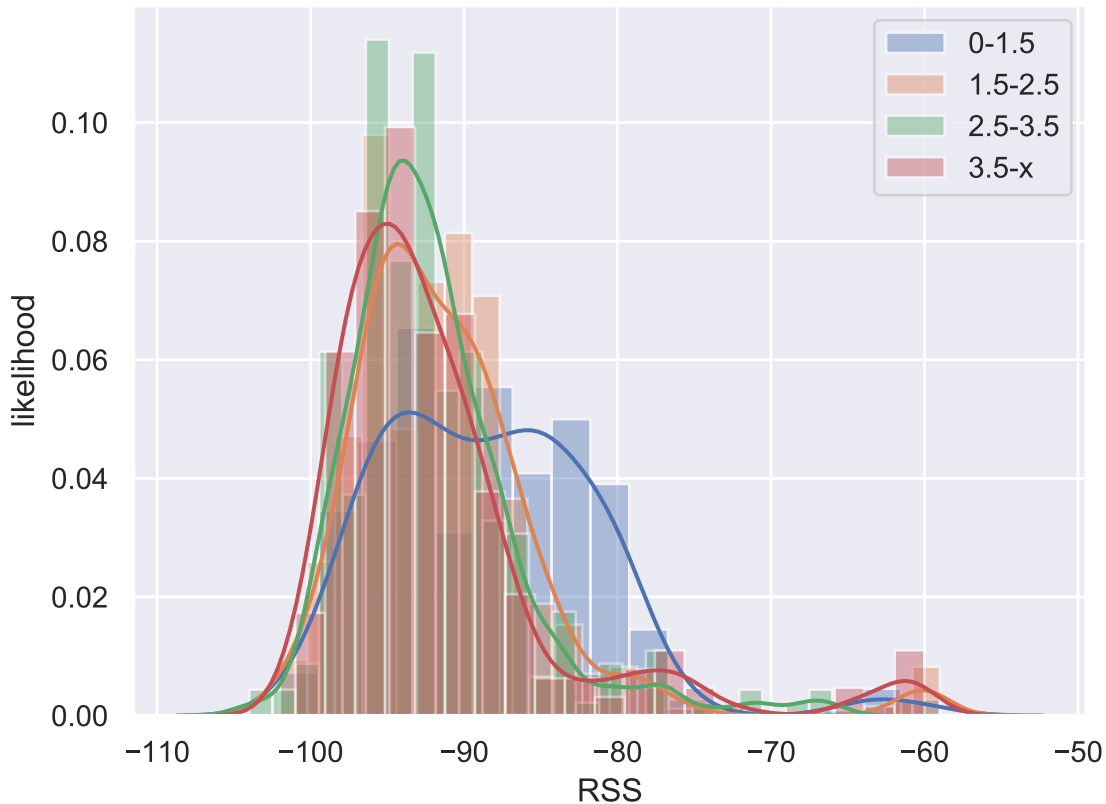


RANGE WINDOW: 60 s  
Confusion matrix Recv: Motorola Trans: S8 Method: method 4



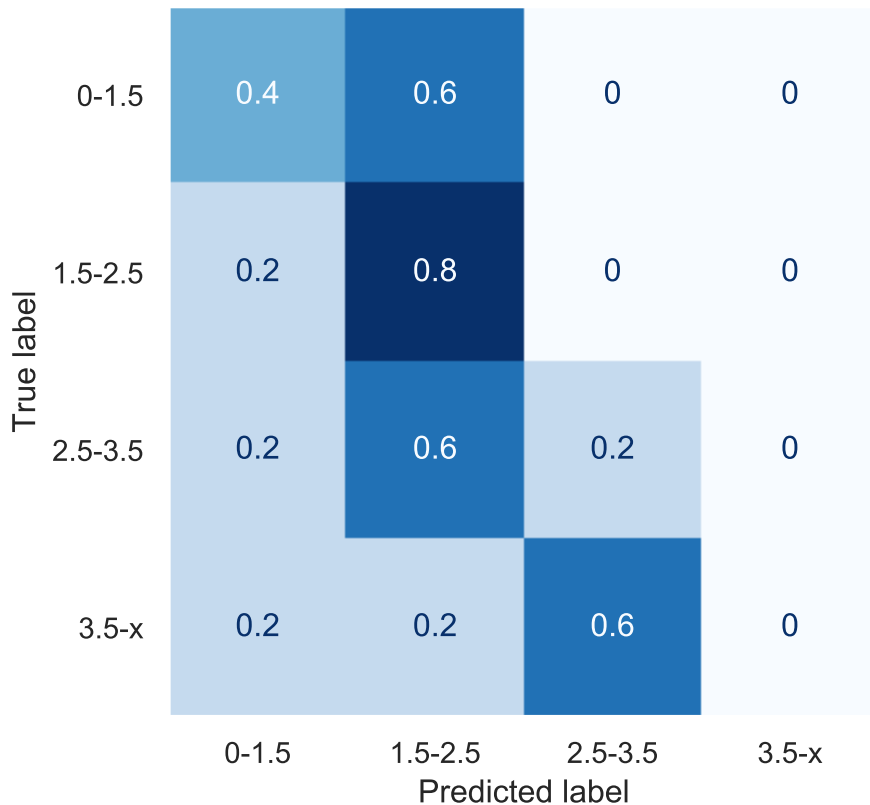


RANGE WINDOW: 60 s  
RSS Recv: SamsungA6 Trans: S8



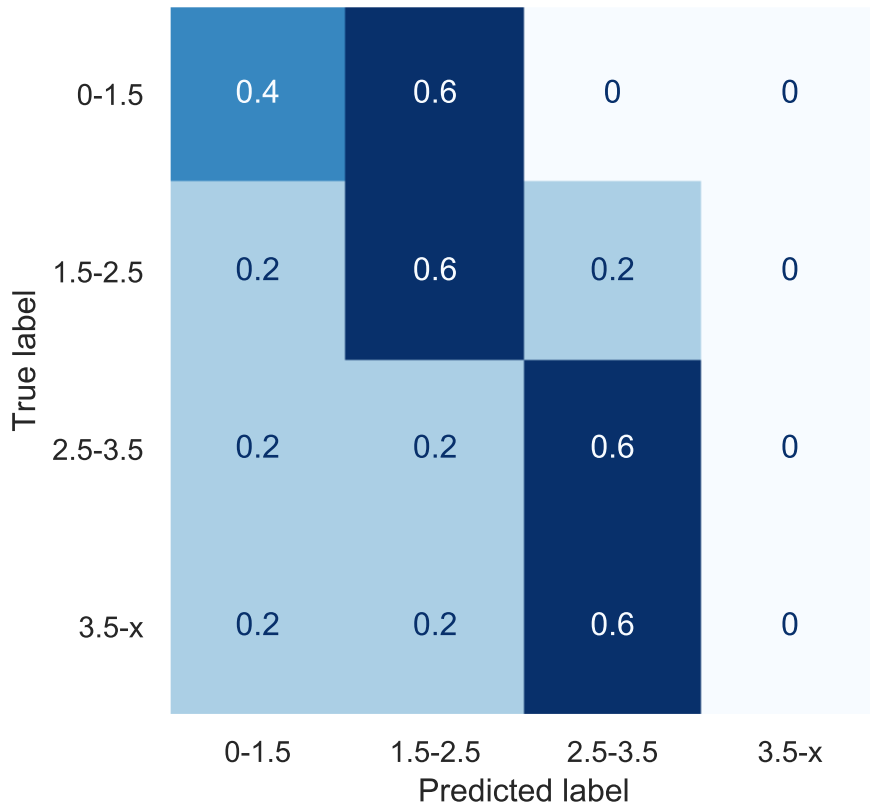
RANGE WINDOW: 60 s

Confusion matrix Recv: SamsungA6 Trans: S8 Method: 1meter



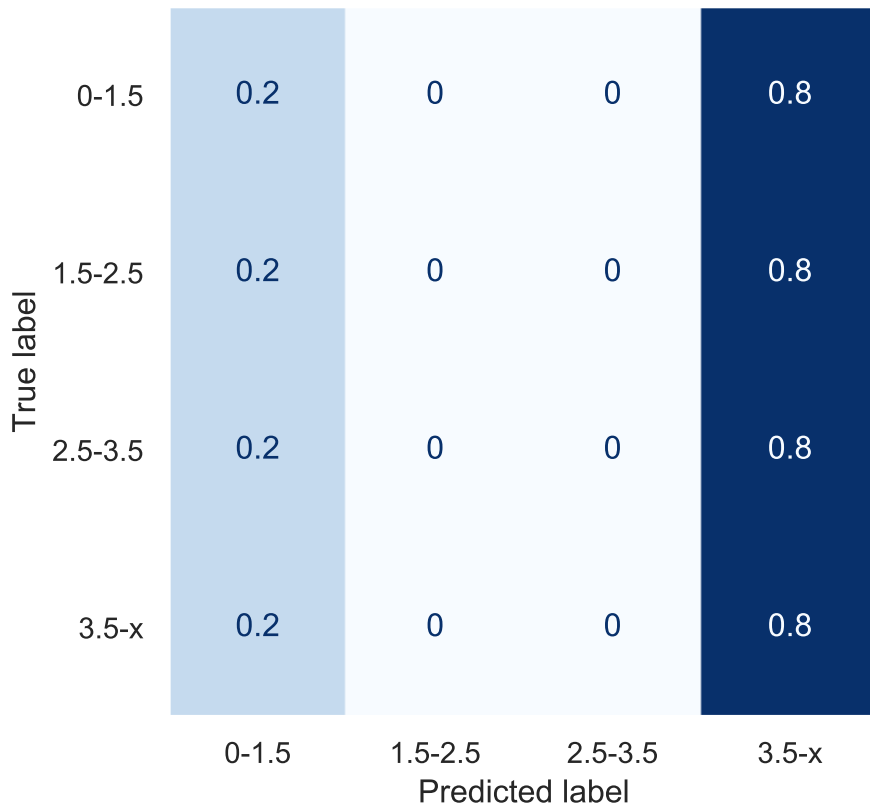
RANGE WINDOW: 60 s

Confusion matrix Recv: SamsungA6 Trans: S8 Method: All\_without\_PL



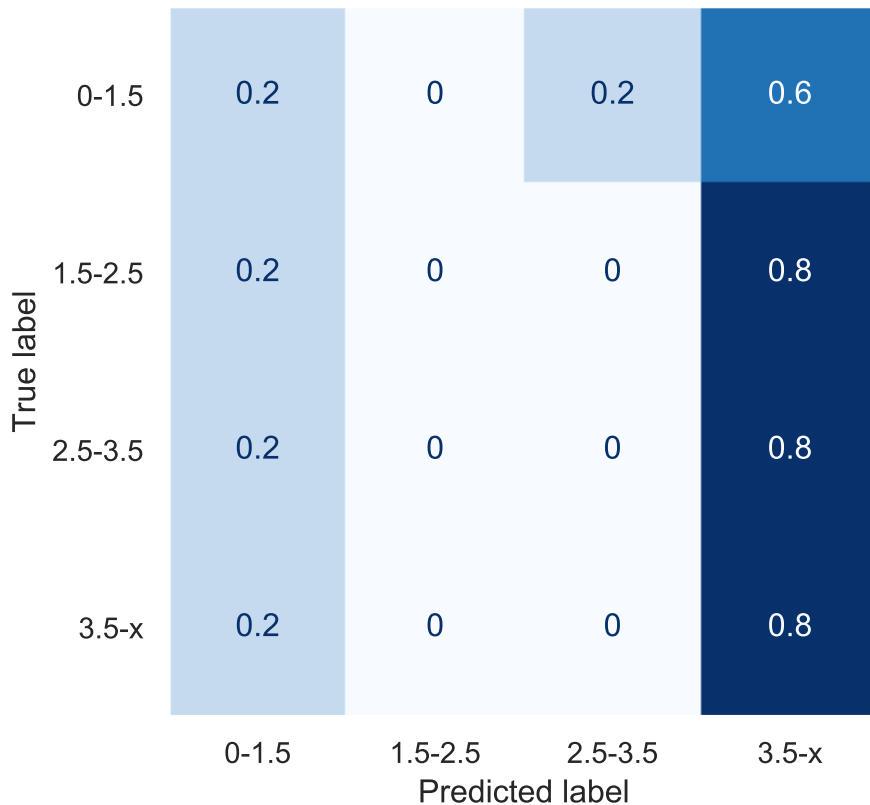
RANGE WINDOW: 60 s

Confusion matrix Recv: SamsungA6 Trans: S8 Method: All\_with\_PL

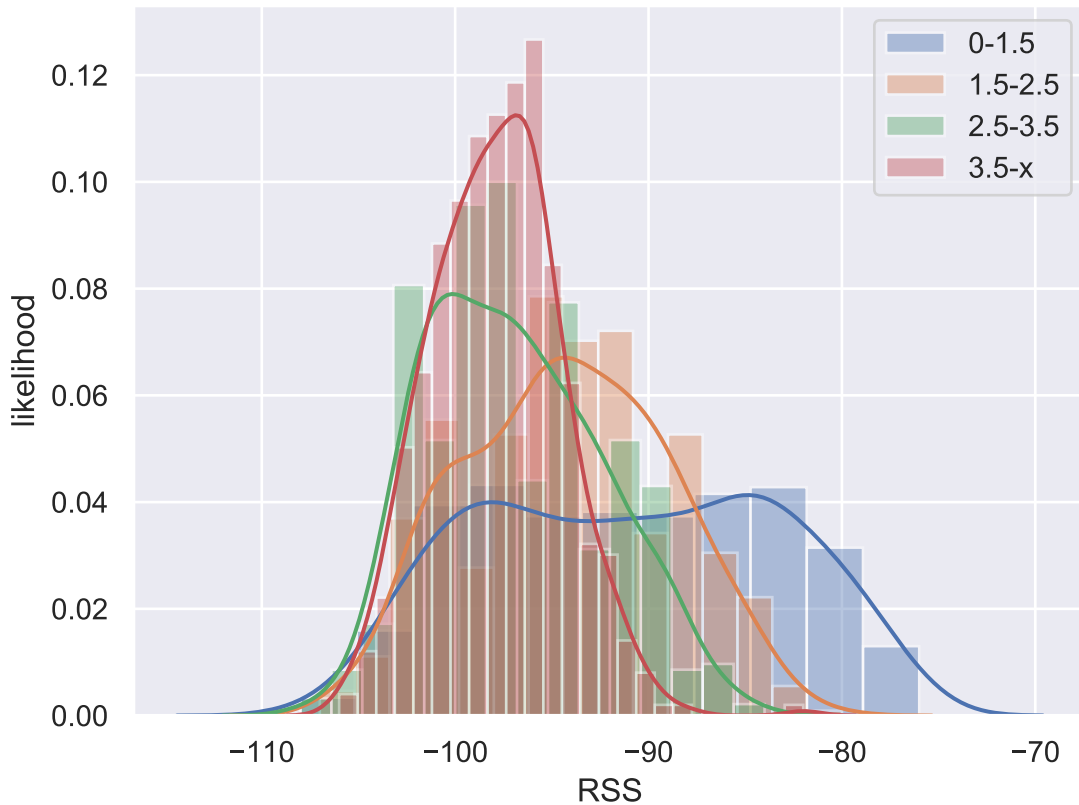


RANGE WINDOW: 60 s

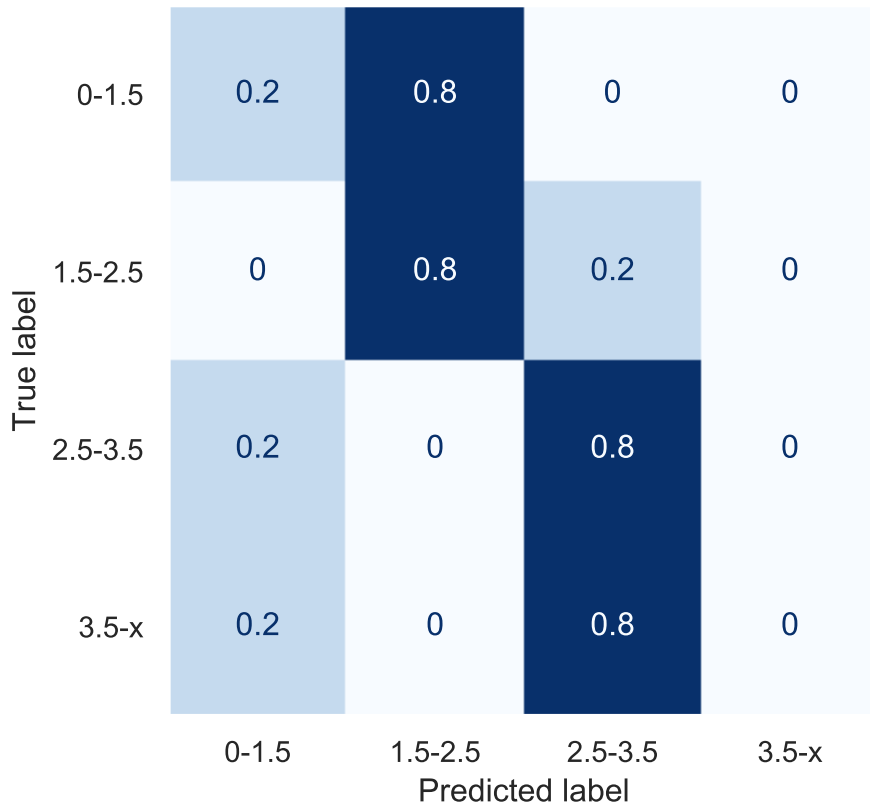
Confusion matrix Recv: SamsungA6 Trans: S8 Method: method 4



RANGE WINDOW: 60 s  
RSS Recv: S708 Trans: S8

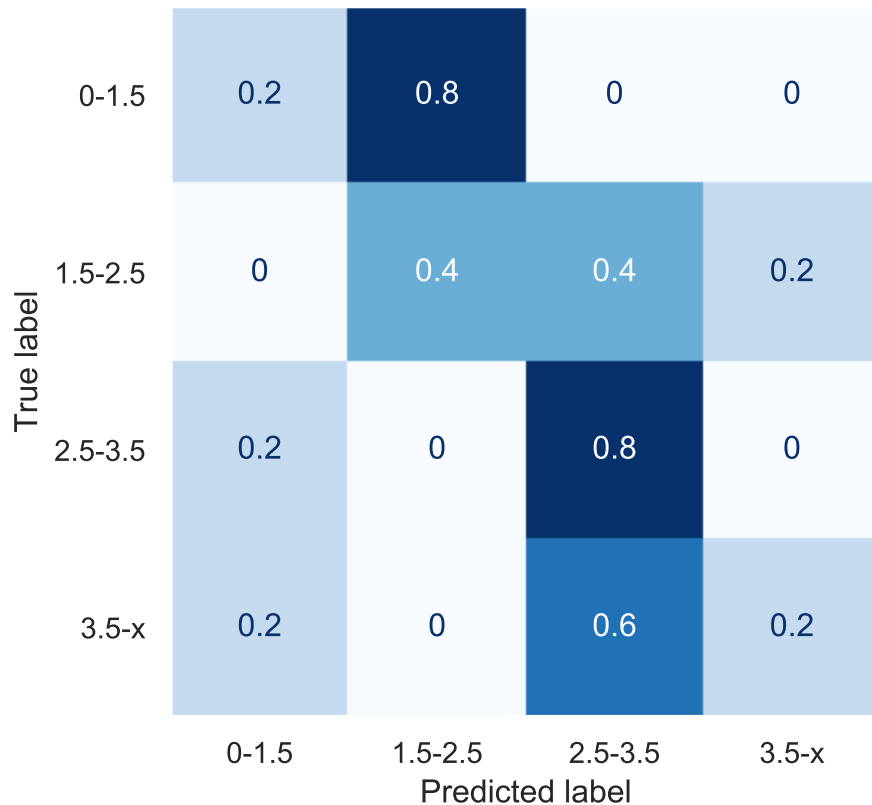


RANGE WINDOW: 60 s  
Confusion matrix Recv: S708 Trans: S8 Method: 1meter



RANGE WINDOW: 60 s

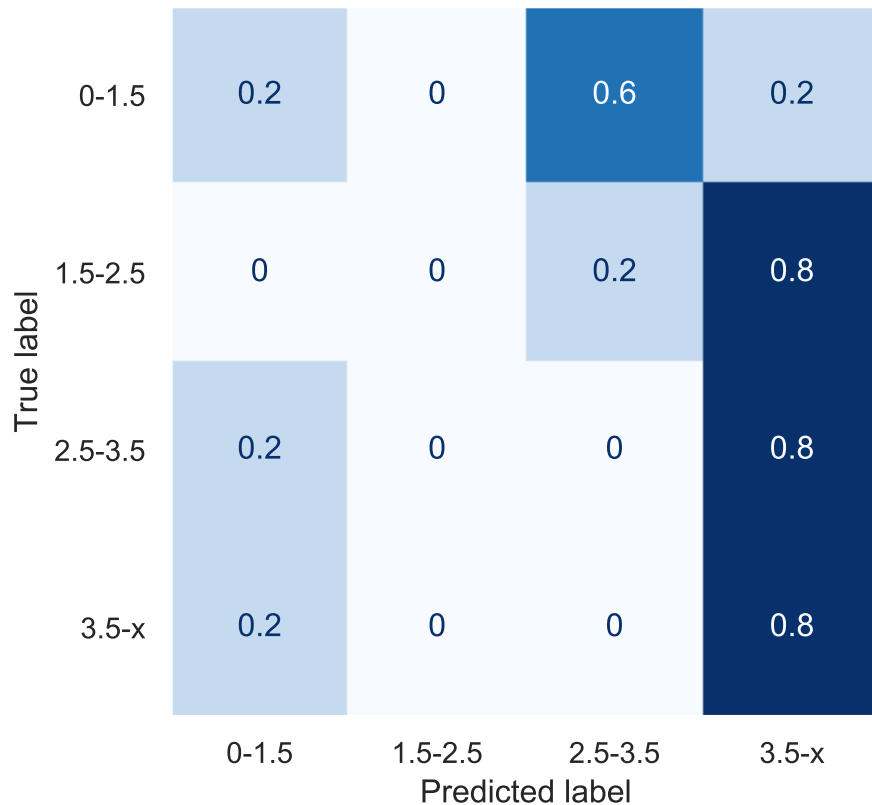
Confusion matrix Recv: S708 Trans: S8 Method: All\_without\_PL





RANGE WINDOW: 60 s

Confusion matrix Recv: S708 Trans: S8 Method: All\_with\_PL



RANGE WINDOW: 60 s

Confusion matrix Recv: S708 Trans: S8 Method: method 4

