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A Machine Learning Approach to Distinguish Between Scintillation and Multipath in GNSS Signals

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Automatic detection of GNSS signals scintillation has been challenged by many anomalies that affect GNSS signals resulting in false scintillation alarms. In particular, the amplitude scintillation metric S_4 and the phase scintillation metric σ_ϕ are affected by multipath, radio frequency interference, satellite and receiver clock anomalies, beside scintillation.

In the last few years, with the rise of machine learning (ML) applications in GNSS field, many ML models have been developed to tackle this challenge. While the early ML models to detect scintillation in GNSS signals did not particularly differentiate between the various anomalies mentioned earlier, more recent works are addressing these anomalies explicitly. Lately, [1] developed a model able to differentiate between phase anomalies caused by scintillation and those caused by clock errors. Furthermore, [2] recently proposed a model able to discriminate between scintillation and multipath in GNSS signals. The latter two models reported above 90% accuracy.

In this paper, we present a comparison between 24 ML models that we developed to discriminate between scintillation and multipath affected GNSS measurements. In particular, we focus on comparing the performance of the models that we trained using 4 different subsets of features ($F_x, x \in \{1,2,3,4\}$). These features are: the signal intensity (SI), the average SI ($\overline{SI}$), the variance in SI (σ_{SI}) and the covariance between the in–phase and quadrature–phase outputs of the GNSS receiver correlators ($cov(I^2,Q^2)$). The summary of the models developed is shown in Table 1. We also evaluate the performance of each model when the data are averaged using 6 different time windows T_w. The evaluation is presented in terms of the overall accuracy of the model (Figure 1 up), scintillation miss detection rate (Figure 1 down), and scintillation false alarm rate.

Moreover, we present statistical evaluation of the data we utilized to train and test the various models. The objective of this statistical evaluation is to verify that the data we used for training and testing the models are representative of all the targeted classes: scintillation, multipath and clean GNSS signals. Finally, we evaluate the correlation between the features we used to train the models and the different classes we are targeting.

Model	Features	Averaging Window T_w					
		1	10	30	60	90	180
$Model_1$	$F_1 = \{SI, \overline{SI}, \sigma_{SI}, cov(I^2,Q^2)\}$	variation (1)	variation (2)	variation (3)	variation (4)	variation (5)	variation (6)
$Model_2$	$F_2 = \{SI, \overline{SI}, \sigma_{SI}\}$						
$Model_3$	$F_3 = \{\overline{SI}, \sigma_{SI}, cov(I^2,Q^2)\}$						
$Model_4$	$F_4 = \{\overline{SI}, \sigma_{SI}\}$						

Table 1. The trained models and the features of each model

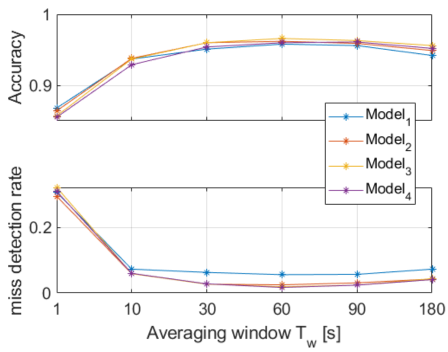

Figure 1. Accuracy of the models.

References

[1] Y. Liu and Y. J. Morton, "Automatic detection of ionospheric scintillation-like GNSS satellite oscillator anomaly using a machine-learning algorithm," *NAVIGATION*, vol. 67, no. 3, pp. 651–662, 2020.

[2] R. Imam and F. Dovis, "Distinguishing ionospheric scintillation from multipath in GNSS signals using bagged decision trees algorithm," in *2020 IEEE International Conference on Wireless for Space and Extreme Environments (WiSEE)*, 2020, pp. 83–88.