Evaluation of the effects of GPS signal reflection and diffraction on different kinds of surfaces in pseudo-range determination. Application to different types of receivers

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1. Abstract

The Infrastructure, Airspace Systems and Airports Department of the Polytechnic University of Madrid (UPM) and the Computer Science and Automatic Department of the National University of Distance Education (UNED), are developing a theoretical model for the assessment of the multipath effects on GPS receivers, for its direct application on GNSS Reference Stations.
This paper presents the results reached so far, in relation to the developed model application for predicting the mentioned multipath effects. These effects have been evaluated theoretically and verified experimentally. Reflection and Diffraction characterisation have been adapted to the nature of the different analysed surfaces; also the evaluation has been performed by simulation of three types of correlator, Standard, Narrow and MEDLL.

2. Objective

The objective of this project is to develop a theoretical model in order to be used to predict the behaviour of a potential site on the expected error in the pseudo-range determination due to multipath effects (reflection and diffraction), in case of a GPS receiver installation. The model is appropriate to be used for simulating whichever type of correlator; standard, narrow and MEDLL.

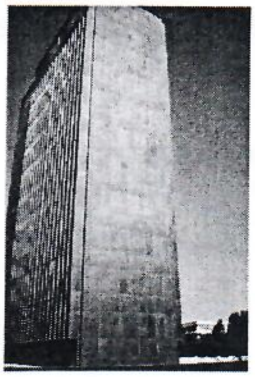
3. Model

The quoted model was used in a first trial phase, simulating in that time, the correlation function that would be obtained in case of applying a standard DLL correlator to the received signals. The model algorithm and the results obtained were presented in the GNSS Symposium held in Genova, October 1999 [1].
Subsequently, a new set of field trials have been carried out in order to gather data to be used for the validation of the model.

4. Description of trial scenarios

Two different scenarios were selected in order to record the data to be used in the quoted assessment. The selection of them were performed considering the existence of a unique multipath or at least, with a higher level amplitude than the others.
The following pictures show the trial scenarios used in the trials. Their main characteristics are the followings:

Characteristics	Scenario	
	Museum	Iberia Hangar
Type of Surface	Metal, Plane surface	Metal, Irregular surface
Dimensions	39 m. in height, 9 m. in width	30 m. in height, 84 m. in width
Distance: Surface-Test point	62,54 m.	51,16 m.



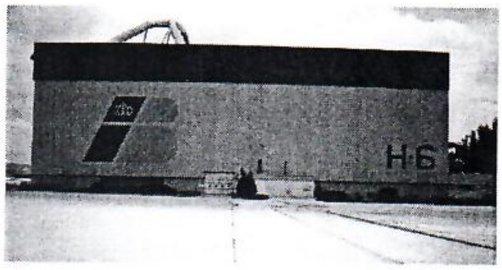


Fig. 1: National Museum of Anthropology

Fig. 2: Madrid-Barajas Airport

5. Trials performed

Since 1998 they have been carried out several recordings. Some of them using a standard receiver and in other cases using a narrow correlator receiver. In every case, only one satellite was tracked at the same time, so that the obtained result corresponds to the pseudo-range error due to multipath for the satellite under study.
The following table presents the data regarding the trials carried out on each of the mentioned scenarios. It indicates the trial date, the tracked satellites, GPS time frame of the recording and the type of receiver used for the test.

Scenario	Date	Satellite	GPS Time	Used Receiver	
				Standard	Narrow
Museum	22/7/98	1	9:15 — 11:00	X	
Museum	31/7/98	1	9:00 — 11:00	X	
Barajas Airport	28/7/99	16	9:40 — 11:10	X	
Barajas Airport	29/7/99	16	9:40 — 11:10	X	
Barajas Airport	23/2/00	15	15:04 — 17:00		X
Museum	2/3/00	29	17:15 — 17:45		X

6. Results

The following figures show the pseudo-range error due to multipath which have been obtained in two scenarios using, in both cases, receivers fitted with standard and narrow correlators.
Each figure contains two different graphics, one of them (green line) corresponds to the theoretical error, and the blue line is the experimental error due to multipath, obtained from the difference between the code and the phase error.
As it can be seen on the figures, in every case, a high correspondence between the experimental and theoretical error exists. This correspondence is maximum in the oscillation frequency and a little bit less in the amplitude value. The amplitude value of the theoretical error is, in general, higher than the experimental one.

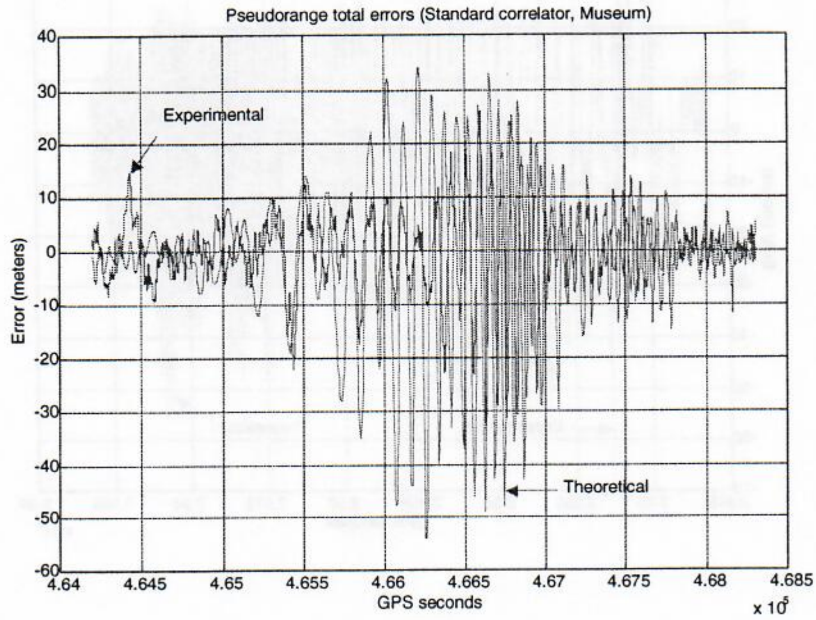


Fig. 3.a
National Museum of Anthropology.
Theoretical and Experimental multipath error. Standard Correlator

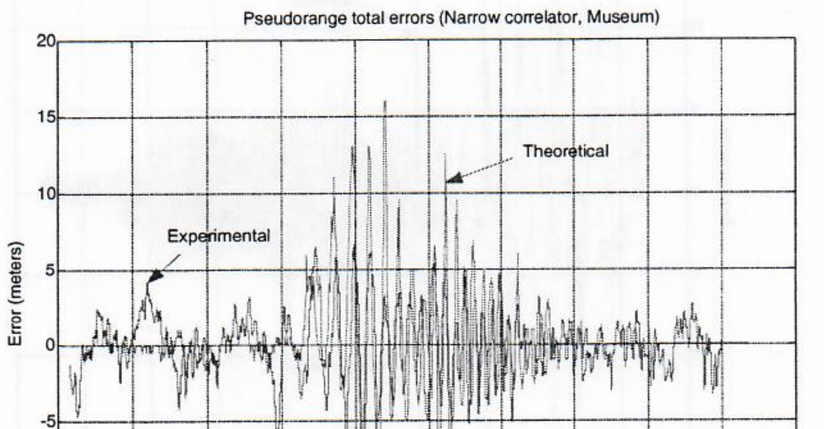


Fig. 3.b
National Museum of Anthropology.
Theoretical and Experimental multipath error. Narrow Correlator

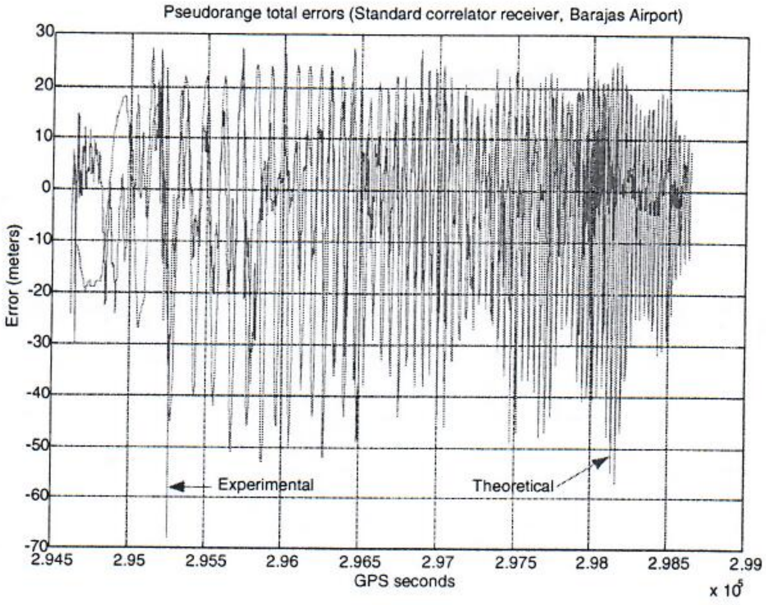


Fig. 4.a
Madrid-Barajas Airport. Iberia Hangar.
Theoretical and Experimental multipath error. Standard Correlator

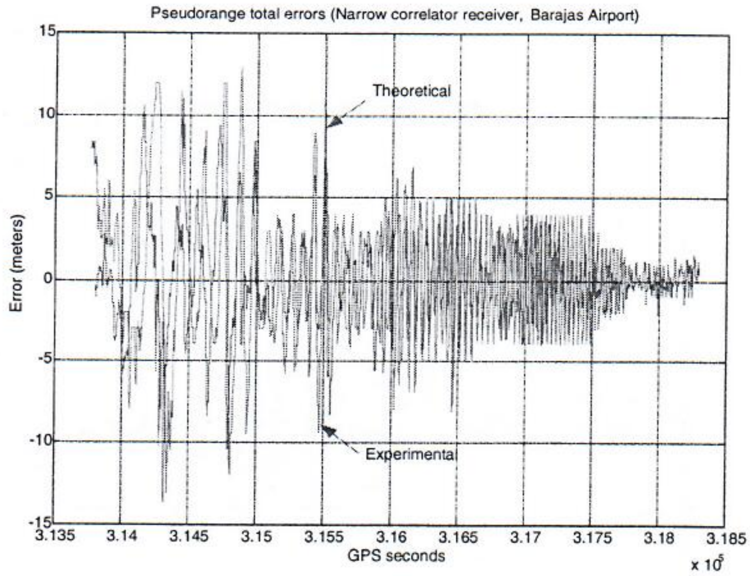


Fig. 4.b
Madrid-Barajas Airport. Iberia Hangar.
Theoretical and Experimental multipath error. Narrow Correlator

7. Analysis of the previous results

The following figures present the correlation factor between the error functions, theoretical and experimental. The red line represents the mentioned correlation factor obtained from the computation performed as indicated below. It must be noted that, in order to represent the functions all together on the same scale, the correlation factor has been multiplied by 10.

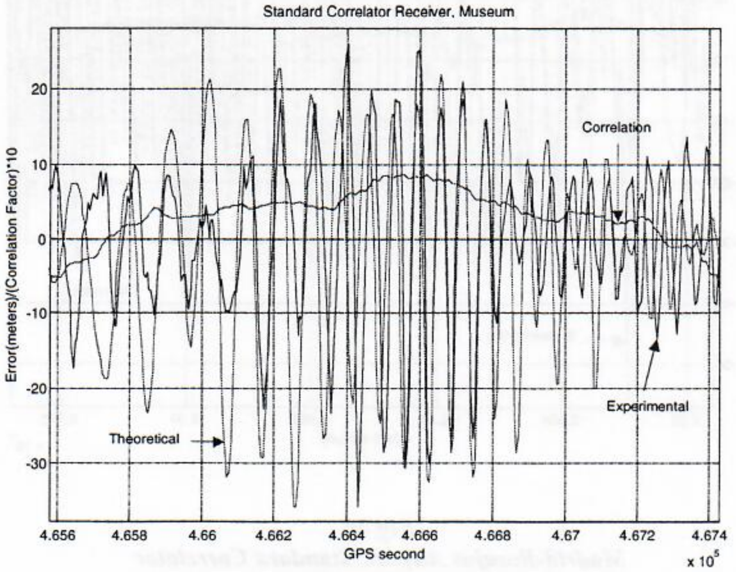


Fig 4a
Museum. Standard Correlator
Correlation factor between theoretical and experimental error signals

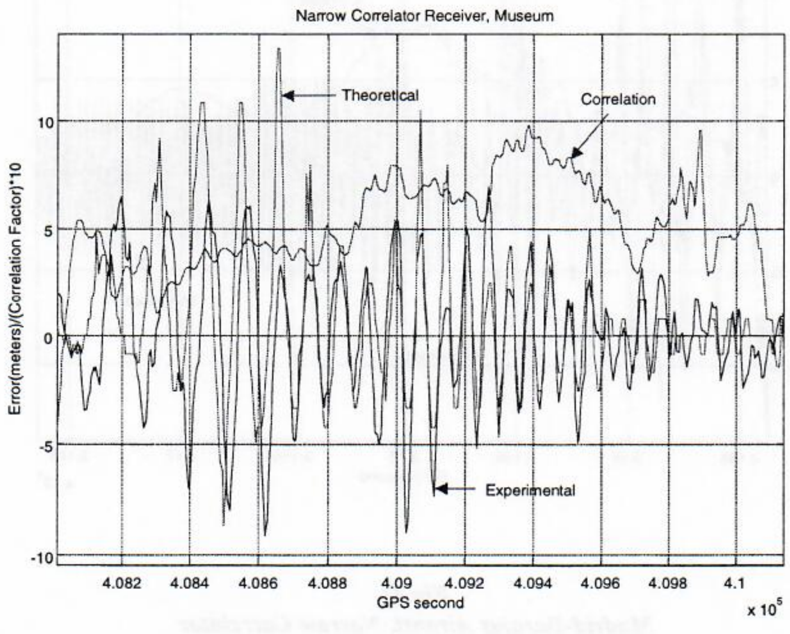


Fig 4b
Museum. Narrow Correlator
Correlation factor between theoretical and experimental error signals

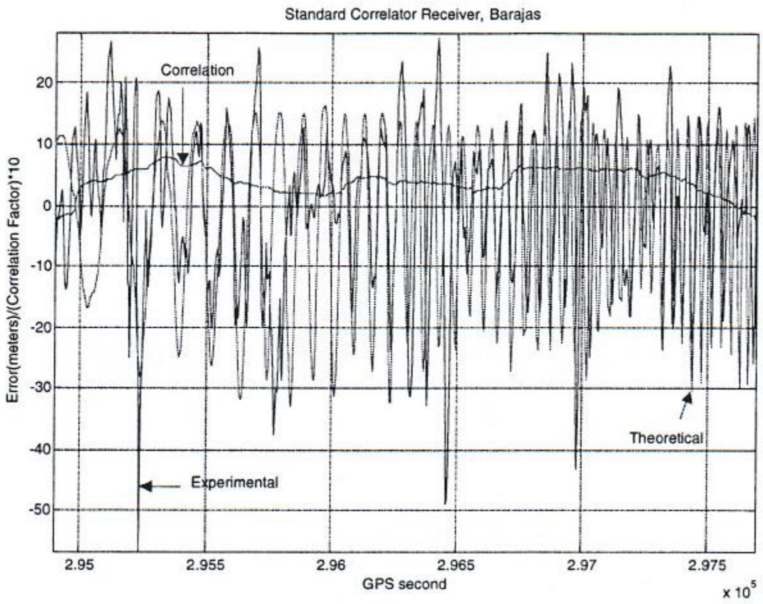


Fig 4c
Madrid-Barajas Airport. Standard Correlator
Correlation factor between theoretical and experimental error signals

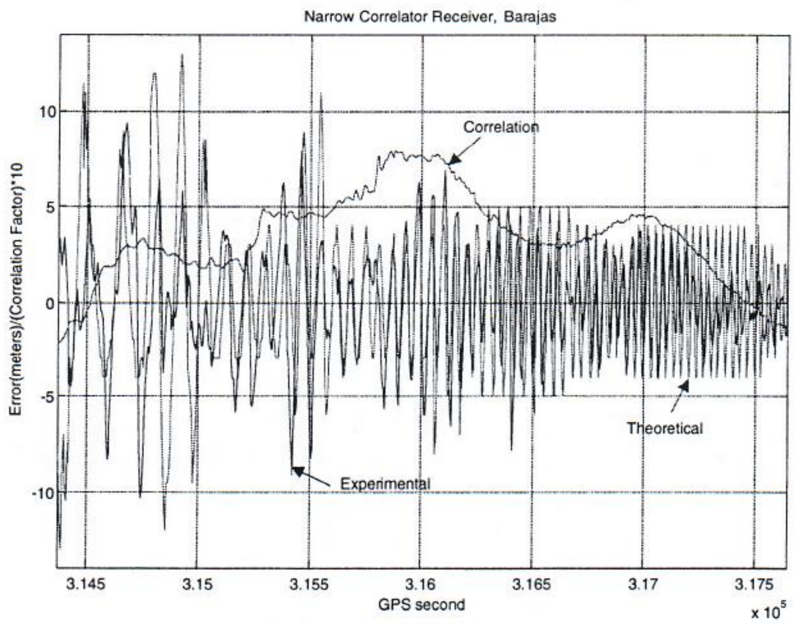


Fig 4c
Madrid-Barajas Airport. Narrow Correlator
Correlation factor between theoretical and experimental error signals

The summary of the results obtained from the performed analysis is presented in the following table.

Site	Receiver (Correlator used)	Correlation between Theoretical and experimental error:	
		Mean Time of correlation	**Mean value of correlation**
Museum	Standard	60%	0.51
	Narrow	75%	0.60
Barajas Airport	Standard	66%	0.54
	Narrow	75%	0.50

The Mean Time of Correlation has been computed as the ratio between the time during which exists positive correlation (both signals, theoretical and experimental are in-phase), and the time during which the reflection occurred (maximum potential time of correlation). The loss of correlation has been considered when the result of the correlation is equal or less than zero.

The Mean Value of Correlation has been computed as the mean of the values obtained for the different samples during the time which the correlation exists. The value for the correlation at the sample **n** has been obtained using the following expression with a correlation interval (2T) of 50 samples.

$$\boldsymbol{Correlation(n)} = \frac{1}{\sum_{i=n-T}^{i=n+T} (error\_t(i))^2} \sum_{i=n-T}^{i=n+T} \left[(error\_t(i) \langle \, (error\_m(i)) \right]$$

Where:

Error_t(i) =	Theoretical error obtained from the model at the sample *i*.
Error_m=	Experimental error obtained at the trial site at the sample *i*.
n:	Total samples number.
T:	25 samples.

8. Conclusion

The high correspondence between the theoretical and experimental values allows to confirm that the developed model is appropriate for estimating the error due to multipath which could be obtained at a particular site.

The difference in the error amplitude, usually higher in the theoretical error, is apparently due to the ideal reflection coefficient value assigned to the reflection surface and to the considered LHP antenna radiation pattern. Future testing will lead to an improvement of the results presented here.

9. Future Activities

Future activities include further validation in other scenarios of the results presented in this paper. Other recording sessions have been carried out recently, using other reflector surfaces. Further regarding sessions are being planned.

10. Acknowledgements

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11. References

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