END-TO-END SIMULATOR FOR GLOBAL NAVIGATION SATELLITE SYSTEM REFLECTOMETRY SPACE MISSION

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1. INTRODUCTION

In recent years there has been a renewal of interest in using signals of Global Navigation Satellite System (GNSS) for remote sensing. Especially, research on GNSS reflectometry (GNSS-R) has yielded promising results on various applications such as altimetry [1], sea state [2, 3], and soil moisture [4]. Currently, a GNSS-R spaceborne demonstrator mission has been proposed for altimetry applications [5], and others have proposed for sea state determination [6].

In order to understand the instrument's performance, it is necessary to simulate the GNSS-R observations including whole conditions of the bistatic scattering measurements. In other words, an end-to-end performance simulator has to be developed. This paper presents a framework for the PAU/PARIS End-to-End Performance Simulator (P/PEPS), including objectives, capabilities, structure, and design considerations. Additionally a preliminary result of GNSS-R observable, Delay Doppler Map (DDM) by using the simulator is illustrated.

2. REQUIREMENTS AND CAPABILITIES OF THE SMIULATOR

The simulator can be used for various applications of a GNSS-R spaceborne mission. Accordingly, the requirements for the end-to-end simulator are different. For example, it is required to find the observed region (referred to as a glistening zone) on the Earth's surface with varying receiver's position in the satellite orbit. Basically, DDM should be generated under given information about transmitters (GPS, Galileo), receiver satellite, and physical properties of glistening zone. To satisfy the requirements, the simulator has the following capabilities:

1) GNSS and receiver satellites orbit simulation,
2) DDM generation based on available ocean and land scattering models,
3) Accurate instrument modeling,
4) Calibration of receiver system,

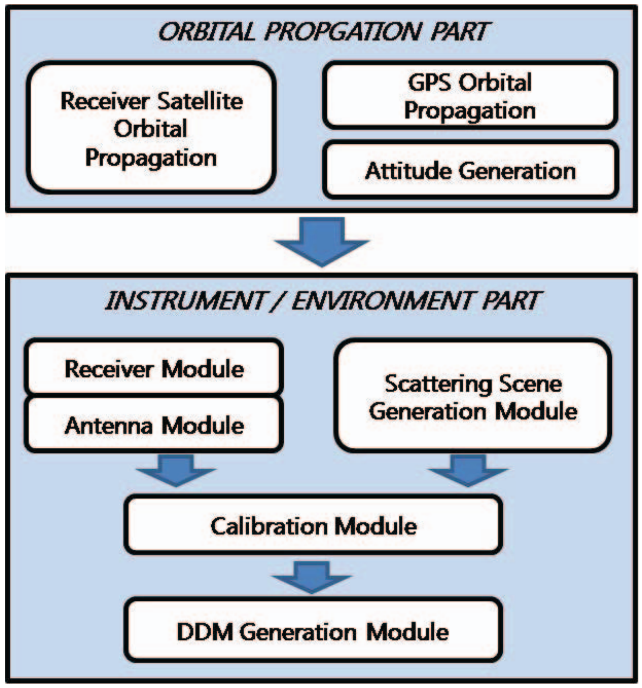

Fig. 1. Structure of the DDM simulation

5) Graphical and comprehensible outputs of simulation results,

6) Friendly user interface.

Among the functions of the simulator, the DDM generation is the core of the simulator, and for accurate modeling of scattering, the actual physical conditions of the glistening zone such as material, wind speed are provided from a database to the scattering model. The simulator is also capable of simulating the receiver hardware effects on DDM, specifically effects of antenna type, receiver's frequency response, and induced noise. As furnishing these capabilities, it becomes convenient to simulate about conditions affecting on the actual GNSS-R satellite observations.

3. STRUCTURE AND IMPLEMENTATION STRATEGY FOR THE SIMULATOR

Figure 1 shows the structure of the DDM simulation process of the simulator. Once a simulation epoch (or event time) is input, the positions and velocities of GPS satellites are calculated. In parallel, the position, velocity, and attitude of the receiver satellite is calculated. Using these outputs, the specular reflection point is found, and the scattering coefficients in the whole glistening zone are calculated based on the scattering model such as the model in [7, 8]. The receiver hardware effects are also included through the antenna and receiver modules. After the calibration module, the observables of the GNSS-R, DDM is simulated as an output of DDM generation module. Throughout the process following the structure, we can simulate how changes of the conditions affect on the DDM.

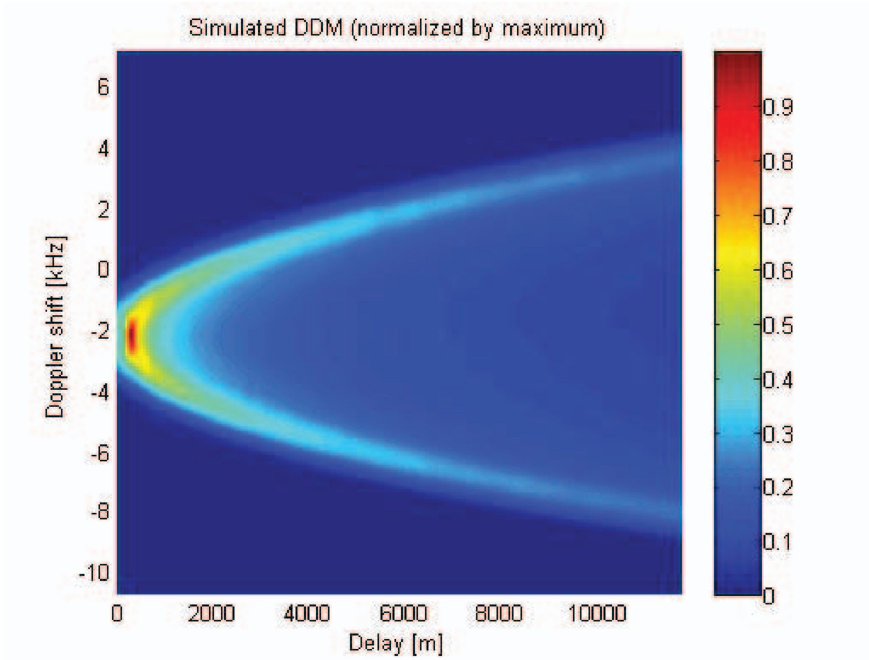

Fig. 2. Simulated DDM using DDM generation module of the simulator

For the purpose of efficient development of the simulator, we are positively using the heritage of the SMOS End-to-end Performance Simulator (SEPS) [9]. The simulation structure shown in Fig. 1 follows the SEPS simulation process, except for the GPS orbital propagation, the scattering scenario generation, and the DDM generation module. These three are specific features of the GNSS-R reflectometer whose output is a computed DDM but using the SEPS database of geophysical parameters. Other modules in Fig. 1 can be efficiently implemented by modifying the SEPS modules because they are common features of spaceborne passive microwave remote sensing.

In the GNSS-R simulation, the most serious problem is a long computation in DDM generation, and it is a bottleneck to make slowdown. This problem is more brutal in the case of spaceborne mission because of the large-sized glistening zone in delay-Doppler domain compared with the case of airborne. As a result, it is very difficult to meet the requirements of simulation speed using double loop integration method. To solve it, an efficient algorithm to simulate DDM is implemented [10], which uses convolution method on delay-Doppler domain decreasing computation time dramatically.

4. PRELIMINARY RESULT OF DDM GENERATION

The development of the simulator is progressing, and the most parts of computation and interface modules such as the DDM generation module have already been built and tested. Figure 2 shows an example of DDM generation module test result. The GNSS-R observable, DDM of the glistening zone in Fig. 2 was generated by using the implemented DDM generation module, and it shows the typical boomerang shape of DDM from a spaceborne mission (as altimetry receiver in PARIS or sea state in PAU).

5. CONCLUSION

This paper has presented the state of the development of an end-to-end performance simulator for a generic GNSS-R space mission. The requirements and expected capabilities are listed, and the simulation structure is designed. For the efficient implementation, the heritage from the SEPS is being exploited. The main algorithms and functional modules have already been implemented and tested. At the conference, the whole instrument simulator will be presented and discussed with performance assessment.

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