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Resonant quantum properties of the environment for GPS signal propagation

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Abstract

Uncontrollable sporadic distortions of satellite signals of global positioning system (GPS) caused by a phase failure and group-delays in a propagation of electromagnetic radiation through a medium take place in periods of high solar activity and geomagnetic disturbances formation in the Earth's ionosphere. Searching of ways ensuring a sustainability of the GPS system is a fundamental scientific and technical problem. Additional background incoherent ultra-high frequency (UHF) radiation is formed at the altitudes of E and D layers of the Earth ionosphere during these periods. Wavelengths of this radiation correspond to a range from a decimeter to a millimeter. This emission is due to transitions between Rydberg states of atoms and molecules which are excited by electrons in plasma, and are surrounded by a neutral particle environment. Reliable information about of UHF radiation flux power in this wavelength range is not currently available. The answer to this question depends entirely on knowledge of impact and radiation quenching of Rydberg states dynamics and the kinetics of their location in a lower ionosphere, i.e. on the quantum optical properties of a perturbed environment. Analysis of existing experimental data has shown that the UHF radiation is formed in the atmospheric layer located at altitudes of 80-110 km. A physical mechanism of the satellite signal delay is due to cascade resonant scattering of GPS signal photons in the decimeter range while passing through this layer over a set of Rydberg states. The most promising approach to studies of the medium optical quantum properties can be a simultaneous analysis of the background additional noise and the GPS signal propagation time delay which determines a positioning error. Using standard methods of noise measurement one cannot detect physical and chemical processes which are responsible for noise formation and errors affecting the positioning Therefore, the problem can be solved if the level of a background noise will be considered as a noise of the measured GPS signal, since propagation delays of the latter are due to one of the most important atmospheric collisional process, i.e. the orbital degeneracy of highly excited states. For this purpose, it is advisable to use the signal-to-noise ratio, where the signal corresponds to a level of a signal obtained by GPS receiver, and a noise corresponds to GPS signal fluctuations.

In this lection a theory current state is examined and ways of its further development are discussed. They are associated with the progress of theoretical methods for describing of the medium neutral particles impact effects on the dynamics of collision and radiation quenching focusing primarily on elementary processes involving molecules of nitrogen and oxygen. It is shown that preliminary calculations of non-adiabatic transitions dynamics between potential energy surfaces (PES) of Rydberg complexes, the construction of appropriate electronic wave functions, calculations of allowed transition dipole moments and also determination of emission line shapes are necessary for quantitative estimations of excited particles influence on a spectrum of incoherent UHF radiation of the atmosphere. These results should be included in the total kinetic scheme, which establishes dependence of UHF radiation on temperature and density of the lower ionosphere. Then the satellite monitoring data of infrared (IR) radiation, accompanying the UHF radiation, can be directly used for detection of Rydberg states and diagnostics of the plasma parameters.

The lecture is based on the materials of the review

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