Modeling and Analysis of Motion Induced Antenna Pointing Errors in Satellite Communication Systems

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Satellite communications on-the-move systems that operate in the Ku-band (11-14 GHz band) and higher frequencies play a significant role in military and civilian communication systems. Satellites at these frequency bands are located in their respective orbits so that the angular distance between adjacent satellites is usually about 2 - 3 degrees. Therefore, in order to limit interference to adjacent satellites, the Federal Communications Commission (Part 25, Section 209) and the International Telecommunications Union (ITU Recommendation ITU-R S. 728-1) have established regulations and standards that impose strict limits on the effective isotropic radiated power (EIRP) from a particular terminal in its off-axis direction. Rough or uneven terrains are commonly encountered in many communications on-the-move applications. In such terrains, the frequent motion of the antenna platform may lead to motion induced antenna pointing errors. Typically, these motion induced antenna pointing errors are small and random. It will be shown that such errors will lead to random variations of the terminal's off-axis EIRP spectral density. Since there are strict limits on the off-axis EIRP spectral density it is necessary to quantify these random variations and in this paper we will present such a technique.

Motion induced antenna pointing errors are slow time-varying random variables and the resulting EIRP spectral density, when the signal is considered stationary in a suitably chosen sliding window, is also time-varying. In order to characterize these time variations, first, we will present a simple statistical model to represent the motion induced antenna pointing errors. Then, with this model the EIRP spectral density variations are quantified using the Wigner distribution, which is useful in the analyses of slow time-varying systems. Using reasonable approximations we will demonstrate that a slow time-varying EIRP spectral density can be derived from the Wigner distribution of the EIRP. Next, for a typical statistical distribution of motion induced antenna pointing errors and a given antenna input power spectral density, it is shown that the slow time-varying EIRP spectral density so derived will exceed its recommended mask with a small probability. This probability is quantified with the boresight EIRP spectral density as a parameter.

A key objective of this paper is to demonstrate that in order to accommodate motion induced antenna pointing errors, which are unavoidable in communications on-the-move applications, the existing regulatory EIRP spectral density mask should be modified. We will suggest such a modification and determine its impact on the interference to other satellite systems. This paper will contain details of some of the results presented at the ITU-R Working Party 4A meeting in November 2005. The focus of this paper is three-fold: first, the motion induced antenna pointing errors are characterized by an appropriate statistical model; second, the effect of these errors on the EIRP spectral density is analyzed and the probability of the EIRP spectral density exceeding the ITU-R S 728-1 mask is determined; third, a modification to this EIRP spectral density mask is suggested and its impact on other satellites is analyzed.