INTERFERENCE ANALYSIS OF UWB DEVICES TO THE SATELLITE SERVICES IN THE 7240-8240 MHZ FREQUENCY BAND

Alexander Pastukh, Evgeny Deviyatkin, Alexandr Savochkin
Institute of Radio and Information Systems (IRIS), Vienna, Austria,
iris@media-publisher.eu

Valery Tikhvinskiy
International Information Technologies University (IITU), Almaty, Kazakhstan

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ABSTRACT

Ultra-wideband radio technology (UWB), is a wireless access technology that allows exchanging of data over a radio channel between over short distances at very high speed and low power consumption. UWB signals are short pulses the entire energy of which is distributed over a given wide region of the spectrum. With a sufficiently high total power transmitted over the air and with low power consumption and a pulsed nature of data transmission, a high data transmission rate can be obtained. This work has done interference analysis of ultra-wide bandwidth technologies (UWB) operating in the frequency band 7240-8240 MHz to the Earth monitoring and meteorological satellite systems that operate in this band. Taking into account the rapid development of users' UWB devices in different frequency bands, the study tries to estimate the long-term impact of aggregate interference from UWB devices located around the satellite Earth stations. The study considers two satellite systems as an example of victim receivers. The UWB density assumptions made in the studies are based on the forecasts of CEPT and UWB Alliance.

KEYWORDS: *UWB, Earth exploration satellites, meteorological satellites, interfernce analysis, Monte-Carlo analysis, spectrum management.*

I. INTRODUCTION

Ultra-wideband radio technology (UWB), is a wireless access technology that allows exchanging of data over a radio channel between over short distances at very high speed and low power consumption. UWB signals are short pulses the entire energy of which is distributed over a given wide region of the spectrum. With a sufficiently high total power transmitted over the air and with low power consumption and a pulsed nature of data transmission, a high data transmission rate can be obtained. UWB technology uses radio signals with a spectrum width of at least 500 MHz allocated in the radio frequency band from 2.86 GHz to 10.6 GHz. UWB has been in use for more than 20 years and most of the devices are used for radar, positioning, and visualization systems. But today UWB technology has also been actively introduced into user devices such as laptops, smartphones, tablets, etc., and these days there is a trend towards a gradual increase of UWB device density. According to UWB Alliance by 2022 more than 500 million UWB devices will be in circulation and by 2025 the rates will exceed 1 billion devices. UWB smartphone accessories will drive a 1:1 chip ratio with smartphones by the end of 2025 [1]. Although UWB is categorized as a low-power device, a high density of devices has the potential to cause harmful interference to the operating radio services. At present, one of the main frequency bands for the development of UWB user devices can be the frequency band 7240-8240 MHz, in which UWB supports channels 8, 9, and 11. Table 1 shows the channels supported by UWB devices [2].

Table 1

Supported UWB channels

№ channel	Central frequency	Bandwidth
1	3494,4 MHz	499,2 MHz
2	3993,6 MHz	499,2 MHz
3	4492,8 MHz	499,2 MHz
4	3993,6 MHz	1331,2 MHz
5	6489,6 MHz	499,2 MHz
6	6988,8 MHz	499,2 MHz
7	6489,6 MHz	1081,6 MHz
8	7488,0 MHz	499,2 MHz
9	7987,2 MHz	499,2 MHz
10	8486,4 MHz	499,2 MHz
11	7987,2 MHz	1331,2 MHz
12	8985,6 MHz	499,2 MHz
13	9484,8 MHz	499,2 MHz
14	9484,0 MHz	499,2 MHz
15	9484,8 MHz	1354,97 MHz

The frequency band 7240-8240 MHz is allocated to various satellite services, including Earth-exploration satellite service, meteorological satellite service, fixed-satellite service, and mobile satellite service [3]. This study does simulations of interference analysis from UWB devices to the Earth stations of the satellite networks. As victim satellites systems, two example systems were considered.

II. SIMULATION PARAMETERS AND SCENARIOS

In UWB transmissions the data is carried in the polarity of the pulses in the BPSK modulation technique, symbol 1 has a phase value of zero degrees and symbol 0 has a phase value of 180 degrees. The transmitting and deployment characteristics of UWB used in the study devices are presented Table 2 [4].

Table 2

Parameters of UWB devices used in simulation

Parameter	Value
Channel bandwidth (MHz)	500
Modulation	BPSK
Antenna gain (dBi)	0
Antenna pattern	Omni
Spectral power density (dBm/MHz)	-41.3
Body loss	4 dB
Number of simultaneously active UWB per km^2	250
Number of UWB located indoors	70%

The first system that is considered a victim receiver is the Earth station of Kanopus. Kanopus is an Earth observation satellite that is designed to collect data for environmental monitoring and mapping, detection of fires, agricultural planning, and assessing land use. It can also be used to monitor man-made and natural disasters. In simulations, the victim receiving Earth station was tracking Kanopus satellite. Figure 1 shows the Earth station of Kanopus satellite while tracking it.

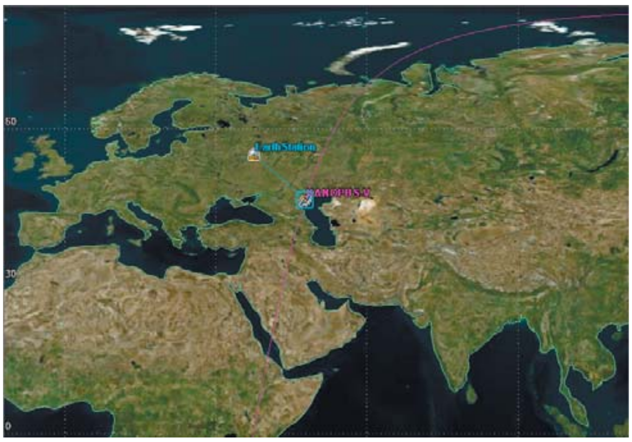

Fig. 1. Earth station tracking Kanopus satellite

Characteristics of the Kanopus satellite system used in simulations are presented in Table 3 [5], characteristics include the Earth station’s receiving parameters, as well as orbital parameters of the satellite to implement the tracking mode of the Earth station.

Table 3

Parameters of Kanopus satellite system

Parameter	Value
Orbit type	Circular
Altitude of satellite (km)	510
Orbit inclination (degrees)	97
Receiving bandwidth (MHz)	123
Noise temperature of ES (K)	130
Antenna gain of ES (dBi)	53
Antenna pattern of ES	Rec. ITU-R S.465
Antenna height of ES (m)	10
Location of ES (degrees)	55 latitude 37.5 longitude

The second system that is considered in simulations as a victim receiver was the Earth station of Elektro-L. Elektro-L is a next-generation series of a meteorological satellites designed for producing images of the Earth's whole hemisphere in both visible and infrared frequencies, providing data for climate change and ocean monitoring in addition to their primary weather forecasting role. Figure 2 depicts the Elektro-L service footprint area as well as the Earth station that is pointed towards the satellite.

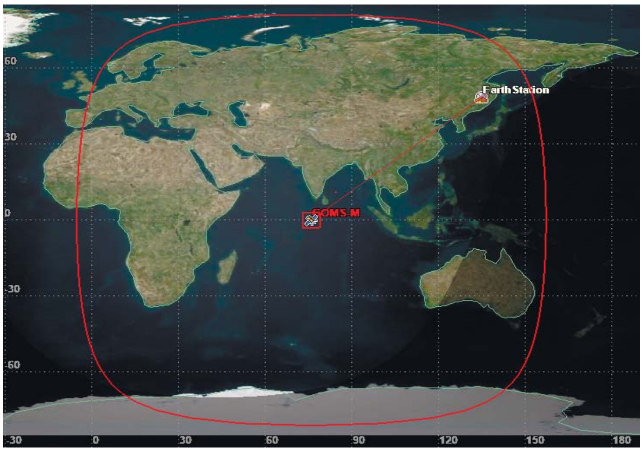

Fig. 2. Earth station pointing towards Elektro-L satellite

Characteristics of the Elektro-L satellite system used in simulations are presented in Table 4 [5], characteristics include the Earth station's receiving parameters, as well as the orbital position of the satellite to definite the antenna pointing of the Earth station.

Table 4

Parameters of Kanopus satellite system

Parameter	Value
Orbit type	Geostationary
Orbital position (degrees)	76
Receiving bandwidth (MHz)	30
Noise temperature of ES (K)	150
Antenna gain of ES (dBi)	50
Antenna pattern of ES	Rec. ITU-R S.580
Antenna height of ES (m)	10
Location of ES (degrees)	48.55 latitude 135.167 longitude

III. SIMULATIONS AND METHODOLOGY

The protection criterion of the satellite services was interference-to-noise ratio (I/N) which according the ITU recommendations is -12.2 dB. To calculate the I/N at each simulation step the following expression can be used [6]:

$$\frac{I}{N}[\text{dB}] = 10\, log_{10}\left(\sum_i 10^{\frac{I_{UWB}(i)}{10}}\right) - (D + NF + 10\, log(B))$$

where, I_{UWB} (i) are the interference from i^{th} active UWB device (dBm); D is receiver noise power density (dBm/Hz); NF is receiver noise figure (dB), B is receiver channel bandwidth (Hz).

The interference from each UWB transmitter can be derived from the below expression [6]:

$$I_{UWB} = P_{TX} + G_{IMT} + G_{ES} - L_p - L_{xpr}$$

where, P_{TX} the transmitted power of the i^{th} UWB device (dBm); G_{UWB} the transmit antenna gain of the i^{th} UWB device towards the victim receiver (dBi); G_{ES} the receive antenna gain of the Earth station towards the interfering station (dBi), L_p the propagation loss from the transmitting UWB and receiving ES (dB), L_{xpr} the polarization loss (dB).

Before the interference simulations were made, the movement of the satellite systems was simulated to define the distribution of elevation angles. The elevation angle is important because it determines the amount of interference the Earth station will receive from UWB generally the lower the elevation angle, the higher interference from UWB there will be. Azimuth in this scenario generally is not important since UWB are randomly distributed around the Earth station and the Earth station is located in the center of the simulated area, however, it was also taken into account. Kanopus satellite movement was simulated for 3 months with a 1-second step, at each step elevation angles and azimuths were defined. Figure 3 shows simulation of Kanopus satellite movement.

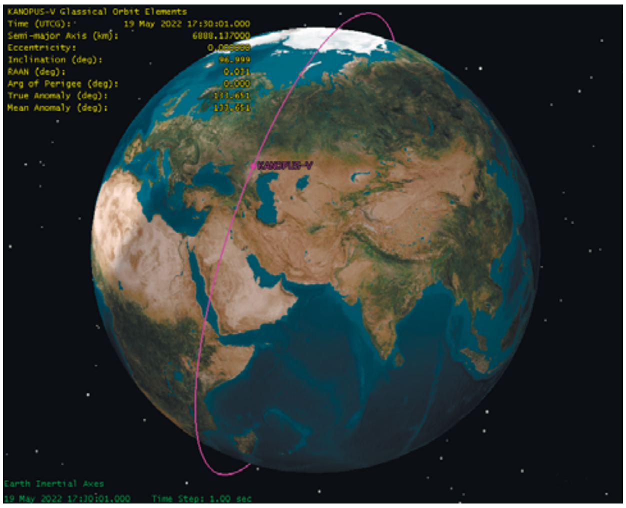

Fig. 3. Earth station pointing towards Elektro-L satellite

After the simulation of the satellite movement was finished, the obtained data array of elevation and azimuth angles was stored and uploaded to the ES during the interference simulations. Figure 4 shows the distribution of azimuths (green lines), elevations (red lines), and distances (blue lines) within the 3 months of simulation.

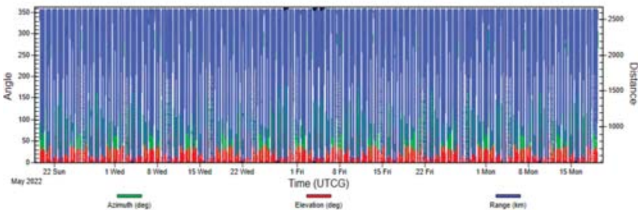

Fig. 4. Earth station pointing towards Elektro-L satellite

For the Elektro-L case, the elevation angle was calculated, however in this case the task was much easier since in the case of geostationary orbit the elevation angle and azimuth would be static. The elevation angle towards the geostationary satellite may be calculated using the following expression [7]:

$$\theta = \cos^{-1}\left(\frac{r_e + h_{GSO}}{d}\sqrt{1-\cos^2(B)\ \cos^2(L_E)}\right)$$

where r_e is the equatorial radius = 6378.14 km; h_{GSO} is the geostationary altitude = 35 786 km; d is the range between the Earth station and the satellite (km); B is the differential longitude (degrees); L_E is the ES latitude (degrees).

Figure 5 shows the slant path from the Earth station towards the GSO satellite. It can be noticed that the elevation angle of the Earth station located in the simulated coordinates equals 11.322 degrees and azimuth equals 245.924 degrees.

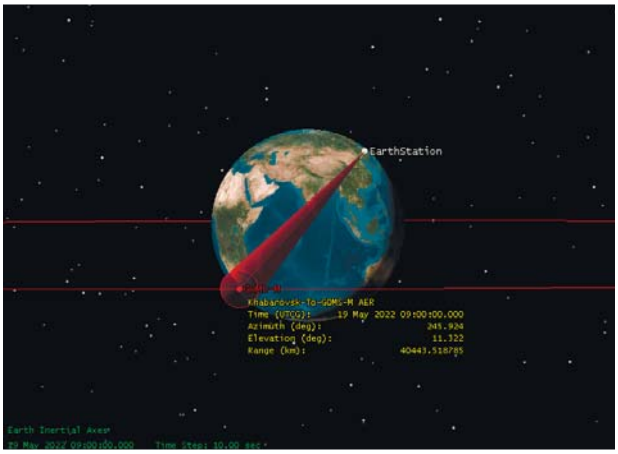

Fig. 5. Earth station pointing towards Elektro-L satellite

For interference simulation, Monte-Carlo analysis was used, and UWB devices were randomly distributed around the Earth station. The simulations considered the area of 4 m2 where UWB devices were randomly distributed around the Earth station. Since typically Earth stations have their territory where UWB devices won't be located, 150 meters protection zone around the Earth stations was configured. Figure 6 provides an example of interference simulation of aggregate interference from UWB devices to the satellite Earth station.

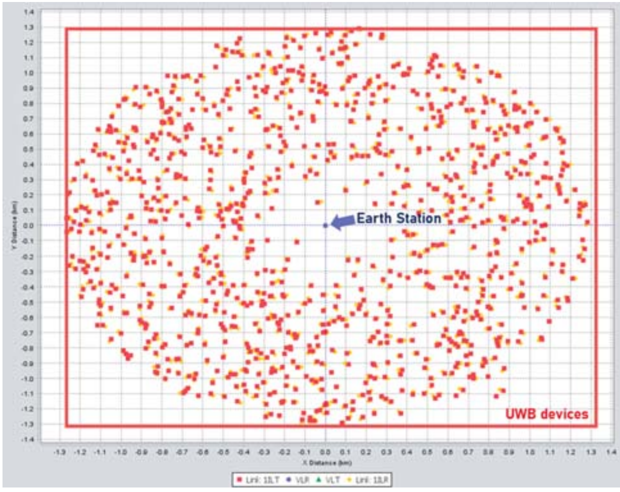

Fig. 6. Earth station pointing towards Elektro-L satellite

To calculate propagation losses in the study Recommendation ITU-R P.2001 [8] for p = 50% which gives median propagation losses between each UWB device and ES; To estimate additional clutter loss Recommendation ITU-R P.2108 [9] was used; To take into account building entry losses for those UWB that are located indoor Recommendation ITU-R P.2109 [10] with 50/50 ratio of building type between traditional and thermally efficient buildings.

IV. STUDY RESULTS

After the simulations, cumulative distribution functions of I/N were obtained and compared with the protection criterion to figure out whether I/N is exceeded at any step or not.

Figure 7 shows the cumulative distribution function of I/N for the Kanopus satellite, Figure 8 shows the vector representation of aggregate I/N for each simulation step. The blue line in both pictures show the threshold border which equals -12.2 dB.

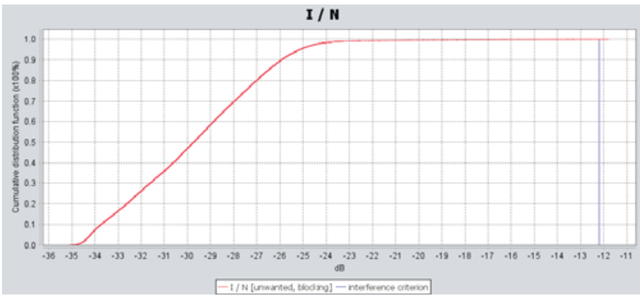

Fig. 7. Earth station pointing towards Elektro-L satellite

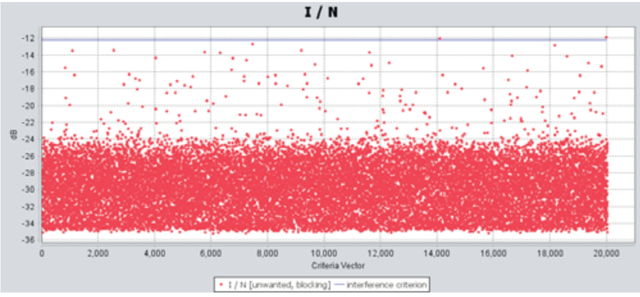

Fig. 8. Earth station pointing towards Elektro-L satellite

The figures above show that the criterion I/N = -12.2 dB is satisfied for each simulation step and that the levels of I/N are close to the I/N threshold only in a very small percentage of simulation steps.

Figure 9 shows the cumulative distribution function of I/N for the Elektro-L satellite, Figure 10 shows the vector representation of aggregate I/N for each simulation step.

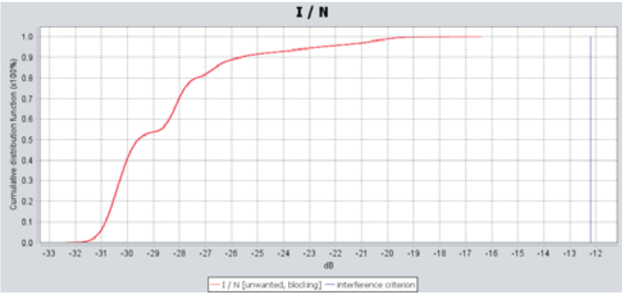

Fig. 9. Earth station pointing towards Elektro-L satellite

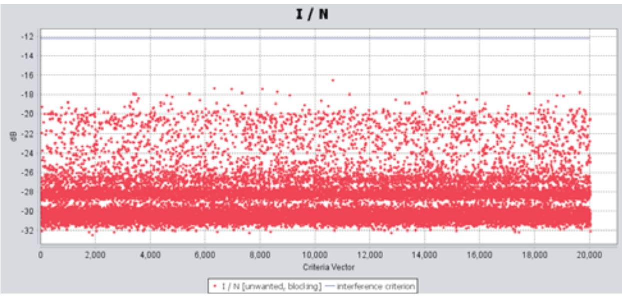

Fig. 10. Earth station pointing towards Elektro-L satellite

The figures above show that criterion I/N = -12.2 dB is satisfied for each simulation step and the levels of I/N are significantly lower than the threshold level.

V. CONCLUSIONS

Overall, the interference analysis results show that for both satellite systems the protection criterion interference-to-noise isn't exceeded. It should be noted that in the study Earth stations were assumed to be located in an urban area, but in practice, the Earth stations are usually located in suburban or rural areas where there is a low density of UWB. Additionally, in many cases, the minimum distance between the UWB devices and an Earth station would be higher than those that were considered in the study. Thus it may be concluded that no harmful interference to the satellite services is expected even when UWB density will reach significant levels.

ACKNOWLEDGMENT

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