Cross-Border Coordination between International Mobile Telecommunications System and Aeronautical Telemetry System in the 1429-1518 MHz Frequency Band

Sarunas Oberauskas[1], Vidas Kalesinskas[2], Mindaugas Zilinskas[1, 2], Evaldas Stankevicius[3, *]
[1]Communications Regulatory Authority of the Republic of Lithuania,
Mortos g. 14, LT–03219 Vilnius, Lithuania
[2]Institute of Applied Electrodynamics and Telecommunications, Vilnius University,
Sauletekio al. 9, LT–10222 Vilnius, Lithuania
[3]Department of Computer Science and Communications Technologies,
Vilnius Gediminas Technical University,
Sauletekio al. 11, LT–10223 Vilnius, Lithuania
evaldas.stankevicius@vgtu.lt

***Abstract*—this paper presents the co-channel compatibility analysis between Aeronautical Mobile Telemetry system (ATS) and International Mobile Telecommunications system (IMT) in the frequency band 1427 MHz–1518 MHz. IMT are developing at staggering rates and mobile operators always search for new possible frequency bands to expand their mobile and fixed communication networks (MFCN) and 1427 MHz–1518 MHz frequency band is attractive due to the qualified radio propagation conditions. However, this band is already operated by other technologies, such as aeronautical networks, radio relay, broadcasting networks, in the neighbouring countries. Co-channel and adjacent channel electromagnetic compatibility have to be evaluated. Electromagnetic compatibility between ATS and IMT is one of the most sensitive issues regarding the decision to identify this band to IMT. This paper was conducted to compare two protection criteria methods, i.e. I/N and C/(I + N).**

***Index Terms*—Aircraft navigation; 4G mobile communication; Electromagnetic compatibility; Interchannel interference; UHF propagation; UHF communication.**

I. Introduction

In today's world radio frequencies are being increasingly used. There is a growing mobile technology development, thus increasing demand for radio frequencies to mobile services [1], [2]. Mobile operators are often faced with the problem of spectrum scarcity. Companies have the resources to expand their networks, but it becomes increasingly difficult to avoid interference between adjacent stations due to ever growing density of wireless apparatus [3], [4].

At World Radiocommunication Conference in 2015 (WRC-15), the frequency bands 1427 MHz–1452 MHz and 1492 MHz–1518 MHz were identified globally for IMT in Radio Regulations (RR) in accordance with Resolution 223 (Rev.WRC-15). CEPT has also issued the ECC Decision (17)06 on "the harmonised use of the frequency bands 1427 MHz–1452 MHz and 1492 MHz–1518 MHz for Mobile/Fixed Communications Networks Supplemental Downlink (MFCN SDL)" and amended ECC Decision 13(03) on "the harmonised use of the frequency band 1452 MHz–1492 MHz for Mobile/Fixed Communications Networks Supplemental Downlink (MFCN SDL)".

All previous studies on this matter have attempted to define the criteria for protection of the ATS and the trigger distances to initiate coordination. However, these studies were mainly based on very conservative approaches which would likely lead to overprotection. The purpose of this paper is to determine a protection criterion acceptable for practical purposes [5], [6].

This paper investigates and compares two possible ways to evaluate the electromagnetic compatibility in co-channel operation between MFCN BS transmitter and ATS ground station receiver based on two protection criteria methods – I/N and C/(I + N). In general, when the information is only available about system sensitivity, I/N criteria could be used. In cases where information is also available on the link budgets for telemetry system, appropriate way to define permitted levels of interference would be the C/(I + N) method.

The paper investigates and proposes the more efficient approach (more efficient use and share of spectrum) to evaluate the electromagnetic compatibility in co-channel operation between MFCN BS transmitter and ATS ground station receiver – the resource of frequencies are limited and better understanding of maximum interference limits would lead to more developed radio services in each country.

II. Technical Characteristics of ATS System

Tracking-type antenna system – main technical implementation of the ground station ATS works only on receiving data from the tested aircraft by slowly tracking the movement of the aircraft. In this case, ATS ground station

Manuscript received 10 December, 2019; accepted 9 April, 2020.

978-1-7281-5868-6/20/$31.00 ©2020 IEEE

antenna pattern is according to the Recommendation ITU-R M.1459-0 [7].

Radar-type antenna system – another distinctive feature of the aeronautical mobile telemetry system is the use of pulse-code signals, which allows in some cases to partially combine the functionality of radar and ATS. Therefore, ATS stations can have as a separate functional implementation and be an additional component of radar equipment. In particular, the reflector-type radar antenna and separate components of the radar feeder system are used both by the radar and by the ATS station. In this operating mode the data from the tested aircraft is received by synchronised rotation with radar. In this case, ATS ground station antenna pattern is according to Recommendation ITU-R M.1851-0 [8].

According to the RR footnote No. 5.342, the service area of ATS stations operating in 1429 MHz–1535 MHz frequency band is limited to the national territory. As the service area is determined by the maximum radius of the system, which in turn is limited by the power budget of the link from the aircraft to the ground level, hence the possibility of data receiving from the aircraft is determined by the flight path of the aircraft within the national territory. Thus, in the course of research, the scenario of the interference from the IMT BS should take into account the effect of interference towards both the main and side lobes of the antenna pattern of the ATS station.

TABLE I. ATS SYSTEM CHARACTERISTICS.

Parameter	Value
Characteristics of ATS on-board transmitter	
Maximum e.i.r.p., dBW	38
Occupied bandwidth of emission, MHz	1/3/5
Operation frequencies, MHz	1429–1518
Maximum antenna height, m	10000
Maximum antenna gain, dBi	6
Antenna pattern on -3 dB level, º	Non-directional or low directional
Main lobe direction	Low hemisphere
Transmission path length, km	up to 320
Characteristics of ATS ground (terrestrial) receiver	
Antenna height, m	10
Polarisation	linear
Thermal noise floor (kTB), dBW/5 MHz	−135.98
Noise figure, dB	7
Maximum antenna gain, dBi	30
Feeder losses, dB	3
Antenna pattern on -3 dB level (average), º	Vertical pattern: 10º; Horizon pattern: 4º
Main lobe direction, °	Azimuth: 0–360º
C/N ratio, dB	13

III. Technical Characteristics of Mobile System

The characteristics of mobile service systems are according to Report ITU-R M.2292-0 [9] and are extracted in Table II.

For the analysis in this paper the channel bandwidth of 5 MHz will be considered, however other channel bandwidth values also may be under consideration.

TABLE II. MFCN SYSTEM CHARACTERISTICS.

IMT base station (BS) characteristics	
Cell radius	4.75 km
Antenna height	30 m
Sectorisation	3 sectors
Downtilt	3 degrees
Frequency reuse	1
Antenna pattern (see Annex 1)	Recommendation ITU-R F.1336 [10] (recommends 3.1) $k_a = 0.7$, $k_p = 0.7$, $k_h = 0.7$, $k_v = 0.3$ Horizontal 3 dB beamwidth: 65 degrees Vertical 3 dB beamwidth: determined from the horizontal beamwidth by equations in Recommendation ITU-R F.1336
Antenna polarisation	Linear / ±45 degrees
Feeder loss	3 dB
Channel bandwidth	5 MHz
Maximum base station output power (5 MHz)	43 dBm
Maximum base station antenna gain	18 dBi
Maximum base station output power/sector (e.i.r.p.)	58 dBm

IV. ATS System Operation

A. Protection Criteria

The maximum permitted interference power level at the receiver input may be specified according to one of the two criteria [11]–[13]:

– "I/N" criterion – where the maximum permitted interference is defined in relation to the thermal noise level (I is interfering signal and N is system thermal noise power);

– "C/(I+N)" criterion – where the value of the maximum permitted interference is defined in relation to a target reduction in the receiver's signal-to-interference-plus-noise ratio (C is wanted signal, I is interfering signal, N is thermal noise). This criterion might be appropriate if the receiver operates at some margin above its minimum sensitivity and in cases where information on the link budgets is available.

B. Coordination Trigger

The main goal of international cross-border coordination is to allow each of the countries a mutual and optimal use of the radio spectrum. Different countries may wish to adopt different approaches to cross-border coordination.

In order to calculate the effect of possible harmful interference a parameter for permissible interference impact on the receiving station needs to be determined. Coordination triggers could be defined as [14]:

a) maximum permitted field strength levels (land mobile and broadcasting services),
b) coordination distances (broadcasting and fixed services, radars),
c) coordination area (broadcasting and space services), triggering power flux density (fixed service).

This paper will analyse the field strength level method.

The required maximum permitted field strength level for the protection of ATS ground stations from interference could be calculated in one of two following ways:

– at the location of ATS station. This should be seen as the primary method since the main objective is to protect the station in the place where it is located. The information on the location of these stations can be obtained from the Master International Frequency Register (MIFR) or from the administrations concerned;

– at the borderline. This should be agreed between neighbouring countries concerned. In such situation the requirements for the protection of ATS ground stations should not impose higher levels comparing to the case of known location. This provides implementation flexibility for the country using ATS without creating additional constraints to the mobile service in the neighbouring countries.

V. Methodology for Field Strength Calculations

A. *Interference Analysis for Different Protection Methods*

The following analysis investigates interference from MFCN BS to ATS ground station based on protection criterion by methods I/N and C/(I + N).

For the I/N method ATS receiver's sensitivity threshold according to Table I is −135.98 dB (when the interference to noise ratio (interference criterion) at 1 dB sensitivity degradation is −6 dB).

For the C/(I + N) method, according to the same table, the transmission path length of the ATS system is up to 320 kilometres and the required C/N is 13 dB.

In order to obtain field strength level at the ATS receiver, the transmission loss from aircraft transmitter should be calculated by the formula from Recommendation ITU-R P.525-2 [15] for the frequency under consideration (1474 MHz is used in this paper) and for isotropically received power involving no feeder loss. To obtain the level at the reference point of the receiver, antenna gain and feeder losses should be taken into account.

B. *Single and Aggregate Interference Simulations*

Due to variety of border shapes, two possible simplified borderline cases could be analysed: straight line type and a ring type (see Fig. 1). For the first case (straight line), the ATS system (ground station and aircraft station) could be placed either perpendicular (scenario 1) or parallel (scenario 2) to the borderline. These two cases could assess the interference from MFCN into main lobe and side lobes of the ATS antenna pattern.

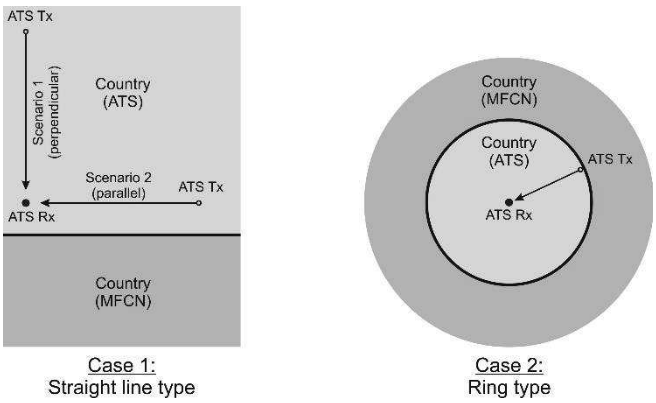

Fig. 1. Borderline cases.

This paper will analyse only scenario 1. In this case the situation where all systems (mobile network base stations, ATS receiver and ATS transmitter) are in the same line is considered. Both radar-type and tracking-type antenna systems will be considered (i.e. antenna pattern according to Recommendations ITU-R M.1851-0 and ITU-R M.1459-0).

Simulations for 1 cell (3 sectors) or BS as interferer and 19 cells (57 sectors) (the maximum number of cells or BSs in SEAMCAT cluster, version 5.3.0) are performed. Since the cell radius is 4.75 km, then the radius of such network will be 38 km, consequently, this would cover an area of 4536 km^2. A system layout is provided in Fig. 2.

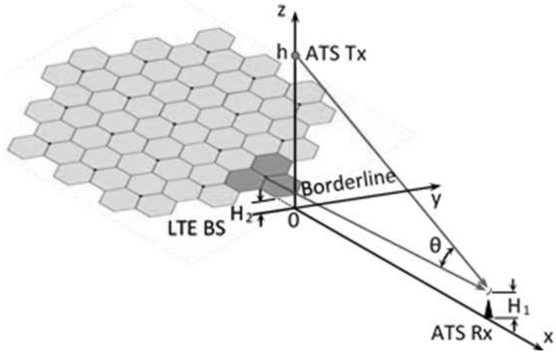

Fig. 2. Aggregate interference from MFCN cluster (scenario 1).

The ATS on-board transmitter is placed above the borderline at the height of 10000 m and 2000 m. Antenna is omnidirectional in lower semi sphere with 6 dBi antenna gain. The ATS ground receiver antenna is always pointing to the aircraft and antenna pattern is according to Recommendations ITU-R M.1459-0. The ATS ground receiver antenna height is 10 m. The nearest base station (reference cell) is 9.5 km from the borderline (i.e. two cell radii) and one of its three sectors is looking directly to ATS. The BS antenna height is 30 m, antenna pattern is in accordance with Recommendation ITU-R F.1336 and the antenna downtilt angle is set to 3 degrees. A flat-earth terrain profile with land path is considered.

First the ATS ground receiver antenna gain of Recommendation ITU-R M.1459 (maximum antenna gain of 29 dBi) towards base station dependence on the distance is analysed.

From Fig. 3 when aircraft altitude is 10000 m, it can be noted that for the distances up to 100 km from the borderline the interference at the ATS ground receiver is received mainly by the side lobe of antenna pattern (with corresponding antenna gain). At the distance of 120 km from the border antenna gain reaches 19.5 dBi and only from 240 km antenna gain exceeds 27 dBi.

It is also worth to note that for aircraft altitude of 10000 m the line-of-sight (LOS) and radio horizon (RH) distances are 368.29 km and 425.03 km accordingly (for aircraft altitude of 2000 m the values are 170.94 km and 197.28 km respectively).

The results of interference from 1 cell and clustered network (19 cells) into ATS ground station using antenna pattern in accordance with Recommendation ITU-R M.1459 for I/N and C/(I + N) calculation methods are provided in Fig. 4 and Fig. 5. The propagation model according to Recommendation ITU-R P.1546-5 [16] is used for the calculation of interfering Received Signal Strength (iRSS) from MFCN BSs to ATS ground station and Recommendation ITU-R P.525-2 is used to calculate wanted signal from ATS on-board transmitter to ATS ground receiver. The calculations were made at 1474 MHz centre frequency with channel bandwidth of 5 MHz of each system.

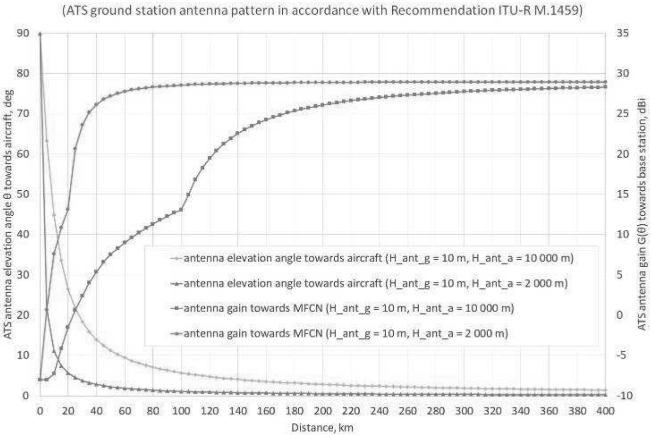

Fig. 3. Aggregate interference from MFCN cluster (scenario 1).

The results for the analysis based on I/N and C/(I + N) methods are provided in the Fig. 4 and Fig. 5.

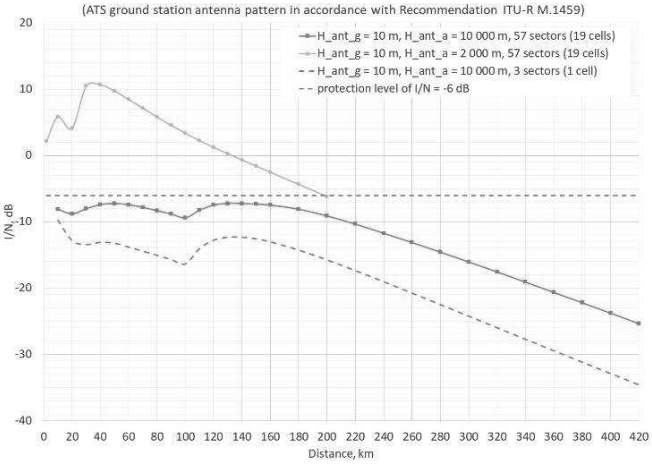

Fig. 4. I/N dependence on distance between ATS and MFCN (ATS antenna according to Recommendation ITU-R M.1459-0).

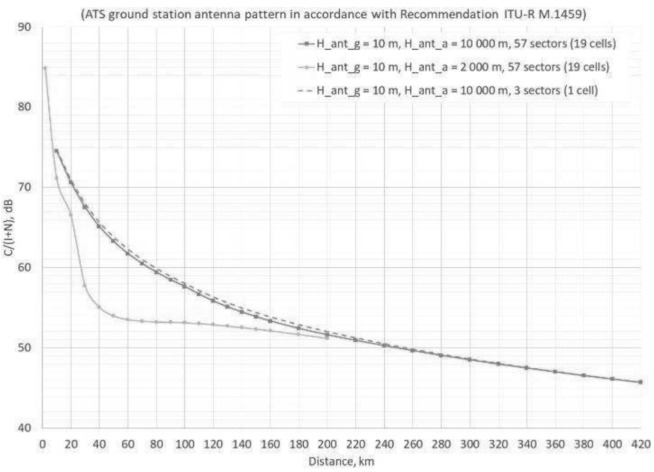

Fig. 5. C/(I+N) dependence on distance between ATS and MFCN (ATS antenna according to Recommendation ITU-R M.1459-0).

From Fig. 4 and Fig. 5 show that results highly depend on aircraft altitude. Using I/N method it can be seen that the coexistence is possible when aircraft is flying at 10000 m altitude and however when the aircraft altitude is 2000 m the protection criteria is always exceeded (until radio horizon). From Fig. 5, it can be seen that using C/(I + N) method systems are always compatible since C/(I + N) is over 48 dB for the interferer of 1 and 19 base stations when the aircraft is operating with the maximum e.i.r.p. which means that there is a margin of 35 dB.

The results of interference from clustered network into ATS ground station using antenna pattern in accordance with Recommendation ITU-R M.1851 for the same calculation methods are provided in the Fig. 6 and Fig. 7. In this analysis in this paper an electrical elevation antenna angle of 11 degrees were used (based on the information provided by ATS users). The horizontal antenna pattern could be two types (sin or cos distribution function). The results in this paper are presented only for sin antenna distribution pattern type as the difference using cos antenna distribution pattern type in the direction of main lobe is very small. This is because almost all interference is received by the main lobe of ATS ground station.

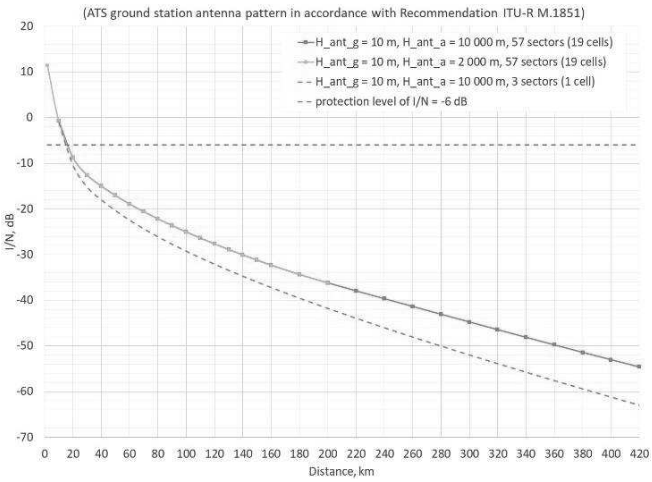

Fig. 6. I/N dependence on distance between ATS and MFCN (ATS antenna according to Recommendation ITU-R M.1851-0).

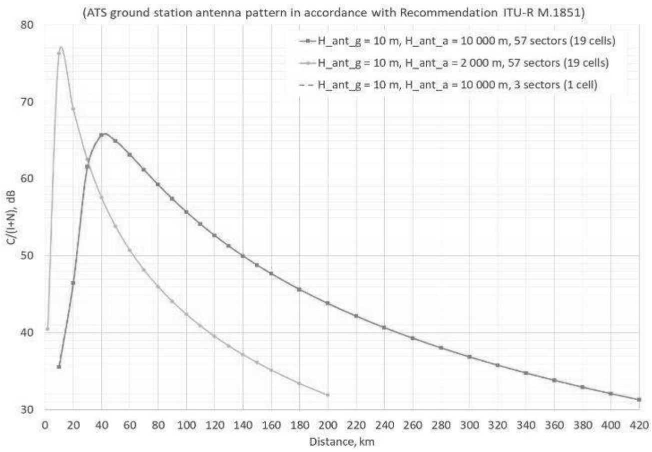

Fig. 7. C/(I+N) dependence on distance between ATS and MFCN (ATS antenna according to Recommendation ITU-R M.1851-**Error! Reference source not found.**).

The results indicate that protection requirement I/N = −6 dB is not exceeded already at the distance around 15 km from the borderline and for method C/(I + N) is over 30 dB, hence there is a margin of minimum 17 dB and this is fulfilled already from the border.

VI. Conclusions

Methods I/N and C/(I + N) were considered for the evaluation of possible interference from MFCN BSs to ATS stations. Although the methods I/N and C/(I + N) show that results depend on the height of the aircraft, however method C/(I + N) clearly shows positive interference margin between 17 dB–35 dB regarding the case leading to successful coexistence between these systems – this conclusion would let to increase the frequency sharing between the radio systems and countries. In case of C/(I + N) method a proper attention should also be drawn to the margin of wanted signal from aircraft in order to account signal losses related with aircraft maneuverer, propagation conditions, etc.

In case of possible aggregate interference from more than one neighbouring country, all concerned parties have to conduct a work to minimise possible harmful interference. In this case it is recommended that all affected countries take all necessary measures to avoid harmful interference while providing possibility to use the frequency band for other countries with less possible restrictions.

References

[1] M. Barazzetta *et al.*, "A comparison between different reception diversity schemes of a 4G-LTE base station in reverberation chamber: a deployment in a live cellular network", *IEEE Trans. Electromagnetic Compatibility*, vol. 59, no. 6, pp. 2029–2037, 2017. DOI: 10.1109/TEMC.2017.2657122.

[2] B. Bojovic, L. Giupponi, Z. Ali, M. Miozzo, "Evaluating unlicensed LTE technologies: LAA vs LTE-U", *IEEE Access*, vol. 7, pp. 89714–89751, 2019. DOI: 10.1109/ACCESS.2019.2926197.

[3] S. Sadjina, C. Motz, T. Paireder, M. Huemer, H. Pretl, "A survey of self-interference in LTE-advanced and 5G new radio wireless transceivers", in IEEE Transactions on Microwave Theory and Techniques, vol. 68, no. 3, pp. 1118-1131, March 2020. DOI: 10.1109/TMTT.2019.2951166.

[4] S. Liu, L. Xiao, Z. Han, Y. Tang, "Eliminating NB-IoT interference to LTE system: a sparse machine learning-based approach", *IEEE Internet of Things Journal*, vol. 6, no. 4, pp. 6919–6932, 2019. DOI: 10.1109/JIOT.2019.2912850.

[5] C. Baquero Barneto *et al*., "Full-duplex OFDM radar with LTE and 5G NR waveforms: challenges, solutions, and measurements", *IEEE Trans. Microwave Theory and Techniques*, vol. 67, no. 10, pp. 4042–4054, 2019. DOI: 10.1109/TMTT.2019.2930510.

[6] R. A. J. Castillo, R. Grunheid, G. Bauch, F. Wolff, S. von der Heide, "Communication analysis between an airborne mobile user and a terrestrial mobile network", *IEEE Trans. Vehicular Technology*, vol. 67, no. 4, pp. 3457–3465, 2018. DOI: 10.1109/TVT.2017.2786543.

[7] Recommendation ITU-R M.1459, *Protection criteria for telemetry systems in the aeronautical mobile service and mitigation techniques to facilitate sharing with geostationary broadcasting-satellite and mobile-satellite*.

[8] Recommendation ITU-R M.1851-0, *Mathematical models for radiodetermination radar systems antenna patterns for use in interference analyses*.

[9] Report ITU-R M.2292-0*, Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses*.

[10] Recommendation ITU-R F.1336-4, *Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz.*

[11] G. Ancans, E. Stankevicius, V. Bobrovs, G. Ivanovs, "Evaluation of LTE and aeronautical radionavigation service electromagnetic compatibility in 694–790 MHz frequency band", *Elektronika ir elektrotechnika*, vol. 22, no. 6, 2016, pp. 99–103. DOI: 10.5755/j01.eie.22.6.17231.

[12] E. Stankevicius, S. Oberauskas, "Electromagnetic compatibility studies: LTE BS vs. aeronautical radionavigation services in 694–790 MHz frequency band", *Electrical, control and communication engineering*, vol. 6, 2014. DOI: 10.2478/ecce-2014-0016.

[13] M. Algharem, M. H. Omar, I. Aldmour, and R. Budiarto, "Multicast Resource Allocation with Opportunistic Scheduling in LTE Networks", *Elektronika ir elektrotechnika*, vol. 24, no. 5, pp. 92-101, Oct. 2018. DOI: 10.5755/j01.eie.24.5.21850.

[14] *Border coordination of the fixed and mobile services*, Regional Radiocommunication Seminar for Colombia, 2013. [Online]. Available: https://www.itu.int/en/ITU-R/terrestrial/workshops/RRS-13-Colombia/Pages/default.aspx

[15] Recommendation ITU-R P.525-2, *Calculation of free-space attenuation.*

[16] Recommendation ITU-R P.1546-5, *Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz.*