Impact of Aeronautical Mobile Telemetry System on MFCN SDL Operating Co-channel in Frequency Band 1452–1492 MHz

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Abstract— This paper presents the co-channel compatibility analysis between Aeronautical Mobile Telemetry system and International Mobile Telecommunications system in the frequency band 1452–1492 MHz. International Mobile Telecommunications systems (i.e., LTE) are developing at staggering rates and mobile operators always searches the new possible frequency bands to expand their networks. 1452–1492 MHz frequency band is attractive due the qualified radio propagation conditions. But this band is already operated by other technologies as radio relay, broadcasting networks and aeronautical networks. Co-channel and adjacent channel electromagnetic compatibility have to be evaluated. Electromagnetic compatibility between Aeronautical Mobile Telemetry and International Mobile Telecommunications is one of the most sensitive issues regarding the decision to designate this band to Mobile Services. This study was conducted to compare the worst case calculations based on Minimum Coupling Loss method and statistical Monte-Carlo simulations in order to obtain more realistic results.

1. 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].

World Radiocommunication Conference in 2012 (WRC-12) approved Resolution COM6/6 which contains the agenda for next conference in 2015 (WRC-15). For this purpose it is proposed to considered frequency bands 1429–1452 MHz, 1452–1492 MHz, 1492–1518 MHz and 1518–1525 MHz as possible candidate bands. During the preparation period for next conference sharing and compatibility studies have been launched to identify possible harmful interference to currently existing services [5]. According to frequency allocation in Section IV to Radio Regulation [6] the primary services in the frequency band 1452–1492 MHz is Mobile except aeronautical mobile service.

This paper compares two possible ways to evaluate the electromagnetic compatibility in co-channel operation between UE receivers of IMT system and airborne transmitters of Aeronautical Mobile Telemetry system based on Minimum Coupling Loss method and statistical Monte-Carlo method [7]. The results show that the compatibility is feasible in only particular configuration of networks.

2. MAIN PARAMETERS OF THE TELEMETRY SYSTEM AIRBORNE TRANSMITTER

Telemetry system could be typically used for air-to-ground information delivery or air-to-air missile [8]. For this study the technical parameters of telemetry system airborne transmitter could be taken from two possible sources:

- Assignments in the Master International Frequency Register (MIFR). These can only be in countries mentioned in RR 5.342 footnote. The entries are labelled with the class of station "MA" (this corresponds to the transmitter in aircraft);
- 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 Services in the frequency bands 1452–1525 MHz and 2310–2360 MHz" [9].

The parameters of telemetry system provided in these two sources differ significant therefore both sets of characteristics provided in Table 1 below were used in compatibility study.

Table 1: Parameters of telemetry system airborne transmitter.

	ITU-R M.1459		**MIFR**
Central frequency	1439.65 MHz, 1460.9 MHz, 1482.15 MHz, 1503.35 MHz		
Channel bandwidth	5 MHz		21.3 MHz
Antenna pattern	Omnidirectional		Omnidirectional
Antenna gain	0 dBi	10 dBi	ITU-R M.1459
e.i.r.p.	13.98 dBW	23.98 dBW	25.15 dBW
Antenna height (maximum)	10000 m		10000 m
Transmission path length	Up to 320 km		Up to 600 km

As telemetry system is air-to-ground communication system therefore airborne transmitter antenna has to cover all radiation angles in the direction of the telemetry system receiving station hence in ideal case it should be isotropic antenna. However, in reality, there are multiple reflections and signal blocking form the fuselage of the aircraft. This can cause variations of the transmitter antenna gain (G_{TX}) pattern (i.e., from 10 dBi to −30 dBi). Such antenna gain variations (see Annex 1 of Recommendation ITU-R M.1459 [9]).

The probability that $G_{TX} \leq 0$ dBi (compared to $G_{\max} = 10$ dBi) is equal to 0.96. Nevertheless the probability does not differ greatly, but the difference of antenna gain values will have huge impact on separation distance between Interfering transmitter and Victim Receiver. Considering these variations, we will use three different cases of telemetry system airborne transmitter antenna gain in this compatibility analysis: a) $G = 0$ dBi, this case could be treated as near realistic; b) $G = 10$ dBi, this case is worst case scenario (i.e., maximum antenna gain of airborne transmitter according to the Recommendation ITU-R M.1459); c) distribution of antenna gain G_{TX}, according to Annex 1 of Recommendation ITU-R M.1459, for Monte Carlo statistical simulations only (Cumulative Distribution Function — CDF). In all cases the omnidirectional antenna type was used.

3. MFCN SDL CHARACTERISTICS

Technical characteristics of IMT UE comply with ETSI standard [10]. Parameters for IMT UE receivers for this study were taken from Report ITU-R M.2292 [11]. For protection criteria trigger based on Interference-to-Noise ratio $I/N = -6$ dB and additional 0 dB value was used. The ratio $I/N = 0$ dB represents relaxed protection requirement. The IMT UE receiver parameters used provided in Table 2.

The IMT UE reception bandwidth can varies from 1.4 MHz to 20 MHz. In this study were used only 5 MHz band regarding that this bandwidth is commonly used in others LTE frequency bands.

Two possible interference criterion were used in order to represent worst case scenario ($I/N = -6$ dB) and more realistic scenario with $I/N = 0$ dB ratio. The assumption of interference criterion

Table 2: IMT UE parameters.

Parameter	**Value**
Receiver bandwidth	5 MHz
Antenna height	1.5 m
Antenna pattern	Omnidirectional
Antenna gain	−3 dBi
Body loss	4 dB
Building penetration loss	15 dB (rural); 20 dB (suburban, urban)
Building blocking for UE (only urban)	10 dB
Indoor user terminal usage	50% (rural); 70% (suburban, urban)
Receiver noise figure	9 dB
Receiver Thermal Noise Level	−98 dBm
I/N target	−6 dB and 0 dB

is very sensitive, because it needs to do not over protect the system. The overprotection of victim receiver leads to non-effective spectrum use.

4. MINIMUM COUPLING LOSS (MCL) ANALYSIS

In this section the calculation results derived by Minimum Coupling Loss method (MCL) are provided. This is deterministic method and it analyses the link budget between two points. Using the MCL method the isolation is calculated which is required between victim and interferer to ensure that there is no interference.

To calculate required separation distances the co-channel interference impact from telemetry system airborne transmitter on IMT UE receiver was analysed. Using Free Space propagation model (Formula (3) of Recommendation ITU-R P.525 [12]) the calculated path loss value was converted into a physical separation distance. ITU-R P.525 propagation model is only applicable on free line of sight cases. It does not consider the refraction of radio waves, the type of earth surface. The interferer antenna height is up to 10000 m, thus ITU-R P.525 recommendation can be applied in this study.

The minimum required path loss (L) was calculated using the formula below:

$$L = P_{TX} + G_{RX} - L_{body} - C_{env} + C_{BW} - I_{\max}, \quad (1)$$

where:
P_{TX} — telemetry airborne transmitter e.i.r.p. (dBW),
G_{RX} — IMT UE receiver antenna gain (dBi),
L_{body} — human body loss (dB),
C_{env} — correction factor for building penetration loss and signal blocking in different environments (dB),
C_{BW} — correction factor for difference in bandwidth (dB),
$I_{\max}$ — the allowed maximum interference level (dBm).
There are three different types of environments, where IMT UE could experience the interference. These are: urban, suburban, and rural. In this study four different environments scenarios were analysed: a) urban indoor (taking into account building penetration loss of 20 dB and building blocking of 10 dB); b) urban outdoor (taking into account building blocking of 10 dB and assuming that IMT UE is not in line-of-sight); c) rural indoor (taking into account building penetration loss of 15 dB); d) rural outdoor. Calculation results of MCL analysis are provided below in Table 3 taking into account different I/N ratio.

From the calculation results it is seen that required protection distance varies significant depending on the protection criteria and characteristics of telemetry system used.

MCL analysis is pure link budget calculation and is worst case scenario therefore it could lead to possible overestimation of required minimum separation distances. In real situations, the telemetry system airborne transmitter will not always be able to influence IMT UE receiver because telemetry

Table 3: Separation distances according to MCL analysis between victim IMT UE receiver and interfering telemetry system airborne transmitter.

Interference criterion	**Telemetry system parameters — Recommendation ITU-R M.1459, $G_{TX} = 10$ dBi**			
I/N	Urban Indoor	Urban Outdoor	Rural Indoor	Rural Outdoor
−6 dB	18.5 km	185 km	104 km	412 km (limited by LoS)
0 dB	9.3 km	93 km	52 km	294 km
	Telemetry system parameters from Recommendation ITU-R M.1459, $G_{TX} = 0$ dBi			
	Urban Indoor	Urban Outdoor	Rural Indoor	Rural Outdoor
−6 dB	5.9 km	59 km	33 km	185 km
0 dB	2.9 km	29 km	17 km	93 km
	Telemetry system parameters from MIFR			
	Urban Indoor	Urban Outdoor	Rural Indoor	Rural Outdoor
−6 dB	10.3 km	103 km	58 km	325 km
0 dB	5.1 km	52 km	29 km	163 km

system airborne transmitter is always in motion (aircraft velocity is up to 1000 km/h) and the servicing the area will differ depending on the parameters of the transmitter. It could be of radius up to 320 km or up to 600 km (using characteristics from Recommendation ITU-R M.1459 and MIFR accordingly). Additionally, IMT UE is not necessarily used in areas of potential occurrence of harmful interference. As interference is not of permanent nature, it would be more naturally to use statistical methods. SEAMCAT software tool [13] based on Monte-Carlo method could give more realistic situation of possible harmful interference.

5. INTERFERENCE SCENARIO FOR SEAMCAT SIMULATION

The SEAMCAT is based on Monte-Carlo simulation method. The principle is to take samples of random variables by using their probability density functions and to generate random samples (snapshots), then to derive the probability of interference by comparing relation of wanted and unwanted signals at victim receiver in each snapshot to its interference criterion. The created interference scenario for simulations in SEAMCAT is provided below in Figure 1. Separation distance (d_{sep}) is the distance between the closest boundary of service area of telemetry system airborne transmitter and location of victim IMT UE.

1000000 snapshots were randomly generated for SEAMCAT simulations. The separations distances acquired by MCL method for rural outdoor environment were used as a starting point. The simulations were performed with relaxed interference criterion $I/N = 0$ dB. According to Report ITU-R M.2292 the proportion of 50% of IMT UE is used indoor and it was also considered in SEAMCAT simulations.

Interference probability (IP) was calculated for different required separation distances (starting from the largest required separation distance obtained by MCL analysis). In order to conduct more detailed analysis four different scenarios were modelled: a) Scenario 1 represents worst case scenario (most pessimistic) with maximum 10 dBi antenna gain. The telemetry system parameters were used according to Recommendation ITU-R M.1459; b) Scenario 2 represents near realistic scenario with 0 dBi antenna gain. The telemetry system parameters were used according to Recommendation ITU-R M.1459; c) Scenario 3 represents usual scenario because telemetry system parameters are used from MIFR where are registered the stations which are operating in real networks; d) Scenario 3 represents the realistic scenario when the gain of telemetry system antenna is reflected as probability function. The results according four modelled scenarios are presented below in Table 4.

Results by Monte-Carlo approach (using SEAMCAT simulations) show that minimum required

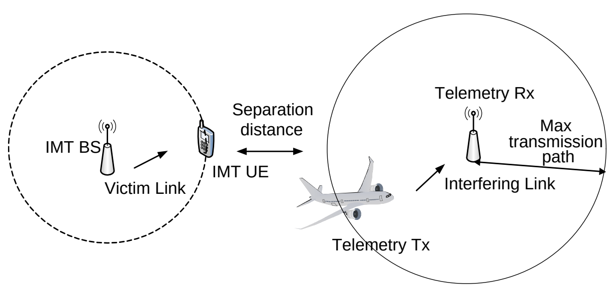

Figure 1: Interference scenario for SEAMCAT simulations.

Table 4: Simulation results using statistical Monte-Carlo approach.

	Scenario 1	**Scenario 2**	**Scenario 4**	**Scenario 3**
Telemetry system characteristics	ITU-R M.1459	ITU-R M.1459	MIFR	ITU-R M.1459
Telemetry system antenna gain	10 dBi	0 dBi	10 dBi	CDF from ITU-R M.1459
d_{sep} for $IP = 0\%$	294 km	93 km	163 km	71 km
d_{sep} for $IP = 0.5\%$	265 km	56 km	95 km	15 km
d_{sep} for $IP = 1.0\%$	250 km	34 km	52 km	not required
d_{sep} for $IP = 2.0\%$	225 km	not required	not required	not required
IP for $d_{sep} = 1$ km	17.4%	1.96%	1.76%	0.75%

physical separation distance between IMT UE receiver and telemetry system airborne transmitter is considerably smaller comparing it to MCL calculations considering certain acceptable interference probability for IMT UE receiver. The separation distance between telemetry interferer and MFCN victim receiver differs from 294 km to 0 km "not required". Such a high difference indicates that the results are very sensitive to the assumptions of this particular interference scenario.

6. CONCLUSIONS

The compatibility results of deterministic link budget analysis according to MCL calculation method indicate significant variations of required physical separation distance (see Table 3) for IMT UE depending on the characteristics of telemetry system airborne transmitter (according to Recommendation ITU-R M.1459 or MIFR) and different receiving environments.

Statistical Monte-Carlo approach (using SEAMCAT tool) allows take into account different proportion of IMT UE indoor and outdoor and make quantitative assessment in order to recalculate the required protection distances more realistically compared to the results obtained by MCL method. Simulations based on Monte-Carlo approach showed that physical separation distance may be reduced significantly considering certain acceptable harmful interference probability for IMT UE (see Table 4). The results of simulation using measured distribution of telemetry system airborne transmitter antenna gain (provided in Recommendation ITU-R M.1459) show that physical separation would be not required in order to protect IMT UE receiver considering that acceptable interference probability is higher than 1%.

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