Paper

Sharing Spectrum UE LTE and Air-Traffic Control Radars in 800 MHz Band

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Abstract—The need to ensure LTE network coverage in sparsely populated and rural areas of Europe (ITU Region 1) has led to a massive use of 800 MHz band (band 20) with its good characteristics of radio wave propagation in LTE networks. However, the frequency band of 800 MHz called "digital dividend" in Region 1 is used on a primary basis not only by the terrestrial mobile service but also by air-traffic control radars (ATCR) that can lead to the creation of harmful interferences at the receivers' input of ATCR. Such scenarios of mutual interferences became possible after granting licenses for LTE-800 frequencies to operators in such countries as Azerbaijan, Kazakhstan, Russia and other CIS countries, so this problem should be solved by operators at the deployment of LTE-800 networks in airports and areas close to them. So far, for such scenarios the ITU and CEPT have not formulated criteria for interference protection. The proposed protection criteria for receivers of ATCR from user devices' interferences of LTE-800 networks were tested by experimental studies and can provide a solution to the electromagnetic compatibility (EMC) problem in a complex electromagnetic environment of modern airports and cross-border coordination of 800 MHz frequency bands in Region 1.

Keywords—EMC, LTE, protection criteria, radio locator.

1. Introduction

Air-traffic control radars perform important tasks to ensure flight safety in the airdrome area, and their performance should not be violated by the influence of unintentional radio interferences from user equipment (UE) of LTE-800 network, which may cover airports and location areas of air traffic radio means of management and control around airports.

To solve this problem it is necessary to develop methods for ensuring the electromagnetic compatibility, which will allow parallel operations of air-traffic control radars (ATCR) and LTE networks in the 800 MHz band on the basis of organizational and technical measures and to develop criteria for interference protection.

Earlier studies [1] presented theoretical values of these criteria under consideration of International Telecommunication Union (ITU) propagation models, but experience has shown that these values need an experimental verification to clarify and reduce conservative theoretical estimates.

The presented measurement results of noise levels and protection criteria are based on experimental estimates obtained on real aerodromes using ATCR equipment and LTE-800 with typical service conditions.

2. Impact of UE LTE on Air-traffic Control Radars at 800 MHz

During experimental studies, one of the worst scenarios was investigated – the impact of a UE LTE-800 on air-traffic control radars in case of co-channel interference. These scenarios, based on experimental approaches, allow to conduct instrumental measurements of interference field strength (relative to 1 dBμV/m) from LTE-800 transmitters and allow to create simulations of UE LTE-800 signals at the antenna input of ATCR receivers on different distances. Channel allocation for LTE-800 and air-traffic control radars in 800 MHz band are shown in Fig. 1.

One scenario of impact of UE LTE on air-traffic control radars is shown in Fig. 2. The scenario consists of multiple interfering links (multiple UE LTE-800) where emissions of their transmitters could impact on a victim – air-traffic control radar, which is located next to airport runway.

Tables 1 and 2 provide technical parameters of UE LTE [2]–[4] in the 800 MHz band and technical characteristics [5] of dispatching radio locator (DRL) in the band 800 MHz respectively.

Air-traffic control radar as a part of radar landing system is used for the identification and control of aircraft flights in the near radius of 50…60 km around the airport runway.

According to the return signal from the aircrafts, displayed on the plan position indicator (PPI) of the radar, objective control of air situation, control of airplane movements in pre-landing modes with a given accuracy in the action zone of radar landing system can be realized.

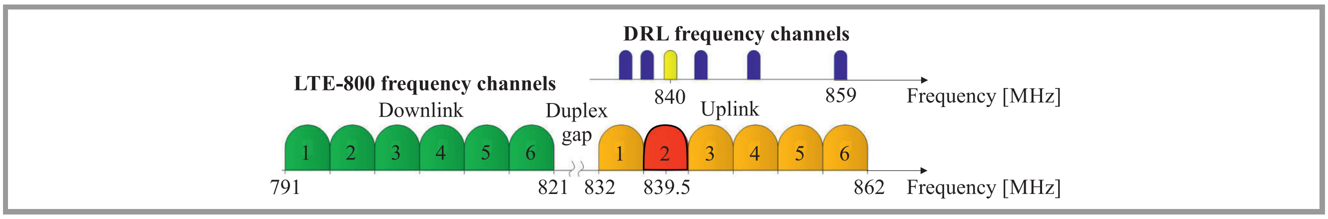

Fig. 1. Channel allocation of UE LTE-800 and air-traffic control radars .

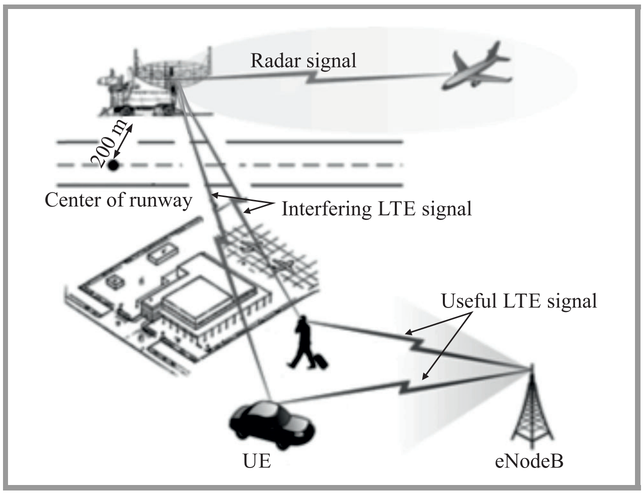

Fig. 2. Scenario of impact of UE LTE-800 on air-traffic control radar.

DRL receiver operates in three modes: "Active", "Passive" and "Selection of moving targets" in the frequency band 800 MHz. DRL receiver parameters are as shown in Table 2 and have the usual features of air traffic control (ATC) systems for false target/clutter reduction, moving target indication (MTI), short/long range selection and video feed to plan position indicator scopes. Its tuning range is the same as the transmitter (Fig. 1).

Table 1
LTE parameters in the 800 MHz band

Parameters	Dimension	UE
Transmit power	dBm/channel	23
Receiver bandwidth	MHz	4.5, 9, 13.5, 18
Channel bandwidth	MHz	5, 10, 15, 20
Reference system noise figure (taken from values quoted in standards)	dB	9
Reference receiver sensitivity (taken from values quoted in standards)	dBm/channel	–97 in 5 MHz –94 in 10 MHz –90 in 20 MHz
Interference criterion I (C/(N+I))	dB	
Interference criterion II (I/N)	dB	–6
Channel spacing	MHz	5, 10, 20
Maximum antenna gain	dBi	0
Antenna height	m	1.5
Feeder loss	dB	0
Cell radius	km	8.633

Table 2
Air-traffic control radar parameters in the 800 MHz band

Parameters	Dimension	DRL-6(8)	DRL-7(10)
Mode of work		Passive	Passive
Maximum antenna gain	dBi	29.5	29.5
Antenna pattern	Grad	Vert. pl. = 22 Hor. pl. = 2.5	Vert. pl. = 45 Hor. pl. = 4
Receiver IF 3 dB bandwidth	MHz	2	2
Polarization circular	H/V	Horizontal	Horizontal
Limit receiver sensitivity	dBW	–128	–135
Pulse repetition rate	Hz	500	550
Pulse duration	μs	2.4	2
Antenna revolution speed	rev/min	10	10
Allowable strength of EMF at the antenna input of ATCR for OFDM-interference (protection level)	dBμV/m	17	17

3. Experiment Description

The goals of the experimental studies on electromagnetic compatibility (EMC) are to confirm the theoretical EMC assessment of air-traffic control radar with user equipment (modems) LTE-800, as well as to develop proposals for adjusting the frequency and terrestrial planning (FTP) of LTE-800 networks that are under consideration. Additional aim of the studies was to determine the influence impact distance from user equipment (UE) transmitter of LTE-800 networks on air-traffic control radar.

The experimental study was conducted on one of the airfields in real operations which is equipped with air-traffic control radar DRL types [5].

The radar landing system including the ATCR DRL of the chosen airport is located on the right side of the axis of airport runway at a distance of 200 m and 200 m from the center of the runway. In the airfield region base stations of LTE-800 networks can be deployed which support LTE sites in place of ATCR DRL location.

In the study of the impact of interference the most frequently used radar mode was considered, which provides identification and control of air targets, it is "passive" mode. Field strength measurement has been conducted for a statistically significant number of measurements. The impact of interference from the UE LTE-800 simulator on the PPI of the ATCR DRL was registered in form of flares, which hid air targets.

4. Features of Experimental Studies

Let us consider the features of conducting the experimental studies. During the experiment, a simulator was used as UE transmitter LTE-800. The structure and test equipment composition of the simulator are shown in Fig. 3.

To ensure detection and to capture the signal of the simulator for measuring the receiver was located at a place near the radar antenna. The effective radiated power (ERP) of the UE LTE simulator was chosen equal to 20 dBW to capture the interfering signal on the measuring receiver. Then the power level of the interfering signal simulator was reduced down to levels that do not influence on the DRL detection performances. The transmitting antenna gain of the UE LTE simulator was chosen equal to 8 dB, the antenna height above ground level was 2 m, the polarization – horizontal. The radiation frequency of the UE LTE simulator was 839.5 MHz.

The impact of the interfering signal on the detection performance of the DRL was investigated by using two means:

- a test unit which includes spectrum analyzer FSH6 Rohde & Schwarz (R&S) and measuring antenna HE300 R&S to measure the strength of the electromagnetic field (EMF), generated by the UE LTE simulator,
- the operative DRL PPI for visual detection of interfering signal, which hid air targets.

The measuring point – the technical position of the ATCR on the place that is described below. The height of the measuring antenna in the experiments was 6 m that is equal to the height of the center of the receiving antenna of real the DRL radar.

The value of allowable strength of EMF generated by the UE LTE simulator at the technical position of the ATCR was identified under consideration of the following factors:

- the maximum ERP of UE LTE in accordance with 3GPP is 200 mW (23 dBm) [2],
- the maximum number of UE LTE served in one sector is 5-10 UE,
- the total (expected under actual use conditions) ERP of URS from UE LTE is 1 W (30 dBm).

The results of experimental measurements and theoretical calculations of the interference impact of UE LTE-800 on RLS placed at the airdromes are presented in Table 3.

Table 3
EMF strength of UE LTE at the antenna input of DRL radar

No.	Distance from DRL [km]	E_{meas} 1) [dBμV/m]	Influence of UE	E_{1546} 2) [dBμV/m]	E_{370} 3) [dBμV/m]
1	1.4	54	Yes	63	71
2	4.3	42	Yes	35	45
3	6.6	30	Yes	31	40
4	6.7	24	Yes	30	39
5	6.8	> 23	Yes	30	39
6	7.4	31	Yes	29	38
7	9.2	24	Yes	26	36
8	11	< 17	No	24	33

1) E_{meas} – experimental measuring strength of electromagnetic field (EMF) generated by the UE LTE simulator at the placement point of the DRL position.

2) E_{1546} – theoretical strength of EMF calculated by ITU-R Rec. P.1546-4 [6].

3) E_{370} – theoretical strength of EMF calculated by ITU-R Rec. P.370-7 [7].

Note: Calculations of strength of EMF by ITU-R methodic were done for 10% of time and 10% of area.

5. Comments and Analysis

The results of experimental studies shown in Table 3 gave us understanding that, when the distance between the DRL radar and the UE LTE simulator is less than 11 km, a harmful interference is observed on the PPI DRL in the form of flashing sector which hides the air targets away from the DRL operator (Fig. 4). The theoretically calculated distance of possible interference influence in accordance with the conditions of the experiment was equal to 13 km. The measured interference field strength at the DRL receiver input, in the absence of indications of interference on the radar display, was 17 dBμV/m, which confirmed the previously defined threshold at 17 dBμV/m [8]. This value of EMF strength is 7/16 dB lower than the calculated values obtained by using methodic of Rec. ITU-R R.1546-4/Rec. R.370-7 (line 8 in Table 3).

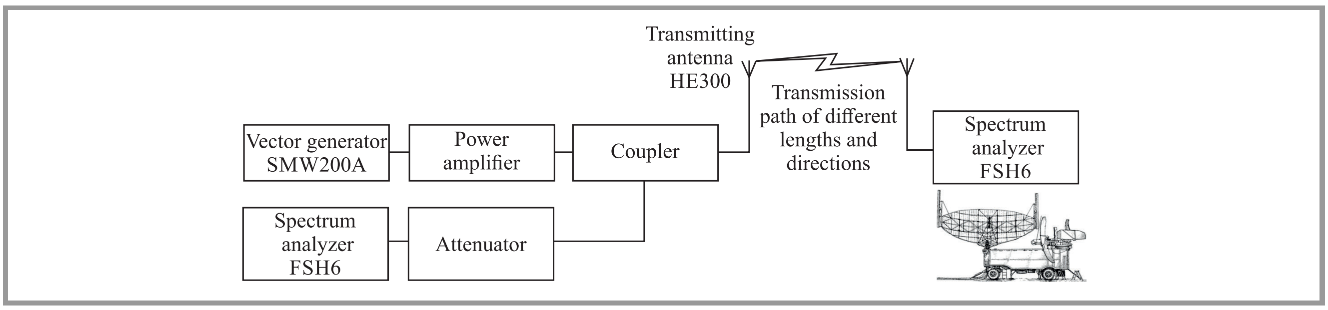

Fig. 3. Scheme of experimental scenario.

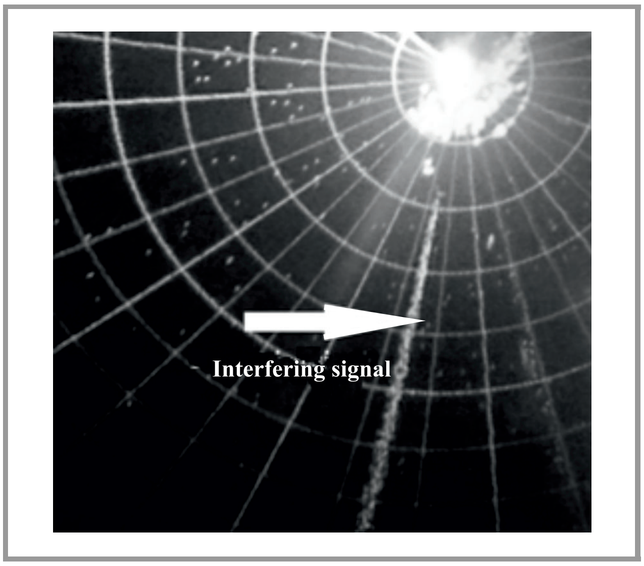

Fig. 4. UE LTE interfering signal on the ATCR PPI.

Thus, the measurement results turned out less conservative and have provided new values criteria for protection from UE LTE interference to receivers DRL radar, which enable them to work together with less restrictions in the case of co-channel interference.

6. Protection Criteria

The ITU defines in the radio regulations several terms relative to interference including: interference, permissible interference, accepted interference, harmful interference, and protection ratios [9]. Other terms that are commonly used, but not specifically defined, are allowable performance degradation, interference protection criteria, and spectrum sharing criteria.
In accordance with the ITU approach to solve a task of sharing spectrum in 800 MHz band for air-traffic control radar DRL types and UE LTE-800 and in accordance with the experimental data two protection criteria were proposed:

- coordination distance between transmitting base stations eNB LTE-800 and receivers of air-traffic control radar DRL types,

- permissible interference field strength (relative to 1 dBμV/m) at the antenna of air-traffic control radar DRL types.

Experimentally obtained distance between transmitting UE LTE-800 and receivers of air-traffic control radar DRL types, which protects against harmful interference to DRL receiver in operation in the frequency band 800 MHz, is 11 km and consequently, coordination distance between transmitting base stations eNB LTE-800 and receivers of air-traffic control radar DRL types, has to equal to 22 km.

Second protection criteria was established as border level of field strength (relative to 1 dBμV/m) on antenna of DRL radar. Harmful interferences below this level will not influence on radar technical performance. In accordance to an experimental measurement results such level 17 dBμV/m on antenna of DRL radar was confirmed.

7. Conclusion

In this paper, interference protection criteria for DRL radar receivers which support their spectrum sharing in 800 MHz band with UE LTE-800 have been proposed and evaluated for some interference parameters. The protection criteria are based on the ITU approach to EMC and experimental data that increase its applicability and usability for EMC task solving in the very complicate electromagnetic environment of modern airports. This paper shows the importance of taking into account this EMC situation for flight security and determining cells in airport zone for LTE-800 RF coverage planning.

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