Analysis of EMC between Medical Short-Range Devices and Equipment of Wireless Systems

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***Abstract*—The analysis of EMC between medical short range devices of body area network system, capsule endoscopy system, active implant system and wireless equipment of mobile stations of cellular communications (LTE and 5G), RLAN equipment, NB IoT sensors operating inside a hospital building is performed. The integrated interference margin is used as a criterion of EMC. Results of the analysis show the following: 1) the equipment of wireless systems can create the interference to all considered types of medical short range devices (as well as medical short range devices can create the interference to receivers of the wireless systems) in case of allocation of emitters and receptors inside the same room or in neighboring rooms; 2) in order to ensure EMC of considered systems, it is advised to set more stringent requirements on characteristics of susceptibility of the medical equipment to radiofrequency electromagnetic fields created by wireless equipment of 4G/5G networks as well as on spurious emissions of transmitters of wireless systems. The results can be used in diagnostics of intersystem EMC in order to ensure safety of use of mobile wireless telecommunication equipment regarding medical vital devices in conditions of mass distribution of 4G/5G wireless information services in hospitals.**

Keywords*—*EMC, medical short range device, 4G/5G cellular communications, radio local area network

I. Introduction

Medical short range devices (MD SRD) are widely used for measuring of vital human body data (temperature, pulse, blood glucose level, electrocardiogram, blood pressure level, respiratory function readings, etc.) in modern hospitals [1]-[3], [5]-[9]. Data is transmitted by low-power transmitters to receivers of MD SRD systems at short distances equal to several meters; therefore these receivers are very sensitive to unwanted signals of different transmitters of wireless systems. Expansion and mass use of wireless systems equipment (medical and non-medical) in hospitals can lead to problem of electromagnetic compatibility (EMC) between MD SRD and wireless systems equipment. For example, medical staff can use mobile phones inside the same room during operation of vital MD SRD system; personal laptops are used to access the Internet or to get local data by the use of radio local area network (RLAN) equipment; sensors of narrow band of Internet of things (NB IoT) are used for medical purpose [4].

The objective of the paper is to perform the analysis of EMC between MD SRD of medical body area network system (MBANS), capsule endoscopy system, and active medical implant system and wireless equipment of mobile stations (MS) of LTE and 5G cellular communications, RLAN access points (AP), and NB IoT sensors operating inside a hospital building.

For this purpose, the three-dimensional computer model of typical floor plan of a hospital containing interference emitters and receptors was developed. EMC analysis was made by computer modeling with the use of three-dimensional multipath model of radio wave propagation (RWP). The decision about the presence or absence of interference is made based on the value of EMC criterion of integrated interference margin (IIM).Then the estimation of damage of the receivers due to interference created by the transmitters is executed. In order to ensure EMC of considered systems, the minimal distance between the emitter and the receptor was estimated by involving free space RWP model.

II. Description of MD SRD and wireless systems

A. Types of considered MD SRD

The following types of MD SRD are considered in EMC analysis.

1) Peripheral (wearable) device of ultra-low power (ULP) wireless medical capsule endoscopy system operating in frequency range from 430 MHz to 440 MHz [5] (SRD 1).

2) Peripheral (wearable) device of MBANS operating in frequency range from 2483.5 MHz to 2500 MHz [6] (SRD 2).

3) Peripheral (fixed) device of low-power active medical implant (LP-AMI) system operating in frequency range from 2483.5 MHz to 2500 MHz [7] (SRD 3).

4) Peripheral (fixed) device of ultra-low active medical implant (ULP-AMI) system operating in frequency range from 402 MHz to 405 MHz [8] (SRD 4).

5) Peripheral (fixed) device of ultra-low power medical data service system (ULP-MEDS) operating in frequency range of 401-402 MHz and 405-406 MHz [9] (SRD 5).

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B. Types of considered equipment of wireless systems

The following types of equipment of wireless systems are considered in EMC analysis.

1) LTE mobile station (MS) operating in the frequency range of 1920-1980 MHz for uplink (UL) and 2110-2170 MHz for downlink (DL) in frequency division duplex (FDD) mode and in the frequency range of 2570-2620 MHz in time division duplex (TDD) mode [10].

2) 5G MS operating in the frequency range of 3400-3800 MHz [11].

3) NB IoT sensor [12] operating in the frequency range of 452.5-457.5 MHz for UL and 462.5-467.5 MHz for DL [10].

4) RLAN AP operating in the frequency range of 5150-5250 MHz [13].

III. Procedure of EMC analysis

A. Initial data

The following initial data and models are used in order to perform EMC analysis.

1) The spectrum mask of the transmitter is constructed based on the requirements (main, out-of-band, spurious emission, etc.) given in [5]-[13]. The spectrum of LTE MS (FDD) transmitter is given as example in Fig. 1. PSD is power spectral density given in dBm/MHz.

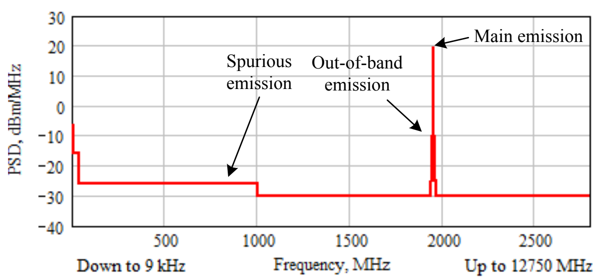

Fig. 1. Spectrum of LTE MS (FDD) transmitter

2) Susceptibility to interference of the receiver is constructed based on the requirements (sensitivity, selectivity, carrier-to-interference ratio, etc.) given in [5]-[13]. SRD 1 receiver susceptibility to interference is given as example in Fig. 2.

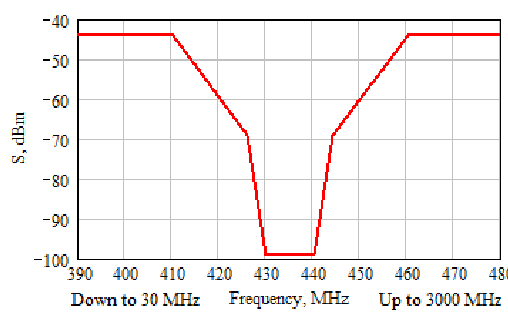

Fig. 2. Susceptibility to interference of SRD 1 receiver

3) The frequencies are selected for performing the analysis of EMC. Hereinafter, they are referred to as the analyzed frequencies f_A. The analyzed frequencies are selected in order to consider different types of interaction between the transmitter and the receiver. Taking into account the quite large difference between the transmitter and receiver frequencies, the following interaction types are considered:

- Type M2S. The main emission falling into the spurious response of the receiver.
- Type O2S. The out-of-band emission falling into the spurious response of the receiver.
- Type S2D. The spurious emission falling into the desired-channel response of the receiver.
- Type S2A. The spurious emission falling into the adjacent-channel response of the receiver.
- Type S2S. The spurious emission falling into the spurious response of the receiver.

The transmitter and receiver frequency is central frequency of the considered frequency band at which the transmitter and receiver operate. The other analyzed frequencies are selected below and above of the transmitter and receiver frequency.

4) For each analyzed frequency, the value of emission power P_e is calculated by integrating the transmitter power spectrum over the influence bandwidth which is calculated as follows:

$$\Delta f_i = \begin{cases} \min(BW_T, BW_R), f_A = f_T \\ \min(10 \cdot BW_T, BW_R), f_A \neq f_T \end{cases}, \text{ Hz}, \quad (1)$$

where BW_T is the transmitter bandwidth, Hz; BW_R is the receiver bandwidth, Hz; f_T is the transmitter frequency, Hz.

5) For each analyzed frequency, the value of the receiver susceptibility S is defined.

The characteristics of the LTE MS (FDD) transmitter emission and the receiver susceptibility in case of influence on SRD 1 receiver is given for analyzed frequencies in Table 1 as example.

TABLE I. The characteristics of the LTE MS (FDD) transmitter emission and SRD 1 receiver susceptibility

LTE mode	Interaction type	f_A, MHz	Δf_i, MHz	P_e, dBm	S, dBm
TDD	M2S	2595	4.5	28	-44
TDD	O2S	2585	10	-5.3	-44
TDD, FDD	S2S	3000	10	-20	-44
FDD	M2S	1950	4.5	25	-44
FDD	O2S	1940	10	-8	-44
TDD, FDD	S2S	30	10	-8.6	-44
TDD, FDD	S2D	435	10	-16	-99
TDD, FDD	S2A	445	10	-16	-67.5

6) Types of antenna of the transmitters and receivers are given in Table 2 and Table 3. The LTE MS, 5G MS, and NB IoT antenna is isotropic. For RLAN AP, type of antenna is real antenna. The type of MD SRD antennas may be different (e.g., either integral antenna or dedicated external antenna implemented in the form of skin patch or belt). In many situations, these antennas are specified as half-wave dipoles. If the orientation of the antenna is fixed, this fixed orientation is used in the model intended for simulation. If the orientation of the antenna can be changed during the system operation (e.g., due to change in position and orientation of the user of a wearable device), the worst-case orientation of the antenna is considered in the model as follows. For a transmitter, the equivalent isotropically radiated power (EIRP) is used instead of the transmitter power and the isotropic antenna with the gain of 0 dB is involved in the model (ref. Table 2). For a receiver, the real antenna is replaced by an equivalent isotropic antenna with the same gain (ref. Table 3).

TABLE II. ANTENNA TYPE OF THE TRANSMITTERS OF WIRELESS SYSTEMS AND MD SRD

Transmitter	Antenna in hardware	Antenna in model	Antenna gain in model, dB
LTE MS (wearable)	unknown	isotropic	0
5G MS (wearable)	unknown	isotropic	0
RLAN AP (fixed)	built-in omni-directional	real antenna pattern	0 (EIRP is used)
NB IoT sensor (wearable)	unknown	isotropic	0
SRD 1: capsule (wearable)	unknown	isotropic (worst-case)	0 (EIRP is used)
SRD 2: sensor or peripheral (wearable)	unknown	isotropic (worst-case)	0 (EIRP is used)
SRD 3, 4, 5: peripheral (fixed)	half-wave dipole	half-wave dipole	0 (EIRP is used)

TABLE III. ANTENNA TYPE OF THE RECEIVERS OF WIRELESS SYSTEMS AND MD SRD

Receiver	Antenna in hardware	Antenna in model	Antenna gain in model, dB
LTE MS (wearable)	unknown	isotropic	0
5G MS (wearable)	unknown	isotropic	0
RLAN AP (fixed)	built-in omni-directional	real antenna pattern	2.8
NB IoT sensor (wearable)	unknown	isotropic	0
SRD 1, 2: peripheral (wearable)	half-wave dipole	isotropic (worst case)	2.18
SRD 3, 4, 5: peripheral (fixed)	half-wave dipole	half-wave dipole	2.18

7) The three-dimensional model of the fragment of hospital floor plan is developed. The fragment of floor plan contains the corridor and several rooms including the treatment room.

The fragment of typical premises plan [14] of a hospital considered for the EMC analysis is given in Fig. 3. The walls height is 3 m and the thickness of internal walls is 0.12 m. The elements of the floor plan have the following materials: the material of walls is brick, the material of floor and ceiling is concrete, and the material of doors is wood.

A typical treatment room of the hospital is considered for the EMC analysis. The room contains a typical set of equipment: a bed, chairs, tables, medical equipment, as well as sanitary equipment. The treatment room has the following dimensions: the length is 4.65 m, the width is 3.7 m, and the height is 3 m.

8) The placement of the emitters of (EM) radiation and receivers in the model of indoor environment is given in Fig. 3 and Fig. 4. The worst-case positions of transmitters (potential sources of interference) and receivers (potential receptors of interference) are considered: the transmitters and receivers are placed at close distance in the same room or in the neighboring rooms.

a) LTE and 5G MS as emitters are located at different places (at three points) of the room (these places could be considered as possible positions of hospital nurse talking by mobile phone) (ref. Fig. 3). The MSs as receptor are located uniformly in the considered room (ref. Fig. 4). The height of each MS above the floor is 1.5 m.

b) RLAN APs are located at different places on the wall of the corridor close to the room containing MD SRD receivers in order to consider the worst case with respect to levels of unwanted signal created by the transmitters to the receivers. The height of each AP transmitter above the floor is 2.8 m.

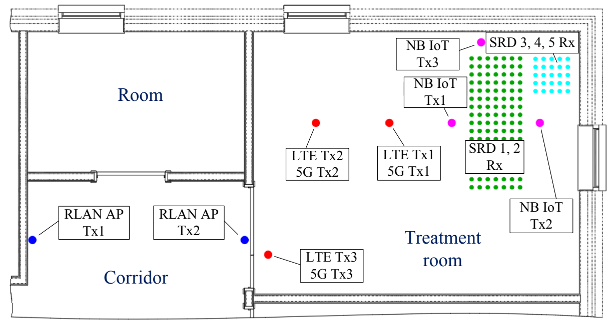

Fig. 3. The placement of wireless systems equipment as emitters and MD SRD as receptors at the fragment of floor plan in the hospital

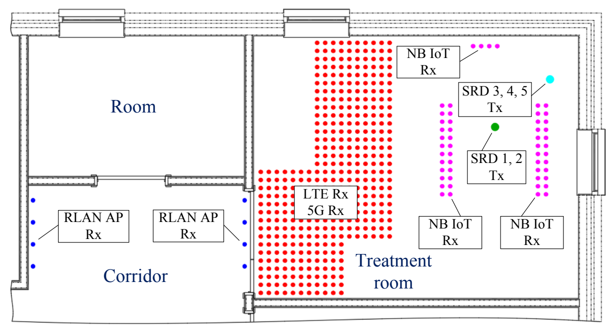

Fig. 4. The placement of MD SRD as emitters and wireless systems equipment as receptors at the fragment of floor plan in the hospital

c) For NB IoT, the infusion monitoring system to monitor the real-time drop rate and the volume of remaining drug during the intravenous infusion was considered as application of NB IoT in smart hospitals [1]. It is assumed that the infusion system is located near the bed of a patient. The height of the NB IoT sensors over the floor is 1.5 m.

d) SRD 1 and SRD 2 systems include the transmitters and receivers located inside or on the human body, i.e., the devices are wearable, and is located over the bed of a patient. The height of these MD SRDs over the floor of the room is 0.8 m. For SRD 3, SRD 4, and SRD 5 systems, the peripheral fixed devices transmit more power than the implantable devices, and receivers of the peripheral devices are more sensitive than the receivers of the implantable devices. Therefore, the peripheral fixed devices of these MD SRD systems are considered in EMC analysis. These devices are located over the table for peripheral fixed devices. The height of the MD SRDs over the floor is 1.0 m.

B. Procedure of EMC analysis by simulation

The following steps are made in order to perform the EMC analysis.

1) The simulation is intended to predict the level P_P of unwanted signal at analyzed frequency from each emitter at the input of each receiver by involving the three-dimensional model of the floor plan and three-dimensional multipath model of RWP. In order to ensure that the energy conservation law is not violated (i.e., the received power must not exceed the transmitted power), levels of unwanted signal are calculated by the formula

$$P_I = \min(P_P, K_{A-A} \cdot P_e)\text{, W,} \quad (2)$$

where P_P is the power of unwanted signal at the receptor obtained by simulation, W; P_e is the transmitter emission power, W; K_{A-A} is the factor of the coupling between the transmitter and receiver antennas, W/W (K_{A-A}=1, the maximum possible value is used).

Results P_I of unwanted signal at the receptor input are obtained as a range of unwanted signal levels because different possible positions of the receivers are considered. The maximum level $P_{I\max}$ of unwanted signal is selected from the range of P_I values.

2) The criterion of EMC is calculated. The interference margin (IM) is used as EMC criterion (interference criterion):

$$IM = P_I / S\text{, W/W,} \quad (3)$$

where S is the receptor susceptibility to interference, W.

The unwanted signal is considered to be tolerable if IM < 1, and interference happens if IM ≥1 (note that 1 W/W is equal to 0 dB).

IM is calculated using the $P_{I\max}$ value and the receiver susceptibility value S.

Then the IIM is calculated by the following equation using IM at each analyzed frequency:

$$IIM = \sum_{i=1}^{n} IM(f_{Ai})\text{, W/W,} \quad (4)$$

where f_A is the analyzed frequency, Hz; n is the number of analyzed frequencies.

The IIM accounts for the simultaneous influence of all types of the transmitter emissions on the receiver.

3) Based on the value of IIM, the decision about the presence or absence of interference is made.

C. Estimation of safe distance between emitter and receptor

Equations (5)-(7) are taken into account in order to calculate of the safe (interference-free) distance between the emitter and receptor.

Free-space attenuation of unwanted signal between isotropic antennas due to RWP, also known as the free-space basic transmission loss L_{bf}, is calculated by the following formula [15]:

$$L_{bf} = -147.6 + 20 \cdot \log f + 20 \cdot \log d\text{, dB,} \quad (5)$$

where f is the frequency, Hz; d is the distance between the antennas, m.

Free-space propagation model is used in the analysis because this model is often considered as a reference for comparison of different propagation models. The additional reason is that the free-space propagation model is very simple and analytically tractable.

The level of unwanted signal at the input of the receiver is calculated by the formula

$$P_I = P_e - L_{bf} + G_R\text{, dBm,} \quad (6)$$

where G_R is the receiver antenna gain, dBi.

The IM is calculated by substituting (6) into (3) taking into account (5):

$$IM = P_e - S + G_R + 147.6 - 20 \cdot \log(f) - 20 \cdot \log(d)\text{, dB.} \quad (7)$$

Based on (7) at IM=0, the minimum distance at which the devices are compatible is calculated as follows

$$d_c = \frac{1}{f} \cdot 10^{\frac{P_e - S + G_R + 147.6}{20}}\text{, m.} \quad (8)$$

IV. RESULTS OF EMC ANALYSIS

The IM was calculated at each analyzed frequency. The interference can be observed both at M2S and S2D interaction simultaneously, because IM > 0 at both transmitter and receiver frequencies in all cases of EMC analysis. The most dangerous interference is observed at the receiver frequency. The result of the calculation of IM in case of influence of LTE MS transmitter radiation on SRD 1 receiver is provided in Table 4 as example.

TABLE IV. RESULTS OF CALCULATION OF IM

LTE mode	Interaction type	f_A, MHz	$P_{I\max}$, dBm	S, dBm	IM, dB
TDD	M2S	2595	-6.7	-44.0	37.3
TDD	O2S	2585	-39.7	-44.0	4.3
TDD, FDD	S2S	3000	-56.7	-44.0	-12.7
FDD	M2S	1950	-7.4	-44.0	36.6
FDD	O2S	1940	-40.0	-44.0	4.0
TDD, FDD	S2S	30	-9.6	-44.0	34.4
TDD, FDD	S2D	435	-34.0	-99.0	65.0
TDD, FDD	S2A	445	-35.3	-67.5	32.2

Worst-case values of IIM are provided in Table 5 and Table 6 for all cases of EMC analysis. These values are obtained for small distances between the emitter device and receptor device. The most dangerous emitter and susceptible receptor, and maximum value of IIM are marked by red color. The least dangerous emitter and susceptible receiver, and minimum value of IIM are marked by yellow color.

TABLE V. THE IIM (DB) TAKING INTO ACCOUNT THE INFLUENCE OF WIRELESS SYSTEM TRANSMITTER RADIATION ON MD SRD RECEIVER

Emitter	Receptor					Aver. IIM
	SRD 1	SRD 2	SRD 3	SRD 4	SRD 5	
LTE MS (TDD)	65.0	39.0	39.1	56.4	56.1	59.1
LTE MS (FDD)	65.0	38.9	39.0	56.3	56.0	59.0
5G MS	65.0	38.3	38.7	56.3	56.0	59.0
RLAN AP	56.5	28.5	25.6	47.1	46.2	50.3
NB IoT	72.5	71.8	62.0	76.6	76.6	74.0
Aver. IIM	67.3	64.8	55.1	69.7	69.7	

TABLE VI. THE IIM (DB) TAKING INTO ACCOUNT THE INFLUENCE OF MD SRD TRANSMITTER RADIATION ON WIRELESS SYSTEM RECEIVER

Emitter	Receptor					Aver. IIM
	LTE MS (TDD)	LTE MS (FDD)	5G MS	RLAN AP	NB IoT	
SRD 1	34.2	40.3	8.0	11.7	42.5	37.9
SRD 2	52.0	58.1	48.9	38.3	64.4	58.6
SRD 3	49.5	55.6	46.3	32.3	61.9	56.1
SRD 4	37.0	43.1	30.7	15.2	61.9	55.0
SRD 5	37.0	43.1	30.7	15.0	61.9	55.0
Aver. IIM	47.2	53.3	43.9	32.3	61.7	

The minimum distance at which the emitter and receptor will be EM compatible is given in Tables 7 and Table 8 for all situations considered above. Maximum and minimum value of safe distance is marked by red and yellow color correspondingly.

TABLE VII. SAFE DISTANCE (M) BETWEEN WIRELESS SYSTEM TRANSMITTER AND MD SRD RECEIVER

Emitter	Receptor				
	SRD 1	SRD 2	SRD 3	SRD 4	SRD 5
LTE MS (TDD)	1005	59	80	549	546
LTE MS (FDD)	1005	58	79	549	545
5G MS	1003	55	77	547	543
RLAN AP	1290	50	73	694	690
NB IoT	1408	1281	653	3519	3519

TABLE VIII. SAFE DISTANCE (M) BETWEEN MD SRD TRANSMITTER AND WIRELESS SYSTEM RECEIVER

Emitter	Receptor				
	LTE MS (TDD)	LTE MS (FDD)	5G MS	RLAN AP	NB IoT
SRD 1	33	54	3	14	66
SRD 2	256	422	212	236	827
SRD 3	256	422	212	188	827
SRD 4	61	100	35	29	827
SRD 5	61	100	35	29	827

Wireless system transmitters can create the interference to all considered types of MD SRD receivers because IIM > 0 in all cells of Table 5. The EMC criterion (IIM) can be equal to 26.6…76.6 dB, depending on the transmitter and the receiver type. The minimum distance at which the devices will be compatible varies from approximately 50 m to 3519 m, depending on the type of wireless system transmitter and MD SRD system.

1) The influence of NB IoT sensor transmitter emission on SRD 4 and SRD 5 receivers is the most dangerous.

2) The influence of RLAN AP transmitter emission on SRD 3 receiver is the least dangerous.

3) In accordance with the average value of IIM

a) RLAN AP transmitter is the least dangerous for MD SRD receivers because the transmitter and the receiver are located in different rooms of considered floor plan.

b) SRD 4 and SRD 5 receivers are the most susceptible to emissions of wireless system transmitters.

c) SRD 3 receiver is the least susceptible to emissions of wireless system transmitters.

MD SRD transmitters can also create the interference to all considered types of wireless system receivers because IIM > 0 in all cells of Table 6. The EMC criterion (IIM) can be equal to 8.0…64.4 dB, depending on the transmitter and the receiver type. The minimum distance at which the devices will be compatible varies from approximately 3 m to 827 m, depending on the type of considered wireless system and MD SRD system

4) The influence of the SRD 2 transmitter emission on NB IoT sensor receiver is the most dangerous.

5) The influence of the SRD 1 transmitter emission on 5G MS receiver is the least dangerous.

6) In accordance with the average value of IIM

a) SRD 2 transmitter is the most dangerous for receivers of wireless systems.

b) SRD 1 transmitter is the least dangerous for receivers of wireless systems.

c) NB IoT sensor receiver is the most susceptible to emissions of MD SRD transmitters.

d) RLAN AP receiver is the least susceptible to emissions of MD SRD transmitters.

The obtained results are pessimistic (worst-case) because the envelopes of emitter spectrum and receptor susceptibility are used for the analysis.

The results of EMC analysis are affected by the following effects of the radio wave propagation (these effects are taken into account by the multipath RWP model): reflections from on-site objects (the reflections may increase the disturbance levels) and penetration of radio waves through the walls of the building (the disturbance level is decreased due to attenuation in the walls).

The results obtained with the use of multipath RWP model are verified by the free-space model of RWP (Fig. 5). The difference between the results obtained by these models can achieve 12 dB because the free-space model does not take into account the reflections from on-site objects.

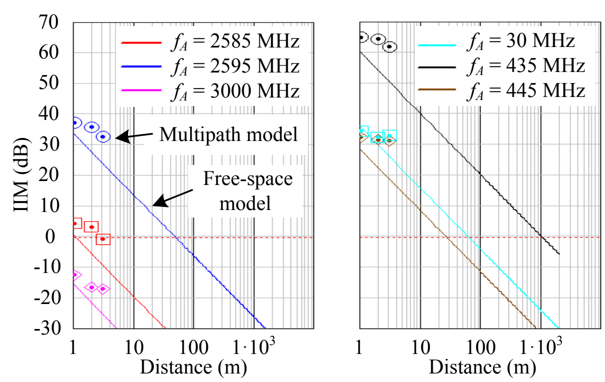

Fig. 5. Dependence of IM on the distance between LTE MS (TDD) transmitter and SRD 1 receiver

V. ESTIMATION OF DAMAGE DUE TO INTERFERENCE

The danger of interference depends on the level of damage to the receiver due to the interference.

For MD SRD receivers, the level of damage depends on availability, type, and maturity of MD SRD adaptation mechanism that helps to avoid the damage.

1) For capsule endoscopy system (SRD 1), the possible damage is errors in data (images from inside patient's gastrointestinal tract) received by data recorder from transmitting camera (capsule).

2) For MBANS (SRD 2), the possible damage is errors in data (temperature, pulse, blood glucose and pressure level, electrocardiogram, respiratory function readings, etc.) received by the hub device; and errors in data (for adjustment of the sensor) received by the sensor from the hub.

3) For active implant systems (SRD 3, SRD 4, and SRD 5), the possible damage is errors in tellecommand and telemetry data received by the implantable device or the associated peripheral receiver. The most dangerous damage is violation of work of vital implantable devices (peacemakers, etc.).

The interference created by MD SRD to wireless systems can be recognized not dangerous in majority of situations, because modern wireless systems use different mechanisms of adaptation (automatic selection of frequency band and subcarriers, control of effectiveness of coding, retransmission of data, etc.).

1) For LTE MS, 5G MS, and RLAN AP receiver, the maximum possible damage is a short-time loss of communication or short-time decrease in data rate.

2) For NB IoT sensor receiver, the maximum possible damage is the errors in data received by the sensor from BS.

In potentially dangerous situations, an experimental examination of presence and damage of interference to the receivers can be required (especially in cases of interference to receivers of vitally important MD SRD systems).

VI. Conclusions

Equipment of considered wireless systems located in hospitals can create the interference to all considered types of MD SRDs in case of allocation of emitters and receptors inside the same room or in neighboring rooms. The MD SRDs can also create the interference to receivers of wireless systems in the same conditions. Compliance with the requirements of standards [5]-[13] does not guarantee absence of interference to MD SRDs and 4G/5G equipment. Therefore, it is advised to set more stringent requirements on susceptibility characteristics of the MD SRD receivers in frequency bands of wireless systems equipment operation, as well as on spurious emission of wireless systems in frequency bands of MD SRD operation.

The possible damage due to interference for MD SRDs is errors in data (vital health information) received by receivers from transmitters of MD SRD system. The most dangerous damage can be violation of work of vital implantable devices. The interference created by MD SRD to wireless systems can be recognized not dangerous in majority of situations. The possible damage is a short-time loss of communication or short-time decrease in data rate.

The used models of characteristics of emission spectra and susceptibility constructed using [5]-[13] are worst case models of envelopes of these characteristics. Therefore, the above estimates are pessimistic. Authors intend to carry out experimental verification of the results to define more precisely necessary restrictions on the distance between MD SRD and 4G/5G equipment and, in general, on possibility of safe use of 4G/5G mobile communications in hospitals.

If results of measurements will show the presence of interference, the measures to eliminate the interference must be taken, e.g., the following: increasing the distance between the emitters and receptors, using emitters and receptors in different rooms of a building, shielding rooms that contain a vital MD SRD system, forbidding or restricting the use of mobile phones (LTE, 5G) and NB IoT sensors during operation of vital MD SRD system inside the same room.

Presented results can be used in diagnostics of intersystem EMC of medical and non-medical wireless equipment in hospitals. The main purpose of such diagnostics is to ensure safety of use of mobile wireless telecommunications regarding medical vital devices in conditions of mass distribution of 4G/5G wireless services.

References

[1] J. L. Toennies, G. Tortora, M. Simi, P. Valdastri, R. J. Webster, “Swallowable medical devices for diagnosis and surgery: the state of the art”, IMechE Proceedings, Vol.224, No.7, 2010, pp.1397–1414.

[2] S. Movassaghi, M. Abolhasan, J. Lipman, D. Smith, A. Jamalipour, “Wireless Body Area Networks: A Survey”, IEEE Communications Surveys and Tutorials, Vol. 16, No.3, 2014, pp.1658–1686.

[3] M. N. Islam, M. R. Yuce, “Review of Medical Implant Communication System (MICS) band and network”, ICT Express, Vol. 2, No. 4, 2016, pp. 188–194.

[4] H. Zhang, J. Li, B. Wen, Y. Xun, J. Liu, “Connecting Intelligent Things in Smart Hospitals Using NB-IoT”, IEEE Internet of Things Journal, Vol. 5, No. 3, 2018, pp. 1550–1560.

[5] ETSI EN 303 520 V1.2.1 (2019-06). Short Range Devices (SRD); Ultra Low Power (ULP) wireless medical capsule endoscopy devices operating in the band 430 MHz to 440 MHz.

[6] ETSI EN 303 203 V2.1.1 (2015-11). Short Range Devices (SRD); Medical Body Area Network Systems (MBANSs) operating in the 2 483,5 MHz to 2 500 MHz range.

[7] ETSI EN 301 559 V2.1.1 (2016-10). Short Range Devices (SRD); Low Power Active Medical Implants (LP-AMI) and associated Peripherals (LP-AMI-P) operating in the frequency range 2483,5 MHz to 2500 MHz.

[8] ETSI EN 301 839 V2.1.1 (2016-04). Ultra Low Power Active Medical Implants (ULP-AMI) and associated Peripherals (ULP-AMI-P) operating in the frequency range 402 MHz to 405 MHz.

[9] ETSI EN 302 537 V2.1.1 (2016-04). ETSI EN 302 537 V2.1.1 (2016-10). Ultra Low Power Medical Data Service (MEDS) Systems operating in the frequency range 401 MHz to 402 MHz and 405 MHz to 406 MHz.

[10] ETSI TS 136 101 V15.10.0 (2020-04). LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception.

[11] ETSI EN 301 908-25. IMT cellular networks; Harmonised Standard for access to radio spectrum; Part 25: New Radio (NR) User Equipment (UE).

[12] 3GPP TR 36.802 V13.0.0 (2016-06); 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); NB-IOT; Technical Report for BS and UE radio transmission and reception.

[13] ETSI EN 301 893 V2.1.1 (2017-05). 5 GHz RLAN Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU.

[14] Hospital layout design CAD drawing, CADBLOCKSfree, Sept. 2015. [Online]. Available: thttps://www.cadblocksfree.com/en/hospital-layout-design.html

[15] Rec. ITU-R P.525-4. Calculation of free-space attenuation.