International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 11 (2015) pp. 30121-30134

http://www.ripublication.com

SAR Considerations of The EM Radiation & System Requirements of The EA Uplink-Downlink LTE Systems and The Performance Evaluation of The Resulting FDD & TDD Duplexing Schemes

V. Rama Krishna Sharma[1], Dr.P.Chandrasekhar[2]
[1]Associate Professor, ECE Dept., DVRCET, HYD, Telangana, India
sharma.vydhyula@gmail.com , sharma.vydhyula@hotmail.com
[2]Associate Professor, ECE Department, Osmania University, HYD, Telangana, India

Abstract

The revolutionary evolution of digital mobile data wireless communication services exerted a need for serious thrust on more efficient ways to address the harmful effects of electromagnetic radiation due to the Uplink power of the mobile terminal on the human body. The Specific Absorption Rate (SAR) value is the standard dosimetric parameter in defining the energy absorbed by the human body exposed to EM radiation. Particularly, smart phones and other portable wireless mobile devices like tablets which are in close vicinity to the human body have vastly increased the complexity of EM radiation on different body regions. Electromagnetic Asymmetry (EA) means that, under the restriction of EM radiation, the equivalent bandwidth of uplink should be narrower than that of downlink in view of the duplexing schemes. Increase in multimedia services and the wide scale use of various applications like web browsing, real-time video and interactive games have resulted in the EA between the uplink and downlink. We present a procedural approach for the evaluation of the Electromagnetic (EM) Radiation influence of the interaction of the mobile terminal with the human body. We also investigate the factors that may influence this interaction. The factors have been considered for different mobile handset models. Homogeneous and heterogeneous models are used for simulation and validation. Long Term Evolution (LTE) introduced by 3rd generation partnership project (3GPP) dominates the mobile communications networks. In this work, a thorough analysis, in view of EA of the Frequency division duplex (FDD) and Time division duplex (TDD) operational modes for uplink and downlink and their performance evaluations have been carried out. Our work is unique, as we discuss performance study based on EM radiation. This paper provides the maximum data throughput investigations for different scenarios in a very comprehensive manner.

Keywords: SAR, EM Asymmetry, EM Radiation, FDD, TDD, LTE, SC-FDMA, FDTD.

Introduction

The proliferation of handheld transceivers has raised the level of concern for possible biological effects of EM radiation absorbed by the humans. A large fraction of power radiated by the mobile terminal is absorbed by the user. Particularly, in the RF and microwave frequency bands, the absorbed EM energy results in the heating of the tissues [12]. The value of 4W/kg is considered worldwide as the threshold for the induction of biological thermal effects [13]. The human head consists of several materials that are responsible for EM energy absorption [14]. Majority of all contemporary mobile communication services are asymmetric, such as high multimedia [15, 16]. The downlink of service requirement is vastly than of uplink both in transmission total amount and transmission rate. The asymmetric characteristic of uplink and downlink due to EM radiation is named as Electromagnetic Asymmetry (EA) between UL and DL. The effects of EM radiation on the surrounding environment are always a controversial problem. With the large-scale use of mobile communications, the total amount of EM radiation has increased and people have to re-evaluate the biological effects of mobile communications [17]. Usage of mobile phones in varied patterns introduces an EM interaction between the mobile terminal and human body. The impact of the mobile terminal on the user is often considered as the exposure of the user to the radiating device.

In view of the public health risk, SAR became a crucial parameter in public discussions and underscores the importance of optimizing the interaction between the mobile handset and user with consumers and mobile manufacturers as the stake holders. Experimental measurements or numerical computations can be used to evaluate the interaction between mobile handset and human body. The experimental way of measuring uses actual mobile phone and a homogeneous human head model with two or three tissues and heterogeneous head model considers more than thirty different tissues but the headset is modelled as a simple box consisting an antenna whereas the headset models are classified as simple and semi-realistic.[1]-[9]. LTE employs Orthogonal Frequency Division Multiplex (OFDM) for and Single Carrier Frequency Division Multiple Access (SC-FDMA). With different frame structures in time domain, it supports FDD and TDD schemes. Based on system bandwidth which varies from 1.4 MHz to 20 MHz different Resource Blocks (RBs) can be addressed in frequency domain. Each RB is 0.5 ms and 180 kHz in time domain and frequency domain respectively. The number of subcarriers and symbols are different for each RB [10], and they depend on the cyclic prefix code and subcarrier spacing. The overview of specifications and performance is provided in [11]. In the context of EA, we system bandwidth of 20 MHz is considered for analysing the maximum throughput for different scenarios and the performance study of TDD and FDD operational modes are discussed for different diversity schemes, code rates and data modulations.

System Considerations

The System considerations are SAR, Assessment of EM Interaction and SAR Exposure Limits.

SAR

SAR is the widely accepted and the most appropriate metric in the determination of the EM exposure from the mobile terminal [18]-[26]. It is expressed as the W/kg of human tissue and is averaged over a volume of either 1 g or 10 g of tissue. SAR measurements are made in two ways where in the first way body phantoms, robot and test equipment is used as shown in figure 1, and the second way by means of mathematical modelling which is very costly and consumes several hours.

(a) SAR Measurement by Index SAR company

(b) SAR Measurement by SPEAG Company

Figure 1: SAR Measurement setups

There are three approaches to calculate the SAR namely the 3-, 6-, and 12-field components approach. The 12-field approach is very complicated but it is most accurate and appropriate from mathematical point of view [27]. The 12-field components approach is preferred by IEEE Standard 1529 [28]. The Specific absorption rate is mathematically written as in equation (1)

$$SAR = \frac{\sigma_E}{2\rho}|\mathbf{E}|^2 = c\frac{dT}{dt} \quad (1)$$

Where, c is the Specific heat capacity,
σ_E is the electric conductivity,
ρ is the mass density of the tissue,
$\mathbf{E}$ is the induced electric field vector and
dT/dt is the temperature increase in the tissue.

Assessment of EM Interaction

The physical head model (phantom) for the assessment of EM interaction, specified in IEEE-Std. 1528 and IEC 62209-1 is Specific Anthropomorphic Mannequin (SAM). It is based on the 90th percentile of survey of American male military personnel and which was developed by IEEE Standards Coordinating Committee 34, Subcommittee

2, Working Group 1 (SCC34/SC2/WG1). The block diagram which illustrates the numerical computation of the EM interaction of mobile terminal with the human body using Finite difference Time domain (FDTD) is shown in figure 2.

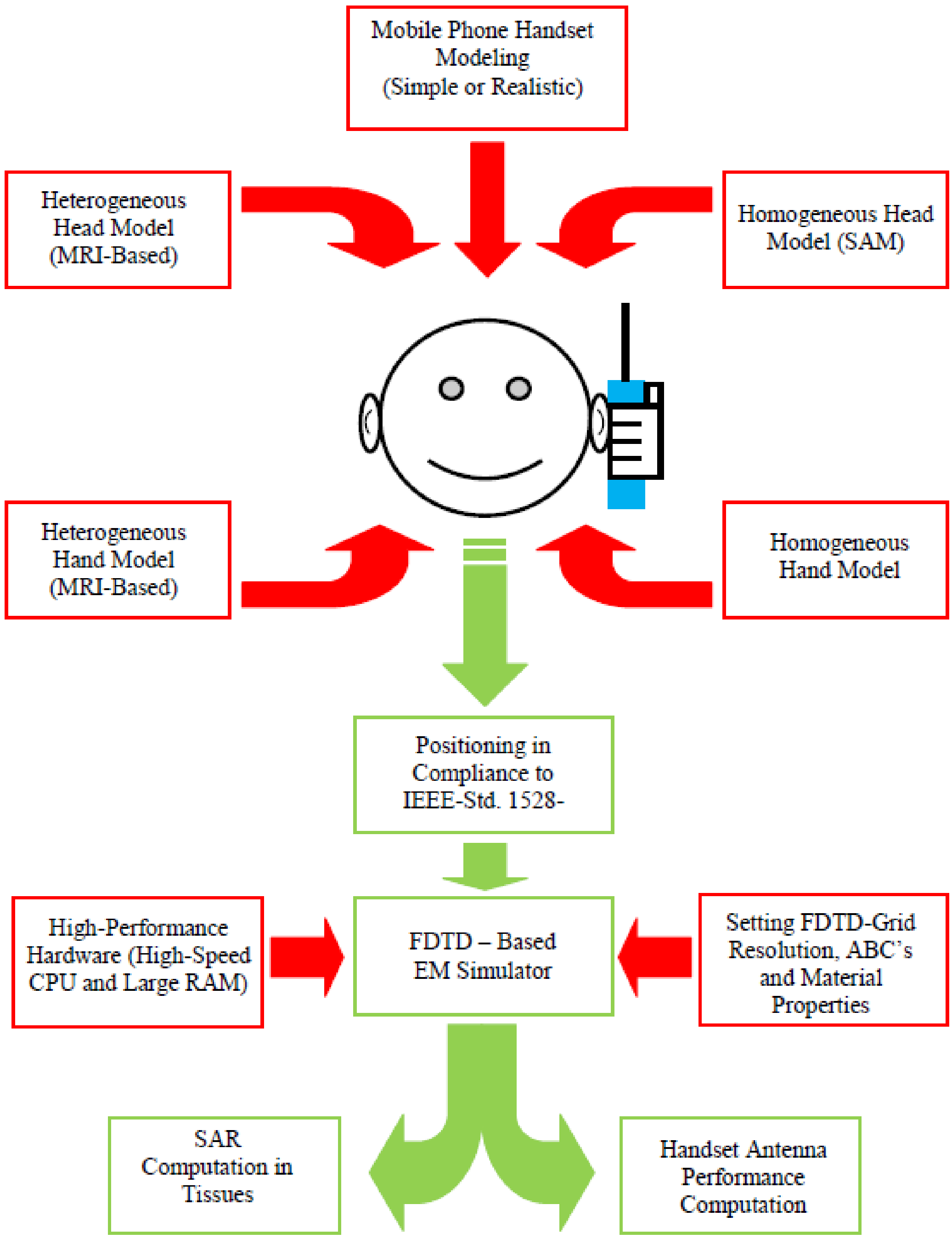


Figure 2: Block Diagram For Numerical Computation of EM Interaction

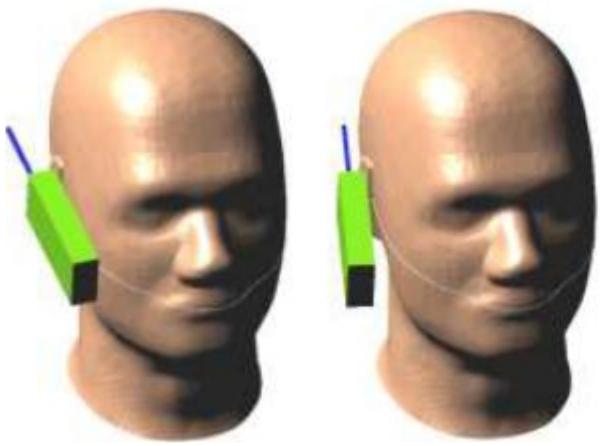
SAR Exposure Limits

For ensuring the protection of public from exposure due to EM fields when mobile transceivers are operated in close vicinity to human body, many countries across the world have regulations which limit the exposure to EM fields. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an independent organization which prescribes the guidelines and recommendations with regard to EM exposure [29]. IEEE provides the standard safety levels [20] of SAR. Also, the European standard EN 50360 specifies the SAR safety limits [21]. Basically, the limits are defined for the exposure to the whole body but most of the SAR testing is concerned about the exposure to the head. The SAR limits of the non-occupational users prescribed in different major regions across the world are shown in Table 1.

Table 1: SAR limits for non-occupational users across different major regions of the world

	USA	Europe	Australia	Japan
Organization/Body	IEEE/ANSI/ FCC	ICNIRP	ASA	TTC/MPTC
Measurement method	C95.1	EN50360	ARPANSA	ARIB
Whole body averaged SAR	0.08 W/kg	0.08 W/kg	0.08 W/kg	0.04 W/kg
Spatial-peak SAR in head	1.6 W/kg	2 W/kg	2 W/kg	2 W/kg
Averaging mass	1 g	10 g	10 g	10 g
Spatial-peak SAR in limbs	4 W/kg	4 W/kg	4 W/kg	4 W/kg
Averaging mass	10 g	10 g	10 g	10 g
Averaging time	30 min	6 min	6 min	6 min

The two compliance test positions showing the generic phone in close proximity to a SAM phantom at cheek and tilt-position in accordance with IEEE-Std. 1528-2003 [18] is shown in figure 2.



(a) Cheek-position (b) tilt-position

Figure 3: SAM Next To Generic Phone

Also, Different head dimensions belonging to different origins show different EM wave interactions. This is mainly because of different pineal size and thickness, the distance between the mobile antenna source and the nearest head tissue varies accordingly. The pooled statistics given in [30], for the generic phone in close proximity to the SAM at cheek and tilt-position and which are normalized to 1 W power are summarized in Table 2.

Table 2: SAR statistics of generic phone [30] at cheek and tilt-positions

Frequency			835 MHz		1900 MHz	
Handset position			*Cheek*	*Tilt*	*Cheek*	*Tilt*
FDTD Computation in literature [26]	Spatial-peak SAR_{1g} (W/kg)	Mean	7.74	4.93	8.28	11.97
		Std. Dev.	0.40	0.64	1.58	3.10
		No.	16	16	16	15
	Spatial-peak SAR_{10g} (W/kg)	Mean	5.26	3.39	4.79	6.78
		Std. Dev.	0.27	0.26	0.73	1.37
		No.	16	16	16	15
Measurement in literature [26]	Spatial-peak SAR_{1g} (W/kg)		8.8	4.8	8.6	12.3
	Spatial-peak SAR_{10g} (W/kg)		6.1	3.2	5.3	6.9

System Requirements

The system requirements section consists of Architecture and physical description.

Architecture

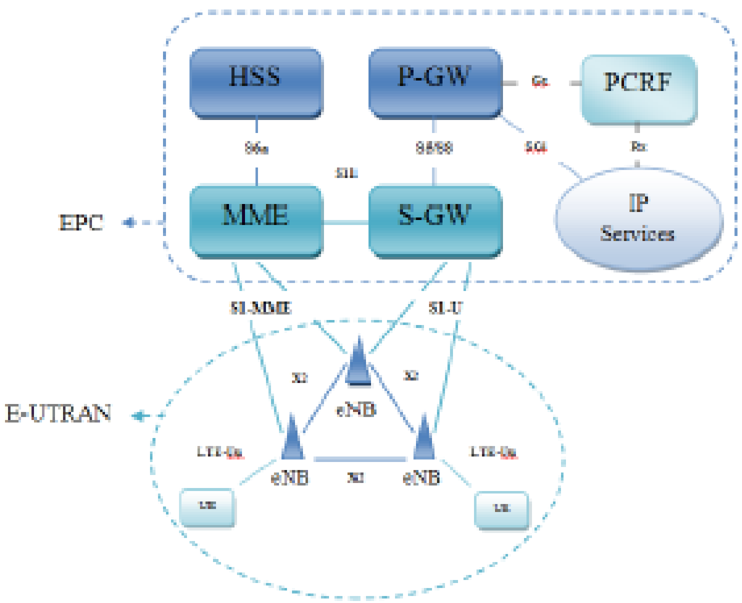


Figure 4: Evolved packet system

The Evolved packet system [31] as presented in figure 4. Consists of Home Subscriber Service (HSS) , Policy control and charging Rules function (PCRF) [32], Packet Data Network Gateway (P-GW), Serving Gateway (S-GW), Evolved packet core (EPC), User Equipment (UE), Mobility Management Entity (MME). Evolved Universal Terrestrial Radio Access (E-UTRA) is the air interface of LTE. P-GW connects UE to external packet data network and acts as an anchor. It also performs the tasks of user packet filtering and policy enforcement. S-GW acts as a mobility anchor. The channels that are assigned for data and control in the PHY layer are shown in Table 3.

Table 3: List of data and control channels

PHY Channel Name	Acronym
Physical Broadcast Channel	PBCH
Physical Multicast Channel	PMCH
Physical Downlink Shared Channel	PDSCH
Physical Uplink Shared Channel	PUSCH
Physical Downlink Control Channel	PDCCH
Physical Random Access Channel	PRACH
Physical Uplink Control Channel	PUCCH

System Description

The Downlink and uplink transmission radio frames are 10 ms each. Two 5 ms half frames are used in TDD and each half frame is divided into 4 subframes and one special subframe but whereas in FDD, each frame consists of ten 1 ms subframes. But in both FDD and TDD each subframe has two slots of 0.5 ms each. Resource blocks (RBs) consists of resource elements (REs) or subcarriers of the same type of modulation. RB configurations are shown in Table 4.

Table 4: Configurations of Resource Blocks

	Normal Cyclic Prefix	Extended Cyclic Prefix	
	Subcarrier Spacing: 15kHz	Subcarrier Spacing: 15kHz	Subcarrier Spacing: 7.5kHz
DL	7x12	6x12	3x24
UL	7x12	6x12	-

The PHY channels and reference signals are mapped into the structure of resource elements.

The allocation counts of resource elements per 10 ms frame to different channels for FDD-DL, FDD- UL and TDD for various antenna configurations and different channel bandwidths are shown in Tables 5, 6 and 7.

Table 5: FDD-DL resource allocation

	SISO		MIMO 2x2		MIMO 4x4	
Channel BW	1.4 MHz	20 MHz	1.4 MHz	20 MHz	1.4 MHz	20 MHz
PDSCH	7,716	149,436	14,736	286,896	28,608	541,888
PDCCH	1,320	10,000	2,400	16000	3,840	16,000
PBCH	276	276	528	528	960	960
Ref S.	480	8,000	960	16000	1440	24,000
P-SS	144	144	288	288	576	576
S-SS	144	144	288	288	576	576

Table 6: FDD-UL Resource Allocation

	SISO	
Channel BW	1.4 MHz	20 MHz
PUSCH	5,760	141,120
PUSCH RS	1,200	23,760
PUCCH (CQI, HARQ ACK/NACK)	2,760	2,760
PUCCH RS	960	960
Sounding RS	120	120

Table 7: TDD Resource Allocation

		Frame Mode 0		Frame Mode 5	
	Channel BW	1.4 MHz	20 MHz	1.6 MHz	20 MHz
Downlink	PDSCH	1,236	29,580	6,204	119,580
	PDCCH	264	2000	1,056	8000
	PBCH	276	276	276	276
	P-SS	144	144	144	144
	S-SS	144	144	144	144
	Ref Signals	96	1600	384	4600
Uplink	PUSCH	3,456	84,672	576	14,112
	PUSCH (RS)	576	14,112	96	2,352
	PUCCH	1368	1368	240	240
	PUCCH (RS)	576	576	96	96
	Sounding RS	72	72	24	24
GP		1,440	24,000	840	12,000
Pilots		144	2,400	84	1,200

Simulations

The Simulations section consists of Simulation Environment and Performance results

Simulation Environment

The results are simulated in MATLAB environment and the relevant parameters are shown in Table 8. The major parameters are Channel bandwidth, Mode of duplexing scheme, channel type, Code rates, subcarrier spacing, frame period and modulation etc.,

Table 8: Simulation Parameters

Parameter	Value(s)
Channel Bandwidth	1.4, 20 (MHz)
Duplex Mode	FDD, TDD
Channel Type	AWGN
FEC Coding Scheme	Turbo coding, R=1/3
Modulation	QPSK, 16-QAM, 64-QAM
Frame Period	10 ms
Subcarrier spacing	15 kHz
Cyclic prefix	Normal(4.69us)
Code Block Sizes	40, 6144
Code Rates	0.75 for QPSK, 0.85 for 16-QAM and 64-QAM
Antenna Diversity	SISO and MIMO4x4
Maximum Iteration for Turbo Coding	10
Min BER	10^{-9}
Max BER	10^{-4}
Number of OFDM Symbols for PDCCH	2 for 1.4 MHz and 1 for 20MHz

Performance Results

The performance results of uplink and downlink for different cases of FDD and TDD are divided into two categories: First, 1.4 MHz bandwidth utilizing single input single output and second, 20 MHz maximum antenna diversity mode.

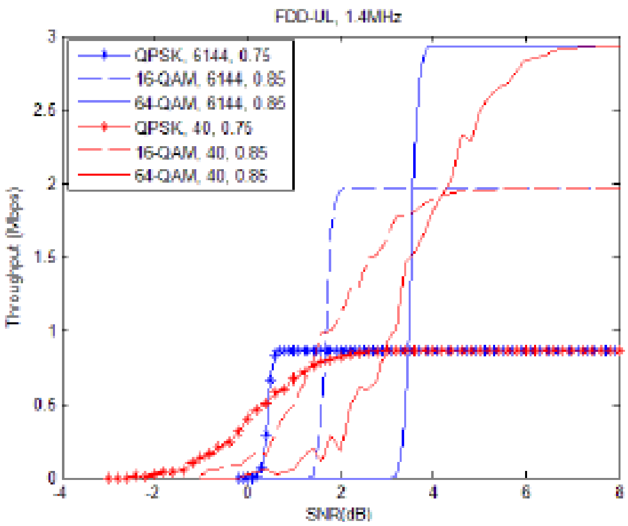


Figure 5: FDD uplink Throughput in 1.04 MHz Bandwidth

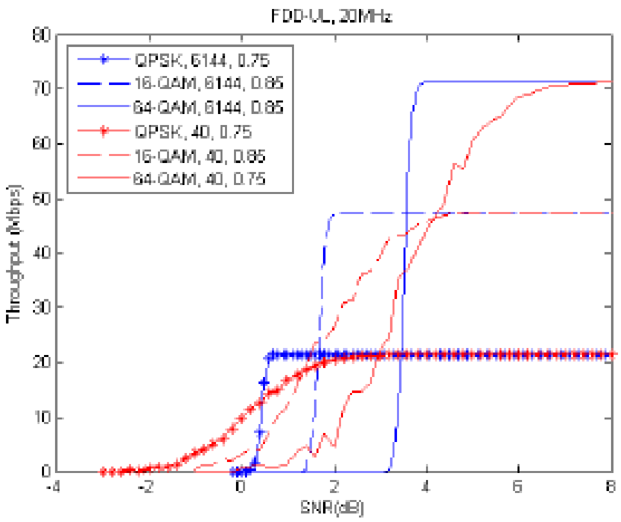


Figure 6: FDD uplink Throughput in 20 MHz Bandwidth

Figures 5 & 6 present the maximum throughput performance in 1.04 MHz and 20 MHz bandwidths based on the simulation parameters. When 64-QAM with code rate of 0.85 is considered then, the UE is will be able to send 2.93 Mbps only with 1.04 MHz bandwidth but with 20 MHz bandwidth the uplink is 71.97 Mbps which nearly 17 times greater.

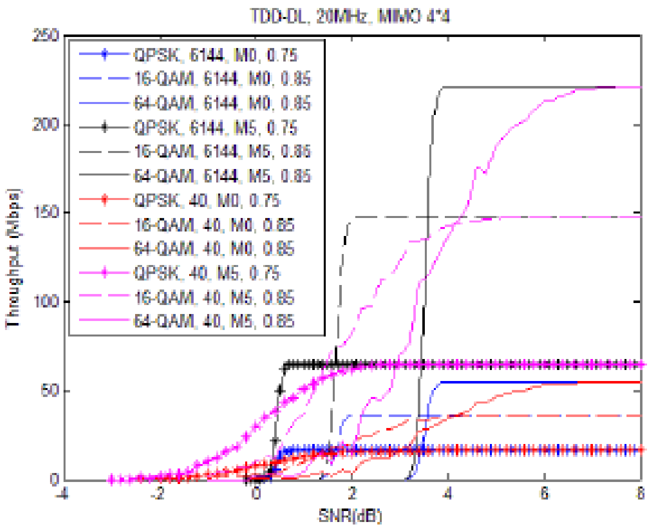


Figure 7: TDD downlink Throughput in mode 0 & mode 5

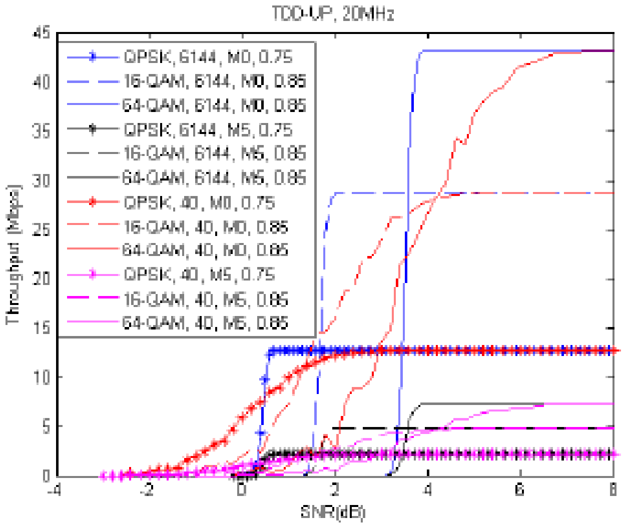


Figure 8: TDD uplink Throughput in mode 0 & mode 5

Figures 7 & 8 present the throughput for mode 0 (with six subframes) and mode 5 (with one subframe) Of TDD. The maximum throughputs in uplink are 43.18 Mbps and 7.19 Mbps in mode 0 & mode 5 respectively.

Conclusion

In view of the EA, an approach for modelling of the EM interaction with human body, the safety limits of exposure and the system requirements required for addressing the EM radiation due to mobile terminals are discussed. This work is a response to the lack of comprehensive study on the relationship between EM radiation at the user equipment and the duplex schemes being used. The main objective was to provide a holistic approach for maximum uplink throughput in both TDD and FDD modes in the context of EA under varied scenarios and configurations with different data modulations and code rates.

References

[1] Chavannes, N., Tay, R., Nikoloski, N.,Kuster, N.: Suitability of FDTD-basedTCAD tools for RF design of mobile phones. IEEE Antennas & Propagation Magazine, vol. 45, no. 6, pp. 52--66 (2003)

[2] Chavannes, N., Futter, P., Tay, R., Pokovic, K., Kuster, N.: Reliable prediction of mobile phone performance for different daily usage patterns using the FDTD method. In: Proceedings of the IEEE International Workshop on Antenna Technology (IWAT '06), White Plains, pp.345--348, NY, USA (2006)

[3] Futter, P., Chavannes, N., Tay, R. et al.: Reliable prediction of mobile phone performance for realistic in-use conditions using the FDTD method. IEEE Antennas and Propagation Magazine, vol. 50, no. 1,pp. 87--96 (2008)

[4] Al-Mously, S.I., Abousetta, M.M.: A Novel Cellular Handset Design for an Enhanced Antenna Performance and a Reduced SAR in the Human Head. International Journal of Antennas and Propagation (IJAP), vol.2008, Article ID 642572, 10 pages (2008)

[5] Al-Mously, S.I., Abousetta, M.M.: A Study of the Hand-Hold Impact on the EM Interaction of a Cellular Handset and A Human Head. International Journal of Electronics, Circuits, and Systems (IJECS),vol. 2, no. 2, pp. 91--95 (2008)

[6] Al-Mously, S.I., Abousetta, M.M.: Anticipated Impact of Hand-Hold Position on the Electromagnetic Interaction of Different Antenna Types/Positions and a Human in Cellular Communications. International Journal of Antennas and Propagation (IJAP), vol. 2008, 22 pages (2008)

[7] Al-Mously, S.I., Abousetta, M.M.: Study of Both Antenna and PCB Positions Effect on the Coupling Between the Cellular Hand-Set and Human Head at GSM-900 Standard. In Proceeding of the International Workshop on Antenna Technology 2008,iWAT2008, pp. 514--517, Chiba, Japan(2008)

[8] Al-Mously, S.I., Abdalla, A.Z., Abousetta, Ibrahim, E.M.: Accuracy and Cost Computation of the EM Coupling of a Cellular Handset and a Human Due to Artefact Rotation. In: Proceeding of 16^{th} Telecommunication Forum TELFOR 2008, November 25-27, pp. 484--487, Belgrade, Serbia (2008)

[9] Al-Mously, S.I., Abousetta, M.M.: User's Hand Effect on TIS of Different GSM900/1800 Mobile Phone Models Using FDTD Method. In: Proceeding of the International Conference on Computer, Electrical, and System Science, and Engineering, (The World Academy of Science, Engineering and Technology, PWASET), vo. 37, pp. 878--883, Dubai, UAE (2009)

[10] 3GPP TS 36.211, Evolved Universal Terrestrial Radio Access (EUTRA),"Physical Channels and Modulation", (Release 8).

[11] D. Astély, E. Dahlman, A. Furuskär, Y. Jading, M. Lindström, S.Parkvall, "LTE: the evolution of mobile broadband", IEEE Communication Magazine, April, 2009.

[12] Toshihiro Togashi, Tomoaki Nagaoka, et al., "FDTD Calculations of Specific Absorption Rate in Foetus Caused by Electromagnetic Waves From Mobile Radio Terminal Using Pregnant Woman Model," IEEE Transactions on Microwave Theory and Techniques, Volume56, Issue2, pp554 – 559, Feb.2008.

[13] Paolo Bernardi, Marta Cavagnaro, et al., "Specific absorption rate and temperature increases in the head of a cellular phone user," IEEE

Transactions on Microwave Theory and Techniques, Volume48, Issue7, pp1118 – 1126, Jul 2000.

[14] C. Gabriel, "Compilation of the dielectric properties of body tissues at RF and microwave frequencies," San Antonio, TX, Tech. Rep. AL/OE-TR-1996-0037, 1996, Brooks Air Force Base.

[15] Holma, H. and A. Toskala, WCDMA for UMTS-Radio Access for Third Generation Mobile Communications, John Wiley & Sons, Ltd., 2000.

[16] Stevens, P., \Operator design and planning issues for UMTS networks," UMTS | The R&D Challenges (Ref. No. 1998/496), IEE Colloquium, 3/1{3/5, 23 Nov., 1998.

[17] Liu, Y., Electromagnetic Biology Effect, Beijing University of Posts and Telecommunications, Jan. 2002.

[18] IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques, IEEE Standard-1528 (2003)

[19] Allen, S.G.: Radiofrequency field measurements and hazard assessment. Journal of Radiological Protection, vol. 11,pp. 49--62 (1996)

[20] Standard for Safety Levels with Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 3 kHz to 300 GHz, IEEE Standards Coordinating Committee 28.4 (2006)

[21] Product standard to demonstrate the compliance of mobile phones with the basic restrictions related to human exposure to electromagnetic fields (300 MHz–3GHz), European Committee for Electrical Standardization (CENELEC), EN 50360, Brussels (2001)

[22] Basic Standard for the Measurement of Specific Absorption Rate Related to Exposure to Electromagnetic Fields from Mobile Phones (300 MHz–3GHz), European Committee for Electrical Standardization (CENELEC), EN-50361 (2001)

[23] Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures — Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz), IEC 62209-1 (2006)

[24] Specific Absorption Rate (SAR) Estimation for Cellular Phone, Association of Radio Industries and businesses, ARIB STD-T56 (2002)

[25] Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Field, Supplement C to OET Bulletin 65 (Edition 9701), Federal Communications Commission (FCC),Washington, DC, USA (1997)

[26] ACA Radio communications (Electromagnetic Radiation – Human Exposure) Standard 2003, Schedules 1 and 2, Australian Communications Authority (2003)

[27] Caputa, K., Okoniewski, M., Stuchly, M.A.: An algorithm for computations of the power deposition in human tissue. IEEE Antennas and Propagation Magazine, vol.41, pp. 102--107 (1999)

[28] Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) associated with the use of wireless handsets – computational techniques, IEEE-1529, draft standard.

[29] ICNIRP, Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz), Health Phys., vol.74, no. 4, pp. 494—522 (1998)

[30] Beard, B.B., Kainz, W., Onishi, T., et al.: Comparisons of computed mobile phone induced SAR in the SAM phantom to that in anatomically correct models of the human head. IEEE Transaction on Electromagnetic Compatibility, vol. 48, no.2, pp. 397--407 (2006)

[31] 3GPP TS 33.401, Technical Specification Group Services and System Aspects; Architecture enhancements for non-3GPP accesses”,(Release 8).