ISSN 1 746-7233, England, UK
World Journal of Modelling and Simulation
Vol. 16 (2020) No. 1, pp. 3-10

A Miniaturized Implantable Monopole Antenna Design for Kidney Cancer Detection

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(*Received January 28 2019, Accepted March 16 2019*)

Abstract. Tumors and cancerous cells' detection and monitoring of the expansion or contraction in their volumes can be efficiently done using the in-body antennas' sensitivity to surrounding tissue environment. This paper presents the design and analysis of a miniaturized monopole antenna covering the Medical Implant Communication Service Band MICS (402-405 MHz). The proposed antenna is used to detect Kidney cancer in its early stages. It is actually, the designed antenna's frequency response with respect to the kidney dielectric properties modification, which turns out to stand as a crucial key factor to provide the information about the development of malignant tissue and its expansion. Different size reduction techniques have been applied to downsize the antenna to be conveniently fit into a lightweight configuration. Thus, the antenna achieved a compact size of 14 x 10 x 0.805 mm3 and is sensitive enough to detect any changes in the volume of the malignant tissues. As the volume of malignant tissue increase from 0 mm^3 to 8076 mm^3 the operation frequency shift from 403.2 MHz to 392 MHz. Thus, the antenna can be used as a tool for early detection of cancerous tissue and its monitoring during treatment of the patient under observation.

Keywords: WBAN, MICS, implantable antenna, kidney, cancer.

1 Introduction

With the rapid progress in wireless communication, the field of wireless body sensors network has experienced a phenomenal growth, supporting many applications including medical and therapeutic systems. The Wireless Body Area Network (WBAN) covers the in-body implantable and on-body wearable sensors, which are widely used to monitor or treat the patients [4, 11]. Many systems have been developed to improve the life style OF the patients and to enhance remarkably the efficiency in treating multiple diseases such as retinal prosthesis [13], gastric diseases diagnosis [2], heart monitoring [5], and cancer diseases detection and therapies [6]. Among these illnesses, cancer is a very dangerous disease, which turns out to stand as the second leading cause of death worldwide [16]. Statistics demonstrate that due to cancer, around 13.2 million deaths are expected in 2030 [17]. The death rate due to cancer can be controlled if the cancer is detected at its early stages and properly monitored during treatment. Therefore, the researcher and engineers are attempting to find new and more practical methods to restrict the tumor not to spread in human body and to develop a monitoring system which monitor the patient under observation [18]. Some cancers type as lungs' cancer, kidney cancer, oral cancer, brain cancer and breast cancer can be completely cured if they were detected and diagnosed at an early stage [18]. As innovation keeps on changing, so too does the practice of medicine. In [7] a spiral Printed Inverted F Antenna PIFA is designed to detect the spreading of malignant tumors in the mouth. In [8] a breast cancer is detected by the use of a bowtie antenna. A UWB pentagon antenna is presented in [15] for microwave

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imaging chiefly for brain stroke and brain tumor detection. The above studies used outside body systems, which limits the detection of small millimeter sized tumors and exclusive monitoring of expansion or contraction in their volumes.

To overcome the aforementioned flaws in detection and monitoring of the tumors, here we proposed a new technique. We have designed an implantable antenna which is very sensitive to the surrounding environment. This sensitivity of antenna can be used as detection and monitoring factor. The Antenna design as intended for application within the in-body environment is a very complicated task owing mainly to the specific properties of the host medium, which can dramatically deteriorate the antenna's performances as well as reject and short circuit the implant [4]. The antenna size that has to be conveniently fit into lightweight configurations is also a critical issue to be overcome [1][14].

In consequent to aforementioned challenges of implantable antennas, this present paper can be set with the aim of providing the design of a miniaturized, implantable monopole antenna to perform an effective detection of kidney cancer. It is actually the frequency response of the proposed antenna, which stands as the most significant key factor for providing crucial information about the expansion of malignant tissue. Different miniaturization techniques are used to downsize the antenna. Consequently, the latter achieved a compact size of 14 * 10 * 0.805 mm^3. The remaining paper is organized as: section 2 describes the antenna design, in section 3, kidney modeling for simulation is discussed, the detection of malignant tissue and its effects on antenna are discussed in section 4, and section 5 concludes the paper.

2 Antenna design

The antenna model geometry with top and bottom views is shown in Fig. 1. The proposed antenna is printed on a 0.635 mm thicker RO3210 substrate having a relative permittivity of 10.2 mm. The choice of such substrate type is not arbitrary but because of its biocompatibility and its high permittivity which can reduce the effective wavelength and thus downsize the antenna [12]. The radiating element presents a meandered configuration, which can successfully increase the antenna's electrical length despite decreasing its physical volume. This makes the antenna conveniently fit into lightweight configurations. A 50 Ω microstrip line feeds the antenna. To avoid the direct contact between the radiating element and the kidney the RO 3210 is also used as a superstrate layer.

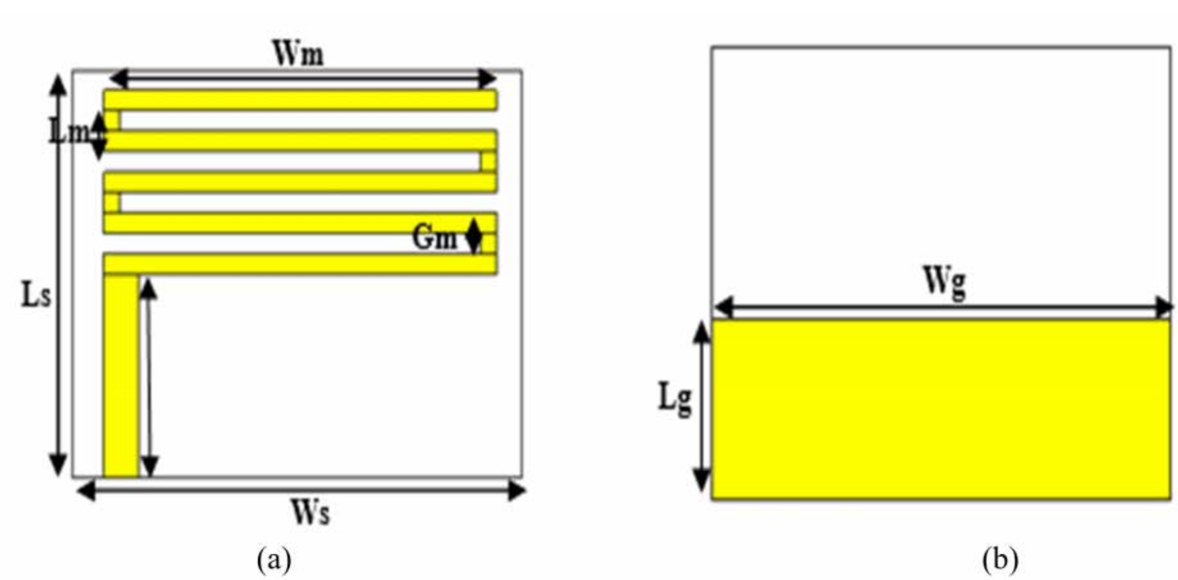

Fig. 1: Configuration of the proposed antenna: (a) Top view, (b) Bottom view The antenna's associated parameters are presented in Table 1.

Table 1: Dimensions of the proposed antenna

Parameter	Value (mm)
Ls	10
Ws	14
Wg	14
Lg	4
Lm	0.5
Wm	12.2
Gm	0.5

3 Design of kidney model

The proposed antenna is used to detect kidney cancer on its early stages as well as controlling the development of malignant tissue. In this respect, for an exact validation of the invasive antenna's performances, simulations have to be conducted in a numerical phantom model. In this regard, the antenna was placed inside a numerical kidney phantom block having a size of 30*24*12 mm^3. Firstly, the antenna as appeared in Fig. 2 is analyzed within kidney in its normal state.

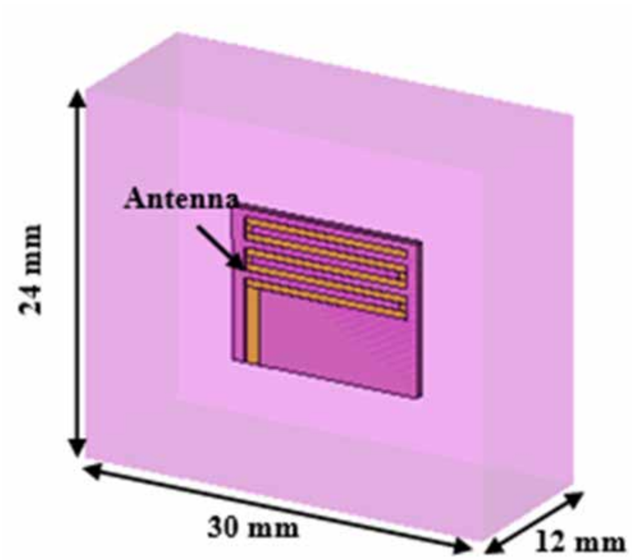

Fig. 2: Antenna configuration as placed in the kidney phantom block

According to Joines, W. T. et al. [10], both the dielectric properties mainly in terms of the relative permittivity and conductivity of malignant tissues are bigger than in normal tissues. Worth noting, in this respect, that the differences in the mentioned properties related to kidney tissues from normal to malignant are about 6%. Thus, the permittivity and conductivity related to the kidney are 70.34 and 1.16 (cancerous case) compared to 66.4 and 1.1 (normal case), respectively.

In fact, cancer is one of the most common diseases in the world, which invades the body. This disease spreads rapidly in the human body. In this respect, a study is made to detect the influence of malignant tissue on the antenna's frequency and hence controlling the development of malignant tissue in the kidney. This study as indicated in Fig. 3 englobes six steps. First, a 196 mm^3 of malignant tissue is used to cover one side of the proposed antenna. Second, a malignant tissue having a size of 265 mm^3 covers two sides of the antenna. Then, the malignant tissue with the size of 530 mm^3 is designed to cover the four walls of the antenna. Concerning the fourth step, the malignant tissue's volume increases and fills the top surface of the antenna. The latter is also analyzed when it is surrounded by a 5258 mm^3 of malignant tissue. In the final step, the antenna is entirely covered by 8076 mm^3 of malignant tissue.

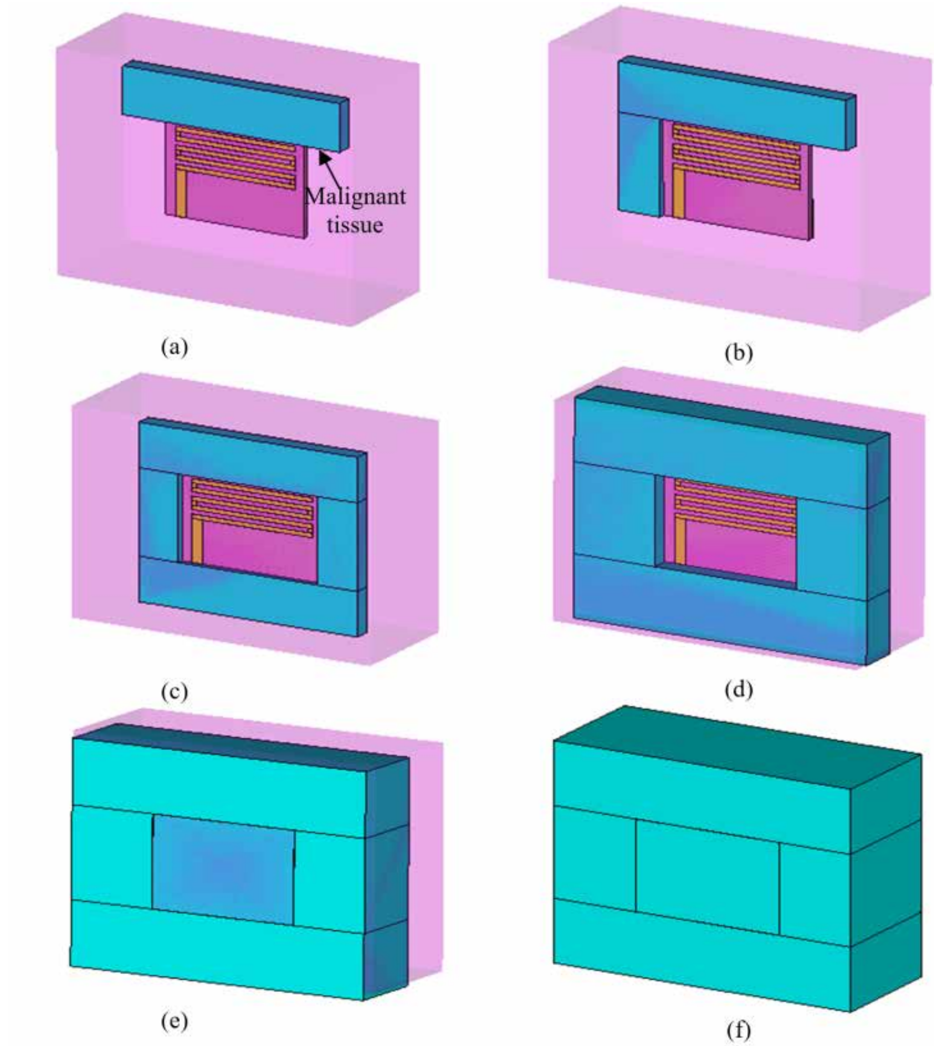

Fig. 3: The proposed antenna covered by different volume of malignant tissue: (a) 196 mm^3, (b) 265 mm^3, (c) 530 mm^3, (d) 2422 mm^3, (e) 5258 mm^3, (f) 8076 mm^3

4 Results and discussion

In this section, the simulated results are discussed to evaluate the effectiveness of the proposed design as well as demonstrating its capacity to detect the tumor.

4.1 The antenna's performances within a healthy kidney

The antenna is firstly optimized to be suitable for the medical application within the kidney. In this regard, the antenna's performances mainly in terms of the reflection coefficient, gain as well as Specific Absorption Rate (SAR) are discussed to demonstrate its robustness.

Fig. 4 shows the simulated reflection coefficient of the invasive antenna. As appeared in the figure, the antenna resonates at 403.2 MHz with -47.05 dB reflection coefficient.

Generally, implantable antennas present a very low gain. This is due to the high conductivity values of human tissues [3]. Fig. 5 portrayed the three-dimensional radiation pattern of the proposed antenna. The latter presents a maximum realized gain of -29.4 dB.

The implantable antenna's radiated power is absorbed by the kidney, which can lead to a critical problem concerning the patient safety. In this regard, the IEEE C95.1.1999 standard restricts the SAR average over 1-g of tissue to be below 1.6 W/Kg [9].

Fig. 6 presents the 1-g average SAR distribution when 1 W of power is delivered to the antenna.

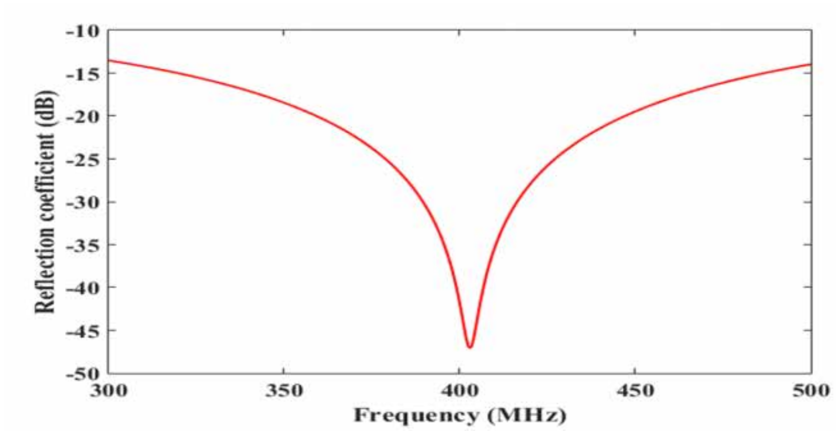

Fig. 4: Simulated reflection coefficient of the antenna

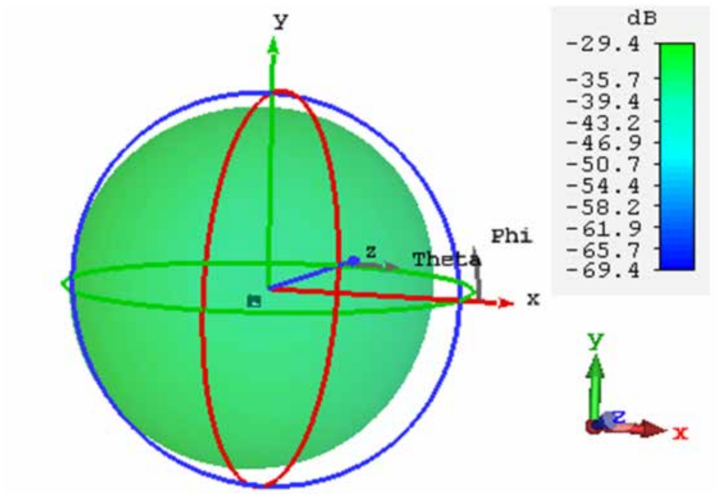

Fig. 5: The three-dimensional radiation pattern of the antenna

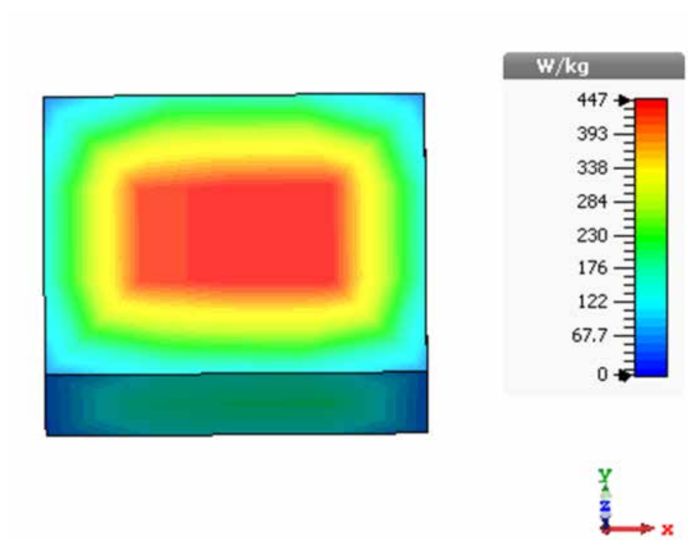

Fig. 6: Simulated 1 g average SAR distribution

As indicated in Fig. 6 the obtained SAR is equal to 447 W/Kg. To keep the patient safety and comply with the above-mentioned SAR restriction, the input power has to be reduced to less than 3.57 mW.

4.2 The effect of malignant tissue on the antenna's resonant frequency

The antenna is analyzed for the different volume of malignant tissue. The influence of the spread of malignant tissue on the antenna's resonant frequency is highlighted in Fig. 7.

Based on the reached results one could well note that the resonant frequency does not prove to be constant. Yet, the tumor generates a noticeable shift in the resonant frequency. The more volume the tumor has, the more shift occurs to the resonant frequency. This shift would help doctors to remove the tumor in its early stages and consequently, treat the patient before tumor spreads in the kidney.

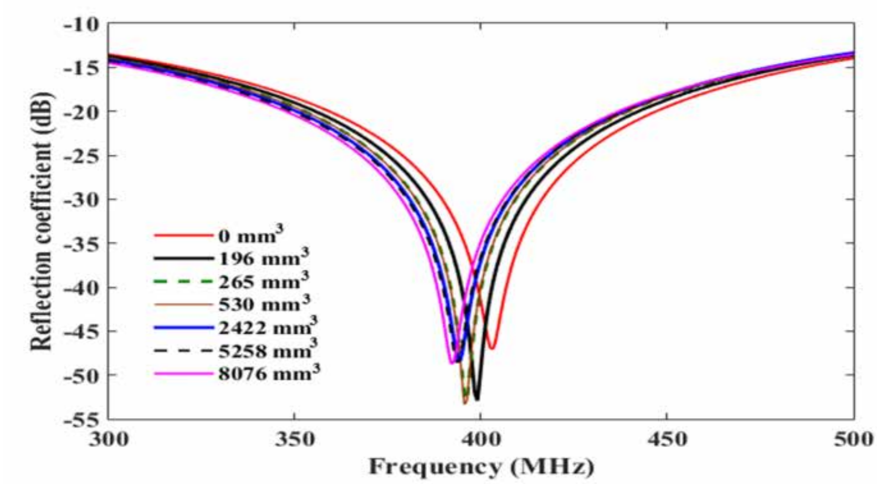

Fig. 7: Simulated reflection coefficient for the different volume of malignant tissues

The numerical values of frequencies obtained according to the development of tumor are presented in Table 2.

Table 2: Malignant tissues' volume and its associated frequency

Parameter	Value (mm)	
Volume (mm^3)	Frequency (MHz)	S11 (dB)
0	403.2	-47.05
196	399	-52.91
265	397.6	-52.84
530	395.5	-53.34
2422	394.1	-48.48
5258	393.3	-48.65
8076	392	-48.75

5 Conclusion

Antennas are very sensitive to their surroundings. This sensitivity can be used as a factor of detection of certain vital signs of human body. This paper focused on the design and analysis of a miniaturized monopole antenna for the detection and monitoring of cancerous tissues, operating at MICS band. The antenna is specially used to detect cancer kidney. The proposed antenna has a very small volume of 14 * 10 * 0.805 mm^3 and is very sensitive to vicinity.

Simulation results appear to indicate well that any change introduced in the kidney dielectric properties mainly in terms of permittivity and conductivity would certainly bring about a noticeable shift in the antenna's resonant frequency. As the volume of malignant tissue increase from 0 mm^3 to 8076 mm^3 the operation frequency shift from 403.2 MHz to 392 MHz. Thus, the antenna can be used as a tool for early detection of cancerous tissue and its monitoring during treatment of the patient under observation. The proposed antenna has the ability to provide information about in which stage is the tumor according to the frequency shift.

References

[1] A. Akbarpour, S. Chamaani. Dual-band electrically coupled loop antenna for implant applications. *Iet Microwaves Antennas & Propagation*, 2017, **11**(7): 1020–1023.

[2] E. Atashpanjeh, A. Pirhadi. Design of wideband monopole antenna loaded with small spiral for using in wireless capsule endoscopy systems. *Progress In Electromagnetics Research*, 2015, **59**: 71–78.

[3] N. Aziz, N. Mohamad, M. Abu, A. Othman. Design of ultra-wideband (uwb) implantable antenna for biomedical telemetry. 2006.

[4] A. Basir, A. Bouazizi, M. Zada, A. Iqbal, S. Ullah, U. Naeem. A dual-band implantable antenna with wide-band characteristics at mics and ism bands. *Microwave and Optical Technology Letters*, 2018, **60**(12): 2944–2949.

[5] A. Bouazizi, G. Zaibi, A. Basir, M. Samet, A. Kachouri. Remote monitoring of cardiac activity using a flexible loop antenna. *International Journal of RF and Microwave Computer-Aided Engineering*, 2019, **29**(4): e21585.

[6] T.-C. Chiang, Y.-S. Huang, R.-T. Chen, C.-S. Huang, R.-F. Chang. Tumor detection in automated breast ultrasound using 3-d cnn and prioritized candidate aggregation. *IEEE transactions on medical imaging*, 2018, **38**(1): 240–249.

[7] O. K. Hammouda, A. Allam. Diagnosis of oral cancers using implanted antennas. *Skin*, 2014, **1**: 38–007.

[8] S. C. Hwang, R. A. Abd-Alhameed, S. W. J. Chung, D. Zhou, H. Al-Ahmad, P. S. Excell. The design of a resistively loaded bowtie antenna for applications in breast cancer detection systems. *IEEE Transactions on Antennas & Propagation*, 2012, **60**(5): 2526–2530.

[9] IEEE Standards Coordinating Committee 28. IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0-3 KHz *IEEE Standard C95.1*, 1999

[10] W. T. Joines, Y. Zhang, C. Li, R. L. Jirtle. The measured electrical properties of normal and malignant human tissues from 50 to 900 mhz. *Medical Physics*, 1994, **21**(4): 547.

[11] R. A. Khan, A.-S. K. Pathan. The state-of-the-art wireless body area sensor networks: A survey. *International Journal of Distributed Sensor Networks*, 2018, **14**(4): 1550147718768994.

[12] R. K. Nehra, S. Rana, v. Sharma. Miniaturization of implantable antenna in ism band for biomedical applications. *Journal of Power Electronics and Devices*, 2018, **4**(3): 11–15.

[13] S. Raghavan, A. Kumar. Microstrip patch antenna for a retinal prosthesis and rf mems technology. *WSEAS Trans Commun*, 2009, **8**: 853–862.

[14] S. A. A. Shah, H. Yoo. Scalp-implantable antenna systems for intracranial pressure monitoring. *IEEE Transactions on Antennas and Propagation*, 2018, **66**(4): 2170–2173.

[15] M. A. Shokry, A. M. M. A. Allam. Uwb antenna for brain stroke and brain tumour detection. **in:** *International Conference on Microwave*, 2016.

[16] R. L. Siegel, K. D. Miller, A. Jemal. Cancer statistics, 2015. *CA: a cancer journal for clinicians*, 2015, **65**(1): 5–29.

[17] M. Garcia and A. Jemal. Global cancer facts & figures 2011. *Atlanta, GA: American Cancer Society*, 2011

[18] National Health Information Society. Oral cancer facts. *Office of the Assistant Secretary for Health, Office of the Secretary, U.S. Department of Health and Human Services, USA*