Using of ISM radio bands for wireless charging of medical implants

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***Abstract.* In this paper, research progress on wireless powering of implantable devices is discussed and summarized. An efficient method of powering of medical implants is a key component for receive progress in dramatic size reduction without traditional implant's limitation of a short battery life. Appeared in recent years publications reports possible ways of using of decimeter size radio waves (midfield powering) as a very efficient method versus near-field inductively coupling power transfer. But proposed frequencies in GHz range are unpractical due to existing regulations in national and international Radiofrequency spectrum regulations, making impossible or very hard following certifications. This article review possible using of GSM or ISM band frequency as a basic frequency for powering of medical implants. Review of possible application in development of commercial available modules for wireless powering was done.**

***Index Terms* – midfield wireless powering, implants, ISM.**

I. INTRODUCTION

The first implantable electrostimulators were first introduced into medical practice in the early 60s of the 20th century, when the first portable pacemaker with high reliability and durability was developed. Since then, the use of these devices in the therapy and diagnosis of various diseases has been growing steadily. A common feature of active implants is the use time limitation caused by capacity of the built-in battery, usually not more than 7-10 years.

In parallel with the development of wireless communications[13], the development of wireless power transfer technologies make it possible to develop the development of electronic devices to an entirely new level. The transition from a portable source of a non-rechargeable battery to receiving energy from an electric and / or magnetic field can significantly reduce the size of the devices themselves, improve quality, safety and ease of use.

II. REVIEW OF PUBLICATIONS AND REQUIREMENTS

The widely used industrial wireless charging standards, such as WPC / Qi (the principle of electromagnetic induction with a frequency of 100-205 kHz operation) cannot be used for charging implants because of the existing limitation the effective range (order of several mm).

The widely used RFID technology has no fundamental limitations at ranges of up to 1 m. At the same time, the transmission efficiency is highly dependent on the mutual axial orientation of the receiving and transmitting antennas. Experiments have shown that in order to obtain a sufficient charging current (10-15 mA), it is necessary to use a transmitter antenna of about 50 cm in size, while the power consumption of the transmitter, made according to the E-class amplifier scheme, reached about 30 W[14]. At the same time, the electromagnetic field strength can exceed the values recommended by SAR - 2.0 W / kg [4].

The authors of another study demonstrated efficient transmission of energy by magnetic resonance at frequencies of the RFID standard, achieving a good result using a 3-axis receiving antenna made by photolithography on silicon[6][10]. The disadvantage of this method is the complexity of manufacturing and the high cost of equipment, which is inaccessible to most developers.

A group of authors from Stanford University [7]conducted a study to find the most optimal frequencies for wireless powering of medical implants in the human body. Although radio waves and / or magnetic resonance with a frequency of several MHz are already widely used for wireless charging of electronics [13], the transition to a decimeter radio wave's range (order of GHz) allows reducing of the antenna's size by 10,000 times, thereby ensuring a high degree of integration of the implanted device. Fig. 1 shows the experimental data of the optimal frequencies, obtained by the authors for an electric power transmission (in this case the maximum obtained is at the frequency of 3 GHz).

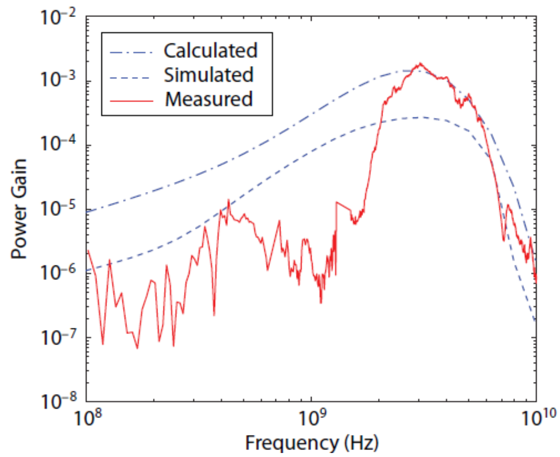

Fig. 1. Power gain vs frequency.

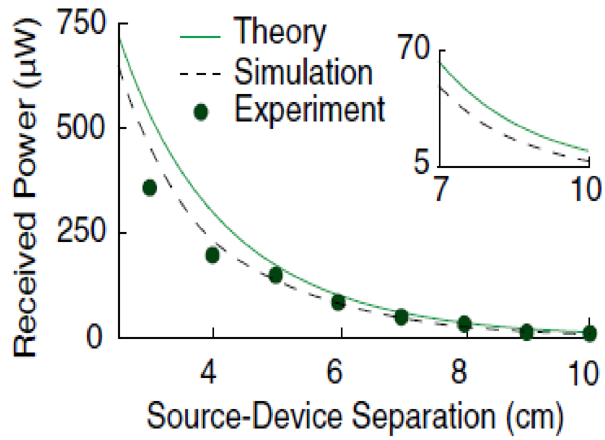

Fig.2. Received power vs distance

It the same time, the authors in a later work used the frequency of 1.6 GHz for the supply of implants of deep deposition - more than 50 mm (Fig. 3) [3]. It should be noted that the authors used a transmitter at 1.6 GHz with a output power of 500 mW, while the input power at the receiver side was, for example, about 90-200 µW at an implantation depth of 4 to 6 cm (Fig. 2).

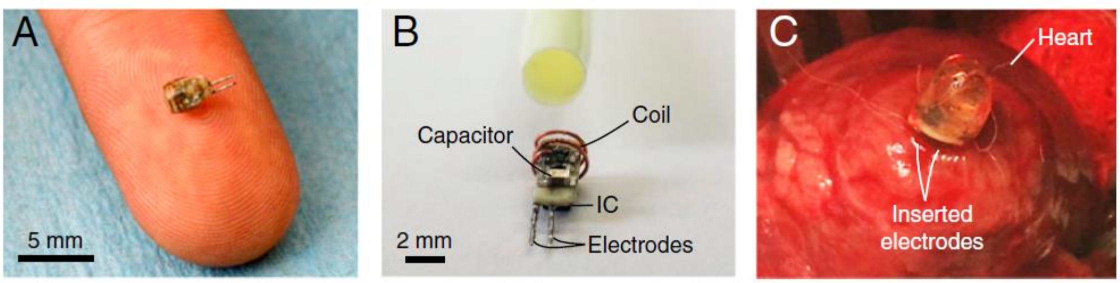

Fig. 3. Microimplant with wireless power and communication channel.

An important point in the development of any medical product is also compliance with the existing standards and regulations. Since in this case wireless charging is carried out through radio waves of the decimeter range, it is extremely important to observe the principle of inadmissibility of using busy frequencies, especially those used for satellite communications, air navigation or for special applications.

Existing national requirements are prescribed in the Radio Regulations of a country, based on the international standard ERC Recommendation 70-03 [2]. Standards and regulations provide for a clear separation of the radio frequency grid for a particular application, and also ration the maximum permissible power of the radio transmitter.

In accordance with the above standards, the **entire frequency range** from 1.4 GHz to 2.3 GHz is already used for many existing applications for aeronautical radio navigation, radio astronomy, satellite, meteorological, space research, etc.

At the same time, the maximum permissible power of an unidentified transmitter is not exceeds very small 10 or 20 mW. The same rule applies to frequencies in the **3.0-3.3 GHz range**, which are also used by radar services. Thus, the absence in this range of free frequencies with the allowed use of transmitters sufficient for power transmission makes the choice of frequency very, very important.

To solve this problem, the author undertook a broad search of existing wireless charge technologies based on electromagnetic waves of the decimeter range, especially in GSM range or ISM (industrial, scientific and medical) bands[1].

Appropriate technology is offered by the US company Powercast® Corporation (Pittsburgh, USA), which uses the radio wave energy of the GSM/ISM band (868-950 MHz). Powercast® offers ready solutions to the task of collecting ambient radio energy in the form of the RF Powerharvester™ Receiver development modules. The product range contains both ready-made miniature receiving modules with a current of up to 50 mA, and FCC certified transmitters with 1 and 3 W output power, with the function of automatic radiation blocking when living organisms are closer than 23 cm[12]. In addition to ready-made modules, Powercast offers developers to use the PCC110 and PCC210 discrete ICs to create their own drives, including those with different frequency bands. The main characteristics of the receiving modules are given in Table 1 [8][9]:

Table 1. Characteristics of receivers from Powercast.

Parameters	***Module type***	
	P1110B	***P2110B***
Frequency, Mhz	868…950	
U_{out}.,V	0…4,2	2,0…5,5
I_{out}. max., mA	50	
Input power, dBm	0…20	-12…10
Antenna type	50 Ohm	
Type of energy store	Li-ion, LiPo, Alc. accumulator, Supercapacitor	Super-capacitor
Dimensions, mm	15.9 x 10.9 x 2.3	15.9 x 13.5 x 2.3

The maximum working distance for wireless charging could be up to 12-14 meters depending on used receiver's antenna. But getting distance up to 1 meter or closer is enough for practical charging of implanted medical device.

Although listed above Powercast® products itself are not designed or intended for application in class III medical devices (like pacemakers or stimulators), they could be freely used for research applications, in order to quick lab engineering and debugging using completed modules. This could save a lot time for researchers, making possible fast and non-expensive concept prototyping.

Basing of the received data, developers could freely build custom RF power received basing of PCC110 RF chips, with followed certification according to rules and regulations, existing in area.

III APPLICATION EXAMPLE

In particular, within the framework of the project carried out by a group of authors, on the basis of the above mentioned modules, a functional concept device of an implanted electrostimulator of the lower esophageal sphincter was manufactured [11][14].

A small device measuring only 20x12x8mm demonstrated the possibility of wireless charging at a distance of up to 3.0 m (independent of orientation Rx and Tx parts), receiving the signal by a miniature ceramic antenna from a 1W power RF transmitter of GSM or ISM band (Fig. 4).

Fig.4 Wireless charged device with Bluetooth control.

The received energy was stored in a 0.1F supercapacitor, while the included miniature Bluetooth module (5x6mm) allowed wireless communication and control.

Basing on the Android 5.0 system with Bluetooth 4.0 (BLE low energy) technology, a mobile application for a smartphone was developed, used to control the device, obtaining device status data or additional sensors (for example, a temperature sensor). Tests confirmed possibility of wireless control of the device at 10 m.

Charging current depending of distance was 1-30 mA.

Device has 3 external current mode stimulation modes.

IV. CONCLUSION

Thus, in order to fulfill the requirements for the wireless power transfer to medical implants, using of GSM or ISM band a frequency is more preferable, that using 1.6Ghz or 3GHz ranges. For example, it could be 868 Mhz for EU zone, 915 MHz for US/Asia, 920 MHz for Japan etc. For most of these frequencies is possible to use transmitters up to 2W or 4W [2].

Moreover, using of GSM frequency allows not only to carry out wireless charging by a special charger, but also to receive additional energy from the electric field of the GSM range that occurs when using mobile phones. Currently, the data show that the London field strength of the GSM900 / GSM1800 standard reaches 1.93 - 6.39 μW / cm2, which is basically enough for the operation of wireless receivers and can only require a small modification [5].

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