Body Absorbed Radiation and Design Issues for Wearable Antennas and Sensors

Stavros Koulouridis

Electrotechnics Laboratory, Electrical and Computer Engineering Department
University of Patras, Rio-Patras, Greece
koulouridis@ece.upatras.gr

Abstract. Wearable antennas and sensors are placed inside the body, on the body or in its very close proximity as part of wireless bi-directional communication networks supporting mainly medical applications. Human bodies, having high dielectric permittivity and losses, can greatly affect elements radiation resulting to unwanted power absorption on one hand (raising safety limits questions) and affecting antennas and sensors performance greatly. To deal with these problems, several configurations need to be investigated including optimum radiating element position, use of multiple elements, antennas' special designs. In this work we evaluate several proposed scenarios found in literature to an effort to draw some basic conclusions.

Keywords: flexible antennas, planar antennas, on-body sensors, implanted devices, power absorption, antenna efficiency.

1 Introduction

Implanted and on body radiating devices are being continuously introduced in the late years. Wireless Body Area Networks (WBAN) and Body Area Networks (BAN) [1], biomedical implants [2], "smart" clothes for firefighters [3], Vests loaded with GPS systems [4], UHF applications [5], place several design needs for integrated sensors, conformal antennas, miniaturized designs, low power devices. Various BAN using a variety of communication technologies (MICS, Wi-Fi, GPRS, UMTS) are considered for the several medical application demands in order to obtain the health picture of a patient. Antennas proposed are usually directional microstrip patches [1], [3], [4] but sometimes (depending on the frequency) omnidirectional solutions are being implemented. Further, common configurations for wearable antennas employ textile materials that replace the classical substrates. When implantable designs are pursued, radiating devices are encapsulated in dielectrics for matching purposes but also for avoiding the direct contact of tissues with the metal [2].

Three basic communication scenarios can be identified for the medical applications. (a) First, we consider cases where on body sensors or wearable (integrated in clothes, helmets, etc) antennas will propagate towards open space and will need to transfer information to surrounding environment or to another antenna on the same body; (b) second comes the situation where an antenna or a sensor are

K.S. Nikita et al. (Eds.): MobiHealth 2011, LNICST 83, pp. 399–402, 2012.

placed inside the body and need to transmit information outside the body. Usually the device outside the body is in direct contact with the skin or integrated in a cloth as part of a t-shirt for example; (c) In third case the communication is taking place inside the body. The small sensor or antenna is planted inside deeper in the body and needs to transmit information to a receiver inside the body, usually placed just under the skin.

In any case, antennas need to operate at the minimum power and certainly under safety limits since absorbed power raise safety and health issues for the antenna carrier and/or those around. Energy losses can degrade antenna or sensor efficiency and can drain battery power. Consequently, radiation links or in general communication capabilities are restricted in conjunction with the radiation scenario they fall under (see above). Further, human body, being a large lossy and complex vessel can make things even harder. Optimum designs should be pursued that take into account all these issues posing contradictory goals.

In this work we will examine several exposure scenarios employed in implanted and wearable antennas field. The effort will be devoted to identifying possible exposure patterns. Some basic conclusions will be drawn for the effect of body on the antenna operation and the result of "smart" loading of the antennas substrate, initially intended to decrease back radiation and mutual coupling of wearable antennas.

2 Exposure Scenarios and Design Issues

In the first case (radiator and receiver placed outside the body) the goal is to decrease the energy lost inside the body or increase the antenna efficiency. Depending on the receiver and radiator position, antenna's polarization needs usually be taken into account. Also, antenna's radiation pattern which can be affected by the body and surrounding objects draws specific limitations on antenna type employed. Hence, in this scenario the antenna might need to have a relatively omnidirectional pattern or a directive pattern if radiator and receiver are at fixed positions (placed for example on the same body). Sometimes more than one antenna collaborate to achieve coverage of the surrounding area. It is very interesting also, that as noted in [4], reported wearable antennas have measured gains close to -10 dBi –the radiating elements are of low efficiency.

Unwanted exposure from wearable antennas can also occur from secondary sources. Multiple antennas on the same body for example could lead to increased absorption, or people in the vicinity of the antenna could significantly alter antenna far field radiation behavior.

Except for the few cases where omnidirectional antennas are proposed, wearable antennas usually consist of patches that require a ground plane. Ground planes supposedly decrease back radiation. However, inefficiency of wearable antennas shows that great fraction of antenna forward radiation returns to the body. Further, commonly used textile loading for flexibility and lightness adds to their inefficiency. Therefore till now wearable antennas capabilities are restricted and a lot remain to be done.

In the second scenario a link is sought between the external antenna and the internal microwave device. Problems can arise from the great difference between the dielectric properties of air and human body. Also unwanted surface waves can occur. Apart from safety issues and possible intervention from other sensors or antennas, power is lost and signal integrity might also worsen. Of importance is also the relative position of the two elements since it might not be fixed, because of different body properies or small movements of the wearable sensor for example.

Last scenario covers the connection between two elements inside the body. One device (sensor for example) performs the measurement, tracks physiology parameters, etc and the other device (antenna for instance) receives the information, stores it or sends it to a receiver outside the body (second scenario). Again the relative position between the two can have many uncertainties. If it is a “smart” pill for instance, obviously there many possible places inside the body. Thus the “receiver” will have to occupy an optimum position and have a relatively broadband pattern in order to cover multiple possibilities.

All three cases will be examined in order to shed more light on the various issues that arise.

3 Operational Frequency and Employed Models

Operation frequency can certainly play a role on the design followed in order to have the best result. Medical Implant Communication Service for example occupies the 402-405MHz frequency band. In these frequencies electromagnetic waves can certainly have increased penetration (as compared to higher frequencies). Yet, electromagnetic devices can have relatively large sizes. To minimize them high dielectrics can be employed which will lead to higher sensitivity to design uncertainties. On the other hand UMTS, Wi-Fi, GPRS, etc services that operate at higher frequencies and can be used for BAN networks for example can certainly allow for more stable designs but will demonstrate lower penetration and this can be a problem if we need to cover second scenario as described above. Hence, frequencies employed need to be taken into account when cases are examined and conclusions are drawn.

Second, the unique body characteristics that each human has can increase uncertainties and design failures especially for the sensitive, to uncertainties, designs. Thus it is necessary that in the design process several models will be employed. In the current work, models from Virtual Population [8] will be used in order to include various body characteristics in the studied problems. SEMCAD X from SPEAG [9] will be used to analyze all the examined cases.

Acknowledgments. The author would like to thank Schmid & Partner Engineering, AG, for providing the SEMCAD software.

References

1. Declercq, F., Rogier, H.: Active Integrated Wearable Textile Antenna With Optimized Noise Characteristics. IEEE T. Antennas Propagation 57, 3050–3054 (2009)
2. Mizuno, H., Takahashi, M., Saito, K., Haga, N., Ito, K.: Design of a Helical Folded Dipole Antenna for Biomedical Implants. In: Proc. 5th European Conference on Antennas and Propagation, Eucap, pp. 3640–3643 (2011)

3. Hertleer, C., Rogier, H., Vallozzi, L., Langenhove, L.V.: A Textile Antenna for Off-Body Communication Integrated Into Protective Clothing for Firefighters. IEEE T. Antennas Propagation 57, 919–925 (2009)
4. Vallozzi, L., Vandendriessche, W., Hertleer, C., Scarpello, M.L.: Wearable textile GPS antenna for integration in protective garments. In: 4th European Conference on Antennas and Propagation, EuCAP (2010)
5. Psychoudakis, D., Volakis, J.L.: Conformal Asymmetric Meandered Flare (AMF) Antenna for Body-Worn Applications. IEEE Antennas Wireless Prop. Letters 8, 931–934 (2009)
6. Gallego-Gallego, I., Quevedo-Terue, O., Inclan-Sanchez, L., Rajo-Iglesias, E., Garcıa-Vidal, F.J.: On the Use of Soft Surfaces to Reduce Back Radiation in Textile Microstrip Patch Antennas. In: 5th European Conference on Antennas and Propagation, EuCAP (2011)
7. Salonen, P., Rahmat-Samii, Y., Kivikoski, M.: Wearable antennas in the vicinity of human body. In: Proc. IEEE Antennas Propag. Soc. Int. Symp., vol. 1, pp. 467–470 (2004)
8. Christ, A., et al.: The Virtual Family – development of surface-based anatomical models of two adults and two children for dosimetric simulations. Physics in Medicine and Biology 55(2), N23–N38 (2010)
9. Schmid & Partner Engineering AG, http://www.speag.com/speag/