Optical Communications Through Tissue

Maria Katsafadou, Melanie Zimmermann, Salman Mahmood,
Sebastian Schostek, Mario E. Giardini

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Maria Katsafadou, Melanie Zimmermann, Salman Mahmood, Sebastian Schostek, and Mario E. Giardini, *Member, IEEE-EMBS**

***Abstract*— In capsule endoscopy, the wireless data transmission technologies currently employed suffer from high path loss, heavily impacting on the capsule power budget. Optical data transmission shows, in principle, scope to overcome this limitation, at least in selected tissues. Bench testing technologies, and Monte Carlo simulations on the impact of light scattering on carrier frequency, will be presented and discussed.**

I. INTRODUCTION

Wireless capsule endoscopy is a mainstay technique for the diagnostics of the small intestine. A wireless link relays images from the capsule to outside the body. Frequencies on the order of 400 MHz minimize the path loss [1]. Yet, the link accounts for at least 50% of the power budget of the capsule.

Infrared light propagates through human tissue [2]. In principle, this allows using light for data transmission. Light attenuation is intrinsically different from radiofrequency attenuation. In tissues with low optical absorption coefficient (e.g. fat, cartilage) the losses [3] are significantly lower than for radiofrequency.

However, due to the highly diffusive optical properties of tissue, the maximum useable carrier frequency decreases with increasing tissue thickness, dropping to 100-200 MHz for a few centimeters of propagation [4]. To date, the limit performance and a strategy for the design of an optical data link for a capsule remain unclear.

II. INVESTIGATING OPTICAL COMMUNICATIONS THROUGH TISSUE

Phantoms are the mainstay to explore the behavior of light propagation through tissue. In our laboratory, a liquid tissue phantom in a reconfigurable cell (Fig. 1) is used to accommodate different scattering and absorption properties.

By using infrared LEDs emitting on the order of 1 mW, we currently transmit at 10 Mbit/s through the phantom and, in vivo, through a 1.5 cm path traversing muscle, bone and skin.

Through thicker tissue, as light enters into the phantom, it diffuses and, in order to increase signal strength, we can aim to collect light over a large surface on the exit face. By collecting light both using a matrix of smaller photodetectors, or by using a large-surface detector (Fig. 2a), the light reaches the detector through multiple paths of significantly different length and, in any case, much longer than the geometrical distance between source and detection point on the detector surface (Fig. 2b).

Fig. 1: Liquid tissue phantom: an acrylic container through which a scattering liquid (milk, Intralipid) mixed with a dye is recirculated. A diffusive window allows coupling of light into the phantom

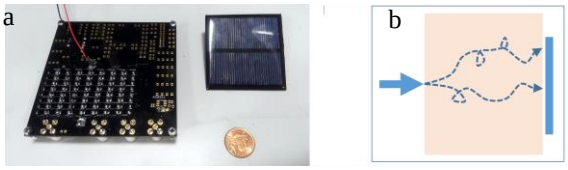

Fig. 2: a) A matrix array of photodiodes and a large-surface detector measuring approximately 5 x 5 cm and b) Multipath effect on light entering and exiting a phantom onto a large detector.

No analytical theory is available to compute the impact of multipath effects on large-surface detection. Monte Carlo simulations are therefore in progress to evaluate limitations to carrier frequency, and will be presented and discussed alongside potential impacts on capsule design.

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M. E. Giardini and M. Katsafadou are with the Department of Biomedical Engineering, University of Strathclyde, Glasgow G1 1QE, UK (M. E. Giardini corresponding author - phone: +44 141 5483042; e-mail: mario.giardini@strath.ac.uk)

M. Zimmermann, S. Mahmood and S. Schostek are with Ovesco Endoscopy AG, Germany.