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Antennas Reconfigured by Living Cells: AntennAlive

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***Abstract*—Reconfiguring the pattern or operating frequency of antennas/resonators is an established field of research. However, until now, reconfiguration using living cells (bacterial or mammalian) has never been considered. In this study, a bio-hybrid implant antenna reconfigured by engineered bacteria or muscle tissue and a pair of on-body reader antennas, that monitors the bio-hybrid device (AntennAlive), is proposed. AntennAlive will enable gateways between living cells that communicate at the nanoscale and the electronic devices that operate at the human scale. It will be used to transform signals received from the living cells through Molecular Nano Communication Networks (MNCN) to Body Area Networks (BAN) that will be used to transfer information to machines and/or humans.**

I. Introduction

With the development of nanotechnology, biology-inspired communication has gained more attention for health applications. Networks of nanomachines undertaking tasks such as sensing, monitoring or, delivering are going to replace the conventional medical techniques in the future [1], [2]. A network of these devices, called Nano-Communication Networks, would be able to perform complex tasks such as continuous health monitoring at the molecular level within the human body. On the other hand, BAN, at the macro-scale have demonstrated high potential in the communication of wearable and implant devices, using electromagnetic waves. However, there is an unclosed gap between these two networks, where the information gathered at the nano or micro-scale is made accessible to the macro-scale BAN and its extensions [3]. In this context, besides molecular communication, which is the most promising paradigm of the nano era, various communication tools such as acoustic communication, nano-mechanical communication, and electromagnetic communication are considered [4].

To link this gap between these two networks, a bio-hybrid device consisting of an implant antenna that is reconfigured by engineered living cells, is used. These cells are the interface of MNCN while the implant antenna is the interface of BAN. When a nano-machine of the MNCN sends a message, the engineered living cells will receive the messenger molecules and respond. This will change the resonant frequency of the implant antenna. In the meantime, an on-body device, part of the BAN, will be sending electromagnetic waves into the body towards the implant and interrogating the reflected signal to track changes in the resonant frequency of the implant antenna. As the reconfiguration takes place, its effect on the transmission coefficient between the reader antennas will be used for tracking.

AntennAlive is a ground-breaking proposition that will initiate a whole new area of research where antenna design meets synthetic biology. Advancements in this area will promote MNCN and the real-time monitoring of events within the body in general.

II. Reconfiguration Using Bacteria

One way to create a bridge between MNCN and BAN is using engineered bacteria. Within this scope, the bio-hybrid device we propose consists of an implant antenna, which inter-

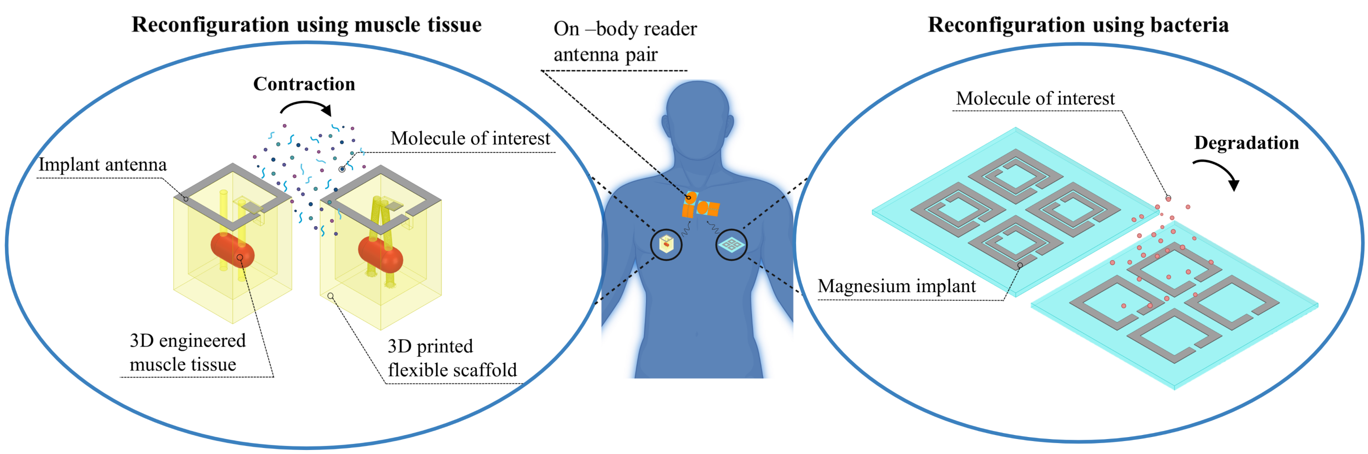

Fig. 1: Demonstration of the AntennAlive concept: reconfiguration using muscle tissue (left) and bacteria (right).

faces with the BAN, a biofilm of engineered bacteria grown on the implant antenna surface, which interfaces with the MNCN as seen in Fig. 1. Here, the engineered bacteria are specifically chosen as Escherichia coli (E. coli), which has a wide usage area in synthetic biology because of its ease of reproduction and manipulation [5]. Also, the engineered E.coli bacteria is a member of Shewanella genera, which has the capability of reducing solid metal oxides [6]. Thus, these bacteria are able to control the degradation rate by donating electrons to the acceptors [7].

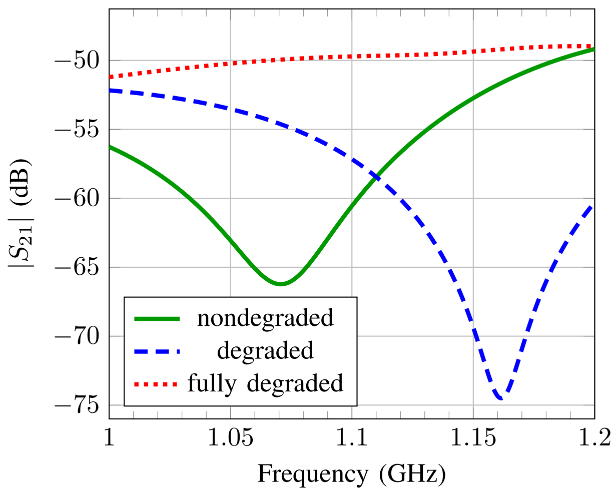

Fig. 2: The transmission coefficient between the reader antennas for reconfiguration using bacteria (1^{st} approach): the change for different stages of degradation can be seen.

The sensing methodology depends on the degradation of the implant antenna, which is manufactured with magnesium. The in-body sensing mechanism is activated when the concentration of the molecule of interest increases in the medium and the engineered bacteria are triggered. Accordingly, the degradation speed of the implant antenna increases, that can be wirelessly tracked by the on-body reader antennas as seen Fig. 2. Thus, the molecular signal is translated into an electromagnetic signal.

III. Reconfiguration Using Muscle Tissue

In the second approach, the engineered muscle tissue is utilized to create a bridge between MNCN and BAN. Engineered muscle tissue contracts in the presence of the molecule of interest [8] which is used to reconfigure the implant antenna in the proposed work. Structurally, the bio-hybrid device is composed of muscle tissue, a 3D-printed flexible scaffold, and an implant antenna. Mechanistically, muscle tissue, which is engineered to respond to particular stimulants, contracts in the presence of the molecule of interest and deforms the scaffold it is attached as seen in Fig. 1. This deformation results in a change in the resonance behavior of the implant antenna. This change is tracked with a pair of on-body reader antennas Fig. 3. Thus, the bio-hybrid device links the MNCN to BAN.

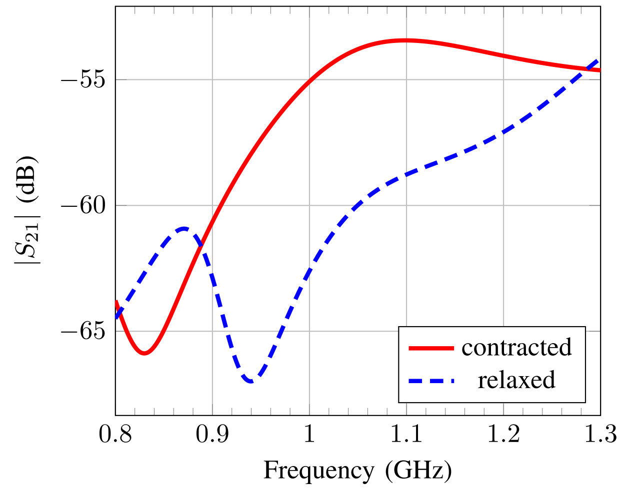

Fig. 3: The transmission coefficient between the reader antennas for reconfiguration using muscle tissue (2^{nd} approach): the change as the muscle contracts can be seen.

IV. Conclusion

AntennAlive holds potential for developing bio-hybrid devices capable of real-time monitoring of any molecular target and wirelessly communicating it to remote readers. These bio-hybrid devices are utilized as bridges between the MNCN and BAN in the scope of this paper. A brief explanation of how is provided along with some initial simulations.

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