V. SUMMARY

In this paper, we present a simulation method and results that utilizes accurate electromagnetic field simulations, using a software based test bench, to study the maximum allowable transmitted power levels from *in vivo* devices to achieve a required bit error rates (BER) at the *ex vivo* node (receiver) while maintaining the specific absorption rate (SAR) under a required threshold.

Using the simulation test bench, we simulated a complete 802.11g OFDM transceiver using the field simulations obtained from HFSS simulation with the ANSYS human body model from which we found the maximum allowable local SAR and the path loss as a function external receiver antenna location. The threshold power derived from these SAR levels was then used in the system simulation to calculate the corresponding BER as a function of external antenna location for data rates of 9, 18, and 36 Mbps.

From the preliminary data found in this study, it is evident that there are limitations when transmitting at high frequencies from *in vivo* devices to *ex vivo* transceivers while still achieving reliable data transmission, since the maximum transmit power is restricted by SAR safety guidelines. Even when operating under very low noise conditions with moderate BER requirements (10^{-3}), reliable data transmission to an external receiver can only be achieved when located very close to the body. But for cases when noise levels increase or the BER becomes more stringent, a relay network or the use of multiple receive antennas, such as in a SIMO system, will be become essential to achieve high data rates.

We also observed from the simulations that the maximum SAR levels occur at points closest to the transmit antenna from which we can conclude that by placing the transmitter further from organs, the power levels could possibly be increased to obtain higher signal levels at the external receiver. In this example, the transmitter was located very close to the small intestine and the spine. Therefore higher BER should be achievable with proper placement of the *in vivo* transmitter (furthest possible distance from organs and tissues).

The test bench can be used to further optimize the system design (e.g. using asymmetrical OFDM, MIMO transceivers, etc.) as well as the antenna architectures and location to meet BER requirements while always staying within the radiation safety guidelines.

ACKNOWLEDGMENT

This research was supported in part by the Florida 21st Century Scholar program, NSF Grant IIP-1217306, the Florida High Tech Corridor Matching Grants Research Program and Jabil Circuits Inc.

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