Human-Structure and Human-Structure-Human Interaction in Electro-Quasistatic Regime

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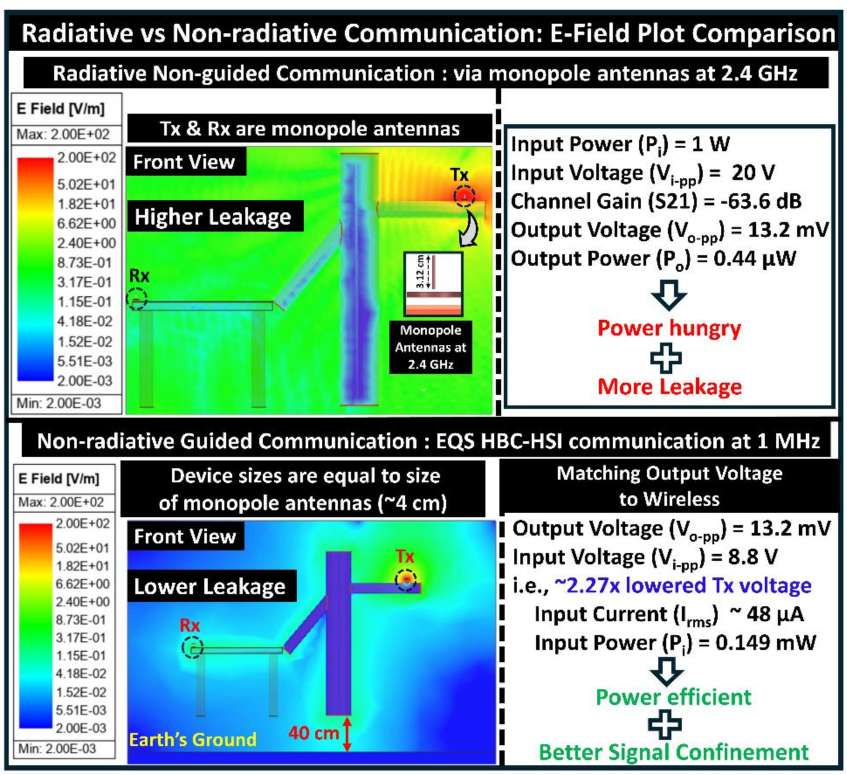
Supplementary Document:

Supplementary Discussion 1: Comparison with traditional wireless communication:

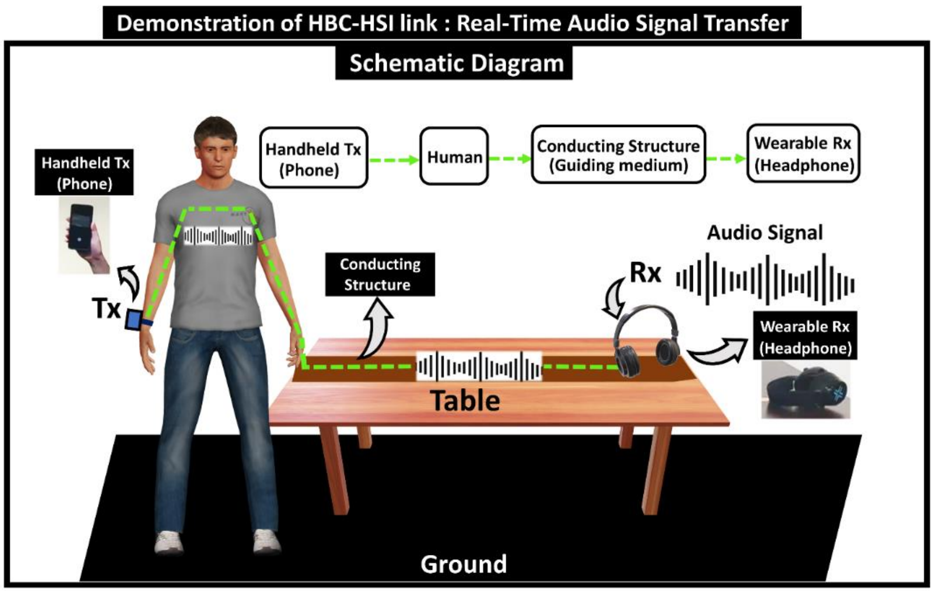
The comparative analysis of the E-field plots of radiative non-guided wireless communication like Bluetooth with the proposed non-radiative guided wireline-like communication is presented in Supplementary Figure 1. For an iso-device dimension (i.e., when the size of the communicating devices (transmitter and receiver)) is comparable to the size of monopole antennas (~4 cm), designed for 2.4 GHz) for iso-voltage reception, the transmit voltage in radiative non-guided wireless communication is higher (~2.27x) than EQS body coupled communication. Besides the lower Tx-voltage to achieve an iso-received voltage, the lower operating current of EQS HBC-HSI link makes it power-efficient, and the better signal confinement makes it more secure over traditional wireless communication.



Supplementary Figure 1: Comparison of Electric field leakage for a wireless monopole antenna transmitter-receiver pair at 2.4 GHz and the proposed HBC-HSI communication link in Electro-Quasistatics. The EQS HBC-HSI link shows better confinement of electric field. ~2.27x lower transmit voltage is required when received voltage is matched to the wireless case. Non-radiative guided communication makes HBC-HSI link power-efficient.

Supplementary Discussion 2: Audio Demonstration via EQS Human Structure Interaction:

This document presents the test setup of an application of the proposed capacitive-coupling-based EQS HBC-HSI communication link in a practical scenario while demonstrating the audio signal streaming from a handheld transmitter (i.e., smartphone) via the human body and a conducting structure to an off-body receiver (i.e., wearable headset), placed on the conducting structure. The schematic for the demonstration setup is illustrated below in Supplementary Figure 2, and the link to the demonstration is provided [2].



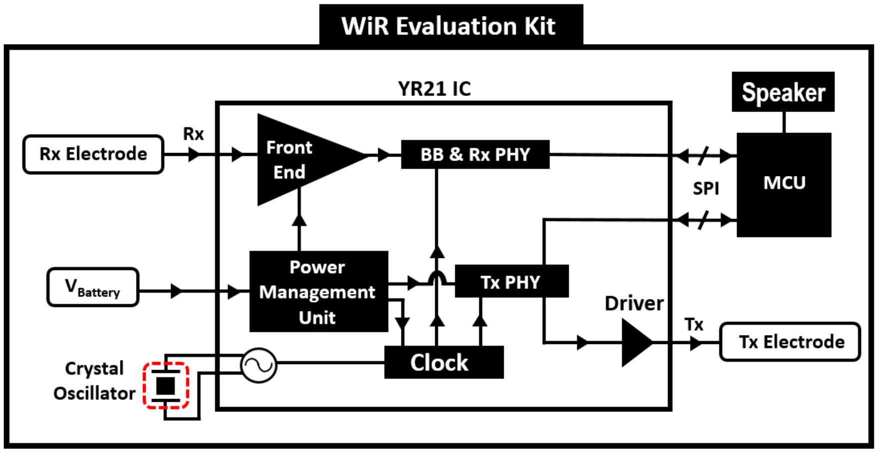
Supplementary Figure 2: The impact of HBC-HSI link in EQS in practical scenario: Demonstration of real-time audio signal transfer via Human Body Communication and the proposed Human-Structure Interaction: Schematic Diagram, representing signal flow from a wearable transmitter through the human body and CS to an off-body receiver (wearable headset), placed on the CS.

Demonstration Setup:

A Wi-R Evaluation Board kit by Ixana [1] is used as a transceiver for demonstrating audio streaming over an on-body-to-off-body link. Utilizing capacitive EQS-HBC while being connected to a smartphone to get powered up and programmed, this transceiver module transmits data through the human body. This communication module, configured to transmit at 18.75 MHz with a peak-to-peak voltage level of 2.5 V, sends 64-bit packets of PRBS data while supporting a peak data rate of 1.44 Mbps. While configured as a receiver node, this module is incorporated in a wearable headset. The low bit-error rate (BER < 10^{-3}) ensures reliable audio transmission.

Description of the Communication Module:

A conceptual system-level block diagram of the employed transceiver module, WiR Evaluation kit by Ixana [1], is presented in Supplementary Figure 3. Enabling reliable digital communication with a bit-error rate (BER < 10^{-3}) and an adequate data rate to support audio streaming over an on-body-to-off-body communication link (through the human body and a guiding conducting structure), this kit is configured to function as a transmitter while being used with a smartphone and as a receiver, while being used in a wearable headset. The working principle of this transceiver module can be briefly summarized as follows: this evaluation kit transmits an On-Off-Keying (OOK) signal at a data rate of 1.44 Mbps. The physical layer block of the transmitter (Tx PHY) transmits the OOK-modulated signal centered at 18.75 MHz. The received signal, picked up at the receiver electrode (Rx), gets amplified through the Front End (FE) and is sent to the Baseband and Rx PHY (BB & Rx PHY). The received signal gets demodulated into its baseband component in the BB & Rx PHY block to retrieve the communicated signal. The necessary clock signal (18.75 MHz) from the "CLK" block is provided to the "Tx PHY" and "Rx PHY" block for their modulation and demodulation operations. The adequate power supply for the optimum functionality of the individual blocks is maintained by the power management unit (PMU).



Supplementary Figure 3: Schematic diagram of the WiR evaluation kit used for demonstrating EQS-HBC-HSI enabled audio streaming application over an on-to-off-body guided communication link. The evaluation kit is configured as a transmitter when used with a smartphone and is configured as a receiver when used in a wearable headset.

The microcontroller unit (MCU) ensures optimal performance of the transceiver IC YR21 by communicating with it using SPI protocol. The speaker of the wearable headset, connected as a peripheral device, acts as an indicator of successful audio streaming.

Supplementary References:

1. Ixana: Wi-R Evaluation Board. https://ixana.ai/products.html

2. Demonstration of Audio Streaming Via EQS Human Structure Interaction. https://github.com/SparcLab/HSI-AudioDemo