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Organic Communication in Plants: A Feasibility Analysis of Magnetic Coupling

Aaron Roopnarine, Sean Rocke, Megan Mahadeo and Jeevan Persad
Department of Electrical and Computer Engineering, The University of the West Indies, aaron.roopnarine@uwi.edu

GOAL OF THE STUDY

This work investigates the feasibility of magnetic field-based organic communication channel (mOCC) communication in vegetation by formulating the communication fabric for it. OCCs use organic matter as a low-power, secure medium for smart farming and healthcare applications. Unlike the well-studied electric field OCCs (eOCCs), vegetation-based mOCCs are largely unexplored. Magnetic coupling offers greater resilience to environmental variations, making it a promising alternative. The study develops empirical channel models for *Artocarpus camansi* (breadnut), *Citrus sinensis* (orange), and *Saccharum officinarum* (sugarcane) (for the 1–100 MHz band), and evaluates IEEE 802.15.6 PHY compatibility through PHY construction and error analysis.

METHODOLOGY OF THE INVESTIGATION

mOCCs employ magneto-quasistatic fields for inductive coupling, governed by Faraday's law. The equivalent circuit, shown in Fig. 1(b), models the Tx/Rx coils as series RL circuits, $Z_{Tx} = R_0 + j\omega L_0$, $Z_{Rx} = R_1 + j\omega L_1$, with mutual inductance, $M = \sqrt{kL_0L_1}$ $(0 \leq k \leq 1)$. The transfer function is $H(\omega) = \frac{j\omega M R_1}{R_0R_1 + j\omega(L_1R_0 + L_0R_1) + \omega^2(M^2 - L_0L_1)}$.

Empirical Path Loss Model Derivation:

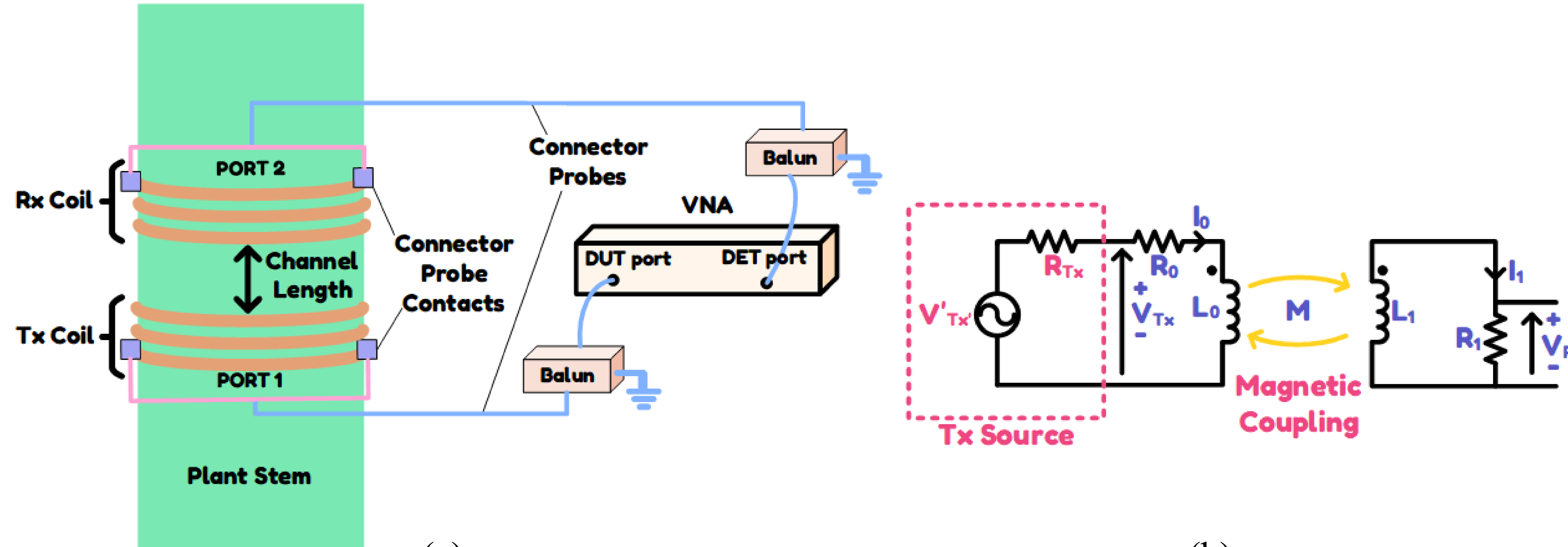
50-turn Litz-wire coils were wound on plant stems (*Artocarpus camansi*, *Citrus sinensis*, *Saccharum officinarum*) with 1 cm initial channel length spacing. Measurements were taken using an Anritsu MS46122B VNA at 0 dBm over 1–100 MHz, with baluns to decouple grounds as shown in Fig. 1(a). Path loss was computed as: $S_{21} = 20\log_{10}(V_{R_x}/V_{Tx})$. The channel length was then varied and the process repeated.

PHY Evaluation:

The IEEE 802.15.6 standard was adapted for mOCC communication using Frequency Selective Digital Transmission (FSDT) within the 18.375–23.625 MHz band. PHY performance was evaluated via Monte Carlo simulations in MATLAB, where random bit streams were modulated, passed through empirical mOCC channel models under varying noise levels, demodulated, and compared to estimate bit error rate (BER) versus signal-to-noise ratio (SNR).

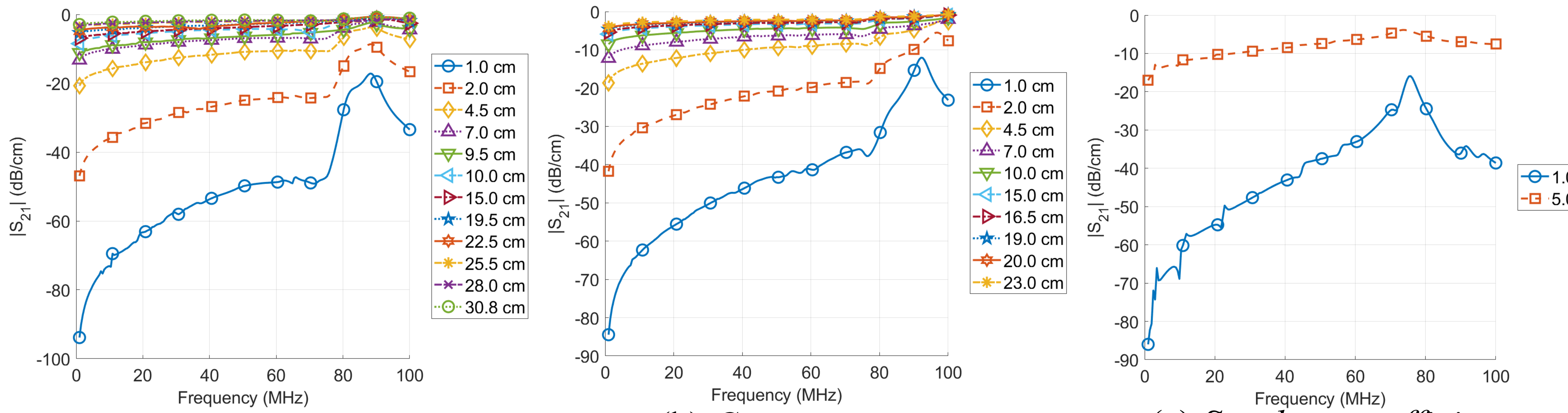
RESULTS AND ANALYSIS

Path loss increased with frequency but was nearly flat between 18–80 MHz, creating a stable flat-fading region that aligns with the IEEE 802.15.6 HBC band, confirming its suitability for mOCCs as shown in Fig. 2.
Error analysis showed low BER across all plant species, confirming feasible voice and video communication within the 18–80 MHz band as shown in Fig. 2.



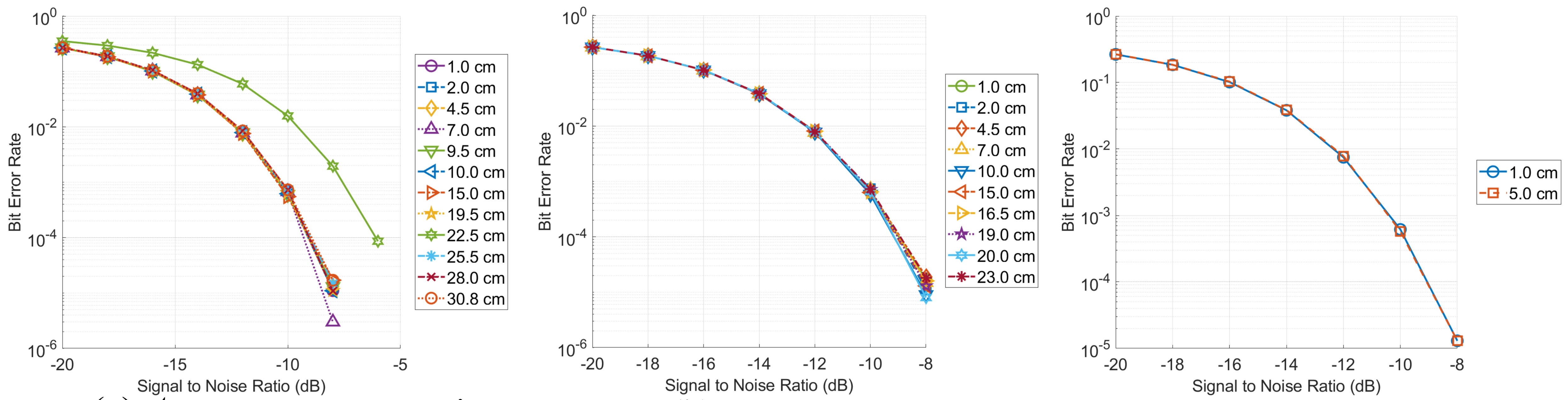
(a) (b)

Fig. 1. (a) Measurement set-up to measure path loss empirically (b) Equivalent circuit model for mOCC



(a) *Artocarpus camansi* (b) *Citrus sinensis* (c) *Saccharum officinarum*

Fig. 2. Pathloss over frequency for different distances for the mOCCs



(a) *Artocarpus camansi* (b) *Citrus sinensis* (c) *Saccharum officinarum*

Fig. 3. The error performance over channel distance for the mOCCs

Citrus sinensis demonstrated the most stable performance, followed by *Saccharum officinarum* and *Artocarpus camansi*. The consistent results indicate uniform magnetic permeability across vegetation, enabling stable coupling.

CONCLUSIONS

Empirical results confirm vegetation-based mOCCs enable reliable data transmission. The 18–80 MHz band exhibits a flat response suitable for IEEE 802.15.6 PHY, with low BER across plant species, validating feasibility for voice and video communication. This establishes a path toward universal OCC standards spanning electric and magnetic coupling. Future work will explore longer channel distances, additional plant types, and non-linear and coil-parameter modeling to advance integration into smart farming and cyber-physical systems.