Connecting and Powering Flexible IoT, *An Insole Case Study*

University of Southampton

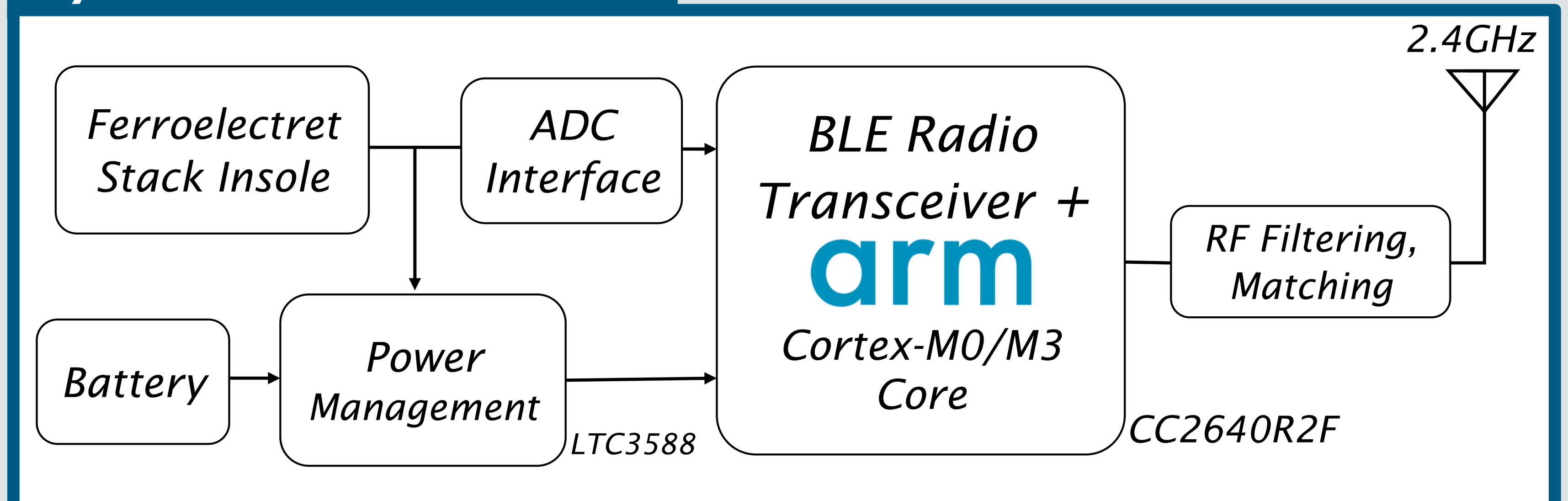
Mahmoud Wagih, Yang Wei, Sheng Yong, Steve Beeby

Abstract

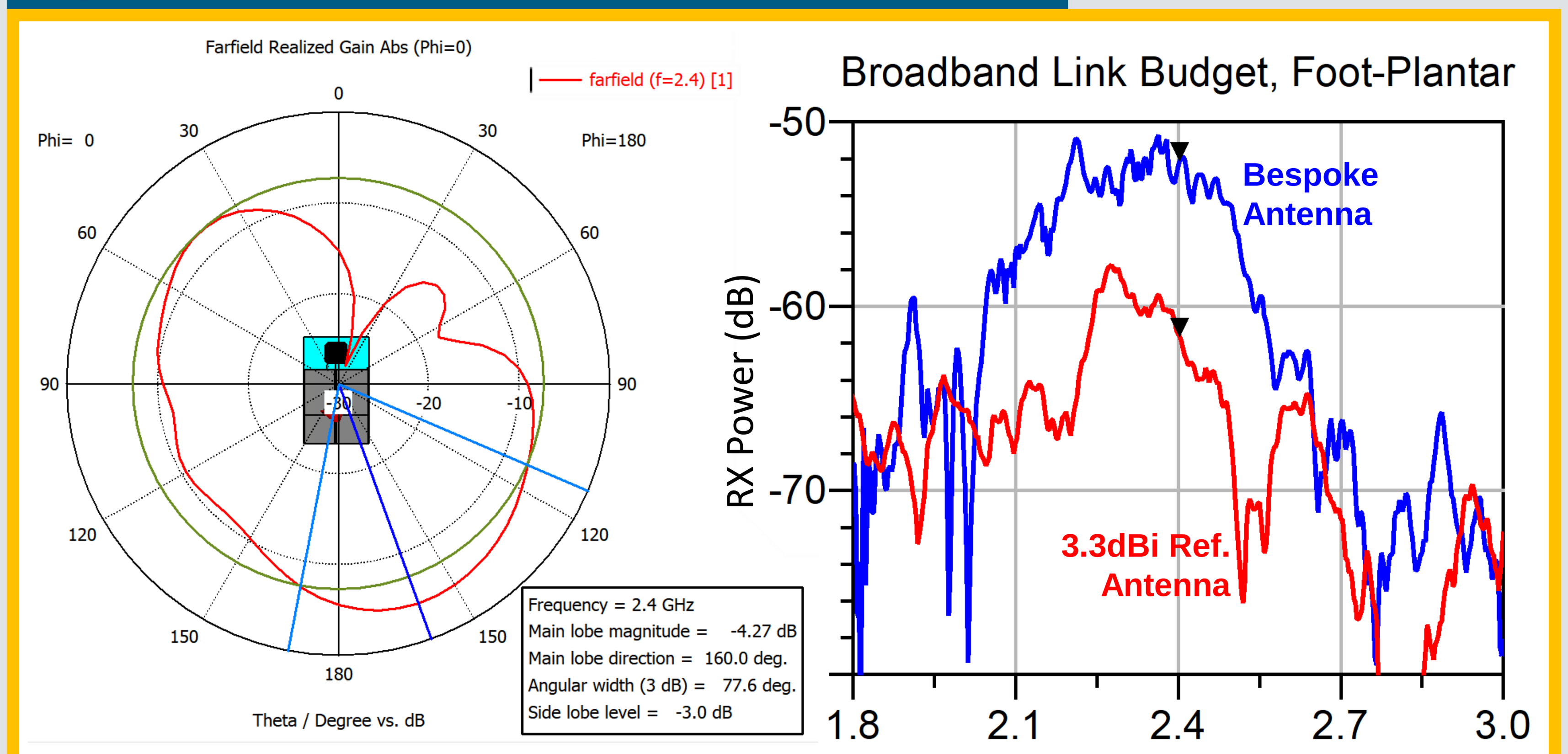
Integration of **Wireless IoT Wearables** *on a* **flexible substrate** *has been hindered by the unavailability of flexible RF frontends for fabric or Polyimide-based circuits. In addition, existing reference antennae are not designed for operation in human proximity. Moreover, the size and lifetime of batteries hinder the realization of a* **Fit-and-Forget** *solution.*

Presented, a **flexible Bluetooth Low Energy (BLE) node**, *with a bespoke* **detuning-resilient antenna** *for* **Body Area Networks (BAN).** *Furthermore, the system can be powered entirely from a flexible* **Ferro-electret energy harvesting** *insole, producing sufficient energy for an* **intermittent BLE beacon**, *advertising every 10 steps. The insole can be utilized to* **prolong battery life** *for high duty-cycle applications by >80%. The designed flexible circuit can be seamlessly adjusted adding* **multiple 2.4GHz wireless protocols support**, *based on Texas Instruments'* **CC26XX 2.4 GHz wireless SoCs**.

System Architecture

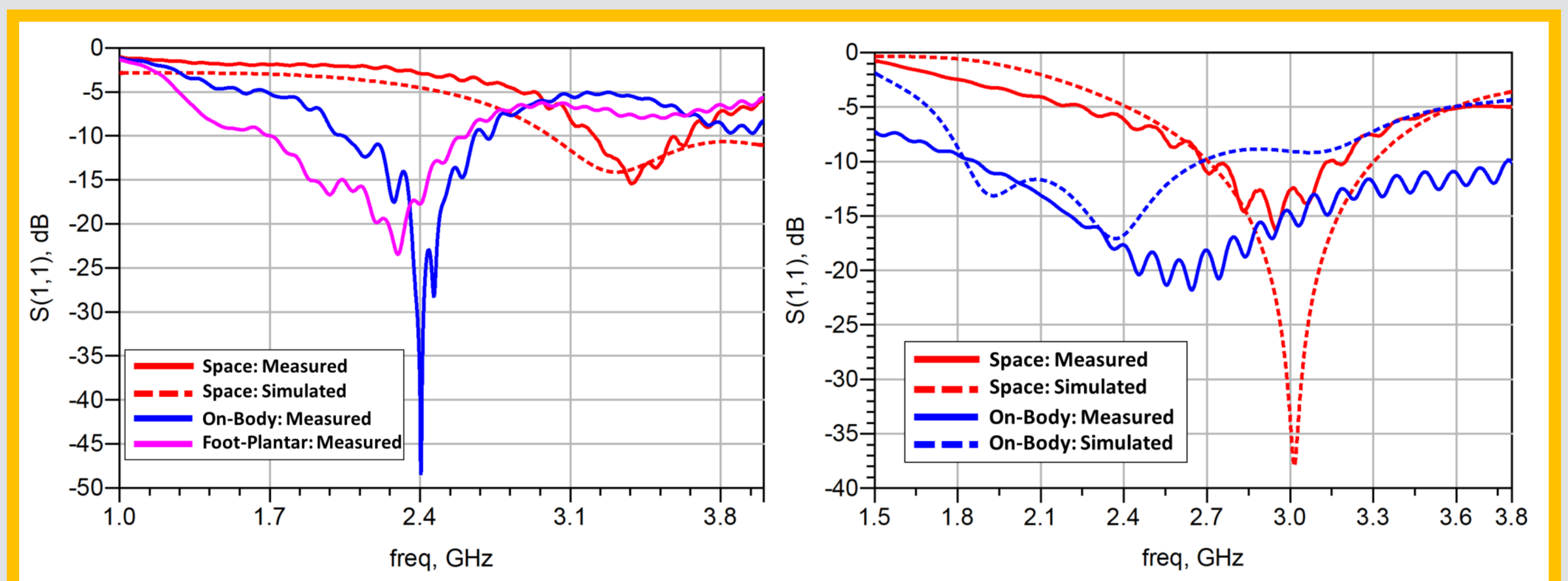


Optimal Wearable RF-Performance



Patch Antenna radiation plot (left) and Link Budget (right)

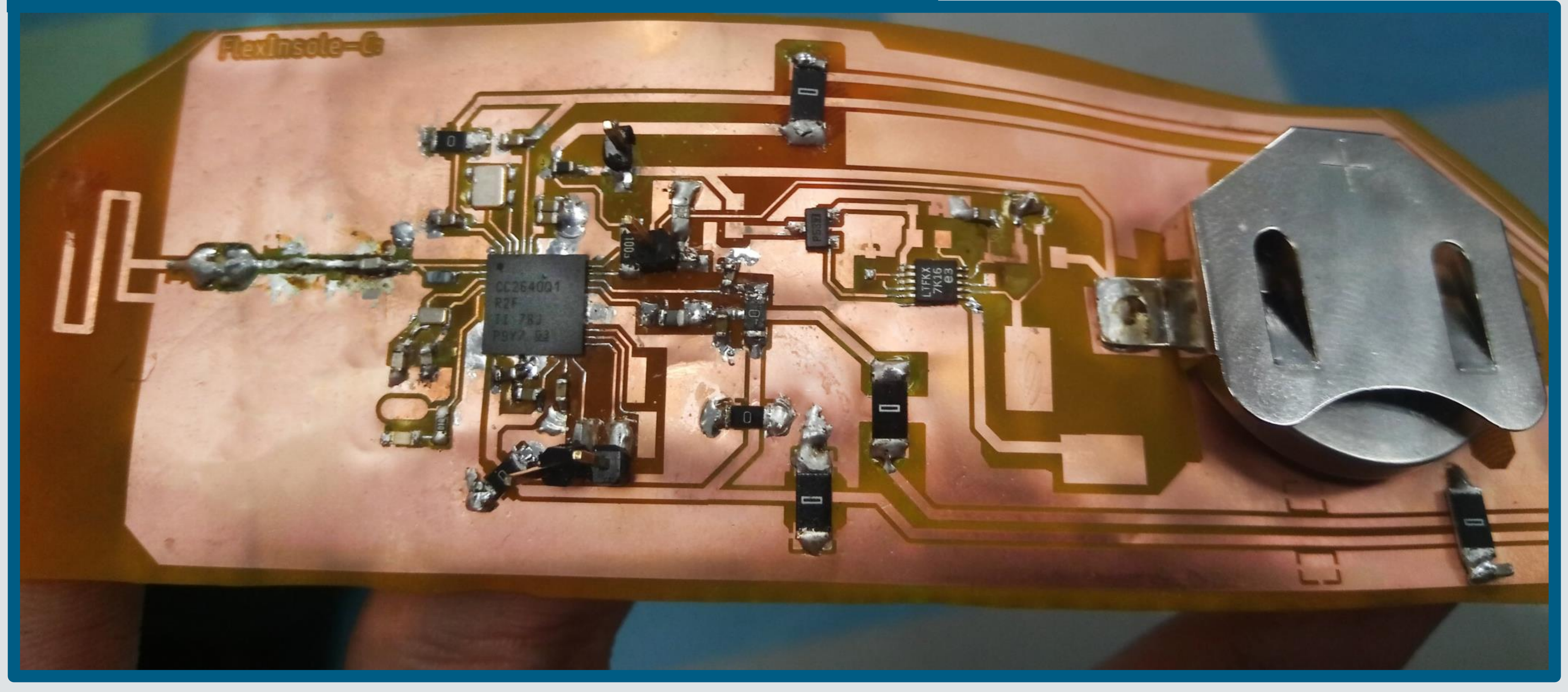
Reference antenna *designs are* ***susceptible to detuning*** *and* ***absorption***, *due to human proximity, constraining the reuse of reference antenna designs in wearable devices for* ***BAN***.



Meandered antenna return-loss s(1,1) (left) and patch antenna (right).

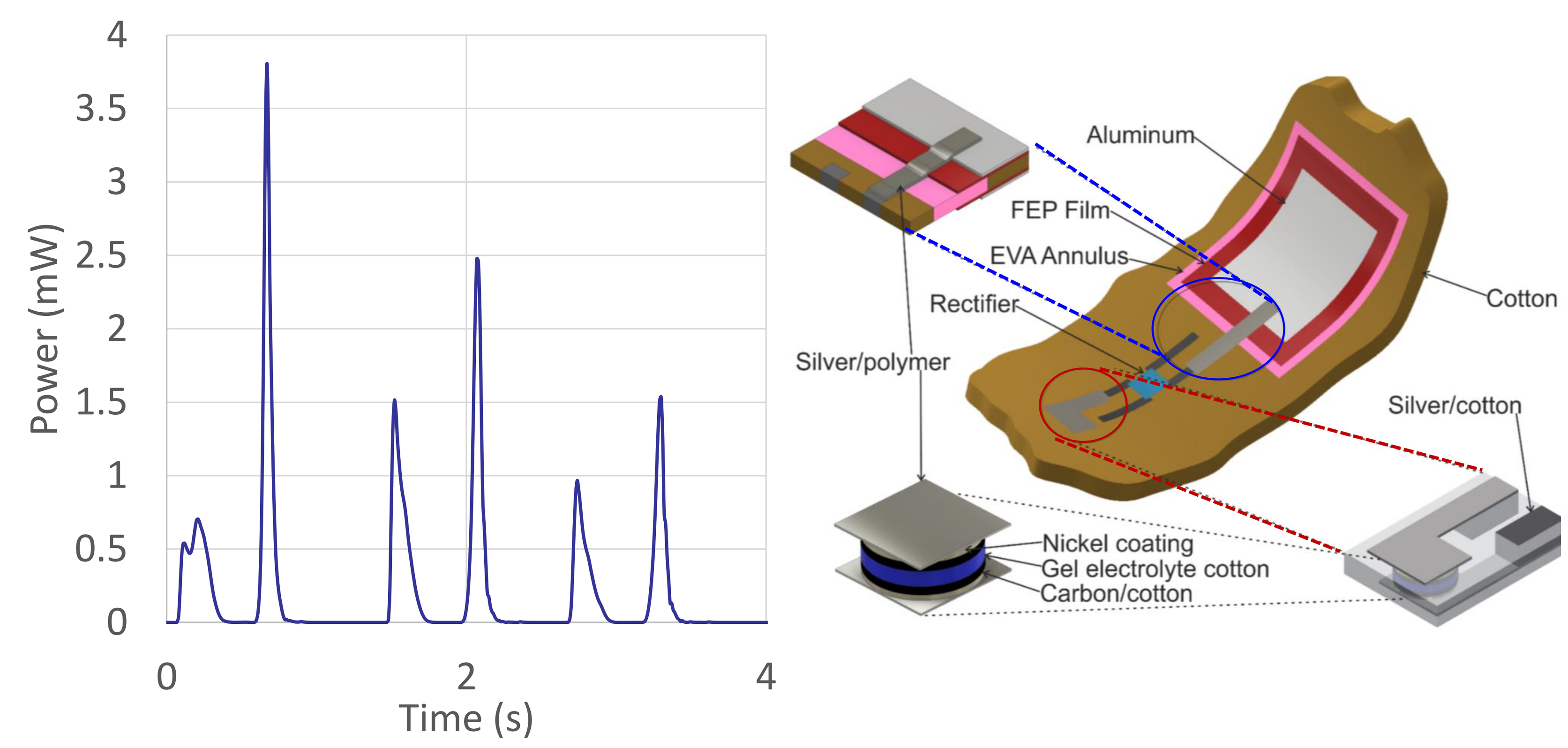
The designed antennae, single-layer patch and meandered antenna, present ***>5dB higher Realised Gain*** *than reference antennae. Furthermore, they occupy* **35%** *and* ***60% less board-area*** *respectively than inverted-F 2.4GHz microstrip antenna. Polyimide substrates demonstrate* ***superior characteristics*** *to FR4; with* ***>13% lower insertion losses*** *at 20GHz.*

Flexible Wireless Transmitter



Ferroelectret Energy Harvesting

The ferro-electret insole harvests step force, in the form of **short voltage pulses** *on compression and release.*

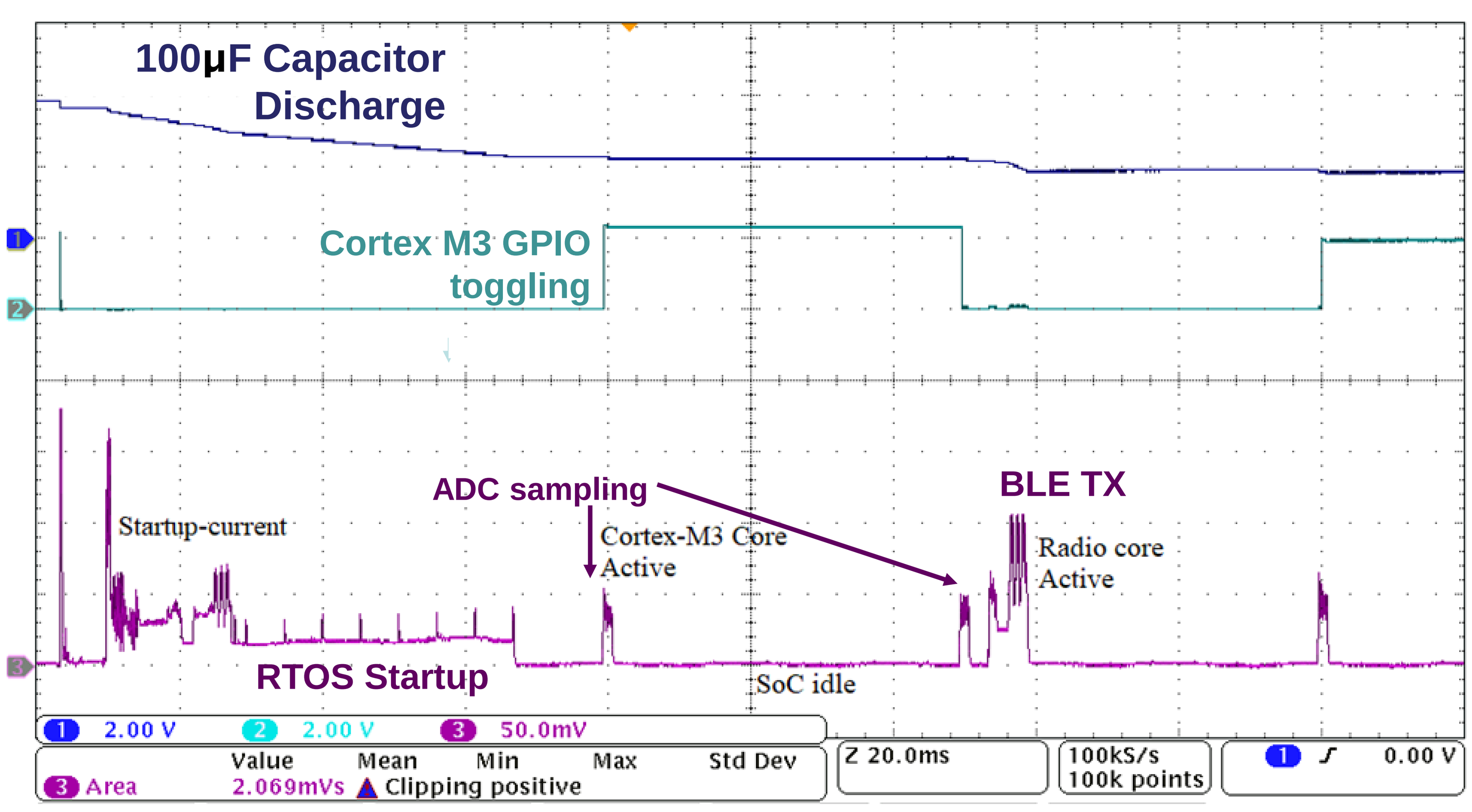


Harvested walking power, on 10MΩ load, during three steps

Energy Harvesting Challenges:

- *High source impedance (10 MΩ), requiring a high-impedance switching interface.*
- *High start-up current of cortex-M-based wireless SoCs.*
- *High capacitor's leakage and equivalent series resistance (ESR).*

Harvested energy is accumulated on **ceramic SMD capacitors**, *only discharging through the CC2640R2F when the capacitor voltage reaches 4.5V. A* **2.7 V hysteresis window** *allows the SoC to start-up and sustain operation for 300ms, sampling an ADC and performing calculations twice, in addition to performing* **a single BLE advertisement**.



Battery-less startup of the CC2640R2F from a 100µF capacitor

Contact: Mahmoud Ashraf Wagih
Email: mahm1g15@ecs.soton.ac.uk
ARM Research Summit: *17-19 September 2018*