Poster– Surface++: A Scalable and Self-sustainable Wireless Sound Sensing Surface

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Figure 1: Applications include (a) Interaction and control: adding Surface++ to objects and surfaces increases smart home assistants' listening range (b) Wearable control: attaching Surface++ to a shirt or jacket allows control using voice or tap gestures (c) Context sensing and surveillance: a Surface++ array extends the acoustic sensing range to almost 10 meters allowing the detection of coughing, laughing, talking, or a baby crying in a large-room setting (d) Outdoor localization: outdoor Surface++ patches can sense and communicate gunshot sounds to indoor transceivers for real-time triangulation of firing locations

ABSTRACT

We present Surface++, which leverages our previous work SATURN [2], a self-powered flexible acoustic sensor, and ZEUSSS [1], a passive wireless sound communication technique using analog backscatter, to create a scalable and self-sustainable wireless sound sensing surface. Our new prototype allows for large area acoustic sensing using modular fabrication techniques with the promise of being fully printable. A single small Surface++ patch can be used to extend voice and gesture input for everyday surfaces, while our more sensitive Surface++ modular array allows for large-area context sensing and localization.

CCS CONCEPTS

• **Human-centered computing** → **Interaction devices**; • **Hardware** → **Power and energy**; **Communication hardware, interfaces and storage**.

KEYWORDS

Self-sustainable; Sensing; Vibration; Sound; Triboelectric Nanogenerator; Flexible electronics, Backscatter Communication; Low-power; Acoustic Localization; Interaction and control

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1 INTRODUCTION

Power has long been a major design constraint for both mobile and ubiquitous sensing applications. Ideally, sensing nodes would work without the need of a wired or replaceable power source. In addition, they would be thin and flexible so that they might conform to the objects on which they are placed. We recently showed the promise of such a self-sustaining acoustic sensor named SATURN [2], and demonstrated its ability to leverage analog RF backscatter to transmit the acoustic signal passively off the sensor [1]. With Surface++, we explore how the performance of the SATURN sensor can be improved to harvest more energy and/or increase its performance as an acoustic sensor. This optimization enables a wide variety of vibration and acoustic sensing applications. In addition, we optimize our design making the system modular and printable.

2 SYSTEM ARCHITECTURE

The system architecture consists of two parts—a single or array of self-sustainable acoustic sensors connected in series and a passive communication component, which are explained below.

SATURN [2] (Figure 2a)[1] uses a Triboelectric Nanogenerator (TENG) [5, 6] to convert tiny vibrations induced on its surface into an electric signal (Figure 2b). Electrically, SATURN can be considered as a variable capacitor and voltage source. Since voltages sources in series add, we connected multiple SATURN patches to form a SATURN array structure (Figure 2c). Each SATURN patch in this array includes a half-wave rectifier (Figure 2d), resulting in

[1]SATURN video: www.youtube.com/watch?v=OLuZHpa_FIM

constructive addition of voltage generated from each patch. Constructing a 3x3 array improves acoustic sensitivity and is able to detect sound sources which are almost 6 meters away, a 3X improvement in range from a single patch backscatter. This modular design is scalable in performance with additional SATURN patches connected in series.

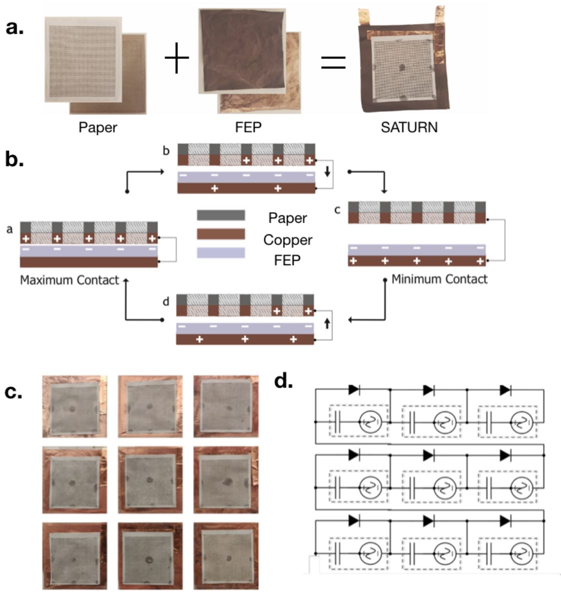

Figure 2: Self-sustainable acoustic sensing (a) SATURN : a thin and flexible self-powered microphone [2] (b) Triboelectric Nanogeneration (TENG) (c) Array of SATURN patches connected together in series with (d) half-wave rectifiers to sum sound signal response

We add passive communication using analog RF backscatter. Our experimental apparatus (Figure 3a) consists of the Surface++ tag and a transmitter-receiver pair operating in the UHF (900 MHz) frequency band. The Surface++ tag consists of a SATURN array and a dipole antenna connected in two different designs, both of which allow for change in impedance when sound is present. The first design (Figure 3b), exploits SATURN as a variable voltage source connected to a JFET, a voltage controlled impedance device to effectively cause impedance change in the tag. The second design (Figure 3c), leverages SATURN itself as a variable capacitor which causes impedance change due to change in reactance of the tag. According to backscatter theory [3], this change in tag impedance causes change in the reflection coefficient of the tag which effectively amplitude modulates the carrier wave signal, such that the back-scattered signal would include the audio signal information, which can be extracted at the receiver end with simple signal processing techniques. Both the designs are impedance matched with the antenna to allow maximum modulation on backscatter signal. The components in the second design specifically can be printed.

3 APPLICATIONS AND DISCUSSION

The self-sustainablity and thin form factor of Surface++ allows it to be added to everyday objects and surfaces. Figure 1 illustrates

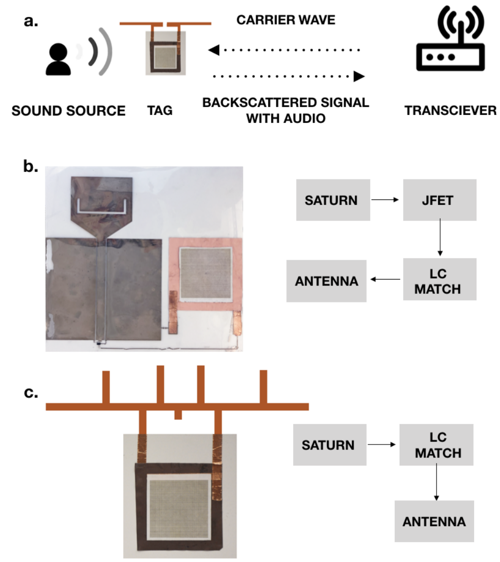

Figure 3: System Architecture: (a) Backscatter apparatus including Surface++ tag and transceiver (b) Surface++ tag design exploiting SATURN as variable voltage source (c) Surface++ tag design exploiting SATURN as variable capacitor

possible applications of Surface++; the applications in 1a and 1c have been demonstrated in working systems. Future research will optimize performance for different sound frequencies as well as for different backscatter radio carriers. Creating a fully printable and cheaply reproducible Surface++ is a priority as it enables different applications. For example, a wide deployment of sensors will enable a demonstration of large scale audio localization for gunshot detection. Surface++ could also be used for acoustic failure monitoring and diagnostics of large scale equipment in areas that are difficult or dangerous to access, such as the turbines in a nuclear power plant. Another technical priority is an analysis of the privacy implications of Surface++ to determine how challenges such as providing notice, choice and consent, and a sense of proximity and locality of the effective range of the device might affect the design [4].

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