# Ubisonus: Spatial Freeform Interactive Speakers

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## ABSTRACT

We present freeform interactive speakers for creating spatial sound experiences from a variety of surfaces. Traditional surround sound systems are widely used and consist of multiple electromagnetic speakers that create point sound sources within a space. Our proposed system creates directional sound and can be easily embedded into architecture, furniture and many everyday objects. We use electrostatic loudspeaker technology made from thin, flexible, lightweight and low cost materials and can be of different size and shape. In this demonstration we will show various configurations such as single speaker, speaker array and tangible speakers for playful and exciting interactions with spatial sounds. This is an example of new possibilities for the design of various interactive surfaces.

### Author Keywords

Interactive architecture; furniture design; interactions; electrostatic loudspeakers; freeform speakers

### ACM Classification Keywords

H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces - Auditory feedback.

## INTRODUCTION

Sound and visuals are important ingredients for creating interactive systems that produce an engaging and believable user experience. Display technology has progressed into more flexible, scalable and freeform configurations by use of OLED screens, projectors and other emerging display technologies. Sound technology has lagged behind relying on traditional surround sound systems limited by audible area, calibration, and bulky components [4].

We introduce *Ubisonus: Spatial Freeform Interactive Speakers*, that can reproduce sound directly from *architecture*, *furniture* and many other *everyday objects* as shown in Figure 1. *Ubisonus* utilizes electrostatic loudspeakers (ESL) that are lightweight, flexible, scalable, and can be made into almost any shape and size. They are highly durable and ideal for use in spatially restrictive and dynamic spaces and structures.

*Ubisonus* demonstrates a novel method for realizing *Programmable Matter* [1], *Programmable Physical Architectures* [6], and *Organic User Interfaces* [3].

## DESIGN OF FREEFORM SPEAKER

### Principal of Electrostatic Loudspeaker Technology

The basic principles of electrostatic sound reproduction are simple and were explored in depth in the 1930s [2]. An audio signal is amplified to ~1000 V and applied to an electrode, charging it relative to the ground potential that is connected to a diaphragm. As the electrode is charged, an electrostatic attraction force is developed between the electrode and the diaphragm. The whole diaphragm produces sound and can continue to produce sounds as objects are placed on it. Additionally, this structure can be used as a microphone by measuring the changing potential between the electrode and the diaphragm.

### Configurations of Our Electrostatic Loudspeaker

*Single-Side Configuration*

The conventional form of ESL (Figure 2a) has both electrode and diaphragm charged. However, this can be dangerous to the human body that normally has the same potential as ground. In our previous work on *3D printed speakers* [5], we connected the diaphragm to ground and the electrode to a HV signal (Figure 2b). Furthermore, we limited the current (~1.25mA) protecting the user from electrical shocks. This simple *single-side* configuration can be used as the surface of tabletops, walls, toys, floating objects, and more.

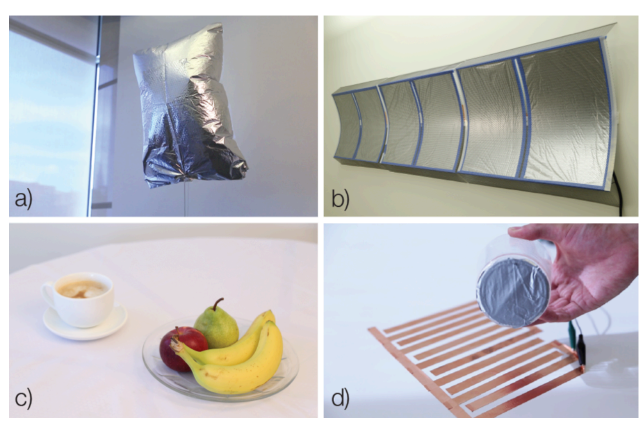


**Figure 1. Examples of *Ubisonus*. (a) *Balloon*. (b) *Large curved wall*. (c) *Speaker table*. (d) *Tangible objects*.**


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*Array Configuration*
An extension of the *single-side* is an *array* configuration as shown in Figure 2c. The array allows ESL to be placed sequentially, where each speaker is independently controlled. Multiple sound patterns can be channeled through individual speakers creating a moving and dynamic sound system (Figure 3).

All speakers in the array can share a common ground plane. Therefore, a single diaphragm surface could be used with multiple speaker electrodes as shown Figure 3 *left*.

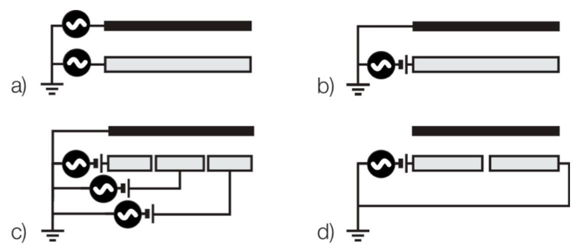


**Figure 2. Configurations of electrostatic speakers.**

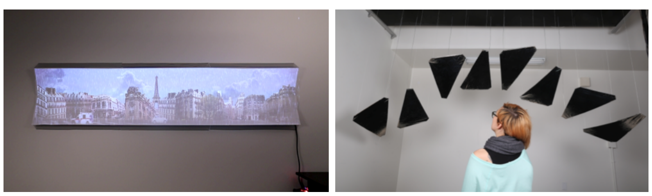

**Figure 3. Freeform electrostatic speakers are arranged to form a curved surface and morphing structures.**


**Figure 4. The surface of a large round table is embedded with an array of freeform speakers.**

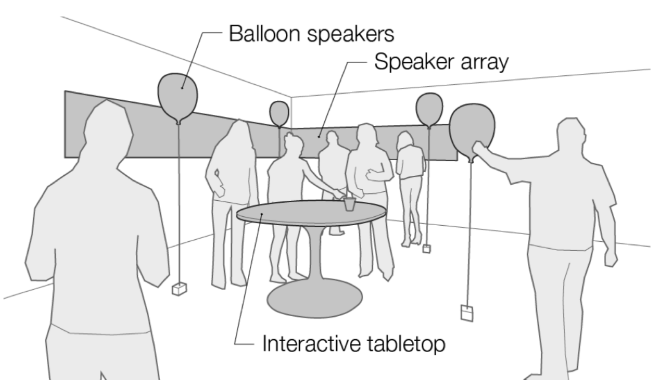


**Figure 5. Users are engaged in interactive sound environments that show *Ubisonus* in architecture, furniture and floating objects.**

*Passive Speaker Configuration*
Figure 2d shows the *passive speaker configuration*. In this configuration, HV and ground electrodes are arranged on the same surface, and an object with a passive diaphragm is placed on the surface. The surface itself cannot produce sound, however, the conductive surface of the object creates a difference in potential between the diaphragm and the HV electrode as well as between the diaphragm and ground.

## DEMONSTRATION AT UIST 2014

We will demonstrate our freeform speaker technology in an interactive sound environment made with *architecture*, *furniture*, and *everyday objects* (Figure 5).

### Architecture: *Wall Scale Speaker Array*

Freeform speakers are a good candidate for embedding in large and complex shaped walls due to their flexibility and scalability. We will integrate the ESL into a wall setting as shown in Figure 1b and will build a small wall for our demonstration.

### Furniture: *Interactive Tabletops*

In this installment, we will integrate an array of nine freeform ESL into the surface of a wooden table to enhance tabletop interactions as shown in Figure 4. Due to the minimal effect of loading on ESL, the weight from plates and cups placed on the table do not affect sound quality. In addition to the use of the panels as speakers, they will also be used as microphones.

A projector will allow us to collocate responsive animated content with sound on the table and wall to create an immersive and engaging experience for the user.

### Everyday Objects: *Tangibles and Floating Speakers*

In some situations, interactions are desired with passive tangible objects. In our demonstration we will include a variety of objects equipped with *passive speakers* as described previously. Figure 1d shows a table with a grid pattern made from conductive tape and a cup with a thin aluminized film diaphragm.

Finally, due to the lightweight nature of ESL, floating objects, such as balloons (Figure 1a) will provide ambient sounds to the user.

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