Swept-Frequency, Magnetically-Coupled Resonant Tags for Realtime, Continuous, Multiparameter Control

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ABSTRACT

We have developed a passive tag reader optimized for applications in human-computer interaction. It sweeps through a 50-300 kHz read frequency, flagging any magnetically-coupled resonators in that range. It is a minimally-complicated circuit, and is able to provide the center frequency, resonance width, and amplitude for each detected tag over a serial line at 30 Hz continuous updates. The tags are easily fashioned, consisting only of an inductor and capacitor or magnetostrictor tag cut to appropriate length. We have written an engaging musical application to demonstrate this system, tagging over 11 different objects and tracking their proximity and state, launching or modifying musical sounds in accordance.

Keywords

RFID, wireless sensing, passive tags, finger tracking, proximity sensing, musical interfaces

INTRODUCTION

Tangible user interfaces [1] will require their associated input devices to have some degree of identification, localization, and sensing. As these input devices become embedded into commonplace smart objects, they will need to be small, wireless, minimally complicated, inexpensive, and batteryless. A solution to this challenge lies in the domain of passive Radio Frequency Identification (RFID) tagging technology. There are several different types of RFID systems currently on the market. Most of these incorporate a simple, low-power CMOS integrated circuit bonded onto an antenna structure, the details of which depend upon the frequency of operation. The CMOS chip is often merely a simple state machine, powered up by the energy conveyed into the tag's antenna by a reader located up to several feet away in the more sensitive systems; after reaching adequate charge, the tag broadcasts its ID and associated data back through its antenna to the reader.

Although chip-based RFID systems are capable of providing many bits of information and ID, they currently have several disadvantages in many HCI applications. Many of these systems update their list of detected ID's slowly, requiring many 10's or 100's of msec between detections. The situation worsens when several tags are simultaneously within range of a single reader. Although many current tagging systems are unable to operate properly with multiple tags present, the anticollision schemes implemented in most multi-tag systems introduce even more delay. In addition, commercial RFID products seldom provide an indication of detected signal strength, corresponding to tag position and orientation (a very useful interface parameter). Likewise, because of the expense of fabricating the tag's chip and bonding it to a potentially complicated antenna structure, today's RFID systems are generally more expensive than simpler technologies, such as resonant analog tags, which were adopted in this study.

RESONANT ANALOG TAGS

The tags that we have chosen here are simple, magnetically-coupled resonances, of the sort commonly used for anti-shoplifting (EAS) systems. At the frequency range used here (50-300 kHz), these are of two types; simple inductor and capacitor series (LC) circuits or metallic glass "magnetostrictor" strips, the mechanical resonators used in Sensormatic's UltraMax [2] EAS system. As the ID of each tag is determined by the center frequency of the resonance, the number of unique ID's is limited by the swept frequency range and the width (Q) of the resonances. In the system described below, we are able to easily incorporate over 20 uniquely ID'ed objects. Although this is far fewer than possible with chip tags, these analog tags can be read out much faster (our current system can update the tag parameters at over 30 Hz) and all tags can be read simultaneously without additional delay or complication. The tags are inexpensive and easily fabricated by either choosing an inductor and capacitor (their resonant frequency is determined by $[2\pi\sqrt{LC}]^{-1}$) or trimming a magnetostrictor strip to the appropriate length. In addition, by making the capacitance, inductance, damping, or mechanical resonance a property of an environmental parameter (pressure, temperature, etc.), these tags may be used as sensors, e.g., as in [3].

SWEPT-FREQUENCY TAG READER

Fig. 1 shows a diagram depicting the tag reader that we are using in our current demo projects. Although other arrangements may provide more sensitivity, our present circuit uses an inductive bridge, where a search coil (currently 11 turns of magnet wire around a 9.5" x 11.5" wooden picture frame, giving roughly 120 µH of inductance) is balanced against a set of reference inductors.

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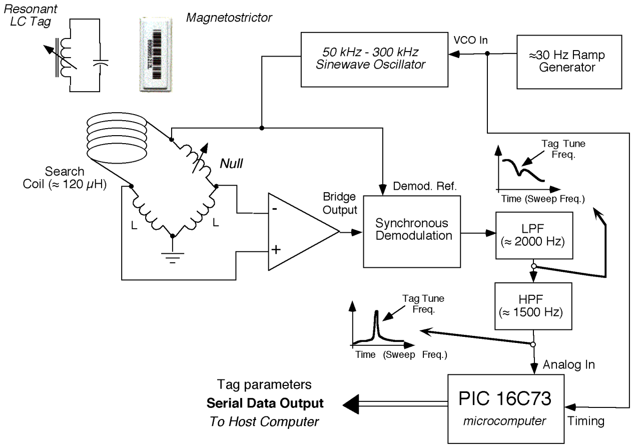

Figure 1: Tag Reader Block Diagram

The bridge excitation is a 20-volt sinusoid, sweeping linearly from 50 to 300 kHz at a 30 Hz repetition. The differential bridge imbalance is synchronously demodulated and low-pass filtered to attenuate noise background. A high-pass filter then enhances abrupt changes in the bridge's null, caused by energy transported out of the search coil when resonant tags are traversed. The entire sweep is monitored by a PIC 16C73 microcomputer, which logs the center frequency, width, and integrated height (e.g., proximity or coupling strength) of each determined peak and transmits them to a host PC through a serial connection after each sweep. Related architectures are used to detect LC shoplifting tags [4] at higher frequencies.

Figure 2: Small LC tag mounted on child's plastic ring

MUSICAL TAG APPLICATION

In order to explore the utility of the swept tag system in a realtime application, we have embedded 11 tags into simple objects and mapped them onto different musical effects. The smallest are made of 1-cm long ferrite-core inductors with shunt capacitors; 4 of these were made and glued onto a child's ring, as shown in Fig. 2. These rings, when placed on the fingertips, could be detected up to 8 inches from the search coil, and the net coupling strength indicated the combined proximity and orientation of each finger (the signal is maximal when the coil's axis is aligned with the local magnetic field, which tends to run along the search coil's axis). Larger coils were used in bigger objects (as it was Halloween, these tended to be plastic goblins, pumpkins, etc., as seen in Fig. 3). These could be detected more than a foot from the search coil, giving a good continuous range of sensitivity. Magnetostrictors were also embedded in other objects; although they have a very high Q (allowing many to be discriminated from one another), the current reader was less sensitive to them, detecting them only when they were inside the search coil.

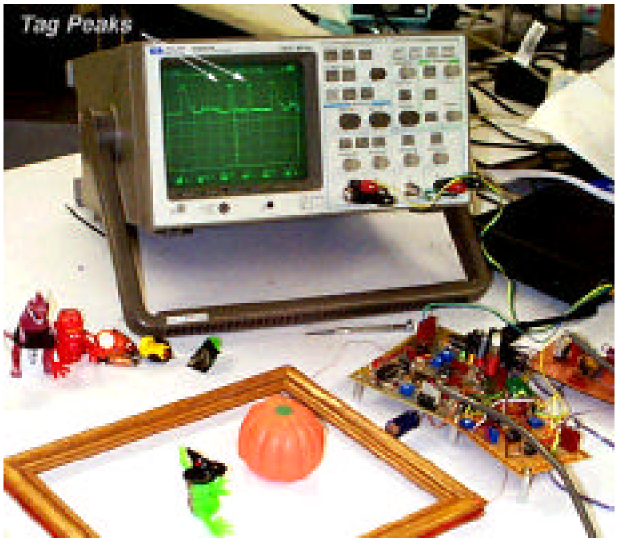

Figure 3: Tag reader and tagged musical objects in action

In the musical example, a harmonic bassline was based on the detected amplitude of 3 of the large tags. The four ring tags produced melodic tones when moved near the reader, and could be played like a piano, with variable velocity. An additional tag transposed notes up an octave, another changed the melodic voices, another created a fuzz distortion when manipulated (by pressing the coil, the resonant frequency was continuously adjusted), and another produced a twinkling sound as it approached the reader.

CONCLUSIONS

We have built a tagging system that is able to detect the identity, proximity, and state of an ensemble of circa 20 passive resonant tags, updating at 30 Hz. We have demonstrated this system in a musical interface, where simple objects were given musical properties when they approached the reader. Future work will explore multi-axis tag tracking, more sensitive readers, and other applications.

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