Collaborative Learning, Research and Science Promotion in a Multidisciplinary Scenario: Information and Communications Technology and Music

Authors:

Carmen Bachiller, Carlos Hernández, Jorge Sastre, Escuela Técnica Superior de Ingenieros de Telecomunicaciones ETSIT, Instituto de Telecomunicaciones y Aplicaciones Multimedia ITEAM Universidad Politécnica de Valencia, Phone: +34 9633879193, Fax: 96 387 71 99, mabacmar@dcom.upv.es, chernan@dcom.upv.es, jorsasma@dcom.upv.es

Abstract — *Information and Communications Technology (ICT) uses not to be vocational for students, moreover the presence that this technology has in society is general, but its knowledge is very superficial. The students of ICT sometimes need additional motivation since the concepts they study are complex and abstract. In this context the authors propose to involve ICT and music in the same scenario, and teaching, researching and science promotion as the main branches of a multidisciplinary project.*

Index Terms — *Information and Communication Technology, Digital Signal Processing, Theremin, Electronic Musical Instruments, Circuit Theory, Science Promotion, Electromagnetic Fields and Antennas.*

INTRODUCTION

The theremin is one of the earliest electronic musical instruments. It is named after the Russian physics Professor Lev Thermen and was invented in 1919. This musical instrument belongs to a very short list of devices which are played without physical contact between the musician and the instrument. That is the fascination and the special feature of this device. It uses two antennas, one for the frequency or pitch control and one for the volume or dynamic control of the musical note produced. The musician could change both parameters by moving his/her hands around the antennas. In this case, the electromagnetic field around the antennas will be changed and be recognized by the hardware immediately.
During the years 2007-08, 2008-09, 2009-10 some professors and students of the Universidad Politécnica de Valencia (Spain) undertook several activities of teaching, researching and promotion around the theremin. The instrument allows to experiment and to understand complex concepts related to ICT studies as electronics, signal processing and electromagnetism. Moreover it raises fascination and curiosity: everybody that has seen a theremin being played wants to know how it works. The project began as a pilot experience in the “Circuit Theory” and “Circuit Theory Laboratory” syllabus for illustrating concepts as inductances, resistors, capacitors and their use in different electronics circuits as oscillators, mixers, amplifiers, etc. Furthermore, it was then used for explaining much more complicated concepts like electromagnetic fields, feedback and stability characteristics, antenna field patterns, polarization, etc, for an advanced group of students that work in a collaborative way to understand and learn these concepts. At the same time the promotion actions began with a series of courses, conferences and concerts given to different audiences: high school students, musicians and music professors, university professors, etc. Finality, trying to improve the knowledge and students’ capabilities and to maintain higher as possible their attention and interest in the subject, the research actions began: several digital signal processing algorithms and techniques are used to control two robot arms that acts like a theremin player, a virtual theremin with a webcam is being developed, the directivity of the antennas is being improved and some multimedia is being added for performances.

THE THEREMIN IN TELECOMMUNICATION STUDIES

The “Circuit Theory” syllabus is taught at the first Semester of the Telecommunication Career at the Escuela Técnica Superior de Ingenieros de Telecomunicación, Universidad Politécnica de Valencia. The Circuit theory presents the students fundamental laws controlling electric circuits. At the end of the course, the students have the ability to analyze some basic linear telecommunication circuits using a set of different techniques, theorems and mathematical tools. The themes studied include the following subjects: concepts and fundamental laws, behaviour of passive and active components like resistors, inductances and capacitors, steady response to a sinusoidal input, fundamental theorems of circuit analysis as Thevenin and Norton theorems, maximum power transfer conditions, etc. The theremin supports the teaching and learning procedures, Figure 1.

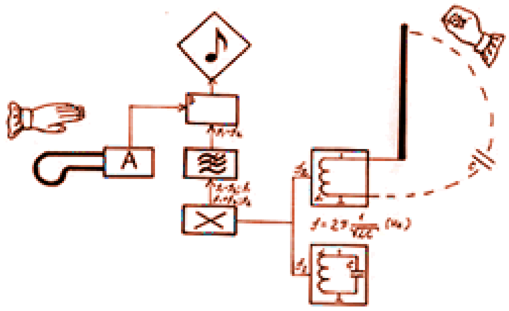


FIGURE 1
PHYSICAL PRINCIPLES OF THEREMIN OPERATION

The "Circuit Theory Laboratory" syllabus is taught at the second Semester of the Telecommunication Career at the Escuela Técnica Superior de Ingenieros de Telecomunicación, Universidad Politécnica de Valencia, and its contents are close related to the Circuit theory syllabus. Among its main objectives the most important is to test in a practice way theoretical concepts. The Circuit theory laboratory prepares the students with sufficient skills in order to handle different laboratory instruments very used in telecommunication and electrical equipments: oscilloscope, function generator, power supply and digital multimeter. The students learn how to use these instruments designing and implementing basic circuits and doing measures of electrical quantities like currents, voltages, power and energy. The therermin is used in the laboratory for measures and circuit description, Figure 2.

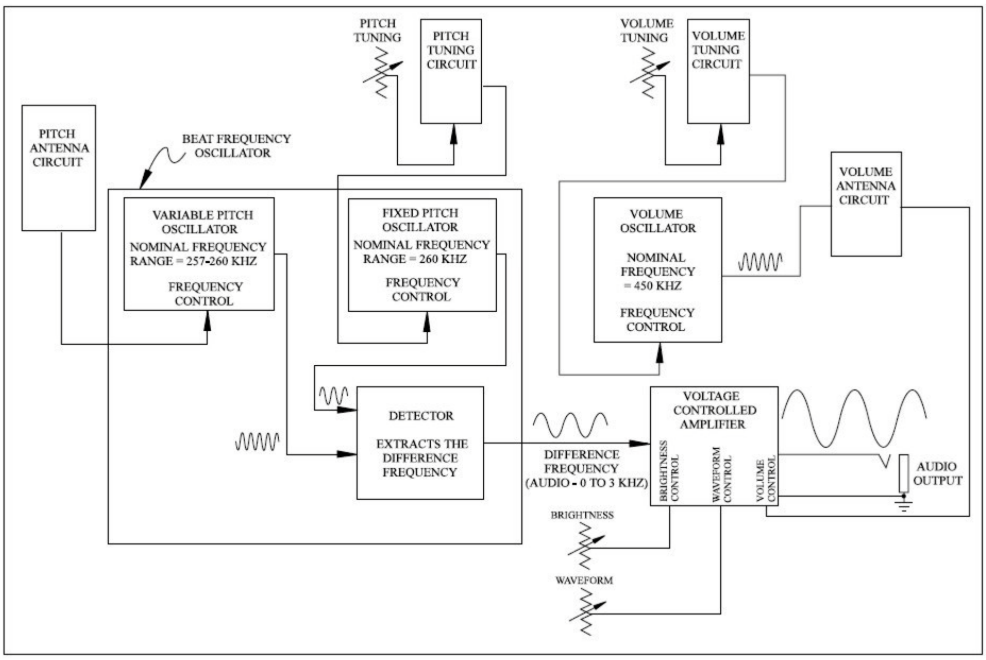


FIGURE 2
THE "ETHERWAVE® THEREMIN" BLOCK DIAGRAM

COLLABORATIVE WORK FOR THE STUDY OF THE THEREMIN OPERATION

This part of the project consisted on the creation of a working group for the teaching and learning in a collaborative way of the main principles of operation of a theremin. In order to extend the classroom "further in time and space" and to promote the collaborative work in a more efficient and wide way, the application Basic Support for Cooperative Work (BSCW) was used. The learning methodology was focused on discovering more than describing, in this way the students developed by their own the subjects of the working plan described below.
The analyzed subjects were the following:

- "Historical introduction to the technology of electronic music"
- "Analysis of the circuits of a Theremin"
    - Circuits for pitch control

- Circuits for volume control
- Antennas
- “Manufacturing of a Theremin of a single antenna”

Five students enrolled the course and finished the Project. The formative activity began on the second term of 2007-08 and finished during the first term of 2008-09. The formative activity was optional and not included in the official curriculum; the students only got two credits for it.

The working plan was agreed by the professor and the students that followed the experience. We had a working plan quite flexible in its weekly implementation, but all the tasks were completed. During the first week the students enrolled the course, were logged in to the collaborative working space BSCW, the contents of the work were distributed and three working groups were formed to address the different tasks. During the second week the students made a bibliographic revision about the technology related to electronic music. During the third and fourth weeks the students analyzed the theremin circuits, they made analysis schematics and simulations in ORCAD for the pitch and volume circuits, they understood each part of the circuits and explained in a detailed document how the operation of the theremin was. Moreover they made some research about the antennas of the theremin: radiation patterns and polarization of the electromagnetic field. During the 6th, 7th, and 8th weeks the students manufactured a simple theremin of 1 antenna: they made the layout and the printed circuit board, they got the components and welded them, mounted the antena and tuned it. The students also participated as laboratory monitors for the Course of Technology and Music. In the laboratory the students helped other students to understand and manufacture their theremins. Finally during the last week of the course the evaluation was made and the students extracted some conclusions. The students considered of importance the following items: they put in practice concepts that they had only learned in theory classes, they tackled problems of inverse engineering (they studied the performance of a device and then they designed and manufactured it), they faced “real life” problems (some of the components to manufacture the theremin were not available in the local market, so they were substituted by others, PCB manufacturers needed the layout in a given format, etc.), they had their first teaching experience in a laboratory helping other students to understand and build their theremins, and finally they had the opportunity to know the origin of electronic music technology, which is a subject that is not well developed during the official courses.

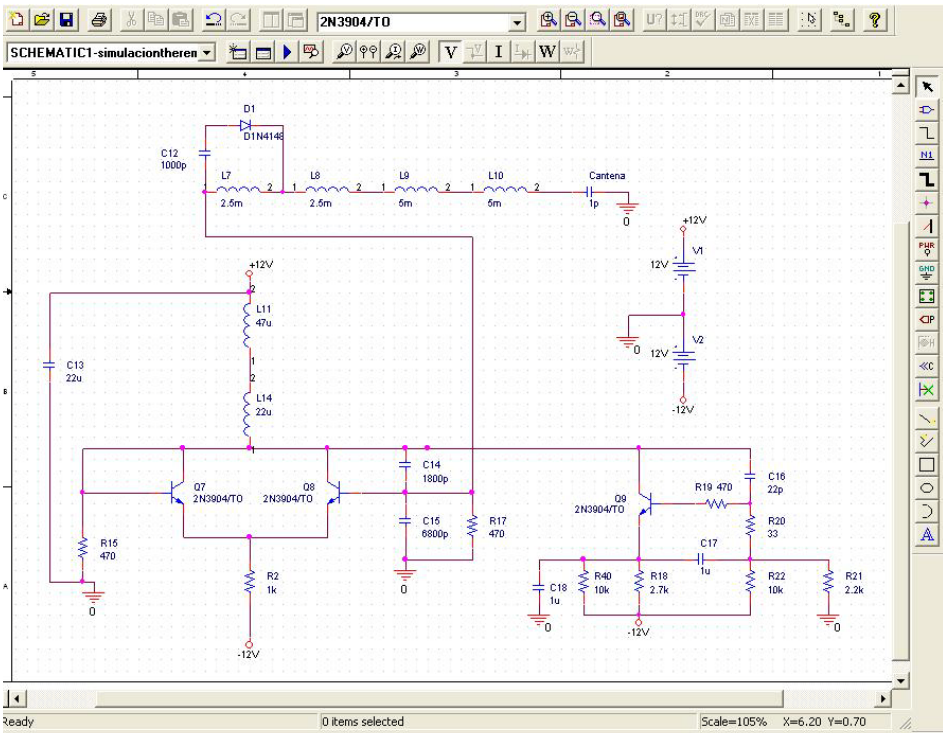


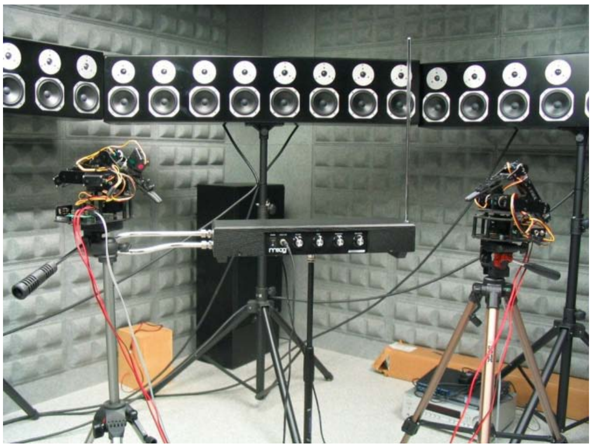
FIGURE 3
SCHEMATIC OF THE PITCH CIRCUIT THAT THE STUDENTS DEVELOPED

RESEARCH PROJECTS

Several research projects related with the theremin, music and multimedia are being carried out completing all the educative levels of this proposal. All of them are being developed as students’ master theses or works, guided by the authors of this paper, in collaboration with other members of the Instituto de Tecnologías y Aplicaciones Multimedia (iTEAM) from the Universidad Politécnica de Valencia (UPV), and the Electro Acoustic Music Laboratory of the Conservatorio Superior de Música Joaquín Rodrigo of Valencia. The projects can be summarized by: *Theremin playing robot* (*Robottheremin*), *Virtual musical instruments*, *Multimedia art for electro acoustic music spectacles*, and *Directive antenna for the theremin*. We describe briefly each of those projects.

Theremin playing robot (robottheremin)

Several digital signal processing algorithms and techniques involving the Fast Fourier Transform (FFT) are used to control two robot arms that play a given musical piece acting as a theremin player, see Figure 4 (left). The musical piece is given by the corresponding musical notes and their durations. An initial calibration is needed to obtain the arm robot position for each musical note (frequency). This project has been carried out by several students from the University of Applied Science (Dresden) with Erasmus Grants in the Universidad Politécnica de Valencia in several courses: Alfred Reisner, Florian Fischer, Nils Wabnik and Andreas Büttner, supervised by Carlos Hernández and Kristina Kelber (HTW, Dresden).



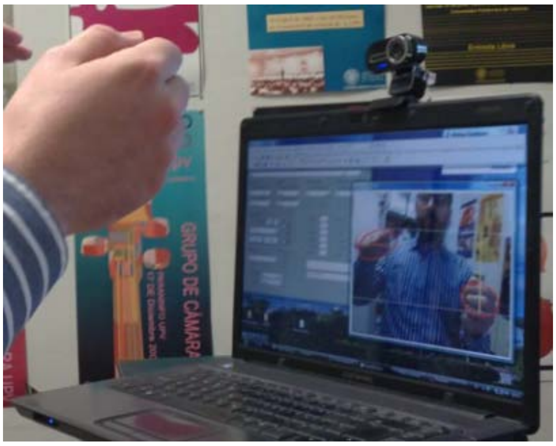


FIGURE 4
ROBOTTHEREMIN (LEFT), VIRTUAL MUSICAL INSTRUMENT (RIGHT)

Virtual musical instruments

Using real-time video processing techniques a virtual musical instrument based on webcams is being implemented, see Figure 4 (right). The system allows substituting the webcam by an electromagnetic field tracking system. It tracks both hands movements to create a virtual instrument based on the same principles of the theremin: right hand controls the pitch and left hand controls the volume. More complex features are being planned to add to the virtual instrument in the future. This project has been also carried out by students from the University of Applied Science (Dresden), Eric Bäckert and one Spanish UPV student, David Simarro, supervised by Carlos Hernández, Kristina Kelber (HTW, Dresden), and Jorge Sastre.

Multimedia art for two electro acoustic music spectacles

The video art part of two musical spectacles composed as two master theses of two musical composition students on Electroacoustic Music is being developed. The composition students belong to the Electro Acoustic Music Laboratory of the Conservatorio Superior de Música Joaquín Rodrigo of Valencia. Both music master theses are supervised by the Electro Acoustic composer Gregorio Jiménez, who is the president of the Spanish Electro Acoustic Music Association (AMEE) and an adviser for the International Confederation of Electroacoustic Music (ICEM). The video art part of one of the two spectacles is being developed as a master thesis of an UPV engineering student, Belén Ceñal, and it involves real-time video processing and creation techniques. The video part of the other project, which is an electro acoustic opera, is being developed by Jorge Sastre, in collaboration with a UPV Fine Arts student, Paco Alarcón, and others: Luis Muñoz, Leopoldo Herreros and Óscar Luis Almagro. A reduced version of both spectacles will be premiered on June 23, 2010. The complete versions will be premiered in the inauguration of the new building of the Conservatorio Superior de Música Joaquín Rodrigo of Valencia, on October, 2010.

Directive antenna for the theremin

Theremin players complain about the interferences that any object in a radius of approximately 3 m produces when playing the theremin, modifying the intonation of the instrument. This is a problem when playing in small scenarios, with other musicians which move along it. A system to improve antenna radiation patterns of pitch antenna of the theremin is being designed. The work is being carried out by the student Amelia Lavinia Ricchiuti, from the Facoltà di Taranto (Università Politecnica di Bari), supervised by Carmen Bachiller, in collaboration with the iTEAM Associate Professor Héctor Esteban, and Jorge Sastre.

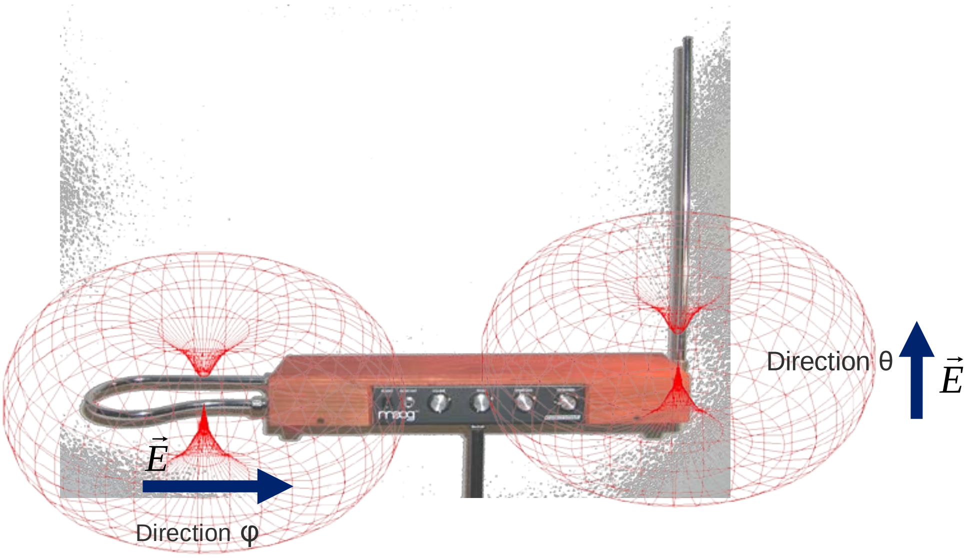


FIGURE 5
RADIATION AND POLARIZATION ELECTROMAGNETIC FIELD PATTERNS OF THE THEREMIN ANTENNAS

Electromagnetic field radiation patterns of the theremin antennas are omni directional. The right antenna is used to control the pitch with horizontal movements of the hand. Any object moving near the theremin will alter the pitch, making the music being out of tune. The left antenna controls the dynamics (volume) of the sounds, with vertical movements of the left hand, and then it is more difficult that moving objects produce so annoying effects on the music as with the right antenna. An array of monopoles has been simulated to provide the required isolation from external objects for the right antenna, and it has been implemented and tested giving promising results, see Figure 6.

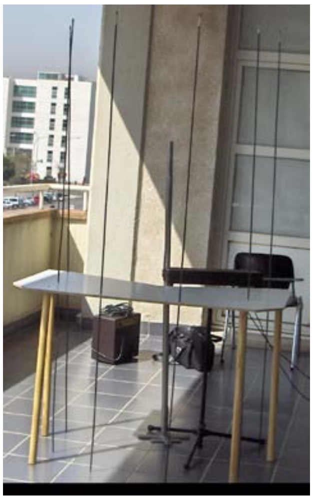


FIGURE 6
ARRAY OF MONOPOLES FOR ISOLATION OF THE THEREMIN PITCH ANTENNA

COURSE OF TECHNOLOGY AND MUSIC

Another branch of the activities that were carried out, was that the development of a course about Electronic Music Technology and a hands on experience building a theremin. The course was addressed to general public, no matter if they did not have a technological background, but specially focused to students and professionals of electronics, communications and audiovisual engineers, and to musicians. The course was offered by the Escuela Técnica Superior de Ingenieros de Telecomunicación (ETSIT), throughout the Permanent Formation Centre of the University. Five professors of the ETSIT which main research is central to audio and music technology participated, and during the manufacturing of the theremins, the students that joined the collaborative experience helped in the laboratory.
The course was organized in four chapters:

- Short history of the use of electronic technology in music:
  - Relationship between physics and music during the Renaissance and the Baroque period
  - Study of the electromagnetic phenomena
  - First electronic devices: Theremin, Martenot…
  - Analogical synthesizers
  - Digital synthesizers
  - MIDI technology
  - Digital Audio Processing
  - Last technology development in electronic music
- Analysis of the operation of a Theremin:
  - Operation principles
  - Circuits for pitch control
  - Circuits for volume control
  - Antennas
  - Controllers for waveform and brightness
- Manufacturing a Theremin:
  - Designing a Theremin of a single antenna
  - Assembling the components in the PCB
  - Assembling the antenna, tuning and testing
- Public demonstration: concert

Zhivago de Second Coming

FIGURE 7
SINGLE ANTENNA THEREMIN, ASSEMBLED PCB OF THE THEREMIN, A LP OF A POP BAND WERE THIS THEREMIN IS PLAYED

The students of the course were supplied with the PCBs, antennas and components and they were assisted in the laboratory since many of them had no previous experience in welding. The course was conducted during November 2008, more than 35 students enrolled it, but it was limited to 25 students for the limitation in number of the laboratory sites, Figure 7.

As a curiosity, one of the attenders to the course was a musician of a pop band ("Second Coming"), and they played the theremin that he manufactured during the course in one of their singles, named "Zivago", of their last work

CONFERENCES AND CONCERTS

The idea was well received and sparked interest among students from other courses, teachers and musicians. The teachers involved thought that a good way to raise awareness of the possibilities of the theremin would be to conduct a briefing. Leveraging that one of the students of first course of Telecommunications Engineering showed interest in the musical possibilities of the theremin and that he is learning to play the instrument, it was organized on May 22, 2008 a talk show about "Theremin: History, Technology and Music", in the ETSIT, covering the following aspects

- Brief history of the use of electronic technology in music
- History and analysis of the functioning of a Theremin
- Influence of the Theremin in the music and film production
- Concert for a Voice (Soprano), Piano, Violin and Theremin

The talk was attended by about 100 people of very diverse nature: many students and professors of telecommunications, but also musicians and conservatory staff, students of Fine Arts and multimedia creators. Following this first experiment the renowned theremin players Randy George, Francisco Isla and Lydia Kavina were contacted, currently they are supporting the initiative in different ways.

Since that first talk in 2008-2010, the authors have given 11 lectures (ETSIT, EPSG, Ateneo, Botanical Garden of Valencia, Conservatorio de Salamanca, Salamanca Casino, Congress 17CUIEET, UPV Science Week, TICnología Meeting, Conservatorio Municipal de Valencia, V CIPHI, XXXII International Contemporary Music Festival ENSEMS), 11 concerts (ETSIT, EPSG, Ateneo, UPV Auditorium (two concerts), Botanical Garden of Valencia, Conservatorio de Salamanca, Salamanca Casino, Congress 17CUIEET, Conservatorio Municipal de Valencia, V CIPHI, XXXII International Contemporary Music Festival ENSEMS), a report and three interviews in local radio and TV, and two works for theremin, composed by Jorge Sastre professor at the UPV, have been premiered.

FIGURE 8
CONFERENCE "THEREMIN: HISTORY, TECHNOLOGY AND MUSIC" AND CONCERT AT THE "SALÓN DE ACTOS DEL ATENEO MERCANTIL DE VALENCIA", 1ST OF MARCH 2009.

REFERENCES

[1] http://en.wikipedia.org/wiki/Theremin, *Theremin*, (accessed January 25th, 2010)

[2] Moog Music Inc., *Understanding, Customizing and Hot-rodding your Etherwave® Theremin*, 2003

[3] Reisner Alfred, *Robottheremin – Music in an Automated Way*, Fachbereich Kommunikationstechnik, 2009

[4] Wabnik, Nils, *Implementation of an Artificial Vision System for the Robotic Arms Controlling the Electronic Musical Instrument "Theremin"*, Diplomarbeit, 2009

[5] Kelber, Kristina; Wabnik, Nils; Hernández Franco, Carlos, *Music Score Recognition System for a Robot Controlling a Theremin*, 18th IEEE Workshop on Nonlinear Dynamics of Electronic Systems, Dresden, 2010

[6] Gomes, André et al., *ThermUS: the Ultrasonic Theremin*, Audio Engineering Society, 2009