Construction of an Varechoic Chamber.

Construction of VARECHOIC CHAMBER

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**VARECHOIC CHAMBER.**

SOUND engineers have built the first test chamber capable of offering an almost infinitely variable range of acoustics. Bell Laboratories, the research wing of the American communications giant AT&T, calls its room a "varechoic chamber". Its acoustics vary from an anechoic state, in which there are no echoes and sounds die almost immediately or not having or producing echoes; sound-absorbent, to an echo chamber in which the walls reflect sound so strongly that it stays alive for well over a second.

**CONSTRUCTION.**

The chamber is clad with hundreds of specially made panels, each of which can be switched between a "dead" state in which it absorbs sound, and a "live" state in which sound is reflected. This is a simple idea, but it is hard to put into practice and no one has managed it before.

Bell built the chamber to help it design microphone and loudspeaker equipment for teleconferencing, where two or more groups of people in different places hold a meeting over the phone lines, using microphones and loudspeakers rather than telephone handsets. The microphones must pick up sound from only one person at a time, and ignore the loudspeaker and any noise from someone else in the room.

A system designed in a dead room will not work well in a real room, where sound may reflect from the walls into the wrong microphone. And all real rooms reflect sound differently. Gary Elko of Bell’s acoustics department worked with mechanical engineer William Ward to design a solution. The varechoic chamber took a year to build and cost about $500 000 when it was finally constructed.

The room is about the size of a large living room or office. Its walls, ceiling and floor are clad with 368 mechanically operated panels, behind which lies a thick layer of sound-absorbing fiberglass. Each panel is made of a pair of stainless steel sheets punctured with a pattern of small holes. The sheets are held tightly together to make them airtight but can slide past each other. When the holes align, sound waves pass through and are lost in the fibreglass. When the panels are out of alignment, the holes are blocked off and sound bounces off the steel sheets.

The outer sheet of each panel is magnetic, and large magnets fitted at the back pull it tightly against its partner to give a good seal. The panels are made completely airtight by a layer of thick oil between the steel sheets. Each panel is equipped with a solenoid switch that controls a high pressure pneumatic air line to manoeuvre it
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between the open and closed positions. The switch is controlled by a personal computer linked to a hand-held remote control.

A light detector in each panel senses whether it is open or closed, and feeds this information back to the control system. At one extreme, when all the panels are open and the room is fully damped, sound reverberates for only 0.1 seconds, making speech sound very dead. At the other extreme, when all the panels are closed, the reverberation time is 1.6 seconds and the room sounds like a cathedral. Closing the panels in a pair of facing walls creates a fluttering echo effect.

Though, Bell has not patented its design and has published the basic details in a technical paper. So anyone with the necessary engineering expertise and $500 000 – approximately #58,000,000 can build one of their own.

VARECHOIC CHAMBER – MURRAY HILLS.

The varechoic chamber, built at Murray Hill in 1994, represents a new design in dedicated variable acoustics facilities. It is made up of 368 digitally controlled panels on the walls, ceiling and floor. Each panel consists of 2 sheets of stainless steel perforated with 0.32 mm holes in a standard staggered (60 degree) pattern with approximately 14% open area and is backed with 10 cm of fiberglass for sound absorption. The rear sheet can be moved relative to the front sheet to seal the holes, allowing the panels to reflect sound or to expose the holes, allowing the panels to absorb sound. This design provides variable acoustics across all six room surfaces and achieves unprecedented variability, flexibility and speed of operation.

The varechoic chamber was built within a section of the old Murray Hill reverberation chamber, which has thick concrete walls and excellent isolation. The room has an independent precision climate control system that allows control of room temperature to 1°C and relative humidity to 1%.

MICROPHONE ARRAY MEASUREMENTS FROM THE VARECHOIC CHAMBER – BELL LABORATORIES.

While constructing the Varechoic Chamber at Bell Labs, the following observations were made. Though, there have been many requests, fractions of the data are available on these pages.

- Room
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**Irdata. Room name**=Varechoic chamber (configuration, 89% open, with fiber glass pillow);

- **Irdata. Room width**=6600 mm
- **Irdata. Room Length**=5850 mm
- **Irdata. Room height**=2750 mm

- **Sources**

  **Irdata.source.name**='Cabasse Baltic';
  XX= [337 1337 2337 3337 4337 5337 6337];
  **Irdata.source.x**= [XX (2:6) XX XX XX XX (2:6)];
  YY= [1438 1938 2938 3938 4938];
  **Irdata.source.y**=YY(1)*ones(1,5) YY(2)*ones(1,7) YY(3)*ones(1,7) ...
                  YY(4)*ones(1,7) YY(5)*ones(1,5];
  **Irdata.source.z**=1600*ones (1, 31);
  **Irdata.source.fname**=char('v02','v03','v04','v05','v06',...
                      'v11','v12','v13','v14','v15','v16','v17',...
                      'v21','v22','v23','v24','v25','v26','v27',...
                      'v31','v32','v33','v34','v35','v36','v37',...
                      'v42','v43','v44','v45','v46');

- **Appliance used**

  **Irdata.microphones.name**='Panasonic WM-61a';
  **Irdata.microphones.x**= [2337:100:4536] +100;
  **Irdata.microphones.y**=ones (1, 22)*500;
  **Irdata.microphones.z**=ones (1, 22)*1400;

- **Visualization**

  plot3 (irdata.source.x,irdata.source.y,irdata.source.z,'*','...
        irdata.microphones.x, irdata.microphones.y, irdata.microphones.z,'+'),
  Grid, axis ('ij');
  axis ([0 irdata.room.width 0 irdata.room.length 0 irdata.room.height]);
  xlabel('x-position [mm]');ylabel('y-position [mm]');zlabel('z-position [mm]');

  for q=1:length(irdata.source.x),
     text (irdata.source.x(q),irdata.source.y(q),irdata.source.z(q),...
           ['\leftarrow ' irdata.source.fname(q,:)]);
  end
  Mmic=length (irdata.microphones.x);
  text (irdata.microphones.x(Mmic),irdata.microphones.y(Mmic), ...
        irdata.microphones.z(Mmic),'\left arrow Microphones');

  title (irdata.what);

  Break;
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plot (irdata.source.x, irdata.source.y,'*', ... 
    irdata.microphones.x, irdata.microphones.y,'+'), 
    grid, axis('ij'); 
axis ([0 irdata.room.width 0 irdata.room.length]); 
for q=1:length(irdata.source.x), 
    text (irdata.source.x(q), irdata.source.y(q), ... 
    ['\leftarrow ' irdata.source.fname(q,:)]); 
end 

text (irdata.head.x, irdata.head.y,['\left arrow ' irdata.head.name]); 

The above calculations were made so as to be able to know the way the components will be able to fit into the arrays meant for each one of them. The picture below shows the illustration above graphically and how they will be in reality when they are fully constructed.

A picture of the room and the set up is shown below. The linear uniform 22-channel microphone array is placed close to the north wall of the varechoic chamber in front of the pink fiber glass pillow. More pictures can be seen here.
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In this data we have impulse responses measured from 31 loudspeaker positions to all the microphones. In this subset of data the percentage of open panels on the walls of the chamber was 89% which corresponds to a T60 reverberation time of 0.28 seconds. The positions are illustrated below in a figure which was produced in Mat lab using the script var89.m. This script also gives detailed locations of loudspeakers and microphones in millimeters so that the origin is north-west floor corner of the chamber and also tell more about transducers used in the measurement.

All impulse responses were computed using a logarithmic sweep excitation (65536 samples) at the sampling rate of 48 kHz. Impulse responses are stored as 22-channel WAVE files. The whole set of 31 22-ch.

• On the left, we see some of the cables. The Tascam pre-amplifiers are placed in a rack behind the Huron.
• The varechoic chamber is controlled using a graphical user interface shown above. Notice the arrays on the system which enable the operator to know what to do at a specific time.

![Varechoic Chamber Interface](image1)

• In the varechoic chamber the microphone array is placed close to the north wall. The fiber glass absorber is placed behind the array. At front we see one of the measurement loudspeakers (Genelec 1030a).

![Varechoic Chamber Setup](image2)

• A closer look at the array, microphone elements are attached to the bar using a plastic ring and they are facing downwards. The microphones are Omni-
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directional, but this placement may make some difference at very high frequencies.

- A picture taken from the north-west corner of the varechoic chamber. Notice the door which was kept open during all measurements.

- A typical HRTF measurement. Picture from the door. Loudspeaker (Genelec 1030a) in position va17.
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• *A HRTF measurement - A picture taken from the south-west corner.*

• *A HRTF measurement - A picture taken from the north-east corner.*
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- *A picture taken close to the ceiling by the south wall. See white markings on the floor which indicate the measurement points.*

![Image of measurements](image1.jpg)

- *An open panel (left) and a closed panel (right).*

![Open vs Closed Panel](image2.jpg)