THE PHONETICS AND LINGUISTICS ANECHOIC ROOM

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1. Introduction

Although speech is ordinarily produced and perceived in noisy and reverberant environments, its complete study requires the availability of echo-free low-noise enclosures. Our Anechoic Low-Noise room was first commissioned in 1948. It consists of a sound isolated chamber with an adjacent control room that contains associated recording and computing equipment. With age the chamber had been gradually deteriorating, principally from the disintegration of the glass-fibre wedges that lined the interior of the chamber. The Wolfson Foundation provided an initial grant for the refurbishment of the facility. A subsequent plan to construct an electricity sub-station adjacent to the chamber increased the extent of the work needed. It became necessary to guard against possible magnetic and acoustic interference, but ironically this has allowed further improvements to be made than were originally possible.

2. Original Construction

The outer walls of the chamber and control room were constructed of brick of 330mm thickness. The constructionally separate chamber area was formed from brieze block walls separated from the outer walls by a cavity approximately 150mm wide. The door into the chamber was sand-filled to provide good attenuation, but its heavy weight had resulted in damage to the door fixings and affected its alignment in the door frame. Inside the chamber a wheeled trolley containing a set of glass-fibre wedges had to be pushed forward to gain entry. All the inner surfaces of the chamber were lined with wedges, fitted in a compressed paper board framework mounted on wooden battens. The walls and ceilings were lined with 200mm*200mm*600mm wedges and the floor with 200mm*200mm*480mm wedges. Above the floor wedges was a gridded working area constructed from 600mm*450mm removable panels. These had a large 50mm grid size to minimise reflections. The only means of ventilating the chamber was to leave the door open sufficiently long for acceptable air exchange to take place. In use, the sound pressure due to outside levels was below the threshold of hearing and the inverse square law was maintained to 90 Hz.

2.1 Measurements

One of the primary concerns when planning the refurbishment was to ensure that

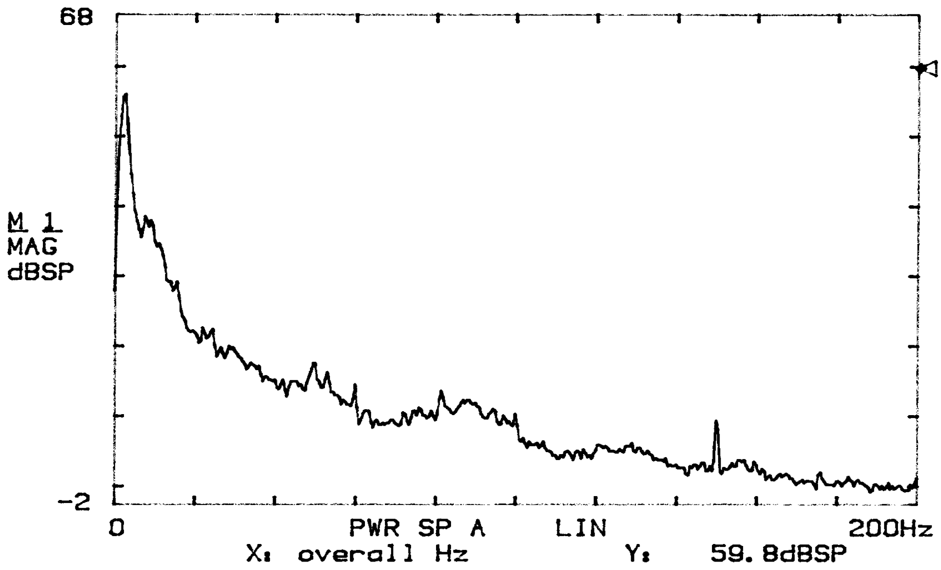

Figure 1a
Plot showing the noise floor of the Anechoic Chamber before the refurbishment measured at 9.30a.m.

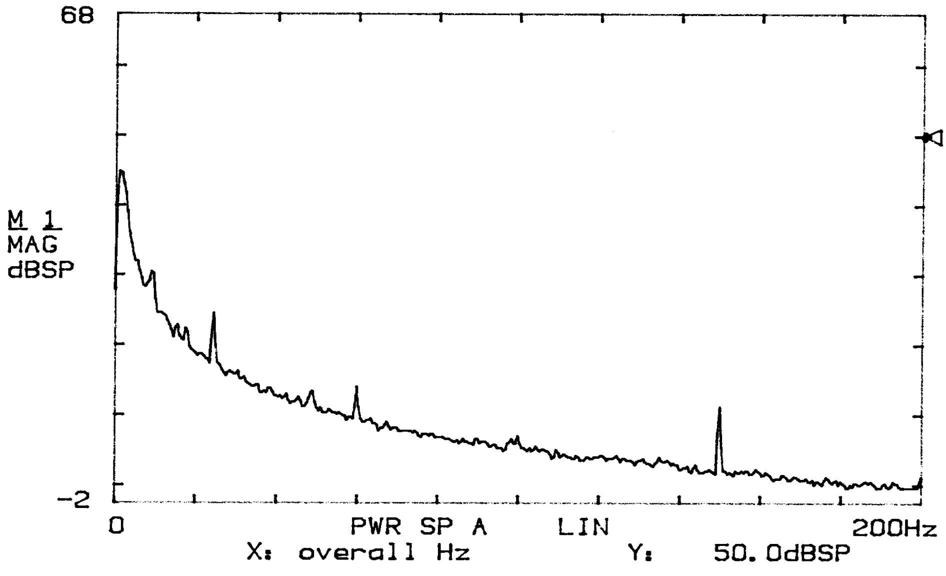

Figure 1b
Plot showing the noise floor of the Anechoic Chamber before the refurbishment measured at 3.00a.m.

the acoustic performance of the room was maintained or bettered. Measurements were therefore made of the noise and reverberation characteristics prior to the refurbishment. Figures 1a and 1b show the averaged noise spectrums at 9.30a.m. and 3.00a.m respectively during the working week. These measurements were made using a Bruel&Kjaer Measurement Amplifier type 2610, fitted with a Pre-amplifier type 2619, and Microphone cartridge type 4134. The increasing noise with decreasing frequency is to be expected due to the Acoustic Mass Law. Figure 1b shows the maximum level is approximately 10dB less during the quiet part of the night. Because a large amount of the noise energy is below 30Hz, high pass filtering of speech recordings can give a useful improvement in signal to noise ratio without significant distortion. If the filtering can be applied after recording, then a technique (Nevard,1990) in which the data is applied both forwards and backwards to the filter, can be used to eliminate phase distortion. The reverberation time measured from the response to an impulsive noise (Figure 2) is approximately 20mS.

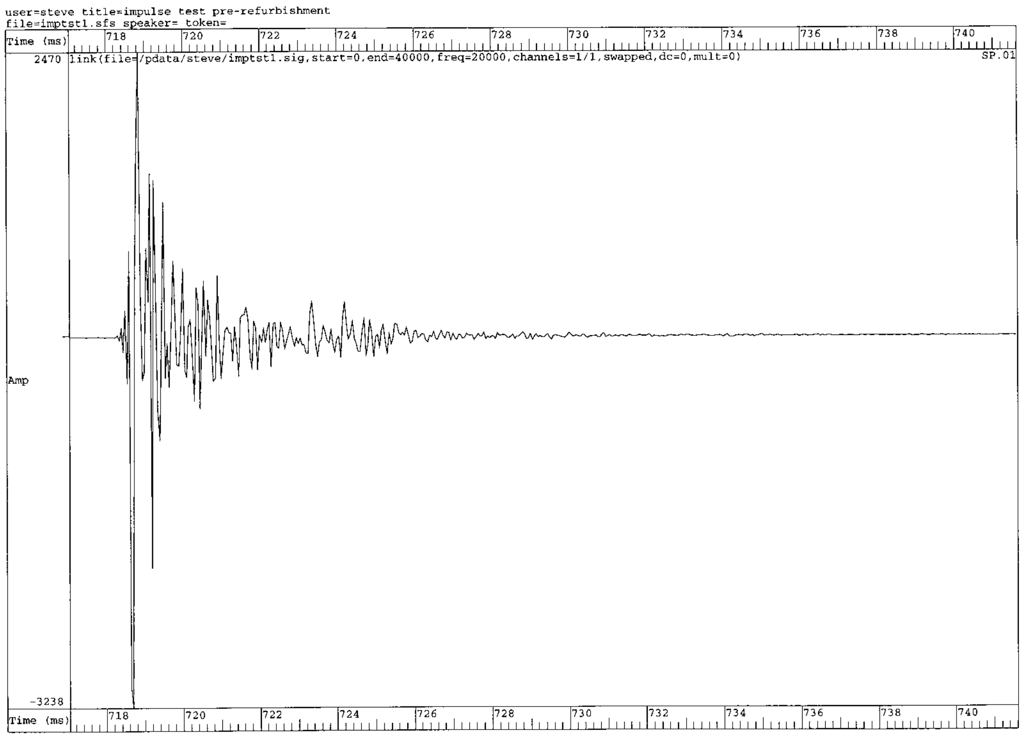

Figure 2
Plot showing the response to an impulsive sound measured before the refurbishment**.**

3. The Refurbishment

Originally, the proposed refurbishment consisted of replacing the door into the chamber, installing air-conditioning, renovating the floor grill and wedge trolley and renewing the glass-fibre wedges and their framework. The replacement wedges were to be of similar size to the original wedges to maintain the reverberation characteristics of the room.

3.1 The Transformer Sub-Station

However, shortly before this work was due to commence the department was informed that an electricity sub-station was to be built adjacent to the Anechoic Room. We were concerned about transformer acoustic noise and vibration and the magnetic fields generated by the transformers, switchgear and associated cabling. To ensure that sufficient precautions were taken to minimise effects within the chamber several actions were taken.

3.11 Acoustic Precautions

A study was carried out (Sound Attenuators Limited,1991) to measure existing noise and vibration levels at the Anechoic Chamber and levels at four London Electricity Board installations. The architects for the new sub-station were then advised on the necessary measures to ensure there would be no interference to the operation of the anechoic chamber. These were the fitting of sound absorbent material to the internal surfaces of the transformer building, the use of air inlet and air discharge acoustic louvres, the use of a 46dB-attenuation acoustic door, and the use of low-noise transformers fitted on anti-vibration mounts. In addition to these measures taken in the sub-station it was decided to incorporate a floating floor within the anechoic chamber. This would give additional immunity to sub-station vibration and also further reduce noise from other sources such as tube trains, building works, etc (the plan to build a new underground railway passing under U.C.L. was an additional reason for this expensive choice of construction).

3.12 Magnetic Precautions

Secondly measurements of the existing magnetic fields in the chamber were made by the London Electricity Board. The field strength in the usual working area of the chamber, with normal equipment switched on, was found to be 0.6 milligauss. A test was carried out to measure the effect of a 3-phase cabling run round the outside of the chamber. The phase currents were between 40A and 80A. These levels were much less than the anticipated (2000 A) current levels in the proposed transformer chamber. The magnetic field strength was remeasured and found to have increased to 16 milligauss. Also measurements were made to determine the effect on a microphone (Shure SM10A) known to be susceptible to magnetic fields. This microphone had been used in the collection of data for the PRE-SCRIBE project and was commonly used in speech recognisers in acoustically noisy environments.

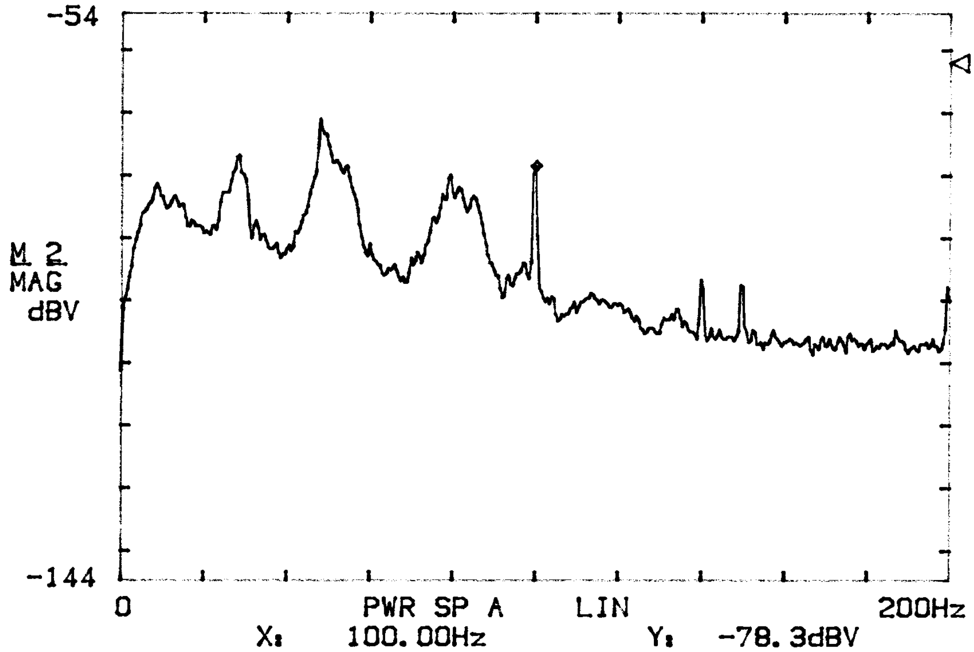

Figure 3a
Plot showing noise floor of microphone SM10A before 3-phase cable connected.

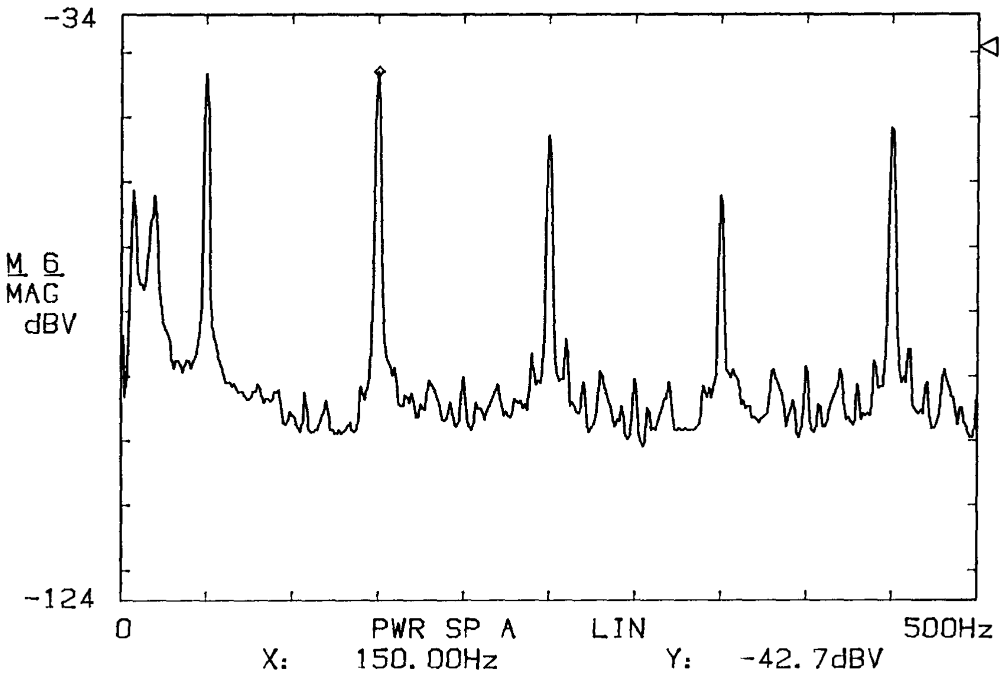

Figure 3b
Plot showing noise floor of microphone SM10A after 3-phase cable connected.

Figure 3a shows the noise floor for this microphone before the 3-phase cable was connected and Figure 3b shows the noise floor after the cable was connected. These tests clearly demonstrated the vulnerability of the inside of the anechoic chamber to external magnetic fields. Therefore a study was carried out (EMC Consultants Limited,1992) to calculate the expected field strengths and recommend necessary precautions to ensure that the field strength in the chamber from sub-station leakage was less than 0.5 milligauss. The recommended solution was to include a magnetic shield within the anechoic chamber providing a minimum attenuation of 24.6dB and modify the planned routing of the sub-station power cables.

3.2 New Construction

The refurbishment was therefore modified to include the above recommendations. The floating floor was designed to have a resonant frequency of 9-10 Hz. This resulted in a raised floor level with a more convenient flat configuration compared to the two levels in the original design. A new inner room was mounted on the floating floor, isolated from the outer walls of the chamber. The walls and ceiling of the inner room were constructed from glass-fibre filled metallic acoustic-enclosure panels (A.E.X. panels) and the floor covered with metal panels. This gave a Faraday cage construction providing electrostatic and some (3dB) electromagnetic screening. The remaining required attenuation to magnetic fields of 21.6dB (rounded to 22dB) was provided by a magnetic shield constructed from four thicknesses of staggered 3mm thick steel plates mounted between the brieze block wall and the A.E.X. panels on the whole of the side of the chamber (North Side) nearest the sub-station, and partially on the East and West sides. In addition on three faces of the chamber 1.2m coils have been mounted. These allow the possibility of generating cancelling magnetic fields in the chamber if desired. The door arrangement into the chamber was redesigned, replacing the rather cumbersome wheeled trolley. The new arrangement consisted of three hinged doors - a door in the outer wall, a door in the A.E.X. panels, and a door that housed the set of wedges to fill the door space. Air conditioning was added to the chamber. The system was designed with very low air velocity to minimise noise generation within the ducts although generally the air conditioning would be switched off during the course of a recording. In addition motorised double dampers were included in both the inlet and outlet ducts. These could be operated to shut the ducts to prevent external noise from entering the chamber. Mounted in the ceiling were "Unistrut" rails to allow the suspension of monitors, microphones, etc. The connector panels between the control room and the chamber were improved to allow a greater number and diversity of signals to be routed. Sand filled bags (pugging bags) were used behind the panels to maintain the acoustic attenuation in this area.

3.3 Measurements

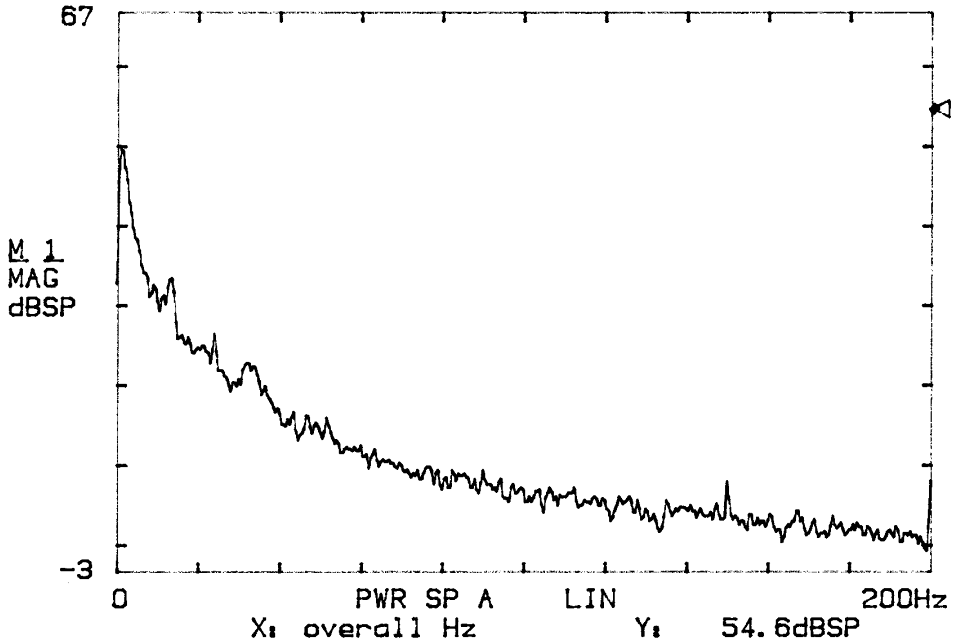

Figure 4a
Plot showing the noise floor of the Anechoic Chamber after the refurbishment, measured at 5.30 p.m, with air conditioning switched off.

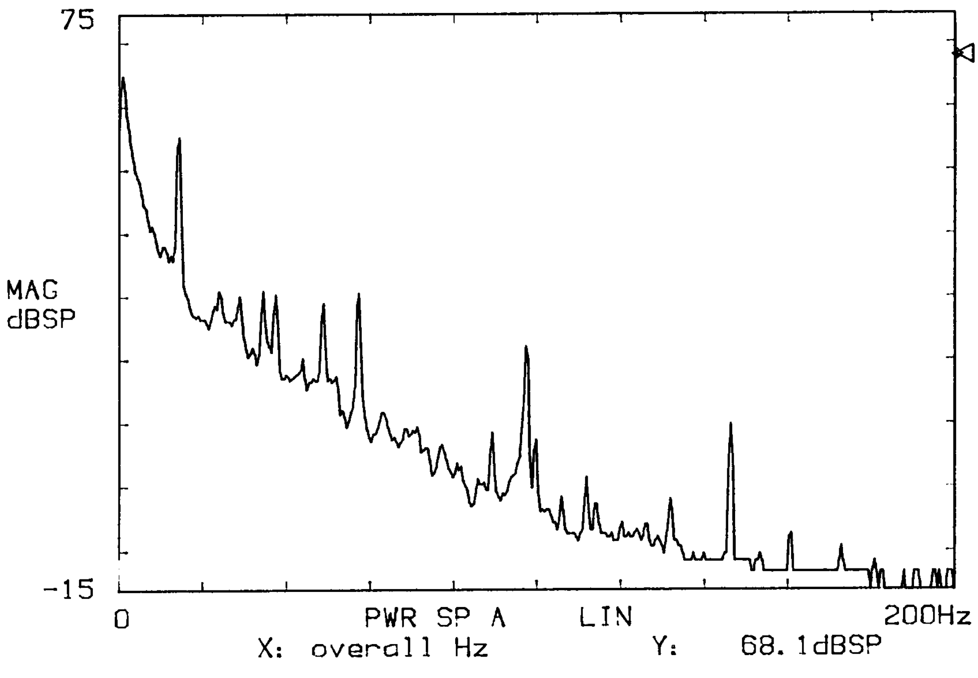

Figure 4b
Plot showing the noise floor of the Anechoic Chamber after the refurbishment with air conditioning switched on.

After the refurbishment was completed a number of measurements were made. The noise floor of the chamber with air conditioning off and ducts closed (recommended state for recording) was remeasured and is shown in Figure 4a. The result is very similar to that of Figure 1a showing no degradation due to the refurbishment. The noise floor with the air conditioning switched on, ducts open and cooling fan rotating (worst case conditions) is shown in Figure 4b. This measurementwas made using a Bruek&Kjaer Type 2231 Sound Level Meter, fitted with a Type 4165 Microphone Cartridge. The response to an impulsive noise was remeasured and is shown in Figure 5. The reverberation time is approximately 20mS and is similar to the value obtained previously.

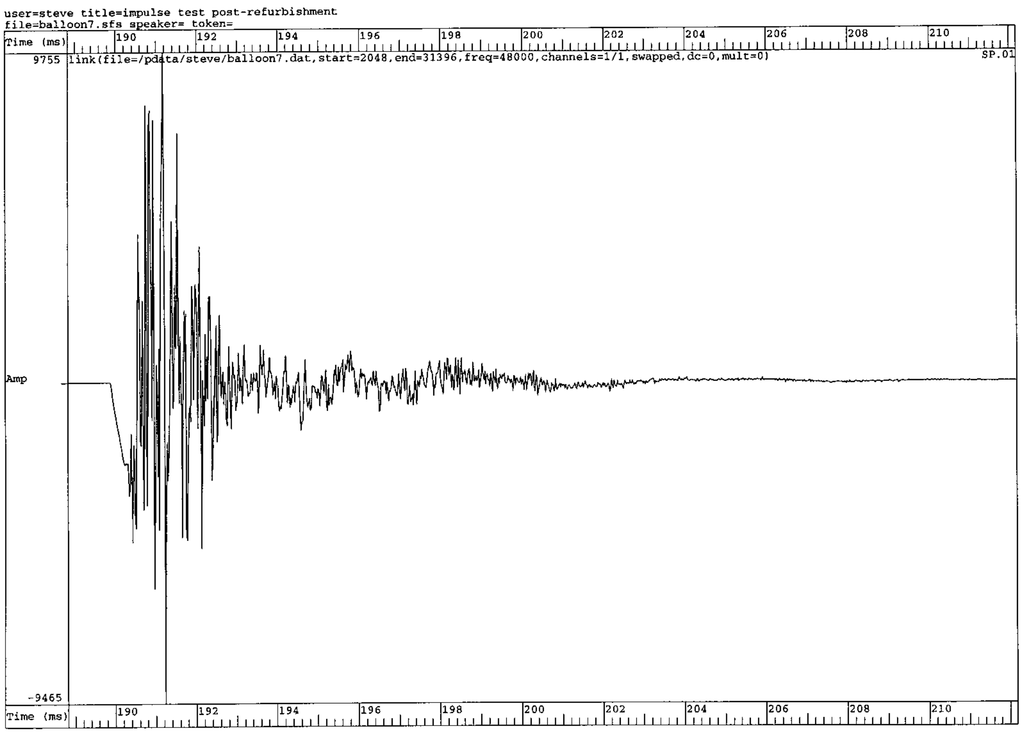

Figure 5
Plot showing the response to an impulsive sound measured after the refurbishment.

EMC Consultants Ltd returned and carried out tests to determine the degree of attenuation provided by the magnetic shield. Measurements were made at a number of positions along the shield and the specified minimum attenuation level of 22dB was met at all locations. At the edges of the shield the attenuation was 31dB, but at all other locations was between 39dB and 41dB. Additionally with the sub-station operational, the Shure SM10A microphone was placed in the Anechoic Chamber and its output examined for evidence of magnetic interference. This is shown in Figure 7. When compared with the pre-refurbishment measurement of Figure 3a the largest 50Hz related component (100Hz) is smaller in the post-refurbishment measurement, therefore showing that no significant leakage into the chamber exists at present.

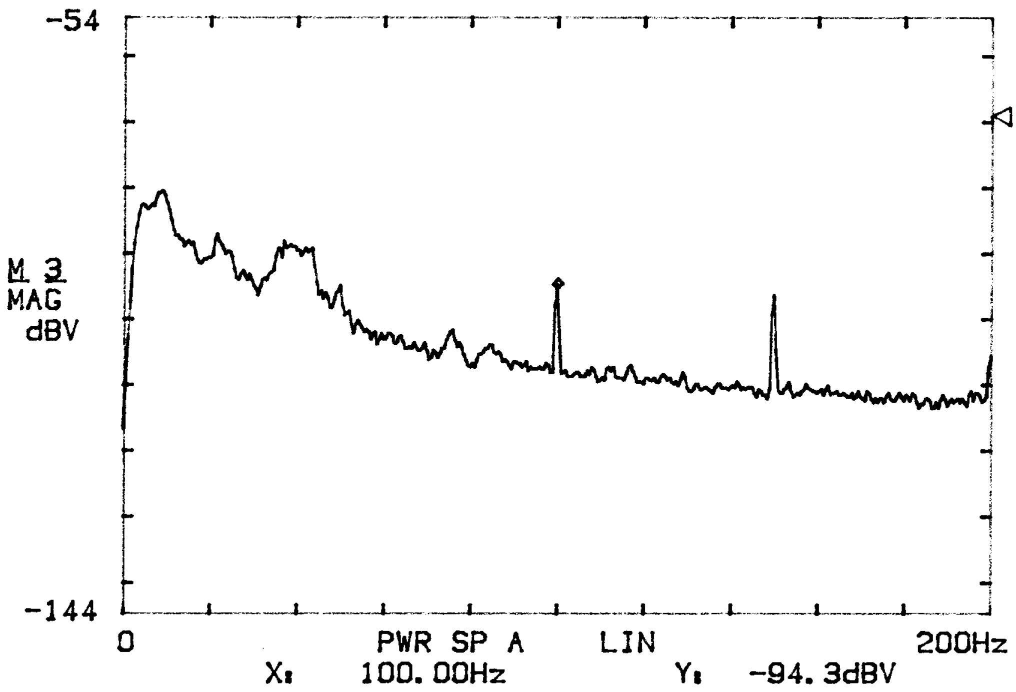

Figure 6
Plot showing the noise floor of microphone SM10A with sub-station operational.

4. Recording Facilities

The control room has been equipped with a range of instrumentation and new Sun and PC computers. This allows multi-channel recording to digital tape recorder or direct to computer hard disc. Extensive computing resources allow rapid processing of data and include a CDROM production facility. The room has been linked to the college computer network to allow rapid transfer of data to other sites and our separate laboratories in Wolfson House.

5. Acknowledgements

We would like to express our thanks to the Wolfson Foundation not only for their financial support but also for their patience during a difficult period. Finally, also, we would like to thank the Provost, Dr Derek Roberts, for the additional support which has led to such an important improvement in U.C.L. and national resources in spoken language research and engineering.

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