Department of Electrical and Computer Systems Engineering

Technical Report MECSE-18-2006

STI Building Screened Room-Testing for Attenuation

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Measurement of the Electromagnetic Screening Effectiveness of the New Screened Room in the STI Building at Monash University

S Jenvey 11-07-06

STI Screened-Room Testing

1. Background

   A new screened-room is being built as part of a transformer testing facility in the Science, Technology and Innovation (STI) building, located beside the ECSE high voltage laboratory. There are already two existing screened rooms used for transformer testing, an older one in the high voltage laboratory and a newer one in building 35 (the EPRI screened room).

   This new screened room in the STI building is to replace (or augment) the existing older screened room located inside the high voltage laboratory. The older room has been deemed inadequate for current requirements.

   The interior of the new screened room in the STI building, is to be electromagnetically isolated from the outside world. To achieve this isolation the screened room is completely lined with aluminium panels. The joints between adjacent panels overlap by 100 mm and are spot welded to each other every 50 mm along the seam between them (Fig. 1).

Figure 1. Inside the STI screened room during construction.
Note the welded seams between the adjacent aluminium lining panels.

   This report presents the results of a measurement program, undertaken by S Jenvey, E Lim and I Reynolds in June/July 2006, which measured the degree of electromagnetic screening provided by aluminium lining of the new screened room.

2. Frequencies for Measuring the Attenuation Provided by the Room Screening

   The screening effectiveness (attenuation) of the room lining was to be measured using a standard technique at frequencies of 10 kHz, 100 kHz, 1 MHz and 10 MHz. Interference during calibration at 1 MHz from AM radio stations required the measurement frequency of 1 MHz to be changed to 900 kHz.

3. <u>Testing and the Relevant Standard</u>

   i. The relevant standard for testing screened rooms such as this one with internal dimensions greater than 2m×2m×2m is IEEE Std 299-1997. (Ref 1.)

   ii. IEEE Std 299 describes a measurement procedure to be used to determine if a screened-room has a shielding effectiveness greater than a specified level (measured in dB). It is a go/no-go test. However in this case the tests described in IEEE Std 299 are used to determine the value of the shielding effectiveness, the attenuation in dB, of the ECSE screened room rather than to conduct a go/no-go test.

   iii. The test basically calls for measuring the signal loss (|S12|) between two copolarised, 30 cm diameter loop antennas separated by two loop diameters plus the thickness of the wall of the shielded room.

      a) The reference loss is first measured between loops with the loops correctly oriented and separated by the requisite distance but with no wall between them.
      b) The loss in the room is measured by repeating the above measurement but this time with the loops either side of the wall being measured. The loops are kept with the same orientation and separation as in the calibration.
      c) The attenuation provided by the room screening is the difference between the loss measured in the room and the reference loss
      d) IEEE Std 299 calls for the attenuation measurements to be taken at the joints between the aluminium sheets used to line the room and around the gap between the room door and the door jam.

4. <u>Room Geometry, Measurement Access and Restrictions</u>

The new screened-room is one level above the ground in the STI building and this building abuts the ECSE high voltage laboratory. Because of the screened room's location it is not practical to perform the tests as detailed in IEEE Std 299 along the seams between all the aluminium panels covering the screened room's walls, ceiling and floor. Measurements could only be taken at panel joints where access was available to both the inside and outside of the room. Some panel joints inside the room were obstructed by large fittings such as the air conditioning while access to the outside of the screened room was limited. A reduced set of measurements at the locations described below had to suffice. The measurement locations were

   a) on the north wall, accessed outside the screened room using the builder's scaffolding (Fig 2)
   b) the east wall of the screened room, accessed outside the screened room but internal to the STI facility, using a scissor lift (Fig 3)
   c) the floor of the screened room, accessed outside the screened room but inside the STI building, using a ladder in the room under the screened room
   d) the screened room door (in the east wall), accessed from outside the screened room from the stairs and landing (Fig 4)

Figure 2. The outside of the STI screened room during attenuation testing. Accessed via the builder’s scaffolding, the light shows the measurement equipment outside the screened room.

Figure 3. On a scissor lift one floor up, measuring outside the east wall of the screened room, inside the STI building.

Figure 4. Measuring attenuation around the screened room door from the stair landing

5. <u>Equipment and Equipment Setup</u>

i. Calibration

Attenuation calibration was done in an obstruction free area on the roof of Building 35 and in room 215 of Building 35.

Figure 5. Calibrating the loop antennas.

The loop antennas were mounted on tripods and set to be copolar and at the required distance apart. One loop was sinusoidally driven at the required frequency by a BWD 604 Minilab function generator connected through its internal power amplifier. The signal level was measured by a CRO in parallel with the loop. The receiving loop was connected to an HP 8591E spectrum analyzer set to the appropriate frequency and a 1 kHz bandwidth. The received signal level was measured in dBm.

For the 10 kHz measurement an additional audio amplifier, set to a fixed gain, was placed between the receiving loop and the spectrum analyzer. This was to keep the received signal well above the spectrum analyzer noise floor of around -65 dBm.

ii. Room measurement

The attenuation of the screened room was measured at twelve locations, numbered A1-A12, with the signal source and transmitting loop inside the room (see Figure 6) and the receiving loop and spectrum analyzer outside of the screened room. The antennas were copolar and separated by the same distance as used in the calibration.

The measurement locations were chosen to be where electromagnetic leakage was most likely, i.e. at the seams between aluminium panels (where they were accessible) and around the door seal (as recommended in IEEE Std 299). Other seams in the room cladding and the penetrations around the air conditioning and the gas inlet were obstructed and so could not be tested.

The final seals have not yet been fitted to the door and its jam so it was tested in a closed state with the gaps between the door and the door jam sealed over with three inch wide copper tape.

The measuring loop antennas were oriented with the plane of the loop normal to the door or wall and orthogonal to the wall panel seams or the gap between the door and the door jam.

Locations A1-A12 within the STI room where the wall attenuation was measured

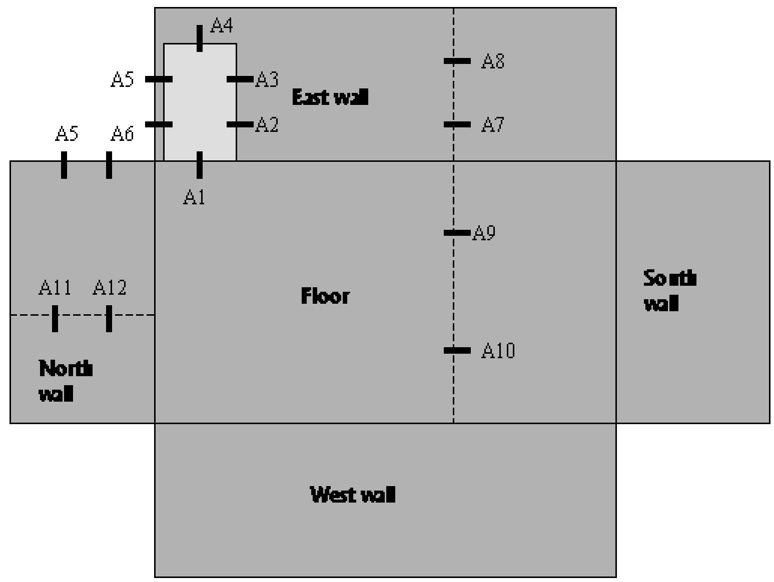

Figure 6.

6. Results
The attenuation derived for the twelve locations at the four frequencies are given in the table below. An expanded version of this table which includes the calibration data and the actual signal levels measured is in Appendix 1.

1/7/2006	Atten.	in dB										
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
10 kHz	10	16.2	20.4	20.2	23.7	24.7	>49.7	>41.3	>41.3	>41.3	>41.3	>41.3
100 kHz	19.5	26.3	28.3	27.3	33.3	33.3	>41.3	>41.3	40.3	>41.3	>41.3	>41.3
900 kHz	34.9	38.9	37.9	37.9	>40.9	>40.9	>40.9	>40.9	>40.9	>40.9	>40.9	>40.9
10 MHz	54.3	65.3	60.3	48.3	>69	>69	65.3	46.3	67.3	63.3	>69	>69

Table 1. Attenuation measured at the twelve locations at four frequencies.

7. Comparisons with the Attenuation Measured in the New EPRI Room
A similar screened room was recently constructed in Building 35 for EPRI testing of transformers. It is lined with copper and has its seams continuously soldered. Testing of the attenuation provided by the copper screening of that room produced the following results (Ref. 2)

Frequency	North Wall Atten dB	East wall Atten dB	South Wall Atten dB	Door closed, Atten dB	Door Sealed Atten dB
10 kHz	>31	>31	>31	31	42
1 MHz	>46	>46	>46	22	53
10 MHz	>66	54	>66	>66	>66

Table 2. EPRI room attenuation measured at four locations at three frequencies.

8. Conclusions

   i. There is significant electromagnetic leakage around the door (Locations A1-A6) even though the gap between the door and the door jam was covered with three inch wide copper tape. Fitting of EM seals such as beryllium- copper spring fingers is expected to significantly reduce this leakage.

   ii. At the spot welded seams between the aluminium panels (locations A7-A12) there is little EM leakage and the attenuation provided by the screening was measured as greater than 40 dB at each of the four frequencies. This level of attenuation should then apply to the room as a whole if the door seals are correctly fitted and any penetrations to the room such as evanescent waveguide ventilation ducts are properly specified and fitted.

   iii. Care should be taken in comparing measurements taken of the attenuation provided by the aluminium lining of the new STI screened room and that of the copper lining of the EPRI screened room.
   The figures for the attenuation in the EPRI room were measured with its door closed but unsealed (due to there being no ventilation in the room at the time of measurement) and so the typical attenuation is about 10 dB less than measured in the STI screened room. However when the EPRI room door was, for a limited time, sealed off with copper tape stuck over the gap between door and door jam the attenuation around the door increased by more than 10 dB. If the gap around the door was the primary EM leakage site then sealing the door with the copper tape could increase the general room attenuation by a similar amount thereby producing similar attenuation to that measured in the new STI screened room.

9. References

1. IEEE Std 299-1997
2 Technical Report MECSE-28-2004,
"EPRI Shielded Room Testing", S Jenvey 2004

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10. Appendix 1

STI Room	Attenuation Tests											
Calibration	Meeasurement	9/6/2006&1-7-06				Separation						
Frequency	Location	Tx Antenna	Zin Tx antenna	Rx Antenna	Zin Rx antenna	edge/edge mm	Vpp (Tx)	Rx dBm	Comments			
10 kHz	B35 roof & 35/	A4-3 turn	1+j0.46	A3 3 turn		400	4.3	13.7	After inclusion of Eric's 2 stage audio amp, ch B 8 ohms out			
100 kHz	B35 roof & 35/	A4-3 turn	1+j4.6			400	14	-38.7				
1 MHz	B35 roof & 35/	A4-3 turn	1+j46			400			Interference from broadcasters requires move to 900 kHz			
900 kHz	B35 roof & 35/	A4-3 turn				400	14	-39.1				
10 MHz	B35 roof & 35/	Untuned Sq Loop		Tuned (50%) Sq loop		400	20	-10.7	Noise floor around -80 dBm			
Room	Measurements	21-6-006										
Frequency	Location	Tx Antenna	Zin Tx antenna	Rx Antenna	Vpp (Tx)	Rx dB @ A1	Rx dB @ A2	Rx dB @ A3	Rx dB @ A4	Rx dB @ A5		
10 kHz	STI lab	A4-3 turn	1+j0.46	A3 3 turn	4.6	3.75	-2.5	-6.7	-6.5	-10		
100 kHz	STI lab	A4-3 turn	1+j4.6		13.5	-58.2	-65	-67	-66	-72		
1 MHz	STI lab	A4-3 turn	1+j46		14							
900 kHz	STI lab	A4-3 turn			14	-74	-78	-77	-77	<-80		
10 MHz	STI lab	Untuned Sq Loop		Tuned (50%) S	17.8	-65	-76	-71	-59	<-80		
Room	Measurements	21-6-006										
Frequency	Location	Tx Antenna	Zin Tx antenna	Rx Antenna	Vpp (Tx)	Rx dB @ A6	Rx dB @ A7	Rx dB @ A8	Rx dB @ A9	Rx dB @ A10	Rx dB @ A11	Rx dB @ A12
10 kHz	STI lab	A4-3 turn	1+j0.46	A3 3 turn	4.6	-11	<-36	<-36	<-36	<-36	<-36	<-36
100 kHz	STI lab	A4-3 turn	1+j4.6		13.5	-72	<-80	<-80	-79	<-80	<-80	<-80
1 MHz	STI lab	A4-3 turn	1+j46		14							
900 kHz	STI lab	A4-3 turn			14	<-80	<-80	<-80	<-80	<-80	<-80	<-80
10 MHz	STI lab	Untuned Sq Loop		Tuned (50%) S	17.8	<-80	-76	-57	-78	-74	<-80	<-80
Room	Attenuation	1/7/2006										
Frequency	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
10 kHz	10	16.2	20.4	20.2	23.7	24.7	>49.7	>41.3	>41.3	>41.3	>41.3	>41.3
100 kHz	19.5	26.3	28.3	27.3	33.3	33.3	>41.3	>41.3	40.3	>41.3	>41.3	>41.3
1 MHz												
900 kHz	34.9	38.9	37.9	37.9	>40.9	>40.9	>40.9	>40.9	>40.9	>40.9	>40.9	>40.9
10 MHz	54.3	65.3	60.3	48.3	>69	>69	65.3	46.3	67.3	63.3	>69	>69
Room	Attenuation	1/7/2006										
Frequency	Comments											
10 kHz	Noise floor around -36 dBm											
100 kHz	Noise floor around -80 dBm											
1 MHz	Interference from broadcasters requires move to 900 kHz											
900 kHz	Noise floor around -80 dBm											
10 MHz	Noise floor around -80 dBm											