Conducted Emission Measurements of HPS1 TESLA 200VDC Power Supply II

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This report describes the conducted emission measurements performed on TESLA HPS1 200VDC power supply used in LVPS for TileCal. Presented measurements were carried out in LVPS production building 512 at CERN. They follow EMI emission test report measurements carried out by G.Blanchot in the ATLAS USA15 control room [1] on the TESLA power supplies. Presented results confirm 17MHz noise spectrum that is claimed to deteriorate the Liquid Argon calorimeter performance. Possible noise reduction is measured and proposed by using common mode ferrites on 200VDC cables.

Devices Used

• Rohde & Schwarz ESPI Test Receiver 9kHz – 3GHz
Spectrum Analyzer, see Figure 1.
- Maximum peak detection method used
- Measured frequency range 150kHz – 100MHz
- Step frequencies, resolution bandwidths, and meas.time used, see following Table 1.

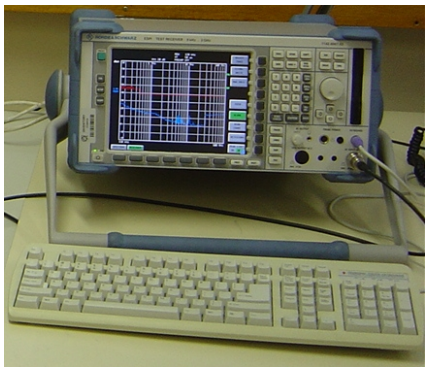


Figure 1.

	RANGE 1	RANGE 2	RANGE 3
Start	9 kHz	150 kHz	30 MHz
Stop	150 kHz	30 MHz	100 MHz
Step Size(A)	80 Hz	4 kHz	40 kHz
Res BW	200 Hz	9 kHz	120 kHz
Meas Time	200 ms	50 ms	50 ms
Auto Ranging	OFF	OFF	OFF
RF Attn	20 dB	20 dB	20 dB
Preamp	OFF	OFF	OFF
Auto Preamp	OFF	OFF	OFF

• Calibrated Current Probe ETS-Lindgren, model 91550-1L, EMC Test Systems Inc, USA

Figure 2.

• TESLA HPS1 3channel 200VDC/8.5A power supply, ID 20LLFZUPB00007, 2006/4 [2].

Figure 3. Tested HPS1 power supply front panel view.

• Three resistive loads of 750W/1.5kW built from Honeywell heaters with cooling ventilators

Figure 4.

Measurement Setup

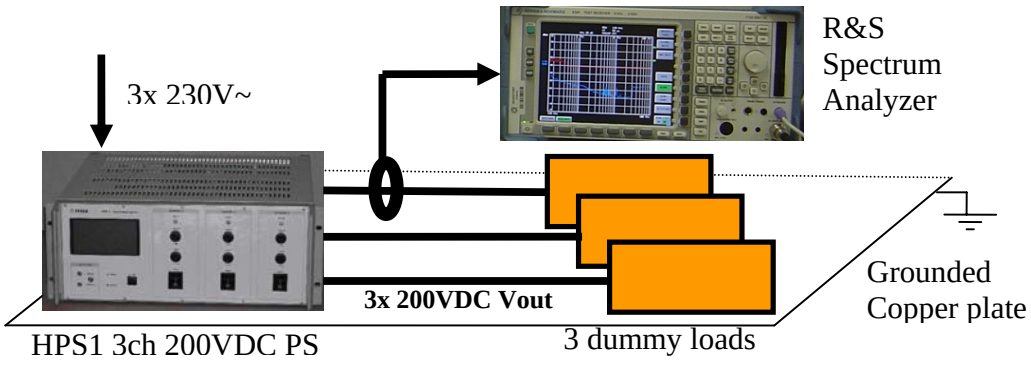
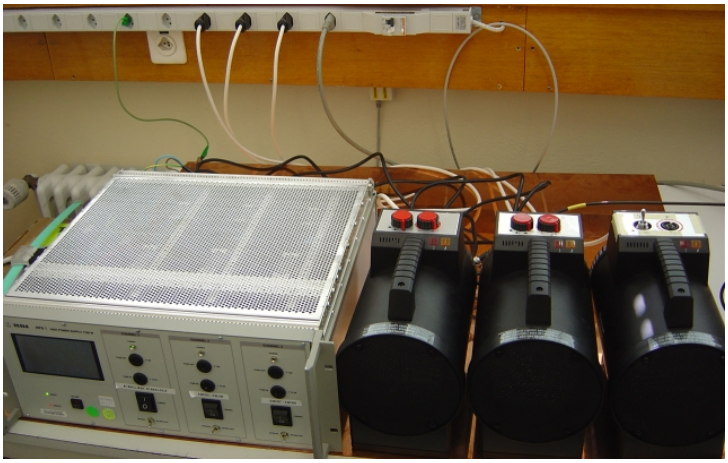


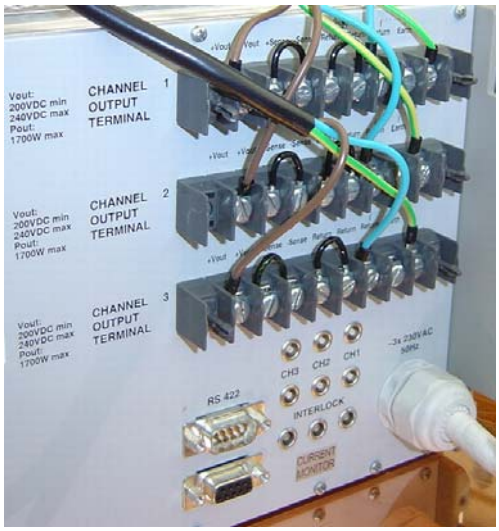
Figure 5.

The measurement setup is shown in Figure 5 above. Three HPS1 200VDC power supply outputs are connected to three resistive dummy loads by using 1m (not shielded) three wire cables (positive, return, and yellow/green dummy load chassis connection. Each dummy loads will simulate real 200V load (~750W) of four finger LVBOXes connected to the HPS1. Each 200V channel of the TESLA power supply can have three states: switched OFF, switched ON (STBY mode), and output enable (200V ON).

The measurement setup photos are shown in Figures 6(a-d). No EMI emission differences were observed between configurations 6(a) and 6(d).

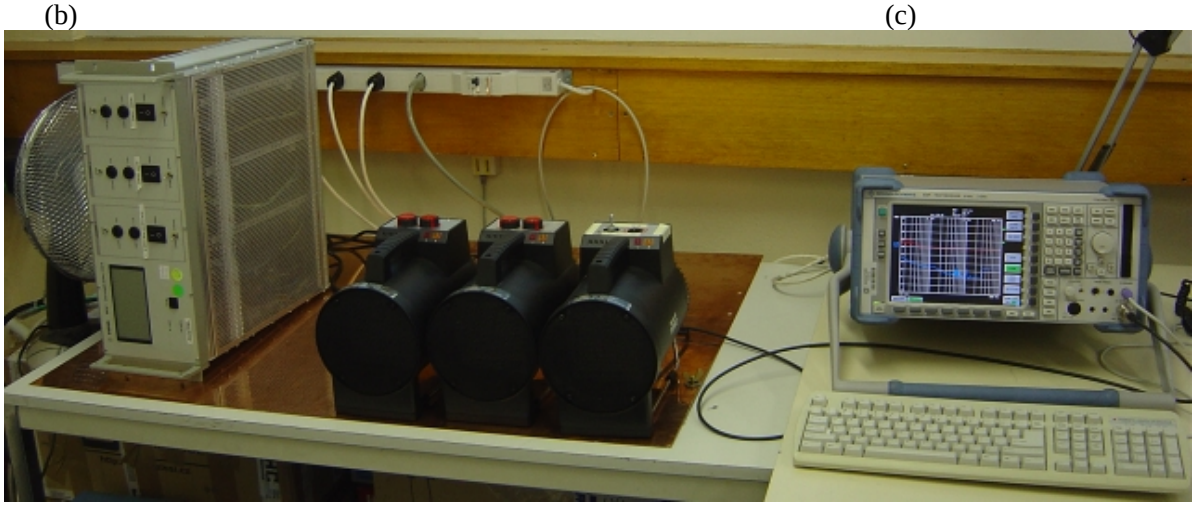


(a)



(b)

(c)



(d)

Figure 6. Measurement setup photos: Initial configuration with HPS1 in horizontal position sitting on a copper grounded plate (a), detail of 200VDC Vout cable connections - brown wire Vout+, blue Vout-, yellow/green wire connected to Earth pin (b), detail of the current probe that is measuring the common mode conducted emission spectrum of one Vout cable (c), and final measurement setup with HPS1 in a vertical position for better instrument cooling (d).

The maximum admissible common mode currents from the tested interconnecting cables (shielding included) for the ATLAS experiment [1] is listed in Table 2. They were obtained from maximum emission voltage limits of the CISPR11 IEC standard assuming 50 ohms connected load.

Table 2. The ATLAS EMI conducted emission limits.

Range	9 kHz to 500 kHz	500 kHz to 100 MHz
Limit	45 dBµA	39 dBµA

Measurement Results

Several configurations of the EMI conducted emissions are measured (150kHz -100MHz range):

- All HPS1 channels are switched OFF, initial measurements.
- First channel is switched ON (STBY mode).
- First channel is switched ON and its output is enabled (200V ON). Main Measurements.
- Suppression of 17MHz peak noise by means of ferrites.
- First channel is 200V ON, other two channels are switched ON and 200V enabled (envisaged).

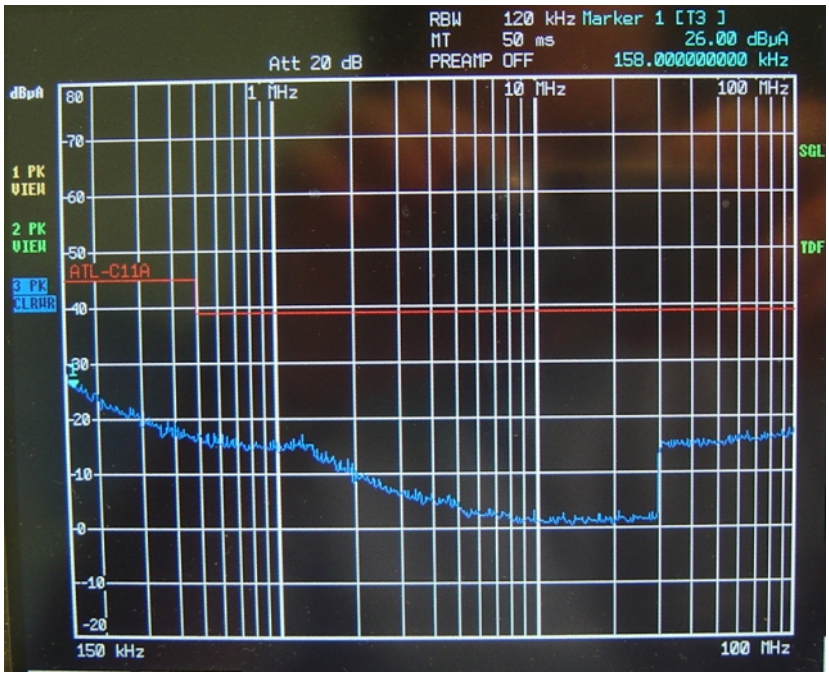


Figure 7. Initial measurements. Background conducted noise with the current probe on the air. All cooling ventilators for dummy loads and HPS1 are running; HPS1 itself is OFF. The observed increase at 30MHz is caused by wider frequency step and wider resolution BW of the spectrum analyzer, see Table 1. The red line is the ATLAS conducted emission limit, see also Table 2.

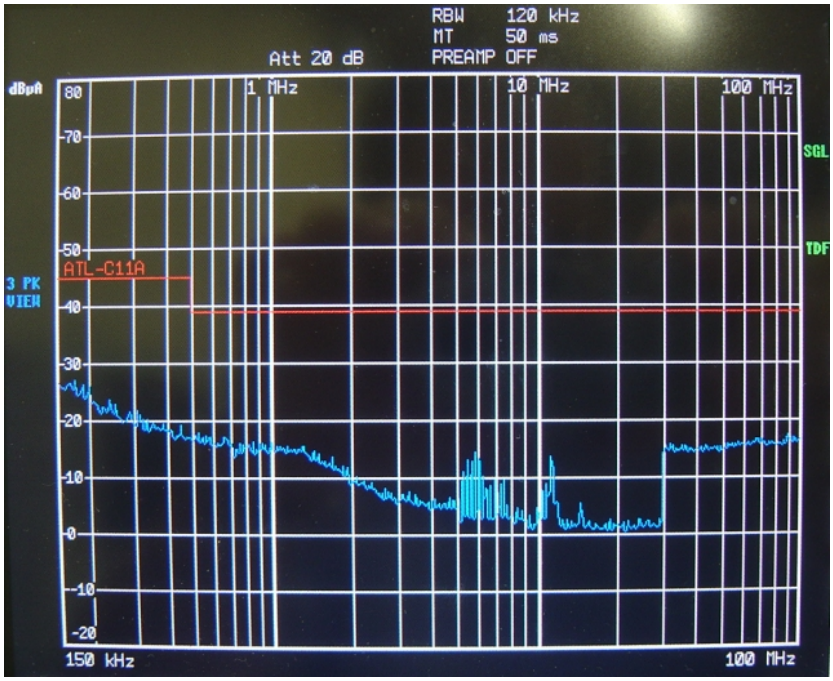


Figure 8. Initial measurements. Background noise of Vout channel 1 cable (1m long), all cooling ventilators and HPS1 power supply are OFF.

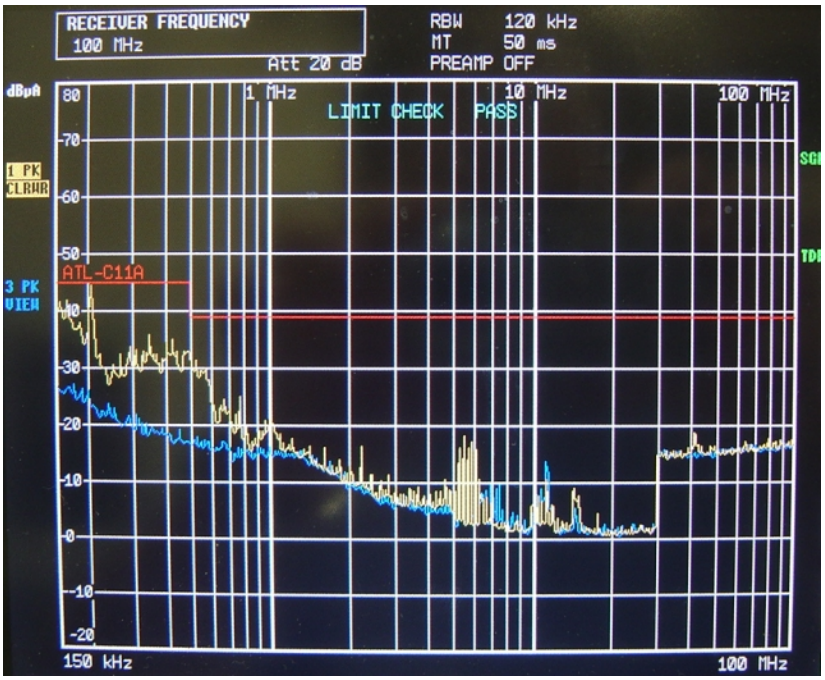


Figure 9. Initial measurements. Blue curve – previous conducted noise measurements of one meter Vout cable from Figure 8, Yellow curve – additional conducted noise created when all cooling ventilators are turned ON; the HPS1 power supply is still switched OFF.

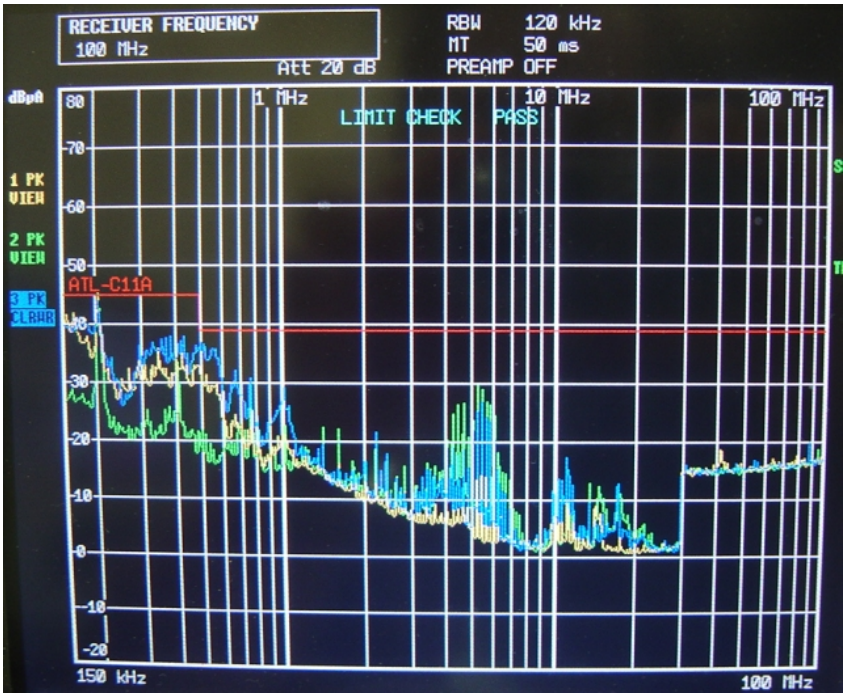


Figure 10. Initial measurements. Comparison of conducted noise measurements for three output channels, all cooling fans for dummy loads and HPS1 are ON, HPS1 power supply is still switched OFF. The Yellow curve - ch1 - as on previous Figure 9, Green curve - ch2, Blue curve presents ch3 cable spectrum, respectively. We can see spectral differences from channel to channel already at low frequencies 150kHz – 1MHz.

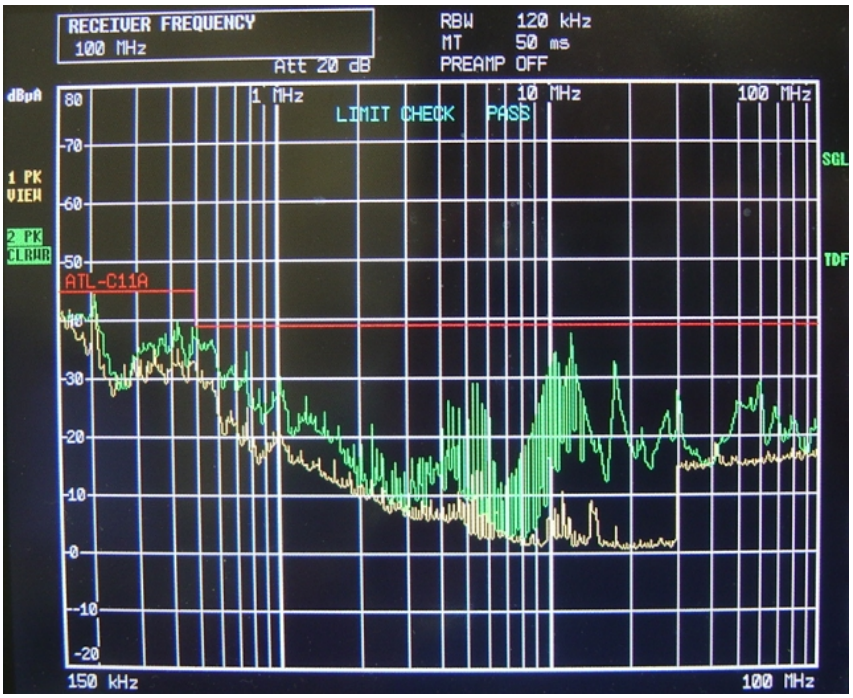


Figure 11. Measured 200V Vout channel at STBY regime. The yellow spectrum – HPS1 power supply ch1 is still switched OFF, all cooling ventilators are ON. The green curve –HPS1 is already ON in standby mode. We can already distinguish the 200kHz switching frequency peak of the DC/DC converter, as well as increasing spectrum at 7-30MHz. It is still below the ATLAS emission limits.

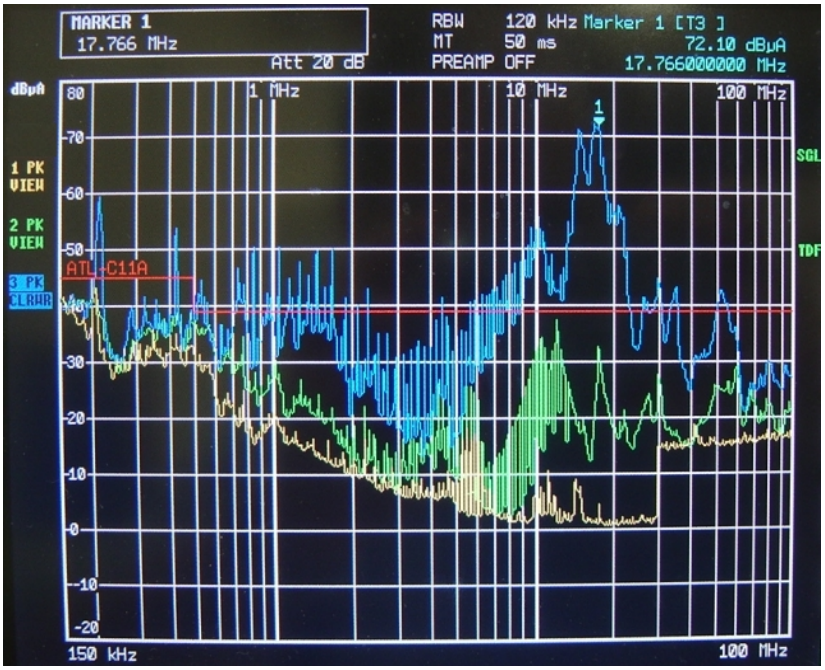


Figure 12. HPS1 ch1 is ON and loaded by an equivalent resistive load (blue curve). The power delivered to the dummy load is 737W. The yellow and green spectra are the same as from Figure 11. We see very high and disturbing peak at 17.7MHz (72.1 dBuA; compare to the ATLAS limit of 39dBuA) as well as increased spectrum from 6 to 22MHz.

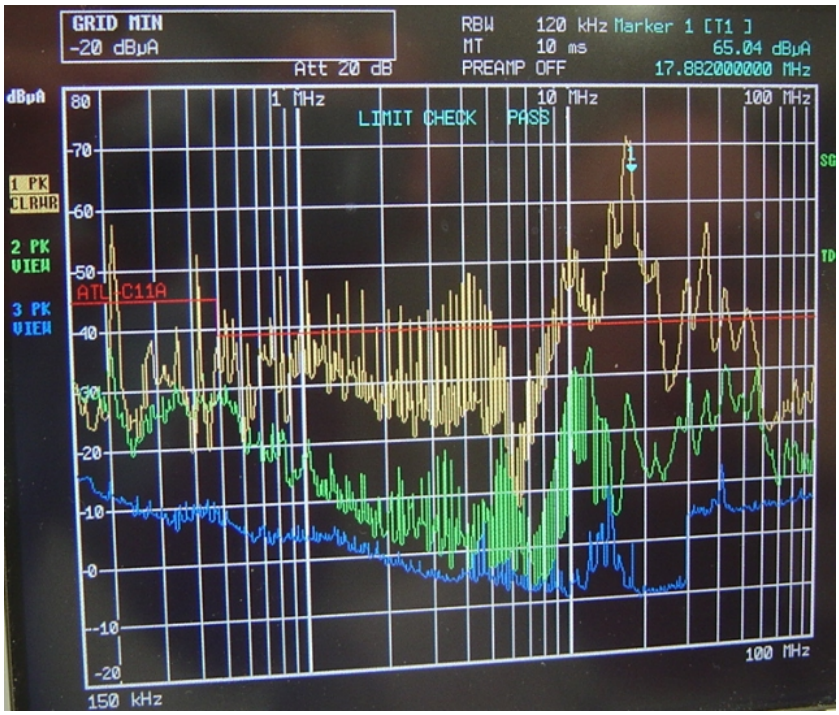


Figure 13. Repetitive measurements on HPS1 CH1 second day. HPS1 ch1 is ON and loaded by equivalent resistive load (yellow curve). The green spectrum corresponds to CH1 in STBY mode, and the blue spectra of CH1 when HPS1 is OFF. Comparing Figures 12 and 13 we can conclude almost identical spectral characteristics when HPS1 is ON or in STBY mode. Again we can see peak of 72dBuA at 17.7MHz. Contrary to this, a difference of min 10dBuA was observed between the background spectra the first and second day when HPS1 was switched OFF.

17MHz Spectrum reduction

A possible reduction of disturbing 17.7MHz common noise peak of 200VDC distribution cables can be using encircled ferrites close to the HPS1 noise source; Georges selected clips-able common mode suppression ferrites from Wuth Elektronik [3], see Figure 14(a-c). Results of several measurements with output ferrites are presented in Figure 15. Summary of measured maximum conducted common mode emissions is listed in Table 3.

(a) (b) (c)

Figure 14. Common mode suppression ferrites with appropriate diameter that enables 2times through ferrite configuration. Photos with one (a) or two (b) mounted ferrites on 200VDC Vout cable. Photo (c) demonstrates the original 200V cable with 2 ferrites setup proposed for the ATLAS USA15 tunnel.

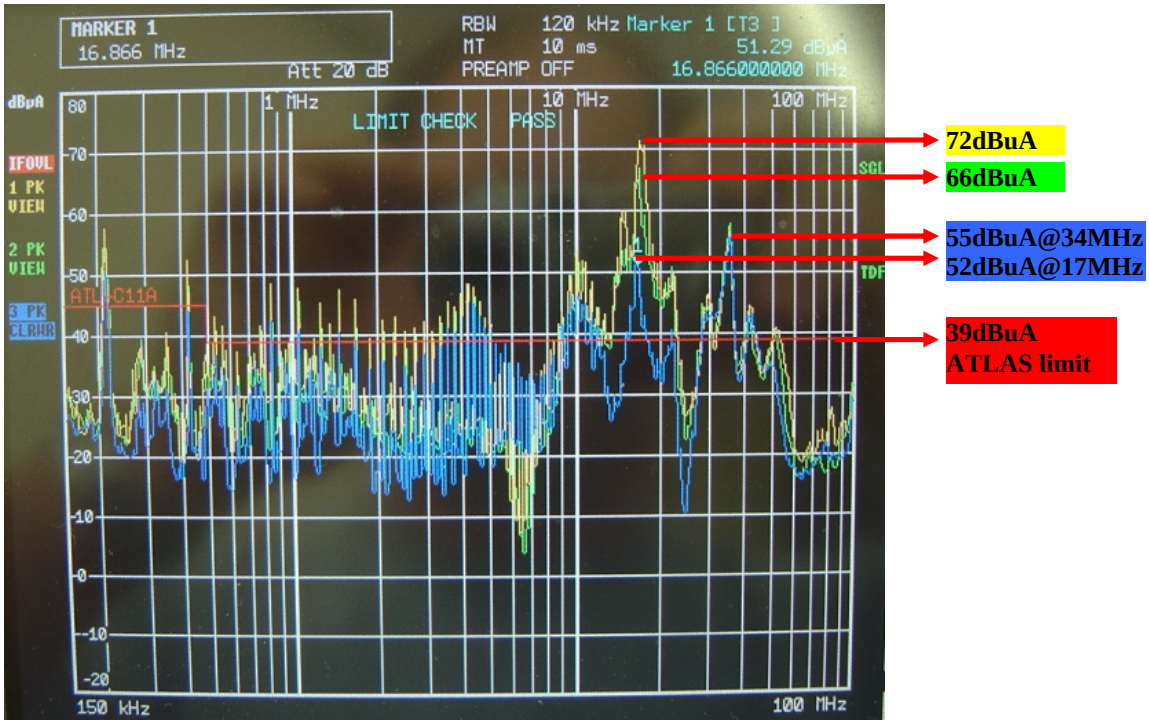


Figure 15. Comparative measurements of 17MHz peak suppression: without ferrites (yellow curve, the same as on Figure 13), with one ferrite (green curve), and with two ferrites mounted on 200V cable (blue spectrum). The HPS1 Vout conducted emission spectrum; ch1 is ON and loaded by resistive equivalent load.

Table 3. Summary of measured details from Figure 15.

Configuration	Max noise [dBuA]	@freq [MHz]	Comments
No Vout ferrites	**72**	**17.7**	Main sw freq 220kHz, 57dBuA
1 ferrite on Vout Fig14(a)	**66**	**17**	Main sw freq 220kHz, 55dBuA
2 ferrites on Vout Fig 14(b)	**52** **55**	**17** **34**	Main sw freq 220kHz, 52dBuA

The selected and measured two ferrites configuration from Figure 14(b) can reduce the 17MHz common current noise from 72dBuA down to 52dBuA. However, it is still 13dBuA more than the required ATLAS limit (39dBuA). Also its harmonic frequency 34MHz is not reduced with the chosen ferrites, as can be seen in Figure 15.

Conclusions

Conducted common current noise emission of HPS1 TESLA 200VDC power supply was measured. The results confirmed 17MHz peak noise as previously measured in the ATLAS USA15. It is very important for Liquid Argon detector electronics performance to find this source of noise (propagated through 200VDC cables) and considerably suppress it.

Possible reduction of 17MHz peak was measured and proposed by means of using two mounted common mode suppression ferrites (2 times through). However, mounted ferrites can not suppress significantly all disturbing common noise spectrum under the ATLAS allowed limits. First initial measurements from the ATLAS PIT still did not confirm success of the proposed ferrite solution.

Due to device availability also other ferrites [4] were found attractive for the 17MHz suppression. More measurements are thus prepared. However, the performance results can be similar to those presented in this report, and may again be found not sufficient for wider frequency band reduction.

Finally, discussion with TESLA Company was started to identify possible parasitic noise sources/resonance circuits inside of the 200VDC power converter that would be responsible for the high common mode spectrum around 17MHz. Some improvements are envisaged to put additional filtering ceramic capacitors to the power converter, as well as to kill the noise by an additional lossy LC filter (designed for the required frequency range) that can be mounted on Vout connector of each channel.

References

[1] G.Blanchot “TileCal Bulk LVPS 200VDC Conducted Emissions Test Report”, ATLAS-TileCal internal report, CERN, 16 July 2007.
[2]"High power supply HPS1 Operational Manual", TESLA Hloubetin, Prague, CZ, technical manual, 2005.
[3] Datasheet of common mode suppression ferrites, Wurth elektronik, type 7427155, www.we-online.de
[4] Datasheet of common mode suppression ferrites, SIBALCO AG, type 7427137, www.sibalco.ch.