Noise and crosstalk comparisons between coaxial and twisted pair versions of the endcap umbilical cable

MR (9/3/05)

Introduction

The ECAL endcap mechanical arrangment requires that the VPT arrays be connected to the VFE cards by a 25 channel umbilical cable. The two main choices are twisted pair and miniature coax, and this note describes noise and crosstalk measurements of 5-channel prototypes of each type.

Figure 1 shows a photo of the VPT setup provided by Tony. Two banks of 5 VPTs are located in the aluminium housing with the copper front face. Pieces of adhesive copper tape obscure the holes through which light pulses can be injected. The two five-channel umbilical cables exit the housing at the rear and in this example the twisted pair version can be seen entering a diecast box, on which the mothercard is mounted. The twisted pairs can be seen plugged into the sockets soldered onto the surface of the mothercard, which can be seen more clearly in the close-up in figure 2. One wire of the twisted pair is plugged into a socket soldered to ground on the mothercard, the other carries the signal to the MGPA input. The outer shield of the umbilical is connected to the mothercard ground, for both twisted pair (fig. 2) and coaxial cable (fig. 3) versions.

Figure 4 shows the diecast box on which the mothercard is mounted, after it has been closed and inverted, with a VFE card plugged in. A low voltage card can just be seen behind the VFE card. This particular VFE card has been modified to allow the outputs of the MGPA chips to be accessed before the ADC chips. The small daughter card plugged onto the VFE card is a differential-to-single ended converter, used to interface the MGPA signals to a wideband true rms milli-voltmeter for noise measurements.

Pulse shape measurements

Figures 5 and 6 show scope pictures of waveforms corresponding to different charge injection conditions. The first stage output waveforms in figure 5 show transmission line effects when the umbilical cable is connected, which look different depending on whether the signal is injected at the MGPA (fig.4) or VPT (fig.7) end of the umbilical. The VPT waveform picture (red trace) is the one that most realistically models the true situation (where the charge would originate from the VPT itself) but whichever way the charge is injected, and through whichever type of umbilical, only very small differences are seen in the pulse shape and amplitude at the chip output in figure 6.

Figures 5 and 6 are included mainly for interest, but looking closely at the red traces in figure 5 it is clear from the amplitude of the overshoot and ringing that there is better matching between the umbilical impedance and the effective MGPA input impedance for the coaxial.

Crosstalk Measurements

Figures 8 – 12 show crosstalk measurements for VFE channels 1 to 5, where the channel numbering convention is from left to right in figure 4. When it is used the light signal is injected on the VPT corresponding to VFE channel 3 (fig. 10), which is the middle VPT for both coaxial and twisted-pair umbilical versions. The scope traces shown in figures 8 – 12 are the outputs of the MGPA high-gain channel. In all cases the VPTs were biased at a dynode voltage of 800 V and an anode voltage of 1000 V.

The light signal was produced by firing a blue LED with a 30 ns pulse from a pulse generator, the resulting light being fed down an optical fibre to avoid the electrical interference that would result if the LED were in the vicinity of the VPT. However, it was found that even with the remote LED, there was some small electrical pick-up from the signal generator, so in the method used here this was measured separately and subtracted.

Figure 10 shows the picture for both coaxial and twisted pair umbilicals, for the channel with the light signal injected. The red trace shows the light pulse, which in both cases has an amplitude of approximately 700 mV, roughly half the full-scale range of the MGPA high-gain channel. The blue trace shows the parasitic electrical pick-up when the light fibre is removed and the VPT access hole covered. For both traces the scope is triggered by a sync pulse from the pulse generator. Some very low level interference can be seen on the blue trace, for both coax and twisted-pair umbilical cases, but with an amplitude of a small fraction of a millivolt.

Figure 8 shows the picture for channel 1, which is one of the channels which does not have the light pulse injected. For the coaxial umbilical case, the blue/red traces showing the response without/with the light pulse are very similar, but not absolutely identical since the difference, shown by the green trace, still shows a small signal at the ~ 0.2 mV pk-pk amplitude level. It is the green trace that represents crosstalk in the VPT/umbilical/VFE system.

Figure 8 thus shows that for the coaxial umbilical case, where the VPT signals are fed individually down miniature coaxial cables within an outer shield, the crosstalk is rather small. This can be contrasted with the twisted pair case where the crosstalk shows up quite clearly, with a maximum pk-pk amplitude of ~ 2 mV. It seems reasonable to assume that the crosstalk originates in the umbilical cable.

Figures 9, 11 and 12 show the corresponding pictures for VFE channels 2, 4 and 5 respectively. The twisted-pair crosstalk amplitudes are slightly larger for channels 2 and 4, either side of the channel receiving the light. Channel 4 in particular shows a slightly different shape to the twisted-pair crosstalk. There are some small differences in the crosstalk for the coax case, but in general the amplitude is rather small.

Noise

Figures 13 and 14 show the measured noise performance for the high and mid-gain channels respectively, for three different first stage gain values (different feedback capacitances C_f in parallel with the appropriate R_f values). Provision was made to allow the umbilical cable to be disconnected by installing shorting links in the position of the barrel AC coupling capacitor on the VFE card (the shorting links are just visible as the blue objects in figure 4). Thus the noise could be measured with and without the cable connected, and provision was also made to allow additional dummy capacitors to be added.

The blue and green bars in figure 13 and 14 show the noise for zero and 56 pF added capacitance, with the cable disconnected in both cases. The red bars show the noise with the cable connected (obviously without any added capacitance). The results displayed in figures 13 and 14 are also given in table 1. The noise for the low gain channel is as usual dominated by the gain stage noise.

Table 1. High, mid and low-gain channel measured noise for 3 different 1st stage gains, for added capacitances of 0 pF and 56 pF, and with the two umbilical cable versions connected.

	High gain channel			Mid gain channel			Low gain channel		
	6.8 pF	8.2 pF	10 pF	6.8 pF	8.2 pF	10 pF	6.8 pF	8.2 pF	10 pF
0 pF	3010	3267	3621	3152	3435	3812	~7000	~8000	~10000
56 pF	3266	3522	3810	3414	3654	4074			
Twisted pr	3478	3686	4093	3673	3849	4175			
coaxial	3563	3868	4155	3759	3991	4364			

The results for 0 pF and 56 pF added capacitance show that the noise has the usual expected weak dependence on input capacitance. When the umbilical cables are connected there is an increase in the noise which seems inconsistent with just the capacitive load. The resulting noise with the umbilical cables can be seen to be exceeding the target 3500 electrons specification, particularly so for the lowest first stage gain (C_f = 10 pF). Comparing coaxial and twisted pair umbilicals, the noise is slightly worse for the coaxial version.

Discussion

The differences between the twisted pair and coaxial umbilical cables have been measured on 5-channel versions of each. The crosstalk measurements indicate that the coaxial version is to be preferred, but the noise performance appears slightly better in the twisted pair case. It is likely that the crosstalk in the twisted pair case could be reduced if the pairs were individually shielded (if such a cable were available).

With the umbilical cables attached the noise appears somewhat worse than would be expected from just the capacitive load. This needs further investigation, but a likely explanation is that the first stage frequency response is modified by the transmission line characteristics of the cable, thereby altering the noise filtering characteristics. The first stage output pulse shapes in figure 5 certainly illustrate a modified response with the umbilical cable attached.

The current choice of first stage feedback components (C_f // R_f) is 10 pF // 3.9 kΩ. The choice was a trade-off between noise and full-scale signal capability, and was informed by a table included in:
http://www.hep.ph.ic.ac.uk/~dmray/pptfiles/EEisues.ppt
which is repeated here as table 2. The fullscale signal column is normalised to the 60 pC requirement for the barrel which corresponds to a feedback capacitance C_f of 39

pF. But there is actually a problem with table 2 in that the value finally chosen for C_f for the barrel was 33 pF, not 39 pF. I'm not sure exactly where the 39 pF came from, but it was a value considered in an early stage of the design, when the overall gains of the signal processing chain in the MGPA were distributed differently between the first, gain and differential output stages.

Table 2. Noise and fullscale signal dependence on C_f//R_f , normalised to the incorrect 39 pF value. Repeated from http://www.hep.ph.ic.ac.uk/~dmray/pptfiles/EEisues.ppt

C_f	R_f	τ	fullscale signal [pC]	R_f noise [e]
6p8	5k6	38.1	10.5	2048
8p2	4k7	38.5	12.6	2236
10p	3k9	39.0	15.4	2475
12p	3k3	39.6	18.5	2700
39p	1k	39.0	60	4900

The consequence of this is that the full-scale signal column values in table 2 are actually less than the true values. Table 3 gives the measured values for the VFE card used in this study, and it can be seen that these do make sense since extrapolating to the 33 pF barrel case gives a value very close to the 60 pC requirement. Comparing tables 2 and 3 it is clear that the fullscale signal requirement that we chose to match with C_f = 10 pF, can actually be accomodated with a value of 8.2 pF.

Table 3. Measured low gain channel full-scale signal for different values of C_f. The fullscale input charge values correspond to a differential output voltage of 1.75 Volts.

C_f	full-scale signal [pC]
6.8 pF	12.8
8.2 pF	15.7
10 pF	18.7

The noise performances measured here for C_f = 10 pF exceed the specification, and particularly so if we are driven to choose the coaxial version of the umbilical. It is table 2 again which is a bit misleading about the noise implications of varying C_f. The noise values in table 2 are correct but only consider the feedback resistor parallel noise contribution. In practice the overall noise includes a contribution from the gain stages, and reducing the first stage gain (by increasing C_f) makes this more significant.

Since we can achieve the full-scale signal requirement of close to 16 pC with a first stage feedback capacitance of 8.2 pF, and this helps keep the noise closer to specification, perhaps we should re-consider our choice for this component.

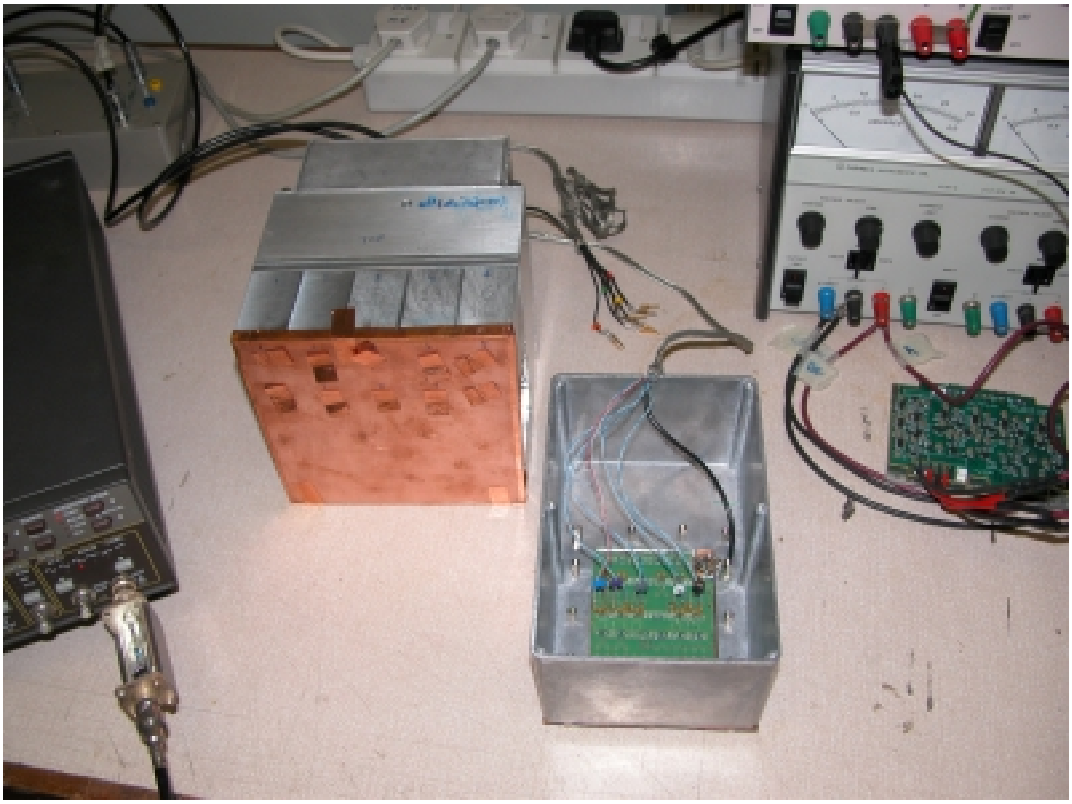

Figure 1. VPT assembly and mothercard mounting box

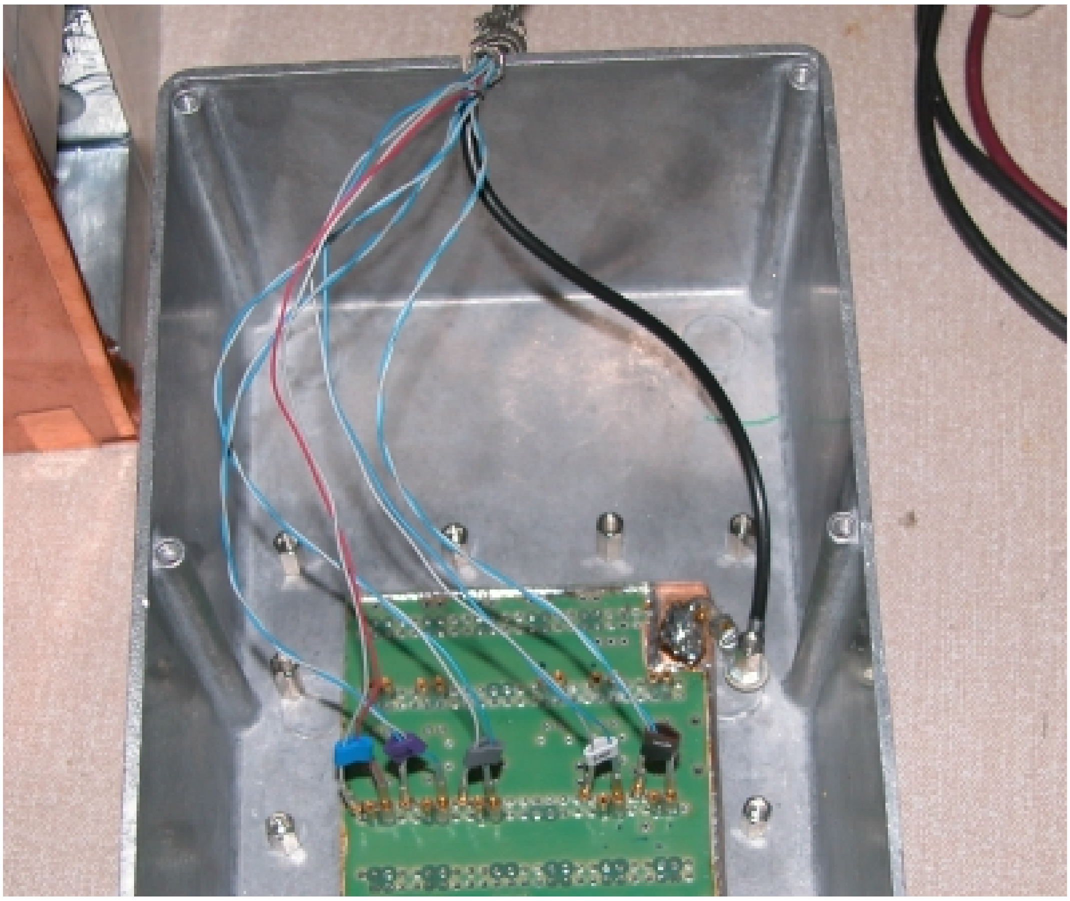

Figure 2. Close-up of twisted pair umbilical connection to mothercard

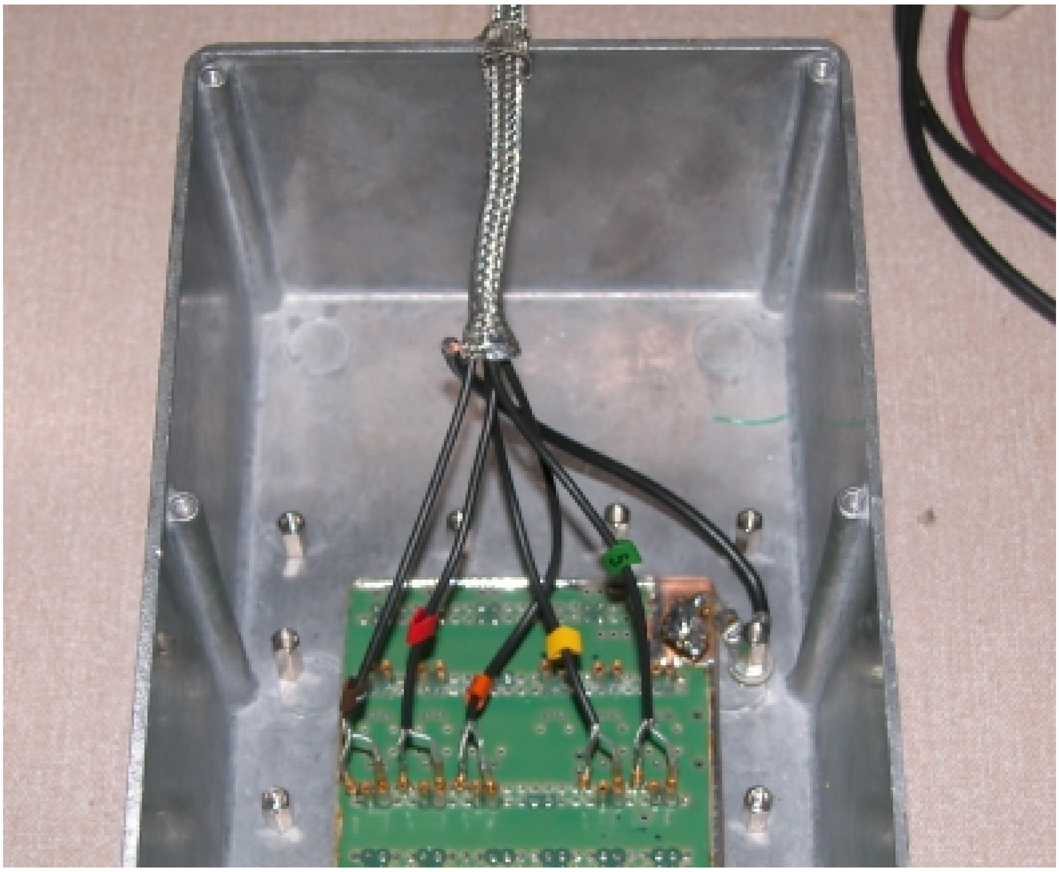

Figure 3.Close-up of coaxial umbilical connection to mothercard

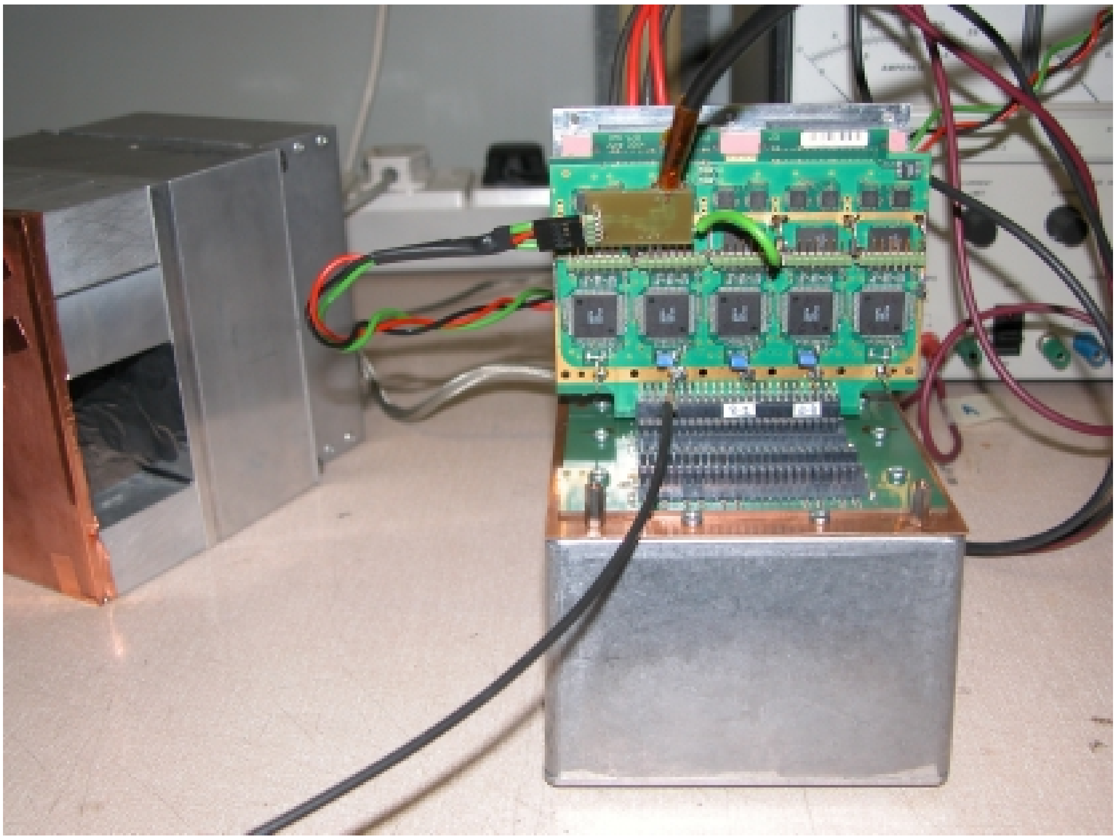

Figure 4. VFE card plugged into mothercard

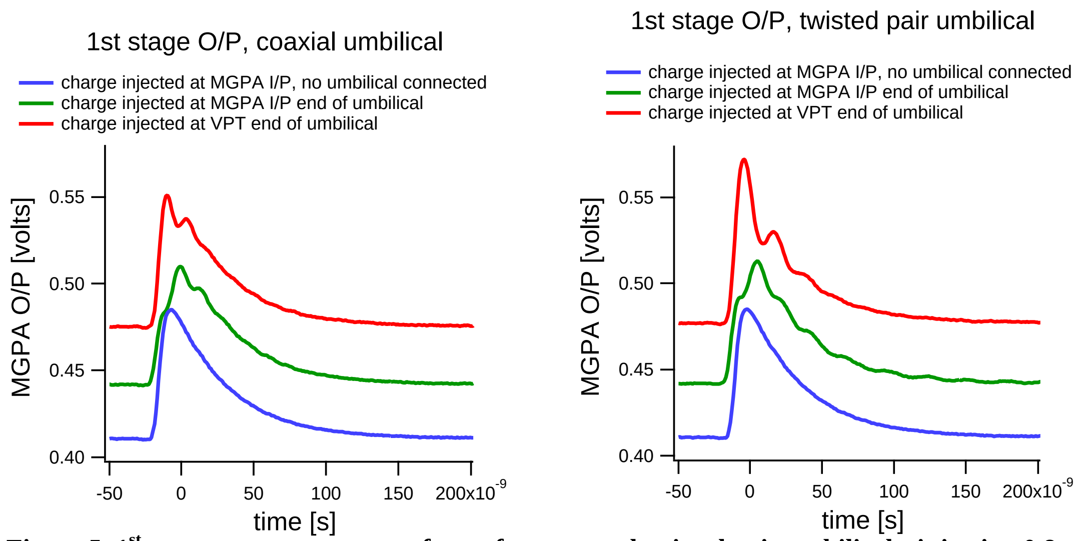

Figure 5. 1st stage scope output waveforms for coax and twisted pair umbilicals, injecting 0.8 pC charge at MGPA I/P end of umbilical, with and without the umbilical connected, and at the VPT end of umbilical. Waveforms have been artificially offset for clarity.

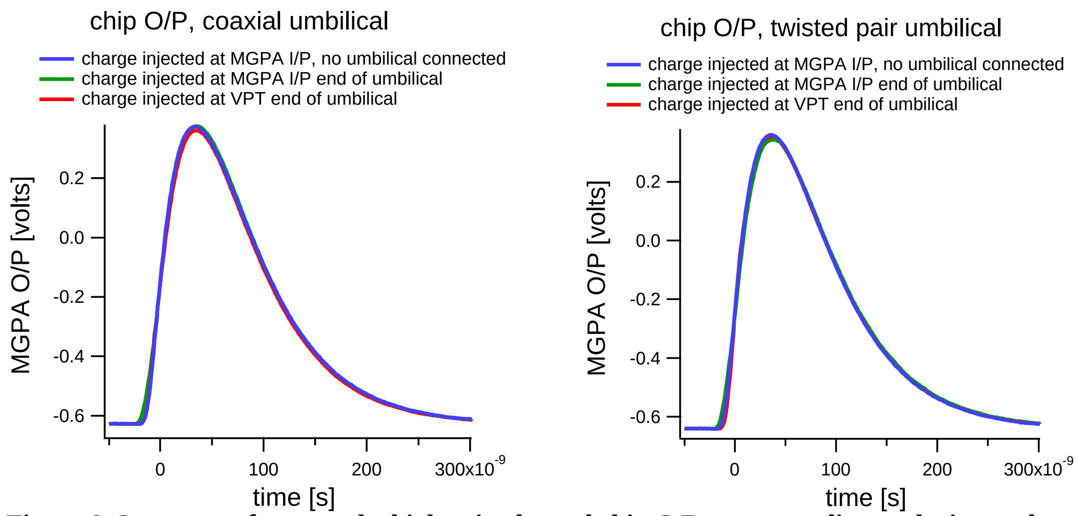

Figure 6. Scope waveforms at the high gain channel chip O/P corresponding to the input charge injection conditions of figure 5.

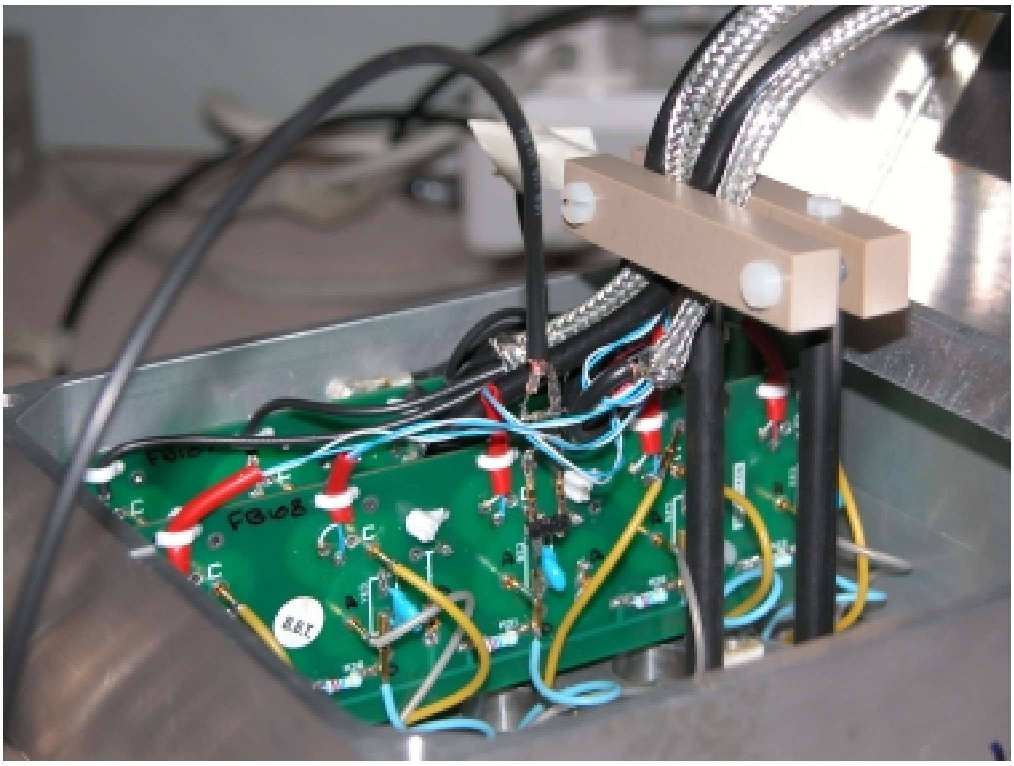

Figure 7. Charge injection at the VPT end of the umbilical

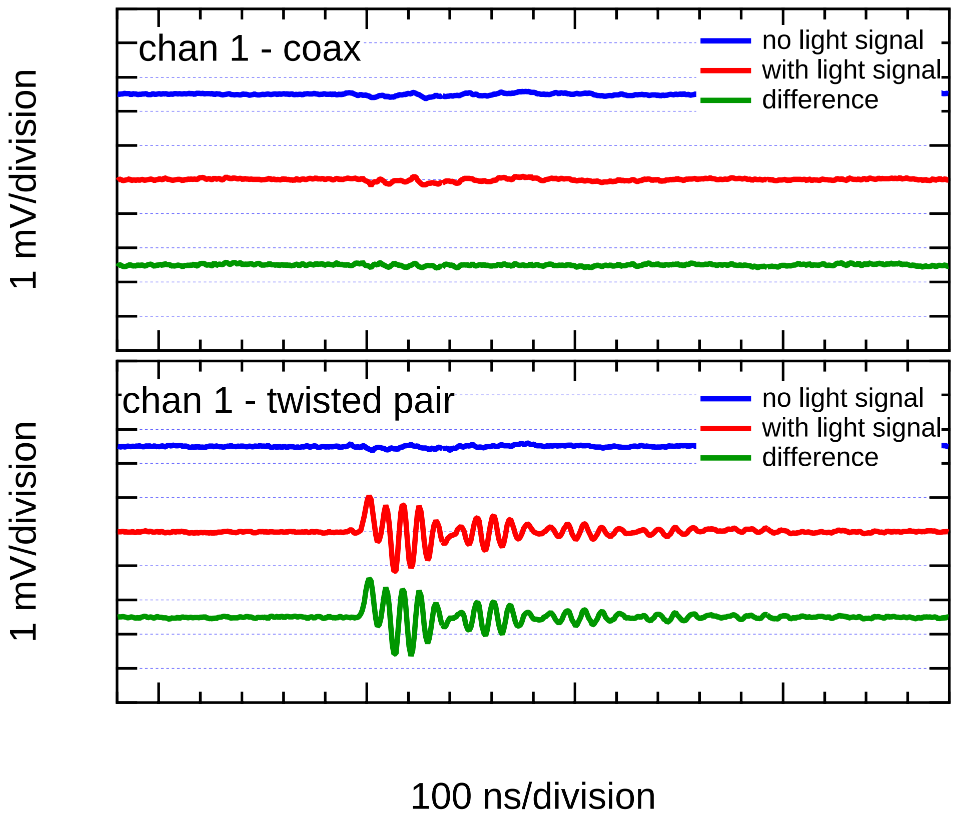

Figure 8. Crosstalk picture, VFE channel 1. Baselines are offset for clarity.

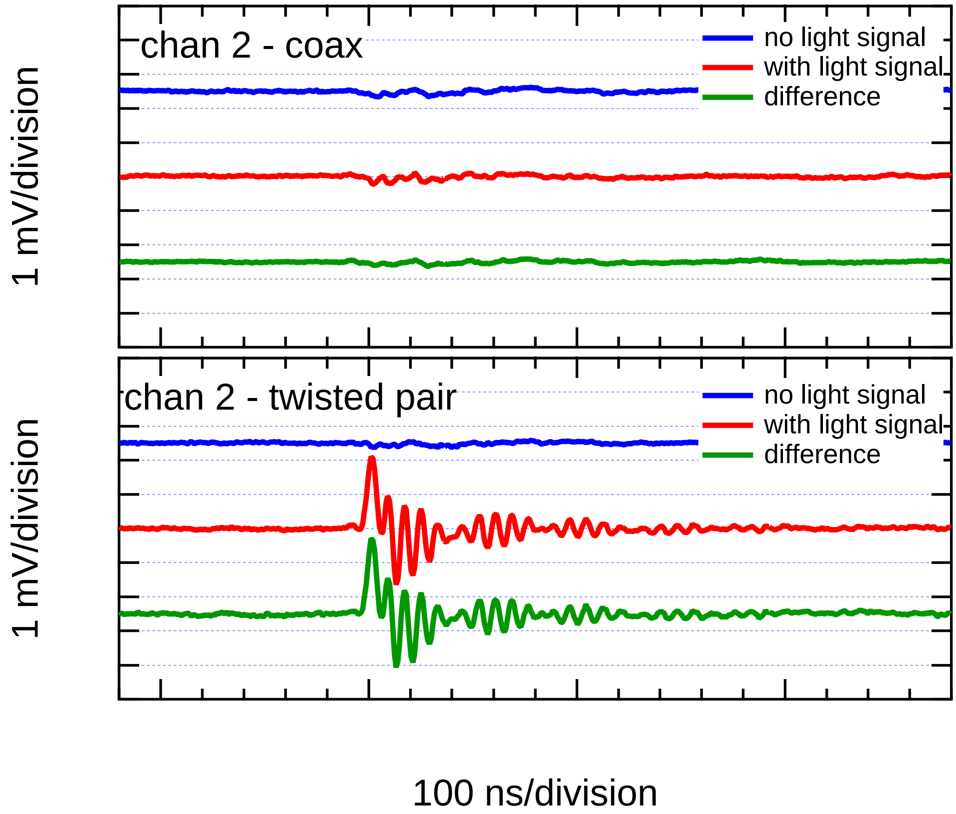

Figure 9. Crosstalk picture, VFE channel 2.

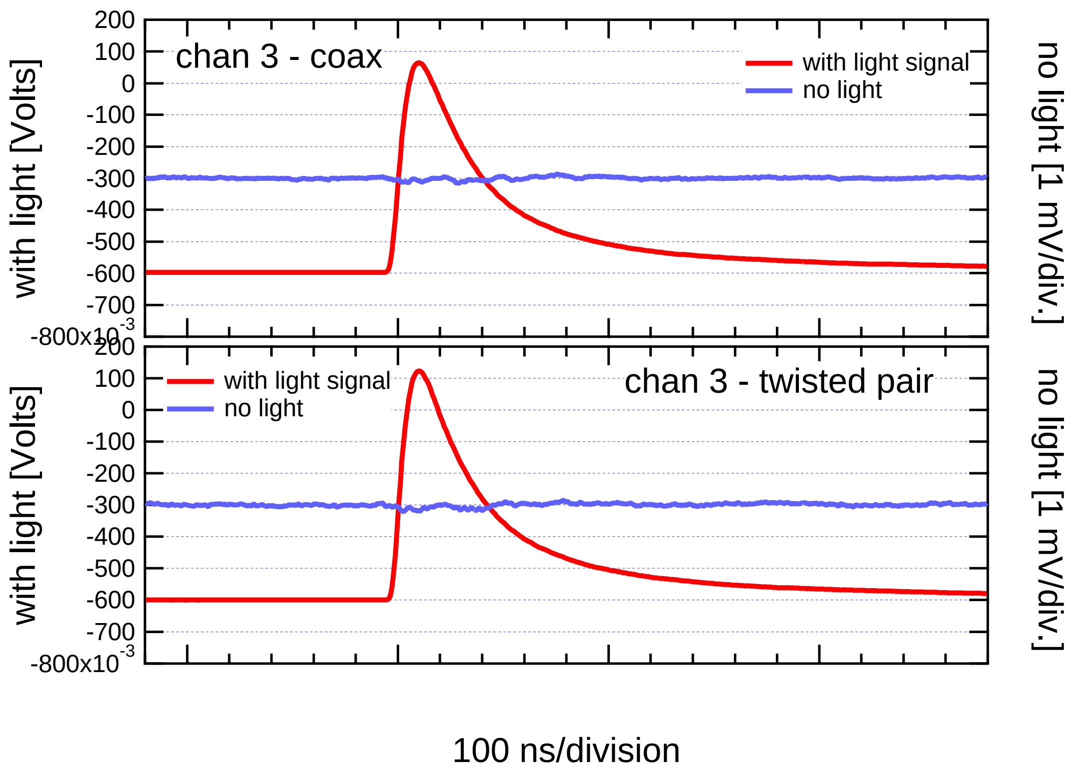

Figure 10. Crosstalk picture, VFE channel 3.

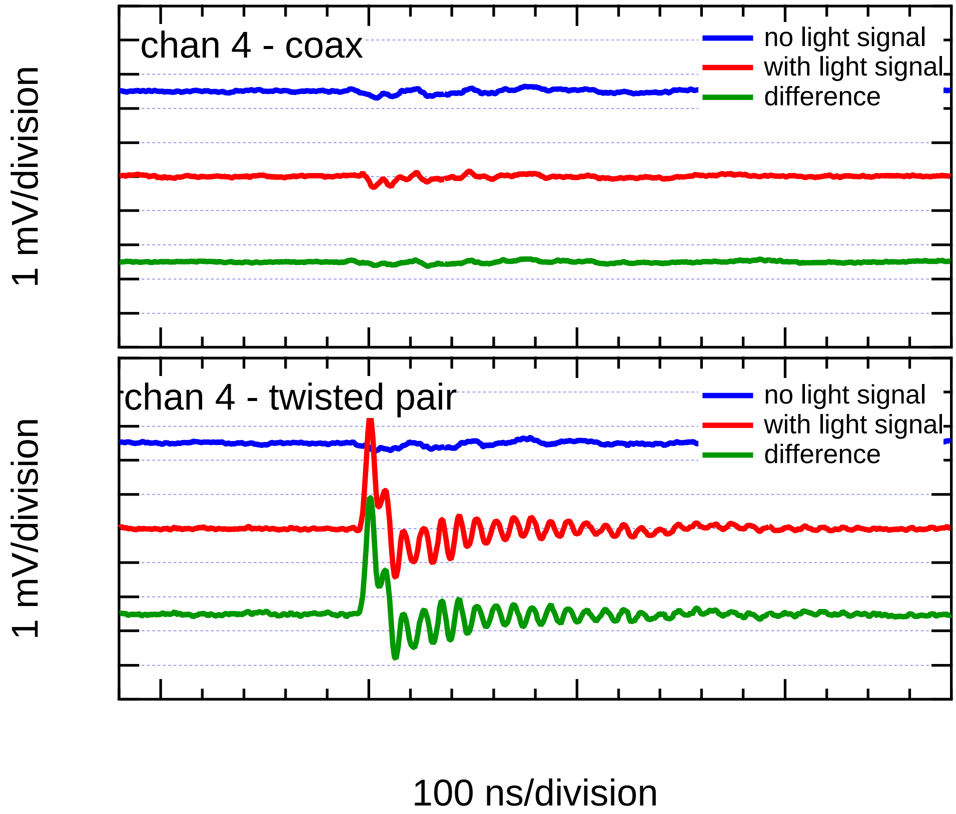

Figure 11. Crosstalk picture, VFE channel 4.

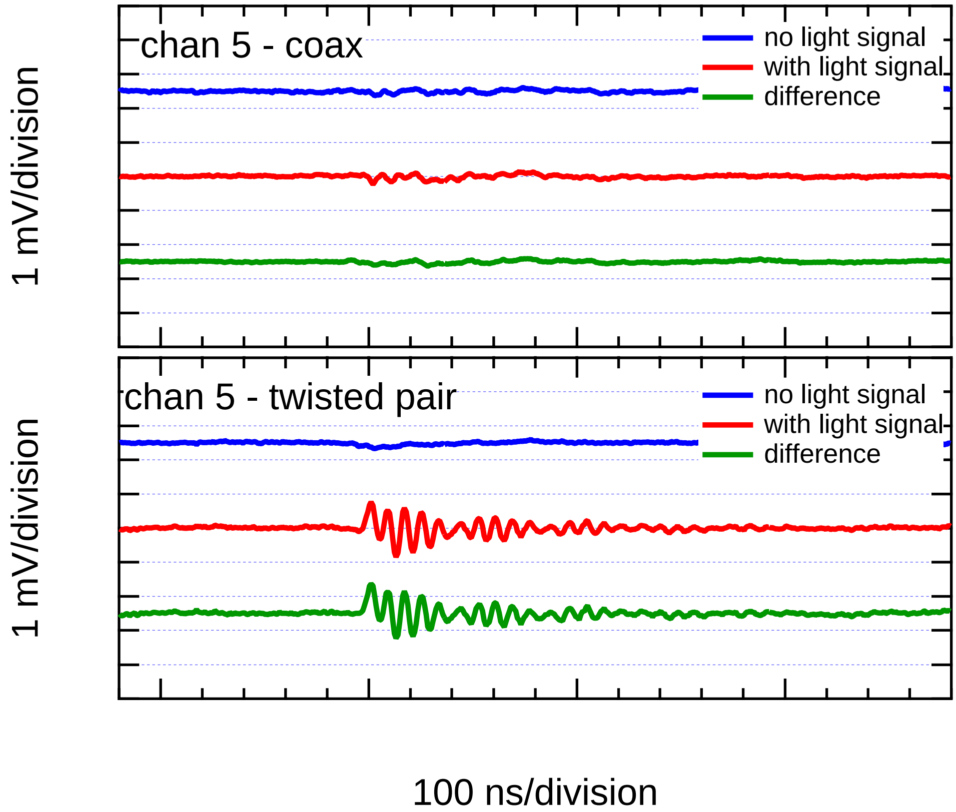

Figure 12. Crosstalk picture, VFE channel 5.

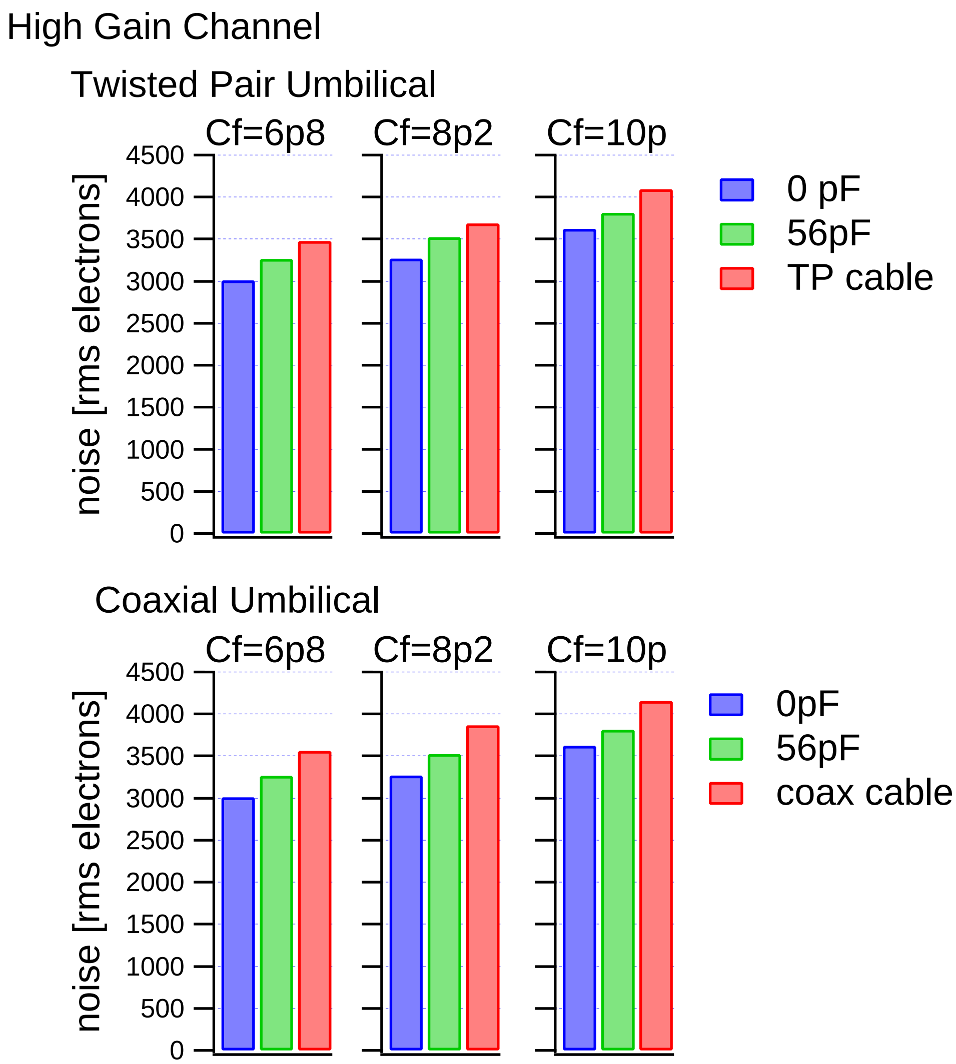

Figure 13. High gain channel measured noise for 3 different 1st stage gains, for added capacitances of 0 and 56 pF, and with the two different umbilical cables connected.

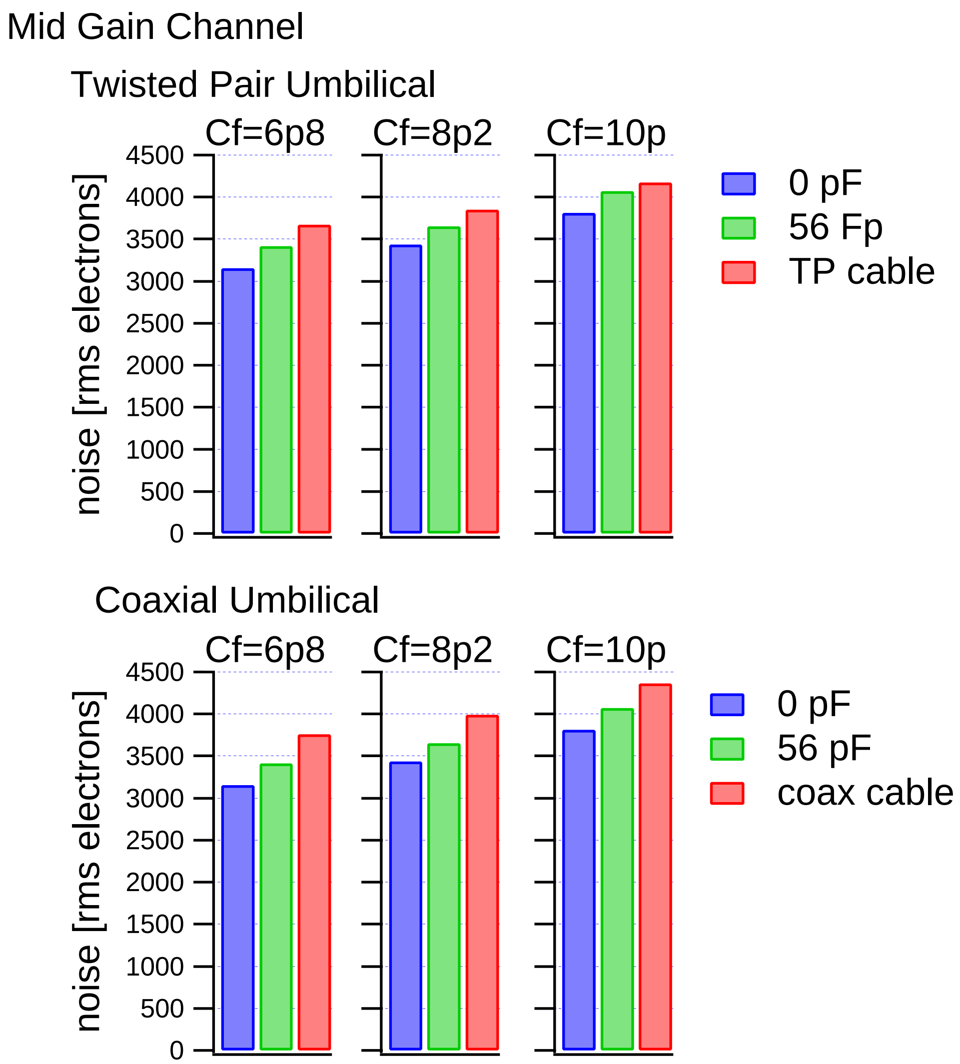

Figure 14. Mid gain channel measured noise for 3 different 1st stage gains, for added capacitances of 0 and 56 pF, and with the two different umbilical cables connected.