Preamplifier R&D at University of Montreal for the drift chamber

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Objective

<u>Develop a large bandwidth preamplifier optimized for cluster counting.</u>

<u>Challenge</u>

Combine large bandwidth with good signal to noise ratio.

<u>Obstacles</u>

-The sense wires / field wire matrix forms a transmission line with a high characteristic impedance.

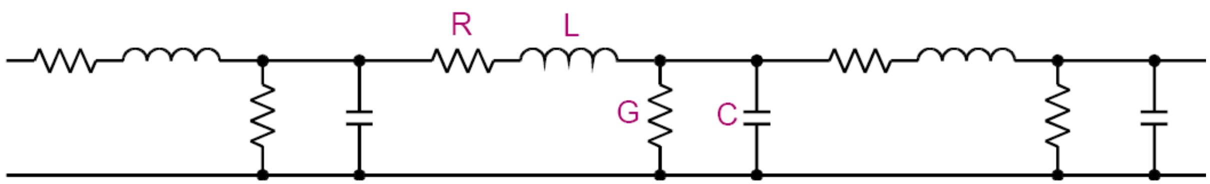
- Remote preamplifier connection requires a transmission line (50 ohms)

- The sense wires have substantial resistivity

- Even a very small capacitive loading on the sense wire produces a significant high frequency loss.

The lossy transmission line model

Sense wire + field wires < == > Coaxial transmission line with ohmic losses



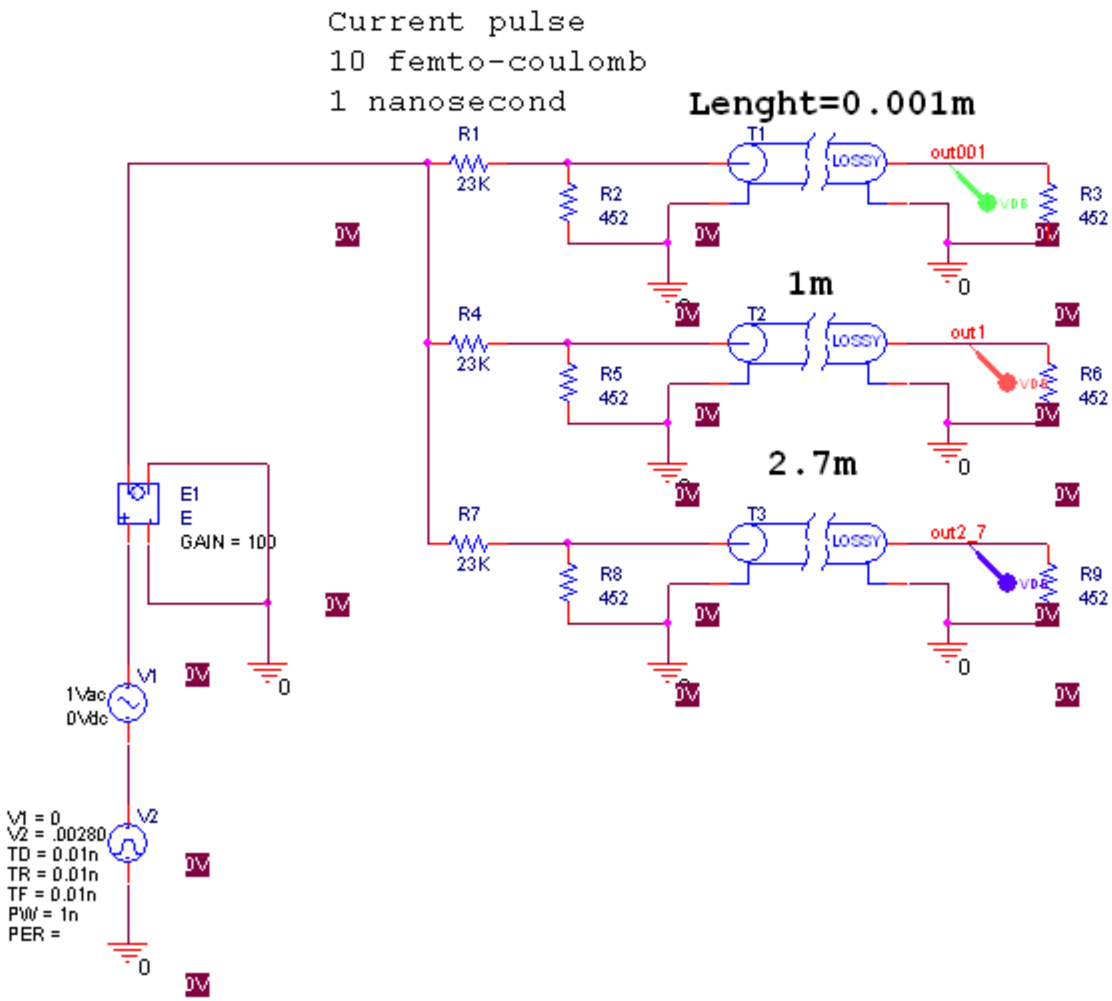
R-L-C-G model

R : resistance per unit length (ohms) : 500 (per meter)
L : inductance per unit length (henrys) for Ǿ=40μ wire : 2150 nH
C : capacitance per unit length (farads) for Ǿ outer = 8mm: 10.5 pf
G : conductance per unit length (ohms $^{-1}$) (dielectric losses) : 10^{-12}

Characteristic impedance $(L/C)^{1/2}$: 452 ohms

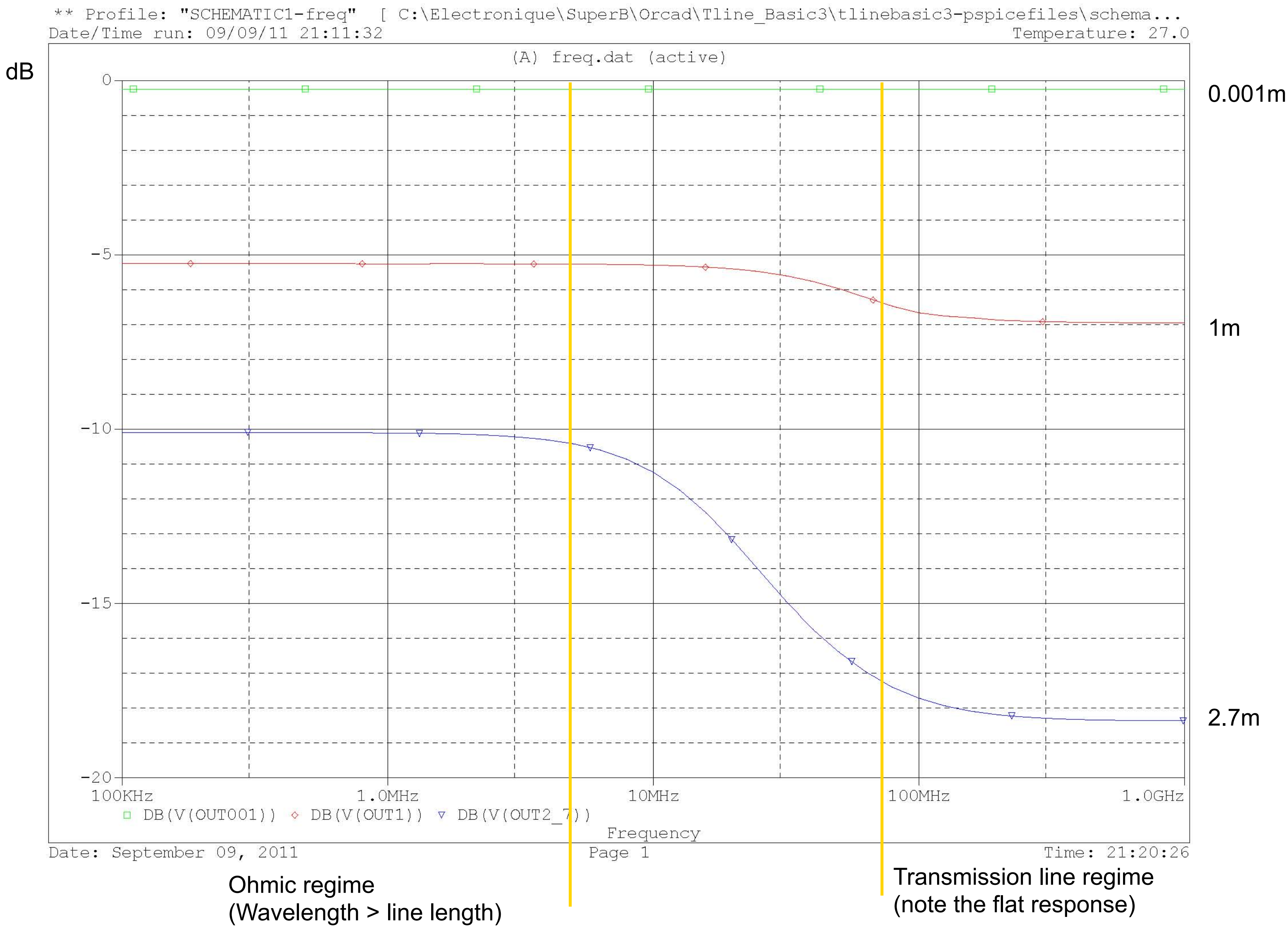
NOTE: frequency dependant skin effect for R with is **not** included in the model

LOSSY TRANSMISSION LINE MODEL

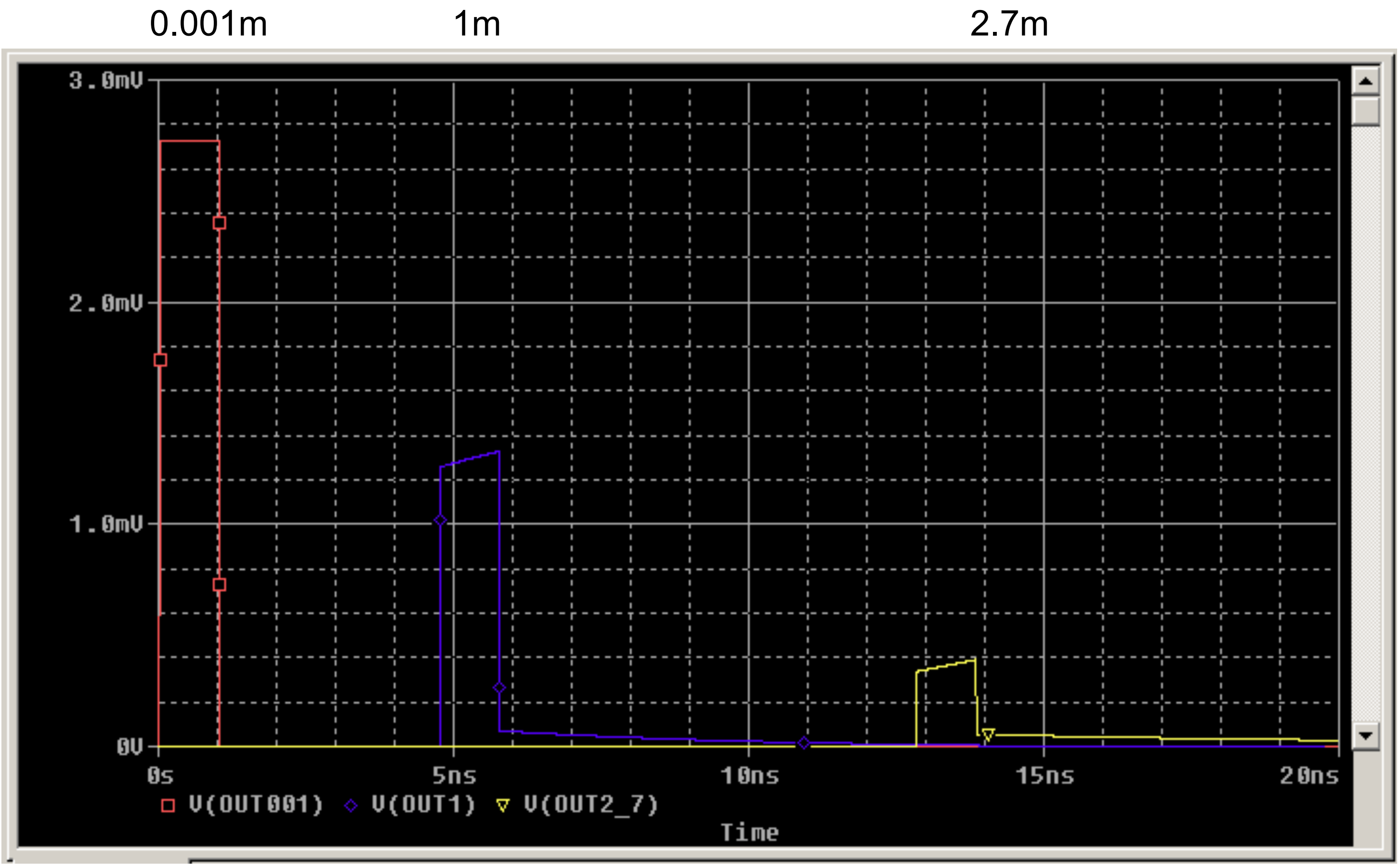


1) Exact termination,
no capacitive load

Attenuation VS frequency



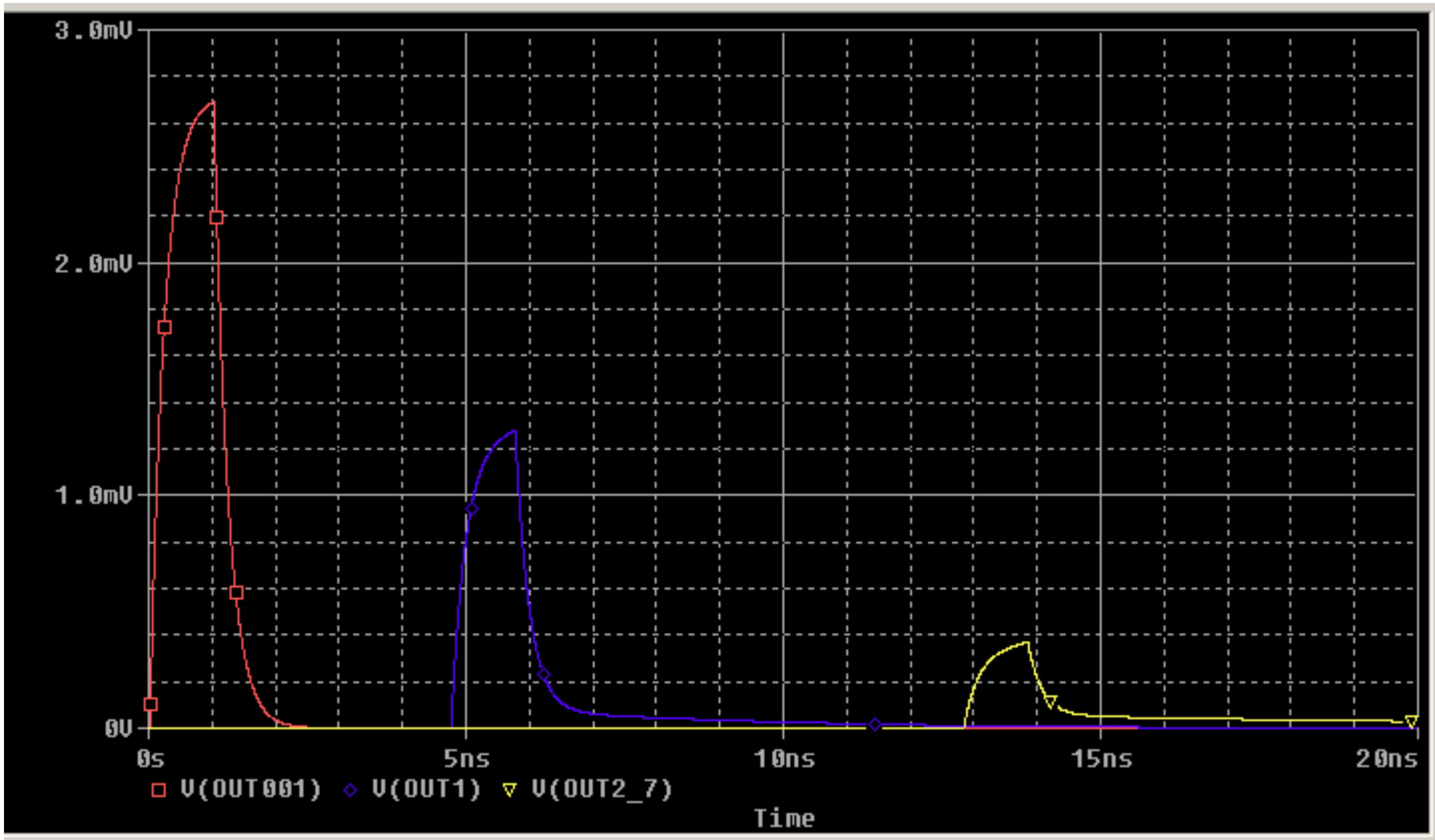
Pulse shape VS line length, 10 femto-coulomb pulse, R load = 452 ohms, C load = 0



1) Without a capacitive load the rise-time is preserved
2) Significant attenuation with length

Pulse shape VS line length, 10 femto-coulomb pulse, 452 ohms , 1 pf load

0.001m 1m 2.7m

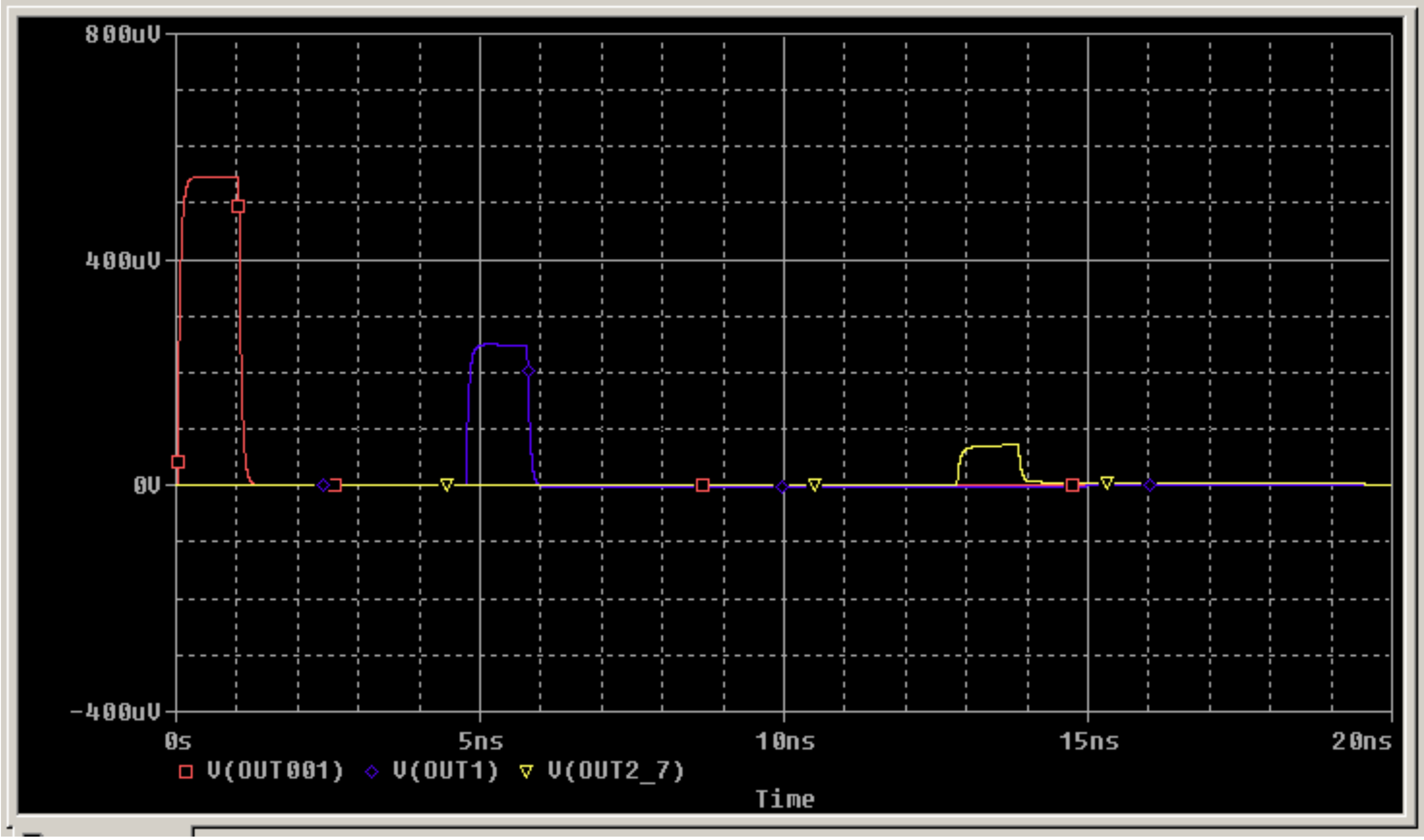


With a capacitive load, rise time is increased independently of length.
Capacitive load should not be much more than 1 pf.

Pulse shape VS line length, 10 femto-coulomb pulse, 1 pf load, 50 ohms termination

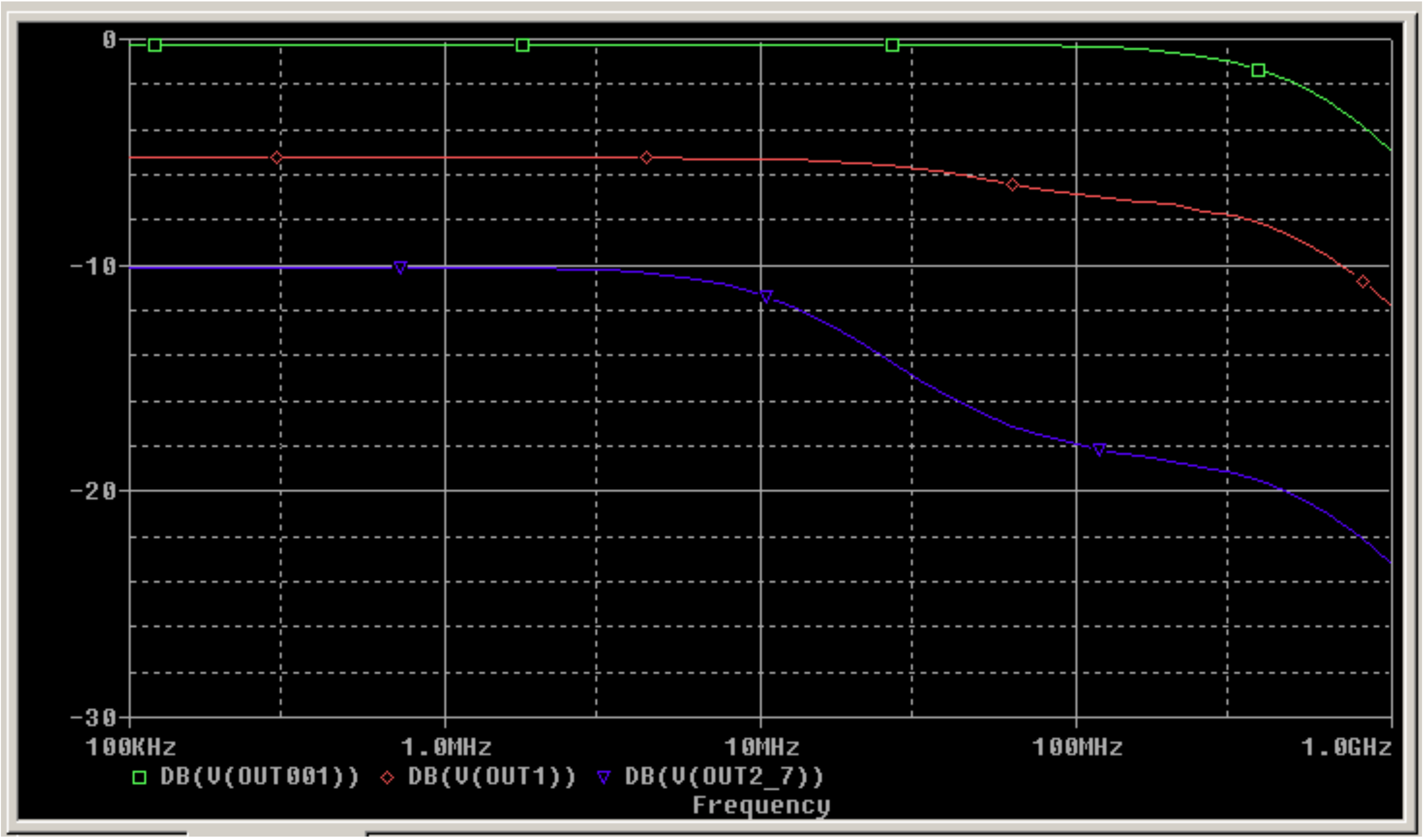
(Note the change of Scale)

0.001m 1m 2.7m



Lower impedance (50 ohms) increases the bandwidth, but the amplitude is reduced by a factor 4.5 in this example

Frequency response, 1 pf load, 452 ohms



0.001m

1m

2.7m

With 1 pf load : relative -3 dB point = 700 MHz

Signal to noise issues

Noise and signal at the end of the transmission line,
10 femto-coulomb 1 nsec current pulse signal
(no amplifier noise)

	Termination impedance at sense wire readout end (452 ohms at other end)	Amplitude at termination	RMS Thermal noise at termination resistor from 100 K Hz to 1 GHz	Signal amplitude/ RMS voltage noise (w 50 ohms amp)
2.7m	50	80 µV	27 µV	3 (0.95)
	452	380 µV	37 µV	10
	5000	600 µV	20 µV	30
0.001m	50	480 µV	27 µV	18 (5.6)
	452	2800 µV	60 µV	47
	5000	4500 µV	57 µV	79

* RMS input referred noise of a typical low noise (6dB noise figure) 50 ohms fast amplifier = **80 µV**

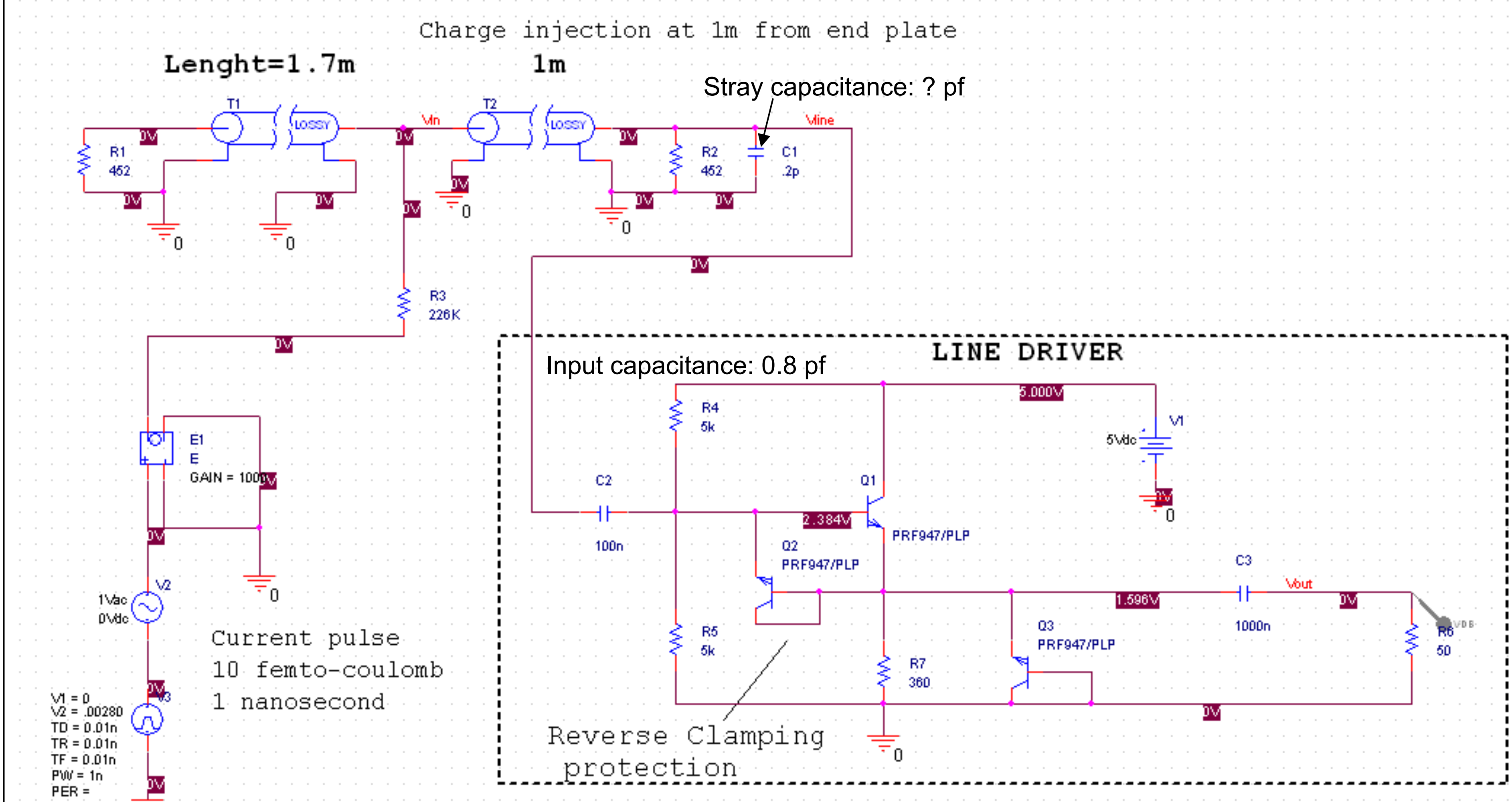
Signal to noise issues (2)

Options:

1) High input impedance amplifier on endplate (not common at high bandwidth)
2) Low input impedance amplifier with impedance matching:
   - Transformer on endplate? (not obvious in a magnetic field)
   - Active element on endplate? (rad-tolerant?)
3) Low impedance amplifier with impedance mismatch
   (can be remote and rad-soft, good bandwidth, unfavorable S/N ratio)

$\Rightarrow$Present work at Montreal: <u>Active 50 ohms line driver at the sense wire</u>
+ remote commercial RF amplifier chips

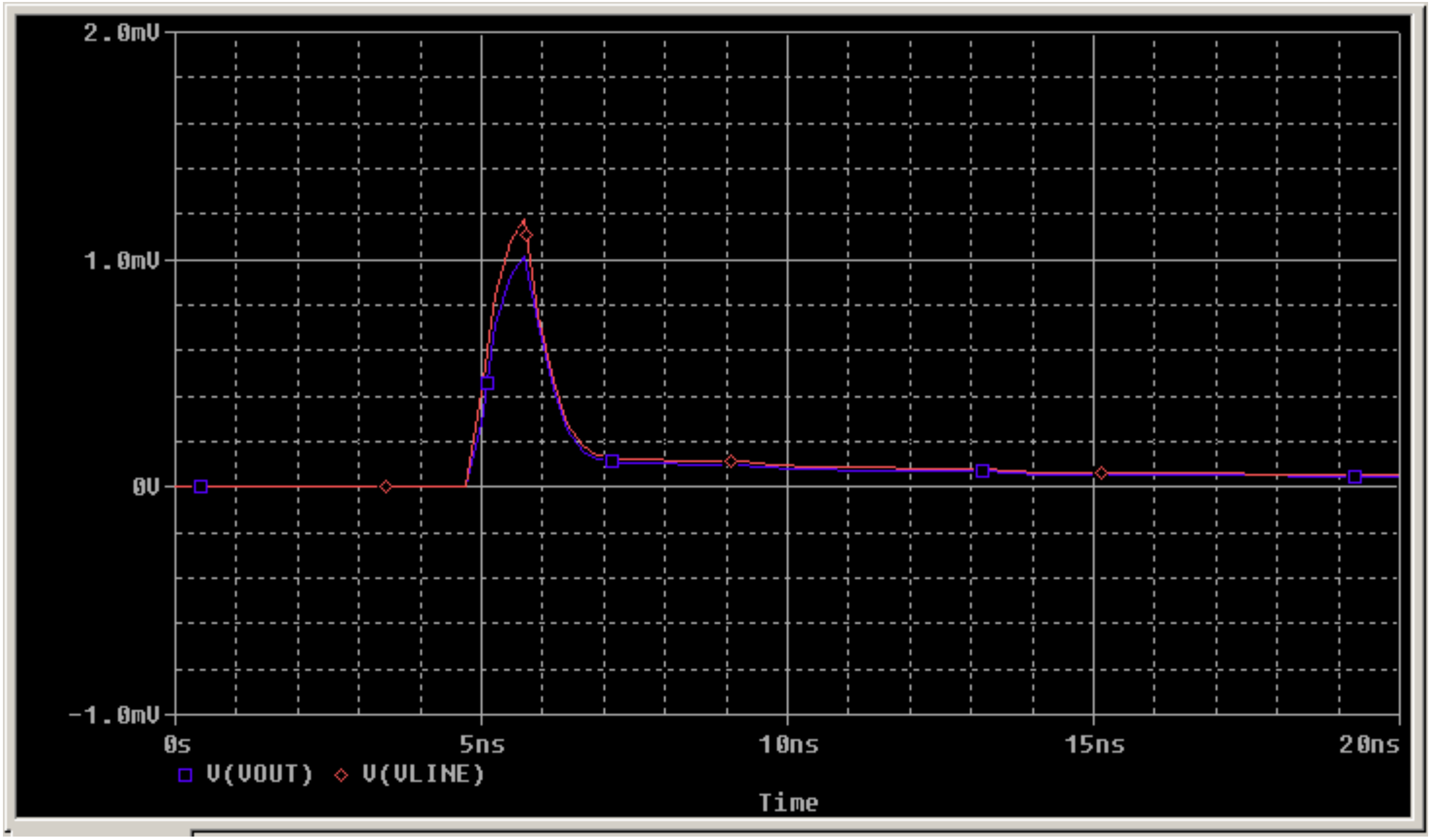
LINE DRIVER MODEL



Line driver response in 50 ohms load (blue line)

Sense wire termination: 452 ohms

Source: 10 femto-coulombs 1 ns pulse at 1 m from endplate



CONCLUSIONS

Output noise of circuit, for 1m position	:	43 μV in 50 ohms load
Input referred noise with a 50 ohms post amplifier	:	90 μV
Output amplitude, 10 fc 1ns pulse	:	950 μV
S/N Ratio	:	**10.5**

S/N Ratio without matching to 50 ohms amplifier:	0.001m	:	5.6
	1.0m	:	**4.0**
	2.7m	:	0.95

==➔ Ratio of signal amplitude/RMS noise can be improved by a factor 2.5