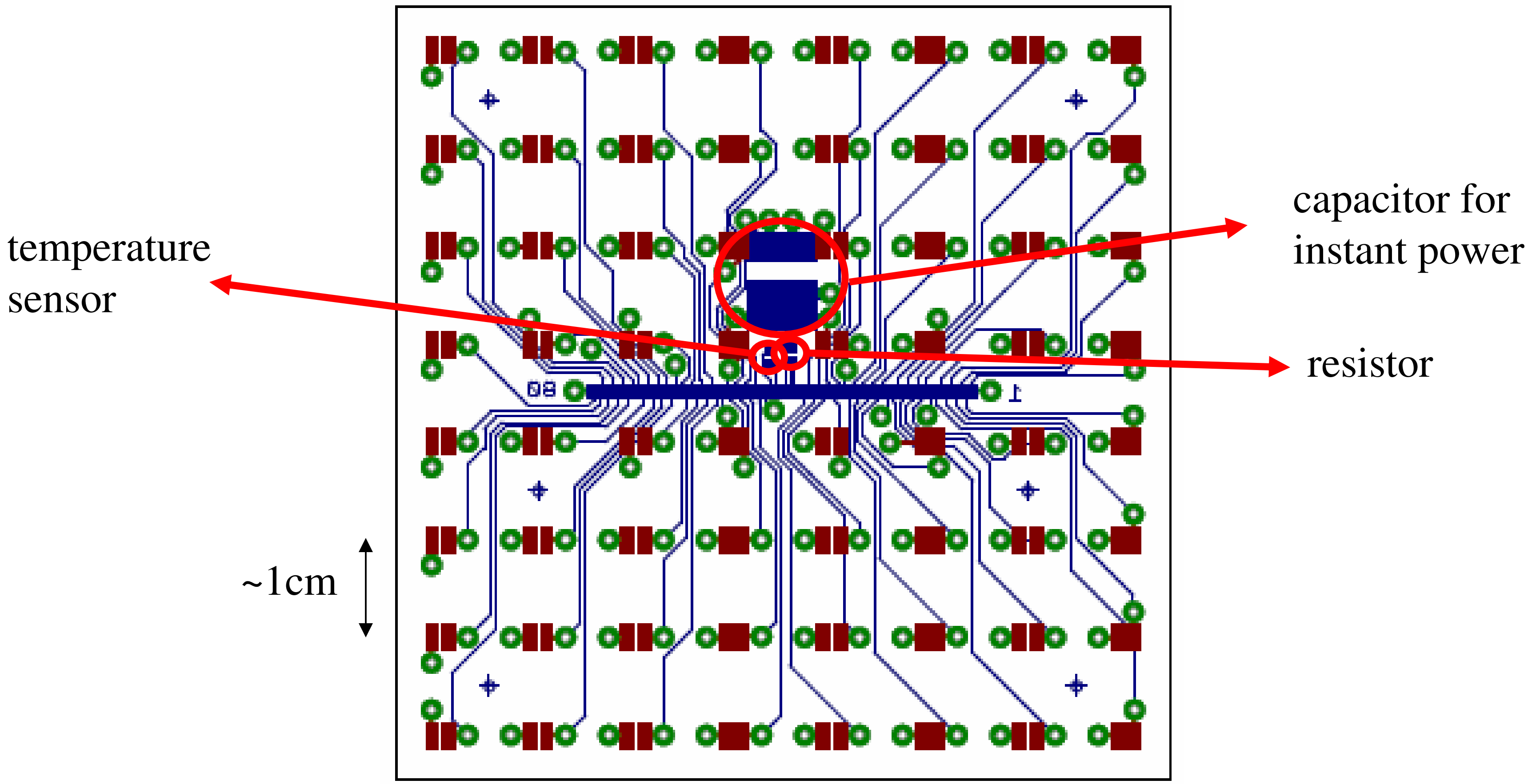
1. DICE board layout (only 2 layers shown)



4-layer PCB

the two additional layers are ground and power

assumptions for simulations:

1. neglect parasitic capacitance up to cable
2. neglect SiPM capacitance

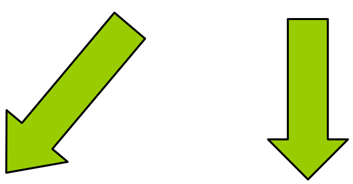
(reasonable a priori for 'slow' signals, **but also limited by present knowledge**)

NEXT-100 SiPM plane

A=8825cm^2

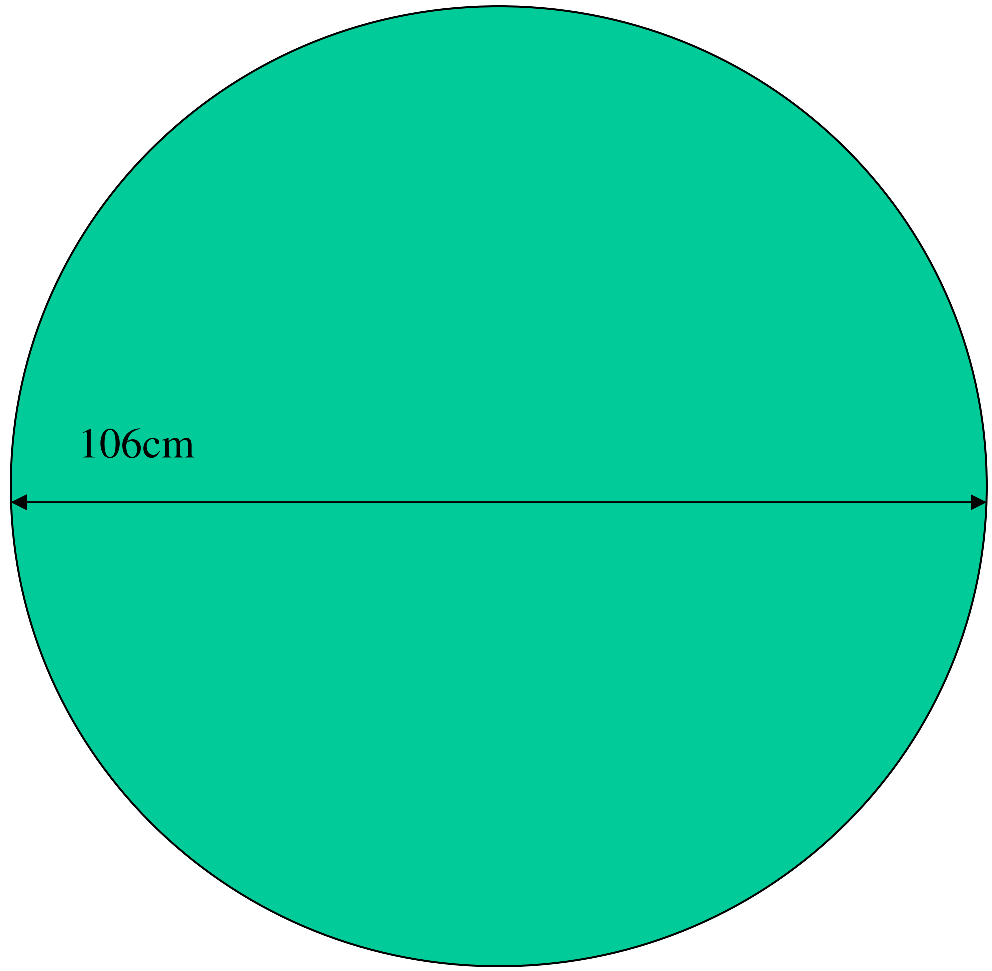
~8825 SiPMs (1cm pitch)
~138 Dice-Boards
~Due to fill-factor (A. Martinez):
111 Dice-Boards
~9.4mm thickness overall assuming
NEXT-DEMO cable.

placement of ZIF connector
seems more critical. From
Derek: 0.3mm x 4.5mm.



3.3cm
additional
thickness

25x2cm
additional
length

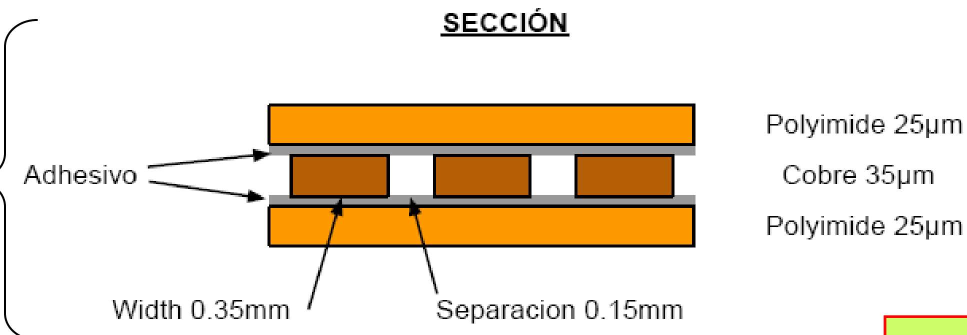


possibly 2 feed-throughs are ok
(will if be possible to shield the ZIF
Connector from inside?)

2. DICE board schematics and cable

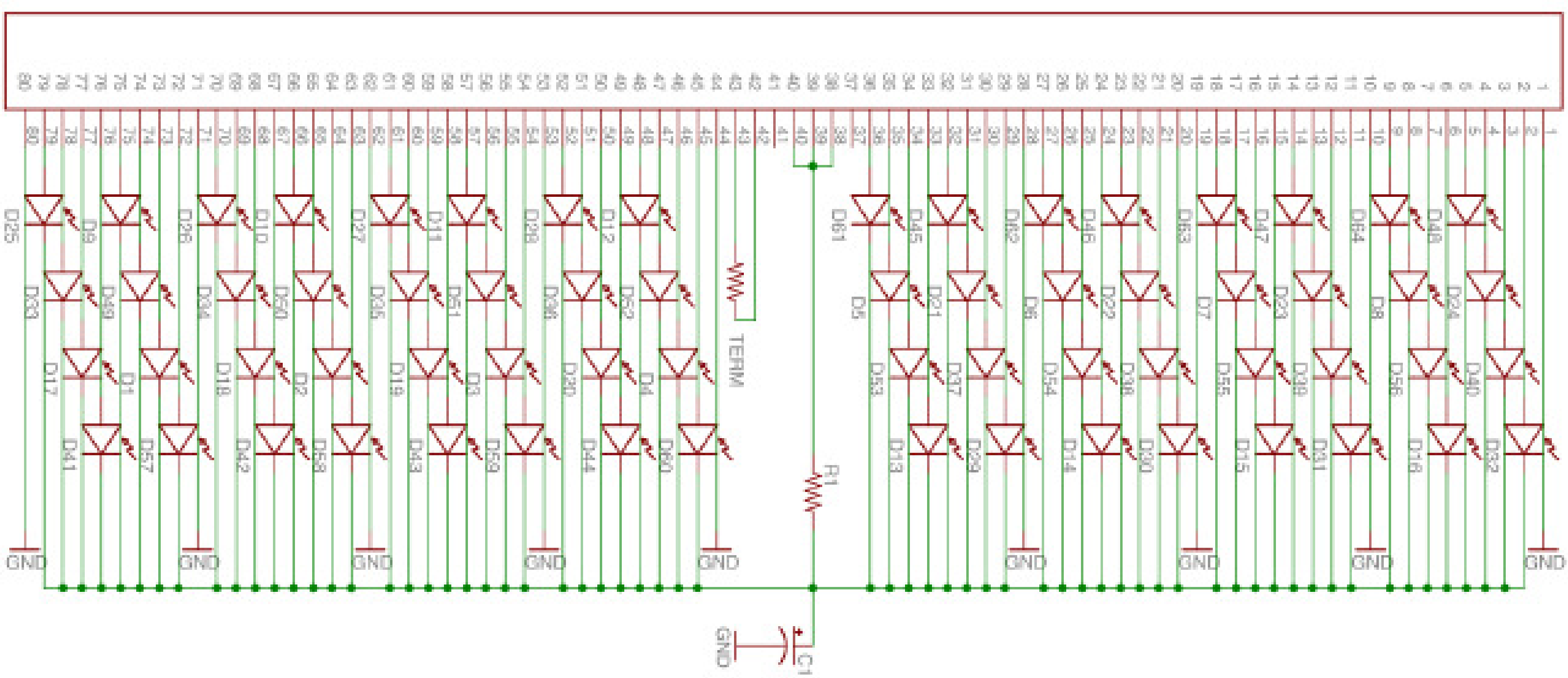
80 traces/cable
trace pitch 0.05cm
64 signals/cable
cable width = 4cm
(0.05 x 80)

re-done

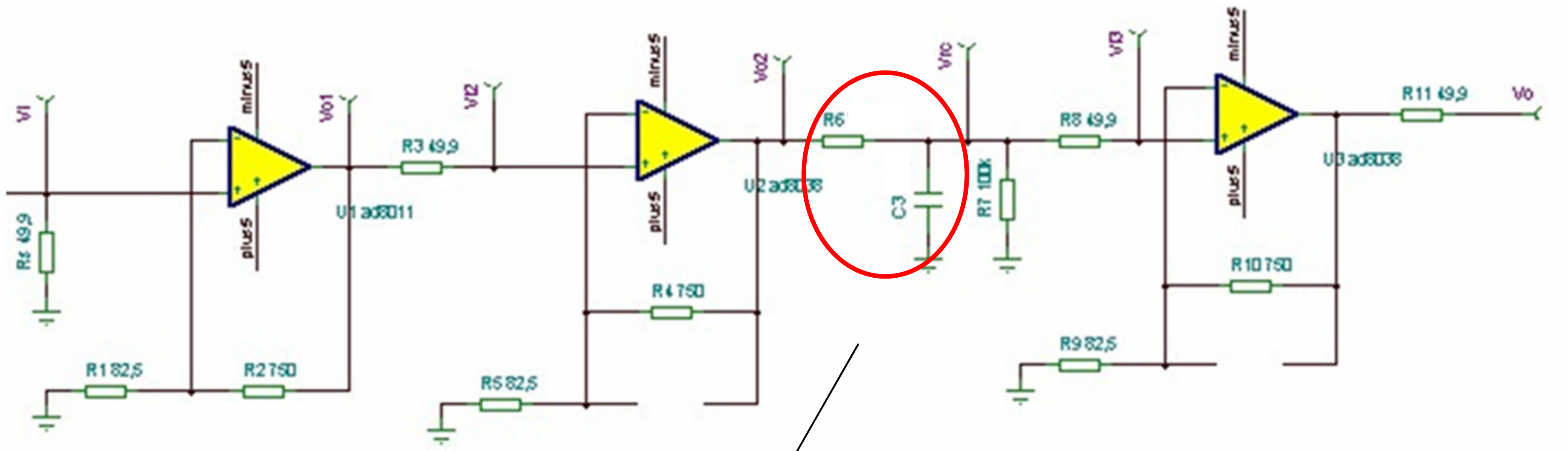


Longitudes: 900mm, 800mm y 650mm
ε (polyimide) = 3.4 ~ 3.6 (@1MHz)

take the largest length for simulations (safe)



3. FEE

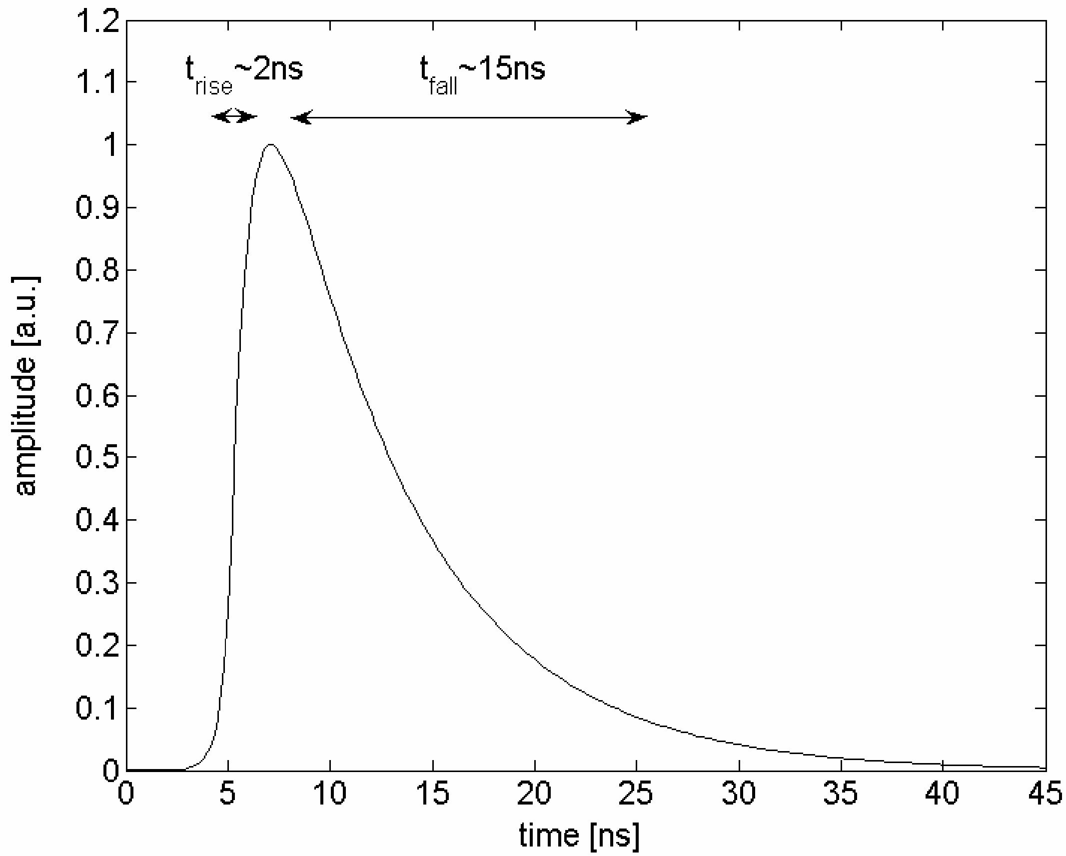


take the shortest bandwidth for simulations (safe)

RC=0.5-2μs (BW~600-150kHz)

It seems from the datasheets of all ASICS that, if running with any recommended feedback loop, they will have a much higher bandwidth, so possibly the RC of the passive integrator dominates the response function. Better could be done if the frequency response function of the system is simulated or experimentally determined (possibly not a practical approach).

4. SiPM input signal



assumed positive in the following for convenience

5. The simulation code

• Based on the solutions for loss-less multi-conductor transmission lines. A convenient matrix implementation is done in Matlab/Octave (open source). Well know procedure, equivalent to pSPICE, APLAC et al.

• Only losses along the conductor (resistive) or between the conductor and ground (dielectric) are considered. They are factorized from the solution. Experimentally, this seems to be a good practical approach as long as losses are not dominating the transmission (an usual desired case). *For the assessment of the present cable this has been neglected, since other effects are clearly of greater relevance.*

cable optimization

constraints

• From connector (cable geometry at the connection):

trace width = 0.3mm, pitch=0.5mm, 80 traces. Plated through hole connection. (J. Samaniego)

• Connector dimensions:

thickness = 3mm, length 4.5mm. (D. Shuman, J. Samaniego)

• Stiffener strip in the connection region:

0.3mm x 4.5mm (thickness x length). (D. Shuman)

• Maximum kapton thickness 127µm (in steps of 12.7µm). (J. Samaniego).

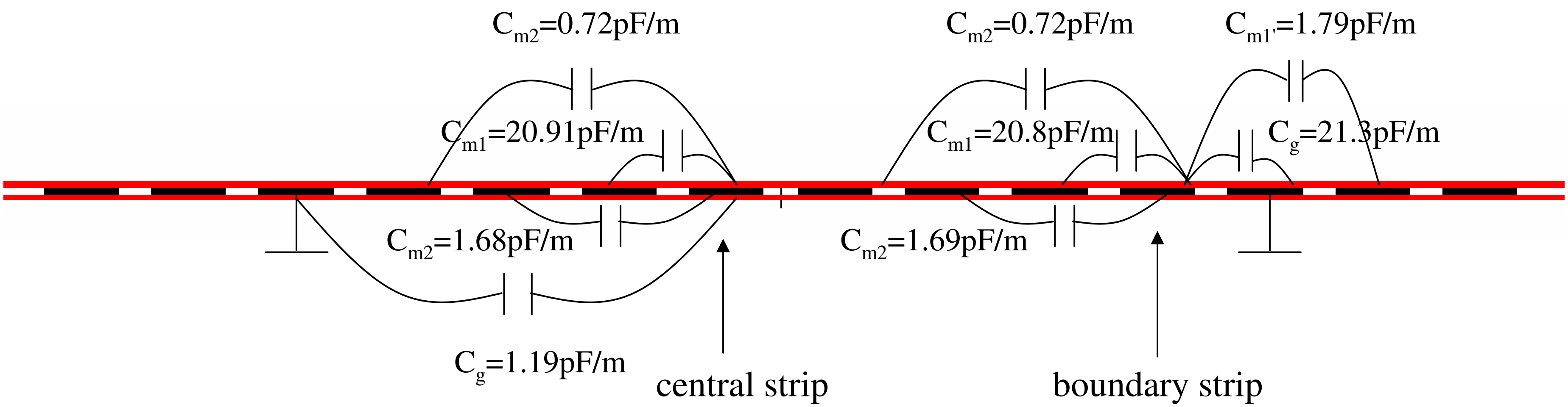
• Minimum kapton thickness for a bond-ply 25 µm (D. Shuman from Fralock).

• Some flexibility for easier connection inside. (D. Shuman)

• Thin copper trace. Down to 5µm is possible?. (D. Shuman)

• Try with Cu/Kapton/Cu/Kapton cables. (D. Shuman)

simulated NEXTDEMO cable: from MAXWELL-2D FEM solver



central strip

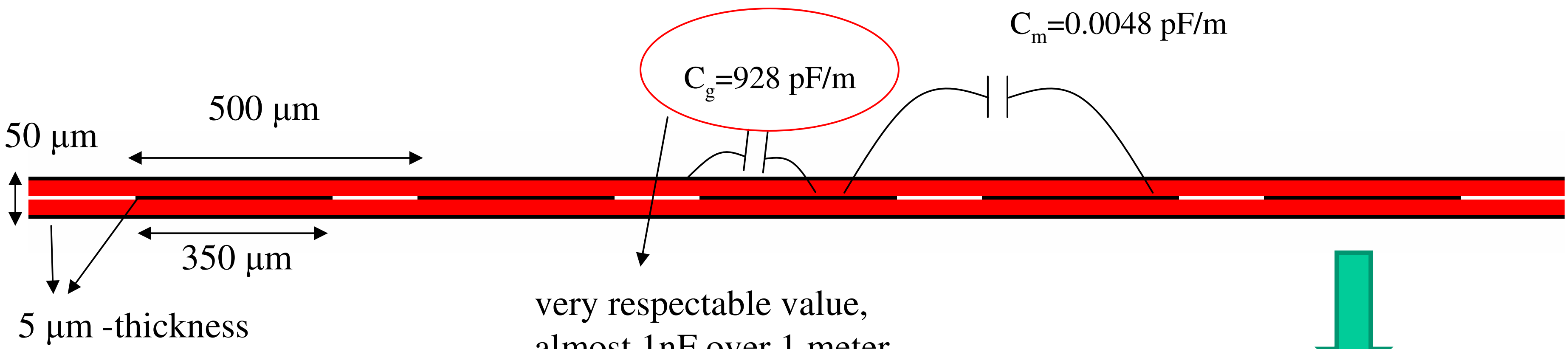
Z_c = 187 Ω → characteristic impedance (here high because the ground plane is far apart)

Z_m/Z_c = 0.65 → coupling coefficient (for any typical design this is usually <0.1, but here ground is far)

v/c = 0. 855 → propagation velocity (very high since there is almost no dielectric)

θ = 1.4 → dispersion term (causes dispersion if much larger than one). It quantifies how much the structure differs from the propagation in a uniform media.

simulated NEXT100 cable (1): from MAXWELL-2D FEM solver



very respectable value,
almost 1nF over 1 meter

Gives 6.6mm thickness /cable

central strip

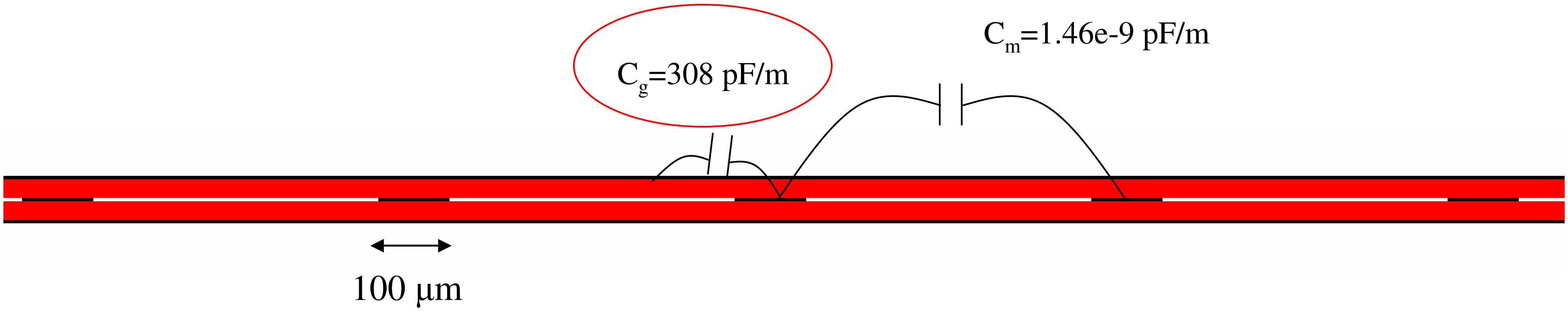
Z_c = 6.7 Ω → characteristic impedance

Z_m/Z_c = 8e-6 → coupling coefficient

v/c = 0. 5 → propagation velocity

θ = 0.0004 → dispersion term

simulated NEXT100 cable (2): from MAXWELL-2D FEM solver



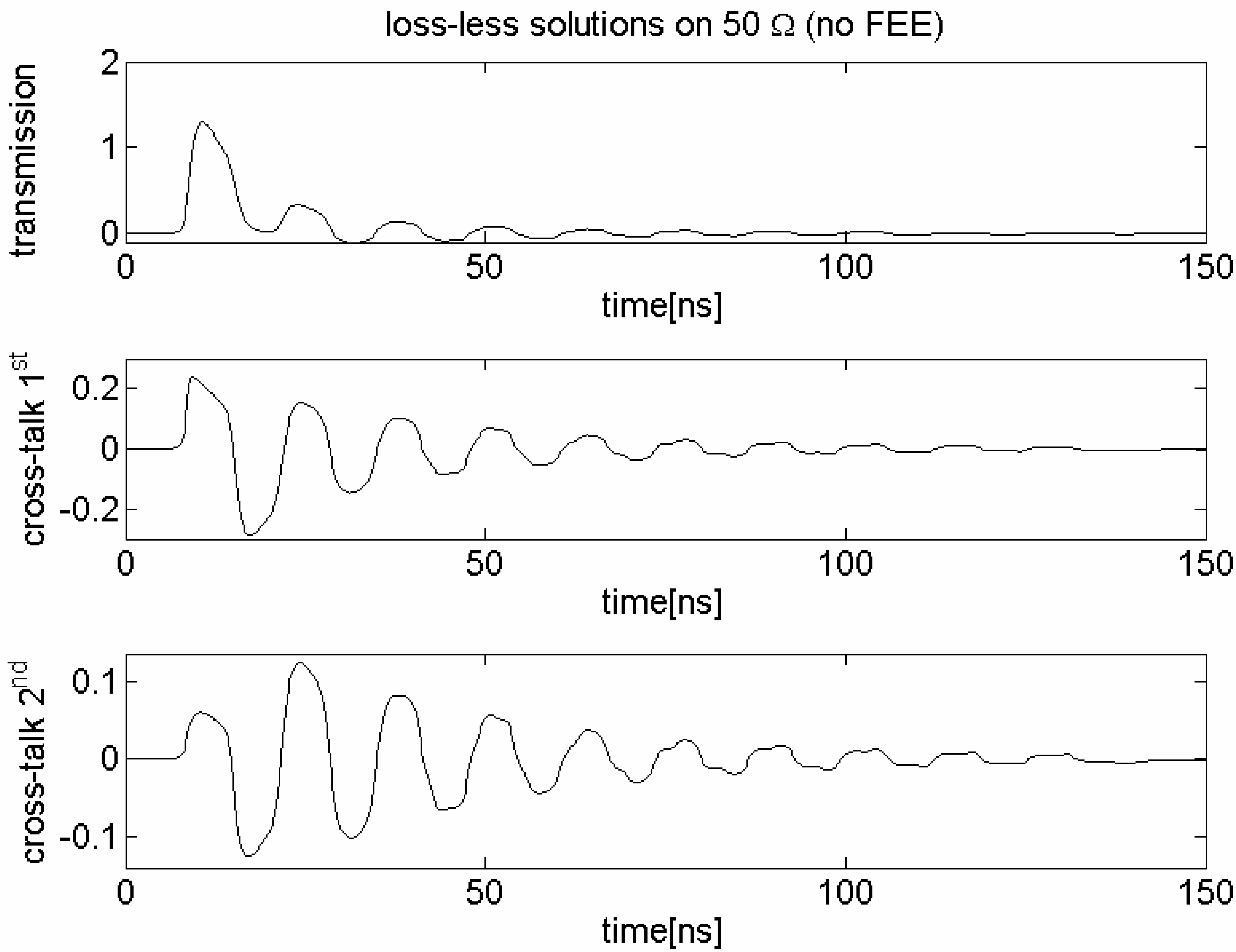
central strip

Z_c = 19.9 Ω	characteristic impedance
Z_m/Z_c = 2e-11	coupling coefficient
v/c = 0. 54	propagation velocity
θ = 1.83e-9	dispersion term

simulated cable signals

for central trace

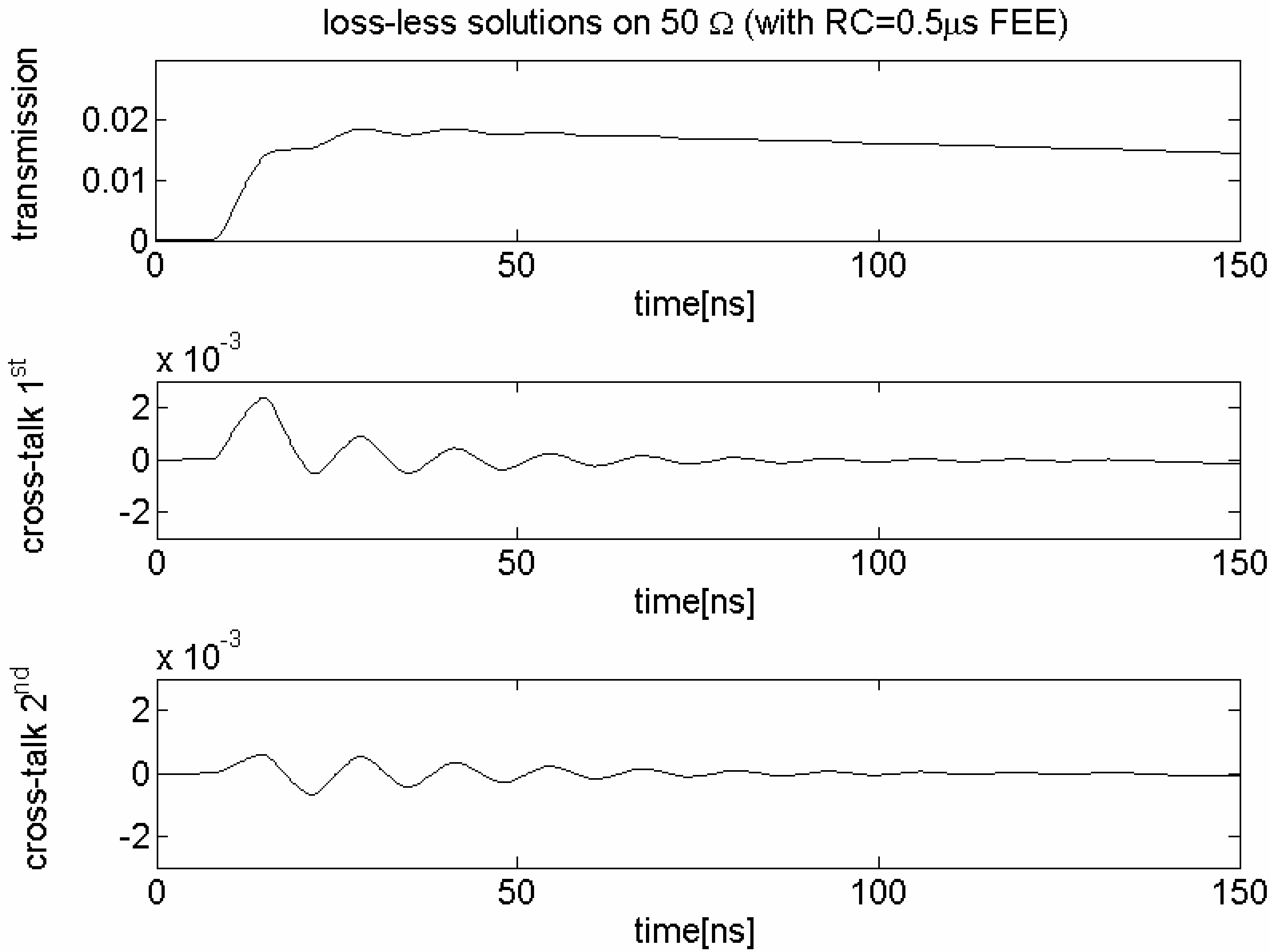
NEXTDEMO



simulated cable signals

for central trace

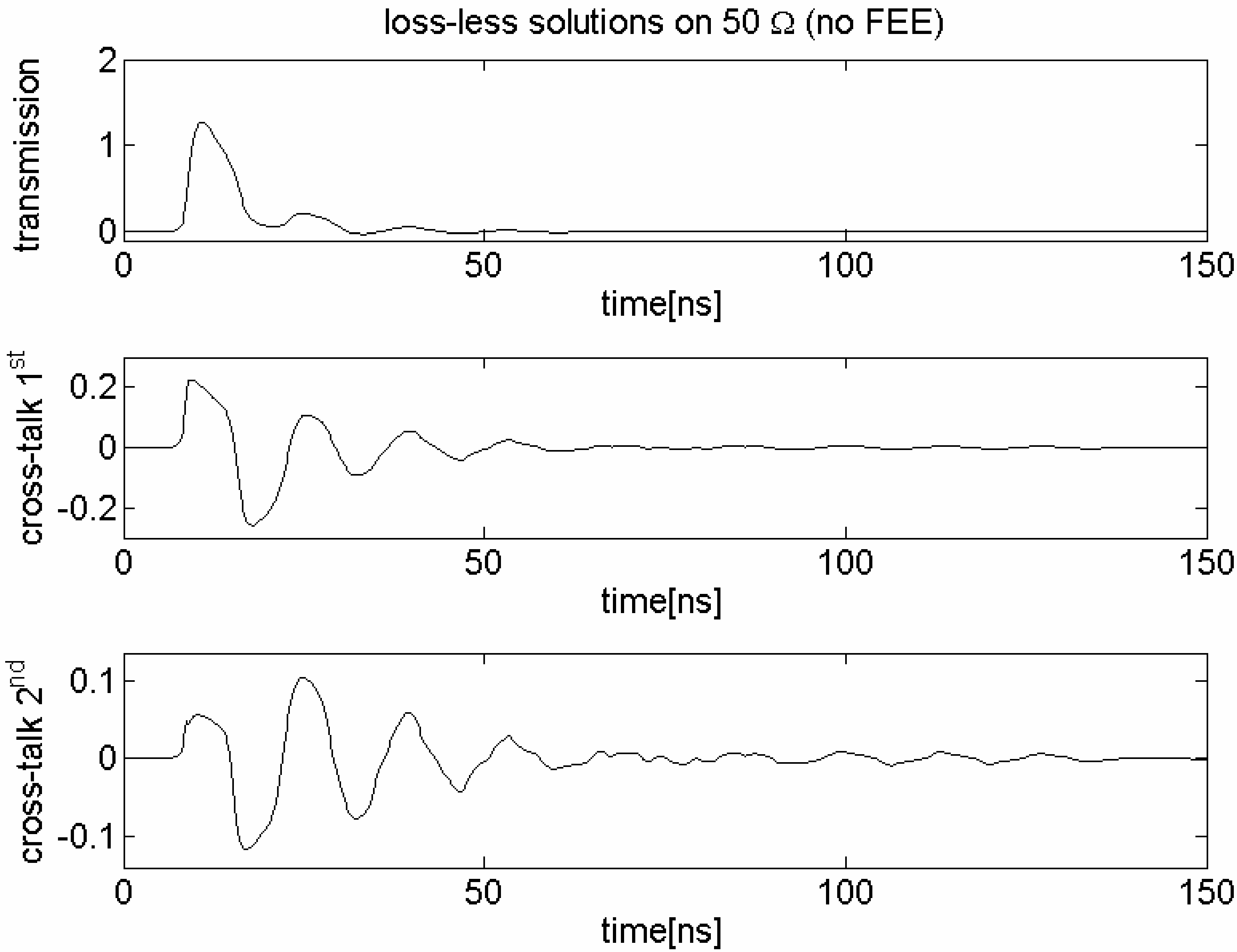
NEXTDEMO



simulated cable signals

for trace close to ground (far-ground side)

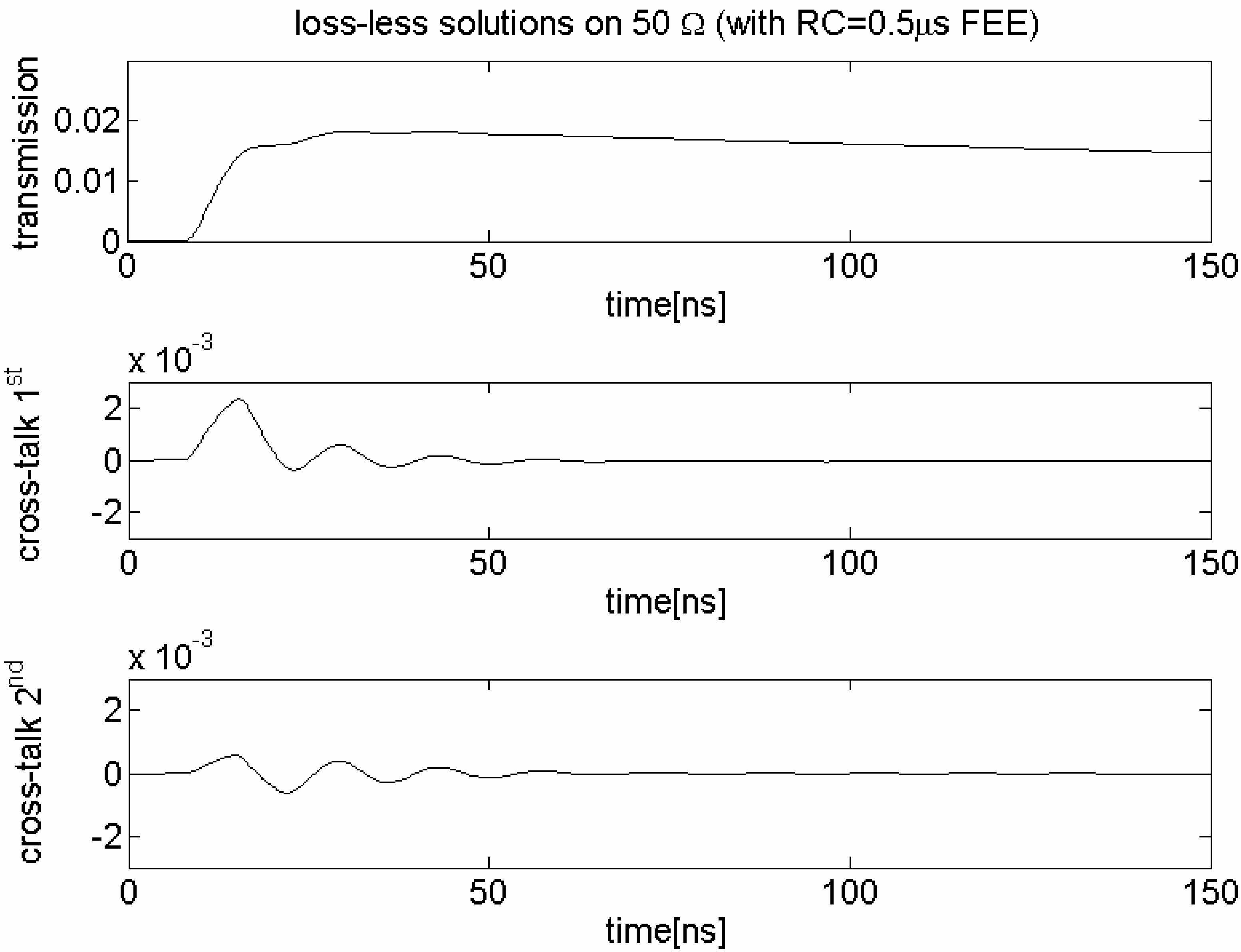
NEXTDEMO



simulated cable signals

for trace close to ground (far-ground side)

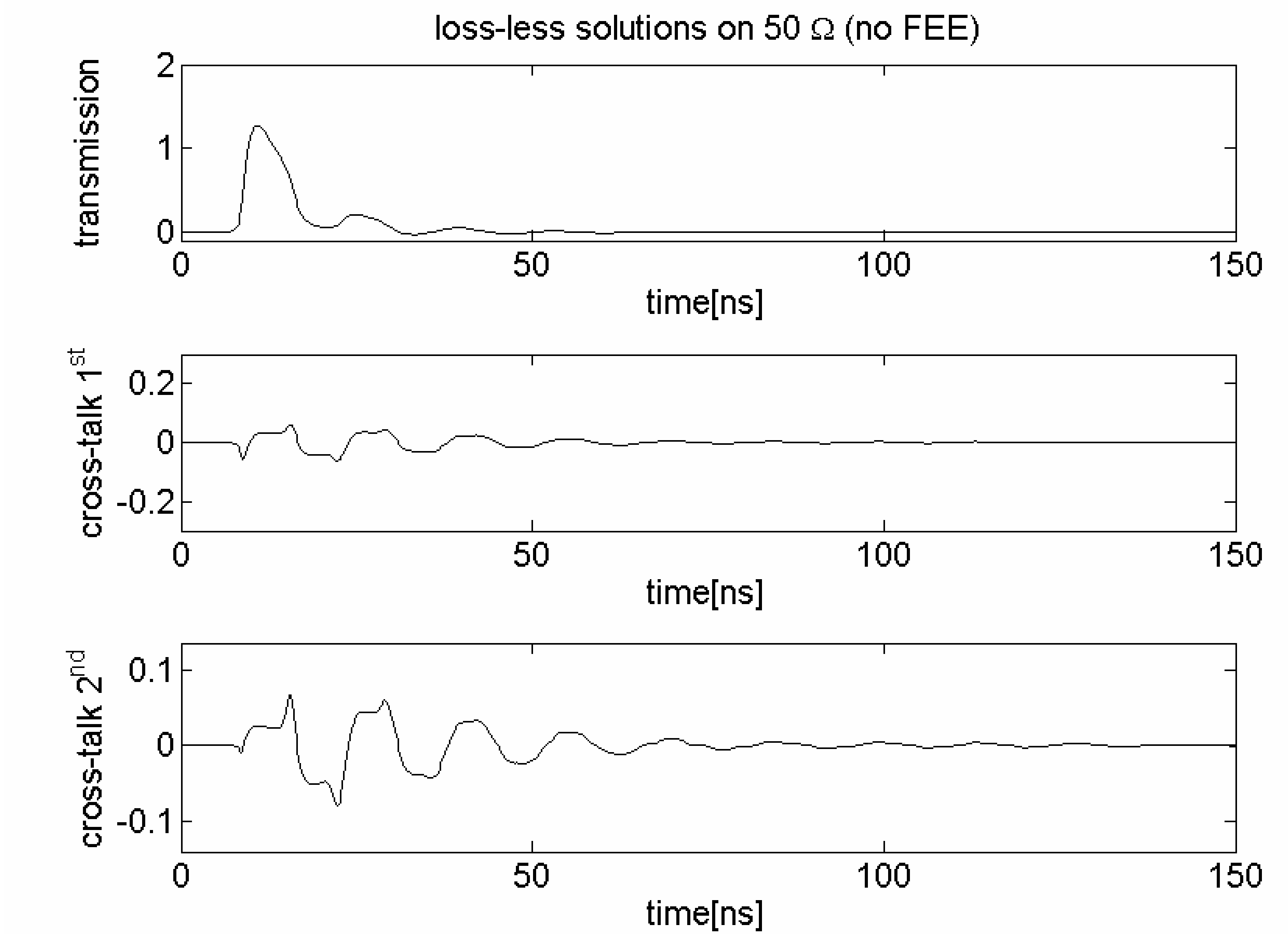
NEXTDEMO



simulated cable signals

for trace close to ground (close-ground side)

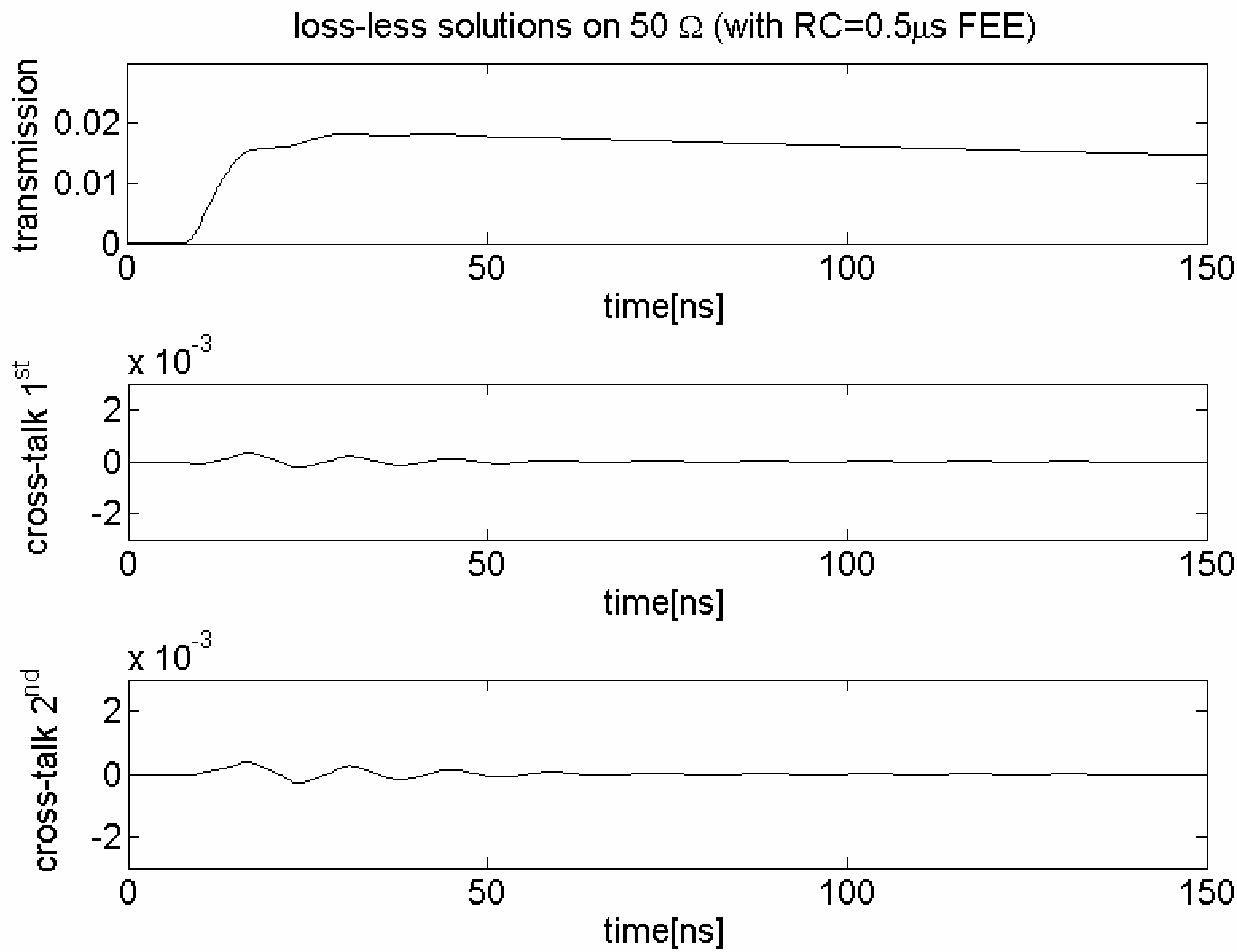
NEXTDEMO



simulated cable signals

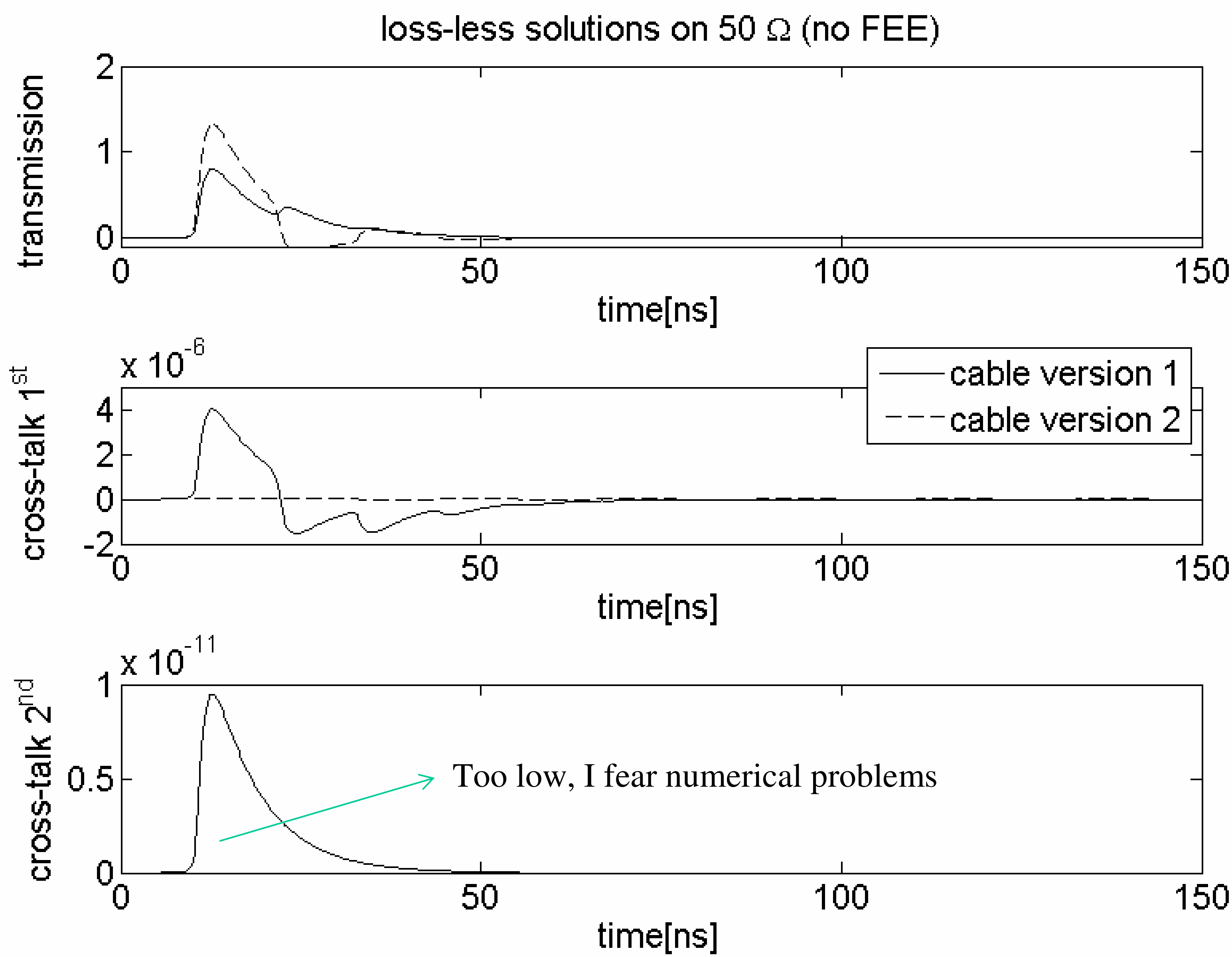
for trace close to ground (close-ground side)

NEXTDEMO



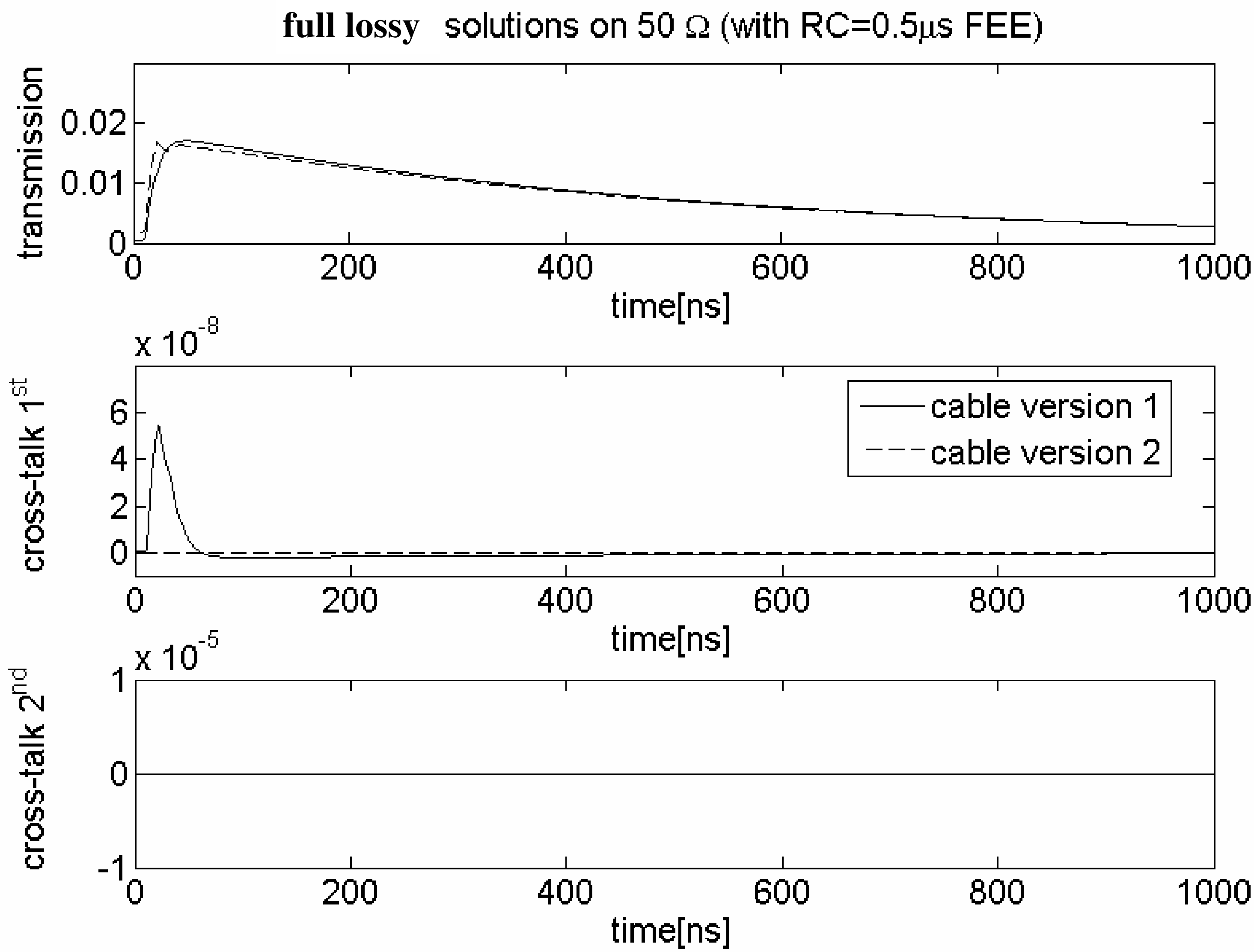
simulated cable signals

NEXT100



simulated cable signals

NEXT100



Conclusions (I)

• Under present constraints, cross-talk and transmission can be improved arbitrarily by increasing the coupling to ground (certainly well below a fraction 1/250pe, where 250pe is the ADC dynamic range). Present cable design has a cross-talk of 1/10pe (different for each trace). Note: Azriel and me are thinking a bit on this, should be possible to come to a conclusion soon. He will do measurements with several capacitances in parallel at the SiPM output to see the effect.

• A symmetric coupling to ground for all strips will help during later studies and data analysis. This ensures same x-talk and same noise for all traces. This is clear.

• Losses (mainly resistive) seem not to be important even for 5µm (thick) x 100µm (wide) cable over 90cm. Some 10% signal decrease. Check again for 4m cable.

• Cable option 1 provides a capacitance to ground of almost 1nF/m and a characteristic impedance of 6.7 Ω. It is essentially the same cable that is currently used, but with a ground plane and thinner copper traces. I have experience routing HF (analog) signals in similar conditions (10Ω, 0.3nF/m), with larger band-width amplifiers (1.5GHz, 50Ω) and up to 1m. Noise was tolerable for the application. Converging… cable option 1 seems the way to go. If we replace the ground plane by meshes the situation will be much more comfortable.

• A good practical condition in order not blow up the noise might be to keep the capacitance with respect to ground to the same level than the capacitance of the SiPM (?). I do not have this input. Converging…

• Cable-1 keeps the pattern necessary for the ZIF connector everywhere so it opens the possibility of ordering rolls, that might save some money. This requires some discussion. I am not sure whether this is really possible. Looks impossible. However building cables of the same length and shifting them by an amount equaling the connector region (ladder instead of arrow configuration) seems possible. This might save quite some money.

Conclusions (II)

• With a reduced copper thickness, the overall cable thickness might be 6.6mm/cable (this is the absolute mininum, since 25µm is the minimum for a bond-ply from Fraloc and the copper thickness cannot be reduced below 5µm. If additional flexibility is required, one might consider segmentation. From a 'profane' point of view, a 2.5mm-thick cable will always have a decent flexibility except perhaps if it is solid copper… (this would mean 3 feedthroughs). With 2 feedthroughs and the proposal in cable 1, the overall thickness per cable will stay within 3mm.

• It is possible to use meshes as ground planes. This might increase flexibility. It is difficult to say, but for the present application, any mesh with a fill-factor of 20%-50% should be ok.
As compared to a solid ground plane, you get:

1. Higher x-talk to neighbor in the same cable. This is ok.
2. Lower coupling to ground. This is ok, indeed a bit better.
3. Higher radiative noise pick-up. Fine with small holes, due to the large RCs of the integrator. Any (allowed) HF pick-up will be dumped at later stages.
4. Higher inter-cable x-talk. Should be fine, needs to be studied if this solution is preferred.

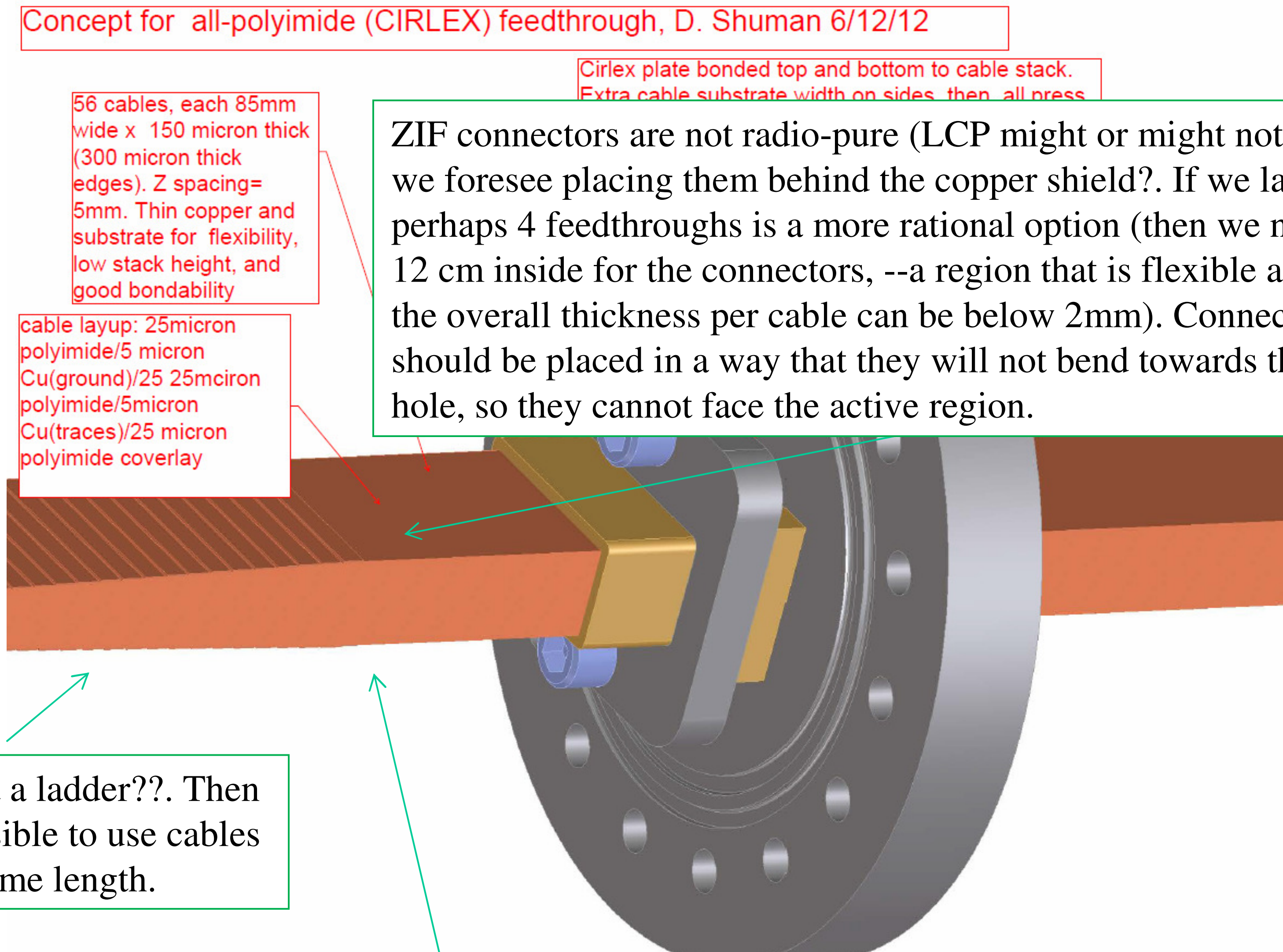
From the specs of LabCircuits, that we have around, this seems clearly the way to go.

• Do not forget that the individual cables have first to go from the SiPM to the thick cable where they will be connected. In particular we need to decide whether we go for a strip-line or micro-strip design. Once connected to the thick cable as long as you have at least a ground plane it all looks strip-line since the neighbor 'closes the box' but it will be different in the cable that sticks out of the SiPM. If possible I suggest to use strip-line everywhere to ease signal transmission and keep characteristic impedance (a prejudice). The cable will be nicer also.

outlook

- Repeat simulations for cable-2 up to 4 meters. Assess losses more critically.
- Check inter-cable x-talk for a ground mesh.
- Evaluate noise-figure.
- Proceed with contacts with company.

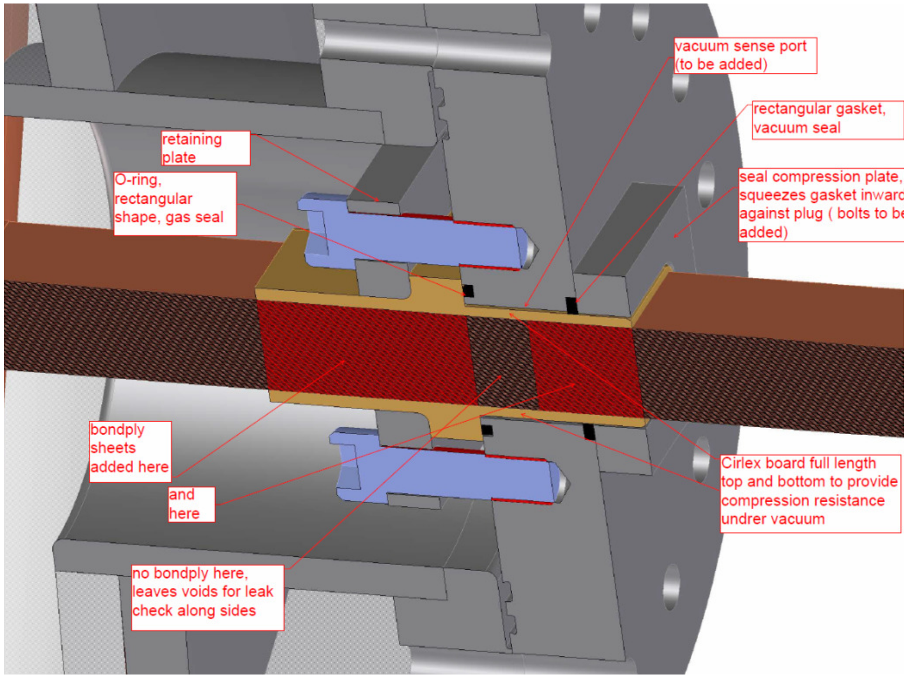
Some extra technical questions

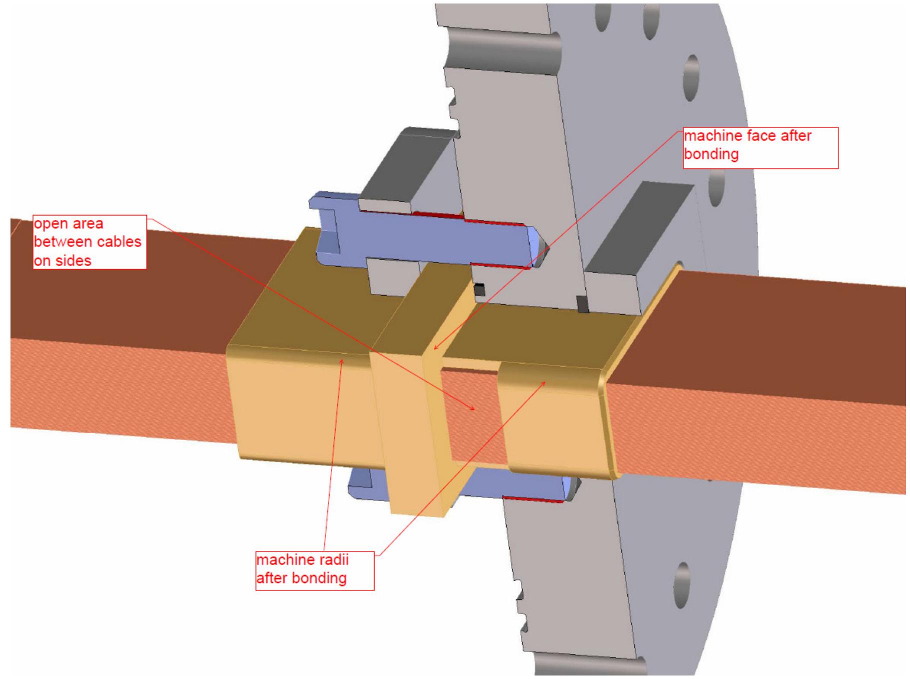


ZIF connectors are not radio-pure (LCP might or might not), could we foresee placing them behind the copper shield?. If we lack space, perhaps 4 feedthroughs is a more rational option (then we need some 12 cm inside for the connectors, --a region that is flexible anyhow, the overall thickness per cable can be below 2mm). Connectors should be placed in a way that they will not bend towards the inner hole, so they cannot face the active region.

Why not a ladder??. Then it is possible to use cables of the same length.

We need some 25cm inside/feedthrough in order to stager the connectors in a ladder, do we have this space??





All polyimide plug should be stronger and more leakproof than an epoxy bonded construction. material has 50 kpsi (350 MPa tensile strength), better than any epoxy. Delamination should not be a concern. Tapered plug concept of previous concept should not be necessary