Frequency dependent Measurement and theoretical Prediction of Characteristic Parameters of Vacuum Cable Micro-Striplines

LArg week, Nov.18 2002 Margret Fincke-Keeler Univ. of Victoria

- Risetime of a typical ATLAS LAr pulse is approx. 20 ns, corresponding to a bandwidth of 17.5 MHz.

- Explore the frequency dependent behaviour of the vacuum cable micro-striplines by performing measurements of the complex characteristic impedance as a function of frequency up to 100MHz.

- Calculate characteristic parameters under the assumption that the high frequency TEM mode approximation can be used.

Measure:

magnitude and phase of the stripline impedance for open circuit and short circuit termination:

$$|Z_{oc}| \qquad \phi_{oc} \qquad |Z_{sc}| \qquad \phi_{sc}$$

→ complex impedances Z_{oc} , Z_{sc}

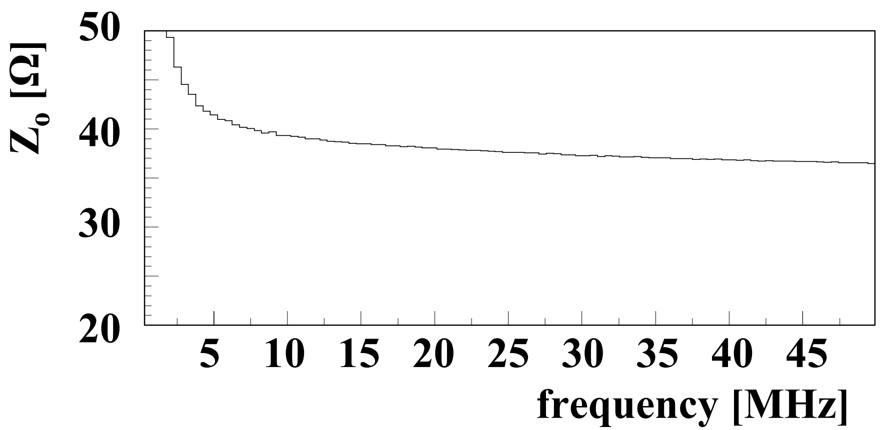
Calculate the complex characteristic impedance: $$Z_o = \sqrt{Z_{sc} Z_{oc}}$$

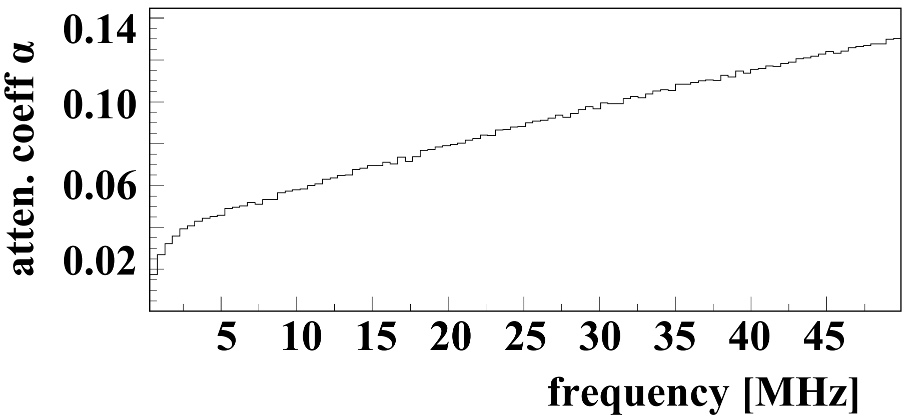
And the quantity: $$\tanh(\gamma l) = \sqrt{Z_{sc} / Z_{oc}}$$

With: l = length of stripline, γ = propagation coeff. = $\alpha + i\beta$

α = attenuation coeff. β = phase change coeff.

Impedance and attenuation coefficient





Calculate:

Resistance $R = \Re e(\gamma\sqrt{Z_{sc}Z_{oc}})$

Inductance $L = \Im m(\gamma\sqrt{Z_{sc}Z_{oc}})/2\pi\nu$

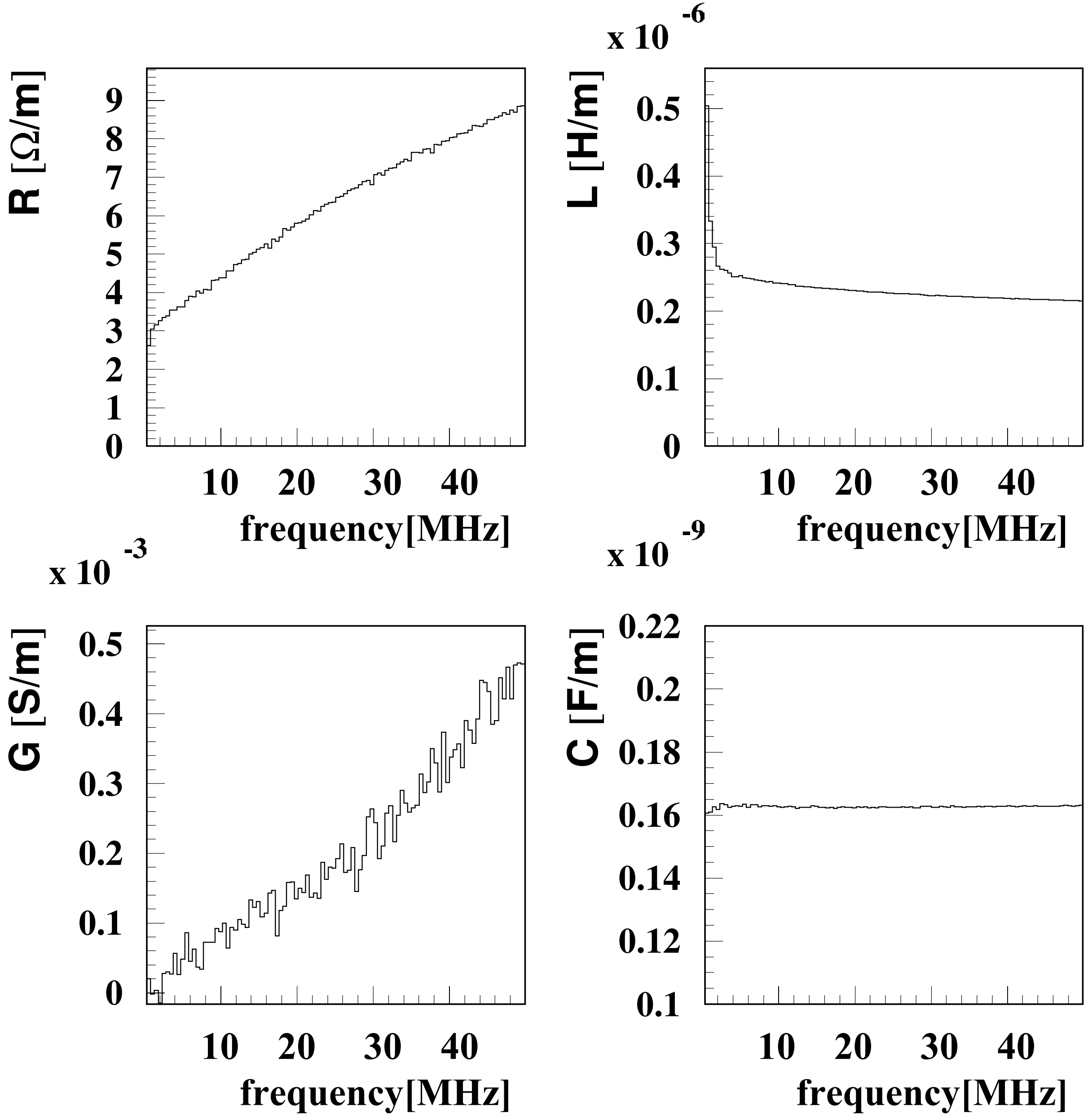
Conductance $G = \Re e(\gamma/\sqrt{Z_{sc}Z_{oc}})$

Capacitance $C = \Im m(\gamma/\sqrt{Z_{sc}Z_{oc}})/2\pi\nu$

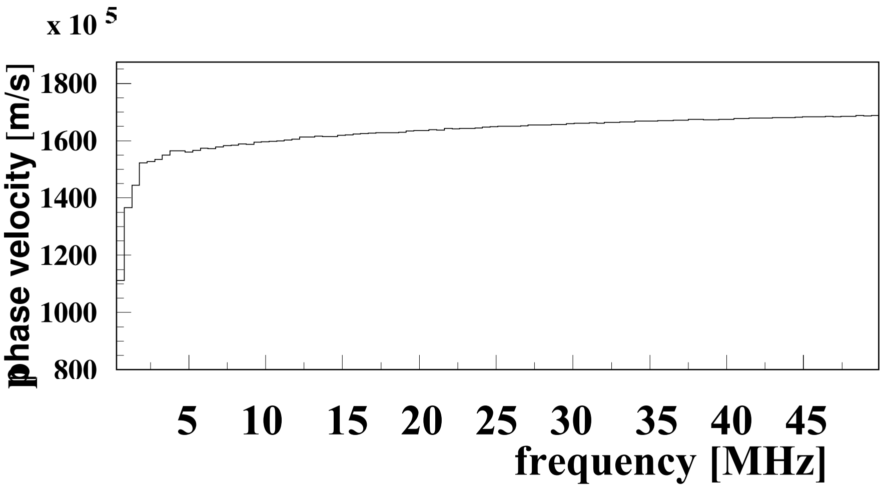
Phase velocity: $\upsilon_p = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}}$

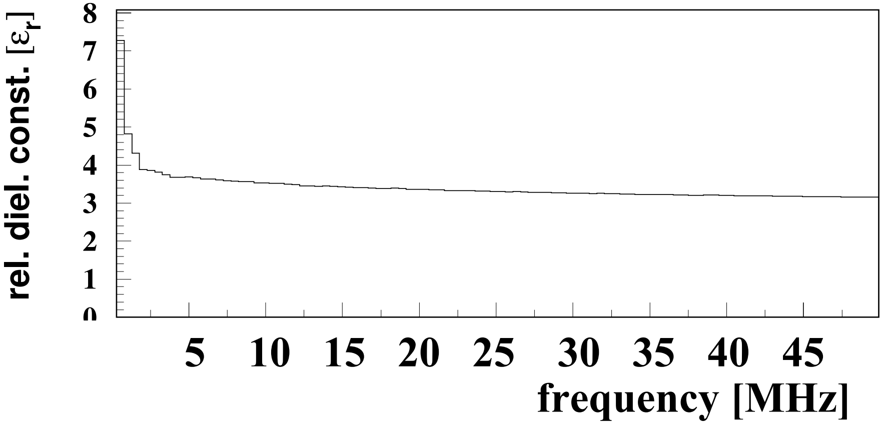
Dielectric constant: $\varepsilon_r = \frac{c^2}{\upsilon_p^{\,2}}$

Primary transmission line parameters: R, L, G, C



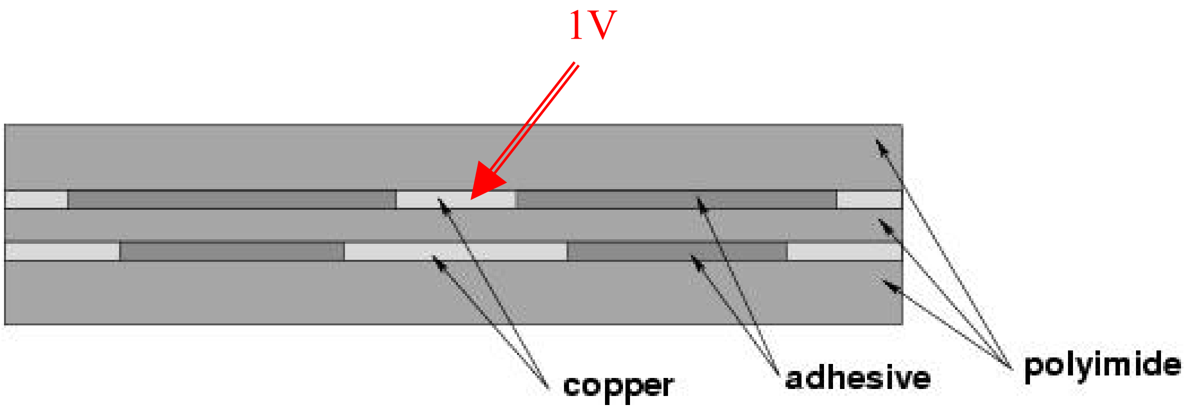
Phase velocity and relative dielectric constant





Theoretical description

For a given strip line geometry, solve Laplace's equation numerically to obtain the capacitance per unit length.



Do the calculation twice: once with ε_r=0 around the copper strips (vacuum)
once with ε_r for polyimide and adhesive materials.

Obtain: capacitance of Cu strips in vacuum C_v
capacitance of Cu strips in dielectric C_ε

$$\Rightarrow \quad Z_o = \frac{1}{c\sqrt{C_\upsilon C_\varepsilon}}$$

	signal width	ground width	strip thick-ness	ε_r Poly-imide	ε_r adhe-sive	C_υ	C_ε	Z_o	
A	200	360	34	3.2	4.0	51.4	172.5	35.4	
B	200	360	34	3.4	4.0	51.4	182.4	34.4	
C	200	360	34	3.2	4.4	51.4	174.1	35.4	
D	200	360	30	3.2	4.0	51.0	171.8	35.6	
E	190	360	34	3.2	4.0	49.7	167.6	36.5	←
F	180	360	34	3.2	4.0	48.3	162.4	37.6	
G	180	315	34	3.2	4.0	47.2	158.8	38.5	
H	220	385	34	3.2	4.0	55.0	171.8	34.3	
I	200 (20μ)	360	34	3.2	4.0	51.2	172.1	35.5	

Now we can calculate: $$L = \frac{1}{c^2 C_\upsilon}$$

We can determine R from the resistivity of copper and the cross sectional area of the copper strips. The skin effect has been taken into account in a simplified approximation. Now we can calculate:

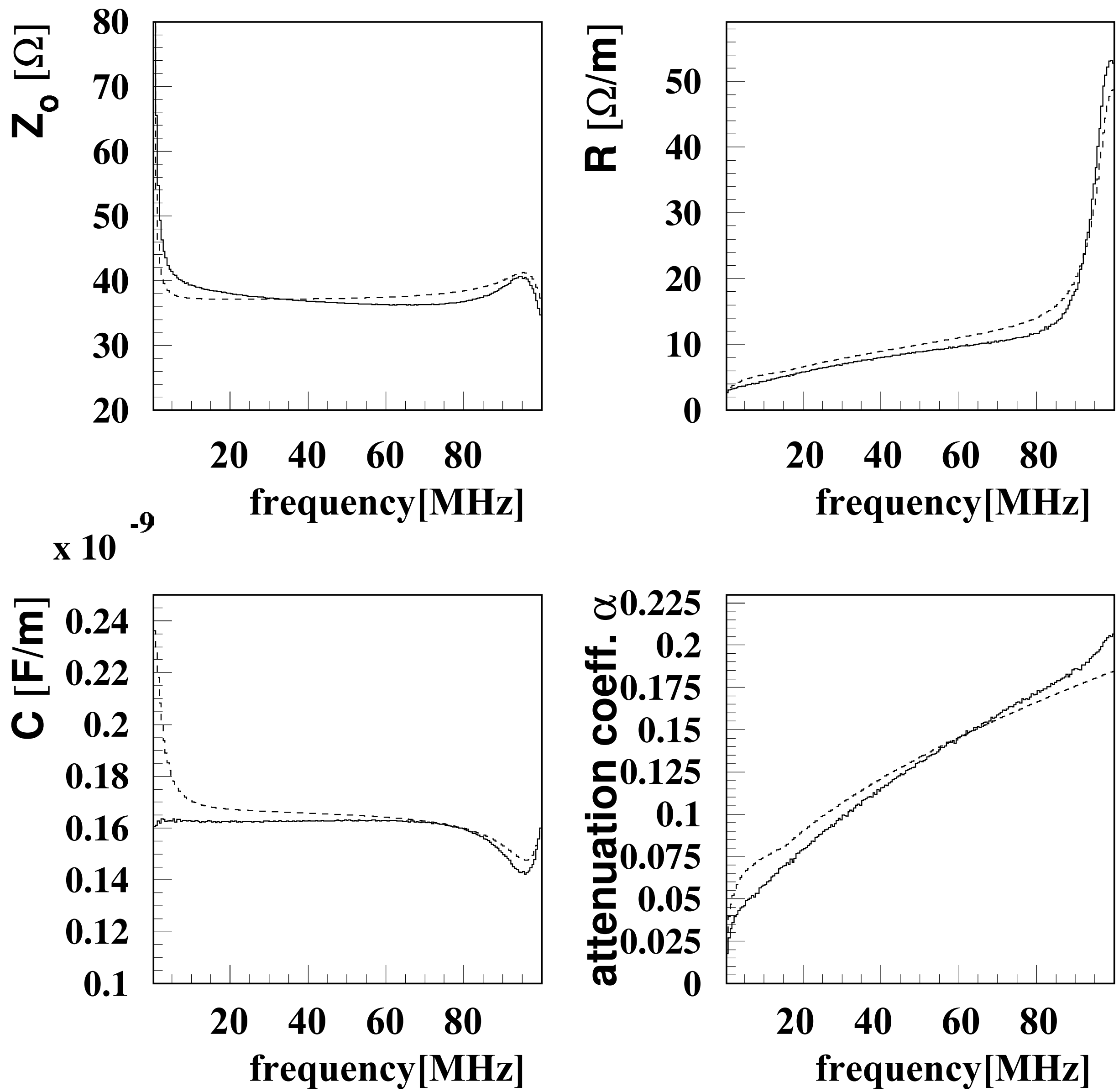
$$\gamma = \sqrt{(R + i\omega L)(i\omega C)}$$

and it follows:

$$Z_{oc} = Z_o \coth(\lambda l_{oc}) \qquad Z_{sc} = Z_o \tanh(\lambda l_{sc})$$

where l_{oc} , l_{sc} are the electrical lengths of the stripline with open circuit and Short cuircuit termination respectively.

Comparison between measurement and theoretical Prediction.



Signal Width = 190µm
Ground width = 360µm
Thickness = 34µm
ε_r (polyimide)=3.2
ε_r (adhesive)=4.0

Conclusions

- The complex characteristic impedance of the vacuum cable micro-striplines has been measured as a function of frequency.

- A numerical solution of Laplace's equation yields the values of the capacitances C_υ and C_ε of the copper strips in vacuum and in dielectric respectively, and allows the calculation of the characteristic line parameters for that geometry.

- The results of the theoretical calculations are in good agreement with the measurement.
  The differences between the calculation and data are most likely due to the approximation and assumptions made for the calculations (e.g. high freq. TEM mode, skin effect).