IPMs IN THE LHC

F. Caspers, A. Grudiev and E. Métral

- **Logics of our analysis $\Rightarrow$ For a reasonable and comprehensive answer to the IPM team**

Review of the analysis and scaling (1/6)

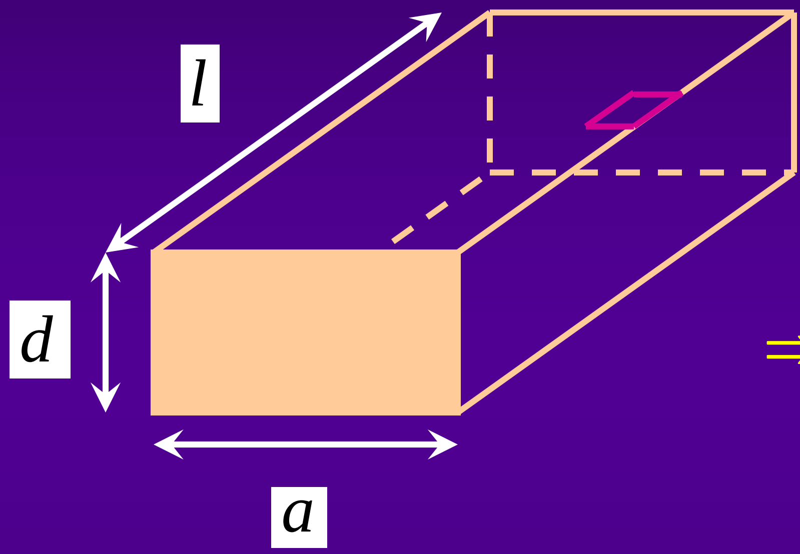
- **AG made HFSS simulations for the real geometry (metallic plates) and found 3 critical trapped modes ⇒ Large induced power for the LHC parameters**

$f_{r1} = 0.248\ \mathrm{GHz}$	$Q_1 = 1228$	$R_{s1} = 215\ \Omega$	⇒	$P_1 = 150\ \mathrm{W}$
$f_{r2} = 0.252\ \mathrm{GHz}$	$Q_2 = 1184$	$R_{s2} = 728\ \Omega$	⇒	$P_2 = 507\ \mathrm{W}$
$f_{r3} = 0.457\ \mathrm{GHz}$	$Q_3 = 6114$	$R_{s3} = 43\ \Omega$	⇒	$P_3 = 20\ \mathrm{W}$

- **These high-Q modes should therefore be damped**
- **Ferrite cannot be used as it will be seen by the beam**
- **FC proposed to put a resistive coating (instead of ferrite), but a resistive coating does not work on a metal (the induced currents will continue to flow into the metal) ⇒ One has first to put a ceramic plate and then add a resistive coating on top of it**

Review of the analysis and scaling (2/6)

- FC proposed to AG to make HFSS simulations using a ("surface") resistance of 100 "Ω per square"



$$R = \rho \frac{l}{S} \qquad S = d\,a$$

$$\Rightarrow \quad R = R_{\text{per square}} \frac{l}{a} \quad \text{with} \quad R_{\text{per square}} = \frac{\rho}{d}$$

- For each square ($l = a$), $R = R_{\text{per square}} = \text{constant}$

- AG verified that the modes were indeed damped: the Q values went from few thousands to a few tens, i.e. a reduction by a factor of ~100

Review of the analysis and scaling (3/6)

- However, the problem is that the IPM team has difficulties to produce this "surface" resistance of 100 Ω per square, because the layer is then too thin

- The IPM team asked whether they can do it thicker, i.e. increase d

Property of the material

- In this case the "surface" resistance will be smaller as $R_{\text{per square}} = \frac{\rho}{d}$

- A smaller "surface" resistance means a lower damping of the trapped modes. Can one accept that? And to which extent?

- FC told us last week YES: This thickness is not so critical (if one uses a "surface" resistance between ~ 30 and 100 Ω per square) as the attenuation curves are flat. Therefore FC recommended an initial window between 30 and 50 Ω per square, which will later increase to 50-100 Ω per square by aging

Review of the analysis and scaling (4/6)

- **The justification of this educated hand-waving guess is in the paper CERN/PS/86-20 (AA): C.R. Carter and F. Caspers, "An Exact Treatment of a Rectangular Waveguide Symmetrically Loaded with Resistively Coated Dielectric Slabs for Maximum Attenuation", 1986**

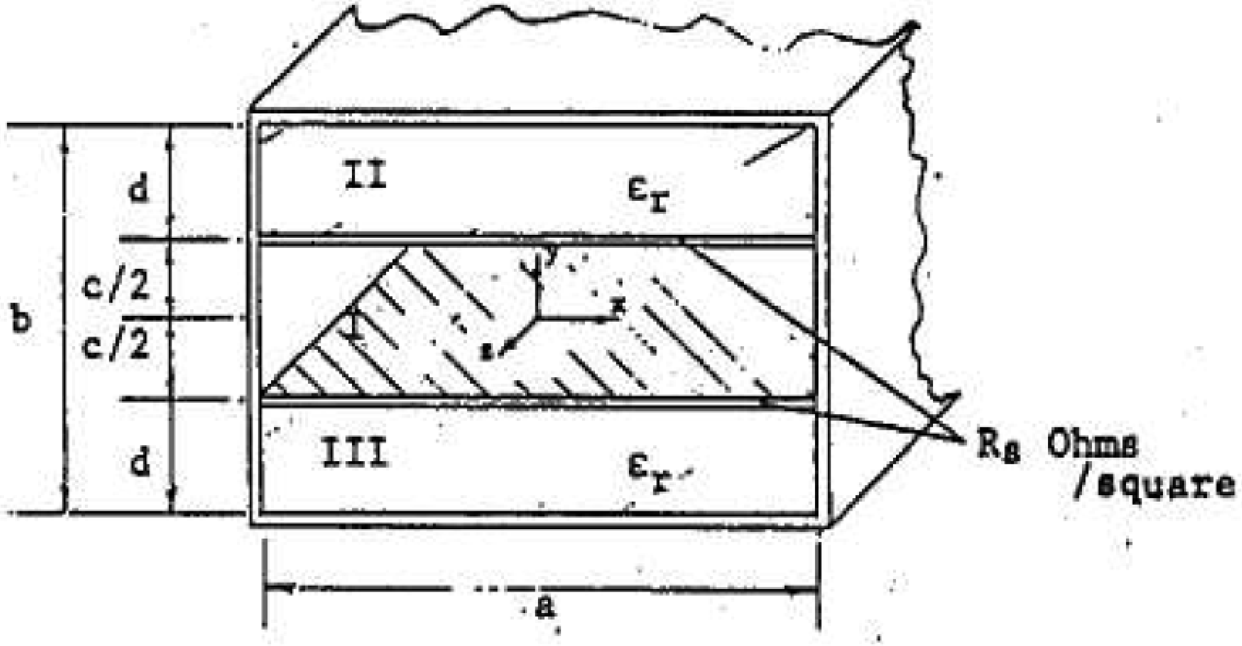


Figure 1: A dielectric-loaded waveguide with resistive coatings on the air-dielectric interfaces of each slab.

Review of the analysis and scaling (5/6)

Attenuation

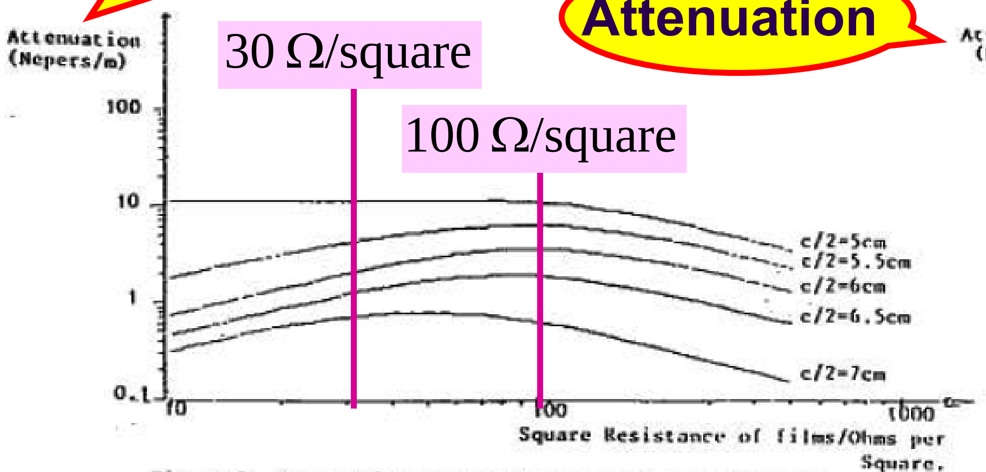


Figure 2: Attenuation due to E-plane resistive films at various positions in a 15x7.5cm waveguide at 1.4GHz.

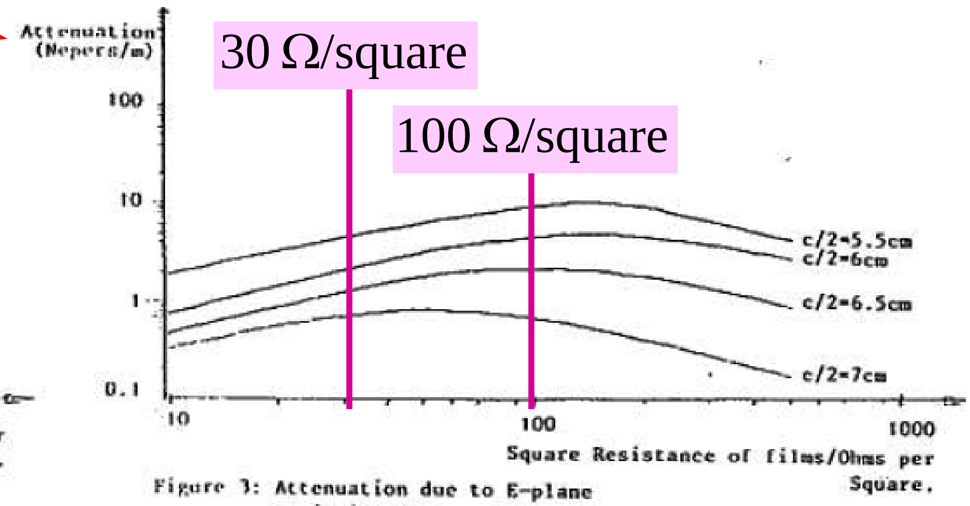


Figure 3: Attenuation due to E-plane resistive film coatings on Alumina (ϵ_r=9.6) slabs of various thickness at 1.4GHz.

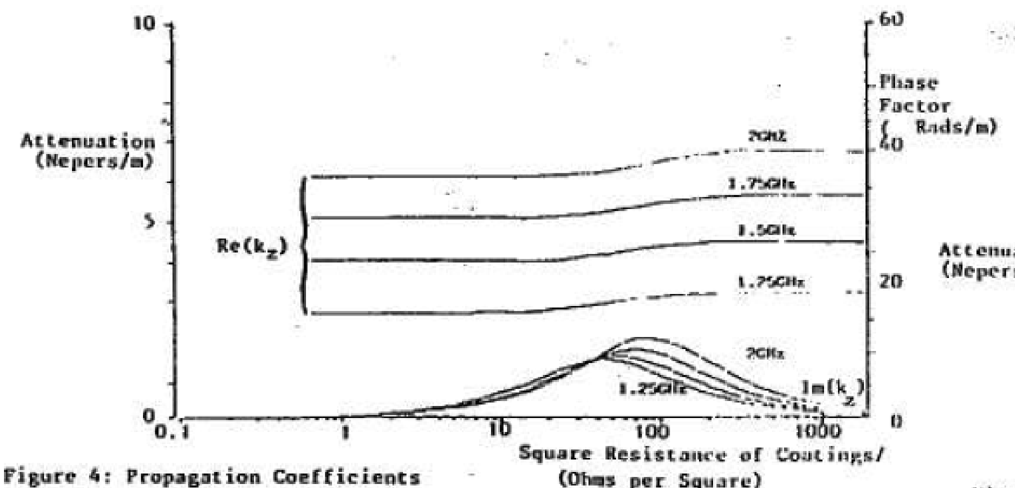


Figure 4: Propagation Coefficients for a 15x7.5cm waveguide loaded with Alumina(ϵ_r=9.6) H-plane slabs, thickness 5mm, with resistive coatings.

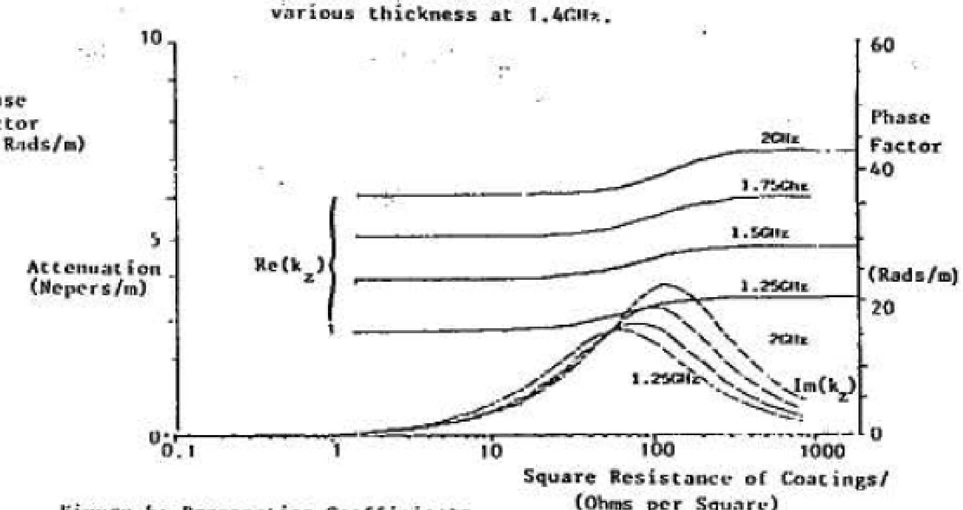


Figure 5: Propagation Coefficients for a 15x7.5cm waveguide, loaded with H-plane dielectric slabs (ϵ_r=3.75), thickness 1cm, coated with resistive films.

Review of the analysis and scaling (6/6)

- **Conclusion: As mentioned by FC, the attenuation curves are rather flat between 30 and 100 Ω per square (factor ~2-3 at max), and no major changes are expected for the damped Q-values when going from 100 Ω per square (values used by AG for the HFSS simulations) to 30**