WS-07, Dielectric Substrate Characterization

Complex Permittivity Measurements with Split-Post Resonator

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Outline of Presentation

- Dielectric resonators in complex permittivity measurements
- Theory of split post dielectric resonators
- Measurement uncertainties and resolution
- Results of measurements
- Split post for ferrite substrates characterization
- Conclusions

Dielectric resonators use in complex permittivity measurements of substrates (history)

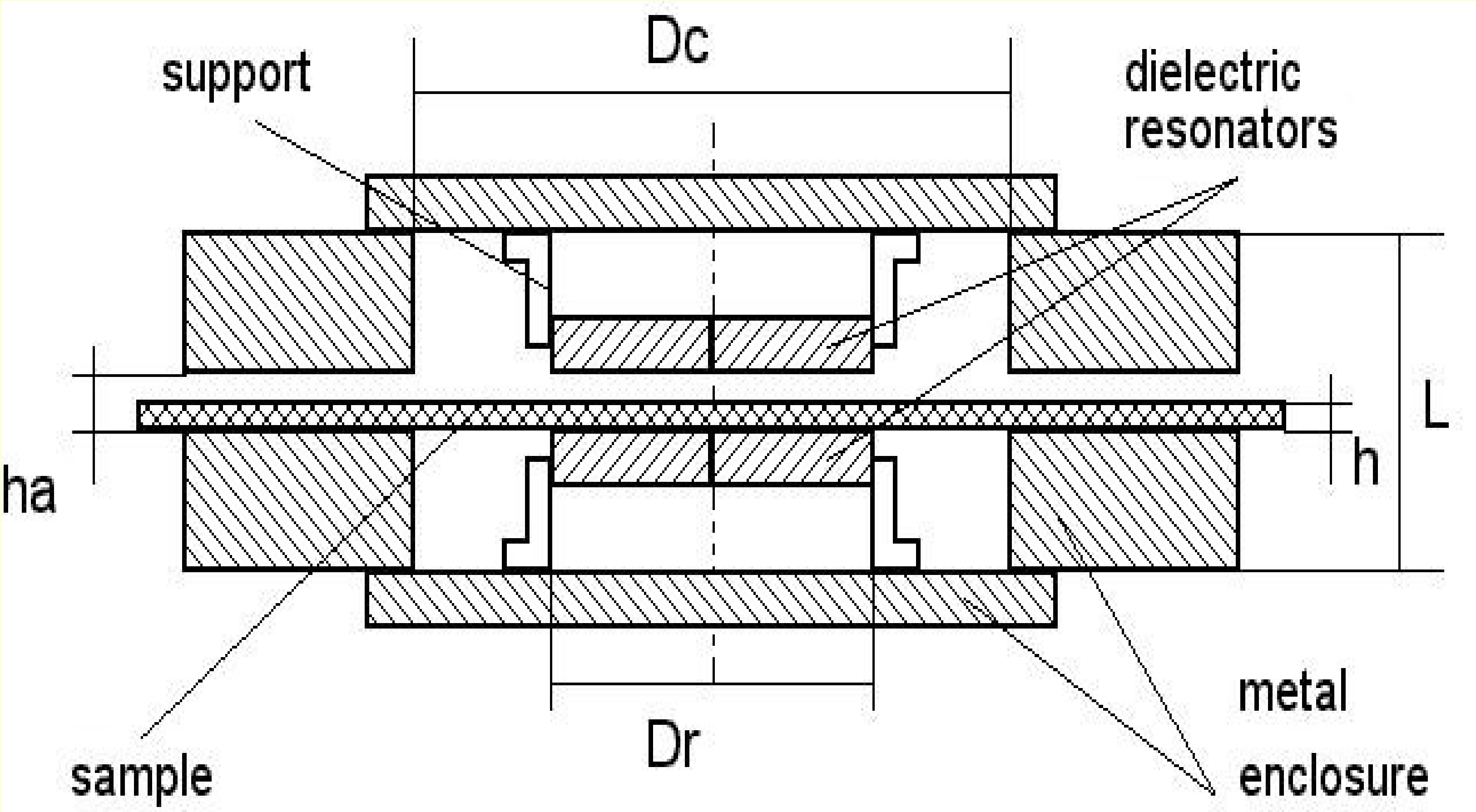
[1] J. DelaBalle, P. Guillon and Y. Garault, AEU Electronics and Communication, vol. 35, pp.80-83, 1981.

[2] J. Krupka and Sz. Maj, CPEM '86 Conference, pp.154-155, Gaithersburg, Maryland, 23-27 June 1986.

[3] T. Nishikawa, K. Wakino, H. Tanaka, and Y. Ishikawa, CPEM ’88 Conference, pp. 154-155, 1988

[4] J. Krupka, R.G. Geyer, J. Baker-Jarvis, and J. Ceremuga, DMMA'96 Conference, Bath, pp.21-24, U.K. 23-26 Sept. 1996.

Schematic diagram of a split post dielectric resonator



Photographs of split post dielectric resonators

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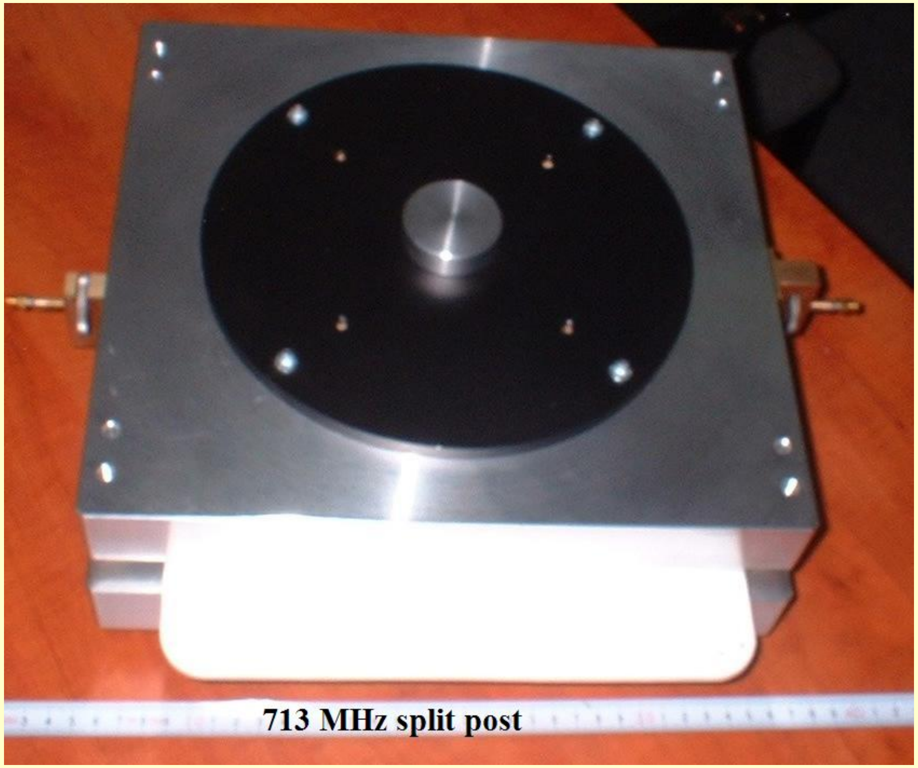
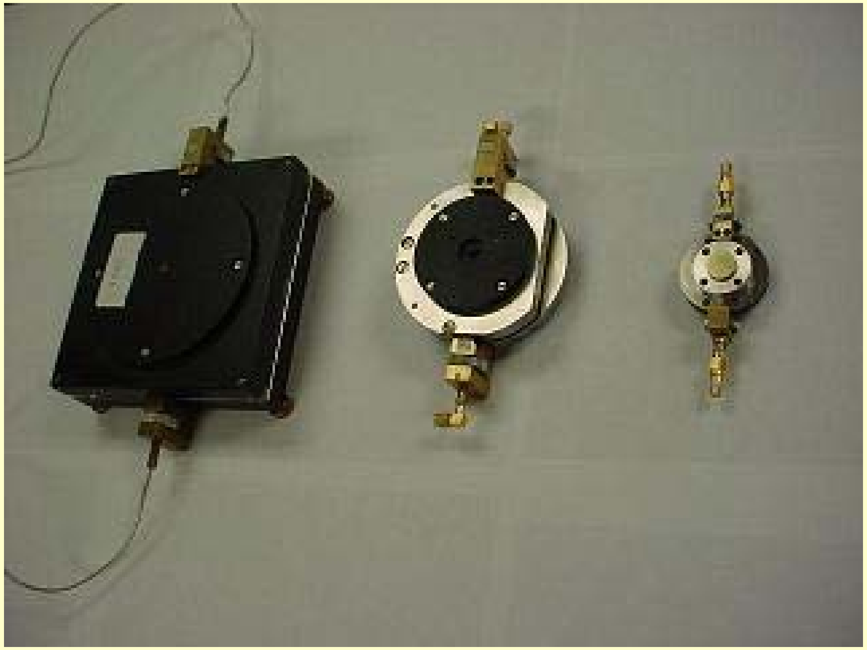
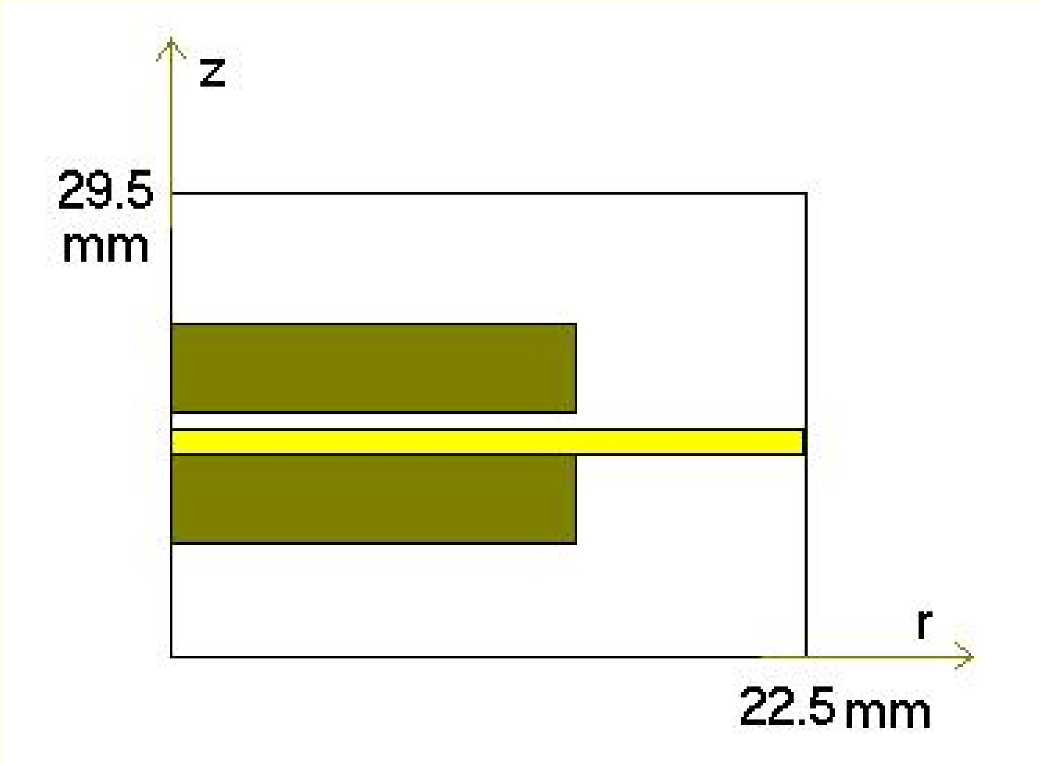




Electromagnetic filed distribution in 1.44 GHz SPDR



Electric field in empty resonator

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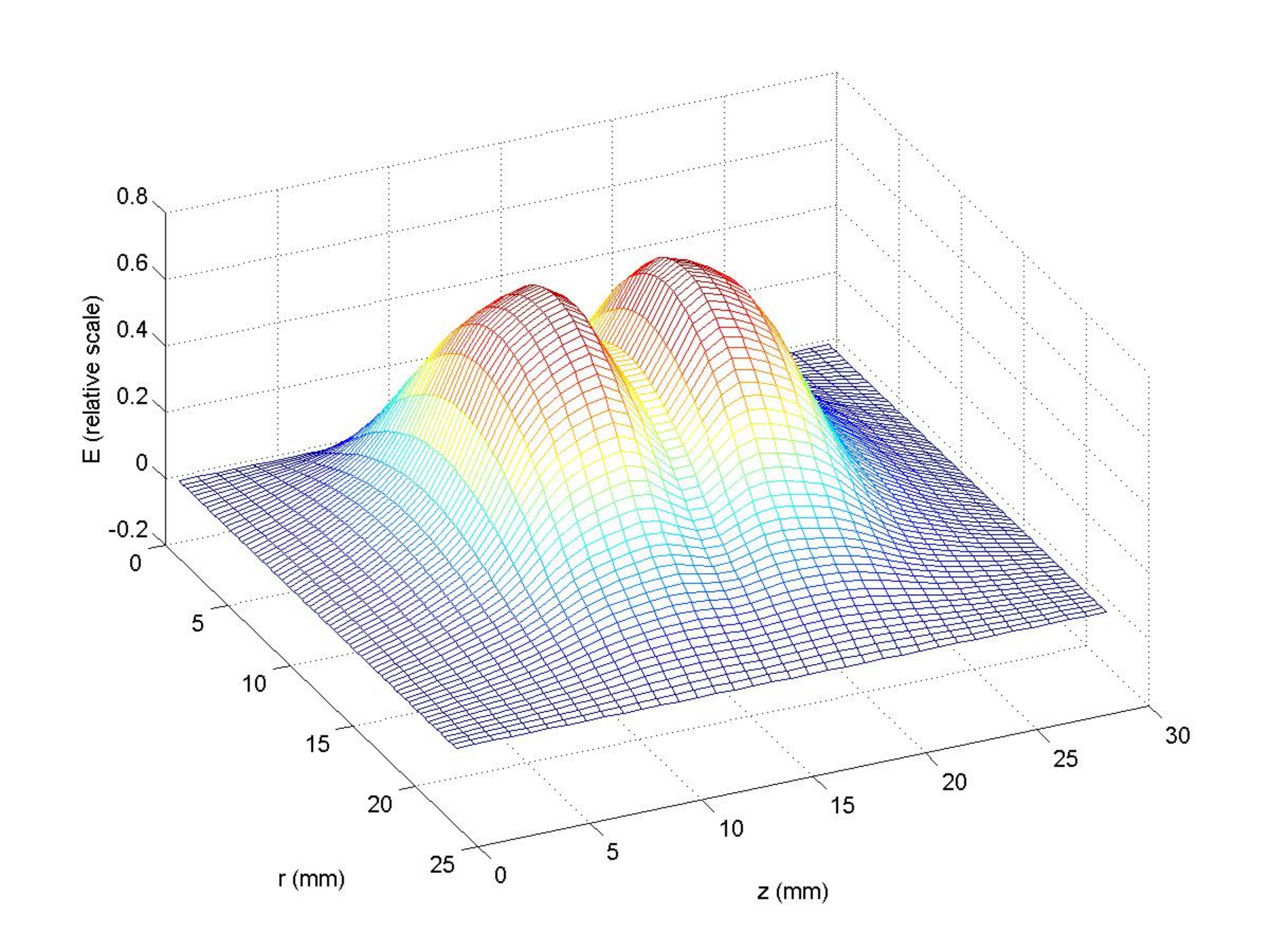
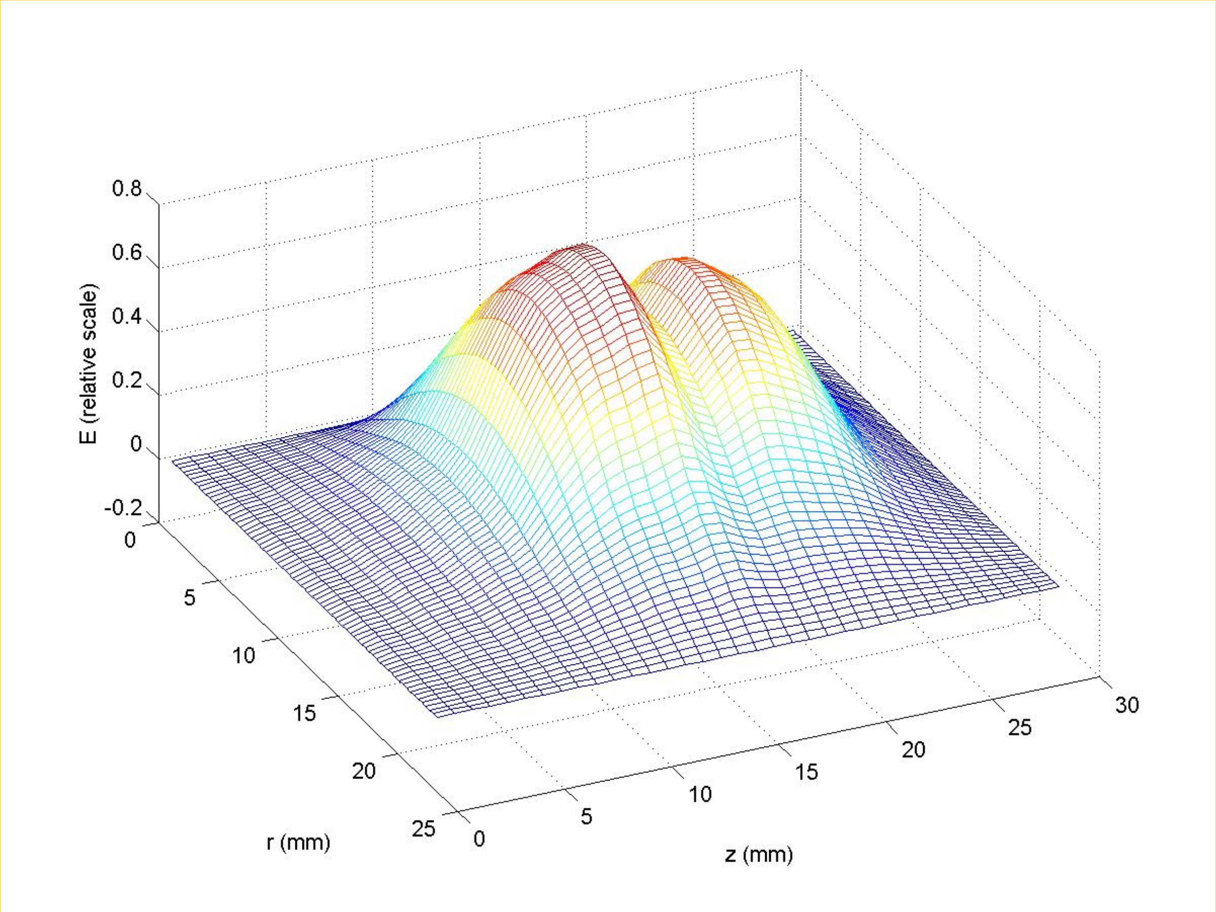


Electric field in a presence of a sample having h=0.2 mm and permittivity 300



Complex permittivity determination

$$\varepsilon_r' = 1 + \frac{f_0 - f_s}{h f_0 K_\varepsilon(\varepsilon_r', h)}$$

h - the thickness of the sample under test

f_0 - the resonant frequency of the empty SPDR

f_s - the resonant frequency of the SPDR with the dielectric sample

K_ε - a function of and h (computed and tabulated for specific SPDR)

Complex permittivity determination

$$\tan\delta = (Q^{-1} - Q_{DR}^{-1} - Q_c^{-1})/p_{es}$$

$$p_{es} = \frac{W_{es}}{W_{et}} = \frac{\iiint_{V_S} \varepsilon_S \mathbf{E}\cdot\mathbf{E}^* dv}{\iiint_V \varepsilon(v)\mathbf{E}\cdot\mathbf{E}^* dv} = h\varepsilon_r' K_1(\varepsilon_r', h)$$

$$Q_c = \frac{\iiint_V \mu_0 \mathbf{H}\cdot\mathbf{H}^* dv}{R_S \oiint_S \mathbf{H}_\tau \cdot \mathbf{H}_\tau^* ds} = Q_{c0} K_2(\varepsilon_r', h)$$

Uncertainties

$$\frac{\Delta\varepsilon_r^{'}}{\varepsilon_r^{'}} = T\frac{\Delta h}{h} + \frac{\Delta K_\varepsilon}{K_\varepsilon} \qquad 1 < \mathrm{T} < 2$$

$$\frac{\Delta \mathrm{K}_\varepsilon}{\mathrm{K}_\varepsilon} = \mathrm{T}_{\mathrm{dr}}\frac{\Delta \mathrm{dr}}{\mathrm{dr}} + \mathrm{T}_{\mathrm{hr}}\frac{\Delta \mathrm{hr}}{\mathrm{hr}} + \mathrm{T}_{\varepsilon\mathrm{d}}\frac{\Delta \varepsilon\mathrm{d}}{\varepsilon\mathrm{d}} +$$

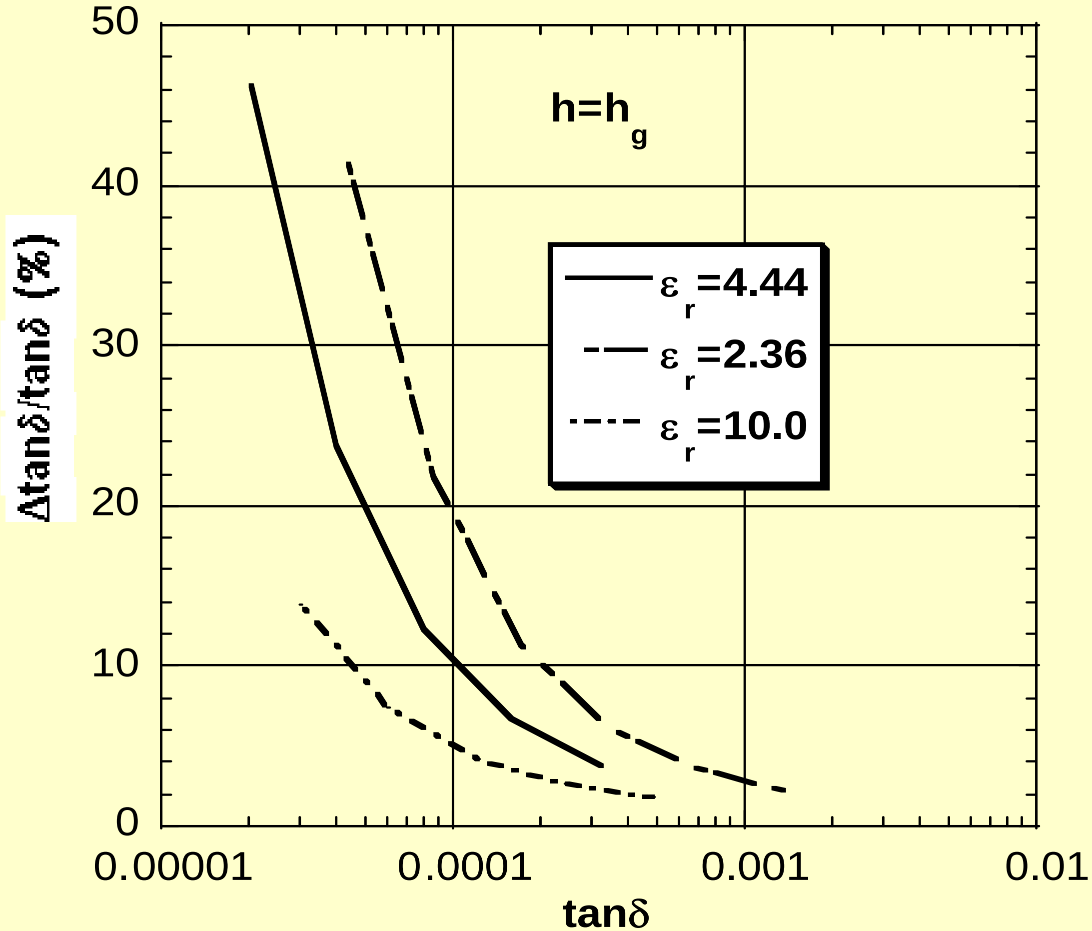
$$+\mathrm{T}_{\mathrm{D}}\frac{\Delta \mathrm{D}}{\mathrm{D}} + \mathrm{T}_{\mathrm{L}}\frac{\Delta \mathrm{L}}{\mathrm{L}} + \mathrm{T}_{\mathrm{hg}}\frac{\Delta \mathrm{hg}}{\mathrm{hg}}$$

$$\frac{\Delta \mathrm{dr}}{\mathrm{dr}} = 0.1\%, \quad \frac{\Delta \mathrm{hr}}{\mathrm{hr}} = 0.5\%, \quad \frac{\Delta \varepsilon\mathrm{d}}{\varepsilon\mathrm{d}} = 0.2\%,$$

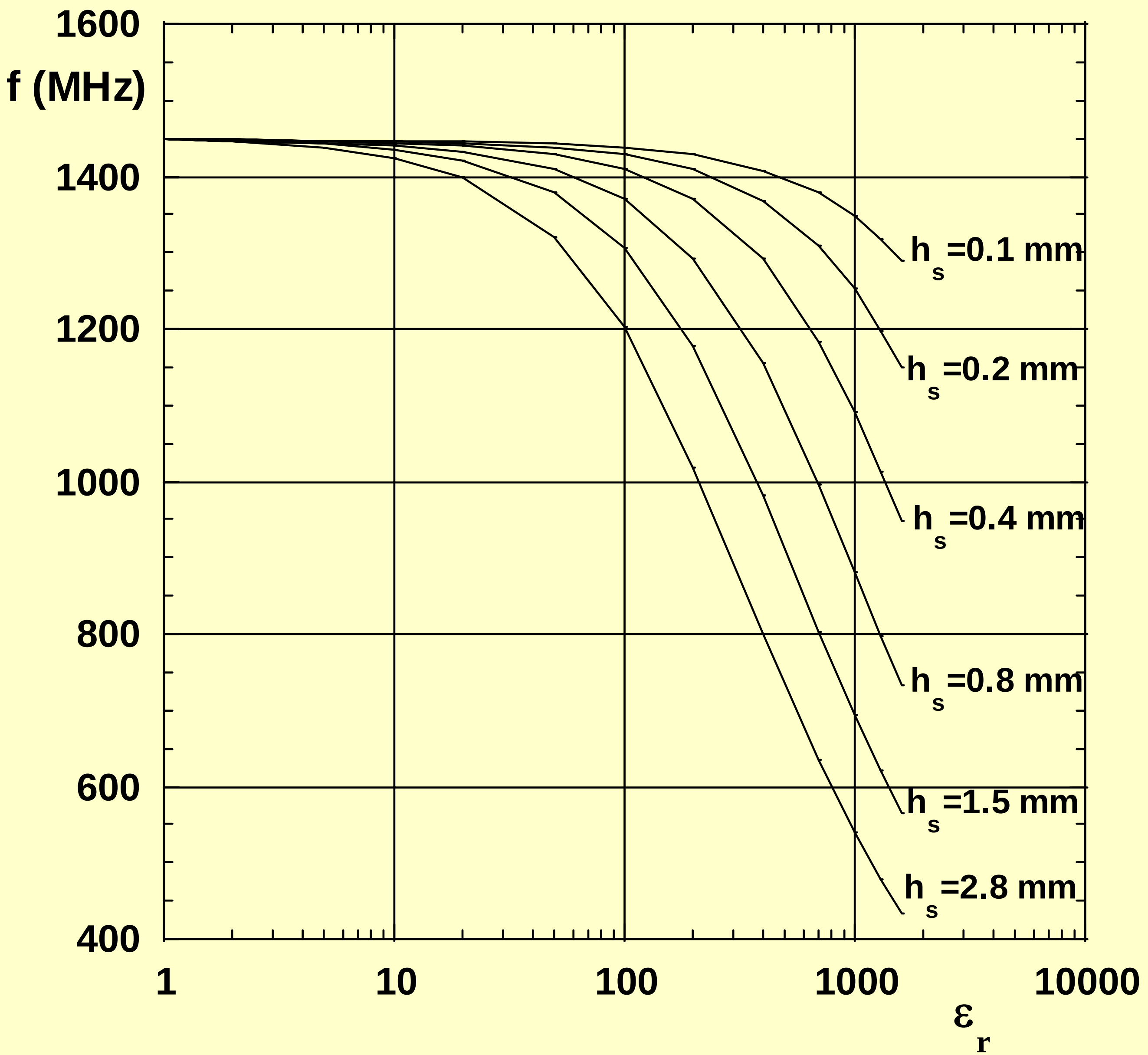
$$\frac{\Delta \mathrm{D}}{\mathrm{D}} = 0.1\%, \quad \frac{\Delta \mathrm{L}}{\mathrm{L}} = 0.2\%, \quad \frac{\Delta \mathrm{hg}}{\mathrm{hg}} = 0.5\%$$

Ucertainties

$$\frac{\Delta \varepsilon_r^{'}}{\varepsilon_r^{'}} \leq 0.15\% + T\frac{\Delta h}{h} \qquad 1 < T < 2$$



Limits for permittivity measurements



Thin dielectric films measurements

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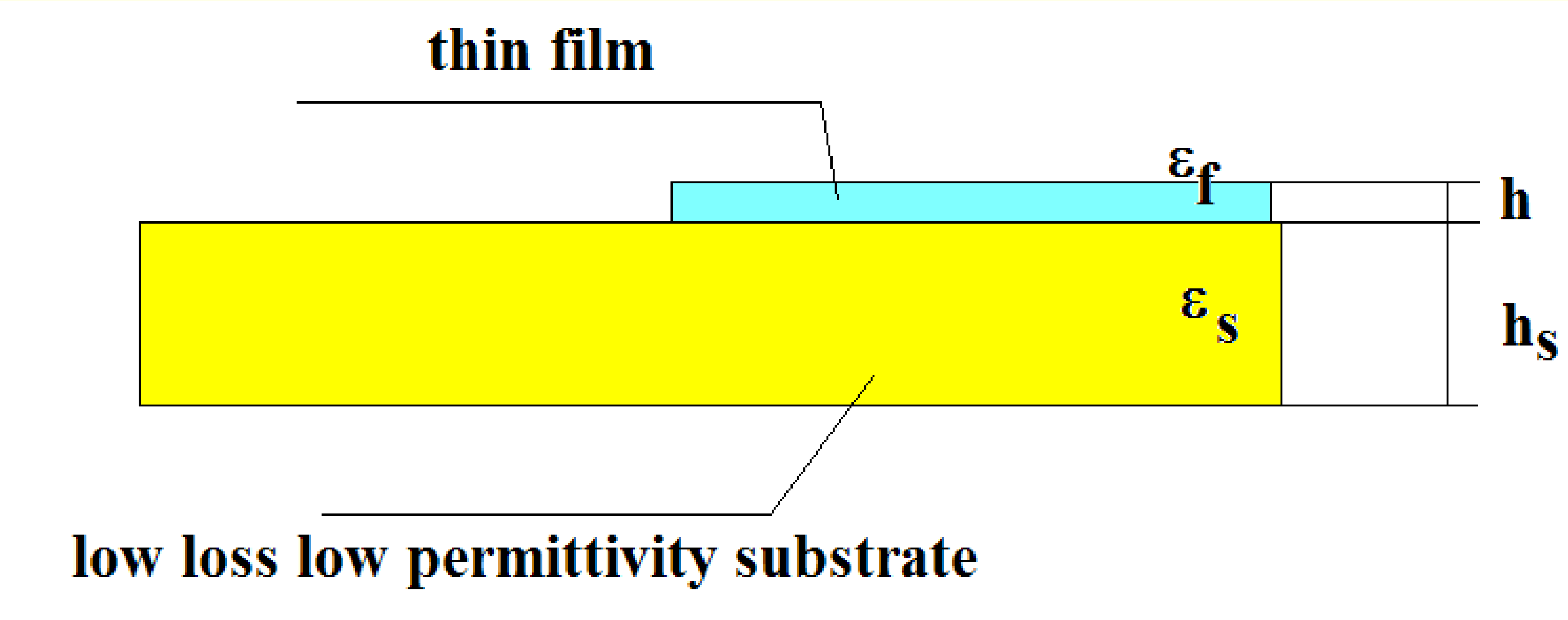

$$\frac{\Delta h_s}{h_s} << \frac{(\varepsilon_f - 1)h}{\varepsilon_s - 1}$$

Permittivity versus frequency shift for thin films deposited on MgO substrate having 10 mm diameter and 0.5 mm thickness for 10 GHz split post

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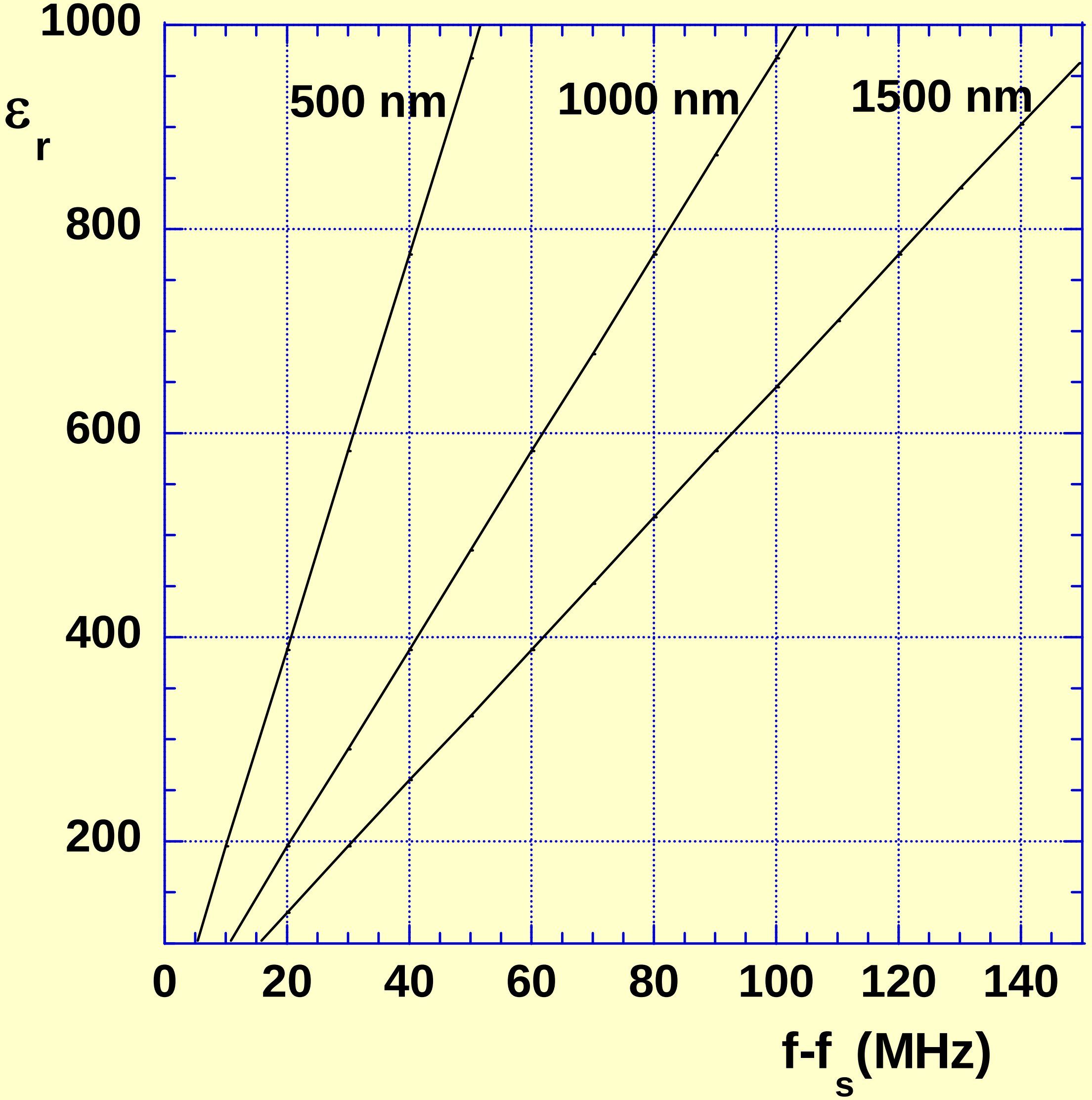

Loss tangent resolution for thin films deposited on a MgO substrate having 10 mm diameter and 0.5 mm thickness for 10 GHz split post

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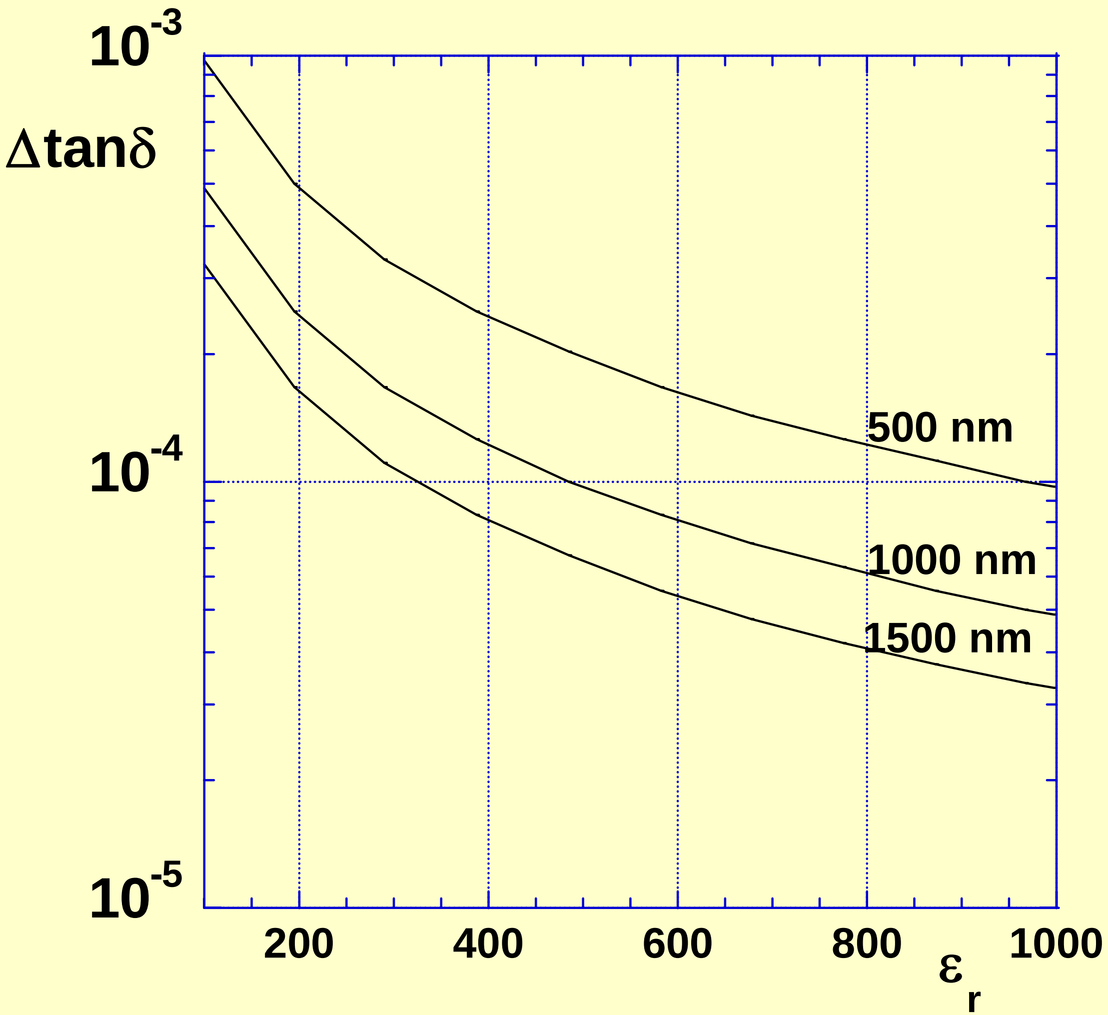


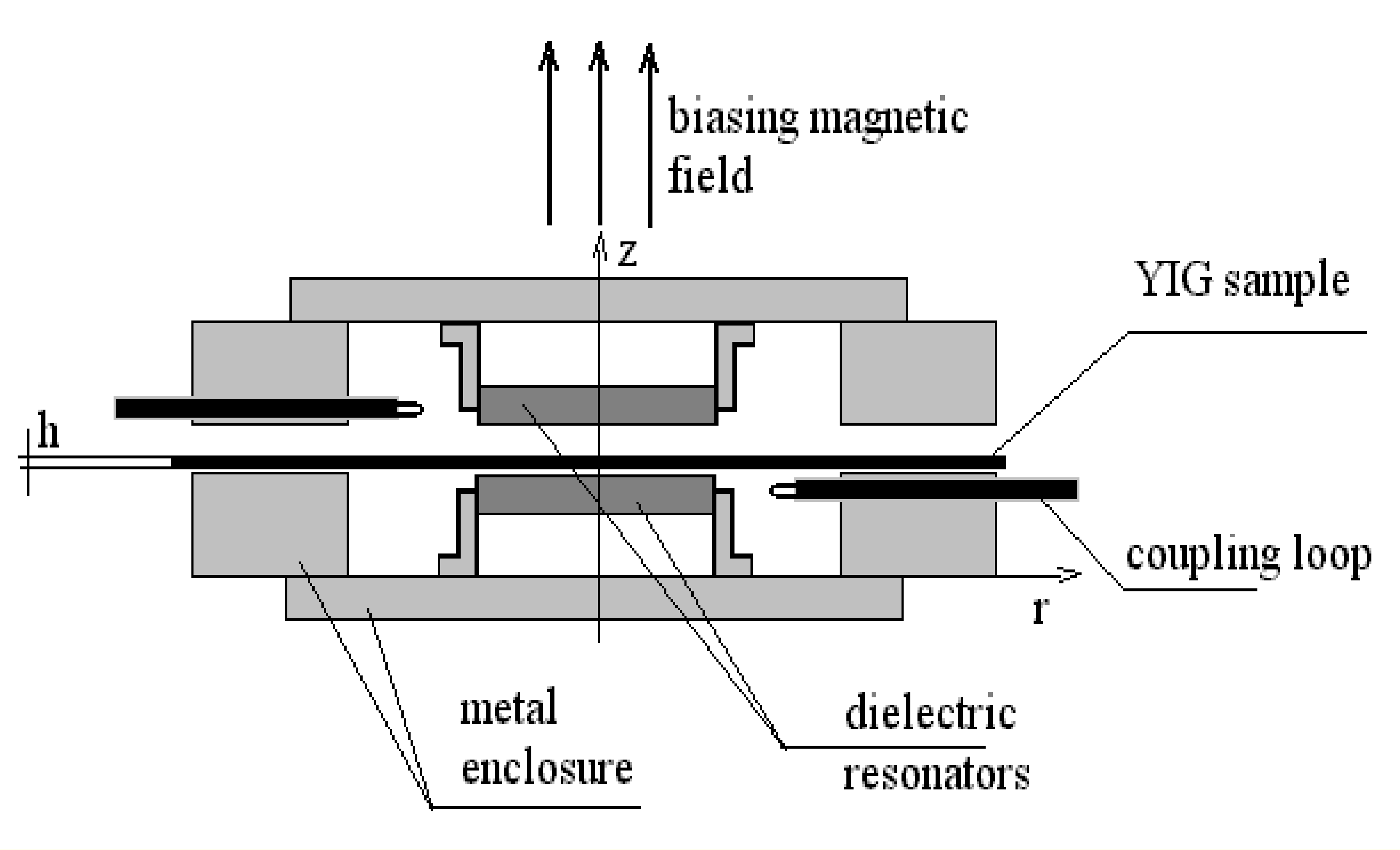
Results of measurements on standard reference materials

	SPDR data		Reference data		
f(GHz)	ε_r'	tanδ	ε_{rr}'	tanδ	Material
3.9	9.420	2.40E-05	9.400	1.0E-05	Sapphire
1.4	4.448	1.15E-05	4.443	1.5E-05	Quartz
2.0	4.454	1.82E-05	4.443	1.5E-05	Quartz
3.9	4.443	2.58E-05	4.443	1.5E-05	Quartz
5.5	4.439	3.40E-05	4.443	1.5E-05	Quartz

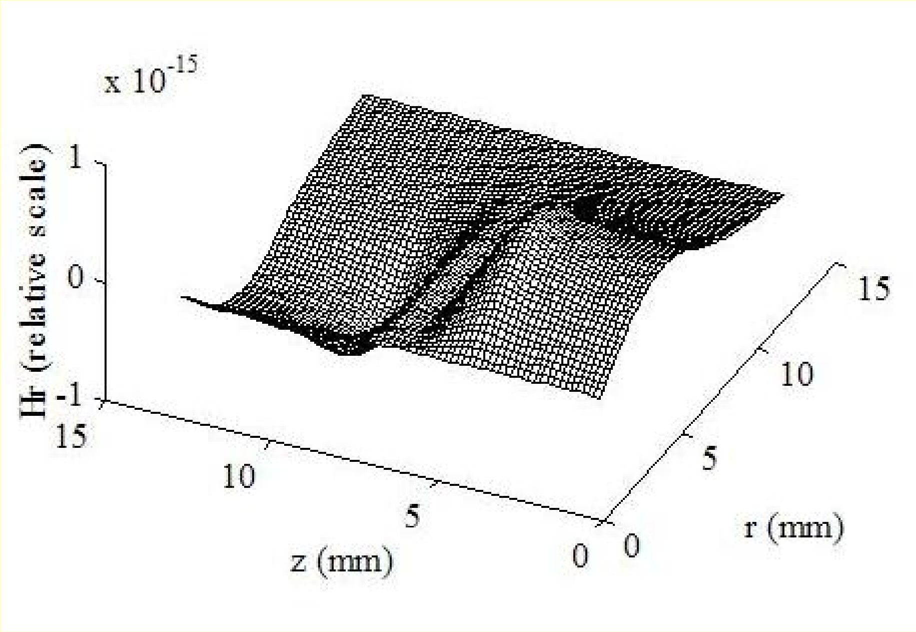
Measurements of stacked polymer films

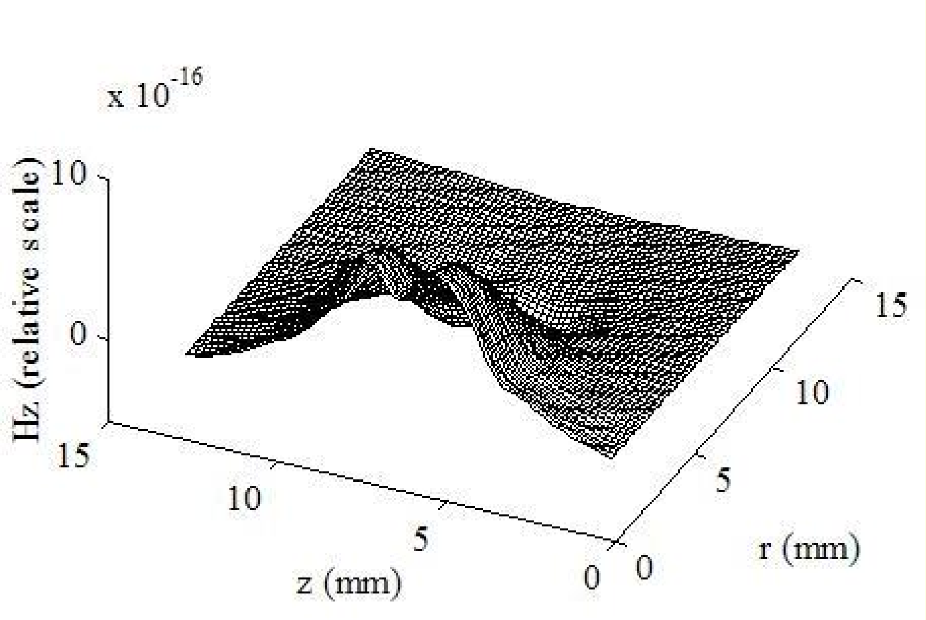
Number of films	h (mm)	ε_r	$\tan\delta$ (10^{-4})
1	0.100	3.19	49
2	0.201	3.20	50
3	0.303	3.20	50
4	0.406	3.20	49
5	0.511	3.19	49
6	0.616	3.18	50

Split post for ferrite substrates characterization

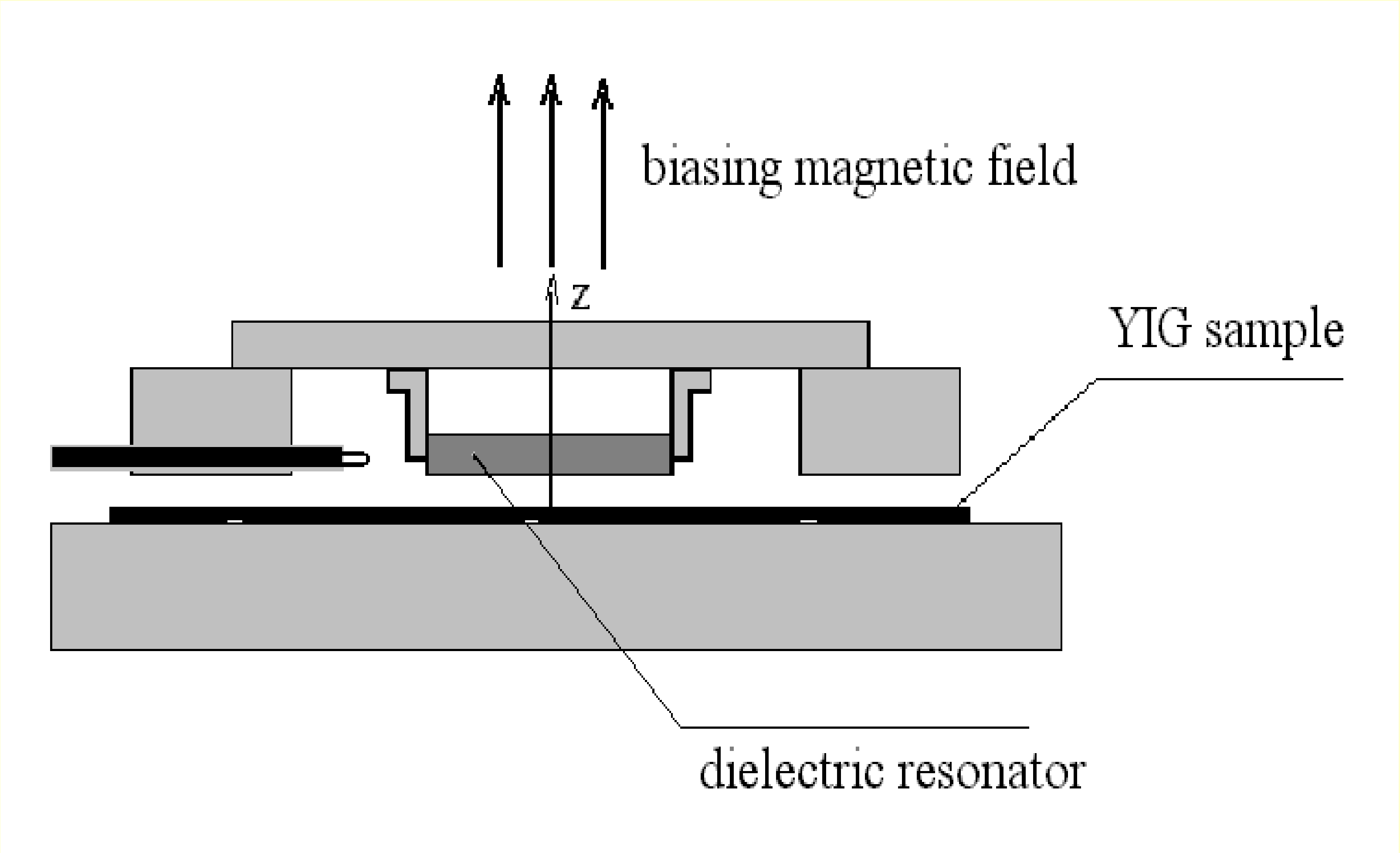


Radial and axial components of the magnetic field in split post dielectric resonator





Single dielectric post for ferrite substrates characterization



Permittivity of YIG measured in split post resonator

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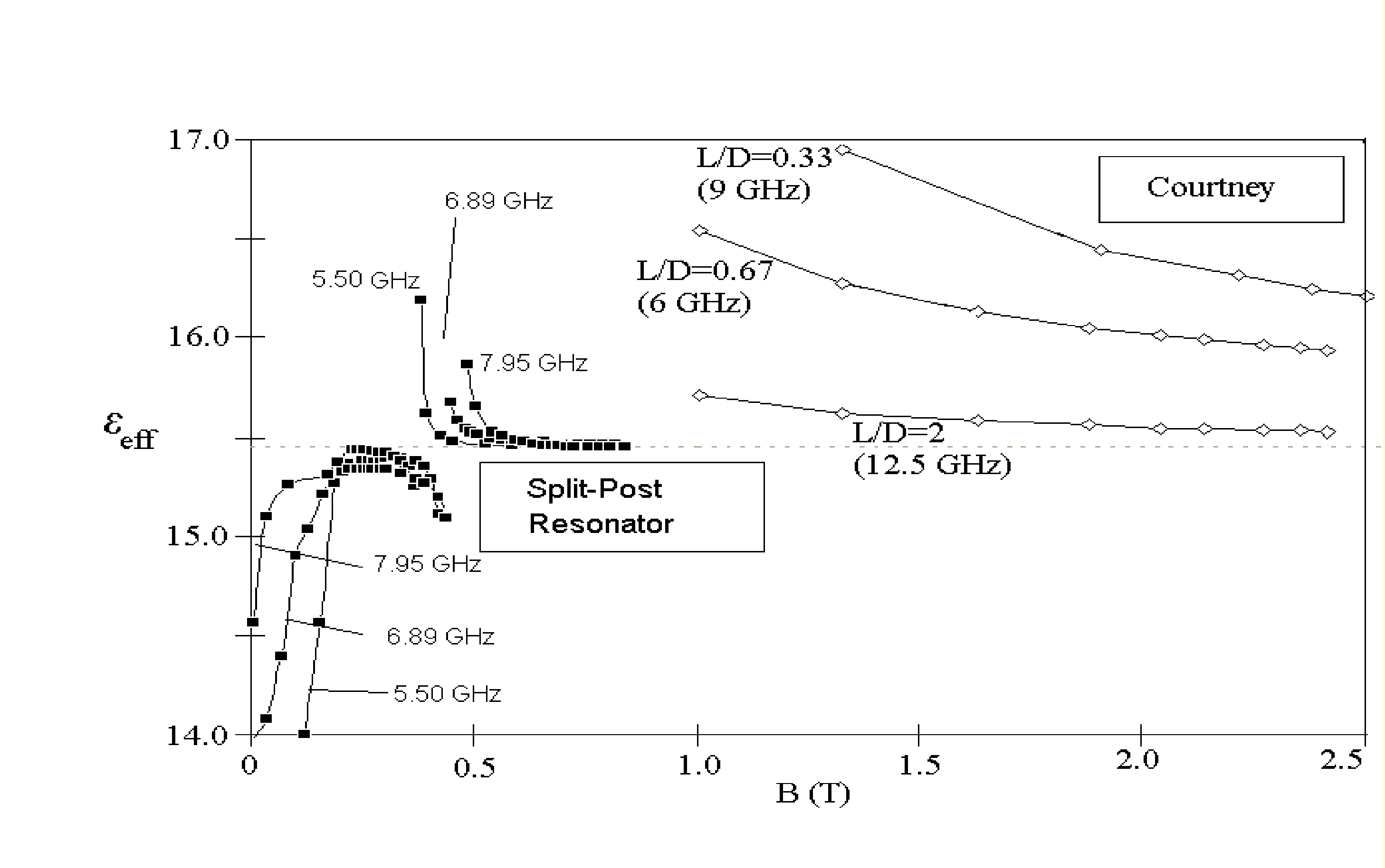

J.Krupka et al., Measurement Science and Technology, vol. 10, pp.1004–1008, November 1999

Permeability of YIG substrates measured in split post resonator

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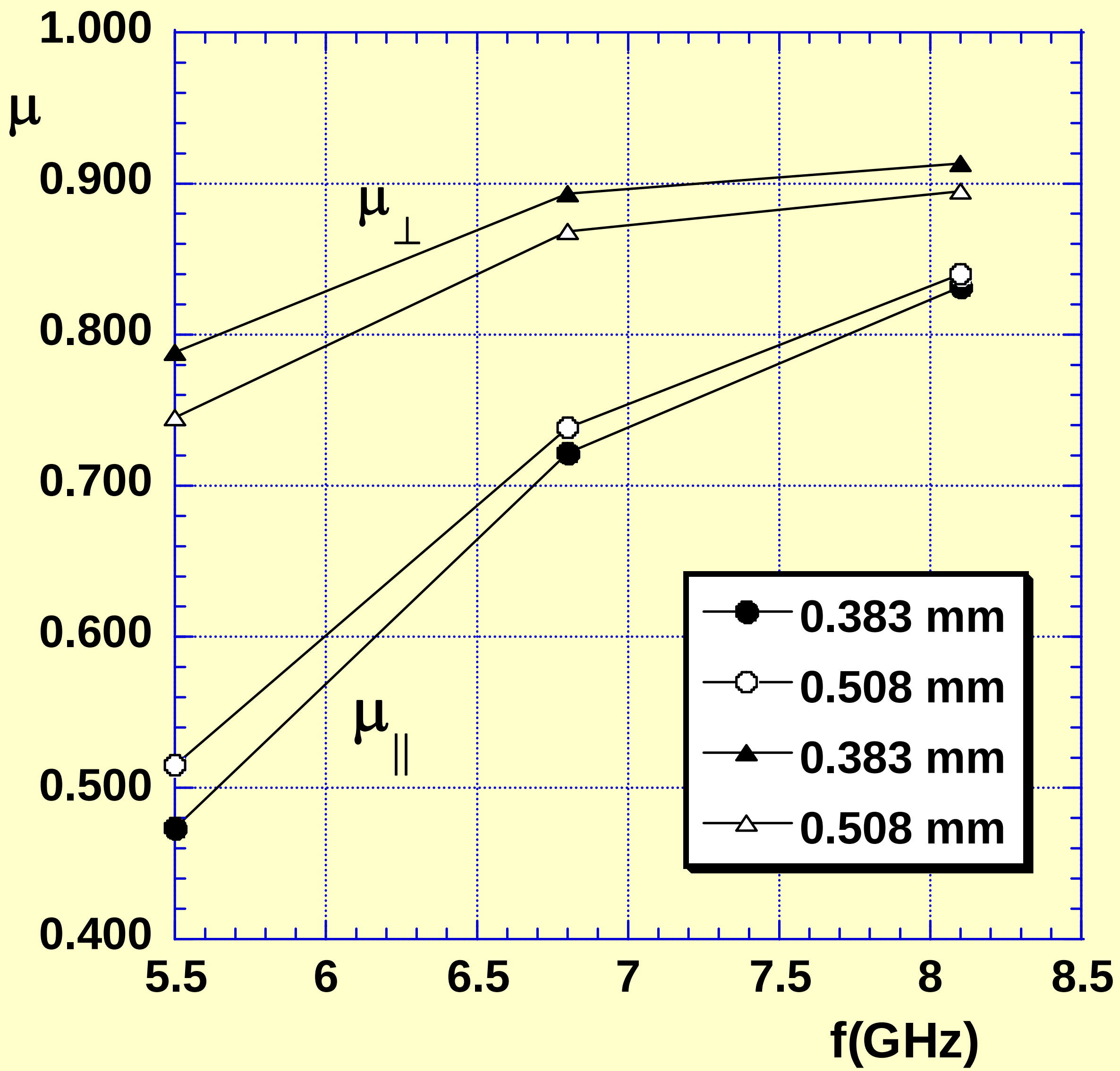

Magnetic losses of YIG substrates measured in split post resonator

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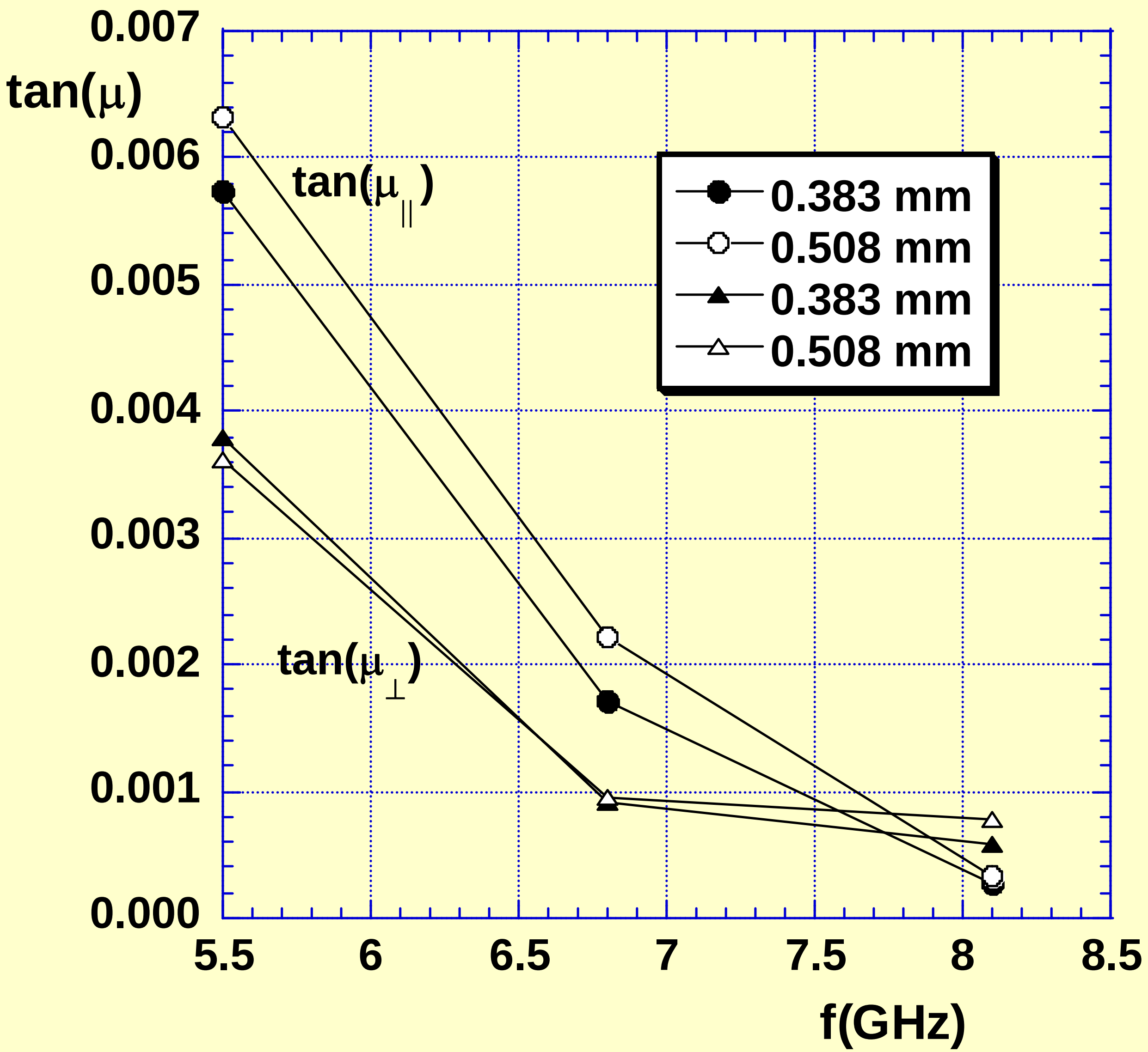

Cryogenic split post resonator

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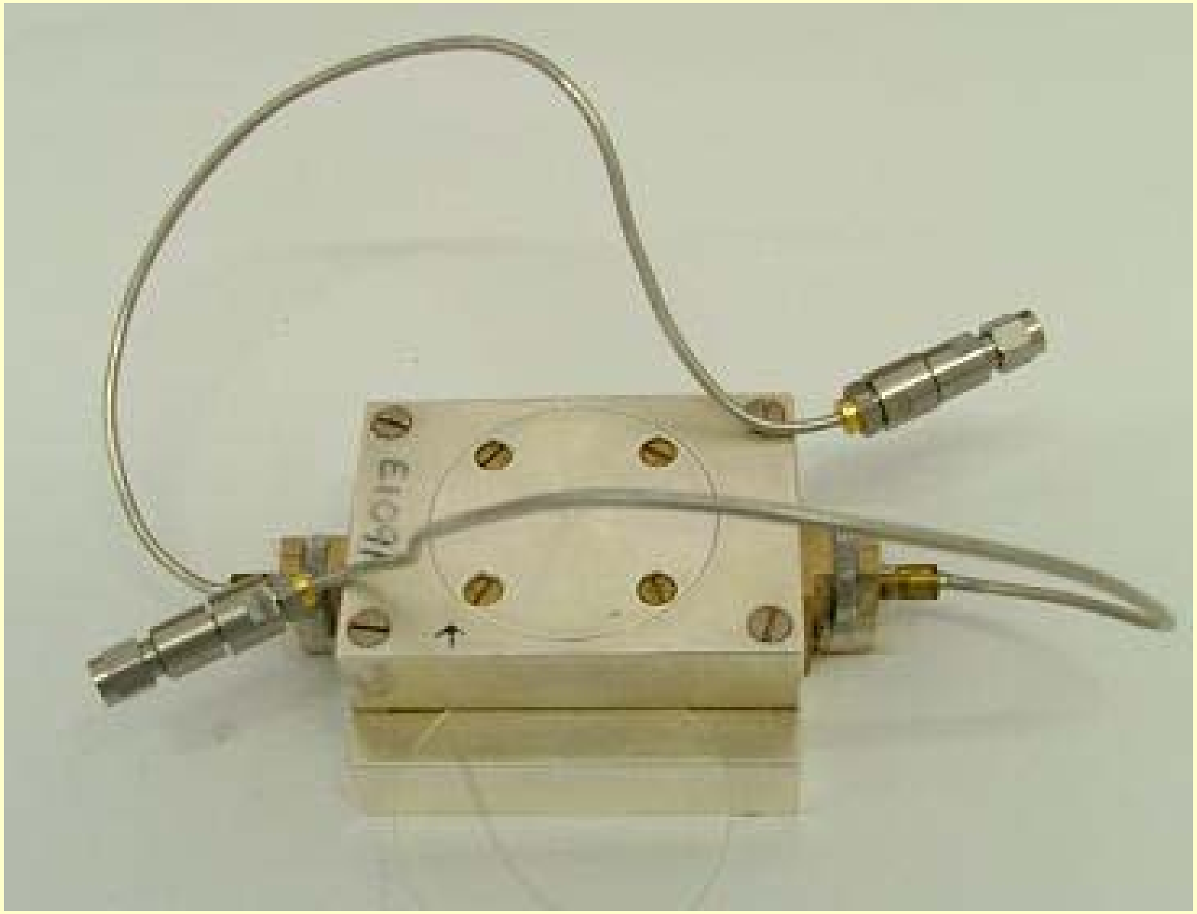
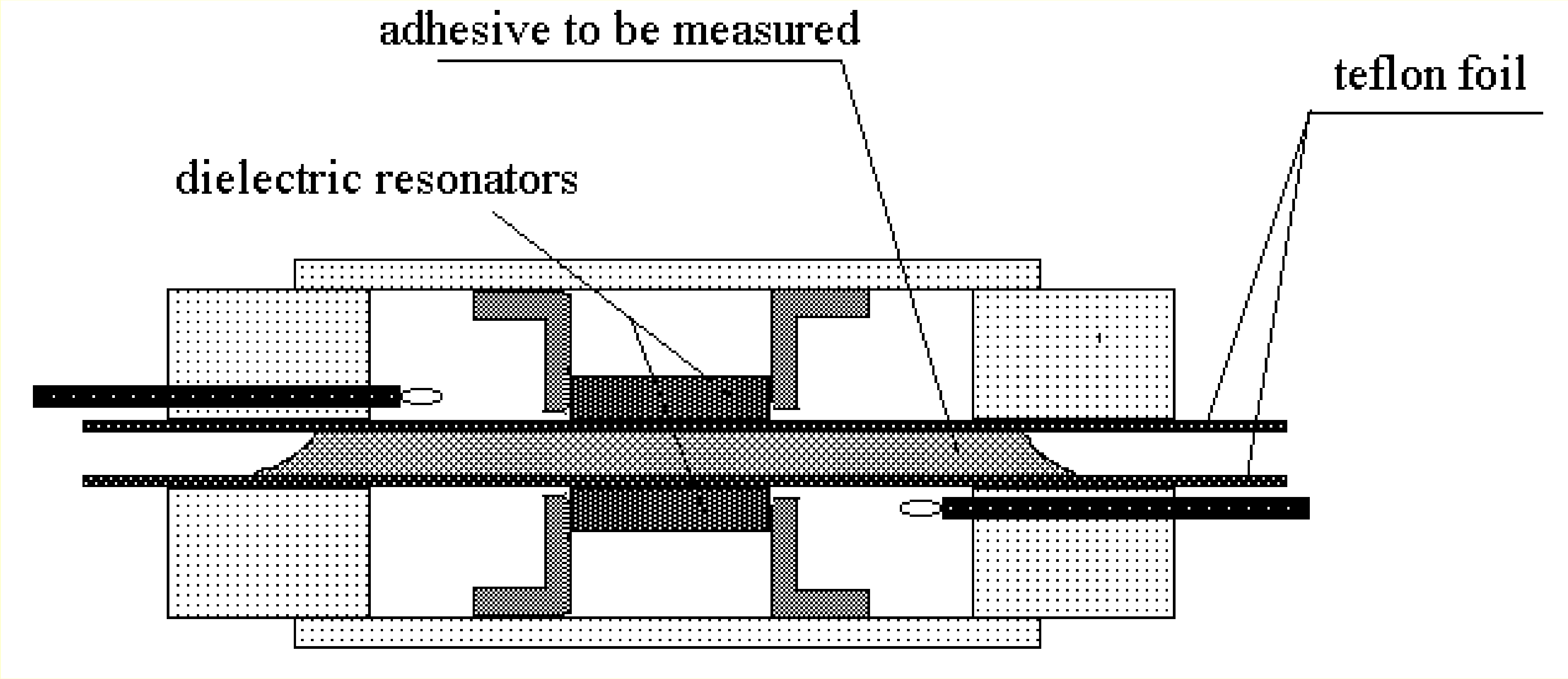


Sketch of a split post dielectric resonator used for adhesive cure monitoring



Conclusions

Split post dielectric resonators are one of the most convenient tools for permittivity and dielectric loss tangent determination of laminar type dielectric materials at frequencies from 1 GHz to 20 GHz

Single post and split post dielectric resonators can be used for measurements of the complex permittivity and complex permeability of ferrite substrates

Thank you very much for your attention

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