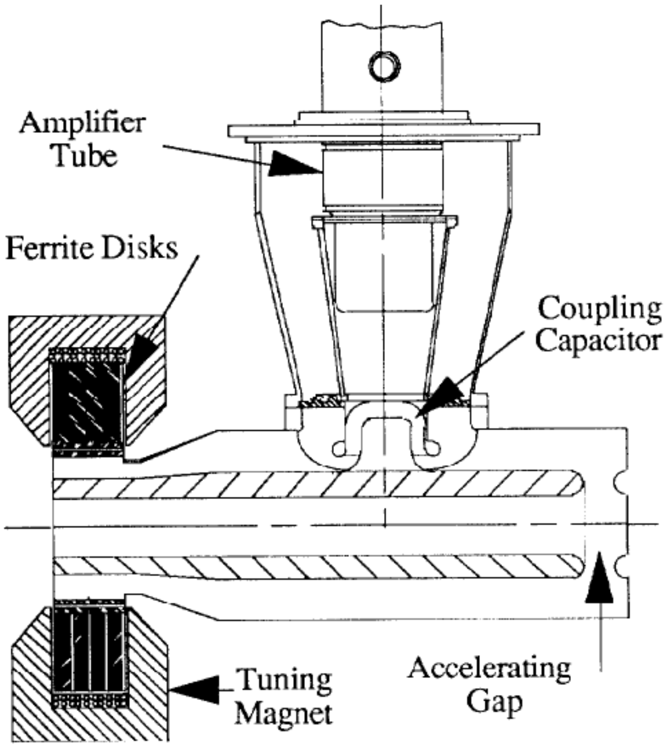
MATERIAL CHARACTERIZATION FOR THE 18 MHZ TO 40 MHZ SWEEP-TUNEABLE RF SYSTEM

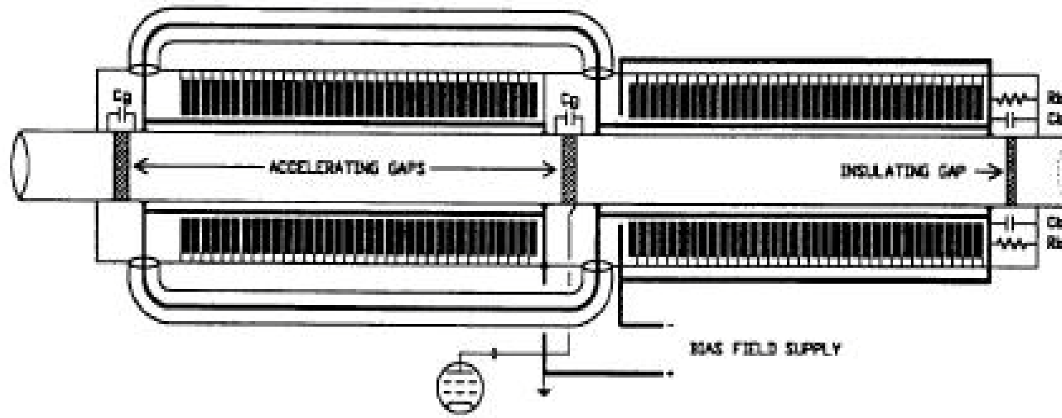
Christine Vollinger, BE-RF

Measurement supported by Fritz Caspers

RF tuning cavity with magnetic bias



Example for perpendicular bias (from Friedrichs, 1991)



Example for parallel bias (from Gardner, 1991; classical method, but less efficient than perp bias, usually used for small tuning ranges.

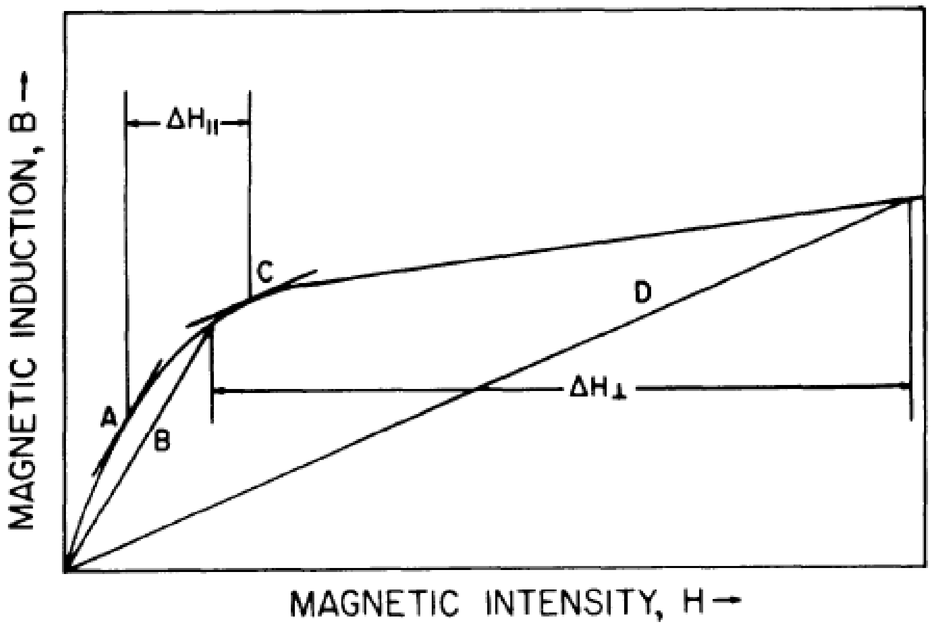
Problem: high tuning range (18-40 MHz) is needed, but no ferrite is known to cover that range.

Parallel plus perpendicular biasing possible ? (one way out...)

- Smythe suggested in 1983 to use
  - transverse bias to get into saturation (lower losses)
  - add'l. parallel bias for tuning (less bias).
- This was never tried before...

$\mu_{par} = \partial B/\partial H$
(tangent)

$\mu_{perp} = B/H$
(secant)

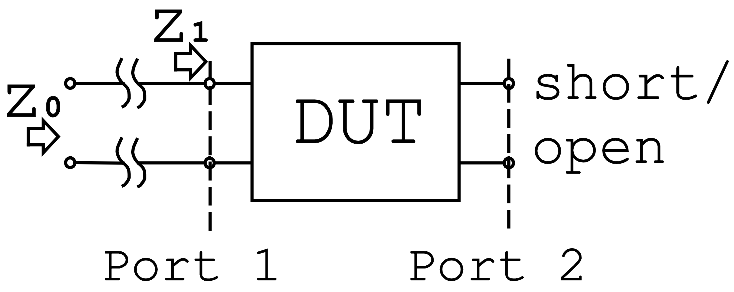


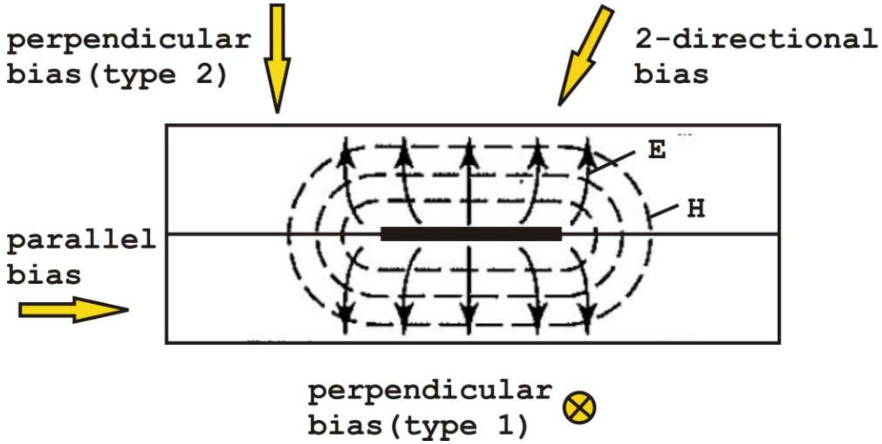
Leads to two primary goals:

1. Characterization of ferrite samples with different saturation and line widths under different bias conditions in the required *f*-range. (This required a dedicated test set-up, since supplier data does not exist – PART 1).
2. Verification of Smythe's claims (PART 2).
3. First requirement for an *f*-range of 18-40 MHz is a μ-range of approx. 5 (since *f* 1 / Sqrt[μ]).
4. Ratio of minimum to maximum *f* is given by Sqrt[μ_{max}/ μ_{min}]; μ_{max} is the value at minimum bias field.

Measurement Set-up

- Problematic: material samples are available in sizes 1"x 1" (or smaller);
- Small sample size led to strip-line set-up on ferrite;
- 1-port frequency swept measurement with NWA chosen to obtain complex S11. From S11, the complex DUT impedance is determined and the complex μ can be calculated;
- Measurement taken with magnetic bias field applied parallel and perpendicular to magnetic RF-field;

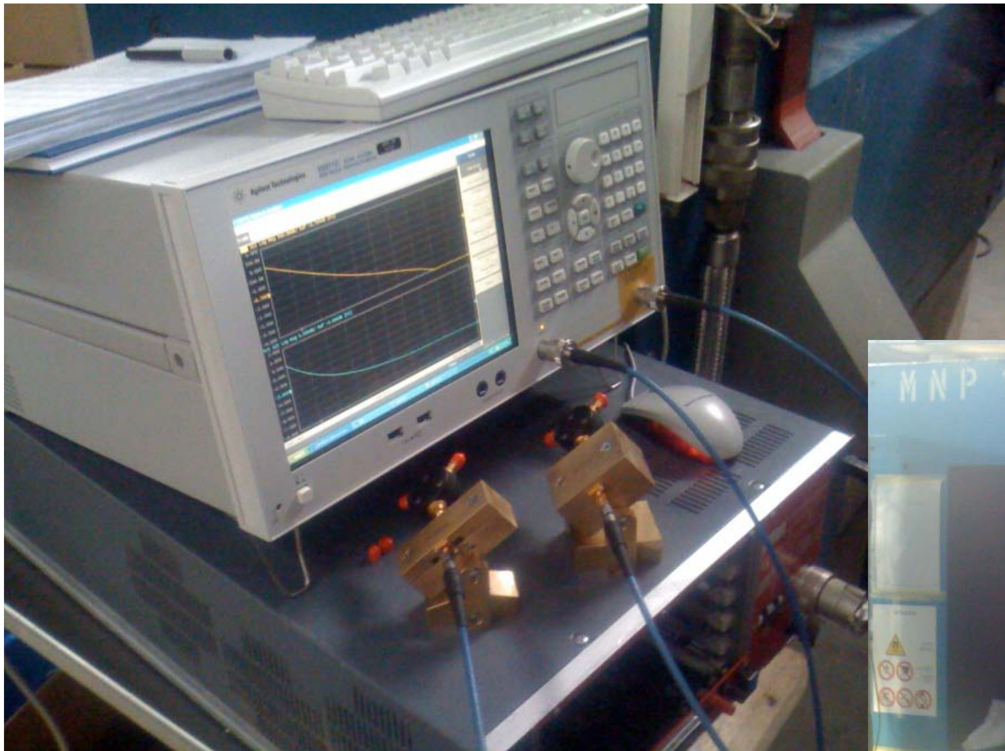




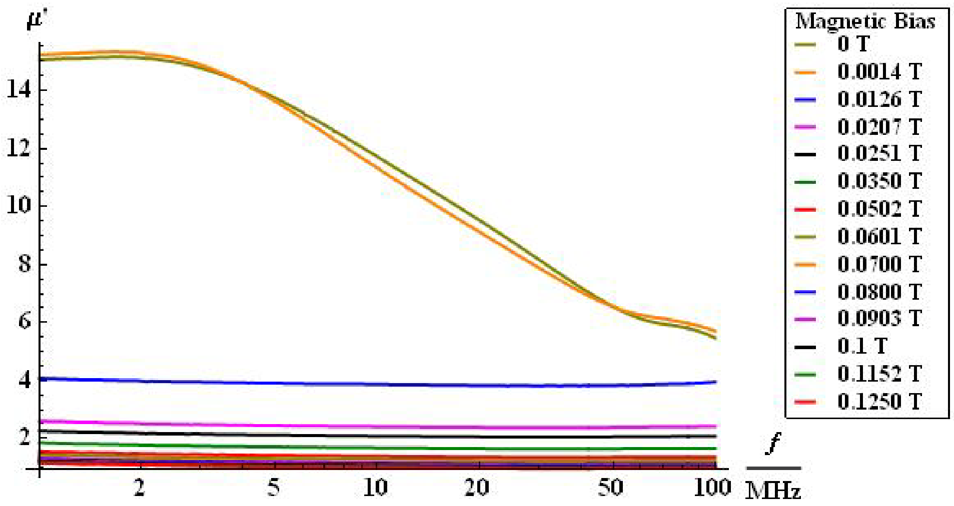
$\mu = \mu' - j\,\mu''$ (dispersive and dissipative part),

where magnetic quality: $Q_m = \mu' / \mu''$.

Measurement set-up

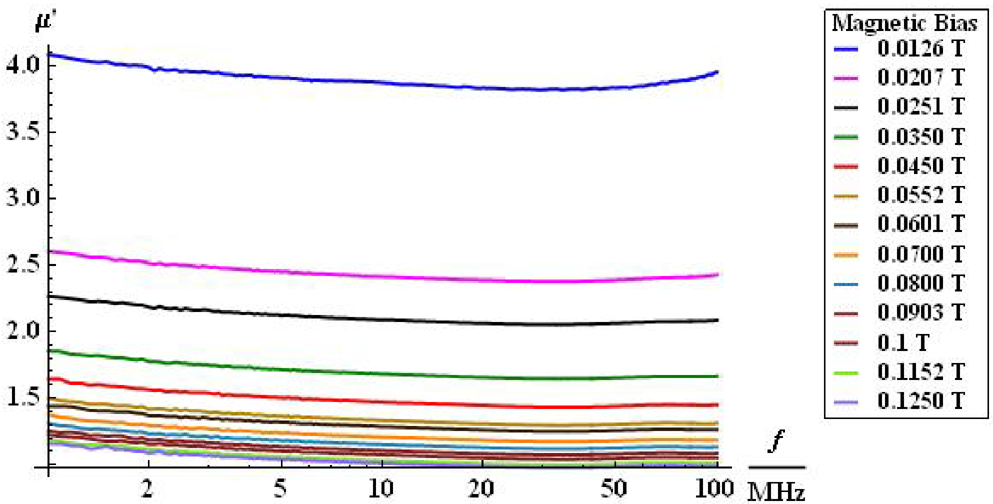


Example:
μ' in perp. Bias "type1" for Material #1 (Y36)



μ'-ratio:

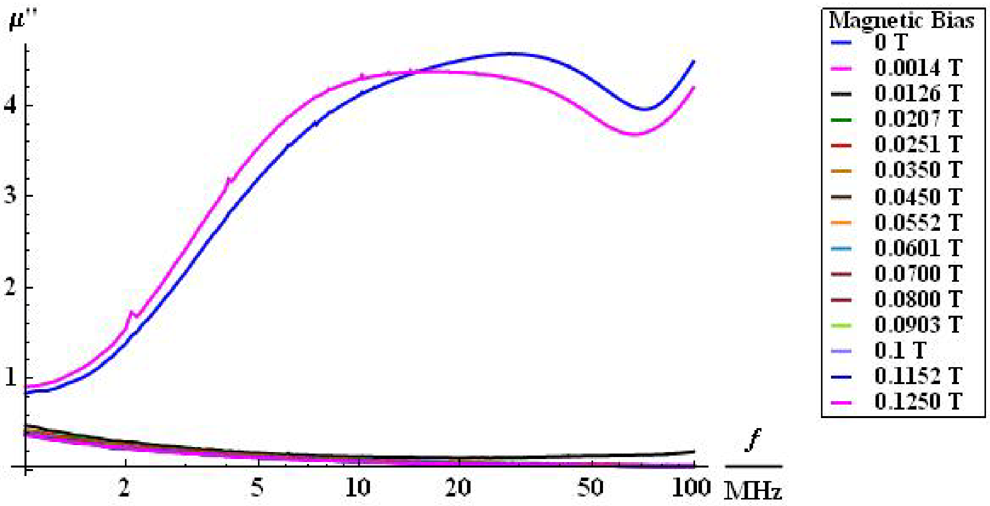
μ'(18 MHz, 0.0014 T)/μ'(40 MHz, 0.1250 T) = 13.7

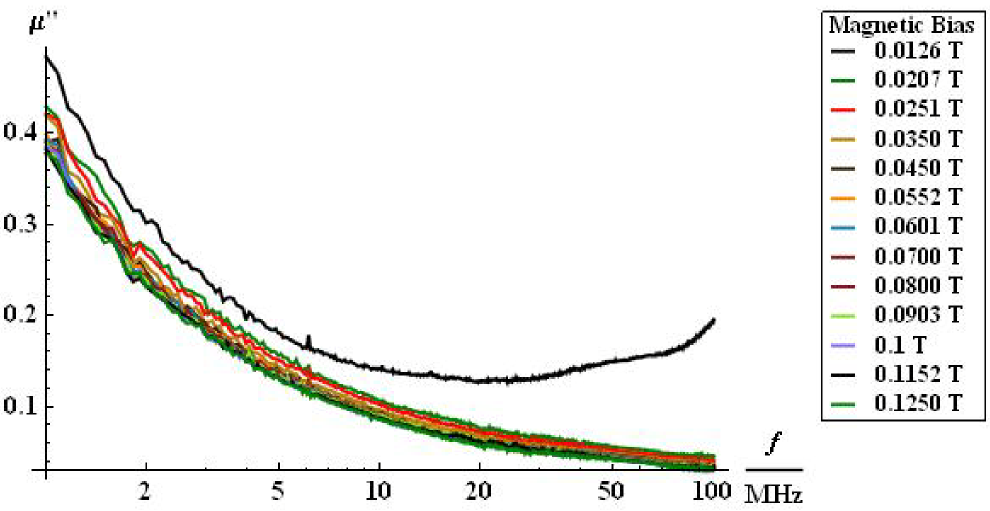


μ'-ratio:

μ'(18 MHz, 0.0126 T)/μ'(40 MHz, 0.1250 T) = 4.4

Example:
μ'' in perp. Bias "type 1" for Material #1 (Y36)

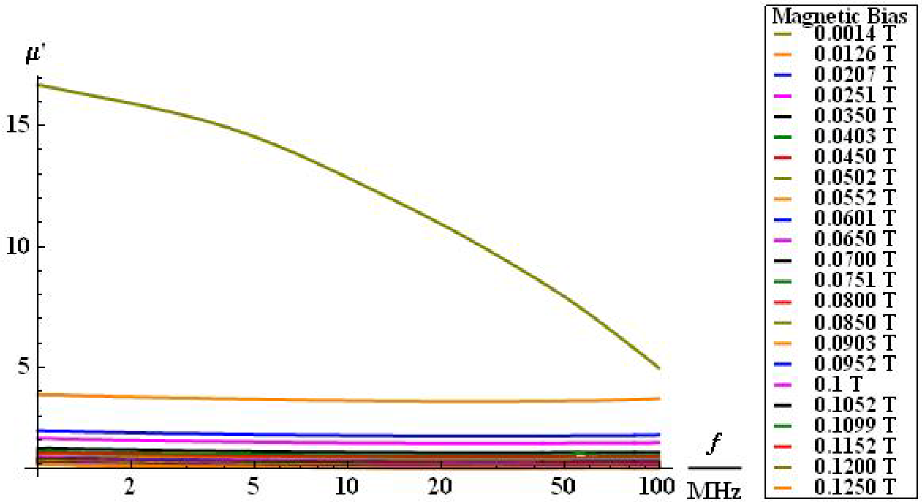




μ''-values:

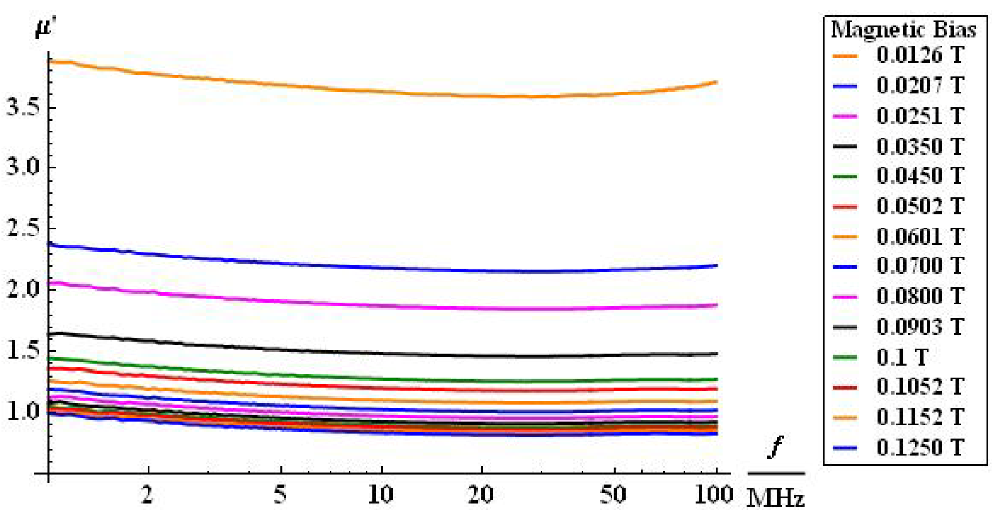
μ''(18 MHz, 0.0014 T)= 4.5
μ''(18 MHz, 0.0126 T)= 0.14
μ''(40 MHz, 0.1250 T)= 0.044

Example:
μ' in perp. Bias "type 1" for Material #2 (G300)



μ'-ratio:

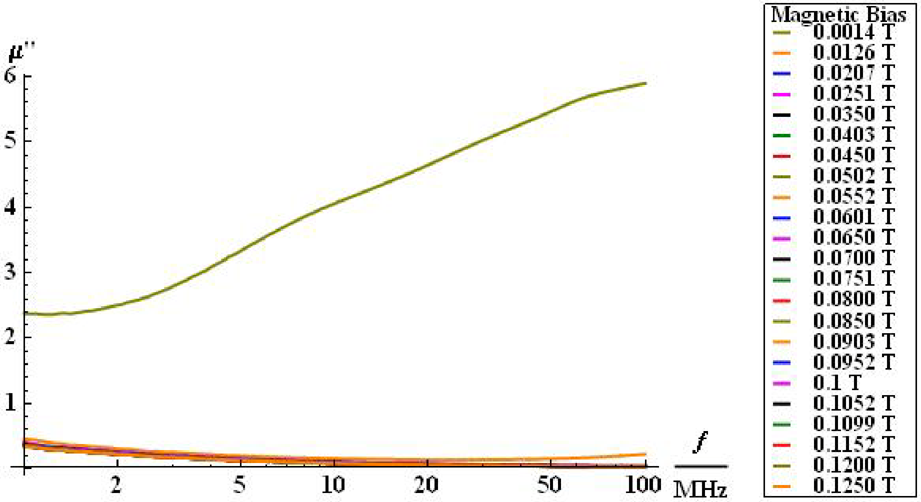
μ'(18 MHz, 0.0014 T)/μ'(40 MHz, 0.1250 T) = 9.7

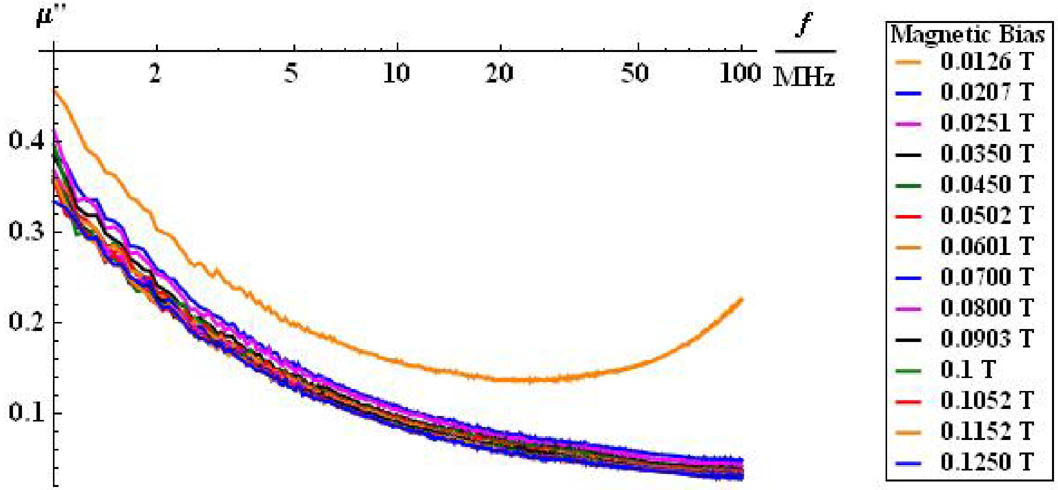


μ'-ratio:

μ'(18 MHz, 0.0126 T)/μ'(40 MHz, 0.1250 T) = 3.9

Example:
μ" in perp. Bias "type 1" for Material #2 (G300)





μ''-values:

μ''(18 MHz, 0.0014 T) = 4.4
μ''(18 MHz, 0.0126 T) = 0.13
μ''(40 MHz, 0.1250 T) = 0.044

Summary (1/3)

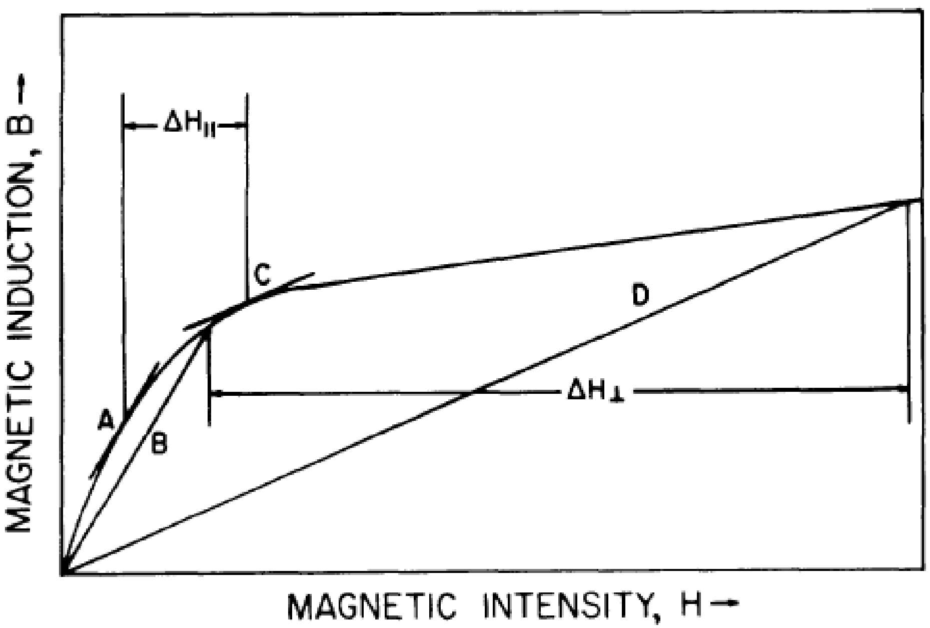
	Y36	G300	G510
μ'-ratio, [0.014 T – 0.1250 T]	13.7 ($\mu''_{,0.014\,T}$= 4.5) ($\mu''_{,0.1250\,T}$ = 0.044)	9.7 ($\mu''_{,0.014\,T}$= 4.4) ($\mu''_{,0.1250\,T}$ = 0.044)	--
μ'-ratio, [0.0126 T – 0.1250 T]	4.4 ($\mu''_{,0.0126\,T}$= 0.14) ($\mu''_{,0.1250\,T}$ = 0.044)	3.9 ($\mu''_{,0.0126\,T}$= 0.13) ($\mu''_{,0.1250\,T}$ = 0.044)	6.4 ($\mu''_{,0.0126\,T}$= 0.62) ($\mu''_{,0.1048\,T}$= 0.043)
μ'-ratio, [0.02 T– 0.01048 T]	--	--	3.8 ($\mu''_{,0.02\,T}$ = 0.16) ($\mu''_{,0.1048\,T}$ = 0.043)

Leads to two primary goals:

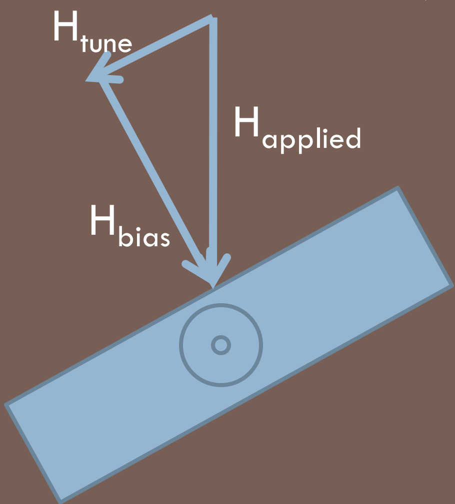
1. Characterization of ferrite samples with different saturation and line widths under different bias conditions in the required *f*-range.
   (This required a dedicated test set-up, since supplier data does not exist – PART 1).
2. Verification of Smythe's claims (PART 2).

Verification of Smythe's Claims (PART 2)

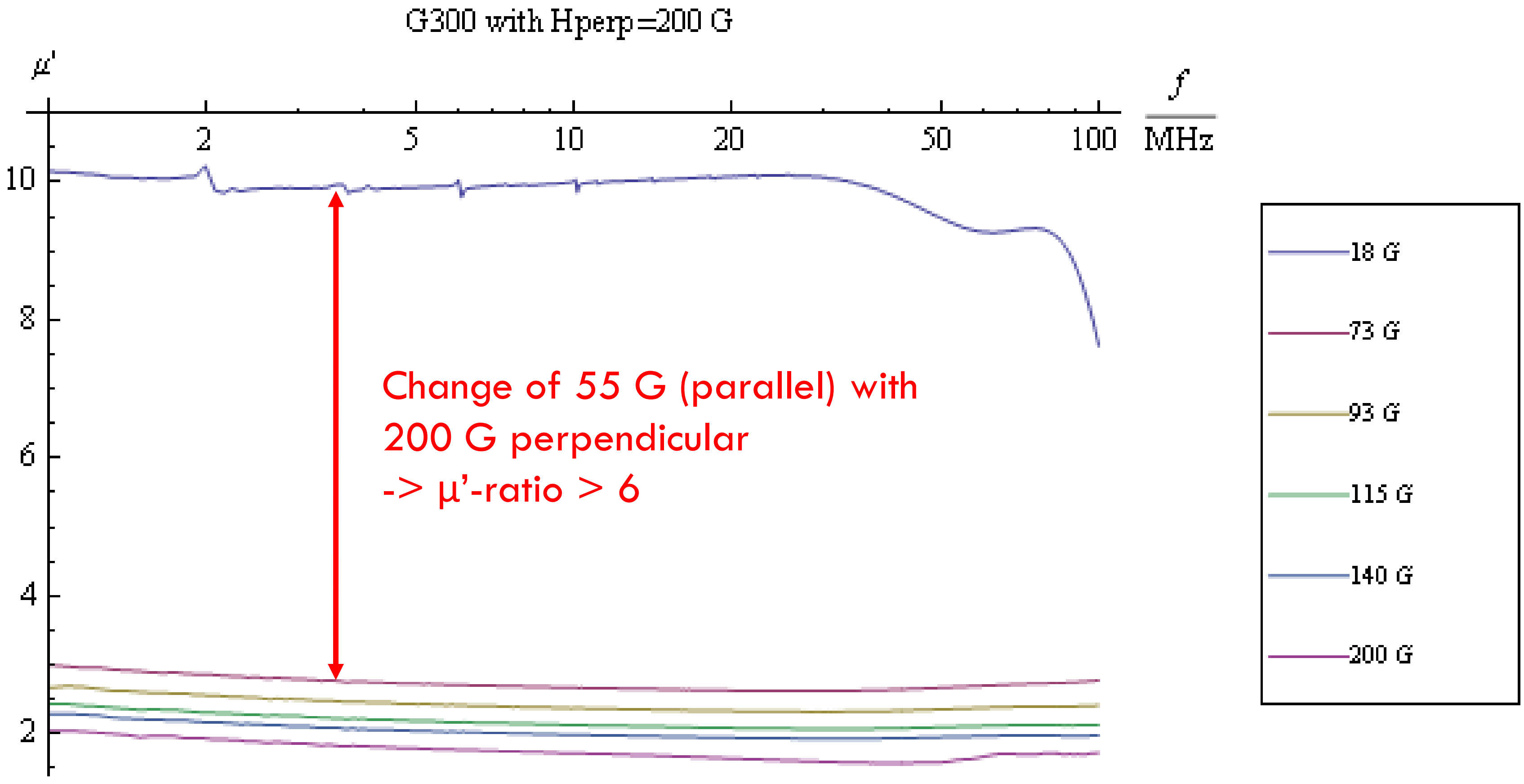
- Smythe suggested in 1983 to use
  - *transverse* bias to get close to saturation (reduces losses)
  - additional *parallel* bias for tuning (less bias required for same μ-range).



Measurement Set-up



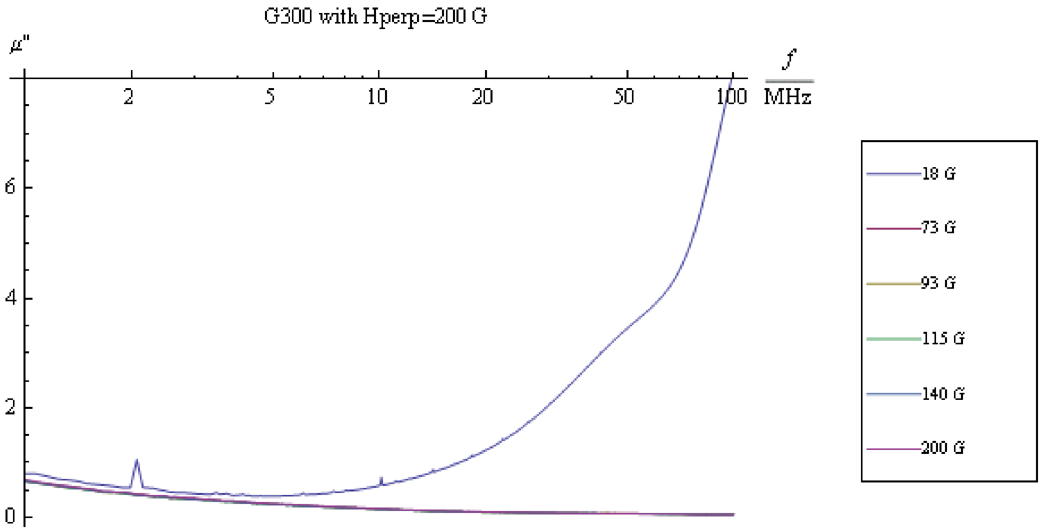
μ’ for Material #2 (G300) in 2-Directional Magnetic Bias

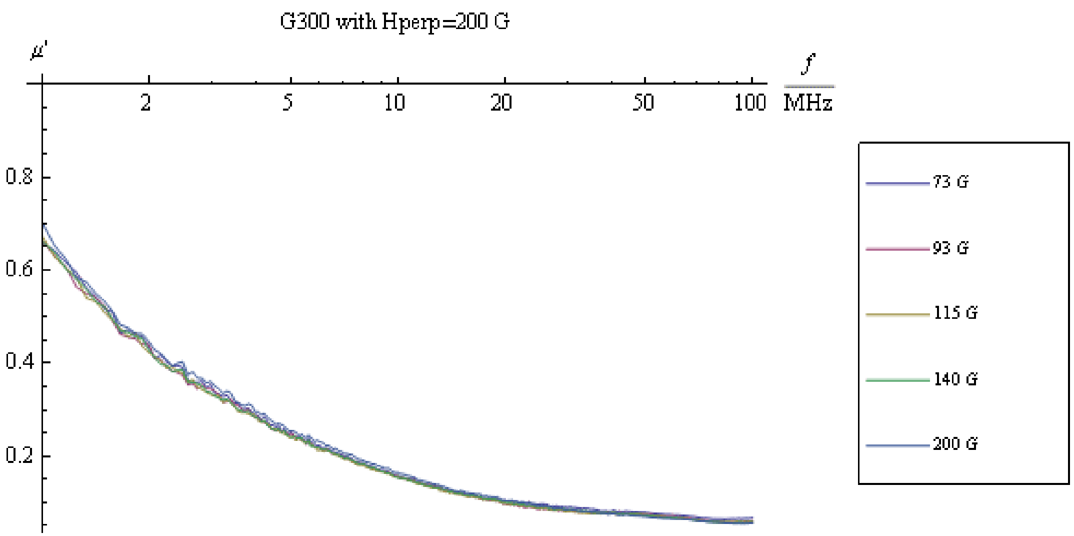


μ’-ratio with Hperp=200G:

μ’(20 MHz,HparBias=18 G)/μ’(40 MHz, HparBias=200 G)= 6.4

μ” for Material #2 (G300) in 2-Directional Magnetic Bias





μ”-values with Hperp=200G :

μ”(20 MHz, H_{par}=18 G) = 1.23
μ”(20 MHz, H_{par}=73 G)= 0.106
μ”(40 MHz, H_{par}=200 G)= 0.105

Summary (2/3)

- Five ferrite samples have been ordered from industry and measured in an external magnetic bias field. This allowed the determination of their available -range and the corresponding values of μ' as a function of frequency and Bias-field.
- Requirement for an *f*-range of 2.2 from 18-40 MHz is a μ'-ratio of approx. 5.

- Measurement set-up is found that appears robust and stable (1-port-measurement with NWA).
- Next step will be to investigate the performance of ferrite rings in a mock-up cavity (will the μ'-ratio hold) and the behaviour under exposure of a 2-directional field.

Summary (3/3)

- The idea of Smythe to use a 2-directional magnetic bias field appeared in 1983, but (to my knowledge) has never been used or further investigated.

- Smythe had no measurement data to support his claims.
- From the measurement done on the G300 sample, it appears as if the method is promising and could work; we will continue further tests with other samples and higher parallel bias fields.

	G300 with perpendicular bias	G300 with 2-directional bias
µ'-ratio, [300 – 1005 Gauss]	4.0 ($\mu''_{,300\ G}= 0.2$) ($\mu''_{,1005\ G} = 0.074$)	--
µ'-ratio, [200 Gauss perpendicular] & [18 – 200 Gauss parallel]	--	6.4 ($\mu''_{,18\ G}= 1.23$) ($\mu''_{,200\ G} = 0.105$)