EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
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CERN - PS DIVISION

PS/ AR/ Note 94-21 (Info.)

FERRIMAGNETIC RESONANCE (FMR)

A METHOD TO MEASURE MAGNETIC FIELDS IN ACCELERATOR ENVIRONMENT (FIRST RESULTS FROM PS)

F. Caspers

Abstract

In order to increase and survey the long term stability of the PS B-train generator, the possibility of using an NMR (Nuclear Magnetic Resonance) based marker system like in the SPS has been investigated. However it turned out that due to the constraints imposed by the PS reference magnet and the time structure of the PS B-train, this kind of solution could not be applied. The reason being that the NMR requires a very homogeneous B-field and also a measurement time beyond 0.1 s. Thus the FMR (ferrimagnetic resonance) using polycrystalline YIG (Yttrium Iron Garnet) spheres has been applied as it is very insensitive to field gradients and the response time is in the order of a microsecond. A YIG-sphere with a loaded Q bandwidth corresponding to a field variation of 2 Gauss has been installed in the PS reference magnet and the performance was monitored over 3 months. It turned out that this "marker " system shows a good long term stability and is suitable to serve as a point-like magnetic reference. Applications for the near future in the PS will cover the range between 500 Gauss and 2 kGauss, but measurements at higher fields are also possible with a suitable synthesizer in the corresponding frequency range (gyromagnetic ratio 2.8 GHz/kGauss).

(Copies of transparencies presented at the 55th PS/AR scientific meeting - 25.7.1994)

Geneva, Switzerland
27 July 1994

F. CASPERS
25. 7. 94

FERRIMAGNETIC RESONANCE (FMR)

A METHOD TO MEASURE MAGNETIC FIELDS IN ACCELERATOR ENVIROMENT

FIRST RESULTS FROM PS

1) INTRODUCTION, NMR IN THE SPS

2) WHAT IS FMR; THEORETICAL AND PRACTICAL ASPECTS

3) DESCRIPTION OF THE SYSTEM INSTALLED IN THE PS-REF.-MAGNET

4) FURTHER DEVELOPMENTS AND FUTURE POSSIBLE APPLICATIONS

INTRODUCTION

IN 1983 THE QUESTION WAS RAISED: CAN WE FIND A METHOD TO MONITOR THE STABILITY OF THE PS-B-TRAIN AND ALSO MEASURE (INDEPENDENTLY) THE AA-BENDING FIELD.

- THE OBVIOUS SOLUTION IS TO INSTALL NMR-(NUCLEAR MAGNETIC RESONANCE) PROBES, LIKE IN THE SPS MAGNETS.

- PROBLEM FOR AA: NO SPACE LEFT IN HOMOGENEOUS FIELD REGION FOR AN NMR PROBE. MAYBE A NMR-PROBE WOULD JUST WORK WITH GRADIENT CORRECTIONS IN THE ACCESSIBLE, BUT INHOMOGENEOUS FIELD (METROLAB DIKIT)

- PROBLEM IN THE PS-REF MAGNET: HIGH FIELD GRADIENTS AND SHORT FLATTOPS

- NMR REQUIRES VERY HOMOGENEOUS FIELD OR MODERATE, BUT STABLE AND KNOWN GRADIENTS FOR GRADIENT CORRECTION COILS.

- MEASUREMENT TIME FOR NMR ON THE FLATTOP (WHICH SHOULD BE "REALLY" FLAT) ~ 0.5 s.

SUGGESTED SOLUTION: FMR

(for RF-experts: A YIG-filter)
YIG = YTTRIUM-IRON-GARNET

- FMR IS AN ELECTRON SPIN (ESR) RESONANCE IN CERTAIN FERRITE MATERIAL WITH A MUCH HIGHER ELECTRON SPIN DENSITY THAN USUAL ESR SAMPLES. ⇒ VERY SMALL PROBE VOLUME

- THE FERRITE SAMPLE MUST BE IN SATURATION MAGNETISATON (BIAS-FIELD), OTHERWISE NO RESONANCE VISIBLE (M_s > 500 Gauss)

- THE RESONANCE FREQUENCY IS RATHER HIGH: 2.8 GHz/KGauss OR 28 GHz/Tesla

- DUE TO SMALL SAMPLE (= SPHERE) VOLUME (DIAMETER HERE = 0.46 mm) INSENSITIVE TO GRADIENTS.

- Q-factor OF THE RESONANCE ~ 1000 THUS FAST RESPONSE TIME (~ 1μs)
- ⇒ TOLERATES HIGH dB/dt

1 Introduction

With the installation of the Nuclear Magnetic Resonance (NMR) System at CERN, the precision improvement of the magnetic field measurement became better than 10 E-5. The SPS Division replaced the old magnetic flux measuring system by the probes of the new NMR system inside the reference magnet (building BA3). All devices have been working satisfactorily for four years in Accelerators Continuous Current (Collider) mode. The NMR system has a response time of a few seconds, which is disadvantageous for measurements during the pulsed (fixed target etc.) mode, especially for flat tops shorter than 2 seconds. For the LEP cycles and for ramps, the PCO/MR and CO sections developed a manually controlled method (see SPS/AOP/Note 88-5 of 8th August 1988), which gives good results which are precise enough but it takes a long time to measure the field values. Only one or two values per hour are readable after difficult adjustments. In 1988 the manufacturer of our NMR probes, METROLAB, worked on an automatic computer aided measurement system for flat tops longer than 2 seconds. The PCO/MR & CO sections tested this arrangement at CERN on the Main Ring Magnet and observed very good results of the equipment presented. Based on this experience, METROLAB carried out an advanced computer aided method to measure the very short LEP cycles and ramps. The prototype was tested at CERN and the results are reported in the following pages together with a short description of all necessary devices.

2 Principle of Operation

In order to measure with great accuracy (≈ 10 ppm) a time variable magnetic field, one can use either of the following two different instruments:

a) **NMR Magnetometer, e.g. METROLAB model PT 2025**
+ a sufficiently homogeneous B-field as in ref magnet MG

b) **Fluxmeter, e.g. METROLAB model PD 5025, a precision digital integrator associated with an appropriate coil system**

The NMR magnetometer can perform measurements of accuracy greater than 10 ppm but requires the field to be stable for approximately 1 second (≈ 0.8 seconds minimum).

* Ref: AOP - Note 88-5 page 1

The fluxmeter system is optimum for measuring "on the fly" fields which vary rapidly with time. However, the measurement presents a time drift which does not allow the required precision.

The new system proposed by METROLAB can combine the two instruments provided that the field cycle features two platforms which are long enough to allow for two NMR measurements. The principle of operation is the following:

- the digital integrator continuously provides a number of counts N_i where "i" indicates a particular interval of time between two external triggering pulses of a user-definable sequence.

- N_i being directly proportional to the corresponding field variations, the measurements of the integrator are intrinsically relative.

- if the field cycle features two platforms where NMR measurements are possible, the integrator's results can be, a posteriori, "corrected" to give the absolute value field shape. Moreover, the NMR measurements of the platforms permit correction of the zero point drift of the integrator thus allowing an accuracy of ≈ 10 ppm.

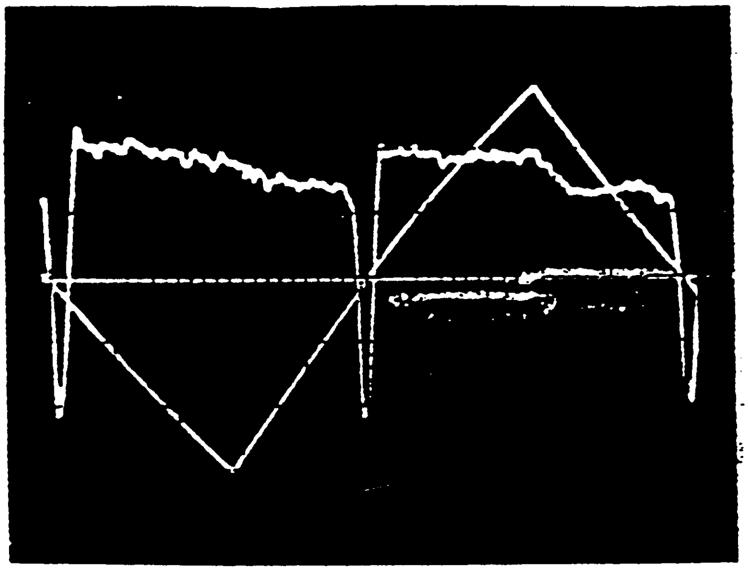
SPS-AOP-Note
PS-5

1.6

I-3 Principe de lecture de la fréquence de résonance

I-3.1 A champ fixe

Il s'agit de rechercher la fréquence de résonance qui ne peut être trouvée qu'en la faisant varier légèrement par une exploration de fréquence autour de la valeur attendue. Au passage dynamique de la fréquence de résonance, la sonde délivre un signal correspondant à sa résonance. Habituellement, cette fréquence d'exploration couvre environ $\pm$ 1 % de la fréquence attendue, en croissant et décroissant linéairement (fonction triangulaire) à basse fréquence (30 Hz dans notre cas). Une fois dans la bonne zone, il faut alors centrer la fréquence "zéro" en symétrisant les deux signaux obtenus, au passage par zéro de la fréquence d'exploration.



Signal de la fréquence d'exploration (triangle)

Signaux de la sonde (en montant et descendant)

Balayage: 2 ms/div

Photo 1: Signaux typiques NMR à champ fixe

La lecture de la fréquence "centrée" indique le champ mesuré (avec les constantes appropriées).

I-3.2 Mesure à champ variable (Méthode Pahud)

Nous avons cherché s'il était possible de mesurer la résonance lors des "pseudo-paliers" des cycles Leptons, et plus précisement aux instants exacts d'injection et d'extraction. En utilisant pour l'instant le matériel existant, nous avons synchronisé le déclenchement d'un oscilloscope à mémoire exactement 10 ms avant le point à mesurer afin de bien visualiser le signal de la sonde. Comme l'oscillateur de wobbulation ne peut pas être contrôlé de l'extérieur, il a fallu de nombreuses mesures afin d'obtenir une lecture correcte (le ripple déforme également le signal), tant sur le flanc montant de la fréquence d'exploration, que sur celui descendant.

La précision du centrage peut s'effectuer dans une gamme de $\pm$ 2 gauss. Cette valeur a bien pu être confirmée par la mesure de tous les points du palier pour lesquels une bonne image du courant (sur oscilloscope) et une lecture digitale valable, dans la milliseconde, ont servi de référence.

SPS - PCO -
Note 89-9

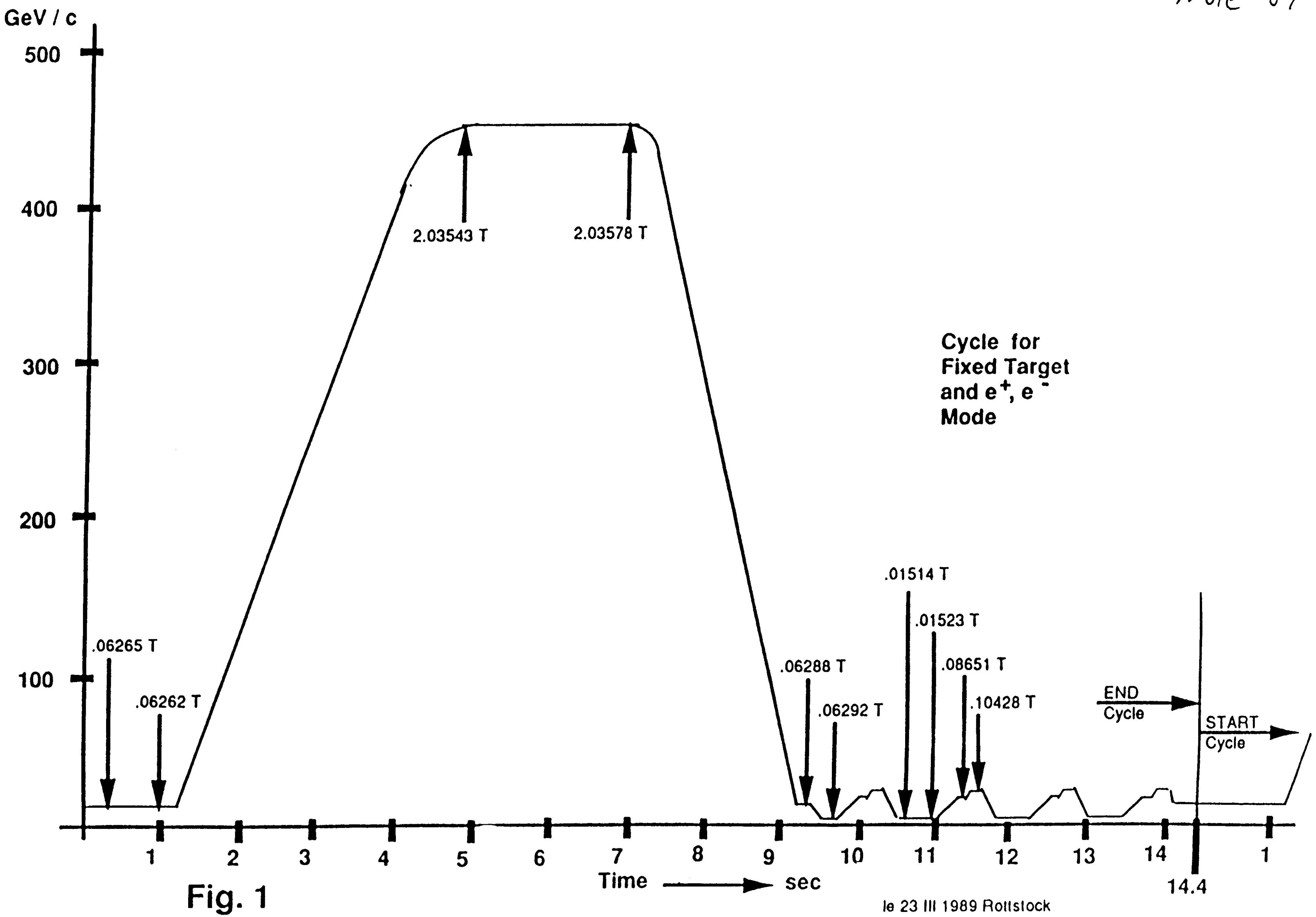


Fig. 1

THE MAGNETIC DIPOLMOMENT m OF AN ELECTRON WITH SPIN d IS GIVEN AS

$$m = \frac{-q \cdot h}{2\, m_e}$$

m_e = RESTMASS OF THE ELECTRON

$h = 6.625 \cdot 10^{-34}\ Ws^2$ (Planck Constan)

$q = 1.6 \cdot 10^{-19}\ As$ (electron charge)

AND THE SPINMOMENT S (often written as D)

$$S = \frac{h}{4\pi} = \frac{1}{2}\hbar$$

WE GET THE GYROMAGNETIC RATIO γ FOR ELECTRONS AS

$$\gamma = \frac{-m}{S} = 2.8\ \mathrm{GHz/KGauss}$$

THIS LEADS TO A LARMOR-PRECESSION FREQUENCY OF

$$f_L = \gamma \cdot H$$

IN GENERAL THE RESONANCE OF THE PRECESSION FREQUENCY FOR AN ELLIPSOID IS GIVEN AS

$$f_0 = \gamma \left[H_0 + \underbrace{H_{A(T)}}_{} + (N_T - N_z) M_S \right]$$

= 0 FOR POLYCRYST. SHERE

H_0 = UNPERTURBED FIELD

$H_{A(T)}$ = CRYSTAL ANISOTROPY FIELD TEMPERATURE

N_T = TRANSVERSE DEMAGNETISATION

N_z = AXIAL DEMAG. FACTOR

M_S = SATURATION MAGNETISATION

FOR A SPHERE:

$$N_T = N_z = 1/3$$

POLYCRYSTAL.SHERE

$$f_0 = \gamma \cdot H_0$$

FOR A DISK:

$$N_T - N_z = -1$$

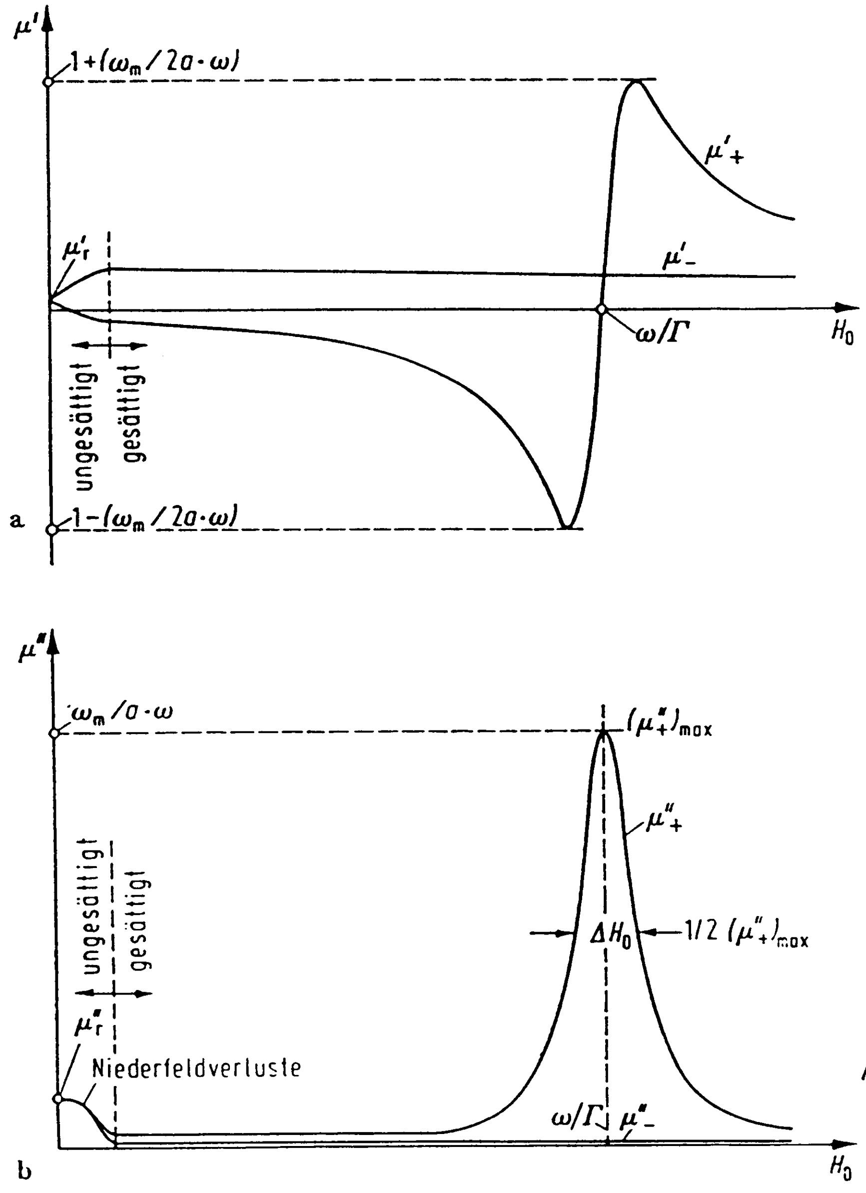
THERE ARE ALSO HIGHER ORDER (MAGNETOSTATIC) MODES AT FREQUENCIES f_m AS

$$f_0 - \gamma N_T M_S < f_m < f_0 + \gamma (0.5 - N_T) M_S$$

IT CAN BE SHOWN, THAT A LINEAR POLARIZED ELECTROMAGNETIC WAVE CAN BE DECOMPOSED INTO 2 COUNTERROTATING CIRCULAR POLARIZED WAVES

IN THE SAME WAY ONE CAN DEFINE A

$$\left.\begin{aligned} \mu_+ &= \mu_+' - j\mu_+'' \\ \mu_- &= \mu_-' - j\mu_-'' \end{aligned}\right\} \quad \text{THIS LEADS TO } k_+ , k_-$$

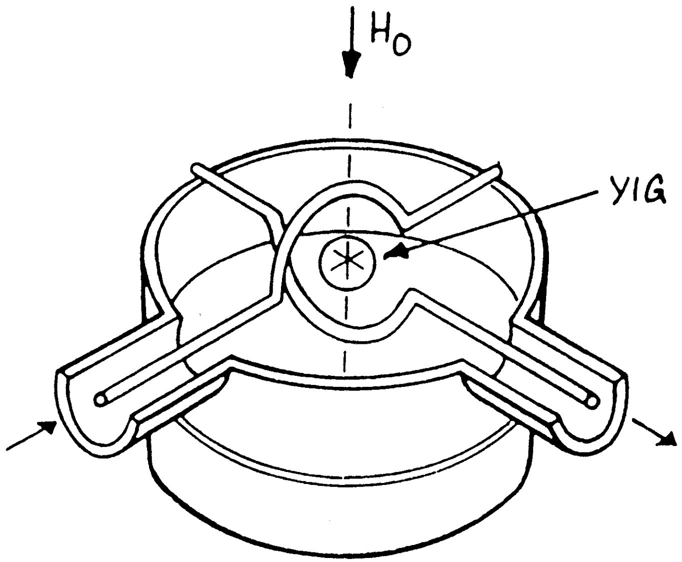


$$\Gamma = \mu_0 \cdot \frac{e}{m_e} = \gamma$$

Abb. 5.8/4a u. b

a μ_+' und μ_-', b μ_+'' und μ_-'' als Funktion des Gleichfeldes. $\boldsymbol{H_0}$ zeigt hierbei in positive z-Richtung

From: Zinke - Brunswig, Lehrbuch der Hochfrequenztechnik Band I, p 233, Springer Verlag 1973

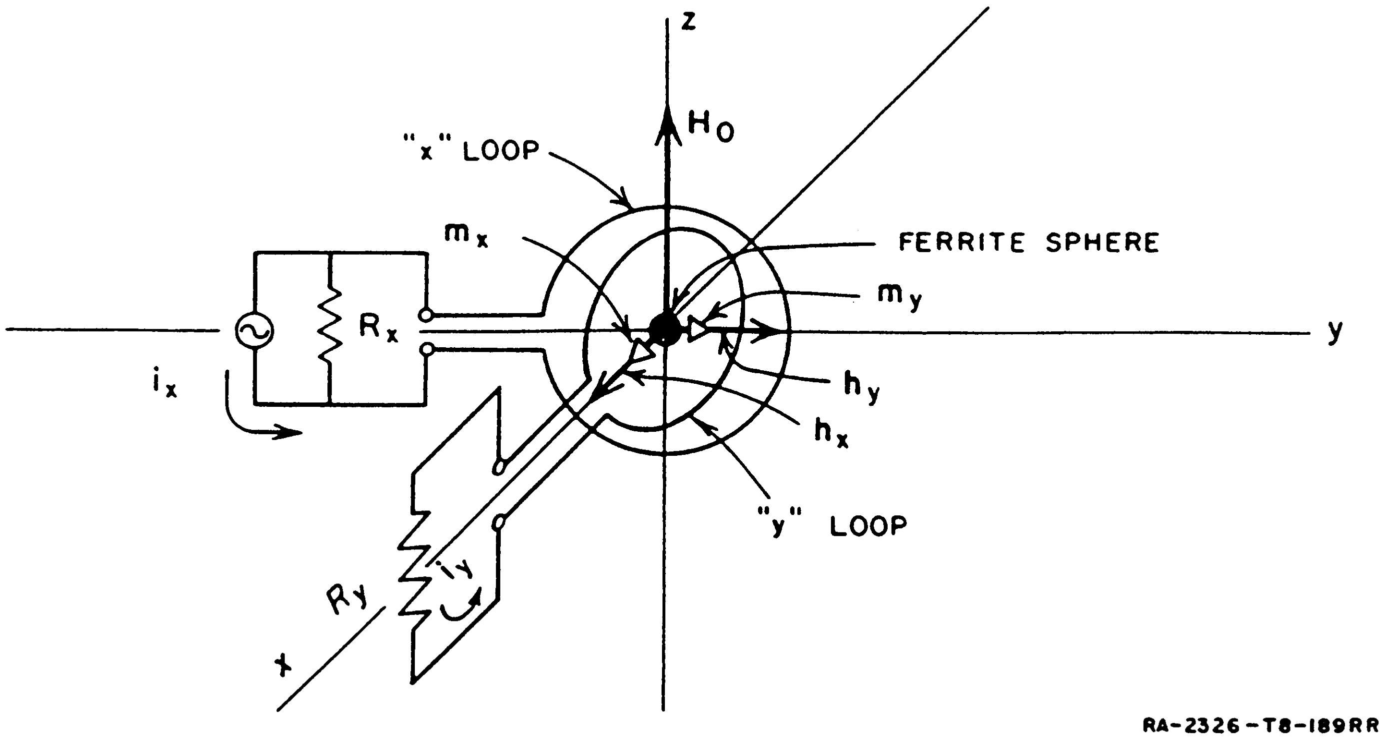


Coupling structure of a single-stage filter

The essential RF-coupling

The RF-energy transfer from a transmission line (a TEM-line) to/from the YIG resonator is established by magnetic coupling from the semicircular loops as shown in Fig. 2. To prevent unwanted coupling in absence of YIG-resonance (off-resonance isolation) the loops must be orientated orthogonally to each other. Coupling of the RF field to the YIG resonator is achieved by concentration of the RF magnetic field in the vicinity of the sphere. Also biasing field must be orthogonal to RF-fields, and best electrical performance is obtained when an uniform RF and biasing field intercepts in the YIG-sphere region.

From: Sievers Lab; Application Note on YIG-tuned devices (P. O. Tammi) page 2

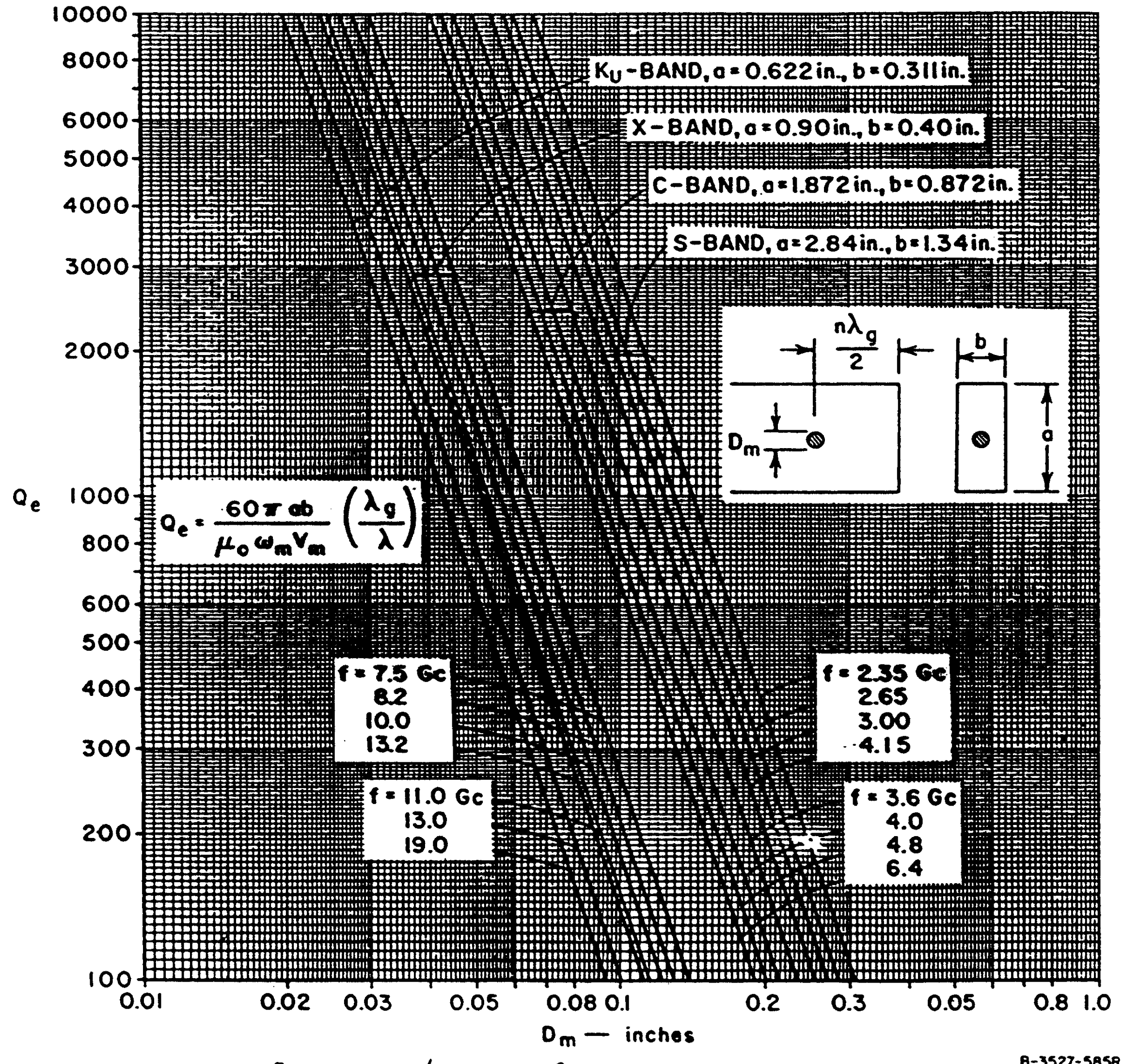


SOURCE: Final Report, Contract DA 36-039 SC-74862, SRI; reprinted in *IRE Trans. PGMTT* (see Ref. 3 by P. S. Carter, Jr.)

A SINGLE-RESONATOR MAGNETICALLY TUNABLE FILTER USING LOOP COUPLING

FROM: G. Matthaei, L. Young, E.M.T JONES
MICROWAVE FILTERS, IMPEDANCE-MATCHING NETWORKS AND COUPLING STRUCTURES
p. 1043

2.6



Q_e = external Q

Q_e vs. SPHERE DIAMETER OF SPHERICAL YIG RESONATOR LOCATED AT A HIGH-CURRENT POSITION IN SHORT-CIRCUITED TE_{1n} RECTANGULAR WAVEGUIDE

FROM: G. Matthaei, L. Young, E.M.T. Jones
MICROWAVE FILTERS, IMPEDANCE-MATCHING
NETWORKS AND COUPLING STRUCTURES

p 1070

Spurious modes
Until now we have assumed that at normal power levels only the "main" resonance (110 magnetstatic mode) is present. Hower, in all YIG-resonators there are higher order resonance modes (spurious modes) present. In the filter transmission curve (fig. 6) these higher modes appear as "notches".

The spurious modes are of two kinds, tracking off-resonance modes having passbands at constant frequency distances from main resonance, i.e. they have the same tuning sensitivity as the main resonance. The spacing between the tracking mode and main resonance decreases with the saturation magnetization of the YIG-spheres.

There are also other modes, passband spuriouses, tuning at faster rates and hence they may cross the frequency of the main resonance. These modes are excited by non-uniformities in the applied RF-field, and couple to and distort the main mode. Such modes are indicated in Fig. 4 and 6. The passband spurioses together with a variation of the interstage coupling in the filter gives a ripple in the passband, typically around 2—3 dB.

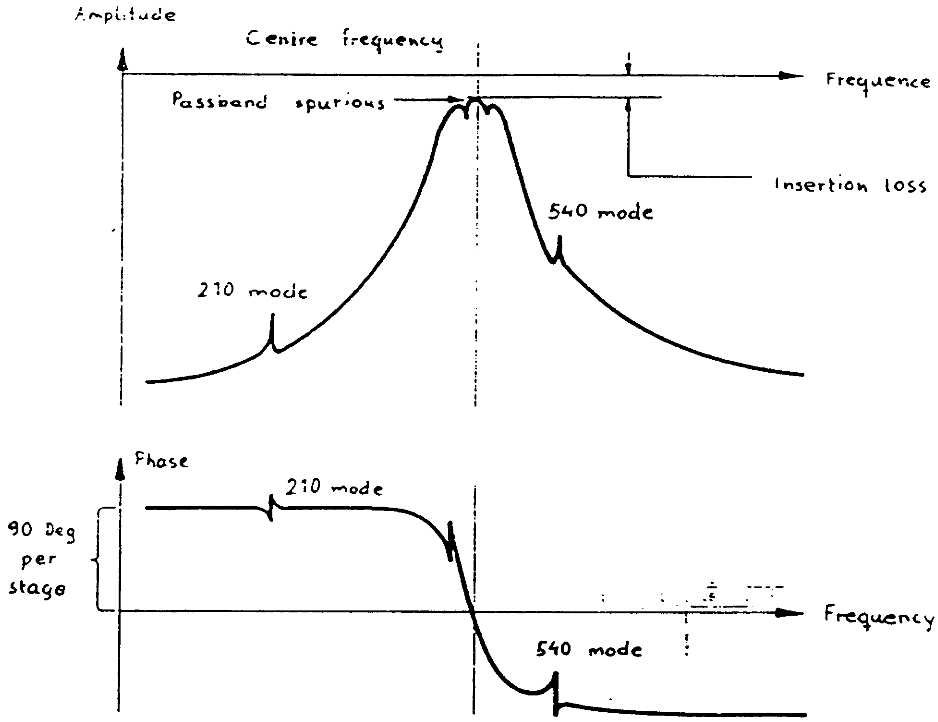


Fig. 6. Passband transmission characteristic of a YIG-fil

From: SIVERS LAB (P. V. Tamm)
YIG Products and Applications
Application note on YIG-tuned oscillators

2.8

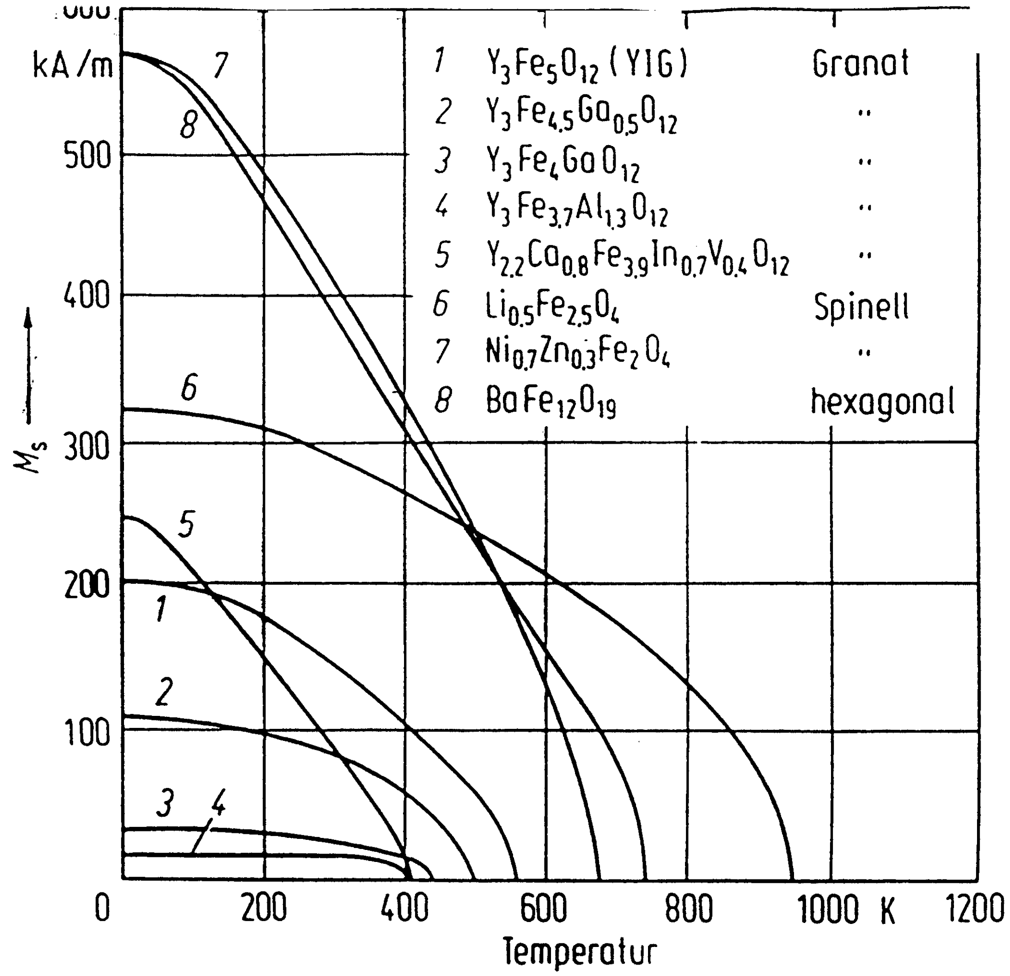


Bild 17. Sättigungsmagnetisierung in Abhängigkeit von der Temperatur für verschiedene Ferrite, die für ferrimagnetische Resonatoren geeignet sind

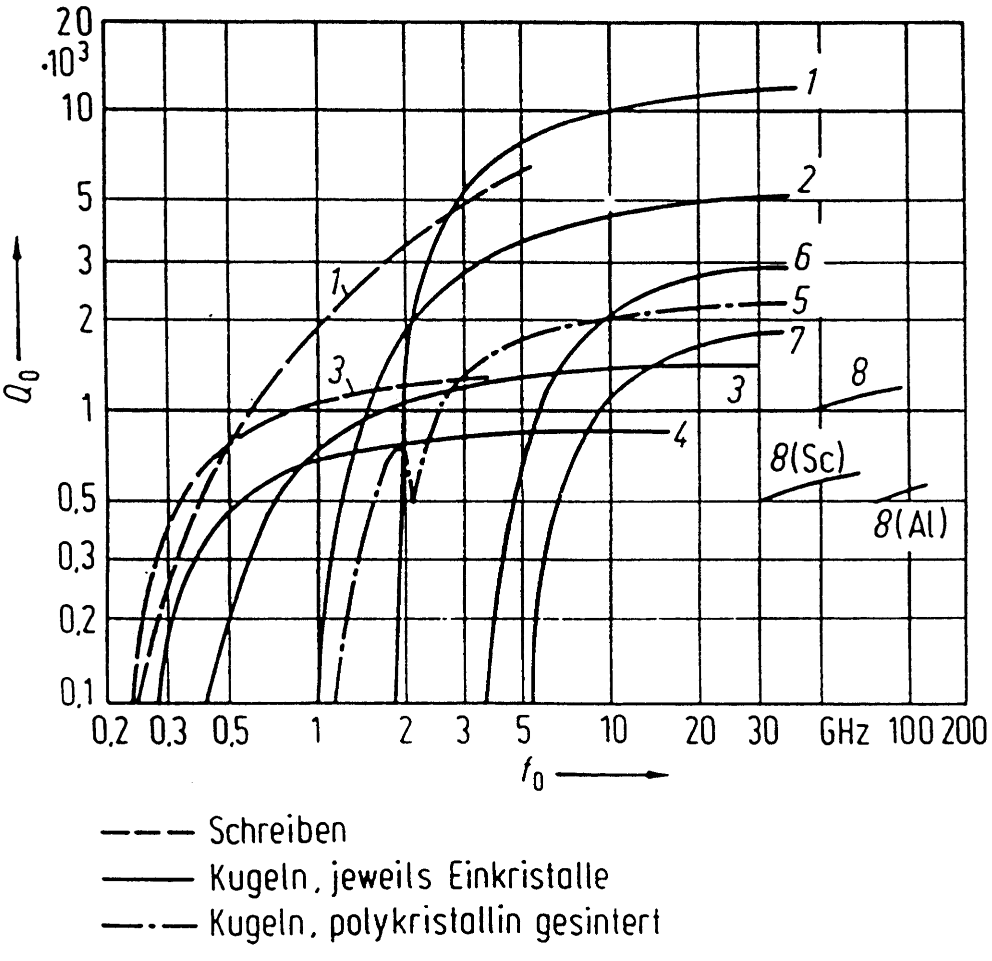
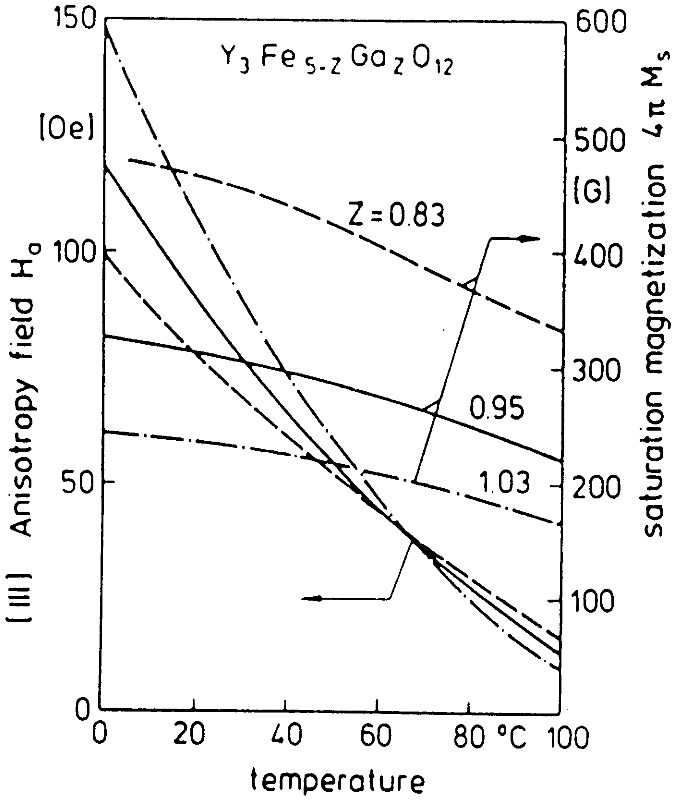


Bild 18. Unbelastete Güte ferrimagnetischer Resonatoren in Abhängigkeit von der Frequenz für verschiedene Ferrite; Kurvenbezeichnung wie in Bild 17

From: Meinke, Gundlach, Taschenbuch der Hochfrequenztechnik, 4. Auflage
pp. L 51/L 52



Polycrystal $\Rightarrow H_a \approx 0$

Fig. 1: Anisotropy field Ha along the easy <111> direction and saturation magnetization 4πM versus temperature for Ga substituted single crystal YIG.

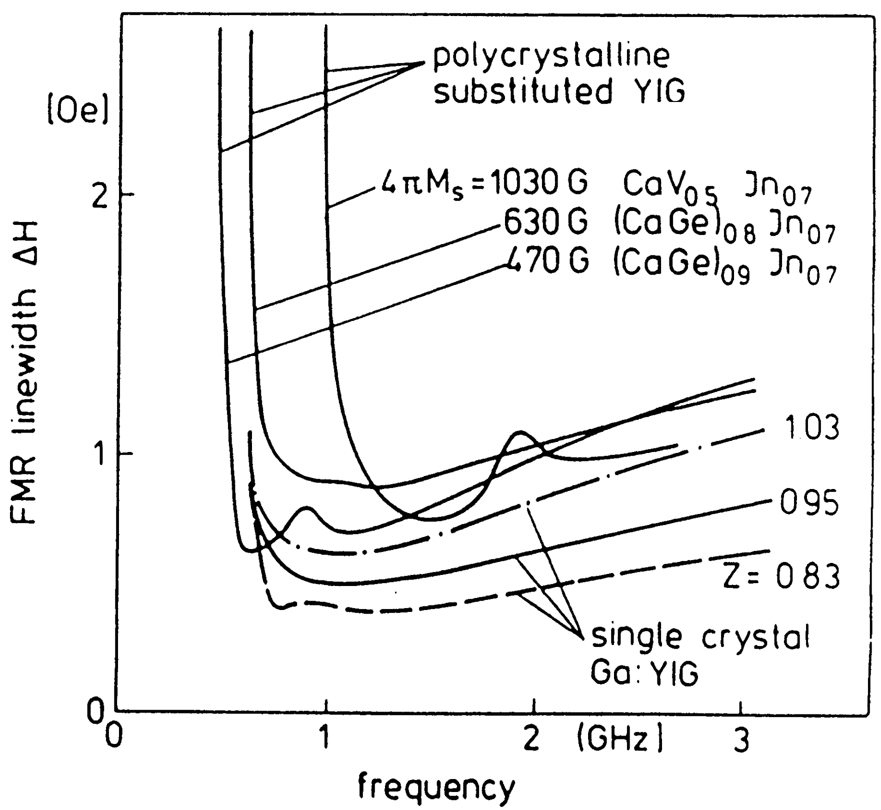
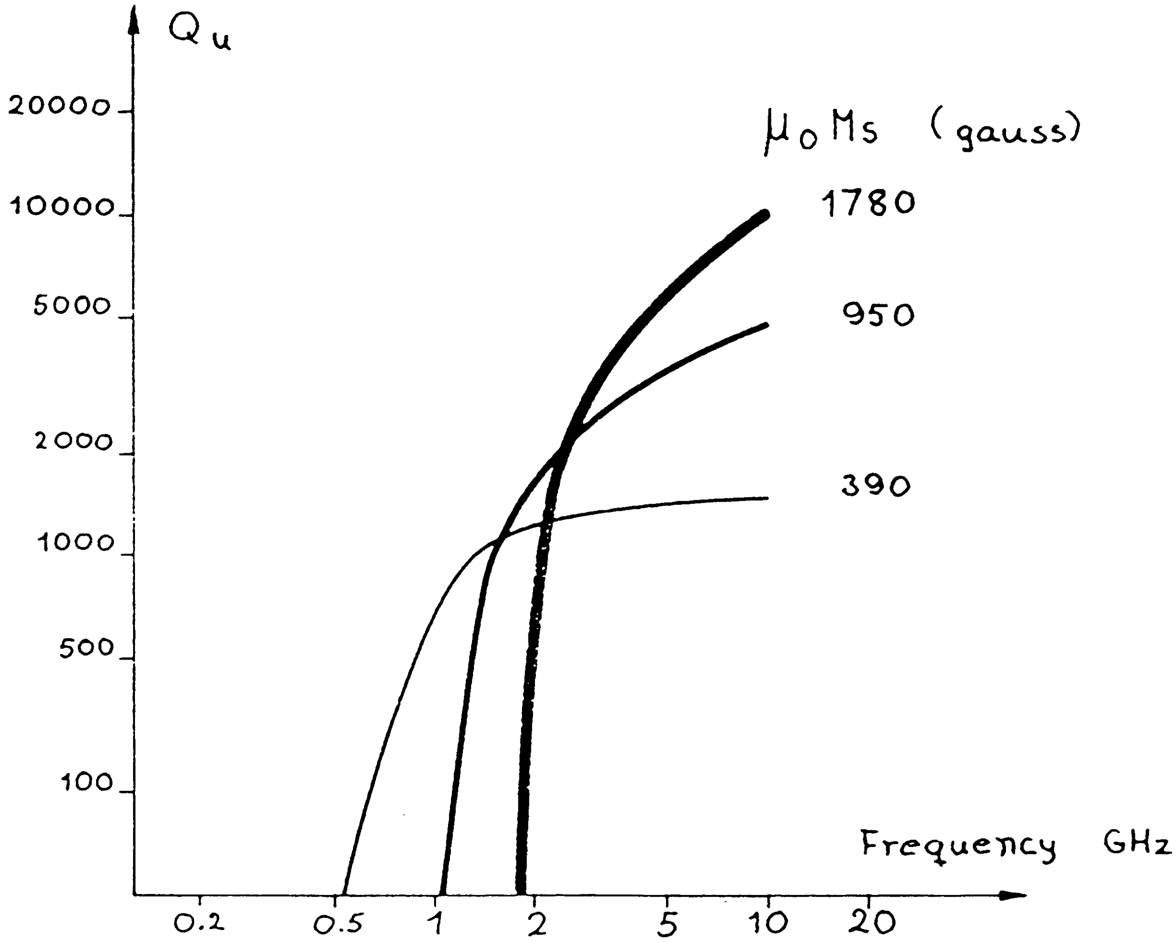


Fig. 2: FMR linewidth ΔH at room temperature versus frequency for spheres of single crystal Ga:YIG and of polycrystalline CaVIn or CaGeIn substituted YIG.

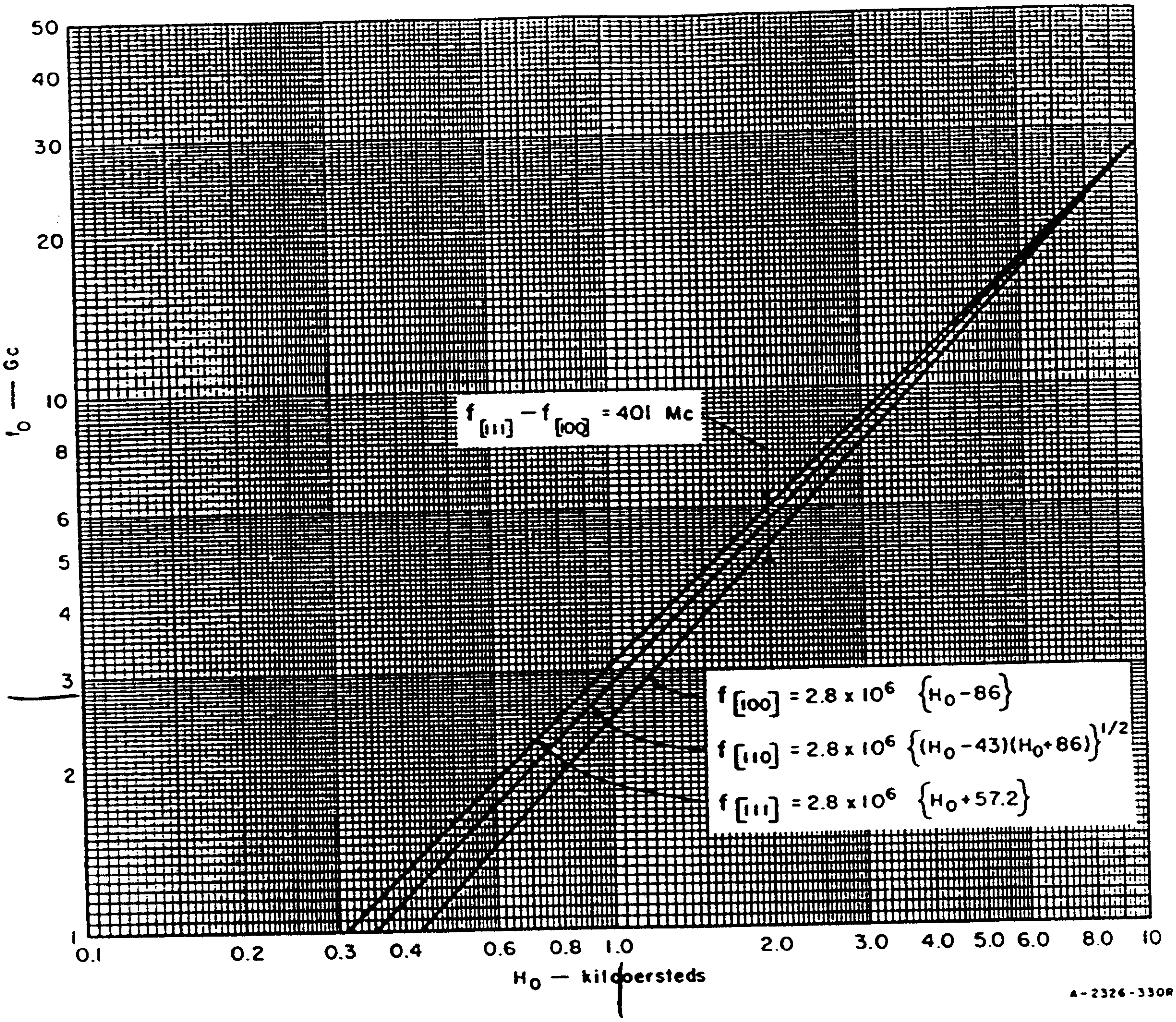
From: F. K. Beckman et. al.; Remote Temperature Sensing in Organic Tissue by Ferrimagnetic Resonance Frequency Measurements
11 th EuMC, Amsterdam 1981, pp 433 - 437

2.9



Unloaded Q-value for a sphere of GaYIG with the saturation magnetization (μ_0 M_s) a parameter

From: SIVERS LAB (P.V. TAMM)
YIG Products and Applications
Application Note on YIG-tuned devices
page 3



RESONANT FREQUENCY OF YIG SPHERE vs. APPLIED dc FIELD WITH FIELD ALONG THE [100], [110], OR [111] PRINCIPAL AXES

CHARACTERISTICS OF A SINGLE CRYSTAL SPHERE

From: G. Matthaei, L. Young, E.M.T. Jones
MICROWAVE FILTERS, IMPEDANCE-MATCHING NETWORKS AND COUPLING STRUCTURES
p. 1034

2.12

$\underline{Y_{2.4}\,Ca_{0.6}\,[Fe_{1.3}In_{0.7}]\,(Fe_{2.7}V_{0.3})O_{12}}$

$4\pi M_s \approx 1200$ Gauss
$\Delta H \sim 1.5$ Oe bei 3 GHz

Dies Material mit niedriger Kristallanisotropieenergie von ca. 200 erg cm^{-3} eignet sich gut für Magnetfeldmessungen oberhalb der Sättigung der Kugel bei ca. 400 Gauss, da das für polykristalline Kugeln typische ΔH-Maximum infolge Kristallanisotropie beim Eintritt der uniformen Präzessionsresonanz ins Spinwellenband ($\omega = 2/3\,\gamma 4\pi M_S$) nicht sehr ausgeprägt ist. Bei Messungen < 800 Gauss muß zur Vermeidung der parametrischen Anregung von Spinwellen mit der halben FMR Frequenz der HF-Leistungspegel niedrig bei ca. -20 dBm gehalten werden.

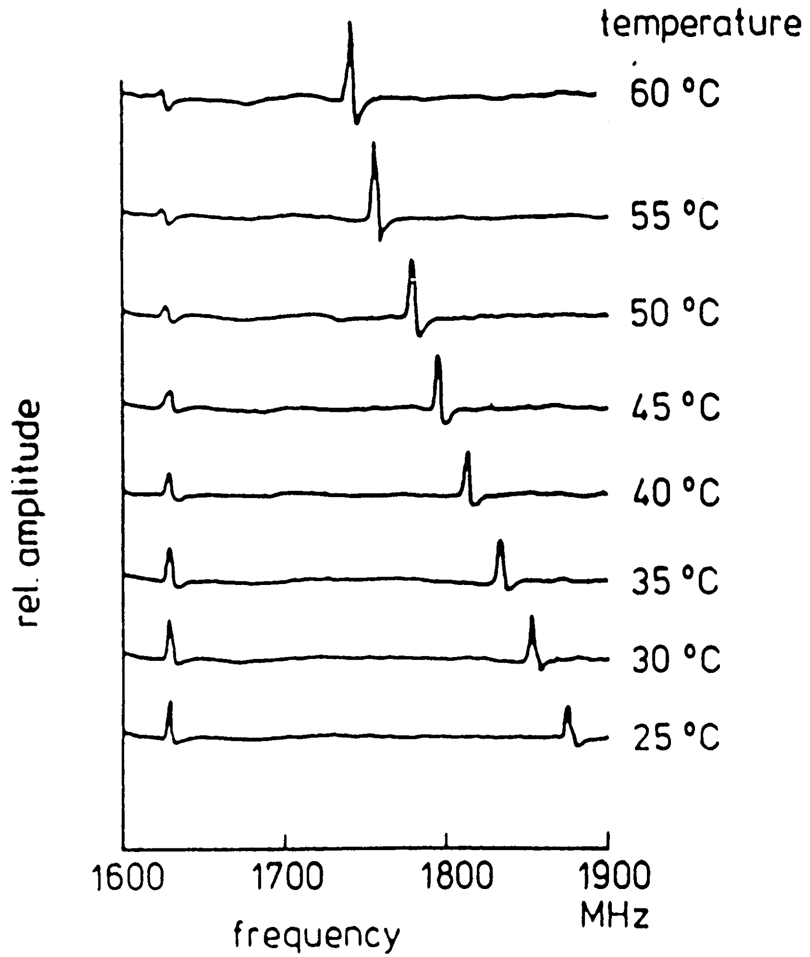


Fig. 5: Measured FMR signals of a single crystal and of a polycrystalline substituted YIG sphere at different temperatures.

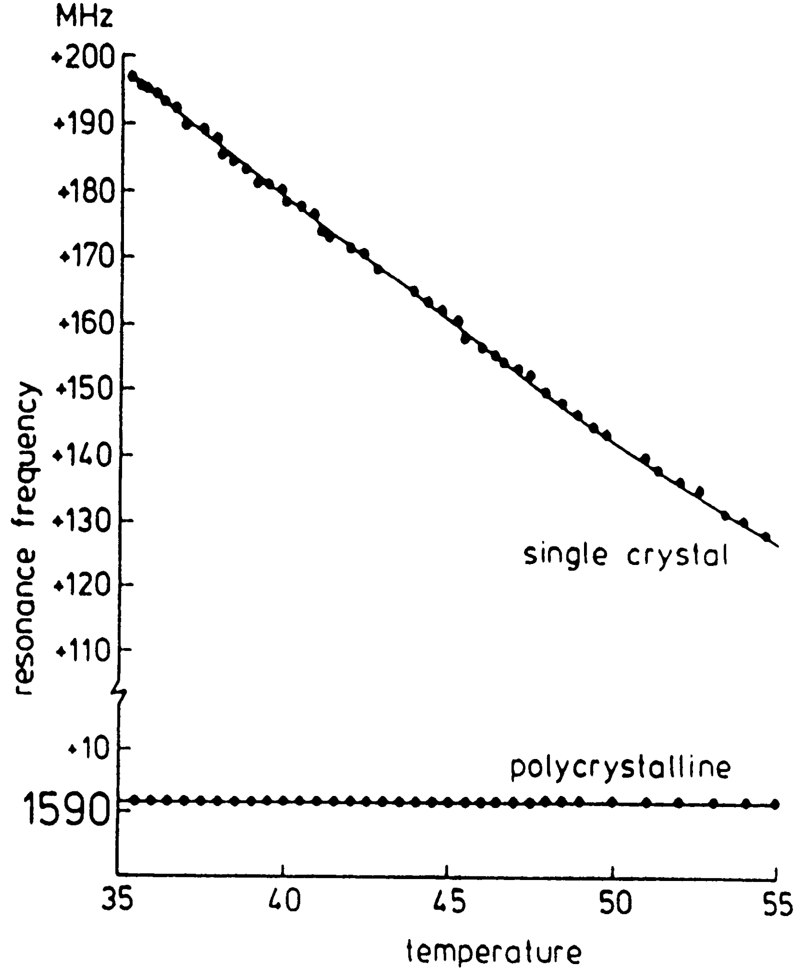
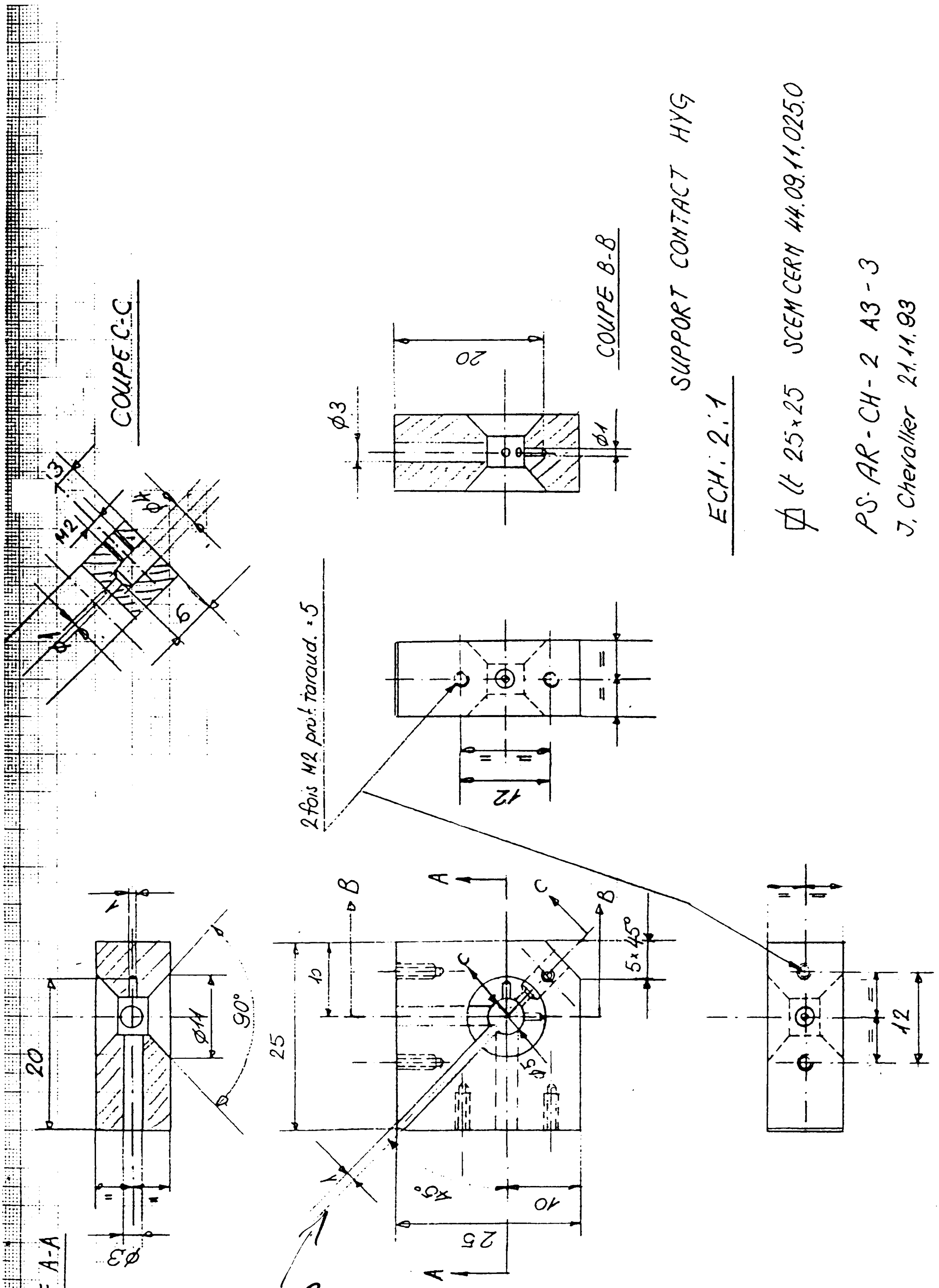


Fig. 6: Measured resonance frequencies of a single crystal and a polycrystalline substituted YIG sphere versus temperature.
from the text: $\frac{\Delta f}{\Delta T} < 20\,KHz/deg\,C$

From: F.K. Beckmann et. al; Remote Temperature Sensing in Organic Tissue by Ferrimagnetic Resonance Frequency Measurement. 11th. Eu. MC, Amsterdam 1981, pp 433-43.



RADIAL CUT TO AVOID EDDY CURRENTS DUE TO $\dot{B}$

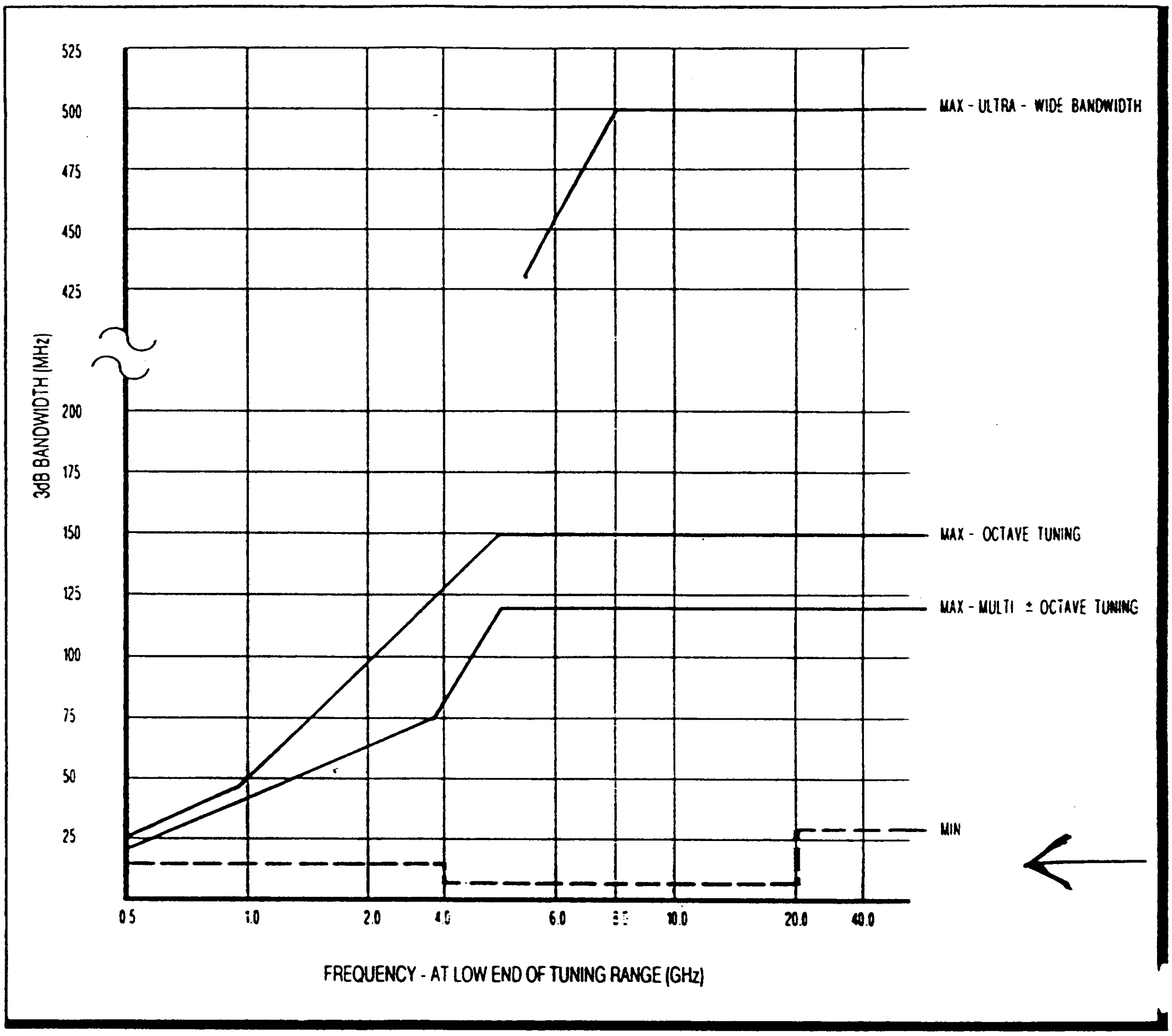


Figure 4 – Range of 3 dB bandwidths available in Ferretec bandpass YIG filters

• **Instantaneous Bandwidth**

Figure 4 shows the wide range of bandwidths Ferretec provides in bandpass filters. Both minimum and maximum achievable bandwidths are shown as a function of the minimum operating frequency of the filter.

Changes in the coupling coefficients occur with frequency, and result in the growth of the bandwidth near the high end of the tuning range. Ferretec's precisely designed structures and proprietary loop configurations minimize this growth while maintaining the best possible VSWR.

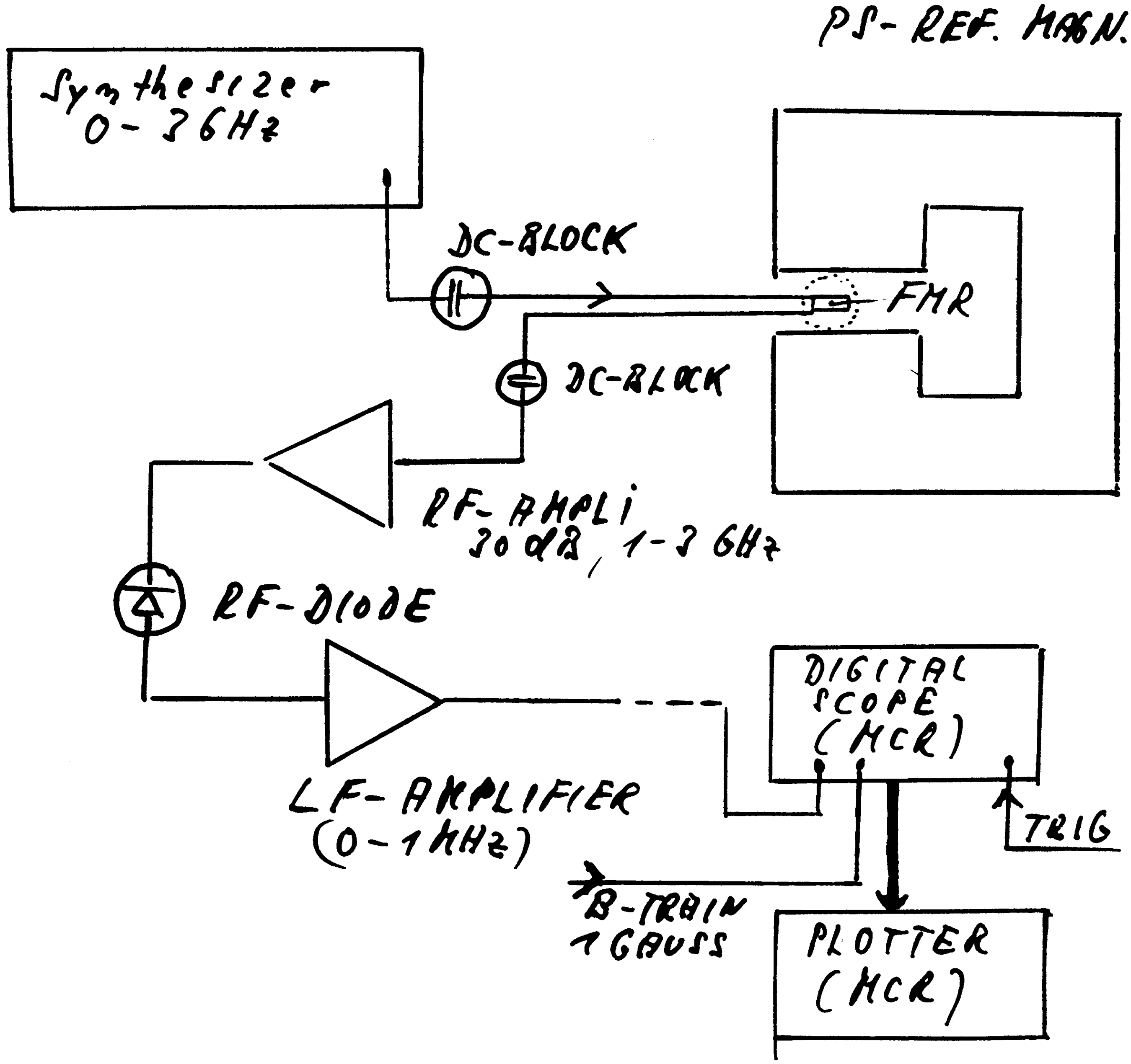
FROM: FERRETEC APPLICATION NOTE "YIG-FILTERS" (page 6)

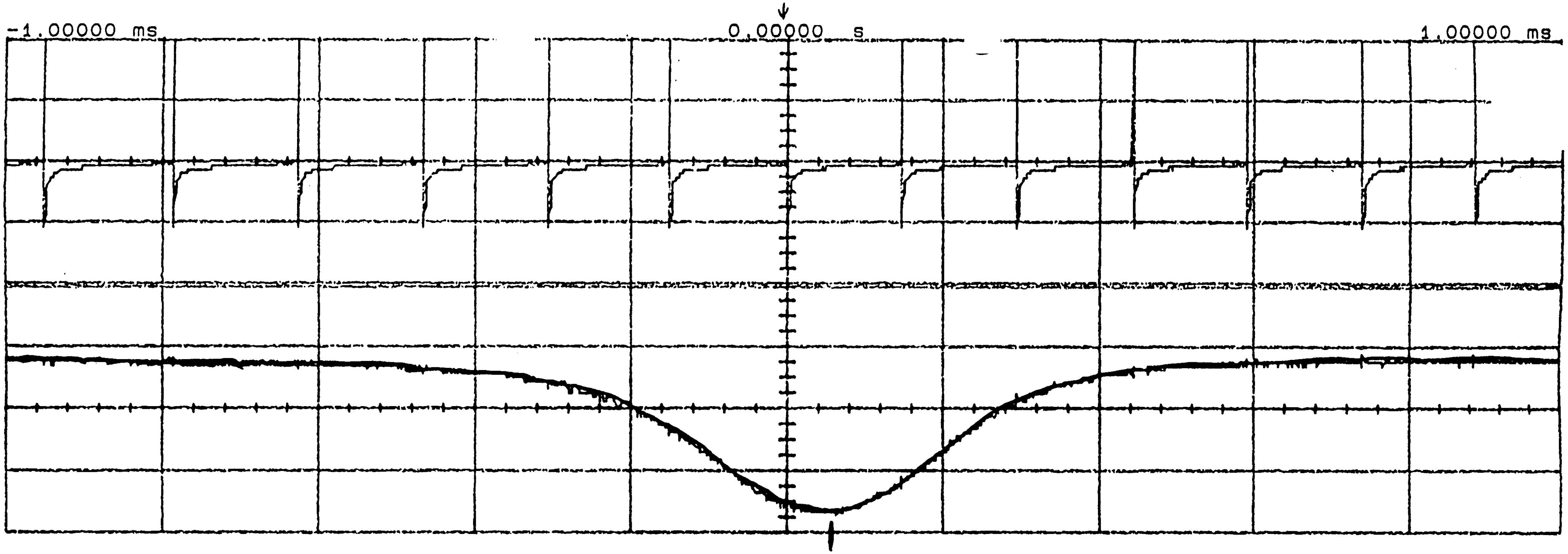
VERY RECENTLY FERRETEC HAS FOUND "SUPER Q" PROPERTIES AT CERTAIN FERRITES (Q > 10000)

PRINCIPLE OF OPERATION FOR THE YIG-FMR PROBE IN PS 101.

- A YIG-FMR TRANSMISSION RESONATOR IS INSTALLED IN ONE OF THE MODULES OF THE PS REF. MAGNET AT THE SAME LOCATION AS THE PEAKING STRIP AND THE PICKUP COILS FOR THE B-TRAIN.
- A SYNTHESIZER IS SET TO A PROGRAMMABLE, BUT VERY STABLE FREQUENCY. (e.g. 2378 MHz)
- WHEN THE B-FIELD, SEEN BY THE YIG-SPHERE CORRESPONDS TO THE (LARMOR-) FREQUENCY SET ON THE SYNTHESIZER, WE GET TRANSMISSION. ⇒ MAGNETIC WINDOW
- THE TRANSMITTED SIGNAL IS SENT VIA AN AMPLIFIER (CABLE LOSSES) TO A DETECTOR DIODE AND THEN TO A DIGITAL SCOPE IN THE MCR.

CIRCUIT DIAGRAM FOR PS - REF. MAGN. MEASUREMENT SETUP





	Timebase	Delay/Pos	Reference	Mode
Main	200 us/div	0.00000 s	Center	Realtime (EXTENDED)
	Sensitivity	Offset	Probe	Coupling
Channel 1	2.00 V/div	0.00000 V	1.000 : 1	dc (50 ohm)
Channel 2	200 mV/div	-200.000 mV	1.000 : 1	dc (50 ohm)

872 Gauss
cycle D ↓

28/6/94

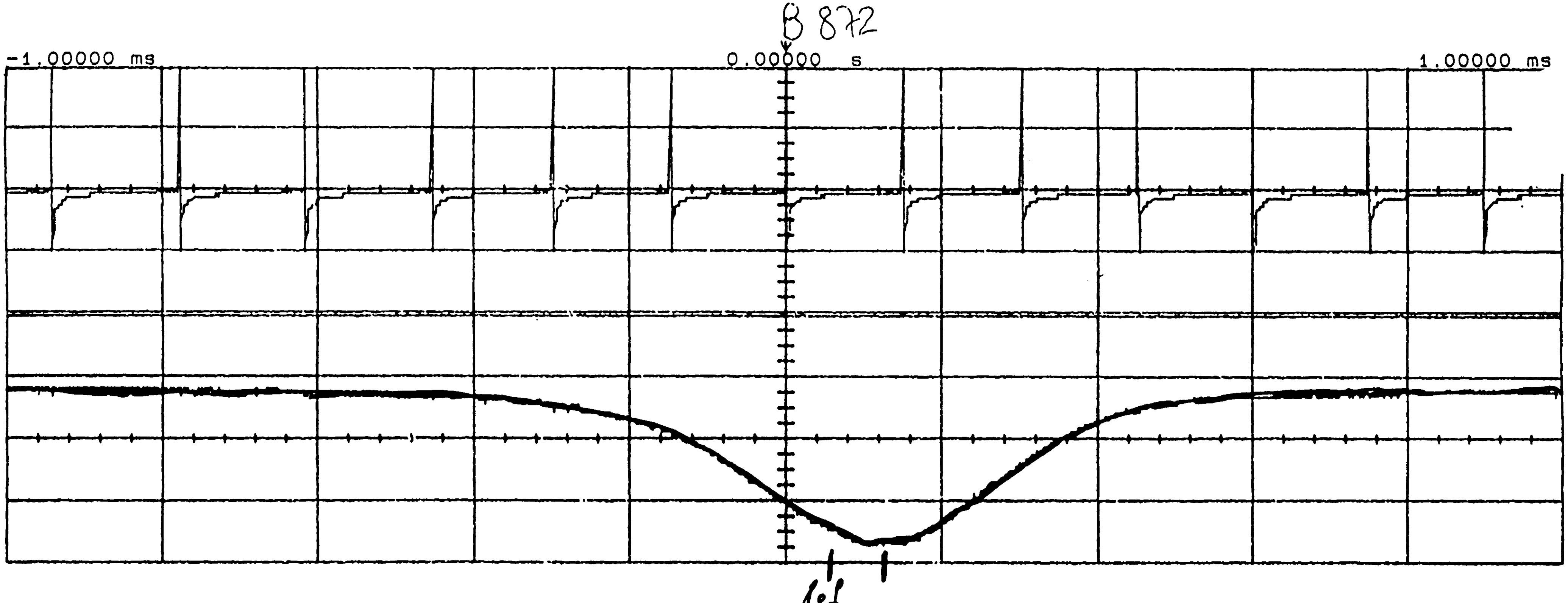
10 : 30

$f = 1239 \times 2$
$= 2478$ MHz

Reference: Chaîne train B n° 3

NORMAL POSITION

3.3

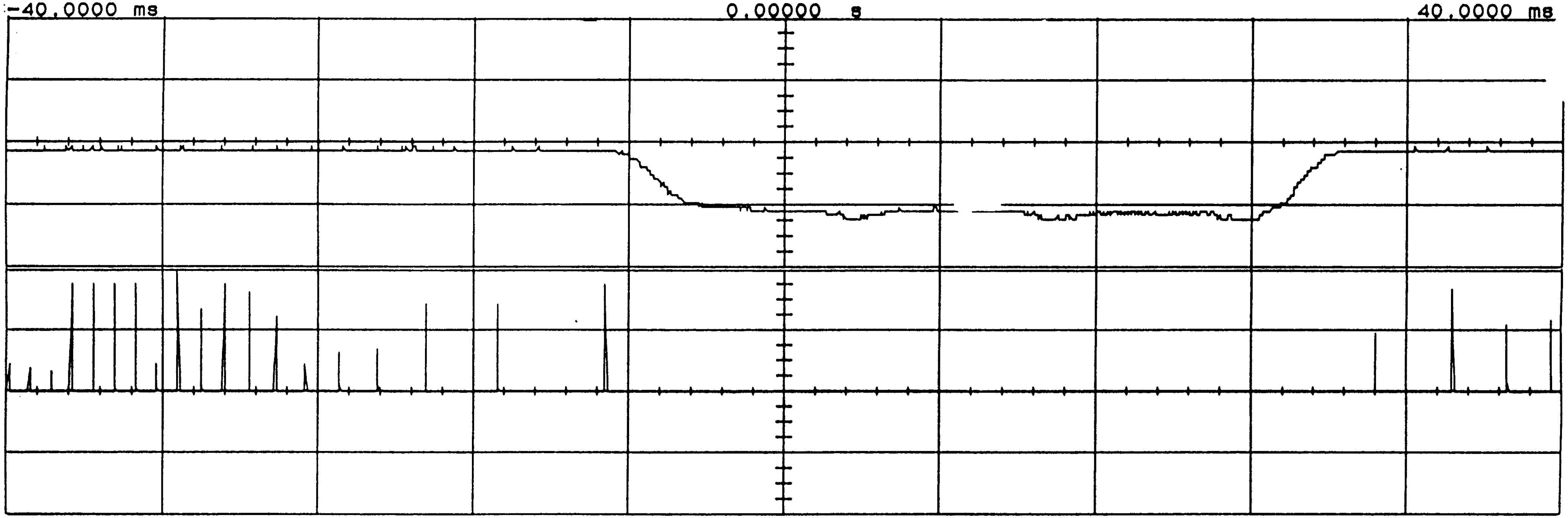


	Timebase	Delay/Pos	Reference	Mode
Main	200 us/div	0.00000 s	Center	Realtime (EXTENDED)
	Sensitivity	**Offset**	**Probe**	**Coupling**
Channel 1	2.00 V/div	0.00000 V	1.000 : 1	dc (50 ohm)
Channel 2	200 mV/div	-200.000 mV	1.000 : 1	dc (50 ohm)

28/6/94

10 : 00

Chaîne train B n° 1



	Timebase	Delay/Pos	Reference	Mode
Main	8.00 ms/div	0.00000 s	Center	Realtime (EXTENDED)
	Sensitivity	Offset	Probe	Coupling
Channel 1	400 mV/div	0.00000 V	1.000 : 1	dc (50 ohm)
Channel 2	1.00 V/div	0.00000 V	1.000 : 1	dc (1M ohm)

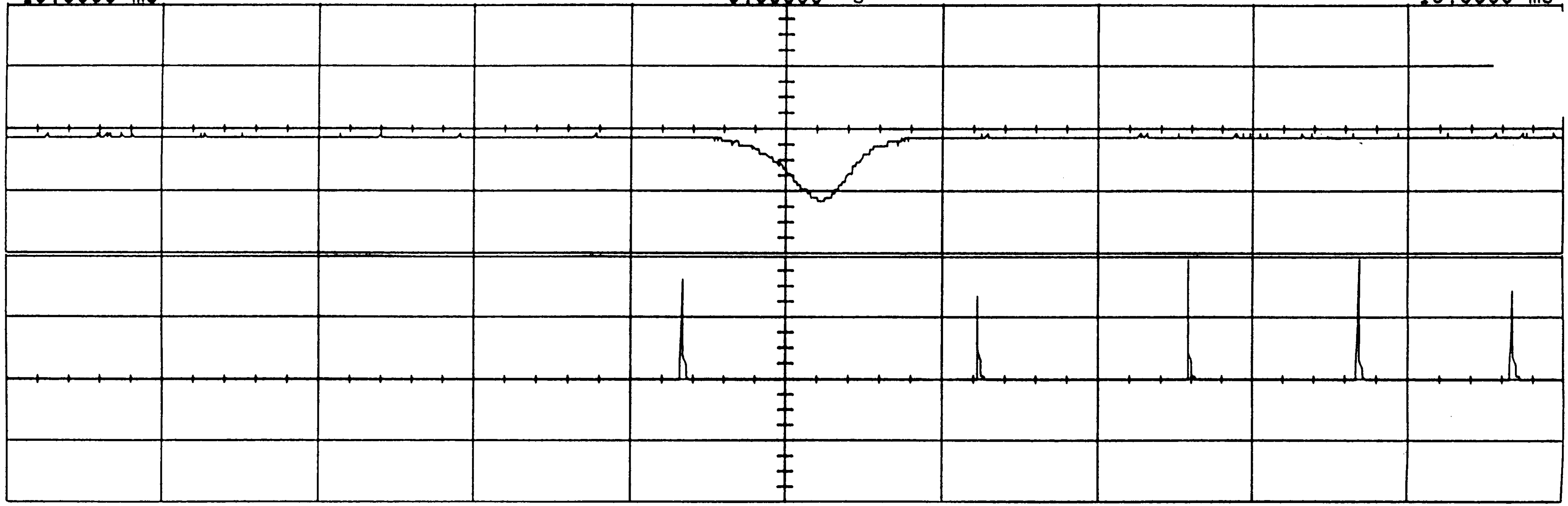
Trigger mode : Edge
On Positive Edge Of Ext1
Trigger Level
Ext1 = 1.00000 V (noise reject OFF)
Holdoff = 320.000 ms

31.3.94
Bhain ↑.
ext. Trigger — Counter on
804 gauss
cycle SFT
104

$1141 \times 2 = 2282$ MHz
$804 \times 2.8 = 2251.2$ MHz
} Measured field is 1.3% higher than average field seen by the beam

814.7 gauss ? = Synthesizer set to 1141 MHz (x2)

3.5

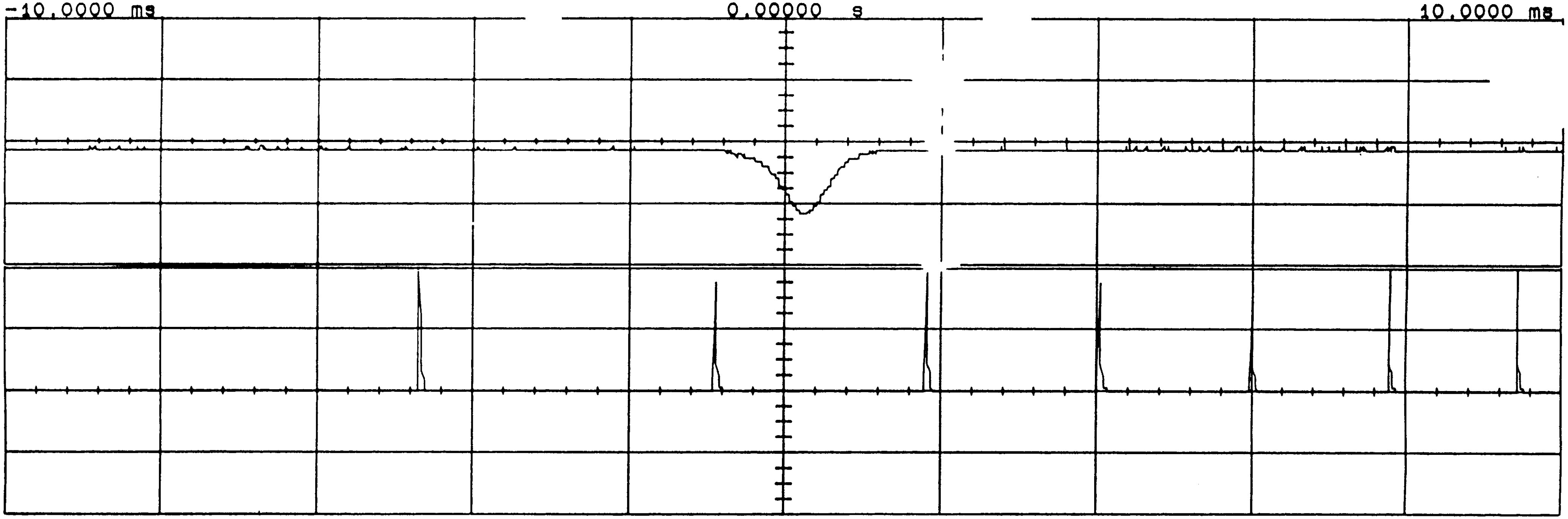


	Timebase	Delay/Pos	Reference	Mode
Main	2.00 ms/div	0.00000 s	Center	Realtime (EXTENDED)

	Sensitivity	Offset	Probe	Coupling
Channel 1	400 mV/div	0.00000 V	1.000 : 1	dc (50 ohm)
Channel 2	1.00 V/div	0.00000 V	1.000 : 1	dc (1M ohm)

Trigger mode : Edge
On Positive Edge Of Ext1
Trigger Level
Ext1 = 1.00000 V (noise reject OFF)
Holdoff = 320.000 ms

31.3.94
β-kaie ↑
ext Trig counter on 814
Cycle SFT (104)
Synthesizer on 1150 (+2)



	Timebase	Delay/Pos	Reference	Mode
Main	2.00 ms/div	0.00000 s	Center	Realtime (EXTENDED)
	Sensitivity	Offset	Probe	Coupling
Channel 1	400 mV/div	0.00000 V	1.000 : 1	dc (50 ohm)
Channel 2	1.00 V/div	0.00000 V	1.000 : 1	dc (1M ohm)

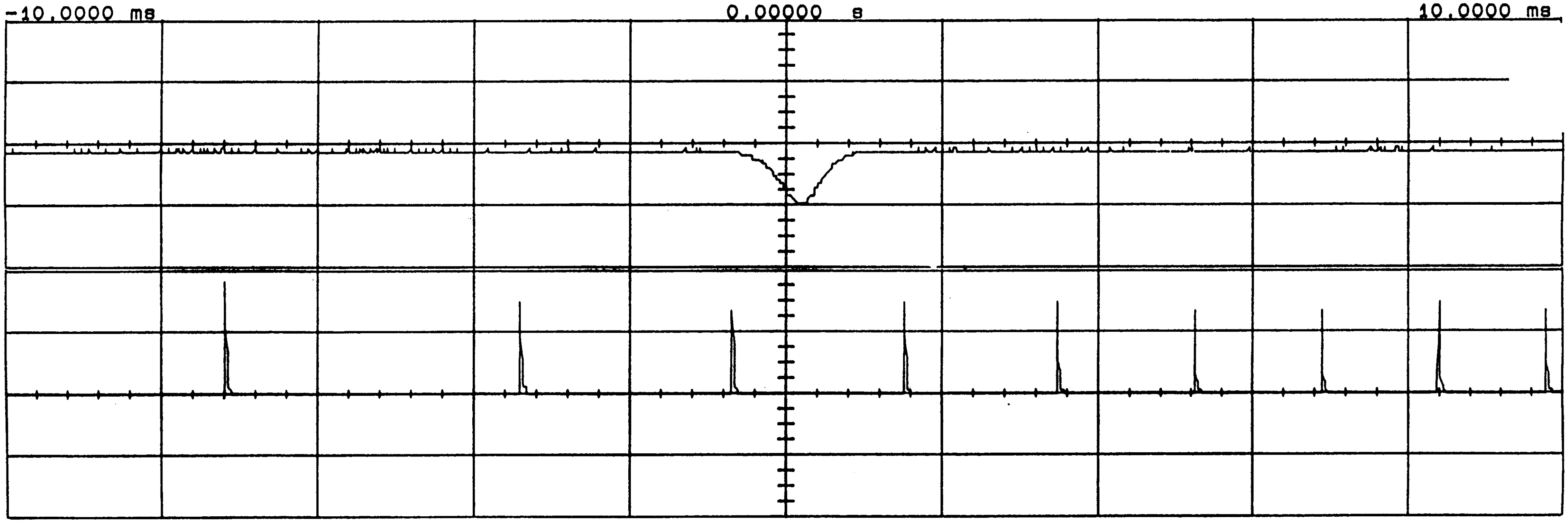
Trigger mode : Edge
On Positive Edge Of Ext1
Trigger Level
Ext1 = 1.00000 V (noise reject OFF)
Holdoff = 320.000 ms

31.3.94

ext. Trigger counter = 824 jau
β-train ?
Cycle SFT (104)

Synthesizer 04 1169 (x) 2

3.7



	Timebase	Delay/Pos	Reference	Mode
Main	2.00 ms/div	0.00000 s	Center	Realtime (EXTENDED)
	Sensitivity	Offset	Probe	Coupling
Channel 1	400 mV/div	0.00000 V	1 000 : 1	dc (50 ohm)
Channel 2	1.00 V/div	0.00000 V	1 000 : 1	dc (1M ohm)

Trigger mode : Edge
On Positive Edge Of Ext1
Trigger Level
Ext1 = 1.00000 V (noise reject OFF)
Holdoff = 320.000 ms

31. 3. 94
ext. Trigger counter on
834 pauses
8-bunch ↑
cycle SFT (104)
Synthesizer on 1183 x (2)

3.8

CONCLUSION + OUTLOOK

- THE FMR - SYSTEM ACTS AS POINTLIKE MEASUREMENT (MARKER) TO SURVEY THE B-TRAIN GENERATOR IN TERMS OF STABILITY.

- THE MEASUREMENT RANGE NOW IS 500 Gauss to ABOUT 900 GAUSS.
- 500 GAUSS LIMITATION DUE TO FMR SATURATION MAGNETISATION
- 900 GAUSS NOW LIMITED BY SYNTHES.

- THE SYSTEM FOR THE PS WILL WORK IN THE NEAR FUTURE 0.5 - 2 KGAUSS (NEW SYNTHESIZER) AND POSSIBLY 0.2 - 2KGAUSS (NEW FERRIT)

- THE NEW SYSTEM WILL ALSO MEASURE ON FLATTOPS (FREQ. MODULATION)

- ANOTHER FMR - SYSTEM IS INSTALLED IN THE LINAC SPECTROMETER - MAGNET LBS, BVT, 10 READOUT VIA NETWORKANALYZER FROM LEAR - CONTROL - ROOM.

Geneva, 17 June, 1994

MEMORANDUM

A/To: PPC

De/From: F. Caspers

Concerne/Subject: B-field marker for the PS B-train based on ferrimagnetic resonance (FMR)

PROPOSAL AND COST-ESTIMATE

THE SYSTEM CONSISTS OF AN FMR FIELD-PROBE ACTING AS A TRANSMISSION RESONATOR. THIS FIELD PROBE IS INSTALLED IN THE PS -REFERENCE MAGNET AND GIVES A REASONABLE RESPONSE ABOVE 500 GAUSS. AN EXPERIMANTAL SETUP USED SINCE APRIL THIS YEAR HAS SHOWN SATISFACTORY PERFORMANCE (RESOLUTION AND STABILITY ABOUT 0.2 GAUSS).THE RELATION BETWEEN B-FIELD AND RESONANCE - FREQUENCY IS GIVEN BY

F=2.8 GHZ/KGAUSS

IT IS PROPOSED TO USE THE FREQUENCY RANGE 1.5-6 GHZ.

SHOPPING LIST:

1 SYNTHESIZER (0-3 GHZ)	15KSFR	
1 FREQUENCY-DOUBLER	1	
2 MICROWAVE AMPLIFIERS	3	(TOTAL)
2 DETECTOR-DIODES	1	(TOTAL)
2 DC BLOCKS	1	(TOTAL)
1 15 VOLT POWER SUPPLY	0.5	
1 LOW FREQUENCY AMPLIFIER	2	
1 DIGITAL SCOPE	5	
1 PLOTTER	2	
2 CAMAC GP-IB INTERFACE	5	(TOTAL)
1 DIVERS	1	
TOTAL	36.5 KSFR	