INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

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SMR.300/38

College on Medical Physics

(10 October - 4 November 1988)

# Introduction to Biomagnetism

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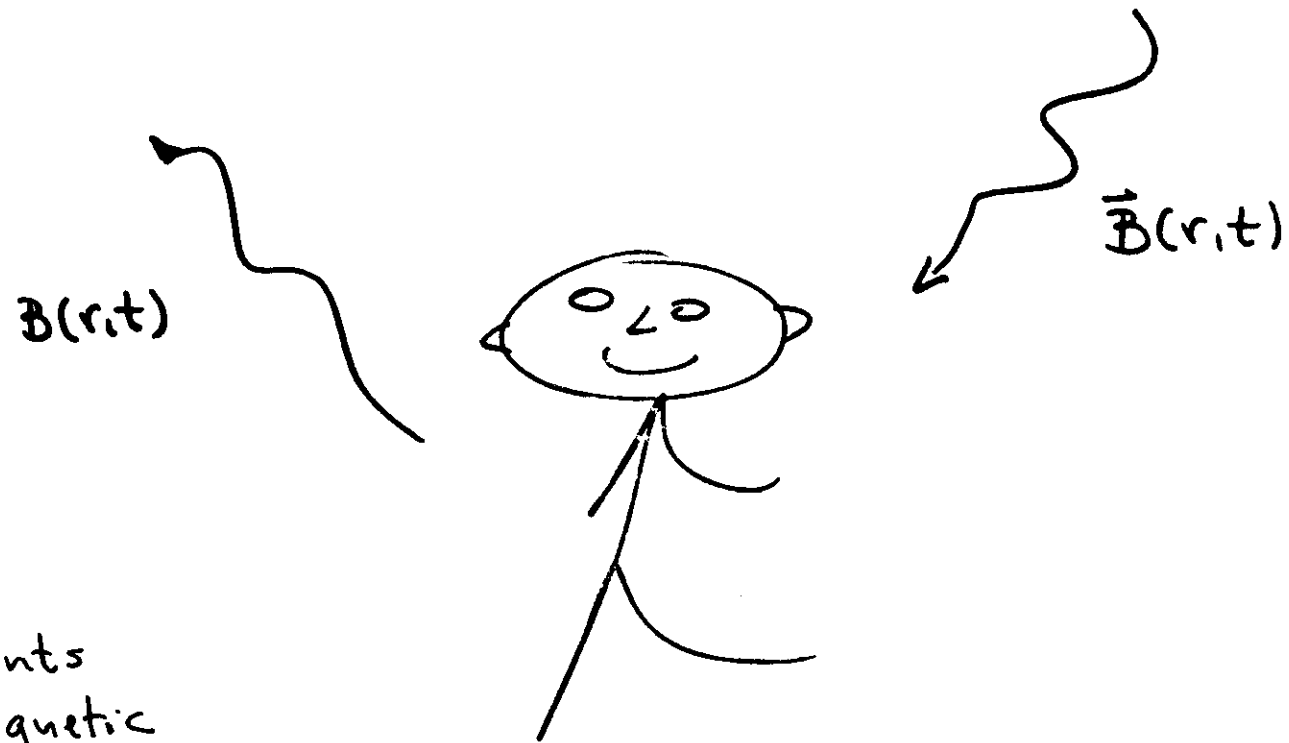
# Biomagnetism $\neq$ Magnetobiology

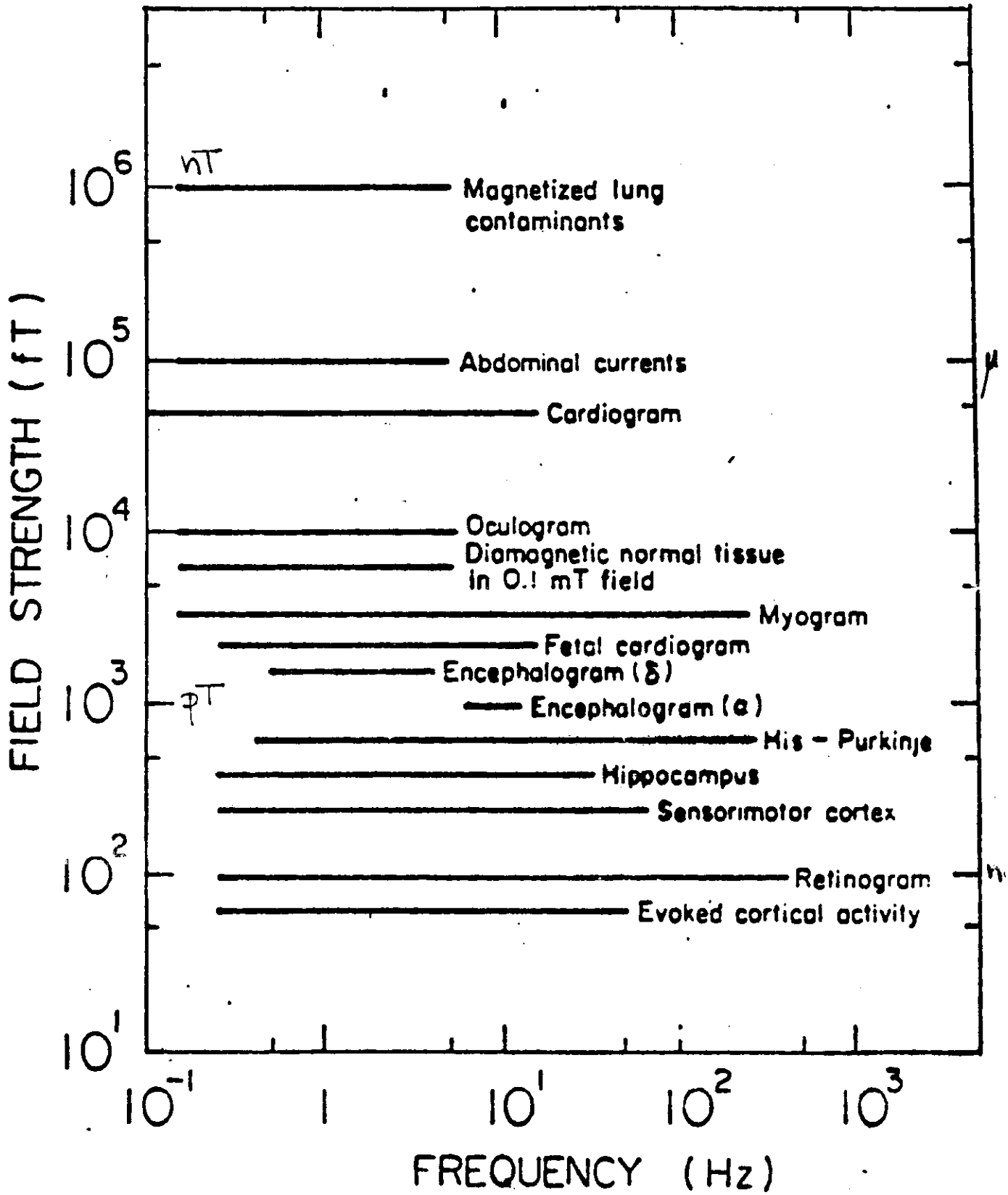



- electric currents
- dia or paramagnetic constituents of the body
- ferromagnetic contaminants of the body

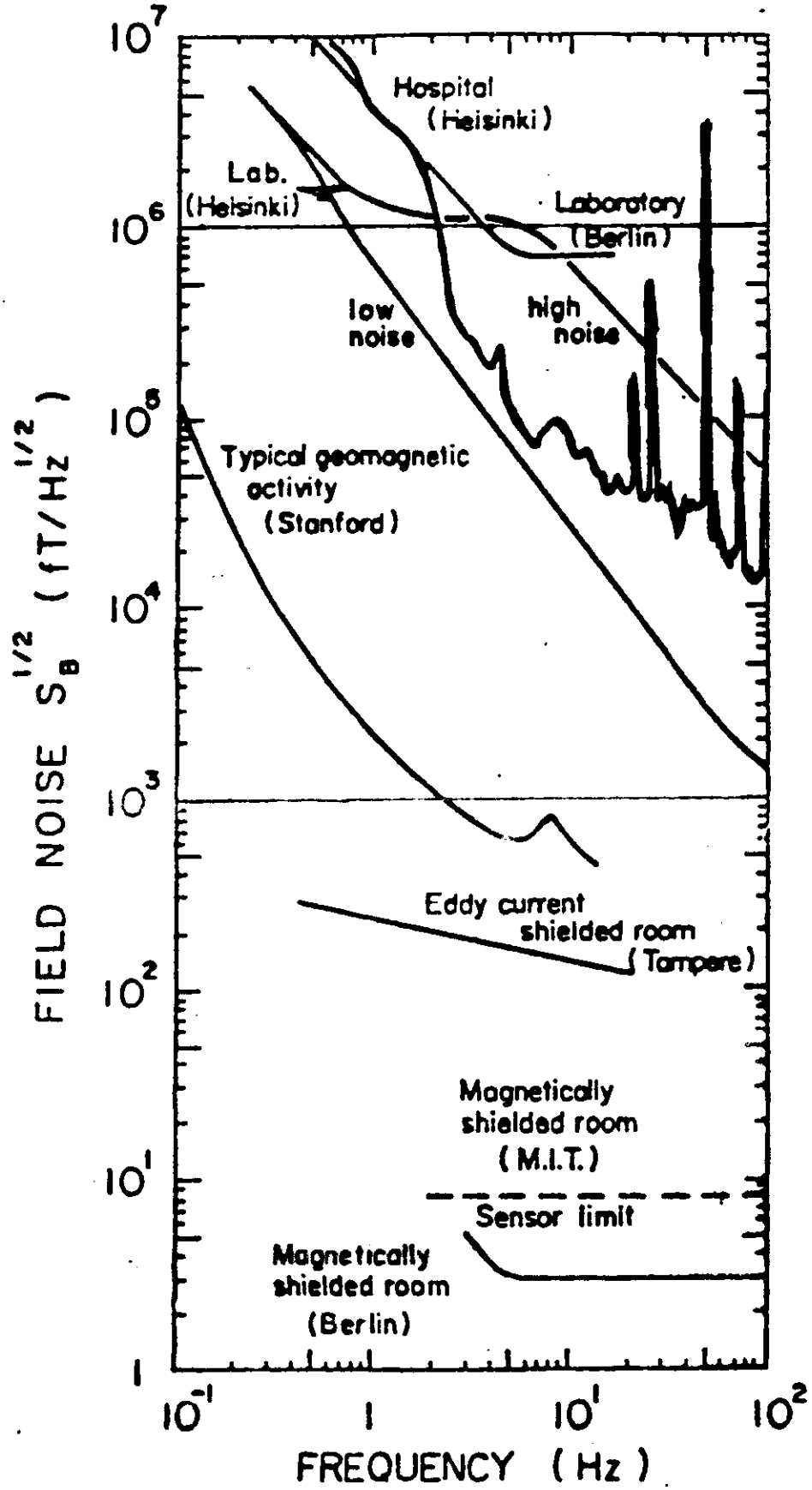
~50fT ⟷ 1 nT

molecular or cellular effects ⟷ behavior & performance

various biomagnetic fields.

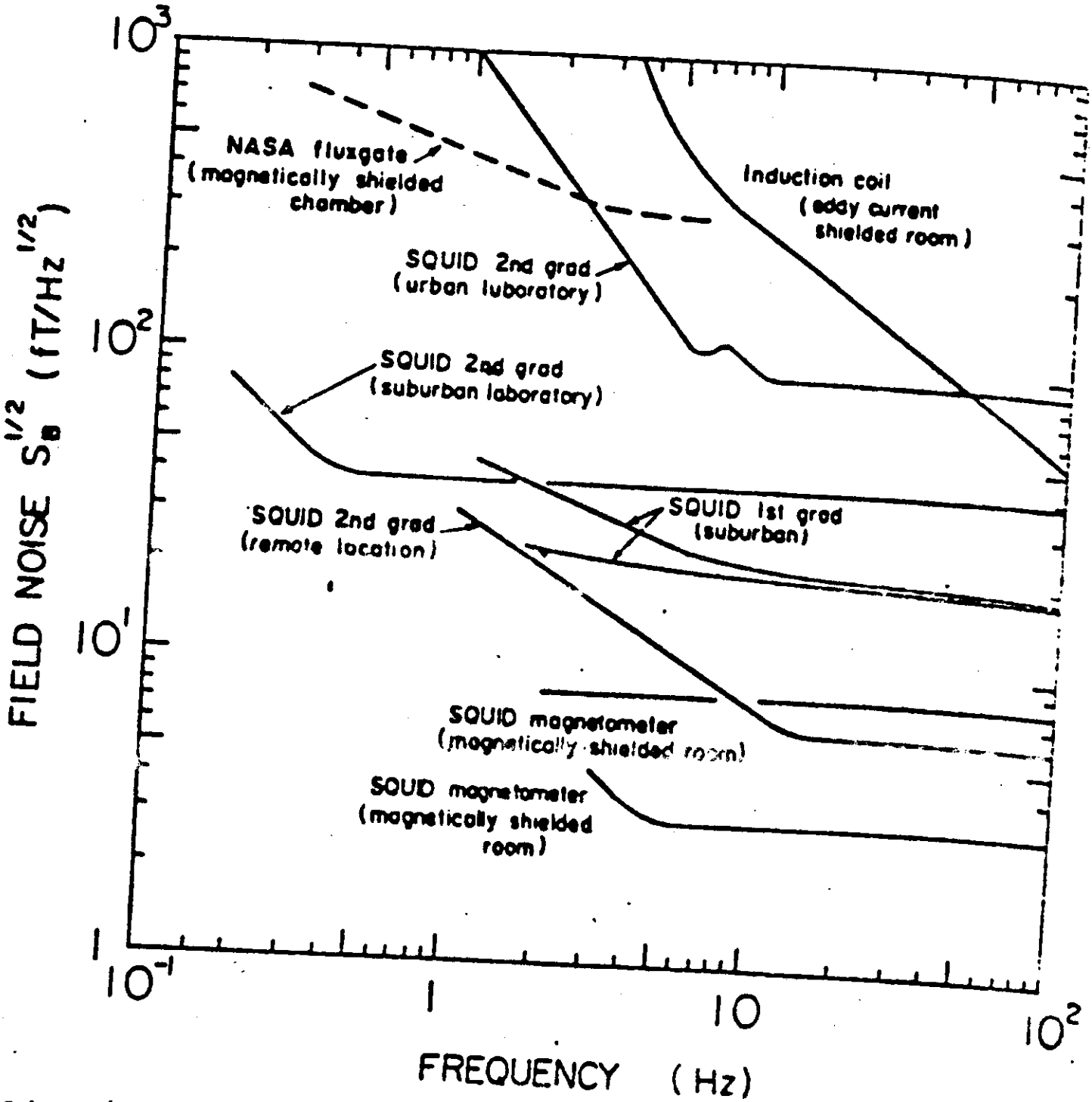



$1fT = 10^{-15}T$ $\quad 1T = 10^4 G$ $\quad B_T = 0.5 G = 50\mu T$




Field noise spectra in various environments

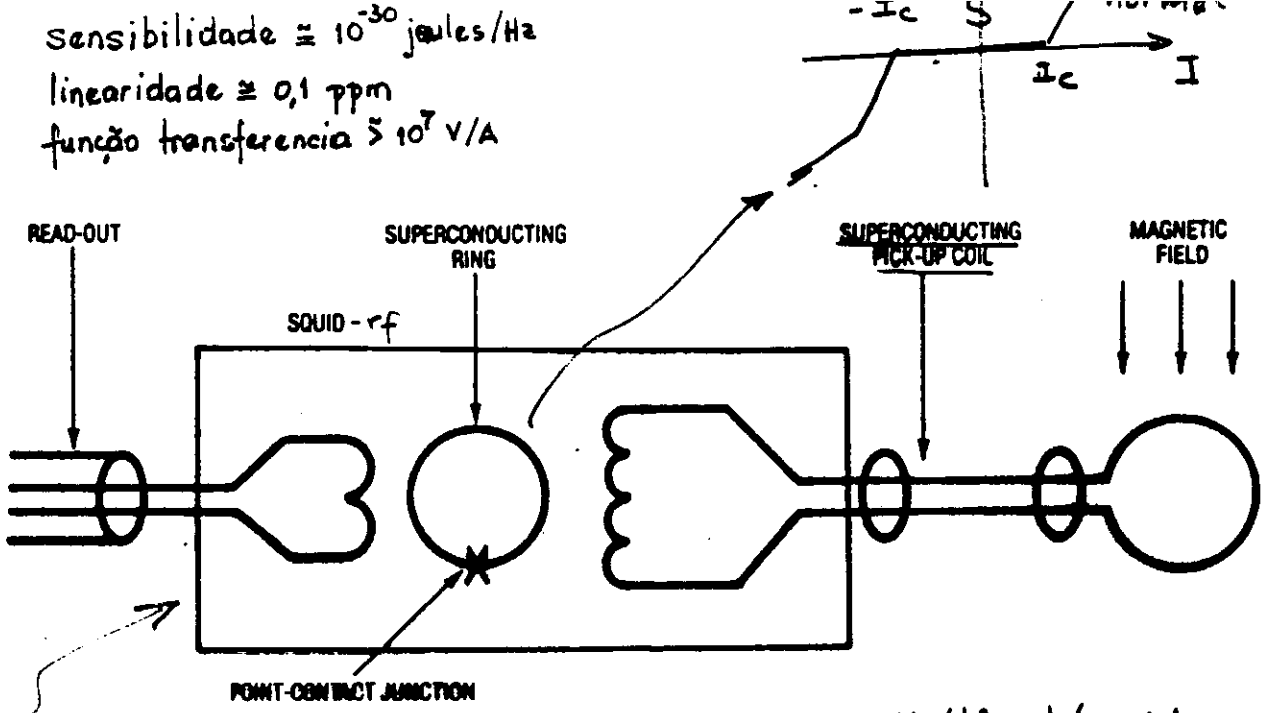
detectors




fluxgate = magnetômetro de saturação de fluxo

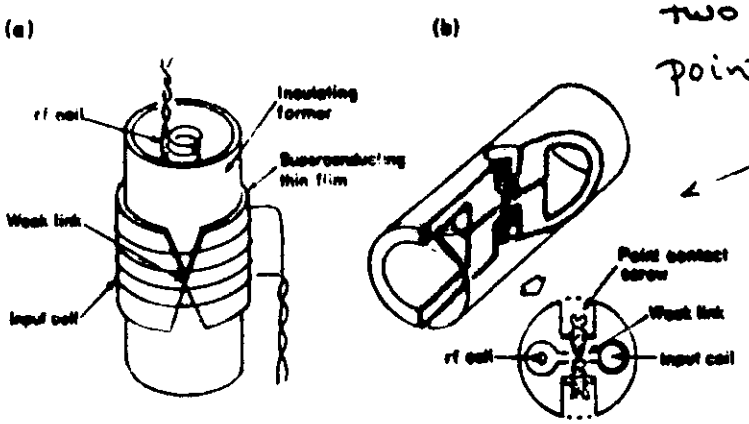
SQUID = SUperconducting QUantum Interference Device

sensibilidade $\cong 10^{-30}$ joules/Hz
linearidade $\cong$ 0,1 ppm
função transferencia $\gtrsim 10^7$ V/A

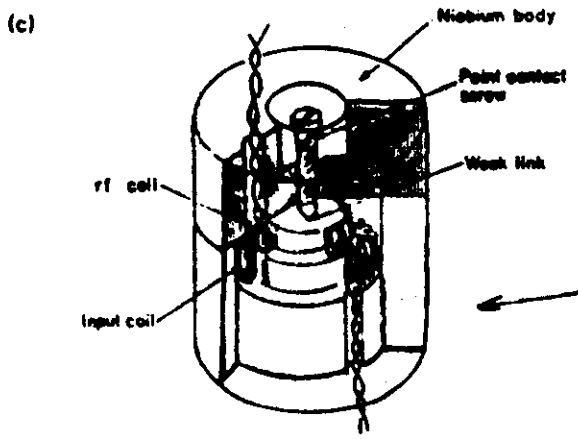



mplificador Paramétrico a T = 4.2K  Hélio Líquido ..

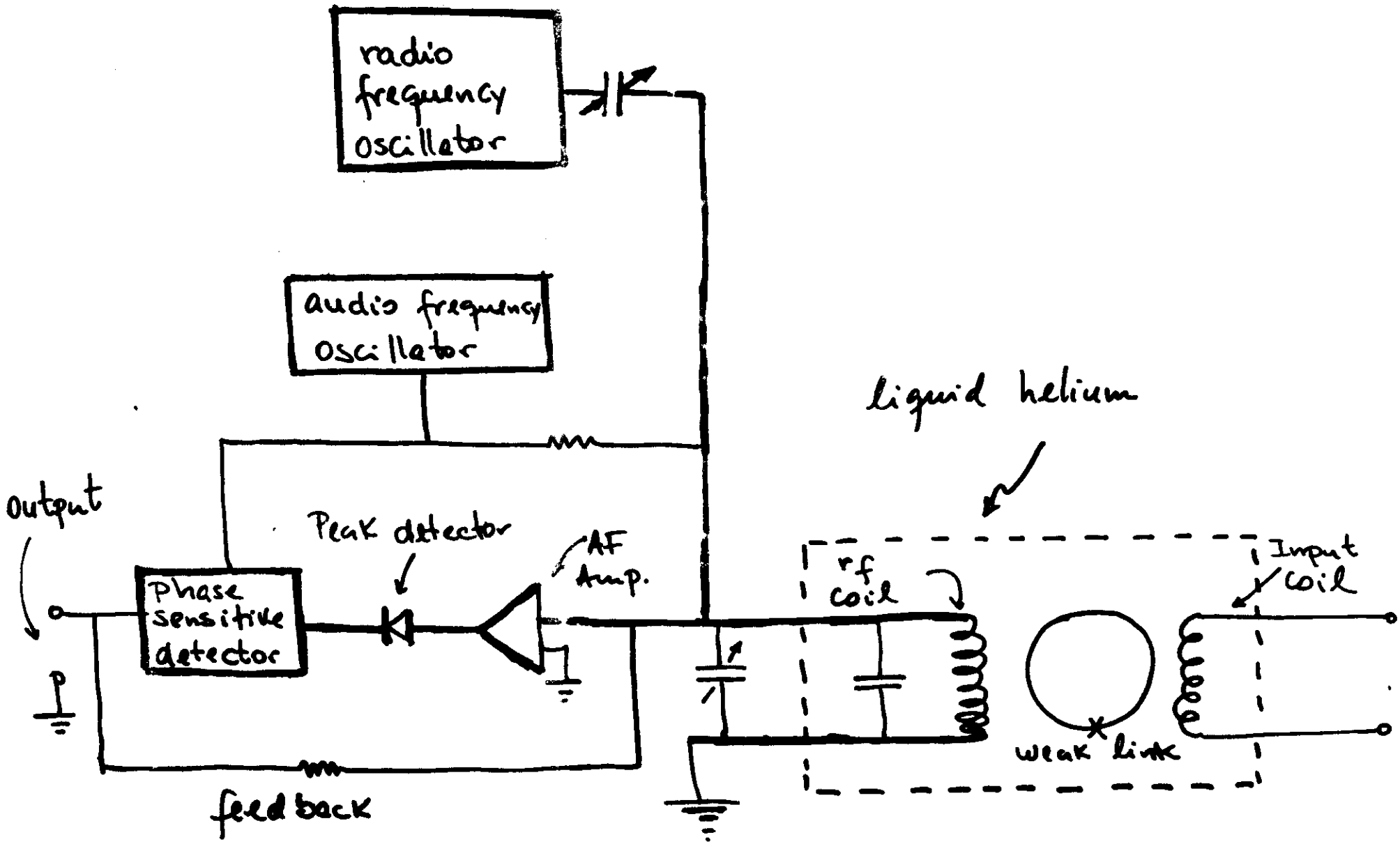
thin film



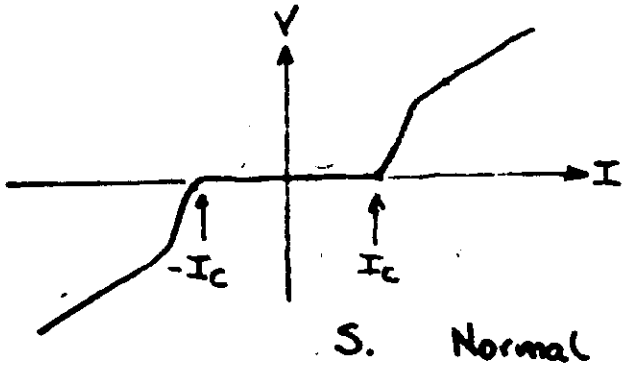

two hole point contact



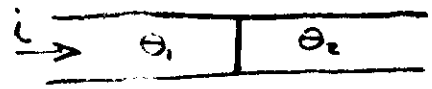

toroidal Point contact


radio frequency oscillator
audio frequency oscillator
liquid helium
output
Peak detector
AF Amp.
Phase sensitive detector
rf coil
Input coil
weak link
feedback

# Equações de Josephson




S. Normal




$\phi = \theta_2 - \theta_1$ = ≠ fase atrav da junção

$\phi = \frac{2}{\hbar} \oint \vec{A} \cdot d\vec{s} = \frac{\Phi}{\hbar}$ (fluxo

$$I_j = I_c \sin\phi$$

$$V_j = \frac{\hbar}{2e}\frac{d\phi}{dt} = \frac{\Phi_0}{2\pi}\frac{d\phi}{dt}$$

$$V_j = \frac{\Phi_0 \sec\phi}{2\pi I_c}\frac{dI_j}{dt}$$

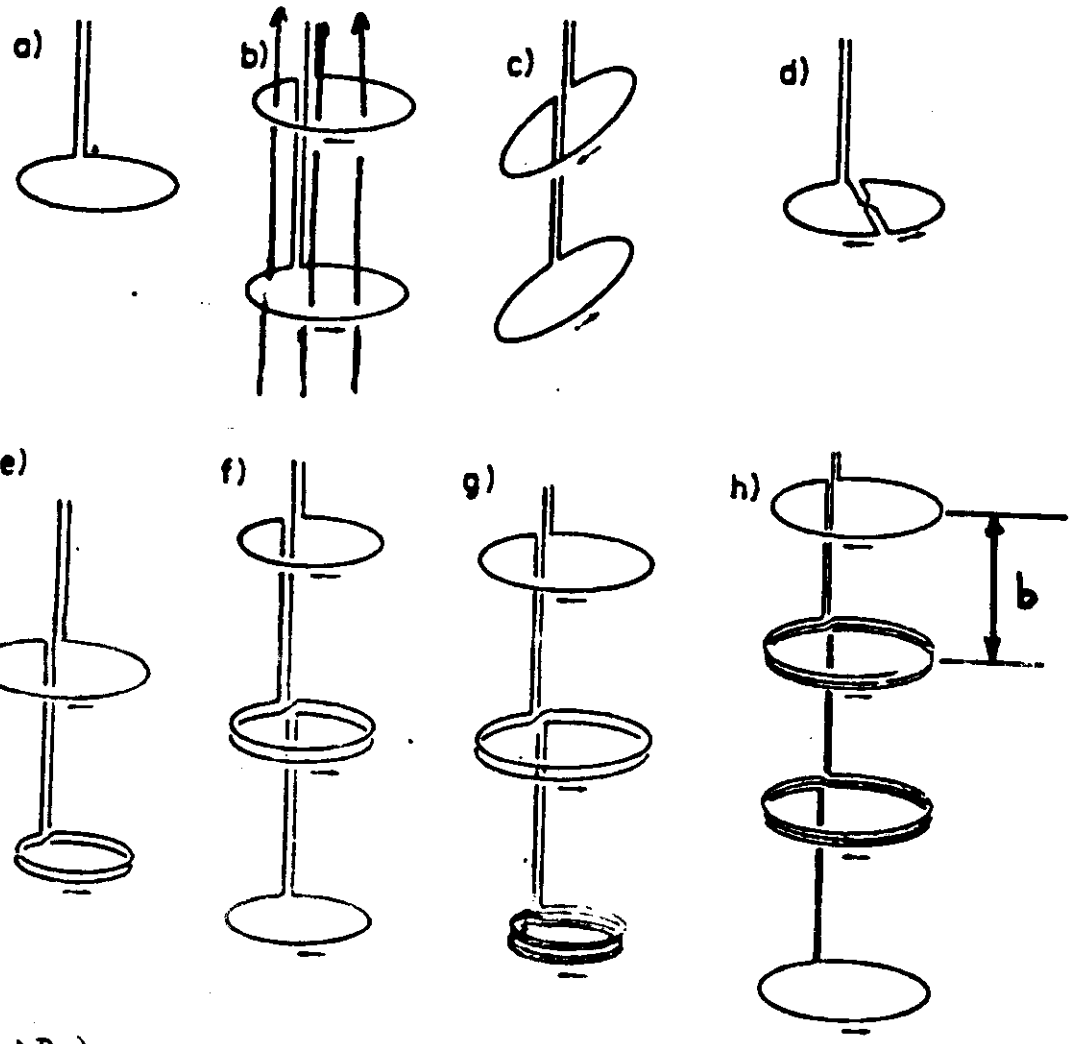
$$= L_j \frac{dI_j}{dt}$$

$$\Phi_0 = 2.07 \cdot 10^{-15}\ \text{wb} = \frac{1}{483\ \text{MHz}/\mu\text{v}}$$

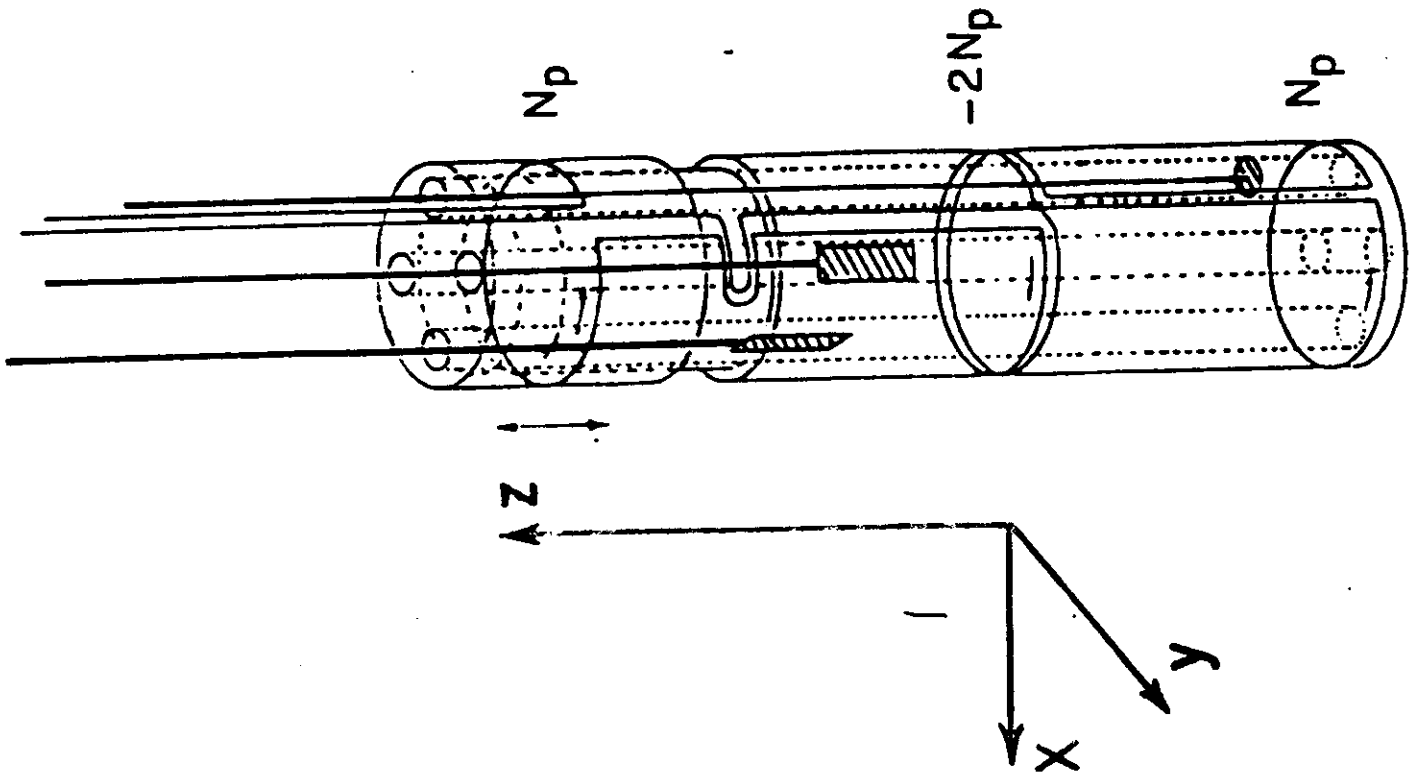
Medida Diferencial – { O sinal é localizado
O ruído é ~ homogeneo no espaço

$3+\frac{\partial B}{\partial z}b+\cdots$

B




$b_{ruido}=\left(\frac{\partial B}{\partial z}\right)b$


$N_p$
$-2N_p$
$N_p$
z
y
x

- SQUIDs are used for detecting the weak magnetic fields produced by the body.

- The environmental noise can be filtered by magnetic shielding or by differential (gradiometers) measurements.

## Applications

- Detection of magnetic fields from the brain
  → magnetoencephalography - MEG

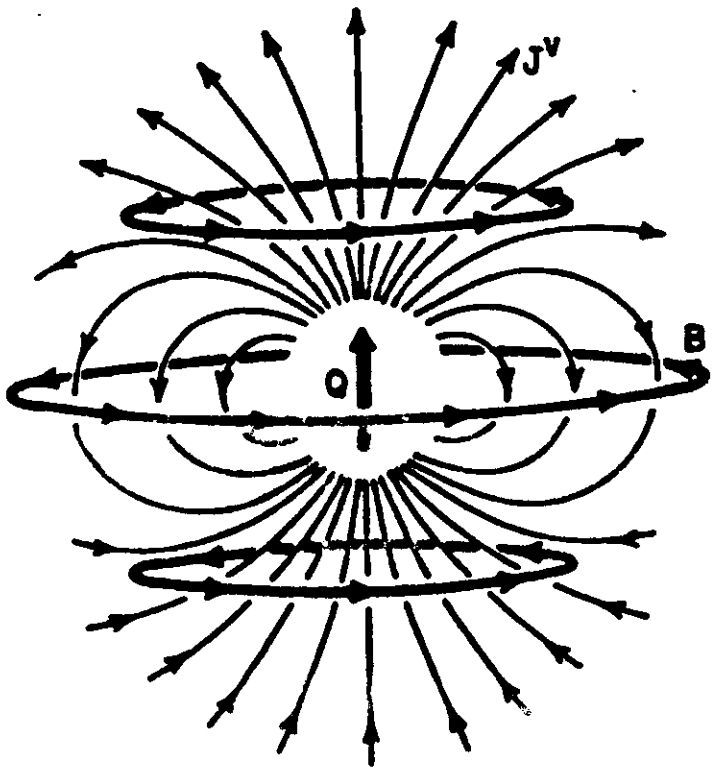
- Detection of iron overload in liver
  ⇒ biosusceptometry

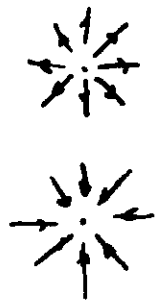
- Detection of magnetic fields from isolated organs axons or bundle of nerves ....

- Correntes Cerebrais
  - impostas (ativas) ⟶ (MEG)
  - Volumétricas (passivas) ⟶ (EEG)

Q will model the impressed current

$J^v$ will model de volume tric current

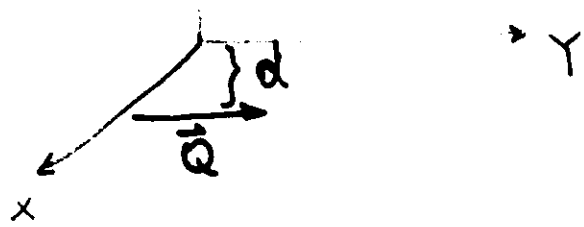


$$d\vec{B} = \frac{\mu_0}{4\pi r^3} \vec{J} \times \vec{r}\, d^3r$$

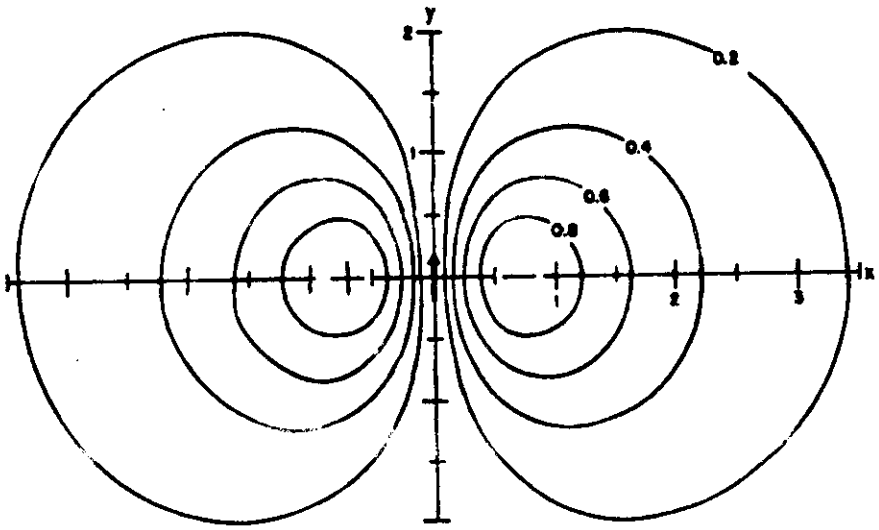
$$B = \frac{\mu_0 Q \operatorname{sen}\theta}{4\pi r^2} \quad \text{onde} \quad Q = \int_{Vol.} \vec{J}\cdot\vec{n}\, d^3r = \text{dipolo de corrente}$$

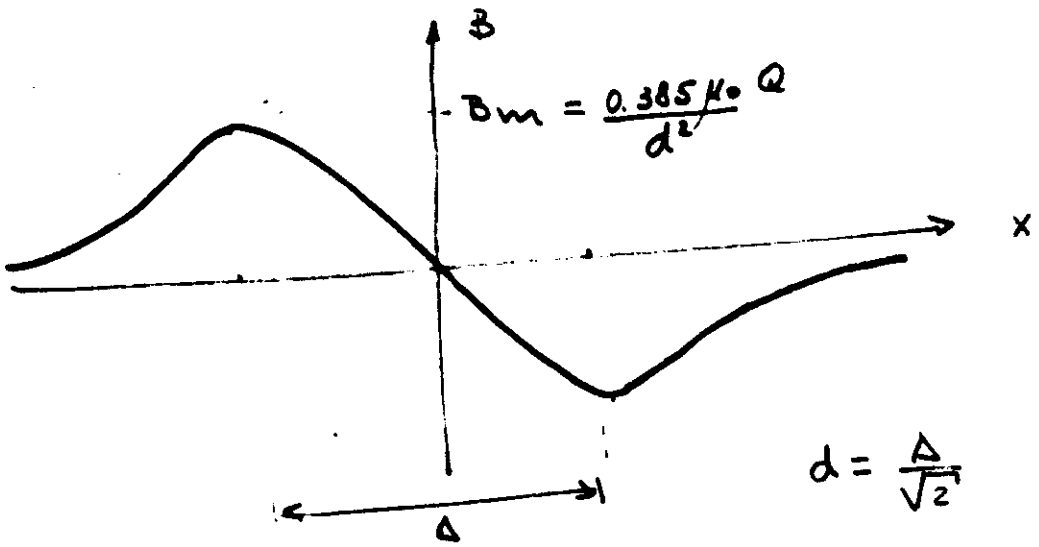
$$Q \simeq i\,\Delta l = \text{Current dipole}$$




$$B_z = \frac{\mu_0 Q}{4\pi d^2} \quad \frac{X}{(1+x^2+y^2)^{3/2}}$$

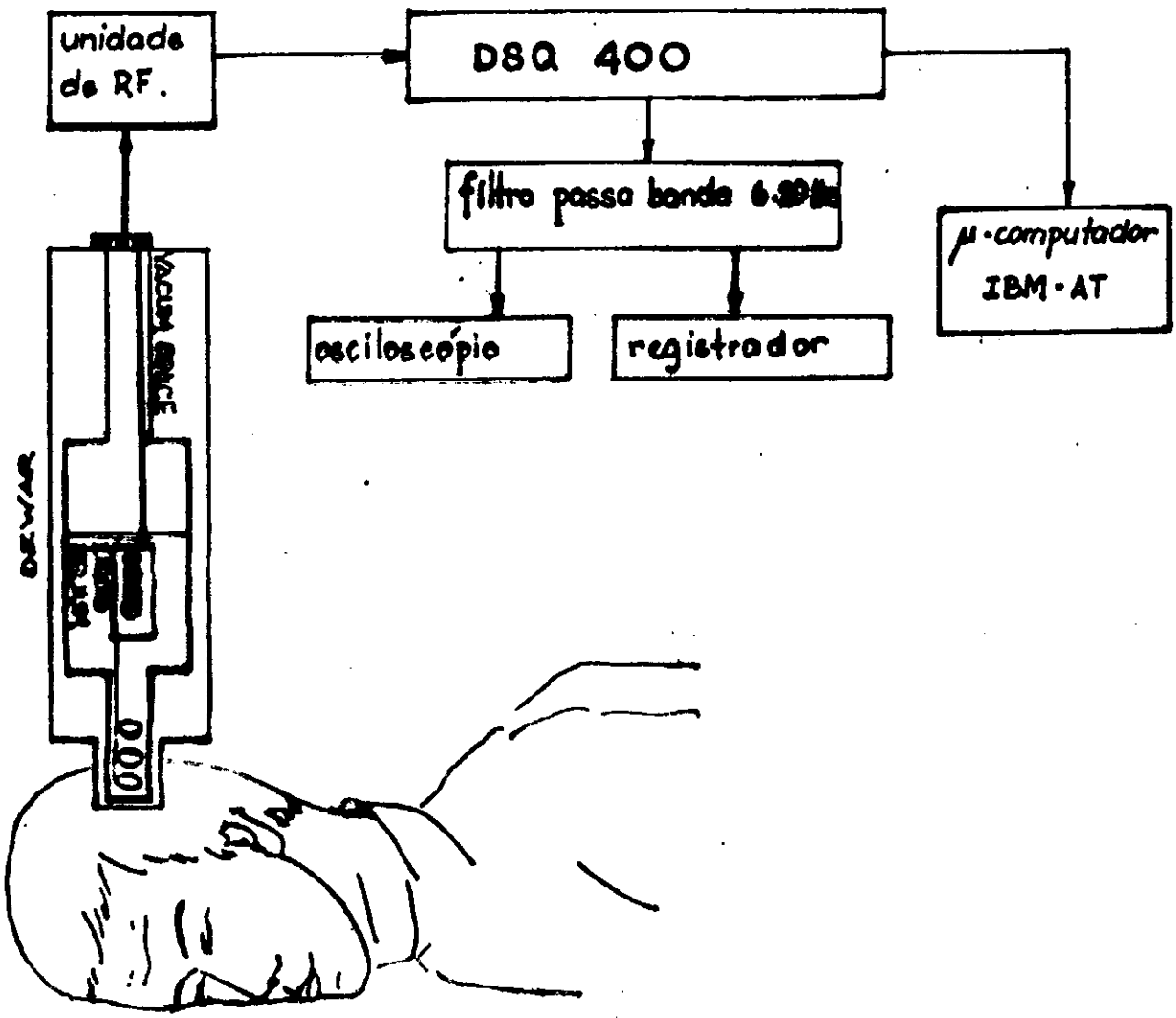
(** estão expressos em unidades de d)




$$d = \frac{\Delta}{\sqrt{2}}$$

Sistema Monocanal

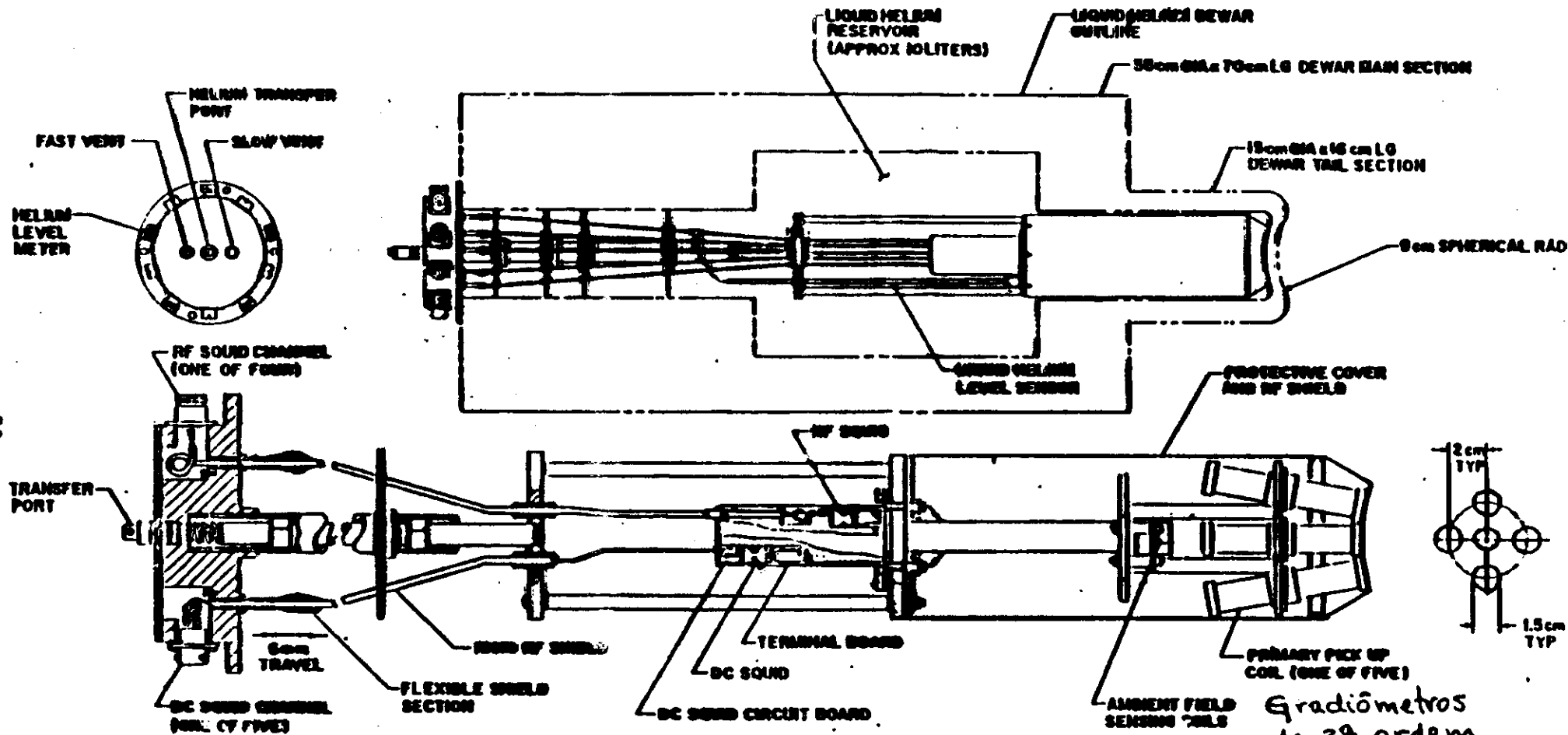



1- Grade de pontos para medida de $B_n$ (~30pto

2- Medida serial → a fonte é estacionária

3- Tempo envolvido ~ 3 hs.

Sistema 5 canais SII com balanço eletrônico




Gradiômetros de 2ª ordem

20

slides

Sistema 7 canais

Jukka Knuutila et. al Rev. Sci Instrum. 58(11):2145-56, nov. 1987

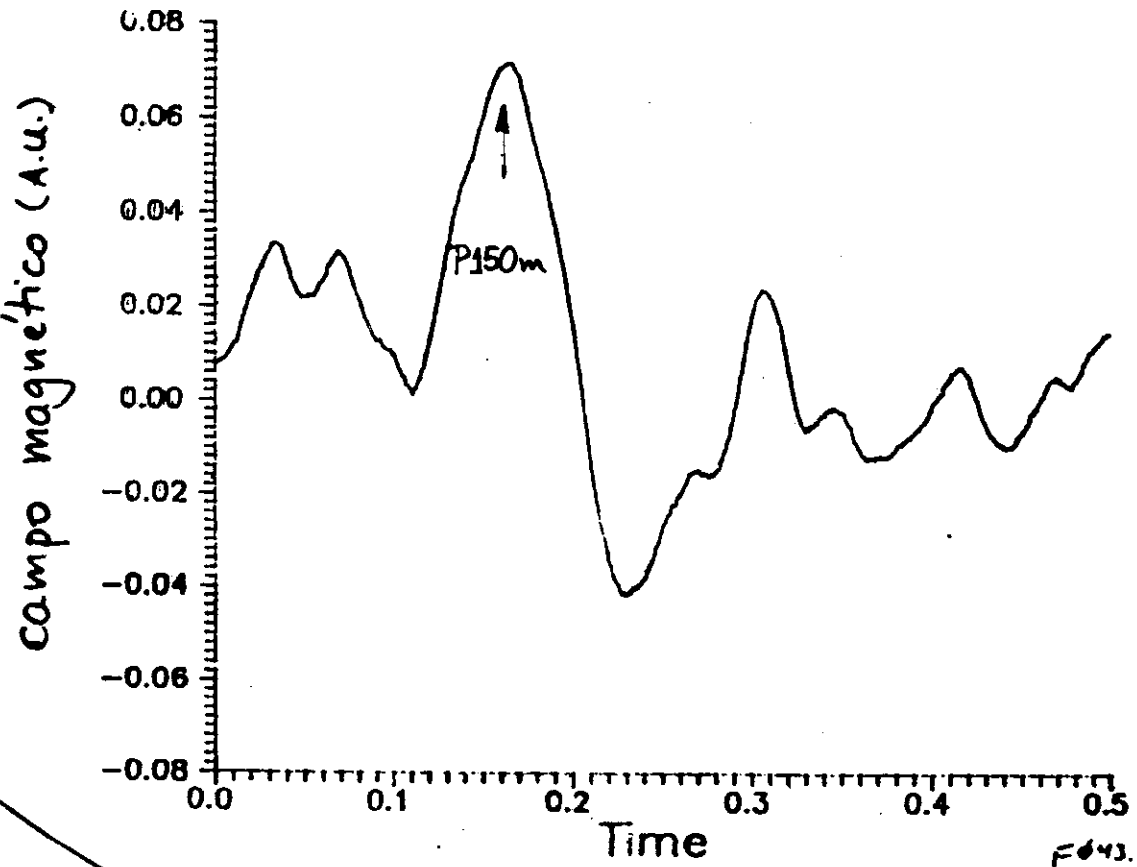
ritmo α

## Campos Evocados Magneticos (CEM)

Onde ?

Quando ?

Quanto ?

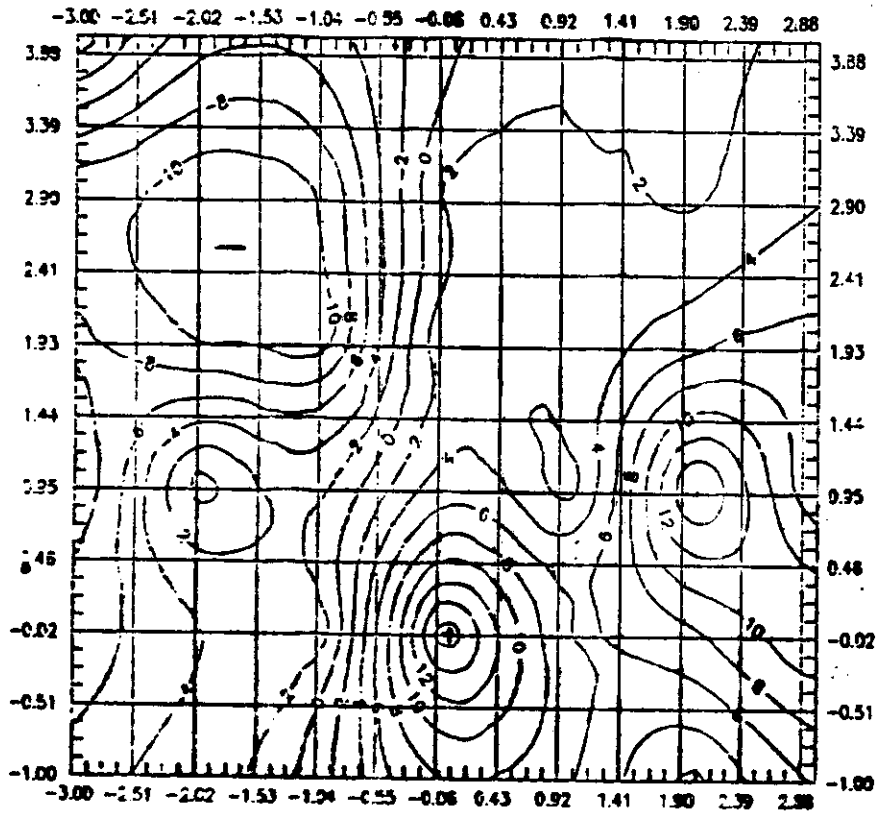



Estímulo: Do
choque elétri co
dedo indicador
1δ e C

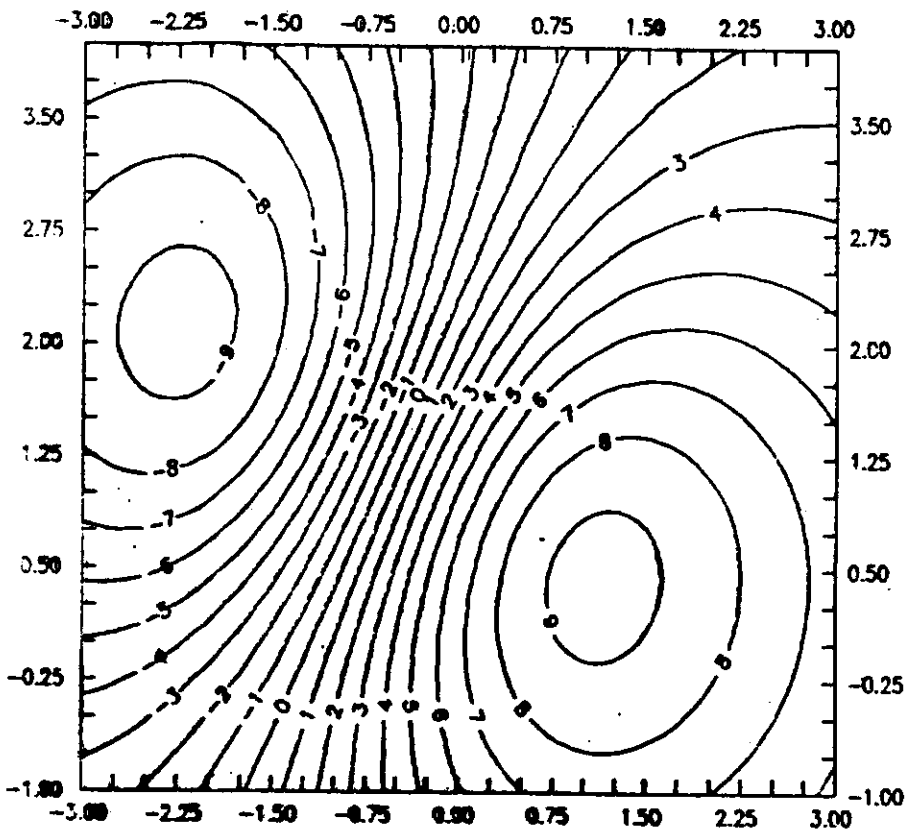
Medida: Bn, m
dia 100 estímul
contralateral

Protocolo: norm
dor sobre dor, d
etc...

EVOKED FIELD OF 150 MS PEAK



FIELD GENERATED BY BEST FIT DIPOLE



T4 is location 0,0; each unit 2 cm.

Vol 24:233-256 (1985)

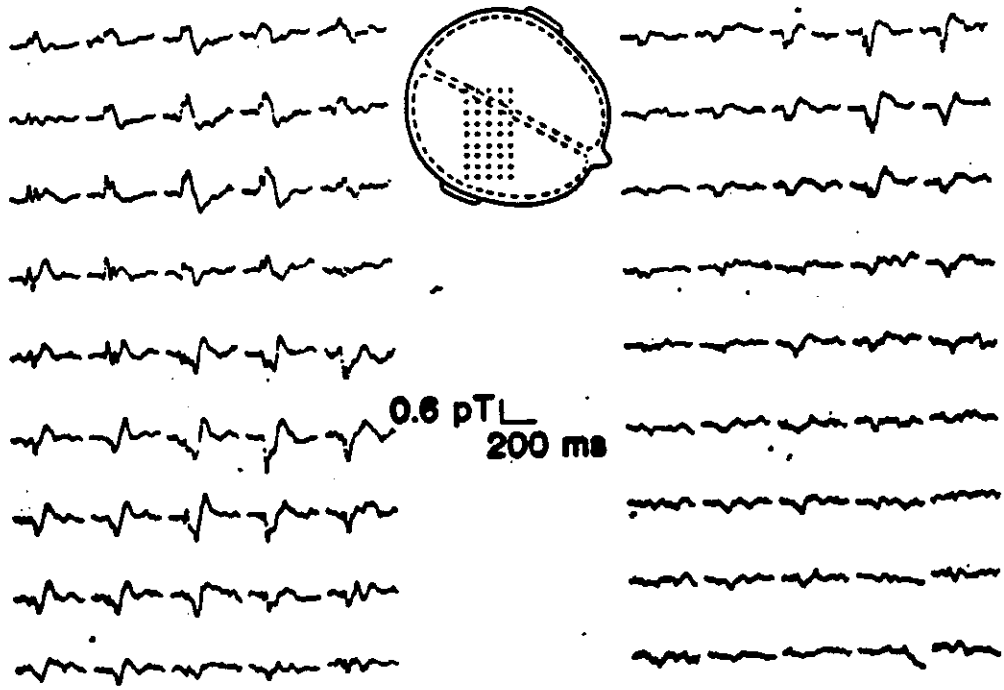



FIG. 6. Magnetic responses to alternate ipsi- and contralateral median nerve stimulations in one subject. The distance between the adjacent measurement points is 2 cm. The passband is 0.5–40 Hz, and about 90 responses were averaged. Upward deflection indicates flux out of the skull. From Hari *et al.* (1984a).

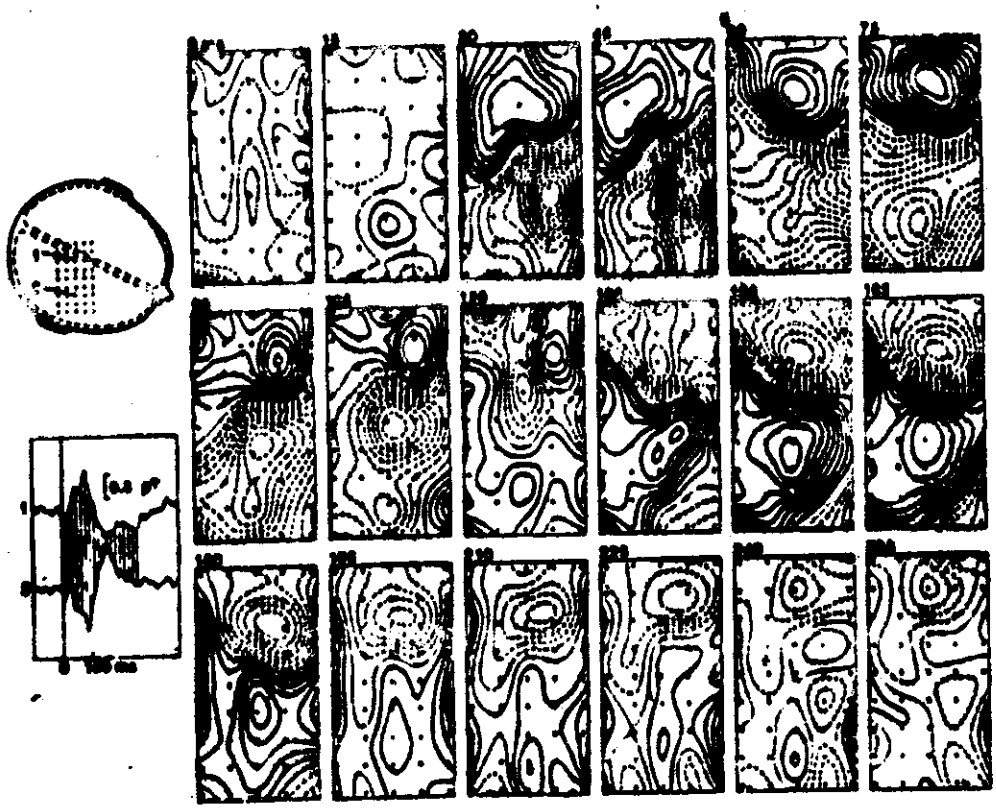
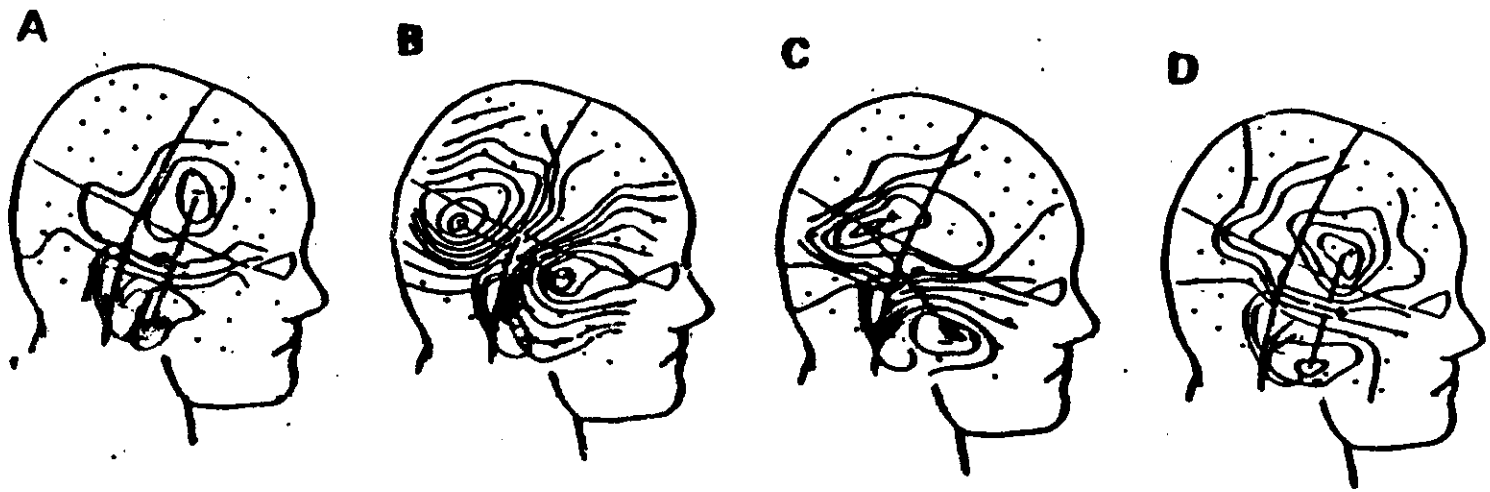


FIG. 7. Isocontour maps for responses elicited by contralateral median nerve stimulation. Continuous lines indicate flux out of the skull and dashed lines flux into the skull. The isofield curves are separated by 50 fT. The grid constant is 2 cm. From Hari *et al.* (1984b).

Evolução de uma sequencia de descargas entre duas fontes deduzidas a partir de um complexo epileptico "intericta"

Epilepsy--




A - Descarga inicial
B - C - 16 ms depois do início. uma segunda fonte aparece (lateral poster
D - A sequencia termina com a descarga da fonte inicial c/ pol. inverti

Barth et al. Science 223, 293 (1984)

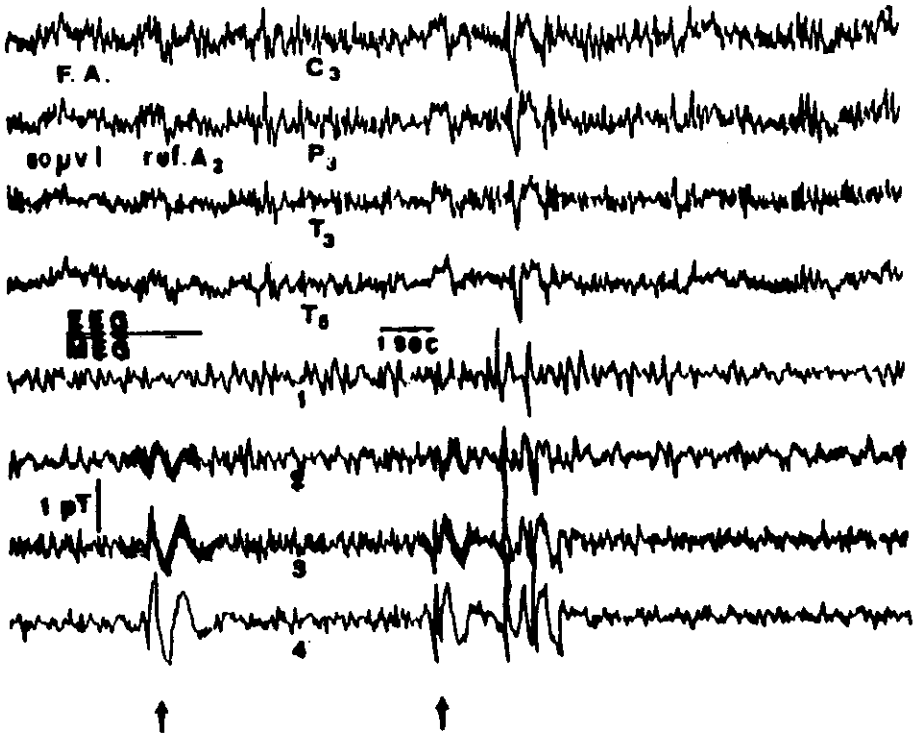
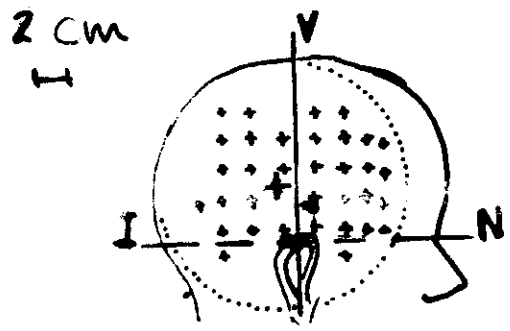
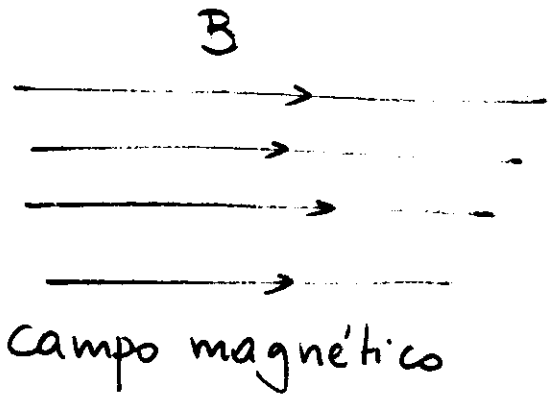



Fig. 6. Simultaneous EEG (upper 4 traces) and MEG (lower 4 traces) as recorded from subject FA at the midpoint between T3 and T5. Note the polarity reversal of the pathological complexes identified by the arrows between traces 2, and 3 and 4




Ricci, G.B. et al. - Electroenceph. clin. Neurophysiol. 66: 358-368 (1987)

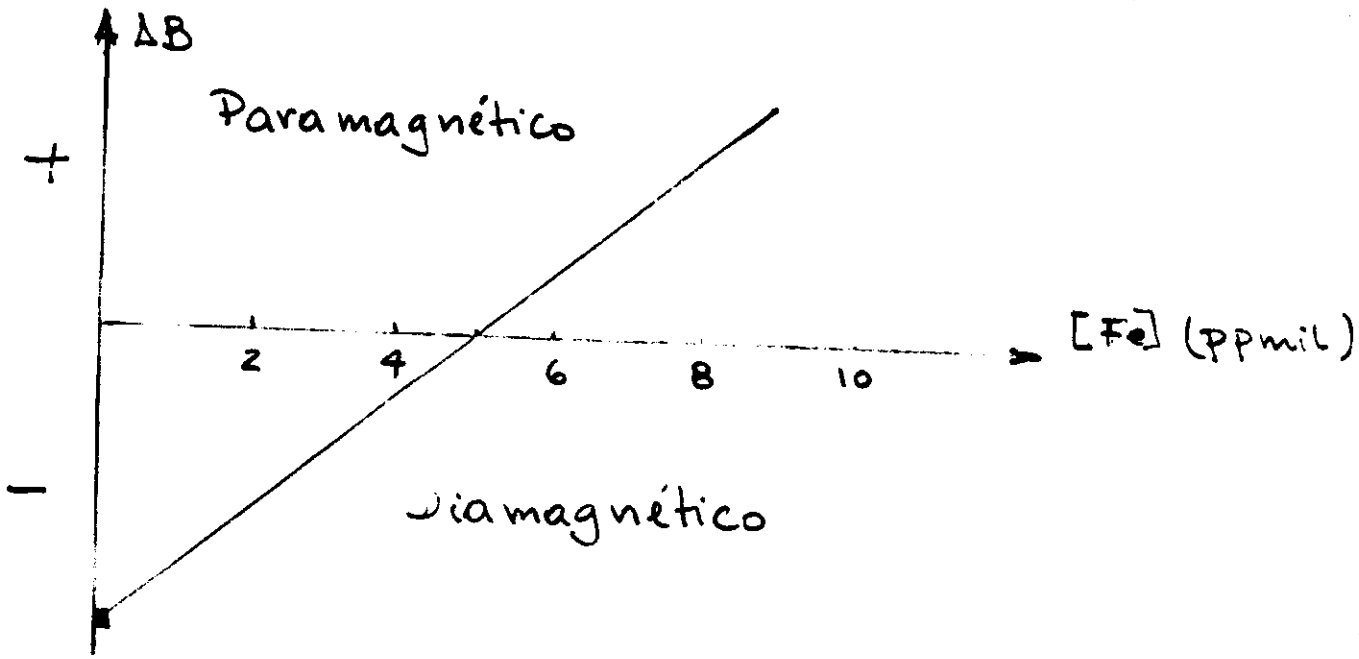
# Biosusceptometria




$B' = B \pm \Delta B$

Amostra

(ferro + tecido → $\chi_{ferro} - \chi_{tec} = \chi^*$)

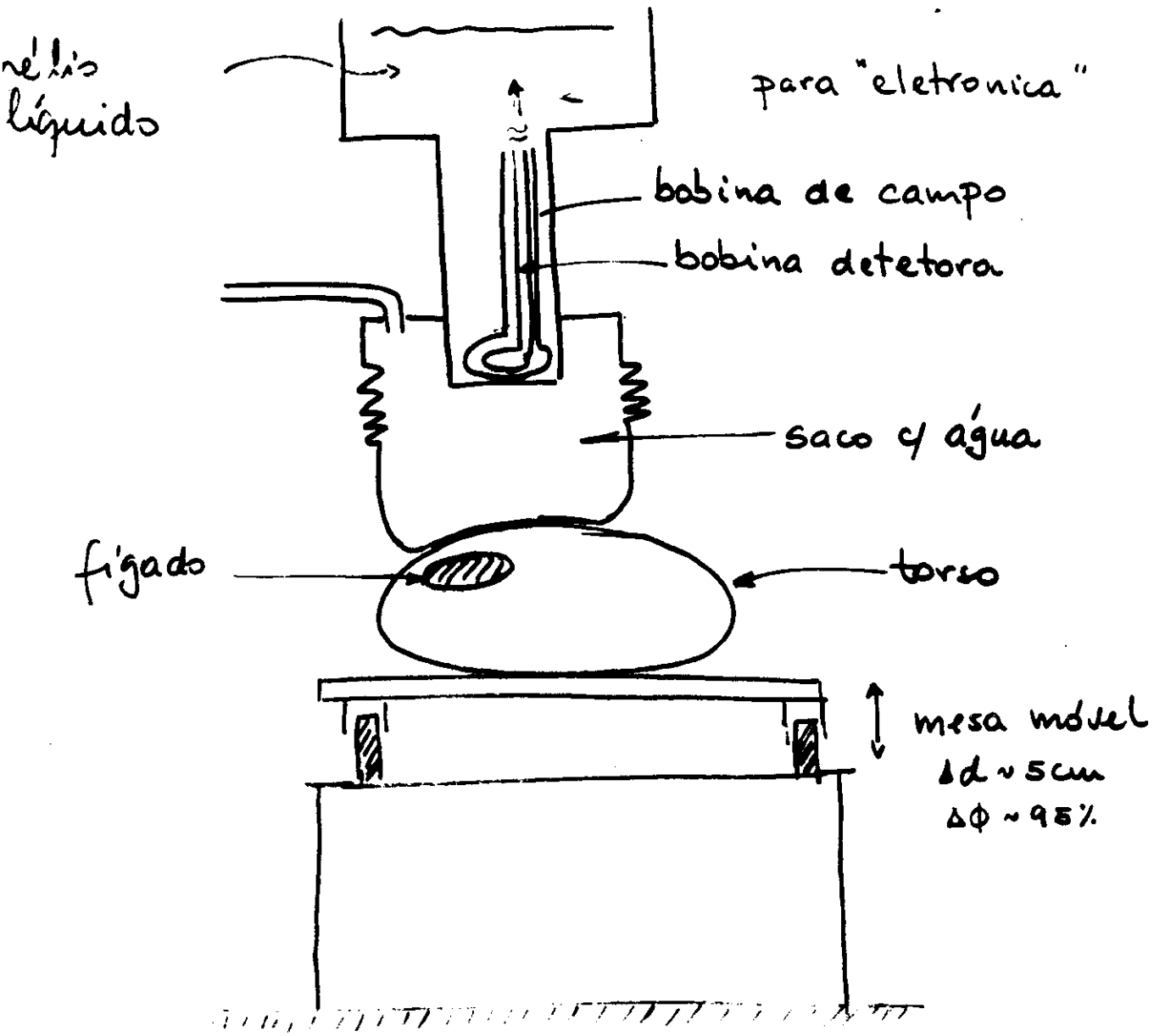



$$\Delta B = \frac{\leq}{3} \chi B$$

Para $B = B_T \rightarrow \Delta B \simeq 400\,pT$

$\chi_{água} = -9 \cdot 10^{-6}$

$\chi_{ferritina} = +\ 10^{-3}$




fluxo magnético medido em função da posição

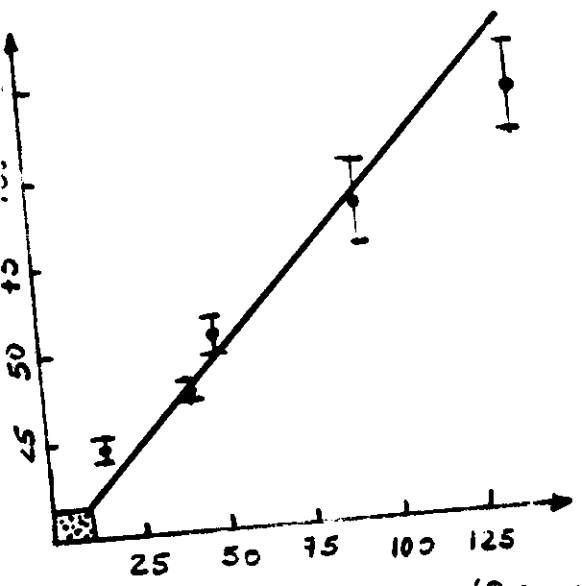
$$\mathcal{E} = A' \exp(\beta'/d) \frac{[\Delta\phi_d - \phi_r]}{\phi_0}$$

$\phi_r$ = fluxo residual

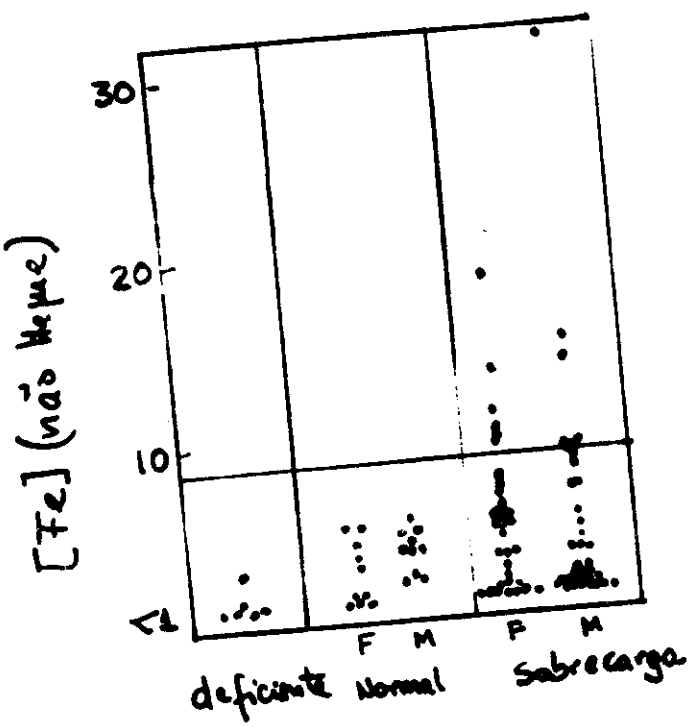
$\phi_0$ = normalização

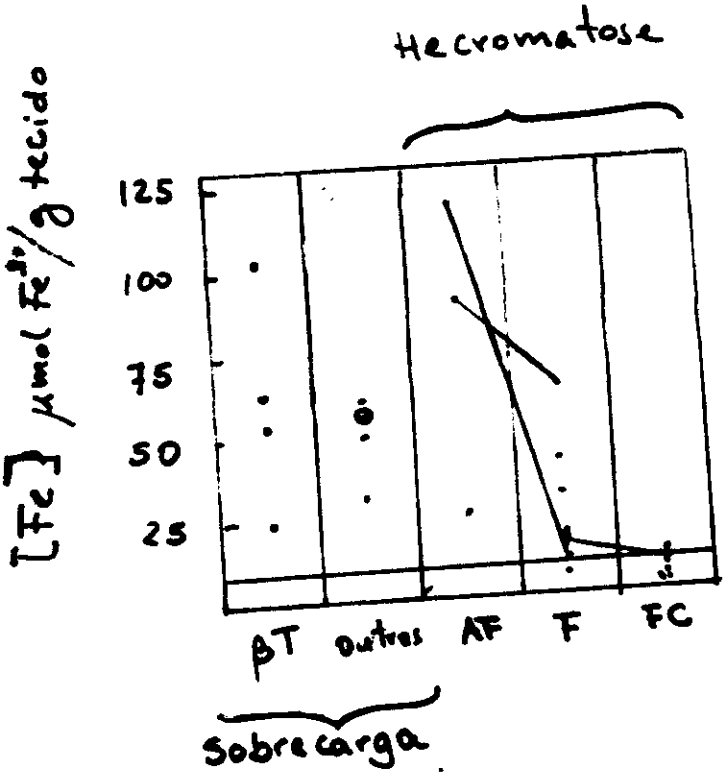
$A' = 1.4 \cdot 10^{-4}$ (decimos) $\quad \beta' = 6 \cdot 10^{-2}$ m

Gary Brittenham et.al
The New Engl. J. Med.
307, 1671-5 (1982)




Medida Química (Biopsia)
(μmol $Fe^{3+}$/g de tecido)




AF - Antes flebotomia
F - terapia de flebotomia
FC - Flebotomia completa

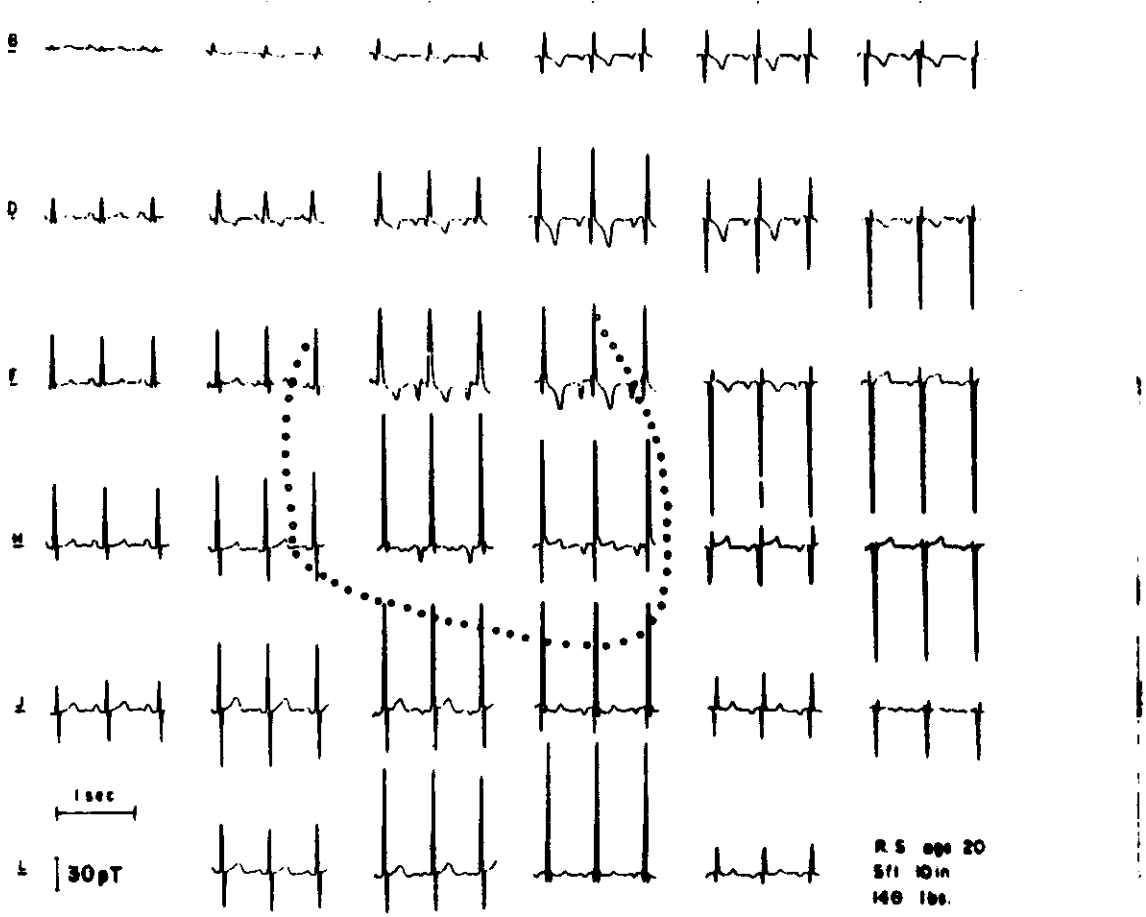



Fig. 9.3.1. An MCG map of the component of the magnetic field perpendicular to the torso surface. The measurement points of the MCGs are separated by 5 cm, with the subject's right side portrayed on the left. (Cohen and MacCaughan 1972b). Upward deflection is field directed into the chest. Am. J. Cardiol. 29: 678 - 685 (1972)

- A medida magnética fornece informações complementares (expansão em multipolos) ao ECG

2- Não existe a necessidade de contatos elétricos → monitoração de pacientes que não podem ter eletrodos ligados ao tórax (queimados)

3- Magnetocardiografia fetal

4- Pletismografia de susceptibilidade magnética

$$\Delta\chi = \chi_{\text{coração}} - \chi_{\text{pulmão}} = -5.6 \cdot 10^{-6}\ (SI/m^3)$$

J.P. Wikswo - Med. Phys. 7(4): 297 - 314 - 1980

5- Medidas "DC"

# References


1 - "Biomagnetism : An Interdisciplinary Approach", Williamson, S.J. et. al (editors) - Plenun Press.

2 - Biomagnetic Instrumentation
Romani, G.L., Williamson, S.J. and Kaufman, L.
R. S. I 53(12): 1815 - 1845 (1982)

3 - Biomagnetism
Williamson, S.J. and Kaufman, L.
J. Mag. Mag. Mat. 22: 129 - 201 (1981)