Sveučilište u Zagrebu
Fakultet elektrotehnike i računarstva

Biomedicinska instrumentacija

Biomedicinska instrumentacija
P10 – Mjerna instrumentacija

za mjerenje električkih i neelektričkih veličina u medicini

Ak.god. 2009./2010.

prof.dr.sc. Ratko Magjarević

Mjerna instrumentacija

- za mjerenje električkih i neelektričkih veličina u medicini- PREGLED
  - nastavak predavanja o primjeni ultrazvuka u medicini – neinvazivno mjerenje brzine protoka krvi
- mjerenje bioelektričkih napona – EKG i EEG
- mjerenje tlaka – invazivno
- mjerenje protoka
  - indukcijska metoda
  - metoda jednokratnog ubrizgavanja sredstva
- mjerenje respiracije
  - spirometar
  - pletizmografija

Profil brzina u krvožilnom sustavu

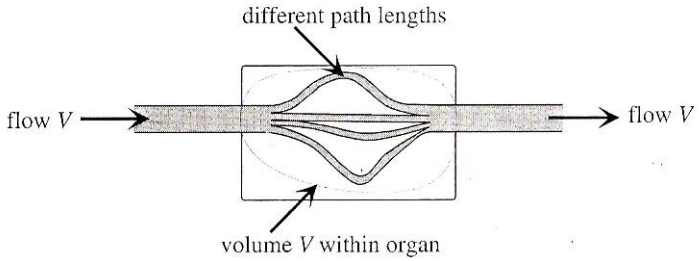
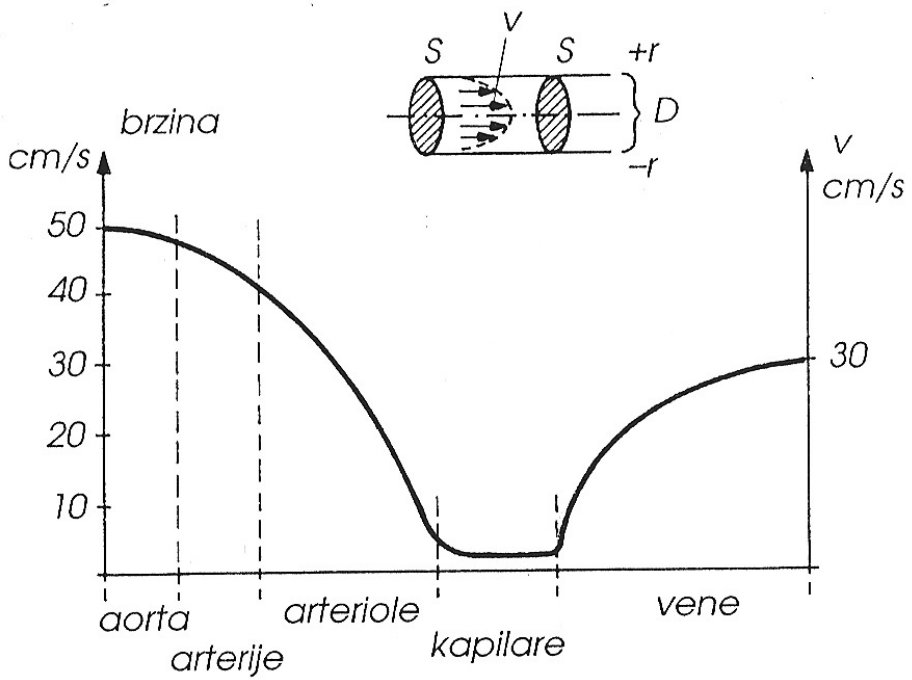


Figure 19.1. *The principle of the indicator dilution method. The indicator is injected on the left and the resulting concentration of indicator is measured on the right.*



UZ metode mjerenja protoka

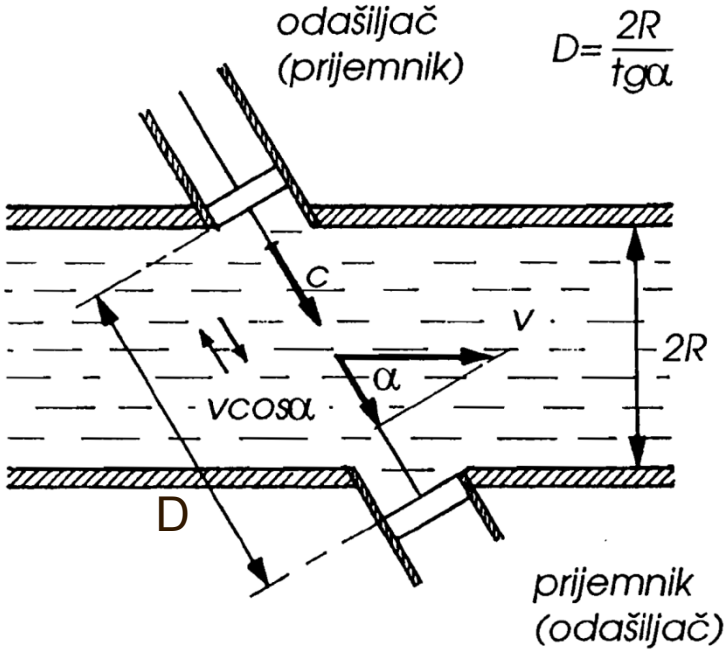
- Mjerenje brzine strujanja krvi temeljena na razlici vremena prolaska

$$t_1 = \frac{D}{c + v \cdot \cos\alpha}$$

$$t_2 = \frac{D}{c - v \cdot \cos\alpha}$$

$$\Delta t = t_1 - t_2 = \frac{2D \cdot v \cdot \cos\alpha}{c^2 - v^2 \cdot \cos^2\alpha}$$

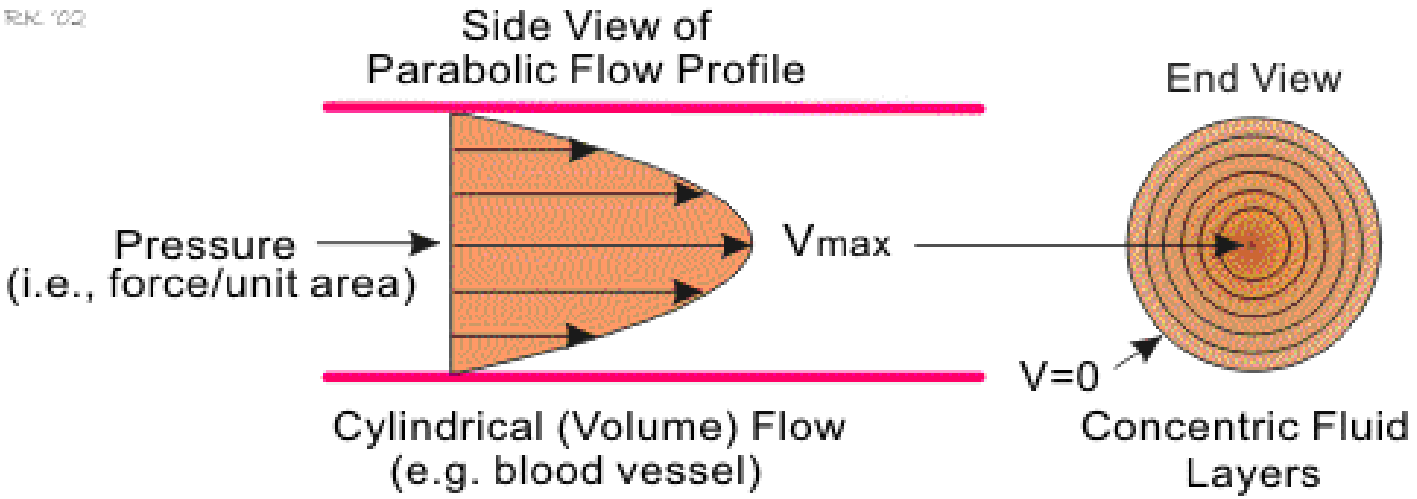
$$\approx \frac{2D \cdot v}{c^2}\cos\alpha \qquad \text{uz } c \gg v$$



gdje je *c* brzina širenja ultrazvuka, *v* brzina protoka tekućine (krvi u žili), a *ti* vrijeme potrebno da ultrazvuk prijeđe put *D* od odašiljača do prijamnika postavljenih na suprotne strane žile promjera *R.* Pri tome vektori brzina ultrazvuka i strujanja krvi zatvaraju kut α.

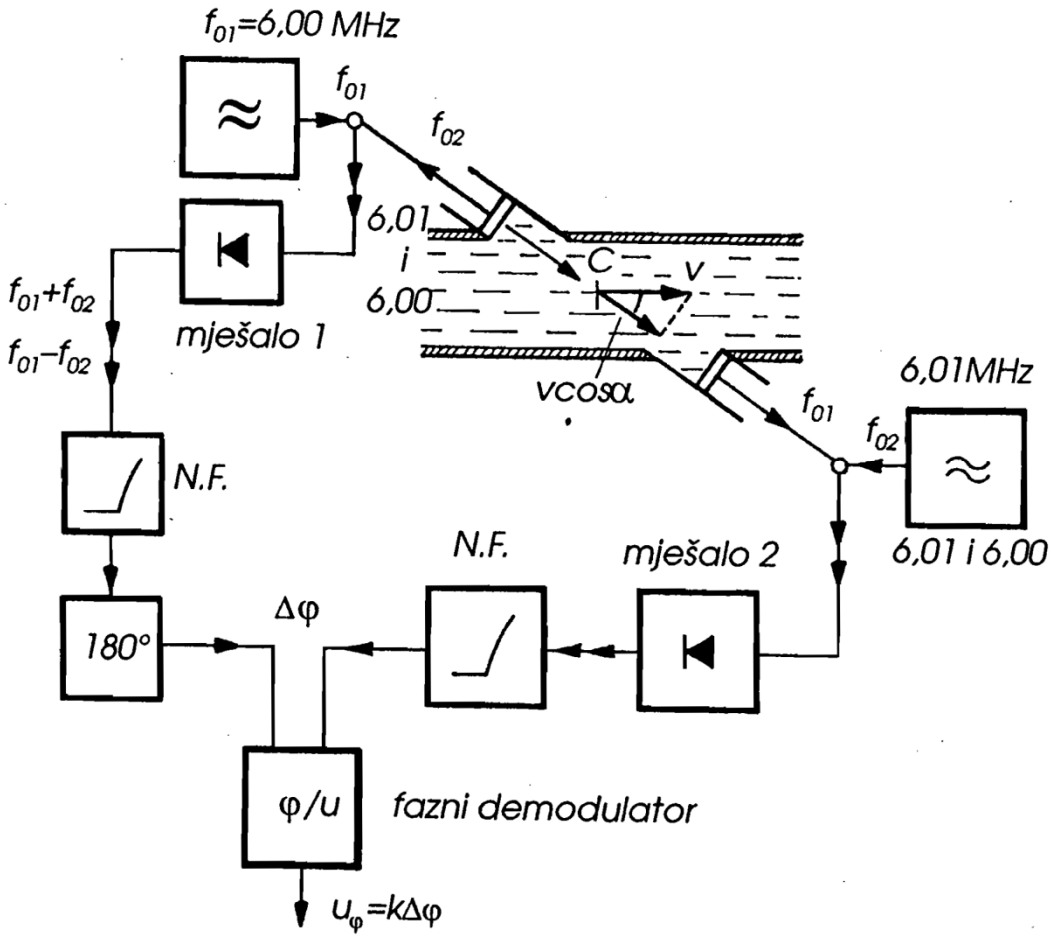
UZ metode mjerenja protoka

- Brzina v je srednja brzina krvi. Naime, krv brzina strujanja krvi nije jednaka u sredini žile i pri rubovima. Govorimo o slojevitom (laminarnom) profilu brzine, koji se opisuje parabolom.



Kont. mjerenje brzine strujanja

- Mjerenje brzine strujanja krvi temeljene na razlici vremena prolaska u kontinuiranom radu



UZ metode mjerenja protoka

- Pri tome se mjerenje razlike u vremenu može svesti na mjerenje razlike u fazi

$$\frac{\Delta\tau}{T} = \frac{\Delta\varphi}{2\pi}$$

$$\Delta\varphi = \frac{4\pi \cdot D \cdot v \cdot f \cdot \cos\alpha}{c^2}$$

$$v = \frac{c^2 \cdot \Delta\varphi}{4\pi \cdot D \cdot f \cdot \cos\alpha}$$

Diskusija

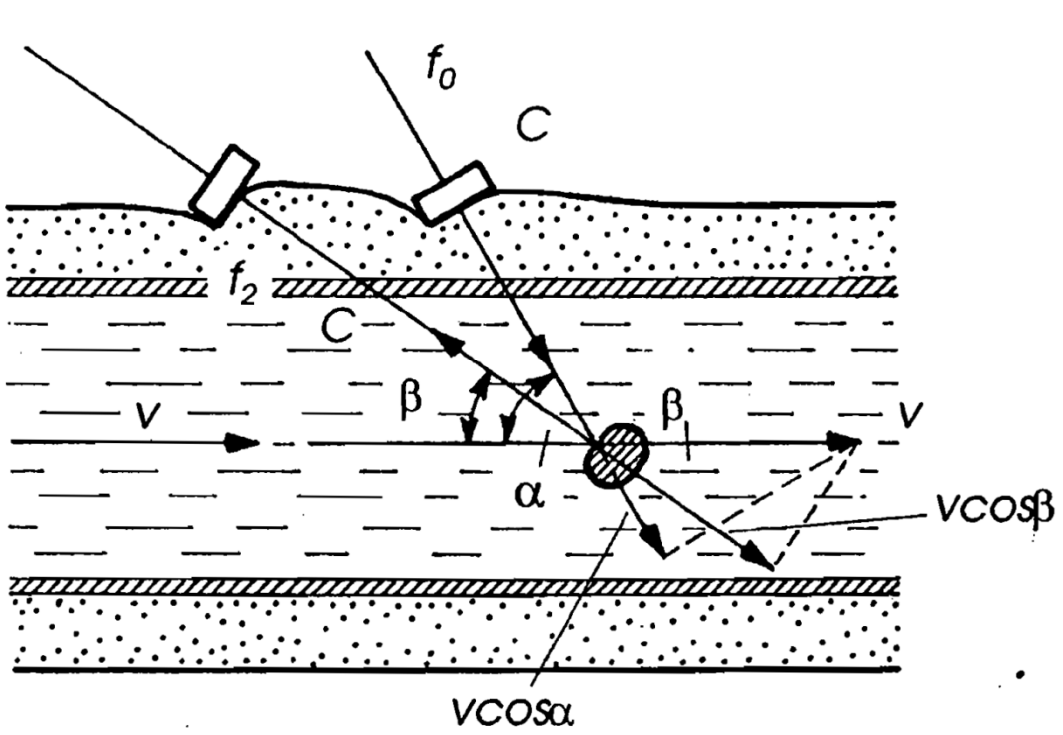
- Koje moguće poteškoće u mjerenju brzine protoka krvi možete uočiti u opisanim metodama?

Mjerenje protoka Dopplerovim efektom

- Mjerenje brzine strujanja krvi temeljene na Dopplerovom efektu

$$f_2 = f_{pr}' \frac{1}{1 + \frac{v}{c}\cos\alpha}$$

$$f_{pr} = f_0\left(1 - \frac{v}{c}\cos\beta\right)$$



Načelo izvedbe uređaja

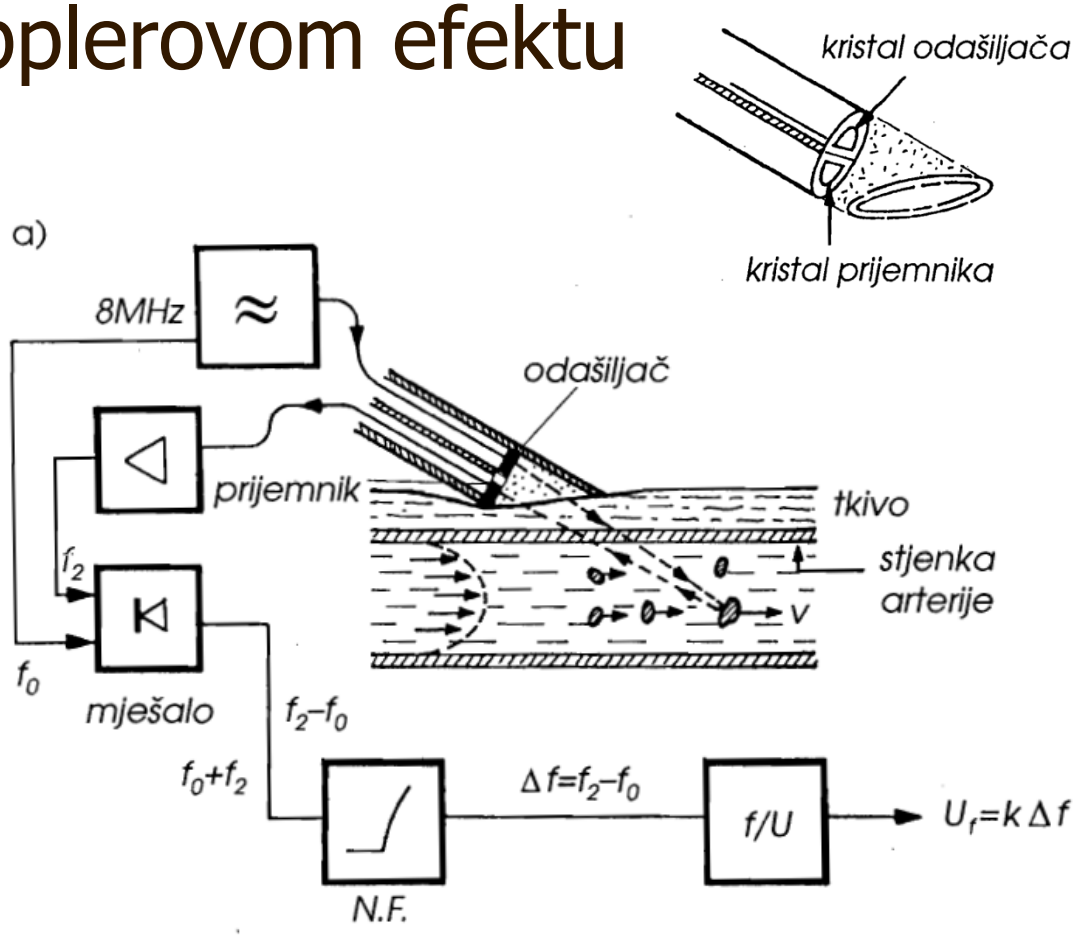
- Izvedba uređaja za mjerenje strujanja krvi temeljene na Dopplerovom efektu

$$f_2 = f_0 \frac{1 - \frac{v}{c}\cos\beta}{1 + \frac{v}{c}\cos\alpha}$$

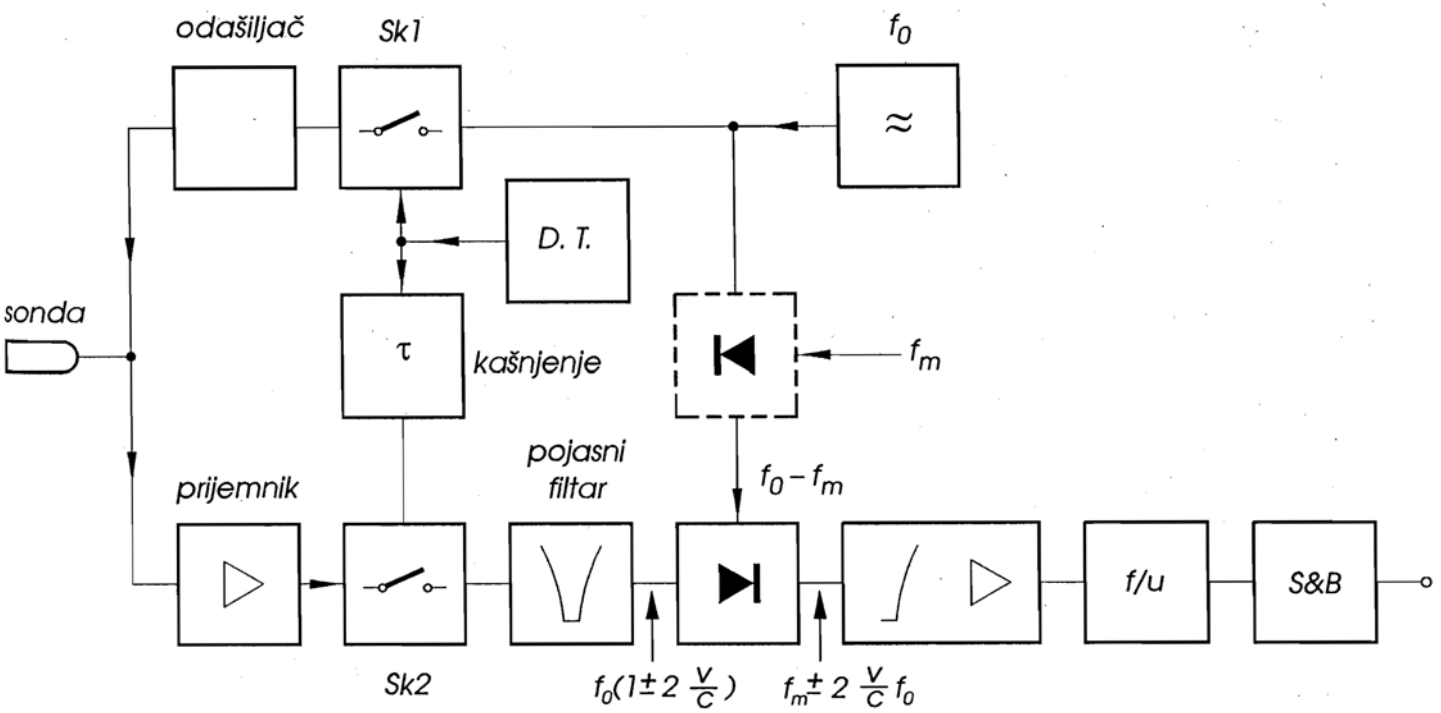
$$\Delta f = f_2 - f_0$$

$$= f\left[1 - \frac{1 - \frac{v}{c}\cos\beta}{1 + \frac{v}{c}\cos\alpha}\right]$$

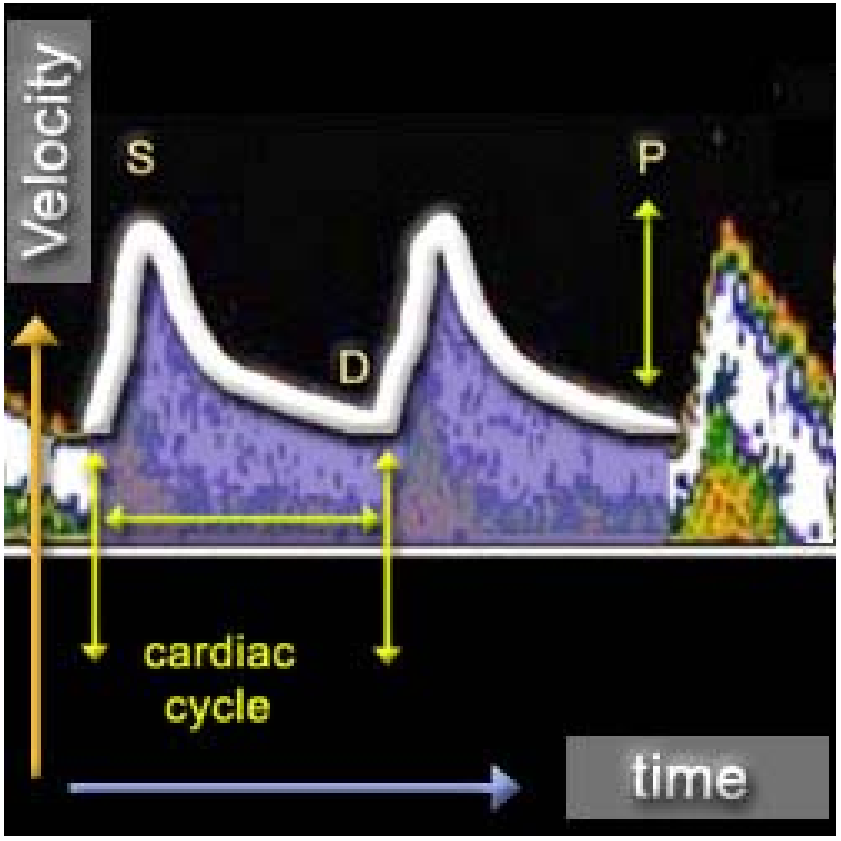
$$= f_0 \frac{c}{v}\left(\cos\alpha + \cos\beta\right)$$



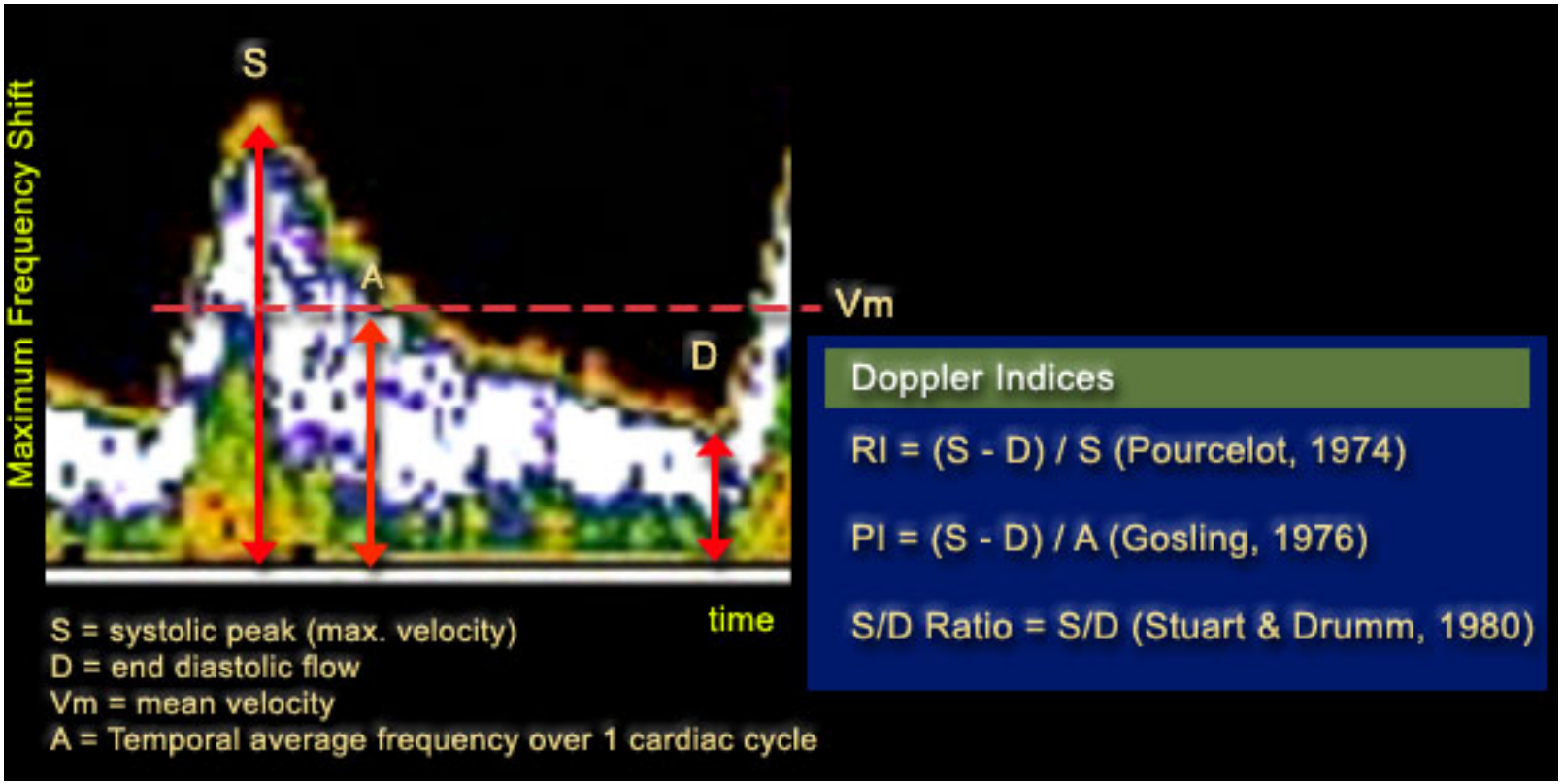
Blok shema


odašiljač
Sk1
f_0
≈
D. T.
sonda
τ
kašnjenje
f_m
pojasni filtar
prijemnik
$f_0 - f_m$
f/u
S&B
Sk2
$f_0(1 \pm 2\frac{v}{c})$
$f_m \pm 2\frac{v}{c} f_0$

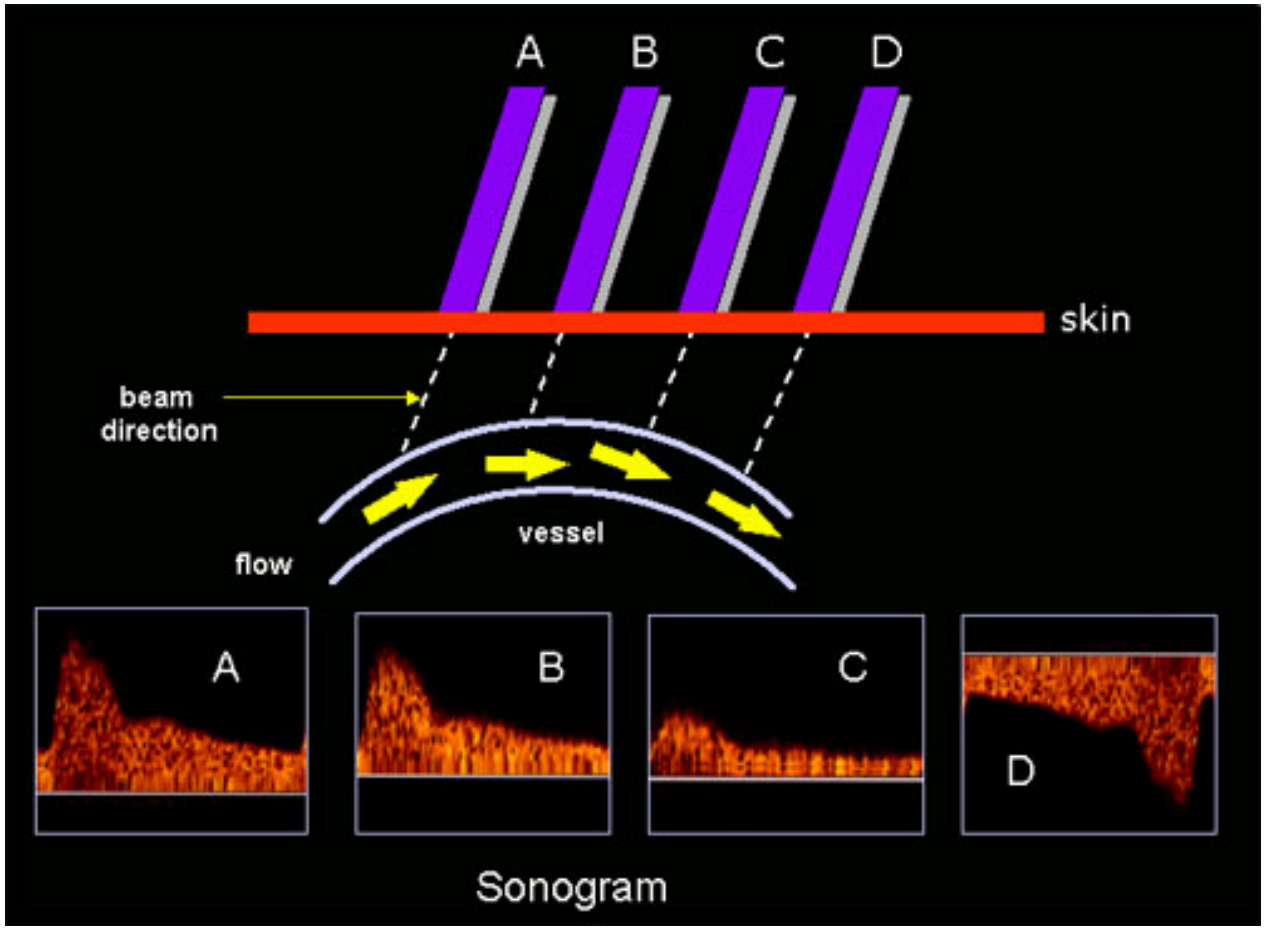
- Promjena brzine tijekom srčane kontrakcije (srčanog ciklusa)



Neki parametri mjerenja brzine protoka



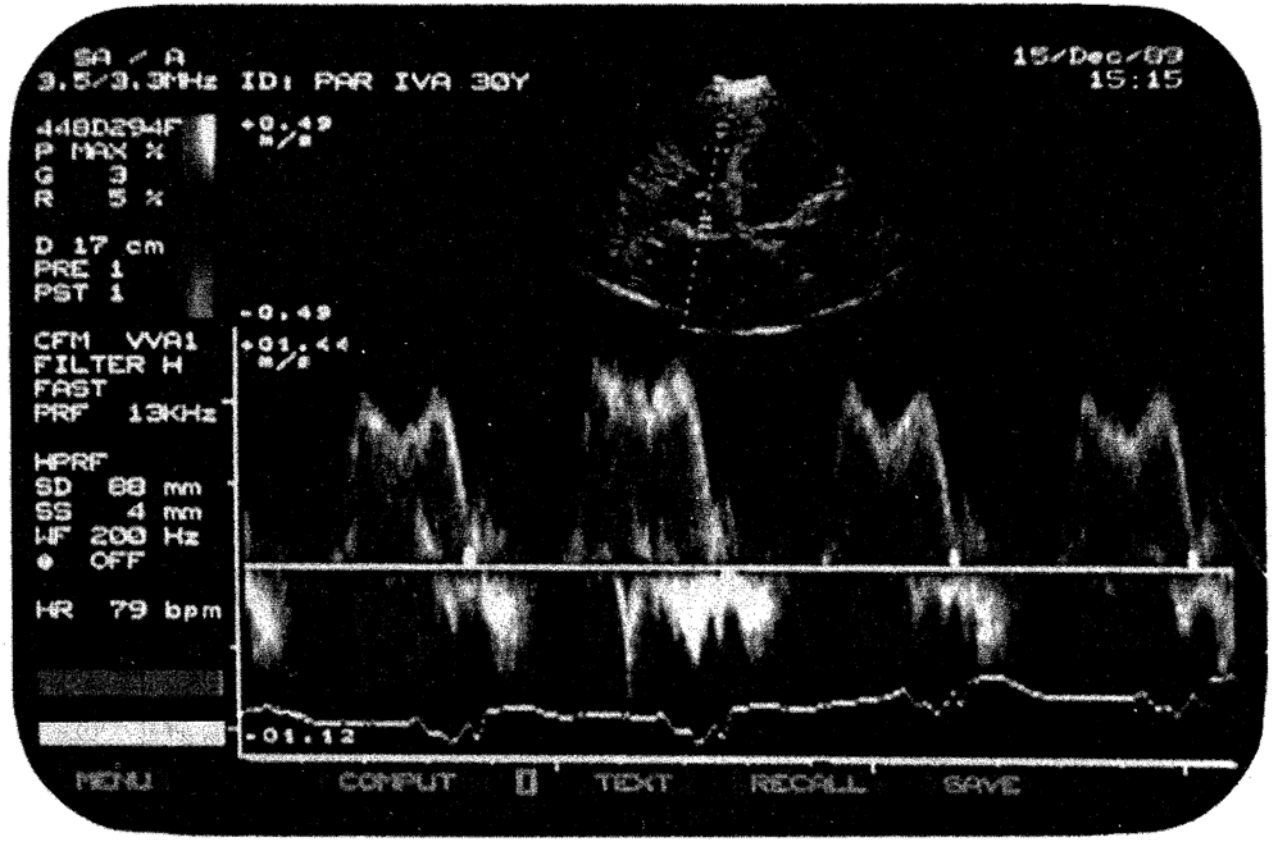
Ovisnost prikaza brzine o kutu

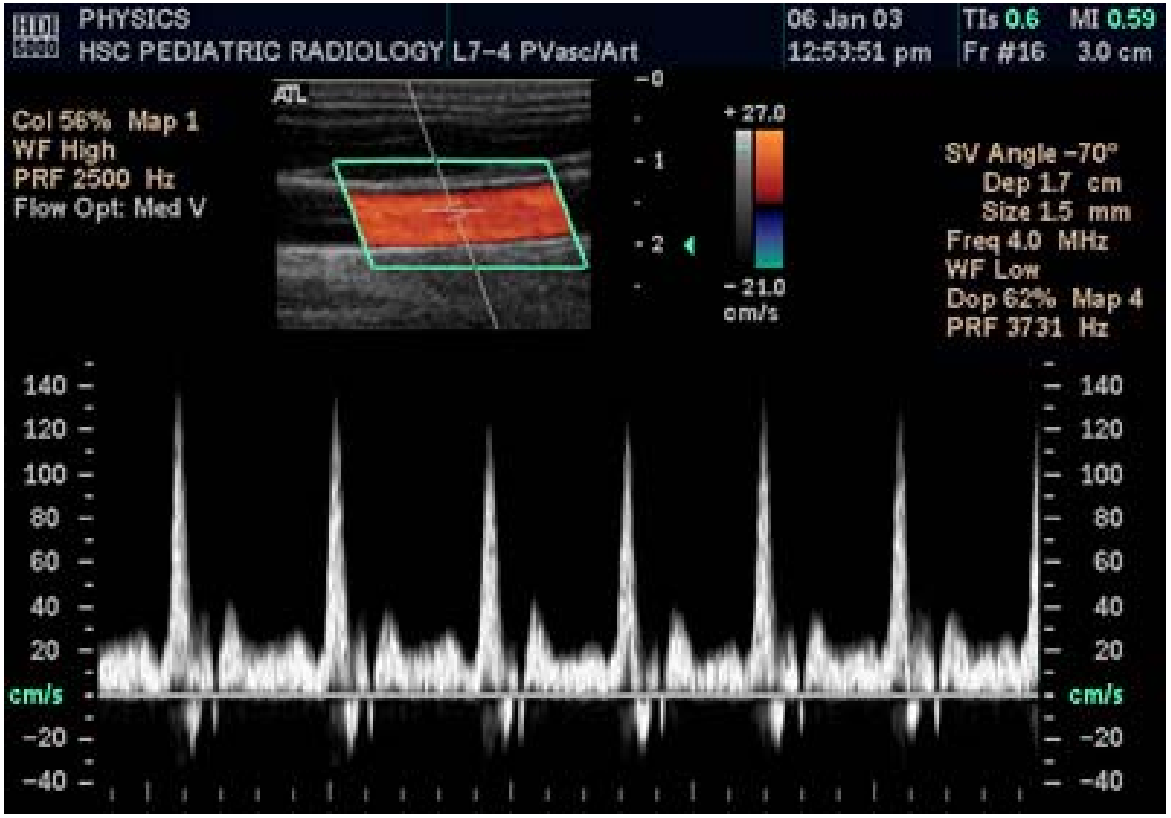


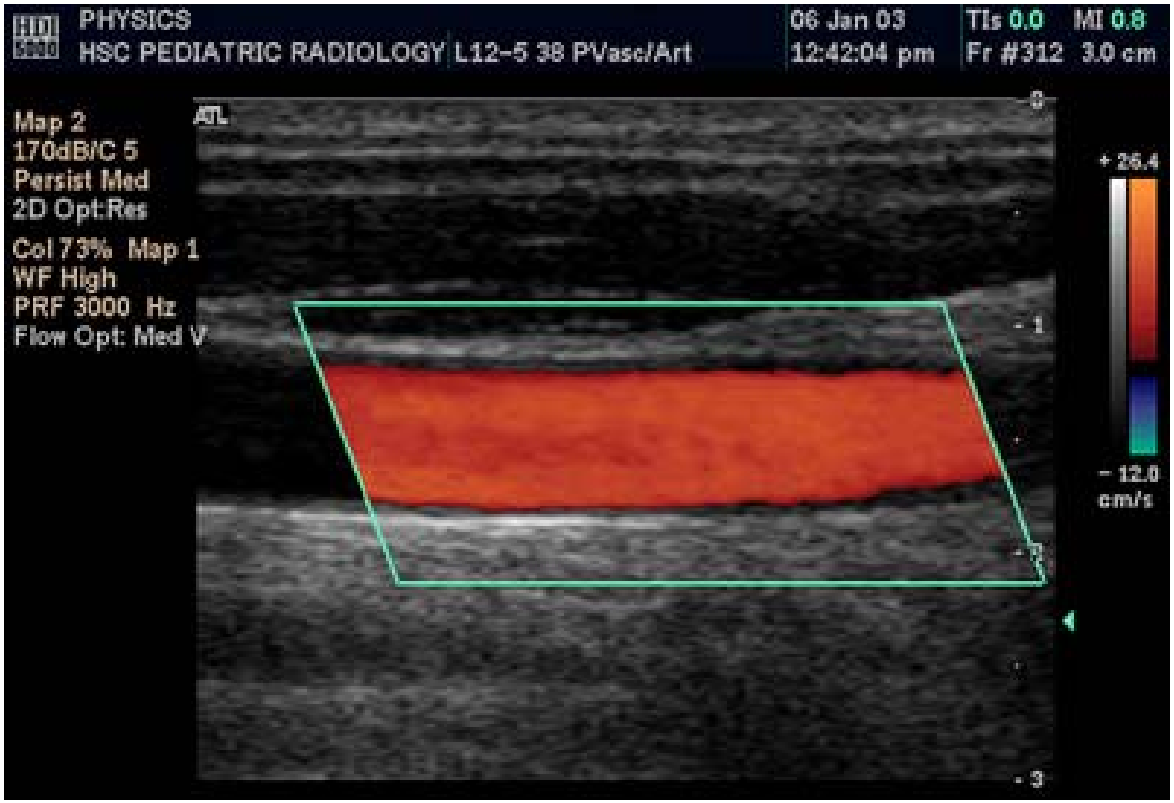
- Ovisnost prikaza brzine o kutu ultrazvučne sonde u odnosu na trajektoriju brzine. **(A)** i **(B)** Signal razlike frekvencija izraženiji je ako je smjer ultrazvuka pod oštrim kutom u odnosu na smjer gibanja krvi. Kut između ultrazvučne zrake i trajektorije brzine protoka je blizu 90°, pa je signal **(C)** mali. U slučaju **(D)** krv se udaljava od izvora ultrazvuka, pa je signal negativan.

Dopplerov efekt

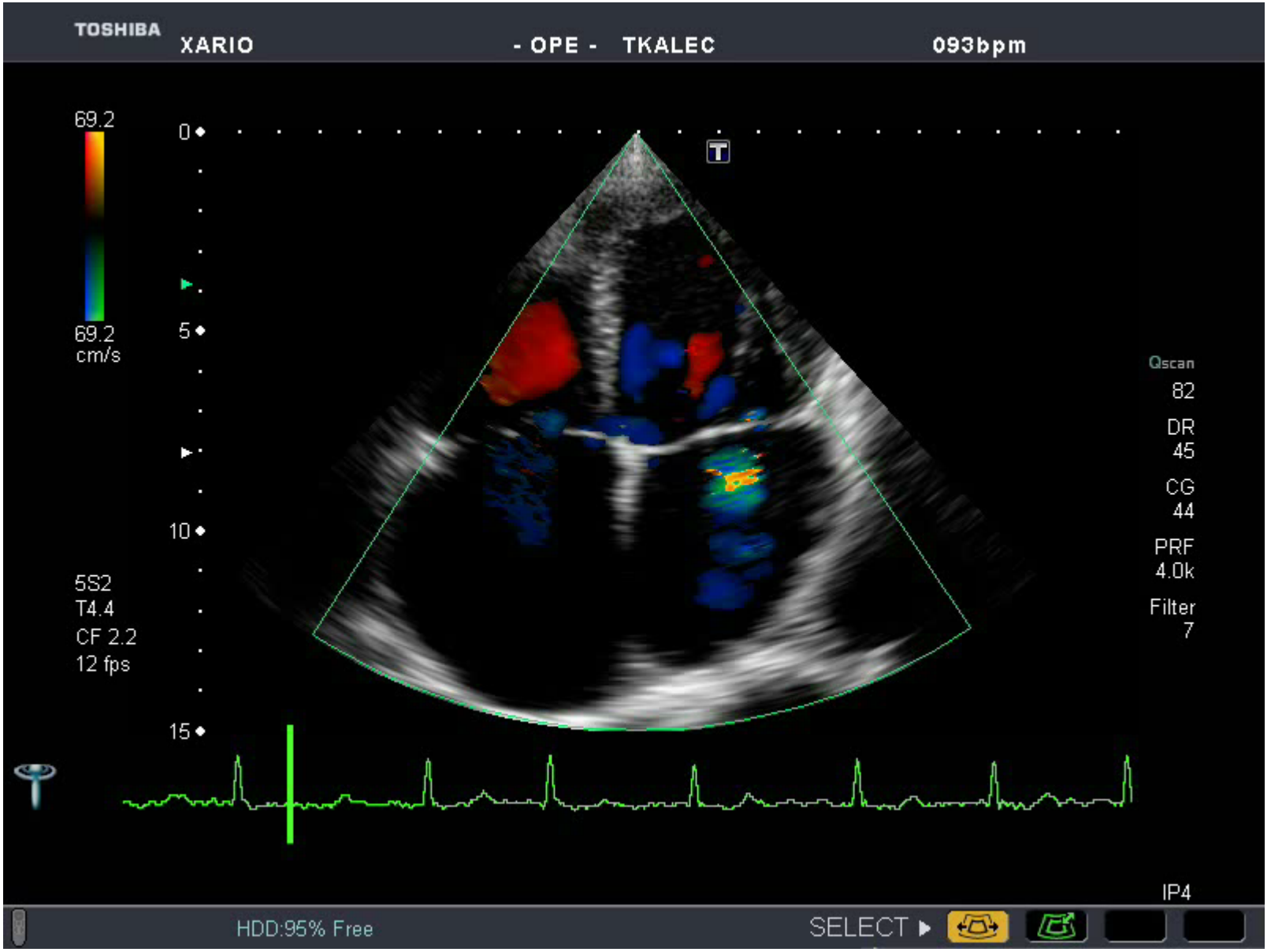
- Sektorski prikaz s pravecem duž kojeg je proveden impulsni Doppler

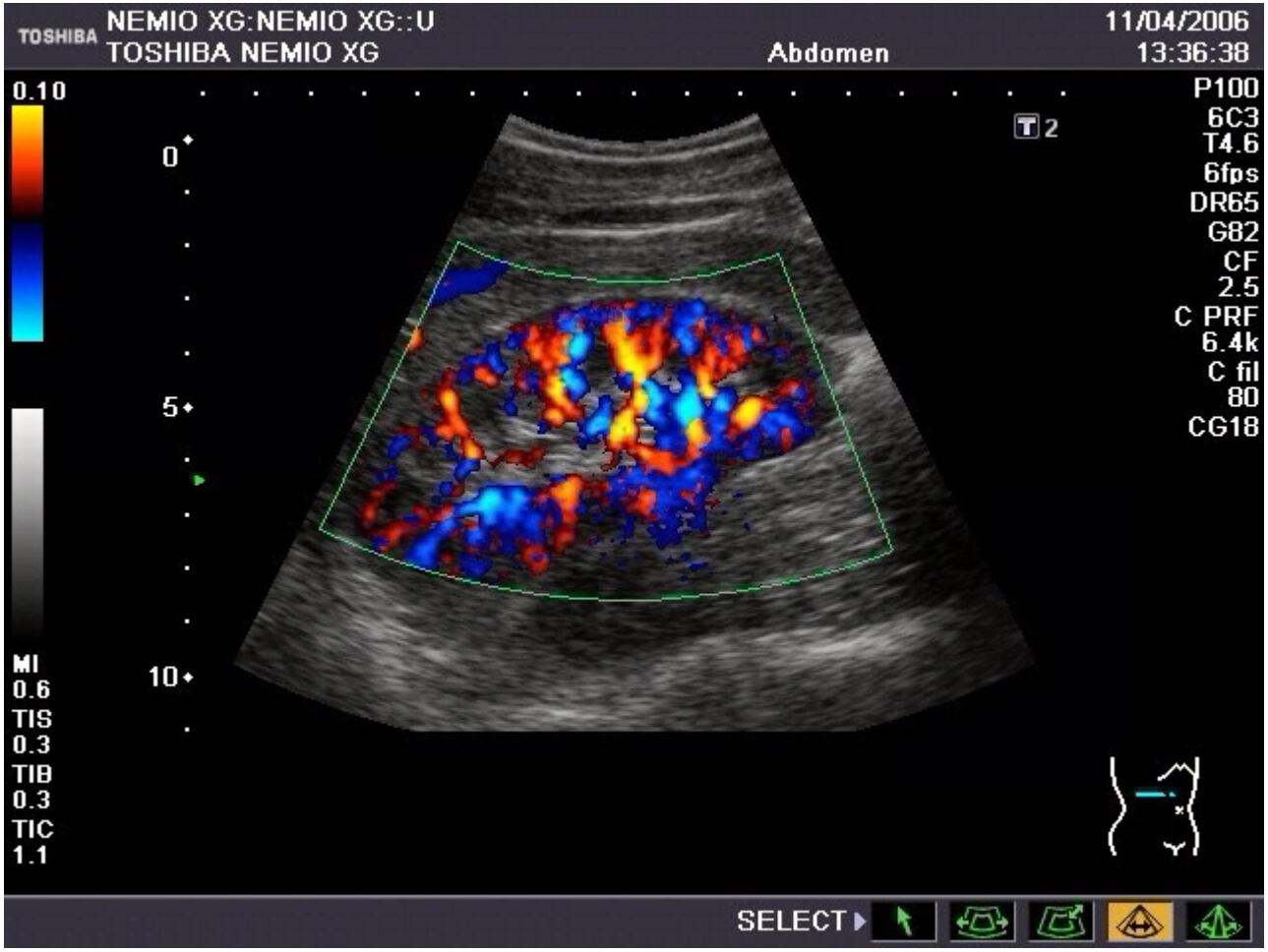



PHYSICS
HSC PEDIATRIC RADIOLOGY L7-4 PVasc/Art
06 Jan 03
12:53:51 pm
TIs 0.6
MI 0.59
Fr #16
3.0 cm
Col 56% Map 1
WF High
PRF 2500 Hz
Flow Opt: Med V
ATL
+ 27.0
- 21.0
cm/s
SV Angle -70°
Dep 1.7 cm
Size 1.5 mm
Freq 4.0 MHz
WF Low
Dop 62% Map 4
PRF 3731 Hz
140
120
100
80
60
40
20
cm/s
-20
-40


PHYSICS
HSC PEDIATRIC RADIOLOGY L12-5 38 PVasc/Art
06 Jan 03
12:42:04 pm
TIs 0.0 MI 0.8
Fr #312 3.0 cm
Map 2
170dB/C 5
Persist Med
2D Opt:Res
Col 73% Map 1
WF High
PRF 3000 Hz
Flow Opt: Med V
ATL
+ 26.4
- 12.0
cm/s

UZV uz mjerenje protoka




TOSHIBA
NEMIO XG:NEMIO XG::U
TOSHIBA NEMIO XG
Abdomen
11/04/2006
13:36:38
0.10
0
5
10
T 2
P100
6C3
T4.6
6fps
DR65
G82
CF
2.5
C PRF
6.4k
C fil
80
CG18
MI
0.6
TIS
0.3
TIB
0.3
TIC
1.1
SELECT

Literatura:

- Šantić, A., "Biomedicinska elektronika", Školska knjiga, Zagreb, 1995
- Breyer, B., "Medicinski dijagnostički ultrazvuk", Školska knjiga, Zagreb, 1991
- Brown, BH., Smallwood, RH., et al., "Medical Physics and Biomedical Engineering, IoP Press, Bristol, 1999

Posjet KBC Rebro

- Klinika za onkologiju i radioterapiju
  - planiranje terapije: CT za dobivanje medicinskih slika i programska podrška za obilježavanje područja zračanja – tumora
  - proračun doza zračenja
  - načini osiguranja položajne točnosti
- Radioterapija
  - linearni akcelerator (LINAC)
  - pozicioniranje pacijenata i kolimatori
- Radikirurgija
  - gama nož (Gamma knife)
  - precizno zračenje tumora glave
  - stereotaktički uređaj za pozicioniranje

Linearni akcelerator (linac)

- Uređaji koji ubrzavaju nabijene atomske čestice ili njihove dijelove linearno, tako da se dobije "zraka" koja se koristi u terapiji tumora
- Linaci malih energija koriste se u svakoj katodnoj cijevi (osciloskopi, monitori) i u rentgenskoj tehnici
- "Meta" ubrzanih čestica je na kraju zrake (zaslon monitora, pacijent..)
-

Primjena LINAC-a u medicini

- Radioterapija i radiokirurgija (radiosurgery)
- Energija zraka 6-30 MeV
- Za terapiju se koriste zrake čestica ili rentgenske zraka nastale sudarom ubrzanih čestica i katode
- Koristi se u terapiji malignih i benignih tumora, s time da je primjena terapije za liječenje benignih tumora ograničena zbog posljedica ionizirajućeg zračenja
- Koristi se za liječenje (kurativno), za pospješivanje druge, najčešće kemo-terapije te palijativno

Blok shema LINAC-a

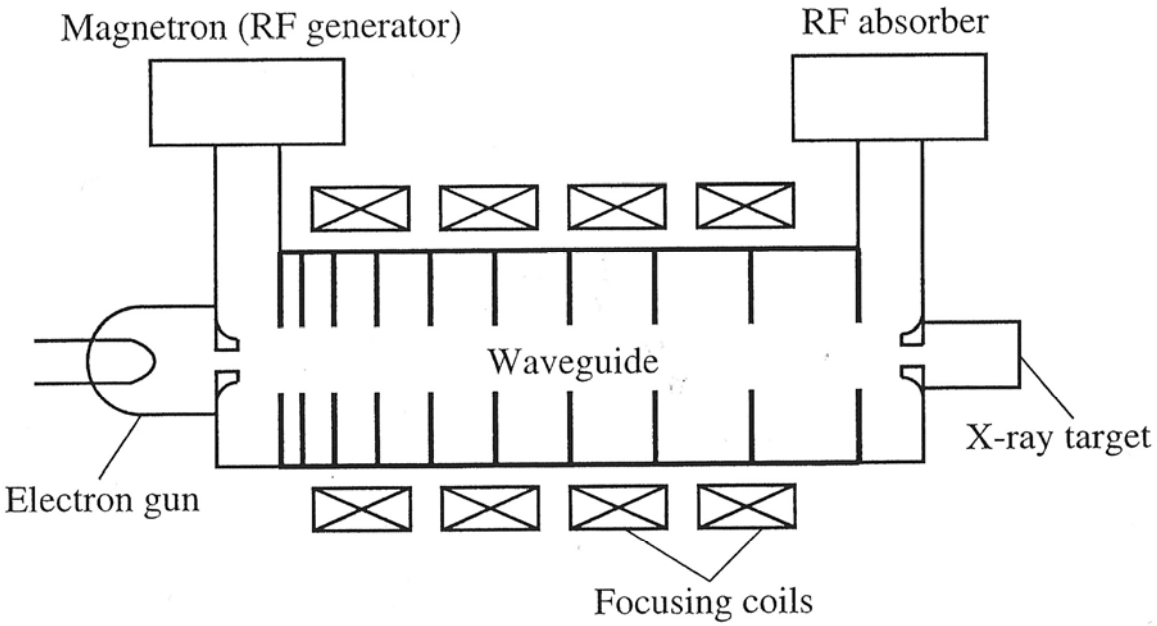
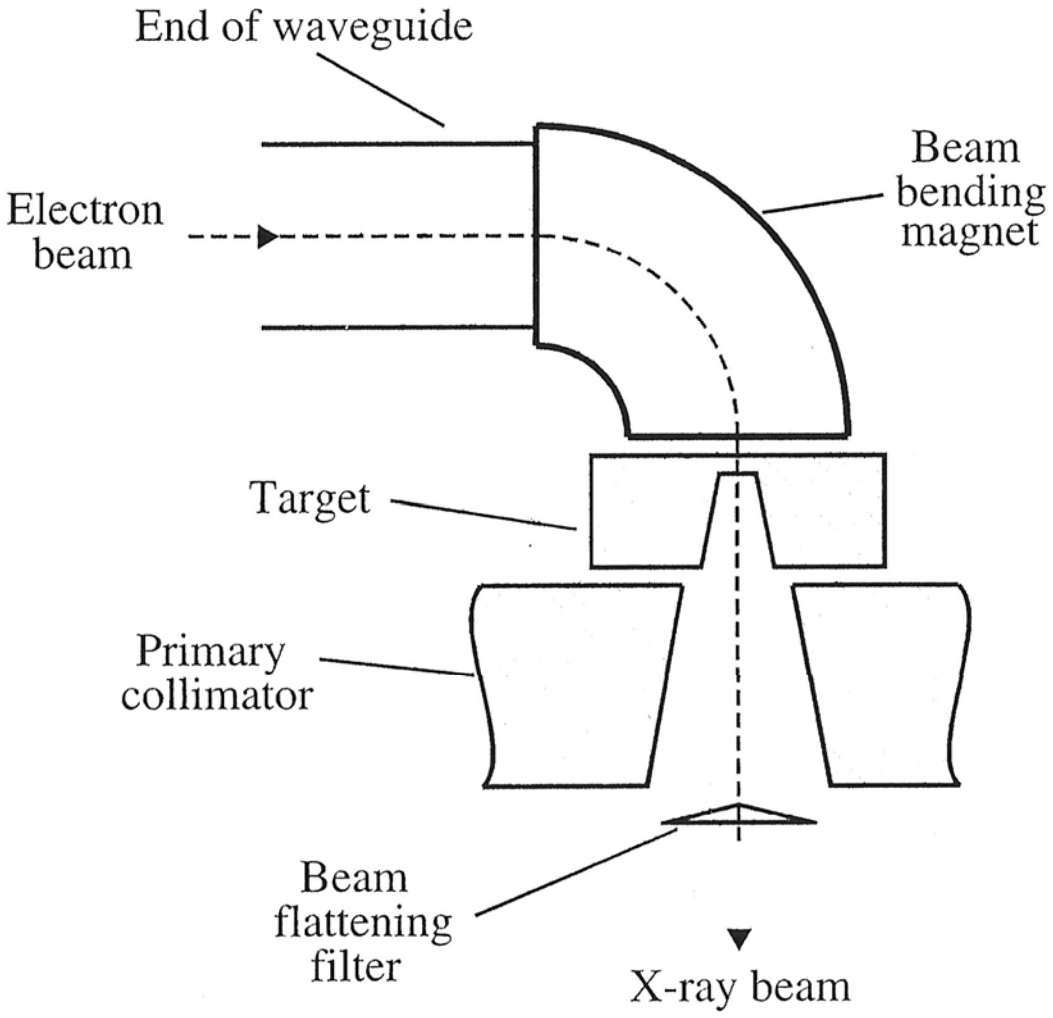
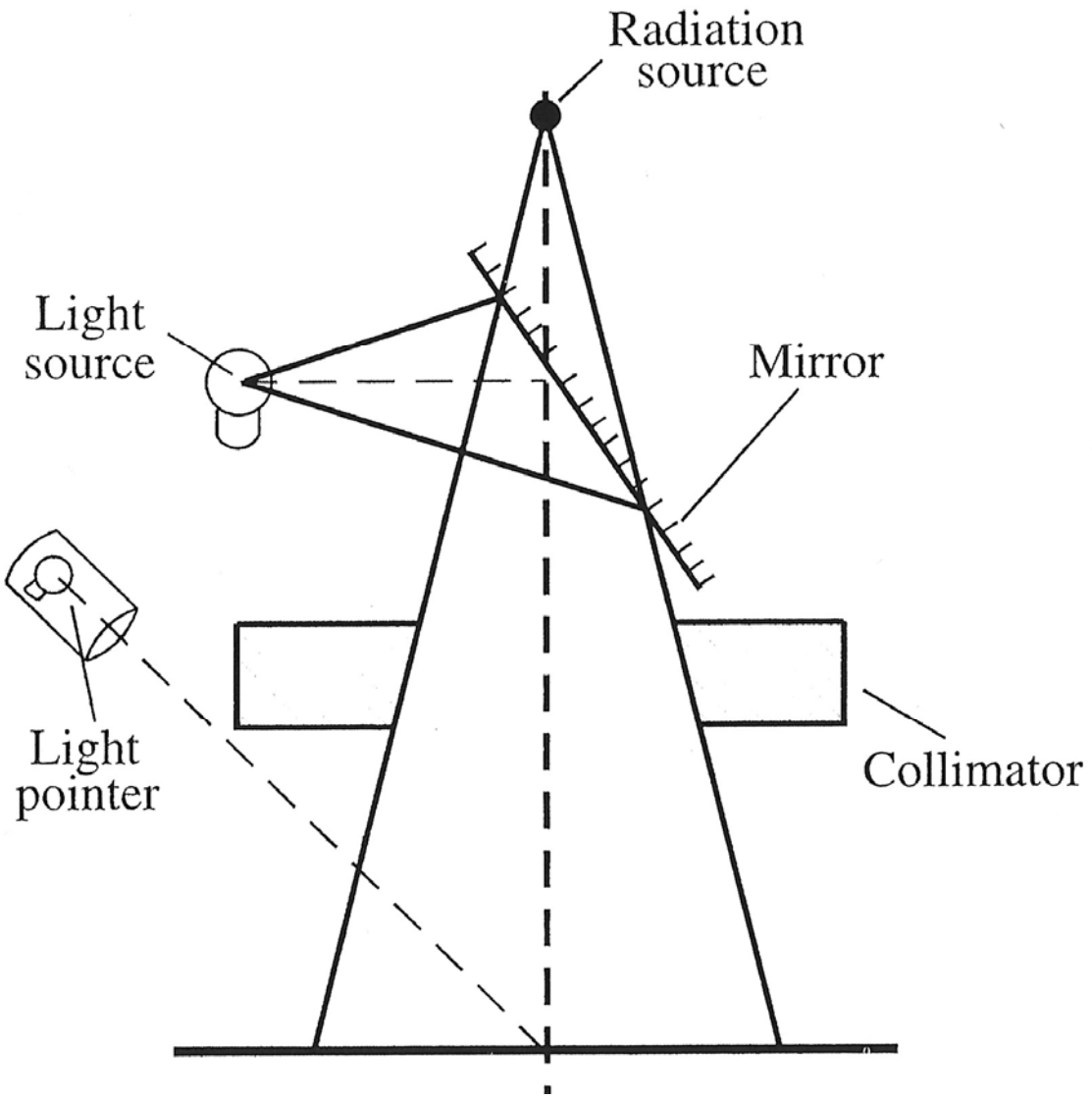


Figure 21.7. *A greatly simplified diagram of a linear accelerator. The interior of the waveguide is maintained at a high vacuum by ion pumps. Electrons from the electron gun are accelerated down the waveguide either to strike the target and thus produce x-rays, or to pass through a thin window to give an external electron beam. The RF energy may be recirculated, instead of being dissipated as heat in the RF absorber.*

Usmjeravanje zrake



Usmjeravanje zrake na cilj

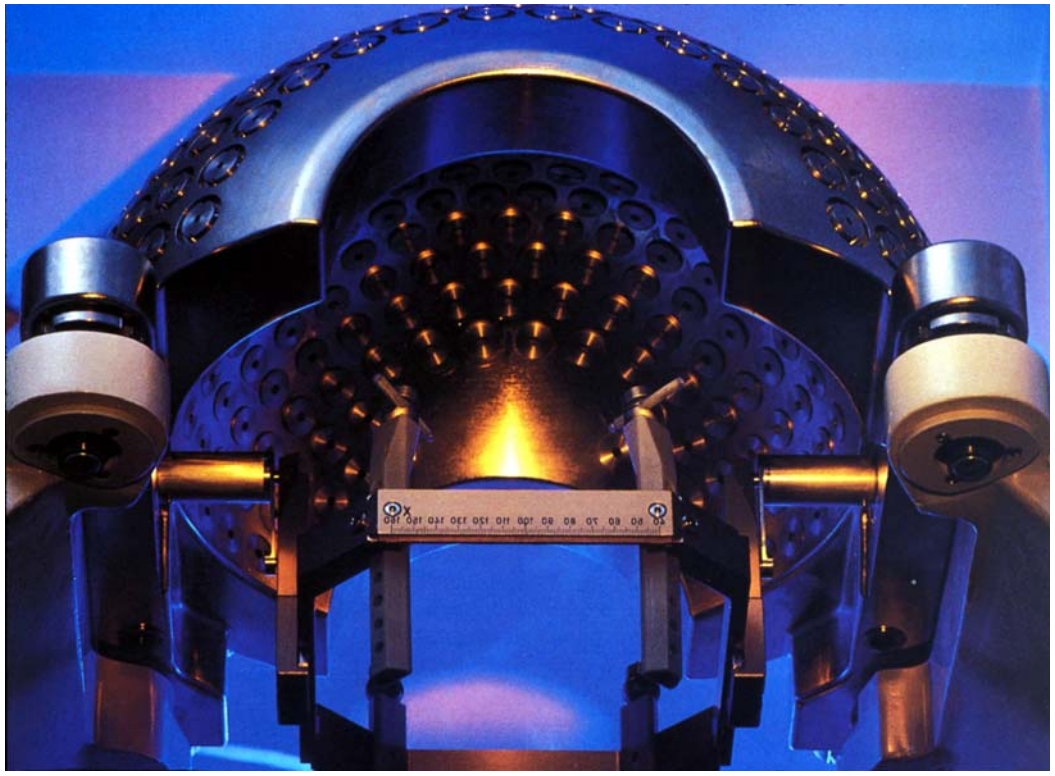


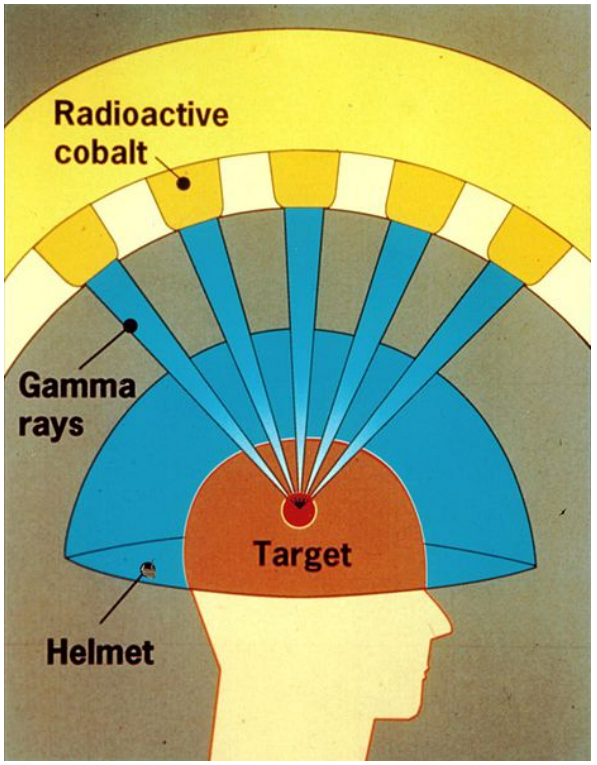
Radiokirurgija

- **Radiosurgery** is a medical procedure that allows non-invasive treatment of benign and malignant tumors.
- It is also known as stereotactic radiotherapy, (SRS) when used to target lesions in the brain, and stereotactic body radiotherpy (SBRT) when used to target lesions in the body.
- It operates by directing highly focused beams of ionizing radiation with high precision.
- There are many nervous diseases for which conventional surgical treatment is difficult or inadvisable due to deleterious consequences for the patient, such as damage to nearby arteries, nerves, and other vital structures.

Gamma knife

- A **gamma knife** is a device used to treat brain tumors with a high dose of radiation therapy in one day.
- f >>10^{19} Hz, and therefore have energies above 100 keV and wavelength less than 10 picometers, often smaller than an atom. Gamma radioactive decay photons commonly have energies of a few hundred keV, and are almost always less than 10 MeV in energy.
- The gamma knife device contains 201 cobalt-60 sources of approximately 30 curies





Pozicioniranje pacijenta

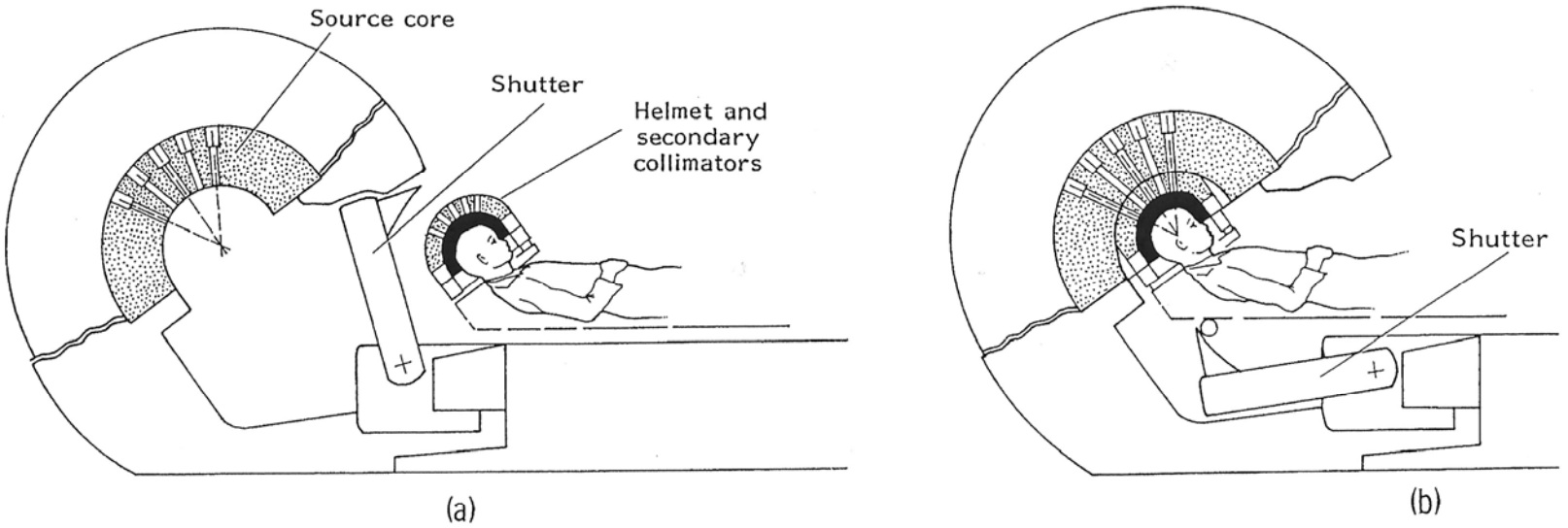


Figure 21.10. *The Sheffield stereotactic radiosurgery unit. When the shutter is dropped the patient is moved such that the secondary collimators in the helmet line up with the primary collimators in the source core. Image kindly provided by L Walton.*

“Gama nož” (*Gamma knife*)