TIBBİ GÖRÜNTÜLEME SİSTEMLERİ

7. HAFTA
MANYETİK REZONANS GÖRÜNTÜLEME FİZİĞİ

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https://www.researchgate.net/profile/Sabri_Uzuner

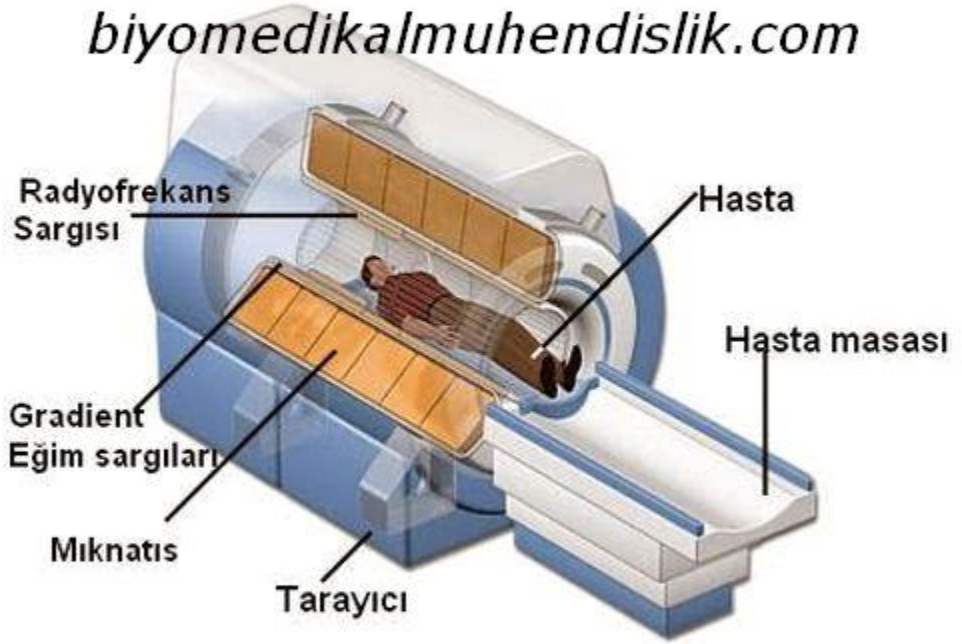
MOTİVASYON

- **Bu bölümde, MRG fiziğinin matematiksel detaylardan arındırılmış bir biçimde incelenmesi, klinik uygulamalar için fiziksel bir alt yapı oluşturulması amaçlanmıştır.**

- MRG Cihazı
- Manyetizma
- Relaksasyon
- Rezonans
- Görüntü oluşumu

MRI

Manyetik Rezonans Görüntüleme (MRG), diğer biyomedikal görüntüleme teknikleri gibi bir **ölçüm** ve **yayın kaynağı**, bu kaynağın yaydığı **ışınım** veya **dalgaların** maddeyle etkileşimi, bu etkileşimin ölçüm kaynağı tarafından **teşhis edilmesi** ve anlaşılır bir görüntünün yapılandırılması şeklinde dört basamakta incelenebilir



Manyetik görüntüleme nasıl çalışır

https://www.youtube.com/watch?v=kmfmGhI8l9E
https://www.youtube.com/watch?v=mhhSBXyqLDQ
https://www.youtube.com/watch?v=5Vt5K42k0VY
https://www.youtube.com/watch?v=SqCQgPI1lMM

Kamil Karaali:

1) https://www.youtube.com/watch?v=ujd58r2GmzI
2) https://www.youtube.com/watch?v=4whbGCXPpPs
3) https://www.youtube.com/watch?v=XLSvZEm5rrA


BRUCHSAL
HALLE


NT EDV-U. COMPUTER
imon Hege
RUHE · BRUCHSAL · FORCHHEIM/OFR. · HALLE · LEIPZI

Timeline of MR Imaging

1924 - Pauli suggests that nuclear particles may have angular momentum (spin).

1937 – Rabi measures magnetic moment of nucleus. Coins “magnetic resonance”.

1946 – Purcell shows that matter absorbs energy at a resonant frequency.

1946 – Bloch demonstrates that nuclear precession can be measured in detector coils.

1959 – Singer measures blood flow using NMR (in mice).

1972 – Damadian patents idea for large NMR scanner to detect malignant tissue.

1973 – Lauterbur publishes method for generating images using NMR gradients.

1973 – Mansfield independently publishes gradient approach to MR.

1975 – Ernst develops 2D-Fourier transform for MR.

NMR renamed MRI

1985 – Insurance reimbursements for MRI exams begin.

MRI scanners become clinically prevalent.

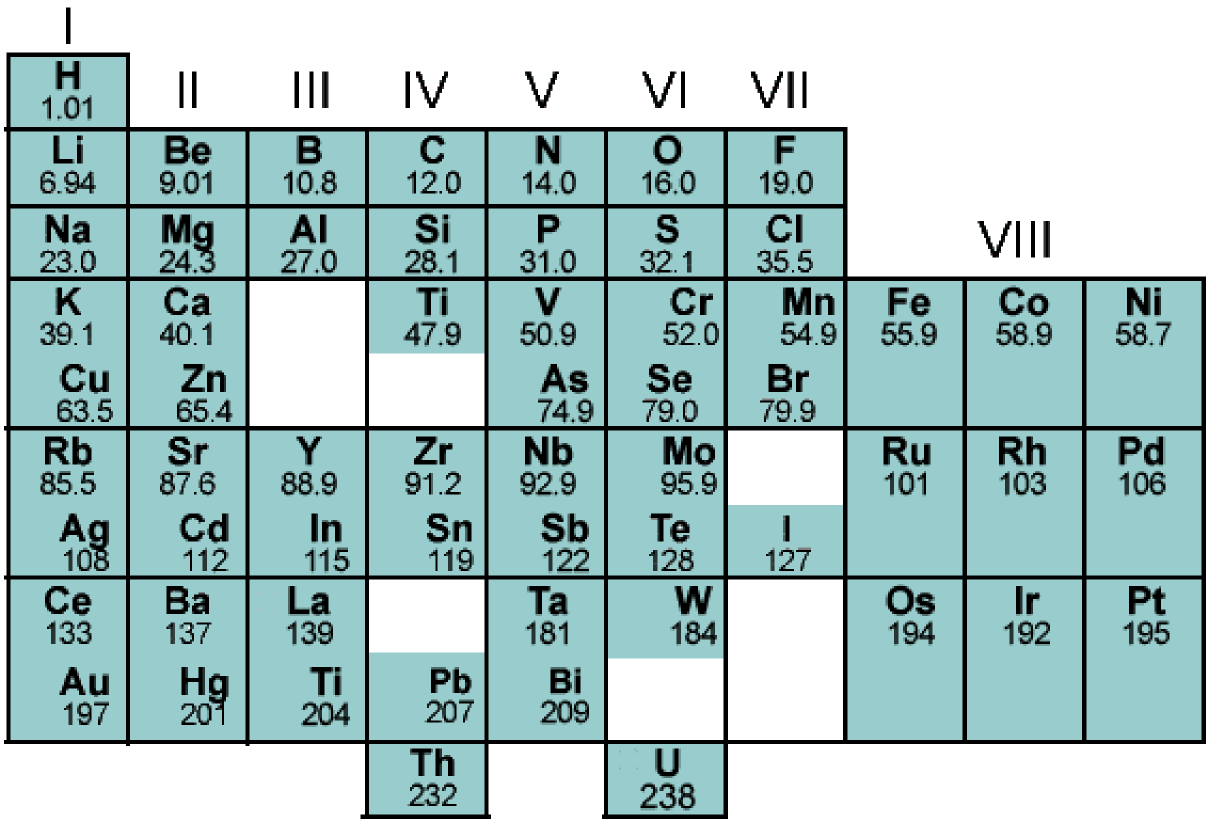
1990 – Ogawa and colleagues create functional images using endogenous, blood-oxygenation contrast.

Nobel Prizes for Magnetic Resonance

- 1944: Rabi
  Physics (Measured magnetic moment of nucleus)
- 1952: Felix Bloch and Edward Mills Purcell
  Physics (Basic science of NMR phenomenon)
- 1991: Richard Ernst
  Chemistry (High-resolution pulsed FT-NMR)
- 2002: Kurt Wüthrich
  Chemistry (3D molecular structure in solution by NMR)
- 2003: Paul Lauterbur & Peter Mansfield
  Physiology or Medicine (MRI technology)

Now not all nuclei are "MRI active"..
Which of the following could produce an MRI image?

Only those with an odd number of protons and neutrons.



^{1}H

^{11}C

^{13}N

^{18}F

^{19}F

^{31}P

- Which isotopes at the right are radioactive?

Common nuclei with NMR properties

•Criteria:

Must have ODD number of protons or ODD number of neutrons.

Reason?

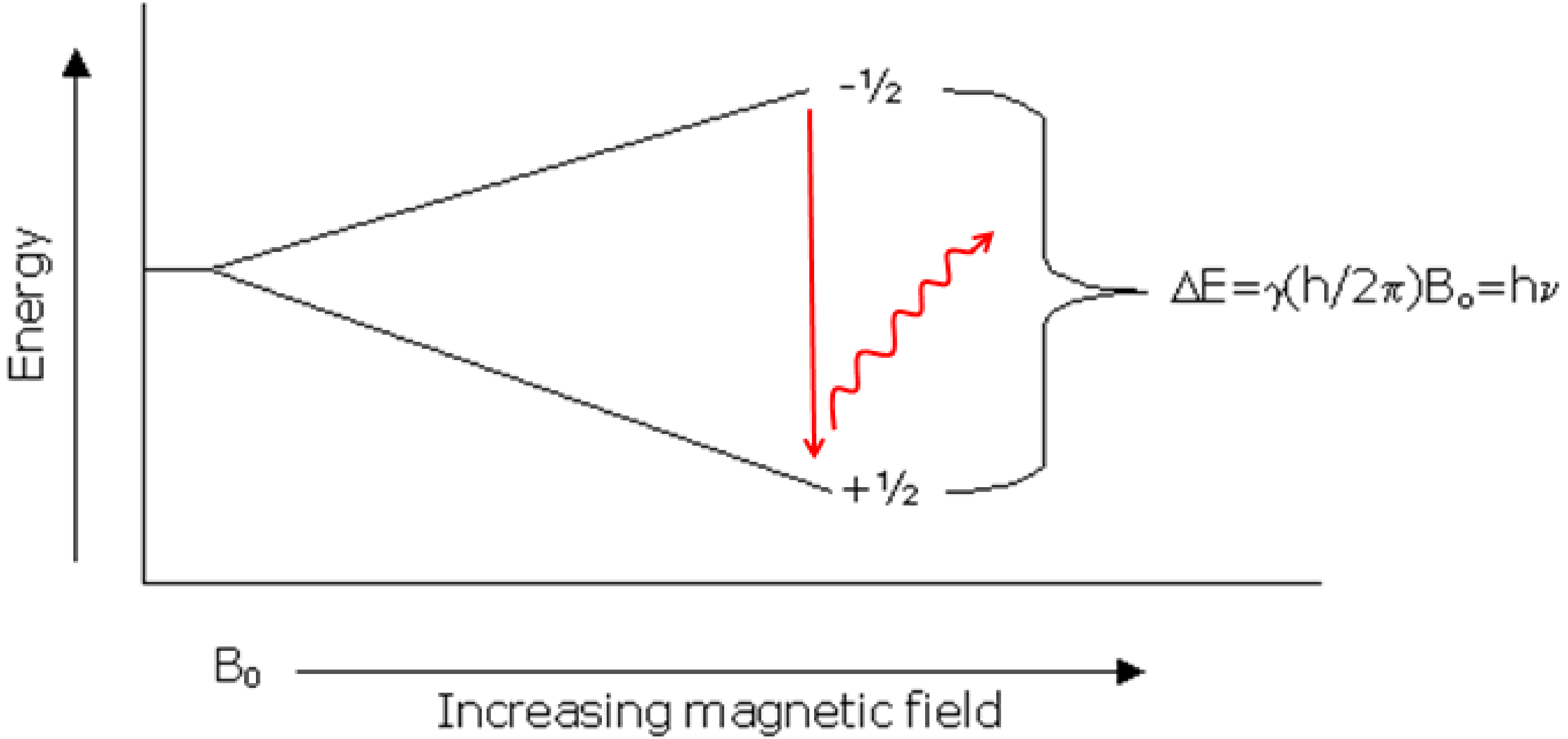
It is impossible to arrange these nuclei so that a zero net angular momentum is achieved. Thus, these nuclei will display a magnetic moment and angular momentum necessary for NMR.

Examples:

^{1}H, ^{13}C, ^{19}F, ^{23}N, and ^{31}P with gyromagnetic ratio of 42.58, 10.71, 40.08, 11.27 and 17.25 MHz/T.

Since hydrogen protons are the most abundant in human body, we use ^{1}H MRI most of the time.

•Does an MRI scanner produce radiation?



The MRI signal is generated by receiving radiofrequency photons that return to their lower energy state.

Is MRI dangerous?

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5081138/

Magnetic Resonance Imaging (MRI) is a versatile imaging modality that **uses magnetic properties of certain atoms present in biological tissues to generate images**.

MRI takes advantage of the phenomenon of NMR: **Nuclear** → Properties of **elementary particles** of atoms nuclei (e.g. protons) are exploited.

Magnetic → When placed in an external magnetic field, **protons** behave such as small magnets.

Resonance → The exchange of energy between two systems (e.g. human body protons and MR imaging device).

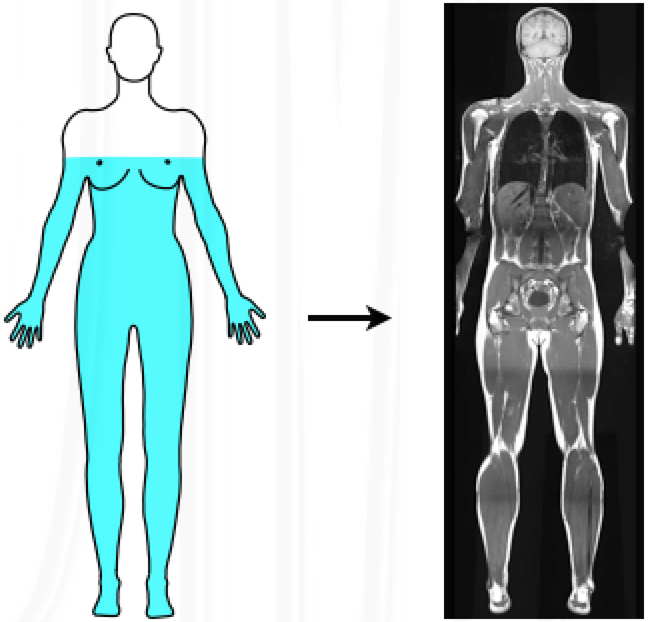
MRI → Acquiring and processing the magnetic resonance (MR) signal to generate images.

Hydrogen atoms are most commonly used to generate MR signal for two reasons:

- the hydrogen atom is composed by one single proton presenting **strong magnetic properties**.

- **the human body is composed of about 70% of water** and water molecules contain two hydrogen atoms.

Water hydrogen atoms from different biological tissues **have different magnetic properties** which translates in different contrast on MR images.

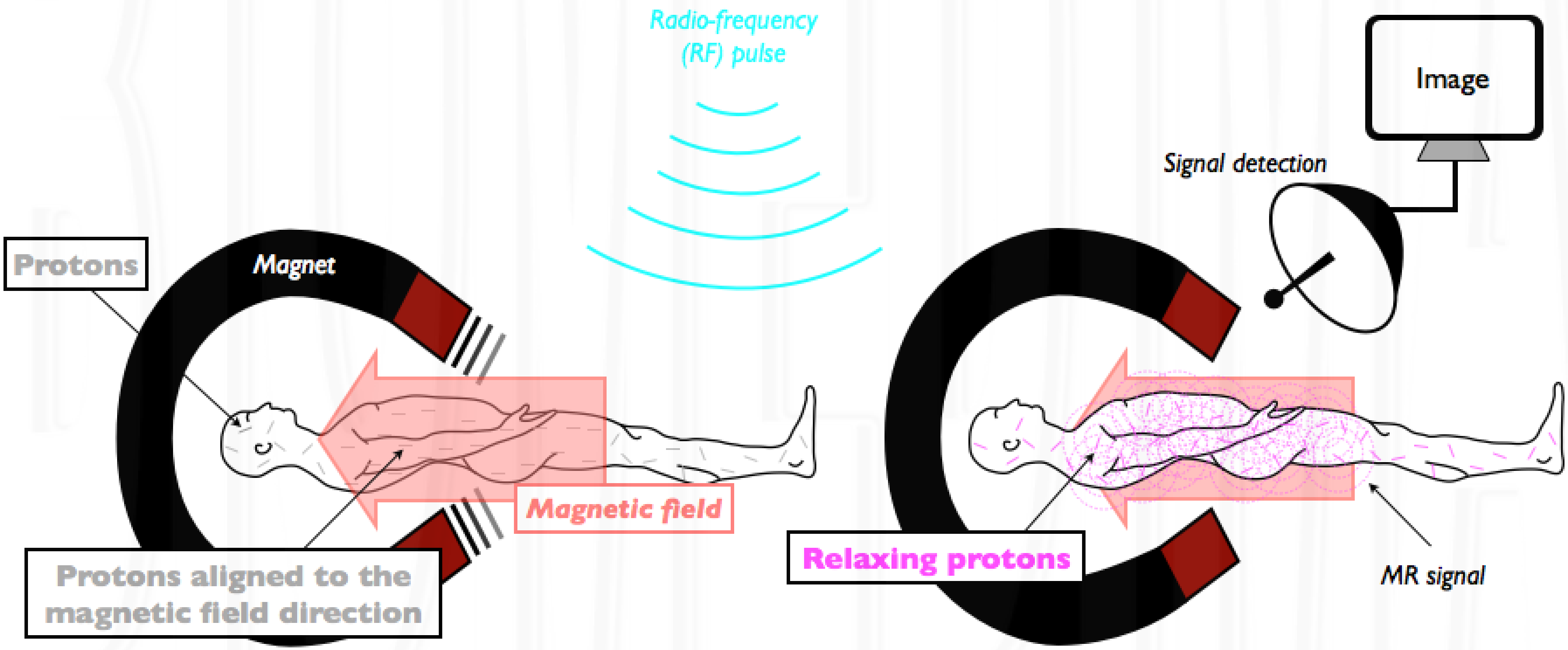


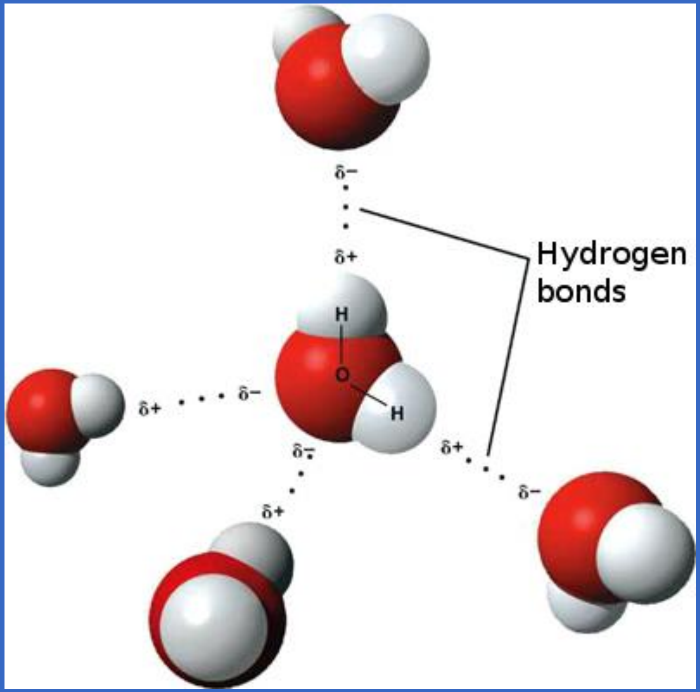
In order **to capture magnetization state changes** of hydrogen atoms (protons) and generate images, the following three basic steps are required:

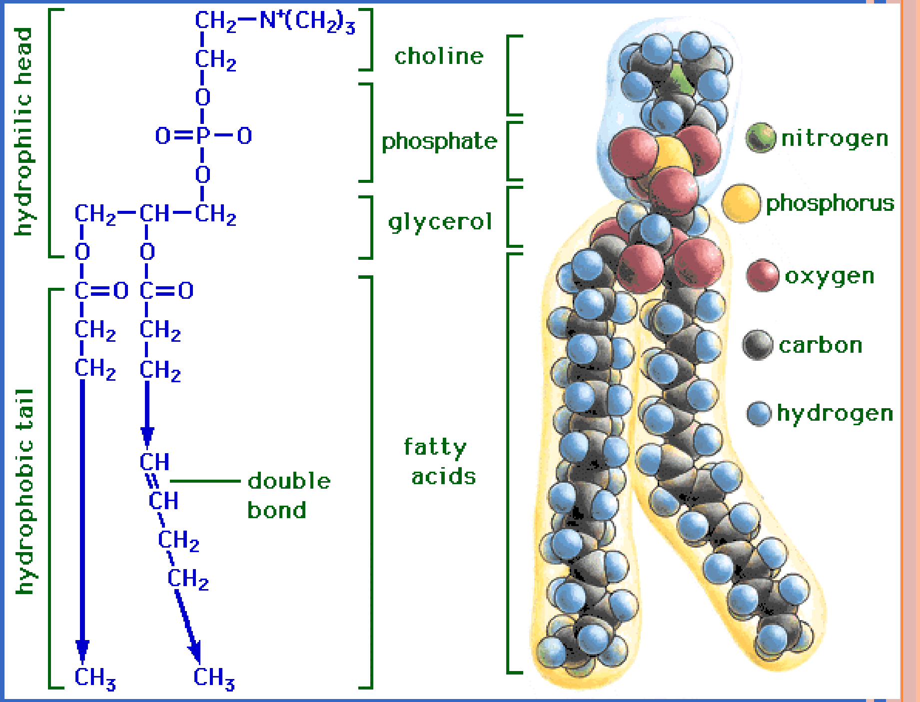
1. The subject to image is placed in a **big magnet. Protons** within the magnetic field align parallel to the field direction in an **equilibrium state**.

2. The subject undergoes an armless **radio-frequency (RF) pulse** that forces protons in a **non-equilibrium state**.

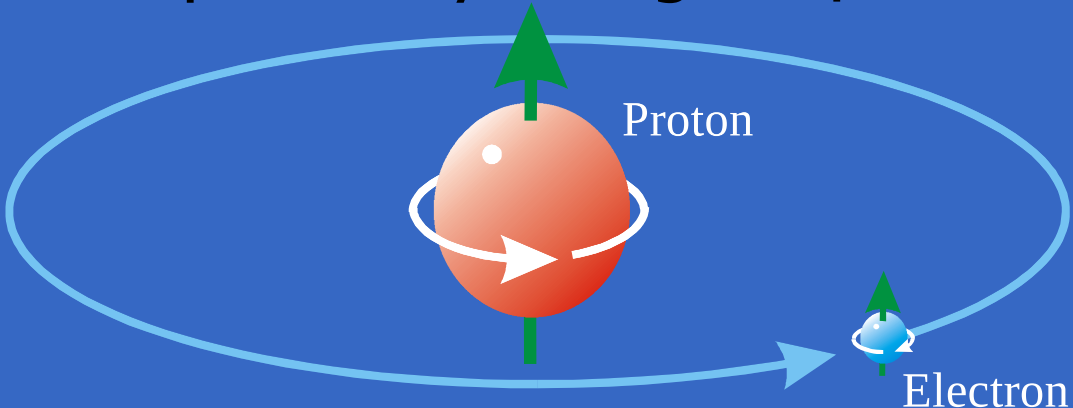
3. When the RF pulse stops, **protons return to their initial equilibrium state (relaxation)** and emit a detectable signal (MR signal) that will be processed to generate images.







A hydrogen atom (whether bound in water or lipid) acts as a small magnet due to the spinning of the positively charged _proton_.



Protons from what compounds comprise an MRI signal?

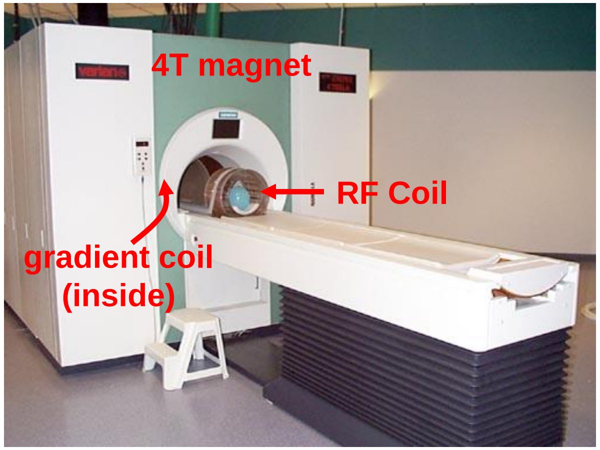
What percentage of your body is composed of water?

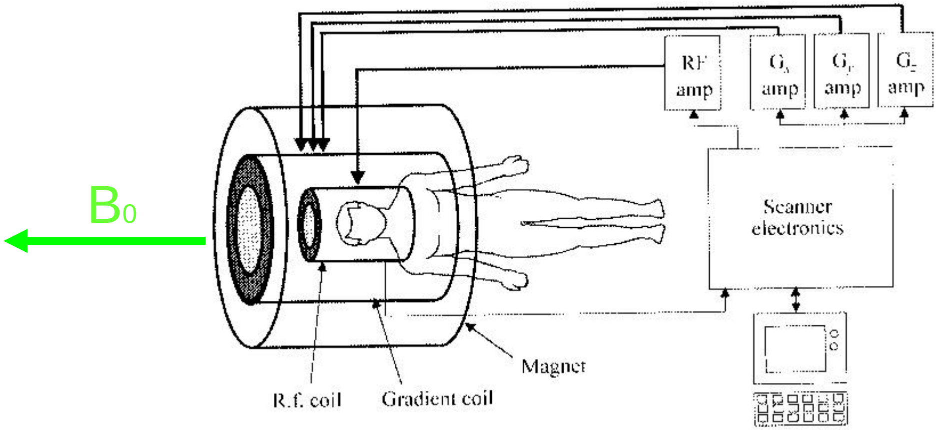
A) 40%-50%, B) 50%-60%, C) 60%-70%, D) 70%-80%

What percentage of your body is composed of fat?

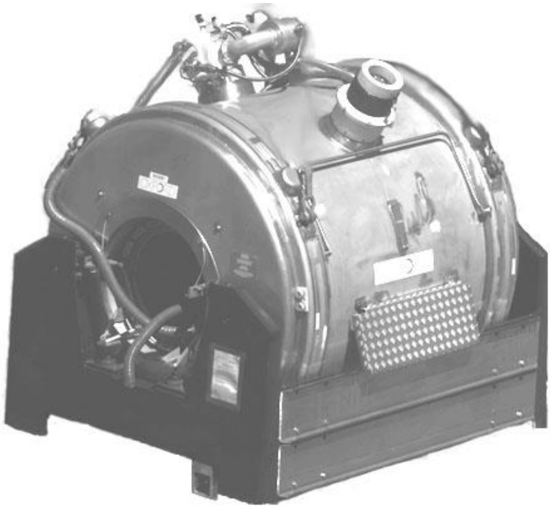
Description	Women	Men
Essential fat	10–12%	2–4%
Athletes	14–20%	6–13%
Fitness	21–24%	14–17%
Acceptable	25–31%	18–25%
Overweight	32-41%	26-37%
Obese	42%+	38%+

EQUIPMENT



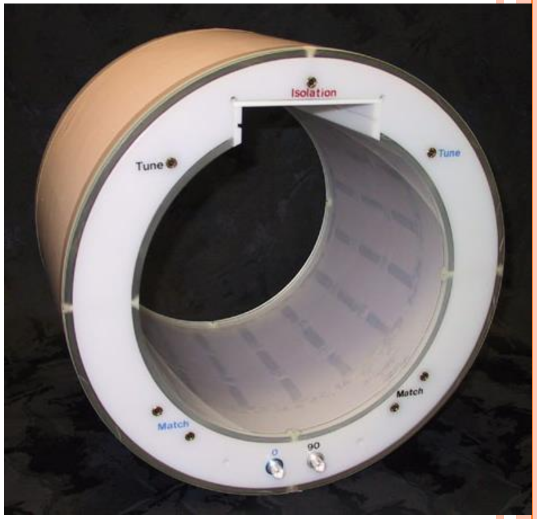


Magnet



Gradient Coil

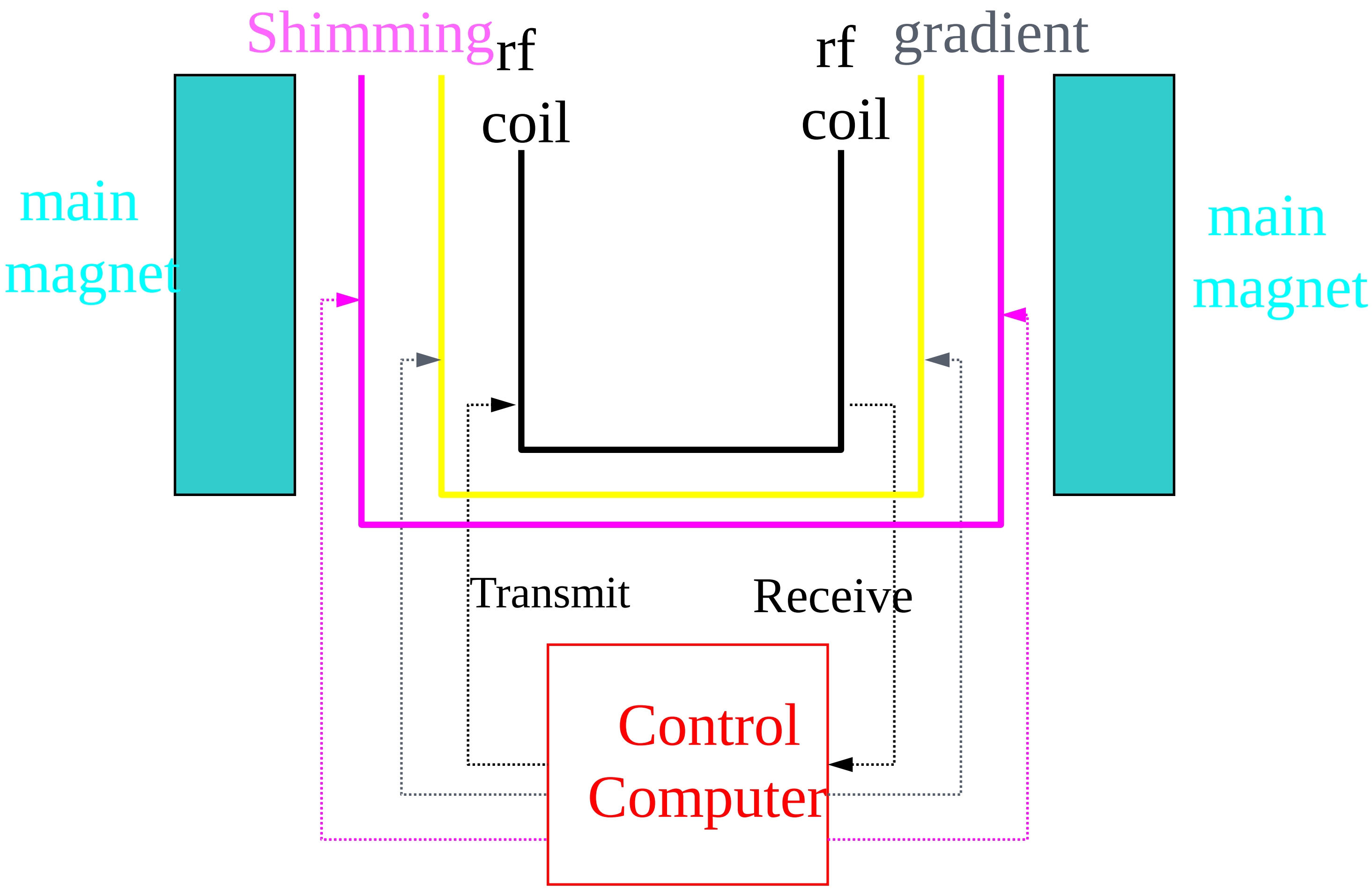
RF Coil



Main Components of a Scanner

- Static Magnetic Field Coils
- Gradient Magnetic Field Coils
- Magnetic shim coils
- Radiofrequency Coil
- Subsystem control computer

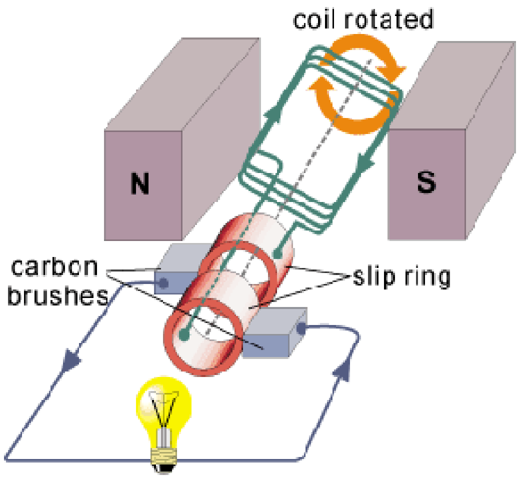
- Data transfer and storage computers
- Physiological monitoring, stimulus display, and behavioral recording hardware

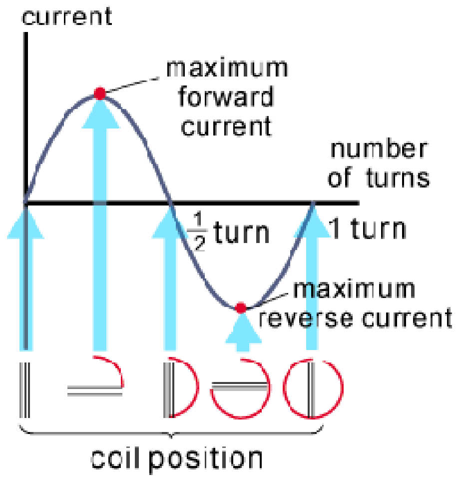


Shimming
rf coil
rf coil
gradient
main magnet
main magnet
Transmit
Receive
Control Computer

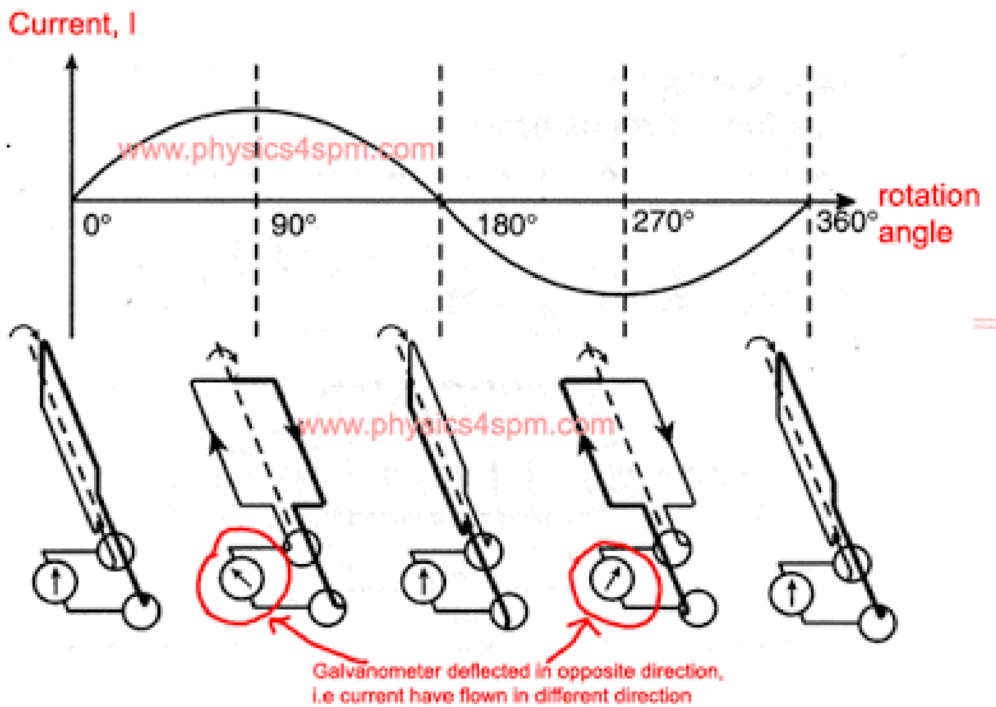
Magnet

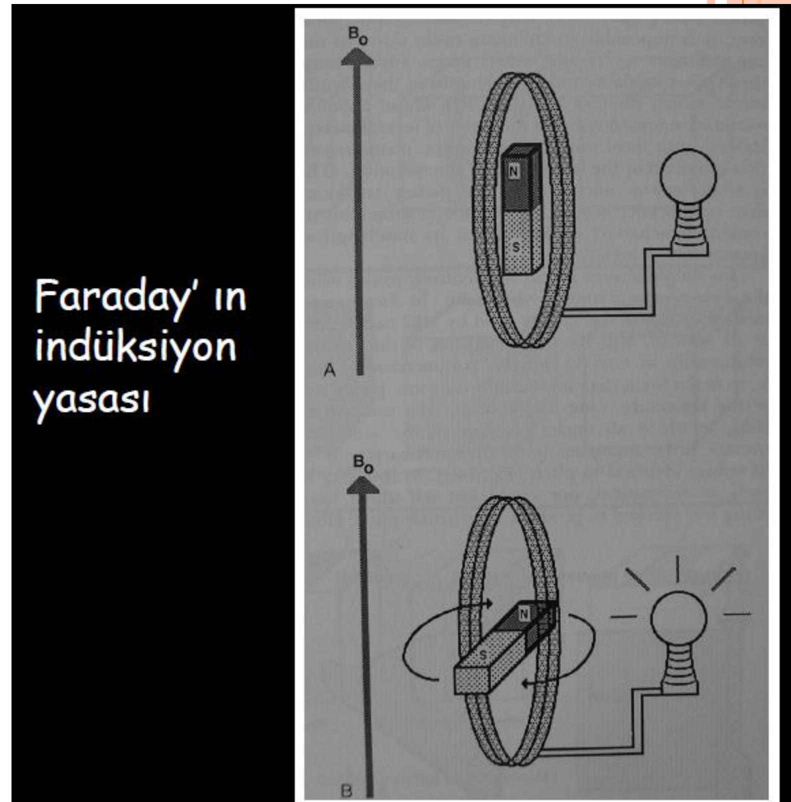
- MRG sisteminin kalbi
  - Güçlü;
  - Homojen;
  - Sabit bir manyetik alan oluşturur





Graph of output current from the AC generator



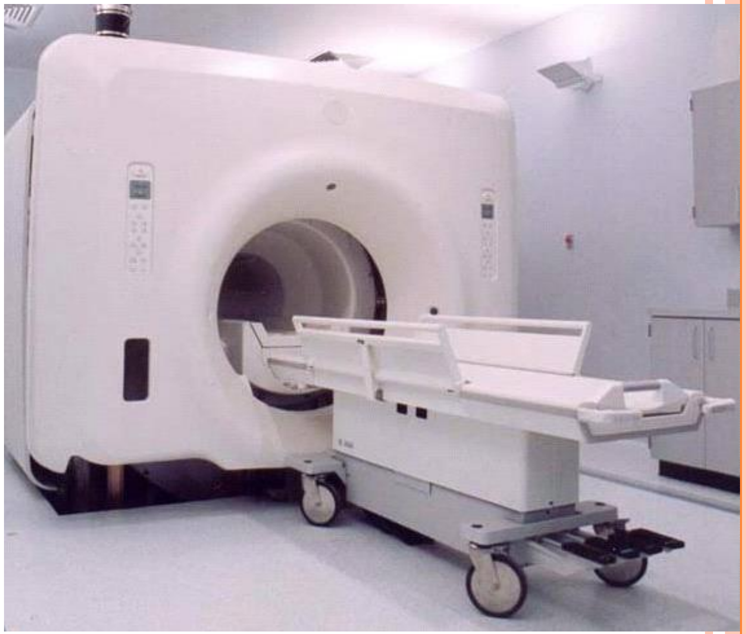


Manyetik alan oluşumu

faradays-law_en.html

•When placed in a "**very**" strong magnetic field, a "**slightly**" greater number of atoms align in the preferred direction with the magnetic field.

Vs.



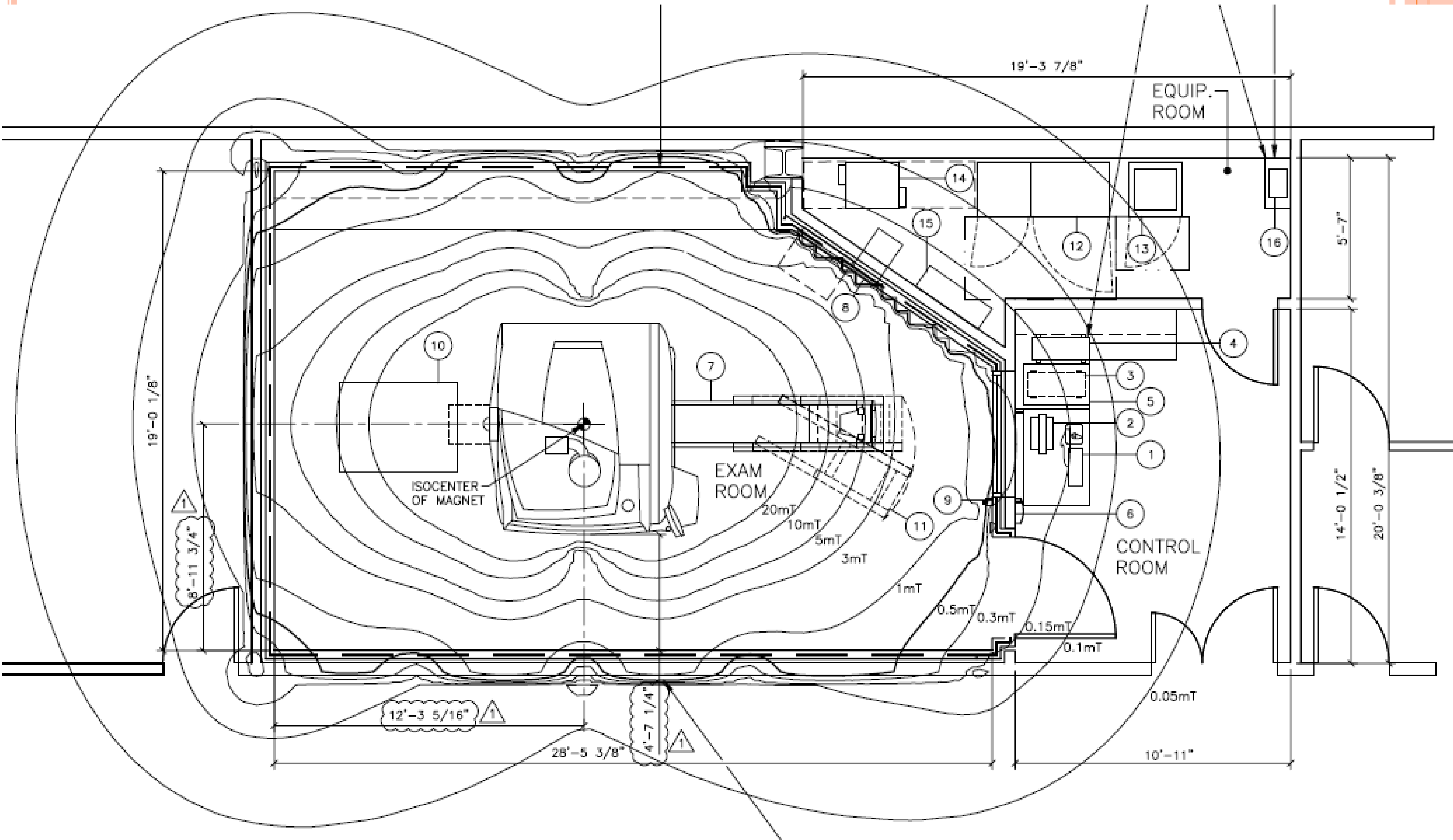
"**very**": The earth's magnetic field is ~ 0.3 Gauss. The scanner at our facility is 30,000 Gauss.

•**Note: 1 Tesla = 10,000 Gauss (Metric)**

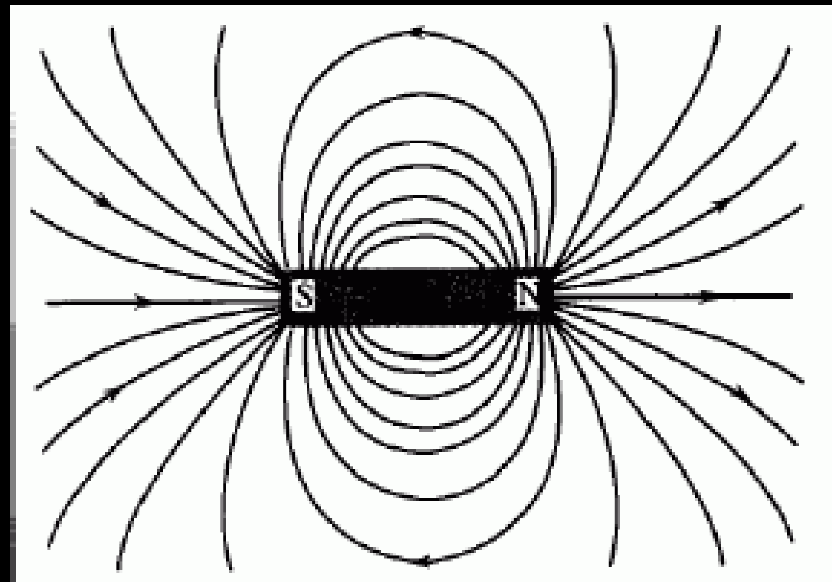
Typical Magnetic Field Map of a Clinical 3T MRI

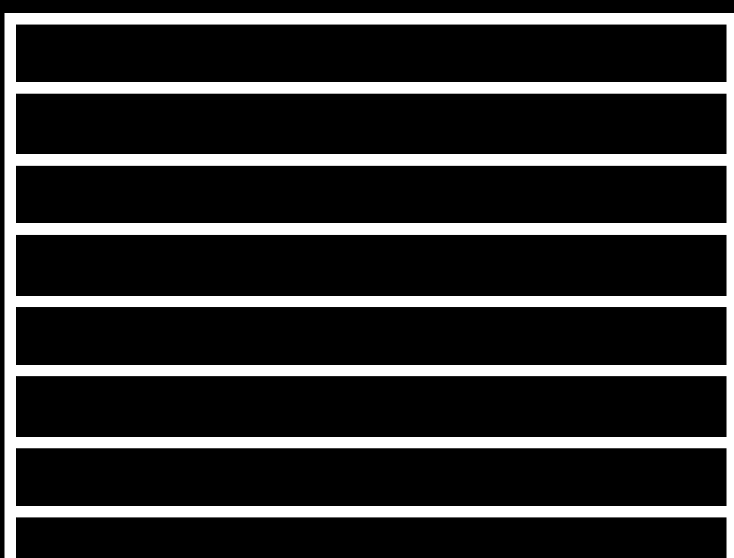
What effects will be felt by a pacemaker, credit cards, earrings, IPAD or cell phone?

https://www.youtube.com/watch?time_continue=140&v=6BBx8BwLhqg



Homojenite



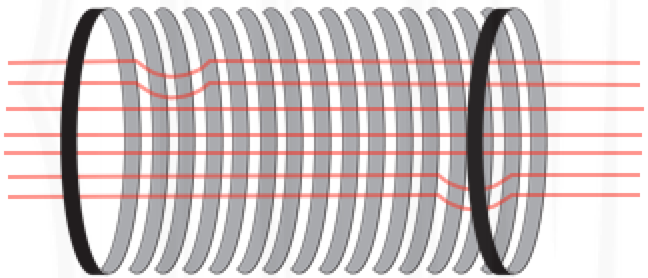


The magnetic field generated by the main superconductive magnet is not perfectly homogenous; **shims passively (cold) or actively (hot) adjust the magnetic field** in order to make it homogenous.

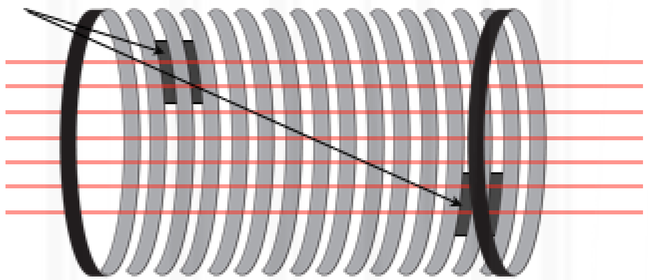
The more homogenous the main magnetic field, the better the final image quality (high resolution and high SNR).

Cold shims: are pieces of magnetic metal (steel). Placed close to the superconducting magnet, they get magnetized and produce their own magnetic field. These shims are initially set up when the superconductive magnet is installed in its definitive environment; they cancel field inhomogeneities due to the surrounding environment and magnet defaults.

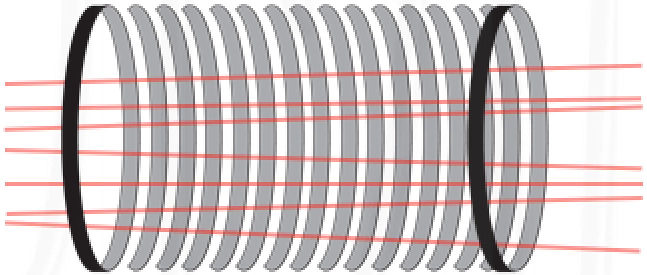
Before

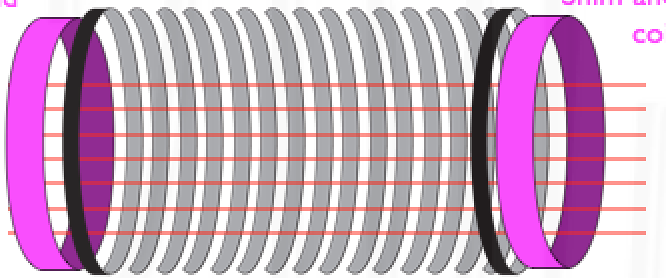


After



Hot shimming: is done using coils (outside of the main magnet coil) with adjustable current. Hot shims are set up before each measurement; they cancel field inhomogeneities created by the subject when placed into the magnet. Gradient coils also serve for the shimming process.





Soru 1

- MRG cihazlarında homojenite birimi nedir?

- A) Gauss / cm
- B) ppm
- C) Tesla
- D) watt/kg
- E) hPa

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- A) Gauss / cm
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- Ppm: parts per million
- Her milyon manyetik alan çizgisi için paralelden sapma gösteren sayı oranı
- Ne kadar küçük ise homojenite o kadar iyi

The magnet is the most expensive component of the MRI system. Three types of magnets are used for MRI; they all provide **homogenous large magnetic fields**. Main differences are magnetic field strengths, energy requirements, production costs and the magnetic field direction.

	Advantages	Disadvantages
Permanent magnets	- little maintenance - no cryogens and no large power supply	- high costs - inhomogeneity of the magnetic field - up to 0.4 T - vertical magnetic field
Resistive magnets	- no cryogens - when current within the coil is switched off, the magnetic field disappears	- constant power supply needed to maintain an homogenous magnetic field - up to 0.4 T
Superconductive magnets	- magnetic field direction along the longer axis of the cylinder - up to 3 T in the clinic and 14 T for research	- cryogens needed to maintain the low temperature of the coils and the superconductivity of the magnet

For MR imaging, **superconductive magnet** are usually used. **Made of a superconductive wire** of several kilometers or miles long, it is **cooled down to close to zero Kelvin** (-273 Celsius degrees) to acquire superconductive properties. Superconductive magnet are **expensive and require regular maintenance.**

Essential features for MRI superconductive magnets are:
- to create a **high, stable and homogenous** magnetic field
- **low energy consumption**
- **a big enough central opening** to enter imaging subjects

Magnet tipleri

- Manyetik alan gücüne göre
  - Düşük Tesla'lı (low-field): 0.2 T altı
  - Orta Tesla'lı (mid-field): 0.2 - 1 T
  - Yüksek Tesla'lı (high-field): 1.5 T üstü

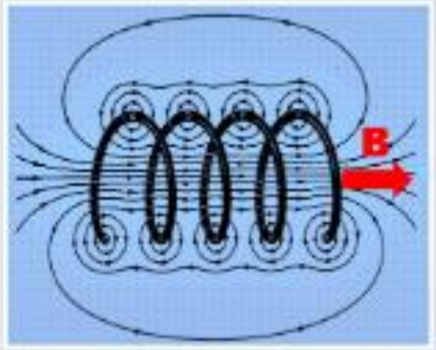
Magnet

- Açık MR

Magnet

Kapalı MR

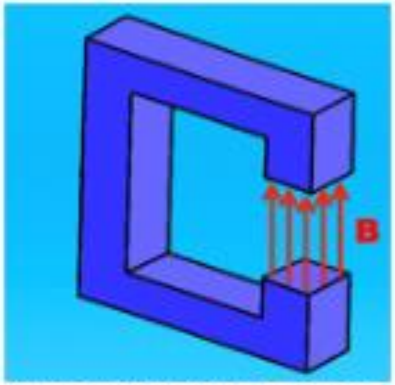
GE Signa 1.5T superconducting scanner



Magnetic field created by solenoid

Closed bore (cylindrical) configuration with superconducting solenoidal design. The coils are bathed liquid helium allowing a stabl homogeneous field to be created, typically 1T and higher.

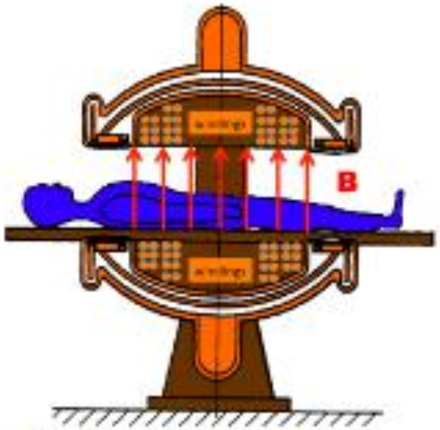
Hitachi Aperto 0.4T permanent magnet scanner



C-shaped permanent magnet

Most **open bore** scanners utilize permanent magnets in C-shaped or horseshoe configuration. These operate at field strengths typically ranging from 0.2T to 1.0T.

Hitachi Oasis 1.2T HFO superconducting



The third design is a **dipolar electromagnet** configuration with coils on either side of the patient. These coils can be superconductive or resistive and range from 0.5T to 1.2T.

Magnet tipleri

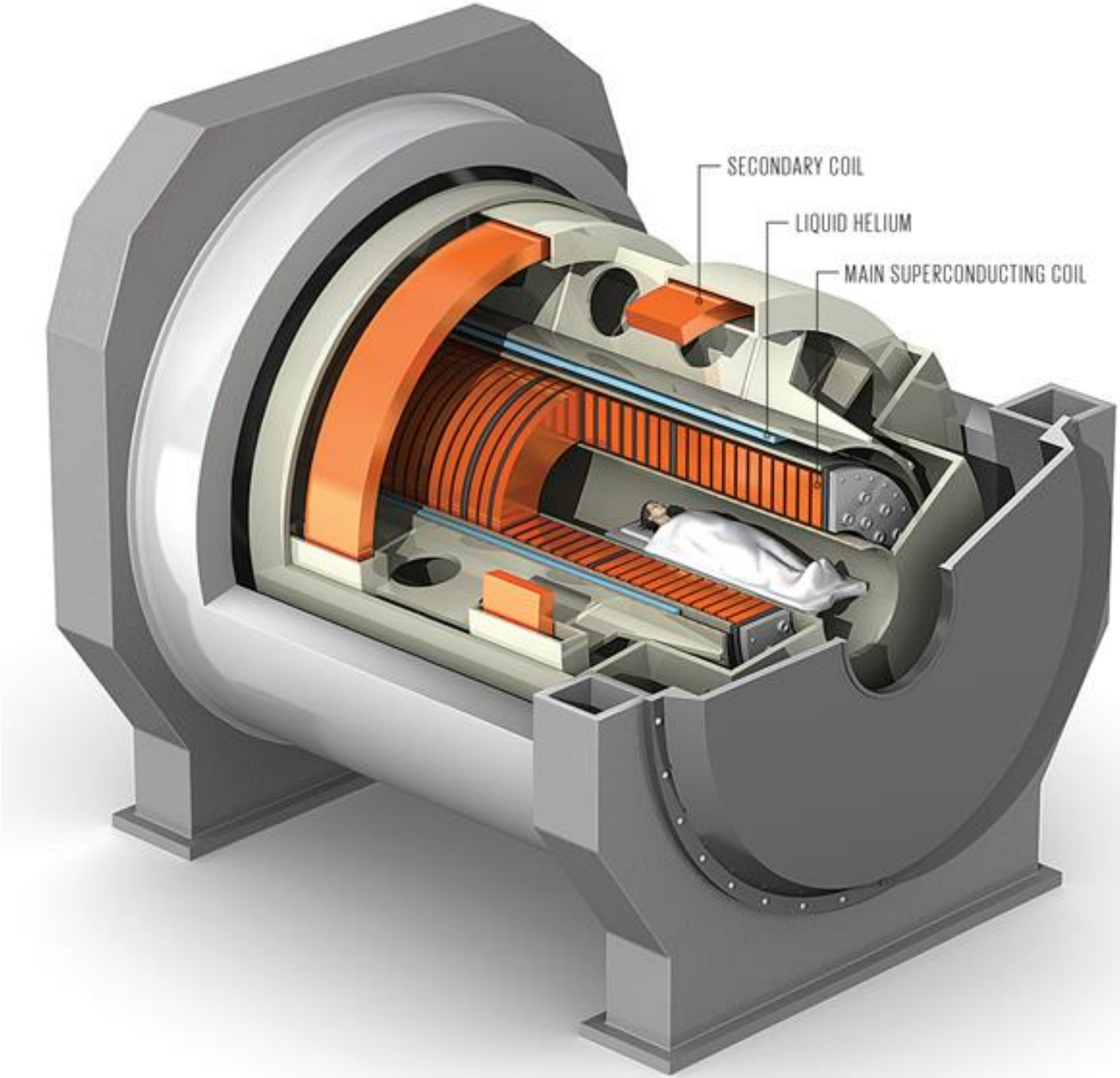
- Manyetik alanın oluşturulma şekline göre
  - Sabit (permanent) magnet
  - Rezistif magnet
  - Süperiletken magnet

Dirençli (Resistive) mıknatıslar, içinden elektrik akımı geçiren bir silindir ya da deliğin etrafına sarılmış çok sayıda iletken teli içeren yapısıyla, manyetik alan oluşmasını sağlarlar. Elektrik kesildiğinde, manyetik alan da ortadan kalkar. Süperiletken mıknatıslara göre daha düşük kurulum bedelleri olmasına karşın, dirençli mıknatıslar, yapısında yer alan iletken tellerin özdirenci nedeniyle, yaklaşık 50KW gibi yüksek güç gerektiren elektrikle çalıştırılırlar. Yaklaşık 0,3 Tesla (T) düzeyini aşan bu tür mıknatısları işletebilmek, işletmeyi engelleyecek kadar yüksek maliyetli olabilir.

Sürekli (Permenant) mıknatıslar, mıknatıs özelliğini, bir dış etkiye bağlı olmaksızın, sürekli sağlayan malzemelerden üretilirler. Bu tür bir mıknatısın manyetik alanı her zaman ve güç kaybı olmaksızın vardır; manyetik alan oluşumu ek maliyet gerektirmez. Ancak bu tür mıknatısların çok ağır olmaları, en olumsuz yönleri. 0,4 tesla düzeyindeki bir manyetik alan oluşturabilen bu mıknatıslar, tonlarca ağırlıkta. Daha güçlü bir manyetik alana gerek duyulduğunda çok çok ağır olduklarından, bu tür sistemlerin kurulum süreci oldukça zor. Sürekli mıknatıslar giderek küçülse de, diğer mıknatıslara göre hâlâ daha düşük güçte alan yaratmakla sınırlılar.

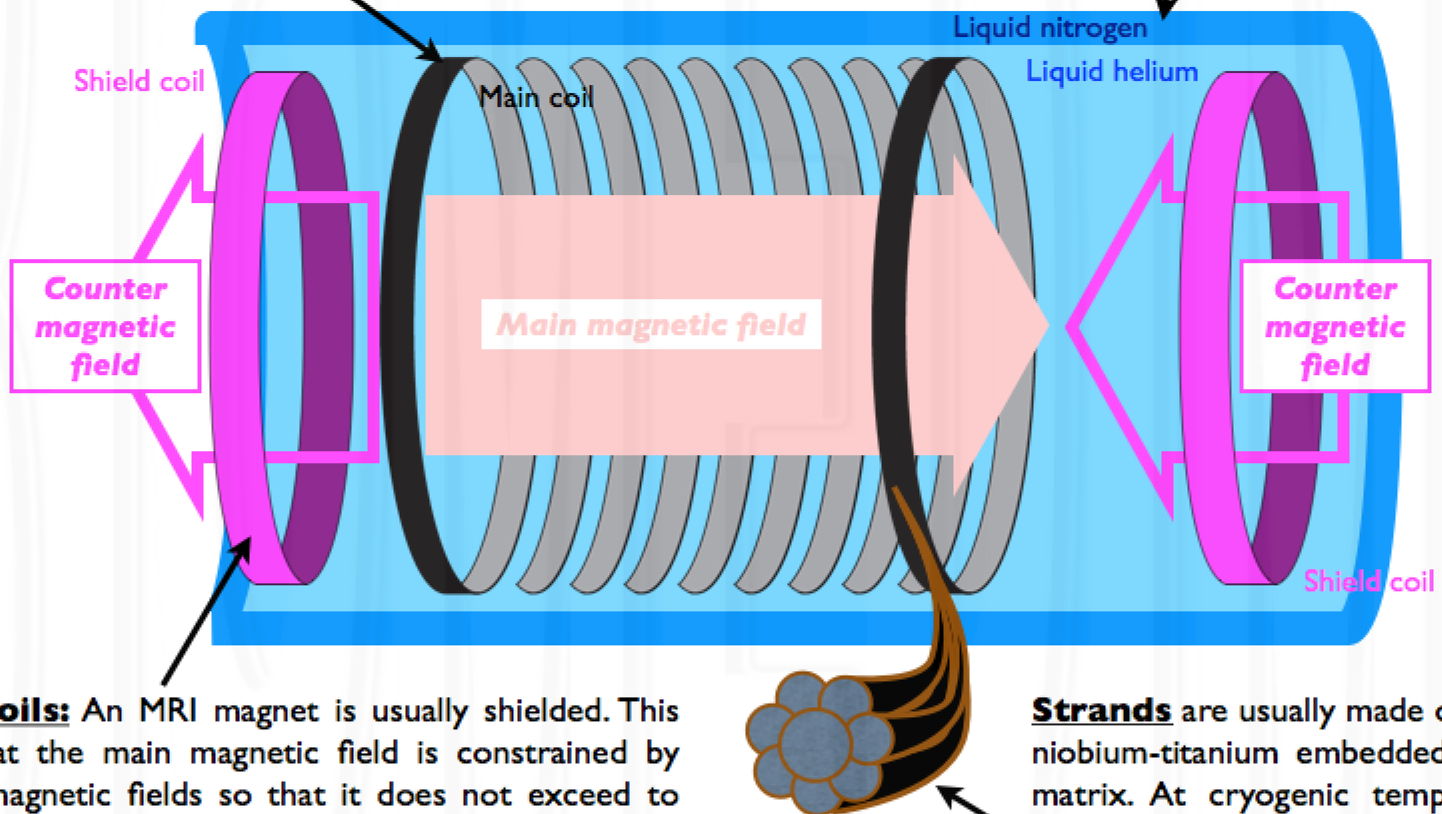
Süperiletken (Superconducting solenoid) mıknatıslar: Dirençli mıknatıslara oldukça benzeyen süperiletken mıknatıslar, yaygın olarak kullanılmaktan uzaklar. Süperiletken mıknatıslar dirençli mıknatıslara oldukça benzerler. En önemli fark, kullanılan tellerin çok düşük sıcaklıktaki sıvı helyumla, sürekli olarak banyo ettirilmesinde yatar. MRI tarayıcının çevresi sıvı helyumla kaplıdır; ama sıvı helyum, vakumlu termoslardakiyle neredeyse aynı biçimde bir vakum tekniğiyle yalıtılmıştır. Hayal edilmesi bile çok güç olan bu soğukluk (10K, -263 derece), sistemin gerek duyduğu elektrik miktarını önemli oranda azaltmaya ve çok daha ekonomik bir işletim yapmaya yarar. Süperiletken sistemler hâlâ çok yüksek maliyetli olmakla birlikte, çok daha yüksek kaliteli görüntülerin elde edilebileceği 0,5 - 2,0 T gücündeki alanları kolayca üretirler.

Mıknatıslar MRI sistemlerin ağırlıkça fazla olmasına neden olurlar, ancak gelişen teknolojiyle üretilen yeni tür sistemlerde ağırlık giderek azalmakta; 8 yaşındaki bir MRI sistem 7 tonu aşan bir ağırlıktayken, yeni tür bir MRI sistemin ağırlığı 4 tona kadar düşürülebilmiş. Yeni mıknatısların boyları da eski modellerde olduğundan daha kısa üretilebilmekte. Mıknatıs uzunluğu, kapalı yer korkusu taşıyan hastalar için çok önemli bir sorun; bu nedenle, yeni sistemler gittikçe hasta dostu hale getirilmekte.


SECONDARY COIL
LIQUID HELIUM
MAIN SUPERCONDUCTING COIL

A superconducting magnet is **an infinite coil** made of superconducting strands in which an electric current is flowing inducing a strong magnetic field inside the coil.
Strands must be cooled down until the point it offers no more resistance to electric current (no energy is lost as heat).

Cryogenic system: the main coil is housed in a thermally insulated container filled with liquid helium. This is the cryostat. In order to keep the cryostat as cold as possible and by this saving liquid helium dispersion, the cryostat is constructed with an outer compartment containing liquid nitrogen or a refrigerating system.



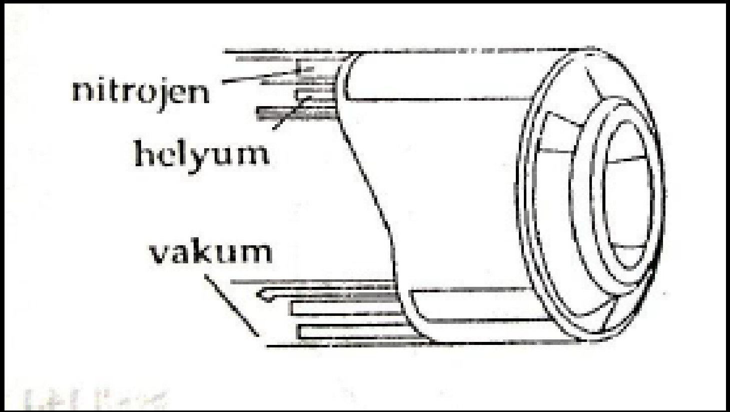
Shield coils: An MRI magnet is usually shielded. This means that the main magnetic field is constrained by counter magnetic fields so that it does not exceed to much outside of the main coil.
Shielding coils are also superconductive coils places on both side of the main coil.

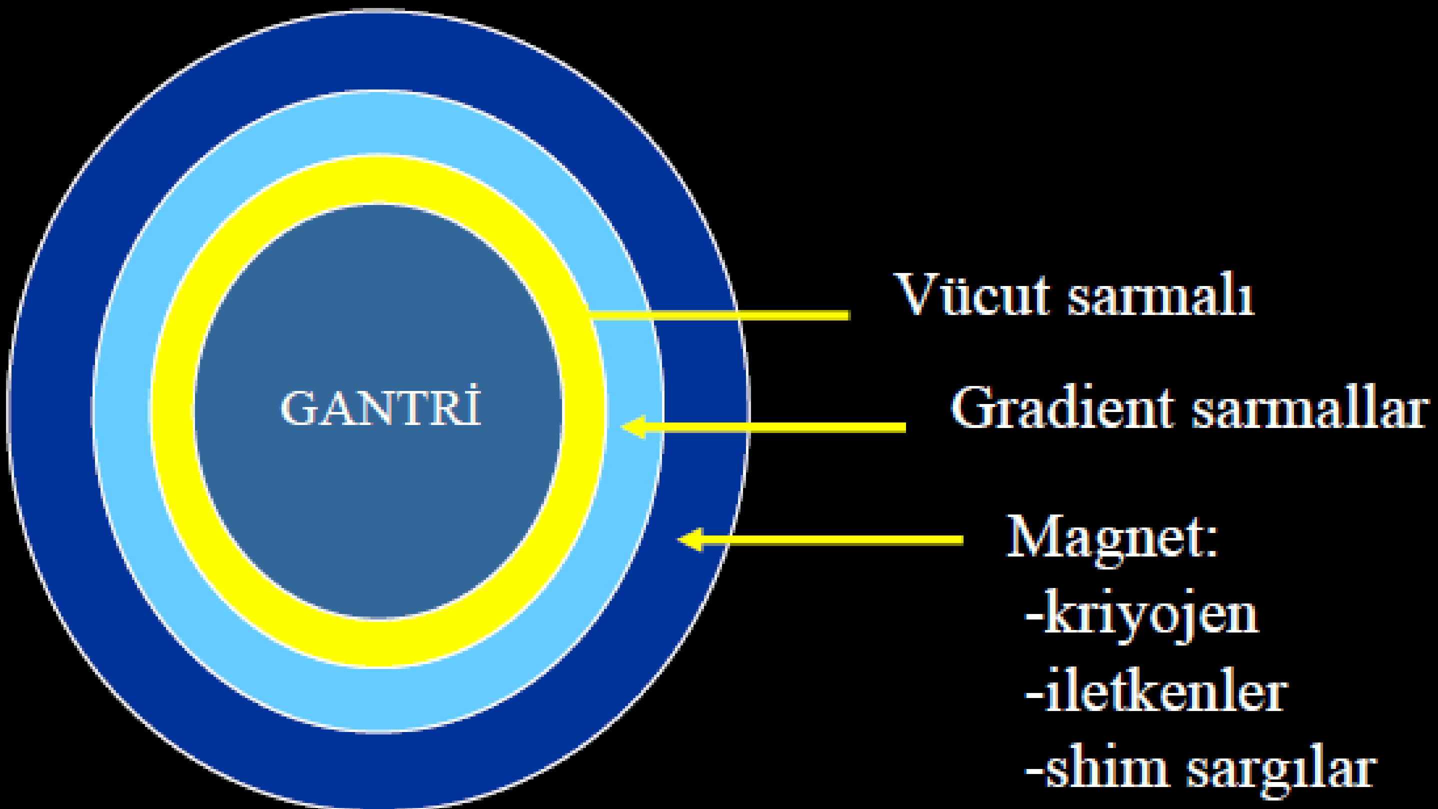
Strands are usually made of filaments of niobium-titanium embedded in a copper matrix. At cryogenic temperatures, the current flow at the surface of niobium-titanium filaments and copper acts as an insulator between strands.

Süperiletken Magnet

- Kriyojen: Kaynama derecesi -160° C (110 K) nin altında olan sıvılar (azot, helyum gibi)

- Kriyostat: İçinde kryojenleri ve bakır iletkenleri bulunduran, iç içe geçmiş ünitelerden oluşan, vakumlu, termos benzeri yapı



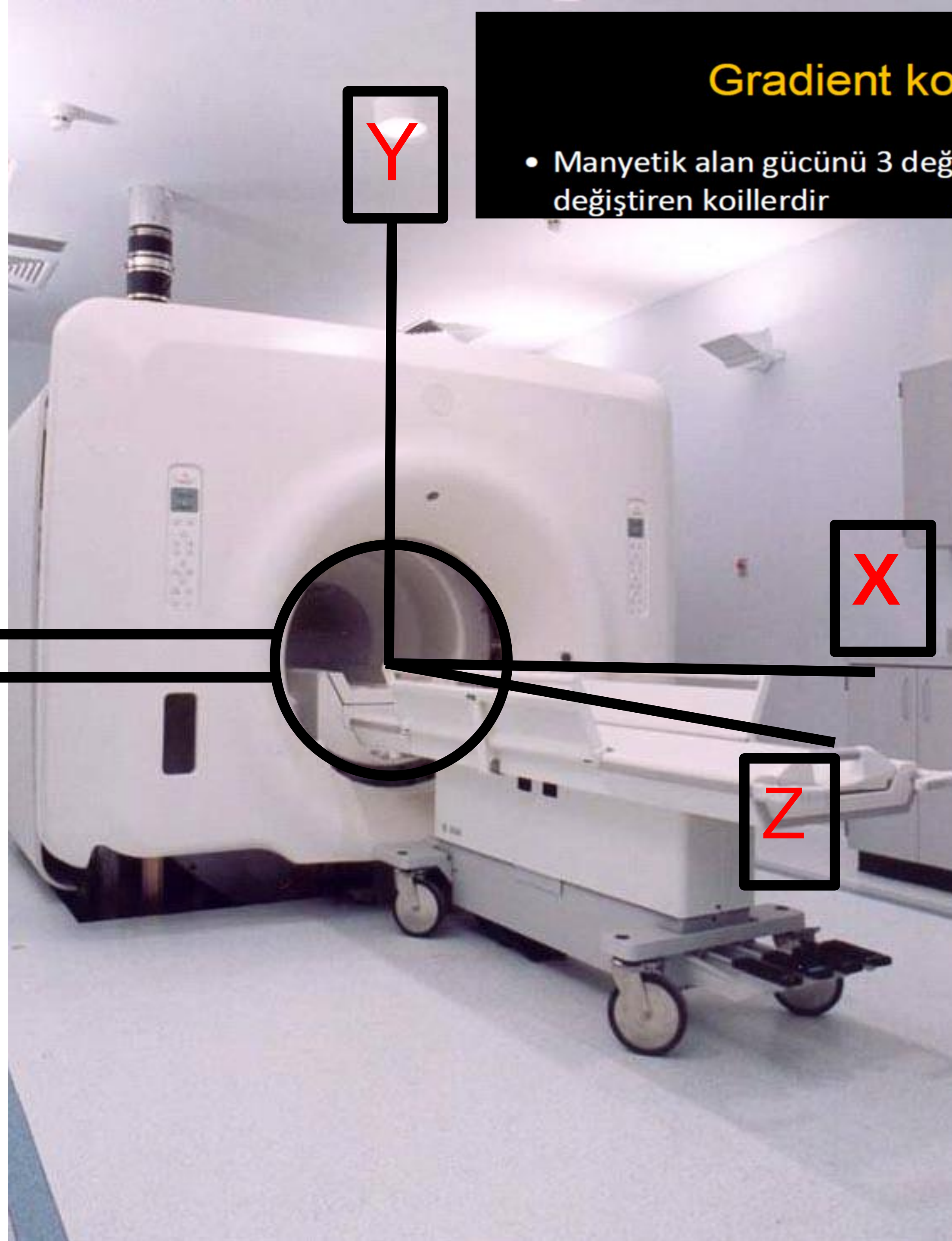

GANTRİ
Vücut sarmalı
Gradient sarmallar
Magnet:
-kriyojen
-iletkenler
-shim sargılar

Gradient koiller

- Manyetik alan gücünü 3 değişik düzlemde değiştiren koillerdir

MRI Scanner

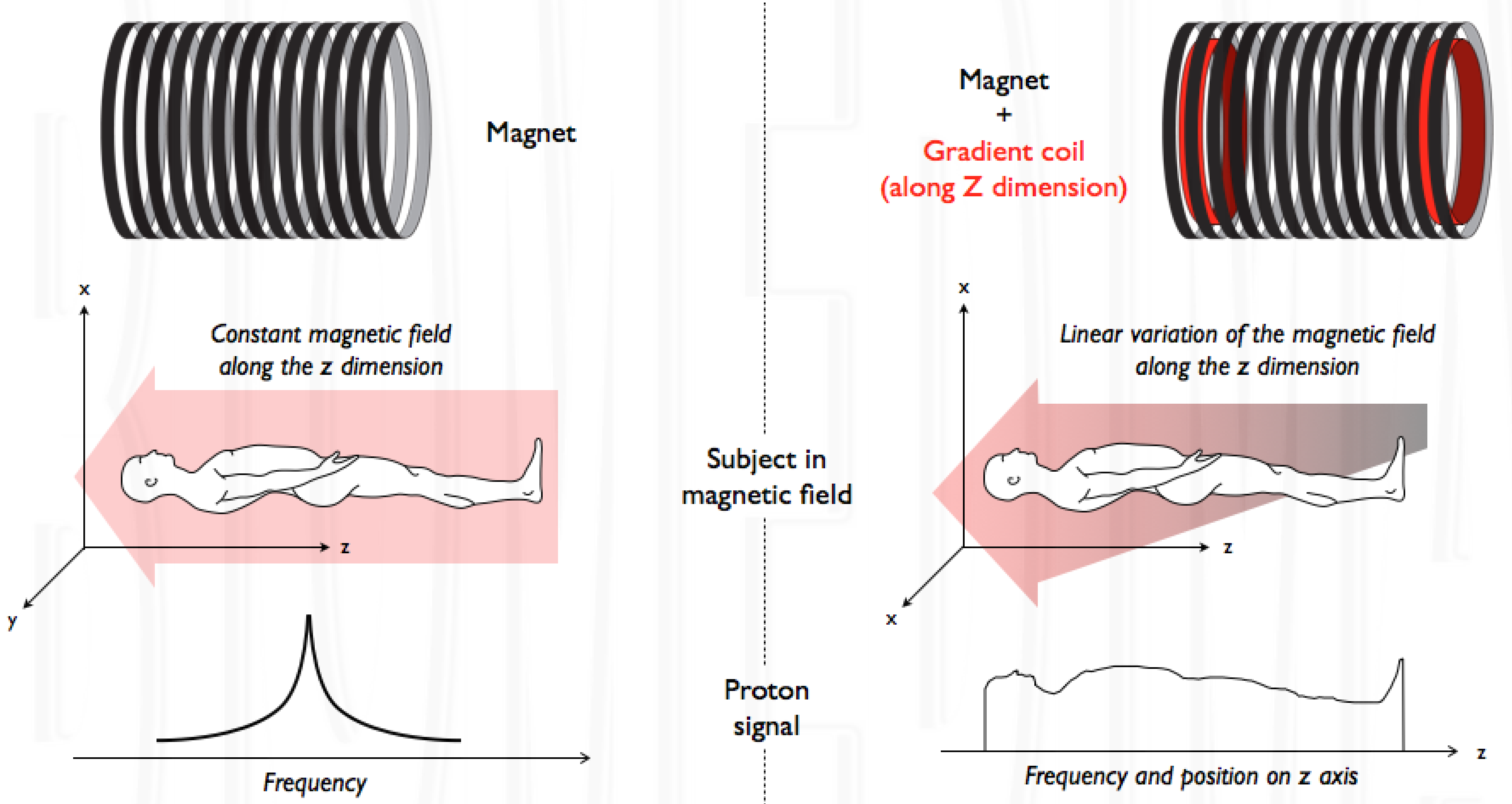
Coil



Gradient koiller

- MRG’ de sinyalin nereden geldiğinin saptanmasını ve dolayısı ile kesit alınabilmesini sağlayan koillerdir

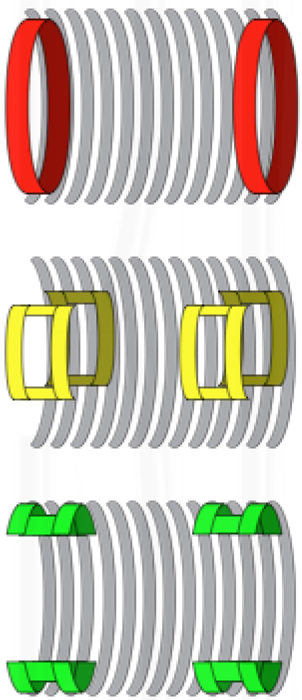
Gradient coils are located **inside the main superconductive coil**. They are at room temperature and allow to **linearly vary the main magnetic field** by superimposing a gradient magnetic field.

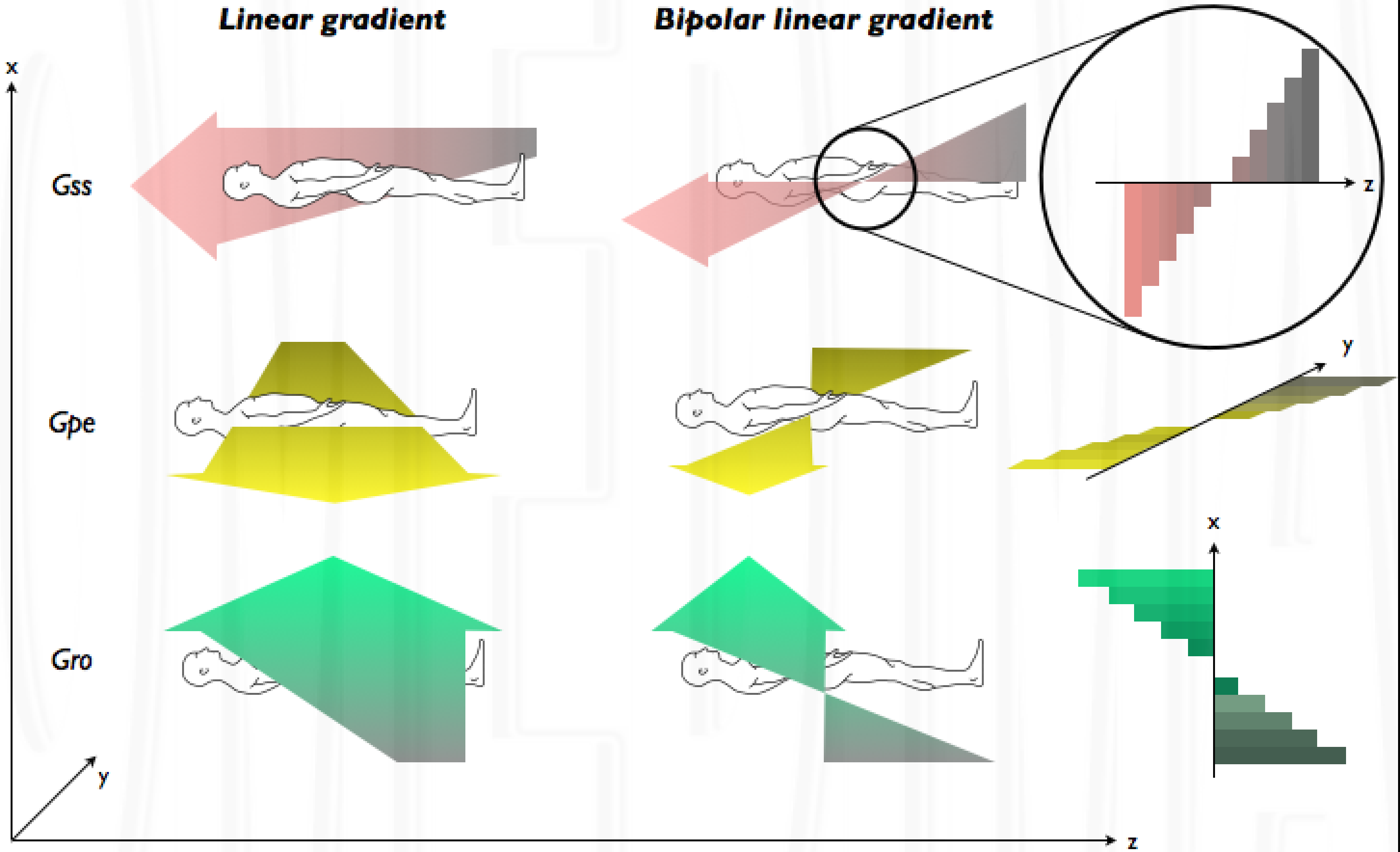


As the spinning frequency of protons is directly proportional to the main magnetic field strength, gradient coils allow to discriminate adjacent protons according to their spinning frequency.

Three sets of gradient coils modulate the main magnetic field **along the three dimensions**. Gradient coils generate a **linear variation of the main magnetic field** allowing to spatially code the MR signal. This applies along the three space directions (x, y and z).

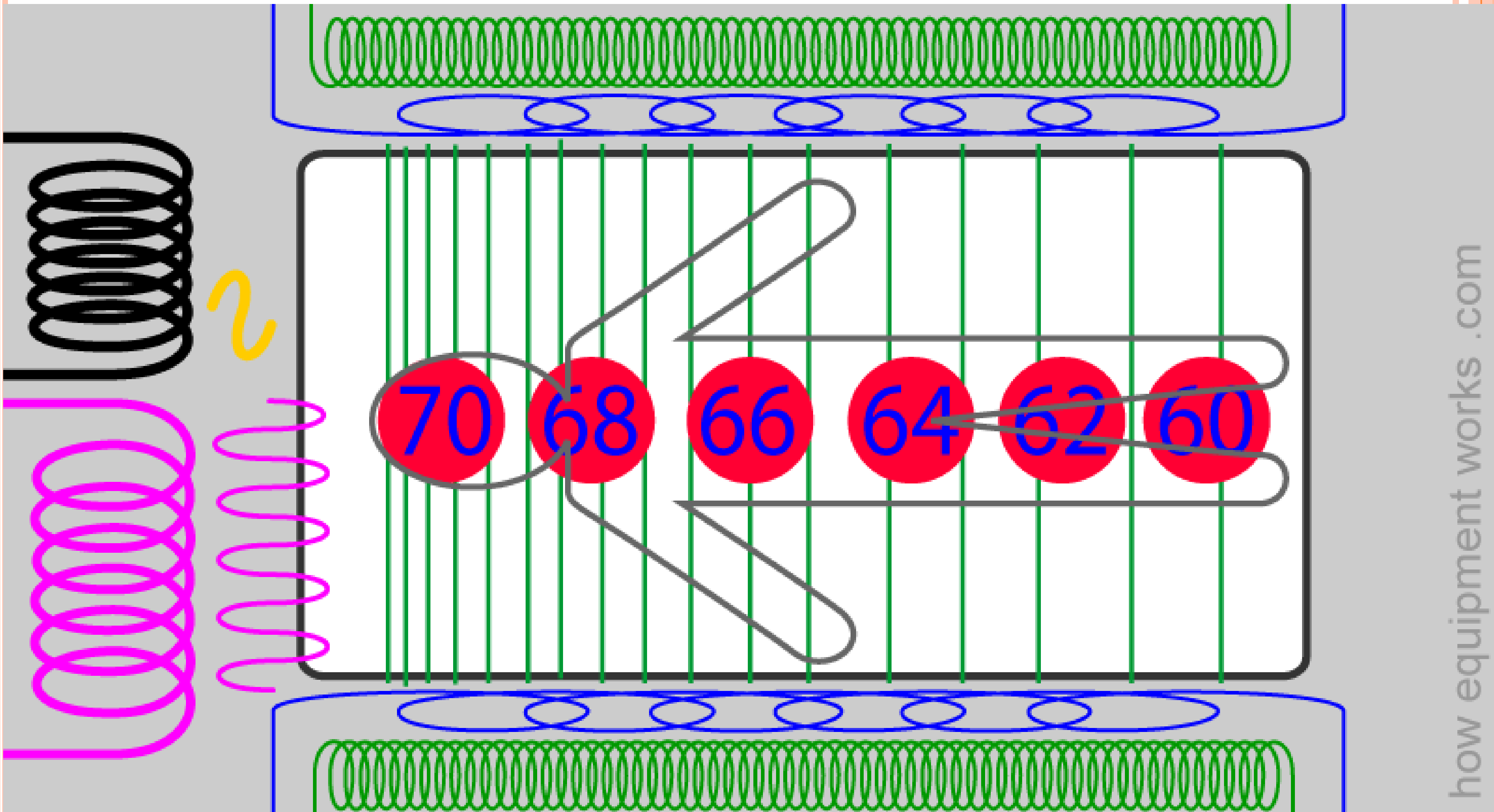
Gradient coils inside the main coil





A gradient is generated by two opposite coils in which circulate opposite electrical currents.

Gradient strengths of 100 milliTesla per meter are achieved with fast switching rates. This allows to achieve **sub-millimetric slice thickness** in the three dimensions.


70
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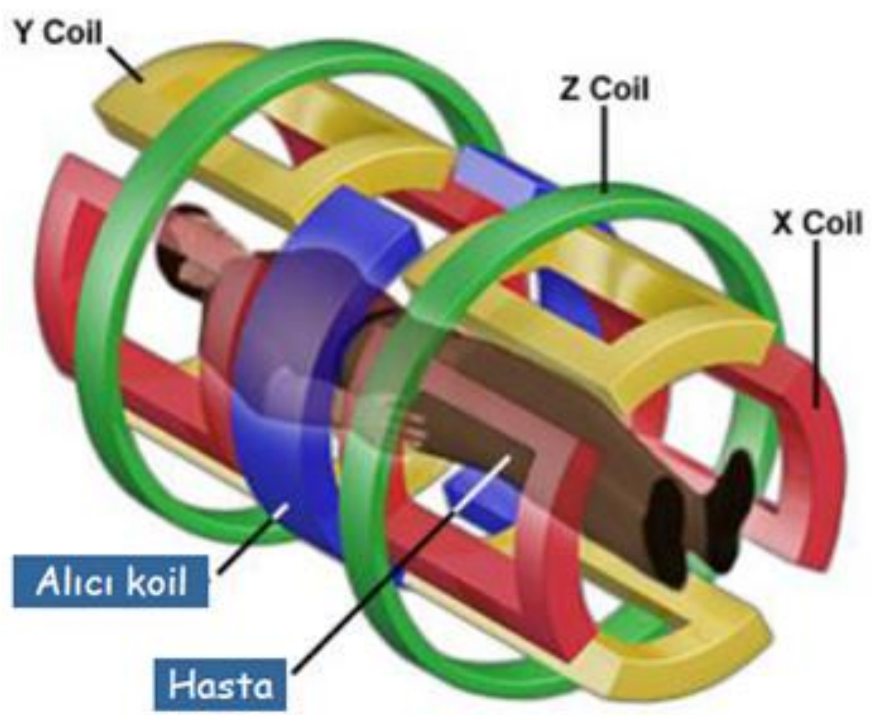
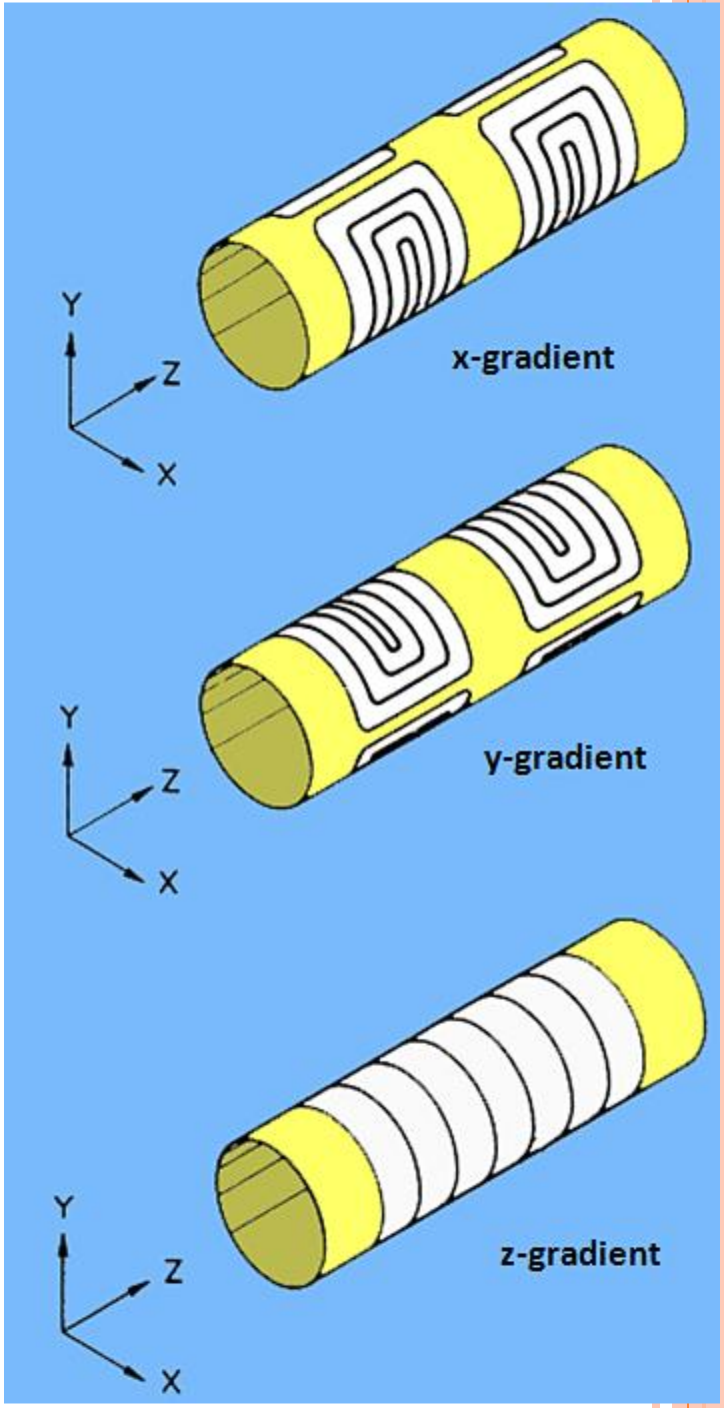
how equipment works .com

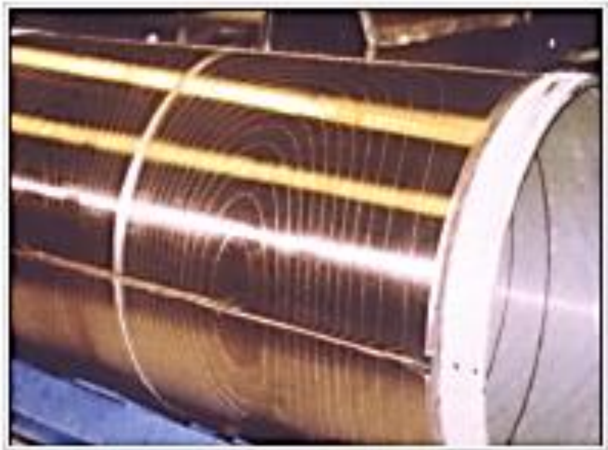
Gradient koiller





Gradient coils with discrete wire windings in a 7T scanner (from Human Connectisome Project)

Gradient coil with thin metallic strips being applied in a fingerprint pattern to a former (courtesy Siemens)



Gradient coil with distributed windings etched into copper conducting sheets (courtesy GEMS)

Detaylı bilgi için:
http://mriquestions.com/gradient-coils.html

Soru 2

- MRG cihazının merkezinde gürültü düzeyi ne kadardır?

- A) 20 dB
- B) 50 dB
- C) 72.3 dB
- D) 110 dB
- E) Sessizlik hakimdir

Soru 2

- MRG cihazının merkezinde gürültü düzeyi ne kadardır?

- A) 20 dB
- B) 50 dB
- C) 72.3 dB
- D) 110 dB
- E) Sessizlik hakimdir

How loud is loud?

20 dB	Ticking watch	85 dB	Average traffic
30 dB	Quiet whisper	95 dB	MRI
40 dB	Refrigerator hum	100 dB	Blow dryer, subway train
50 dB	Rainfall	105 dB	Power mower, chainsaw
60 dB	Sewing machine	110 dB	Screaming child
70 dB	Washing machine	120 dB	Rock concert, thunderclap
80 dB	Alarm clock (two feet away)	130 dB	Jackhammer, jet plane (100 feet away)

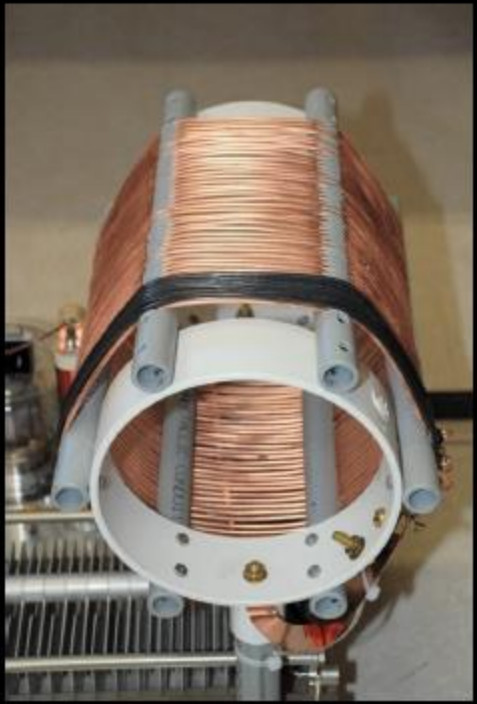
Fast imaging sequences such as EPI/Spiral used in functional neuroimaging (fMRI) can play upwards of 100+ decibels inside the bore of the scanner.

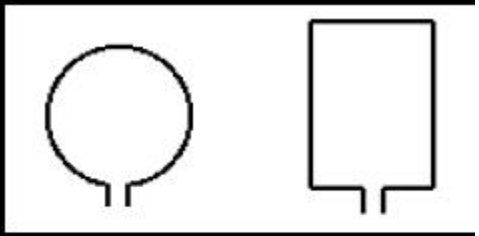
RF koiller

- Kullanıldıkları anatomik bölgeye göre
- Kafa, vücut, ekstremite, spine, TME,....

- Dokudaki protonları uyarmak için RF pulsunu gönderen ve gelen sinyali algılayan bakır sargılar.

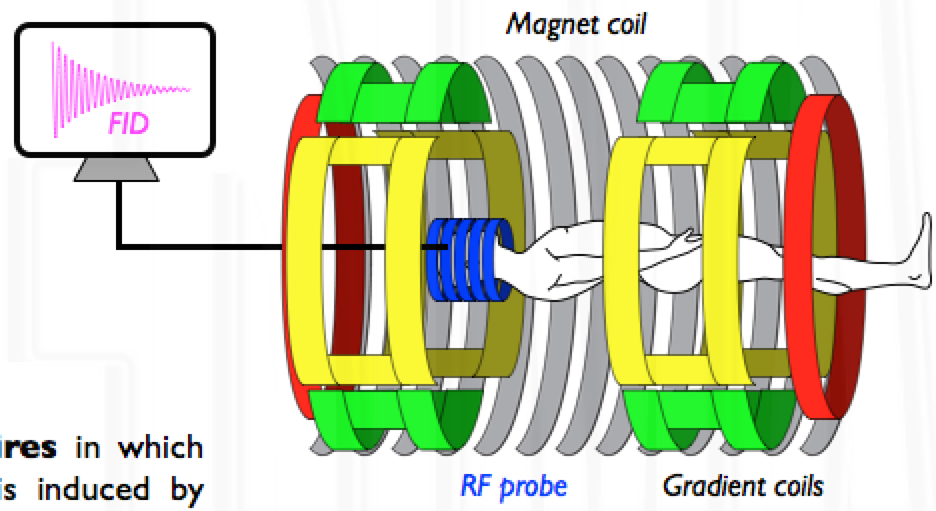
- Koil= sargı=sarmal=bobin





Radio frequency (RF) probes

During an MRI experiment, **a RF probe emits RF pulses** to tilt protons spins in a non-equilibrium state; then protons relax and **a RF probe records the emitted signal**.

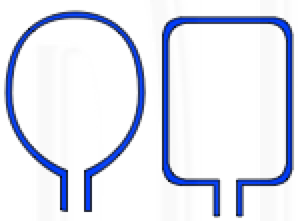


<u>RF emission/reception strategies</u>:

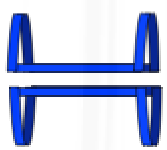
- emission and reception are performed by the same coil: **a transmit-receive coil.**
- emission is performed by a fixed coil located inside the main magnetic field coil and a small probe, wrapping the anatomical region to image, records the signal.

RF probes are composed by **coils of conductive wires** in which either a current circulate (RF emission) or a current is induced by proton magnetic changes (RF reception).

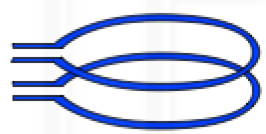
The closer the receiving RF coils, the better the signal-to-noise ratio.



Surface coils
Made of many individual coils connected to each other assembled in a layer wrapping the body part to image.



Whole-volume coils
Barrel-shaped coils surrounding either the whole body or a specific region to image.



Helmholtz pair coil
Two circular coil parallel to each other. Used for pelvis or spine imaging.

Recording proton signal is critical for MR image quality as **it directly relates to signal-to-noise ratio (SNR).** Relaxation signal is weak and noise relatively strong; for optimal signal detection, RF probes must be positioned:

- within the magnet as close as possible to the area to image (probes shape must match the anatomical part to image)
- at right angles to the main external magnetic field

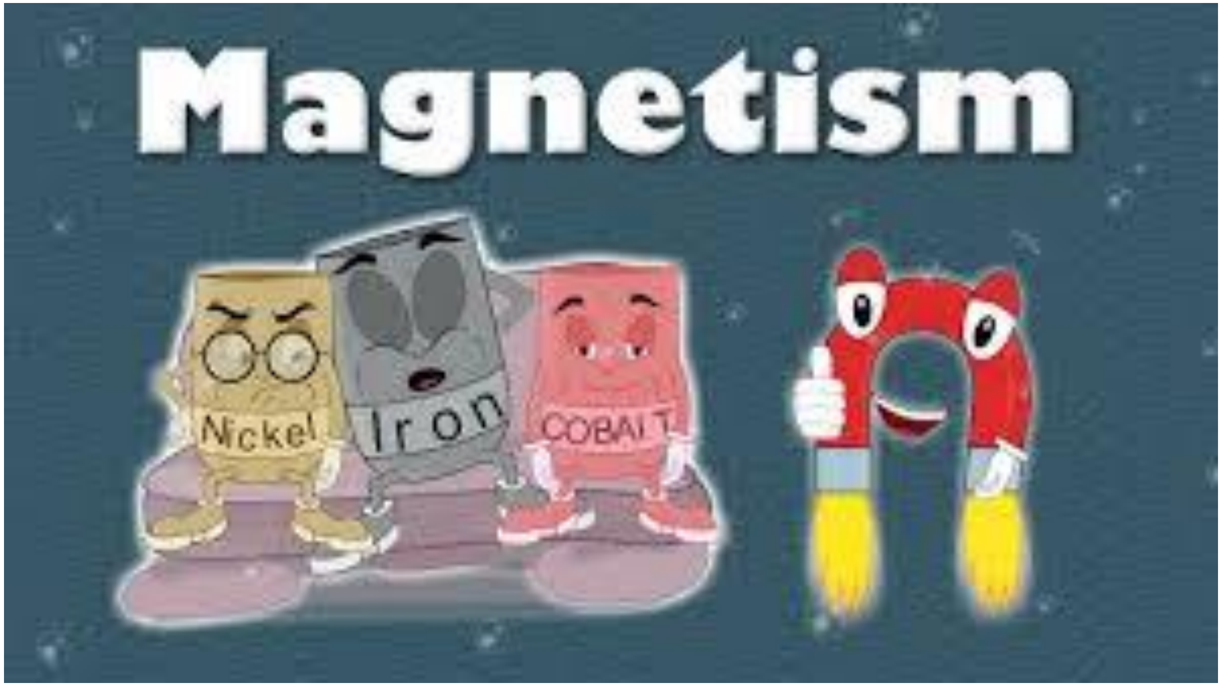
Manyetik

Rezonans

Görüntüleme

Manyetizma

İki cismin arasındaki çekme veya itme kuvveti



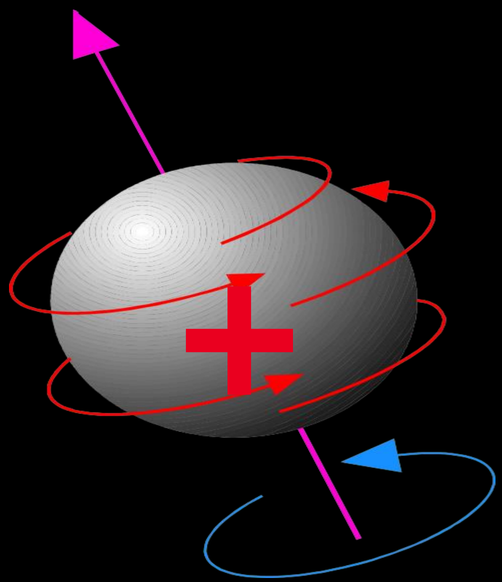
Manyetizma

Mikroskopik (Nükleer) manyetizma

Eksternal (dışsal) manyetizma

Mikroskopik (nükleer) manyetizma

Elektrik yüklü parçacıkların hareketi ile oluşur



elektrik yük

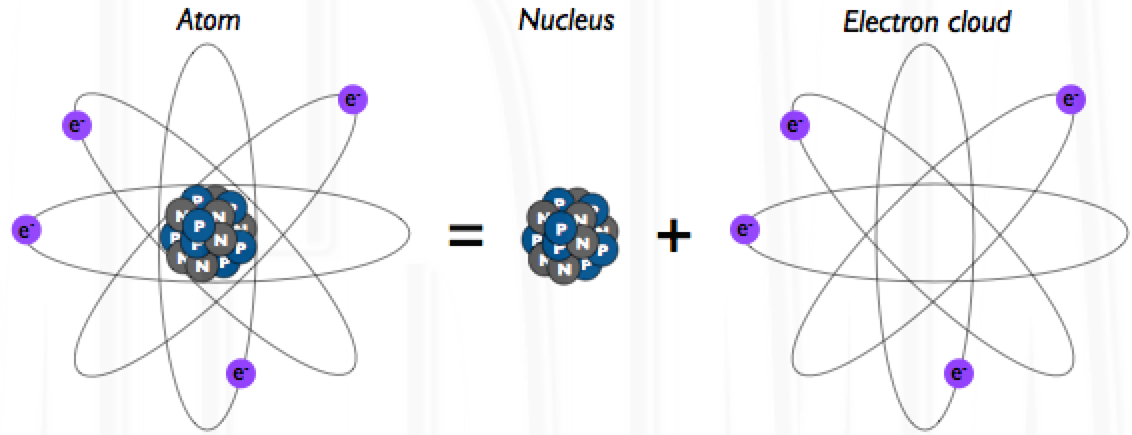
+

rotasyon

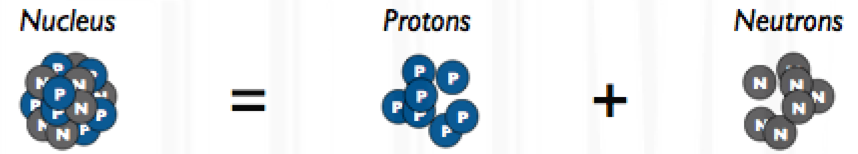
manyetizma

Atoms consist of **a dense nucleus** surrounded by **orbiting electrons**.

The nucleus, always positively charged, is composed by **positively charged protons (P)** and **neutral (not charged) neutrons (N)**.



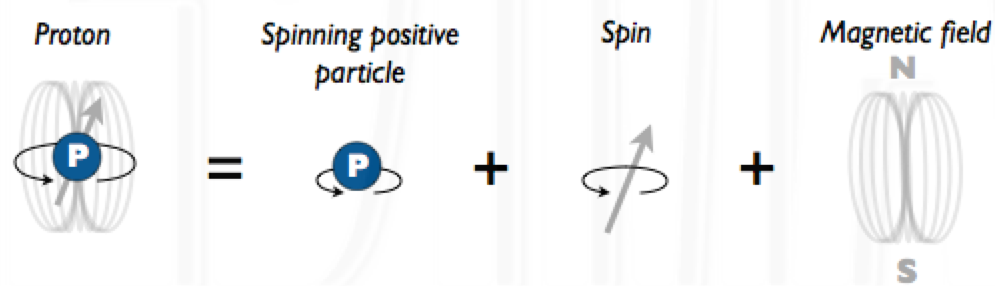
Negatively charged electrons balance the positive charge of the nucleus.



The hydrogen atom is composed of one proton and one electron.

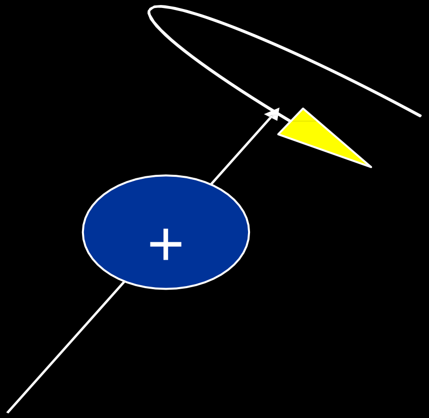
The spin is the intrinsic magnetic angular moment (rotation around a North/South axis). It is a fundamental property of elementary particles such as protons.

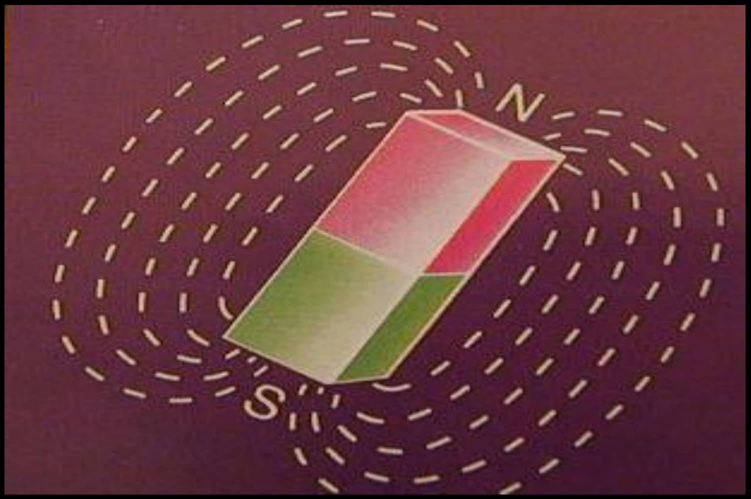
The consequence of a spinning positive charge (proton) is the creation of a tiny magnetic field around it.



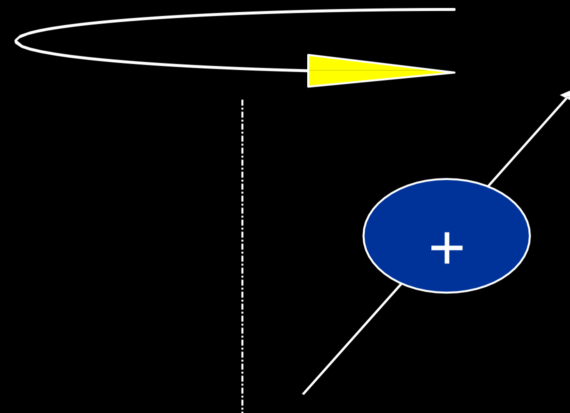
NUCLEUS	γ (MHz/T)	NATURAL ISOTOPIC ABUNDANCE (%)	RELATIVE SENSITIVITY*	SPIN
^{1}H	42.576	99.985	1	½
^{2}H	6.536	0.015	0.0096	1
^{13}C	10.705	1.108	0.016	½
^{14}N	3.076	99.635	0.001	1
^{15}N	4.315	0.365	0.001	½
^{17}O	5.772	0.037	0.029	3/2
^{19}F	40.055	100	0.834	½
^{23}Na	11.262	100	0.093	3/2
^{31}P	17.236	100	0.066	½
^{33}S	3.266	0.74	0.0023	3/2
^{39}K	1.987	93.08	0.0005	3/2

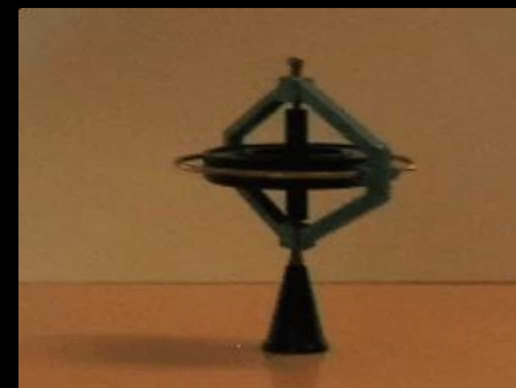
Spin





Salınım (Presesyon)



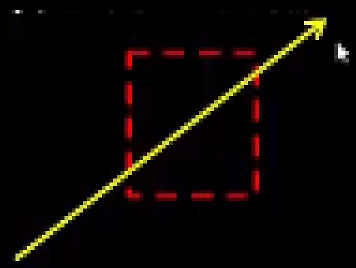


gyroscope

Dışsal Manyetik Alan (B_0)

Gauss / Tesla birimi ile ölçülür

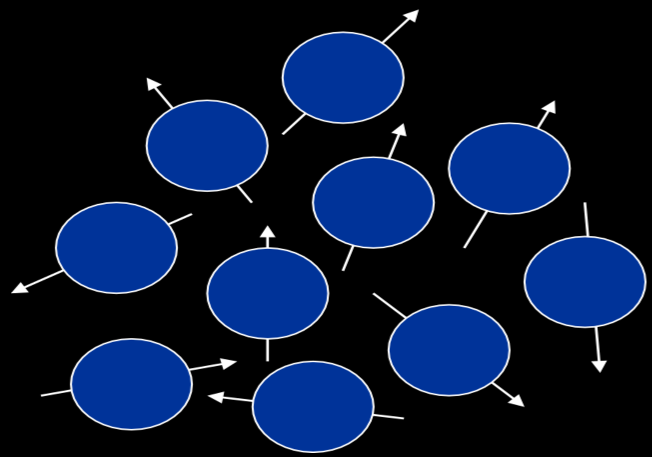
1 Gauss = 1 santimetrekarede 1 manyetik alan çizgisi

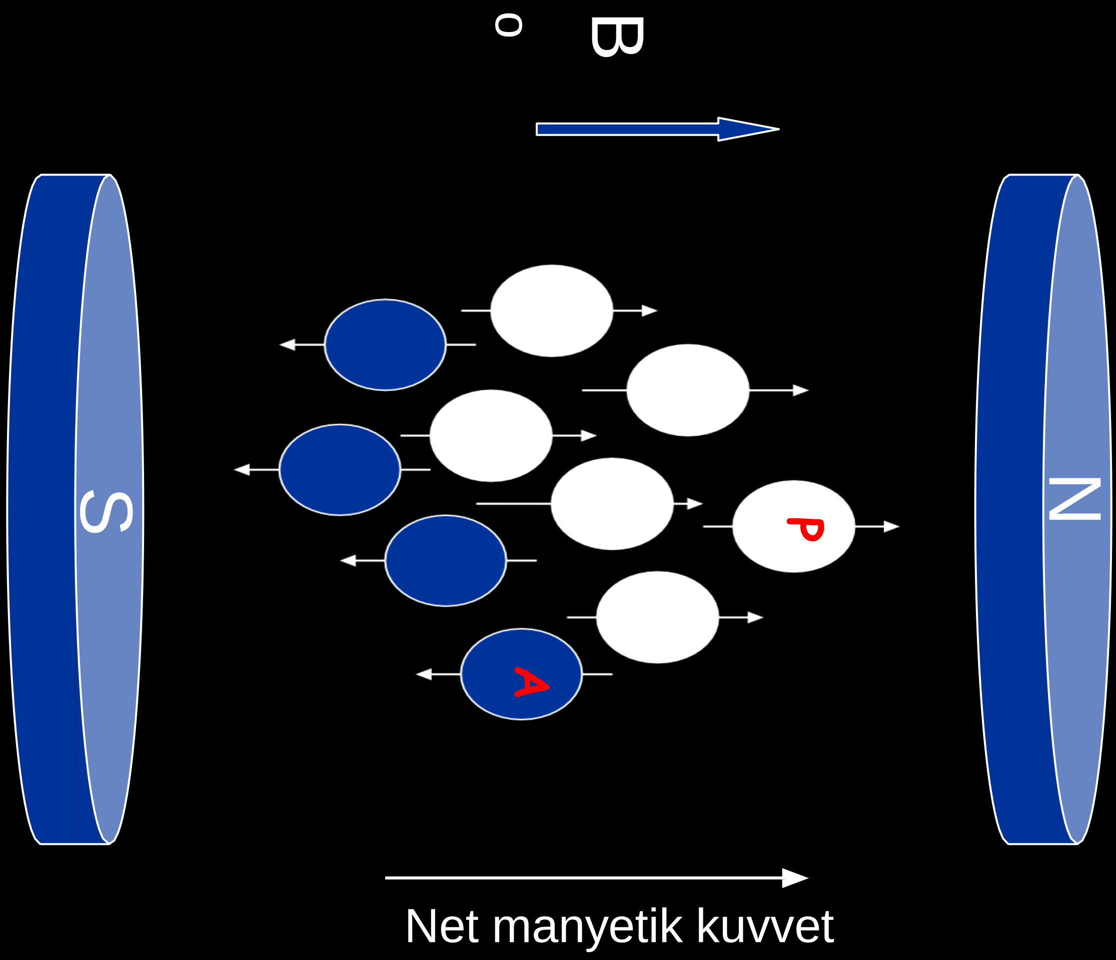


Yerkürenin manyetik alan gücü 0.5 Gauss'tur

10.000 Gauss = 1 Tesla

Dış manyetik alan yok




B
o
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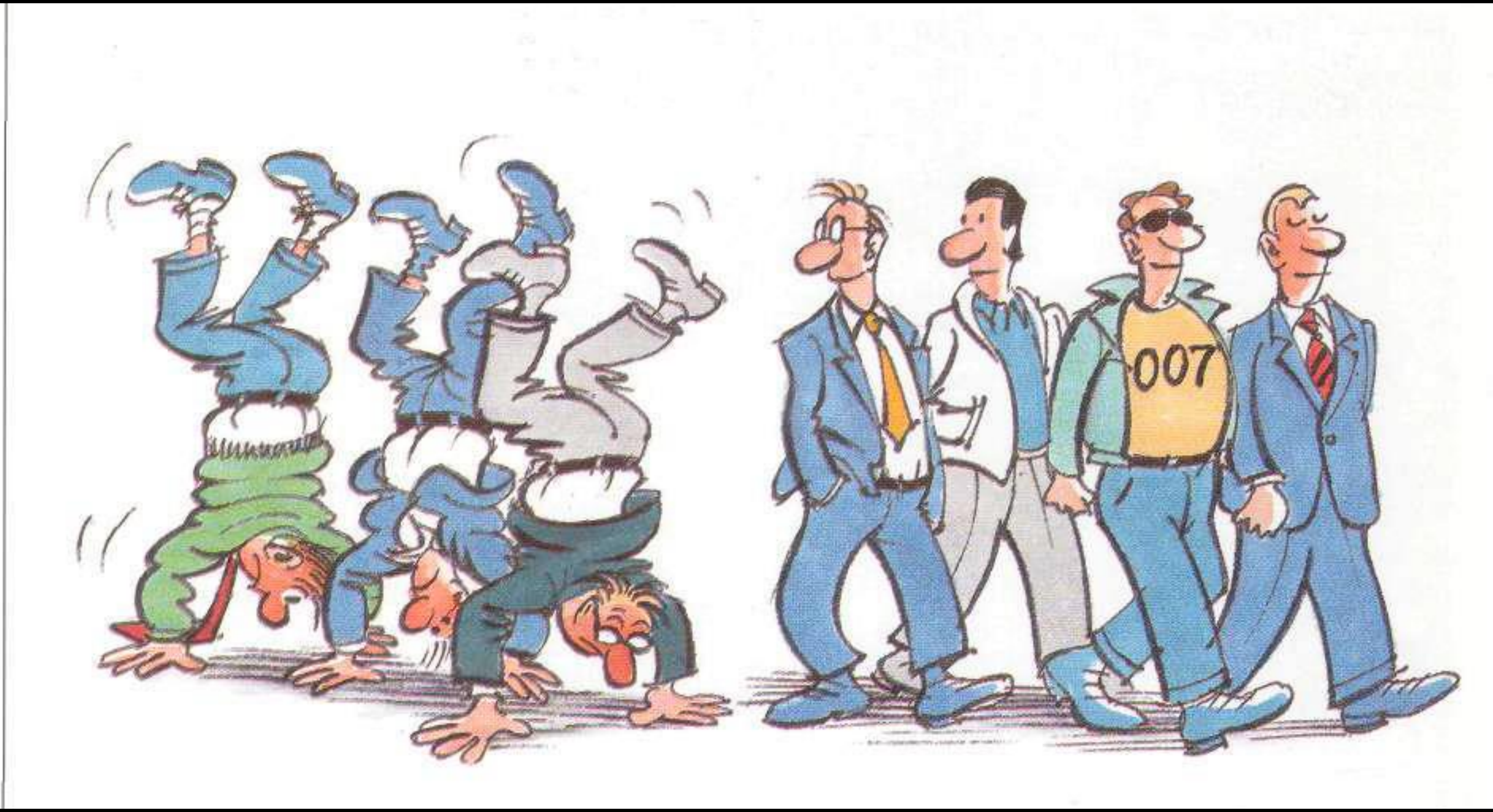
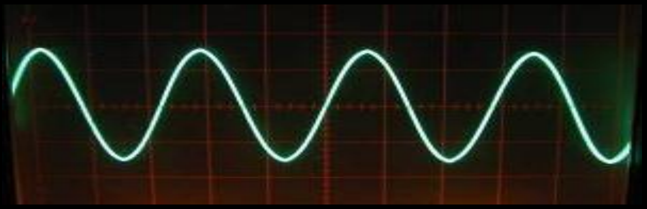
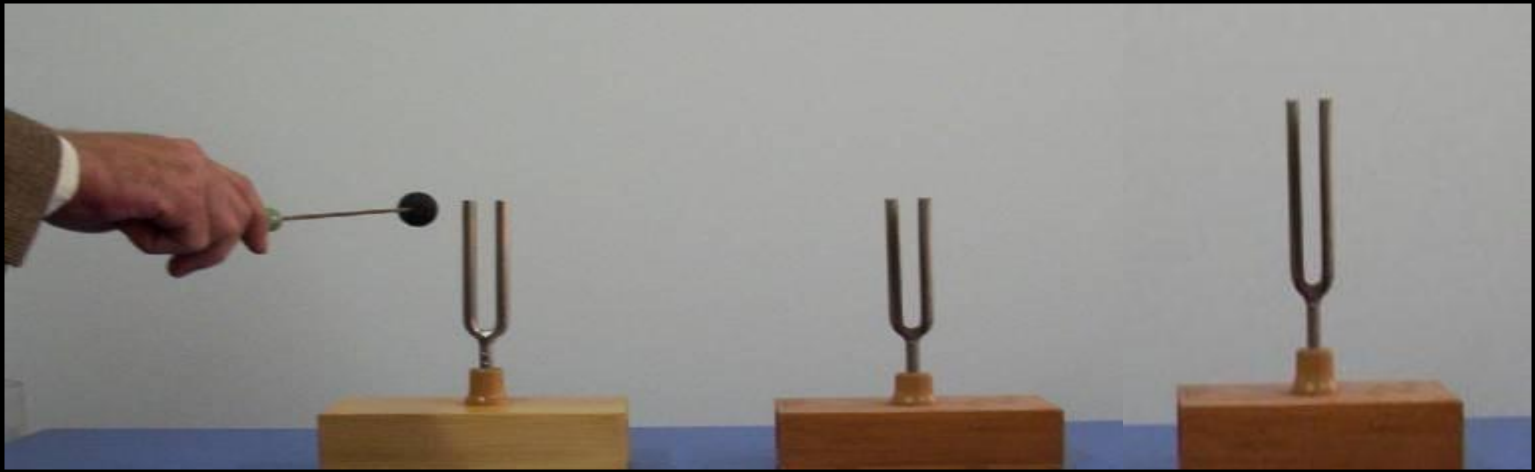
Net manyetik kuvvet



Antiparalel Paralel

Rezonans

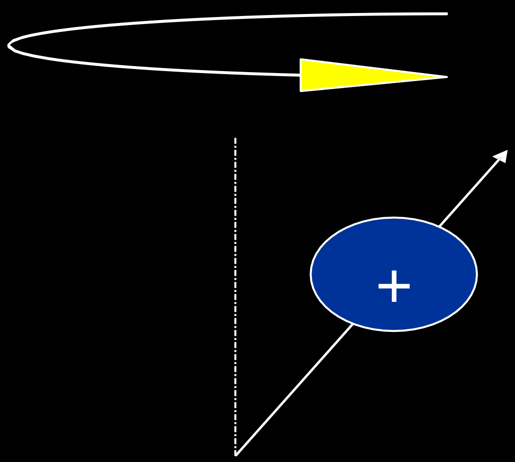




Rezonans

Belirli bir frekansta titreşen sisteme (aynı frekans ile) enerji aktarımı

MRG pratiğinde protonların salınım frekansına eşit frekansta radyo dalgaları ile enerji aktarılması ya da uyarılmasıdır



Protonların salınım frekansı kaçtır?

Larmor Denklemi

$$\omega_0 = \gamma . B_0$$

Frekans = Sabit x Dış manyetik alan gücü

Soru 3

- Hidrojen için γ değeri nedir?

- A) 11,1 MHz
- B) 23,2 MHz
- C) 43,6 MHz
- D) 63,9 MHz
- E) Ölçülemez

Soru 3

- Hidrojen için γ değeri nedir?

- A) 11,1 MHz
- B) 23,2 MHz
- C) 43,6 MHz
- D) 63,9 MHz
- E) Ölçülemez

1 Tesla:
proton salınım frekansı 42.6 MHz
(γ)

1 Hz = Saniyede bir salınım

SORU:
1.5 T da salınım frekansı ne olur ?
63.9 Mhz

RF pulsu

- Güçlü manyetik alan (B_0) içindeki protonlar, Larmor frekansına eşit frekansta radyofrekans (RF pulsu) ile uyarılır (enerji aktarılır)

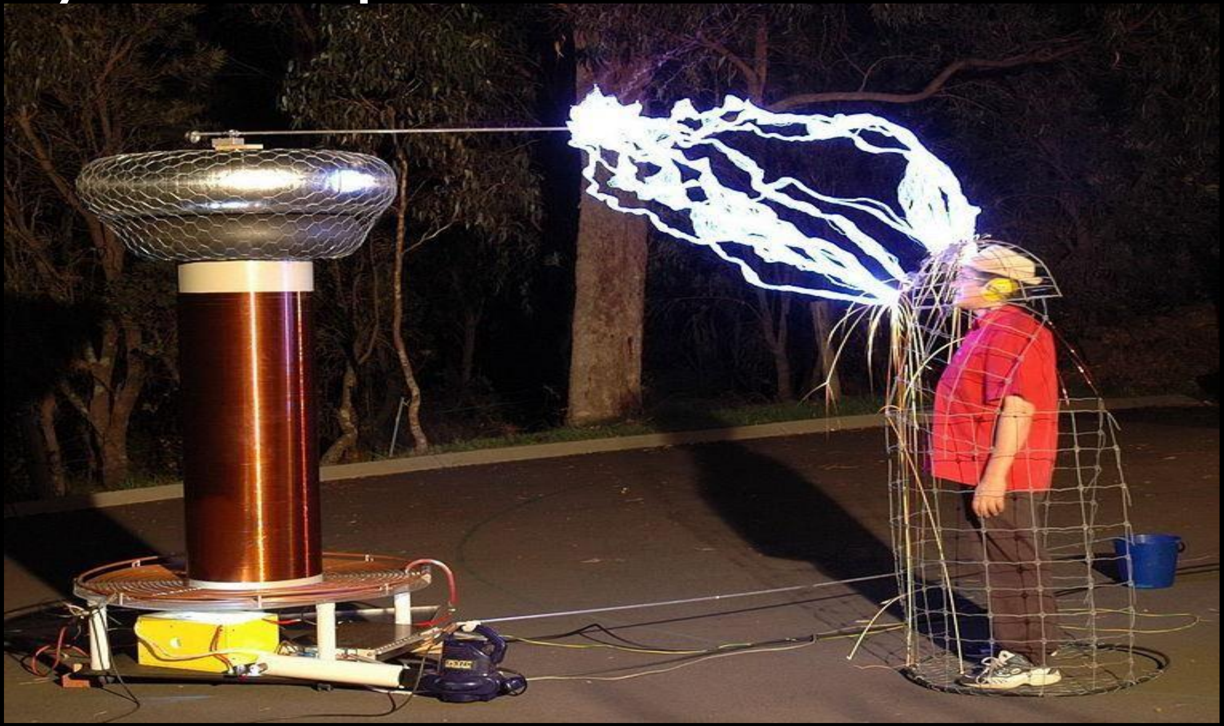
- RF dalgası, radyo istasyonlarının kullandıkları frekans spektrumu içinde kalan bir elektromanyetik dalga türüdür.

- Elektrikle çalışan birçok aygıt benzer radyo dalgaları üretir (asansör, otomobil vb gibi hareketli olanlarda daha belirgin).

- Dış kaynaklı RF dalgaları manyetik inhomojeniteyi bozabilir. Bu nedenle çekim odaları izole edilir (Faraday kafesi).

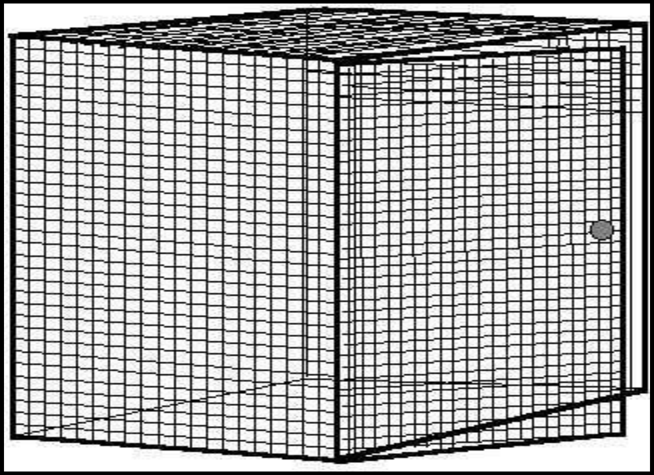
Shielding (kalkanlama)

- Faraday kafesi prensibi



Shielding (kalkanlama)

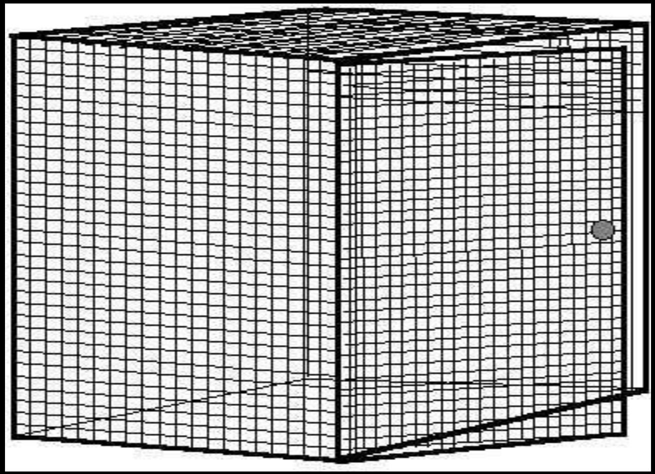
- Faraday kafesi prensibi



- İletken tellerden örülmüş kafes yapısı, içerideki hacme elektriksel alanların geçişine izin vermez

Shielding (kalkanlama)

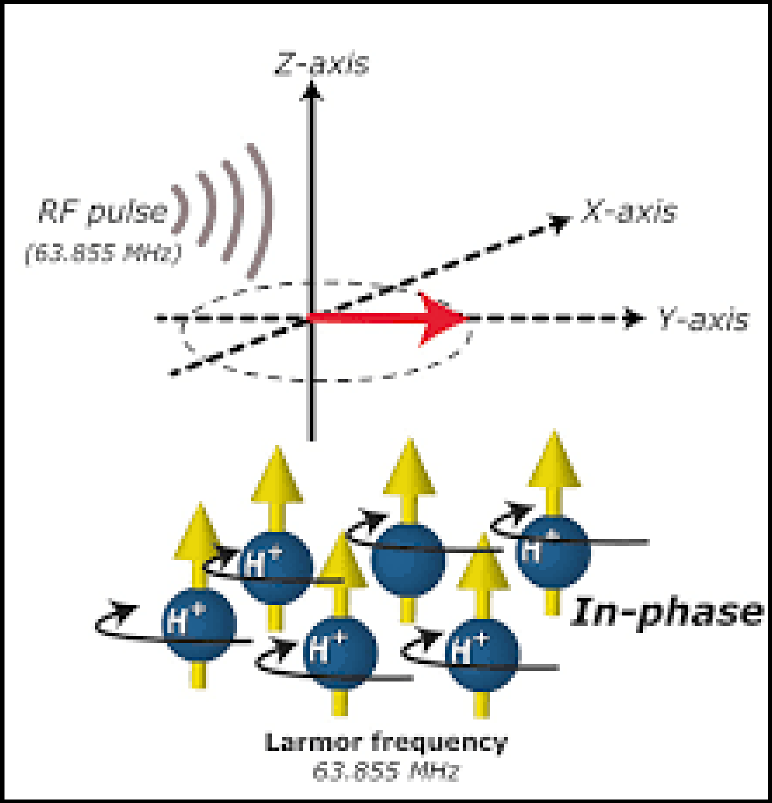
- Çekim odasının duvarları bu tip iletken teller ve levhalar ile sarılır
- (pasif kalkanlama)

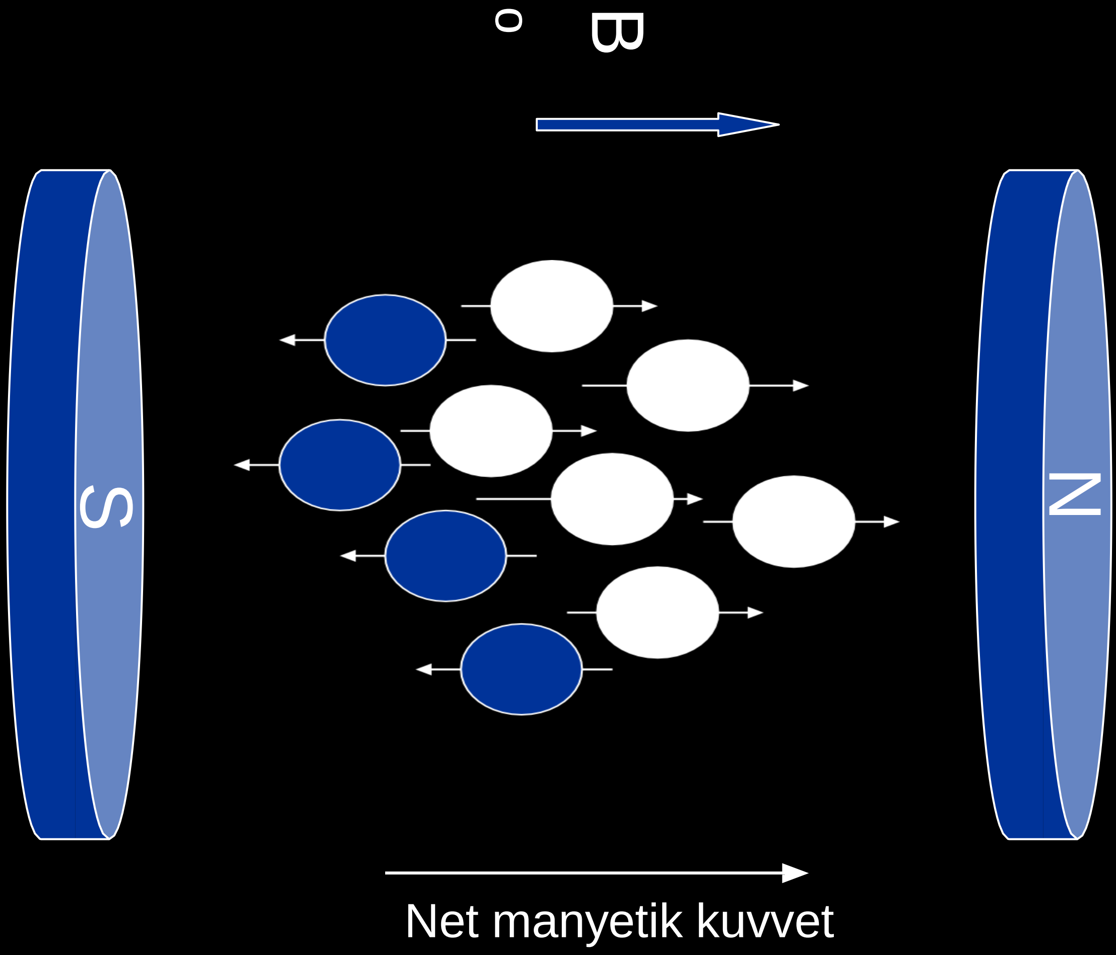


Relaksasyon ?

Relaksasyon

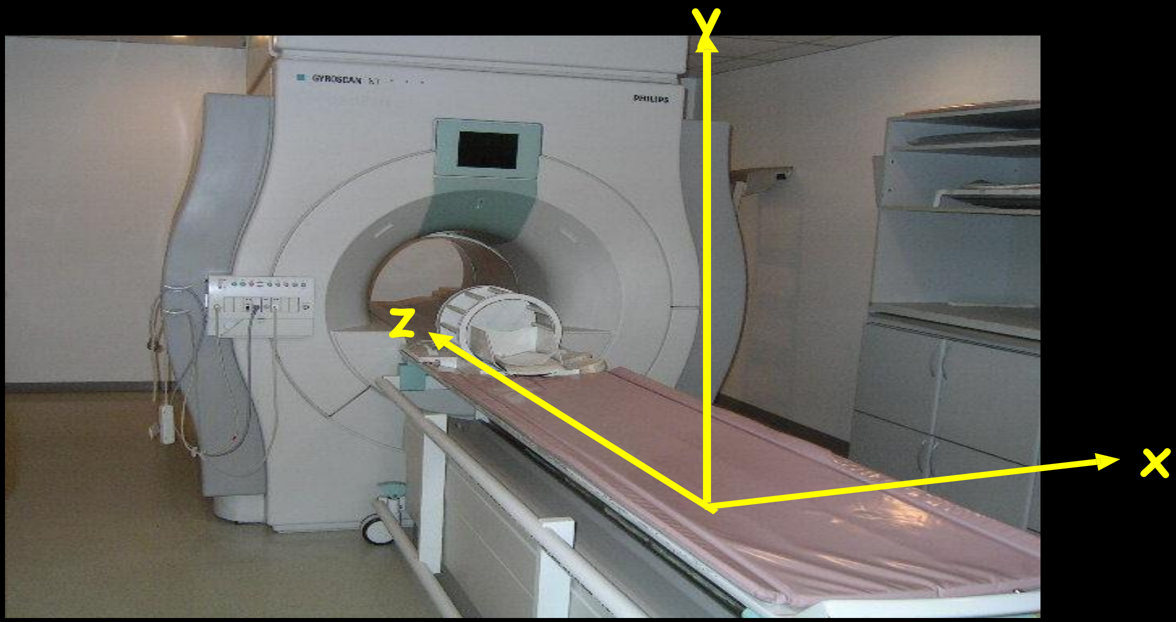
Rezonans sonucu dokuya aktarılan enerjinin sonlandırılması ile dokudaki protonların eski enerji seviyesine dönmesidir



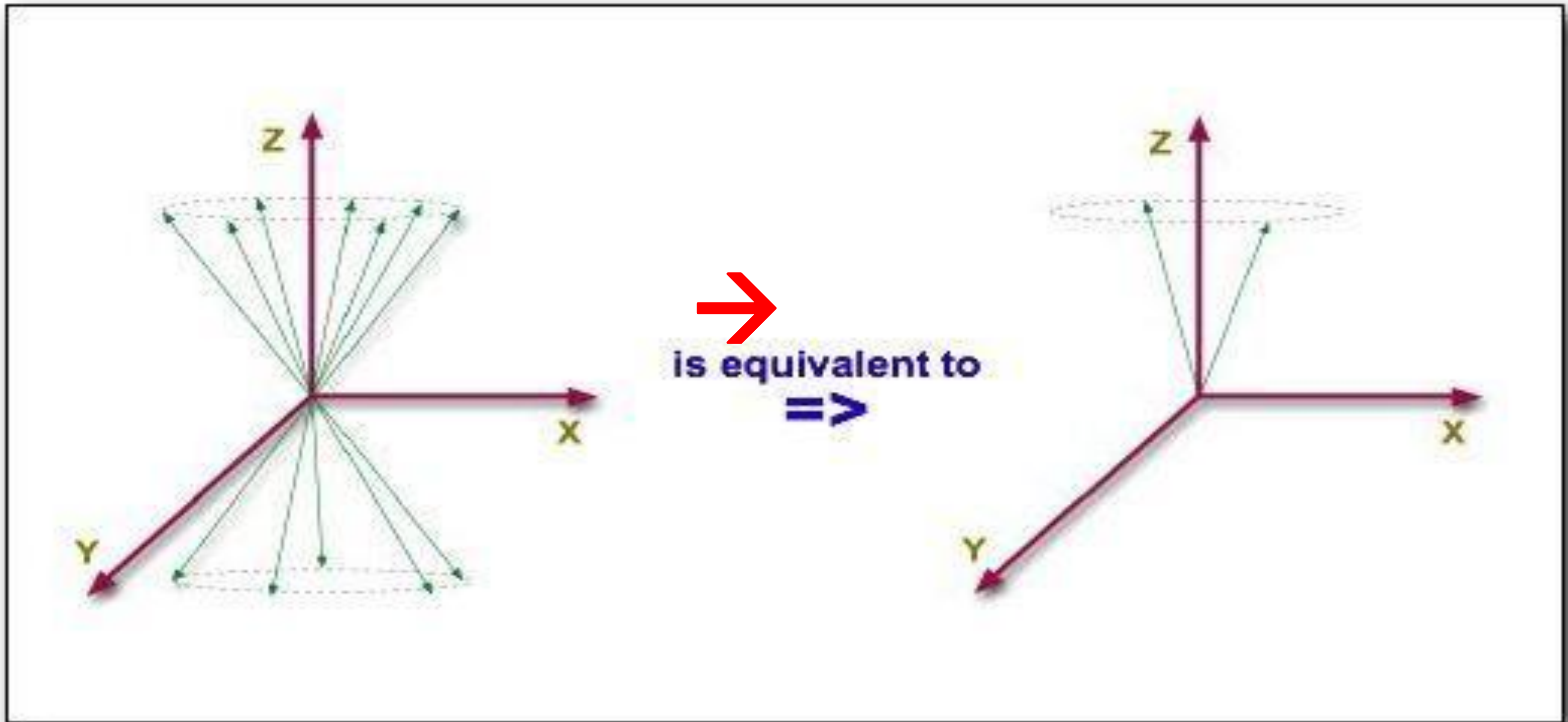



B
o
S
N
Net manyetik kuvvet

- B_0 yönündeki aksa z aksı veya longitudinal aks, buna dik olan düzleme de x,y düzlemi ya da transvers düzlem denir.

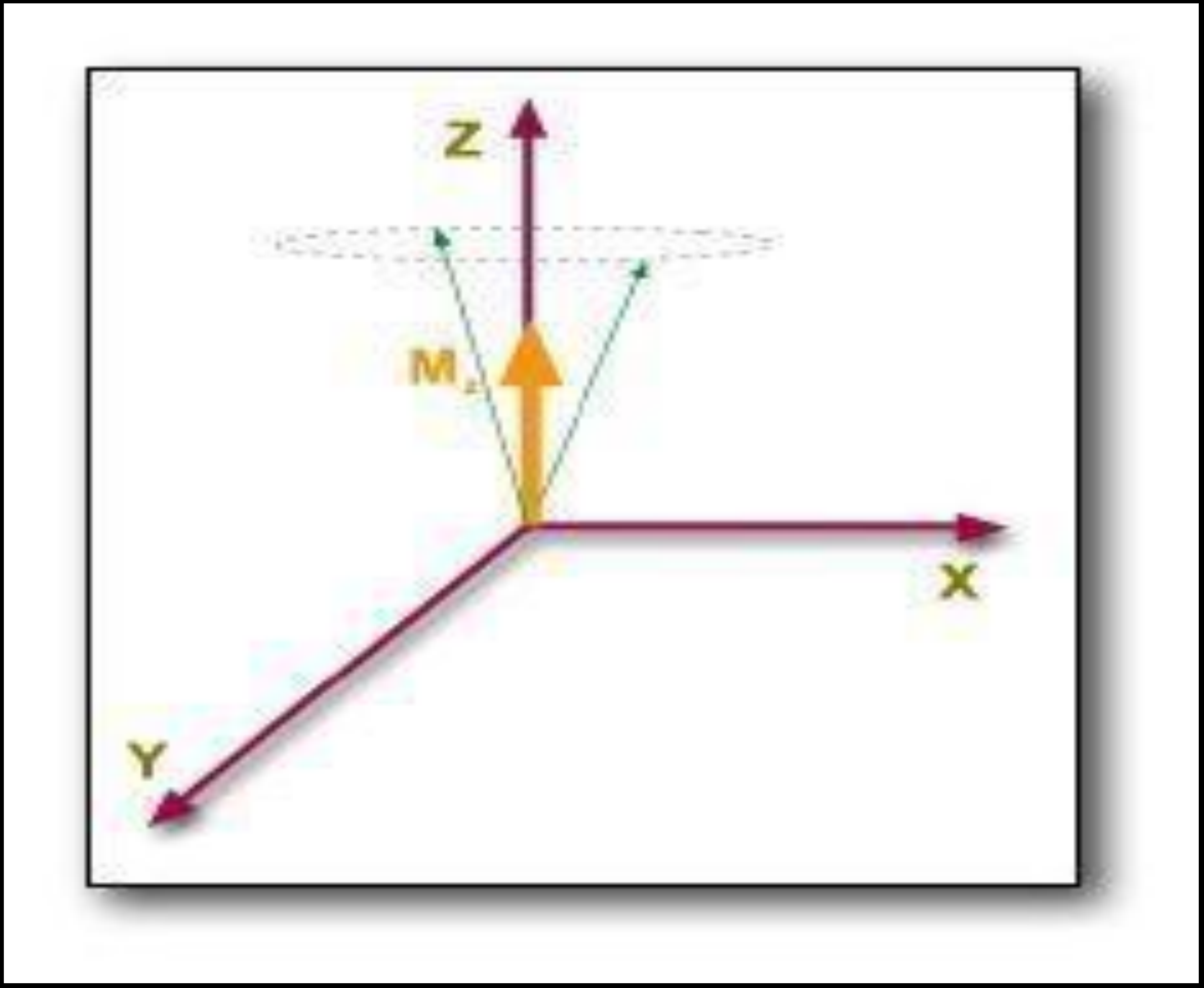


GYROSCAN
PHILIPS
y
z
x



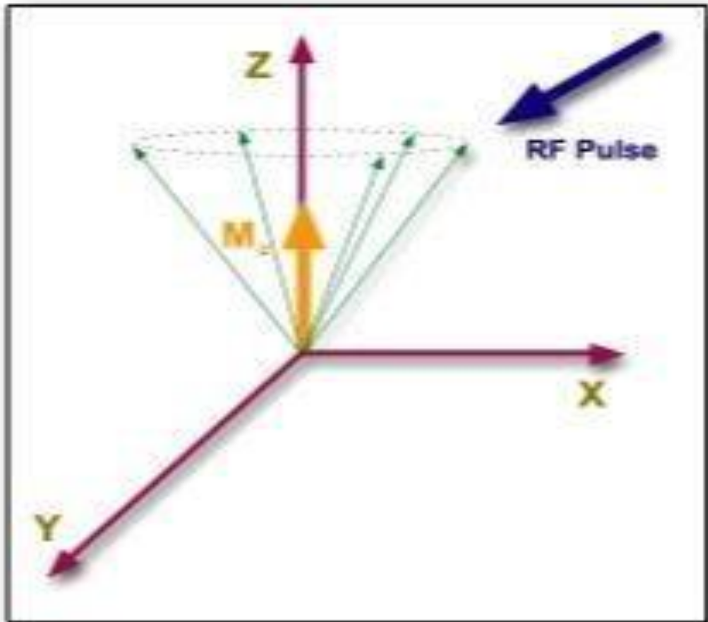
Z
X
Y
is equivalent to
=>
Z
X
Y

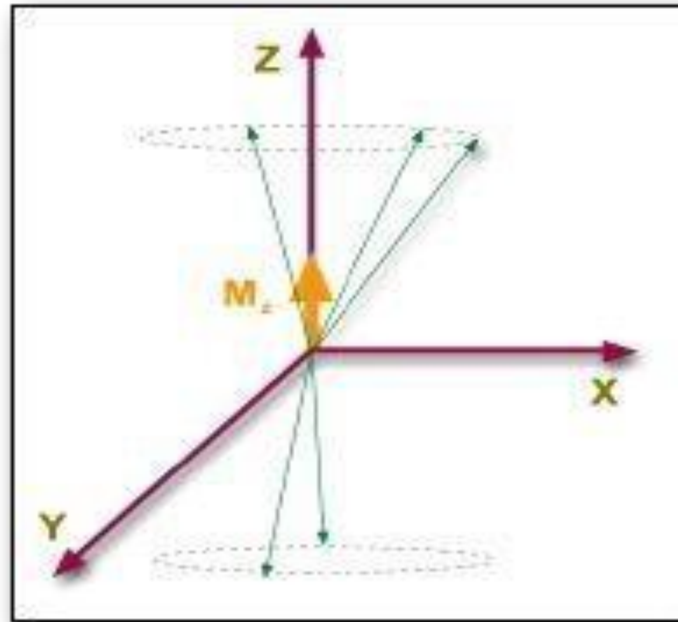
M=doku manyetik vektörü



RF pulsu

- RF pulsu verilince iki etki meydana gelir
  - Protonlardan bir kısmı yüksek enerji seviyesine (anti-paralel konum) geçer, longitudinal manyetik vektörü küçülür.
  - Diğer bir etki de protonların “in-phase” konumuna geçmesidir


Z
RF Pulse
M
X
Y

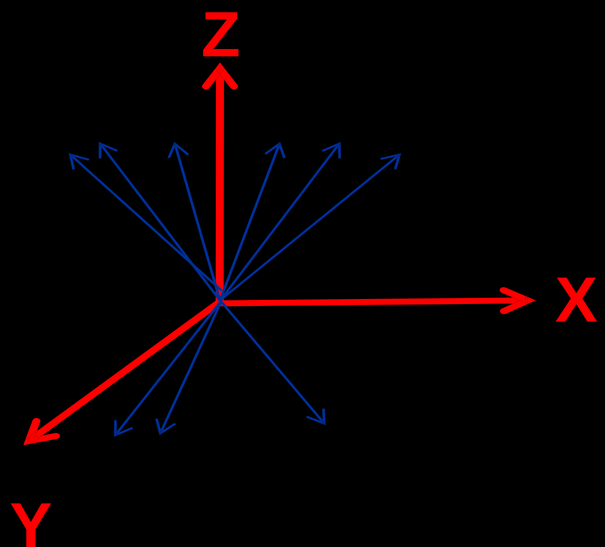

Z
M
X
Y

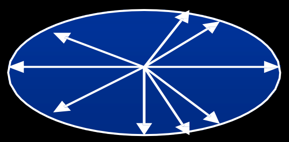
In-phase / Out-of-phase

- RF uygulamasının önemli bir sonucu da protonların out-of-phase konumundan in-phase konumuna geçmesidir.

- Transvers manyetizasyonun oluşumu bu sayede olur.

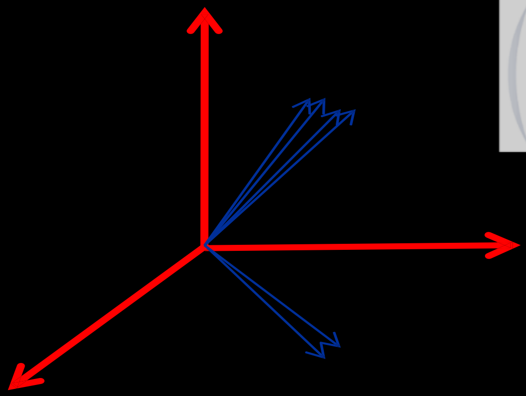
- Diğer bir etki de protonların “in-phase” konumuna geçmesidir



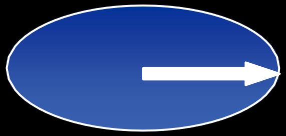


out of phase

- Diğer bir etki de protonların “in-phase” konumuna geçmesidir

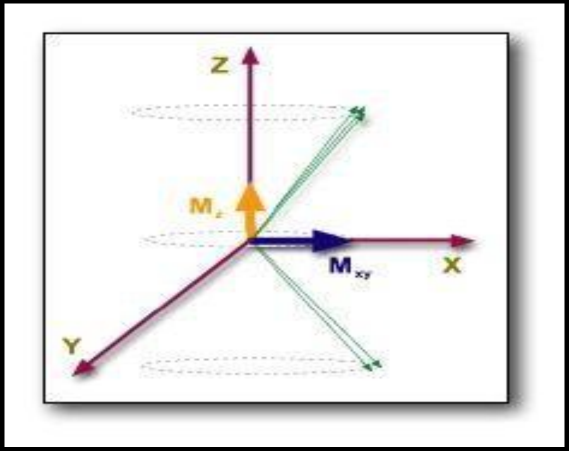


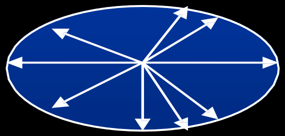
RF



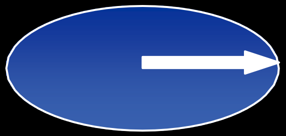
in phase

- M_z küçüldü, $M_{x,y}$ oluştu





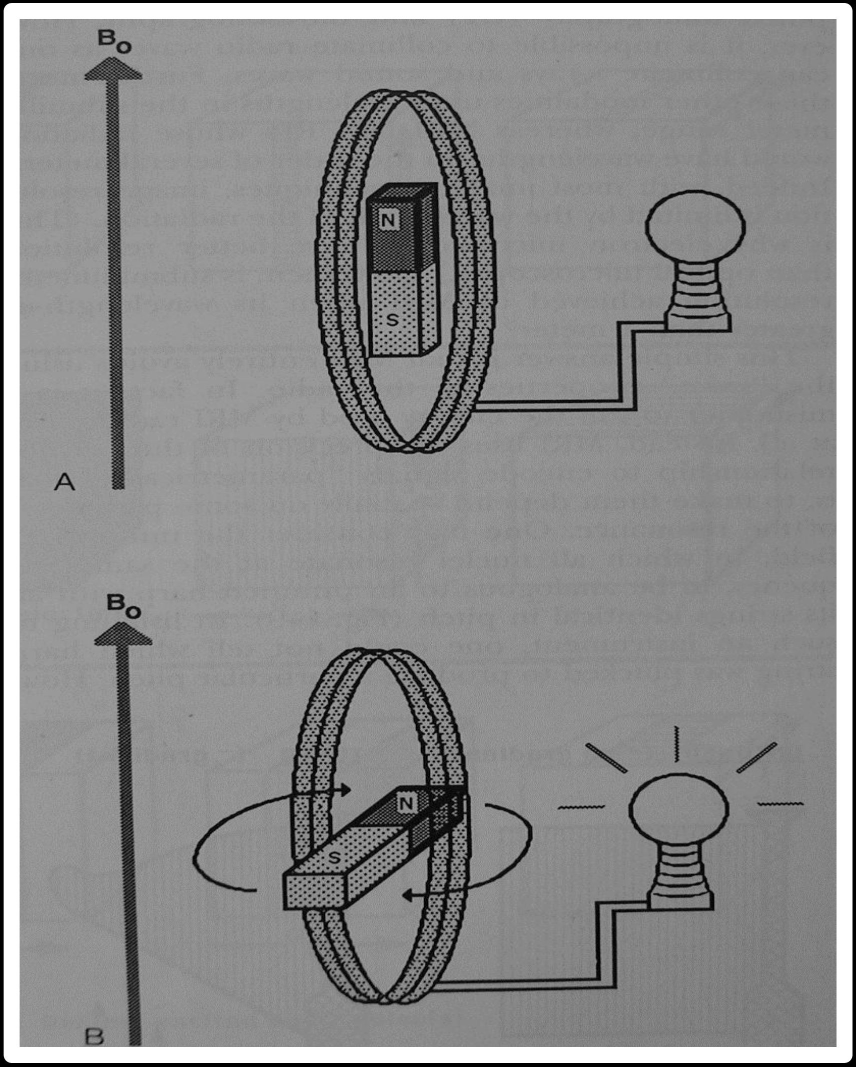
out of phase

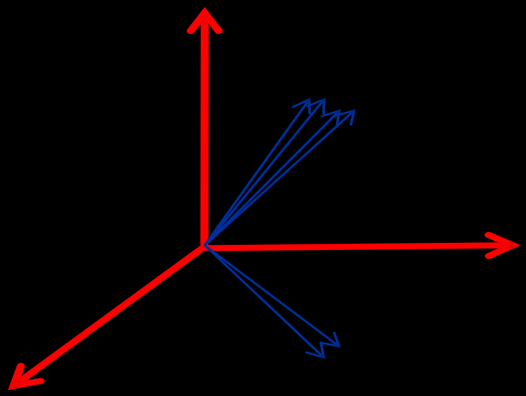


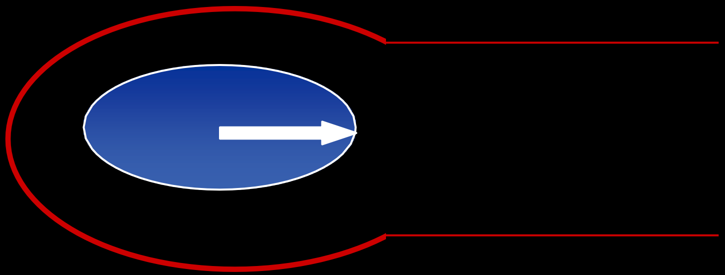
in phase

- Transvers (x,y) düzlemde oluşan manyetik vektör neden bu kadar önemli??

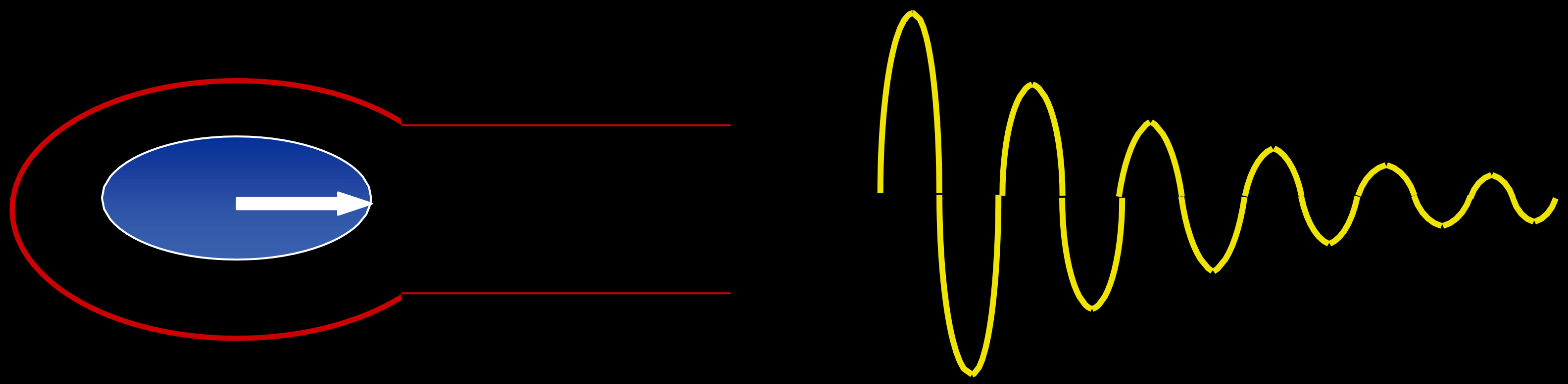
Faraday' ın indüksiyon yasası







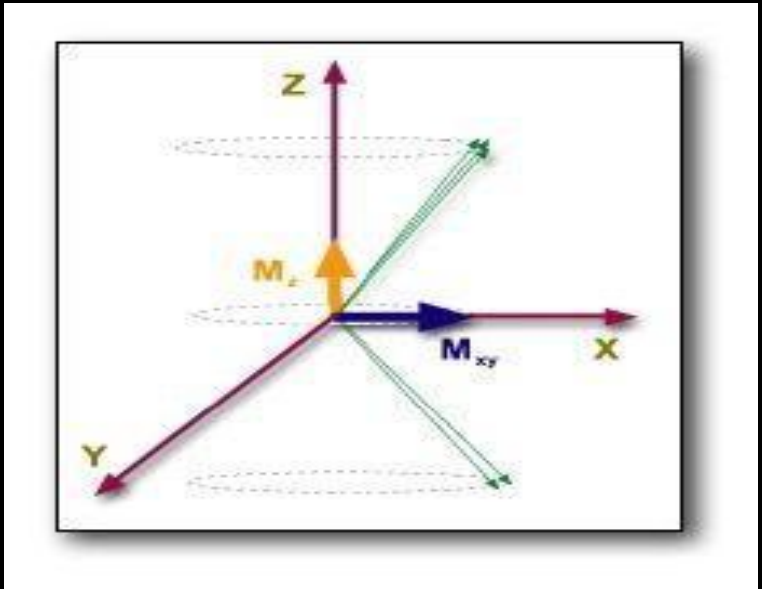
MR Sinyali



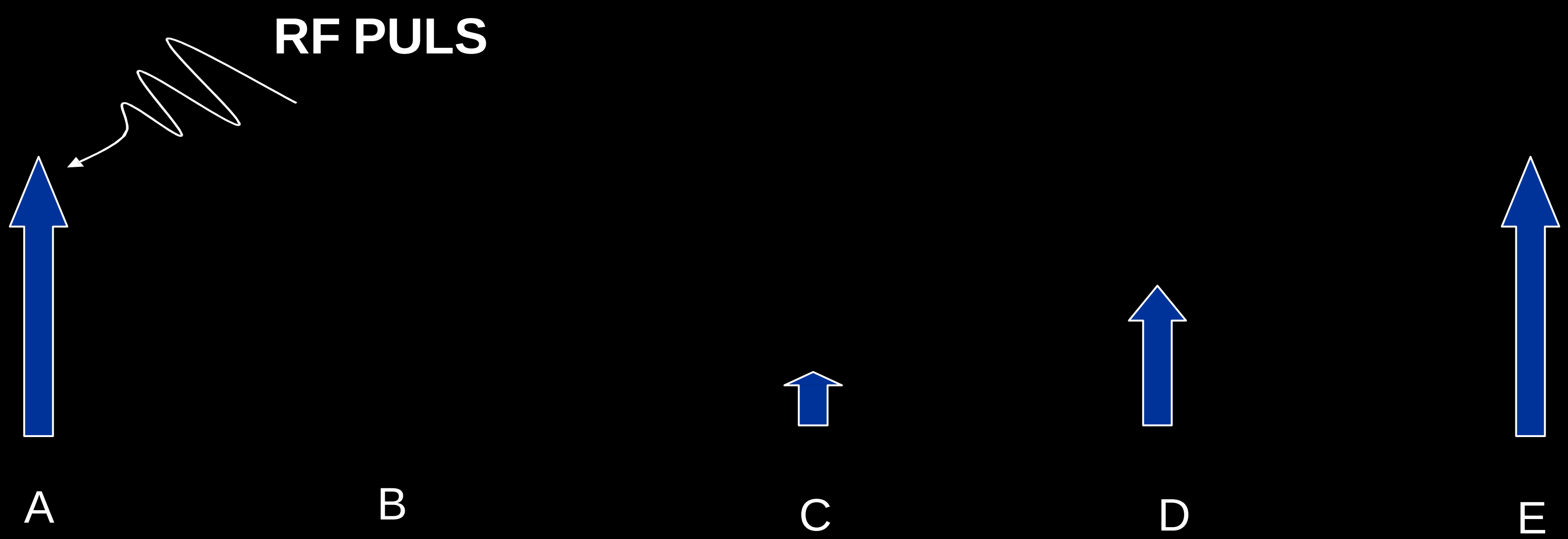
Neyi ölçüyoruz?

- Doku manyetizasyonundaki bu değişim süreci, RF antenlerinde Larmor frekansına eşit frekanslı bir alternatif elektrik akımı oluşturur.
- Böylece dokudan gelen sinyal ölçülebilir ve bu sinyallere göre görüntüler oluşturulabilir.

- Her zaman transvers düzlemdeki manyetizasyon ölçülür
- Longitudinal düzlemden ölçüm yapma imkanı yoktur.



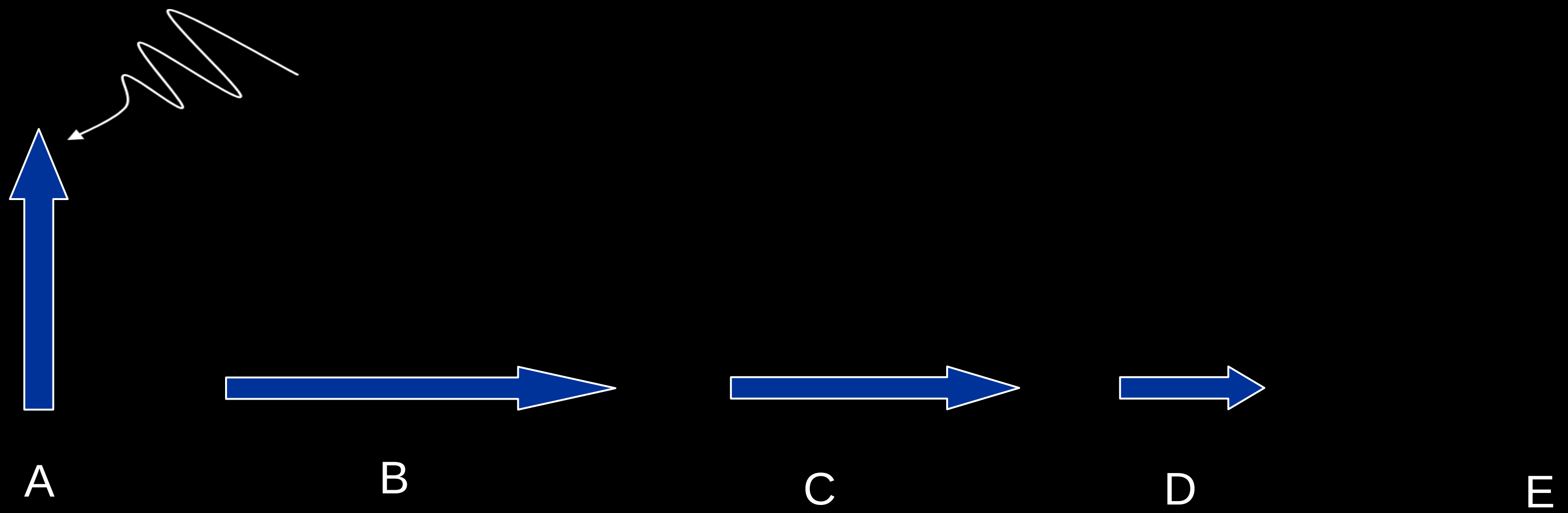
Longitudinal relaksasyon



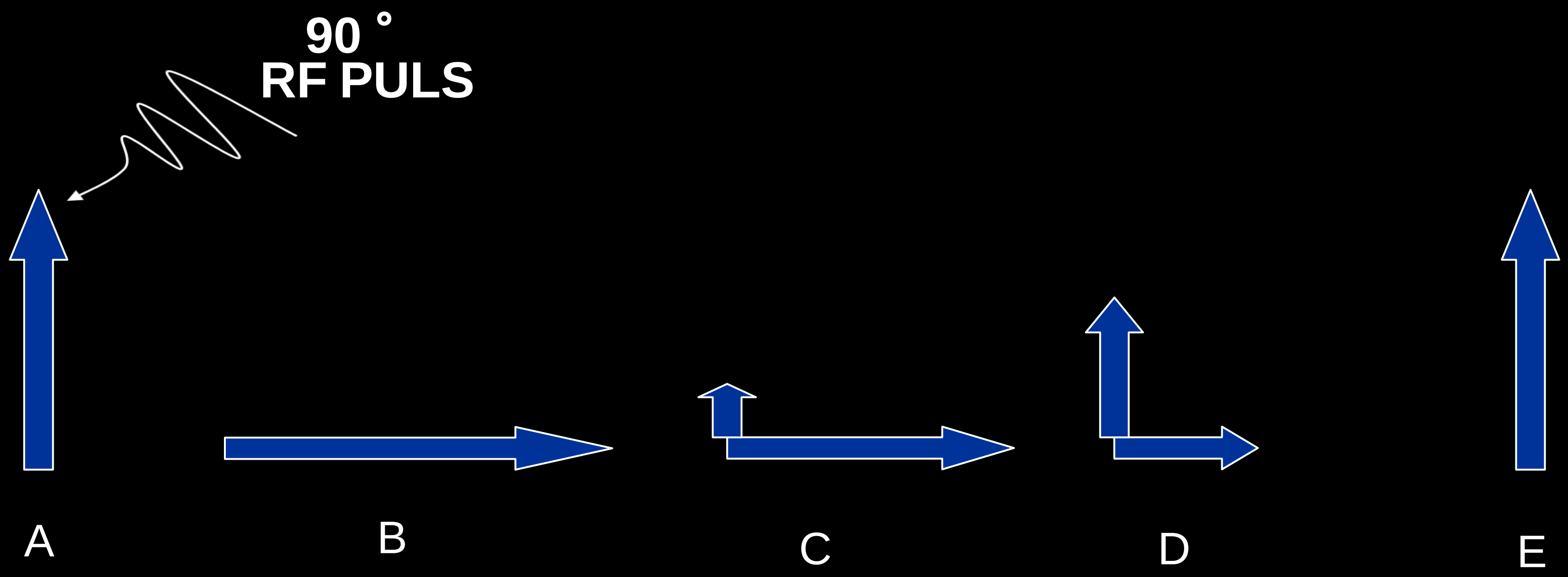
Spin-lattice relaksasyon

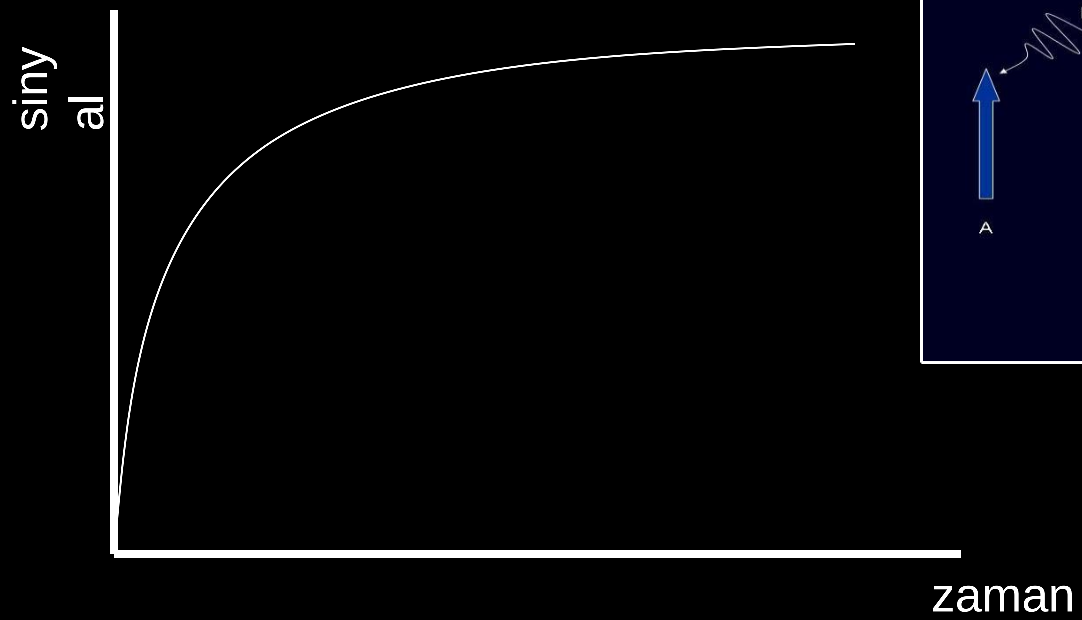
Transvers relaksasyon

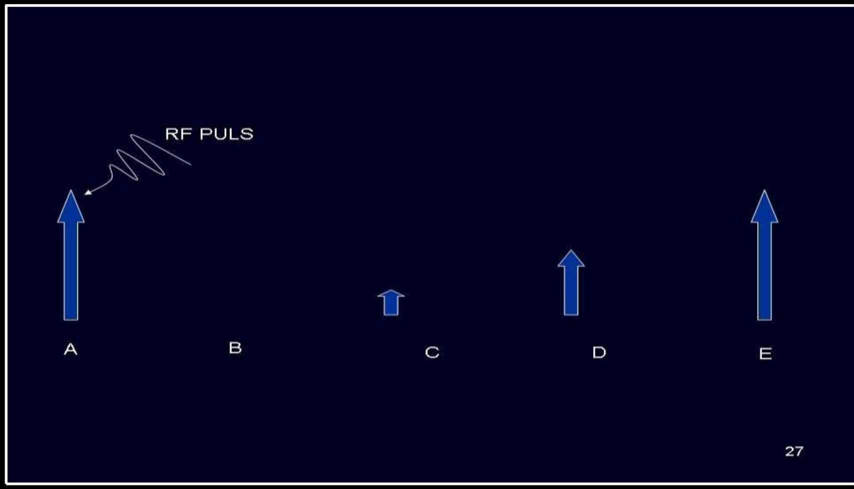
RF PULS



Spin-spin relaksasyon


90 °
RF PULS
A
B
C
D
E





Long
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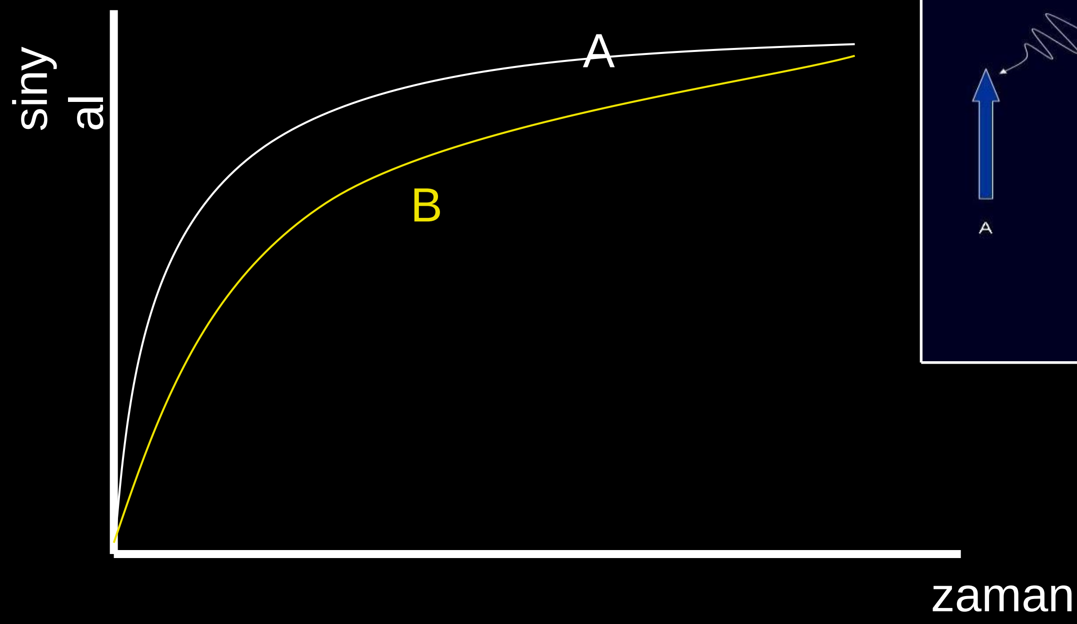

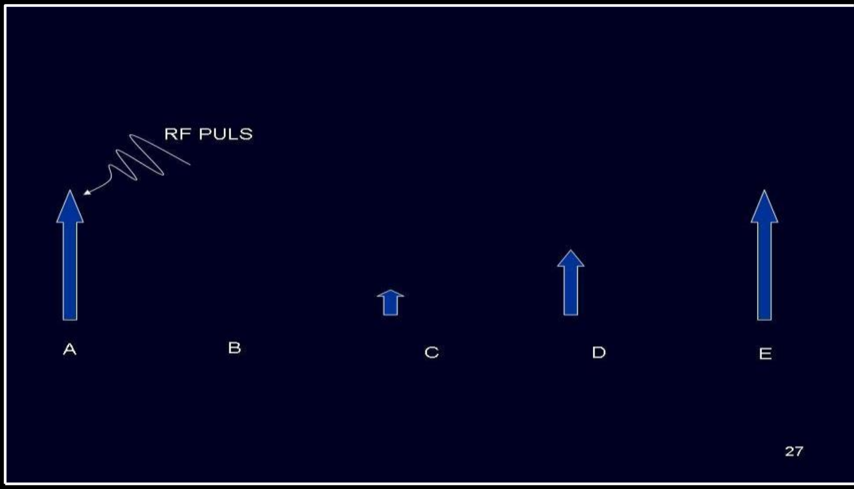

Long

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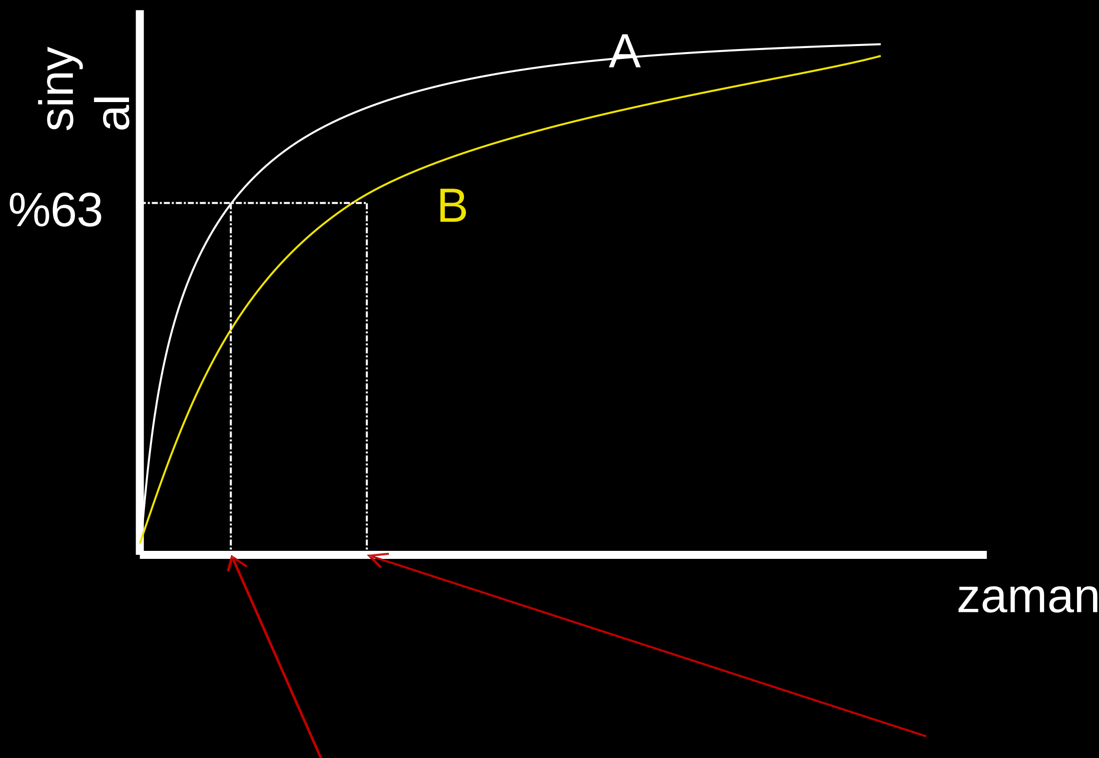
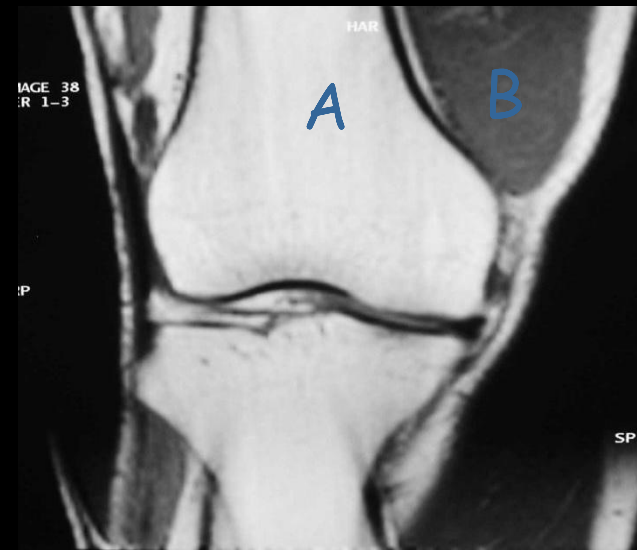
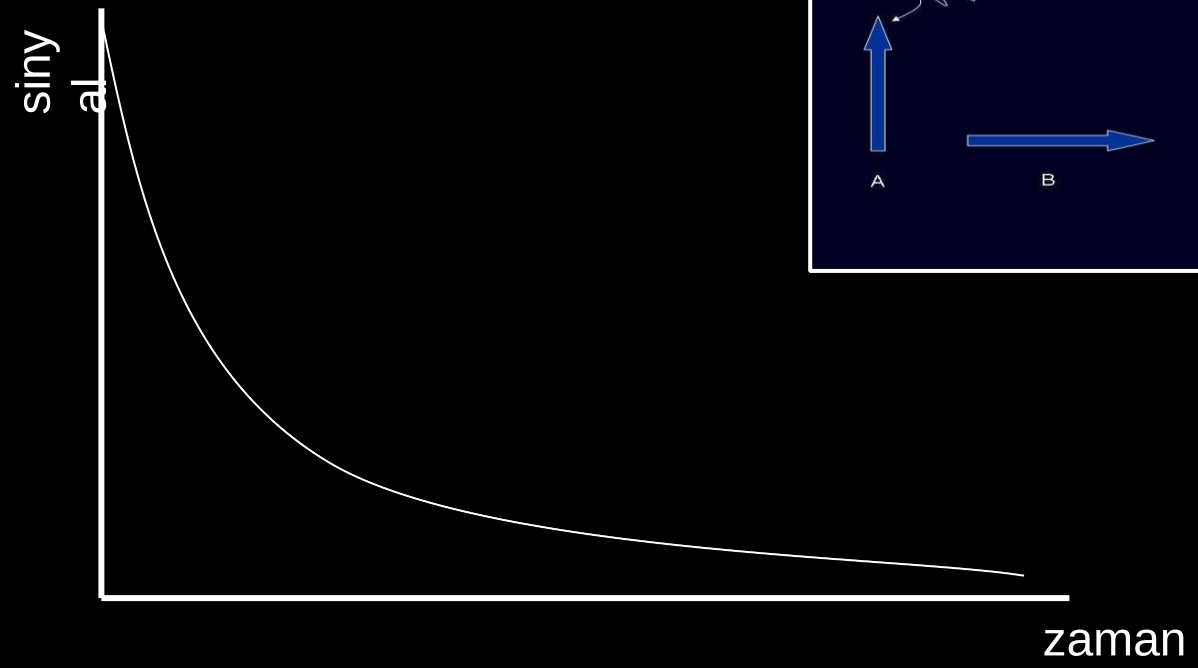
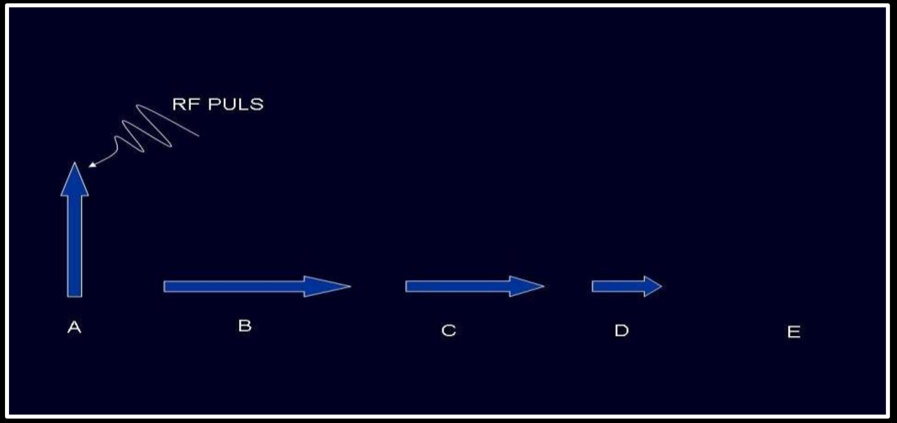




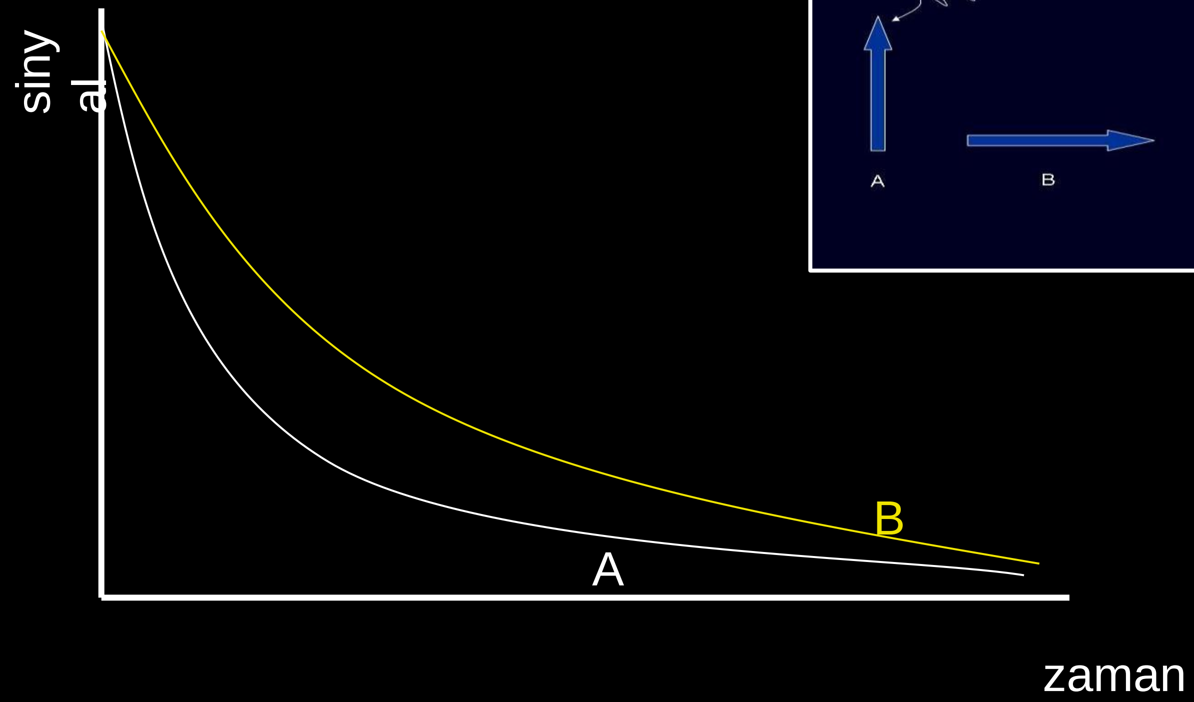
T1 zamanı (B dokusu)

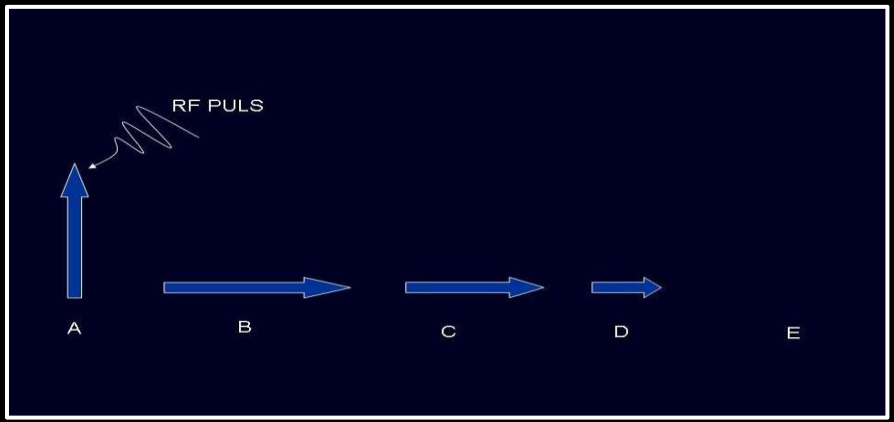
T1 zamanı (A dokusu)



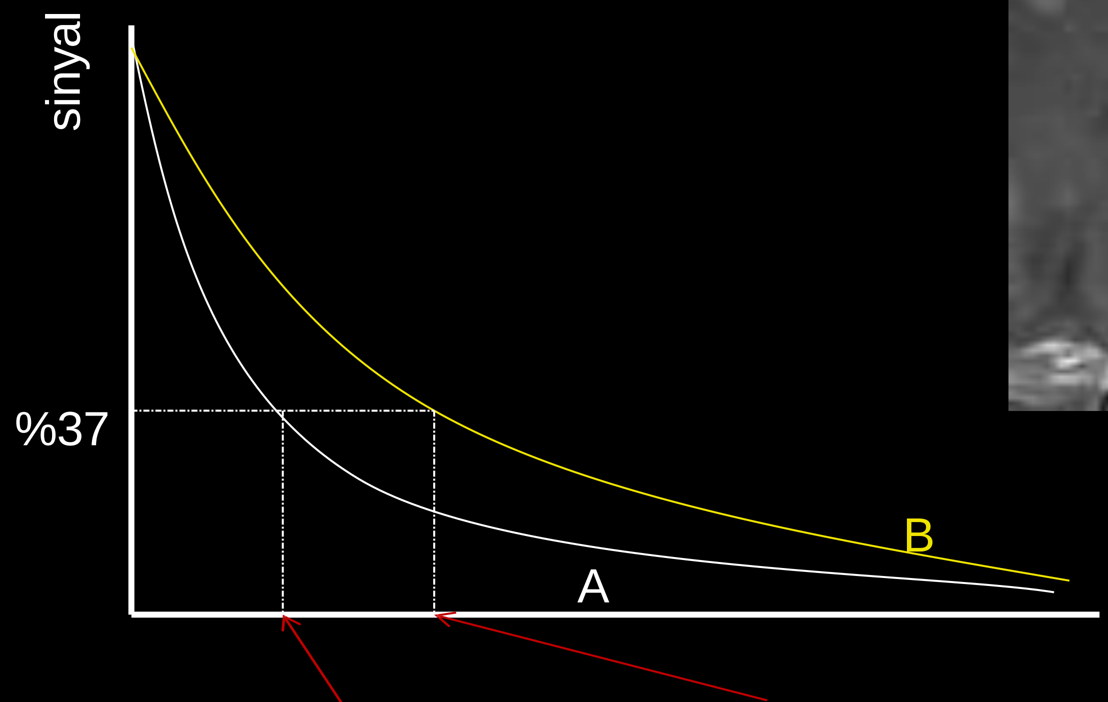


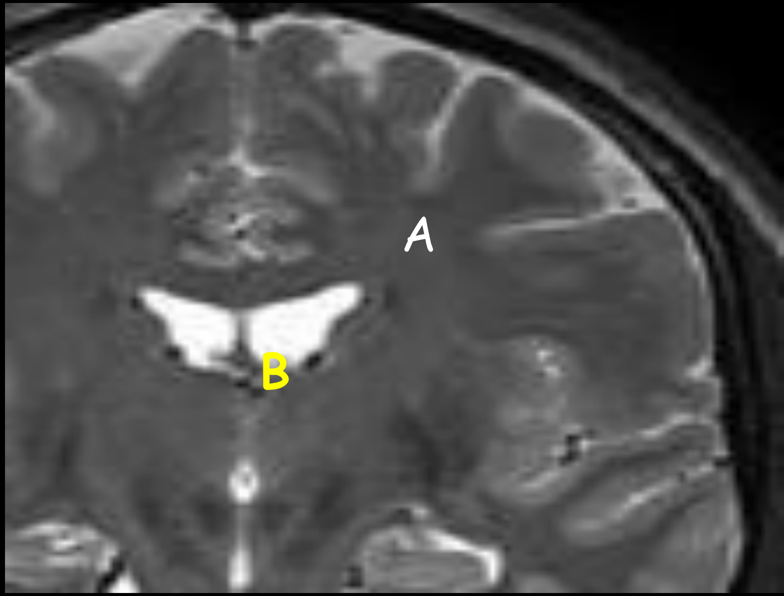
Transvers relaksasyon (T2 relaksasyon)





Transvers relaksasyon
(T2 relaksasyon)



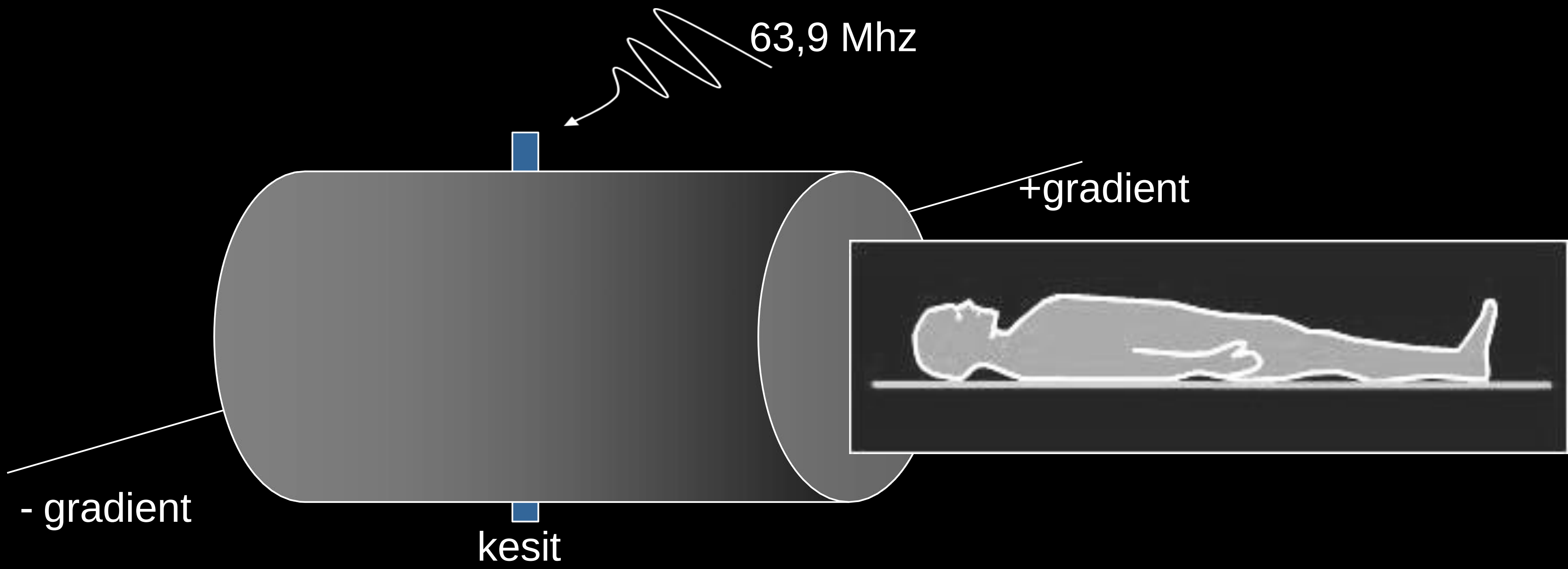


T2 zamanı (b dokusu) T2 zamanı (A dokusu)

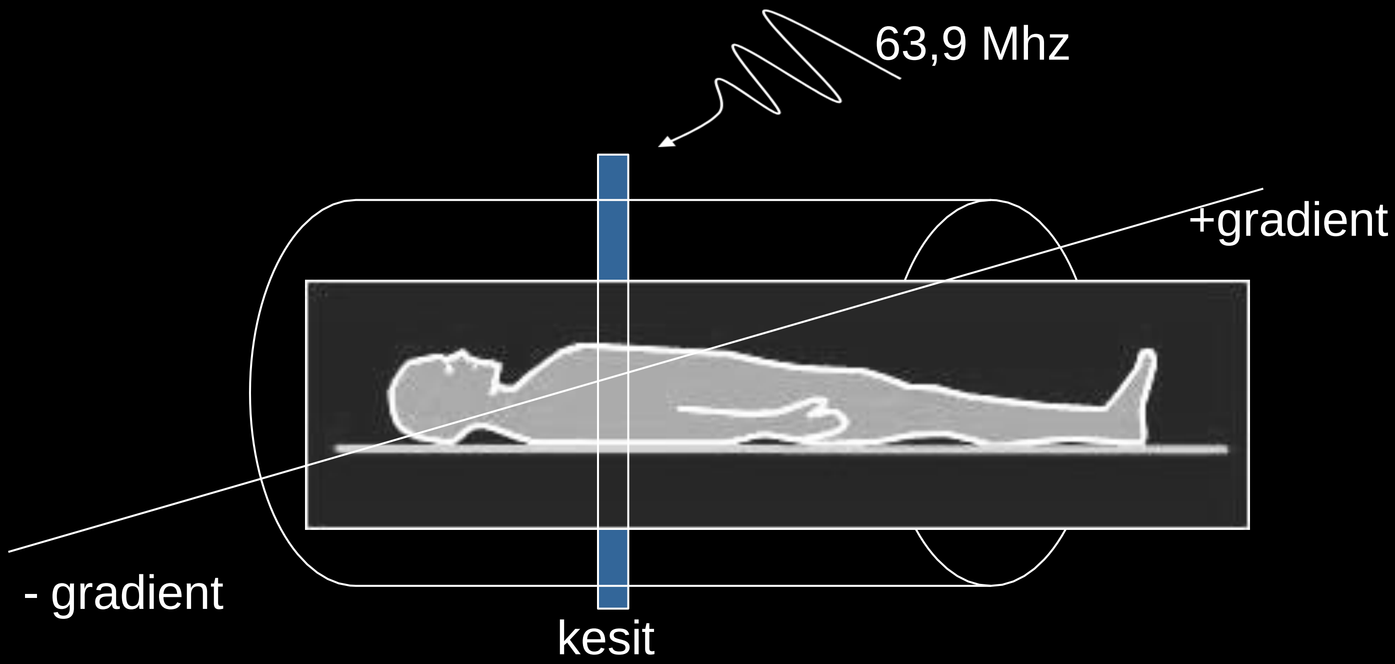
- T1 ve T2 relaksasyonları, aynı anda başlayıp birlikte devam eden, ancak devam etme süreleri birbirinden farklı olan süreçlerdir.

- T1 değeri sıfırdan başlar, maksimum seviyesine doğru ilerler, T2 ise maksimumdan başlayarak sıfıra doğru azalma gösterir.

MRG'de Nasıl Kesit Alınır?



63,9 Mhz
+gradient
- gradient
kesit


63,9 Mhz
+gradient
- gradient
kesit

Kesit kalınlığı

- Kesit kalınlığı iki şekilde değiştirilebilir:
- RF pulsunun band genişliği değiştirilerek (64-65 Mhz yerine 64-64.5 MHz)

- Gradient sargı gücü değiştirilebilir
- (1 gauss/cm yerine 2 gauss/cm)

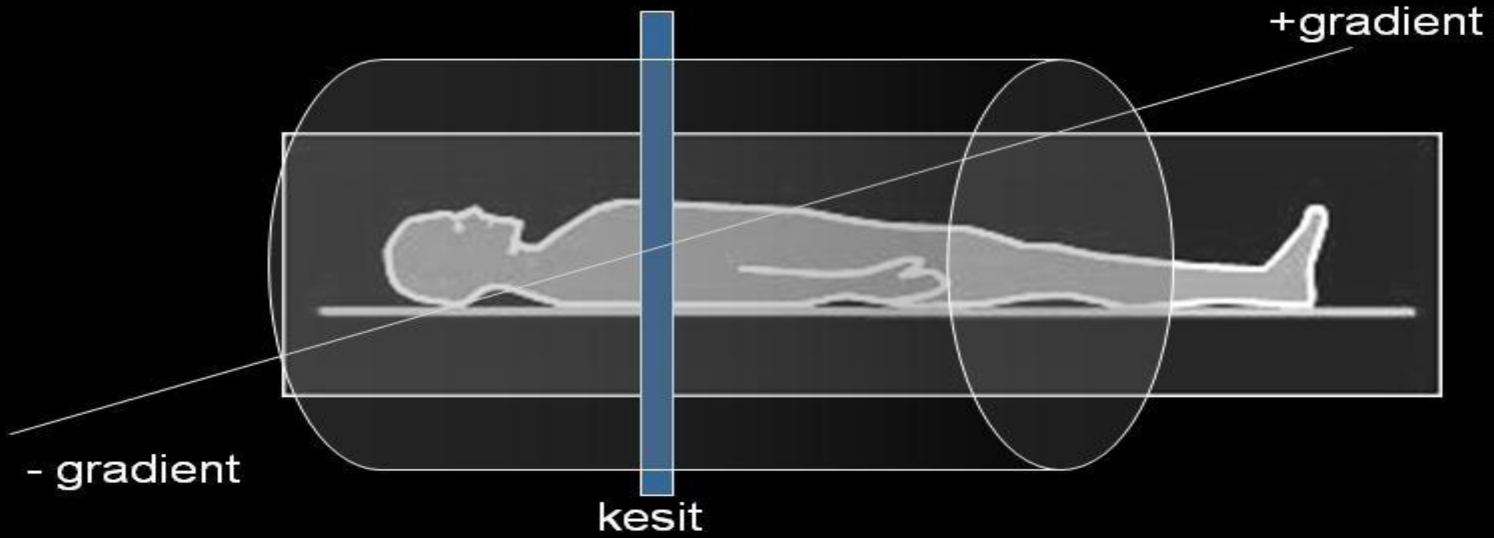
- Kesit kalınlığı: RF BW / (γ. GA)

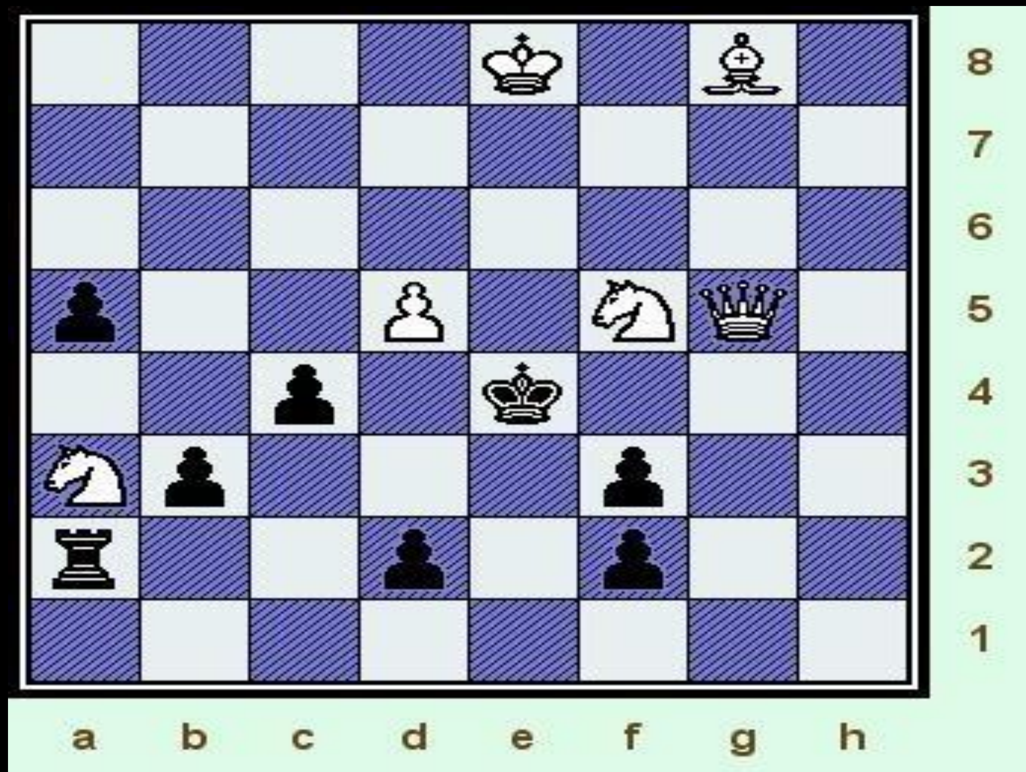
RF BW: RF band genişliği

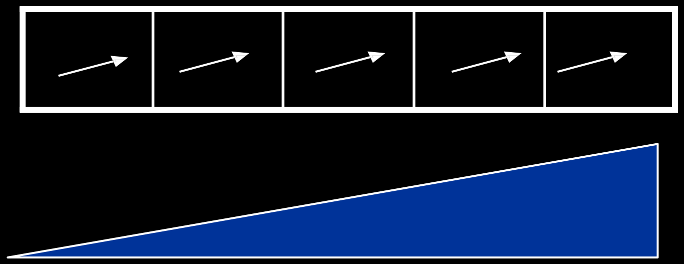
γ : gyromanyetik sabit GA :

Gradient amplitüdü

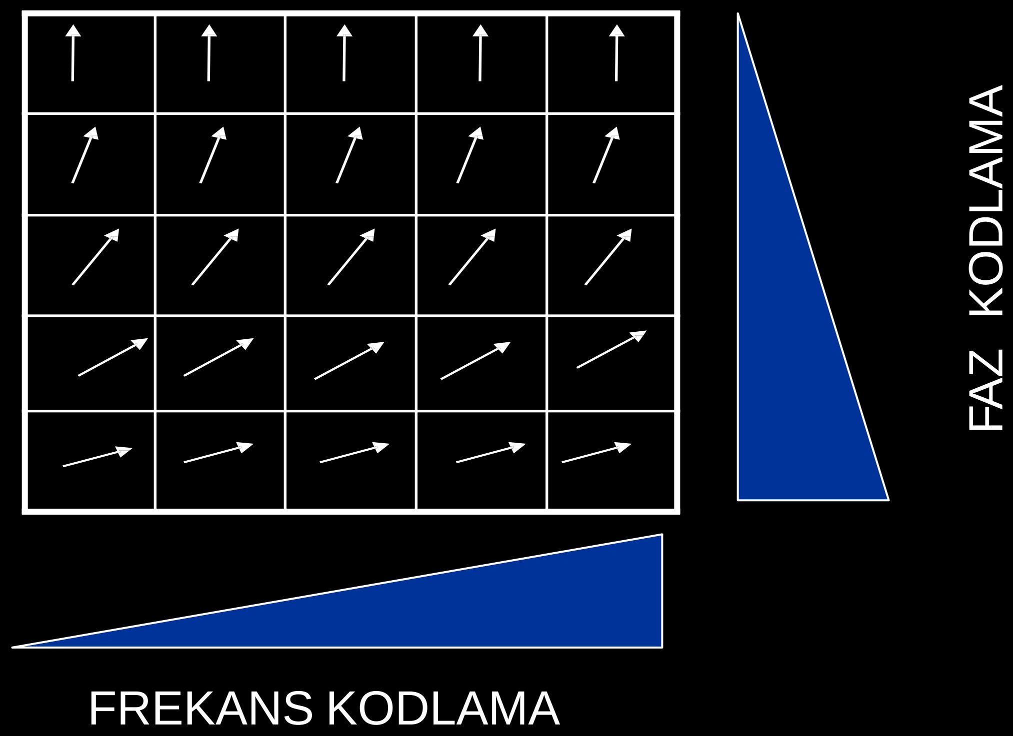
z ekseni tamam, ya x,y ??



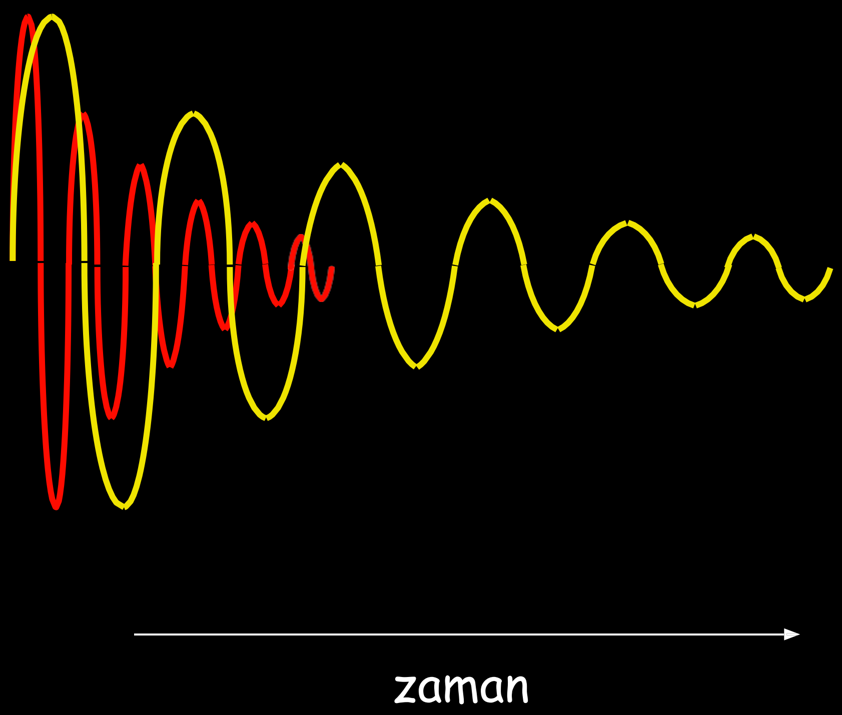

8
7
6
5
4
3
2
1
a b c d e f g h



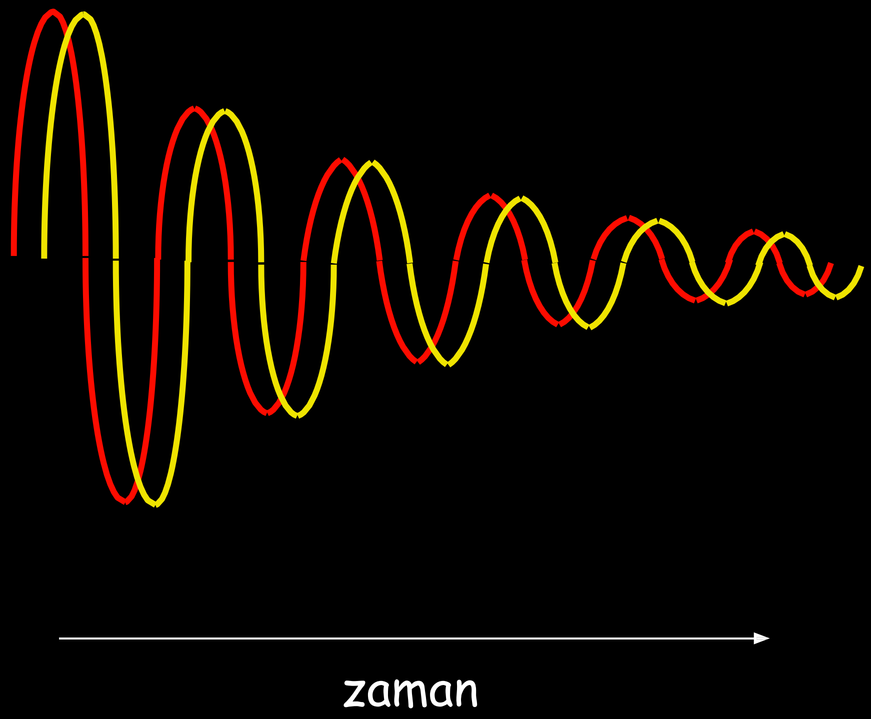
FREKANS KODLAMA

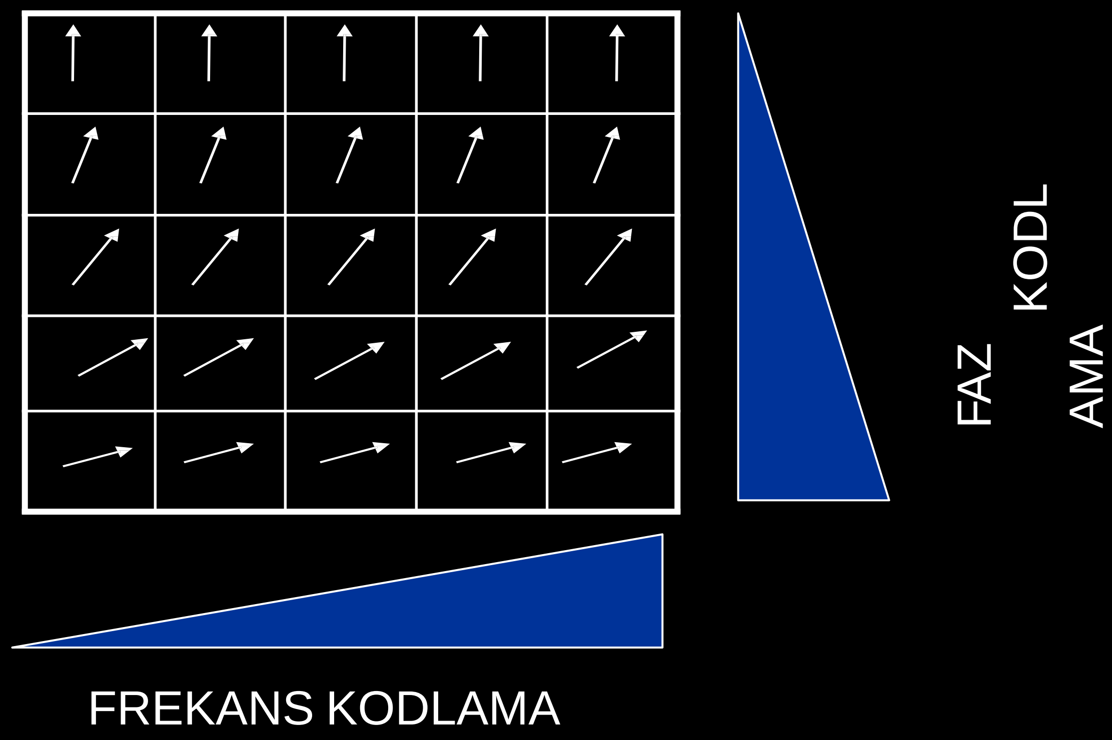

FAZ KODLAMA
FREKANS KODLAMA

Frekans farklı



Faz farklı

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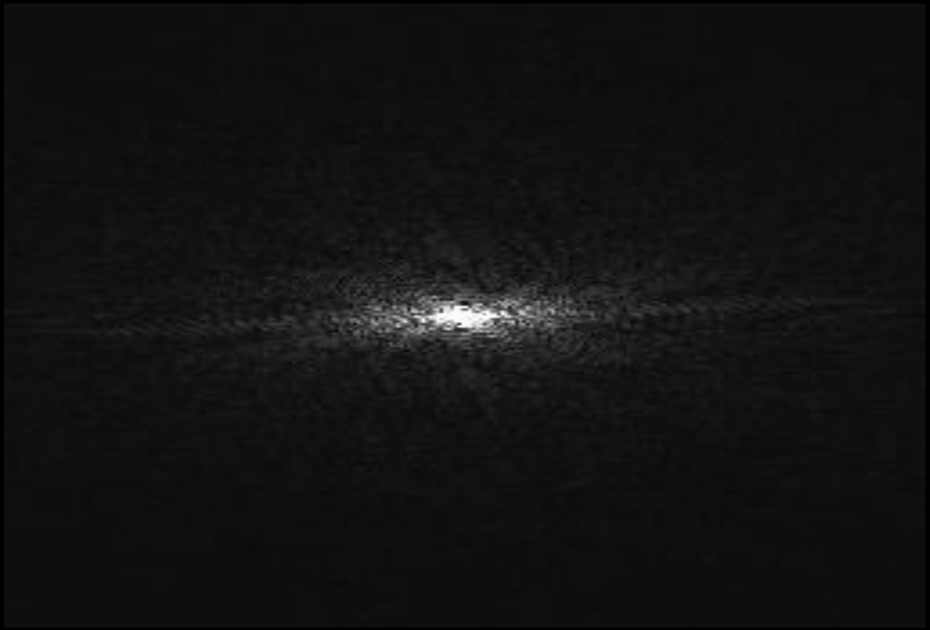
FREKANS KODLAMA



K-space

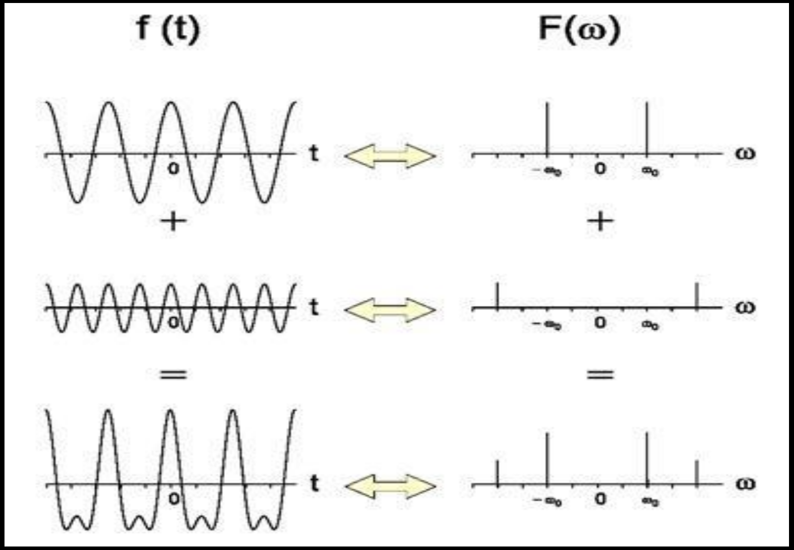
- Sekans elde edilirken, sayısal MR sinyallerinin biriktiği “geçici görüntü deposu”

- K-space dolduğunda görüntünün son haline ait tüm veri mevcut

Fourier transformasyon

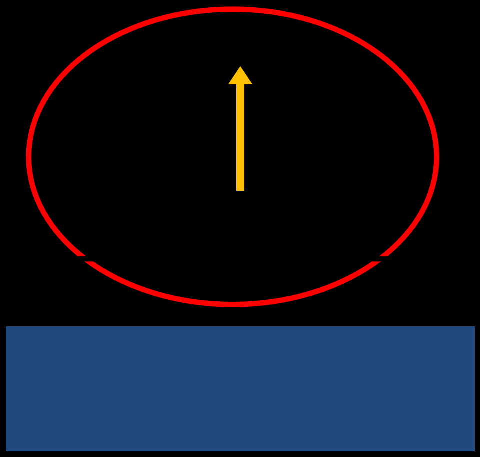
$$F(k) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) e^{-ikx} dx$$

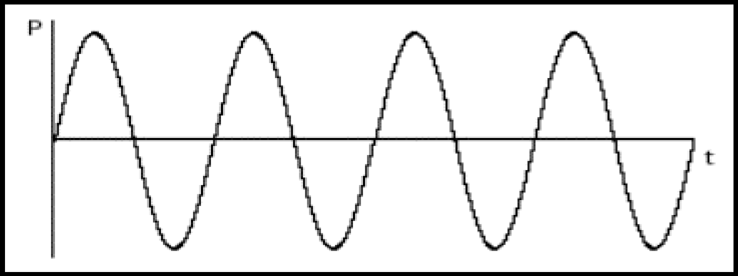
$$f(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} F(k) e^{ikx} dk$$



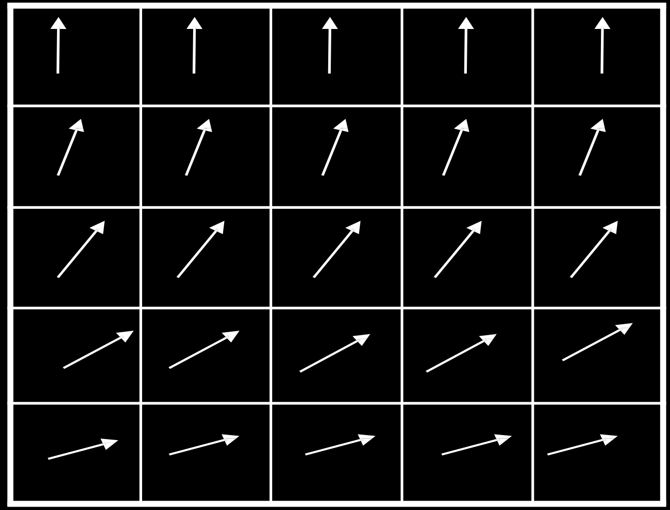
Jean Baptiste Joseph Fourier
(1768-1830)

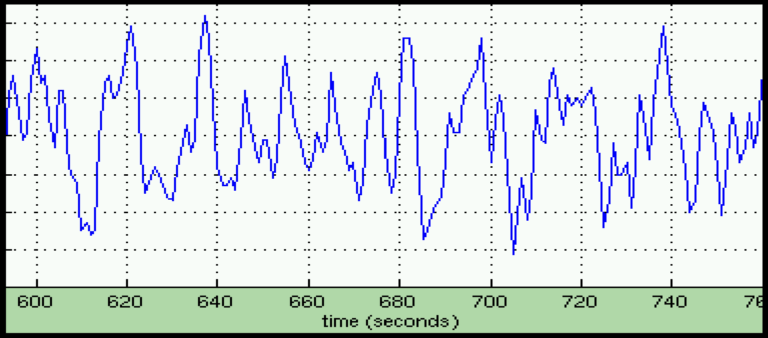
Fourier transformasyon



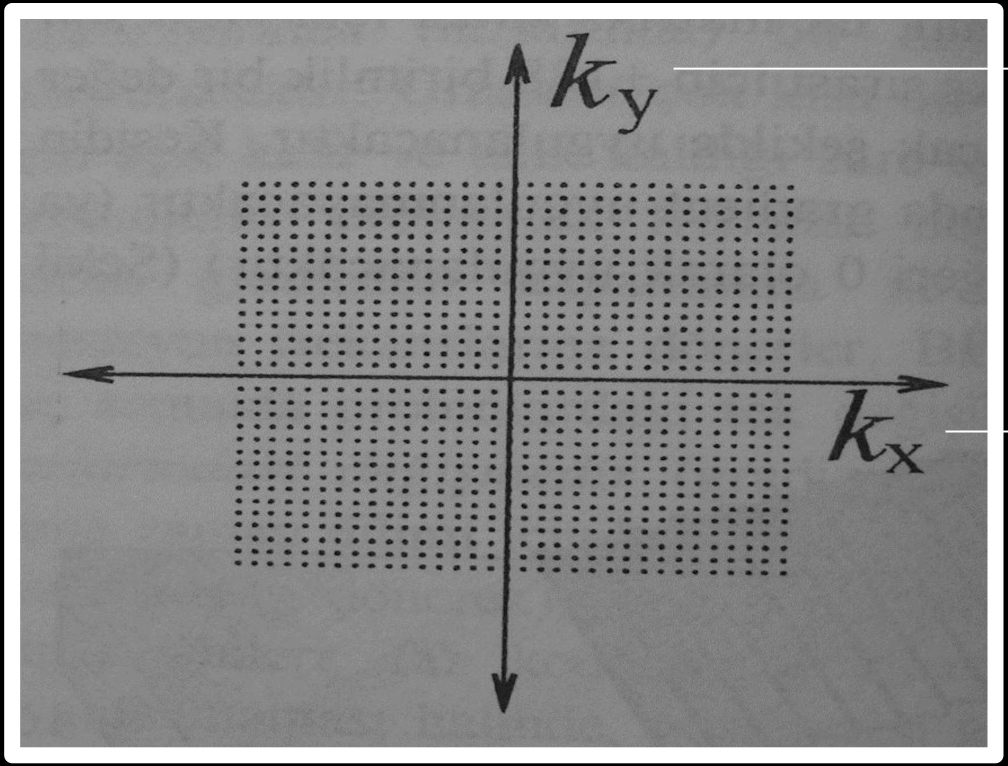


Fourier transformasyon



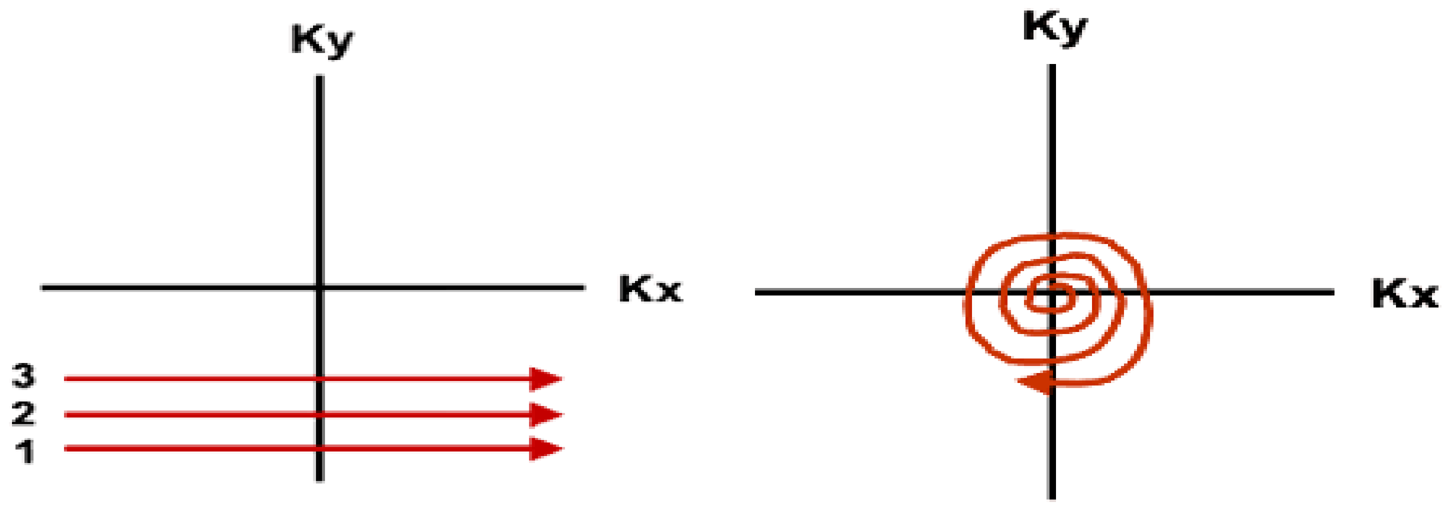


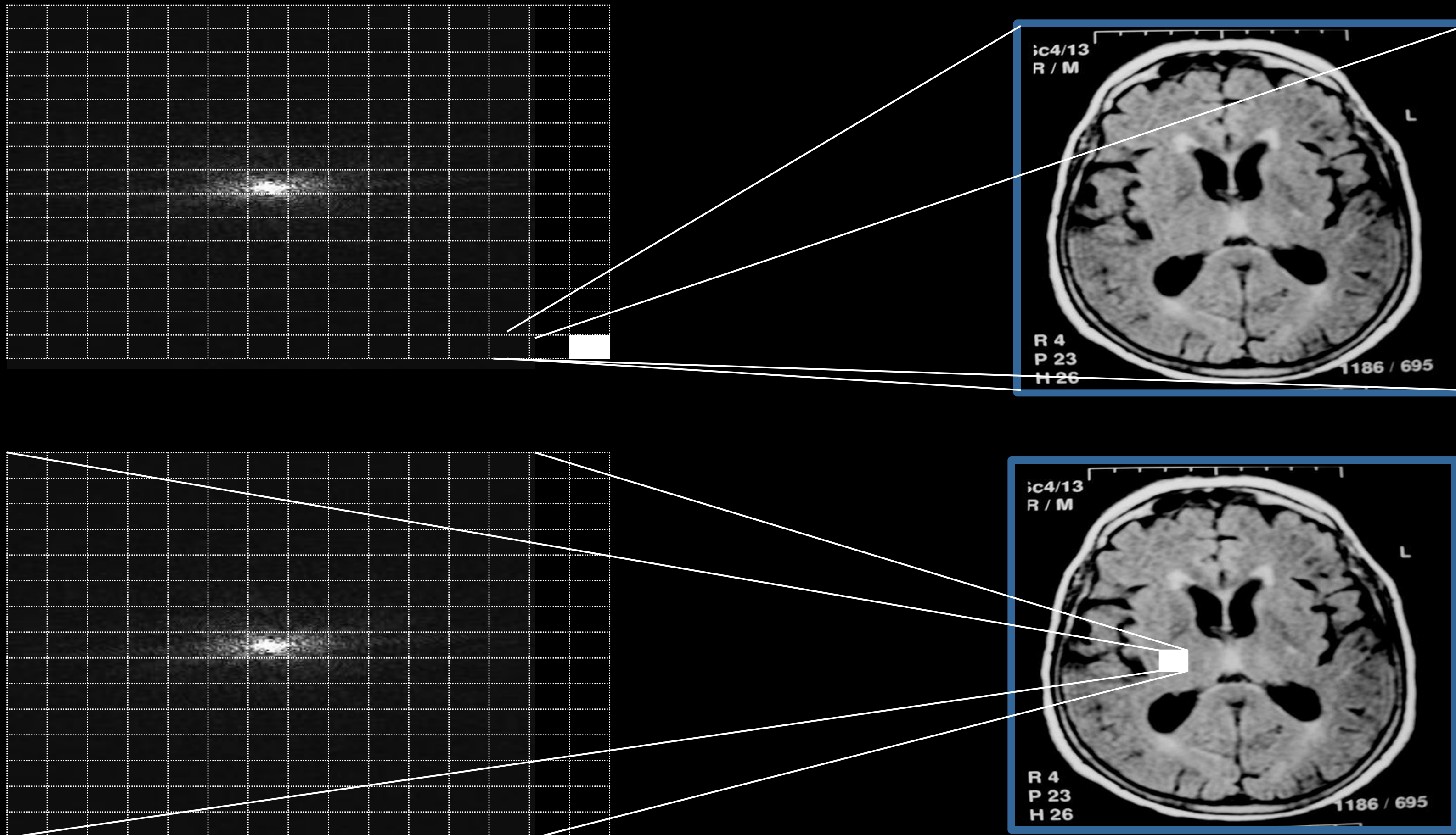
K-space



faz

frekans

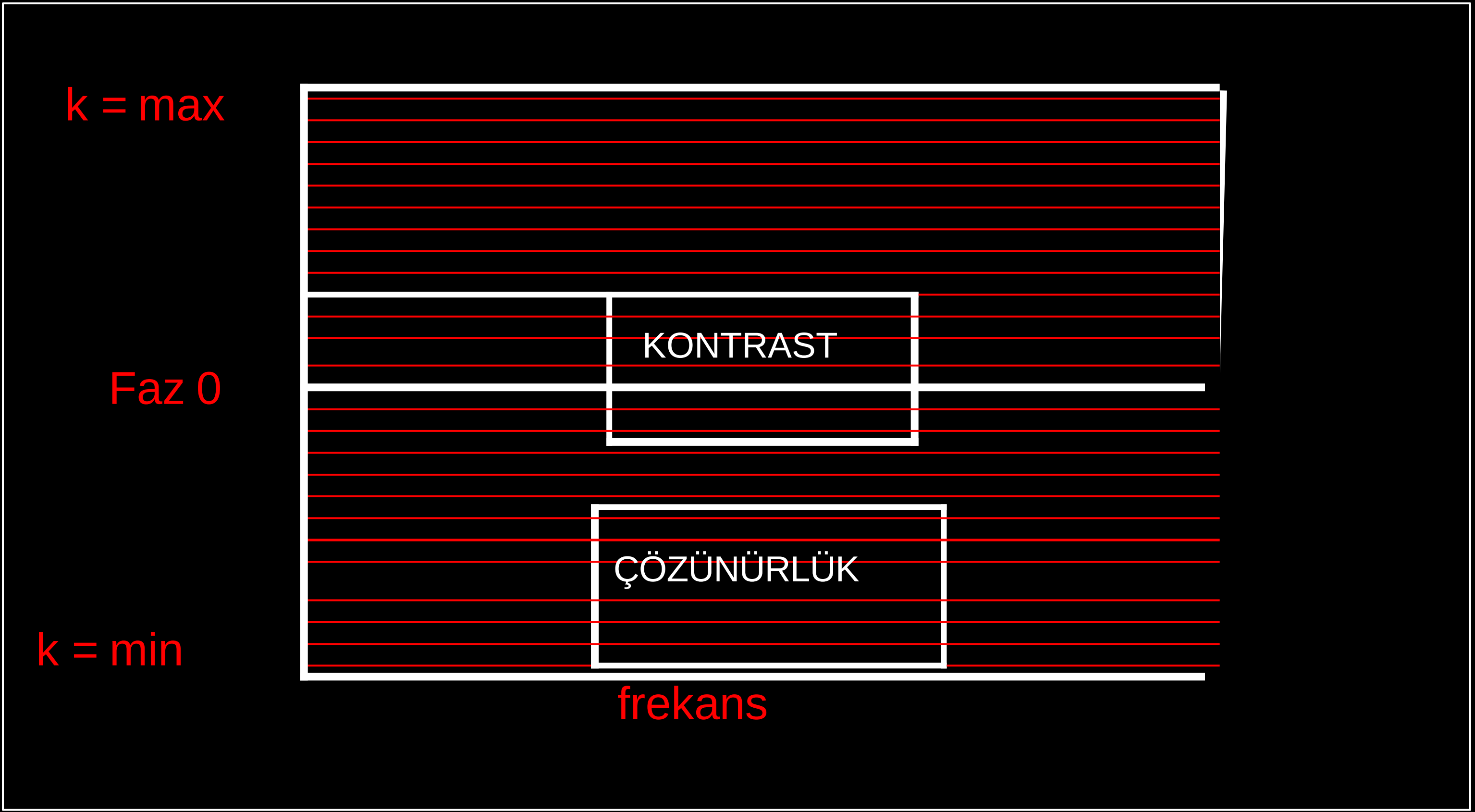

Ky
Kx
3
2
1
Ky
Kx

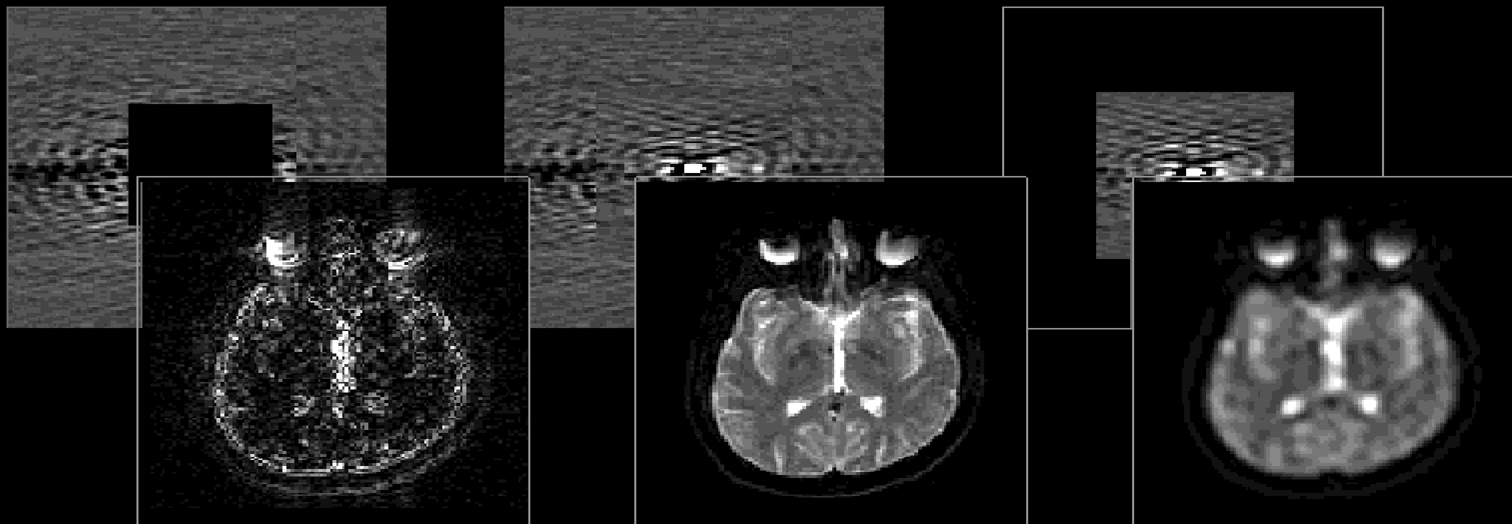

c4/13
R / M
L
R 4
P 23
H 26
1186 / 695
c4/13
R / M
L
R 4
P 23
H 26
1186 / 695

K-space

- K-space’ in merkez kısımları görüntünün kontrast (ve SNR) bilgisini içerir (=düşük frekanslı sinyaller)

- K-space’ in dış kısımları ise görüntünün çözünürlük (kenar keskinliği) bilgisini içerir (=yüksek frekanslı sinyaller)


k = max
KONTRAST
Faz 0
ÇÖZÜNÜRLÜK
k = min
frekans



Perifer **Tüm** **Merkez**

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KAYNAKLAR

- Temel Radyoloji, Manyetik rezonans görüntüleme fiziği, Dr. Oktay Algın, Dr. Ali Çağlar Özen, Dr. Ergin Atalar
- http://www.biomedima.org/en/home/contact?modality=3&slide=131

TEMEL MRG
FİZİĞİ

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July 7, 2009