

# Yazılım Tabanlı Radyo - GİRİŞ -

Barış DİNÇ  
TA7W / OH2UDS

Dünyadaki Mars Projesi / Mars on Earth Project  
<http://www.marsonearthproject.org>

# Gündem

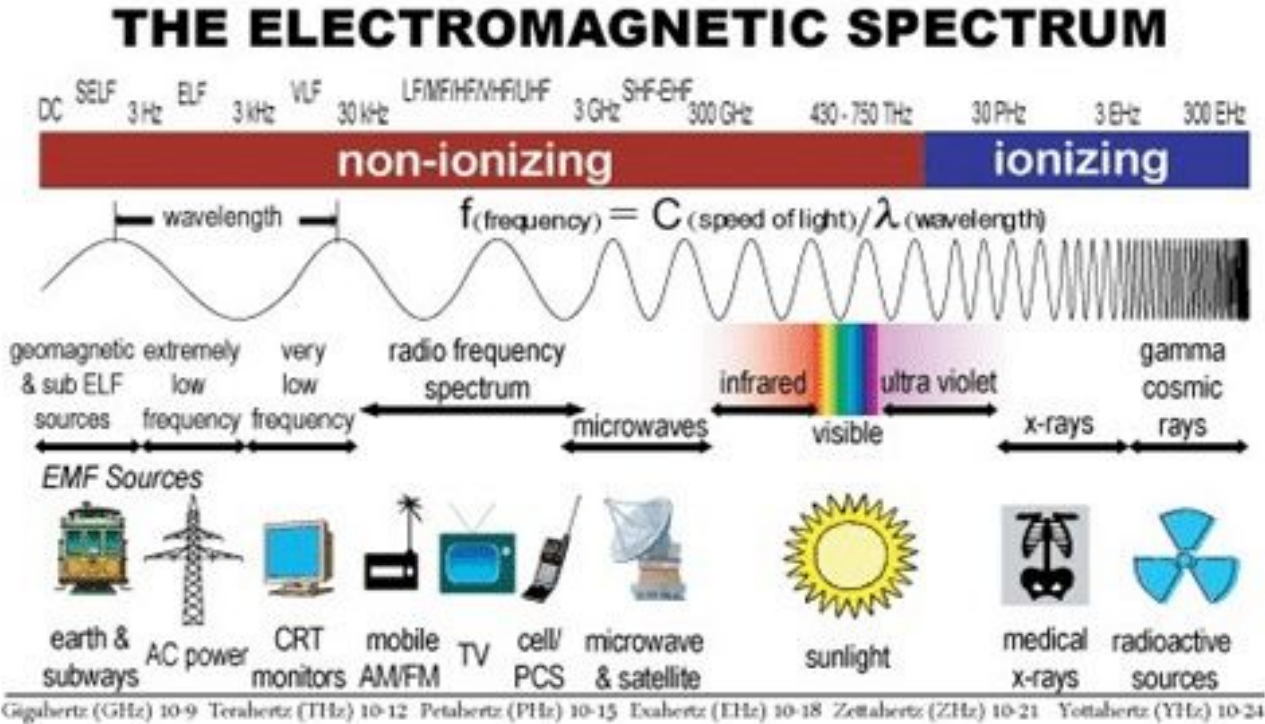
## GİRİŞ

- Tanıtım
- Radyo Nedir ?
- Kompleks Sayıların Dünyası
- Yazılım Tabanlı Radyo (SDR) Nedir ?
- Örnek SDR Donanımları
- Örnek SDR Yazılımları
- SDR Proje Örnekleri

## Devamı

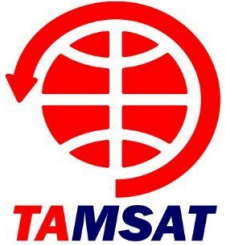
- uSDX'e yakından bakış
  - Donanım
  - Yazılım
- mCHF'e yakından bakış
  - Donanım
  - Yazılım
- GNURADIO ile SDR
  - Giriş
  - Konvansiyonel (AM,FM, SSB, CW)
  - Sayısal Haberleşme (FSK, ASK, GFSK, GMSK)
- Python ile SDR

# Elektromanyetik Spektrum



# TANITIM

1974/Trabzon  
Elektronik Mühendisliđi  
Astronomi ve Uzay Bilimleri  
TA7W / OH2UDS (1990)  
Uzay ve Haberleşme



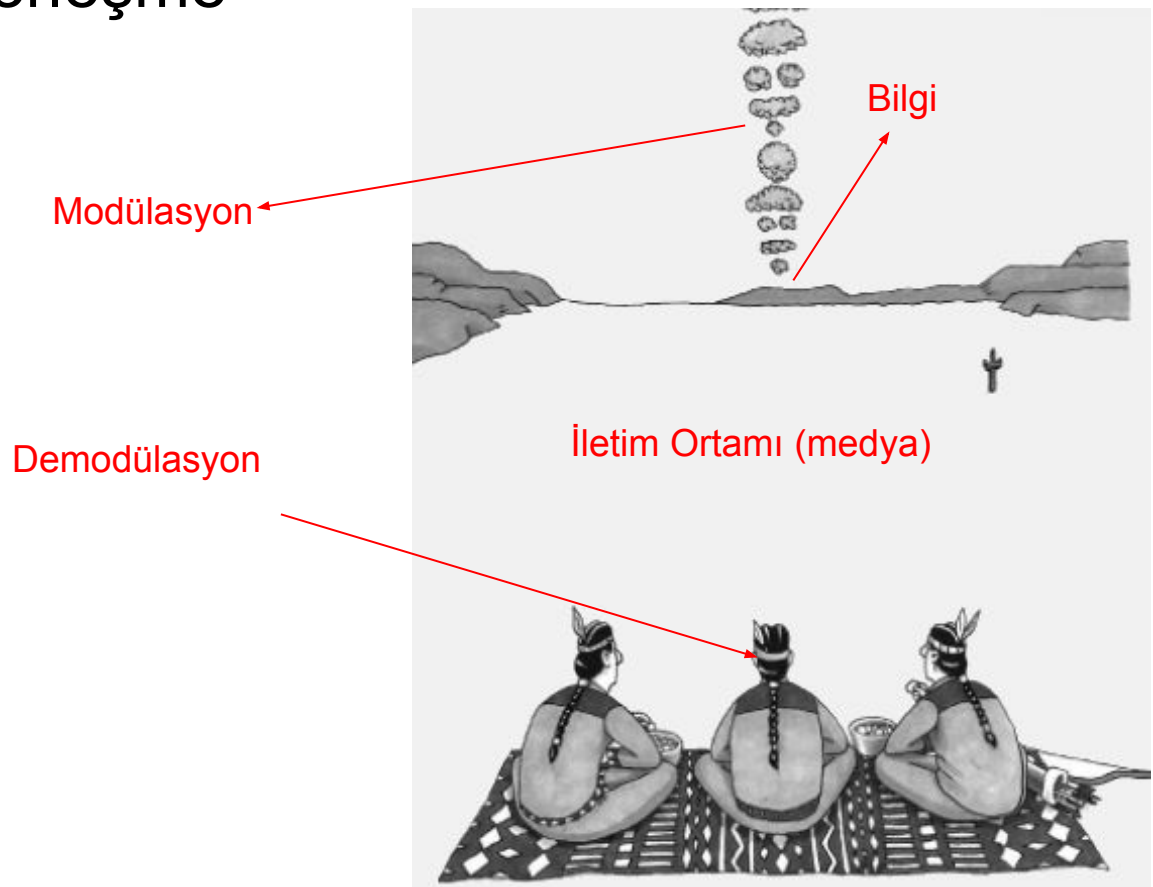
## DÜNYADAKİ MARS PROJESİ (DMP)

Mars on Earth Project

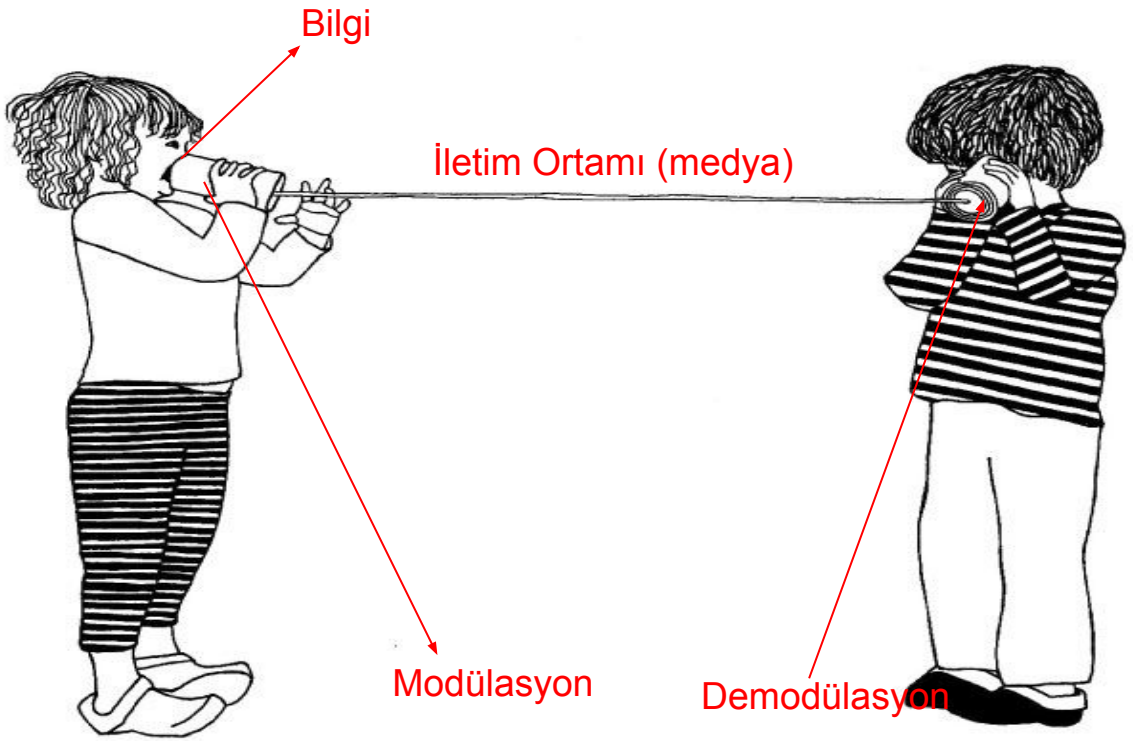
[www.marsonearthproject.org](http://www.marsonearthproject.org)

HABERLEŞME

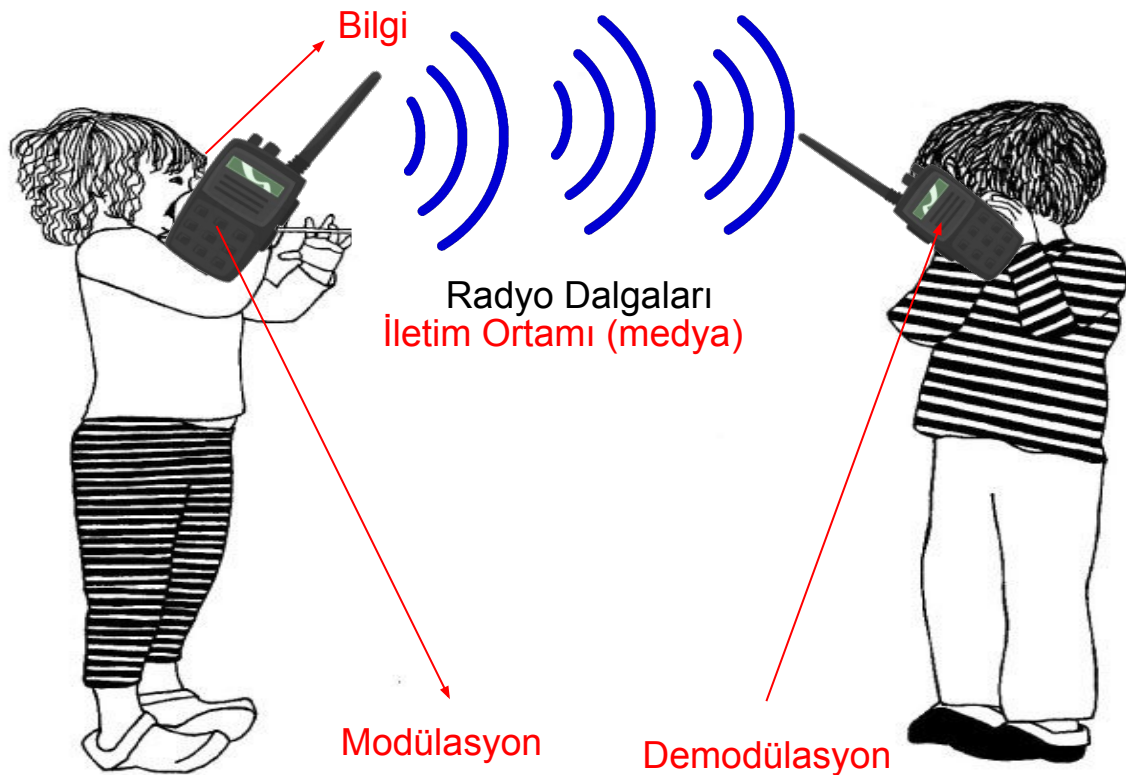
# Haberleşme



# Haberleşme

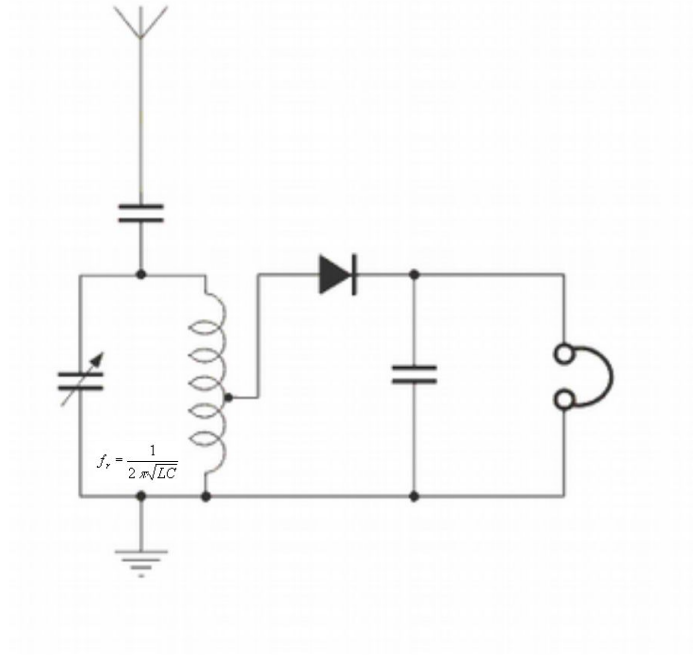


# Haberleşme



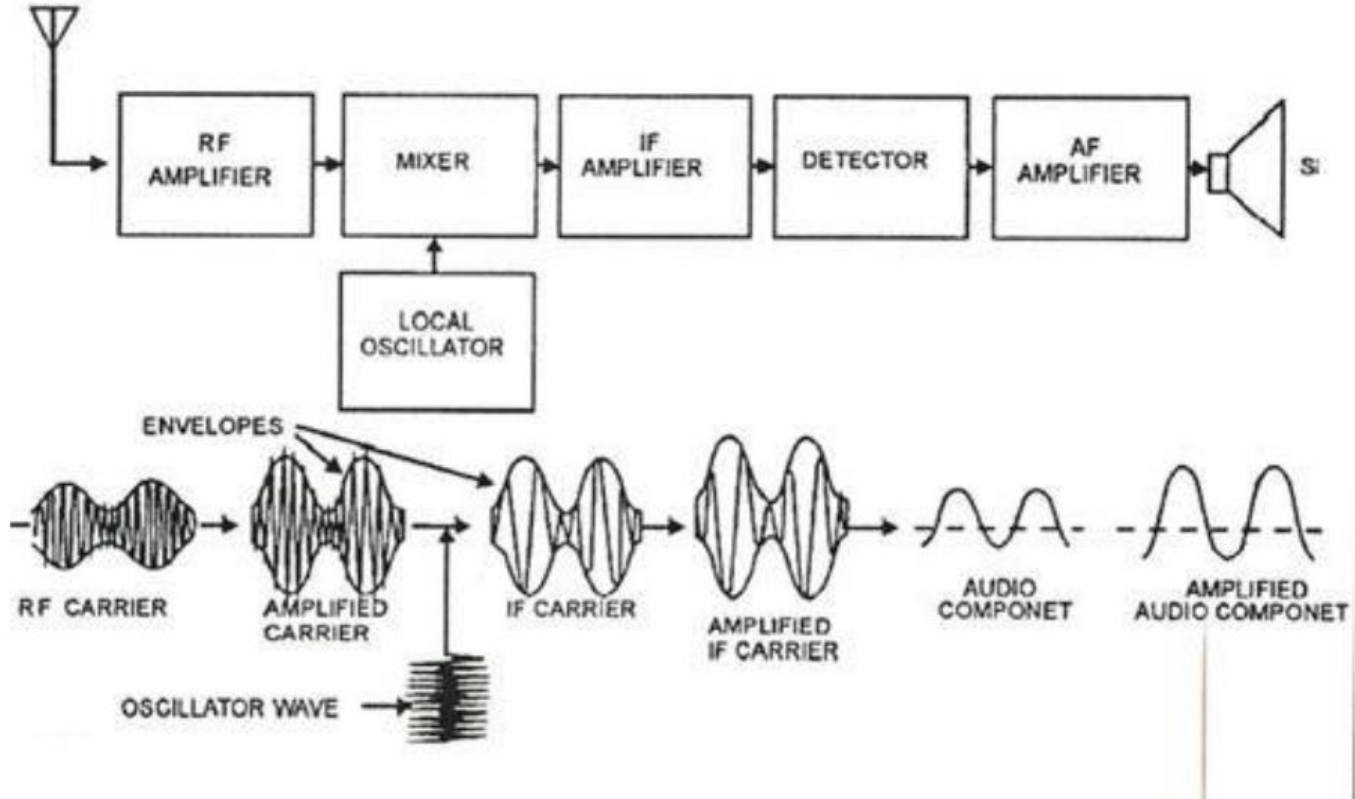


# Radyo Nedir ? (1/2)



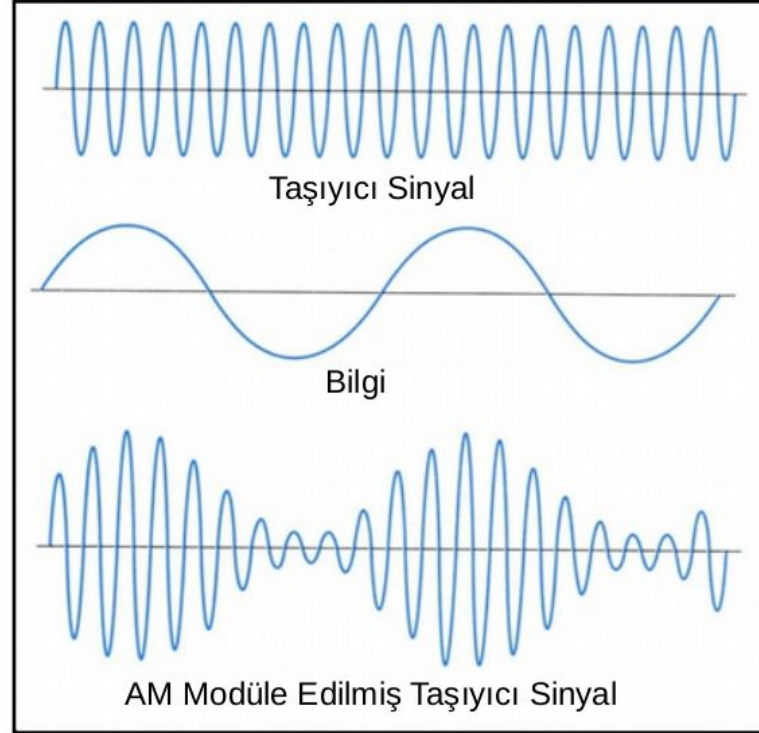
En Basit Radyo Alıcısı

# Radyo Nedir ? (2/2)



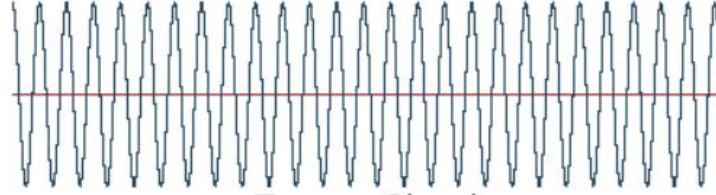
Süperheterodin Radyo Alıcısı

# Modülasyon Nedir ? (AM)

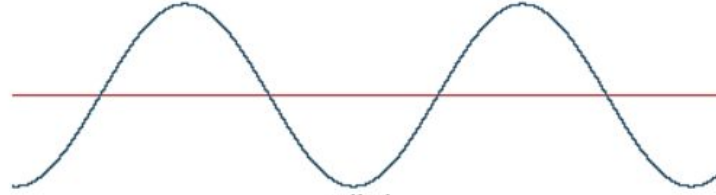


Genlik Modülasyonu (AM)

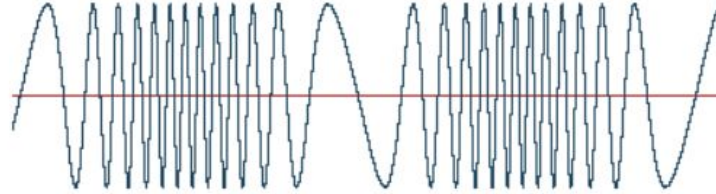
# Modülasyon Nedir ? (FM)



Taşıyıcı Sinyal



Bilgi



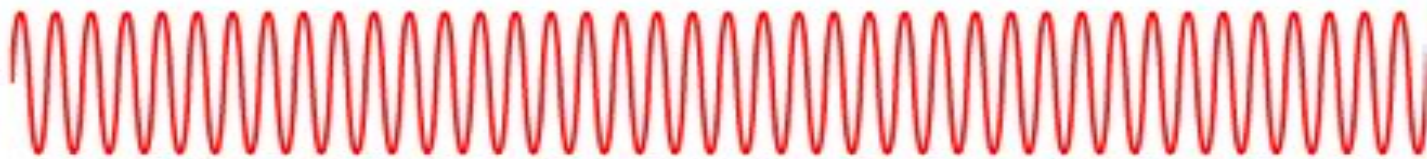
FM Modüle Edilmiş Taşıyıcı Sinyal

Frekans Modülasyonu (FM)

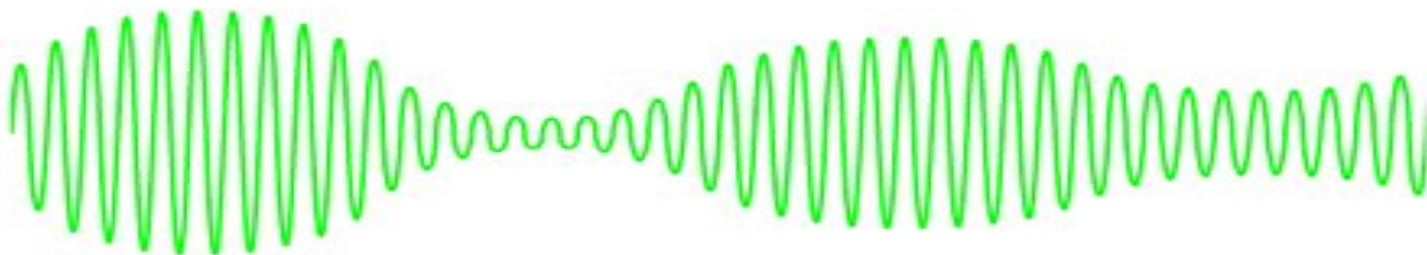
Modulator



Carrier



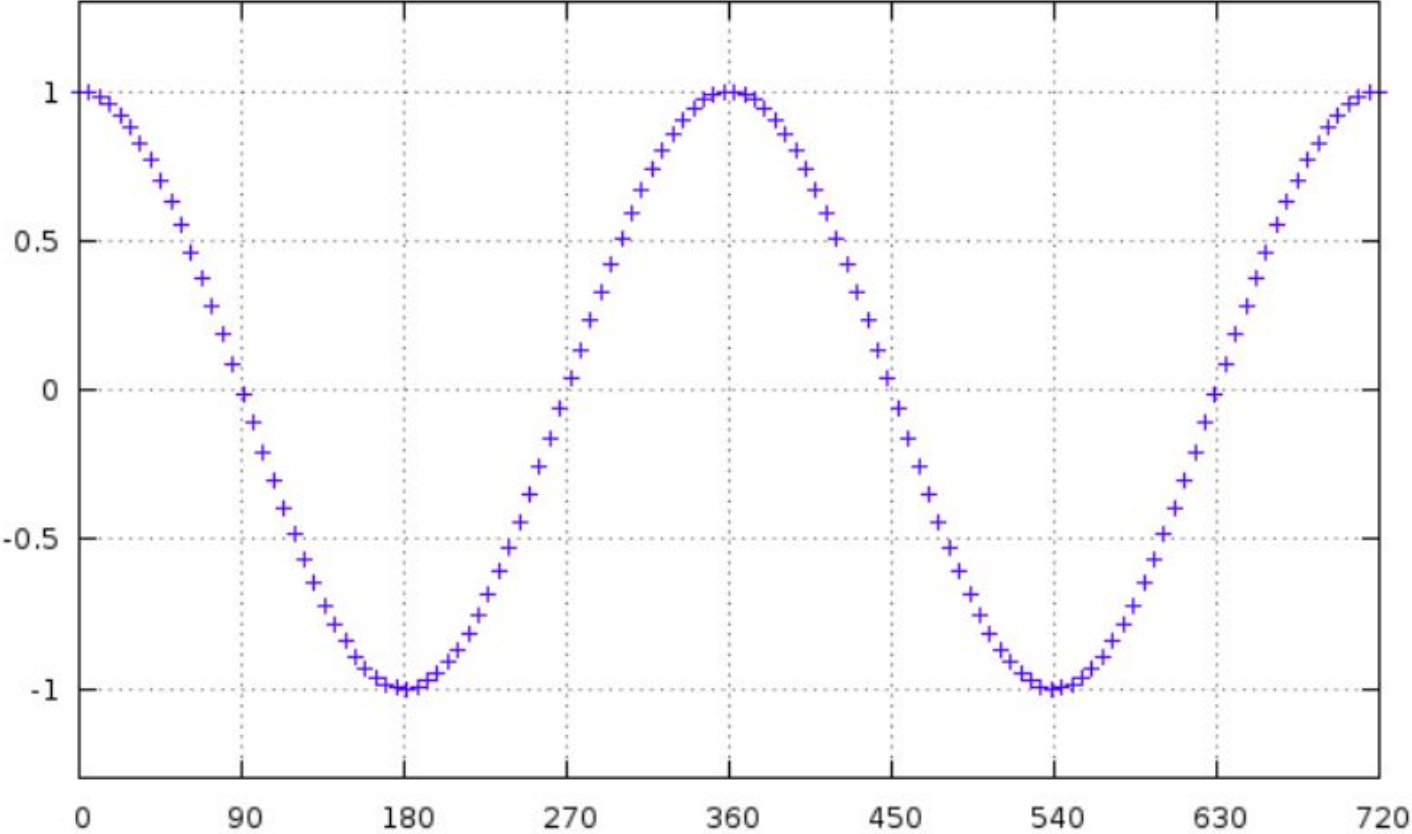
Amplitude  
Modulation



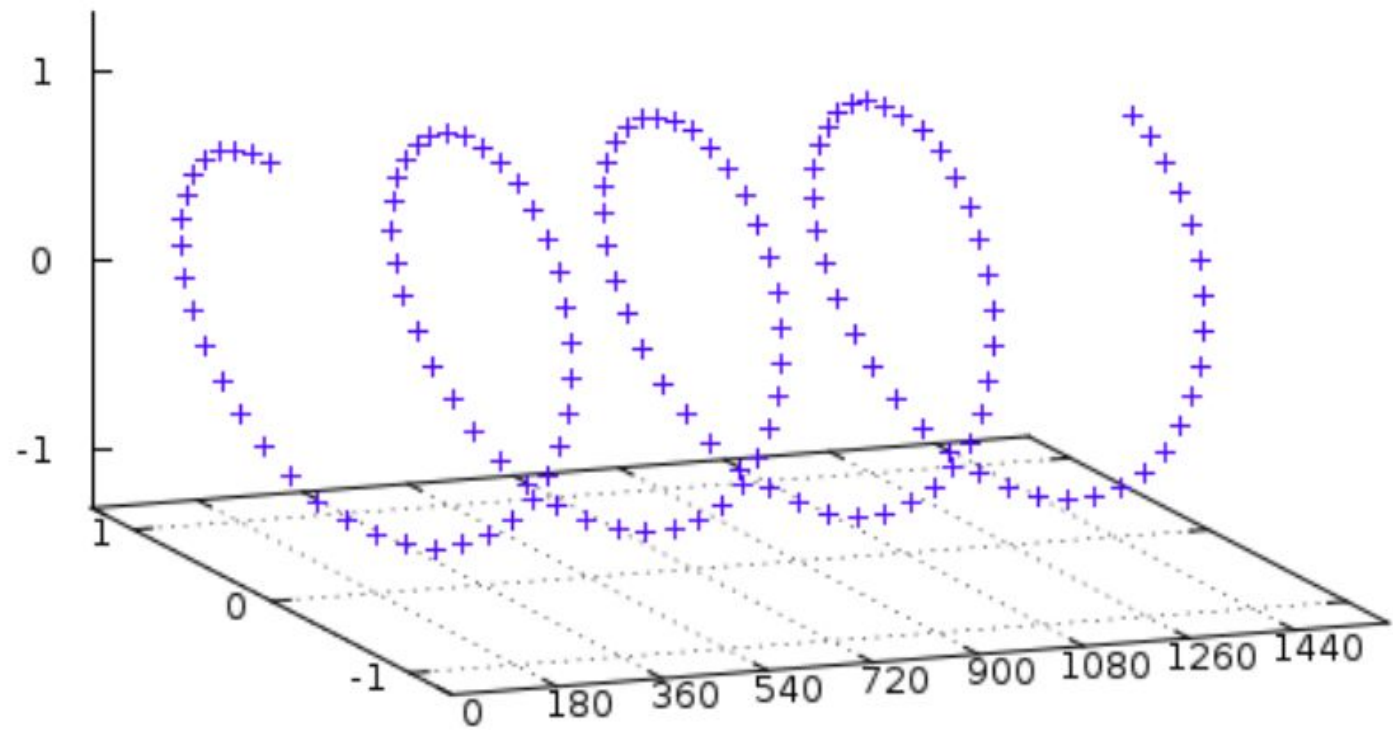
Frequency  
Modulation



# Birazcık MATEMATİK !



# Birazcık MATEMATİK !



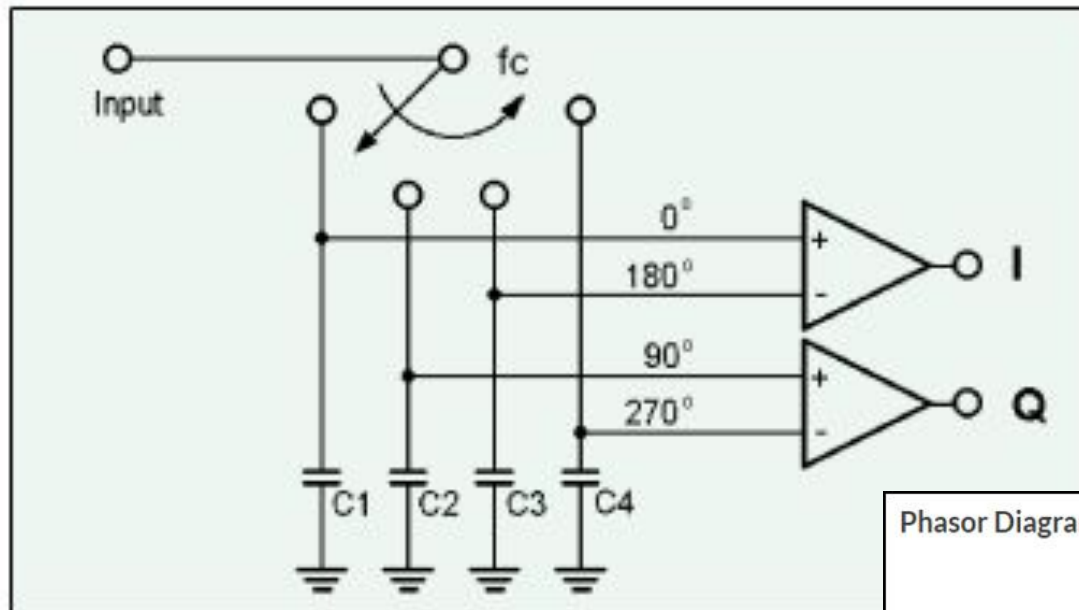
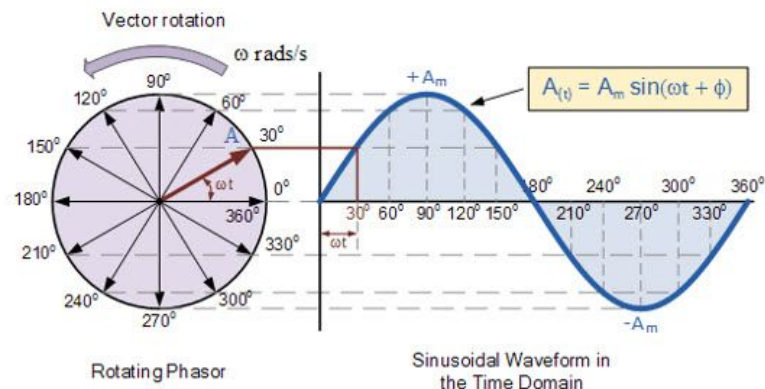


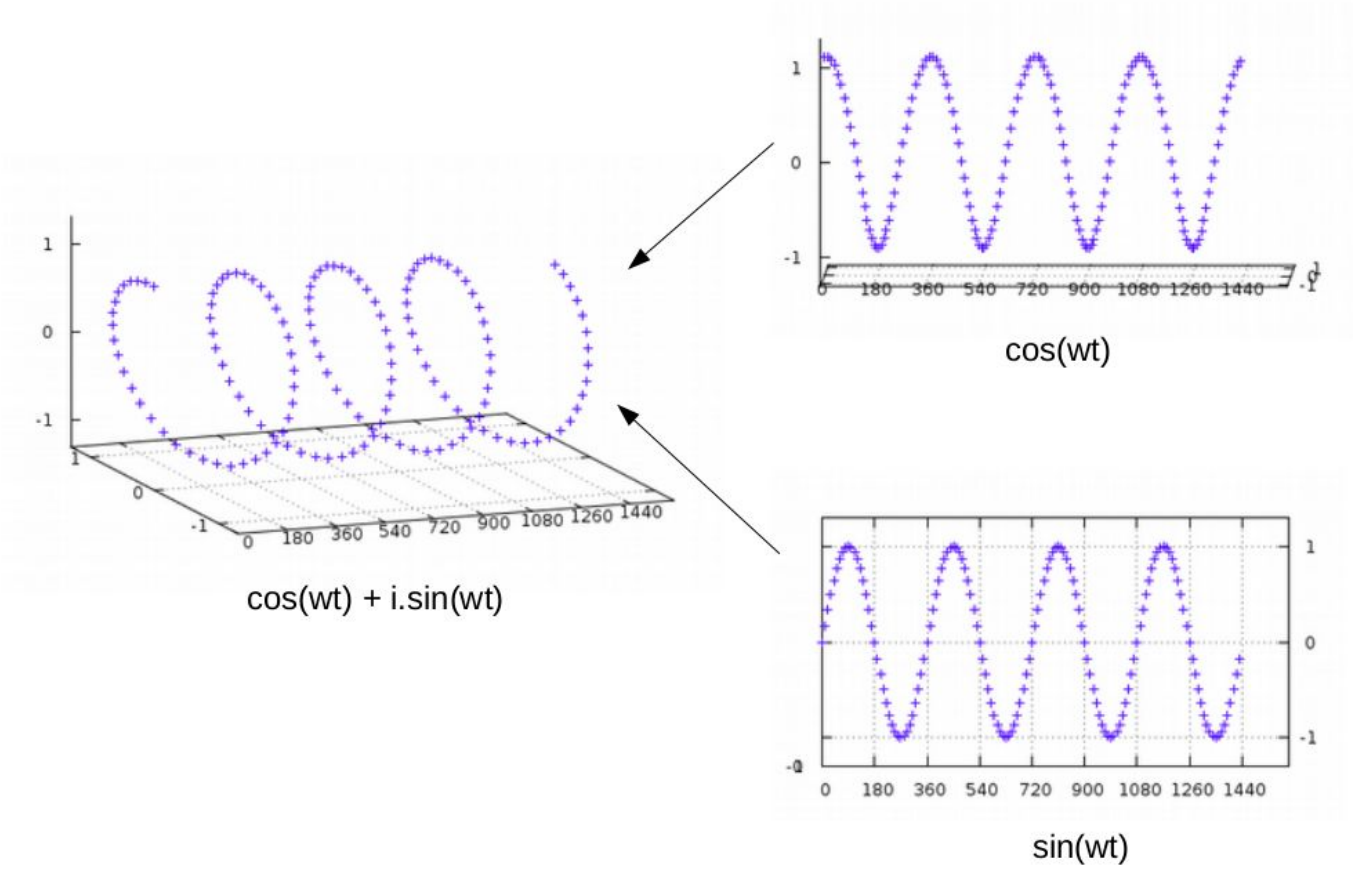
Fig. 2- A quadrature sampling detector is nothing but a four-way switch rotates (moves across all four outputs) at the RF carrier frequency. The capacitors sample the voltage during each quarter waveform, or phases, which are fed to amplifiers to create the in-phase and quadrature signals, I and Q.

### Phasor Diagram of a Sinusoidal Waveform

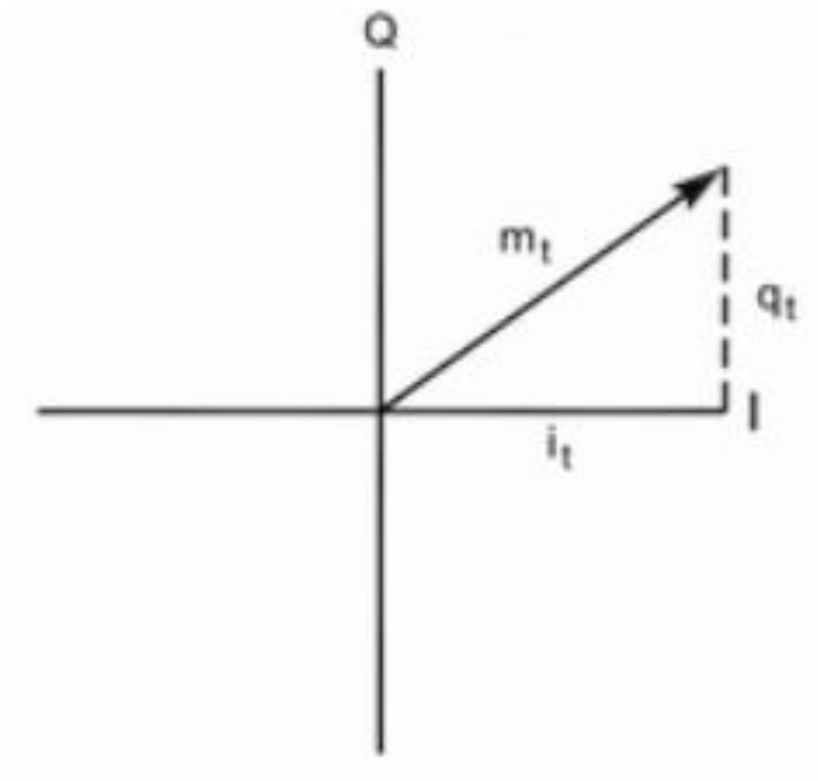




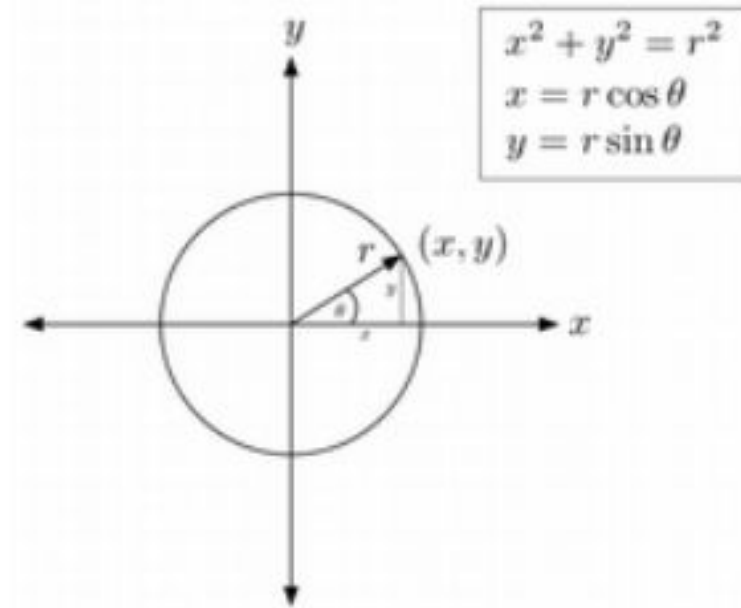
# Birazcık MATEMATİK !



# Birazcık MATEMATİK !

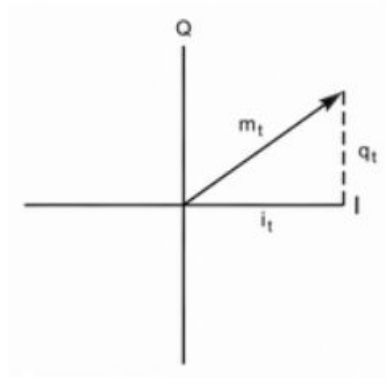
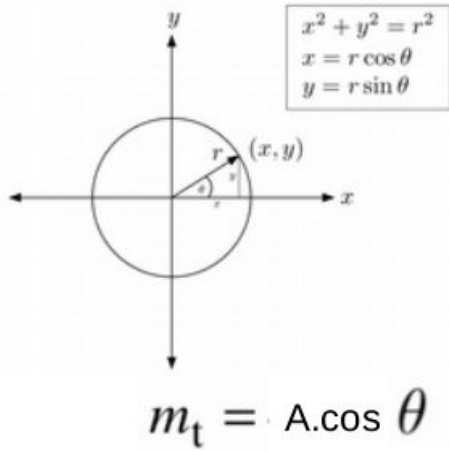
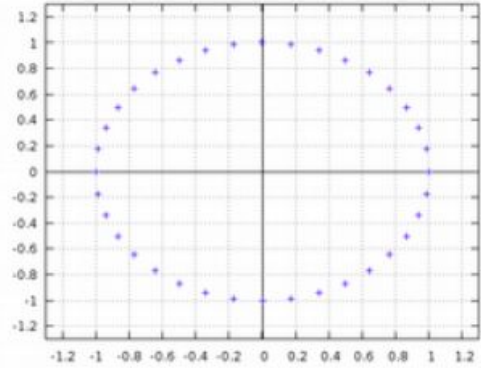


# Birazcık MATEMATİK !



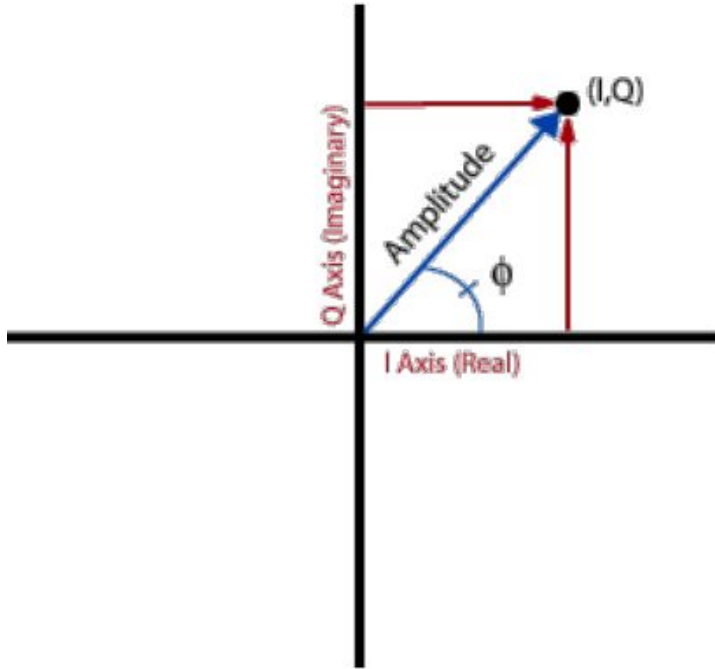
$$m_t = A \cdot \cos \theta$$

# Birazcık MATEMATİK !



$$m_t = \sqrt{I_t^2 + Q_t^2}$$

# Birazcık MATEMATİK !



Koordinat :  $(I,Q)$

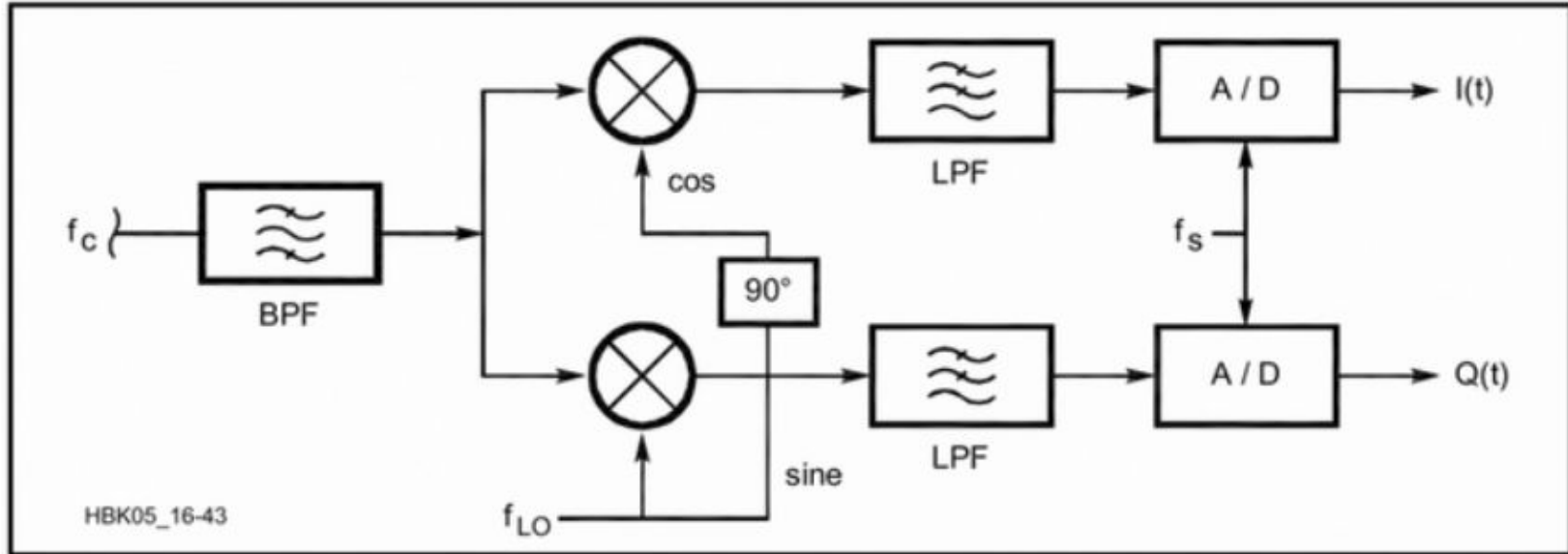
Vektör :  $[I,Q]$

Komplex Sayı :  $I+Qi$

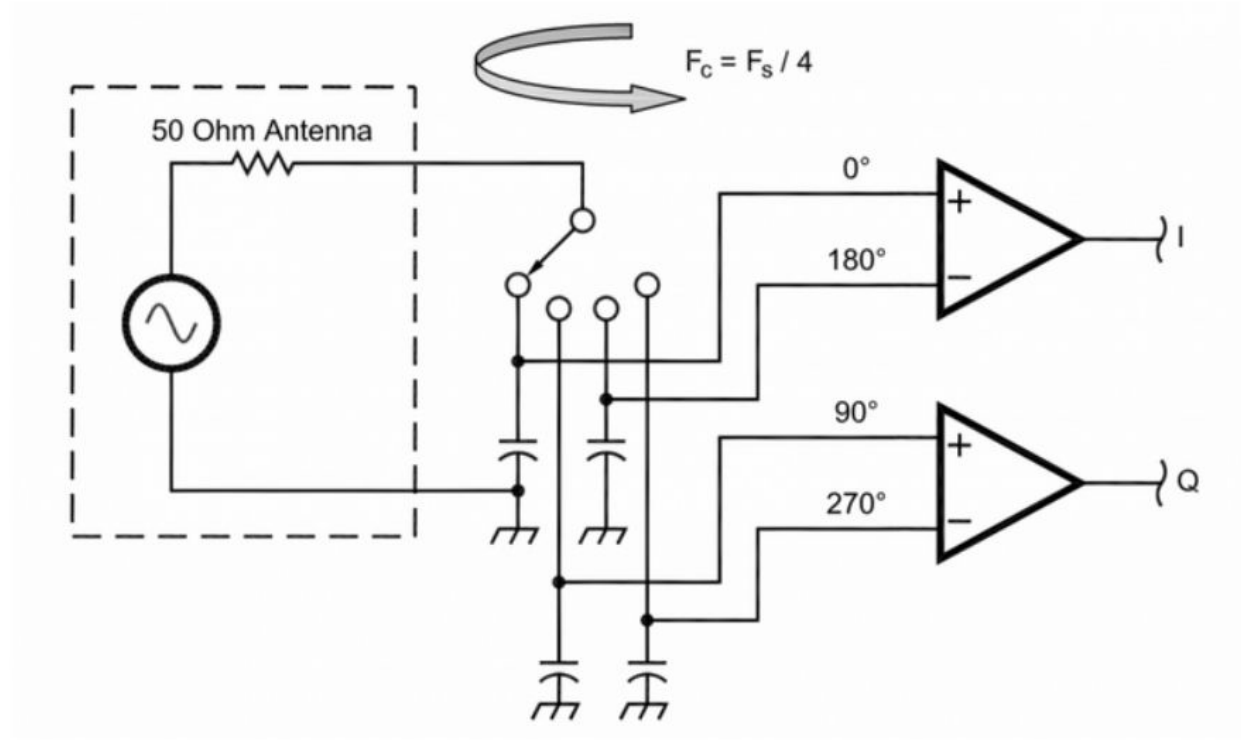
Polar :  $I=A.\cos(wt)$ ,  $Q=A.\sin(wt)$

Euler :  $A(\cos(\phi) + i \cdot \sin(\phi))$   
 $Ae^{i\phi}$

# Yazılım Tabanlı Radyo Nedir ? (1/3)

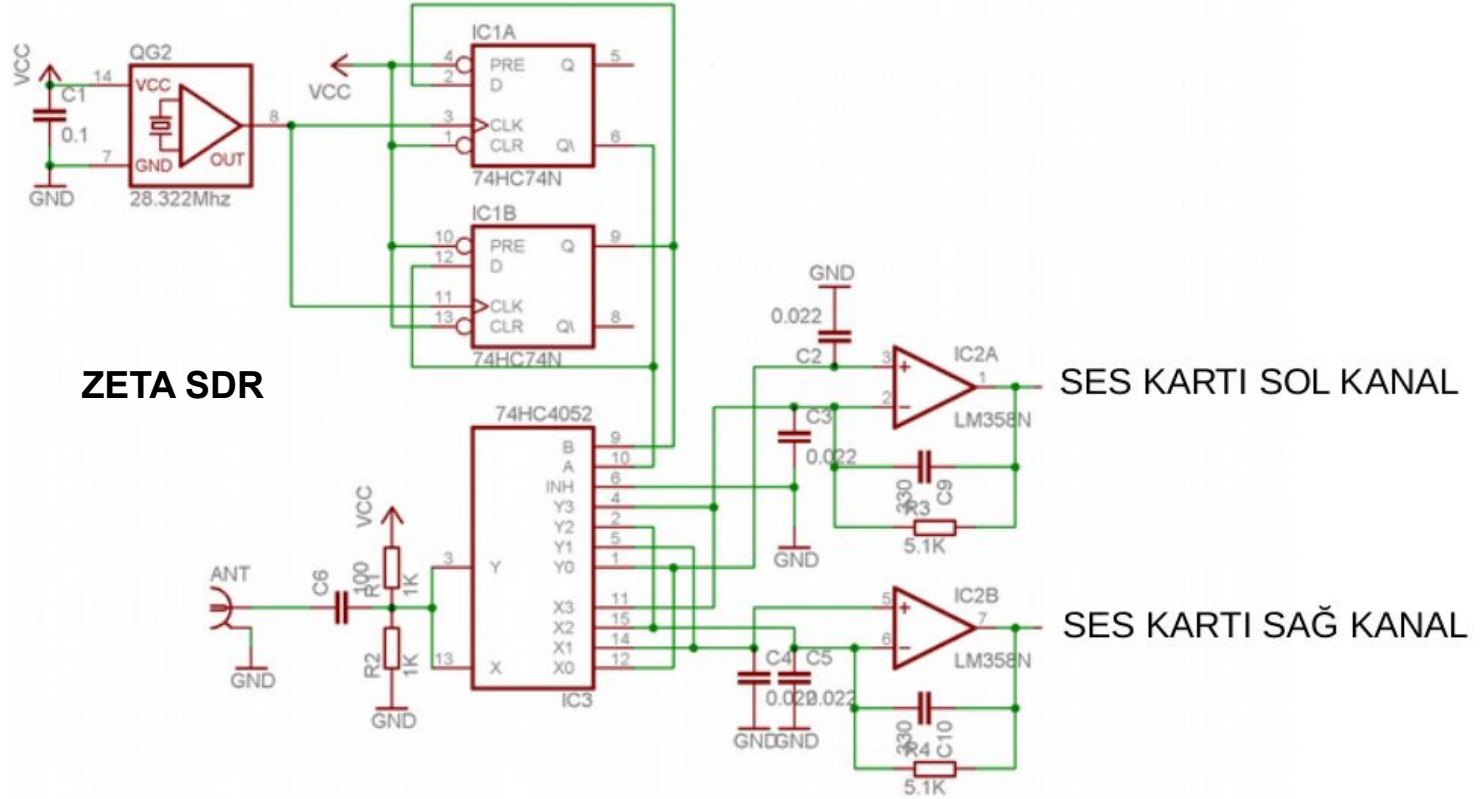


# Yazılım Tabanlı Radyo Nedir ? (2/3)



Tyloe Detektörü

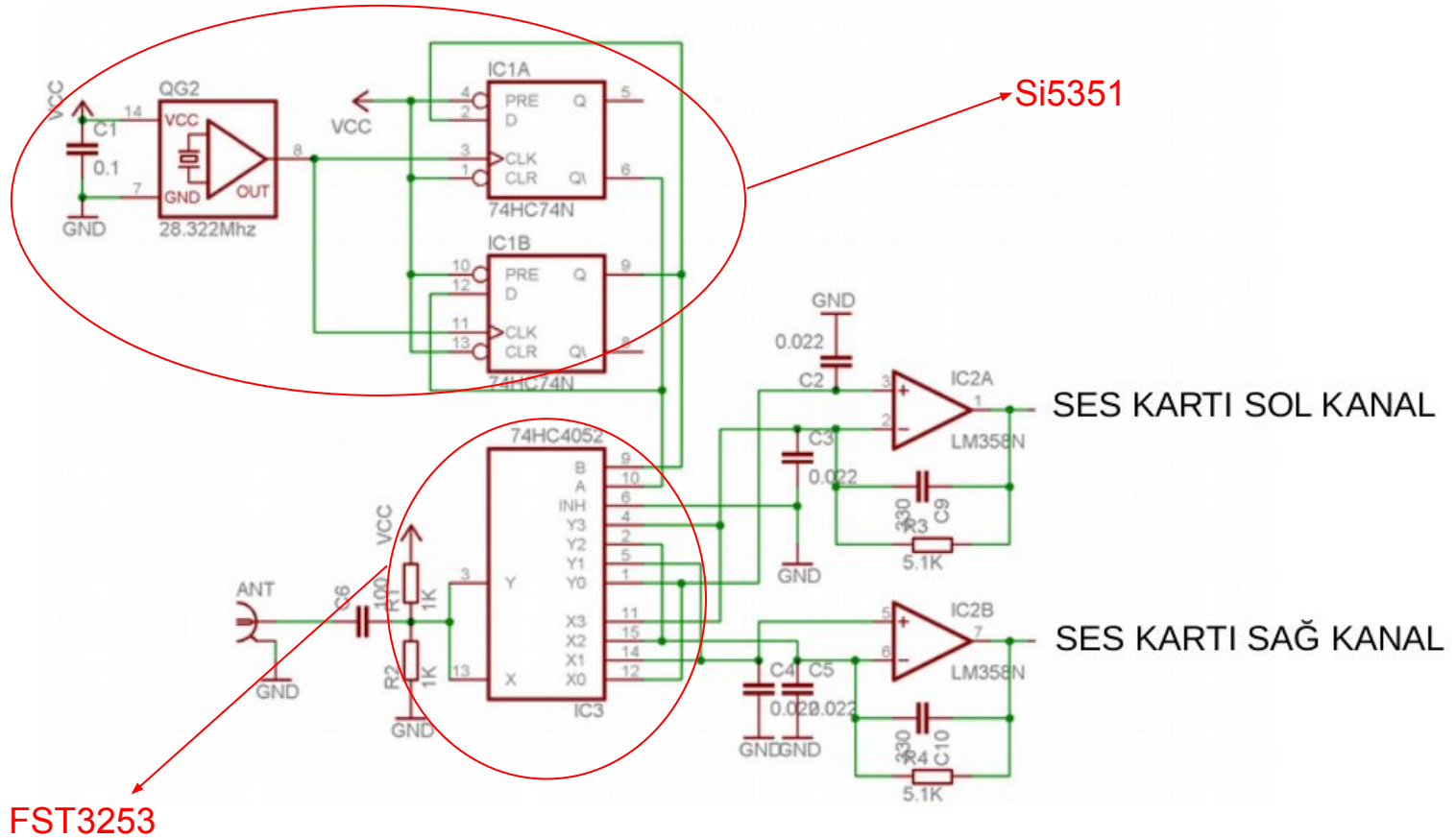
# Yazılım Tabanlı Radyo Nedir ? (3/3)



(Yaklaşık Maliyet 10 TL)

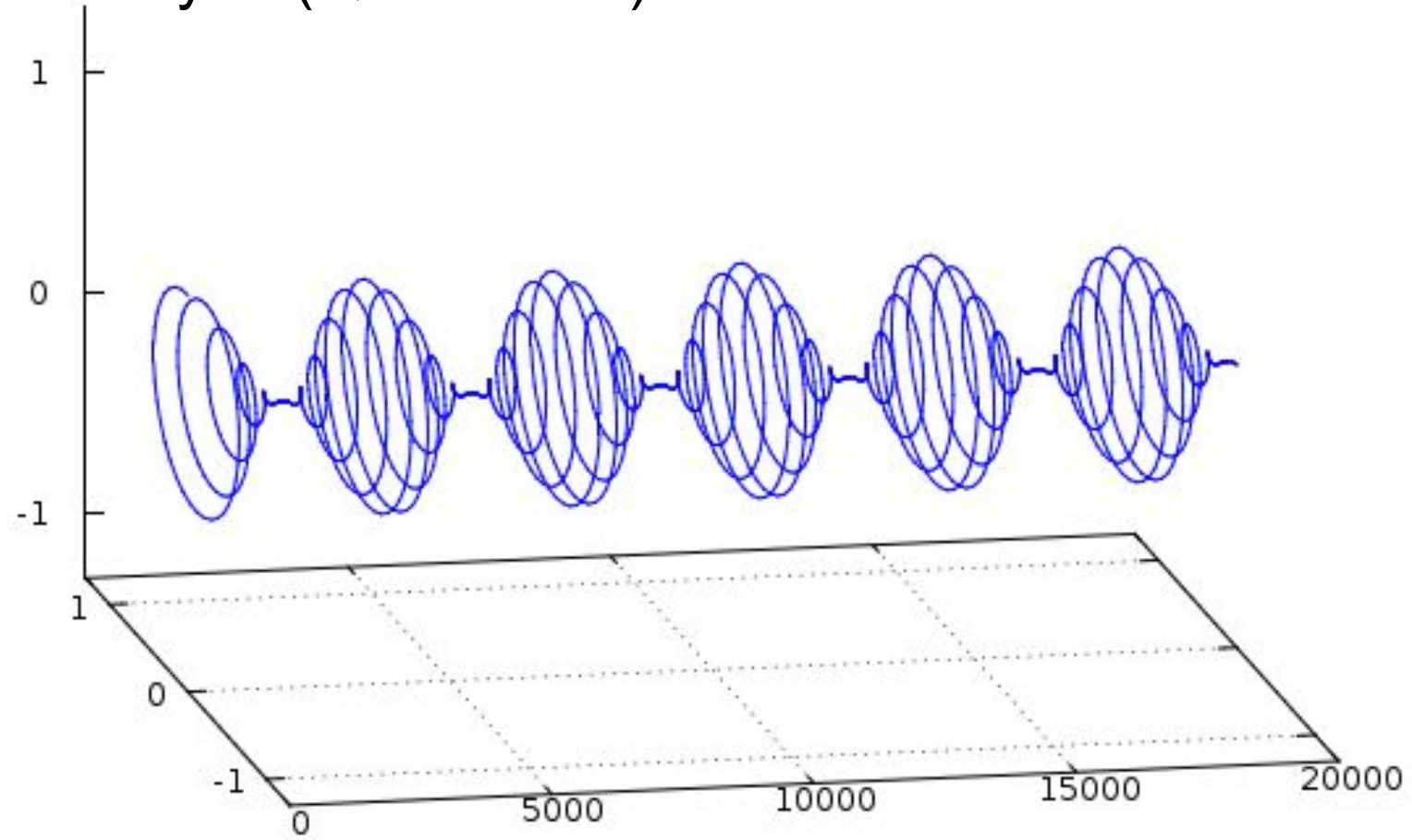


# Yazılım Tabanlı Radyo Nedir ? (3/3)

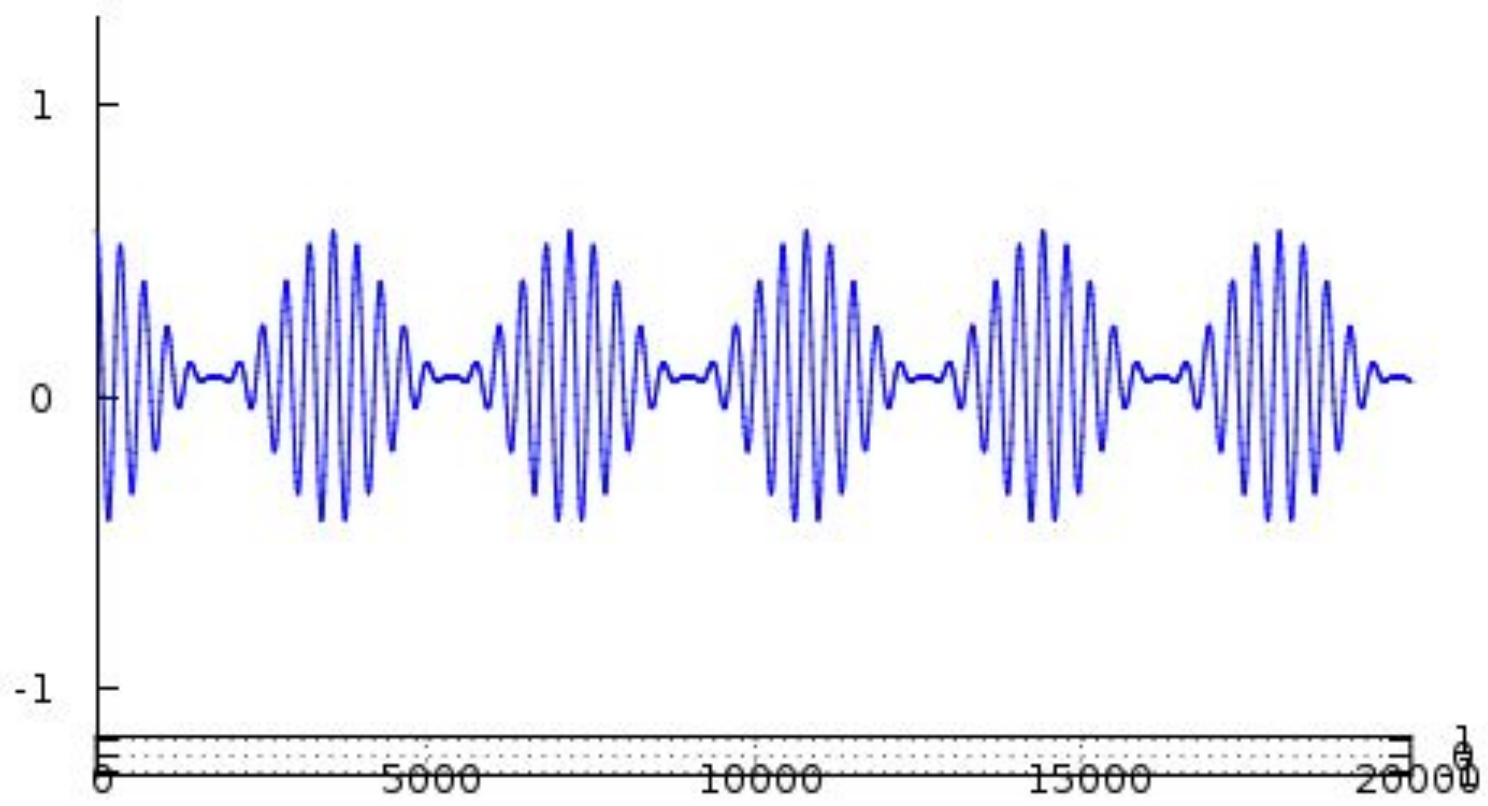


(Yaklaşık Maliyet 10 TL)

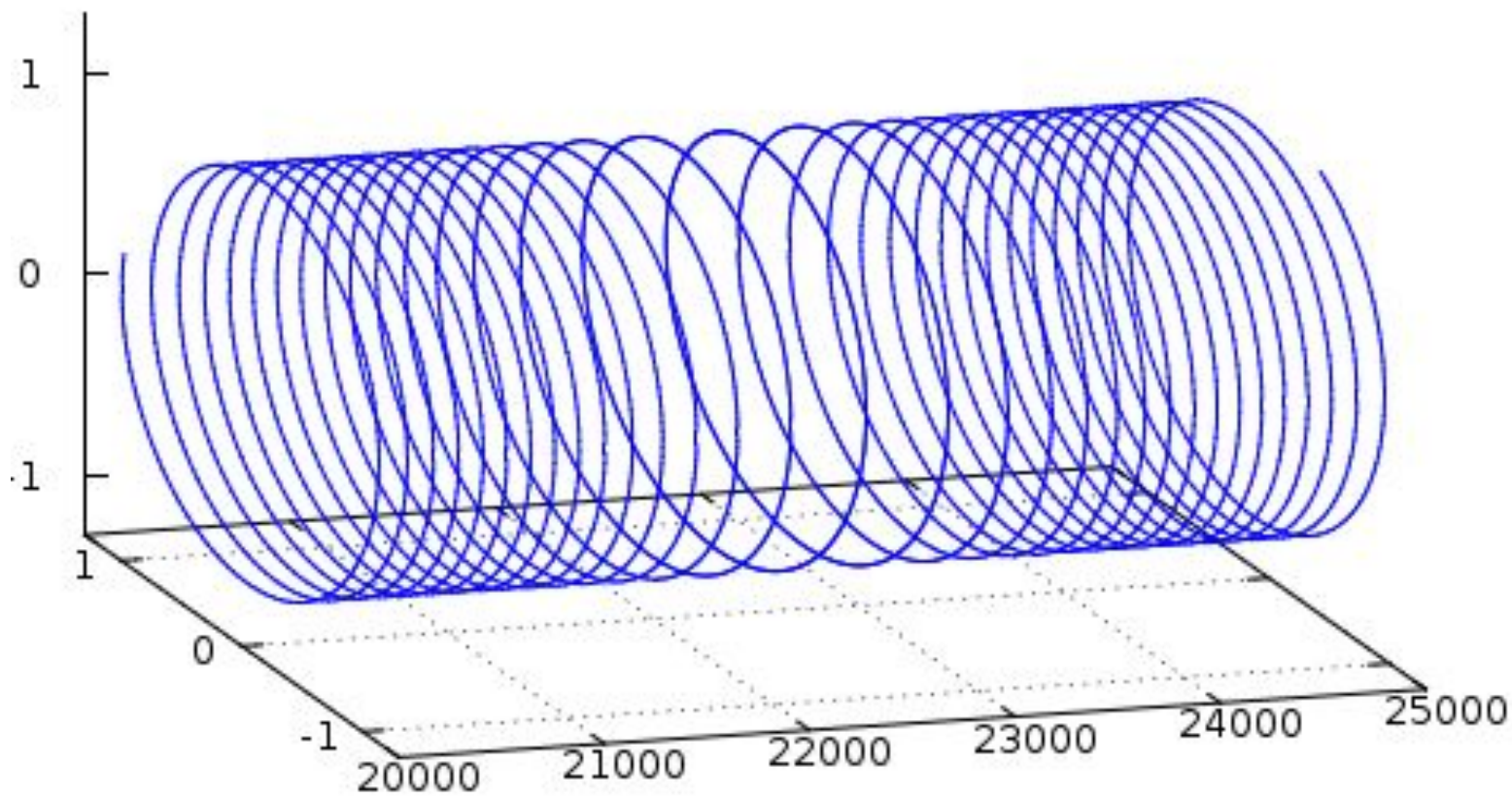
# AM Modülasyon (Quadrature)



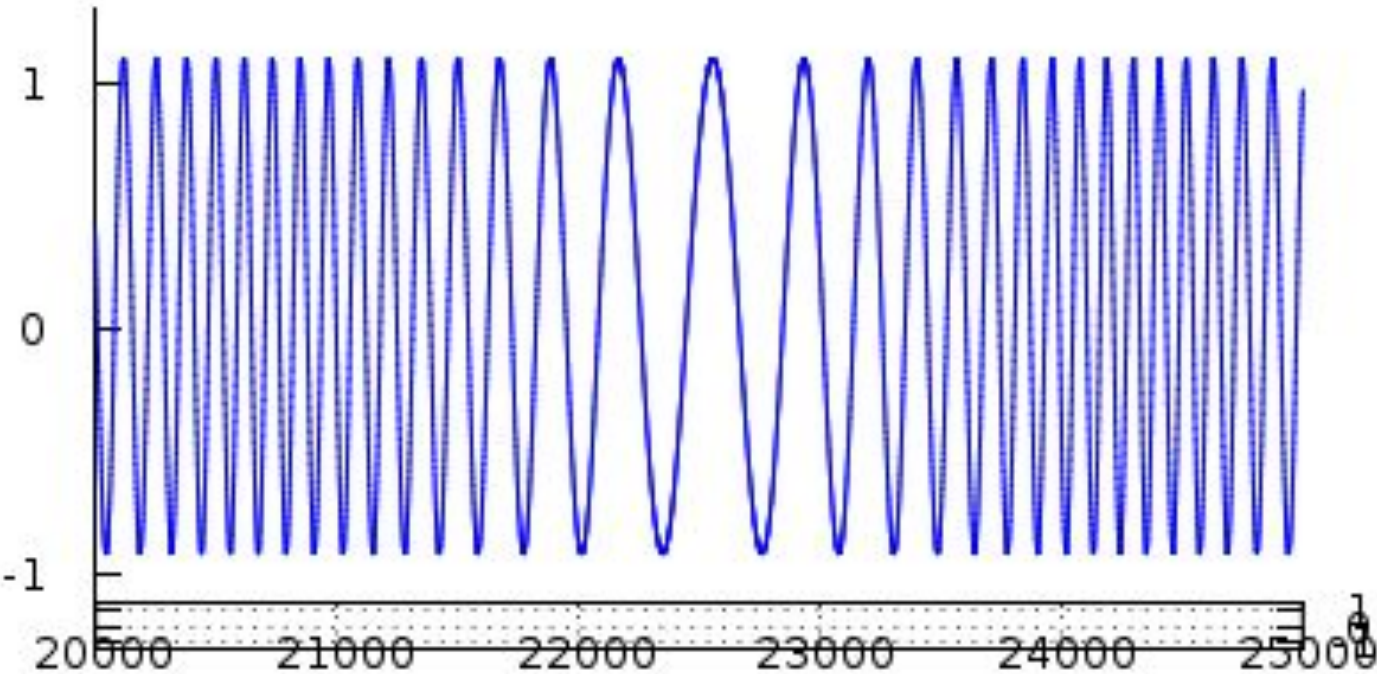
# AM Modülasyon (Quadrature - Sadece I veya Q)



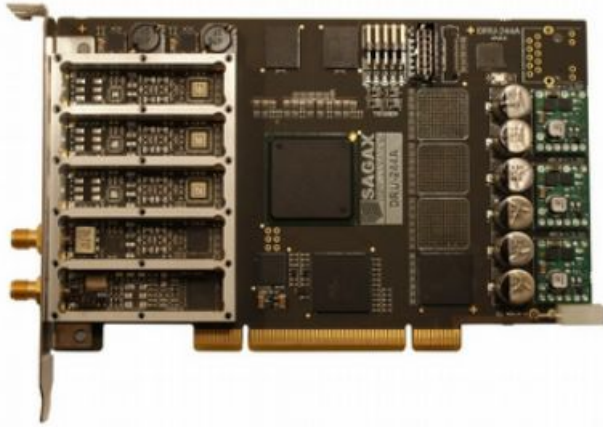
# FM Modülasyon (Quadrature)



# FM Modülasyon (Quadrature - Sadece I veya Q)



# Örnek SDR Donanımları



**BW > 500 Mhz  
>> \$40.000**

**SAGAX QUADRUS**



# Örnek SDR Donanımları



**B Serisi : < 20Mhz BW, ~\$1500**



**N Serisi : 25Mhz BW, ~\$2500**



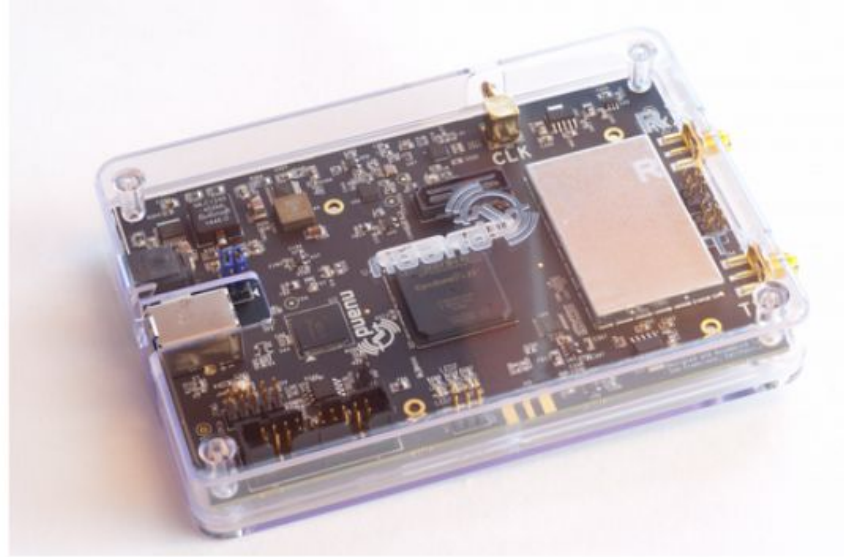
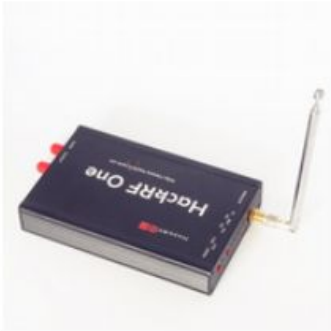
**E Serisi : 50Mhz BW, ~\$4500**



**X Serisi : 150 Mhz BW, ~\$7500**

Ettus Research

# Örnek SDR Donanımları

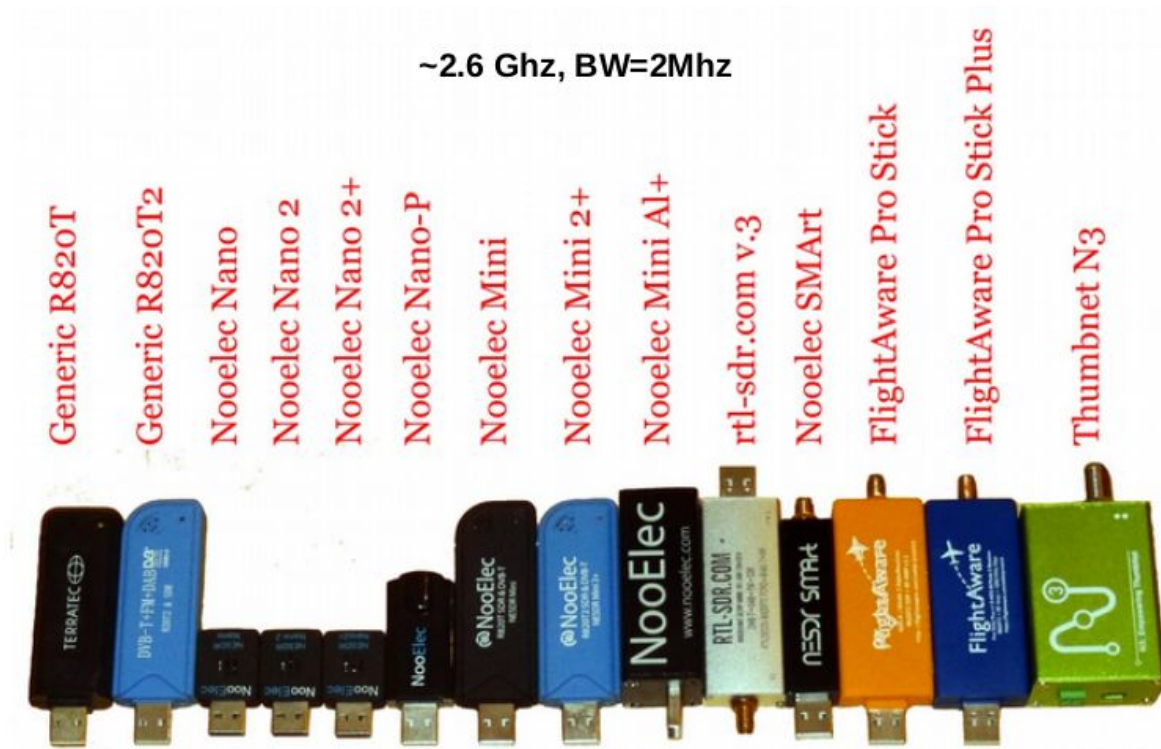


BW ~20Mhz  
~\$300

HackRF ve BladeRF



# Örnek SDR Donanımları



~2.6 Ghz, BW=2Mhz

RTL SDR

<\$10

# Örnek SDR Telsizler



STM32-SDR-RXTX Kit-001

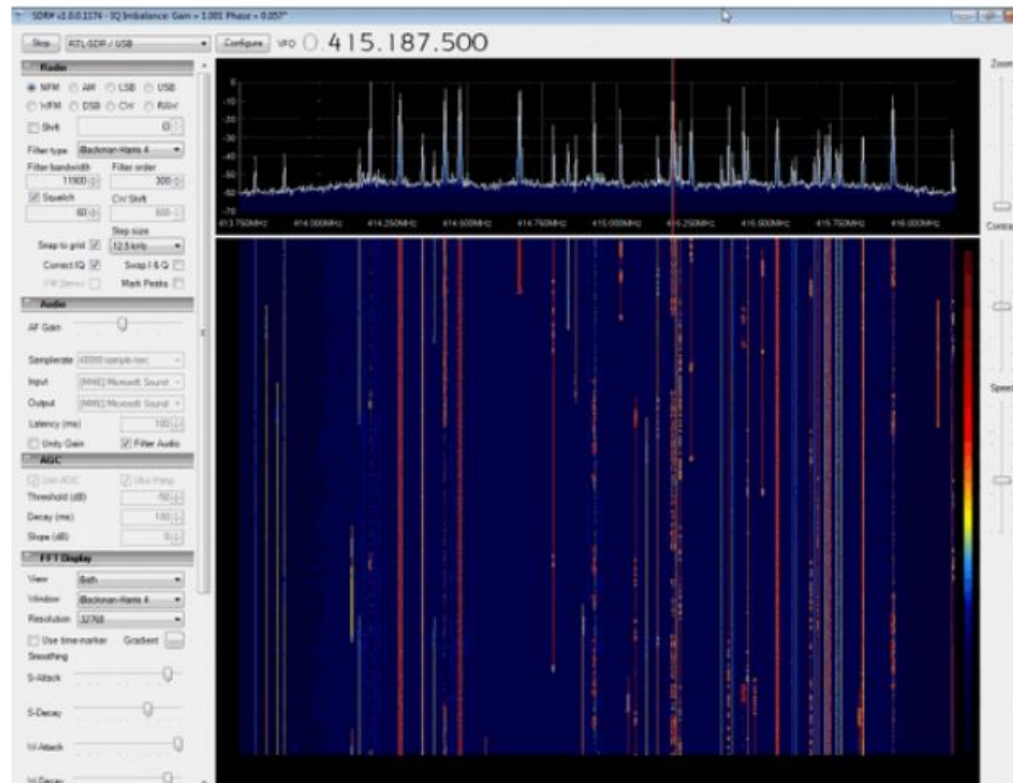


# Örnek SDR Telsizler



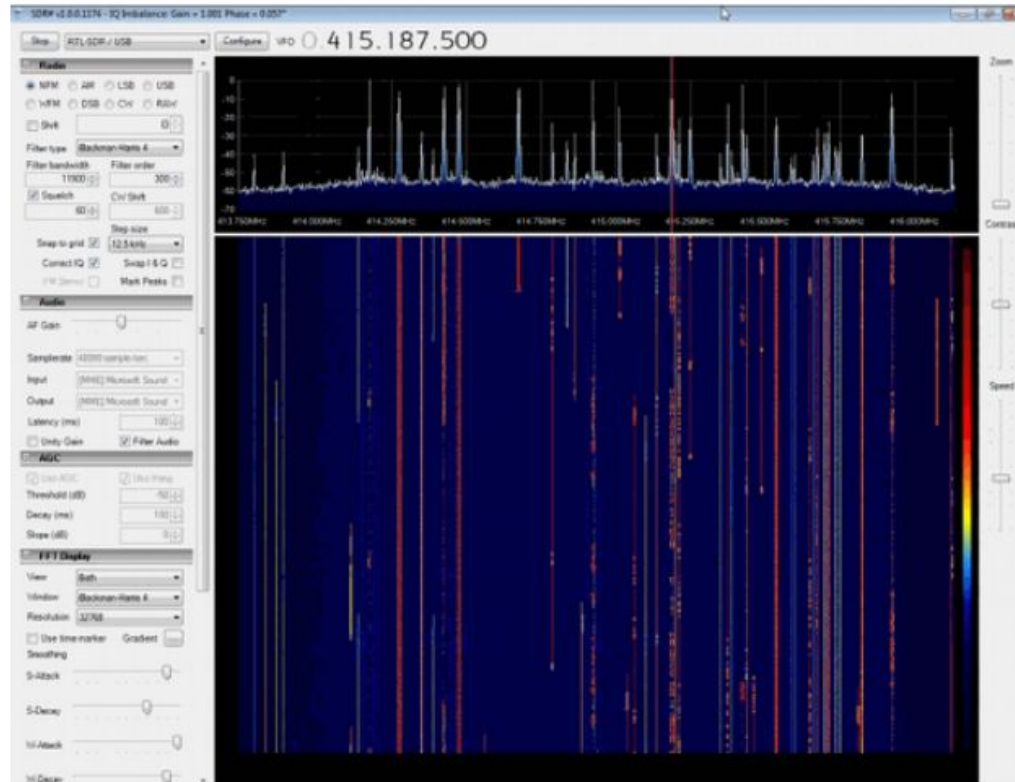
# Hazır Yazılımlar

## SDR# (Windows) (Free)



# Hazır Yazılımlar

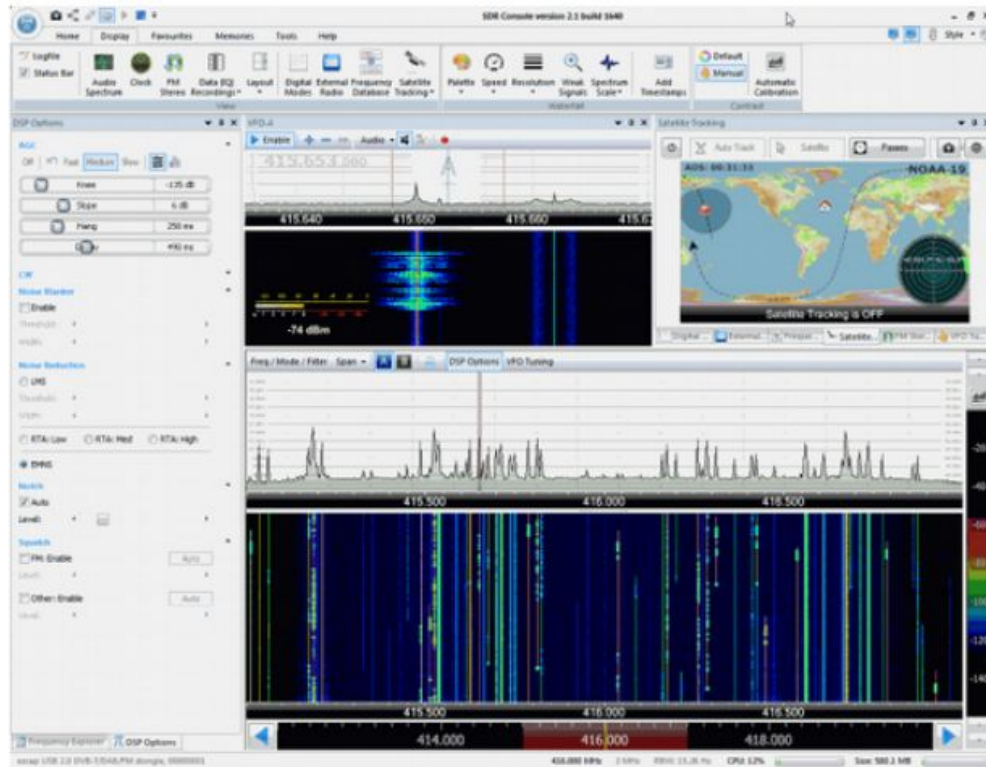
SDR# (Windows) (Free)





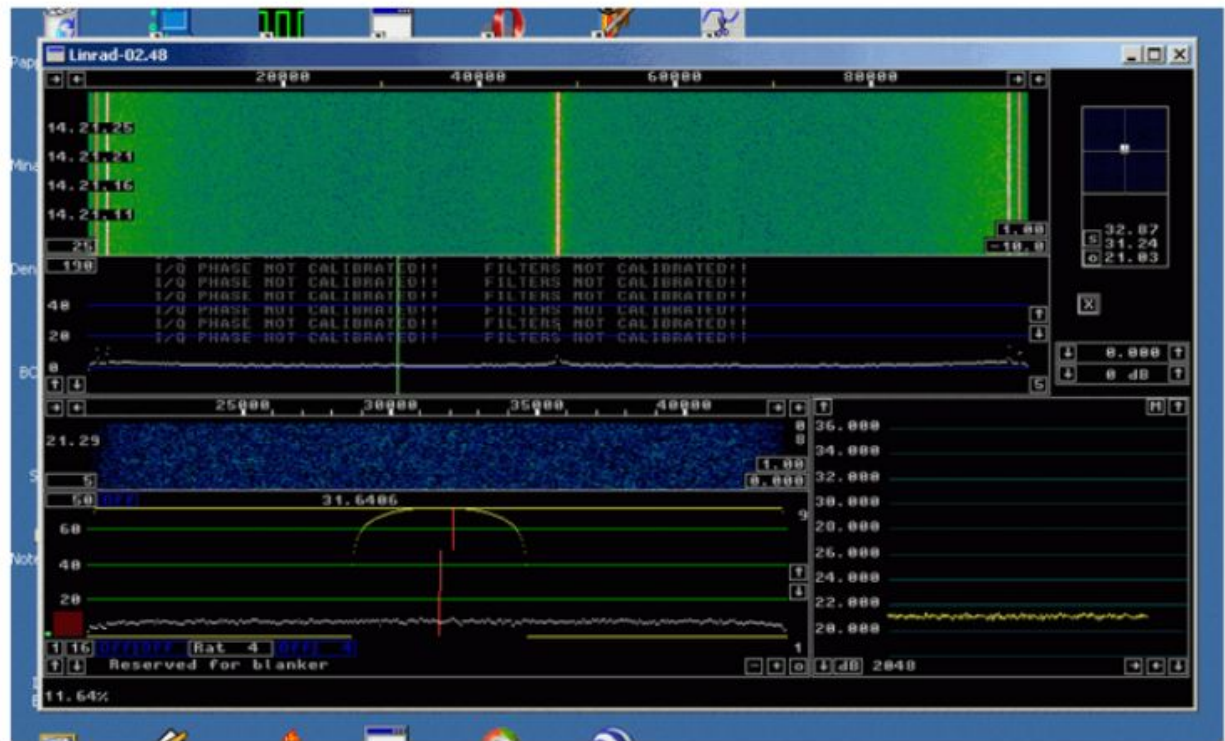
# Hazır Yazılımlar

SDR-RADIO.COM V2 (Windows) (Free)



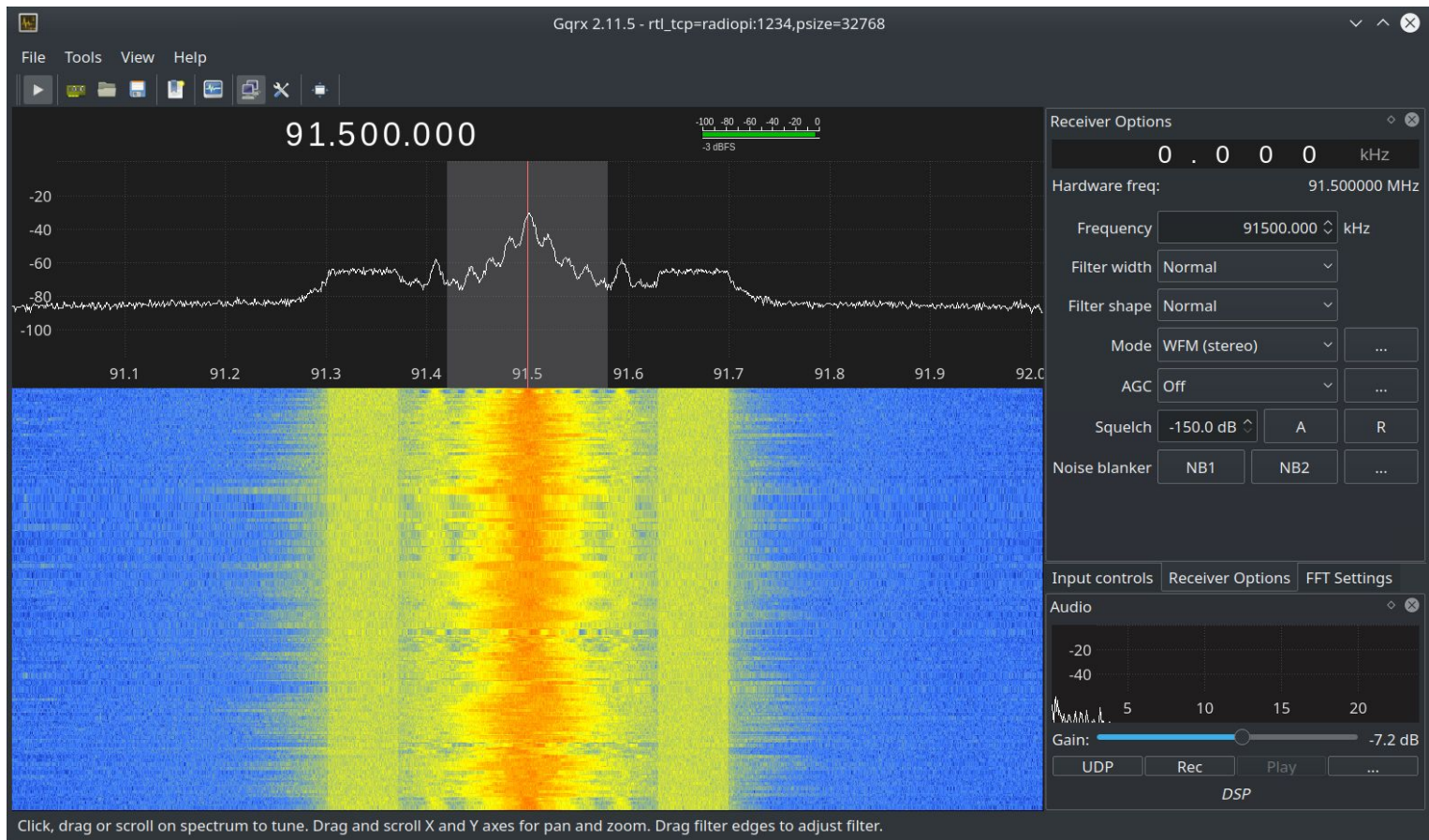
# Hazır Yazılımlar

Linrad (Windows/Linux/Mac) (Free) ([Related Post](#))



# Hazır Yazılımlar

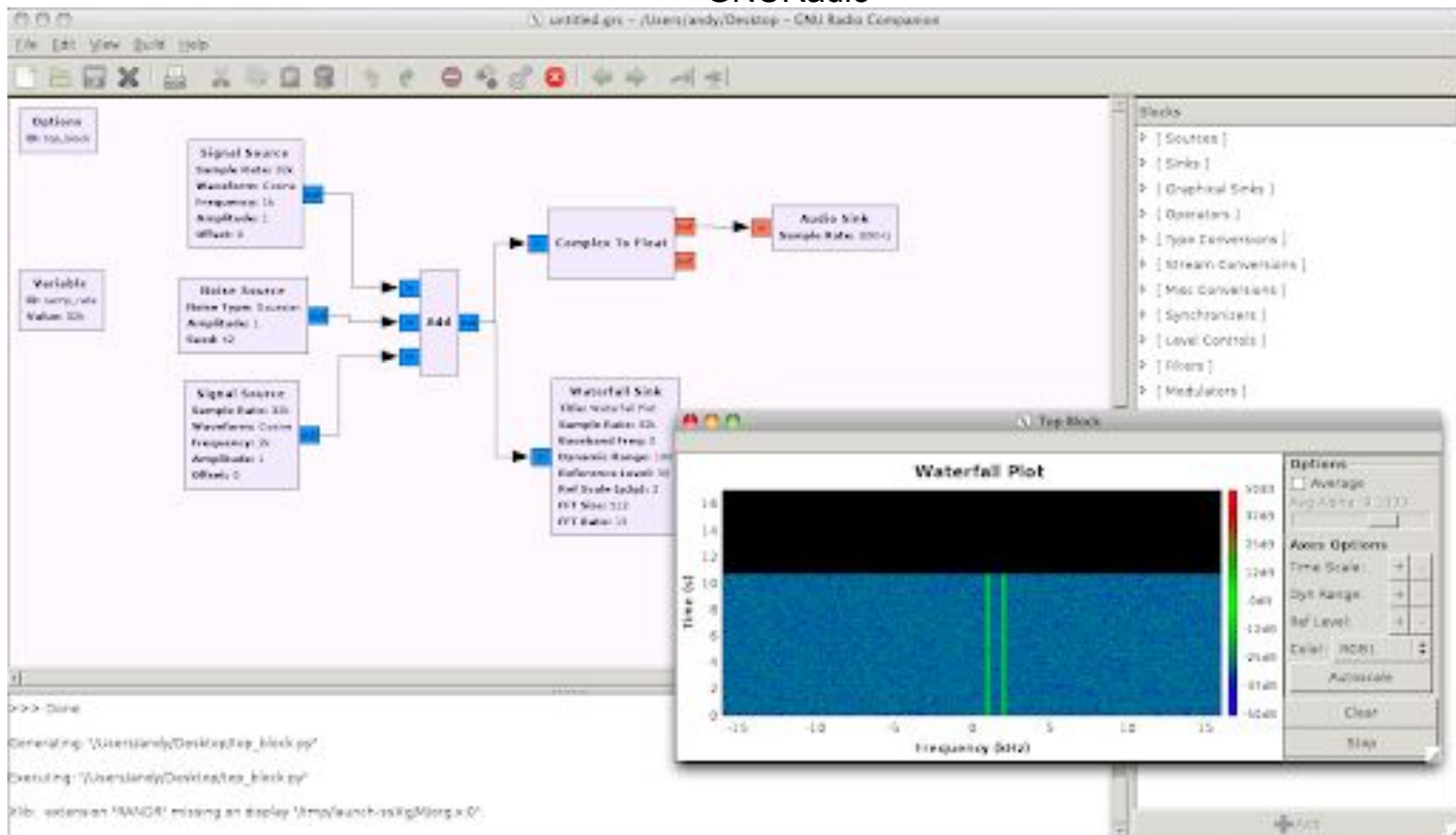
## GQRX





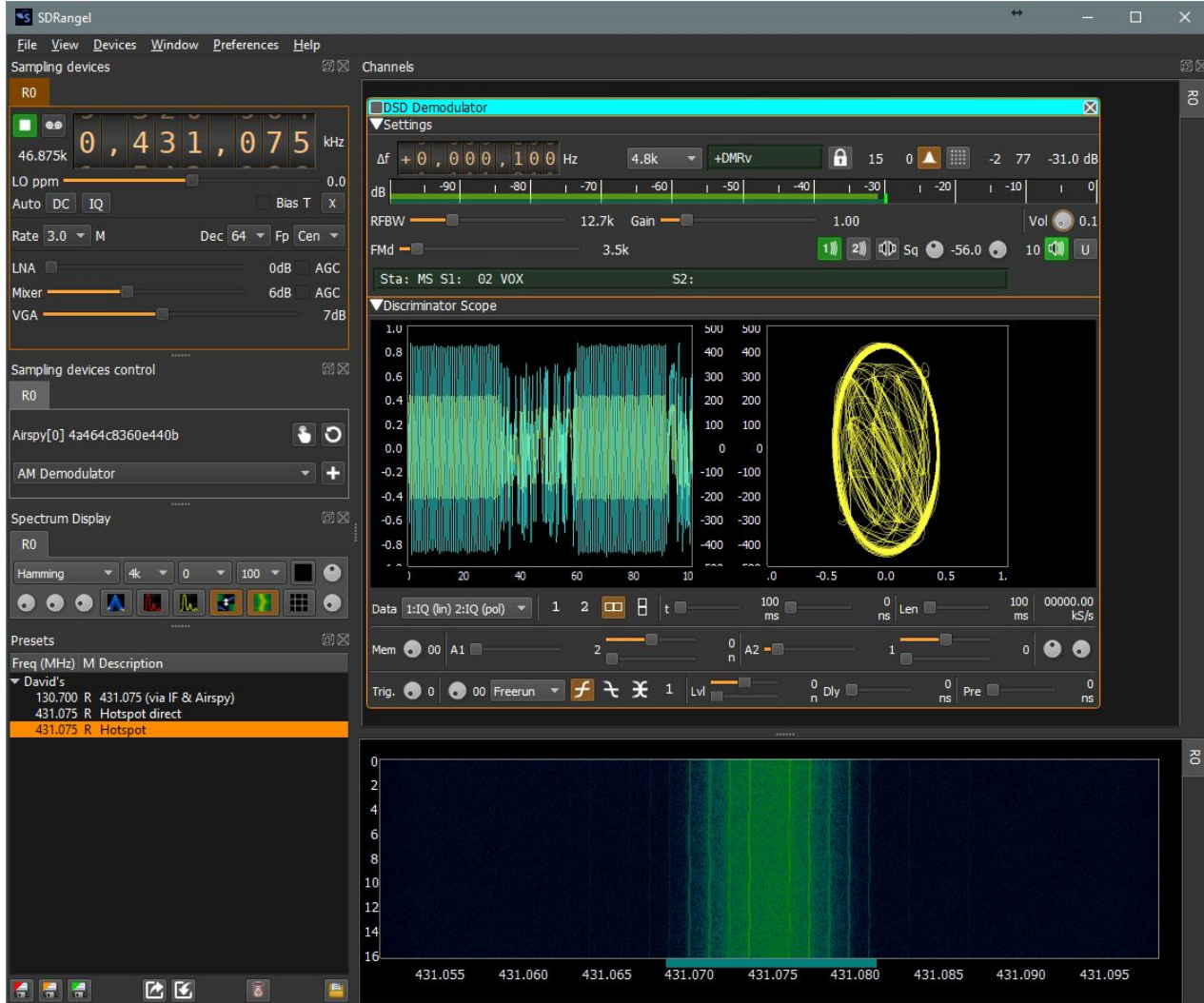
# Hazır Yazılımlar

## GNURadio



# Hazır Yazılımlar

SDRangel



# Hazır Yazılımlar

SDRTouch



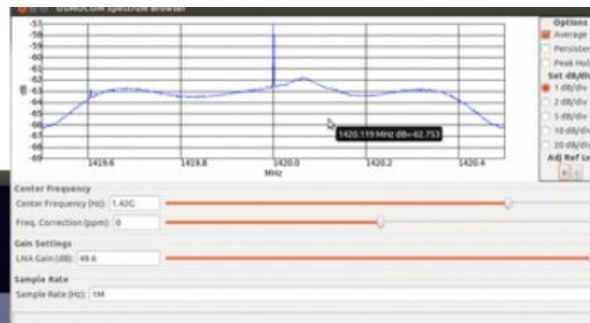
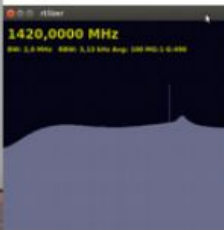
# SDR ile Neler Yapılır ? Projeler

The collage illustrates various projects and applications of Software Defined Radio (SDR). It includes:

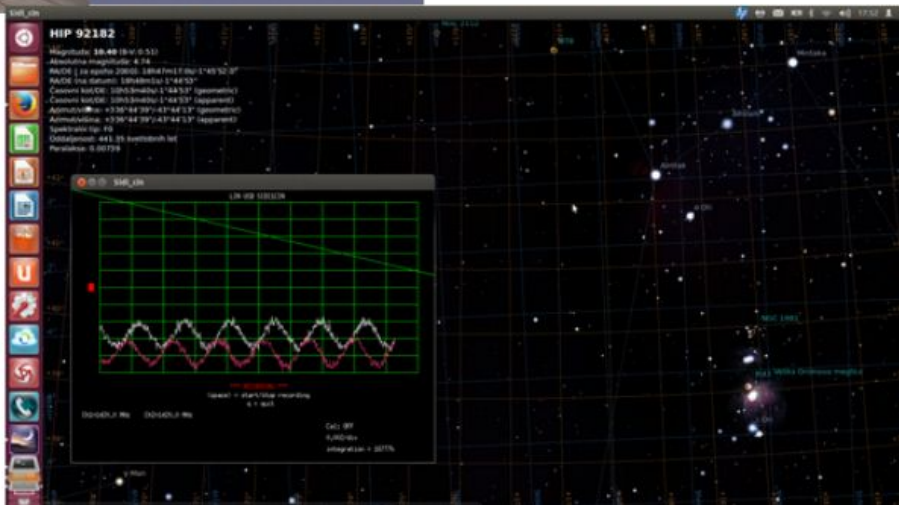
- Hardware Diagram:** A schematic showing an aircraft transmitting a 1000 MHz ADS-B signal. The signal is received by an eight-element collinear antenna connected via a Type F connector to an RG-6U cable. This cable leads to an MCX connector, which is plugged into a Receiver (RB20T Tuner Chip) inside an OVB-TV Tuner Dongle. The dongle is connected to a PC running Windows. The PC's software interface shows a map with aircraft positions. The PC is also connected to an ADS-B Hub via a USB port. The hub is connected to the Internet, which is then connected to another ADS-B Hub.
- Flight Data Table:** A screenshot of a flight data table with columns: ID, Flight, Altitude, Speed, Lat, Lon, Track, Messages, Seen. The table lists several flights, including one with ID 23975 and another with ID 23976.
- Map Interfaces:** Several screenshots of maps showing aircraft positions. One map shows a large area with many aircraft, another shows a smaller area with fewer aircraft, and a third shows a map with a list of aircraft on the right side.
- Software Interfaces:** Screenshots of various software interfaces, including a flight data table, a map, and a software interface with a list of aircraft on the right side.



# SDR ile Neler Yapılır ? Projeler

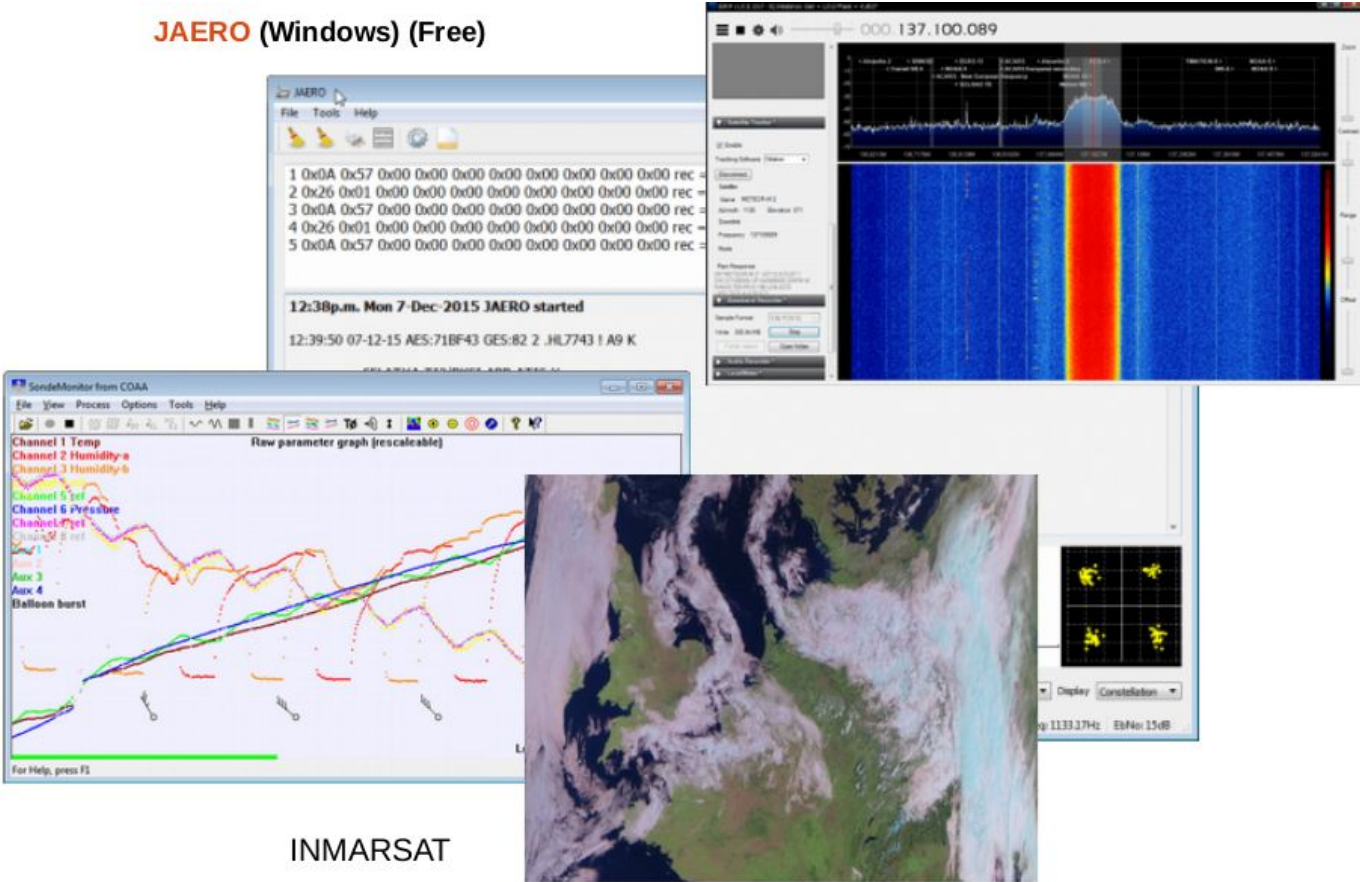


1420Mhz Hydrogen Line



# SDR ile Neler Yapılır ? Projeler

JAERO (Windows) (Free)



# SDR ile Neler Yapılır ? Projeler

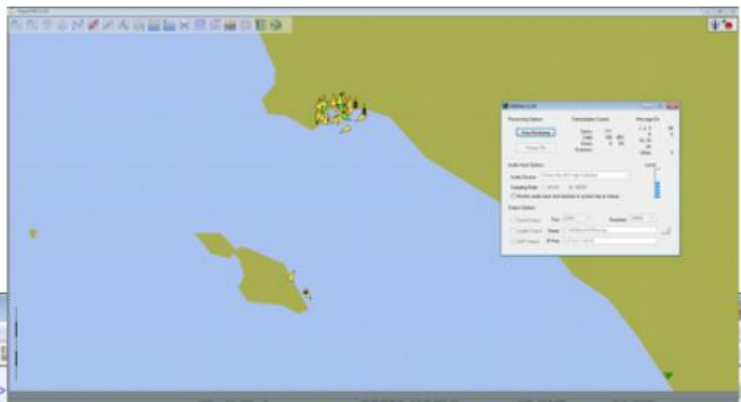
**AISMon (Windows) (Free) (Related Post) – AIS**

**OpenCPN (Windows) (Free) (Related Post) – AIS**



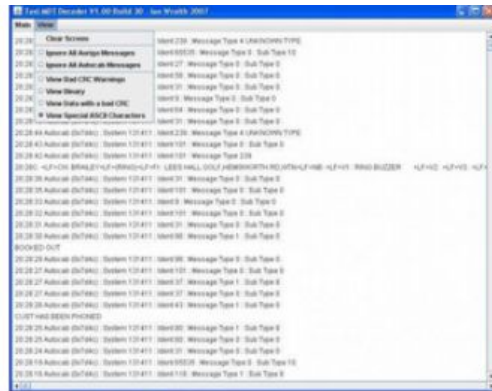
ShipPlotter from COAA - Ship view

Ship name	name	callsign	IMO no	latitude	longitude	status
367003560	SOLANA	NDC3179	0000001	33°46.026N	118°13.027W	unknown
366989970	LARCONA	WCD2171	0000000	33°46.029N	118°13.221W	under way
477990700	SAGACIOUS NIKE	VR4V4	9117789	33°45.725N	118°15.500W	sailing
366892150	366892150 [US]	unknown	0000000	33°46.256N	118°12.801W	under way
357458000	357458000 [PA]	unknown	0000000	33°45.547N	118°16.604W	under way
367017440	367017440 [US]	unknown	0000000	33°46.245N	118°12.734W	under way
211235130	211235130 [DE]	unknown	0000000	33°46.006N	118°16.294W	under way
367014480	367014480 [US]	unknown	0000000	33°46.036N	118°13.223W	under way
366760650	366760650 [US]	unknown	0000000	33°44.410N	118°16.680W	under way
353886000	353886000 [PA]	unknown	0000000	33°45.655N	118°13.099W	under way
366809920	366809920 [US]	unknown	0000000	33°45.954N	118°14.341W	under way
366978690	366978690 [US]	unknown	0000000	33°45.857N	118°15.760W	under way
367007830	367007830 [US]	unknown	0000000	33°45.705N	118°11.690W	unknown
215425000	215425000 [MT]	unknown	0000000	33°44.125N	118° 9.620W	under way
366925920	366925920 [US]	unknown	0000000	33°46.062N	118°13.021W	no command
309424000	309424000 [BS]	unknown	0000000	33°46.330N	118°13.530W	under way
366938510	366938510 [US]	unknown	0000000	33°46.044N	118°13.052W	under way
366982330	366982330 [US]	unknown	0000000	33°45.679N	118°13.124W	under way
366760710	366760710 [US]	unknown	0000000	33°44.667N	118° 9.420W	no command
366755020	366755020 [US]	unknown	0000000	33°44.380N	118°16.600W	under way
538002327	538002327 [NR]	unknown	0000000	33°43.530N	118°15.600W	under way
366982340	366982340 [US]	unknown	0000000	33°46.174N	118°13.271W	under way

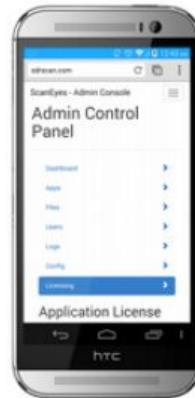


**ShipPlotter (Windows) (Trial/Paid) (Related Post) – AIS**

# SDR ile Neler Yapılır ? Projeler

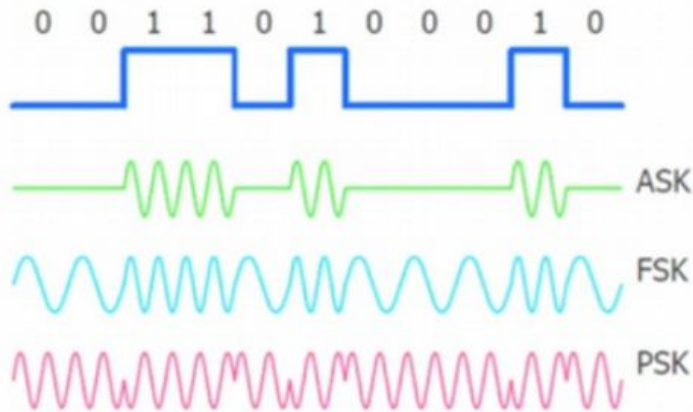
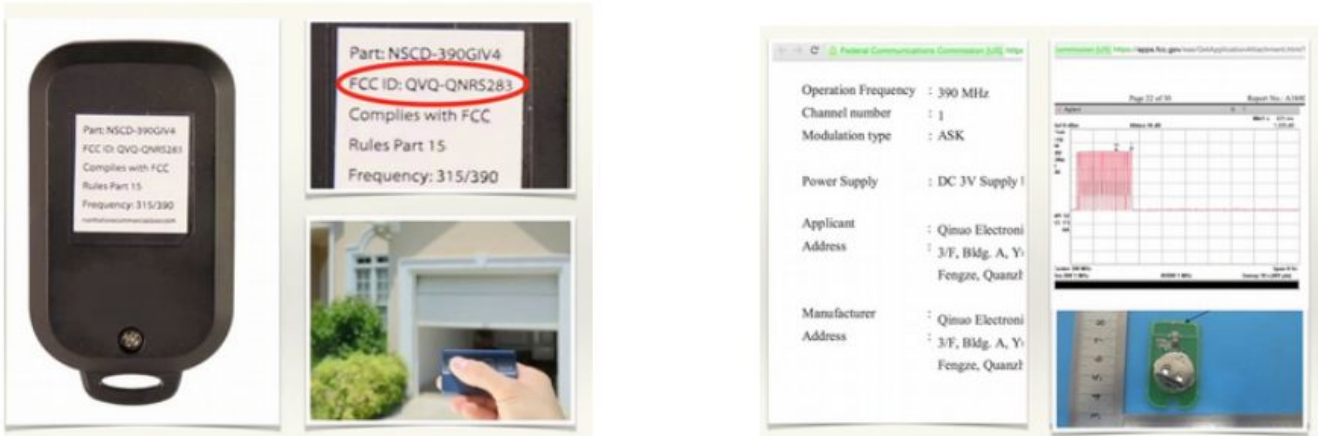


Digital Radio

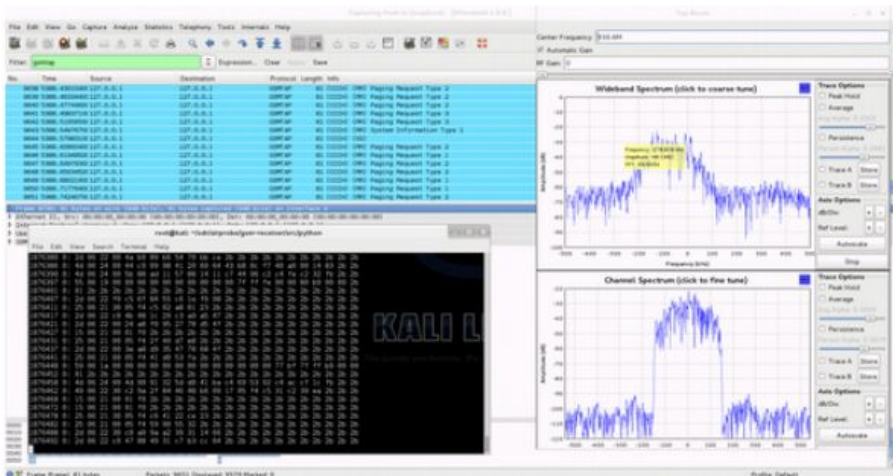




# SDR ile Neler Yapılır ? Projeler



# SDR ile Neler Yapılır ? Projeler



# Ne kadar kodlama bilmeliyim ?

RTLSDR'ye bağlantı

```
use Radio::RTLSDR;

my $freq = shift || 104.5;
$freq *= 1_000_000;

my $rf_sample_rate = 2_000_000;

my $radio = Radio::RTLSDR->new(freq => $freq,
                                sample_rate => $rf_sample_rate);
```

Ses Kartına Bağlantı

```
open(my $audio_sink,
      '|-:raw',
      "play -t raw -r $audio_sample_rate -e float -b 32 -c 1 -");
```

Sinyal Gelince

```
$radio->rx(sub {
  # process raw radio samples in $_[0]
  # this callback will be called several times per second...
});

$radio->run; # enter event loop
```

# Adim adim SDR

## **USB den okuyup dosyaya yazalim**

```
rtl_sdr -f 101.1M -s 256k -n 2560000 kayit.iq
```

## **IQ dosyalari uzerinde SDR demodulasyonu yapalim**

```
cat kayit.iq | fm_cozucu.py > ses.raw
```

## **Simdi de kaydi dinleyelim**

```
sox -t raw -r 256000 -b 16 -c 1 -L -e signed-integer ses.raw -d rate 32000
```

# Ne kadar kodlama bilmeliyim ?

## Veri İşleme

```
use PDL;  
  
my $data = pdl()->convert(byte)->reshape(length($_[0]));  
  
${ $data->get_dataref } = $_[0];  
$data->upd_data();  
  
$data = $data->convert(float);  
  
$data -= 128;  
$data *= 1000000;  
  
my $I = $data->slice([0,-1,2]);  
my $Q = $data->slice([1,-1,2]);
```

## RF Filtreler

```
## Decimate 4:1, 2000k -> 500k  
  
$I = PDL::DSP::Fir::Simple::filter($I, { fc => 0.12, N => 81, });  
$Q = PDL::DSP::Fir::Simple::filter($Q, { fc => 0.12, N => 81, });  
  
$I = $I->slice([0,-1,4]);  
$Q = $Q->slice([0,-1,4]);
```

# Ne kadar kodlama bilmeliyim ?

FM Demodüle İşlemi

```
use PDL::Complex;

my $prev = $I->slice([0, -2]) + (i * $Q->slice([0, -2]));
my $curr = $I->slice([1, -1]) + (i * $Q->slice([1, -1]));

my $deriv = ($prev->Cconj() * $curr)->Carg();

## FIXME: retain previous values:
$deriv = $deriv->append($deriv->at(-1));
```

Sese de filtre uygulayalım

```
my $audio =
  PDL::DSP::Fir::Simple::filter($deriv, { fc => 0.4, N => 32 });

$audio = $audio->slice([0,-1,10]);
```

DİNLEYELİM.....

```
print $audio_sink ${ $audio->convert(float)->get_dateref };
```

# Daha sonrasında neler öğreneceğiz ?

- RTLSDR'ye yazılım yazalım, dinleyelim
- uSDX donanımına çok detaylı bakış
- McHF donanımına çok detaylı bakış
- GNURadio yazılımı ile oynayalım (Giriş)
- Kendi SDR Cihazımızı Tasarlayalım
- GNURadio yazılımı ile oynayalım (İleri Seviye)