ELE 361

Konu2: Kablolu Kablosuz ve Optik Sistemler

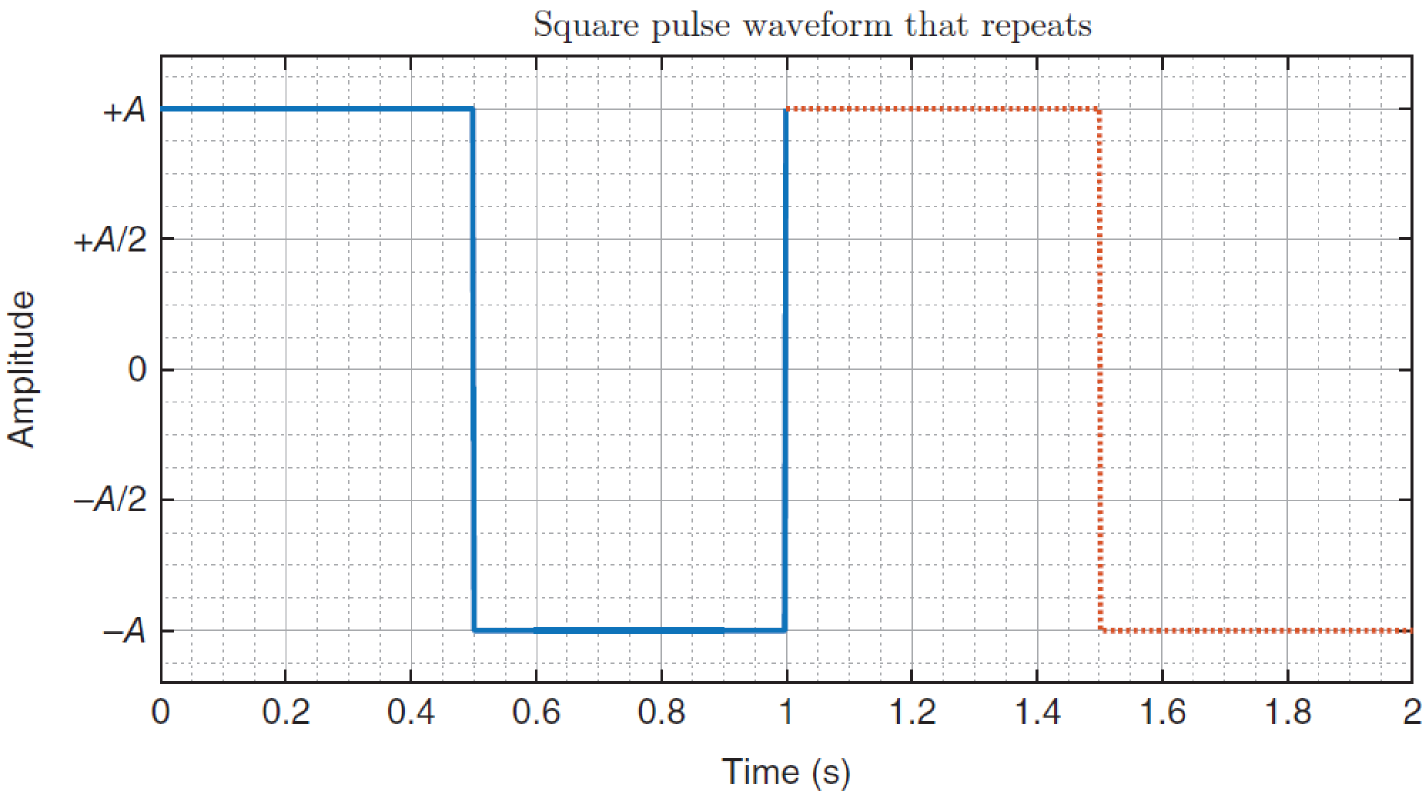
2.3.1 Bilinen Sinyalin Frekans Analizi

- Periyodik sinyal $x(t) = x(t + \tau)$
- Periyot
- Temel frekans
- Açısal frekans
- Harmonikler

2.3.1 Fourier Seri Açılımı

- $a_0 = \frac{1}{\tau}\int_0^{\tau} x(t)dt$
- $a_k = \frac{2}{\tau}\int_0^{\tau} x(t)\cos k\omega_0 t\, dt$
- $b_k = \frac{2}{\tau}\int_0^{\tau} x(t)\sin k\omega_0 t\, dt$
- $x(t) = a_0 + a_1 \cos \omega_o t + a_2 \cos 2\omega_o t + \cdots + b_1 \sin \omega_0 t + b_2 \sin 2\omega_0 t + \cdots$

Örnek: Kare Dalga



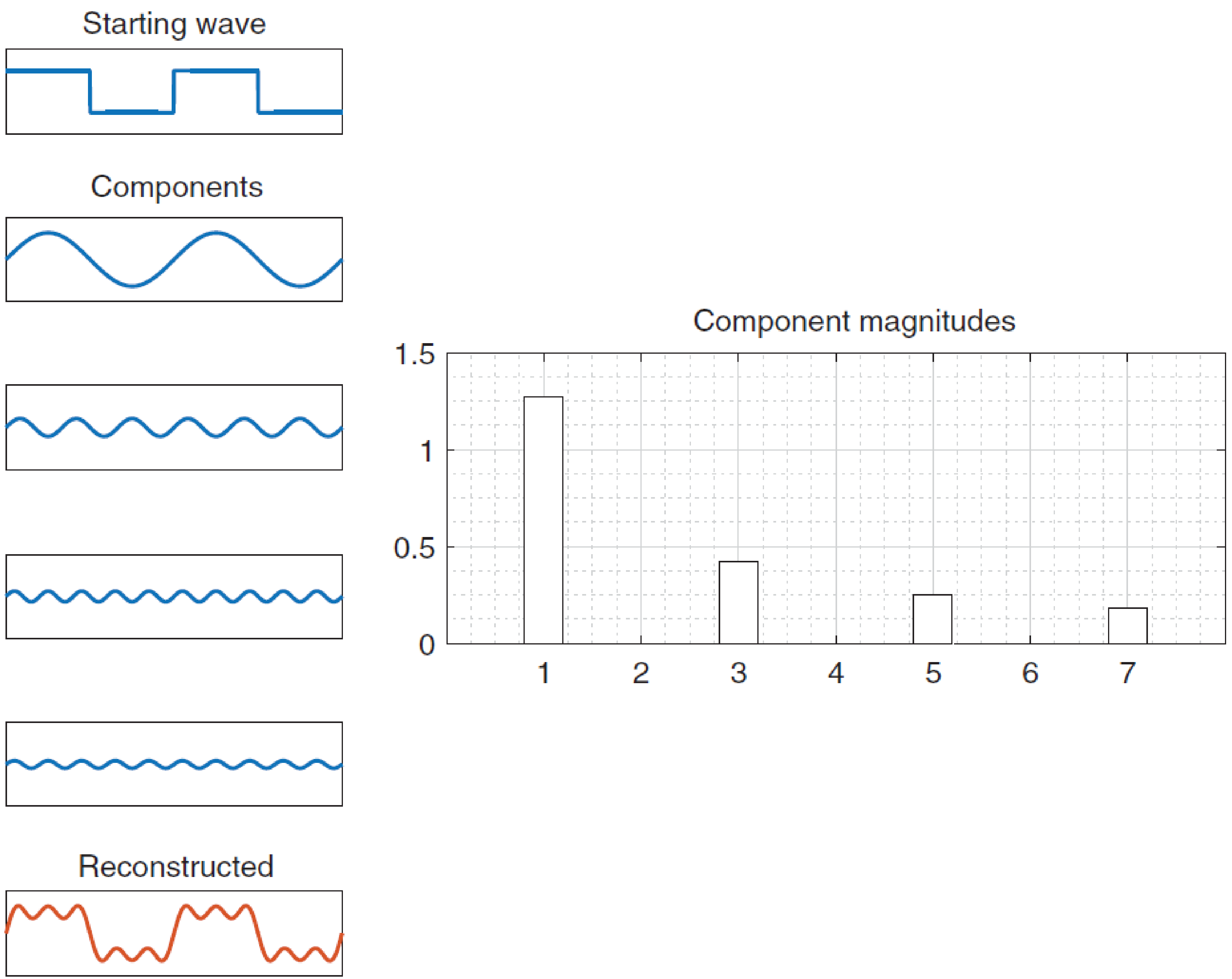


Figure 2.2 Approximating a square waveform with a Fourier series. The Fourier series

2.3.2 Ölçülen Sinyalin Frekans Spektrumu

- Fourier dönüşümü
  - $X(f) = \int_{-\infty}^{\infty} x(t) e^{-j2\pi f t} dt$
- Numerik olarak hesaplanabilir ama sonsuz integral aralığı problemdir.
- Sonlu sürede integral alınca normalde olmayan bileşenler ortaya çıkar
- Bu sorunu çözmek için sinyal yumuşatılır
- Hamming penceresi
  - $w_n = \begin{cases} 0.54 - 0.46 \frac{2n\pi}{M} & 0 \leq n \leq M \\ 0 & otherwise \end{cases}$

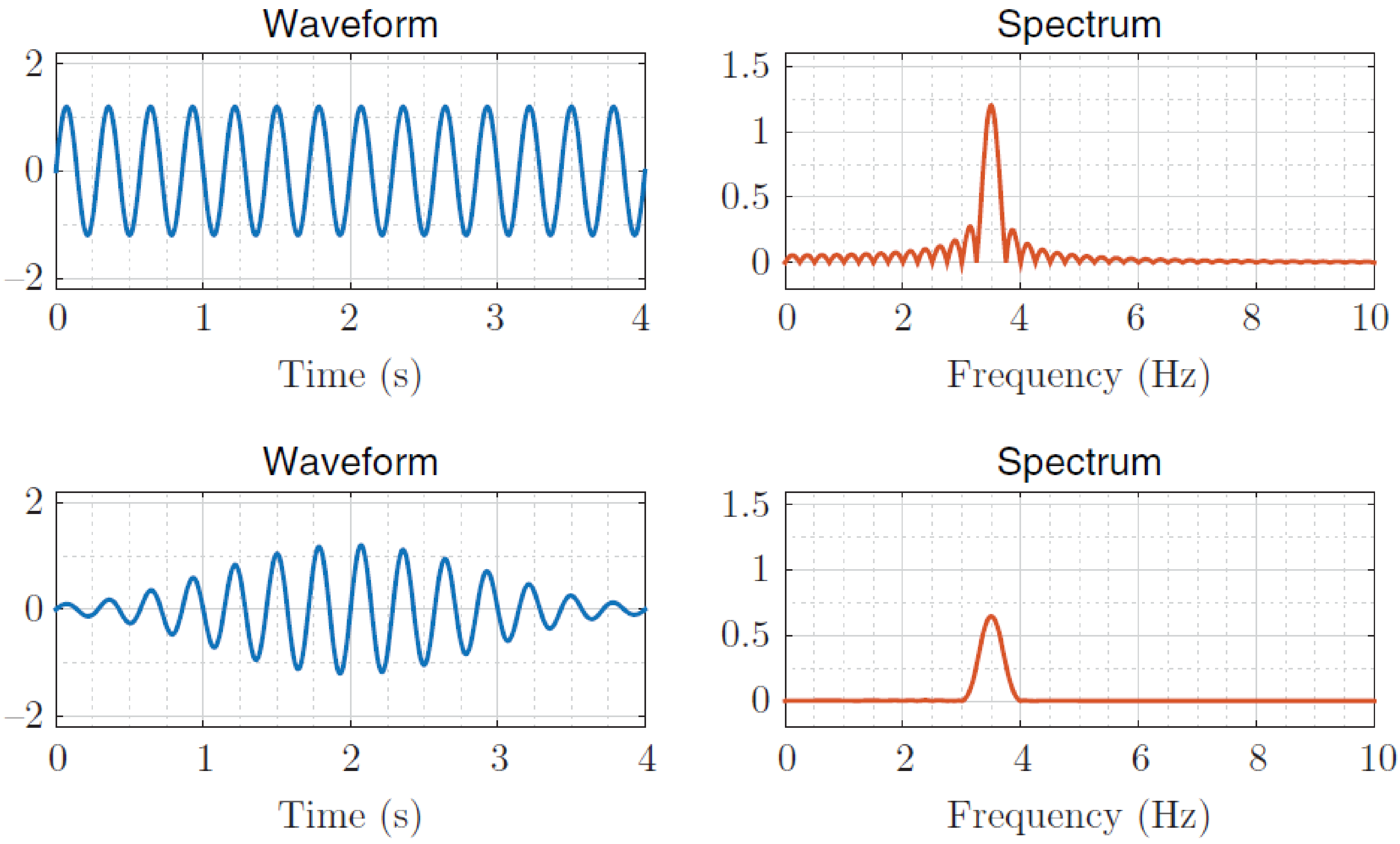


Figure 2.3 Using the Fourier transform to calculate the frequency magnitude of a signal. The use of a window to taper the signal provides a smoother picture, but less resolution.

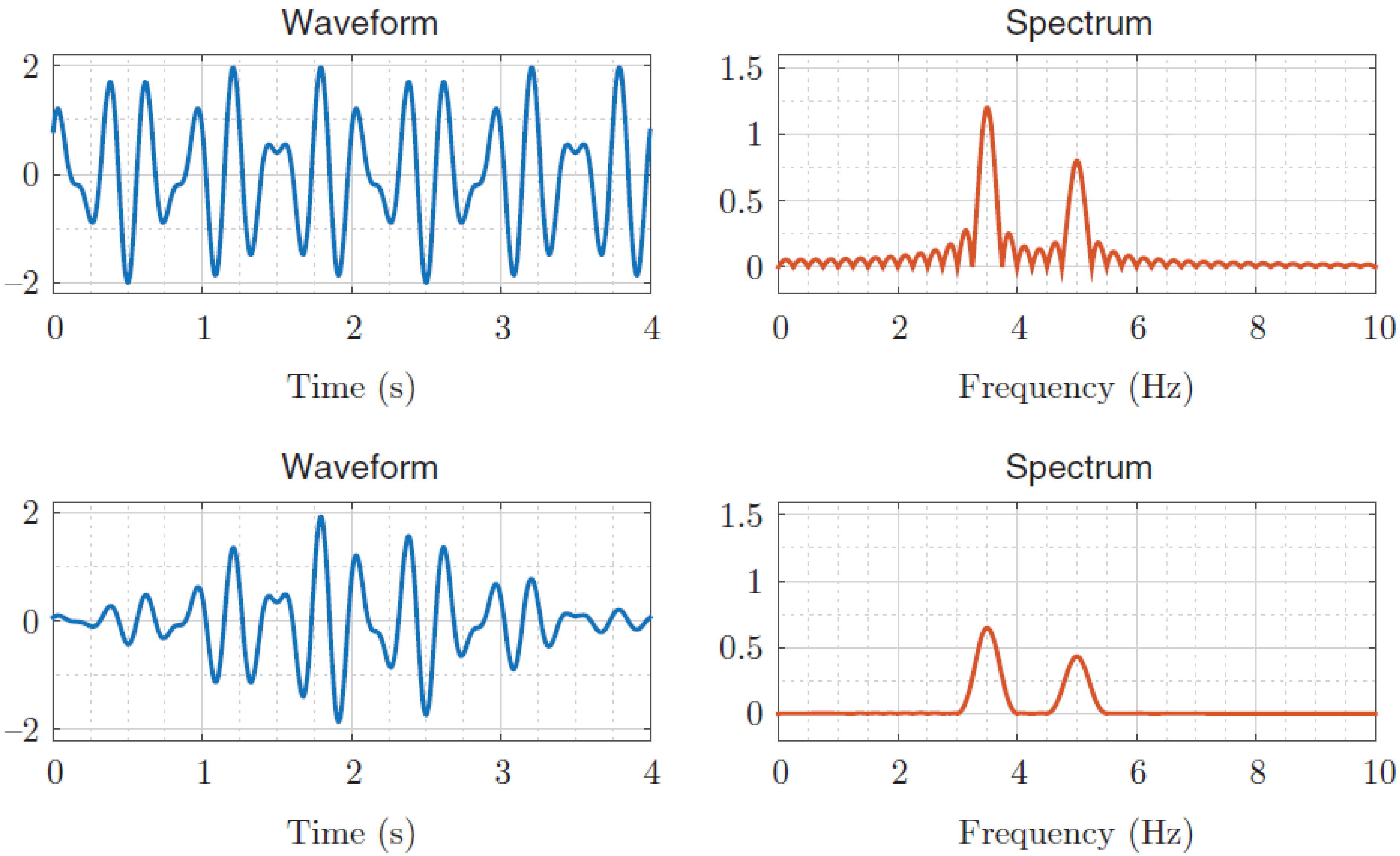


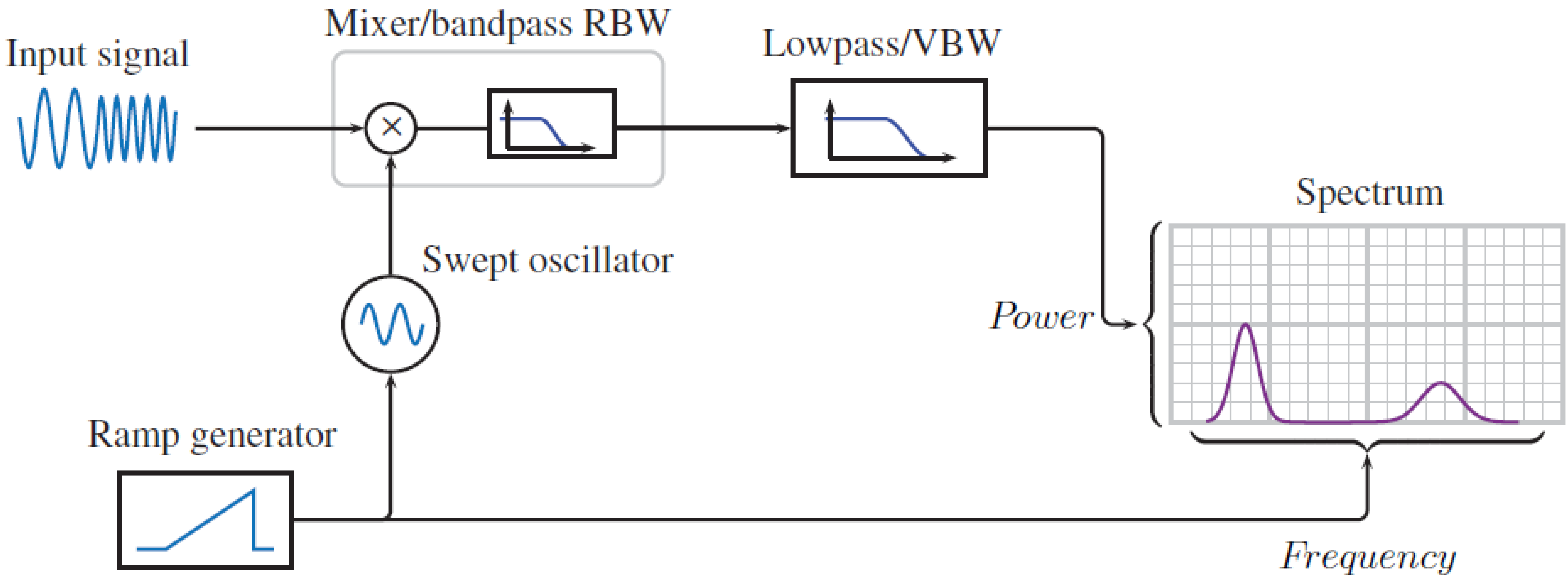
Figure 2.4 Using the Fourier transform to calculate the frequency magnitude where two underlying sinusoidal signals are present. It is able to resolve the presence of the two components.

```
function [Xm, faxis, xtw] = CalcFourierSpectrum ( xt , tmax ,fmax , UseWindow )
%---------------------------------------------------
dt = tmax / ( length ( xt ) - 1) ;
t = 0: dt : tmax ;
%---------------------------------------------------
xtw = xt ;
if ( UseWindow )
% window
fw = 1/ (2*tmax ) ;
% Hamming window
fw = 1 / ( tmax ) ;
w = 0.54-0.46*cos (2*pi*t / tmax ) ;
xtw = xt.*w;
end
% continuous f requency range
OmegaMax = 2*pi*fmax ;
dOmega = OmegaMax* 0.001 ;
%---------------------------------------------------
fvec = [ ];
Xmvals = [ ];
p = 1;
for Omega = 0 : dOmega : OmegaMax
coswave = cos(Omega*t);
sinwave = -sin(Omega*t);
% perform the Four ier Transform v i a numerical i n t e g r a t i o n
Xreal = sum( xtw .*coswave*dt ) ;
Ximag = sum( xtw .*sinwave*dt ) ;
mag = sqrt (Xreal*Xreal + Ximag*Ximag ) ;
% s c a l e f requency to Hz , magnitude to maximum time
fHz = Omega/(2*pi);
mag = 2*mag/tmax ;
% save f requency and magnitude
faxis(p) = fHz ;
Xm(p) = mag ;
p = p + 1;
end
%---------------------------------------------------
end
```

FFT – Fast Fourier Transform

```
fs = 100; % sampling frequency
t = 0:(1/fs):(10-1/fs); % time vector
S = cos(2*pi*15*t);
n = length(S);
X = fft(S);
f = (0:n-1)*(fs/n); %frequency range
power = abs(X).^2/n; %power
plot(f,power)
Y = fftshift(X);
fshift = (-n/2:n/2-1)*(fs/n); % zero-centered frequency range
powershift = abs(Y).^2/n; % zero-centered power
plot(fshift,powershift)
```

Frekans Spektrumu



- Ramp generator (yükselen bir sinyal üretir)
- Swept oscillator (voltage controlled oscillator – artan frekans üretir)
- Mixer (RBW): Giriş sinyalini sinüs ile çarpar (düşük ve yüksek frekans oluşur)
- Low pass (VBW) : yüksek frekansı elemine eder, güç hesaplanır
- Oluşan değerler çizdirilir

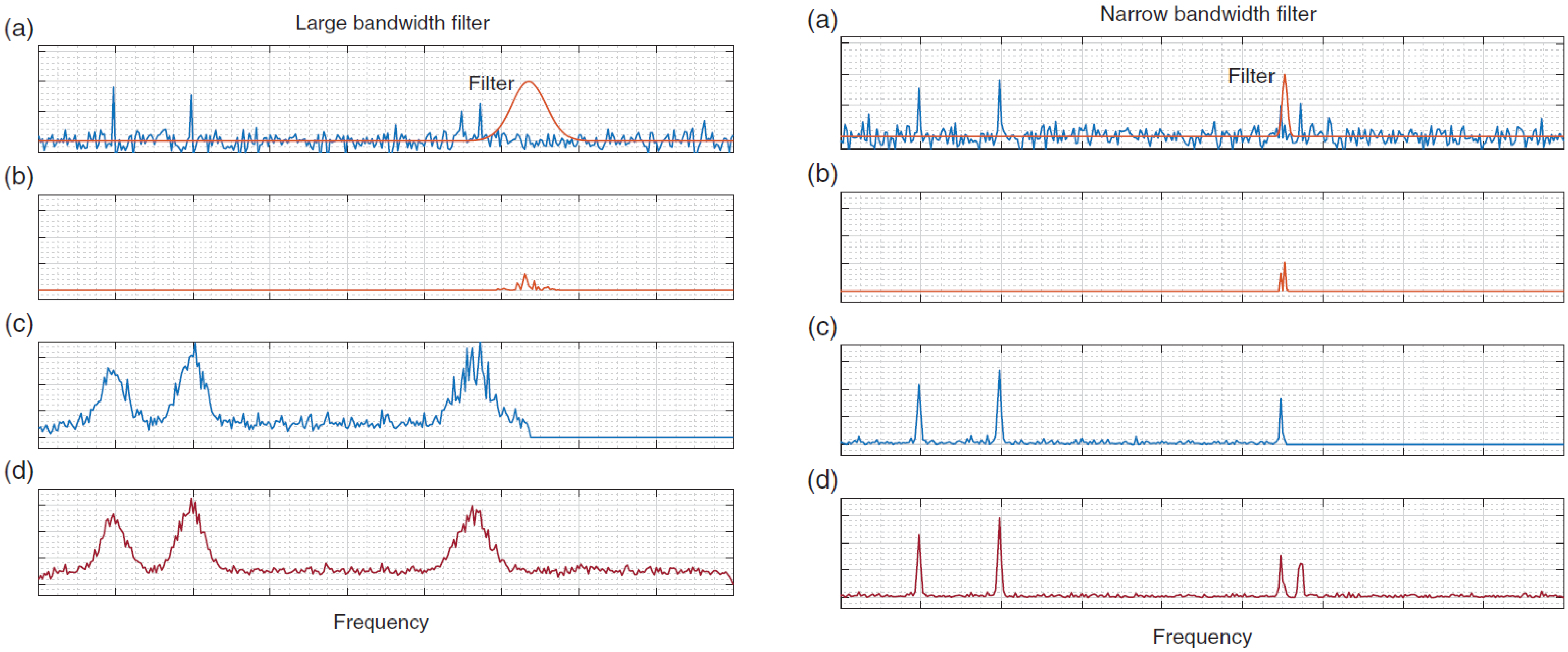


Figure 2.6 Spectrum analysis stages with a wide window as it progresses (top) and a narrow window (bottom). Progressively, we see the input signal and RBW bandpass filter (a), the bandpass filtered signal (b), the accumulated bandpass filtered signal as the sweep progresses (c), and the final result after VBW lowpass filtering (d). The two close peaks in the input are able to be resolved with the narrower filter on the right.

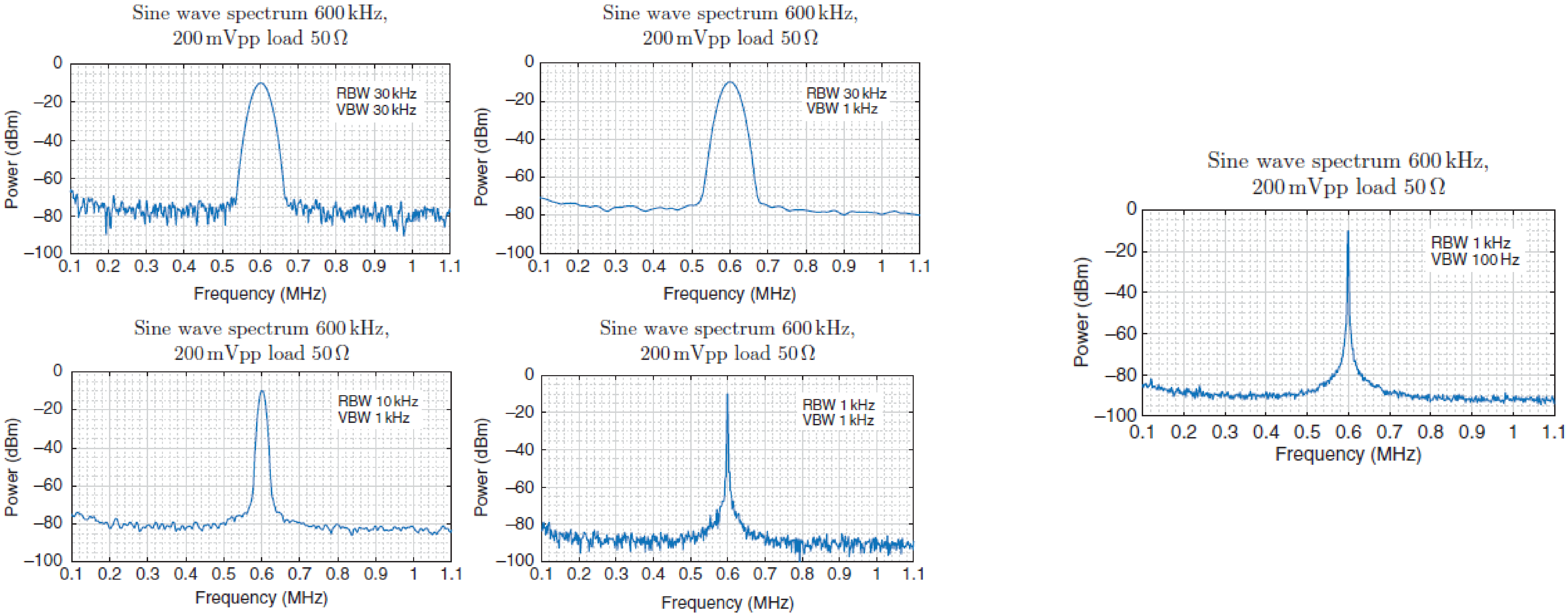


Figure 2.7 The measured spectrum of a sine wave, as both VBW and RBW are adjusted. A narrower RBW gives better signal resolution and lower noise floor, but takes more time to sweep across the band of interest. A lower VBW smooths the resulting display, but leaves the noise floor unchanged.

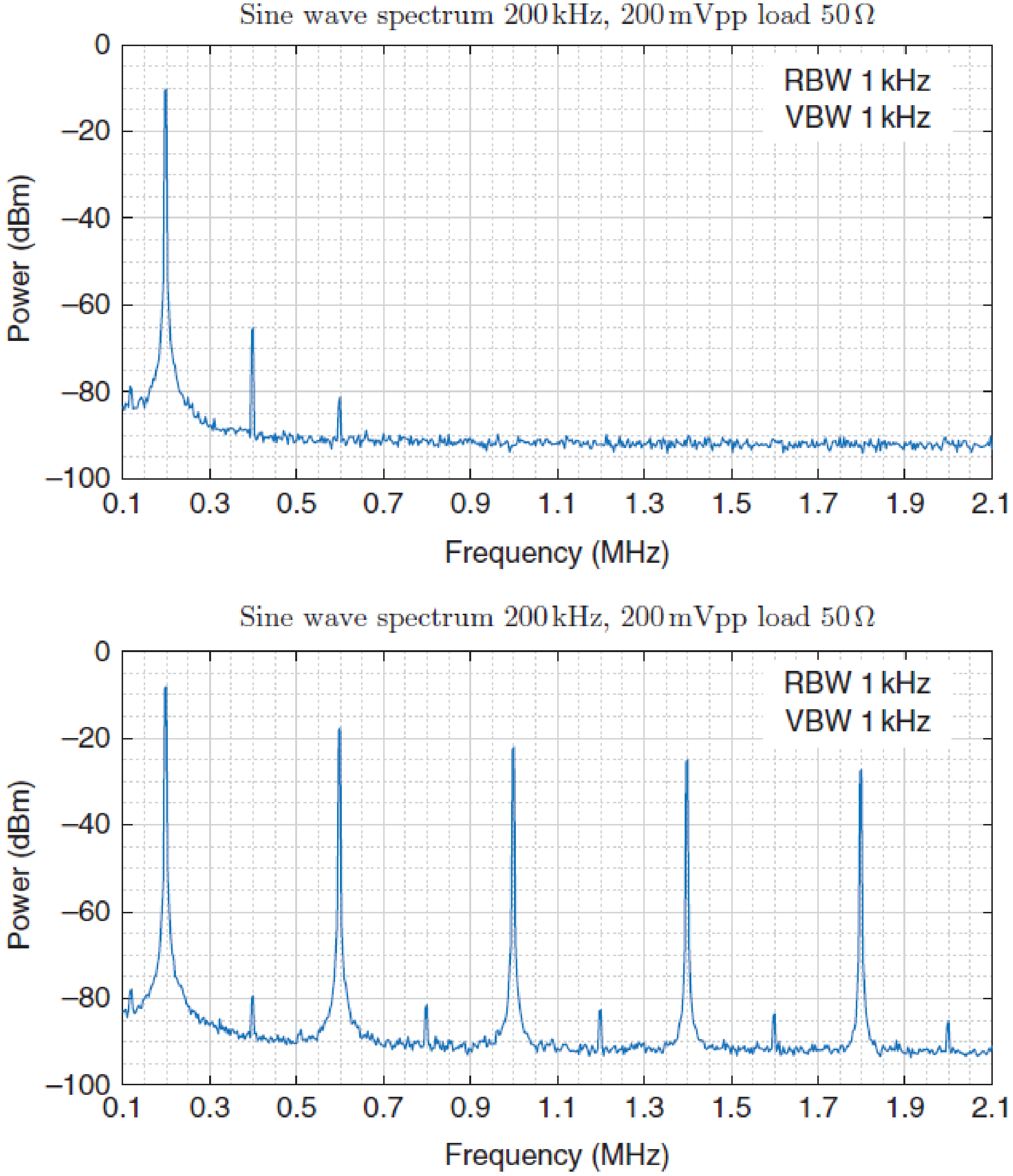
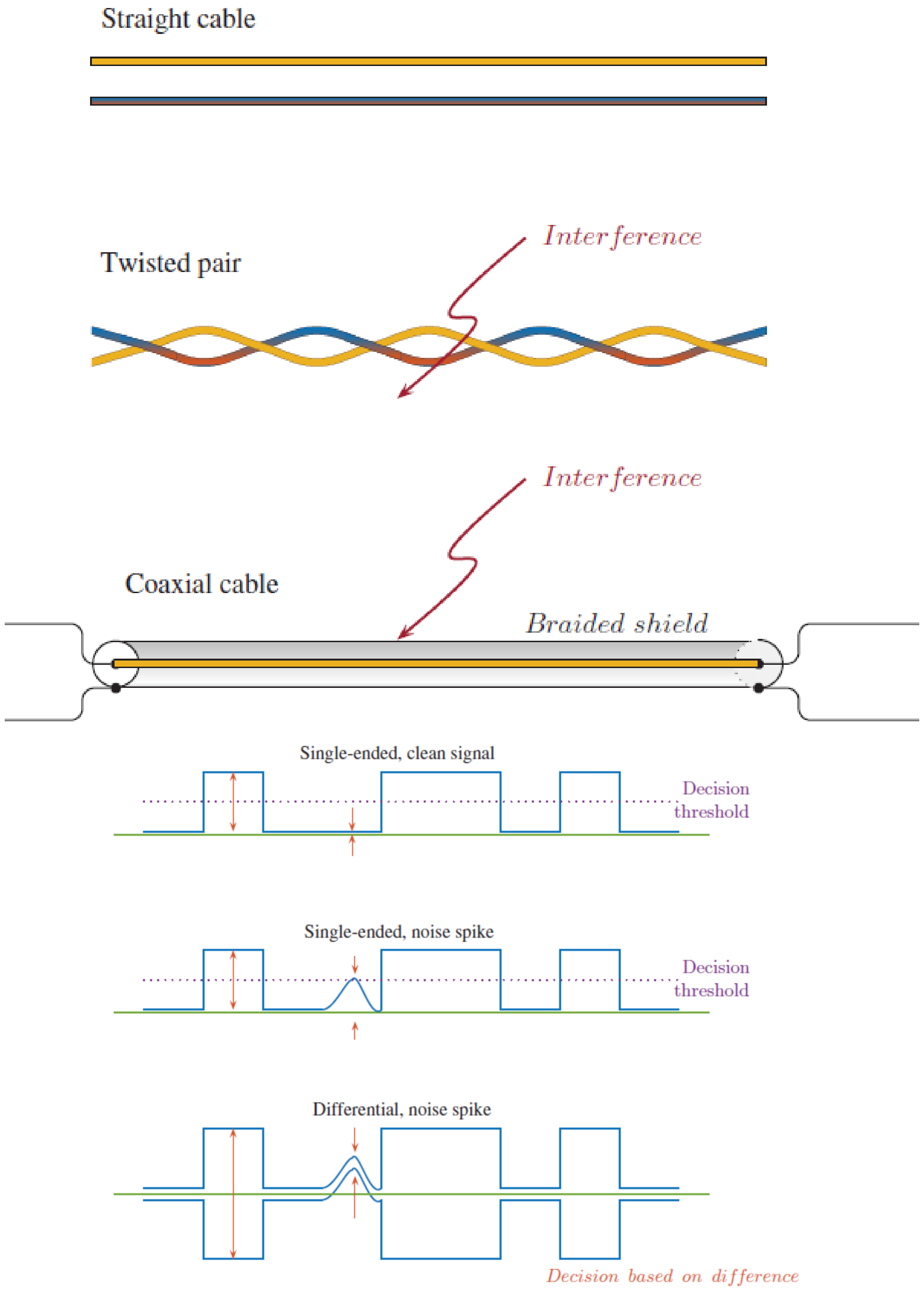


Figure 2.8 Top: measured spectrum of a "pure" sine wave. Note the spurious peaks at the first and second harmonics, due to imperfections in the waveform generation. Bottom: the spectrum of a square wave. Note the frequencies of the harmonics are integer multiples of the fundamental and that their amplitudes decay successively as 1/3, 1/5, … if the decibel scale is converted to a ratio.

2.4 Kablolu Haberleşme

- Bakır kablo (telefon kablosu)
  - Bir kablo voltaj, diğeri referans (toprak)
  - Girişim (anten etkisi yapar)
  - Çözüm (toprak ve voltaj kablolarını burgulamak)
- Eş eksenli kablo (TV kablosu)
  - Çekirdek ve etrafında örgü (daha maliyetli)
  - Daha yüksek frekans
  - Daha geniş bant (TV yayını)
- Diferansiyel sinyal göndermek
  - İki kablo arasındaki voltaj farkı dış etkilerden etkilenmez
  - Biraz daha karmaşıktır
- Empedans (Z_0): Sürücü ve alıcı devreyle uyumlanmalı
  - RG58 (50 Ohm), RG59 (75 Ohm), RG6 (75 Ohm, 7mm çap)



2.4.2 Darbe Şekillendirme

- Darbe (pulse) nedir?
  - Bir bit veya sembolü taşıyan sinyal dalgası
- En basit darbe: Kare
- Art arda bitler → Art arda darbeler
- Gönderilen kare sinyal kabloda değişiyor (gürültü, bozulma)
- Alıcıda:
  - Eşik değeri ne olacak?
  - Zamanlama ne olacak?

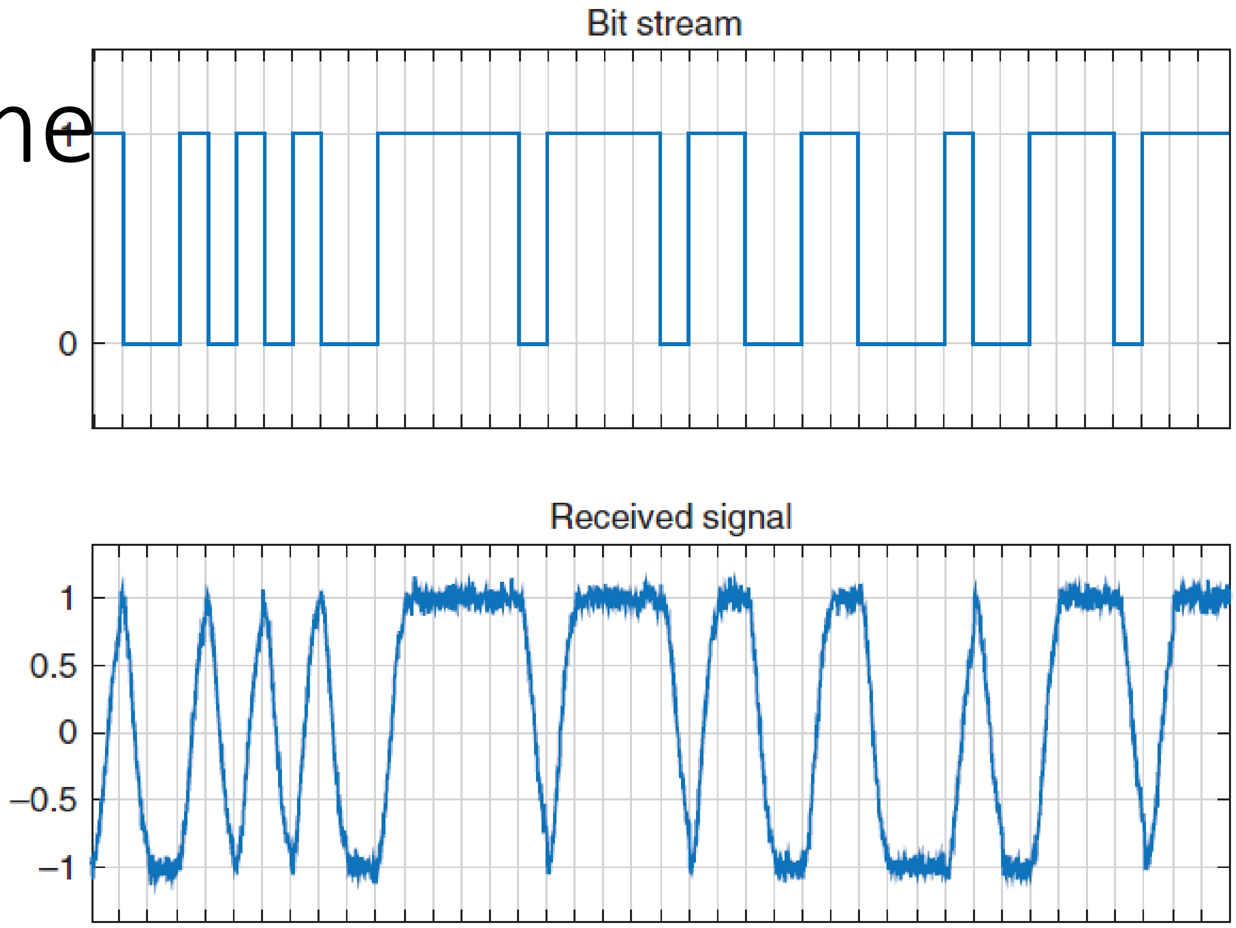
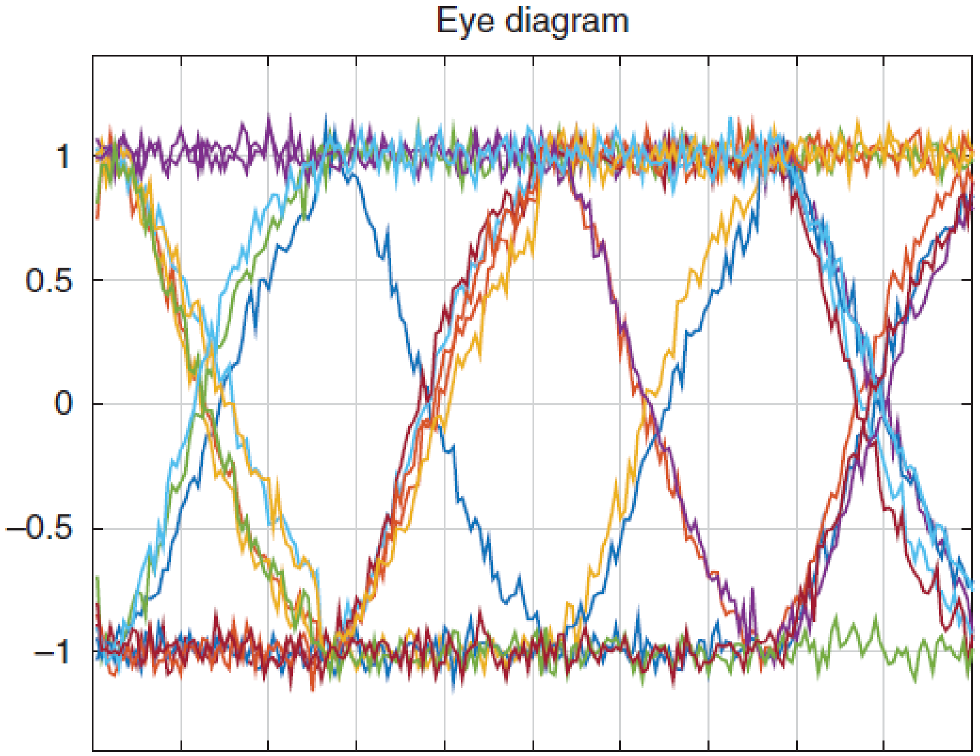


Figure 2.11 Transmitted pulse sequence and the corresponding received signal. Cable impairments and external interference combine to reduce the quality of signaling.

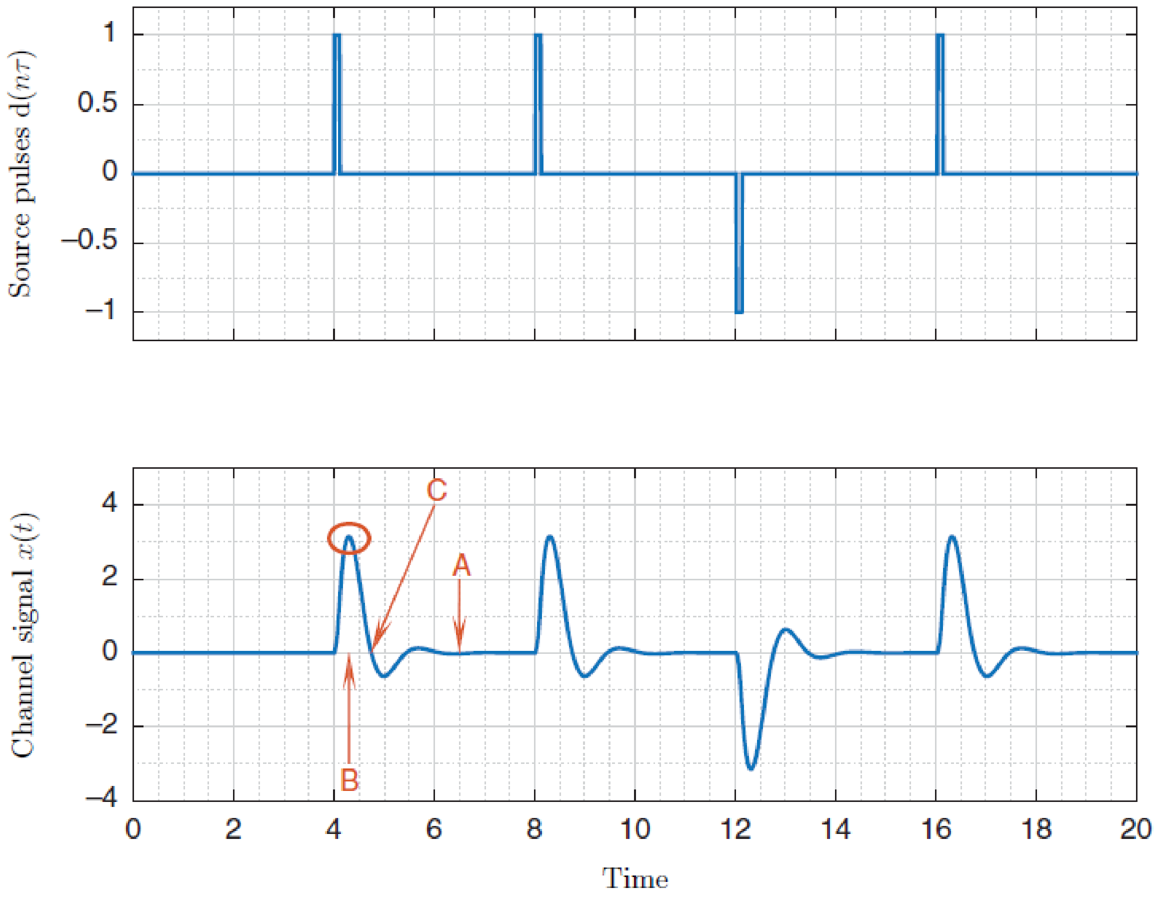
2.4.2 Darbe Şekillendirme (Göz Diyagramı)

- Bir darbe süresinde gelen darbelerin üst üste bindirilmesiyle yandaki diyagram oluşur.
- Ortada göz benzeri bir açıklık vardır
- Bu açıklık ne kadar büyük ise kanal kalitesi o kadar iyidir.
  - Kanaldaki gecikme ve gürültü kötüleştikçe açıklık kapanır



2.4.2 Darbe Şekillendirme

- Haberleşme kanalının etkisi
  - Sinyali zamanda yayvanlaştırıyor
- Bir darbe tamamen öldüğü zaman ikinci bir darbe gönderiliyor.
- Darbe hızını artırmak için ne yapmalıyız.
- C noktasının özelliği ne?
- Darbeyi ona göre ayarlamak iyi bir çözüm olabilir mi?
- Sinc fonksiyonu: $h(t) = \dfrac{\sin(\pi t/\tau)}{\pi t/\tau}$



2.4.2 sinc darbesi

- Sembol süresi 0.4
  - Tam o anda ve **katlarında** fonksiyon sıfır
  - Demek ki o anlarda yeni darbeler iletilebilir

- İki problem
  - Nedensel değil
  - Sonsuz süreli

- Sincplot.m

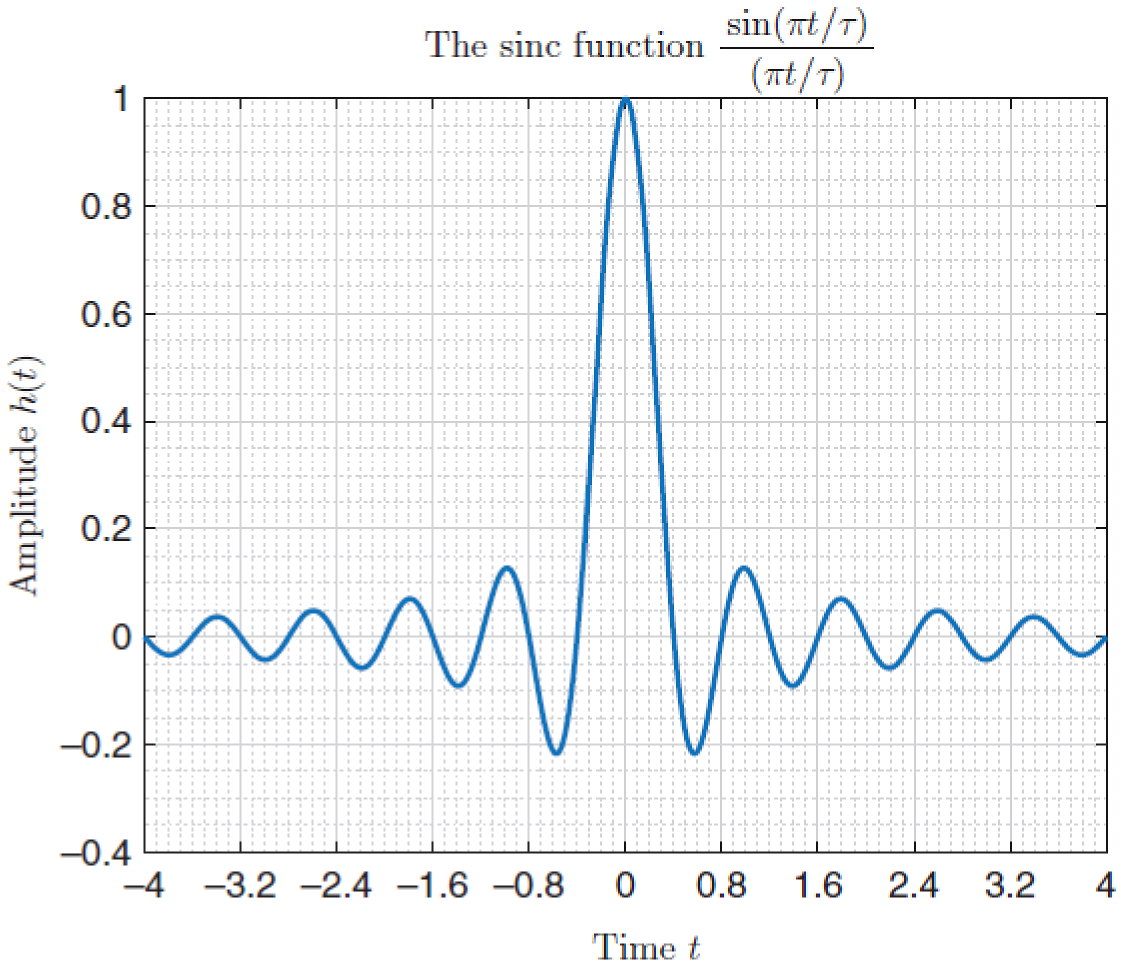
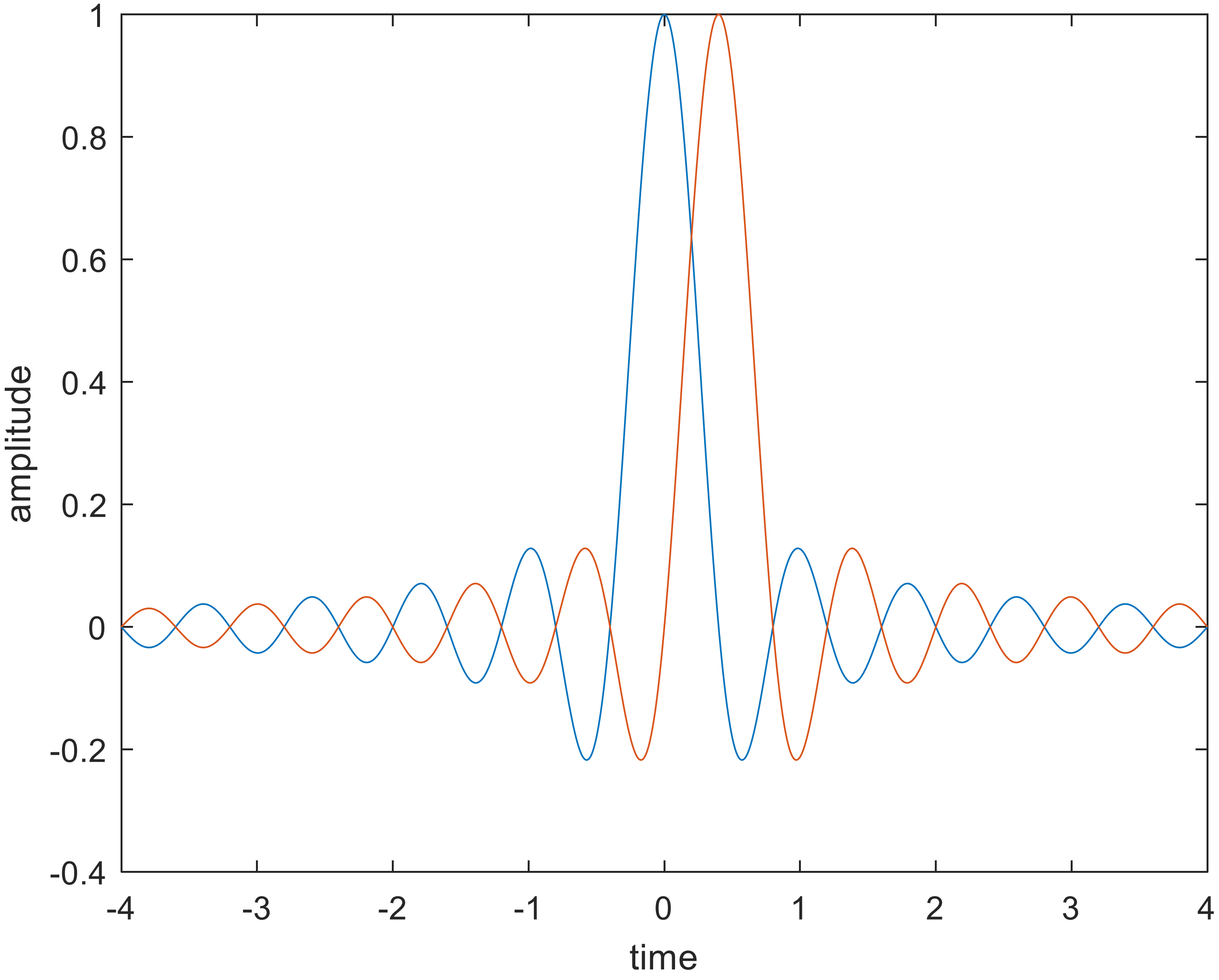


Figure 2.14 The sinc function with $\tau = 0.4$, centered about zero.

Bir darbe süresi farkıyla gönderilen iki sinc

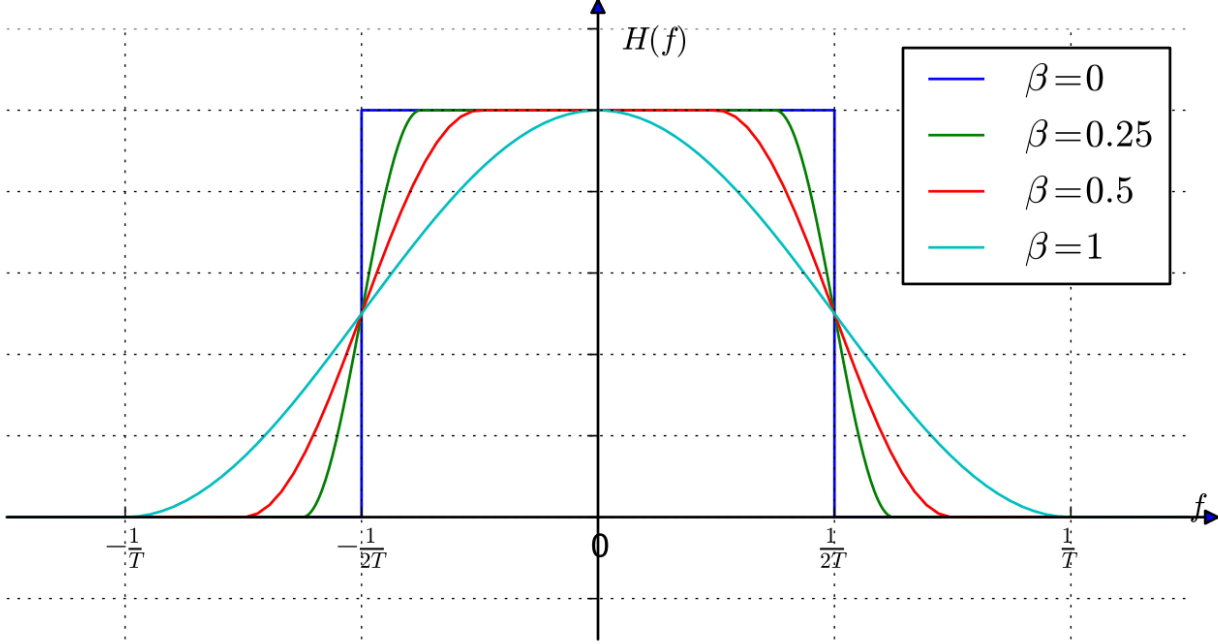


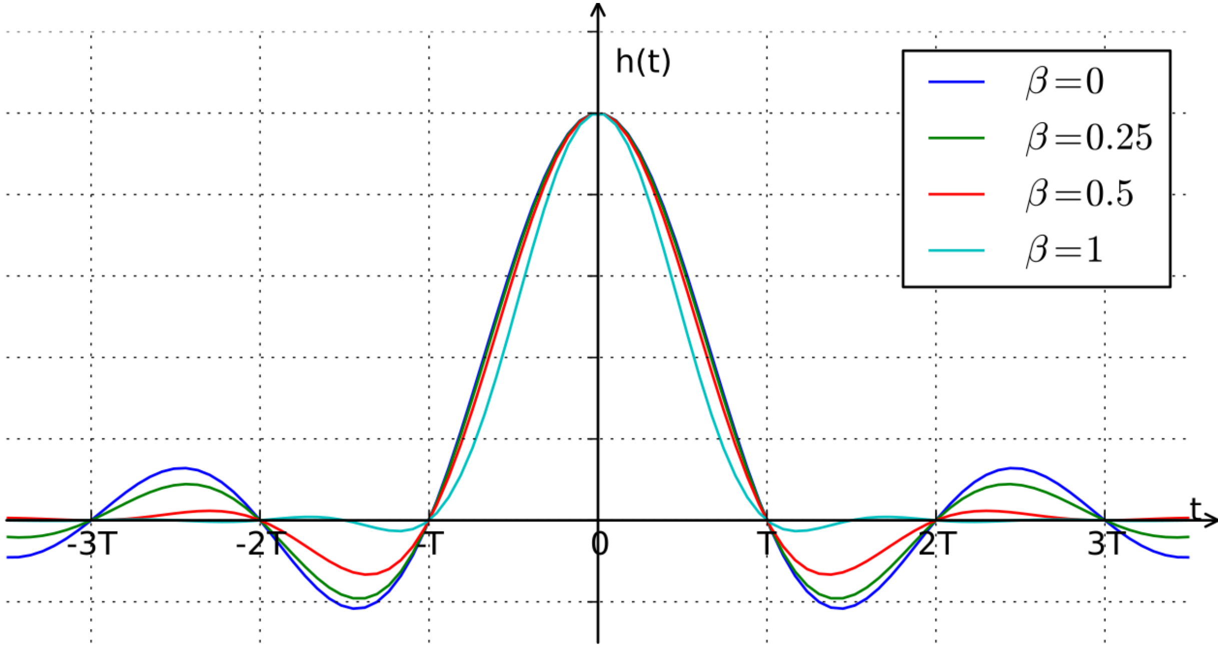
2.4.2: sinc - frekans alanı

- $sinc(t) = \frac{\sin \pi t}{\pi t} \rightarrow^{\mathcal{F}} \Pi(f) = \begin{cases} 1 & |f| < \frac{1}{2} \\ \frac{1}{2} & f = \mp\frac{1}{2} \\ 0 & diğer \end{cases}$
- Ölçekleme kullanarak:
  - $h(t) = \frac{\sin\left(\frac{\pi t}{\tau}\right)}{\frac{\pi t}{\tau}} \rightarrow^{\mathcal{F}} H(f) = \tau\Pi(f\tau) \begin{cases} \tau & |f| < \frac{1}{2\tau} \\ \frac{\tau}{2} & f = \mp\frac{1}{2\tau} \\ 0 & diğer \end{cases}$
  - $H(f)$'i çizelim

Raised Cosine

- Sinc fonksiyonu belli aralıklarla 0 değeri alıyor
  - Ancak , yavaş sönümleniyor. Ne zararı var?
- Raised cosine: sinc gibi ama daha hızlı sönüyor
- β:
- T:





Raised Cosine

- Yükseltilmiş Kosinüs (Raised Cosine)
- $X_{rc}(f) = \begin{cases} T, & 0 \leq |f| \leq \frac{1-\beta}{2T} \\ \frac{T}{2}\left[1 + \cos\frac{\pi T}{\beta}\left(|f| - \frac{1-\beta}{2T}\right)\right], & \frac{1-\beta}{2T} \leq |f| \leq \frac{1+\beta}{2T} \\ 0, & |f| > \frac{1+\beta}{2T} \end{cases}$
- $x_{rc}(t) = sinc\left(\frac{t}{T}\right) \frac{\cos\left(\frac{\pi\alpha t}{T}\right)}{1-\frac{4\alpha^2 t^2}{T^2}}$
  - avantajı: kuyrukları $1/t^3$ mertebesinde zayıflar

2.4.3 Hat Kodu ve Senkronizasyon

- Kablolu (ör. Ethernet) ve fiber haberleşme
  - Tabanbant sinyal (kare sinyaller)
    - Sinüs (taşıyıcı) kullanılmaz
  - Senkronizasyon
- Senkronizasyon
  - %0.1 hata az görünse de
  - 500 bit sonra %50 eder!
  - Uzun 1 veya 0 serisi
  - Başlangıç noktası neresi

Bazı Hat kodları

- Biphase mark encoding
  - 2 kat bant
- NRZ-I – Invert on 0
- Alternate Mark Inversion
- Manchester Encoding
  - 2 kat bant
- Multilevel 3 encoding
- 4B5B Bit Level Mapping
  - 5 bitlik sürede 4 bit gönderir

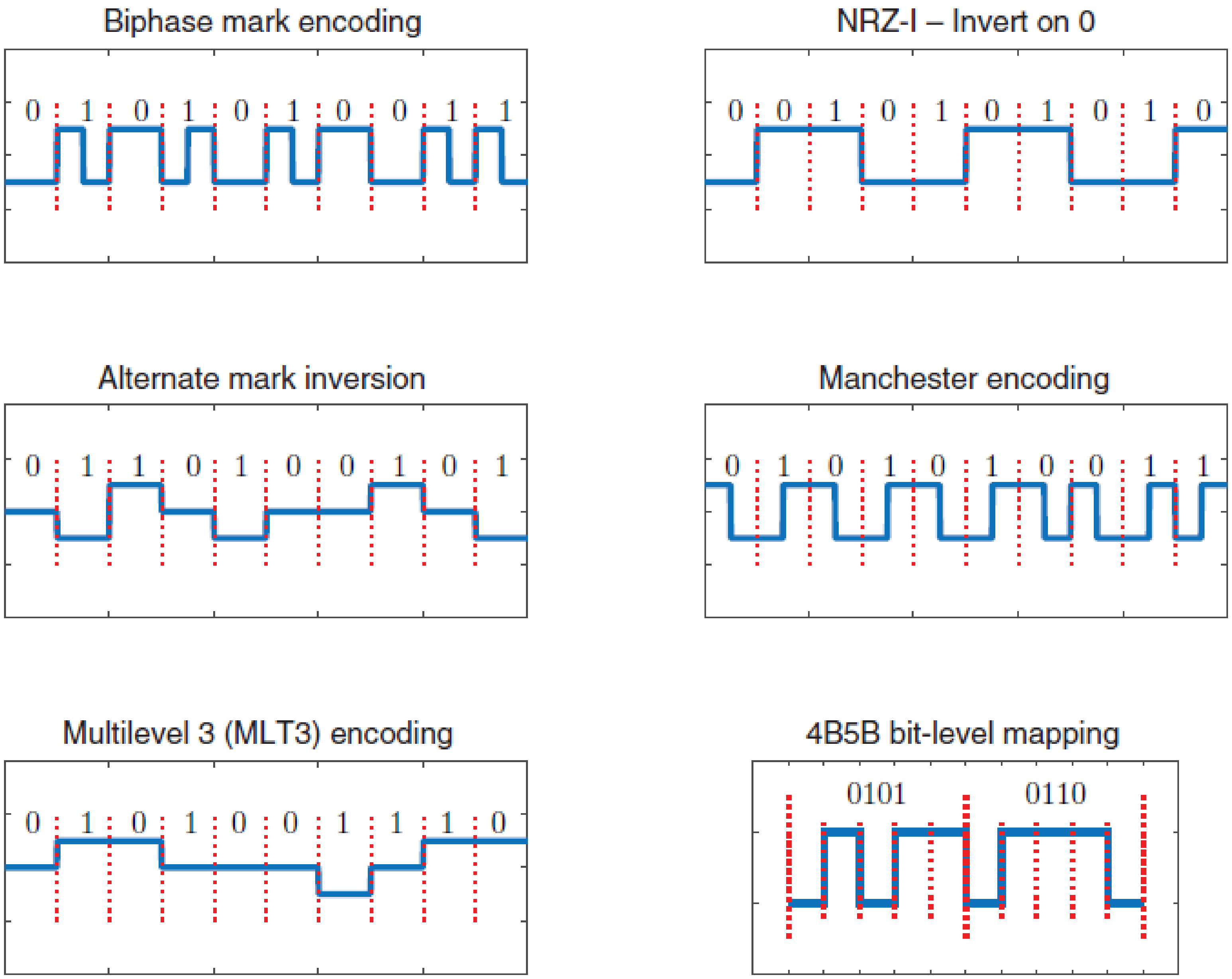


Figure 2.19 Some representative line code waveforms. A coding method must balance the requirements for receiver synchronization with minimal bandwidth. Note that NRZ-I is shown for invert on zero convention (as used in USB).

Bant Genişlği

- Ethernet
- Bakır kablo (twisted pair)
  - Cat-3: 16 MHz
  - Cat-5: 100MHz.
- Ethernet
  - 10BASE-T: 10Mbps
  - 100BASE-TX: 100 Mbps
- MLT3: Düşük bant genişliği
  - Ama 0,0,0,0,0,... olursa?
- 4B5B: 32 kombinasyonun 16'sı
  - 31.25 MHz, daha iyi senkronizasyon
- Gigabit Ethernet: 4 kablo çifti, 4PAM (2bit/Tb), 8B10B kodlama

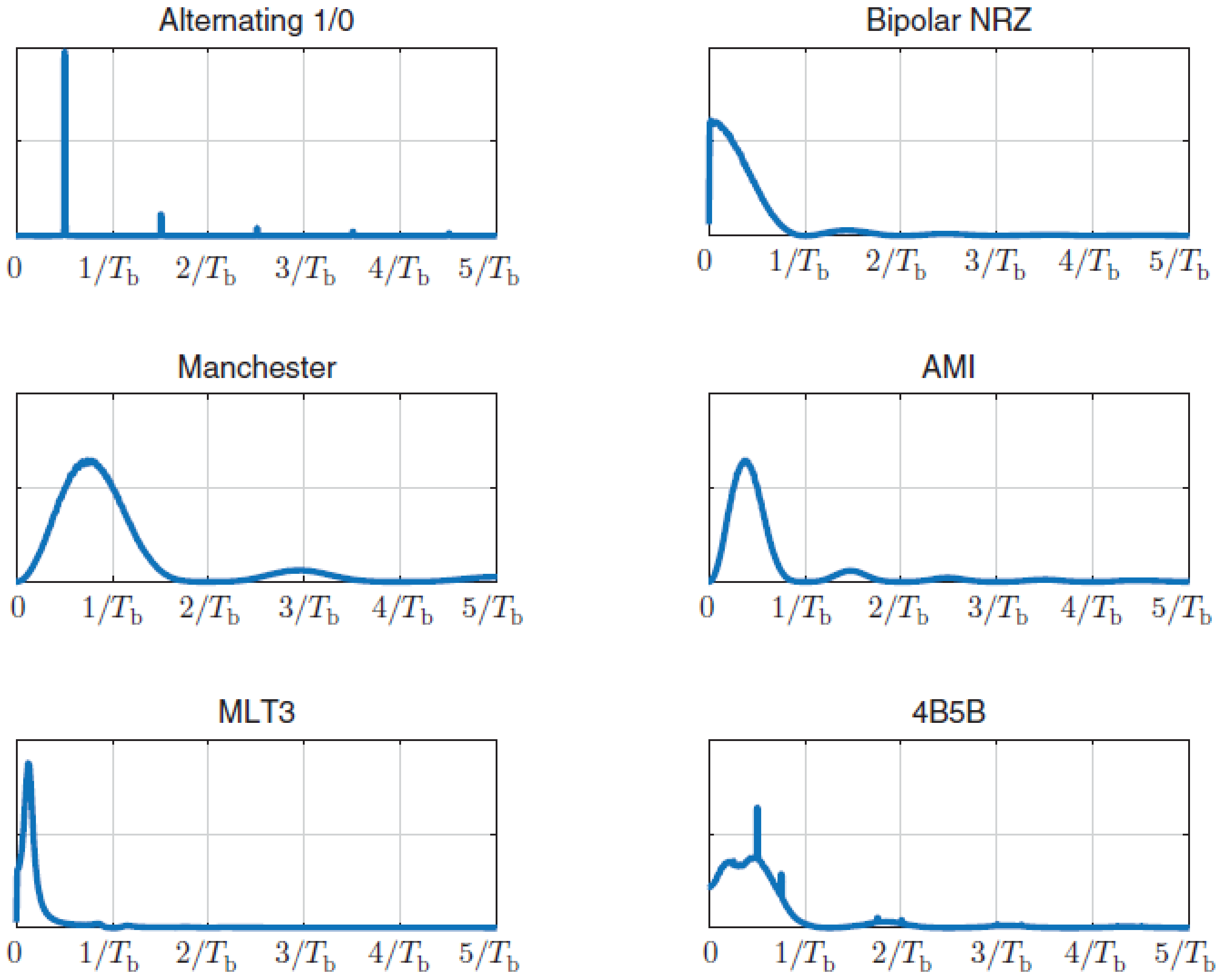


Figure 2.20 Spectra of some common line codes, derived from encoding a very long string of random binary data. The alternating 1/0 spectrum is shown for reference: It has a primary component at half the bit rate, with discrete harmonics at successively lower power levels.

Örnekleme Zamanlama Hatasının Etkisi

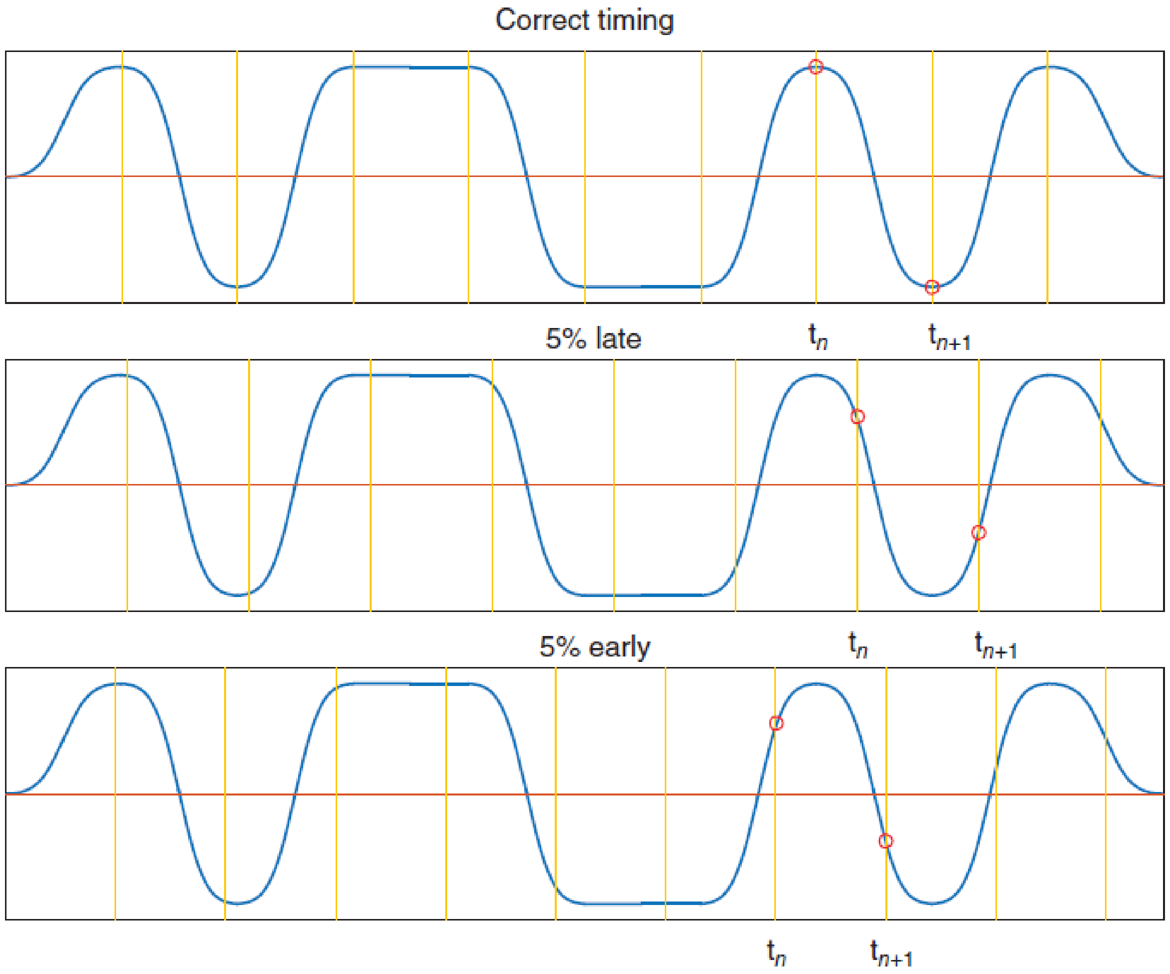


Figure 2.18 The effect of sampling a waveform early or late. Incorrect timing at the receiver results in sampling the waveform's amplitude at the wrong time with respect to the transmitter, and hence the resulting sample value may be incorrect.

2.5 Radyo ve Kablosuz İletim

- Radyo Frekans (RF)
  - EM spektrum, çok geniş bir aralık
- Havada ve uzayda ilerleyebilir
- Radyo , TV, Bluetooth, ZigBee, WiFi, GSM, LTE, 5G, Uydu
- Farklı frekanslar farklı davranış gösterir
- Görünür ışık
  - 620nm (kırmızı)
  - 380nm (mor)

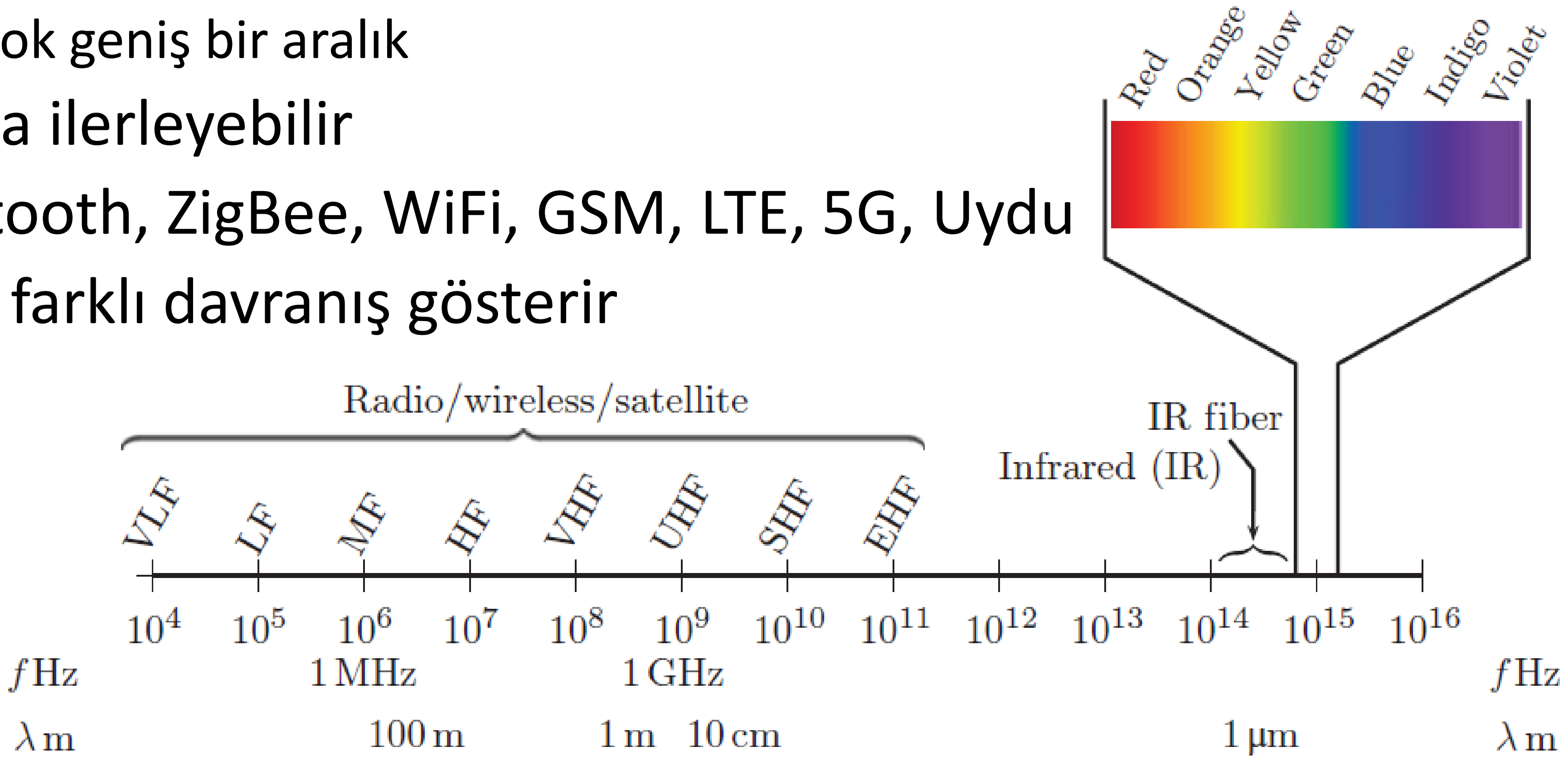


Figure 2.49 The portion of the electromagnetic spectrum important for telecommunications. Radio, wireless, and satellite systems use the frequency ranges shown. At extremely high frequencies, infrared (IR) is used in fiber optics. Still higher in frequency is the visible light spectrum.

Table 2.1 Radio-frequency (RF) band designations.

Abbreviation	Frequency range	Description
ULF	<3 Hz	Ultra low frequency
ELF	3 Hz–3 kHz	Extremely low frequency
VLF	3 kHz–30 kHz	Very low frequency
LF	30 kHz–300 kHz	Low frequency
MF	300 kHz–3 MHz	Medium frequency
HF	3 MHz–30 MHz	High frequency
VHF	30 MHz–300 MHz	Very high frequency
UHF	300 MHz–3 GHz	Ultra high frequency
SHF	3 GHz–30 GHz	Super high frequency
EHF	30 GHz–300 GHz	Extremely high frequency
—	300 GHz–3 THz	Submillimeter

Source: Adapted from IEEE (1997a).
The center block indicates the range of the most commonly used terrestrial (earth-bound) frequencies.

Table 2.2 Microwave band designations.

Band designation	Frequency range
L	1–2 GHz
S	2–4 GHz
C	4–8 GHz
X	8–12 GHz
Ku	12–18 GHz
K	18–27 GHz
Ka	27–40 GHz
V	40–75 GHz
mm	100–300 GHz

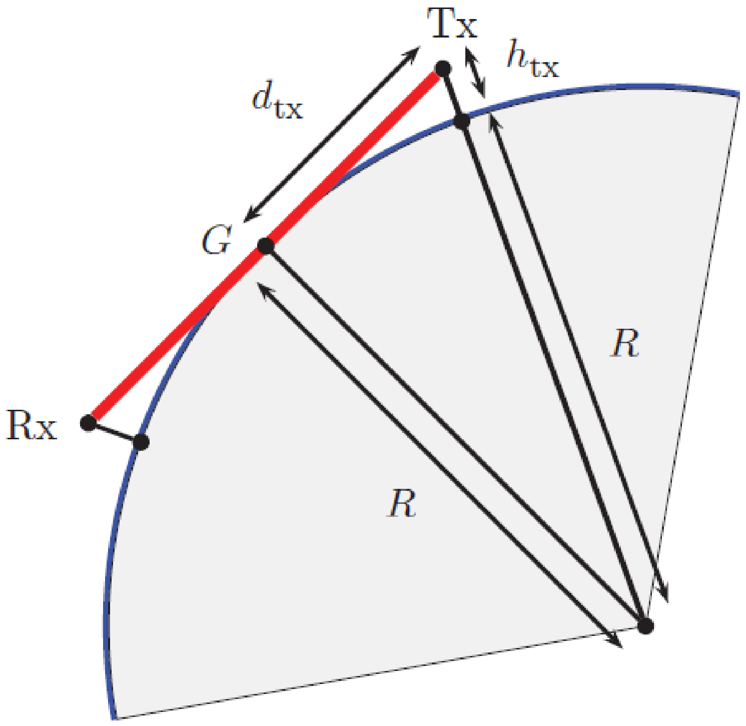
Source: Adapted from IEEE (1997b).
Some variations exist throughout the world, with some nonstandard terminology also commonly encountered.

2.5.2 Radyo Dalgalarının Yayılımı

- <1MHz: Yer dalgası
- HF-VHF: İyonosferik yansıma, büyük antenler
  - HF: Çok uzun mesafeler (kıtalararası)
  - VHF: Acil durum, seyrüsefer, kara ve deniz
- UHF (mikrodalga): Görüş alanı iletimi, engellerden saçılım
  - Karasal TV, hücresel, engellerde kırınım ve yansıma, daha küçük anten
  - MIMO
- Ku-Ka-K: Uydu haberleşmesi , 6G
  - SHF: Su buharı tarafından emilim (30GHz), atmosferik emilim, insanlar, ağaçlar tarafından engellenme
  - Çok küçük antenler, ultra yoğun MIMO
- Frekans arttıkça, **frekans bandı** da artar
- Frekans bandının kontrolü
  - International Telecommunication Union (ITU)
  - Bilgi Teknolojileri ve İletişim Kurumu

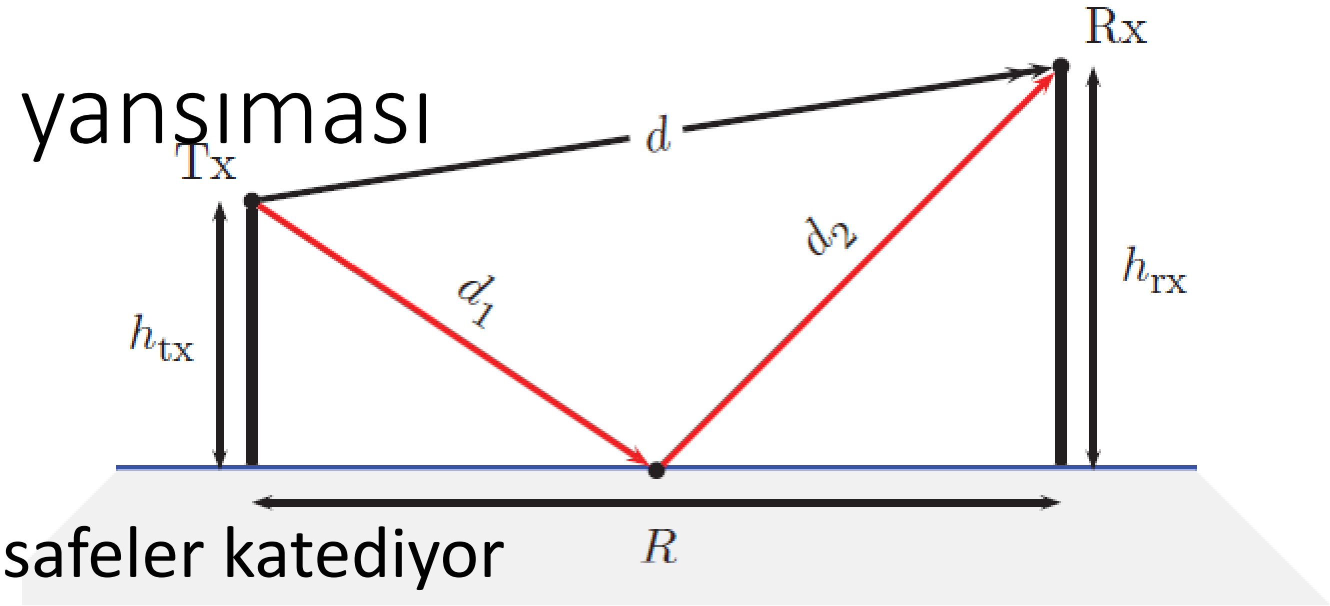
2.5.3 Görüş Alanı (LoS)

- Vericiler genelde yükseğe konur
  - Binalar , dağlar ve hatta dünya yüzeyi
- Yandaki şekilde verilen bir verici yüksekliği (h_{tx}) için maksimum iletim mesafesini (d_{tx}) türetelim
  - $R = 6370km$



2.5.4: Radyo dalgalarının yansıması

- Sinüzoidal bir sinyal
- İki farklı yoldan ulaşıyor
  - (kırmızı ve siyah yollar)
- Alıcıya ulaşan iki sinyal farklı mesafeler katediyor
  - Faz farkı oluşuyor
  - Faz farkı sıfır: Birbirini güçlendirir
  - Faz farkı 180 derece: Birbirini sıfırlar/zayıflatır



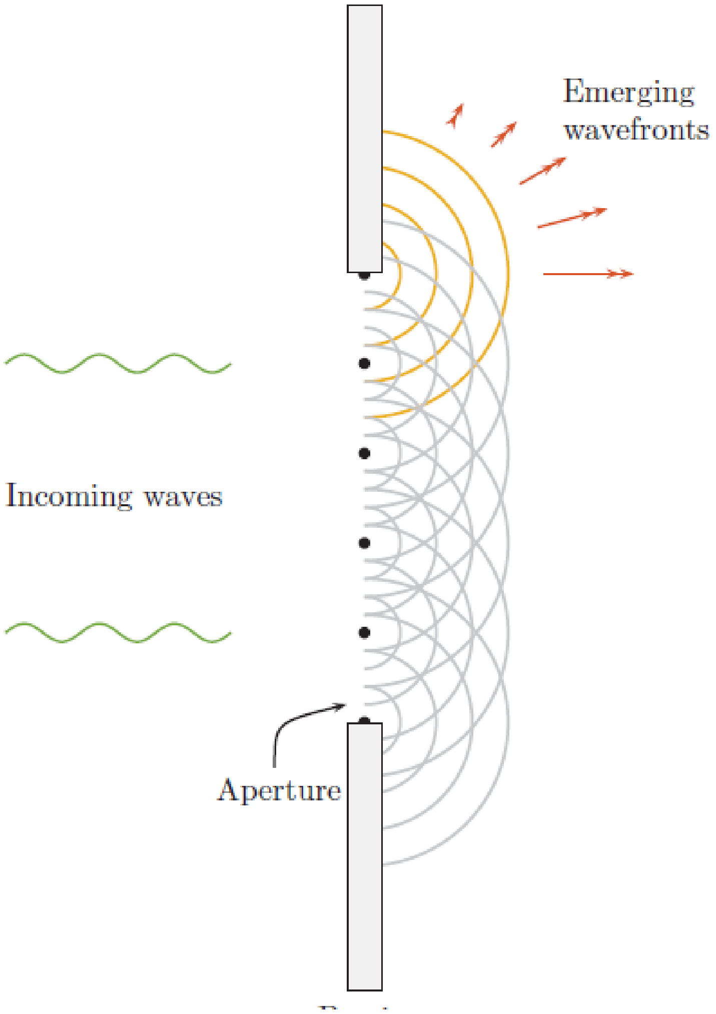
2.5.4: Radyo dalgalarının yansıması

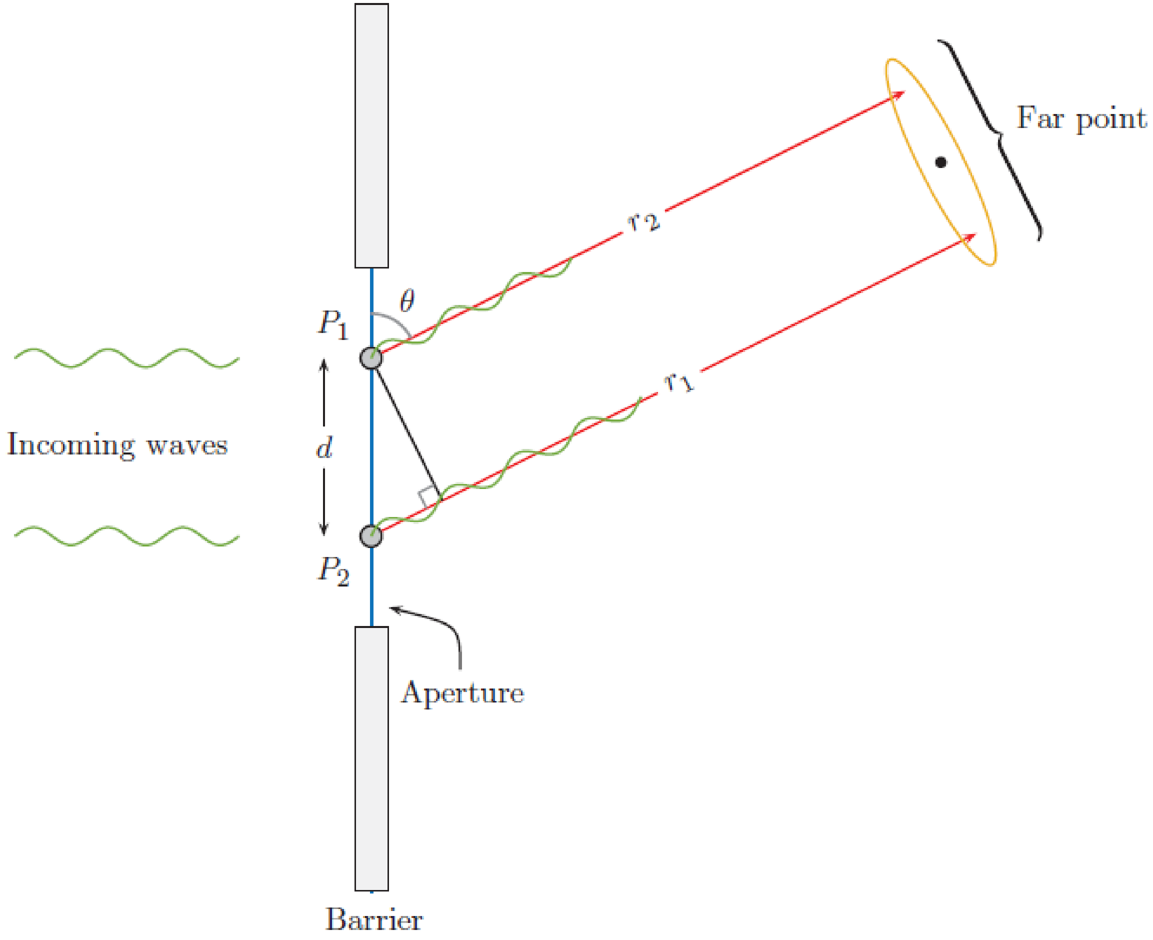
- Devam…

- Mesafe farkı: $\Delta d = \frac{2h_{tx}h_{rx}}{R}$
- Faz farkı (rad): $\phi = \frac{2\pi}{\lambda}\Delta d$

2.5.5 Radyo Dalga Kırınımı

- Huygens/Fresnel prensibi: Bir açıklıktan geçen dalga
  - Küçük dalgacıklar oluşur ve etkileşime girer





2.5.5 Kırınım

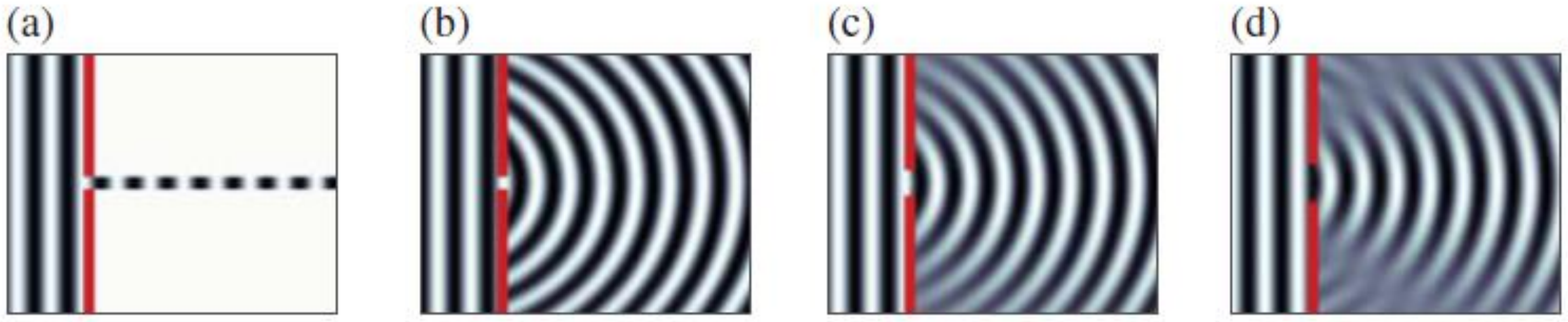
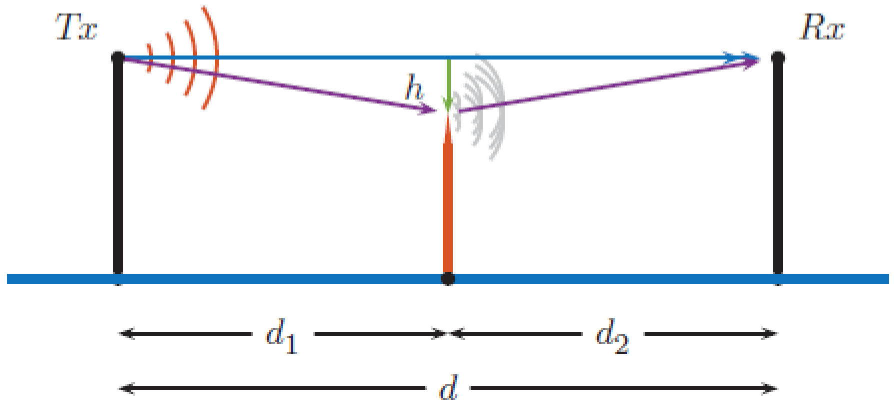


Figure 2.54 Diffraction at an aperture. Image (a) is shown assuming no diffraction; (b), (c), and (d) illustrate the situation as the aperture gradually increases.

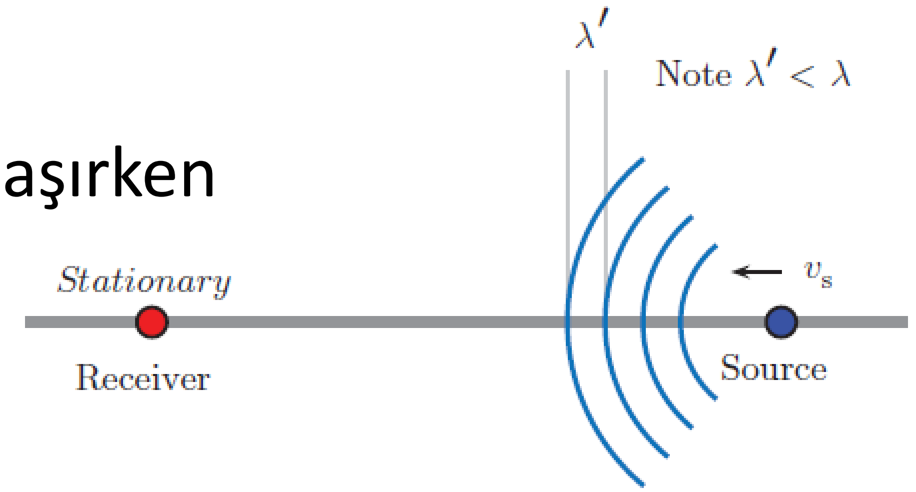
- Tam görüş alanında olmayan engeller kırınım yaratır
- Bıçak ucu kırınımı
  - Yine iki yol var. Yol ve faz farkını türetelim

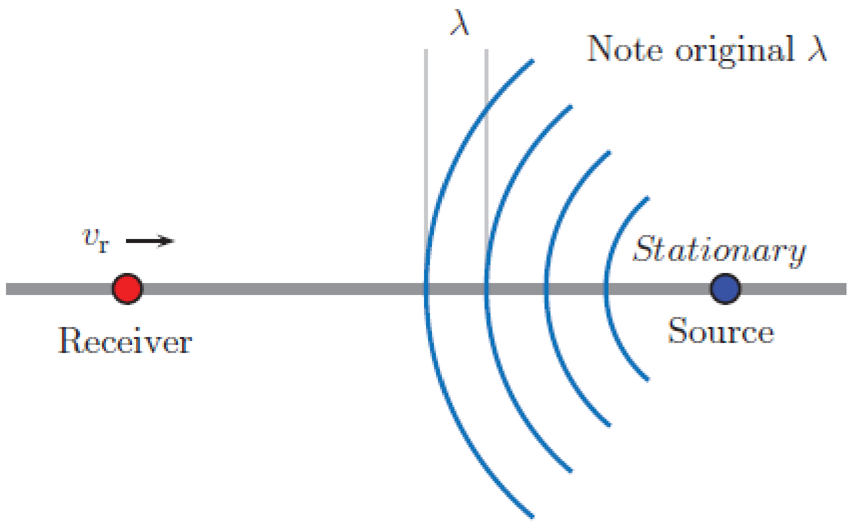


2.5.5 Kırınım

2.5.6 Hareketli Alıcı ve Verici

- Ambulans bize yaklaşırken sesi daha ince, uzaklaşırken sesi daha kalın gelir : Doppler etkisi
  - Bir taşıyıcı (sinüzoidal) dalga gönderelim
    - $c =$ ışık hızı, $f = \frac{1}{\tau}$: frekans
    - Kaynağın hızı (yaklaşıyor) v_s
  - Ardışık dalgalar arası mesafe
    - $\tilde{\lambda} = \frac{c}{f} - v_s\tau = \frac{c}{f} - \frac{v_s}{f} = \frac{c-v_s}{f} < \lambda$
      - $\tilde{f} = \frac{c}{\tilde{\lambda}} = \frac{f}{1-\frac{v_s}{c}}$
  - Kaynak uzaklaşırken
    - $\tilde{f} = \frac{c}{\tilde{\lambda}} = \frac{f}{1+\frac{v_s}{c}}$
- Etkisi: Taşıyıcı senkronizasyonu bozulur
- Ör. 2Ghz frekans, 100km/saat hız?





2.5.7 Radyo Dalgalarını İletmek ve Yakalamak

- Eş yönlü anten
  - İletim gücü: P_t
  - r uzaklıkta elektromanyetik akı $\frac{P_t}{4\pi r^2}$
  - Pratik uygulamada yönlü anten gerekir
- Yarım Dalga Dipol
- Yayılım örüntüsü
- $E(\theta) = K \dfrac{\cos\left(\frac{\pi L}{\lambda}\cos\theta\right) - \cos\frac{\pi L}{\lambda}}{\sin\theta}$

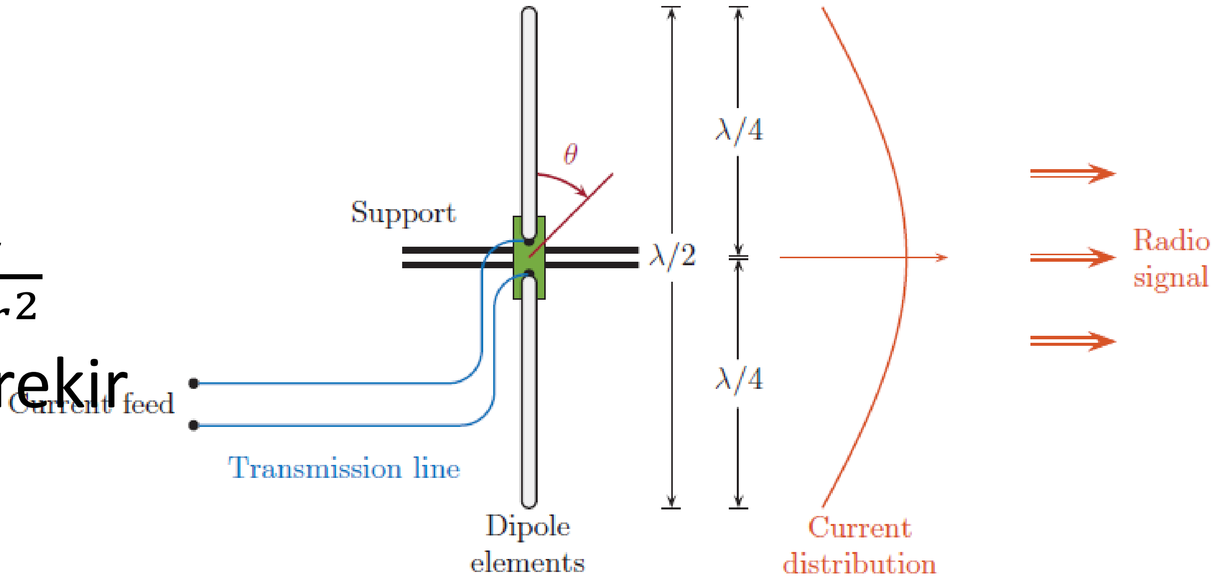


Figure 2.58 A basic half-wave dipole. The support beam is electrically insulated from each arm of the dipole. Note that the angle toward a receiver θ is measured from the dipole arms, and thus the direction of maximum intensity or sensitivity is perpendicular to the dipole arms ($\theta = 90°$). The total length of the dipole is L, and in this case it is $L = \lambda/2$. As a result, each arm is a quarter wavelength.

2.5.7 Radyo Dalgalarını İletmek ve Yakalamak

- Güç $P(\theta) = E^2(\theta)$
- Simit şeklinde bir örüntü
- Yarım güç hüzme genişliği
  - Tanım:

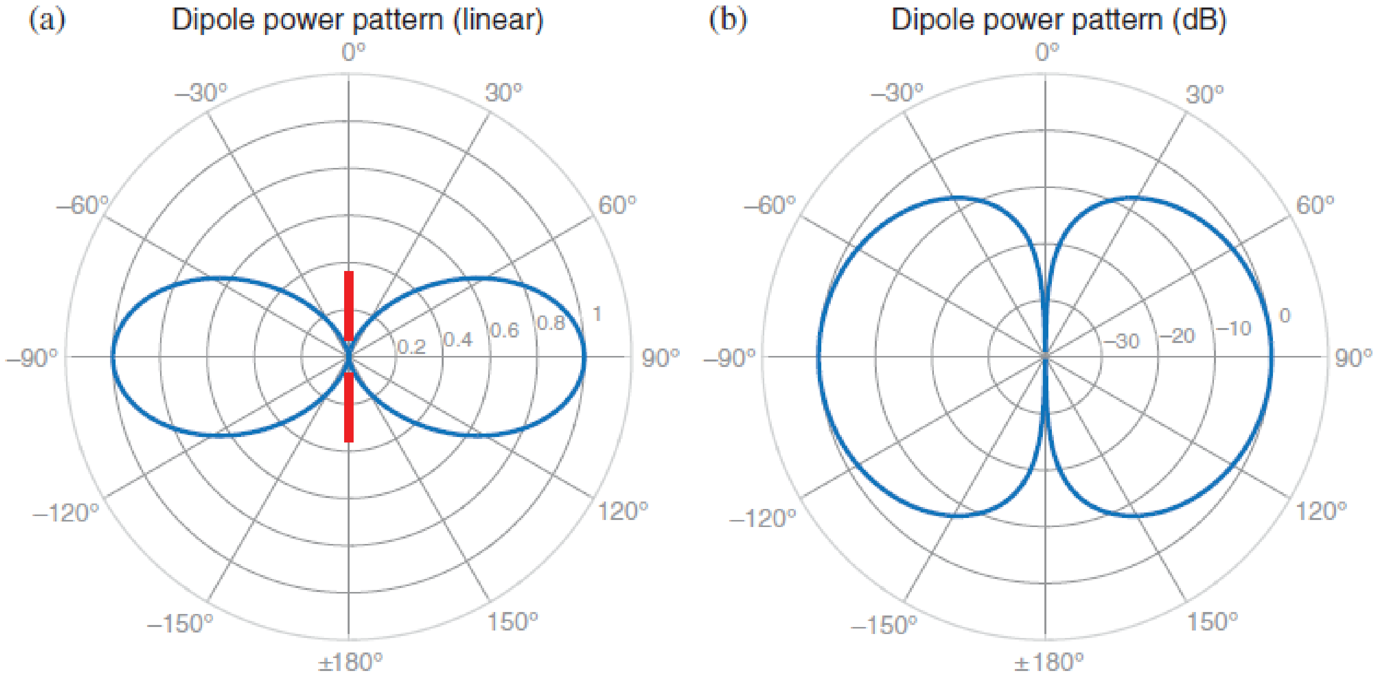


Figure 2.59 The normalized dipole pattern. From this, we may determine the relative field strength of a transmission at a given angle or, alternatively, when used as a receiving antenna, the sensitivity when aligned with respect to a transmitter. (a) Linear scale. (b) Decibel (logarithmic) scale.

2.5.7 Radyo Dalgalarını İletmek ve Yakalamak

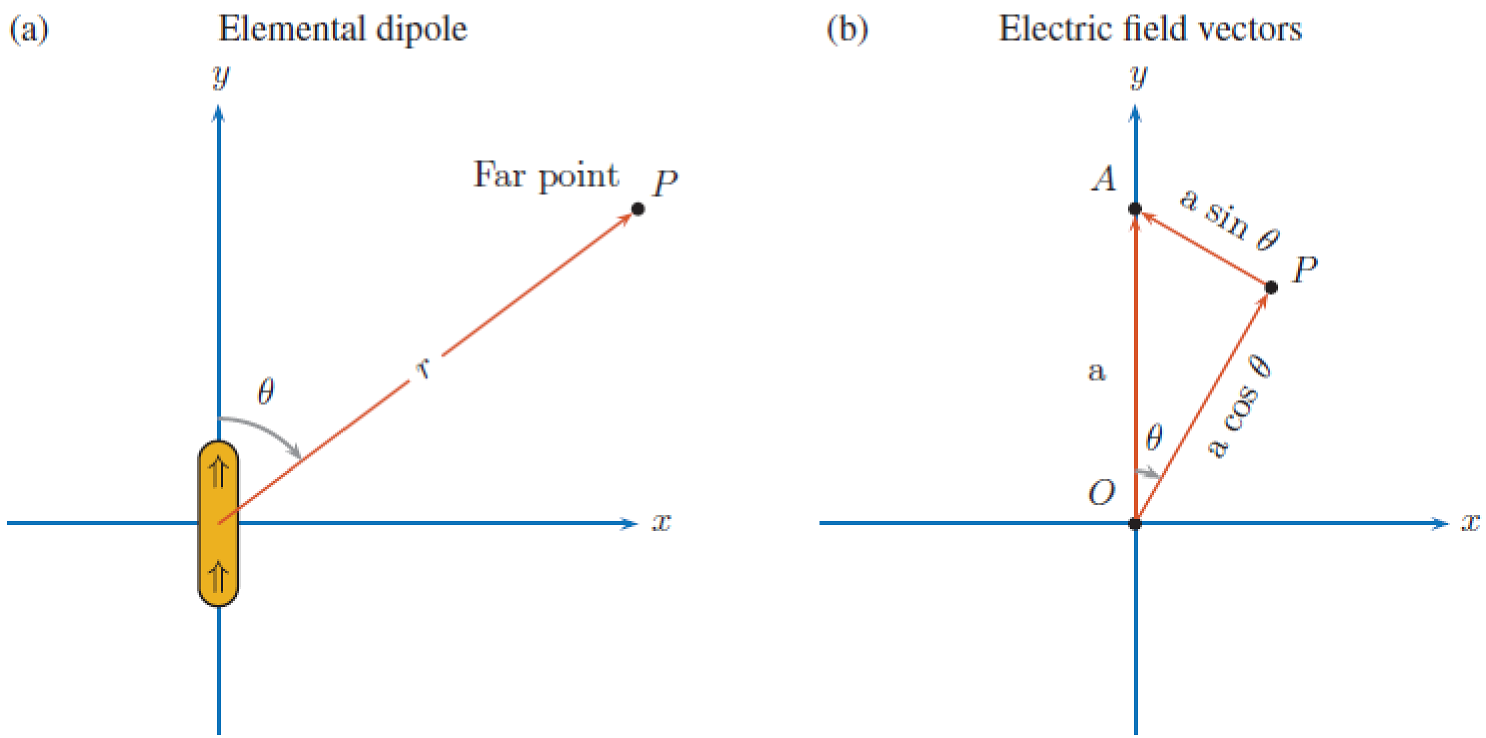
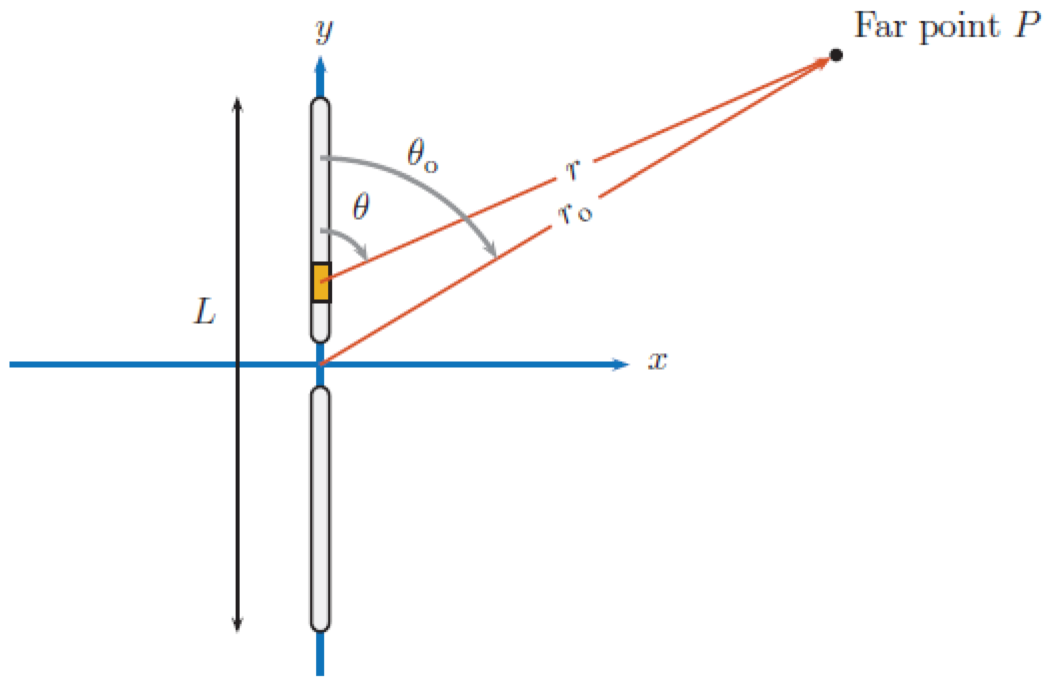


Figure 2.60 An elemental or Hertzian dipole (a) consists of a hypothetical current-carrying element. It is used as the basis for modeling more complex antenna types. The electric field vectors are decomposed into orthogonal (perpendicular) components (b).

```
x = -2 : 0.1 : 2 ; y = -2 : 0.1 : 2 ;
Nx = length(x); Ny = length(y) ;
L = 1.0 ; % use to simulate a longer antenna L = 0.1 ; % use to simulate a point source
[X, Y] = meshgrid ( x , y ) ;
id = find ((X==0)&((Y<=L/2)&(Y>=-L/2)));
omega = 2*pi ; dt = 0.01; tmax = 4; lam = 1; beta = 2*pi/lam ;
for t = 0:dt:tmax
Isum = zeros(Ny,Nx);
Idip = zeros(Ny,Nx) ;
for i = 1:length(id)
xo = X(id(i)); yo = Y(id(i));
% cosine current p r o f i l e
Io = cos (pi*yo/L);
% use for Hertzian point dipole with small L
%Io = 4 ;
% save dipole cur rent at t h i s point
Idip(id(i))=Io;
dX = X-xo ;
dY = Y-yo ;
% distance plot from current point
R = sqrt(dX.^2 + dY.^2);
theta = atan2(dX,dY);
I = Io*cos ( omega*t-beta*R).*sin(theta);
% division by zero if R=0 , but this is only on the dipoleitself
i=find(abs(R)<eps);
R(i)=1;
I = I./R;
Isum = Isum + I ;
end
figure(1);
set(gcf, 'position',[20 90 450 300]);
meshc (X, Y, Idip ) ;
figure(2);
set (gcf, 'position', [500 90 450 300]);
IsumDisp = Isum*1 + Idip*40;
mesh(X,Y, IsumDisp);
set(gca,'zlim' , [-20 4]);
figure(3);
set(gcf, 'position',[1000 90 400 300]);
IsumDisp = abs(Isum)*10 + Idip*200 + 80;
image ( IsumDisp ) ;
colormap(parula(255));
axis('off');
drawnow
pause(0.05);
end
```



2.5.7 Radyo Dalgalarını İletmek ve Yakalamak

- Yagi anten (karasal TV anteni)
  - Yansıtıcı, dipol ve yönlendiriciler

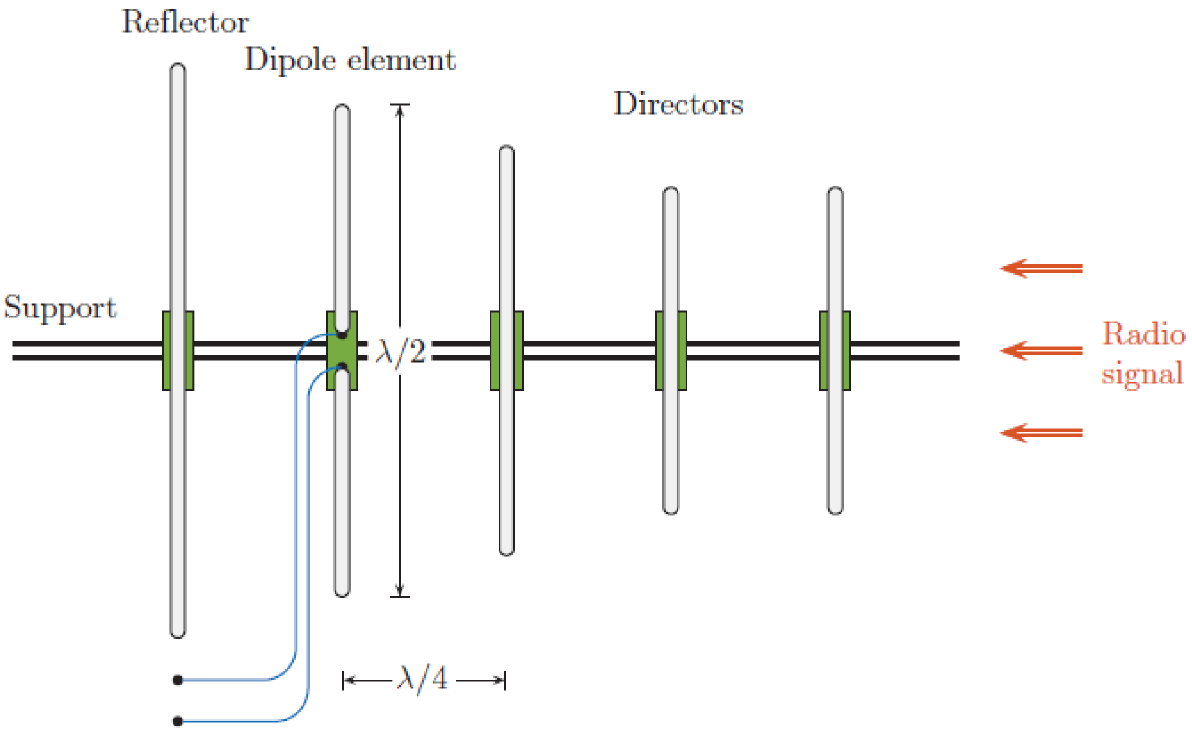


Figure 2.64 A half-wave dipole, when combined with one or more directors and a reflector, forms a Yagi antenna.

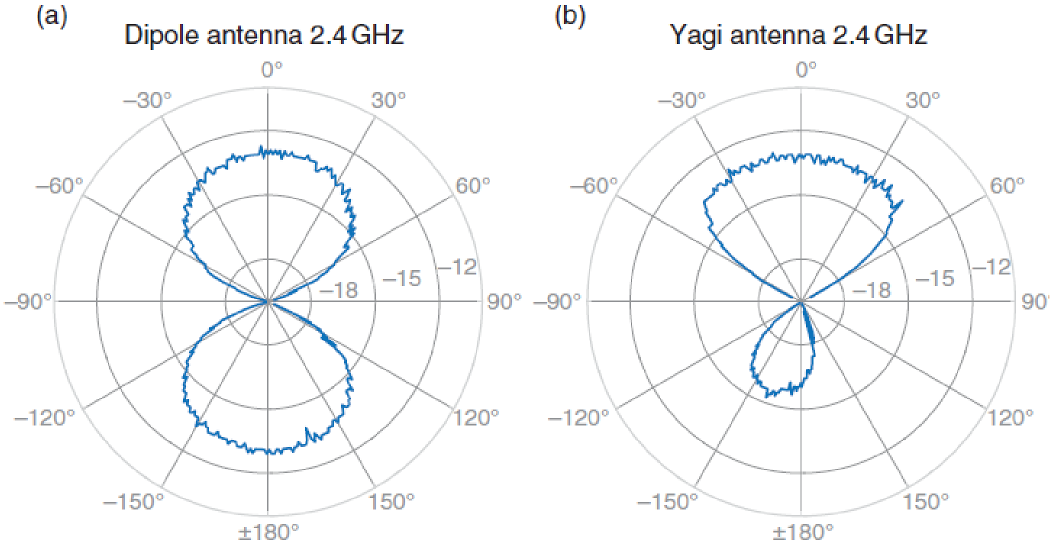


Figure 2.65 Experimental measurements of antennas at 2.4 GHz. (a) Dipole antenna. (b) Yagi antenna.

Log-periyodik anten: Genişbant

- $\frac{L_1}{D_1} = \frac{L_2}{D_2} \ldots$
- Dikkat: Ardıık dipoller ters bağlanmış

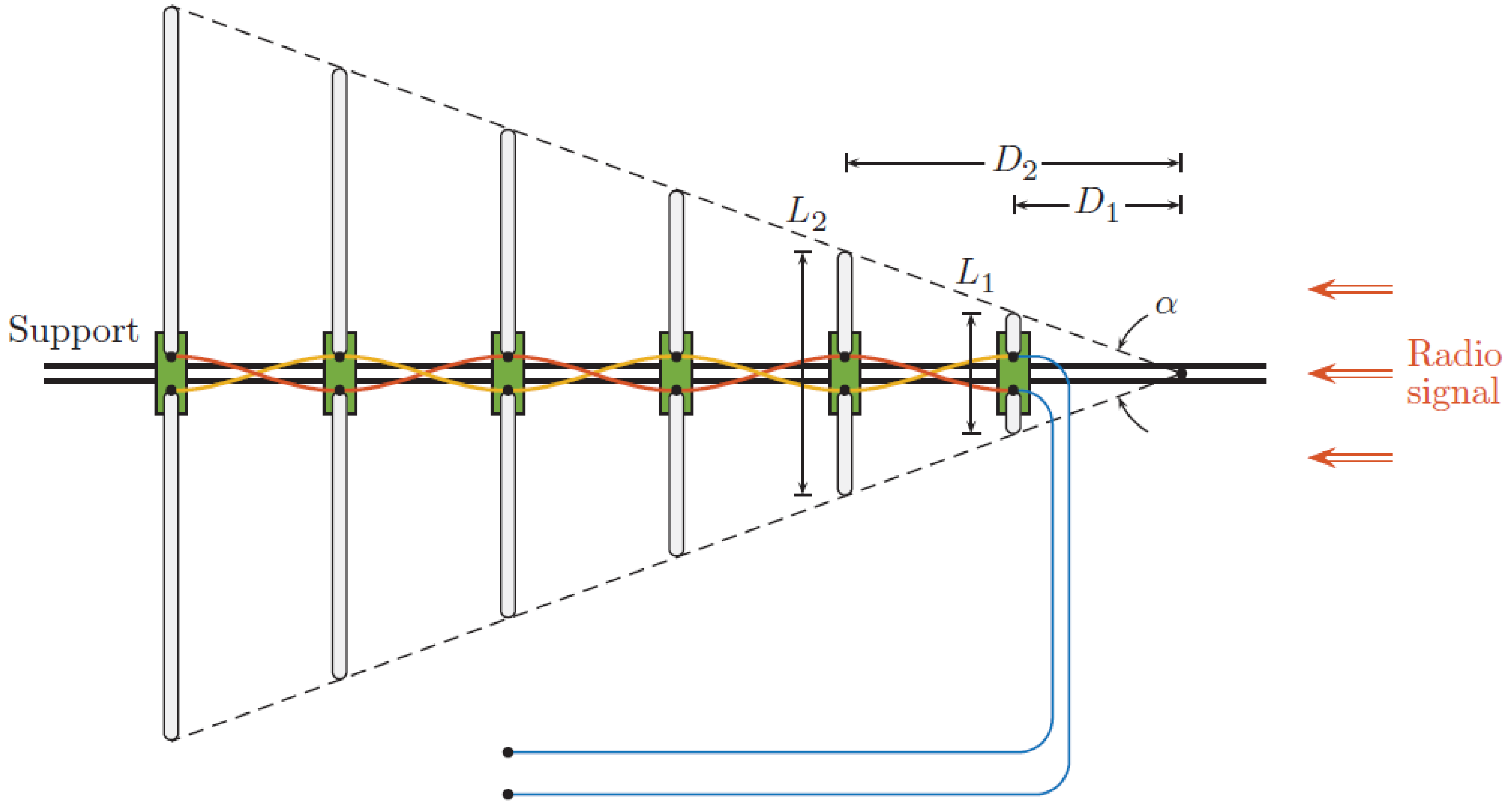
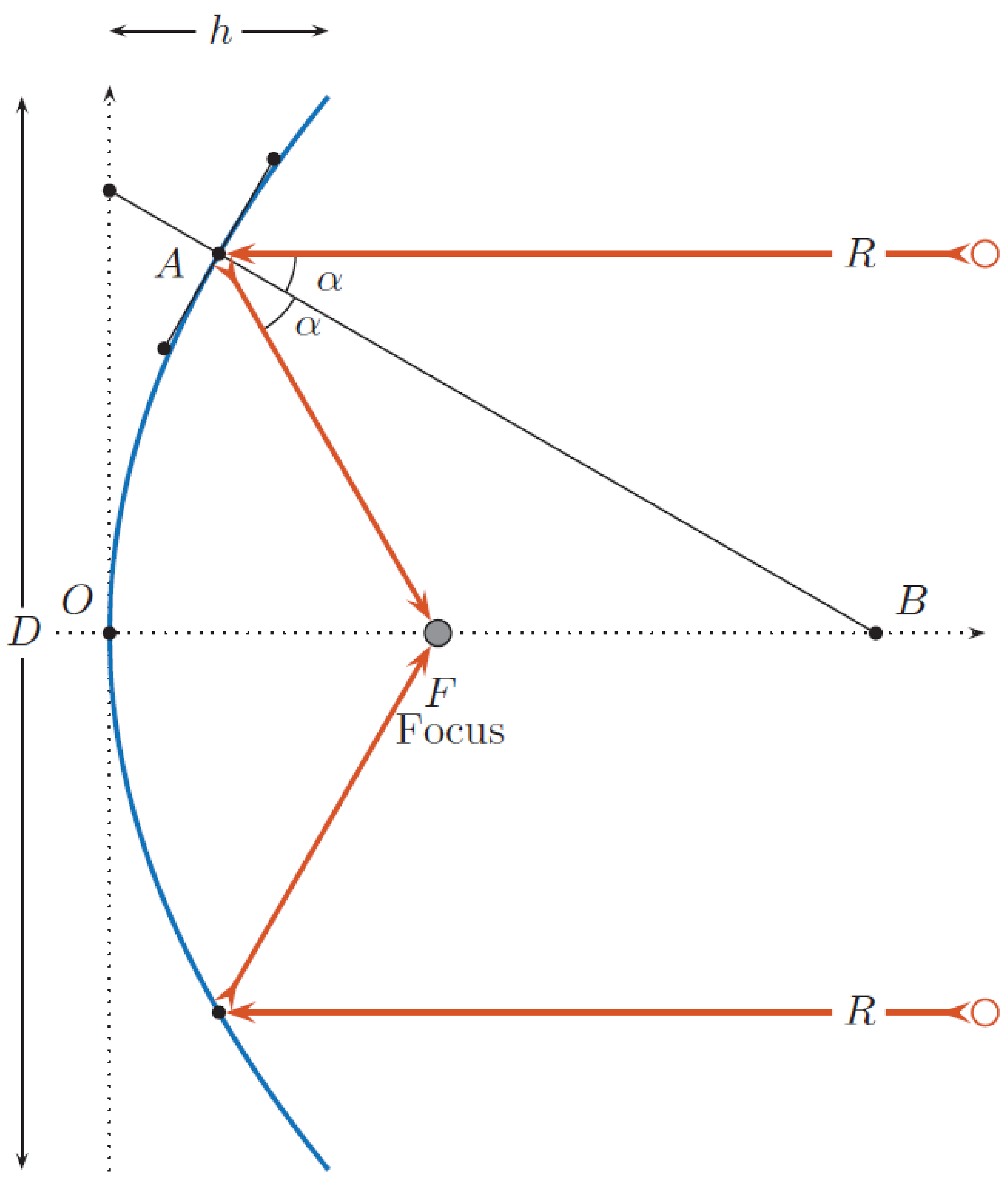


Figure 2.66 A log-periodic antenna formed by multiple half-wave dipoles. Note the reversal of the interconnections between successive dipoles, which effects a phase reversal.

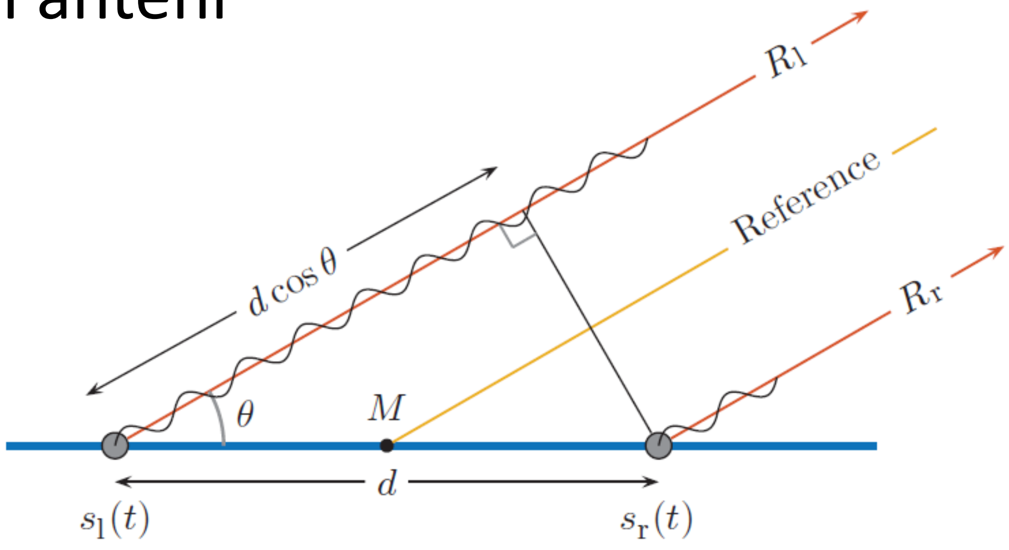
Parabolik Reflektör

- Enerjiyi odaklar
- Yüksek yönlülük
- Parabol: $y^2 = 4fx$
- $(x, y) = \left(h, \frac{D}{2}\right) \rightarrow f = ?$
- Gelen bütün ışınlar odağa doğru yansır



Dizilim antenler

- Önceki antenlerin ışıma yönünü değiştirmek için anteni fiziksel olarak oynatmak gerekir.
- Dizilim antenlerin ışımaları yönlendirilebilir
- İki eş yönlü elemanlı anten dizisi
- Elemanlar arası zaman farkı ?
- Orta noktayı referans alalım
- $\phi_r = \frac{\beta d}{2} \cos\theta + \psi$
- $\phi_l = \frac{\beta d}{2} \cos\theta - \psi$
- $E(\theta) = K[I_o \cos(\omega t + \phi_l) + I_o \cos(\omega t + \phi_r)]$
-



Dizilim antenler - devam

- Anten aralığı: $d = \frac{\lambda}{2}$ olsun

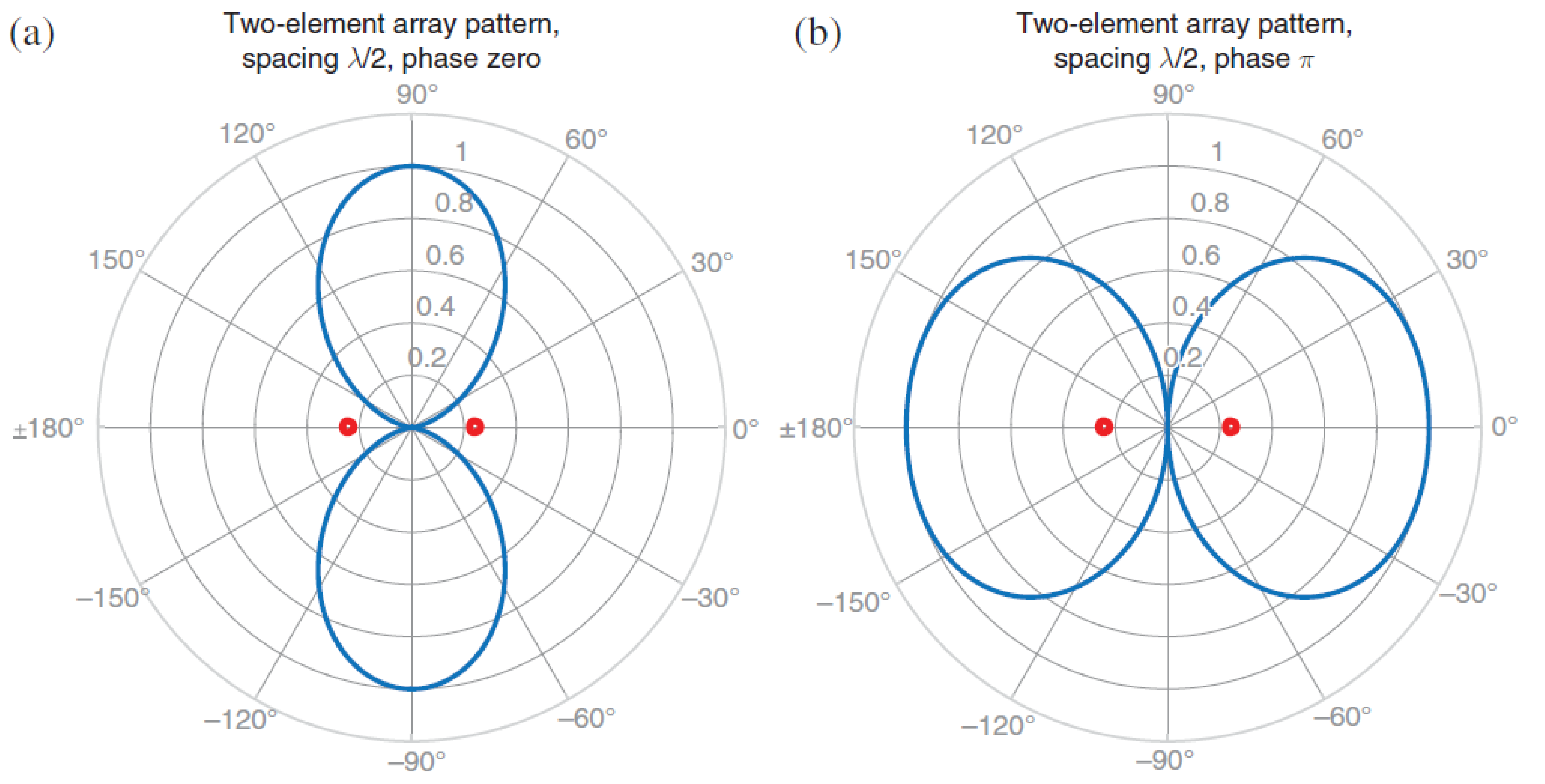


Figure 2.69 Changing the relative phases produces the two patterns illustrated. Note that the $\theta = 0$ axis is along the horizontal, corresponding to the axis of the radiator elements, whose relative positions are indicated. (a) $\psi = 0$, $d = \lambda/2$. (b) $\psi = \pi$, $d = \lambda/2$.

2.5.8 Kablosuz Alıcı-Verici

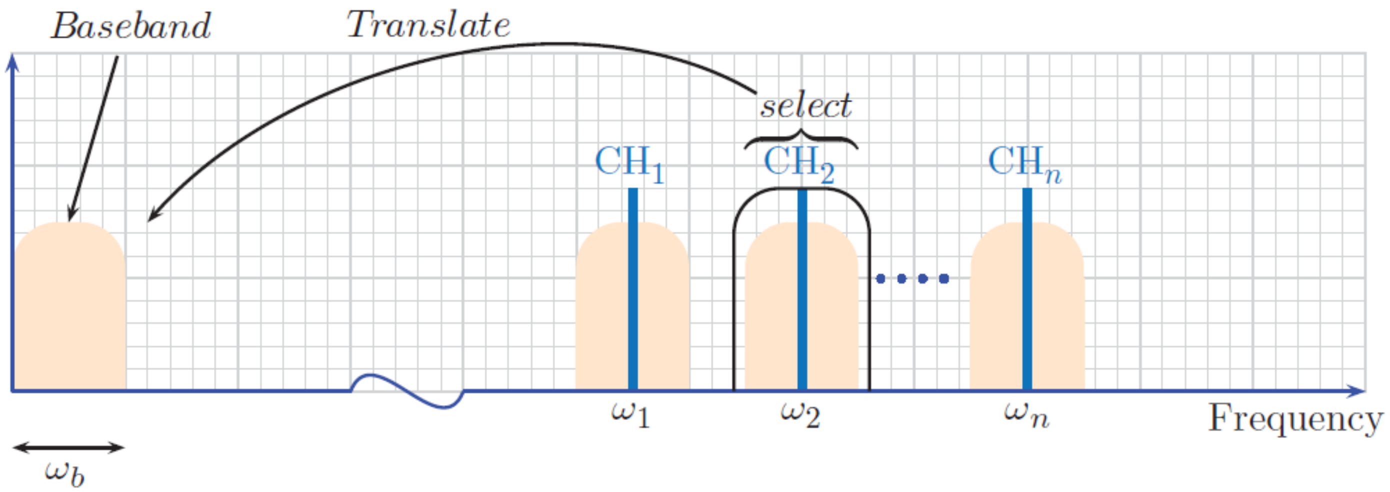


Figure 2.70 Receiving a radio signal means selecting a particular RF band and translating it back to the baseband. Sending a signal is the reverse – translating from the baseband up to RF. The actual bandwidth taken up in the RF area is invariably greater than the bandwidth of the baseband signal.

- Sinyali antenle basmak için önce antenin kullanılabileceği hale getirmek gerekir (baseband →passband)
  - Bir banda taşımak gerekir (tabanbant sinyal antenle yayılamaz)
    - AM: $u(t) = m(t)\cos(\omega t)$
    - AM: (5kHz)500-1500 kHz, FM: (200kHz)88-108 MHz, WiFi: (20MHz)2.4GHz
- Antene gelen sinyal bant geçirgen bir sinyaldir
  - Alıcıda önce bir ara frekansa taşınır

2.5.8 Kablosuz Alıcı: Basit bir radyo alıcısı

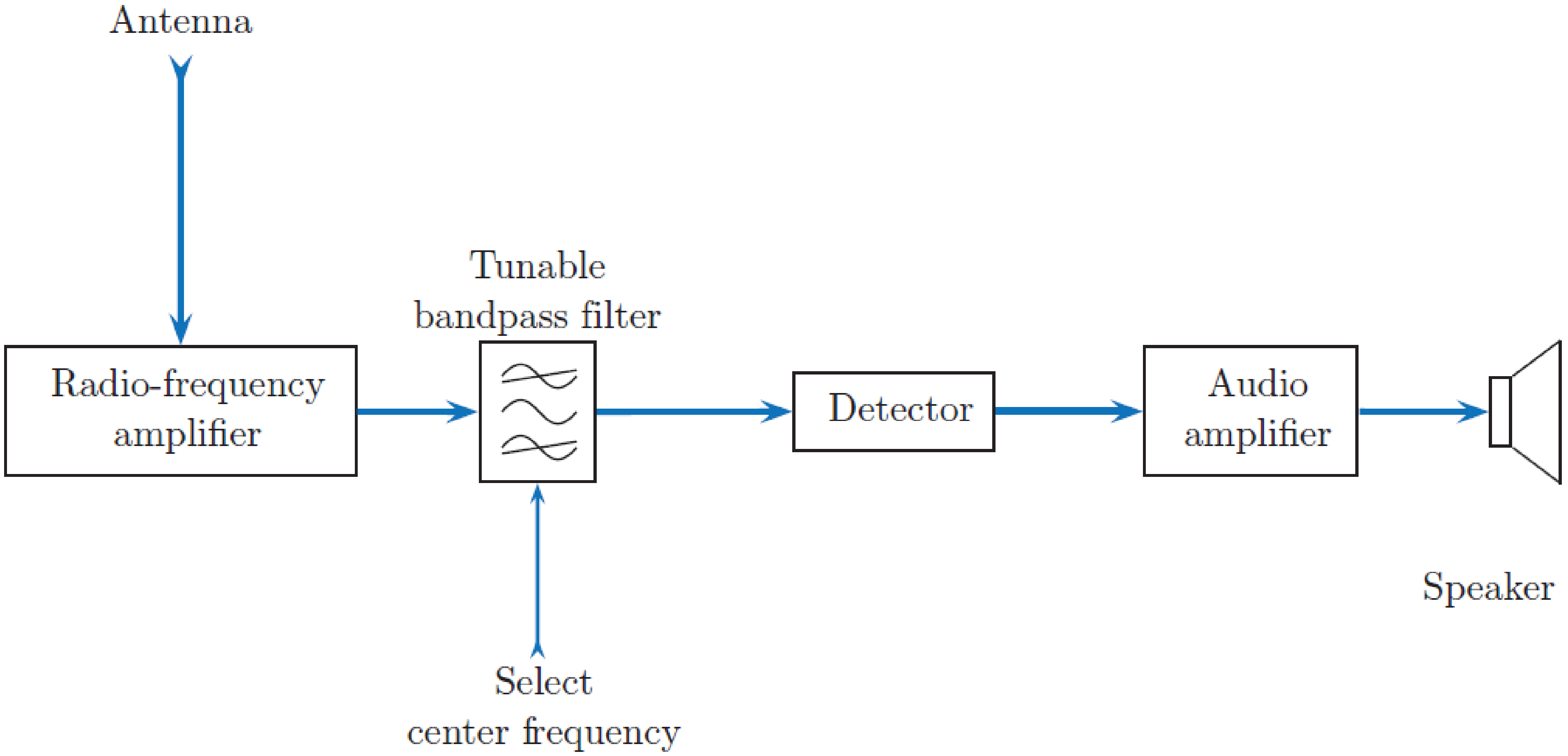


Figure 2.71 The Tuned Radio Frequency (TRF) receiver is essentially just a bandpass filter followed by a detector. The very weak received RF signal is first amplified, and the particular band of interest is selected using a filter. The information signal must be selected from that, and originally this was just a "detector" before more sophisticated modulation methods were devised

2.5.8. Superheterodyne Receiver (Armstrong-1921)

Not: Hemen hemen bütün kablosuz teknolojilerde bu alıcı yapısı var

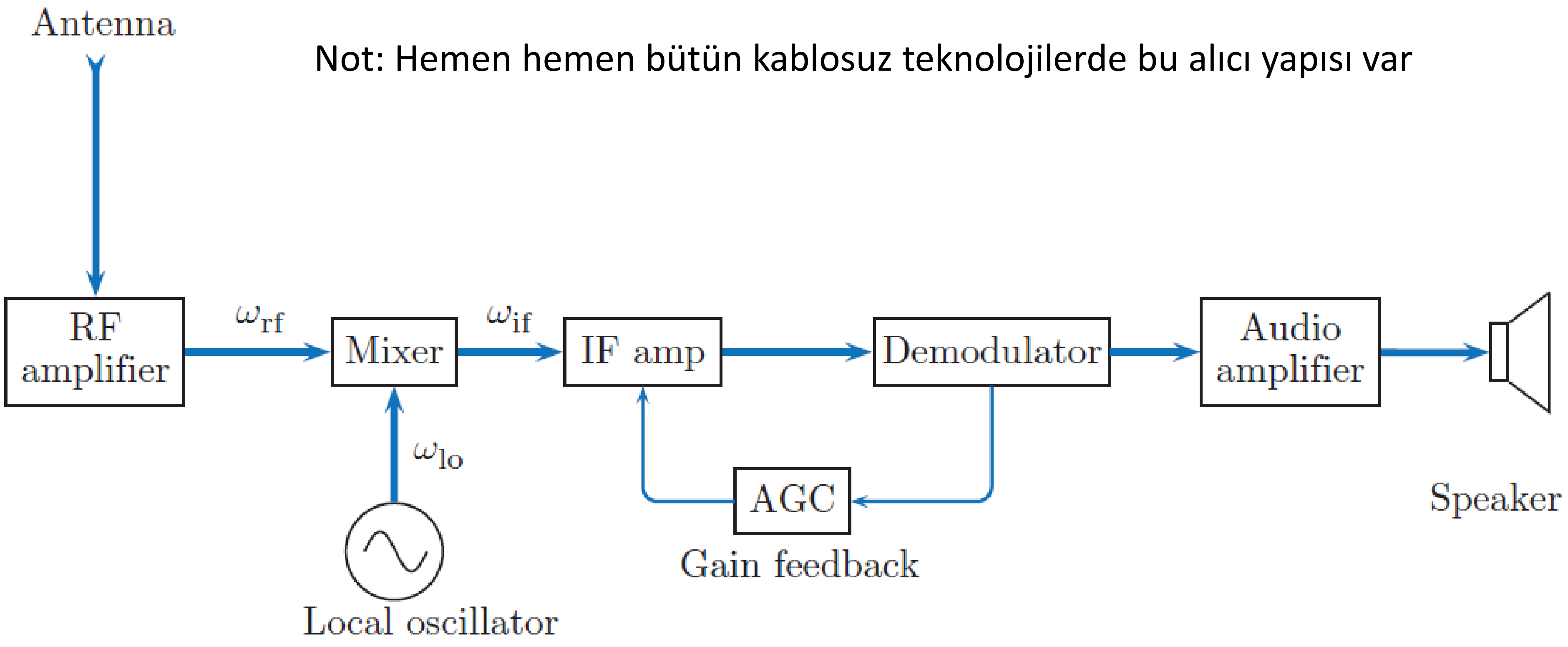
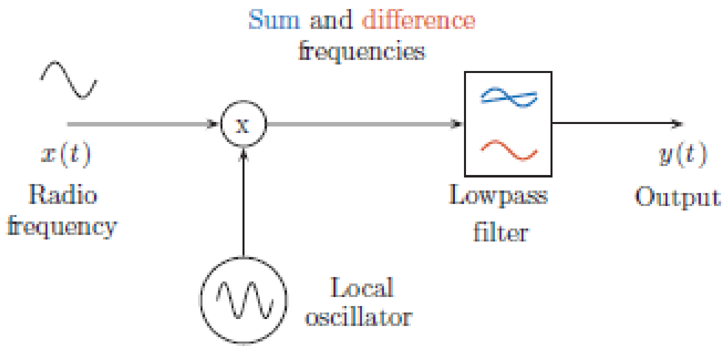


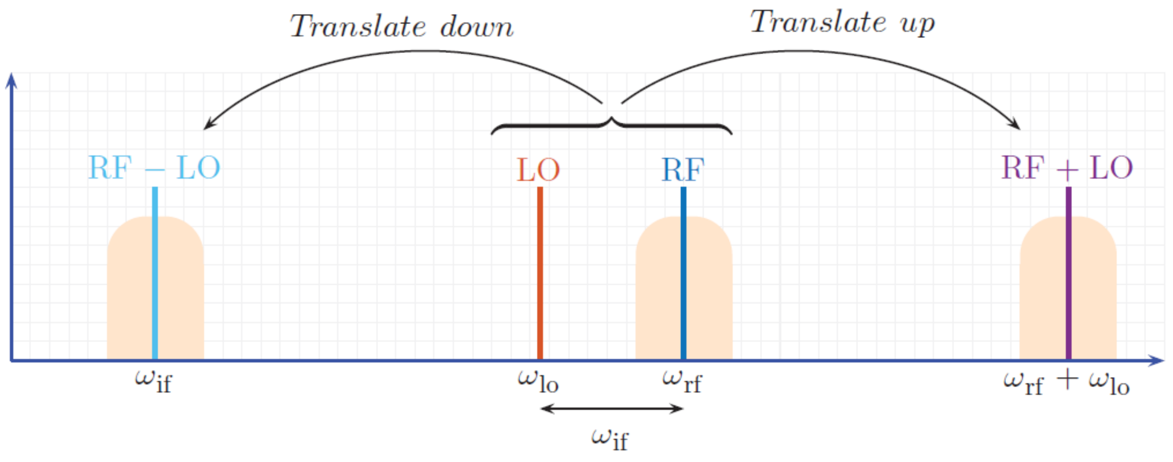
Figure 2.72 The general principle of heterodyning in a receiver. The Radio Frequency (RF) is mixed down using the Local Oscillator (LO) to produce an Intermediate Frequency (IF), which is then demodulated according to the modulation method used at the transmitter. The final stage shown is the Audio Frequency (AF) output. The Automatic Gain Control (AGC) feedback loop is used to adjust the output amplitude to maintain a constant output irrespective of the presence of strong or weak radio signals.

2.5.8. Superheterodyne Receiver (devam)

- Önce ara frekansa çekilir
  - ör. AM: $\omega_{IF} = 2\pi 455kHz$, FM: $\omega_{IF} = 2\pi 10.7MHz$
- Ara frekans için tek bir güçlü, keskin bir filtre tasarlanmıştır, istenen kanalı (ω_{RF}) çeker, yan bantları atar.
- AM sinyali $m(t)A_{rf}\cos(\omega_{RF}t)$
- Yerel osilatör $A_{lo}\cos(\omega_{LO}t)$
- $\omega_{LO} = \omega_{RF} - \omega_{IF}$

Figure 2.74 A signal mixer for downconversion consists of an oscillator and a signal multiplier, followed by a lowpass filter. The difference frequency will always be lower, and hence it is removed by an appropriately designed lowpass filter.

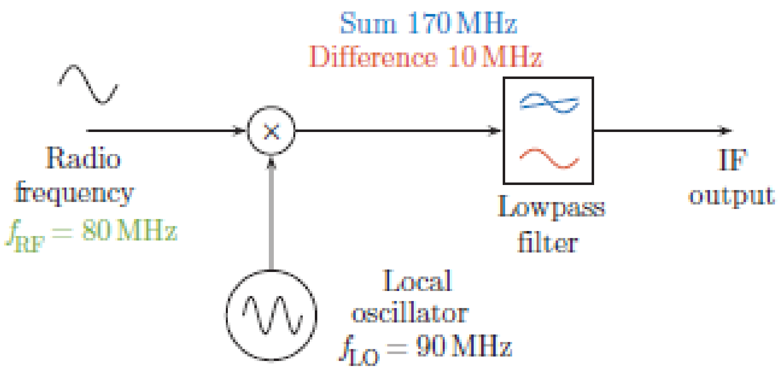


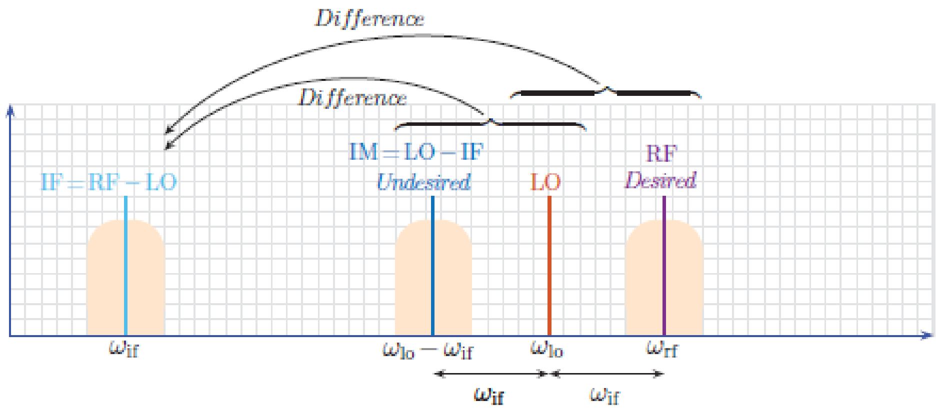


2.5.8. Superheterodyne Receiver (eşlenik frekans)

- Eşlenik frekans $\omega_{IM} = \omega_{RF} + 2 \times \omega_{IF}$
  - Mixer işlemi sonucu bu frekans istenen frekansla çakışır.
  - Önceden elemine edilmesi gerekir (RF amplifier bu işi yapar)

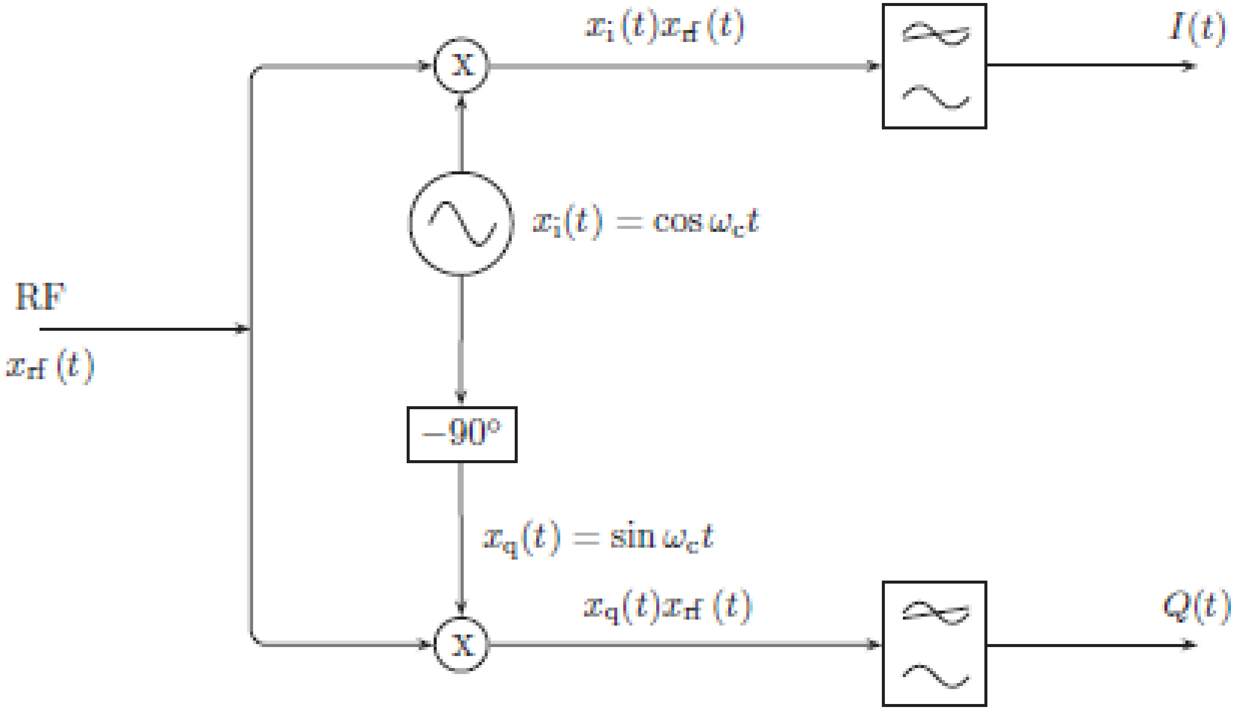
Figure 2.77 Mixer example with an image frequency present.





Direct conversion

- Ara frekans yoktur. Doğrudan tabanbanta çekilir.
- **Sayısal haberleşmede kullanılır**
- İki osilatör var, sinüs ve kosinüs
- Tabanbant Sinyalin gerçel ve karmaşık kısımları elde edilir.



2.5.9 Intermodulasyon

- Şu ana kadar doğrusal bir sistem var saydık (cos ile çarpım ve filtreleme)
- Gerçekte yükselteçler doğrusal olmayan etkiler yapar
- Bu etkiler farklı frekansta sinyaller doğurur (istenmeyen mixer etkisi)
- $y(t) = G_1 x(t) + G_2 x^2(t) + G_3 x^3(t)$
- $y(t) = y_1(t) + y_2(t) + y_3(t)$
- Özellikle kübik terimler problem yaratır.

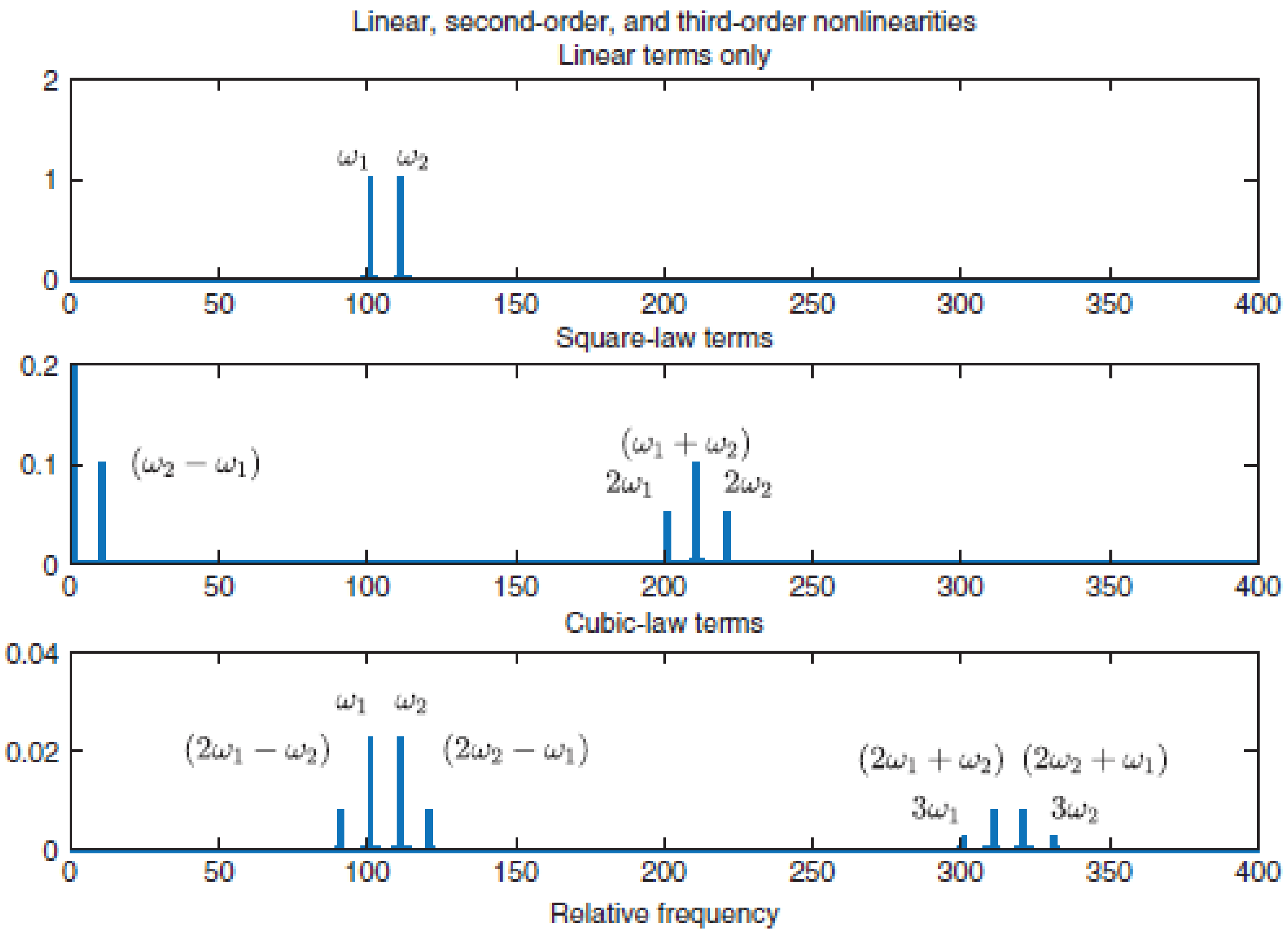


Figure 2.81 Illustrating the effect of a nonlinearity in the amplifier system, resulting in intermodulation terms. The example shown uses $G_1 = 1$, $G_2 = 0.1$, and $G_3 = -0.01$. The frequency scale is arbitrary. Note that the amplitude scales are not equal.

2.5.10 Gürültü ve Girişim

- Çoklu kullanıcı: Girişim ve gürültü

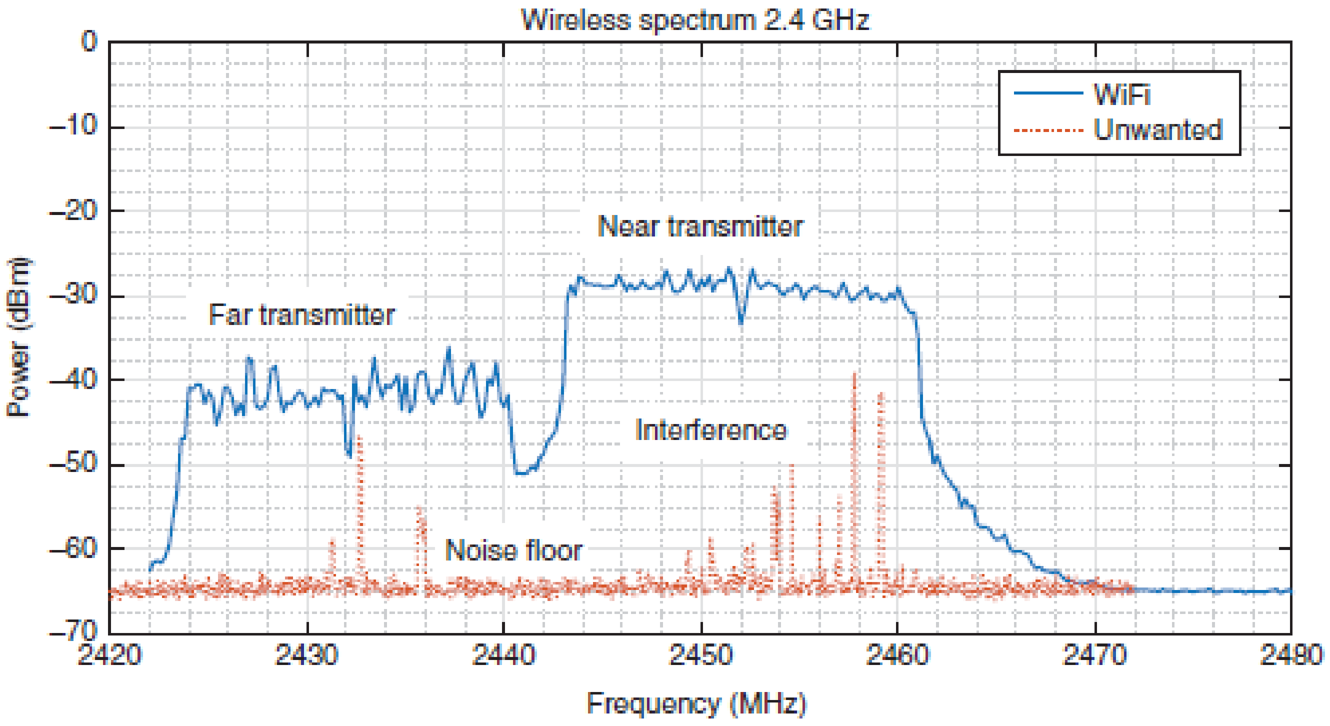


Figure 2.82 Wireless 2.4 GHz channel usage and interference. Two separate WiFi networks may or may not interfere with each other, background interference may exist for short or long periods of time, and background noise is always present.

2.6 Optik Haberleşme

- Kablolu ve kablosuz gördük
  - Fiberoptik (ışığın fiberglass içinde ilerlemesi)
    - Yüksek bant genişliği ve veri hızı
    - Girişime karşı direnç
    - Çok düşük kayıp ve uzun mesafe haberleşme
  - Gerekenler
    - Bir ışık kaynağı (belli bir dalga boyunda)
      - Fiberoptik: Lazer diyodu (IR)
    - Işık kılavuzu
      - Fiberglas (esnek)
    - Karşıda gelen ışığı elektriğe çeviren bir alıcı
      - Fotodiyot
  - Problemler
    - Işığa bilgi yüklenmebilmesi için modüle edilebilmeli (ör. Yakıp söndürme)
    - Yayılan dalga boyunun dalga kılavuzuna uyumlanması
    - Karşıda gelen ışığı voltaja çevirmek

2.6.1 Optik Haberleşme Prensipleri

- Fiber optik : Infrared
- Görünür ışık: 650nm - 400nm (frekans?)
- Ultraviyole, Kızılötesi
- near IR: 0.78 – 3 µm, mid IR: 3 – 50 µm, far IR: 50 – 1000 µm (ISO, 2009).
    - Mevcut sistemler: 1310 - 1550 nm
- Detektör:
    - Spektral olarak örtüşmelidir

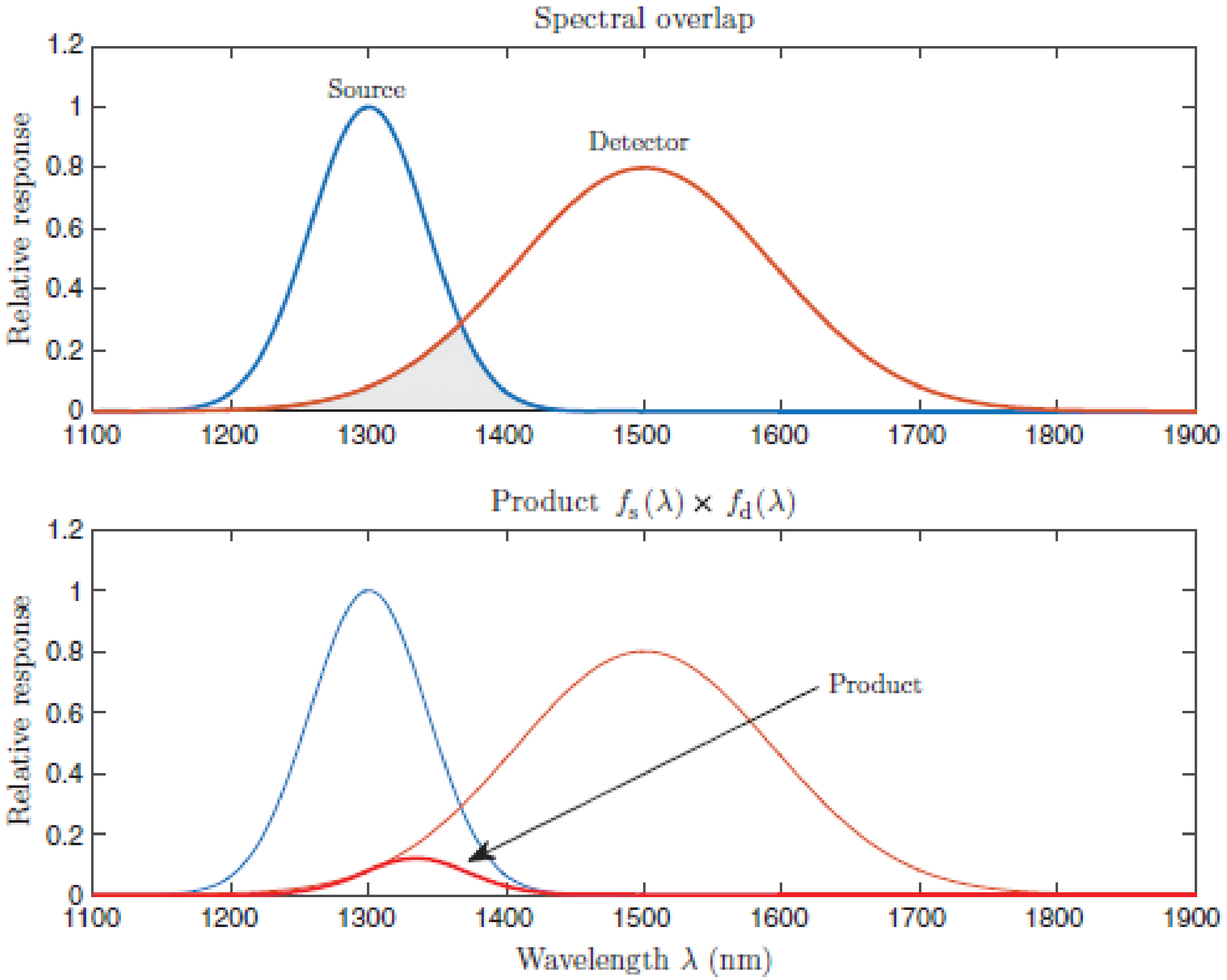


Figure 2.83 Illustrating an optical emitter and detector response overlap. Precise matching is almost never possible. This leads to a smaller electrical signal at the detector output, as well as additional noise due to the wider detector bandwidth.

2.6.2 Optik Kaynaklar

- LED,
  - PN diyot
  - Daha ucuz
  - Daha geniş alana yayılır
  - Farklı dalga boyları farklı hızda ilerler ve kare dalgada bozulma oluşur
- LD
  - optically resonant cavity
  - Light Amplification by Stimulated Emission of Radiation
  - Standing wave oluşur
  - Daha dar bir hüzme oluşturur
  - Daha pahalı
  - Gücü daha dar bir spektruma sığdırır

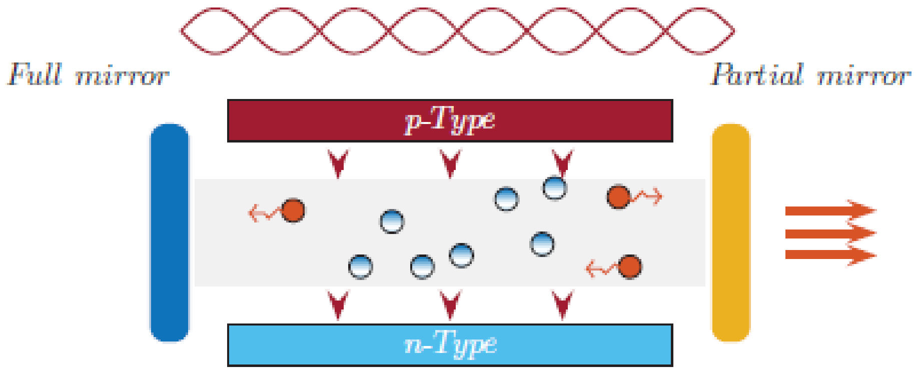
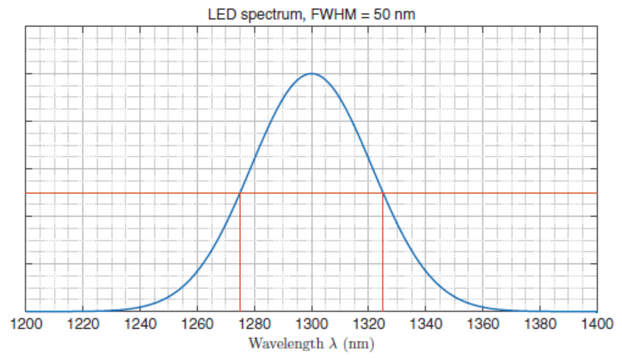
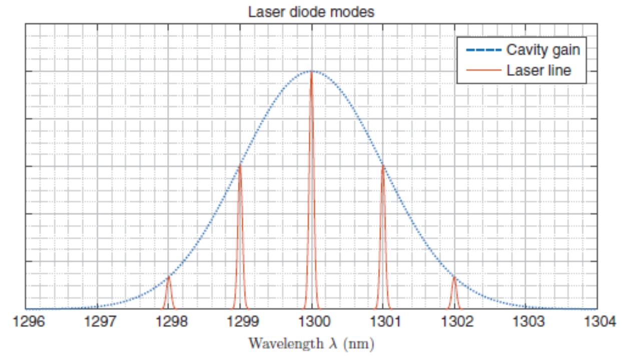


Figure 2.84 Illustrating the basic laser principle. External energy is supplied by the junctions at the top and bottom, stimulating the emission of cascades of photons. The lasing medium has a high gain over a defined optical wavelength. The stimulated radiation thus emitted bounces back and forward within the cavity to form a standing wave, with a fraction released to provide the laser output.





2.6.2 Optik Kaynaklar

- Frekans ve dalgaboyunda bir değişiklik olduğunda
- $v_c = (f + \Delta f)(\lambda + \Delta\lambda)$
- $c = f\lambda_0$
- $\Delta\lambda = -\frac{\lambda^2}{2nL}$

2.6.3. Fiberoptik - Kırılma

- Single mode
- Multi mode
- Infrared
- İç çekirdek daha yüksek kırılma indisine sahip
- Işık fiberglas içinde tam yansıma yaparak ilerler (kırılma indisi)
  - $n = \frac{c}{v}$
  - Kırılma indisi yaklaşık sabittir ama dalgaboyuna bağlıdır
- $\sin\theta_1 = \frac{A'B}{L}$
- $\sin\theta_2 = \frac{AB'}{L}$

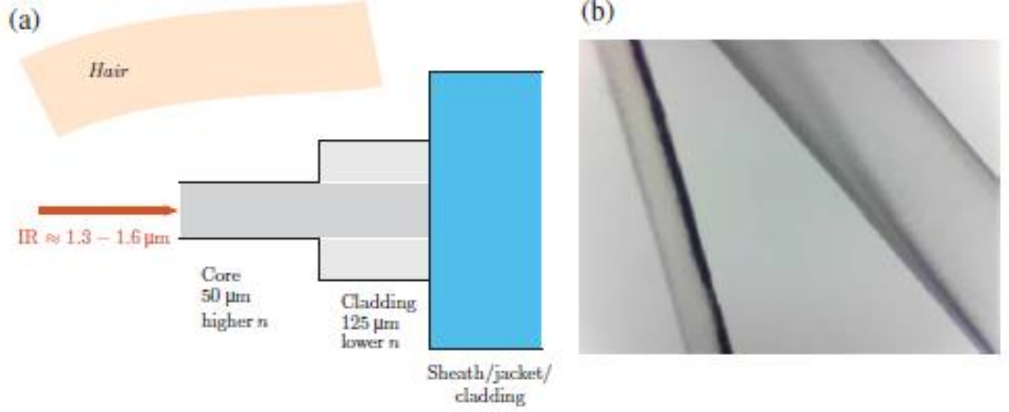
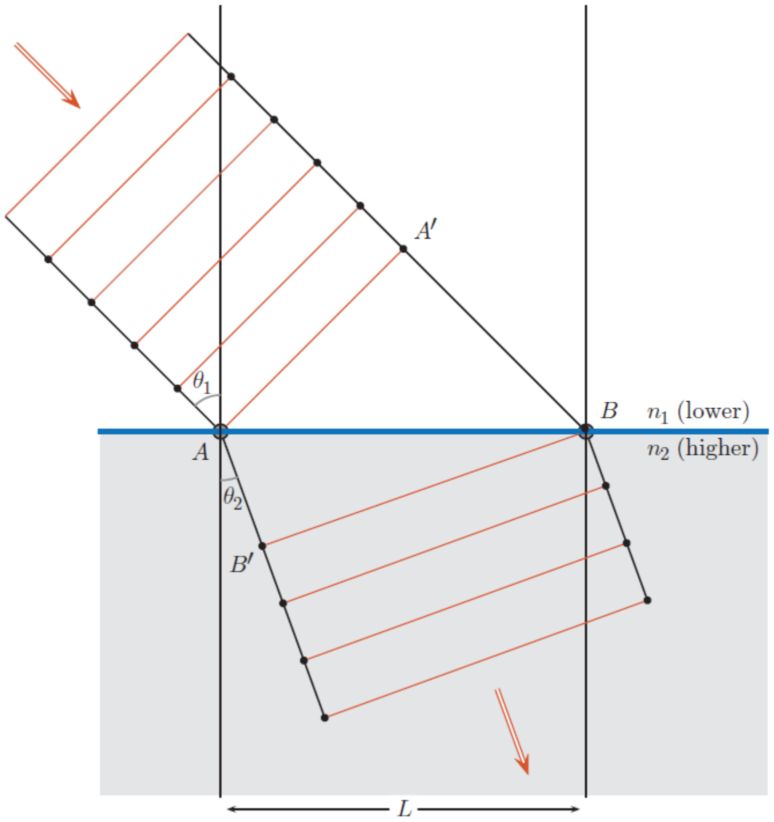


Figure 2.86 Multimode step-index fiber cross section (a), with typical sizes shown. More examples are given at the Fiber Optic Association The Fiber Optic Association (n.d.). The image in (b) shows a single-mode optical fiber with a human hair. The magnification is ×500.



2.6.3. Fiberoptik - Yansıma

- Işık yüksek kırılma indisinden düşüğe doğru gidiyor
  - Çıkışta açı artıyor
- Kritik açıdan sonra: tam yansıma
- Fiber kablonun çalışma şekli
- $n_{air} \sin\theta_e = n_1 \sin\theta_1$
- $n_1 \sin\theta_2 = n_2 \sin\theta_3$

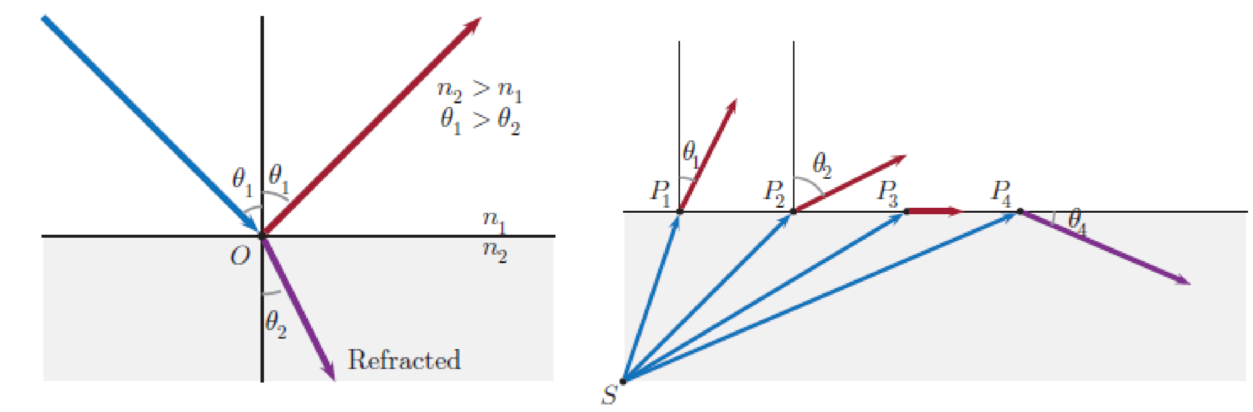
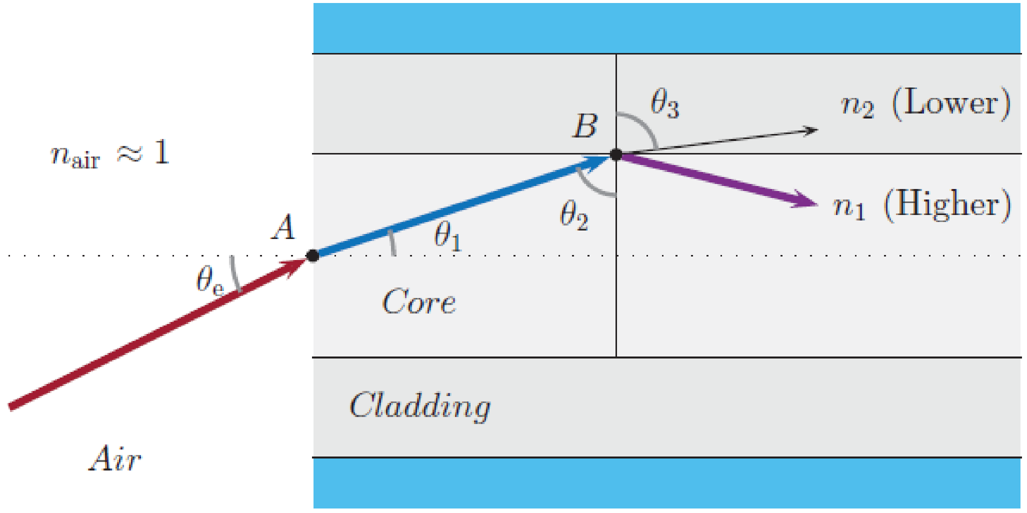


Figure 2.88 Principle of refraction at an interface (left) and total internal reflection (right). This shows that light emanating from a point *S* may be kept inside the material with higher refractive index, provided the outside material has a lower refractive index, and the angle is shallow enough with respect to the axis of the core.



2.6.4 Fiber optik kayıplar

Table 2.3 Transmission medium broad comparison.

Medium	Frequency range	Attenuation dB km^{-1}
Twisted pair (UTP)	1 kHz – 1 MHz	5–150
Coaxial cable (Coax)	1 MHz – 1 GHz	1–50
Optical fiber	~300 THz	0.2–1

Indicative figures only; see Henry (1985).

- Bakır kablolara göre çok iyi performans
- Kayıplar: fiberdeki su buharı
- Uygun dalgaboylarını seçmek lazım : 1310, 1550, 1625 nm
- Ör 1dB/km kayıp olsa…

2.6.4 Fiber optik kayıplar

- Fiber parçaları ya kaynak yoluyla , ya da optik konektör ile bağlanır
- Toplam kayıplar dB kayıpların toplamıdır (veya doğrusal kayıpların çarpımıdır)

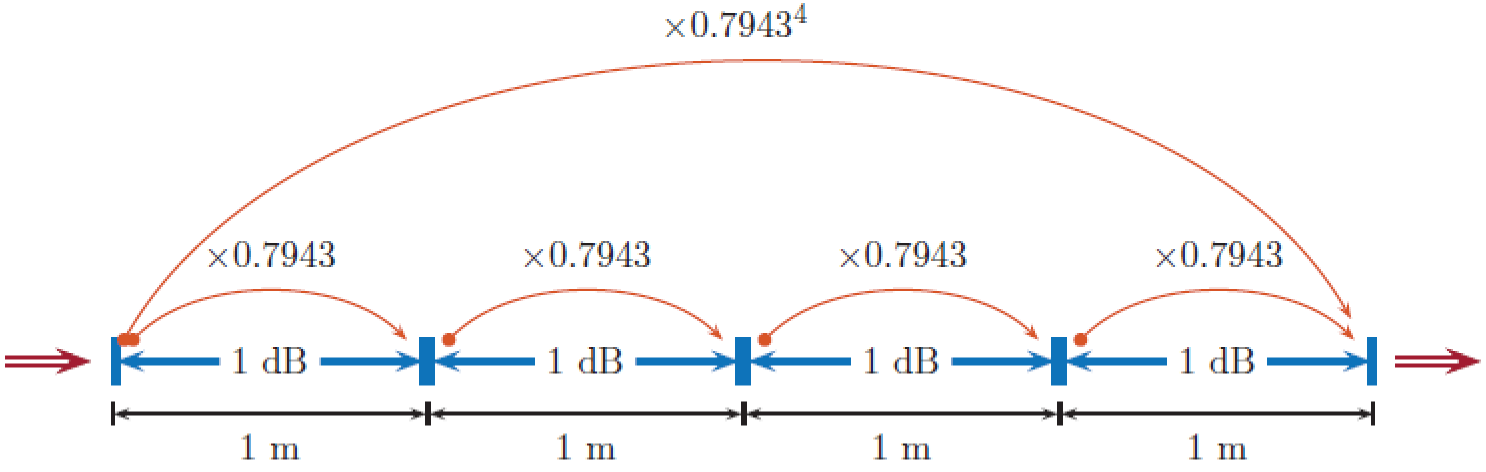


Figure 2.90 Illustrating the calculation of fiber loss over four segments. The numerical gains, which are less than unity, are multiplied. But an equivalent method, arguably easier in practice, is to add the dB figures. The dB figures are understood to be negative, since they represent a loss (<0 dB).

2.1 A wireless Local Area Network (LAN) uses the 2.4 GHz band. What is the corresponding wavelength?

2.2 Plot the Hamming window equation as given in Equation (2.15). Verify that it gives a smooth "taper" function, starting at $0.54 - 0.46 = 0.08$ and ending at 0.08, and a peak of $h = 1$.

2.3 Power levels and voltage magnitudes may be determined from a spectrum analyzer display.

a) In Figure 2.7, the sine wave amplitude is 200 mV peak to peak. Verify that this corresponds to the power level of −10.30 dBm shown on the figure.

b) Determine the absolute and relative voltages of the harmonics in Figure 2.8, and compare to the power levels that were measured as −8.20, −17.73, −22.18, and −25.10 dBm.

2.5 Using the tapered frequency response for the raised-cosine filter (Section 2.4.2), evaluate the integrals for Equations (2.27) and (2.28) to give the time-domain impulse response for the raised cosine filter.

2.6 A coaxial cable with unknown termination impedance is subjected to a pulse from a matched signal source. The pulse is from 0 to 2 V when measured open circuit at the source itself. The waveform monitored at the signal source is shown in Figure 2.94.

a) Determine the line length, assuming that the propagation velocity is 2×10^8 m s^{-1} for this particular cable.

b) Determine the termination impedance as a proportion of the characteristic impedance.

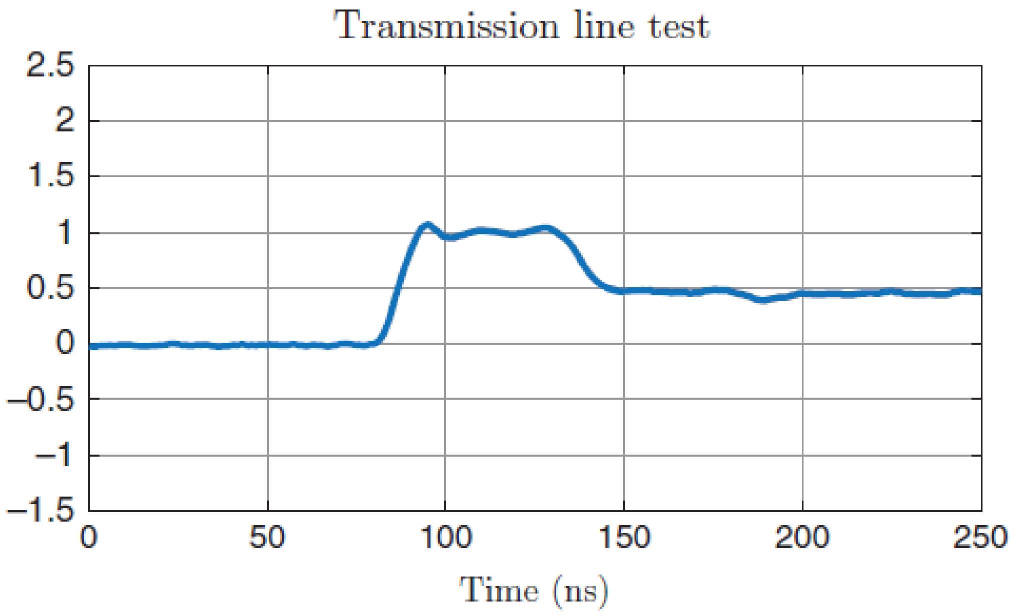


Figure 2.94 Transmission line with a square pulse input.

2.8 The binomial approximation is used in determining some approximations for antennas. This states that $(1+x)^{\alpha} \approx 1+\alpha x$ for $x \lesssim 0.5$. Plot these functions using MATLAB to determine if this is a reasonable approximation.

2.9 A 1 GHz radio signal is transmitted from a stationary transmitter toward a receiver moving at 100 km h^{-1}. Calculate the approximate frequency shift.

2.10 The isotropic radiators in a phased array as shown in Figure 2.69 are fed by the same current magnitudes with equal phases and have a separation of $d = \lambda$. What is the shape of the pattern produced?

2.11 Given an incoming RF signal ω_{RF} and a local oscillator at frequency ω_{LO}, mathematically derive the output frequencies from an ideal mixer. Explain the significance of having two output frequencies. What image frequency would also produce a spurious IF signal?

2.12 An FM system is designed for an intermediate frequency (IF) of 10.7 MHz. Suppose we wish to tune stations over the FM band from 88 to 108 MHz.

a) At the lower end of the band, what would the local oscillator (LO) frequency need to be in order to let the difference frequency through, for tracking above the RF? For tracking below the RF?

b) At the upper end of the band, what would the local oscillator (LO) frequency need to be in order to let the difference frequency through, for tracking above the RF? For tracking below the RF?

c) Explain why the range of frequencies is not as dramatic as with an AM receiver operating in the 540 – 1600 kHz band with an IF of 455 kHz.

2.13 Section 2.5.8 showed the local oscillator (LO) as having a frequency below that of the radio frequency (RF). This is termed low-side injection. It is also possible to have the LO frequency higher than the RF, which is termed high-side injection.

a) Draw a diagram similar to Figure 2.73, which shows high-side injection.

b) For the same IF of 10 MHz, what would the required LO frequency be in order to receive an RF signal of 100 MHz?

c) For this LO frequency, and a required IF of 10 MHz, what image frequency might be fed through?

2.14 The 2.4 GHz wireless channels 1–13 are separated by 5 MHz and have a width of 20 MHz (IEEE, 2012). Channel 1 has a center frequency of 2412 MHz, and it follows that channel 13 is centered at 2472 MHz. What two channels are in use in Figure 2.82?