TSEK02: Radio Electronics Lecture 2: Modulation (I)

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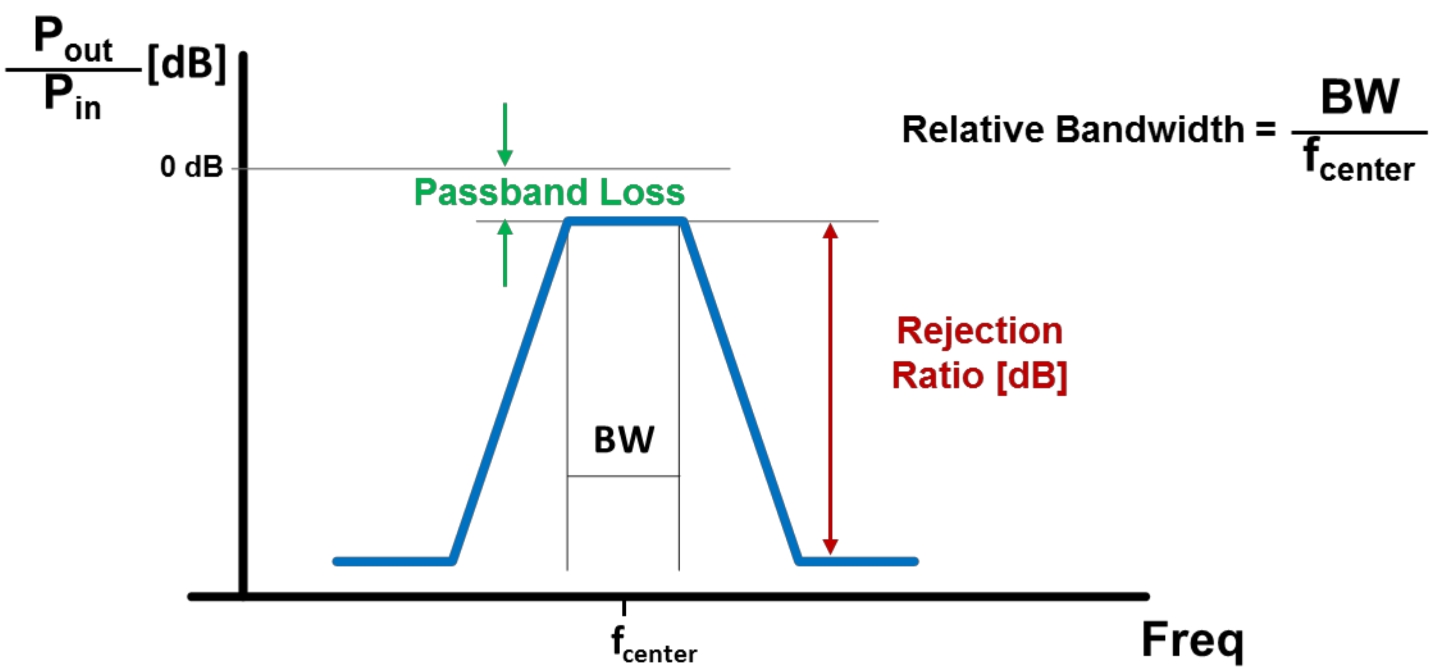
LINKÖPING UNIVERSITY

Basic Definitions

- Time and Frequency
- dB conversion
- Power and dBm
- Filter Basics

Filter

- Filter is a component with frequency selective response



An Overview of Modulation Techniques: chapter 3.1 – 3.3.1

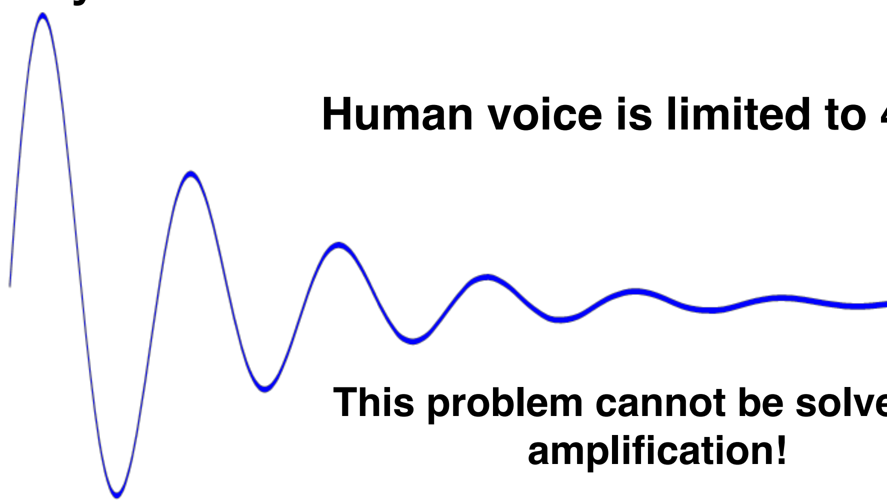
- Introduction
- Analog Modulation
  - Amplitude Modulation
  - Phase and Frequency Modulation
- Digital Modulation
- Bandwidth considerations

An Overview of Modulation Techniques: chapter 3.1 – 3.3.1

- **Introduction (3.1)**
- Analog Modulation
  - Amplitude Modulation
  - Phase and Frequency Modulation
- Digital Modulation
- Bandwidth considerations

Need for Modulation

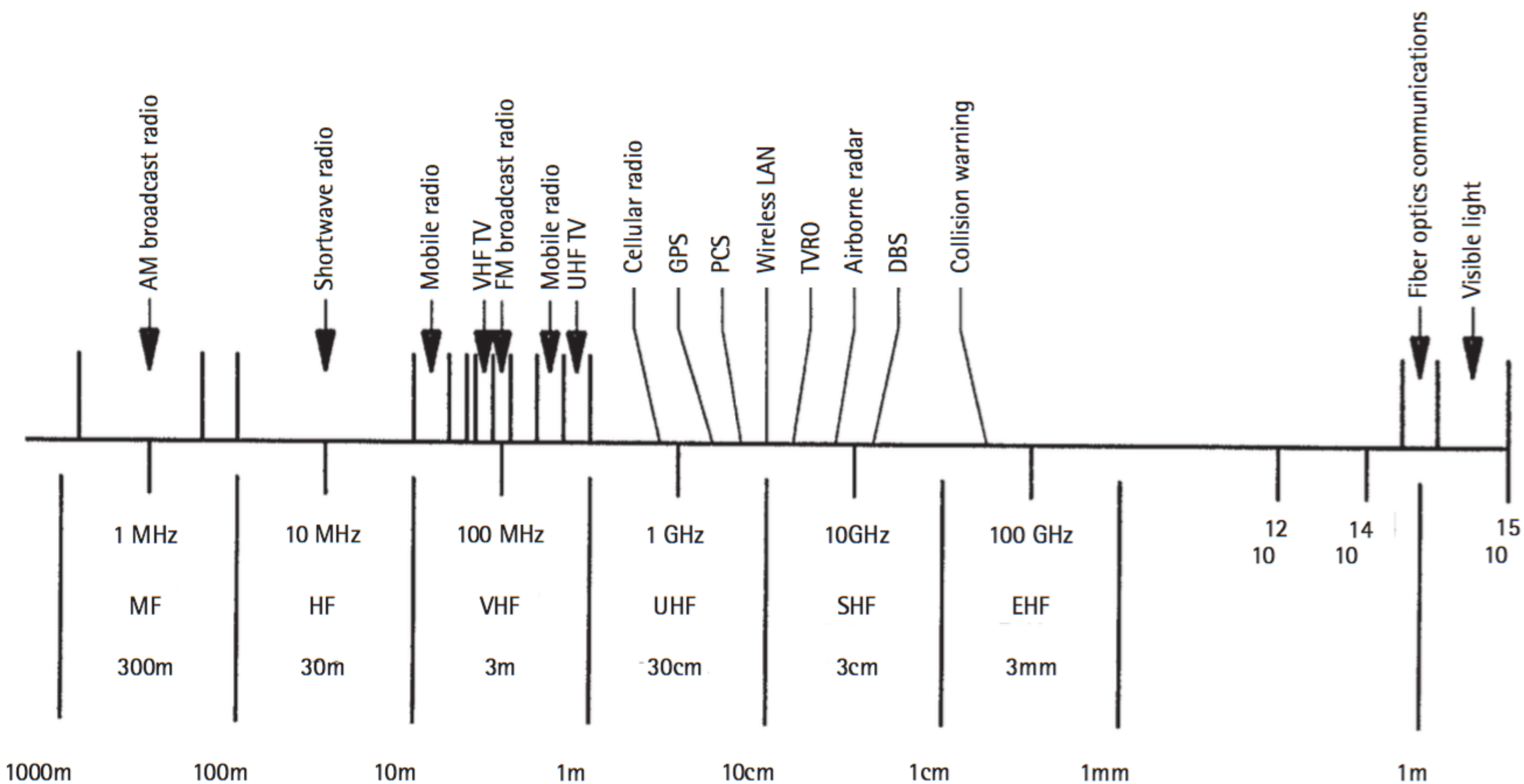
- Every channel has a cut-off frequency ($f_{cut\text{-}off}$)
  – Theoretically, signals with $f > f_{cut\text{-}off}$ cannot propagate through the channel. There may also be a lower frequency limit.



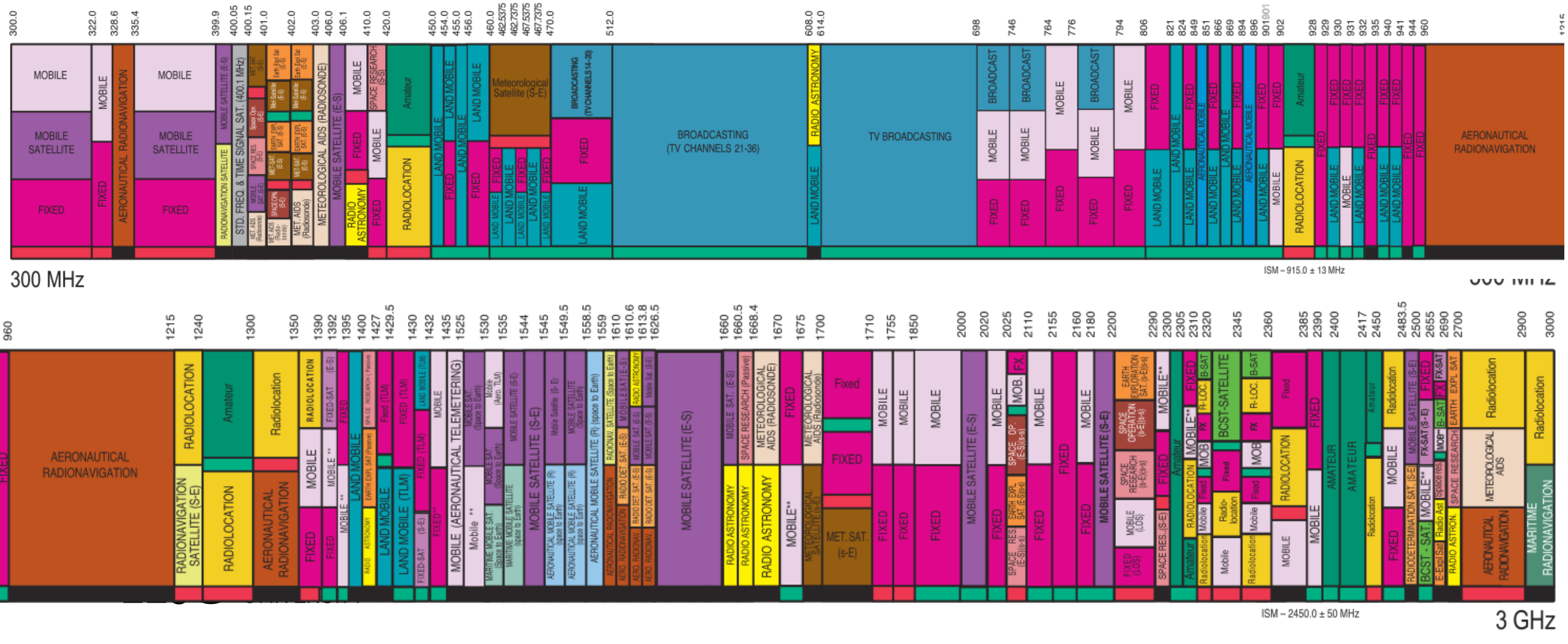
Human voice is limited to 4 kHz < $f_{cut\text{-}off}$

This problem cannot be solved by amplification!

The electromagnetic spectrum



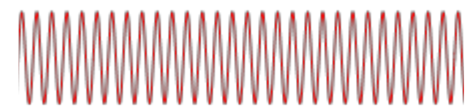
- USA frequency allocation 0.3 – 3 GHz



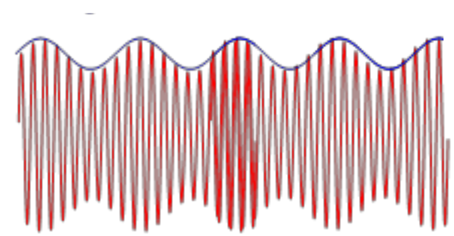
What is Modulation?

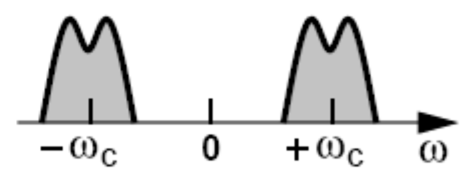
- ”Information signal”, $f < f_c$

- ”Radio Frequency signal”, $f > f_c$



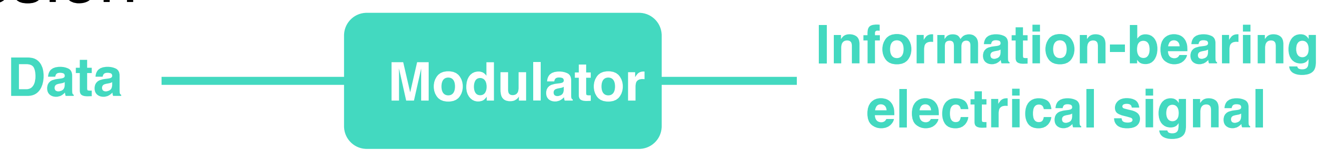
- Modulation: carry the information signal on the radio frequency carrier

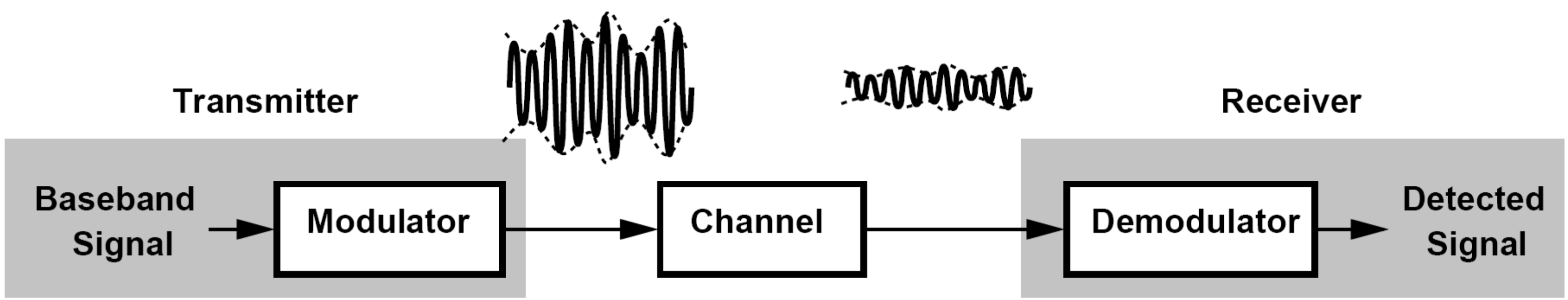




Modulation

- Modulation refers to turning information into (electrical) signals which are suitable for transmission

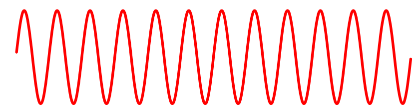




Modulation Types

- Signal properties are varied according to the information

- Properties of an RF signal
  - Amplitude
  - Frequency
  - Phase

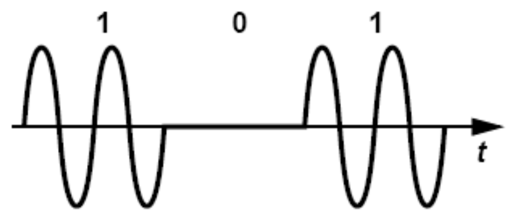


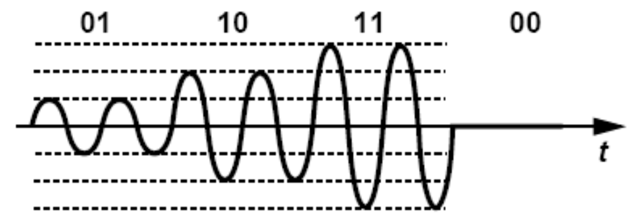
$$A\ Cos\ (\omega t + \varphi)$$

- This variation could be continuous (analog modulation) or in discrete steps (digital modulation)

Modulation aspects

- Detectability





- Bandwidth efficiency
- Power efficiency

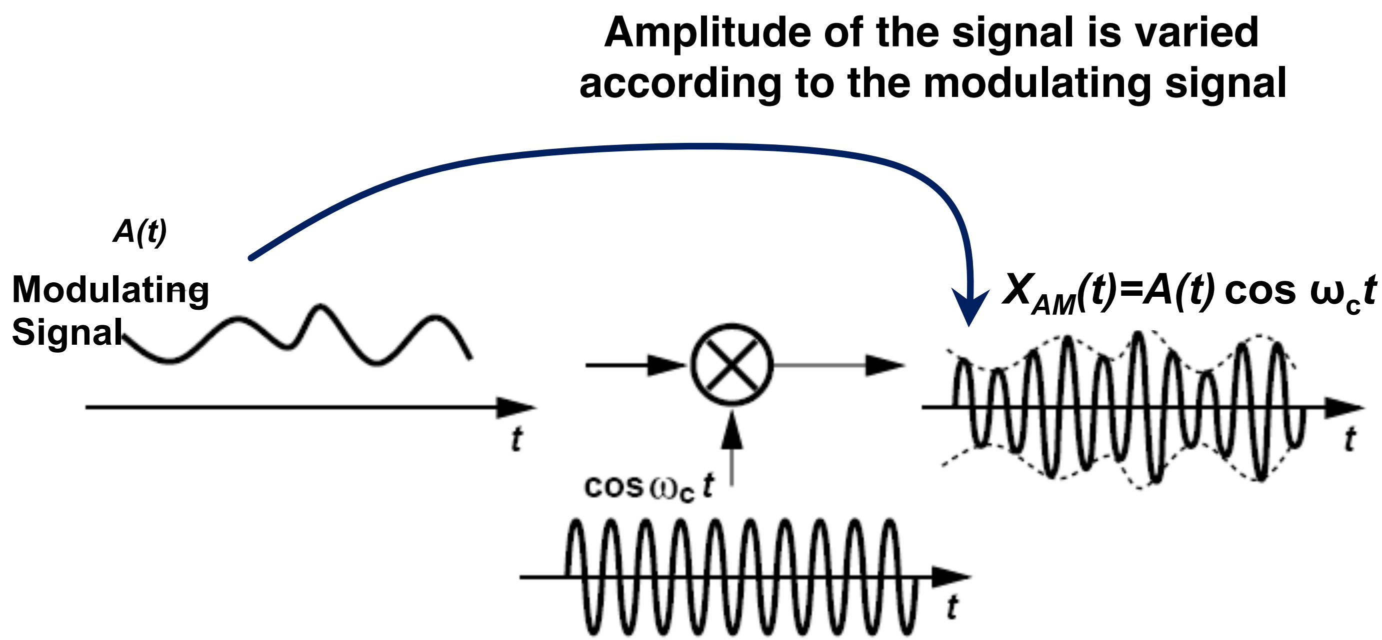
- Complexity, required bandwidth, sensitivity to noise, sensitivity to nonlinearity, ...

An Overview of Modulation Techniques: chapter 3.1 – 3.3.1

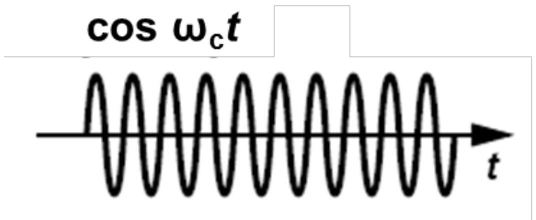
- Introduction
- **Analog Modulation**
  - **Amplitude Modulation (3.2.1)**
  - Phase and Frequency Modulation
- Digital Modulation
- Bandwidth considerations

Amplitude Modulation (AM)

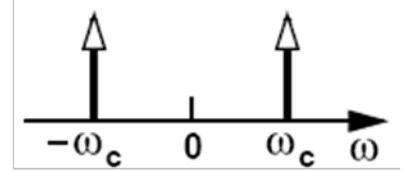
- Multiplication of a baseband signal with a single-tone sinusoidal (called the carrier)

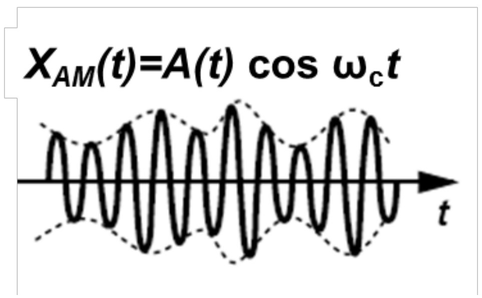


Amplitude Modulation in frequency domain



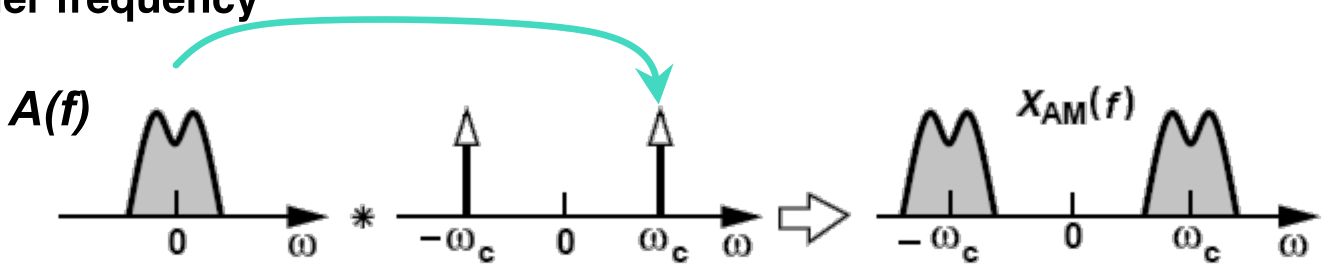
Contains one frequency





Multiplication in the time-domain corresponds to <u>convolution</u> in frequency-domain

Zero will be shifted to the carrier frequency



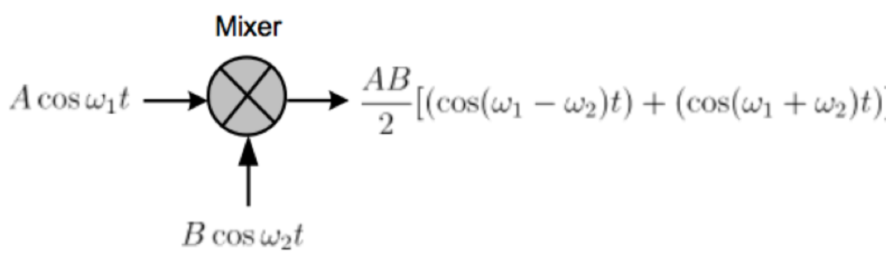
From TSEK03 RFIC

Fundamental

- A mixer basically multiplies two signals in the time domain. From this perspective mixing can occur in any nonlinear device.

$$(A\cos\omega_1 t)*(B\cos\omega_2 t) = AB/2[(\cos(\omega_1-\omega_2)t) + (\cos(\omega_1+\omega_2)t)]$$

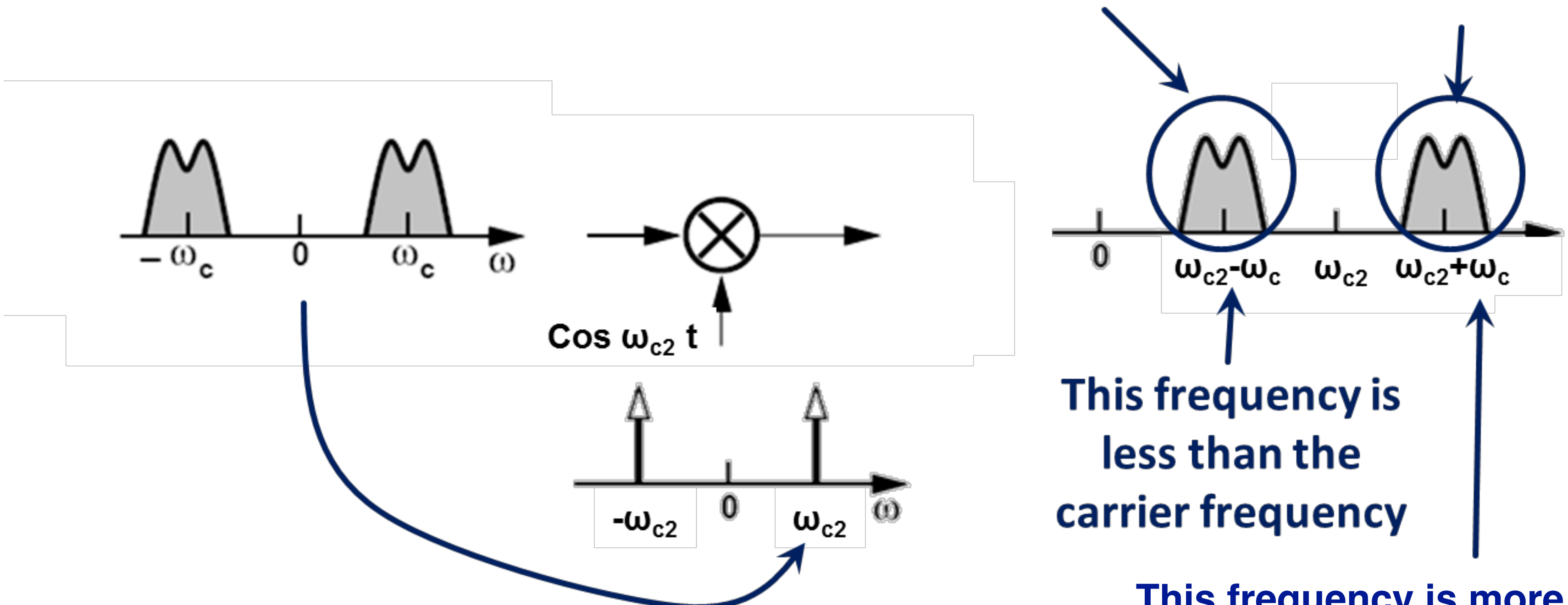
Downconverted component　　Upconverted component



Amplitude Modulation/Frequency Conversion

this part is called
Lower SideBand (LSB)

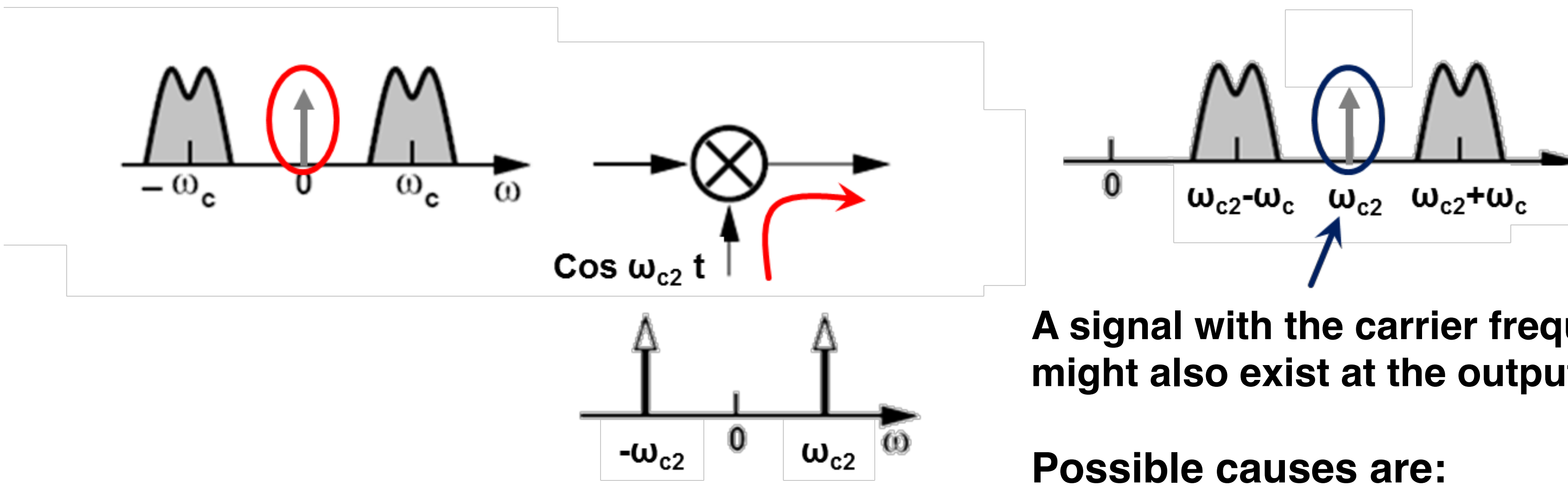
this part is called
Upper SideBand (USB)



Zero will be shifted to the carrier frequency

This frequency is more than the carrier frequency

Amplitude Modulation/Frequency Conversion



A signal with the carrier frequency might also exist at the output.

Possible causes are:

1. DC component at the input

2. Leakage

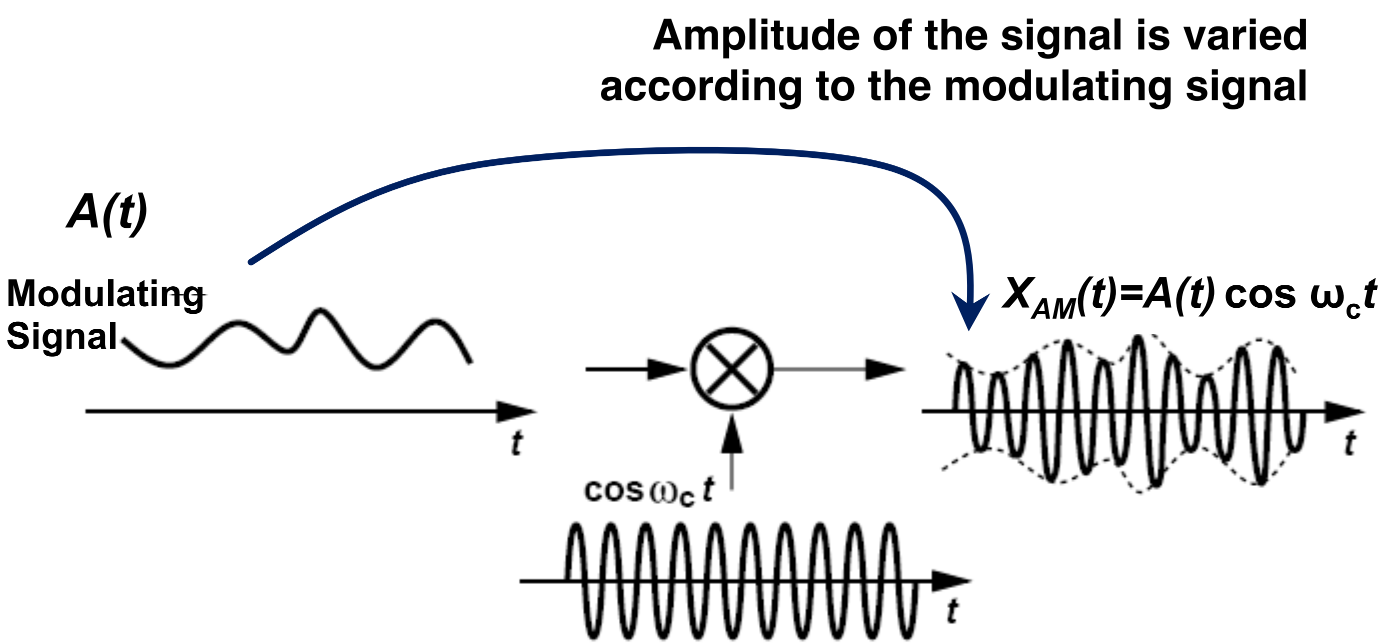
AM Variants

- Variants of AM are
  - Double-sideband
  - Double-sideband suppressed-carrier (DSB-SC)
  - Single-Sideband (SSB)

Main problem to be solved: higher bandwidth, more power is needed (wasted)

Amplitude Modulation (AM)

- Multiplication of a baseband signal with a single-tone sinusoidal (called the carrier)



Amplitude Detection (demodulation)

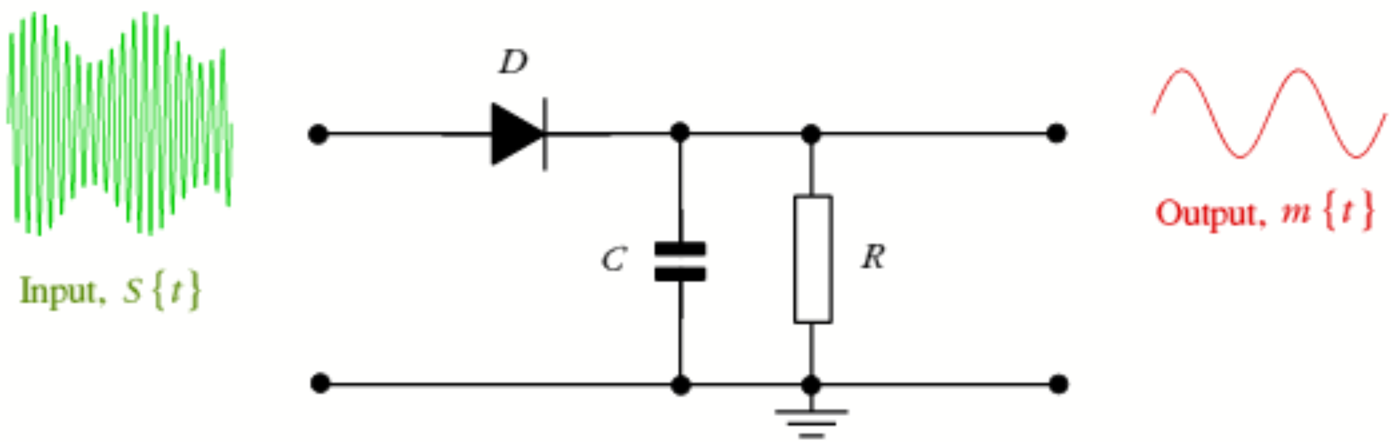
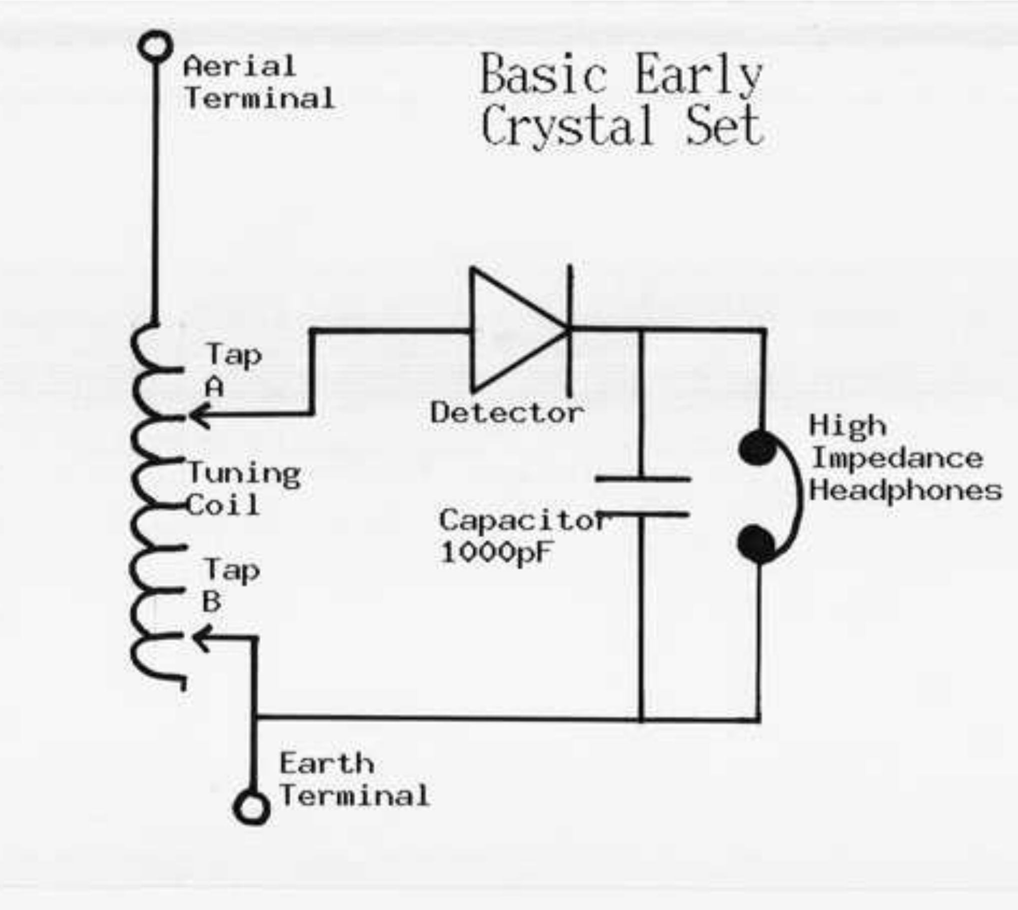


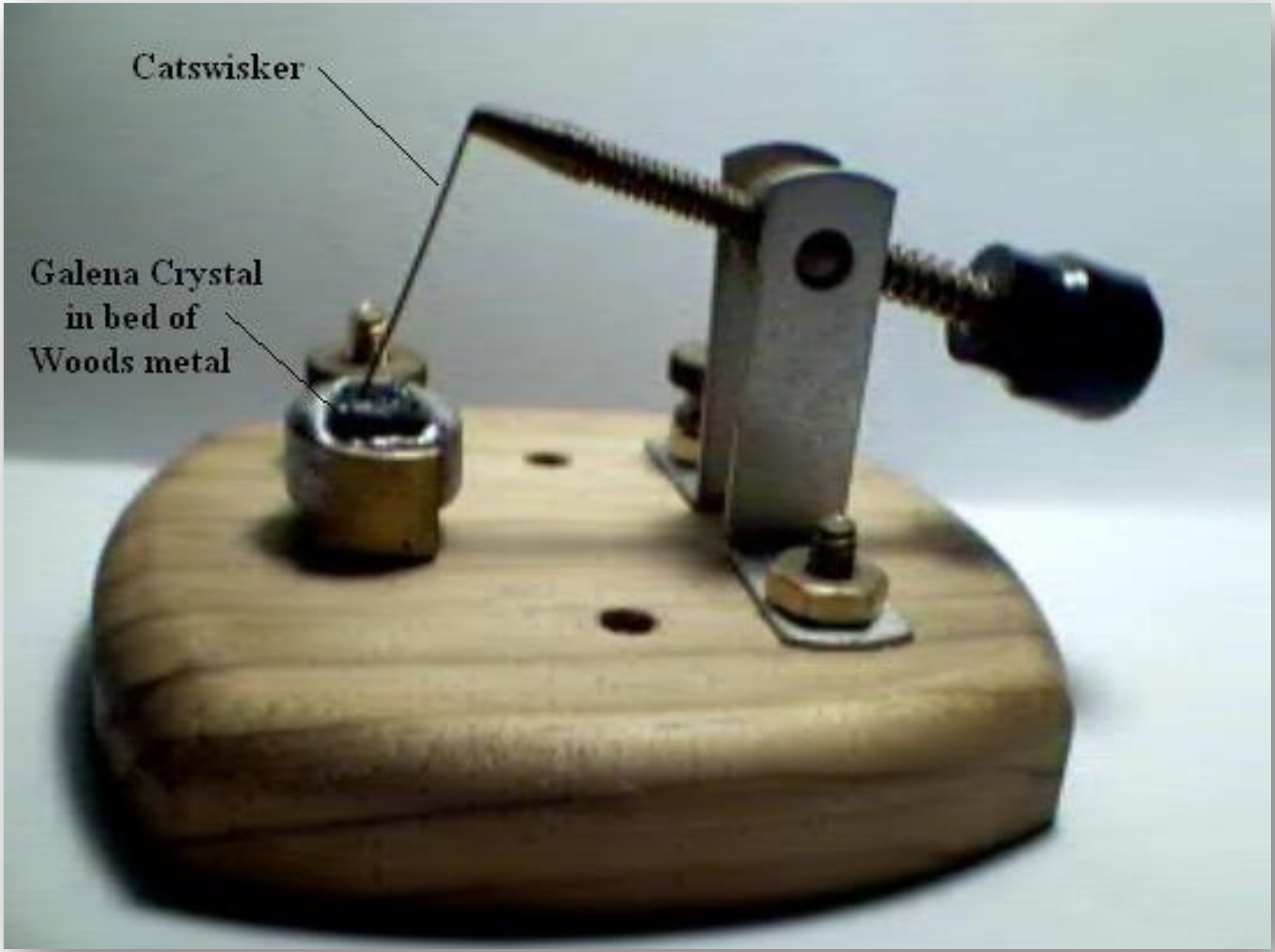
Figure 9.2 Envelope Detector (AM Demodulator/Detector).

AM Radios

- Frequency (typ): 500 – 1700 kHz



1970s-era crystal radio marketed to children. The earphone is on left. The antenna wire, right, has a clip to attach to metal objects such as a bedspring, which serve as an additional antenna to improve reception.


Catswisker
Galena Crystal
in bed of
Woods metal

Those were the days….


WONDER HOW TO
STEAMPUNK R&D
WONDERHOWTO
GADGET HACKS
NEXT REALITY
NULL BYTE
R&D PODCASTS
FOR SALE
NEW HERE? INTRODUCE YOURSELF!
IMPROVEMENTS/SUGGESTIONS
GADGET HACKS
FOOD HACKS DAILY
HOW TO
The Complete Guide on How to Build a Crystal Radio—Plus How They Work
BY AUSTIN SIRKIN
01/04/2013 3:04 AM
There's a lot that goes into making a nice crystal radio set, so this is going to have to be broken down into two parts. The first part is the actual making of a functional
HOT

An Overview of Modulation Techniques: chapter 3.1 – 3.3.1

- Introduction
- Analog Modulation
  - Amplitude Modulation
  - **Phase and Frequency Modulation (3.2.2)**
- Digital Modulation
- Bandwidth considerations

Phase and Frequency Modulation

- In the most general form an RF signal can be represented as

$$S(t) = A \cos \phi(t)$$

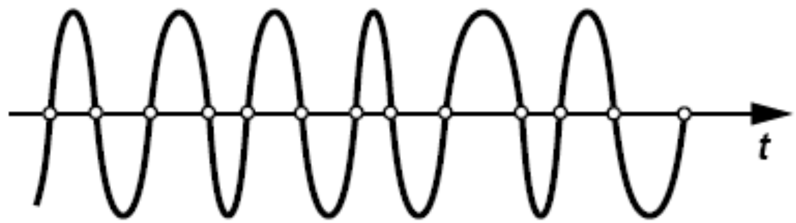
  - $\phi(t)$ is called total phase
  - Instantaneous frequency is defined as $d\phi(t)/dt$
  - In this respect, phase and frequency modulation are essentially the same, except for an integration

PM **FM**

$$x_{PM}(t) = A_c \cos[\omega_c t + m x_{BB}(t)] \quad x_{FM}(t) = A_c \cos[\omega_c t + m \int_{-\infty}^{t} x_{BB}(\tau) d\tau]$$

Phase and Frequency Modulation

- Typical FM/PM waveform



- Note:
  - Amplitude is constant (immune to noise)
  - Data is contained in zero crossing intervals
  - The modulated signal has (theoretically) infinite bandwidth

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Edwin Howard Armstrong

From Wikipedia, the free encyclopedia
(Redirected from Edwin H. Armstrong)

Edwin Howard Armstrong (December 18, 1890 – January 31, 1954) was an American electrical engineer and inventor. He has been called "the most prolific and influential inventor in radio history".[2] He invented the regenerative circuit while he was an undergraduate and patented it in 1914, followed by the super-regenerative circuit in 1922, and the superheterodyne receiver in 1918.[3] Armstrong was also the inventor of modern frequency modulation (FM) radio transmission.

Armstrong was born in New York City, New York, in 1890. He studied at Columbia University where he was a member of the Epsilon Chapter of the Theta Xi Fraternity. He later became a professor at Columbia University. He held 42 patents and received numerous awards, including the first Institute of Radio Engineers now IEEE Medal of Honor, the French Legion of Honor, the 1941 Franklin Medal and the 1942 Edison Medal. He is a member of the National Inventors Hall of Fame and the International Telecommunications Union's roster of great inventors.

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1 Early life
2 Early work
3 FM radio
4 Personal life
5 Suicide
6 Legacy
7 Honors

Edwin H. Armstrong

Developed and advanced the utility of FM technology.

Born December 18, 1890
Chelsea, Manhattan, New York, New York, U.S.[1]

Armstrong invented the frequency modulator in 1933

FM Radio

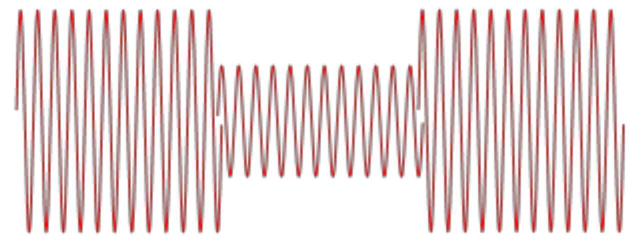
- Frequency (typ): 88 – 104 MHz

An Overview of Modulation Techniques: chapter 3.1 – 3.3.1

- Introduction
- Analog Modulation
  - Amplitude Modulation
  - Phase and Frequency Modulation
- **Digital Modulation (3.2)**
- Bandwidth considerations

Digital Modulation

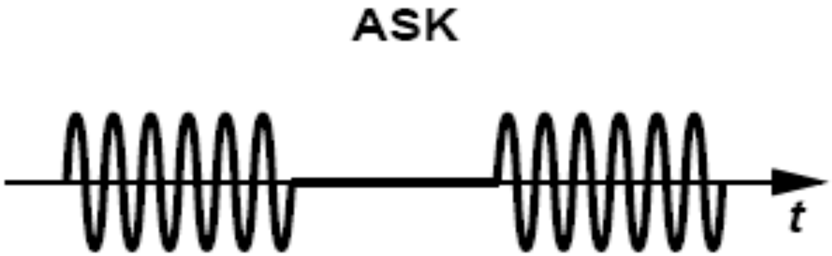
Analog
Amplitude Modulation (AM)



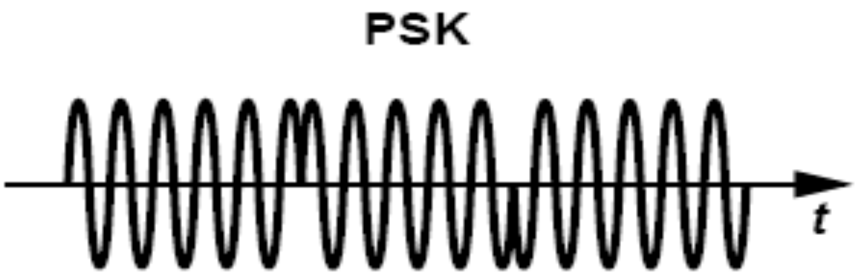
Digital
Amplitude Shift Keying (ASK)

Digital Modulation is more immune to noise
=> can work with a smaller SNR

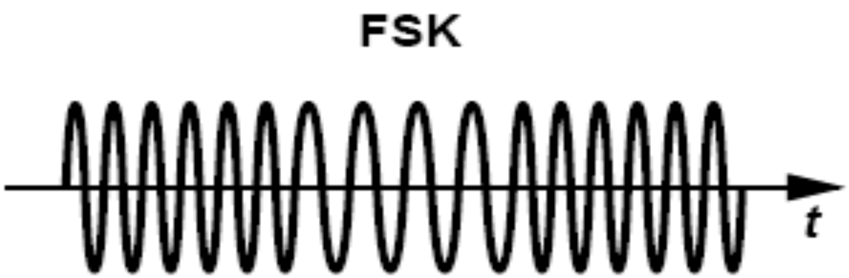
Binary Digital Modulation



Binary Amplitude Shift Keying (ASK)



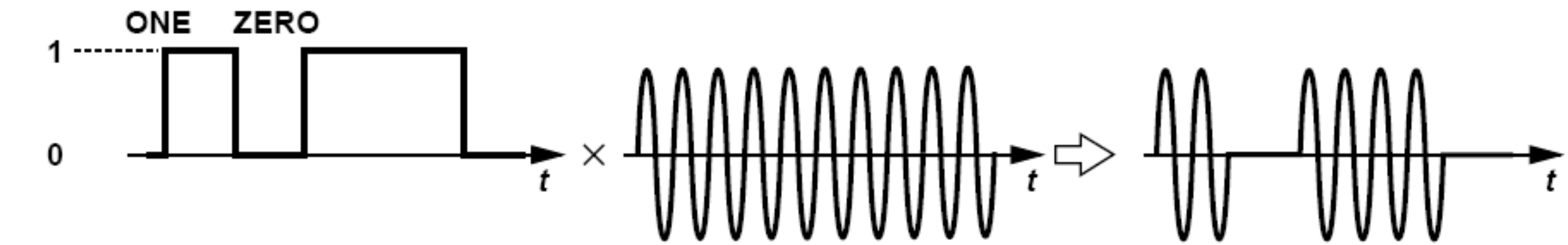
Binary Phase Shift Keying (PSK)



Binary Frequency Shift Keying (FSK)

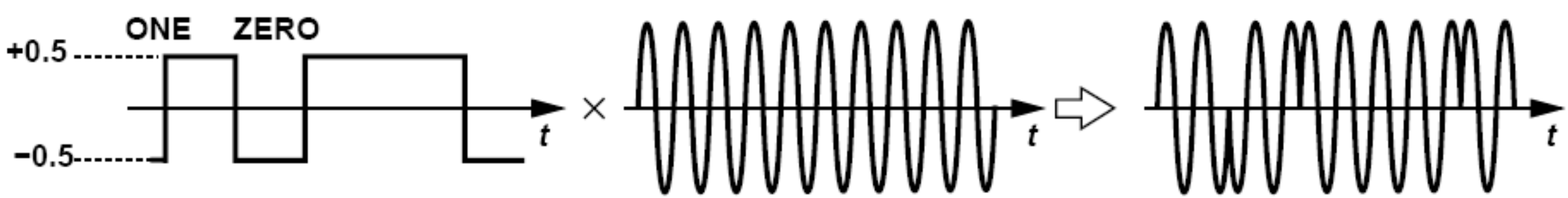
Binary Digital Modulation

- ASK



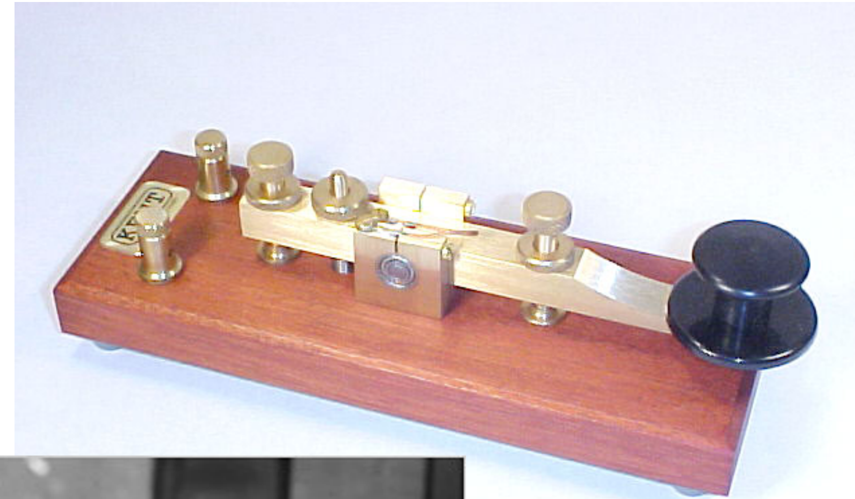
(a)

- PSK



(b)

- Keying!



An Overview of Modulation Techniques: chapter 3.1 – 3.3.1

- Introduction
- Analog Modulation
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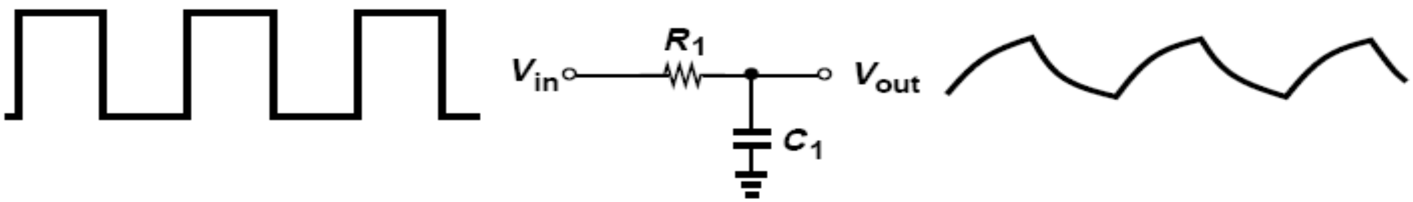
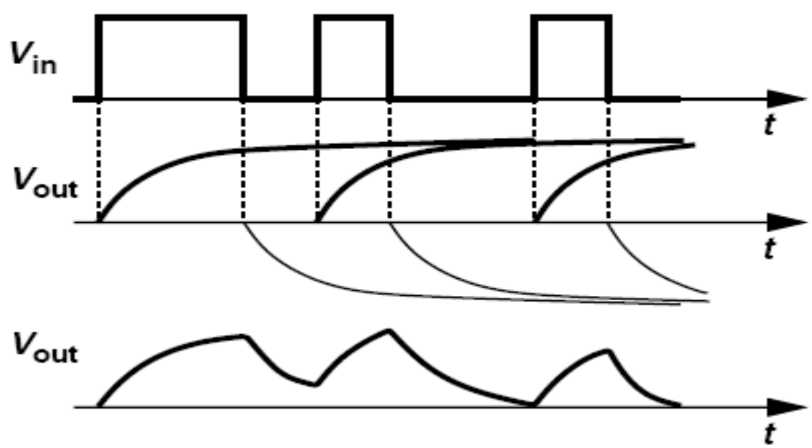
- Digital Modulation
- **Bandwidth considerations (3.3.1)**

Bandwidth

- Linear time-invariant systems can "distort" a signal if they do not provide sufficient bandwidth



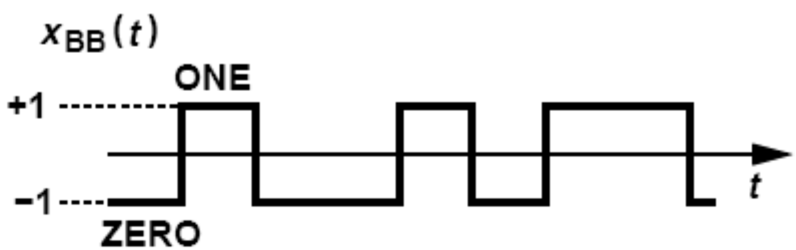
(a)

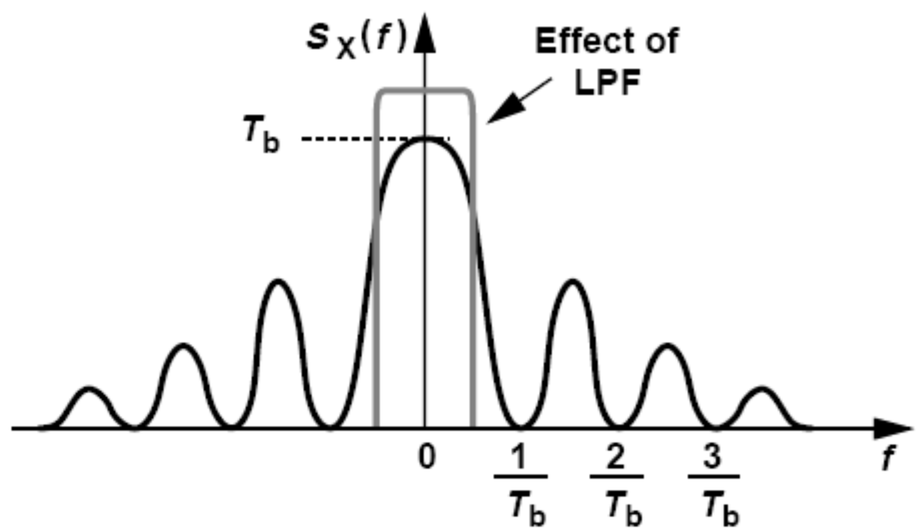


Each pulse extends in time and spills to the time slot of other pulses. This is called Inter Symbol Interference (ISI).

Bandwidth

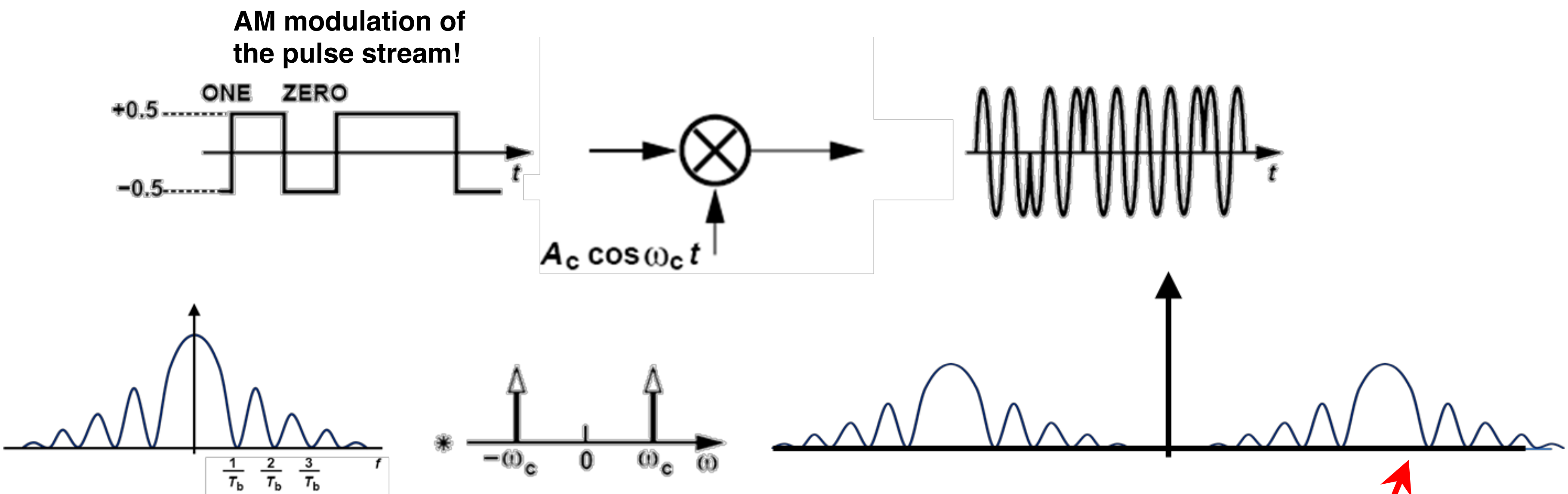
- What is the bandwidth of a random pulse stream (Ex. 3.5)?
  - It extends as a sinc^2 function $\quad \mathrm{sinc}(x) = \dfrac{\sin(\pi x)}{\pi x}.$
  - The main lobe stops at $R_b = 1/T_b$ (T_b is the bitrate)





Bandwidth

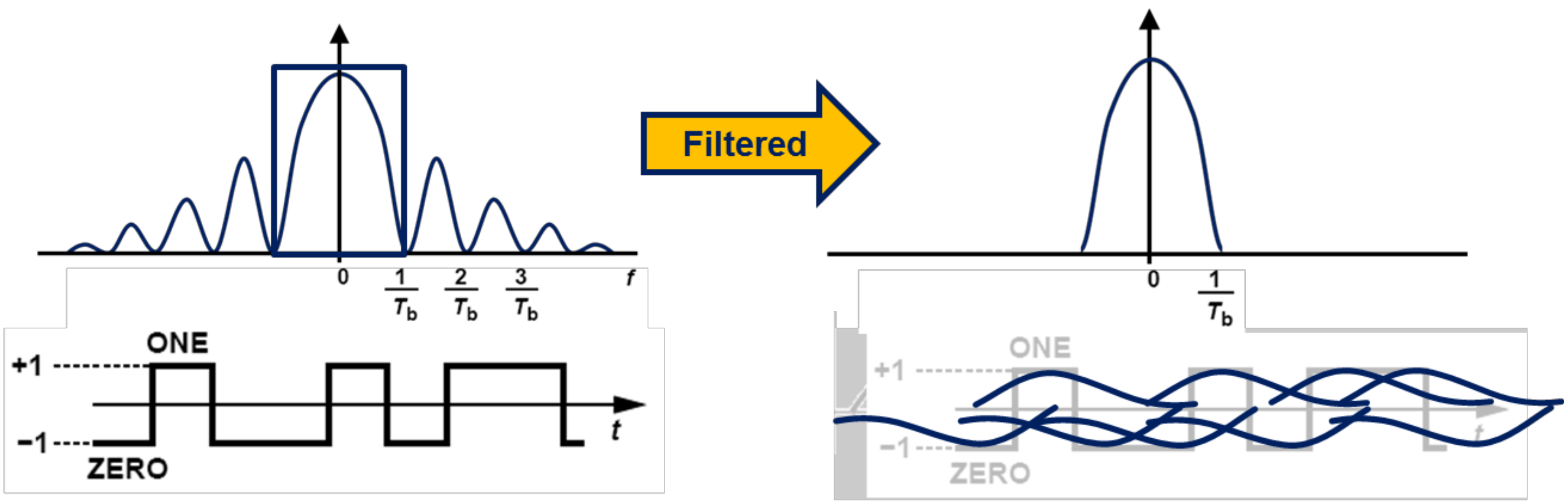
- What is the bandwidth of a Binary PSK (BPSK) signal?
  – BPSK can be expresses as multiplication of a pulse stream and a sinusoidal



Regulations do not allow us to transmit a signal with unlimited bandwidth!

Inter-Symbol-Interference (ISI)

- We need to limit the bandwidth of the baseband signal
- What happens if we just limit the bandwidth by filtering?



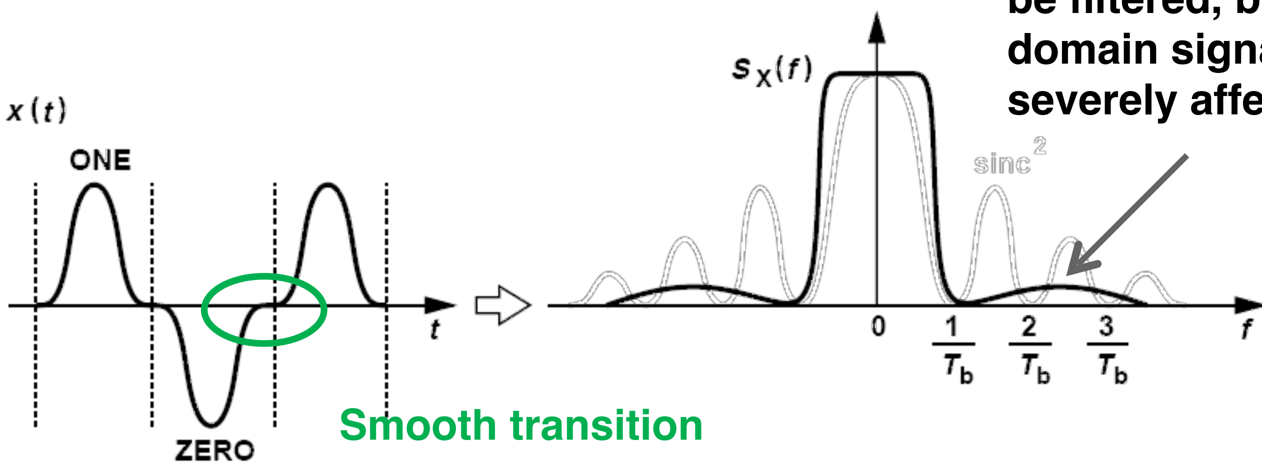
Each pulse extends in time and spills to the time slot of other pulses. This is called Inter Symbol Interference (ISI).

ISI results in distortion and error in detection

Pulse Shaping

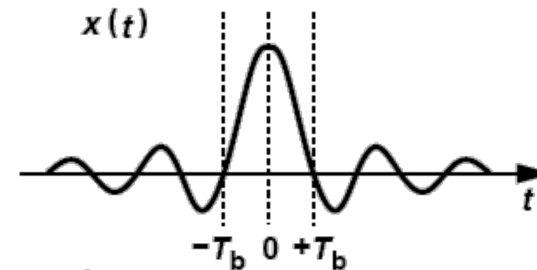
- Instead of just filtering the signal, we can shape the pulses to occupy less bandwidth
- Smoother pulses take less bandwidth

These parts should still be filtered, but the time domain signal will not be severely affected

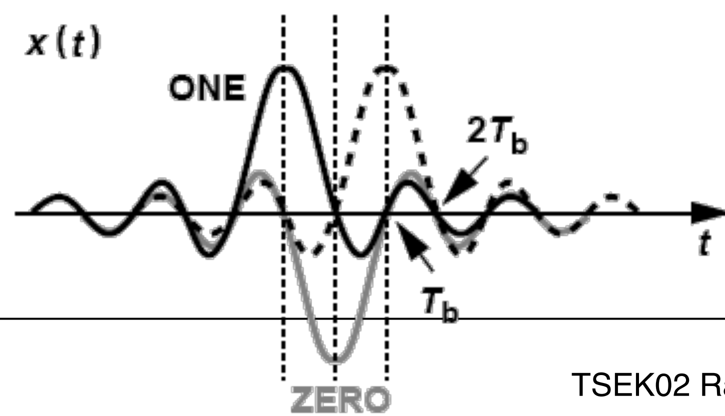


Pulse Shaping – Nyquist Pulse

- *Harry Nyquist* noticed that pulses may extend beyond the symbol period but in order to avoid ISI, their value should be zero in the middle of other pulses.
- So he proposed a smart pulse shape



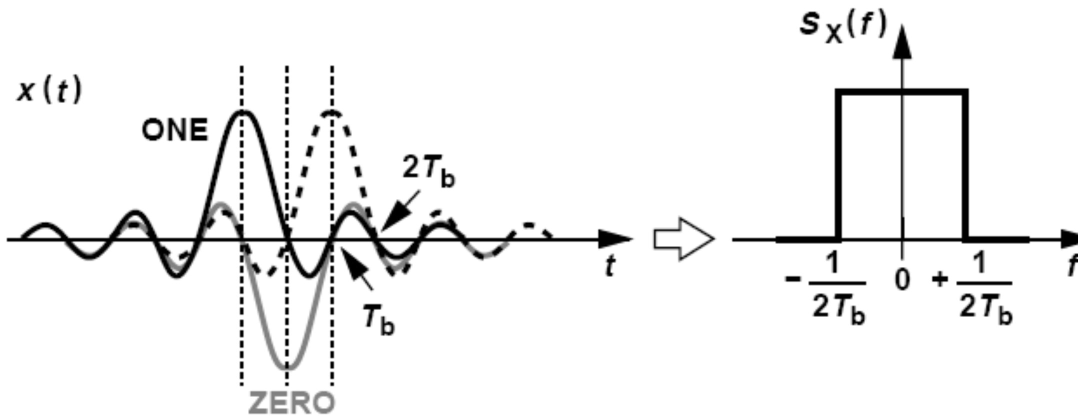
  – Notice that this is in time domain
- By using this pulse, no ISI will be introduced



Optimum Bandwidth

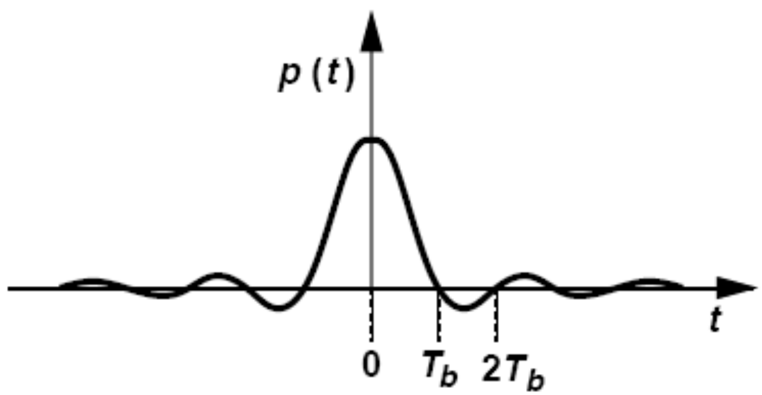
- *Nyquist* pulse not only removes ISI but also results in the minimum bandwidth for the modulated signal
- With *Nyquist* pulse, the modulated RF signal occupies $R_b=1/T_b$ Hz

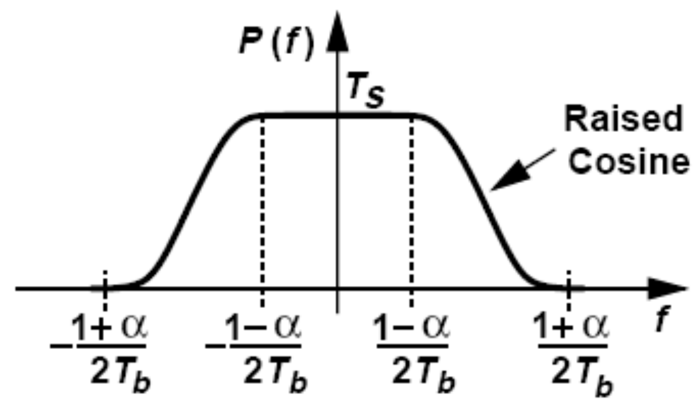
The absolute theoretical minimum bandwidth required to transmit R_b pulses per second!



Raised Cosine Pulse

- In practice, generating *Nyquist* pulses are very difficult so other similar pulses are used, such as the Raised Cosine

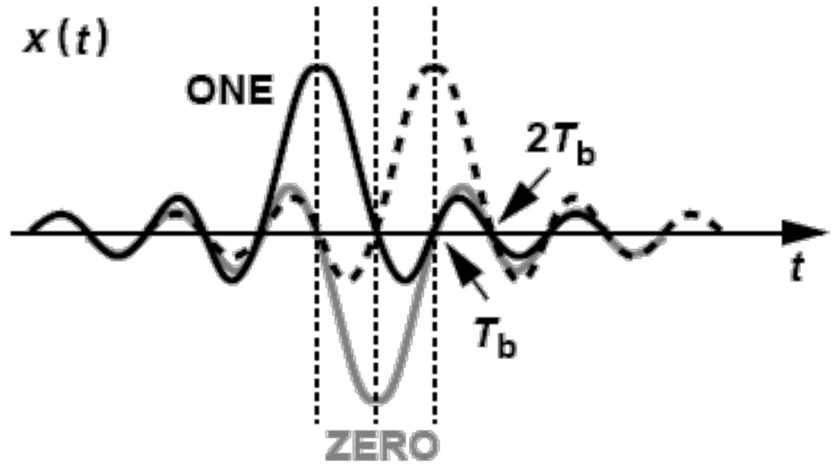




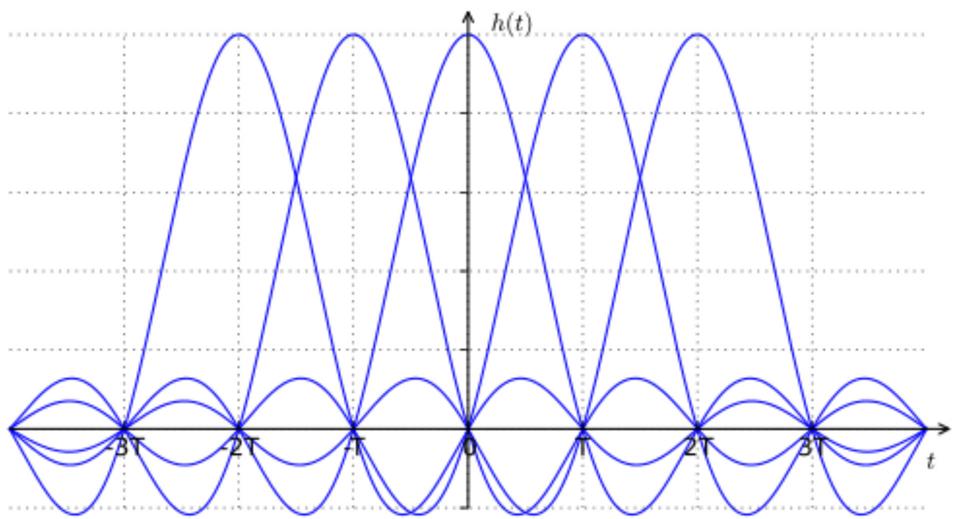
$$p(t) = \frac{\sin(\pi t/T_S)}{\pi t/T_S} \frac{\cos(\pi \alpha t/T_S)}{1 - 4\alpha^2 t^2/T_S^2}$$

0<α<1 is the roll-off factor, typical values: 0.3 - 0.5

ISI



Nyquist pulse



Consecutive raised-cosine impulses, demonstrating zero-ISI property

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Harry Nyquist

From Wikipedia, the free encyclopedia

Harry Nyquist (*né* Harry Theodor Nyqvist; /ˈnaɪkwɪst/, Swedish: [nyːkvɪst]; February 7, 1889 – April 4, 1976) was a Swedish born American electronic engineer who made important contributions to communication theory.[1]

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3 Career
4 Technical contributions
5 See also
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7 External links

Harry Nyquist

Harry Nyquist (1889–1976)

Born	February 7, 1889 Stora Kil, Nilsby, Värmland, Sweden
Died	April 4, 1976 (aged 87) Harlingen, Texas, U.S.
Residence	United States
Nationality	American
Fields	Electronic engineer
Institutions	Bell Laboratories
Alma mater	Yale University University of North Dakota
Doctoral advisor	Henry Andrews Bumstead

Personal life [edit]

Nyquist was born in the Stora Kil parish of Nilsby, Värmland, Sweden. He was the son of Lars Jonsson Nyqvist (b. 1847) and Katrina Eriksdotter (b. 1857). His parents had seven children: Elin Teresia, Astrid, Selma, Harry Theodor, Aemelie, Olga Maria, and Axel.[2] He emigrated to the USA in 1907.

Education [edit]

He entered the University of North Dakota in 1912 and received B.S. and M.S. degrees in electrical engineering in 1914 and 1915, respectively. He received a Ph.D. in physics at Yale University in 1917.

Career [edit]

He worked at AT&T's Department of Development and Research from 1917 to 1934, and continued when it became Bell Telephone Laboratories that year, until his retirement in 1954.

Nyquist received the IRE Medal of Honor in 1960 for "fundamental contributions to a quantitative understanding of www.liu.se

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