Mobile Communications

TCS 455

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Part I

Office Hours:
BKD 3601-7
Tuesday 15:00-16:00
Friday 14:00-16:00

Chapter 1

Review & Introduction

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Chapter 1

Review & Introduction

1.1 Mobile Communications

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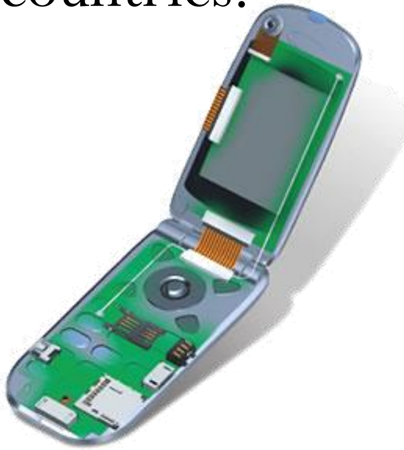
Overview of Mobile Communications

- Wireless/mobile communications is the **fastest growing** segment of the communications industry.
- Cellular systems have experienced **exponential growth** over the last decade.
- Cellular phones have become a critical business tool and part of everyday life in most developed countries, and are rapidly replacing wireline systems in many developing countries.



Mobile?

- The term "mobile" has historically been used to classify all radio terminal that could be moved during operation.
- More recently,
  - use "**mobile**" to describe a radio terminal that is attached to a high speed mobile platform
    - e.g., a cellular telephone in a fast moving vehicle
  - use "**portable**" to describes a radio terminal that can be hand-held and used by someone at **walking speed**
    - e.g., a walkie-talkie or cordless telephone inside a home.
    - 802.11?

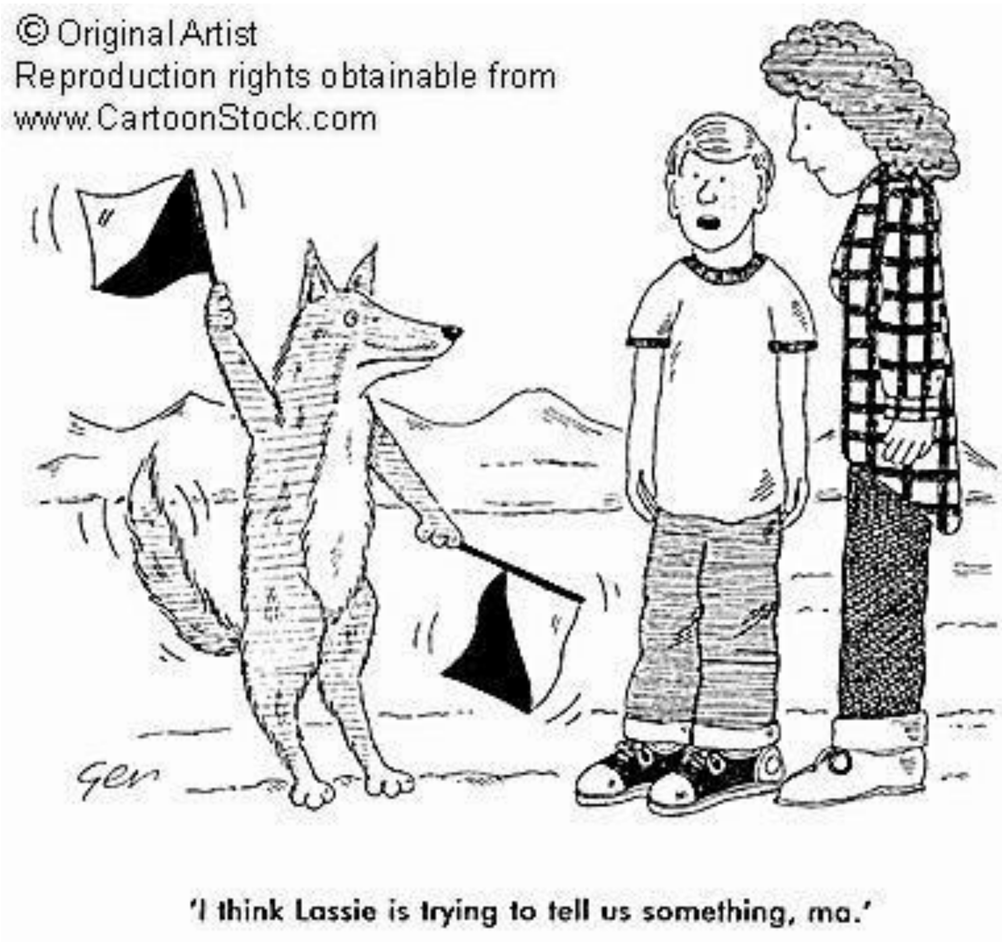
[Rappaport, 2002, p 9]

[Goldsmith, 2005, Section 1.1]

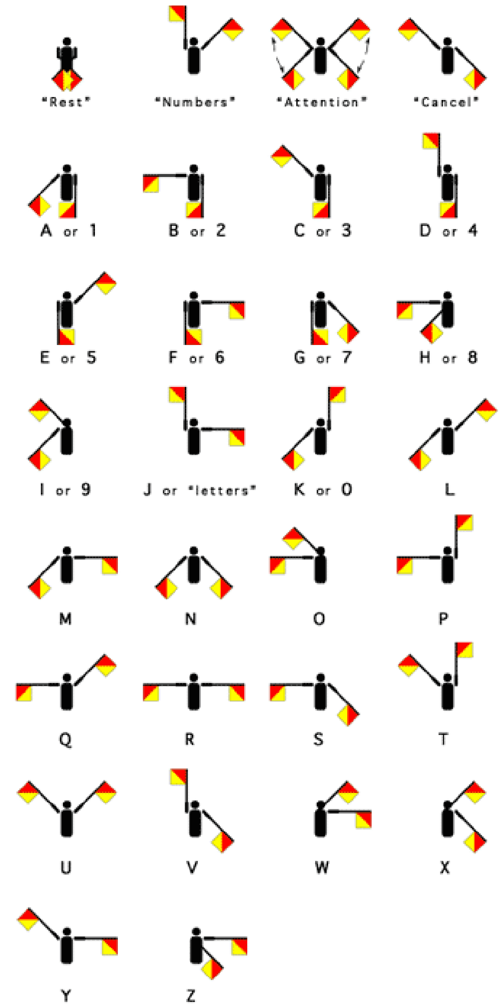
History of Wireless Communications

- The first wireless networks were developed in the Pre-industrial age.
- These systems transmitted information over **line-of-sight** distances (later extended by telescopes) using **smoke** signals, torch signaling, flashing mirrors, signal flares, or semaphore **flags**.

Semaphore



'I think Lassie is trying to tell us something, ma.'



History: Radio

- Early communication networks were replaced first by the **telegraph network** (invented by Samuel **Morse** in 1838) and later by the telephone.
- In 1895, **Marconi** demonstrated the first radio transmission.

- Early radio systems transmitted **analog** signals.
- Today most radio systems transmit **digital** signals composed of binary bits.
- A digital radio can transmit a continuous bit stream or it can group the bits into packets.
- The latter type of radio is called a **packet radio** and is characterized by **bursty** transmissions

History: ALOHANET

- The first network based on packet radio, **ALOHANET**, was developed at the University of Hawaii in 1971.
- ALOHANET incorporated the first set of protocols for channel access and routing in packet radio systems, and many of the underlying principles in these protocols are still in use today.
- Lead to **Ethernet** and eventually wireless local area networks (**WLAN**).

History: Pre-Cellular (1)

- The **most successful** application of wireless networking has been the **cellular telephone system**.
- The roots of this system began in 1915, when wireless voice transmission between New York and San Francisco was first established.
- In 1946 public **mobile telephone** service was introduced in 25 cities across the United States.

History: Pre-Cellular (2)

- The equipment was expensive at $2,000
  - At that time was more than the price of a typical new car.
- These initial systems used a **central transmitter** to cover an **entire** metropolitan **area**.
  - Inefficient!
  - Thirty years after the introduction of mobile telephone service, the New York system could only support 543 users.
- The mobile units weighed about 10 kilograms and put out a steady 20-25 watts.
- The central transmitters that communicate with the mobile units broadcast 200 to 250 watts.

[Klemens, 2010, Chapter 3]

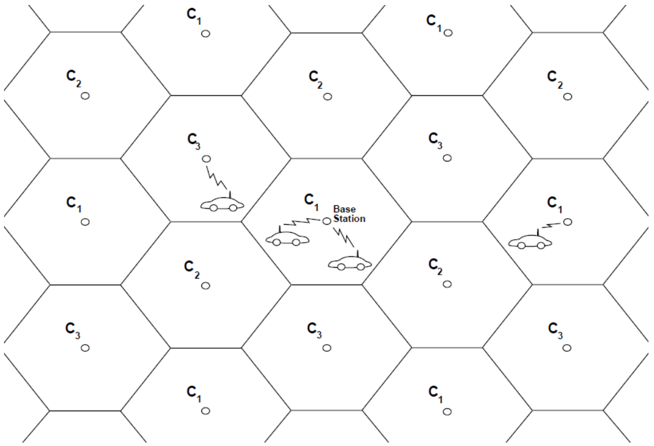
History: Pre-Cellular (3)

- The central station could reliably communicate with the mobile units up to a radius of approximately 25 miles.
- Beyond that, up to a radius of 60 to 100 miles, the signal was too weak for consistent service, but strong enough to interfere with any other mobile radio system.
- As a result, the central transmitters had to be at least 100 miles apart, leaving a 50 mile **blank space** between them.
- So a customer could use the sporadic and unreliable service only within the confines of one area.

[Klemens, 2010, p 46]

History: 1G Cellular (1)

- A solution to this capacity problem emerged during the 50's and 60's when researchers at AT&T **Bell Lab**oratories developed the **cellular concept**.
- Cellular systems exploit the fact that the power of a transmitted signal falls off with distance.
- Thus, two users can operate on the same frequency at spatially-separate locations with minimal interference between them.
  - Frequency reuse



History: 1G Cellular (2)

- **Japan** had the **world's first commercially available** cellular phone system.
  - Nippon Telegraph and Telephone (NTT) created a cellular test system for Tokyo in 1975, with the result coming to market in 1979.
- The first trial in America of a complete, working cellular system was held in Chicago in the late 1970's.
- Resulted in the creation of a standard: Advanced Mobile Phone System (**AMPS**) [1983]
  - Worked well.
  - May even have worked too well.
    - Its satisfactory performance lowered the demand for a better system, allowing Europe to take the lead by creating a digital cellular system first.

History: 2G Cellular

- The second generation (**2G**) of cellular systems, first deployed in the early 1990's, were based on digital communications.
- The shift from analog to digital was driven by its higher capacity and the improved cost, speed, and power efficiency of digital hardware.
- While second generation cellular systems initially provided mainly **voice** services, these systems gradually evolved to support **data** services such as email, Internet access, and short messaging.
- Unfortunately, the **great market potential** for cellular phones led to a proliferation of (incompatible) second generation cellular standards.
- As a result of the **standards proliferation**, many cellular phones today are **multi-mode**.

Announcement (L2: Nov 12)

- HW1 posted. Due Nov 23 (Tuesday)
- Tuesday lecture moved to 1 PM; same room.

Chapter 1

Review & Introduction

1.2 Fourier Transform and Communication System

Office Hours:
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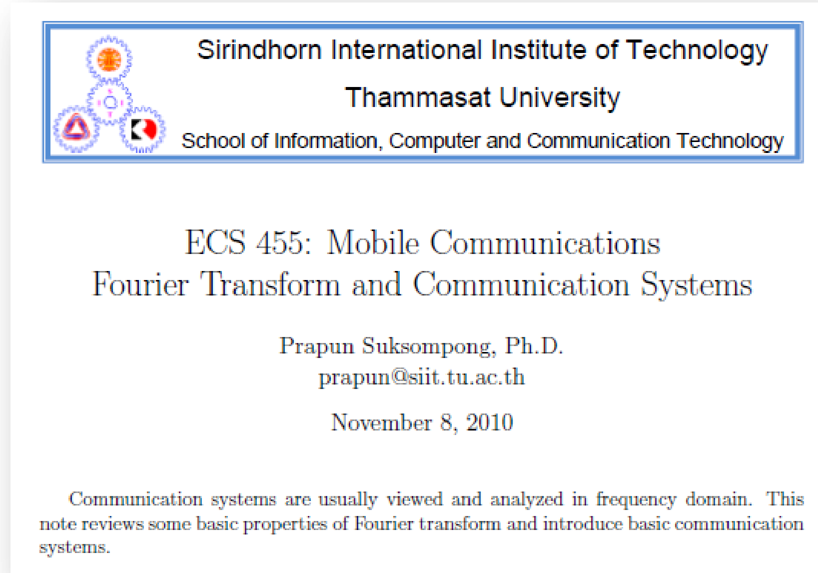
Thursday 9:30-11:30

Notes #1

- Fourier Transform
- Modulation
- More on HW1



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ECS 455: Mobile Communications
Fourier Transform and Communication Systems

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Communication systems are usually viewed and analyzed in frequency domain. This note reviews some basic properties of Fourier transform and introduce basic communication systems.

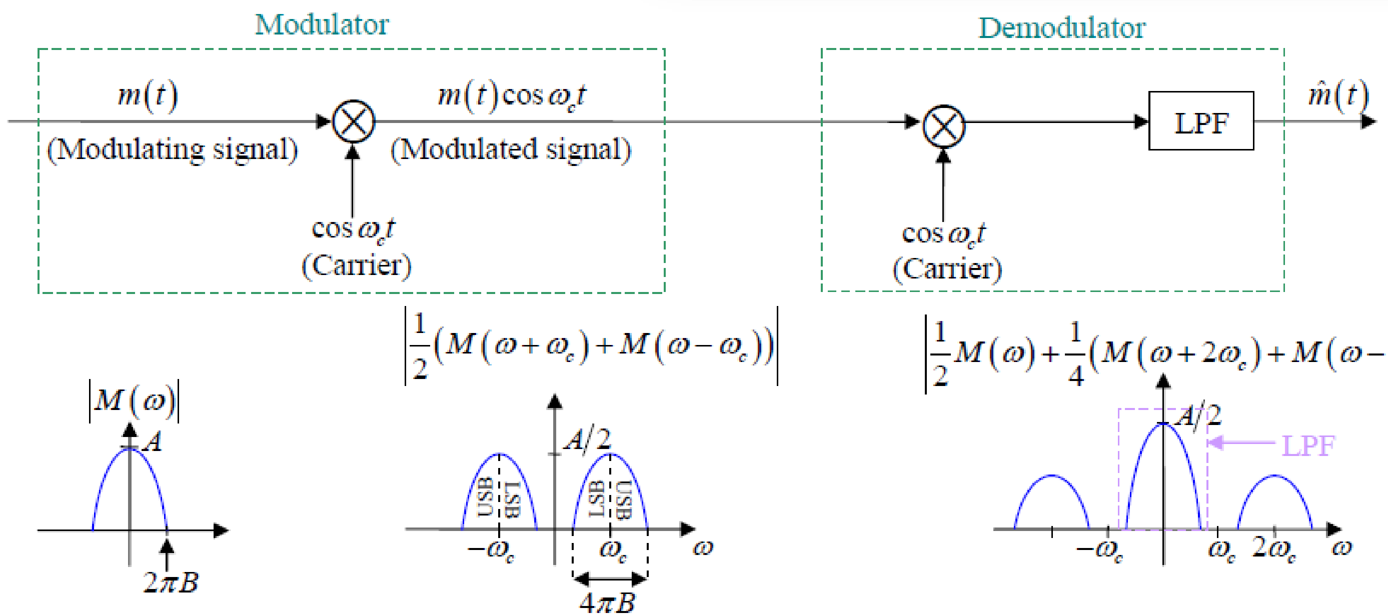
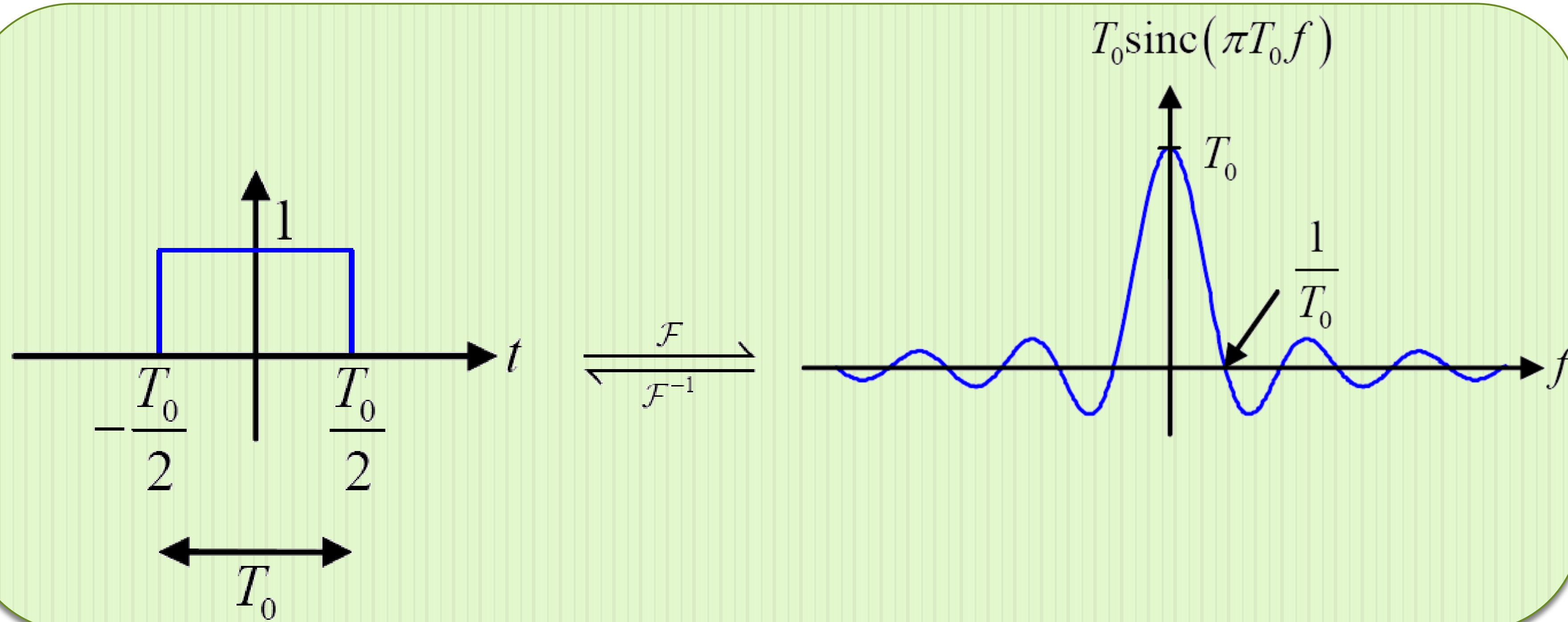


Figure 6: DSB-SC modulation and demodulation

Frequency-Domain Analysis

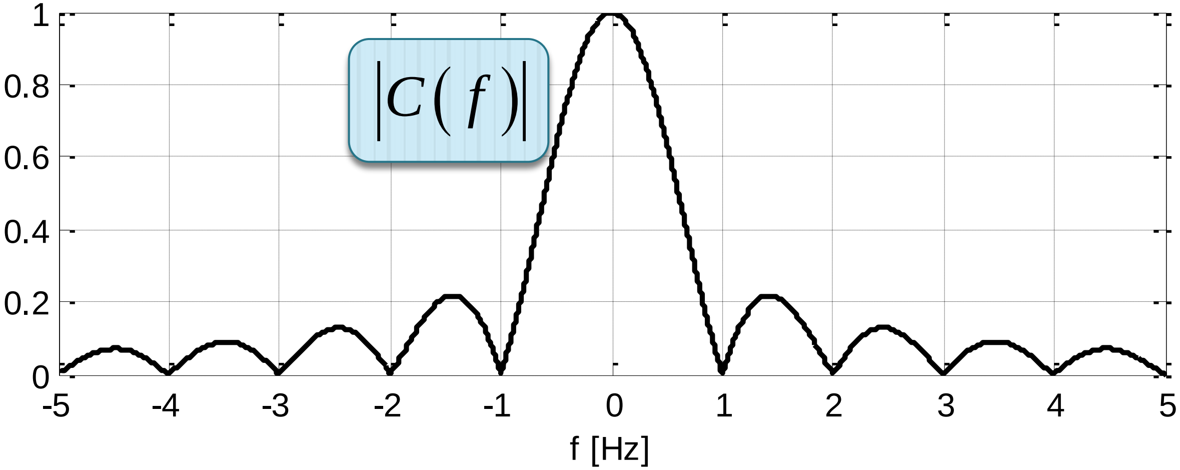


Shifting Properties: $g(t - t_0) \overset{\mathcal{F}}{\rightleftharpoons} e^{-j2\pi f t_0} G(f)$ $\quad e^{j2\pi f_0 t} g(t) \overset{\mathcal{F}}{\rightleftharpoons} G(f - f_0)$

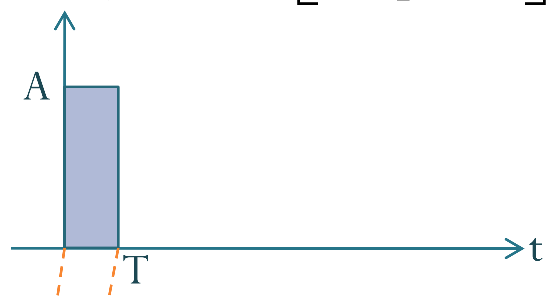
Modulation: $m(t)\cos(2\pi f_c t) \overset{\mathcal{F}}{\rightleftharpoons} \frac{1}{2} M(f - f_c) + \frac{1}{2} M(f + f_c)$

Spectrum of Digital Data

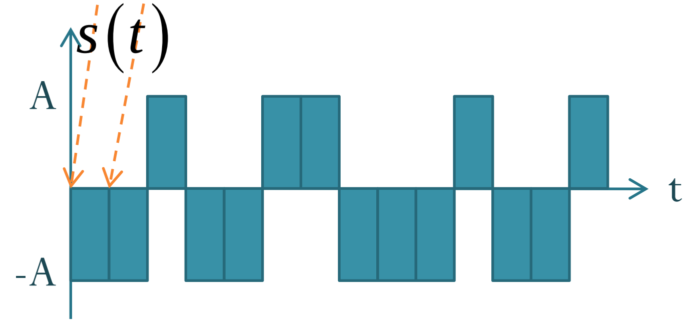
$(A=1, T=1)$



$$c(t) = A \times 1\left[t \in [0, T)\right]$$



m = [-1,-1,1,-1,-1,1,1,-1,-1,-1,1,-1,-1,1,-1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,-1,1,-1,1]



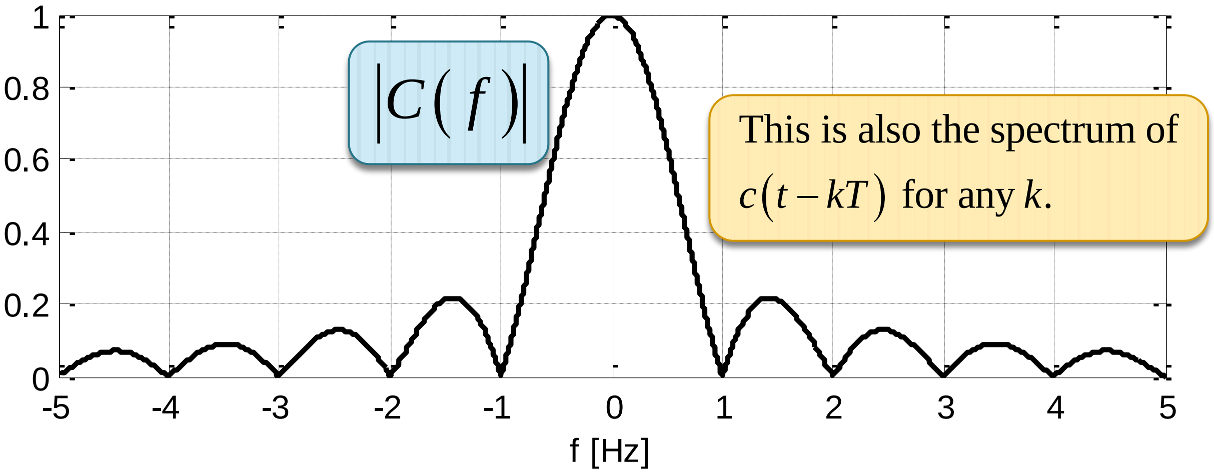
Can you sketch the spectrum of $s(t)$?

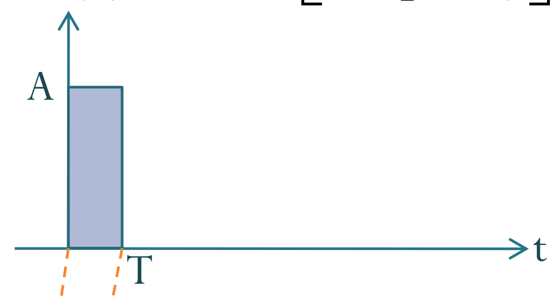
Spectrum of Digital Data

$\left(A=1, T=1\right)$

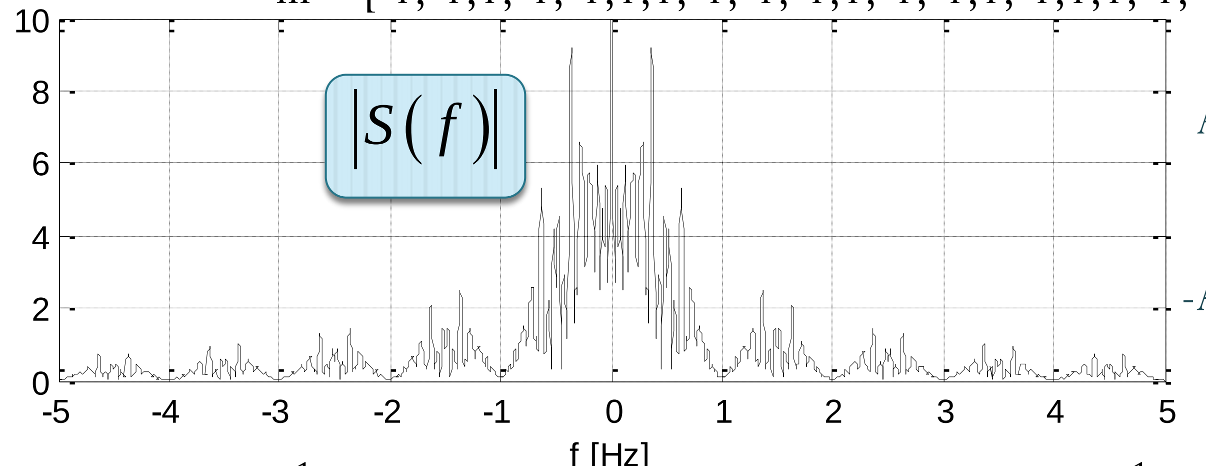
$$c\left(t\right)=A\times 1\left[t\in\left[0,T\right)\right]$$

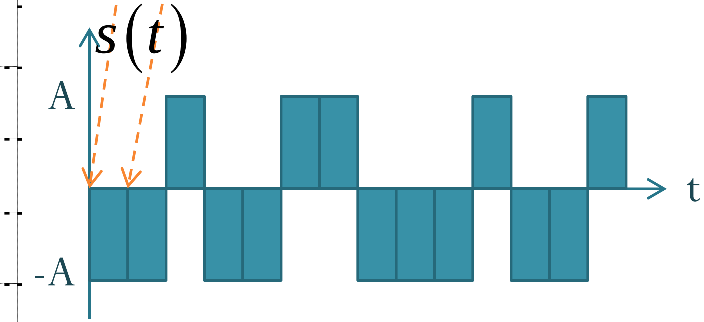
This is also the spectrum of $c\left(t-kT\right)$ for any k.





m = [-1,-1,1,-1,-1,1,1,-1,-1,-1,1,-1,-1,1,-1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,-1,1,-1,1]





$$s\left(t\right)=\sum_{k=0}^{n-1}m_k c\left(t-kT\right)\xrightarrow{\mathcal{F}}S\left(f\right)=C\left(f\right)\sum_{k=0}^{n-1}m_k e^{-j2\pi fkT}$$

Important Formula

$$e^{j\theta} = \cos\theta + j\sin\theta$$

$$2\cos^2 x = 1 + \cos(2x)$$

$$2\sin^2 x = 1 - \cos(2x)$$

$$G(f) = \int_{-\infty}^{\infty} g(t) e^{-j2\pi ft} dt$$

$$\cos(2\pi f_c t + \theta) \overset{\mathcal{F}}{\rightleftharpoons} \frac{1}{2}\delta(f - f_c)e^{j\theta} + \frac{1}{2}\delta(f + f_c)e^{-j\theta}$$

$$g(t - t_0) \overset{\mathcal{F}}{\rightleftharpoons} e^{-j2\pi ft_0} G(f)$$

$$e^{j2\pi f_0 t} g(t) \overset{\mathcal{F}}{\rightleftharpoons} G(f - f_0)$$

$$m(t)\cos(2\pi f_c t) \overset{\mathcal{F}}{\rightleftharpoons} \frac{1}{2}M(f - f_c) + \frac{1}{2}M(f + f_c)$$

Transmitted Signal

$$s(t) = \overbrace{m_I(t)}^{\text{In-phase component}}\cos(\omega_c t) - \overbrace{m_Q(t)}^{\text{Quadrature component}}\sin(\omega_c t)$$

$$= \mathrm{Re}\left\{\underbrace{\left(m_I(t) + jm_Q(t)\right)}e^{-j\omega_c t}\right\}$$

- ❑ Complex baseband signal
- ❑ Complex envelope of $s(t)$
- ❑ Compex lowpass equivalent signal of $s(t)$