Mobile Communications

TCS 455

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Lecture 17

Office Hours:
BKD 3601-7
Tuesday 14:00-16:00
Thursday 9:30-11:30

Announcements

- Read
  - Chapter 9: 9.1 – 9.5
- HW4 is posted.
  - Due at the beginning of the class on Tuesday (Jan 12).
- SIIT Job Fair 2010

SIIT Job Fair 2010

- **Wednesday January 13**
- Ground Floor & In front of UFM Bakery
- @ SIIT Main Building, Rangsit Campus
- Time: 9.00 – 16.00 hrs.
- Prepare several sets of
  - copy of transcript
  - resume
  - 1 inch photo

Chapter 4

Multiple Access

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Last time:

- Allocation of spectrum: Licensed vs. unlicensed
- Multiple Access: FDMA vs TDMA

Today

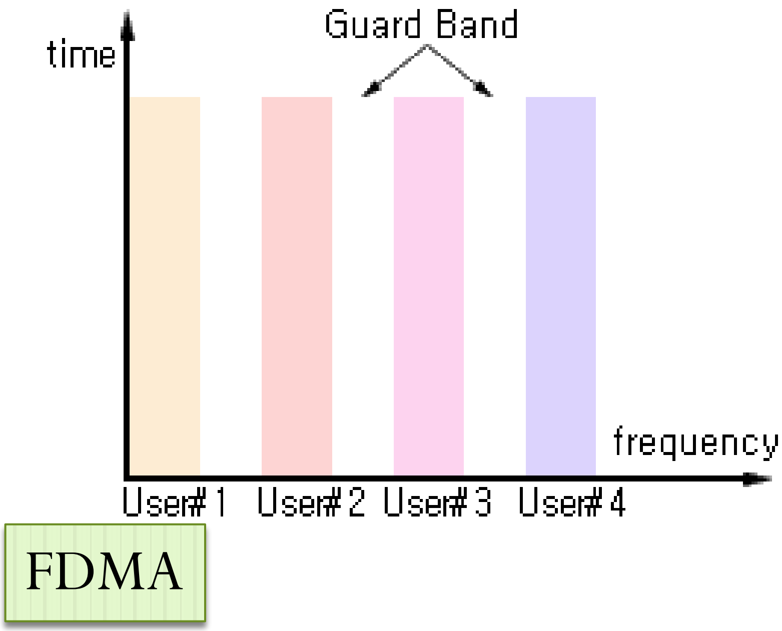
- Pop Quiz!
- Closed book. Closed notes. No calculator.
- Separate into groups of no more than three persons.

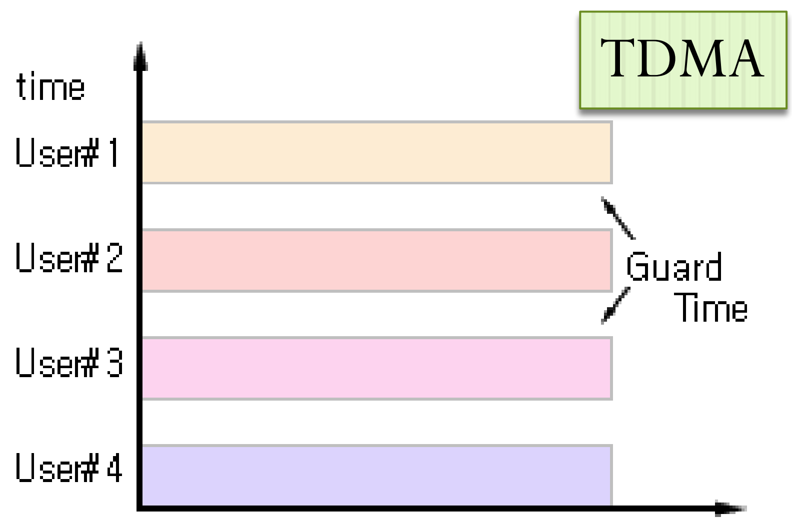
Parameter	Fixed WiMAX	Mobile WiMAX	HSPA	1x EV-DO Rev A	Wi-Fi
Standards	IEEE 802.16-2004	IEEE 802.16e-2005	3GPP Release 6	3GPP2	IEEE 802.11a/g/n
Peak down link data rate	9.4Mbps in 3.5MHz with 3:1 DL-to-UL ratio TDD; 6.1Mbps with 1:1	46Mbps[a] with 3:1 DL- to-UL ratio TDD; 32Mbps with 1:1	14.4Mbps using all 15 codes; 7.2Mbps with 10 codes	3.1Mbps; Rev. B will support 4.9Mbps	54 Mbps[b] shared using 802.11a/g; more than 100Mbps peak layer 2 through-put using 802.11n
Peak uplink data rate	3.3Mbps in 3.5MHz using 3:1 DL-to-UL ratio; 6.5Mbps with 1:1	7Mbps in 10MHz using 3:1 DL-to-UL ratio; 4Mbps using 1:1	1.4Mbps initially; 5.8Mbps later	1.8Mbps	
Bandwidth	3.5MHz and 7MHz in 3.5GHz band; 10MHz in 5.8GHz band	3.5MHz, 7MHz, 5MHz, 10MHz, and 8.75MHz initially	5MHz	1.25MHz	20MHz for 802.11a/g; 20/40MHz for 802.11n
Modulation	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM	QPSK, 8 PSK, 16 QAM	BPSK, QPSK, 16 QAM, 64 QAM
Multiplexing	TDM	TDM/OFDMA	TDM/CDMA	TDM/CDMA	CSMA
Duplexing	TDD, FDD	TDD initially	FDD	FDD	TDD
Frequency	3.5GHz and 5.8GHz initially	2.3GHz, 2.5GHz, and 3.5GHz initially	800/900/1,800/1,900/2,100MHz	800/900/1,800/1,900MHz	2.4GHz, 5GHz
Coverage (typical)	3–5 miles	< 2 miles	1–3 miles	1–3 miles	< 100 ft indoors; < 1000 ft outdoors
Mobility	Not applicable	Mid	High	High	Low

Multiple Access Techniques

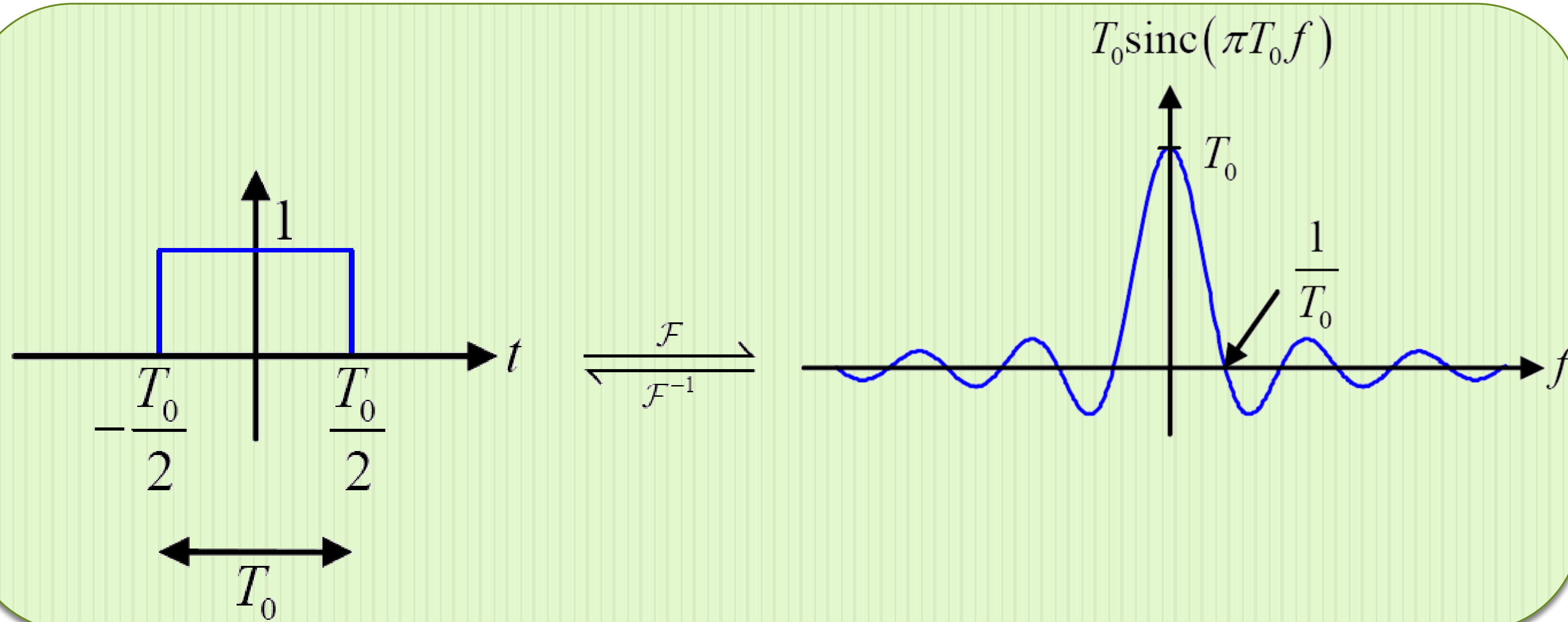
- Allow **many** mobile users to **share** simultaneously a finite amount of radio spectrum.
- For high quality communications, this must be done without severe degradation in the performance of the system.
- Important access techniques
  1. Frequency division multiple access (FDMA)
  2. Time division multiple access (TDMA)
  3. Spread spectrum multiple access (SSMA)
     - Frequency Hopped Multiple Access (FHMA)
     - Code division multiple access (CDMA)
  4. Space division multiple access (SDMA)
  5. Random access
     - ALOHA

Guard Band vs. Guard Time





Frequency-Domain Analysis

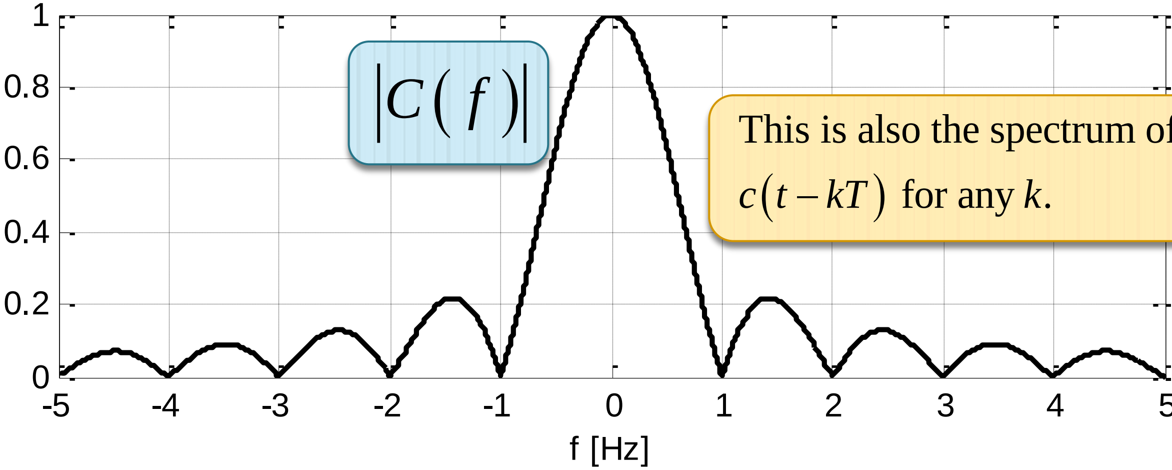


Shifting Properties: $g(t-t_0) \overset{\mathcal{F}}{\rightleftharpoons} e^{-j2\pi f t_0} G(f)$ $\quad e^{j2\pi f_0 t} g(t) \overset{\mathcal{F}}{\rightleftharpoons} G(f-f_0)$

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

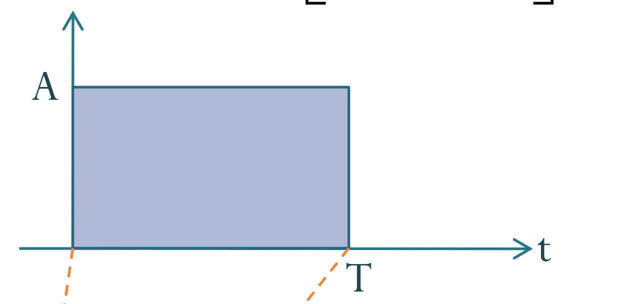
Spectrum of Digital Data

$$(A=1, T=1)$$

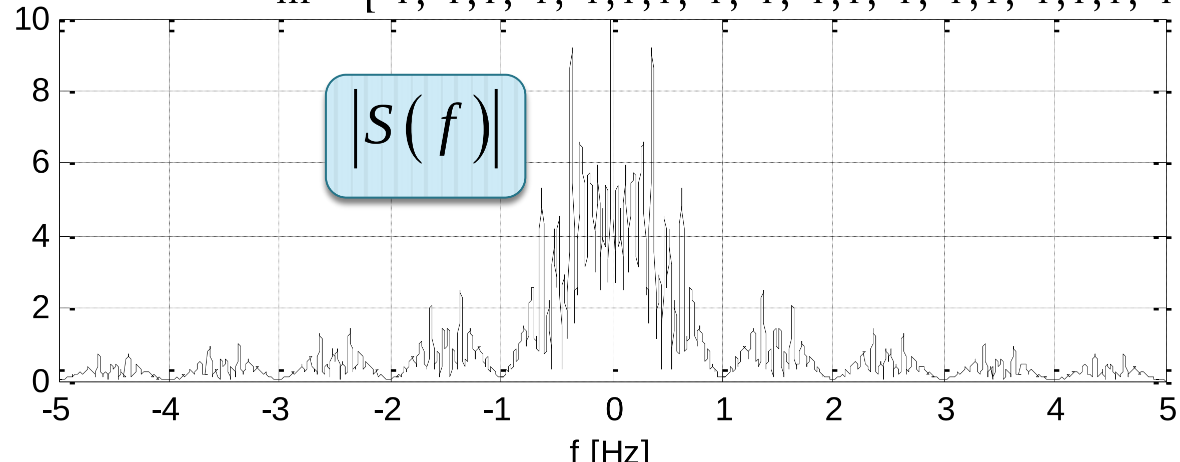


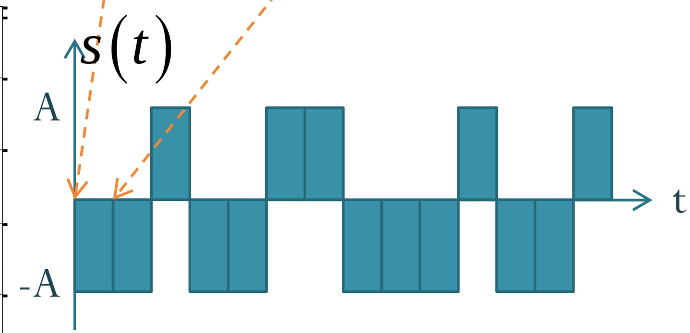
This is also the spectrum of $c(t-kT)$ for any k.

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



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]

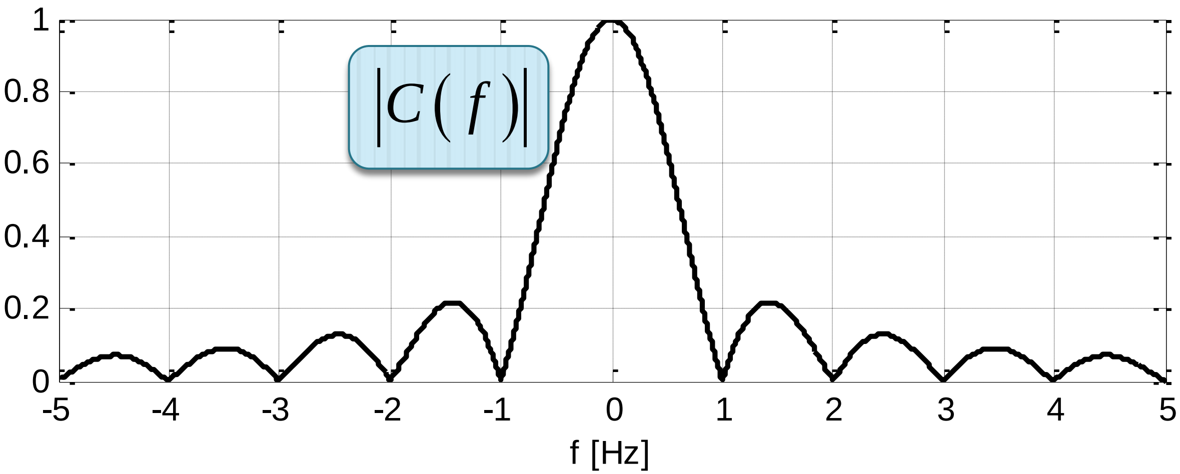




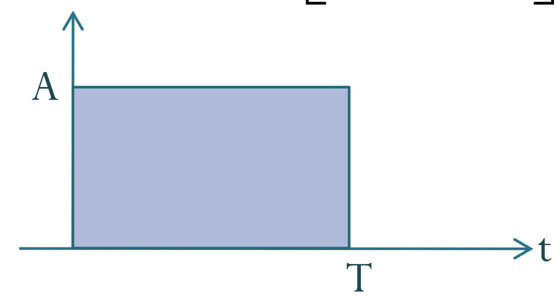
$$s(t) = \sum_{k=0}^{n-1} m_k c(t-kT) \xrightarrow{\mathcal{F}} S(f) = C(f) \sum_{k=0}^{n-1} m_k e^{-j2\pi fkT}$$

TDMA Spectrum

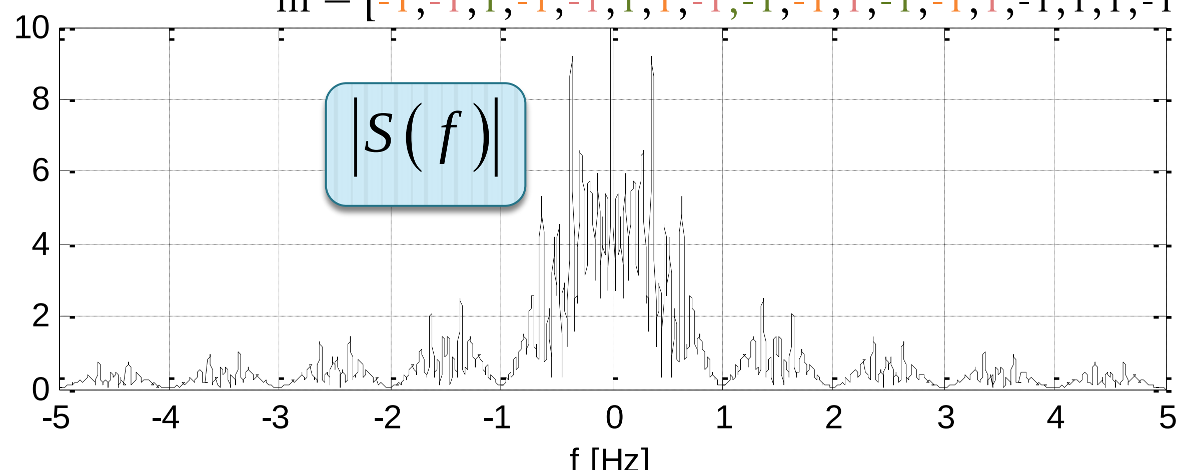
$\left(A=1, T=1\right)$

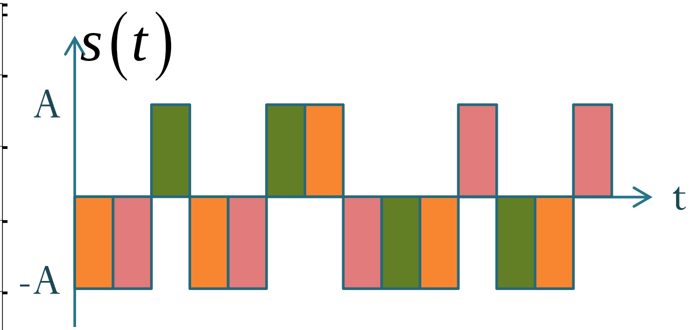


$$c(t) = A \times 1\left[t \in [0,T)\right]$$



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





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

Spread spectrum multiple access (SSMA)

- Historically spread spectrum was developed for ***secure*** communication and ***military*** uses.
- Spread spectrum signals have the following characteristics:
  - **Difficult to intercept** for an unauthorized person.
  - Easily **hidden**. For an unauthorized person, it is difficult to even detect their presence in many cases.
  - **Resistant to jamming**.
  - Provide a measure of immunity to distortion due to multipath propagation.
  - Asynchronous multiple-access capability.

Spread spectrum conditions

Spread spectrum refers to any system that satisfies the following conditions [Lathi, 1998, p 406]:

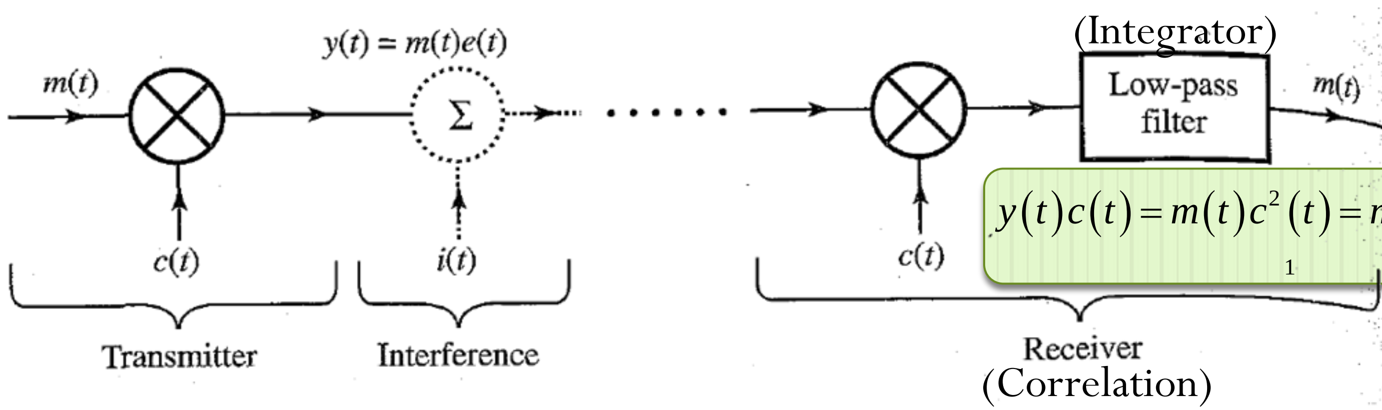
1. The spread spectrum may be viewed as a kind of modulation scheme in which **the modulated (spread spectrum) signal bandwidth is much greater than the message (baseband) signal bandwidth.**
2. The **spectral spreading** is performed by a **code** that is **independent** of the message signal.
   - This same code is also used at the receiver to despread the received signal in order to recover the message signal (from the spread spectrum signal).
   - In secure communication, this code is known only to the person(s) for whom the message is intended.

Spread spectrum (2)

- The spread spectrum scheme increases the bandwidth of the message signal by a factor N, called the **processing gain**.
- Although we use much higher BW for a spread spectrum signal, we can also multiplex large numbers of such signals over the same band.
- Many users can share the same spread spectrum bandwidth without interfering with one another.
  - Achieved by assigning different code to each user.
  - Frequency bands can be reused without regard to the separation distance of the users.

Useful even for single user!

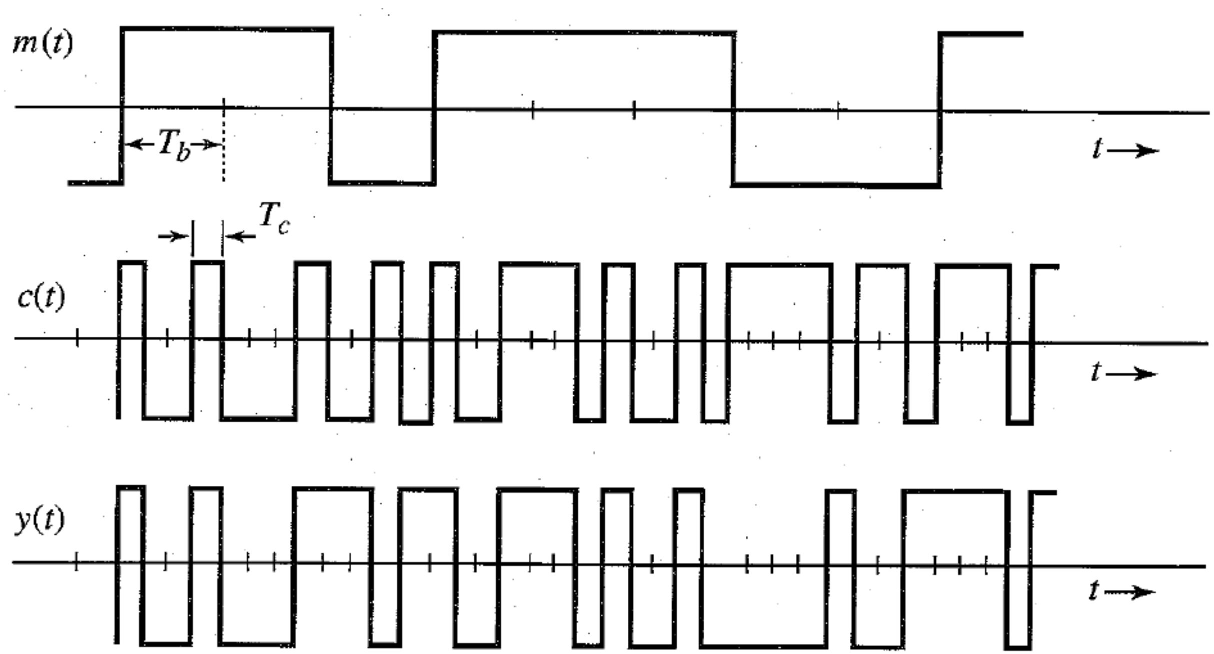
DS/SS System



$$y(t)c(t) = m(t)\underbrace{c^2(t)}_{1} = m(t)$$

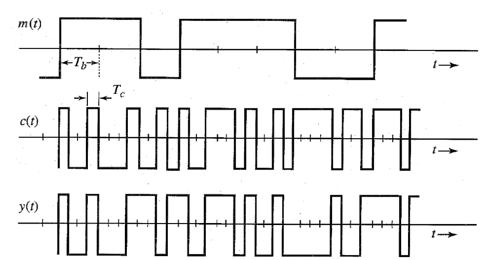
Message signal (polar binary signal)

Polar signal representing **psuedonoise (PN)** sequence. (Think of this as a pseudorandom carrier)



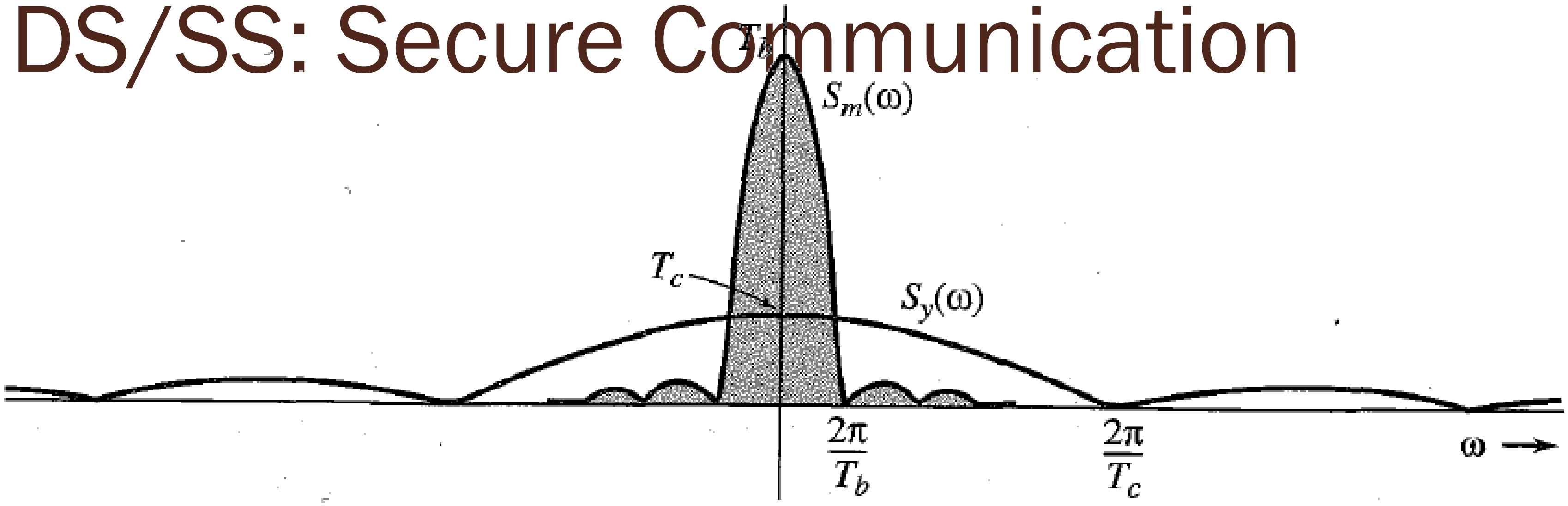
DS/SS

- The spectral spreading signal c(t) is a pseudorandom signal
  - Appear to be unpredictable
  - Can be generated by deterministic means (hence, pseudorandom)
- The bit rate of c(t) is chosen to be much higher then the bit rate of m(t).
- The basic pulse in c(t) is called the **chip**.
- The bit rate of c(t) is known as the **chip rate**.
- The auto correlation function of c(t) is very narrow.
  - Small similarity with its delayed version



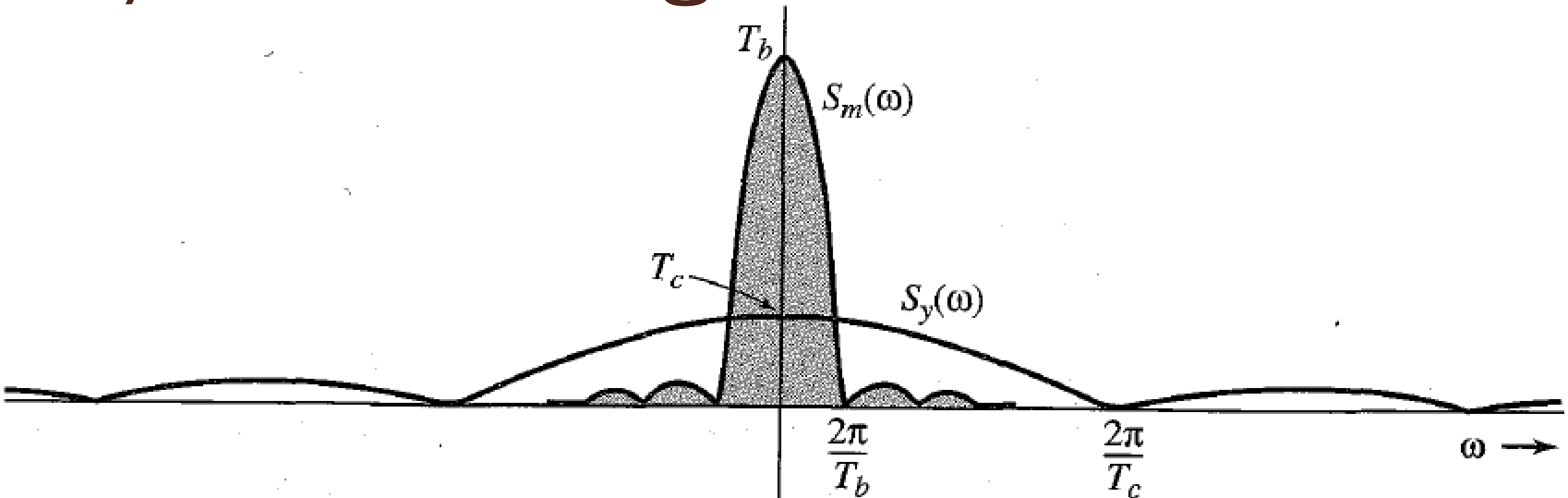
- In multiuser (CDMA) setting, the crosscorrelation between any two codes $c_1(t)$ and $c_2(t)$ is very small
  - Negligible interference between various multiplexed signals.
- Notice that the process of detection (despreading) is identical to the process of spectral spreading.
  - Recall that for DSB-SC, we have a similar situation in that the modulation and demodulation processes are identical (except for the output filter).

DS/SS: Secure Communication



- Secure communication
  - Signal can be detected only by authorized person(s) who know the pseudorandom code used at the transmitter.
  - Signal spectrum is spread over a very wide band, the signal PSD is very small, which makes it easier to hide the signal within the noise floor

DS/SS: Jamming Resistance



$$\left(y(t)+i(t)\right)c(t)=m(t)c^2(t)+i(t)c(t)=m(t)+i(t)c(t)$$

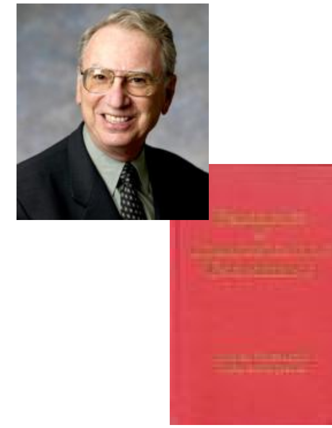
- Jamming Resistance
  - The decoder despreads the signal y(t) to yield m(t).
  - The jamming signal i(t) is spread to yield i(t)c(t).
  - Using a LPF, can recover m(t) with only a small fraction of the power from i(t).
- Caution: Channel noise will not spread.

DS/SS: Multipath Fading Immunity

- The signal received from any undesired path is a delayed version of the DS/SS signal.
- DS/SS signal has a property of low autocorrelation (small similarity) with its delayed version, especially if the delay is of more than one chip duration.
- The delayed signal, looking more like an interfering signal, will not be despread by c(t) effectively minimizes the effect of the multipath signals.
- What is more interesting is that DSISS cannot only mitigate but may also exploit the multipath propagation effect.
  - This is accomplished by a **Rake receiver**.
  - This receive designed as to coherently combine the energy from several multipath components, which increases the received signal power and thus provides a form of diversity reception.
  - The rake receiver consists of a bank of correlation receivers, with each individual receiver correlating with a different arriving multipath component.
  - By adjusting the delays, the individual multipath components can be made to add coherently rather than destructively.

Code Division Multiple Access (CDMA)

- Qualcomm
- Founders: two of the most eminent engineers in the world of mobile radio
  - Irwin Jacobs is the chairman and founder
  - Andrew J. Viterbi is the co-founder
    - Same person that invented the Viterbi algorithm for decoding convolutionally encoded data.
- 1991: Qualcomm announced
  - that it had invented a new cellular system based on CDMA
  - that the capacity of this system was 20 or so times greater than any other cellular system in existence
- However, not all of the world was particularly pleased by this apparent breakthrough—in particular, GSM manufacturers became concerned that they would start to lose market share to this new system.
  - The result was continual and vociferous argument between Qualcomm and the GSM manufacturers.



CDMA

- SSMA
- Direct Sequence Spread Spectrum (DS/SS)
- All users use the same carrier frequency and may transmit simultaneously.
- Users are assigned different "**signature waveforms**" or "code" or "codeword" or "**spreading signal**"
- The narrowband message signal is multiplied (modulated) by the **spreading signal** which has a very large bandwidth (orders of magnitudes greater than the data rate of the message).
- Each user's codeword is ***approximately orthogonal*** to all other codewords.
- Should not be confused with the mobile phone standards called cdmaOne (Qualcomm's IS-95) and CDMA2000 (Qualcomm's IS-2000) (which are often referred to as simply "CDMA")
  - These standards use CDMA as an underlying channel access method.