SPREAD SPECTRUM COMMUNICATION

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CONTENTS:

- INTRODUCTION
- WHY SPREAD SPECTRUM COMMUNICATION?
- HOW IT WORKS
- SPREAD SPECTRUM TECHNIQUES
- APPLICATIONS
- CONCLUSION

INTRODUCTION TO SPREAD SPECTRUM COMMUNICATION

Spread-spectrum radio communications is a favorite technology of the military because it resists jamming and is hard for an enemy to intercept, Just as they are unlikely to be intercepted by a military opponent

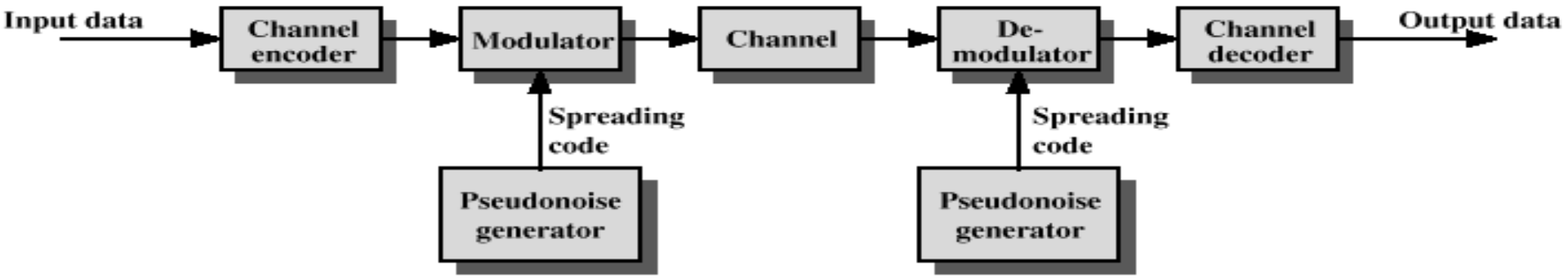


Figure 7.1 General Model of Spread Spectrum Digital Communication System

Overview of Spread Spectrum Communications

- Spread Spectrum is a means of transmission in which the data sequence occupies a bandwidth in excess of the minimum bandwidth necessary to send it.
  - Effectively the signal is mapped to a higher dimension signal space
- Signal spreading is done before transmission by using a spreading sequence. The same sequence is used at the receiver to retrieve the signal
- Spread Spectrum is most effective against interference (intentional or non-intentional) with fixed energy.
- Main commercial applications in wireless and GPS.

Spread Spectrum Background

- Like the computer, the basic technology, spread spectrum, has no single specific inventor
- As is often reported in popular press, Hedy Lamarr was awarded an early frequency hopping spread spectrum patent during WWII

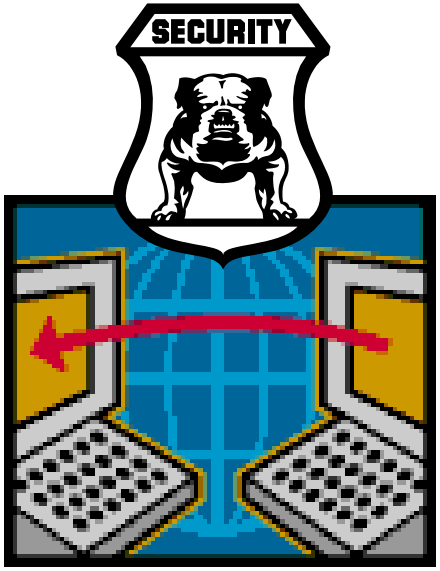
Why Spread Spectrum?

- Spread spectrum signals are distributed over a wide range of frequencies and then collected back at the receiver
  - These wideband signals are noise-like and hence difficult to detect or interfere with
- Initially adopted in military applications, for its resistance to jamming and difficulty of interception
- More recently, adopted in commercial wireless communications

NEED FOR SPREAD SPECTRUM

- **SECURITY**

- Safeguards for physical security must be even greater in wireless communications
- Encryption: intercepted communications must not be easily interpreted
- Authentication: is the node who it claims to be?



How Spread Spectrum Works

- Spread Spectrum uses wide band, noise-like signals. Because Spread Spectrum signals are noise-like, they are hard to detect.
- Spread Spectrum signals are also hard to Intercept or demodulate.
- Further, Spread Spectrum signals are harder to jam (interfere with) than narrowband signals.
- These Low Probability of Intercept (LPI) and anti-jam (AJ) features are why the military has used Spread Spectrum for so many years.

Spreading Codes

- A noise-like and random signal has to be generated at the transmitter.
- The same signal must be generated at the receiver in synchronization.
- We limit the complexity by specifying only one bit per sample, i.e., a binary sequence.

- Spread Spectrum signals use fast codes that run many times the information bandwidth or data rate.

  These special "Spreading" codes are called "Pseudo Random" or "Pseudo Noise" codes. They are called "Pseudo" because they are not real Gaussian noise.

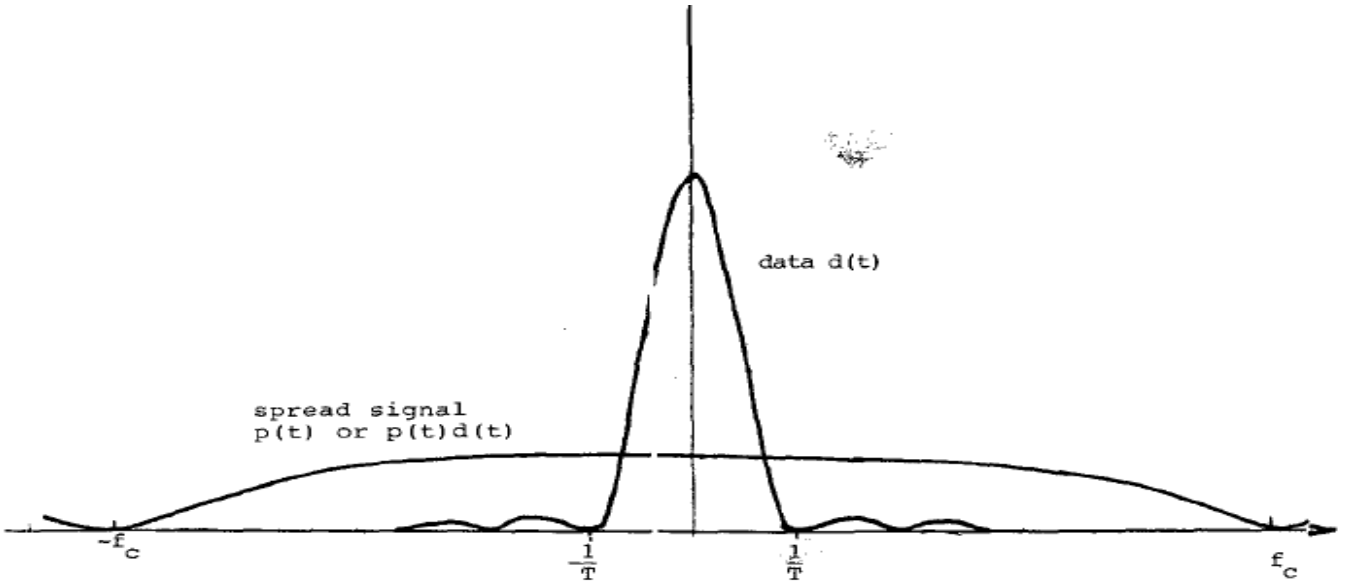


Fig. 3. Power spectrum of data and of spread signal.

PN Sequences

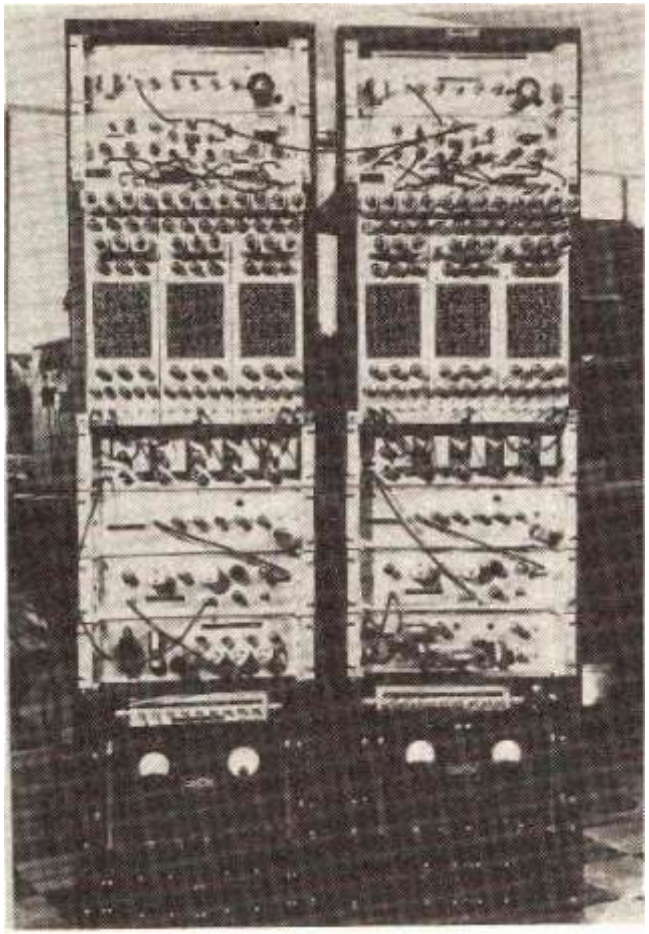
- PN generator produces periodic sequence that appears to be random
- PN Sequences
  - Generated by an algorithm using initial seed
  - Sequence isn't statistically random but will pass many test of randomness
  - Sequences referred to as pseudorandom numbers or pseudonoise sequences
  - Unless algorithm and seed are known, the sequence is impractical to predict

Important PN Properties

- Randomness
  - Uniform distribution
    - Balance property
    - Run property
  - Independence
  - Correlation property
- Unpredictability

1953 MIT Lincoln Lab System

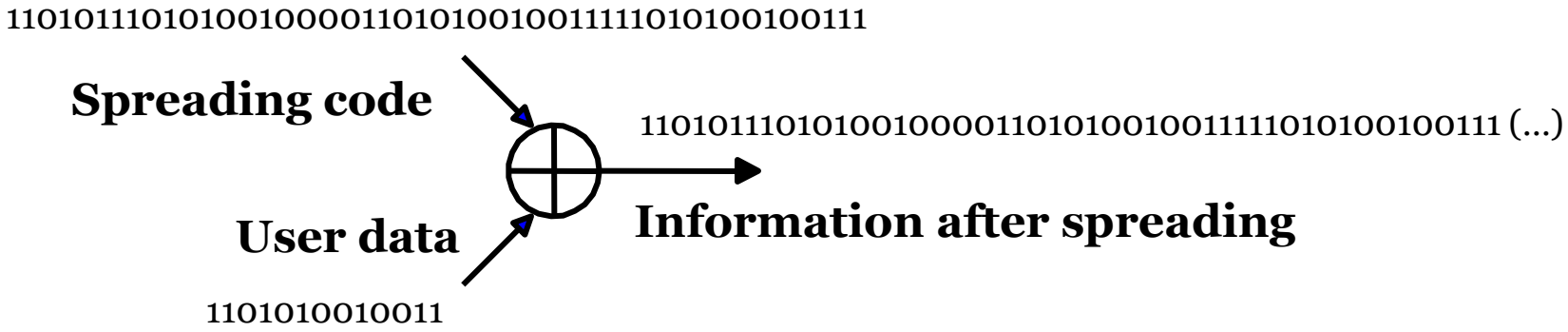
- Developed by Paul Green as a thesis project
- One of earliest PN systems
- Technology of the day limited size



SPREAD SPECTRUM TECHNIQUES

- THE MAJOR SPREAD SPECTRUM TECHNIQUES ARE
- DSSS
- FHSS

Direct Sequence Spread Spectrum (DSSS)

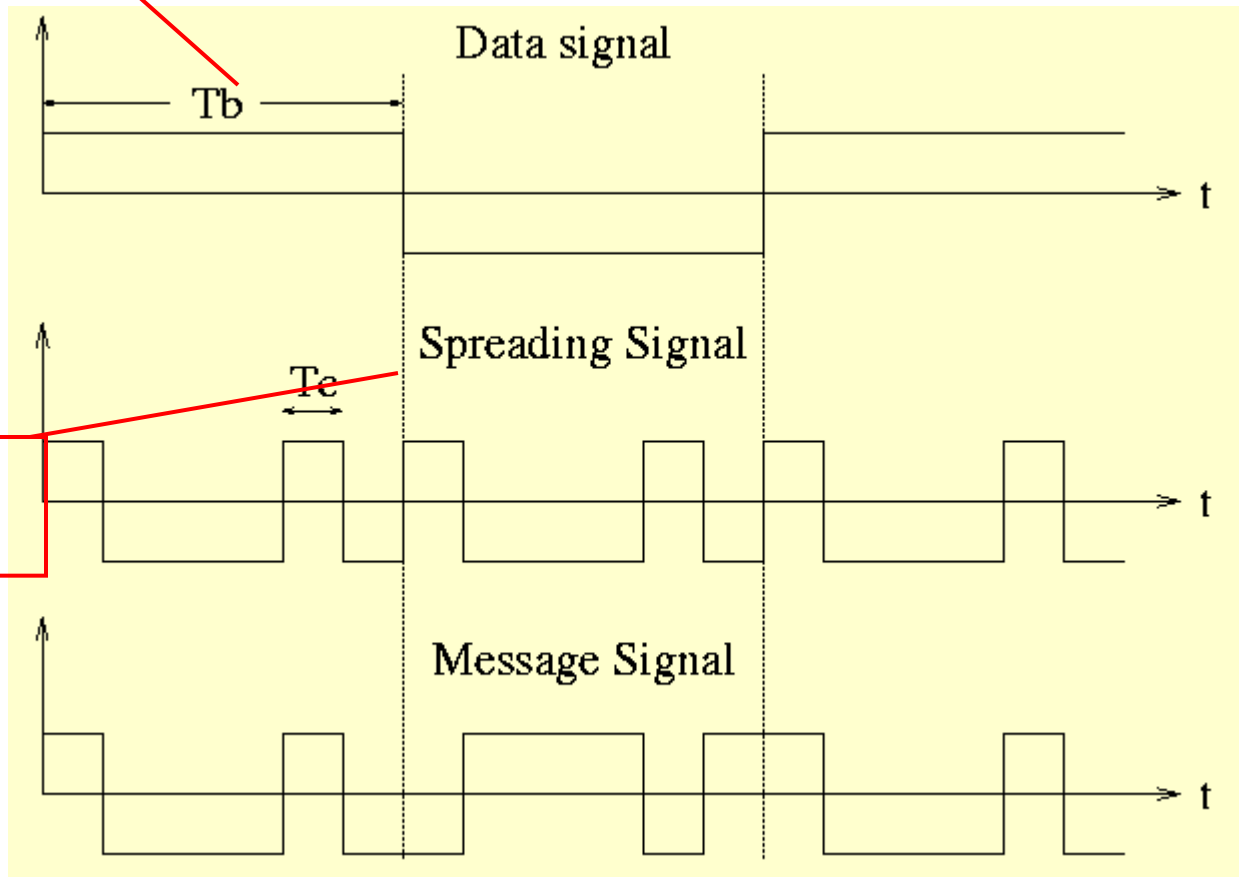


- Data signal is multiplied by a spreading code, and resulting signal occupies a much higher frequency band
- Spreading code is a pseudo-random sequence

Processing Gain (spreading factor)

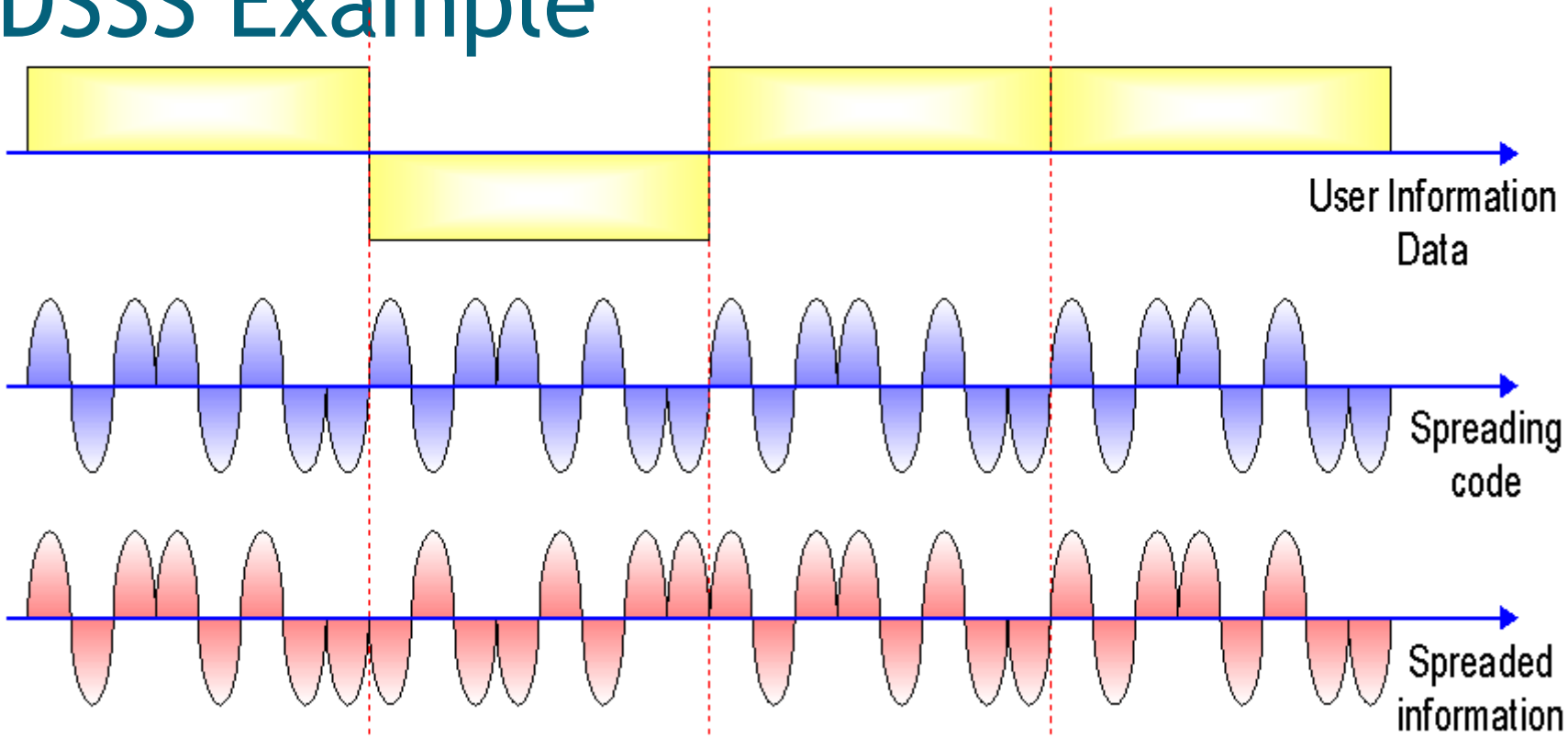
Period of one data bit

PG = SF = Tb / Tc



Period of one chip

DSSS Example



Frequency Hopping Spread Spectrum (FHSS)

- Data signal is modulated with a narrowband signal that *hops* from frequency band to frequency band, over time
- The transmission frequencies are determined by a spreading, or hopping code (a pseudo-random sequence)

Frequency Hoping Spread Spectrum

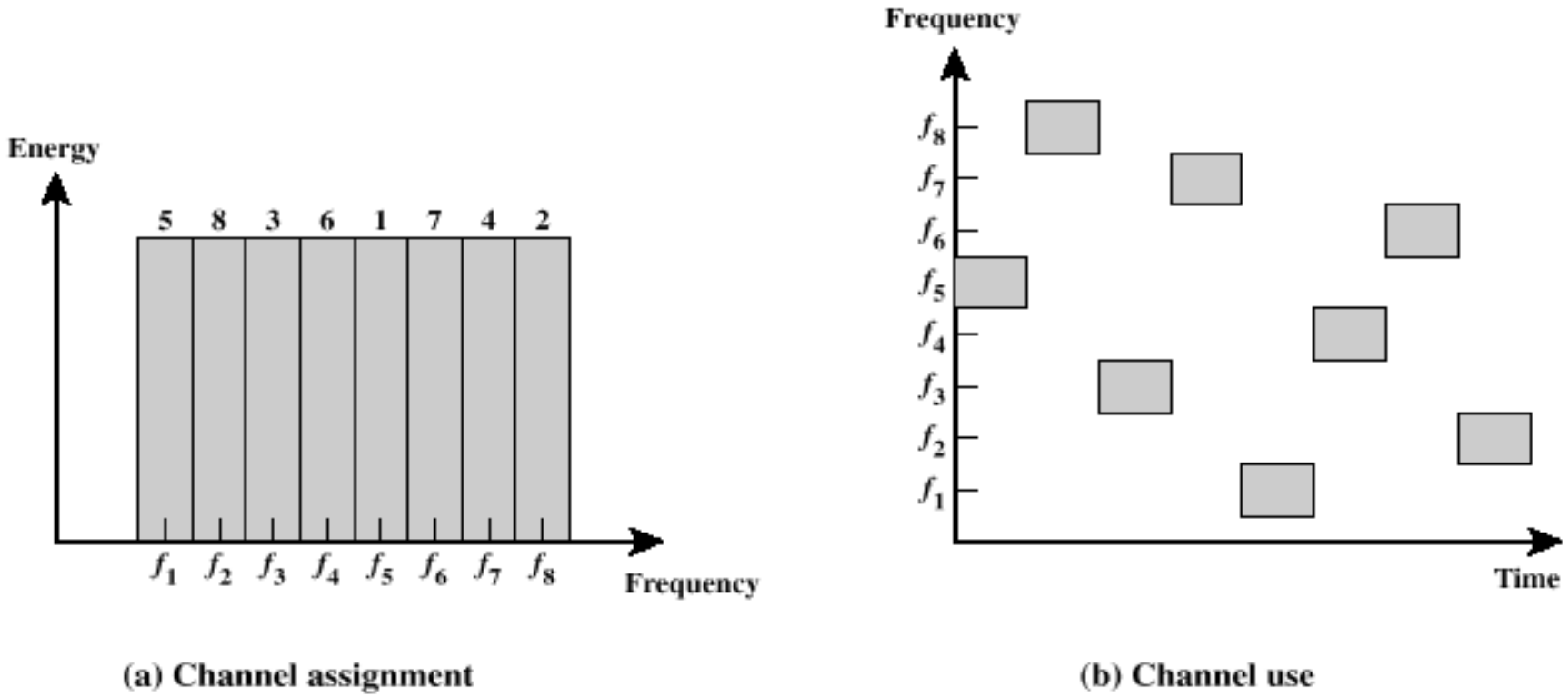
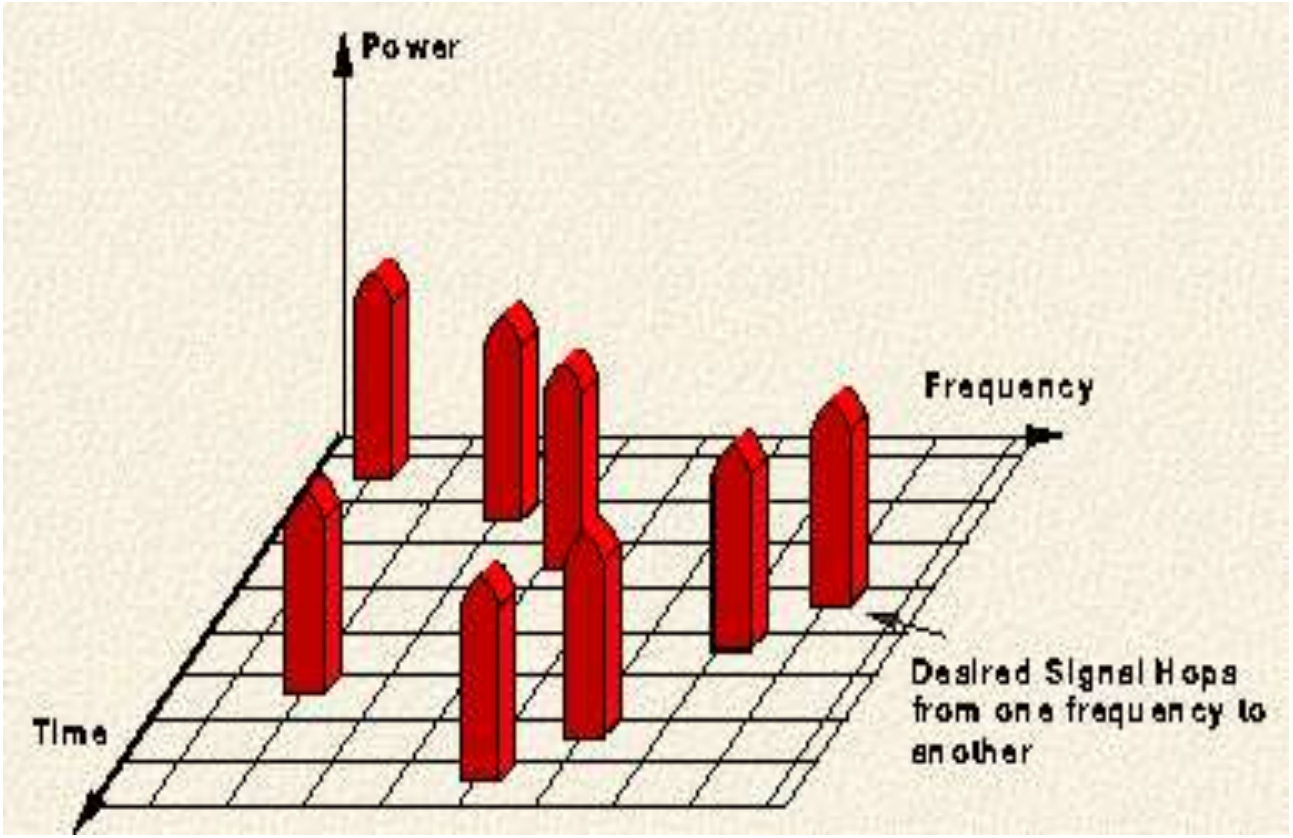


Figure 7.2 Frequency Hopping Example

Frequency Hopping

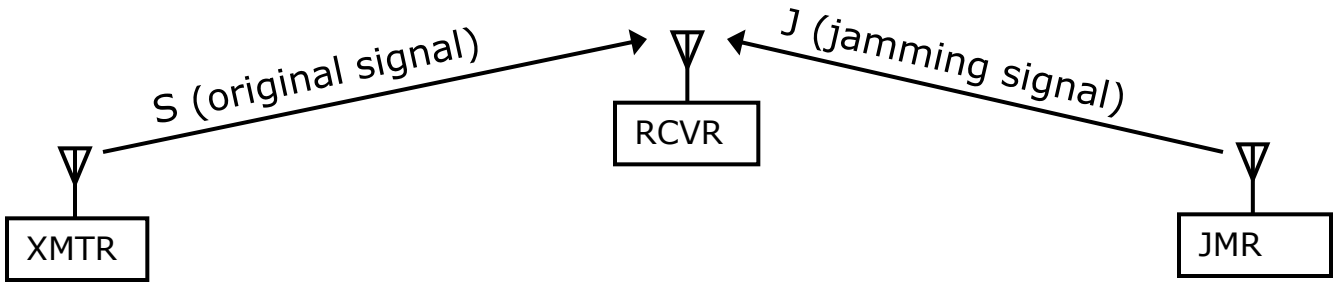
the carrier frequency is 'hopping' according to a unique sequence



APPLICATION

Motivation: radio channel availability

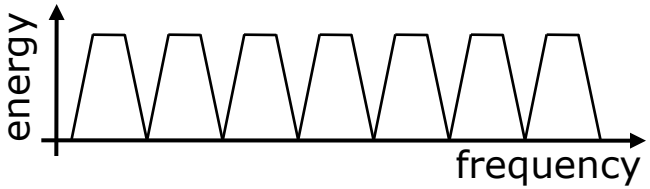
- Radio-jamming is ever-present threat to radio channels
- This is an attack on the availability of signals
  - Denial-of-Service (DoS) attack

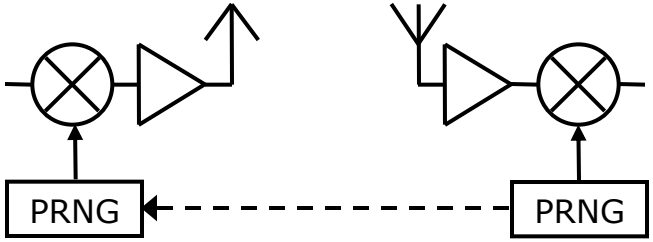


- Traditional anti-jamming techniques rely on pre-shared secret codes (keys) to increase channel availability

Motivation: anti-jamming communication

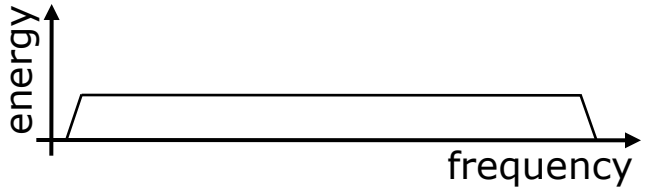
- Spread-Spectrum Techniques
  - FHSS (Frequency Hopping Spread Spectrum)

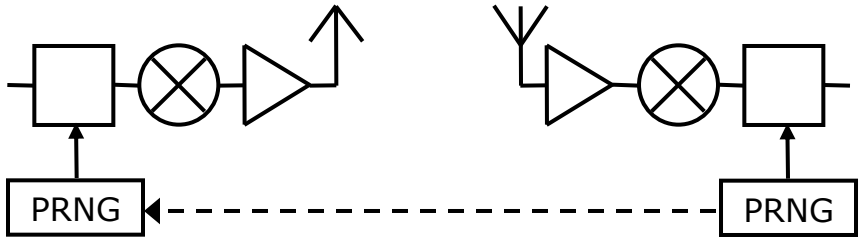




Hopping sequence (PRNG seed) must be known to the sender and receiver but not the jammer.

  - DSSS (Direct-Sequence Spread Spectrum)





Spreading code (PRNG seed) must be known to the sender and receiver but not the jammer.

BLUETOOTH

Bluetooth phone and headset

Bluetooth printer module

- Universal framework to integrate a diverse set of devices in a seamless, user-friendly, efficient manner
- Devices must be able to establish ad hoc connections
- Support for data and voice
- Similar security as cables
- Simple, small, power-efficient implementation
- Inexpensive!

Code Division Multiple Access

- Multiple Transmitters → 1 Receiver
- Choice of unique sequences to spread the data bits
- Ability of receiver to distinguish between data streams

Advantages of Spread Spectrum

1. *Reduced crosstalk interference:*
2. Better voice quality/data integrity and less static noise
3. Lowered susceptibility to multipath fading
4. Inherent security:
5. *Co-existence:*
6. Longer operating distances
7. Hard to detect:
8. Hard to intercept or demodulate:
9. Harder to jam

Conclusion

- Spread spectrum promises several benefits such as higher capacity and ability to resist multipath propagation. Spread spectrum signals are difficult to intercept for an unauthorized person, they are easily hidden. For an unauthorized person, it is difficult to even detect their presence in many cases. They are resistant to jamming. They provide a measure of immunity to distortion due to multipath propagation. They have multiple access capability
- .
- Spread spectrum is now finding widespread civilian and commercial applications such as cellular telephones, personal communications and position location. For example, DS/SS is used in electronic Industries Association's Interim Standard IS-95 for cellular telephones, as well as wide range of position location systems such as the global position location and other vehicle location and messaging systems.

THANK YOU!!

OVERVIEW