Future

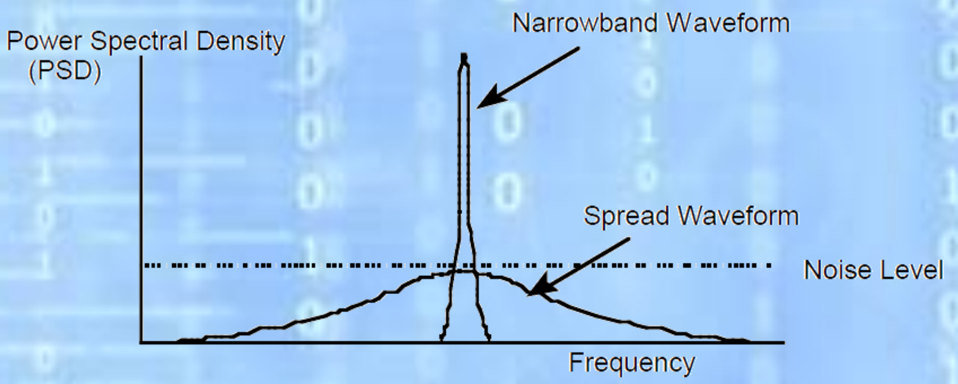
Spread Spectrum 101

History

Presented by Brad KN9B

What is Spread Spectrum

- Transmitted signal is spread over a wide frequency band
- Extremely bandwidth inefficient compared to NB
- Can coexist with multiple ND & SS signals
- SS receiver does not see ND & SS signals since it is listening to a much wider bandwidth at a prescribed code sequence



Comparison of a narrowband signal with a Direct Sequence Spread Spectrum signal. The narrowband signal is suppressed when transmitting spread spectrum.

What is Spread Spectrum

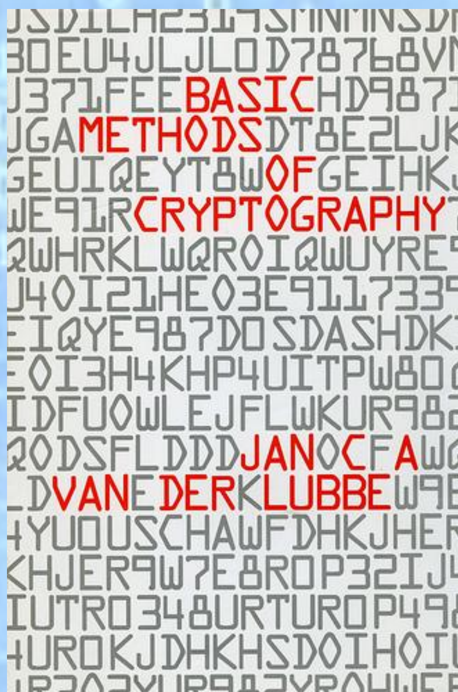
- **SS receiver does not see ND & SS signals since it is listening to a much wider bandwidth at a prescribed code sequence**

Interesting text with a message in plain sight or is it noise?

What does it mean?

What is Spread Spectrum

- **SS receiver does not see ND & SS signals since it is listening to a much wider bandwidth at a prescribed code sequence**



Interesting text with a message in plain sight or is it noise?

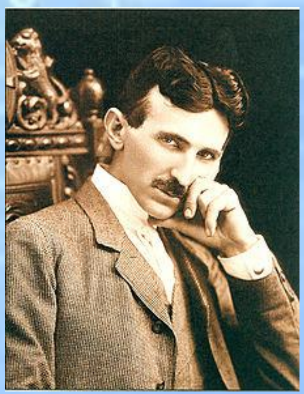
What does it mean?

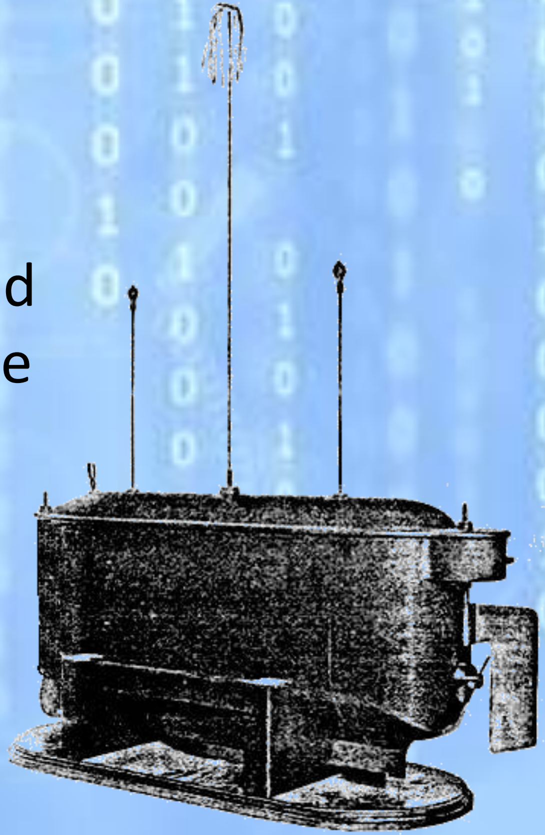
Basic Methods of Cryptography
Jan C.A. Van Der Lubbe

Spread Spectrum History

- **On November 8, 1898 Nikola Tesla patented a radio controlled robot-boat.**

- Tesla demonstrated his RC boat in 1898, Madison Square Garden.
- Tesla's robot-boat was a Radio Controlled torpedo and included anti-jam FHSS of the control signals.





Spread Spectrum History

- **On August 11, 1942 Hedy Lamarr patented a FHSS radio controlled torpedo.**
  - She proposed that rapid changes in radio frequencies could be used slotted paper rolls similar to player-piano rolls to synchronize the frequency changes in transmitter and receiver, and it even called for exactly eighty-eight frequencies, the number of keys on a piano.

Spread Spectrum Today

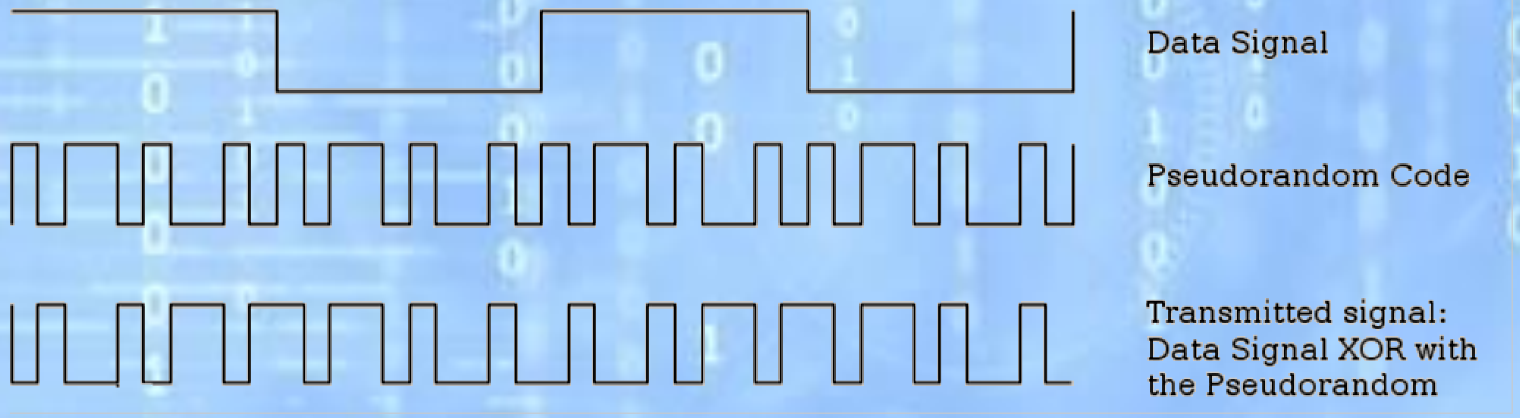
- **Satellites**
  - Reduced Interference & Low Power Users
- **Military**
  - Anti-JAM, LPI/LPD, GPS
- **Cell Phones**
  - Spectrum Reuse via combined Spatial - FHSS - CDMA Techniques
- **Consumer Products**
  - WIFI, Bluetooth, Cordless Phones, GPS and so forth
- **Amateur Radio**
  - Satellite, Packet, LOS Links

Spread Spectrum Methods

- **Direct-sequence spread spectrum (DSSS)**
- **Frequency-hopping spread spectrum (FHSS)**
- **Chirp spread spectrum (CSS)**
- **Time-hopping spread spectrum (THSS)**

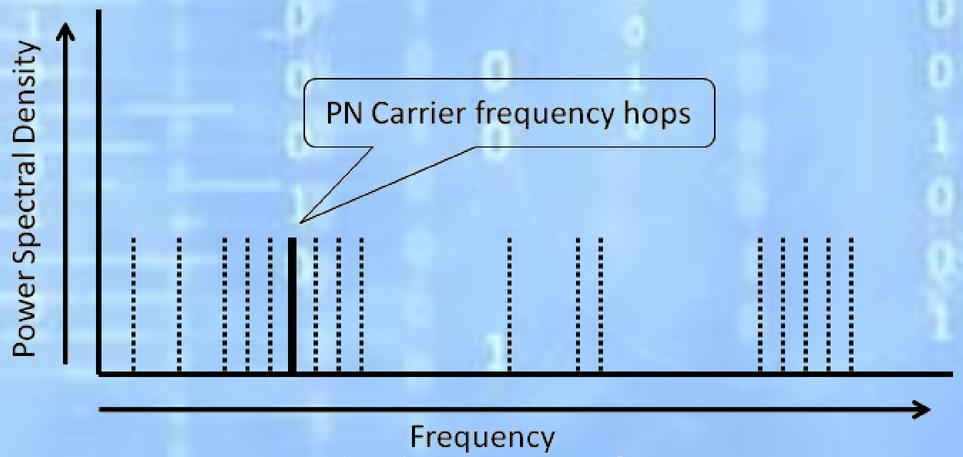
Direct-sequence spread spectrum (DSSS)

- DSSS data is modulated by a pseudorandom code sequence (PN) string.
- The phase of the transmitted signal is changed in accordance with this code PN.
- The speed of the code sequence is called the chipping rate, measured in chips per second (cps).
- The receiver recovers the data by multiplying the signal with a copy of the code sequence



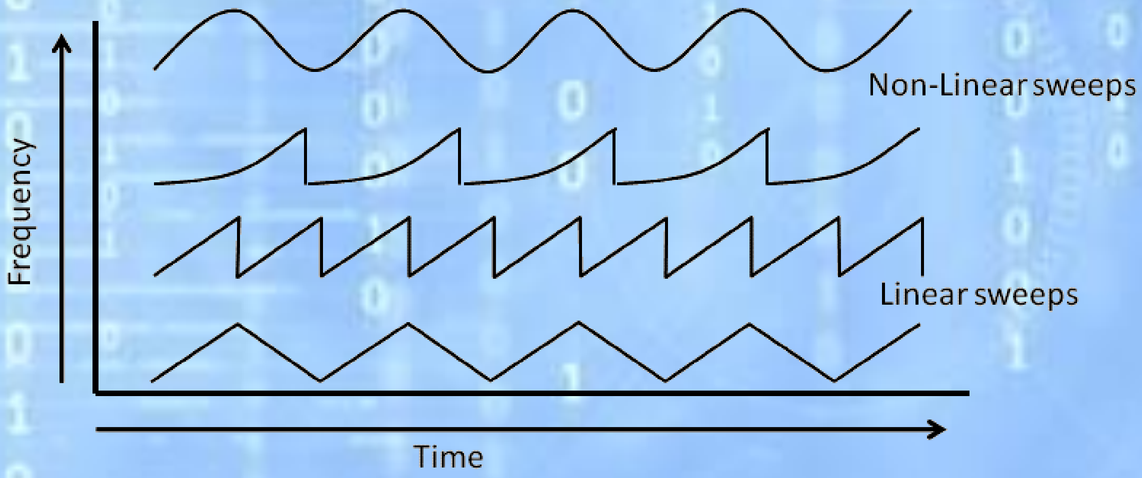
Frequency-hopping spread spectrum (FHSS)

- The FHSS carrier frequency of the transmitter changes (1 mSec. or less hops) in a PN code sequence.
- The order of frequencies selected by the transmitter is dictated by the code sequence.
- The receiver tracks these carrier hops
- The receiver IF and demodulation are NB



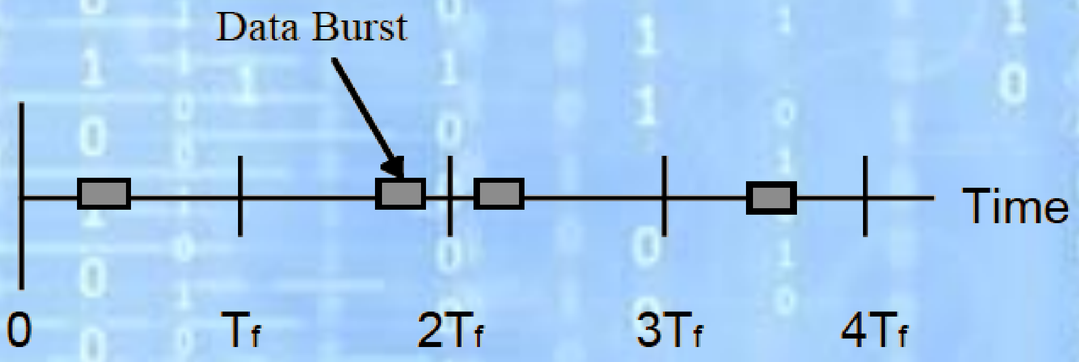
Chirp spread spectrum (CSS)

- **CSS uses a swept carrier frequency with a repeated sequence**
- **The frequency change depends on the spreading function**
  - Linear frequency chirp sweep, sweeping either up or down
  - Non-linear frequency chirp sweep, sweeping either up or down
- **The receiver IF and demodulation are NB**



Time-hopping spread spectrum (THSS)

- NB Tx & Rx
- The Tx period and duty cycle of a PN sequence
- Often used in combination with other SS methods



Each burst of data and the exact time each burst is transmitted is determined by a PN sequence.

Spread Spectrum Implementation

- **Receiving**
  - The spectrum spreading is removed and the signal is demodulated

Spread Spectrum is very simple stuff, just like finding the car in this picture

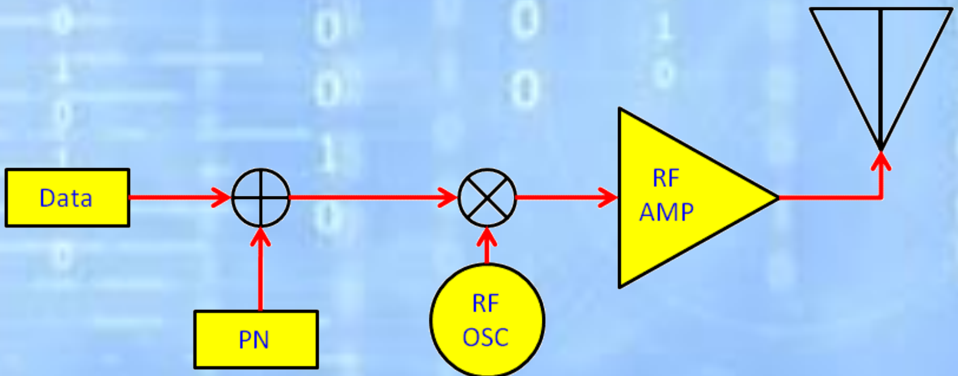
Spread Spectrum Implementation

- **Receiving**
  - The spectrum spreading is removed and the signal is demodulated

- Spread Spectrum is very simple stuff, when you know when to look for the car
- The PN known by the Tx & Rx is the key that tells you when to look

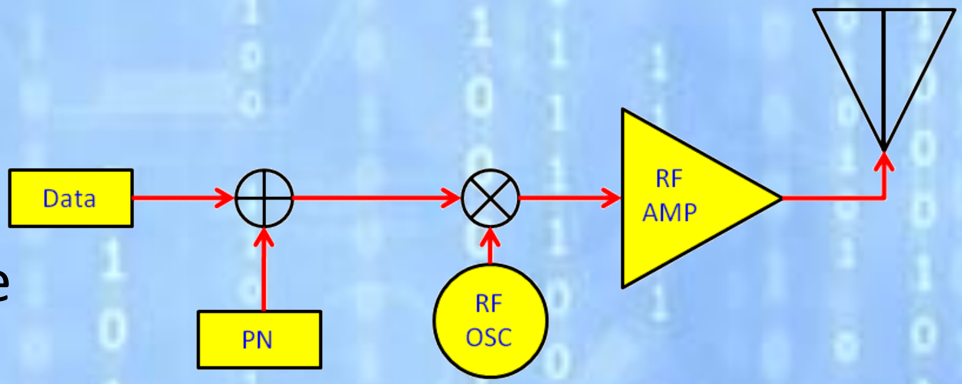
Spread Spectrum Implementation

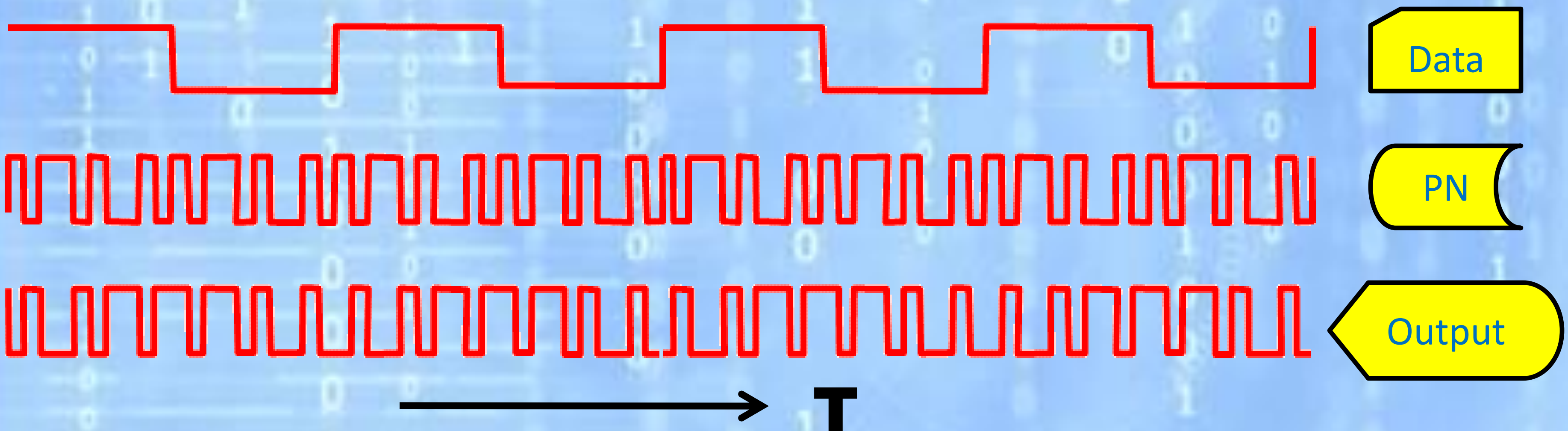
- **Transmitting**
  - The sequence code (DSSS) or sequence frequency(FHSS) is generated by a pseudorandom (PN) generator.
  - The PN is a fixed length that repeats itself exactly.
  - The data is modulated by a code sequence.
  - The RF output is controlled by the resulting sequence.



Spread Spectrum Implementation

- **Transmitting**
  - PN is fixed & known
  - PN is ~1000 X data rate



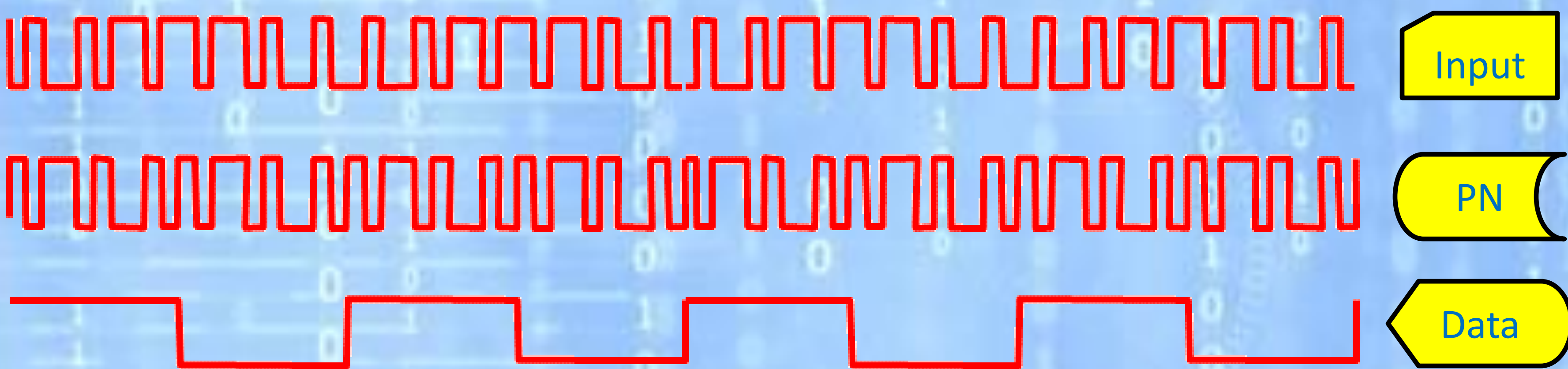


Spread Spectrum Implementation

- **Receiving**
  - The spectrum spreading (DSSS, FHSS) modulation is removed and the signal is demodulated
  - The signal is correlated (de-spread) when the proper synchronization of the common PN at both the transmitter and receiver is achieved.
  - Synchronization is the most difficult aspect of the receiver.
    - Detection (Initial Acquisition)
    - Lock (Tracking)

Spread Spectrum Implementation

- **Receiving**
  - The spectrum spreading (DSSS, FHSS) modulation is removed and the signal is demodulated



Spread Spectrum Implementation

- **Receiving**
  - Synchronization is the most difficult aspect of the receiver.
    - Detection (Initial Acquisition)
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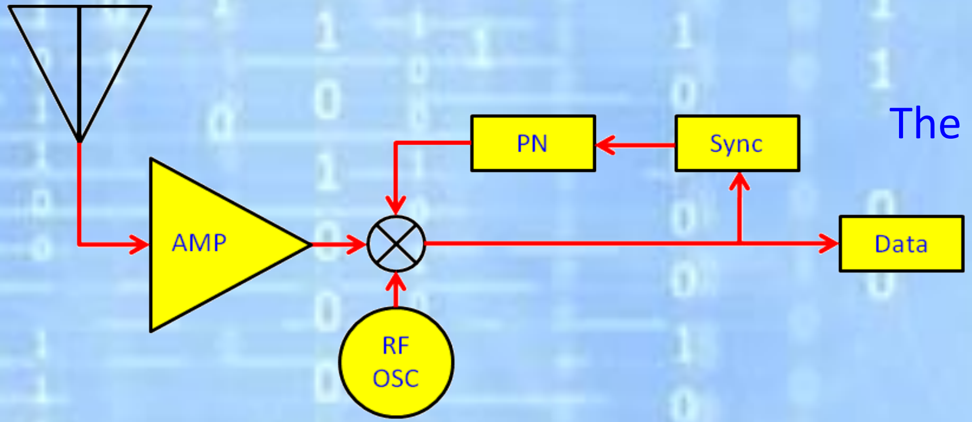


The Synchronization samples the data stream
- Integrates & Low Pass Filter
  - No-Sync = Zero, the average of Noise
  - Sync = Positive Value (Integrated Data)
- Works like most PLL Circuits

Spread Spectrum Implementation

- **Receiving**
  - Synchronization is the most difficult aspect of the receiver.
    - Known PN Code (3 Letter Code by date)
    - Detection (Start of Message)
    - Lock (Message Groups)

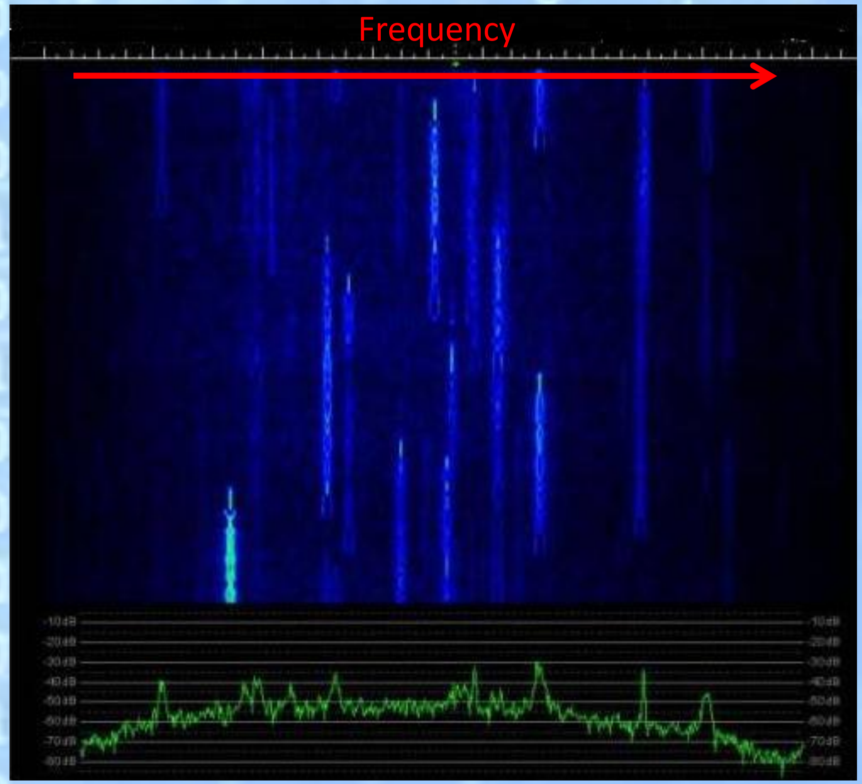
Classic example of PN the Enigma Machine

Processing Gain

- Gain is derived from knowing where to look & integrating many samples per data bit

X = Freq →
Y = Time ↑
Z = PSD ●
"Waterfall"

X = Freq →
Y = PSD ↑
"A-Scope"



Typical combined spectral display of newer communications receivers provides the operator with a 30 Sec. time window view of band activity. Very helpful when looking for weak signals.
"Eyeball Integration"

Processing Gain

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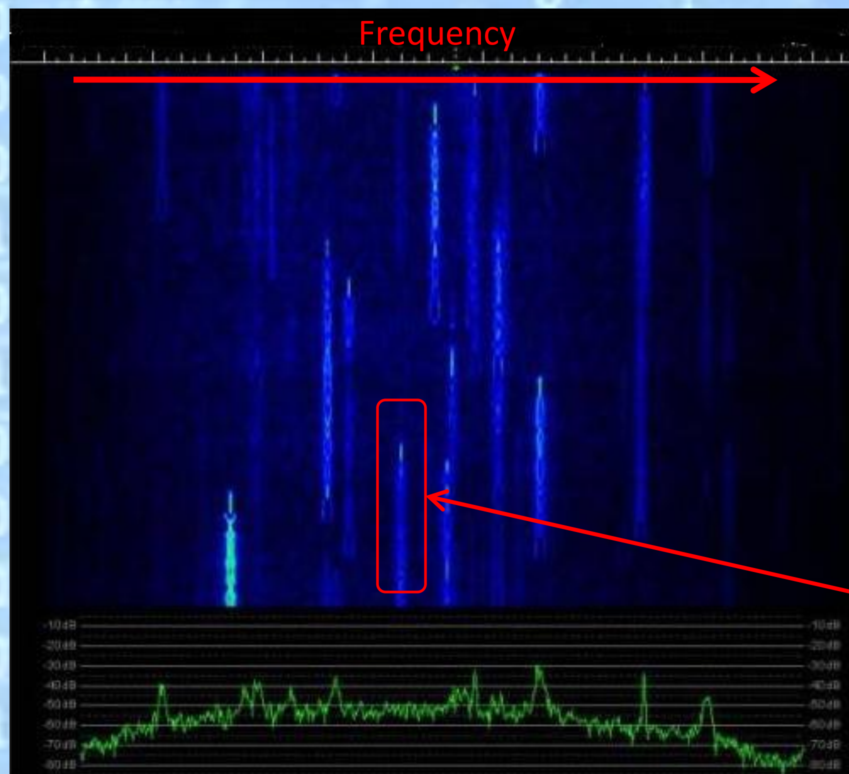

In the case of FHSS this spectral display could be just a 3 uSec. time window view of band activity

1 uSec. HOP sample that will be integrated with a 1000 more to determine a single bit of the 5-8 bits that make a symbol

Processing Gain

- Shannon's Information-rate theorem where the capacity of a channel is proportional to its bandwidth and the signal-to-noise ratio on the channel $C = W \log_2 (1 + S/N)$

C = capacity in Kbits per second, W = bandwidth in KHz, S/N = signal power ratio (not dB)

Description	Bit Rate	Kbits per sec	KHz	dB	ratio
2.4K MODEM	2.4 Kbits	9.571	3	9.1	8.128305
9.6K MODEM	9.6 Kbits	9.571	3	9.1	8.128305
56K MODEM	56 Kbits	55.808	3	56	398107.2
RTTY Baudot	1.5 Kbits	1.480	15	-11.5	0.070795
RTTY Baudot	1.5 Kbits	1.442	1,000	-30	0.001
CW EME UHF	1 bit	0.001	30,000	-76	2.51E-08

EME Example

NB Rx Sen	126
Rx Antenna Gain	30
SS Gain	76
Tx Antenna Gain	30
Tx Output	20
	282

435 MHz EME Loss 282.27 dB

Spread Spectrum Part 97

- **§ 97.305 Authorized emission types.**

  SS modulation emission may be transmitted on:
  - 222-225 MHz, 420-450 MHz, 902-928 MHz
  - 1240-1300 MHz, 2300-2310 & 2390-2450 MHz
  - 3.3-3.5 GHz, 5.650-5.925 GHz, 10.00-10.50 GHz
  - 24.00-24.25 GHz, 47.0-47.2 GHz, 76-81.0 GHz
  - 122.25-123 GHz, 134-141 GHz, 241-250 GHz
  - Above 275 GHz
- **Maximum Power 100 W with APC**

Spread Spectrum Part 97

- **Station ID every 10 Min & end**
- **Detailed Transmission Logs only if directed**
  - SS method, frequencies, chip rate, the code rate, synchronization method, modulation type
  - Description of information
    - voice, text, data, facsimile, television, etc
  - Frequency used for Station ID
  - Transmission Start & Stop Times

Caution bad data on WWW

FCC Docket No 10-62

- **Notice of Proposed Rule Making (NPRM)**
  - Released March 16, 2010
- **Current**
  - Maximum Power 100 W with APC
- **Proposed**
  - Maximum Power 10 W no longer require APC

Ref #4,16

Spread Spectrum Part 15

WiFi

- Industrial, Scientific and Medical (ISM) bands
- Spread spectrum modulation, low-power radios coexist with ISM radiators.
- There are three bands, each to address the mixed use.
  - The first is for indoor use with integrated antenna for the consumer SS products & ISM sharing scope.
  - The second chunk is for mixed use
  - The third for outdoor use with provisions for a user-installable (23dBi) antenna.

0 dBW + 23 dB = 23 dBW (200 W) or up to 34 Miles LOS

Spread Spectrum Part 97 & 15

Use COTS as the core SS engine

- 1999 The FCC drop the spreading method restrictions allowing Amateur Radio use of 802.11 commercial equipment
- 2004 Linksys / Cisco WRT54 family of switch/routers go open source Linux

802.11 Protocol	Freq. GHz	Bandwidth MHz	Modulation
a	5	20	OFDM
b	2.4	20	DSSS
g	2.4	20	OFDM, DSSS
n	2.4/5	20	OFDM
n	2.4/5	40	OFDM

A great marriage

What good is Spread Spectrum

- **Advantages:**
  - "Processing Gain"
  - Resists interference
  - Has the ability to eliminate or alleviate the effect of multipath interference
  - Can share the same frequency band (overlay) with other users
- **Disadvantages:**
  - Bandwidth inefficient
  - Implementation ~~is~~ somewhat more complex
    - ASIC & DSP improving homebrew exponentially

Amateur Radio SS Resources

- KB9MWR Web site: www.qsl.net/kb9mwr/projects/wireless/plan.html
- TAPR Web site: www.tapr.org (out of date)
- 1995 QEX article by NK6K: http://www.qsl.net/n9zia/ss.qexss.html
- Green Bay Professional Packet Radio: www.gbppr.org
- ARRL Web site: http://www.arrl.org/tis/info/HTML/high-speed-digital/
  - "Nontraditional Field Day? You Bet! (HSMM)," (Eclectic Technology) Steve Ford, WB8IMY, QST, November 2006.
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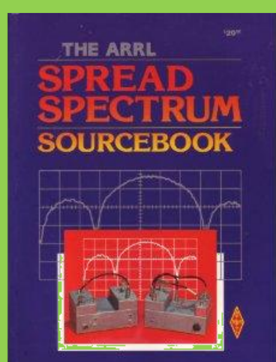
  - "HSMM Radio Equipment," John Champa, K8OCL, and John B. Stephensen, KD6OZH, QEX, November 2004.
  - "High Speed Multimedia Radio," Kris L. Mraz, N5KM, QST, April 2003.
  - "HSMM Experiments on the 6M Amateur Band," Progress Report on VHF OFDM Modem submitted by John B. Stephensen, KD6OZH.
  - "Using IEEE 802.11B Operating Under Part 97 of the FCC Rules," by Walt DuBose, K5YFW, et al.



American radio Relay League
"Spread Spectrum Sourcebook,"
ARRL, [1991]

- The only book just for Amateur Radio SS
- Great for understanding SS & Operation
- Very out of date in hardware & software
- Very out date for Part 97

Caution bad data on WWW

References

Ref #	Source Material
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