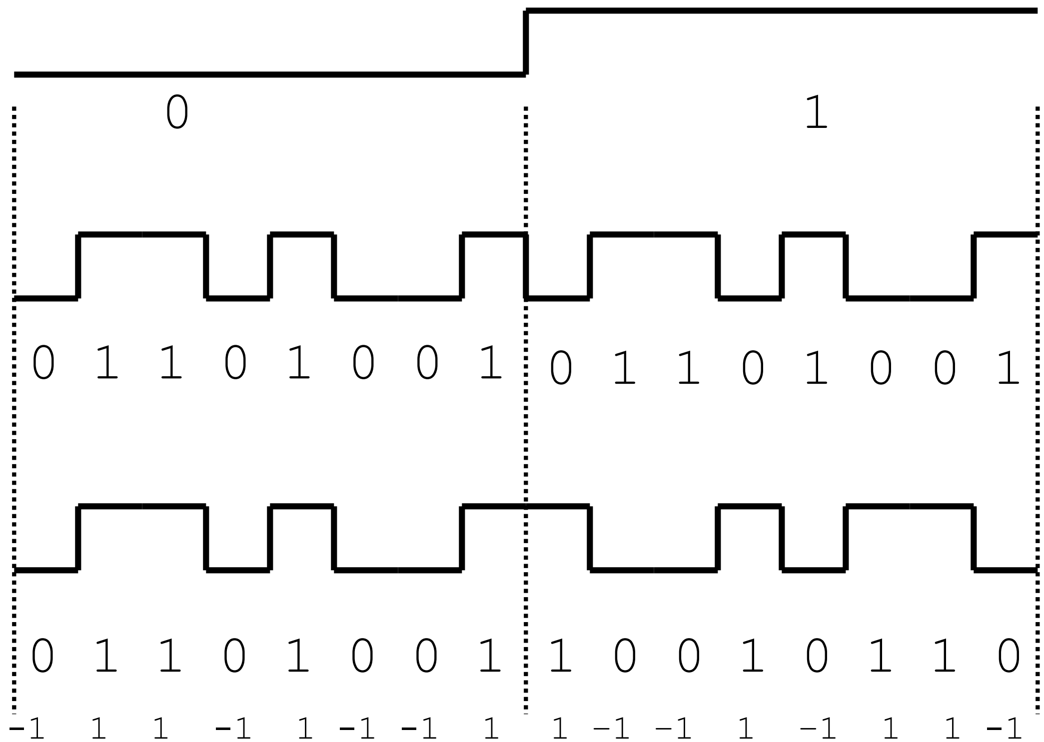
DSSS

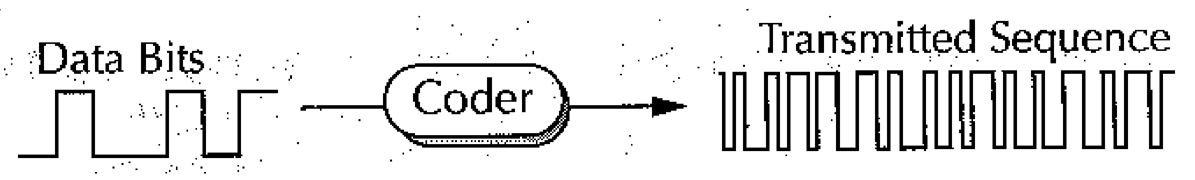
Direct Sequence Spread Spectrum (DSSS)

- Example modulating two symbols
- Data
- Code 7
  - 01101001
- Modulated code

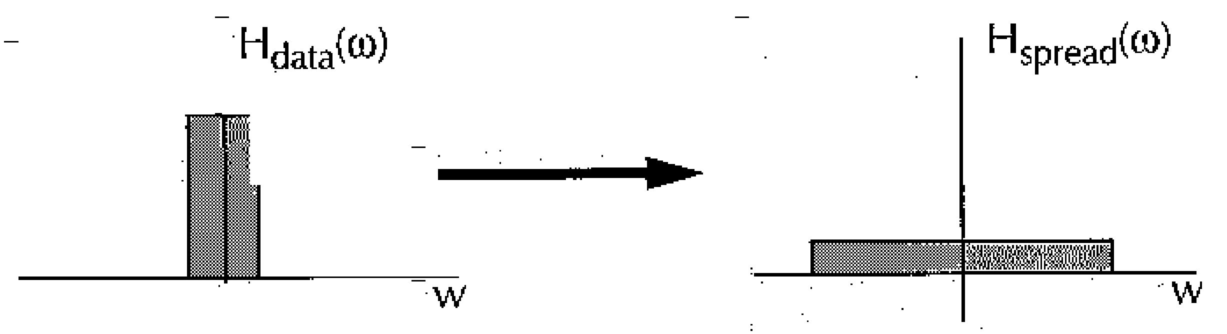


Direct Sequence Spread Spectrum (DSSS)

- Time Domain:
  Spread rate = N • Bit Rate



- Frequency Domain:
  Transmit bandwidth = N • Data bandwidth



[Sam Sheng, 1999]

Direct Sequence Spread Spectrum (DSSS)

- Transmission (spreading)
  - Each receiver assigned a unique orthogonal code
- Reception (despreading)
  - Done by correlation of the received signal with a synchronized replica of the spreading signal to recover transmitted data bits

Walsh Codes

- Length-8 Walsh code matrix
  - Built by recursively applying the Hadamard transform

0	0	0	0	0	0	0	0	unused
0	1	0	1	0	1	0	1	code 1
0	0	1	1	0	0	1	1	code 2
0	1	1	0	0	1	1	0	
0	0	0	0	1	1	1	1	
0	1	0	1	1	0	1	0	
0	0	1	1	1	1	0	0	
0	1	1	0	1	0	0	1	code 7

- Shown here with elements [0,1], but do math with [-1,+1]

Example Symbol I
7 users, Walsh 8 codes

- Input data (7 users)
  - -1 1 -1 1 1 1 -1
- Output waveform

  -1 -5 -1 3 3 -1 3 -1
- Received data
  - -8 8 -8 8 8 8 -8

Example Symbol I
7 users, Walsh 8 codes

- Input data (7 users)
    - -1 1 -1 1 1 1 -1
- Output waveform

  -1 -5 -1 3 3 -1 3 -1
- Output waveform + noise

  +3 -5 -1 3 3 -1 3 -1
- Received data
    - -8 8 -8 8 8 8 -8

Example Symbol II
7 users, Walsh 8 codes

- Input data
  - 1 1 -1 -1 -1 -1 -1
- Output waveform

  3 -1 -1 3 -5 -1 -1 3
- Received data
  - 8 8 -8 -8 -8 -8 -8

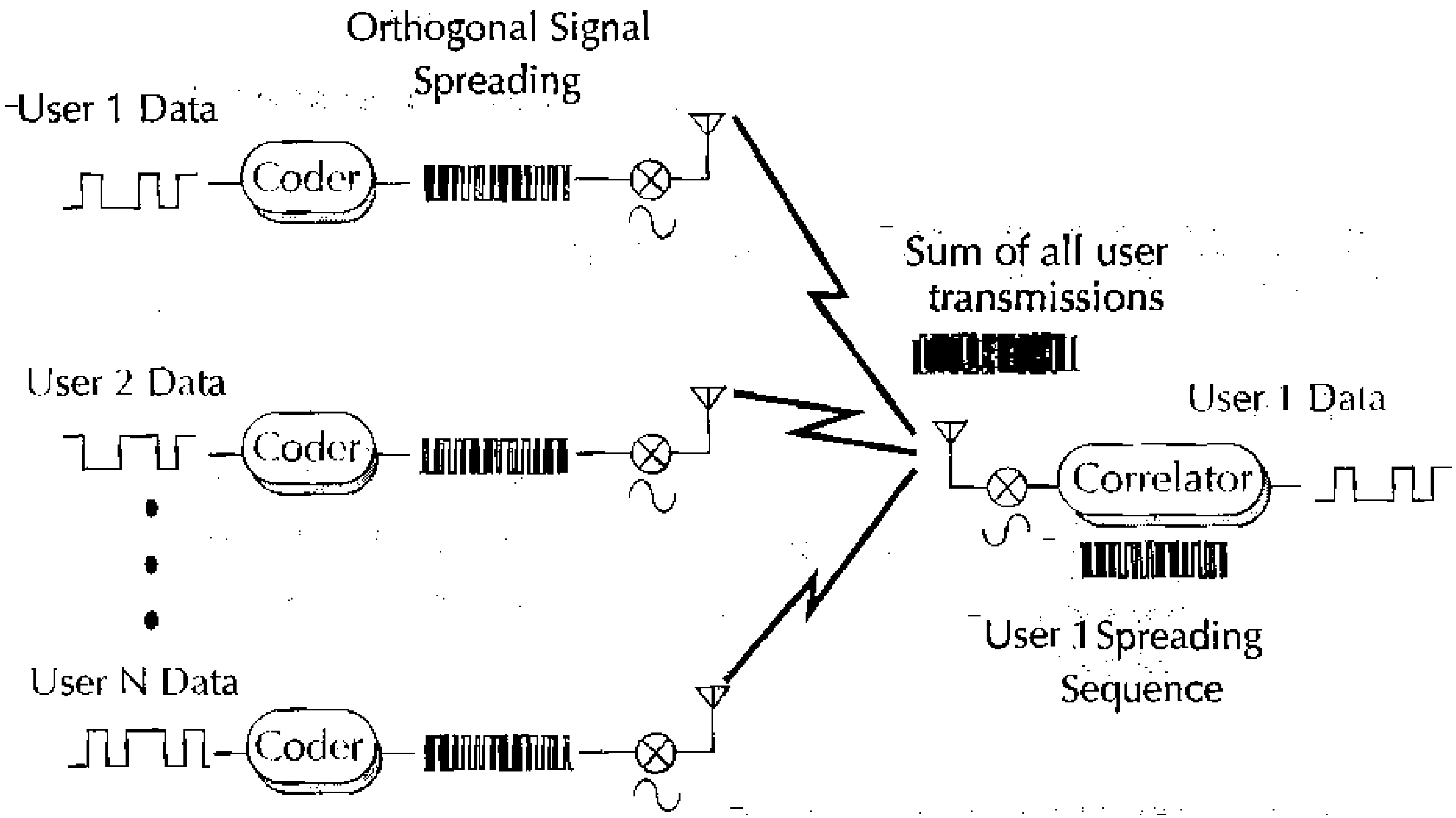
CDMA Code Properties

- Spreading codes should have special properties
  - 1) Autocorrelation as similar to an impulse as possible
    - One peak when a code is correlated against copies of itself
    - Multipath resilience
      - 00110011
        00110011
        00110011

CDMA Code Properties

- Spreading codes should have special properties
  - 2) Crosscorrelation as small as possible for pairs of codes
    - Want codes to be independent or orthogonal with respect to each other
    - Multiple user separation
      - One user's transmission on its code results in a net reception of approximately 0 on other codes
    - code 1 01010101
      code 2 00110011

Example CDMA "Reverse Link" (cell phone -> cell tower)



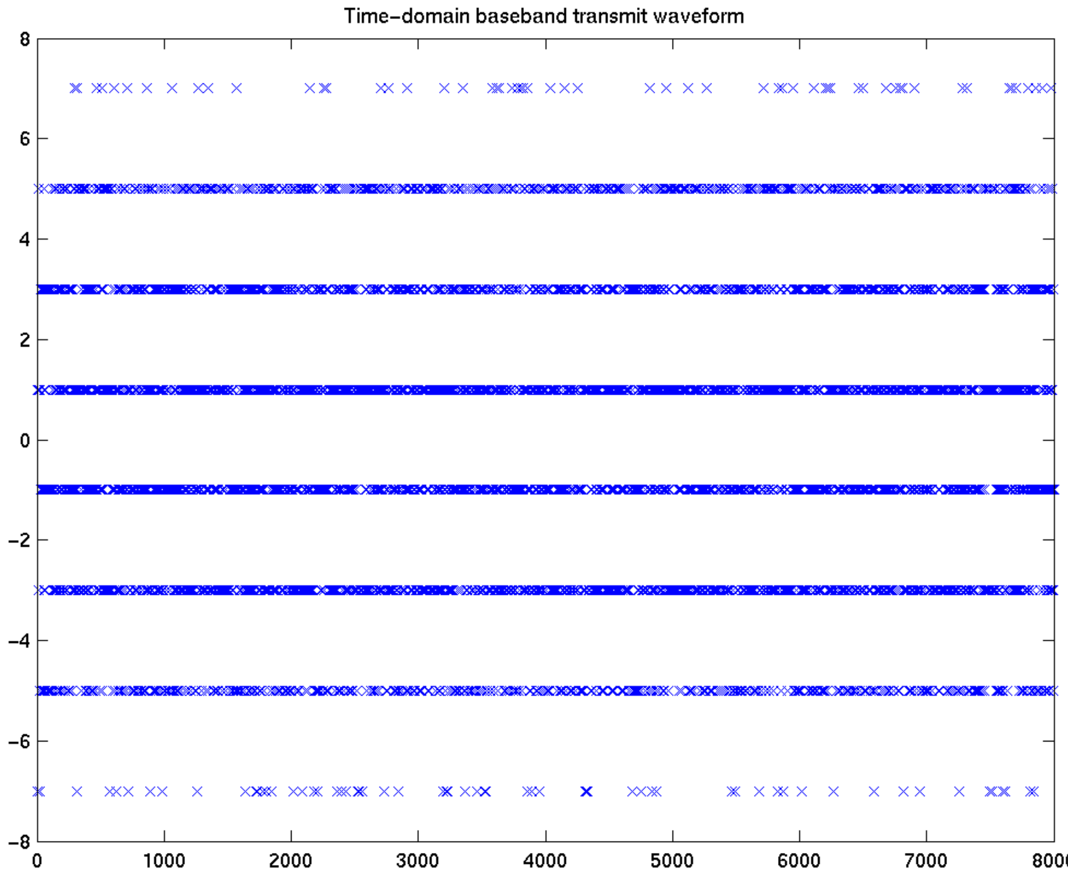
[Sam Sheng, 1999]

CDMA Example: IS-95

- Digital cellular system combines CDMA and FDMA
- Forward link (tower -> phone) different than reverse link
  - (Reverse link transmissions not synchronized)
- Uses 869-894 MHz (reverse) and 824-849 MHz (forward) bands
- Signal bandwidth 1.25 MHz, 0.27 MHz guard band
- Chip rate 1.2288 Mchips/s
- Orthogonal length-64 Walsh codes used for forward link (spreading factor of 64)

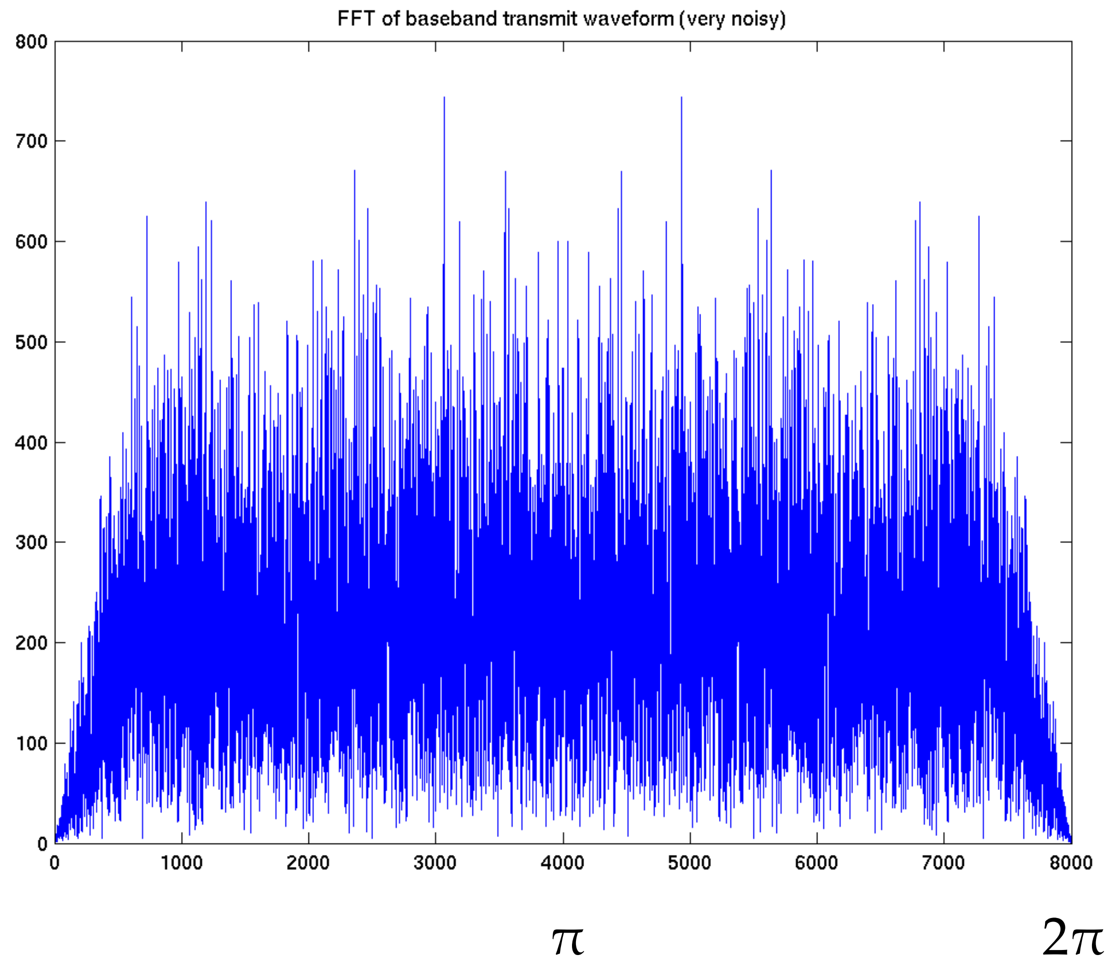
CDMA Transmit Samples

- Length-8 Walsh codes, 7 users, 1000 symbols
- Discrete valued samples [-7, +7]
- Odd values only



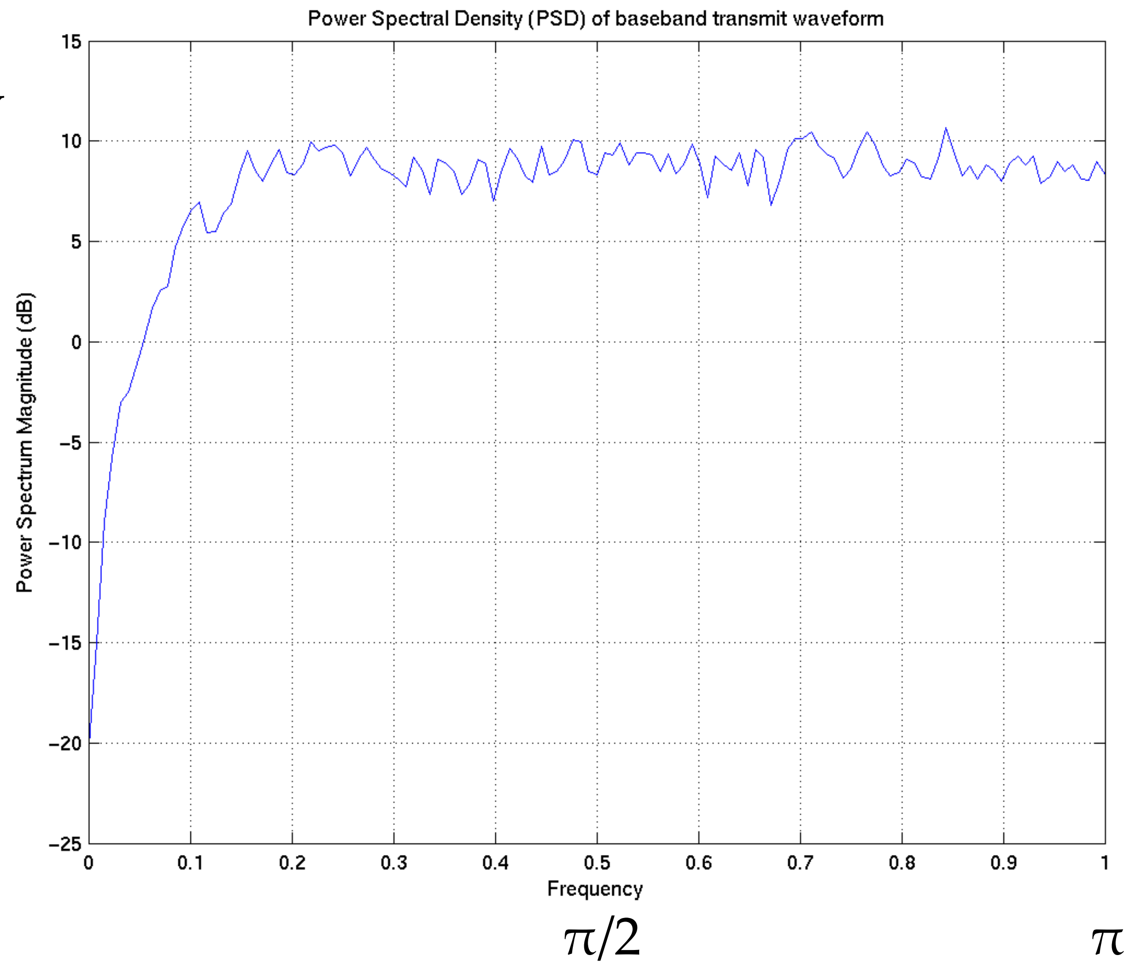
Baseband Transmit Spectrum

- `abs(fft(waveform))`
- 8000 frequency “bins” result in noisy approximation
- Remember the sampling frequency (f_s) is 2π in the digital frequency domain



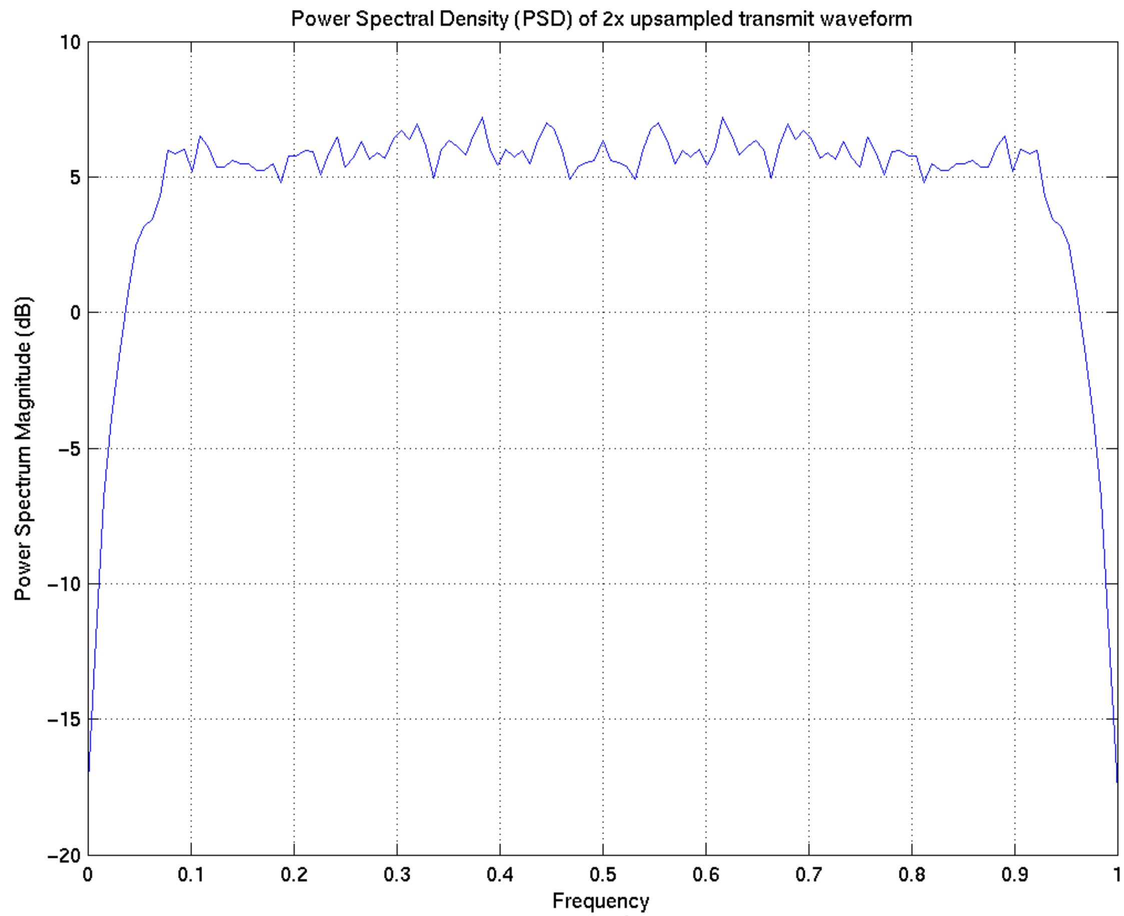
Baseband Transmit Spectrum

- `psd(waveform)`
- fewer frequency "bins"
- Note spectrum is zero at DC



2x Upsampled Transmit Spectrum

- Note null at DC now at π (one half f_s) also



$\pi/2$ π

4x Upsampled Transmit Spectrum

- Null at DC now at $\pi/2$, π, and $3\pi/2$ (not shown)