

DSSS

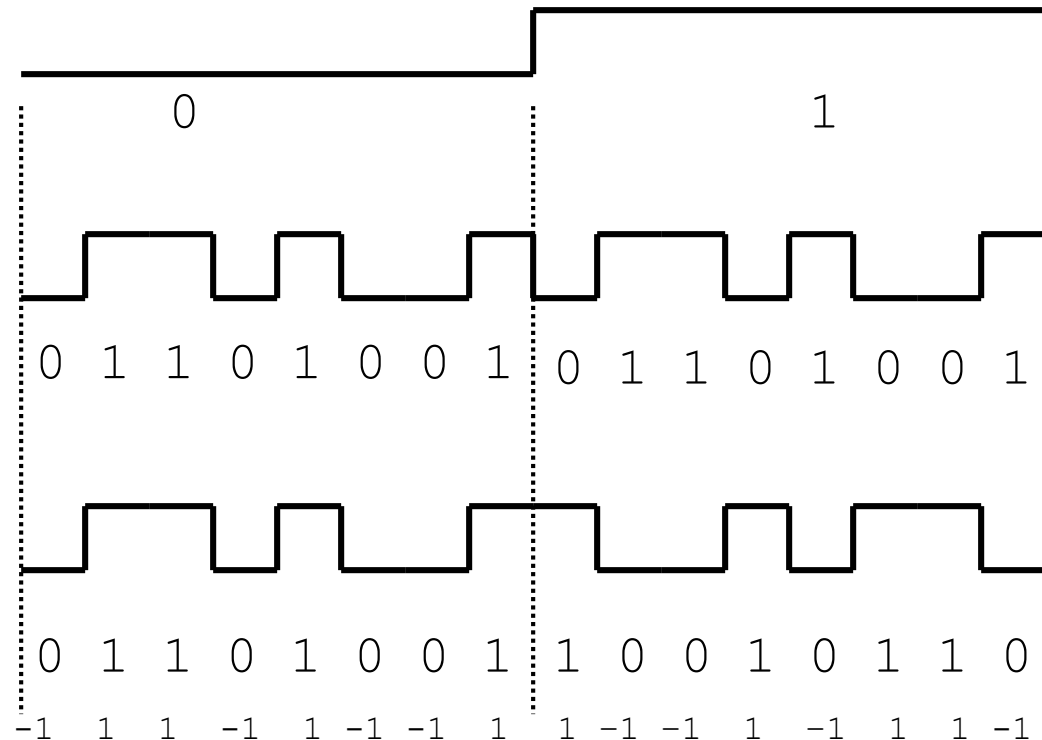
Direct Sequence Spread Spectrum (DSSS)

- Example modulating two symbols

- Data

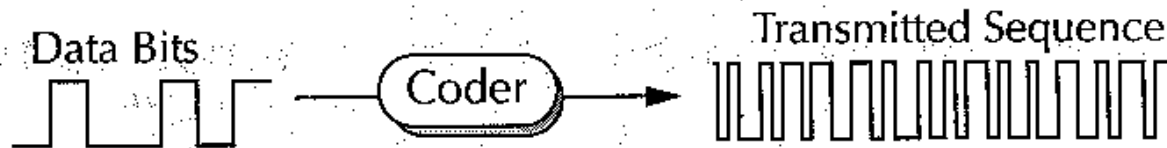
- Code 7
– 01101001

- Modulated code

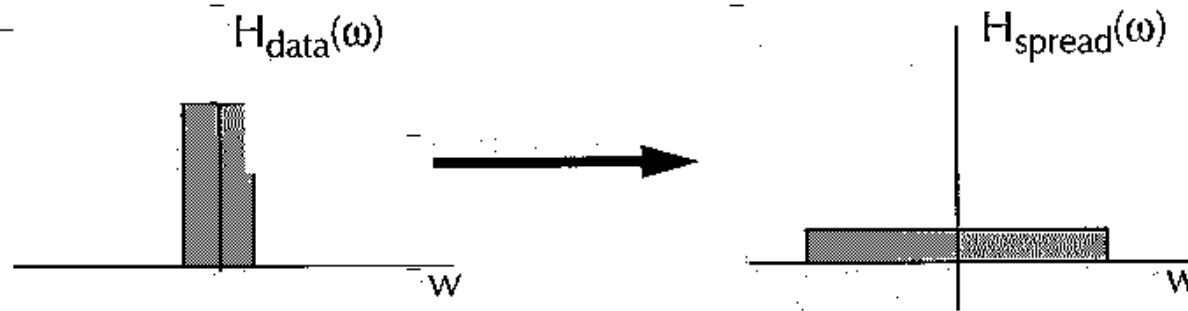


Direct Sequence Spread Spectrum (DSSS)

- Time Domain:
Spread rate = $N \bullet \text{Bit Rate}$



- Frequency Domain:
Transmit bandwidth = $N \bullet \text{Data bandwidth}$



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

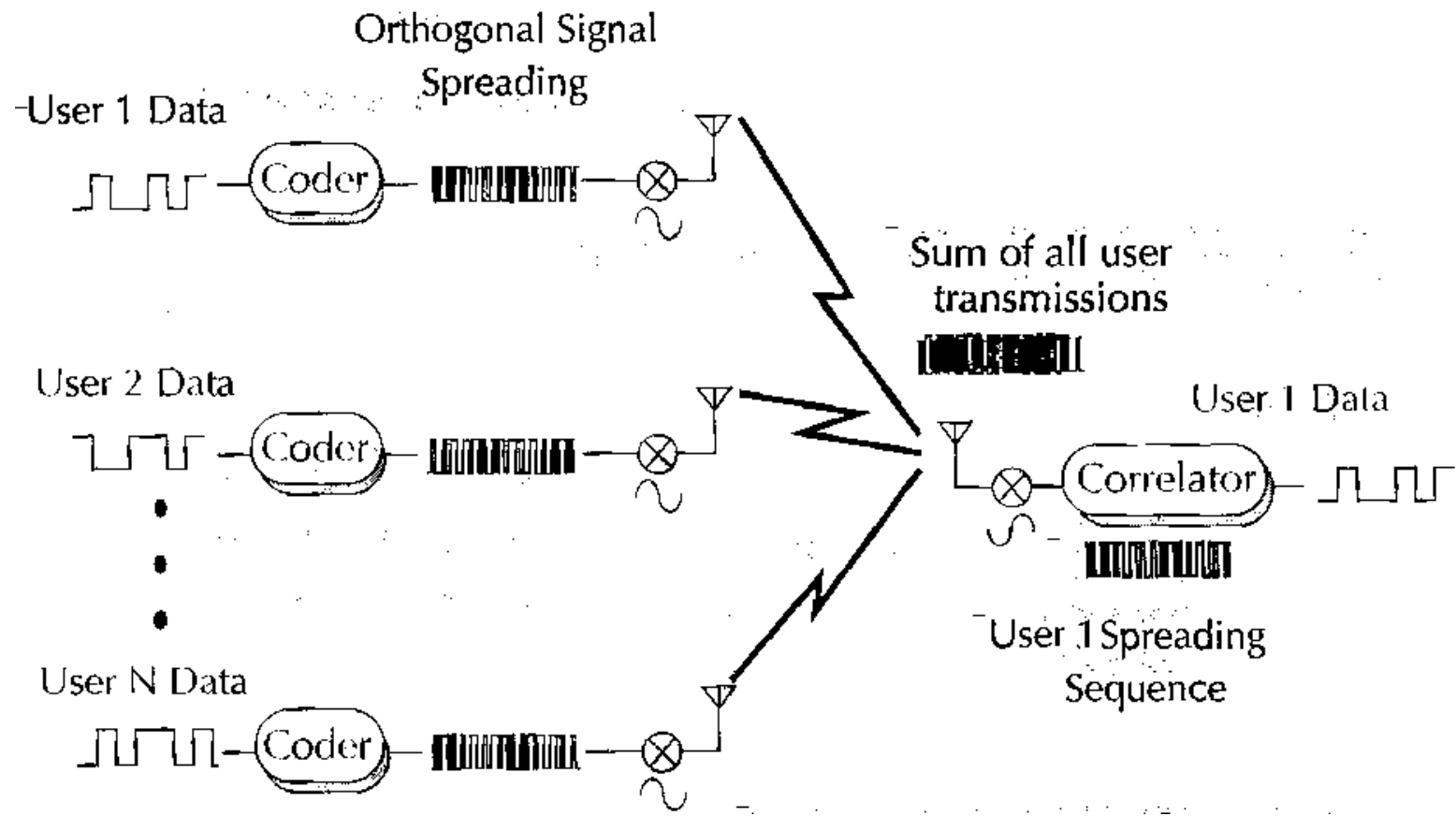
CDMA Code Properties

- 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)

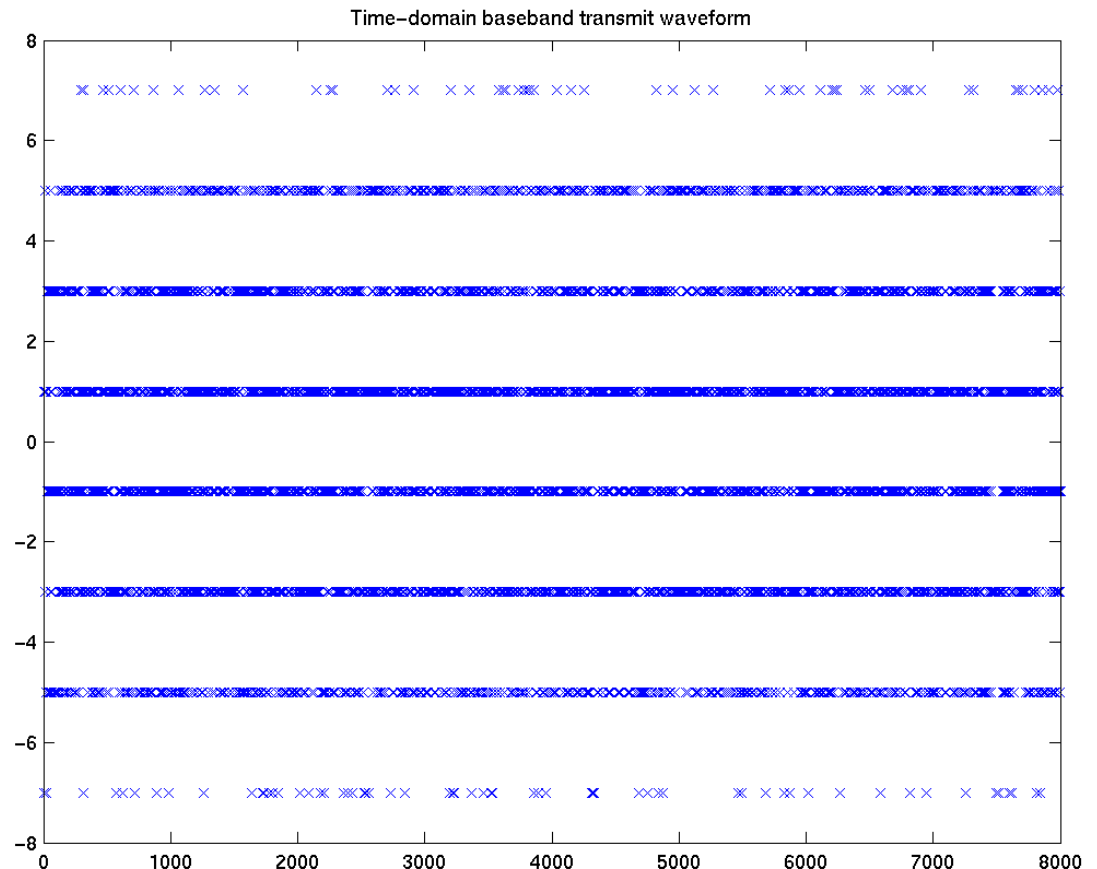


CDMA Example: IS-95

- 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)

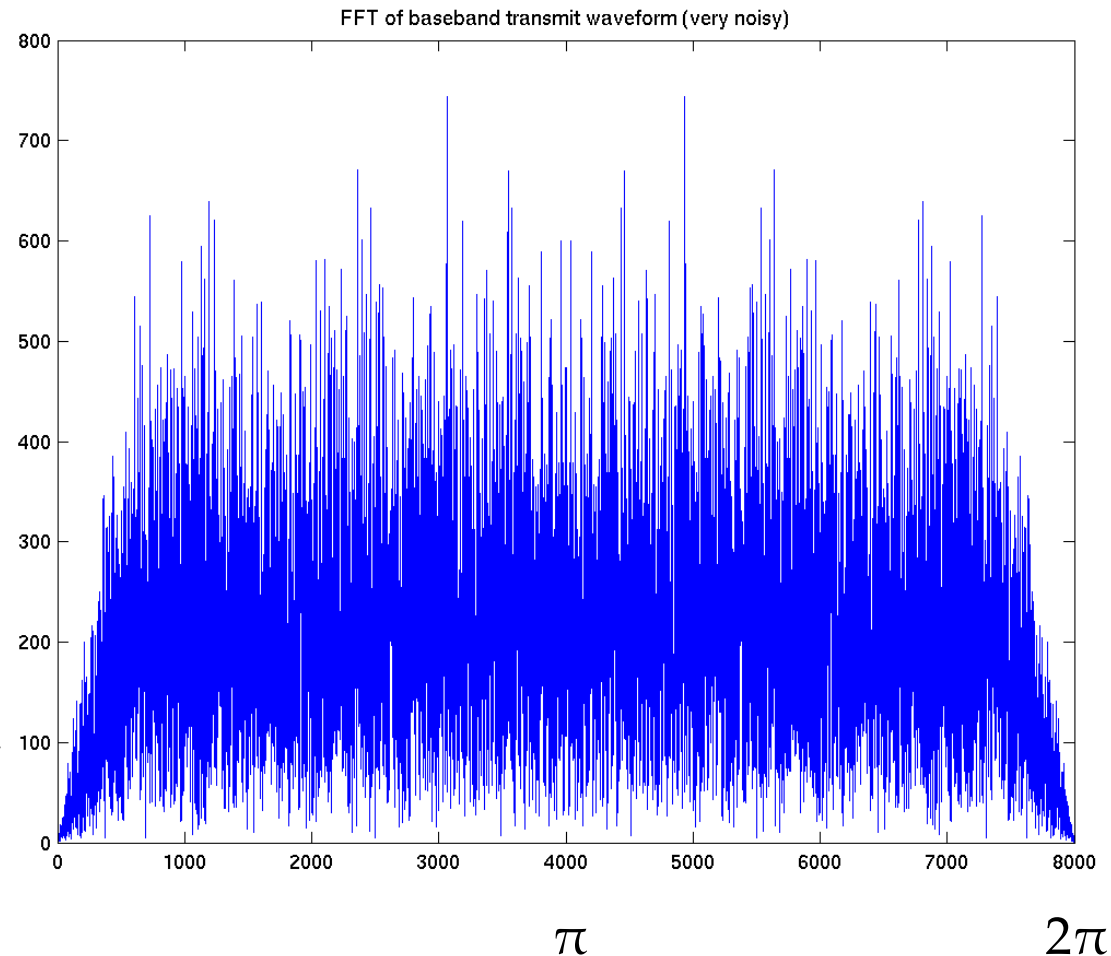
CDMA Transmit Samples

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



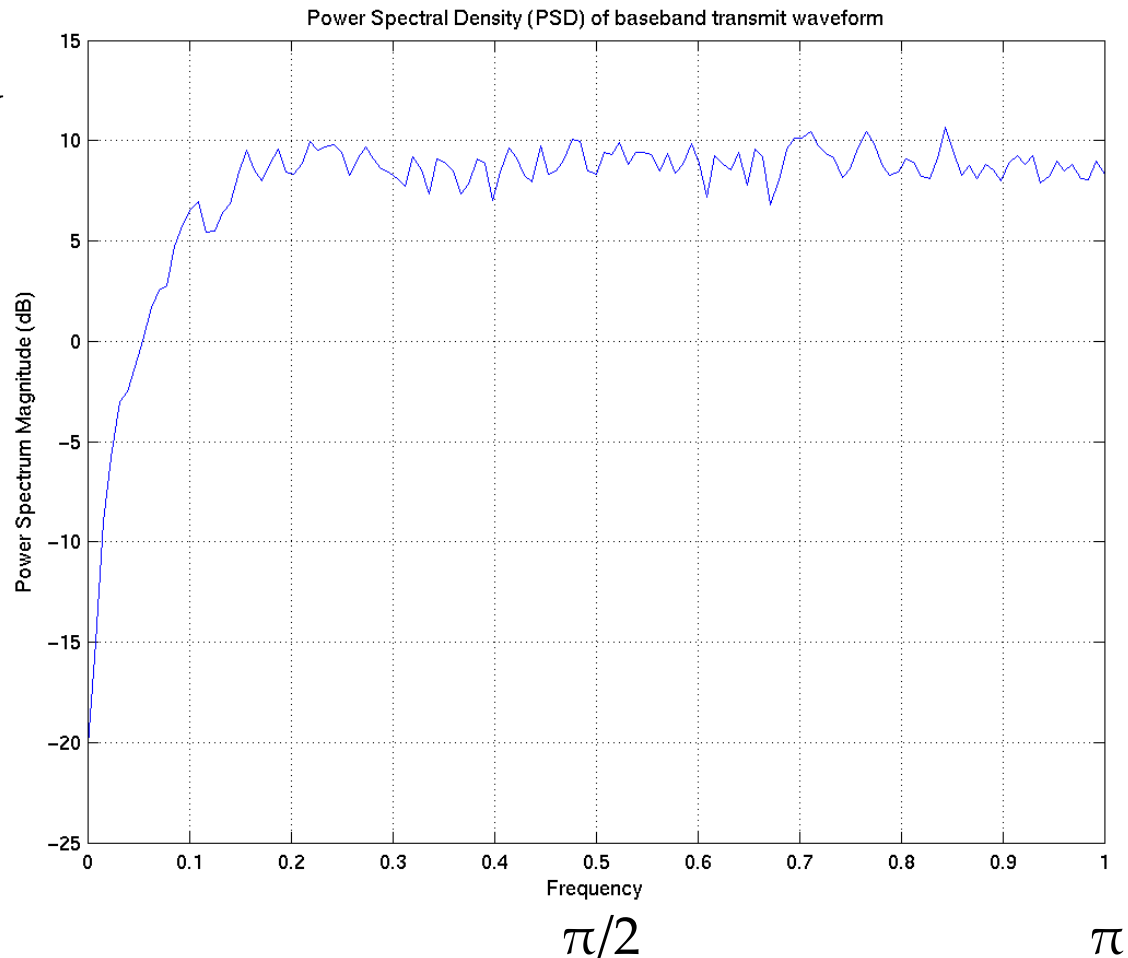
Baseband Transmit Spectrum

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



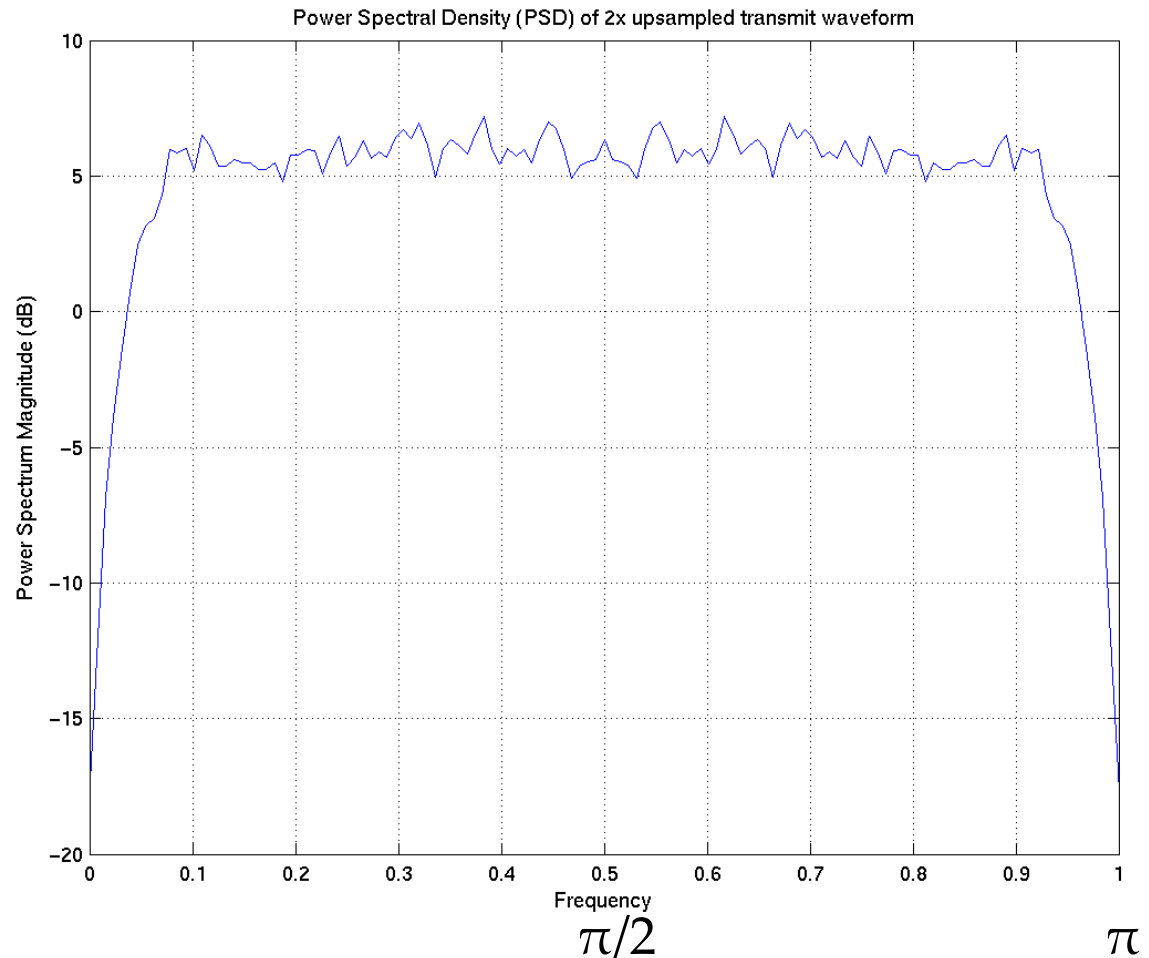
Baseband Transmit Spectrum

- `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



4x Upsampled Transmit Spectrum

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

