IEEE802.11a

- **OFDM**
- **IEEE802.11a**

Review

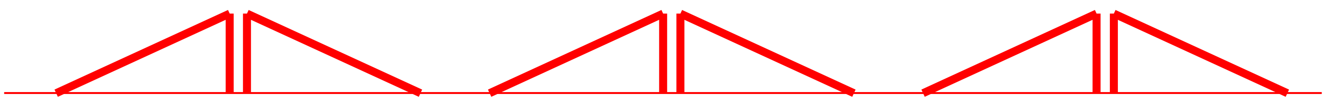
- IEEE 802.11 Architecture
- Protocol Structure
- PHY Layer
- MAC Layer

Physical Layers in IEEE 802.11a andb

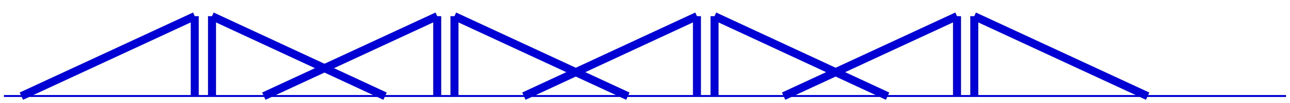
- **IEEE 802.11a**
  - **Makes use of 5-GHz band**
  - **Provides rates of 6, 9 , 12, 18, 24, 36, 48, 54 Mbps**
  - **Uses orthogonal frequency division multiplexing (OFDM)**
  - **Subcarrier modulated using BPSK, QPSK, 16-QAM or 64-QAM**
- **IEEE 802.11b**
  - **Provides data rates of 5.5 and 11 Mbps**
  - **Complementary code keying (CCK) modulation scheme based on DSSS.**

OFDM(1)

- FDM - problems
  - spectrally inefficient.
  - large no. of modulators & demodulators required.
- In OFDM
  - spectral inefficiency - overcome? use “orthogonal carriers”.
  - Second problem - overcome? use IFFT/FFT.
- Orthogonality of carriers
  - satisfy $$f_k = f_0 + \frac{k}{T_s}, k = 1,2,\ldots, N-1$$
  - time domain
    - » integer no. of cycles of each carrier in “Ts”.



Normal FDM required ‘guard bands’ to separate the channels



OFDM uses partially orthogonal carriers, allowing some overlap

OFDM (2)

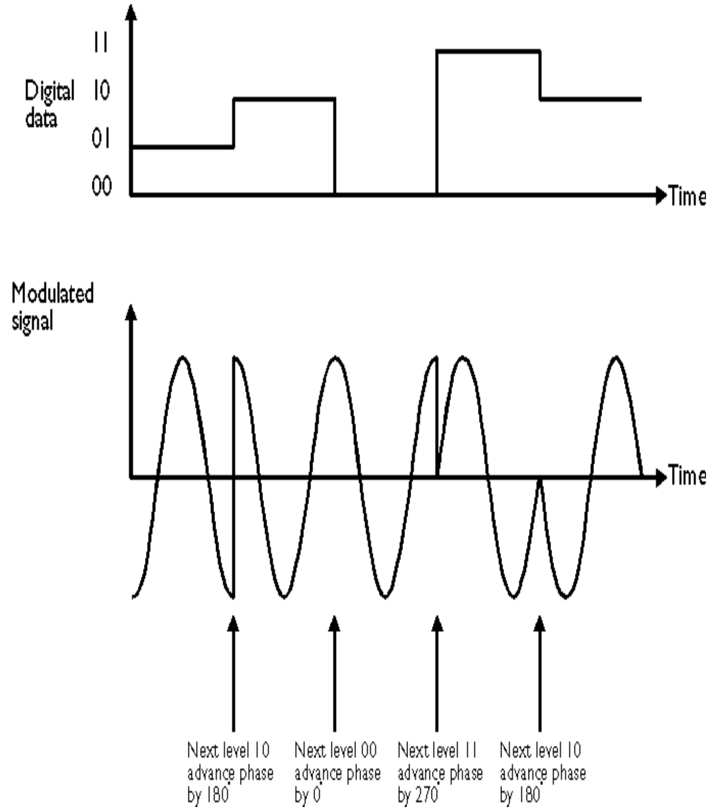
- **Multi-carrier modulation scheme**

Amplitud

Group Photo

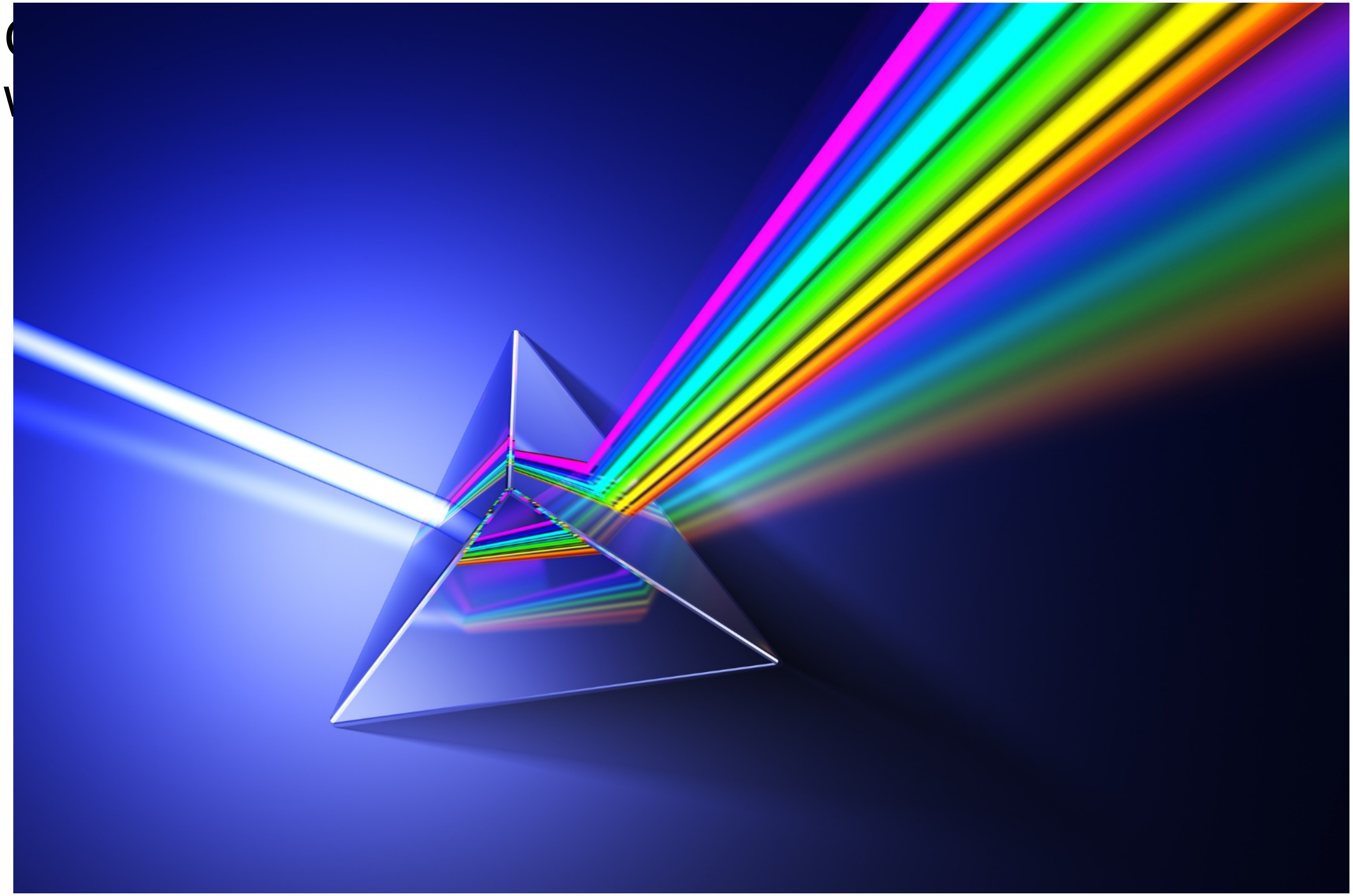
OFDM (3)

- **Parallel Data Streams**
- **Data Encoding is based on multi-level Modulation**
- **Multiple Carriers are combined through the Fourier Series**
  - **Computed by Inverse Fast Fourier transform**



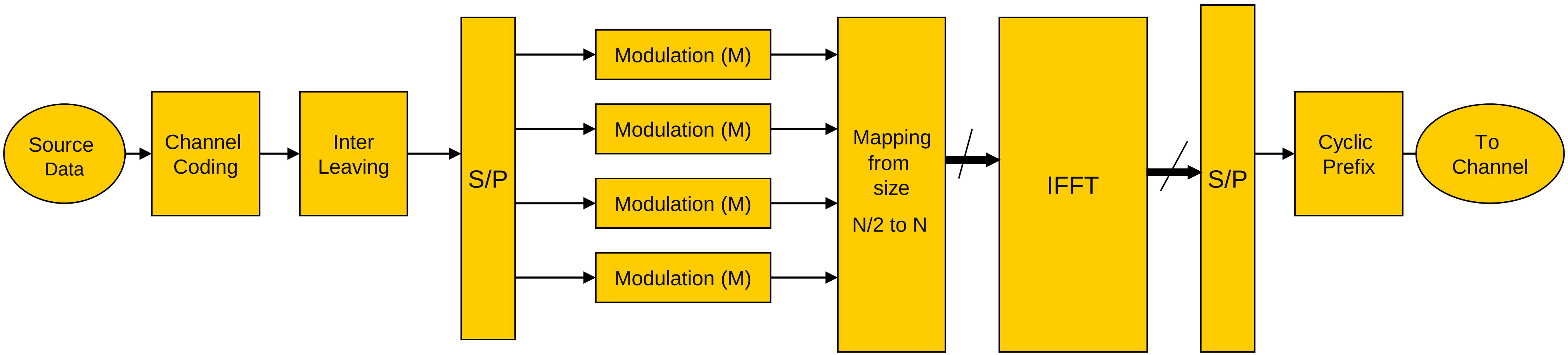
4-QAM modulation

OFDM (4)



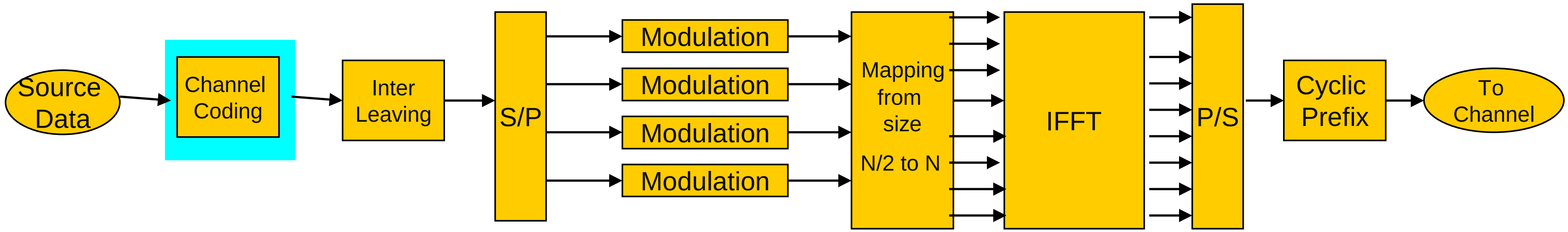
Prism – IFFT/FFT

OFDM Transmitter



Bits per OFDM symbol = (IFFT_Size/2) * $\log_2(M)$

Channel Coding



BCH Code	Convolutional code;
n = 31; k=16; t = 3;	Rate = ½ ; K=7

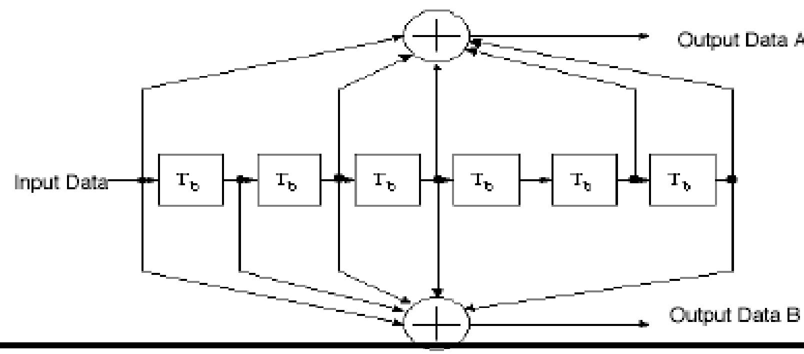
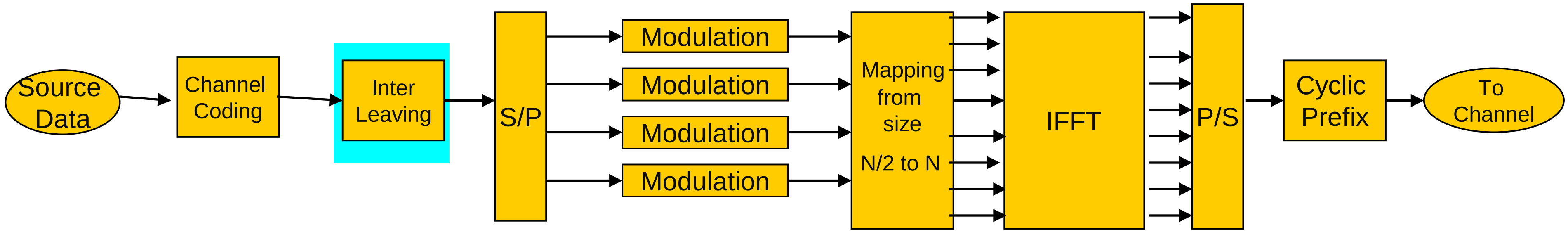


Figure 114—Convolutional encoder (k = 7)

Interleaving



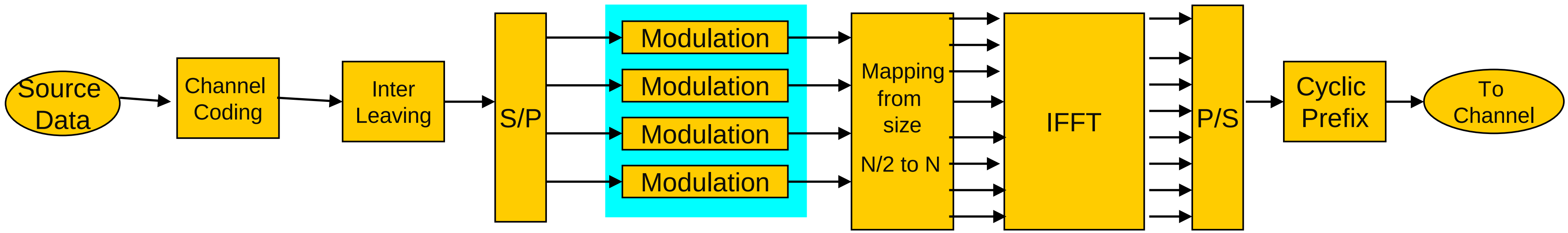
Fill in

b1	b4	b7	b10
b2	b5	b8	b11
b3	b6	b9	b12

Read out

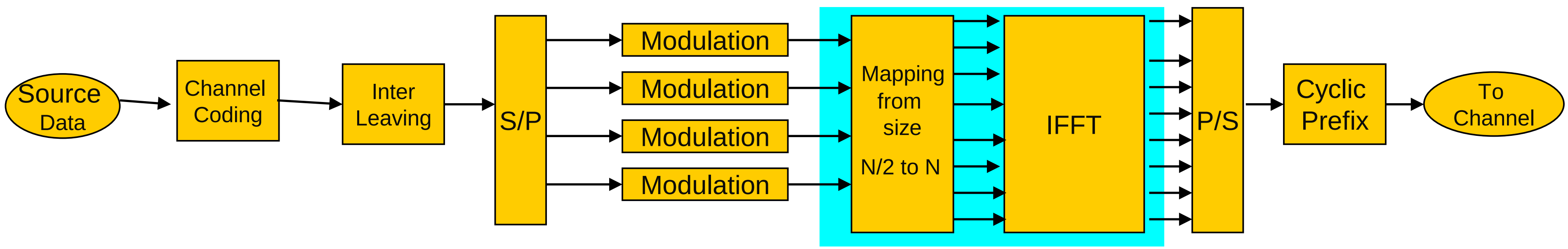
b1 b4 b7 b10 b2 b5 b8 b11 b3 b6 b9 b12

Modulation Schemes Used

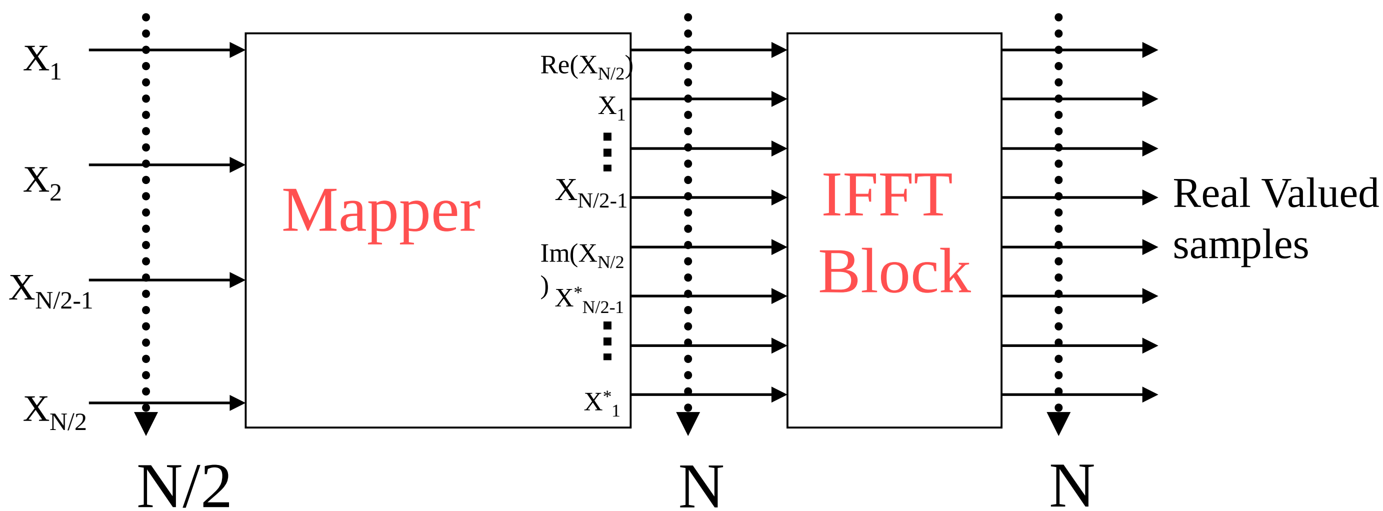


- QPSK (4-QAM)
- 16-QAM
- 64-QAM

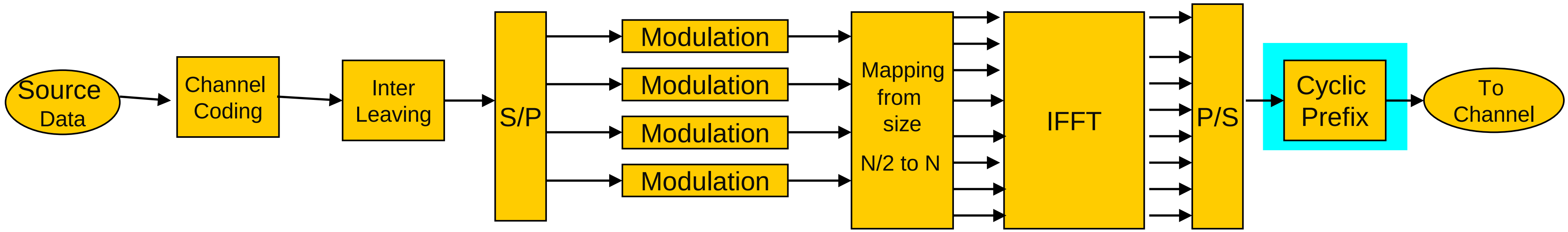
N/2 to N Mapper and IFFT



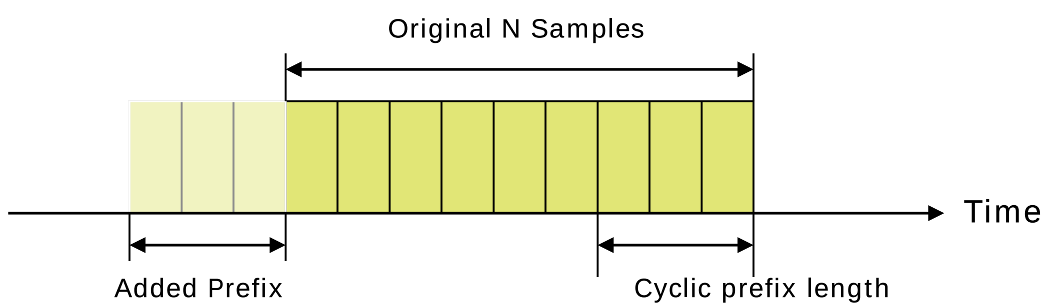
$$X^*_{n-k} = X_k \text{ where } k : 1, \ldots n/2$$



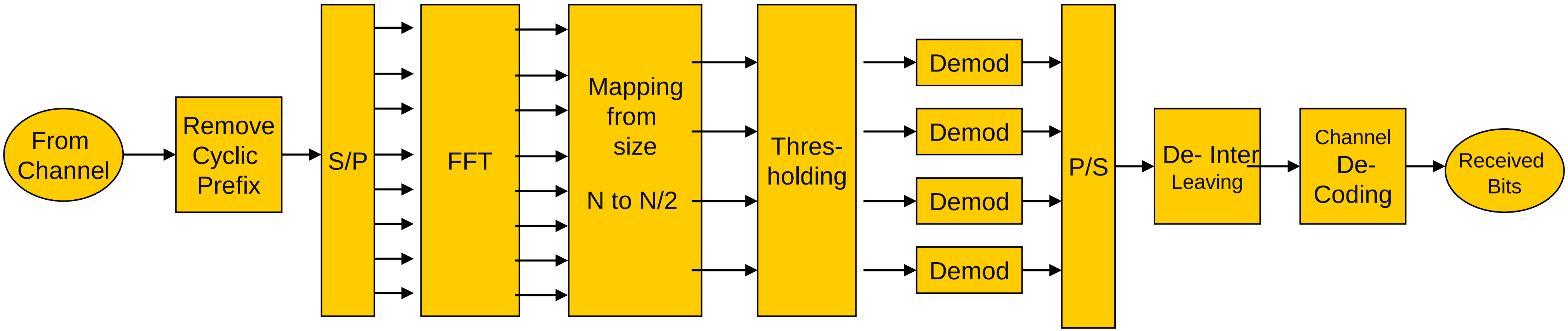
Adding cyclic prefix



$$x(n) * h(n) = X(k)H(k)$$



OFDM Receiver

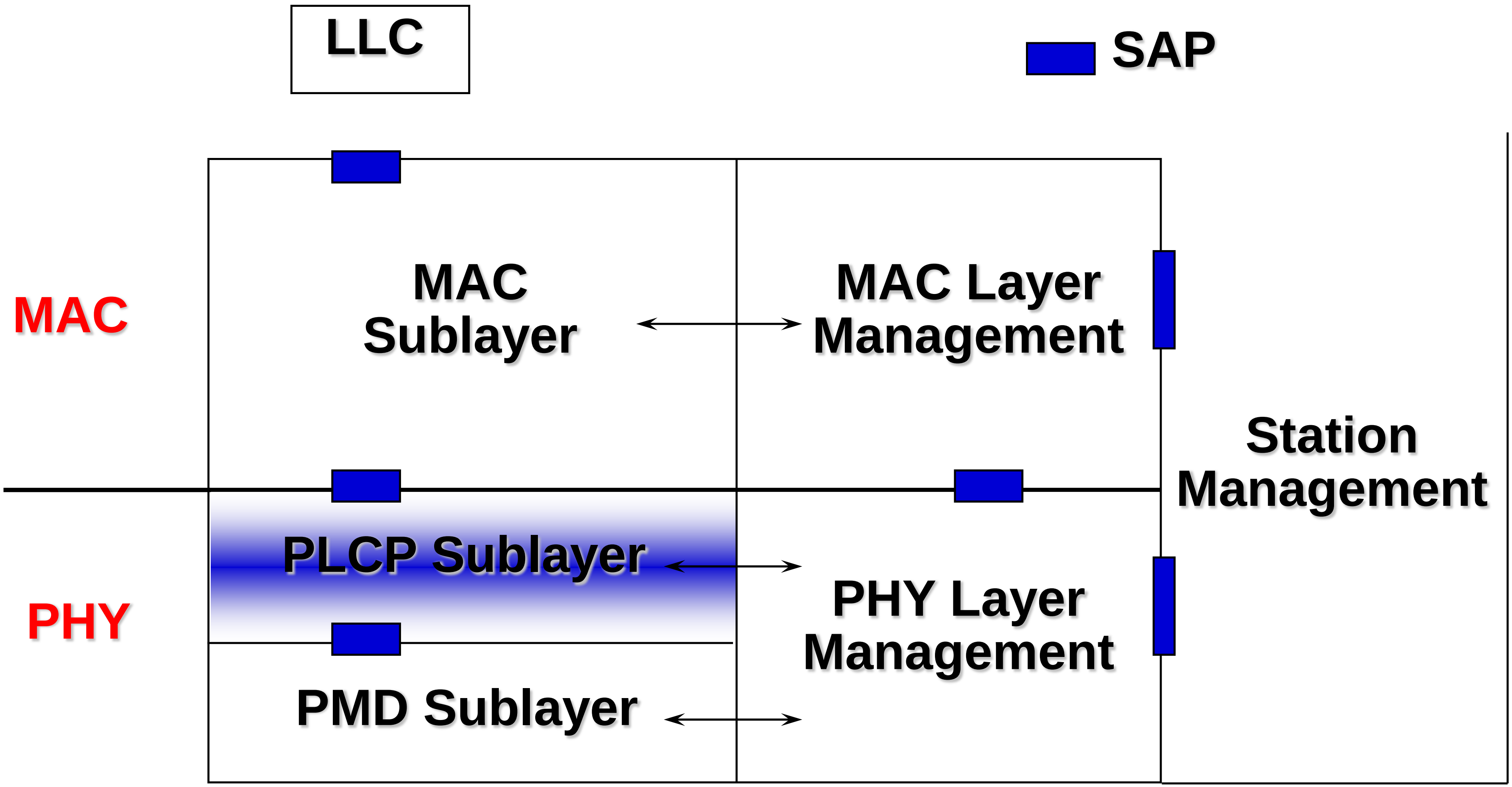


Why OFDM?

- Reduces ISI and effects of frequency selective fading, eliminating the need for equalization
  - *Time domain*: lengthened symbol period is larger than the channel time dispersion.
  - *Frequency domain*: each subchannel has sufficiently small width and can be considered ideal (i.e. flat).
  - To completely remove ISI and ICI, it's necessary to add a cyclic prefix, which causes negligible rate loss.
- Spectrally efficient
- Less sensitive to sample timing offsets than single carrier systems

Physical Layer Specification (in IEEE 802.11a)

PLCP (PHY Convergence) Sublayer

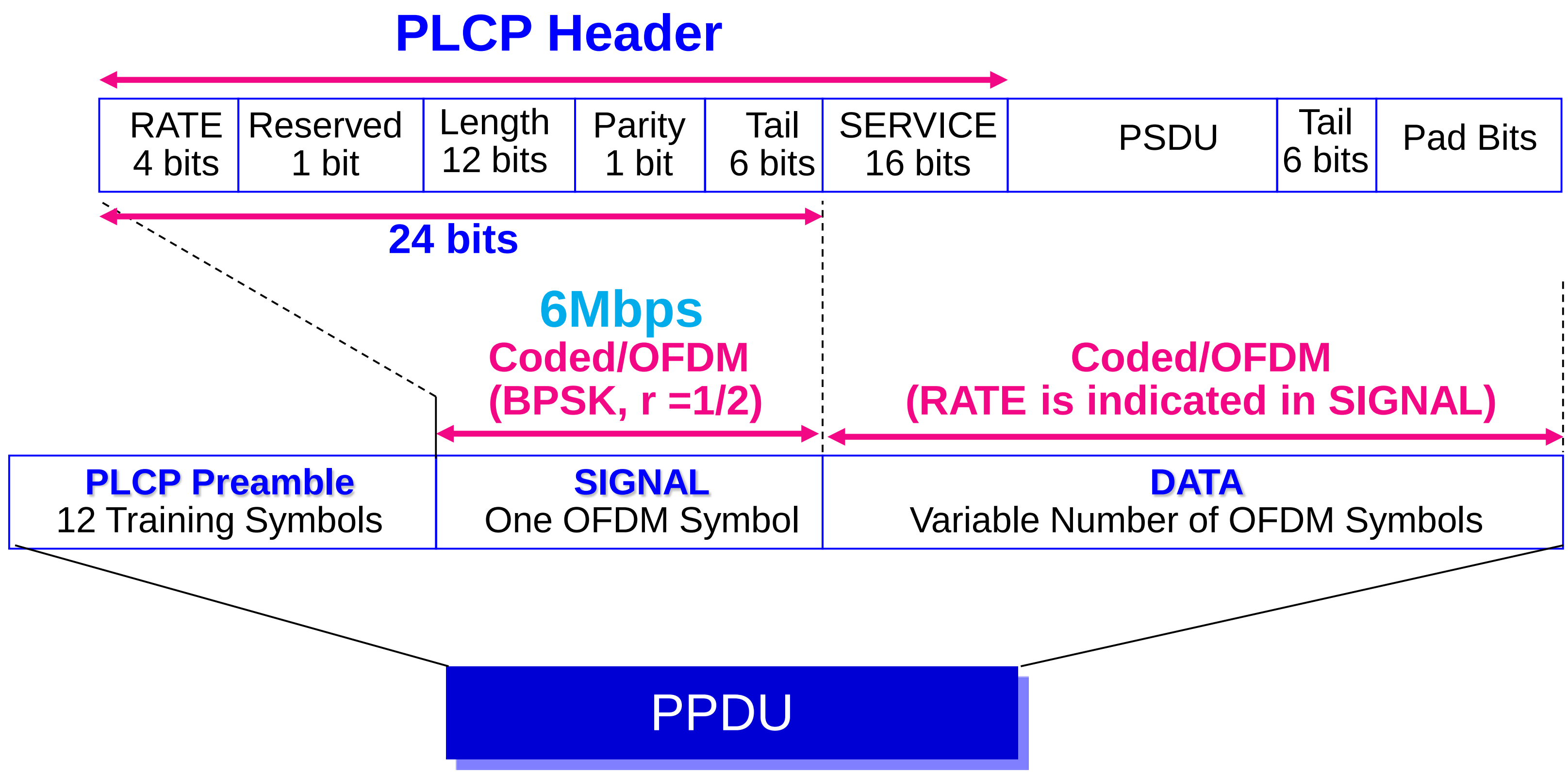


IEEE 802.11a PLCP

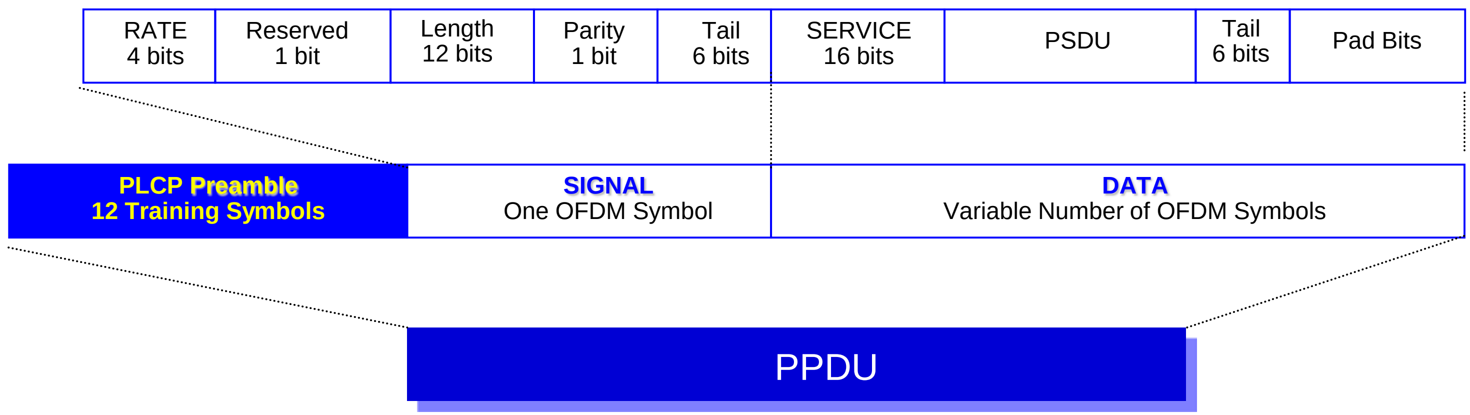
Table 77—RXVECTOR parameters

Parameter	Associate primitive	Value
LENGTH	PHY-RXSTART.indicate	1–4095
RSSI	PHY-RXSTART.indicate (RXVECTOR)	0–RSSI maximum
DATARATE	PHY-RXSTART.request (RXVECTOR)	6, 9, 12, 18, 24, 36, 48, and 54
SERVICE	PHY-RXSTART.request (RXVECTOR)	Null

IEEE 802.11a PLCP frame format

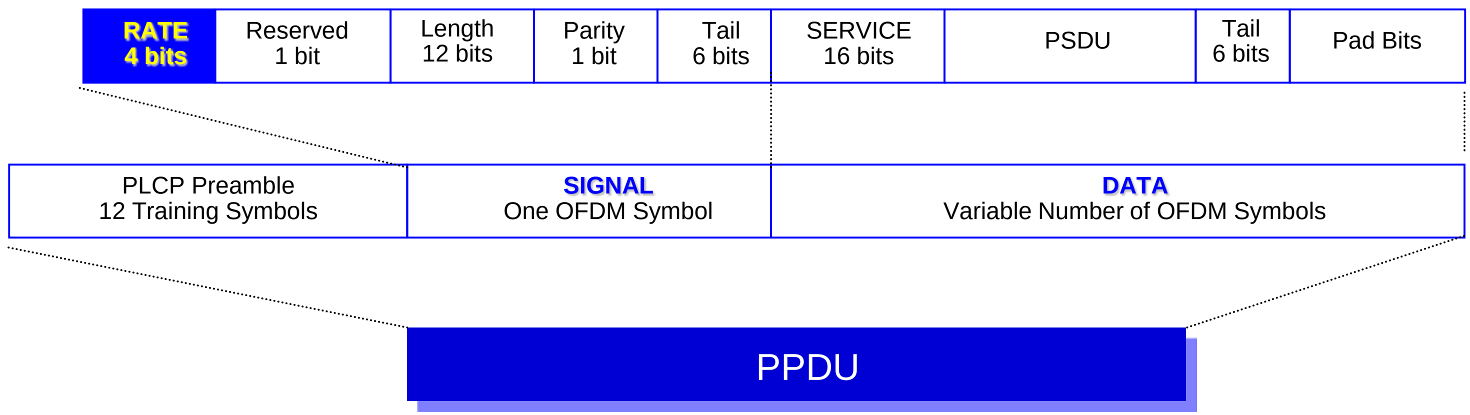


PLCP Preamble



1. **preamble field contains**
   - **10 short training sequence**
     - » used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver
   - **2 long training sequence**
     - » used for channel estimation and fine frequency acquisition in the receiver
   - **and a guard interval (GI)**

PLCP Rate/Length



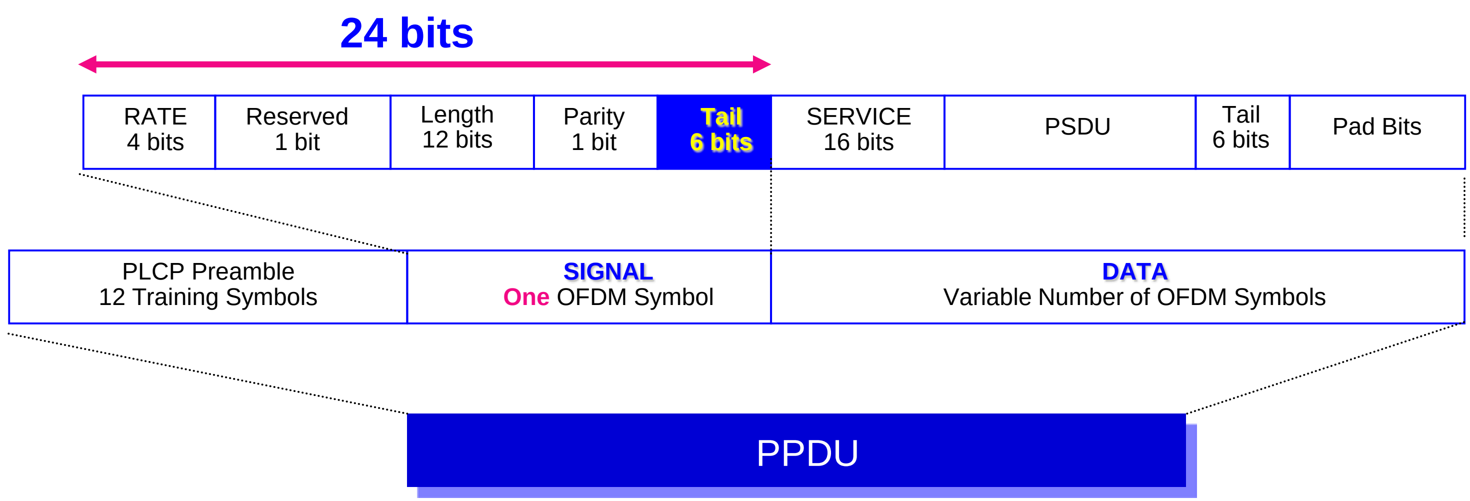
- **Data Rates (determined from TXVECTOR)**
  - **1101 : 6Mbps (M)**
  - **1111 : 9Mbps**
  - **0101 : 12Mbps (M)**
  - **0111 : 18Mbps**
  - **1001 : 24Mbps (M)**
  - **1011 : 36Mbps**
  - **0001 : 48Mbps**
  - **0011 : 54Mbps**

Rate-dependent Parameters

Table 78—Rate-dependent parameters

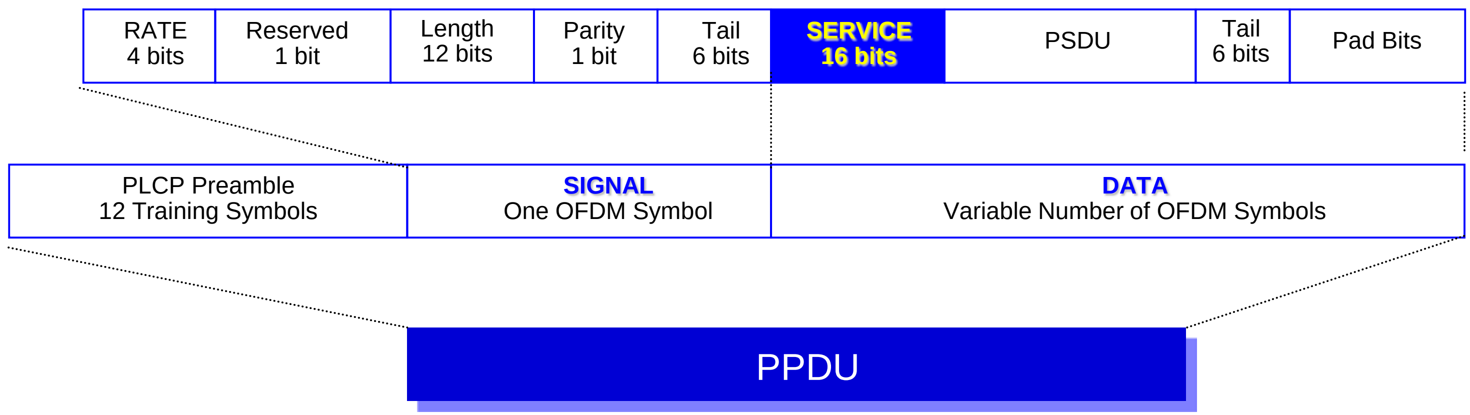
Data rate (Mbits/s)	Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})	
$\boxed{6}$	BPSK	1/2	1	48	$\boxed{24}$	(for SIGNAL field)
9	BPSK	3/4	1	48	36	
12	QPSK	1/2	2	96	48	
18	QPSK	3/4	2	96	72	
24	16-QAM	1/2	4	192	96	
36	16-QAM	3/4	4	192	144	
48	64-QAM	2/3	6	288	192	
54	64-QAM	3/4	6	288	216	

PLCP Tail Subfield

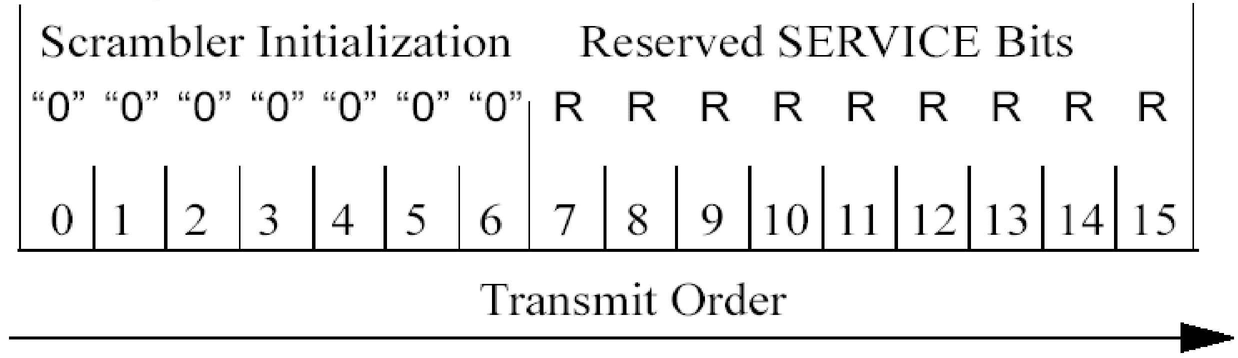


- **6 'zero' bit**
- **to make the length of SIGNAL field to be 24 bits (for the N_{DBPS}=24 in 6Mbps mode)**
- **to facilitate a reliable and timely detection of the RATE and LENGTH fields**

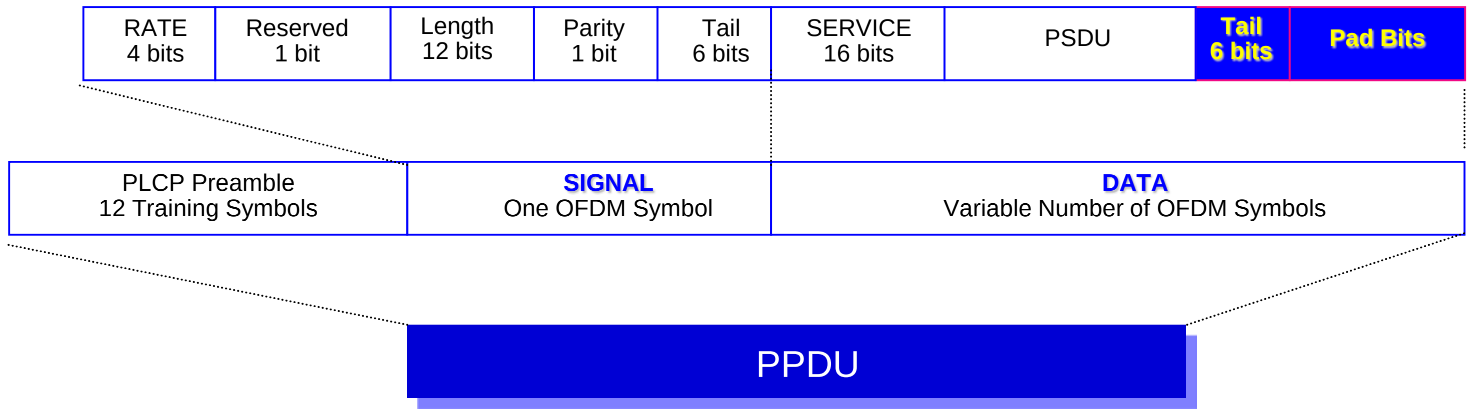
PLCP Service



For synchronization

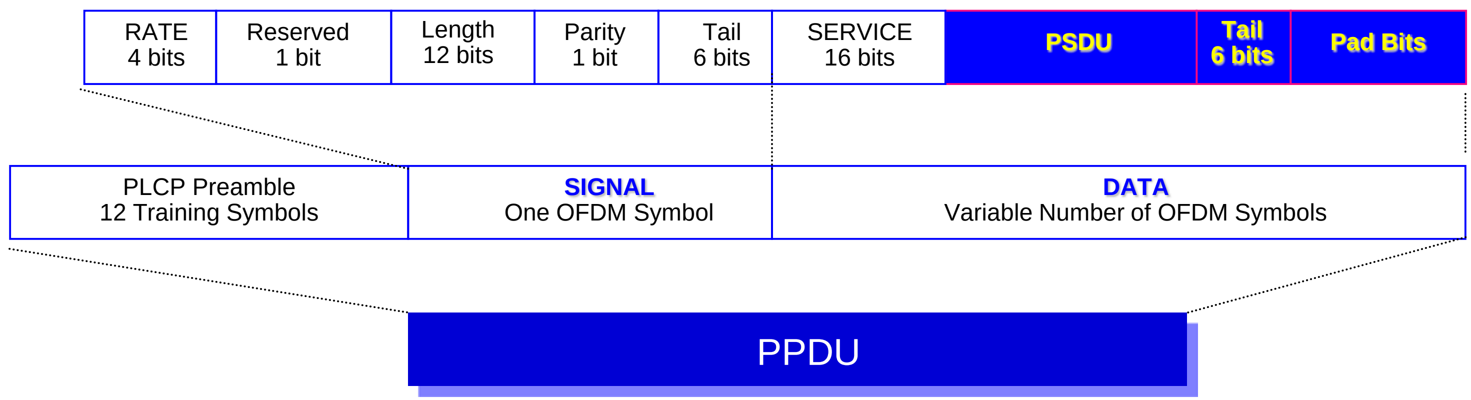


PLCP PSDU tail



- Append **6** non-scrambled tail bits for PSDU to return the convolutional code to the "zero state"
- Add pad bits (with "zero" and at least 6 bits) such that the length of DATA field is a multiple of $\mathbf{N_{DBPS}}$

PLCP DATA encoding



1. encode data string with convolutional encoder (include punctured coding)
2. divide encoded bit string into groups of **N_{CBPS}** bits
3. within each group, perform data interleaving
4. For each of the groups, convert bit string group into a complex number according to the modulation tables (see next page)
5. divide the complex number string into groups of **48** complex numbers, each such group will be associated with one OFDM symbol
   - map to subcarriers –26~-22, -20~-8, -6~-1, 1~6, 8~20, 22~26
   - **4** sucarriers –21, -7, 7, 21 are used for pilot
   - subcarrier 0 is useless
6. convert subcarriers to time domain using inverse Fast Fourier transform (IFFT)
7. append OFDM symbols after SINGNAL and un-convert to RF freq.

Modulation Tables

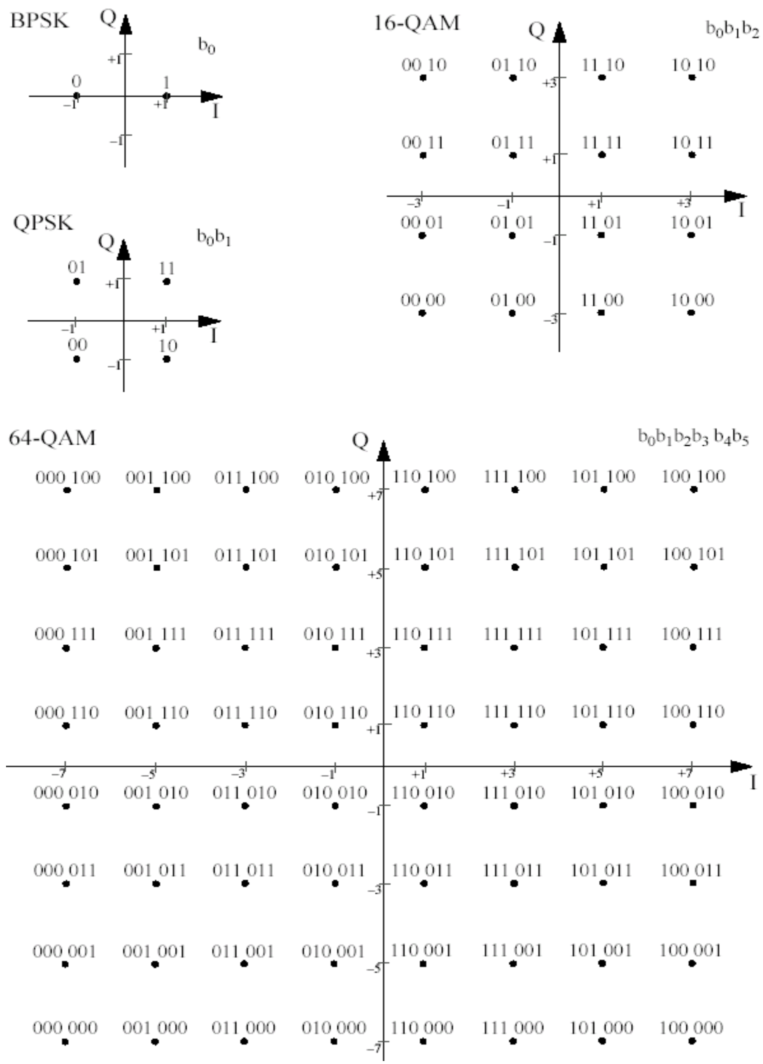


Table 82—BPSK encoding table

Input bit (b_0)	I-out	Q-out
0	–1	0
1	1	0

Table 83—QPSK encoding table

Input bit (b_0)	I-out
0	–1
1	1

Input bit (b_1)	Q-out
0	–1
1	1

Table 84—16-QAM encoding table

Input bits (b_0 b_1)	I-out
00	–3
01	–1
11	1
10	3

Input bits (b_2 b_3)	Q-out
00	–3
01	–1
11	1
10	3

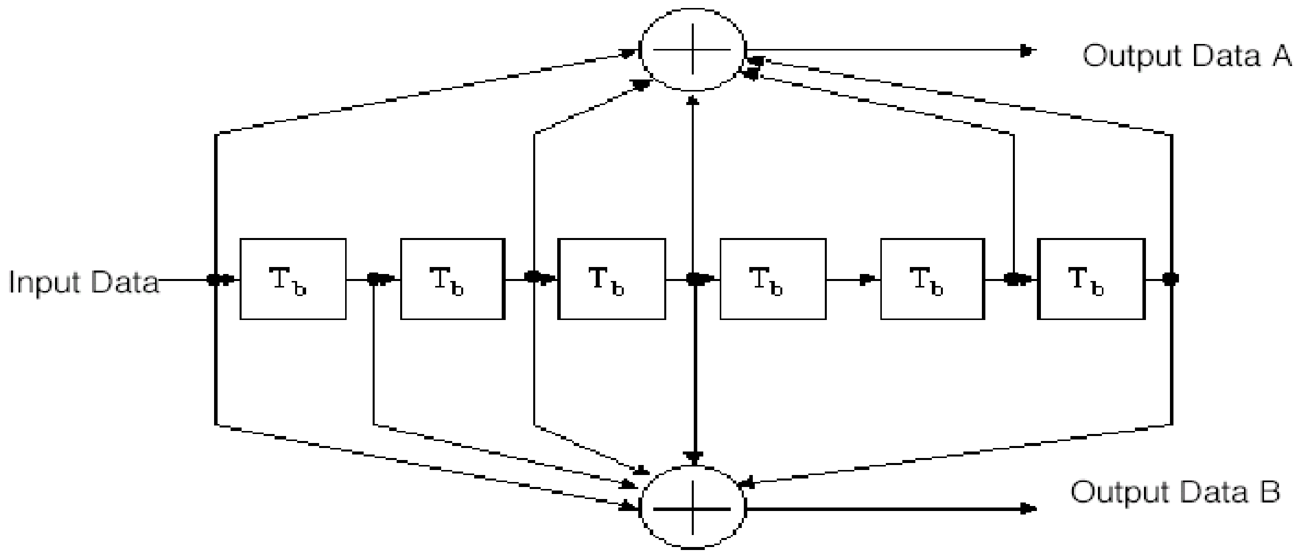
Table 85—64-QAM encoding table

Input bits (b_0 b_1 b_2)	I-out
000	–7
001	–5
011	–3
010	–1
110	1
111	3
101	5
100	7

Input bits (b_3 b_4 b_5)	Q-out
000	–7
001	–5
011	–3
010	–1
110	1
111	3
101	5
100	7

Convolutional Encoder

- use the industry-standard generator polynomials,
  - g0 = 133_8 and g1 = 171_8, of rate R = 1/2,



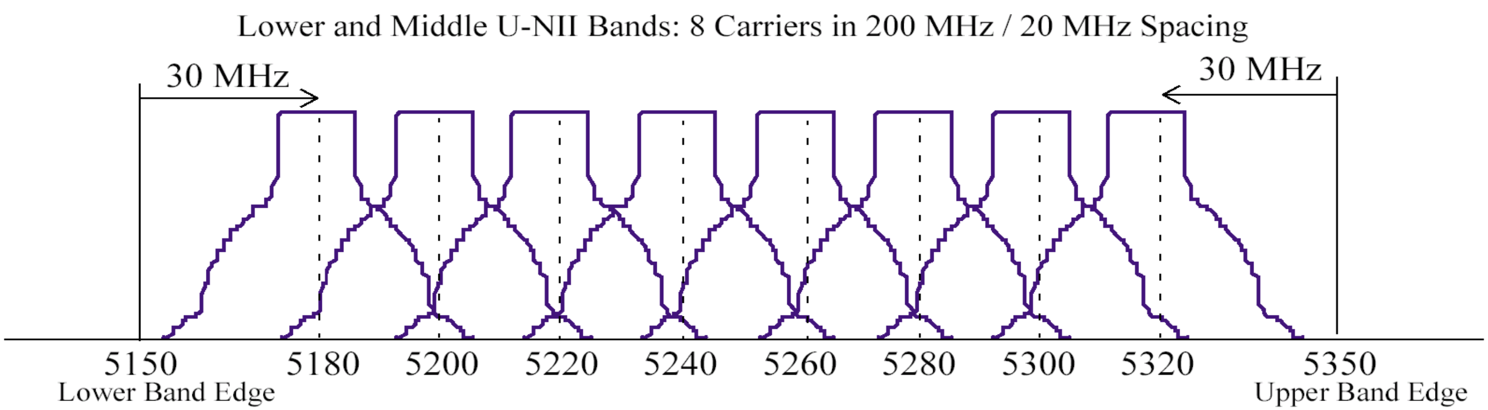
(first output)

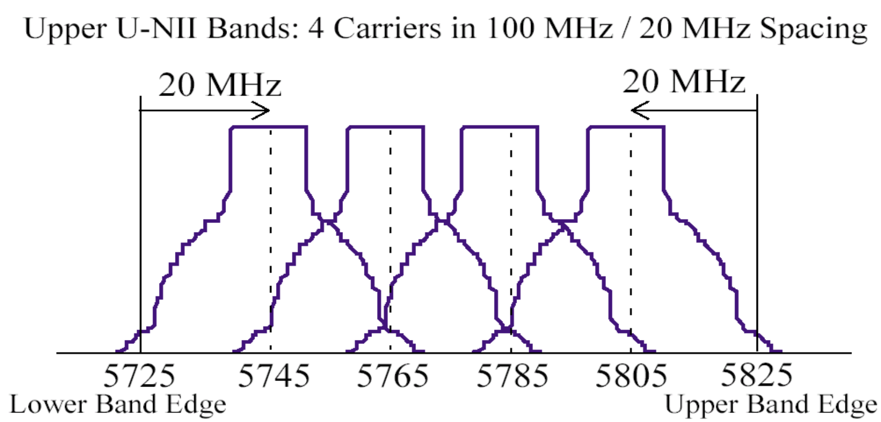
(second output)

Figure 114—Convolutional encoder (k = 7)

Channelization

- 8 independent channels in 5.15GHz-5.35GHz
- 4 independent channels in 5.725-5.825GHz





Class Quiz

- What are the two main features of OFDM?
- How is the channel impairments dealt with in OFDM?
- What data rates can be achieved in IEEE802.11a?