

System Architecture

2018 Fall Intro LTE

Chap4:OFDMA

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Modulation Technique

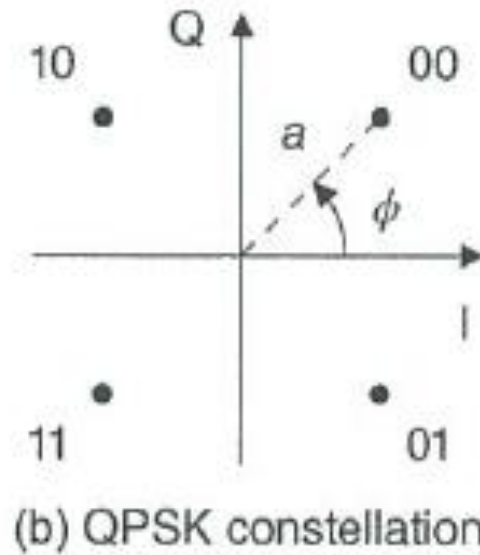
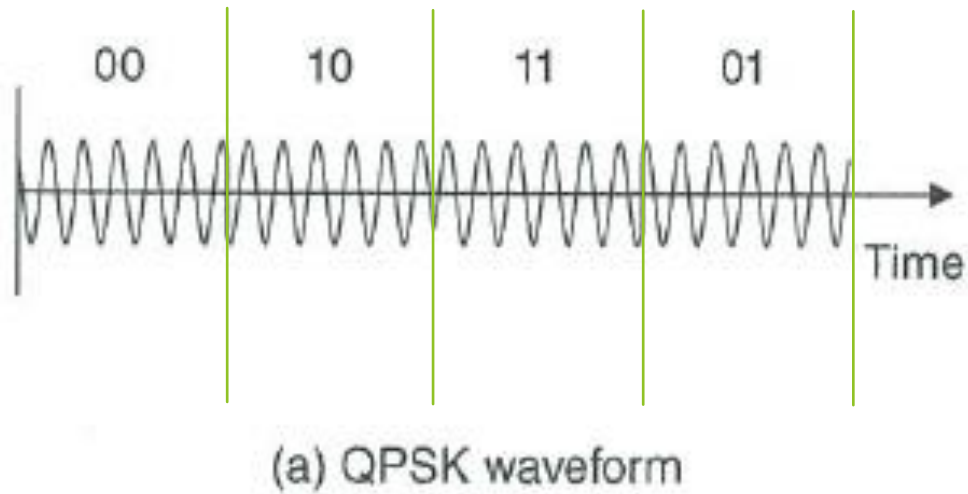


Figure 3.2 Quadrature phase shift keying. (a) Example QPSK waveform. (b) QPSK constellation diagram

Modulation schemes used in LTE

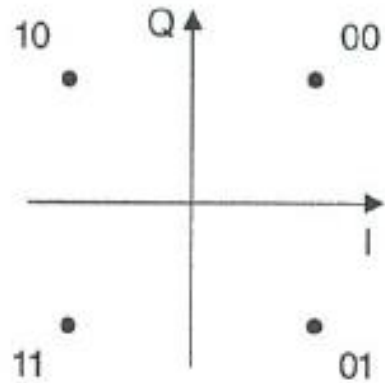
Constellation shows Phaser

= Amplitude and Phase at signal starting point

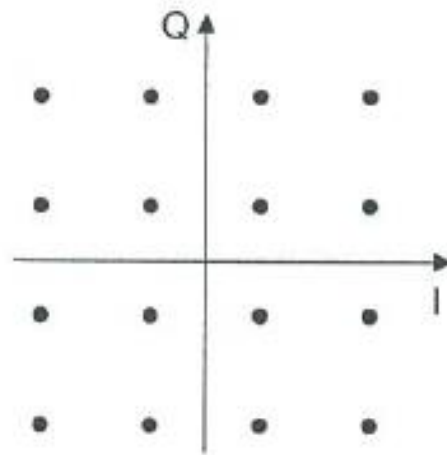
BPSK (1 bit per symbol)



QPSK (2 bits per symbol)



16-QAM (4 bits per symbol)



64-QAM (6 bits per symbol)

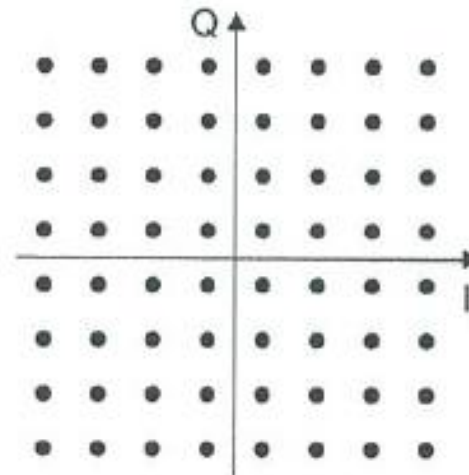


Figure 3.3 Modulation schemes used by LTE

Modulation Process

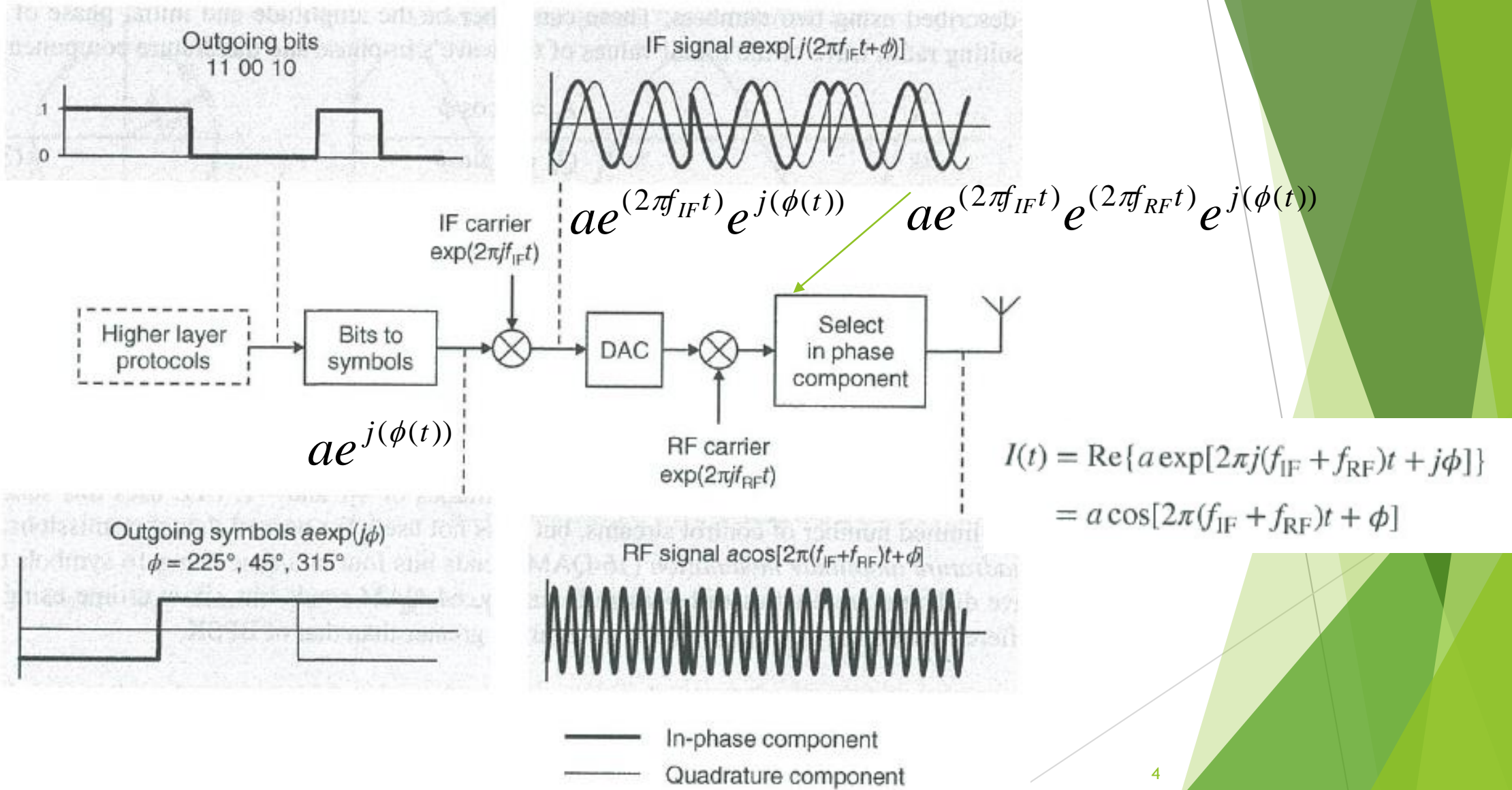


Figure 3.4 Block diagram of the modulator in a wireless communication system

Demodulation Process

$$a \cdot \cos(2\pi(f_{IF} + f_{RF})t + \phi + \psi) + noise$$

$$I(t) = a \cos[2\pi(f_{IF} + f_{RF})t + \phi + \psi]$$

$$= \frac{a \exp\{j[2\pi(f_{IF} + f_{RF})t + \phi + \psi]\} + a \exp\{-j[2\pi(f_{IF} + f_{RF})t + \phi + \psi]\}}{2}$$

$$\frac{1}{2} a e^{(2\pi f_{IF} t + \phi + \psi)} + noise'$$

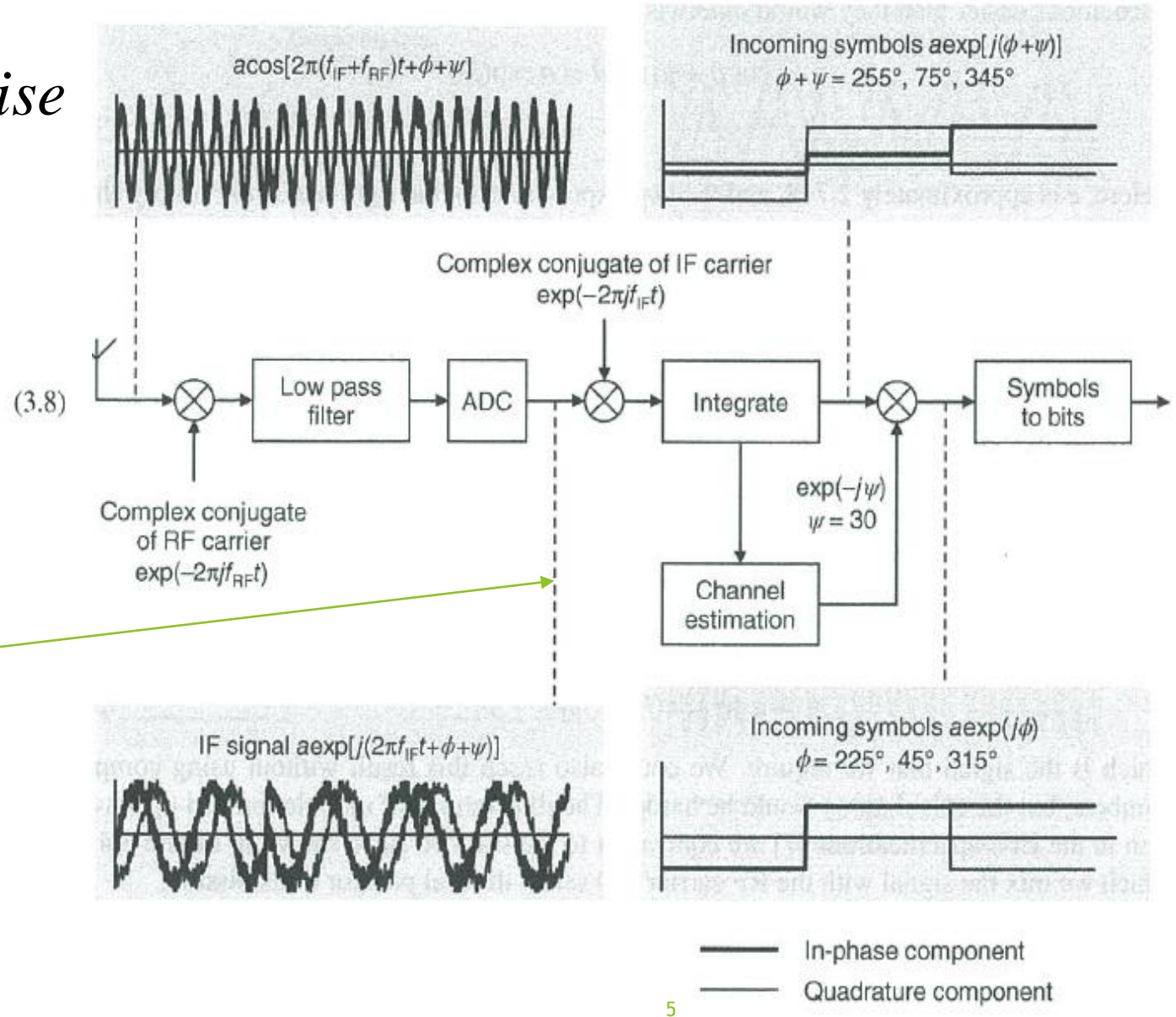


Figure 3.5 Block diagram of the demodulator in a wireless communication system

Channel Estimation

3.1.5 Channel Estimation

There is one more complication: the phase of the incoming signal depends not only on the phase of the transmitted signal but also on the receiver's exact position. If the receiver moves through half a wavelength of the carrier signal (a distance of 10 cm at a carrier frequency of 1500 MHz, for example), then the phase of the received signal changes by 180° . When using QPSK, this phase change turns bit pairs of 00 into 11 and vice versa, and completely destroys the received information. We can express this issue by including an arbitrary phase shift ψ in the received signal. In Figure 3.5, the phase shift is 30° .

To deal with this problem, the transmitter inserts occasional *reference symbols* into the data stream, which have a transmission time, amplitude and phase that are defined in the relevant specifications. In the receiver, a *channel estimation* function measures the incoming reference symbols, compares them with the ones that the specifications defined, and estimates the phase shift ψ that the air interface introduced. It can then remove this phase shift from the incoming symbols by multiplying them by the complex number $\exp(-j\psi)$. The phase shift does not change much from one symbol to the next, so the reference symbols only need to take up a small part of the transmitted data stream. The resulting overhead in LTE is about 10%.

Bandwidth is proportional to how much information transferred

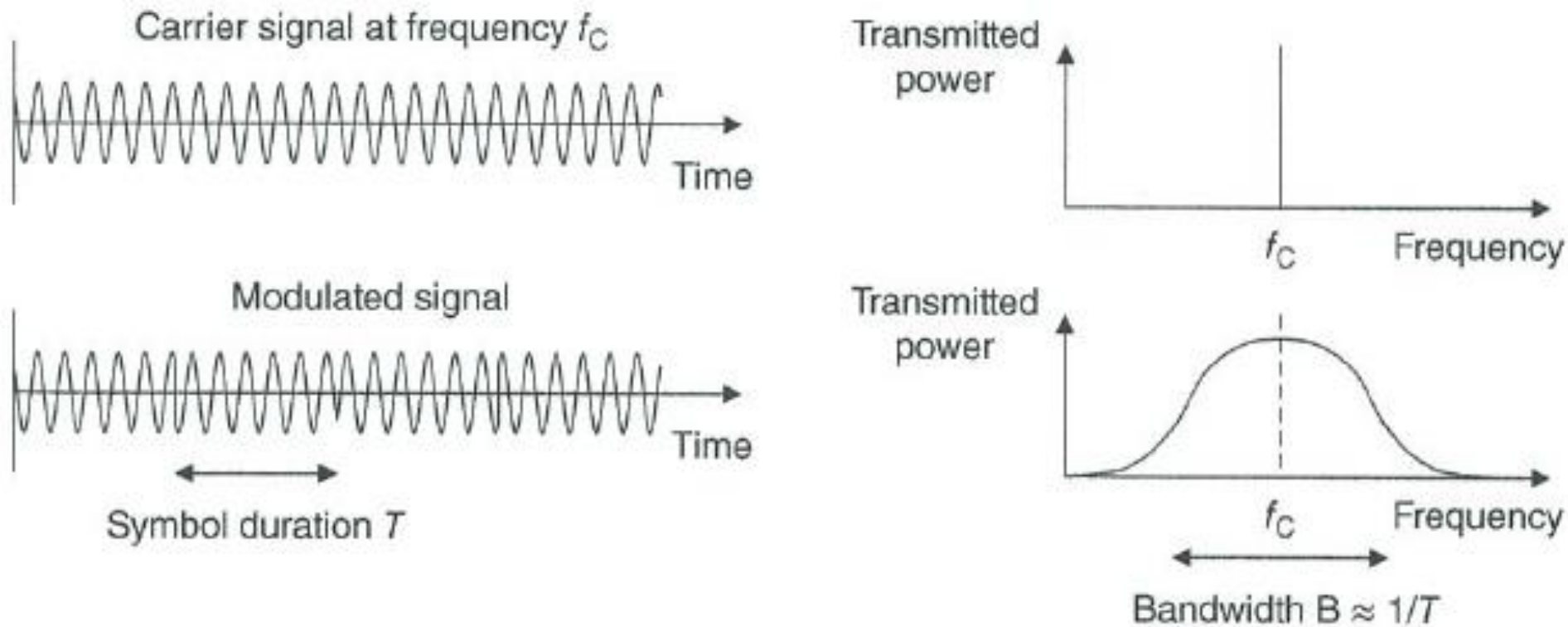


Figure 3.6 Relationship between the bandwidth and symbol duration of a modulated signal

Wireless channel always have multipath

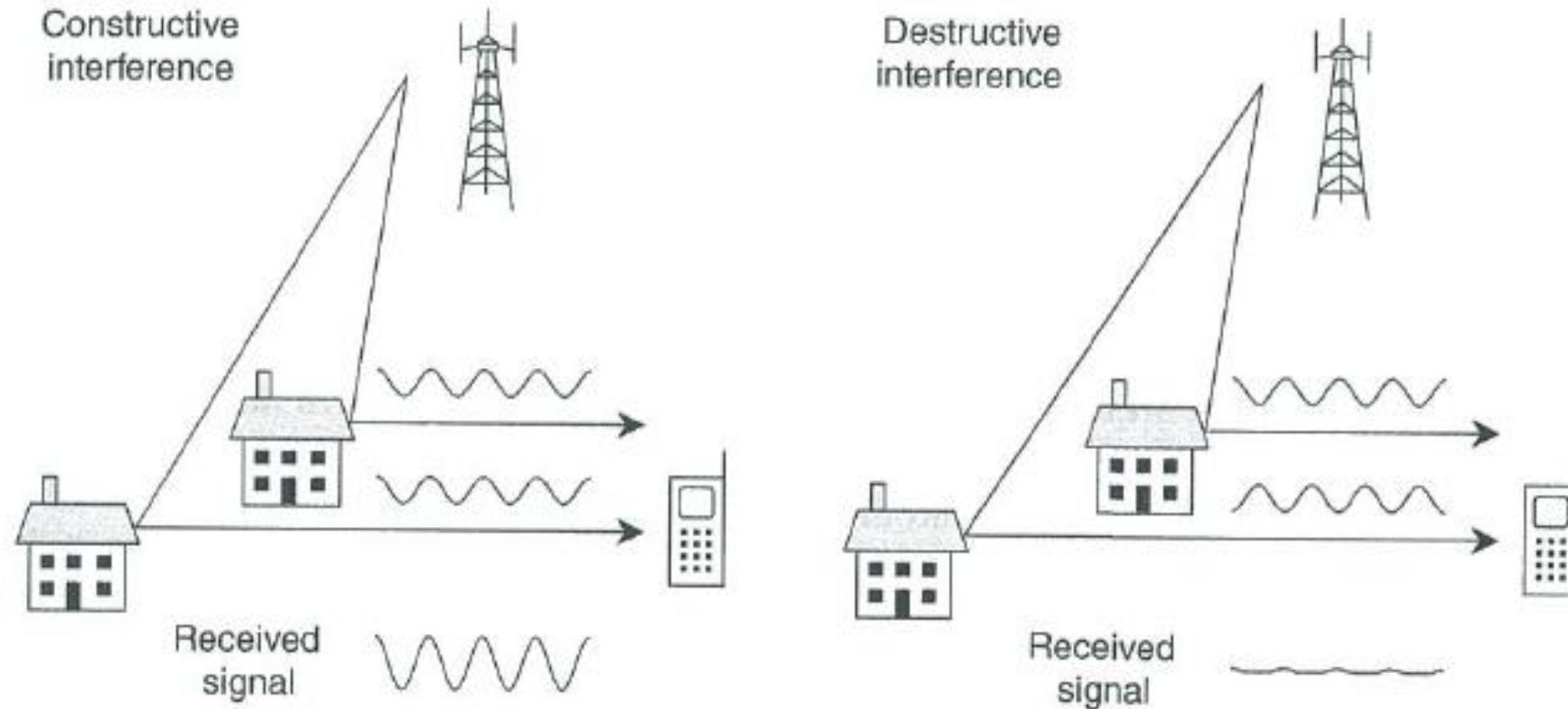


Figure 3.9 Generation of constructive interference, destructive interference and fading in a multipath environment

Multipath causes delay spread -> frequency selective fading

Mobile reception causes Doppler -> time selective fading

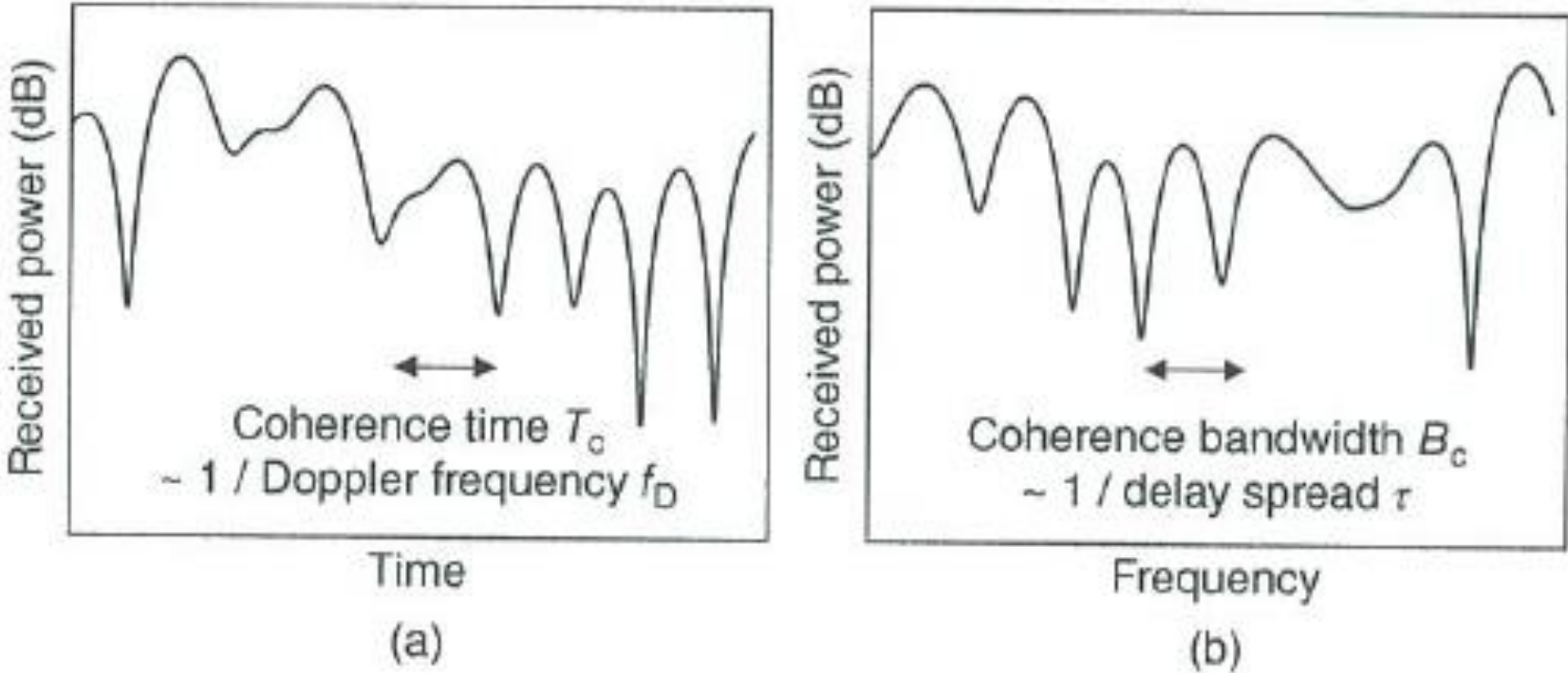


Figure 3.10 Fading as a function of (a) time and (b) frequency

OFDMA = Parallel Communication

$$\Delta f = \frac{1}{T} \quad (4.1)$$

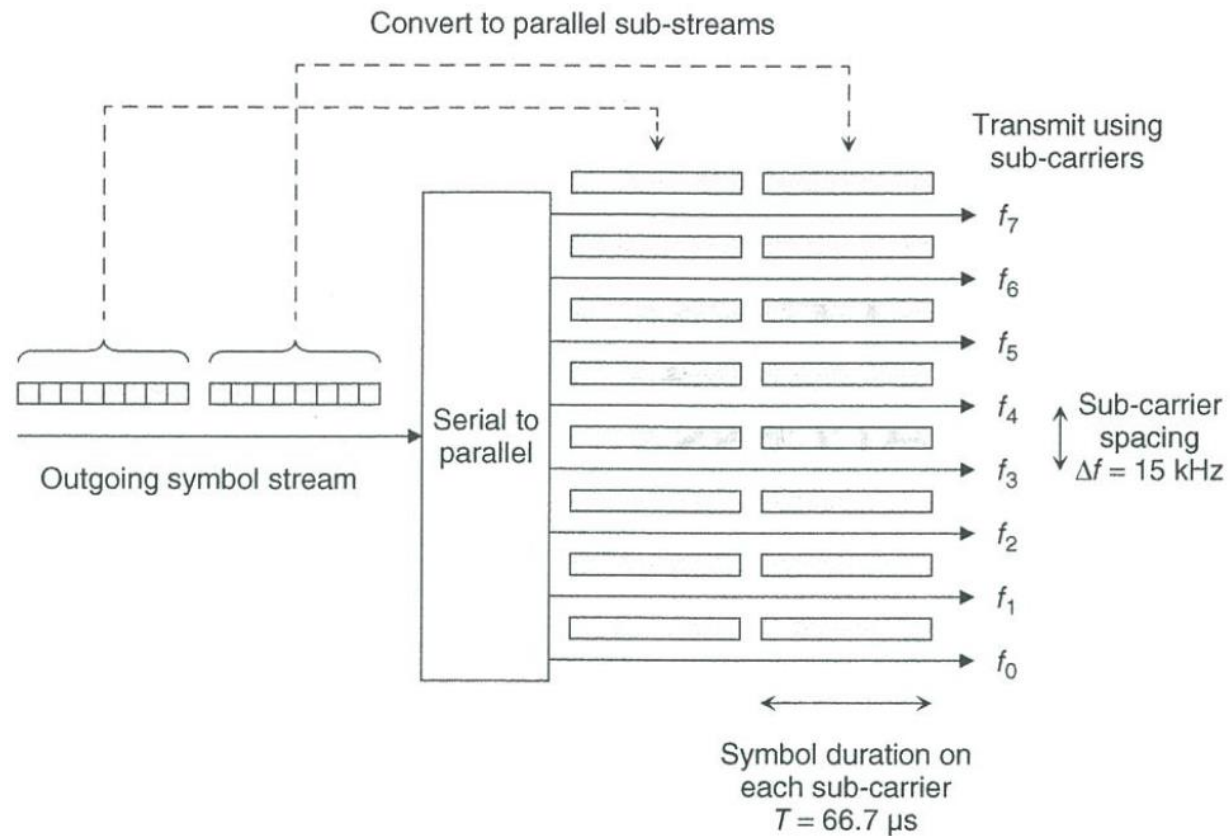


Figure 4.1 Division of the frequency band into sub-carriers using OFDM

OFDM Transmitter

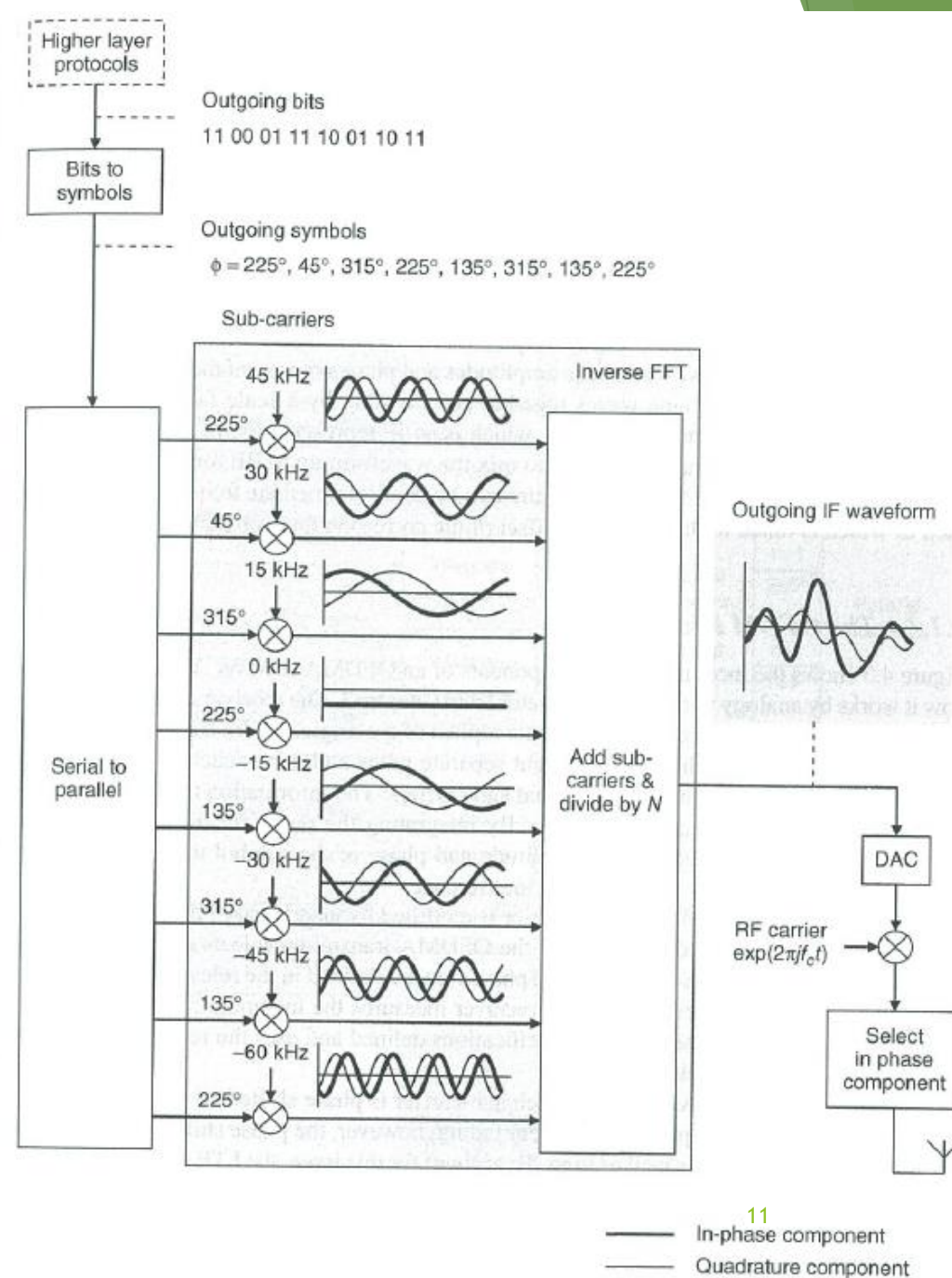


Figure 4.2 Processing steps in an OFDM transmitter

OFDM Receiver

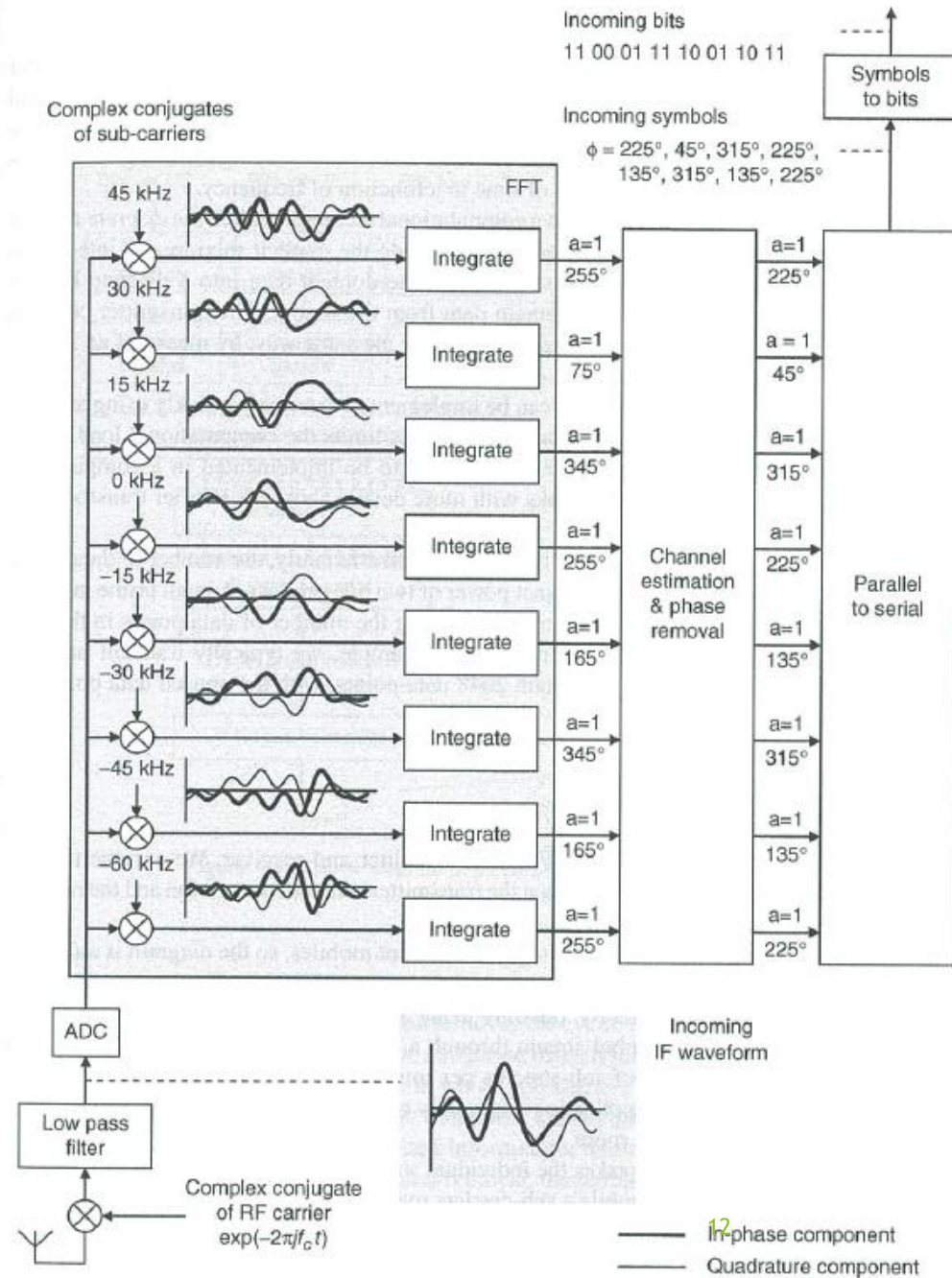


Figure 4.3 Processing steps in an OFDM receiver

OFDMA System

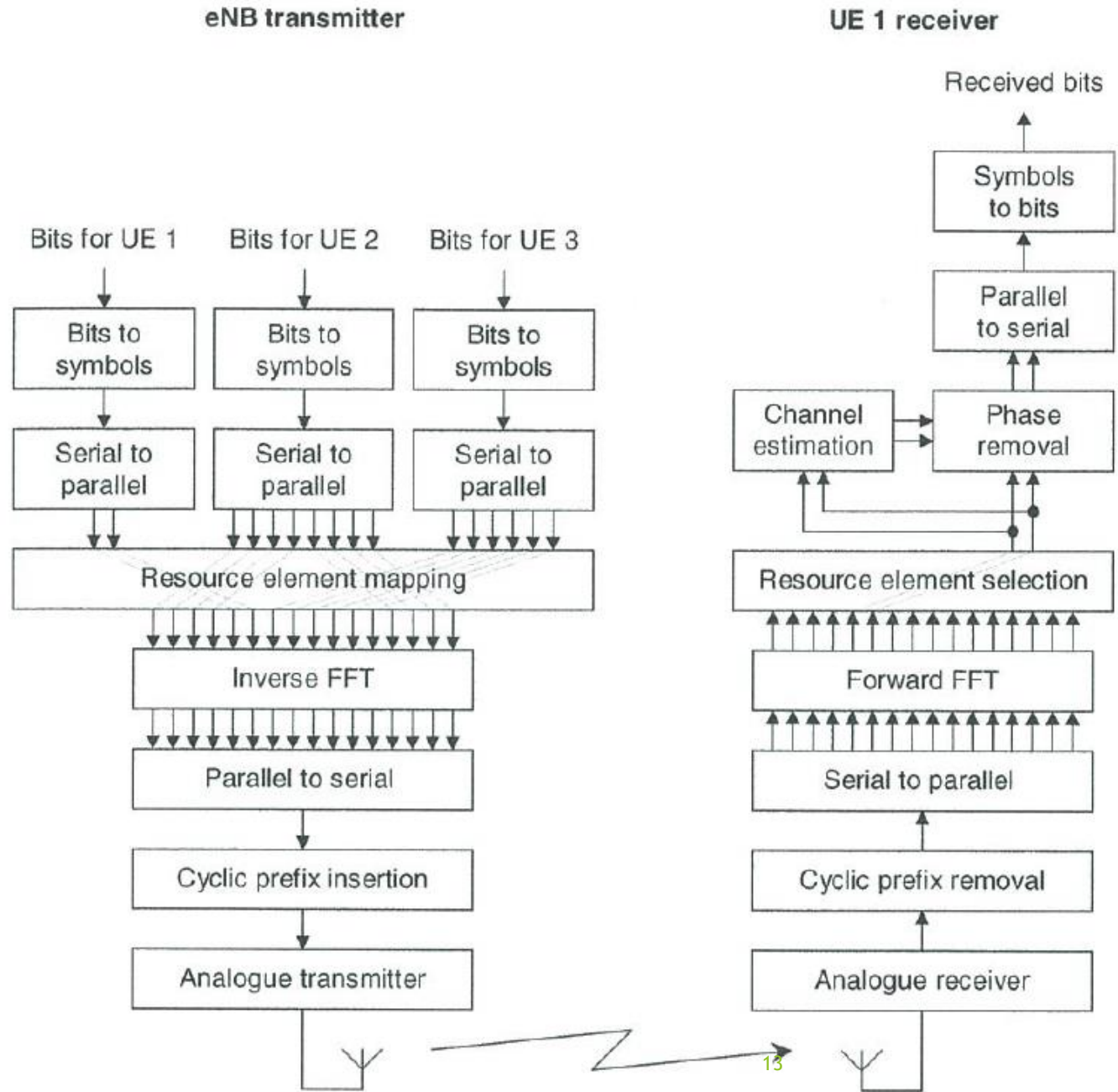


Figure 4.4 Block diagram of an OFDMA transmitter and receiver

DFT (FFT) & IDFT (IFFT)

$$Z(f_n) = \sum_{k=0}^{N-1} z(t_k) \exp(-2\pi j f_n t_k) \quad (4.2)$$

$$\begin{aligned} t_k &= k\Delta t & k &= 0, 1, 2, \dots, N-1 \\ &= \frac{kT}{N} \end{aligned} \quad (4.3)$$

$$\begin{aligned} f_n &= n\Delta f & n &= 0, 1, 2, \dots, N-1 \\ &= \frac{n}{T} \end{aligned} \quad (4.4)$$

$$Z_n = \sum_{k=0}^{N-1} z_k \exp\left(-\frac{2\pi jnk}{N}\right) \quad (4.5)$$

$$z(t_k) = \frac{1}{N} \sum_{n=0}^{N-1} Z(f_n) \exp(2\pi j f_n t_k) \quad (4.6)$$

$$z_k = \frac{1}{N} \sum_{n=0}^{N-1} Z_n \exp\left(\frac{2\pi jnk}{N}\right) \quad (4.7)$$

If only 15KHz Subcarrier

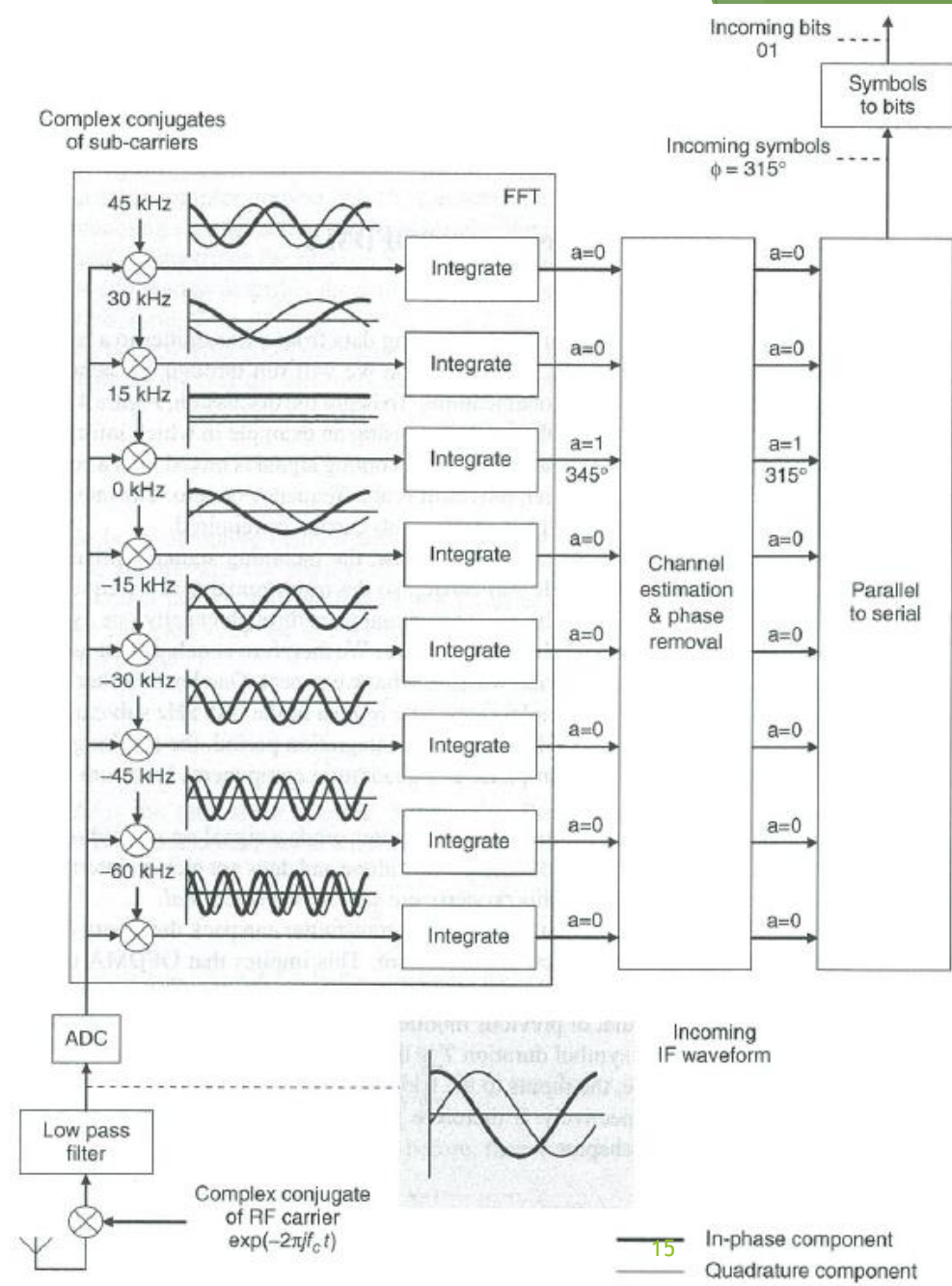


Figure 4.5 Processing steps in an OFDM receiver, in which the information arrives on the 15 kHz sub-carrier alone