13.1 INTRODUCTION

Optical decoding entails detecting an optical signal and retrieving (or demodulating) binary coded information from the received modulated lightwave based on one of the three coding techniques discussed earlier:

- Detecting optical amplitude level if amplitude-shift keying (ASK) is used.
- Detecting phase change (from 0 to 180°) if phase-shift keying (PSK) is used.
- Detecting frequency change (from \( \omega - \Delta \omega \) to \( \omega + \Delta \omega \)) if frequency-shift keying (FSK) is used.

Because each technique is different from the others, clearly the receiver device and the overall design differ as well.

13.2 ASK DEMODULATORS

ASK demodulators use photodetectors that directly detect incident photonic amplitude. Based on a threshold level, incident amplitude above it is interpreted as logic 1 and below it as logic 0. When the incident amplitude is ambiguous due to photonic noise sources, an erroneous 1 or 0 may be produced. To remove noise from the signal, the retrieved signal is low-pass-filtered and sampled by a local phase-locked loop (PLL) at the expected incoming bit rate.

It should be pointed out that for long fiber lengths signal attenuation weakens the incident light at the receiver considerably, and it is counted in single-digit photons per bit (logic 1); the amount is known as the quantum limit of the receiver.
Consequently, the incoming signal should be coupled with the receiver with no losses, the signal should be dispersion-compensated, and the sensitivity of the receiver should be very high.

### 13.3 PSK AND FSK DEMODULATORS

PSK and FSK demodulators are based on coherent (homodyne and heterodyne) principles. This means that in addition to the received optical signal from the fiber, the receiver must have one or two local oscillators (optical sources) to interact with the received optical signal and to extract binary information. The basic principle of a homodyne PSK demodulator (without noise) is as follows (Figure 13.1).

![Figure 13.1 Basic principle of a homodyne PSK demodulator.](image)

The received optical modulated signal $\omega_S$ is mixed coherently with a locally generated frequency $\omega_{LO}$. These frequencies are the same, and they interact interferometrically. Clearly, when both frequencies are in phase, there is maximum optical contribution; otherwise, they cancel each other. Because this arrangement is based on optical interference, phase stability is important. The mixed optical signal is detected by a photodetector that provides electrical output of logic 1 or 0. Clearly, the demodulator becomes more complex when noise is included.

The basic principle of a homodyne FSK demodulator (without noise) is as follows (Figure 13.2). The received optical modulated signal $\omega_S$ is split into two equal parts. Then, each part interacts interferometrically with a locally generated frequency, one part with $\omega_1 = \omega_S - \Delta\omega$ and the other with $\omega_2 = \omega_S + \Delta\omega$. Because each local frequency coincides with the frequency of a logic 0 or a logic 1, it is obvious that if two optical filters, $OF_1$ and $OF_2$, are used, each centered at one of

![Figure 13.2 Basic principle of a homodyne FSK demodulator.](image)
the two respective frequencies, the temporal bits 1 and 0 are recognized. Upon re-
combining the two halves in the time domain, the complete data bit stream will be
recovered. Because this arrangement is based on optical interference, optical phase
alignment and stability are important. Again, the demodulator becomes more com-
plex when noise is included.

A simplified FSK demodulator can be constructed by passing the received opti-
cal modulated signal $\omega_S$ through a tunable filter tuned to pass the frequency
$\omega_2 = \omega + \Delta \omega$. Whenever this frequency is detected, logic 1 is generated; otherwise, logic
0 is detected (Figure 13.3). The tunable filter provides the flexibility of selecting a
given frequency and acts like an FSK-to-ASK converter. As usual, the demodulator
becomes more complex when noise is included.

![Figure 13.3 A simplified FSK demodulator.](image)

**EXERCISES**

1. Could a receiver designed to detect a PSK signal detect an FSK signal?
2. A PSK modulator shifts the phase by $180^\circ$ thus decoding a 1 or a 0, or two states, de-
   pending on the received phase. How many states are possible in a PSK modulator that
   shifts by $30^\circ$?
3. A signal has traveled about 200 km of fiber without amplification. Comment on the re-
   ceiver precautions for reliable signal detection.
4. Consider a PSK receiver. How do the received signal and the local oscillator interact to de-
   code the signal?
5. Consider an FSK signal. What kind of optical device is required to decode the signal?

**REFERENCES**

   Lightwave Technology*, vol. 6, no. 11, 1988, pp. 1750–1769.
   Has Come,” *IEEE Communications Magazine*, vol. 28, no. 5, May 1990, pp. 5–14.

**STANDARDS**

[3] IEEE 802.3ab, 1000BaseT.
[4] IEEE 802.1 to 802.6, Local Area Networks.