

Table 1.1 SONET/SDH bit rates

SONET	SDH	B (Mb/s)	Channels
OC-1		51.84	672
OC-3	STM-1	155.52	2,016
OC-12	STM-4	622.08	8,064
OC-48	STM-16	2,488.32	32,256
OC-192	STM-64	9,953.28	129,024
OC-768	STM-256	39,813.12	516,096

building block of the SONET has a bit rate of 51.84 Mb/s. The corresponding optical signal is referred to as OC-1, where OC stands for optical carrier. The basic building block of the SDH has a bit rate of 155.52 Mb/s and is referred to as STM-1, where STM stands for a *synchronous transport module*. A useful feature of the SONET and SDH is that higher levels have a bit rate that is an exact multiple of the basic bit rate. Table 1.1 lists the correspondence between SONET and SDH bit rates for several levels. The SDH provides an international standard that appears to be well adopted. Indeed, lightwave systems operating at the STM-64 level ($B \approx 10$ Gb/s) are available since 1996 [19]. Commercial STM-256 (OC-768) systems operating near 40 Gb/s became available by 2002.

1.2.3 Modulation Formats

The first step in the design of an optical communication system is to decide how the electrical signal would be converted into an optical bit stream. Normally, the output of an optical source such as a semiconductor laser is modulated by applying the electrical signal either directly to the optical source or to an external modulator. There are two choices for the modulation format of the resulting optical bit stream. These are shown in Figure 1.9 and are known as the *return-to-zero* (RZ) and *nonreturn-to-zero* (NRZ) formats. In the RZ format, each optical pulse representing bit 1 is shorter than the bit slot, and its amplitude returns to zero before the bit duration is over. In the NRZ format, the optical pulse remains on throughout the bit slot and its amplitude does not drop to zero between two or more successive 1 bits. As a result, pulse width varies depending on the bit pattern, whereas it remains the same in the case of RZ format. An advantage of the NRZ format is that the bandwidth associated with the bit stream is smaller than that of the RZ format by about a factor of 2 simply because on–off transitions occur fewer times. However, its use requires tighter control of the pulse width and may lead to bit-pattern-dependent effects if the optical pulse spreads during transmission. The NRZ format is often used in practice because of a smaller signal bandwidth associated with it.

The use of the RZ format in the optical domain began to attract attention around 1999 after it was found that its use may help the design of high-capacity lightwave systems [54]–[56]. By now, this format is used almost exclusively for WDM channels designed to operate at 40 Gb/s or more. An example of the usefulness of the RZ format is provided by the so-called pseudo-linear systems [57] that employ relatively short op-