

## Multilevel Signaling

Multilevel signaling is often used as a means of compressing the bandwidth required to transmit data at a given bit rate. In a simple binary scheme, two single symbols, usually two voltage levels, are used to represent a 1 and a 0. The symbol rate is therefore equal to the bit rate. The principle of multilevel signaling is to use a larger alphabet of  $m$  symbols to represent data, so that each symbol can represent more than one bit of data. As a result, the number of symbols that needs to be transmitted is less than the number of bits (that is, the symbol rate is less than the bit rate), and hence the bandwidth is compressed. The alphabet of symbols may be constructed from a number of different voltage levels. Fig. 1 shows an example for a four-level scheme.

In the four-level scheme, groups of two data bits are mapped to one of four symbols. Only one symbol need be transmitted for each pair of data bits, so the symbol rate is half the bit rate. The drawback of the multilevel scheme is that symbols are separated by a smaller voltage than in the binary scheme. This means that when noise is added to the data signal (cross talk or impulse), the probability of the noise changing one symbol to another is increased. The symbol separation could be increased to that of the binary scheme by increasing the peak-to-peak transmitted voltage by a factor of  $(m - 1)$  for an  $m$ -level scheme, but this is generally not possible given fixed power supply voltages, and in any case it increases the power required for a transmitter.

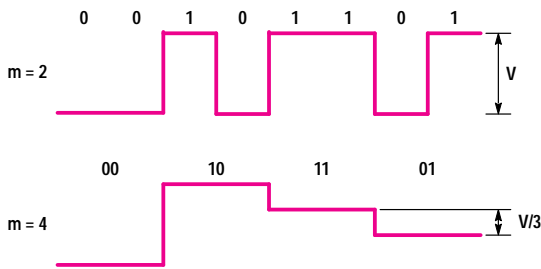


Fig. 1. Two-level and four-level signaling.

The susceptibility of a scheme to errors caused by noise is measured by the ratio of signal separation to noise. Fig. 2 shows the signal-to-NEXT-noise ratio plotted against the transmission bandwidth for several multilevel schemes and for multi-pair schemes for a bit rate of 100 Mbits/s. A 16-level scheme reduces the bandwidth to 25% of the bit rate, but the S/NEXT ratio is 13 dB (a factor of 4.5) worse than for a four-pair scheme with 25 Mbits/s per pair, which is the scheme used in the 100VG-AnyLAN standard.

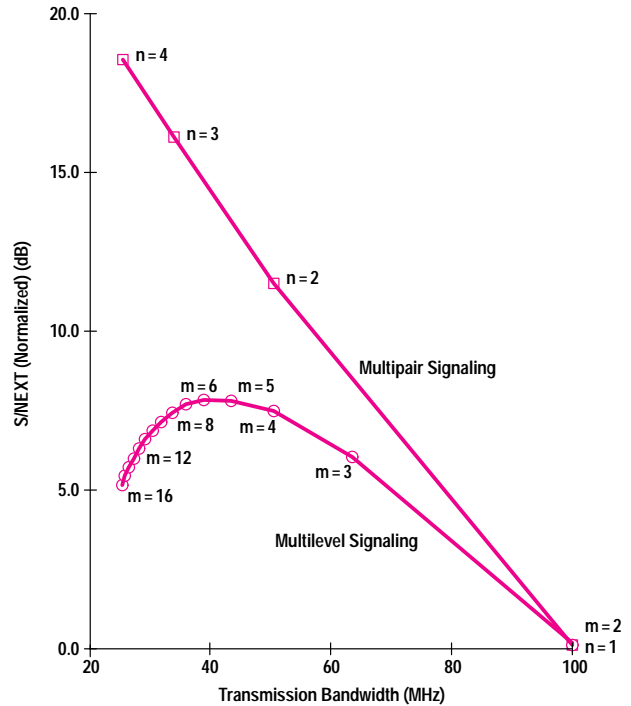


Fig. 2. Susceptibility to errors from noise.