Other explanations of block interleaving from communications textbooks:

From: John G. Proakis, "Digital Communications", 2nd Ed., McGraw-Hill, 1989.

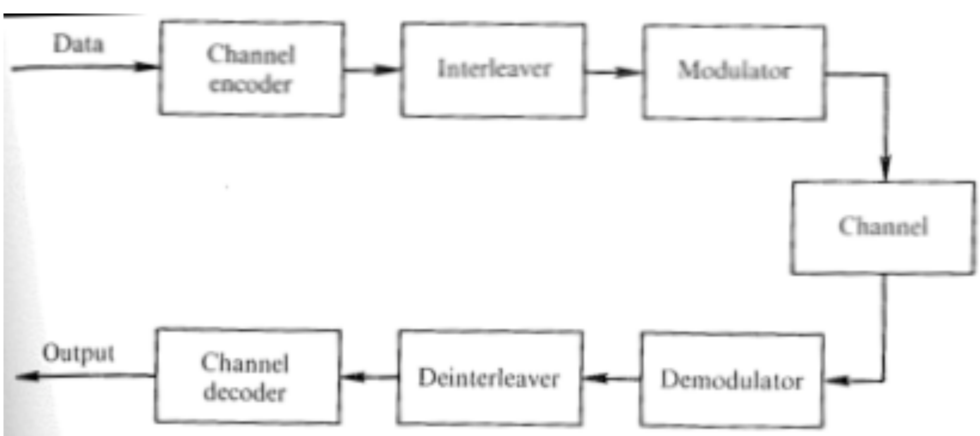
5.2.10 Interleaving of Coded Data for Channels with Burst Errors

Most of the well known codes that have been devised for increasing the reliability in the transmission of information are effective when the errors caused by the channel are statistically independent. This is the case for the AWGN channel. However, there are channels that exhibit bursty error characteristics. One example is the class of channels characterized by multipath and fading, which is described in detail in Chap. 7. Signal fading due to time-variant multipath propagation often causes the signal to fall below the noise level, thus resulting in a large number of errors. A second example is the class of magnetic recording channels (tape or disk) in which defects in the recording media result in clusters of errors. Such error clusters are not usually corrected by codes that are optimally designed for statistically independent errors.

Considerable work has been done on the construction of codes that are capable of correcting burst errors. Probably the best known burst error correcting codes are the subclass of cyclic codes called Fire codes, named after P. Fire (1959) who discovered them. Another class of cyclic codes for burst error correction were subsequently discovered by Burton (1969).

A *burst* of errors of length b is defined as a sequence of b-bit errors, the first and last of which are 1's. The *burst error correction capability* of a code is defined as one less than the length of the shortest uncorrectable burst. It is relatively easy to show that a systematic (n, k) code, which has $n - k$ parity check bits, can correct bursts of length $b \leq [(n-k)/2]$.

An effective method for dealing with burst error channels is to interleave the coded data in such a way that the bursty channel is transformed into a channel having independent errors. Thus, a code designed for independent channel errors (short bursts) is used.



A block diagram of a system that employs interleaving is shown in Fig. 5.2.24. The encoded data are reordered by the interleaver and transmitted over the channel. At the receiver, after (either hard or soft decisions) demodulation, the deinterleaver puts the data in proper sequence and passes it to the decoder. As a result of the interleaving/deinterleaving, error bursts are spread out in time so that errors within a code word appear to be independent.

The interleaver can take one of two forms—a block structure or a convolutional structure. A block *interleaver* formats the encoded data in a rectangular array of m rows and n columns. Usually, each row of the array constitutes a code word of length n. An *interleaver of degree* m consists of m rows (m code words) as illustrated in Fig. 5.2.25. The bits are read out column-wise and transmitted over the channel. At the receiver, the deinterleaver stores the data in the same rectangular array format, but it is read out row-wise, one code word at a time. As a result of this reordering of the data during transmission, a burst of errors of length $l = mb$ is broken up into m bursts of length b. Thus, an (n, k) code that can handle burst errors of length $b \le [(n-k)/2]$ can be combined with an interleaver of degree m to create an interleaved (mn, mk) block code that can handle bursts of length mb.

A *convolutional interleaver* can be used in place of a block interleaver in much the same way. Convolutional interleavers are better matched for use with the class of convolutional codes that is described in the following section. Convolutional interleaver structures have been described in the literature by Ramsey (1970) and Forney (1971).

From: Theodore S. Rappaport, "Wireless Communications Principles and Practice", Prentice-Hall, 1999.

6.12 Interleaving

Interleaving is used to obtain time diversity in a digital communications system without adding any overhead. Interleaving has become an extremely useful technique in all second generation digital cellular systems, due to the rapid proliferation of digital speech coders which transform analog voices into efficient digital messages that are transmitted over wireless links (speech coders are presented in Chapter 7).

Because speech coders attempt to represent a wide range of voices in a uniform and efficient digital format, the encoded data bits (called *source bits*) carry a great deal of information, and as explained in Chapters 7 and 10, some source bits are more important than others and must be protected from errors. It is typical for many speech coders to produce several "important" bits in succession, and it is the function of the interleaver to spread these bits out in time so that if there is a deep fade or noise burst, the important bits from a block of source data are not corrupted at the same time. By spreading the source bits over time, it becomes possible to make use of error control coding (called *channel coding*) which protects the source data from corruption by the channel. Since error control codes are designed to protect against channel errors that may occur randomly or in a bursty manner, interleavers scramble the time order of source bits before they are channel coded.

An interleaver can be one of two forms – a block structure or a convolutional structure. A block interleaver formats the encoded data into a rectangular array of m rows and n columns, and interleaves nm bits at a time. Usually, each row contains a word of source data having n bits. An interleaver of degree m (or depth m) consists of m rows. The structure of a block interleaver is shown in Figure 6.17. As seen, source bits are placed into the interleaver by sequentially increasing the row number for each successive bit, and filling the columns. The interleaved source data is then read out row-wise and transmitted over the channel. This has the effect of separating the original source bits by m bit periods.

At the receiver, the de-interleaver stores the received data by sequentially increasing the row number of each successive bit, and then clocks out the data row-wise, one word (row) at a time.

Convolutional interleavers can be used in place of block interleavers in much the same fashion. Convolutional interleavers are ideally suited for use with convolutional codes.

There is an inherent delay associated with an interleaver since the received message block cannot be fully decoded until all of the nm bits arrive at the receiver and are de-interleaved. In practice, human speech is tolerable to listen

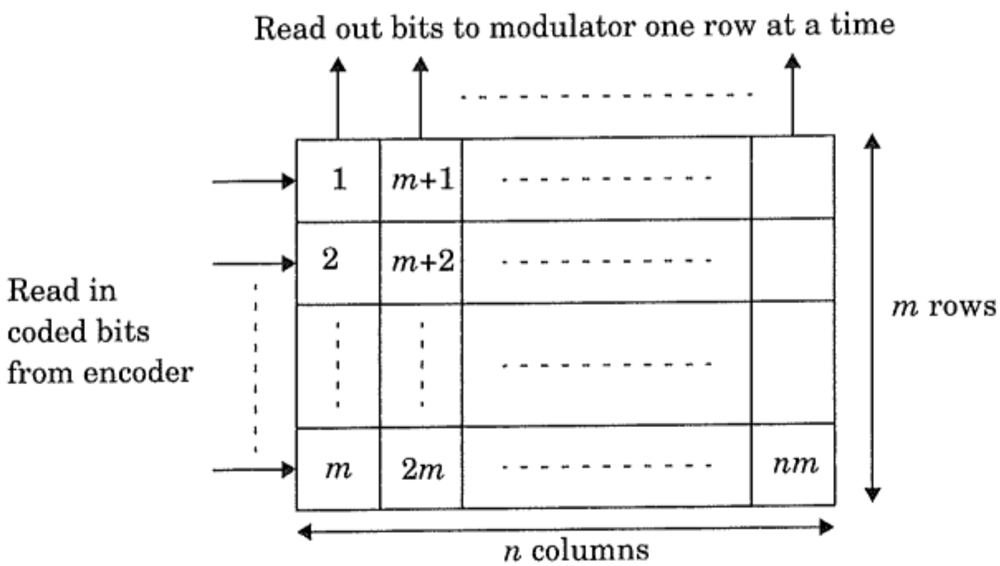


Figure 6.17
Block interleaver where source bits are read into columns and read out as n-bit rows.

to until delays of greater than 40 ms occur. It is for this reason that all of the wireless data interleavers have delays which do not exceed 40ms. The interleaver word size and depth are closely related to the type of speech coder used, the source coding rate and the maximum tolerable delay.