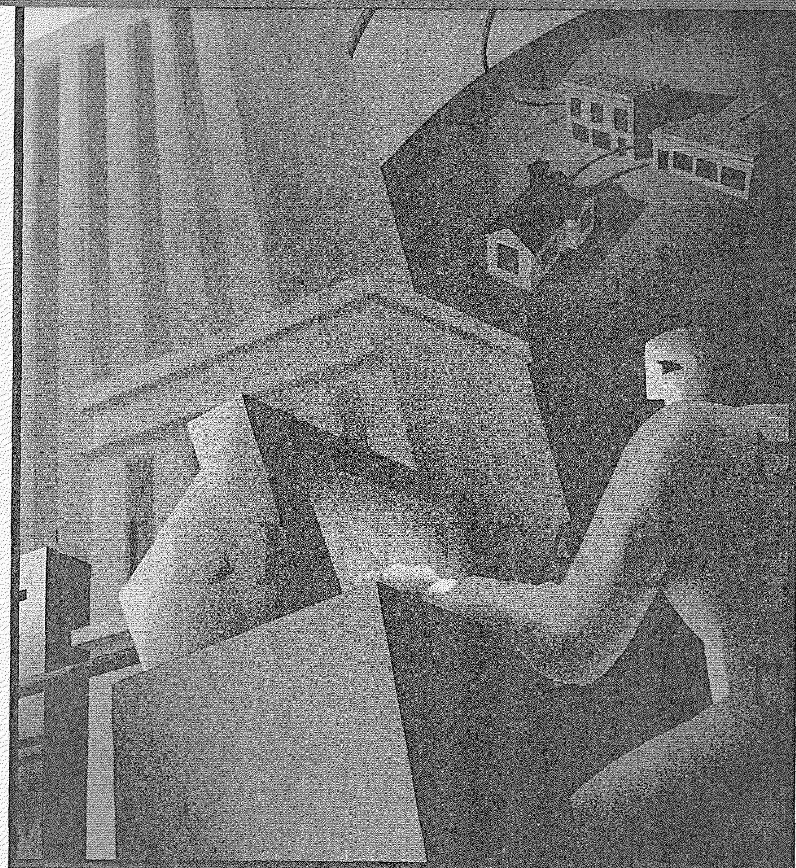

George Abe

A comprehensive review of the technical, business, and regulatory challenges of high-speed residential networks

Residential Broadband

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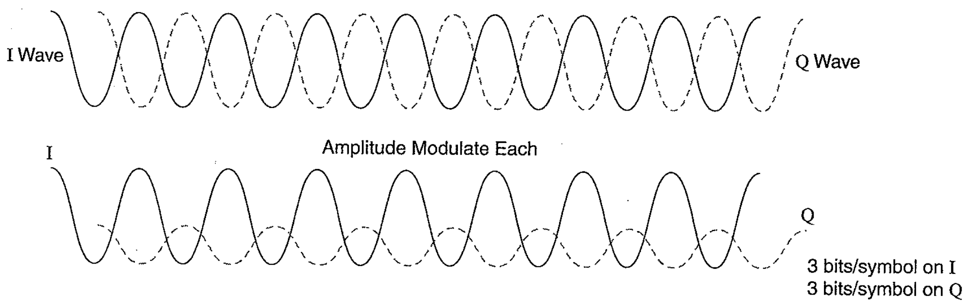
Figure 2-6 *QAM Modulation*



Discrete Multitone

QPSK, QAM, and CAP are examples of modulation techniques that permute a single carrier (or two copies of a single wave, slightly offset from each other). These are called *single-carrier techniques*. Frequency, amplitude, and phase of the carrier can be modulated to encode information. These are well-understood techniques with a lot of industrial and defense experience behind them.

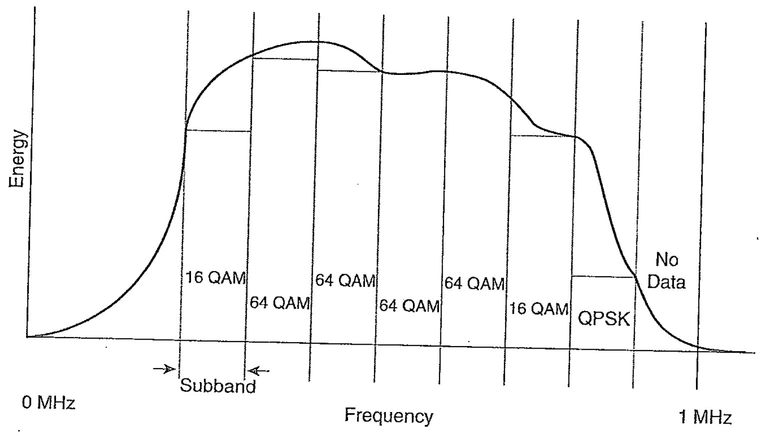
But with the development of *digital signal processing (DSP),* multicarrier techniques are now possible. Multicarrier techniques use an aggregate amount of bandwidth and divide it into *subbands*, thereby yielding multiple, parallel, narrower channels. Each subband is encoded using a single-carrier technique (such as QAM), and bit streams from the subbands are bonded together at the receiver. Important examples of multicarrier techniques include orthogonal frequency division multiplexing (OFDM) and discrete multitone (DMT).

Consider Figure 2-7, which shows an example of multicarrier modulation using the current ANSI T1.413 standard for ADSL. Here, 1 MHz is segmented into 256 subbands of 4 kHz each. The transmitter modulates each subband using a single-carrier modulation technique. The receiver accepts the subband and bonds the 256 carriers together.

OFDM and DMT differ in that OFDM uses a common modulation scheme for each subband. That is, each subband transfers the same number of bits per second. OFDM is used in European over-the-air broadcast digital television. In the case of over-the-air broadcast, all subbands are presumed to have uniform noise characteristics, so a common modulation technique makes sense.

DMT enhances the OFDM model by allowing variable spectral efficiency among the subbands. Some subbands can use more aggressive modulation schemes than other subbands. DMT is used in wired media such as ADSL, where the noise characteristics of each subband may differ. Subbands, which have high noise problems, can be avoided.

Figure 2-7 *Multicarrier Modulation*



Multicarrier techniques have a latency penalty (time delay to transmit a digital bit) compared with single carrier. In the DMT case for ADSL, there are 256 subbands of 4 kHz each. So no bit can travel faster than allowed by 4 kHz, even if the line was perfectly clean.

One of the noisiest debates about modulation techniques is between proponents of DMT and proponents of CAP for use in ADSL. DMT for ADSL uses 256 subbands, whereas CAP uses a single carrier with amplitude modulation, very similar to QAM. At the time of this writing, CAP has an advantage over DMT in that it consumes less power (thereby generating less heat) and costs less because it is more mature (more units in the field, greater integration). It is easy to see how DMT scales and why DMT has been selected by ANSI T1E1.4 and the International Telecommunications Union (ITU). Furthermore, a number of U.S. telephone companies have selected DMT. Because of these factors (and because of commercial issues with respect to the licensing of CAP), it appears DMT is gaining the upper hand for ADSL.

Considerations in Selecting Modulation Techniques

Selection of modulation technique for each Access Network has been highly contentious, partly because there's a lot of money at stake. Standards organizations for cable TV, xDSL, and HDTV have spent years arguing the requirements of modulation, let alone the choice. While commercial self-interest, academic background, national pride, embedded base and personal ego play a role, there are engineering and cost tradeoffs to consider as well.