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Broadband Internet Access

Interactive Multimedia

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bines the appropriate amplitudes of the sine and cosine of the carrier frequency, thus creating the phase and amplitude shifts associated with the correct constellation point. Finally, the signal is filtered to assure that it does not interfere with other channels. Note that the resulting signal contains substantial energy at the carrier frequency; this should not be surprising.

DMT for ADSL

ADSL devices (the ATU-C and ATU-R) have been built that use QAM, CAP, and DMT technology as line codes. However, the official standard line code for ADSL is DMT, as defined by the American National Standards Institute ANSI T1.413 standard in 1995 for ADSL. Although DMT is often said to be "newer" than CAP or QAM, DMT was actually invented years ago by Bell Labs. DMT was never implemented until recently for many reasons, not the least of which was that CAP and QAM were sufficient for all telecommunications purposes common at the time.

DMT works by first dividing the entire bandwidth range on the formerly analog passband limited local loop into a large number of equally spaced subchannels. Technically, they are called *subcarriers*, but many people still call them subchannels. Above the preserved baseband analog signaling range, this bandwidth usually extends to 1.1 MHz. The entire 1.1 MHZ bandwidth is divided into 256 subchannels, starting at 0 Hz. Each subchannel occupies 4.3125 kHz, giving a total bandwidth of 1.104 MHz on the loop. Some of the subchannels are special, and others are not used at all. For example, channel #64 at 276 kHz is reserved for a pilot signal.

Most DMT systems use only 250 or 249 subchannels for information. The lower subchannels, #1 through #6 in most cases, are reserved for 4 kHz passband analog voice. Because 6 times 4.3125 Hz is 25.875 kHz, it is common to see 25 kHZ as the starting point for ADSL services. Note that a wide *guardband* is used between the analog voice and the DMT signals. In addition, the signal loss at the upper subchannels, such as #250 and above, is so great that it is difficult to use them for information transfer on long loop at all.

There are 32 upstream channels, usually starting at channel #7, and 250 downstream channels, which gives ADSL its distinct asymmetric bandwidth. Each of the subchannels is 4.3125 kHz wide, of course, and only when echo cancellation is used are there actually 250 downstream subchannels. When only FDM is used for echo control, there are typically 32 upstream channels and only 218 or less downstream channels because they no longer overlap. The upstream channels occupy the lower end of the spectrum for two reasons. First, the signal attenuation is less here, and customer transmitters are typcially lower-powered than local exchange transmitters, which is a concern. Second, there is more noise at the local exchange with the possibility of crosstalk, so it only makes sense to use the lower portions of the frequency range for the upstream signals.

When ADSL devices that employ DMT are activated, each of the subchannels is "tested" by the end devices for attenuation. In actual practice, the "testing" is a complex kind of handshaking procedure, and the parameter used is gain (the reciprocal of the attenuation). The noise present in each of the subchannels is measured as well.

Not all of the subchannels are used for information transfer, as mentioned above. Some are reserved for network management and performance measurement functions. For instance, in the downstream direction, only 249 of the 256 subchannels available downstream are typically used for information transfer.

Usually, each of the numerous subchannels employs its own coding technique based on QAM. This may strike some as odd, given the fervor that vendors have when seeking to distinguish CAP/QAM and DMT. Nevertheless, there obviously is at some of QAM in DMT. The real attraction of DMT is not so much that it is different than CAP and QAM, but rather that based on DMT's performance monitoring, some subchannels will carry more bits per baud than others. The total throughput is the sum of all the QAM bits sent on all the active subchannels (some may be completely "turned off").

Moreover, all of the subchannels are constantly monitored for performance and errors. The speed of an individual subchannel or group of subchannels can actually vary, giving DMT a granularity of 32 kbps. In other words, a DMT device might function at 768 kbps or 736 kbps (that is, 32 kbps less), depending on operational and environmental conditions. Just by way of comparison, CAP devices usually offer 340 kbps granularity (768 kbps or 428 kbps), but pure QAM can offer granularity as fine as 1 bps, which means that there is nothing that technically limits CAP/QAM to one level of granularity but not another. In fact, some vendors of CAP-based ADSL equipment have claimed 32 kbps granularity, and even RADSL capabilities, for their latest products. It should be noted that these CAP RADSL products modify their spectrum when the rate changes, and now become a real issue to manage with regard to spectral compatibility.

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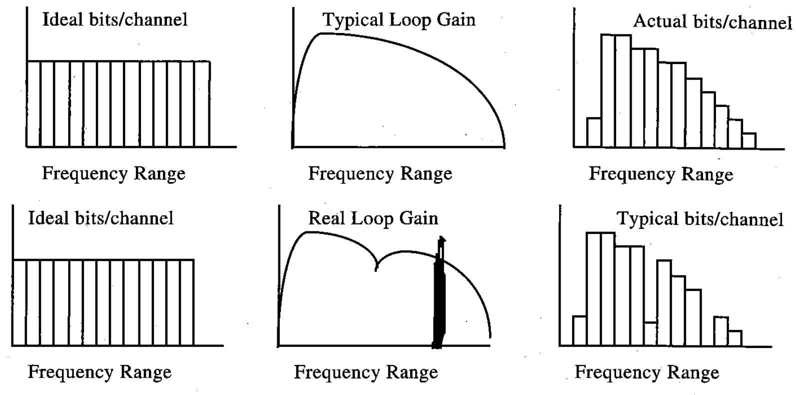
Figure 8-6
DMT in operation



Experts generally concede that finer granularity is a benefit that can maximize user acceptance and deployment situations.

Discrete Multitone (DMT) Operation

Figure 8-6 shows discrete multitone technology in operation in an ADSL device on a typical local loop. The figure actually has two parts. The upper shows a kind of ideal situation, such as that found in a straight run of 24 gauge copper wire less than 18,000 feet without a lot of outside noise (good luck finding one of those). The only real attenuation effects come from the distances and frequencies involved. The lower part of the figure shows a typical local loop in the real world.

Consider the design ideal first. Across the frequency range, on the left, there exists a targeted maximum number of bits per second per subcarrier (channel) that the device would like to send and receive. However, the middle figure shows the situation on a typical loop. The gain (the reciprocal of the attenuation) is better or worse depending on frequency. At higher frequencies, distance effects dominate; at lower frequencies, impulse noise and crosstalk dominate. This leaves a broad middle range (about 25 kHz to 1.1 MHz) for signals, with the gain slowly dropping off with increasing frequency.