What is DBS, and what makes it work?

Steve Srebranig - January 09, 2003

DBS (direct-broadcast satellite) is now as commonplace as cable TV. But the apparent ease with which you get clear pictures and sound from your television somehow ignores a half-century's worth of hard work and innovation. There is much behind that power button on your "free-for-the-cost-of-subscribing" satellite receivers, and important items allow this technology to function well.

Advent of DBS

Analog transmissions use signals in the 2- to 4-GHz range because rain doesn't affect these frequencies. And, at a few meters across, the dish antenna is a reasonable size. But, to bring satellite communication to the masses, you need to locate the receiving antenna virtually anywhere and keep it inconspicuous. (You don't want your home to resemble a broadcast uplink station.) A dish antenna measuring less than 2 feet in diameter accomplishes these aesthetic needs and performs well in the 12- to 18-GHz range where the frequency is high enough to provide good gain and directivity—important traits for densely packed satellites. Though transmitting analog is difficult in the noise-prone higher frequencies, digital approaches existed by the early 1990s.

Three important attributes of digital communication help create a satellite mass market: First, digital compression allows huge programming capacity. Second, you can multiplex several digital channels onto a single carrier, and, third, digital error correction allows a much lower power and a far more noise-tolerant signal over that of an analog transmission.

Because you can quantify all information that you push through a digital channel, you can calculate the limits of the amount of information. The theoretical limit of information through a channel is called the Shannon Limit (after Claude Shannon, who began information theory). You approach the Shannon Limit by adding redundant bits to the information you send, manipulating them in a standard way to arrive at the correct information, although noise distorts it. The Viterbi algorithm (symbol correction), turbo coding (bit correction), and Reed-Solomon (byte correction) are standard methods of FEC (forward-error correction).
In 1977, the World Administrative Radio Council allocated three regions for the DBS service: Region 1 for Europe, Region 2 (Western Hemisphere), and Region 3 (Asia/Pacific). The Council defined the standard 9° spacing between satellite clusters.

The FCC set up Region 2 DBS satellites and transponders by granting licenses for the CONUS (Continental United States) for the following orbital locations: 61.5° West, 101° West, 110° West, 119° West, 148° West, 157° West, 166° West, and 175° West. The satellites at 101, 110, and 119° cover the full continental United States and are known as Full CONUS satellites, while the others are Partial CONUS.

The two primary standards for DBS systems are DVB (digital video broadcasting), an "open," worldwide standard, and DirecTV, a "closed," North American standard. DVB-S (1994) specifies normal QPSK (quadrature-phase-shift-keying) modulation, and DVB-DSNG (1997) specifies advanced modulation for news and other data services (DVB is now creating a new DBS standard, DVB-S2, to use newer technological innovations in modulation and FEC.) The DirecTV standard (1994) is similar to DVB-S, but differences, such as data-packet size (188 bytes/packet for DirecTV versus 204 for DVB), and slight differences in the transport streams keep them from being functionally interchangeable.

The ODU (outdoor unit) attaches to the outdoor end of a 75Ω RF cable; the other end attaches to the satellite receiver at your TV. The parabolic dish antenna is the initial portion of the ODU. The main electronics of the ODU downconverts the signal from the satellite’s 12 to 13 GHz to the receiver’s 1 to 2 GHz, so you can use a convenient coaxial cable to carry the signal.

DBS systems use QPSK to encode digital information. Figure 1 shows the conceptual process of converting a digital bit stream into a QPSK analog signal. Figure 2 shows the "constellation" that the QPSK signal creates, yielding four 2-bit symbol states.

**DBS-upload/download process**

Figure 3 outlines the DBS steps to deliver standard television programming from a production studio (analog audio/video) to a residence (reconstituted audio/video signal). The process digitizes the analog audio/video, and MPEG-2 compresses and multiplexes it with others to create a single transport stream.

The process then uses the Reed-Solomon algorithm to encode the transport stream, and a process called energy scrambling adds pseudorandom bits to the transport stream to ensure bit transitions for synchronization and a zero average power. It then interleaves the stream to provide burst-error protection. The transport stream proceeds through Viterbi soft FEC, which provides bit-level redundancy.

The final bit stream continues through logic that separates it into two alternating bit streams: one containing odd-numbered bits, and the other containing even-numbered bits. A digital-to-analog process then creates two RF signals from these bit streams. One of these signals undergoes a 90° phase shift (designated Q for quadrature) and combines with the other signal (designated I for in-phase) to provide one QPSK signal.

The uplink station converts the QPSK signal to a predefined 1- to 2-GHz frequency and then further converts this signal to a DBS uplink frequency of approximately 17 GHz. The uplink station amplifies and transmits the signal to the satellite.

The satellite converts the 17-GHz signal to approximately 12.5 GHz, amplifies it, and transmits it
back to Earth along with all other signals it has received. The DBS dish antenna outside the residence receives the signal from the satellite and directs it to the ODU electronics. The electronics downconverts all signals to the 1- to 2-GHz range, amplifies them, and sends them down a 75Ω coaxial cable to the satellite receiver, which tunes to a specific carrier frequency and acquires the original QPSK signal.

The tuner converts the QPSK signal back to individual I and Q signals. It sends these to a demodulator, which converts them back to digital bit streams and combines these odd and even bits to form the original bit stream.

Viterbi FEC decodes the bit stream; the deinterleaver assembles the bit stream into its original sequential byte form; the descrambler removes the pseudorandom bits and then uses Reed-Solomon error correction to fix any byte errors in each block of the transport stream.

The bit stream is now the original multiplexed transport stream, which arrives at the back end decoding of the satellite receiver. The system then demultiplexes the correct channel and uses MPEG-2 to decode it. It then performs a digital-to-analog process to deliver the original audio/video signal to the television.

References