HELICAL SCAN TECHNOLOGY: ADVANCEMENT BY DESIGN

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Tape Technology: History

Tape began as the primary storage medium for computers in the 1950s. Over the years, tape has moved from its role as the primary storage medium to a backup and archival medium.

Early tape drives recorded data on open reels with half-inch tape in seven parallel tracks. The open reel designs evolved through the 60s and 70s by moving to nine parallel tracks, increasing bit density, and increasing tape speed. The reel type tape drives are still used in movies and commercials to present the image of a computer or data processing.

In the late 70s and early 80s, half-inch tape evolved from the open reels to closed single reel cartridges. The tape cartridges use the same parallel technologies developed from reel type tape drives and evolved them by adding more parallel tracks, improved media, and increased bit and track density. In recent tape history, serpentine recording has been adopted from the quarter-inch tape and applied to half-inch tape cartridges.

The quarter-inch tape technology became popular in the 1980s as computers became smaller and less expensive and the tape drives followed the trend. The quarter-inch technology featured a cartridge that contained two reels, a drive wheel, and a band to move the reels. Since almost the entire tape path is contained in the cartridge, the tape drive that accepts the cartridge is relatively simple and must only supply the heads and capstan drive. The technology also featured serpentine recording, in which the data tracks are written from beginning to end, the heads repositioned, and recording continued in the opposite direction. This technology has evolved with wider tape, improved cartridge designs, increased bit and track densities, and improved media.

In the late 1980s, helical scan tape technology moved from the video, audio, and instrumentation tape world to mainstream data storage by providing a ten fold increase in storage capacity. The previously mentioned tape technologies all recorded data in tracks parallel to the edges of the tape and are considered to be linear technology (figure 1). Unlike linear technology, helical scan technology records data on tracks that are at an angle to edge of tape (figure 2) by means of a rotating scanner in which heads are mounted. Tapes with helical scan technology first emerged in an 8 mm tape width followed closely by 4 mm width. Recently, helical scan technology has been applied to half-inch tape for data storage.

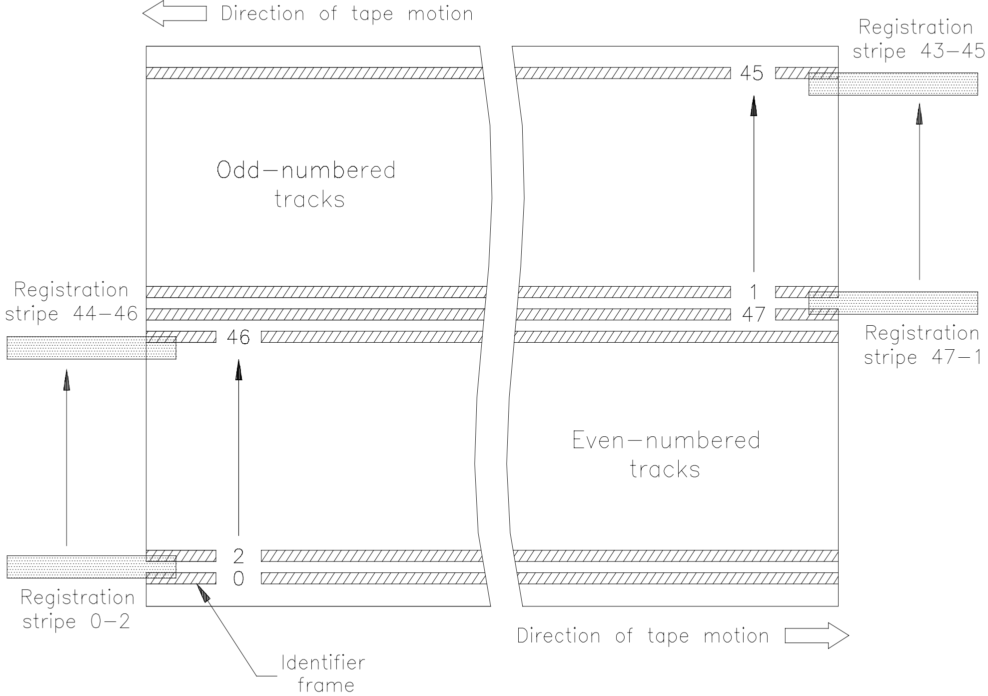

Figure 1 – Linear technology track format

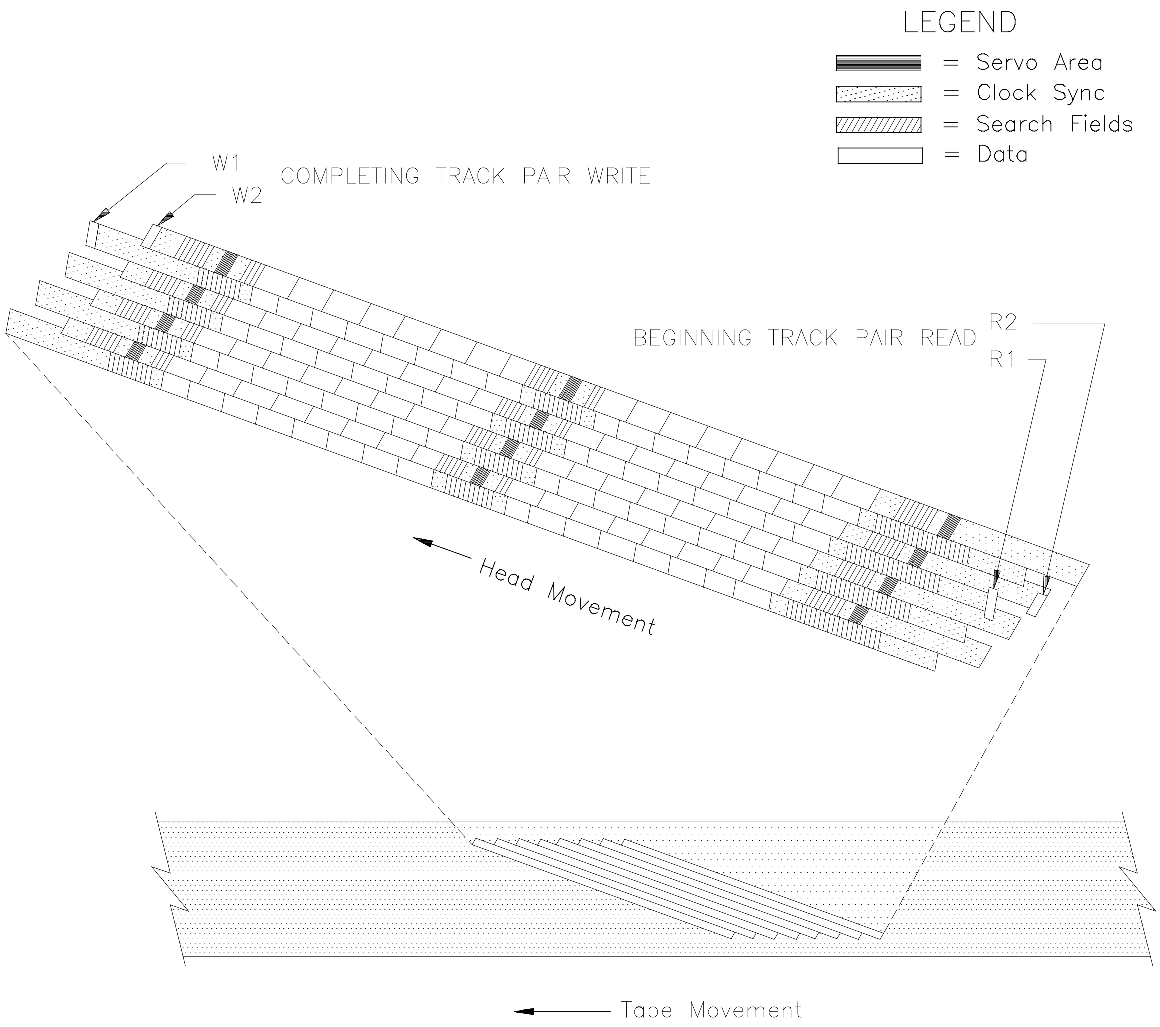

Figure 2 – Helical scan technology track format

Tape Technology: Advancing into the Future

Table 1 shows the relative characteristics of current helical scan and linear tape technologies. These characteristics play an important role in how both technologies will advance into the future. The main difference in the technologies is in how the head to tape speed is generated. In linear technology, the heads are stationary and the tape is moved at a high speed across the heads. In helical scan technology, the tape moves very slowly with a high-speed rotating head. Because of the low tape speed, the tape tension is lower in helical scan technology. The shorter track lengths in helical scan technology allow for higher track densities, because it is easier to keep closely spaced tracks straight over a shorter distance. Since helical scan technology evolved from the video and audio world into data storage, the recording formats have not been optimized for data storage which results in low format efficiencies. The linear bit density for both technologies are equal.

	Helical Scan Technology	Linear Technology
Tape Speed	Low	High
Tape Tension	Low	High
Track Length	Short	Long
Track Density	High	Low
Format Efficiency	Low	High
Linear Bit Density	High	High

Table 1 – Tape technology characteristics

Magnetic tape will continue to dominate in the removable media market place because of the high capacity, high performance, and the low cost of the media. Both the linear and helical technologies must continue to increase their capacity and performance to match the increasing needs of the data storage industry. Both technologies can apply similar techniques to increase the capacity and performance, but helical scan technology will emerge as the winner in capacity and performance because of the characteristics of the technology.

Advancement in Capacity

The capacity of a tape product is a function of tape area and how efficiently the tape area is used. Helical scan technology has the advantage over linear technology in advancing the capacity in both of these areas.

The primary method to increase capacity for a tape product is to use more tape. To some extent, a product's capacity is limited by the cartridge chosen to contain the media, but the technology chosen (linear vs. helical) has a large impact on the thickness of the tape and therefore the amount of media that will fit in a cartridge.

Linear technology relies on the media moving very fast past a stationary head, whereas helical scan technology moves the tape very slowly past a rotating head. To put the speeds into perspective, a helical scan tape drive moves tape at around 1 inch per second and a linear tape drive moves tape at 160 inches per second. The difference in speed becomes an even greater factor when the tape must operate in a start/stop mode. Accelerating and decelerating the tape to the speeds required for linear technology puts the tape at a much higher tension and requires a thicker and stronger media. Linear tape drives typically have tape tensions that are 8 to 10 times greater than helical tape drives. Because of the high speed and the high tape tension, linear technology will not advance toward thinner media and higher capacities as quickly as helical scan technology. With thinner media, helical scan tape drives will be able to put more tape in the cartridges and have larger capacities.

Tape area efficiency, or the amount data recorded per square unit of tape, is a function of format efficiency, linear bit density, and track density.

The total recorded information on tape is comprised of the user data, error correction code (ECC), servo data, search and position data, and data format overhead. Format efficiency is defined as the number data bytes the user sends to the tape drive divided by the number of bytes written to tape and is expressed as a percentage. Because of the overhead required for ECC, the optimum format efficiency is around 75%. Figure 3 shows the format efficiencies for some common linear (DLT 7000 and TR-5) and helical tape (Mammoth and DDS-3) technologies. The format efficiency is already very close to optimal for linear technology. Helical scan efficiencies are much lower. This is due to the fact that most the helical scan formats were borrowed from the audio and video industry and were not optimized for data as the linear technologies were. This offers the helical scan technology an easy opportunity for capacity advancement that is not available to linear technologies.

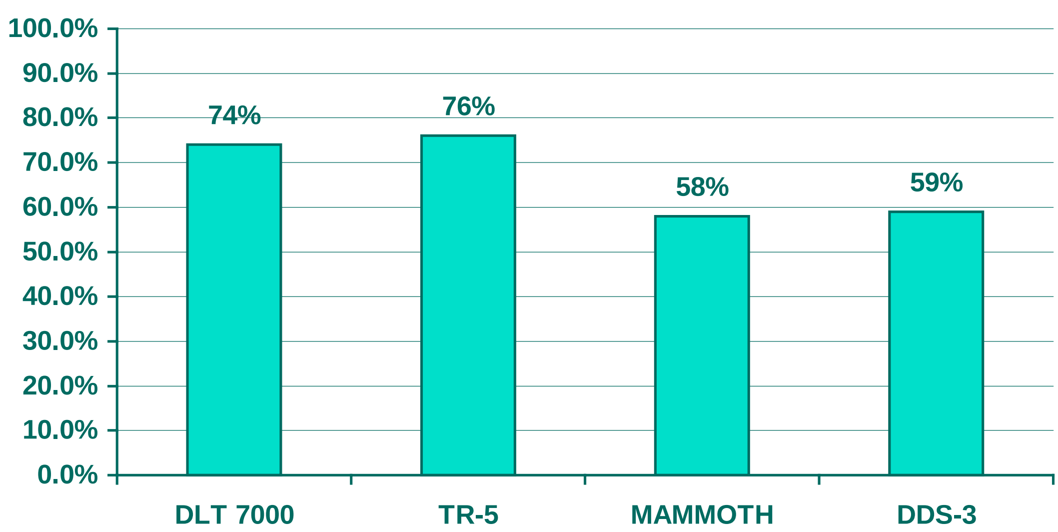

Figure 3 – Format efficiency

The measurement of how closely the bits are recorded along a track is the linear bit density. The linear bit densities for both helical scan and linear technologies have tracked each other closely over the years (figure 4). Helical scan technologies can use advanced metal evaporated (AME) media, whereas linear technologies cannot because of the orientation of the magnetic particles. AME media allows for even higher growth in bit densities than the MP media that linear technology drive use. As linear bit densities increase, the power and overhead of the ECC must increase, and thus decrease the format efficiency. Most helical technologies already have the necessary correction power built into the ECC to handle the higher bit densities. The DLT linear tape technology will require great improvements in ECC, which will reduce format efficiency.

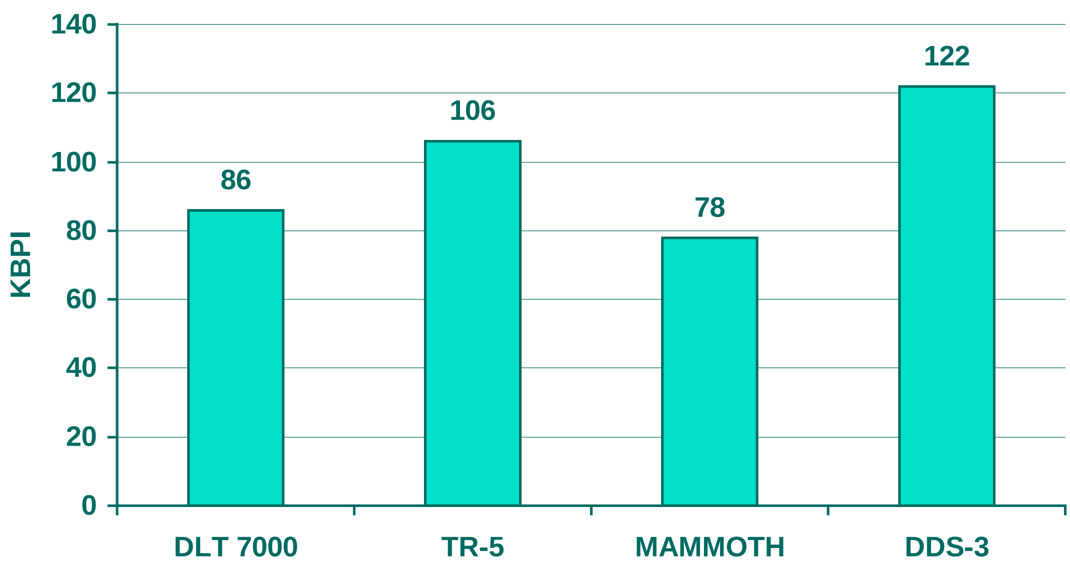

Figure 4 – Linear bit density

The largest opportunity to increase capacity for linear tape technologies is to increase the track density. Track density is a measurement of how closely the tracks are spaced. Current technology track densities are shown in figure 5. Linear technologies currently have track densities six to seven times lower than helical scan technologies. The reason for this large difference in track density is the length of the tracks. Helical scan tape drives have track lengths that are less than 3 inches in length compared to linear technology with track lengths of longer than 1500 feet. The longer the tracks, the harder it is to keep the heads correctly positioned on the track for the entire read or write operation.

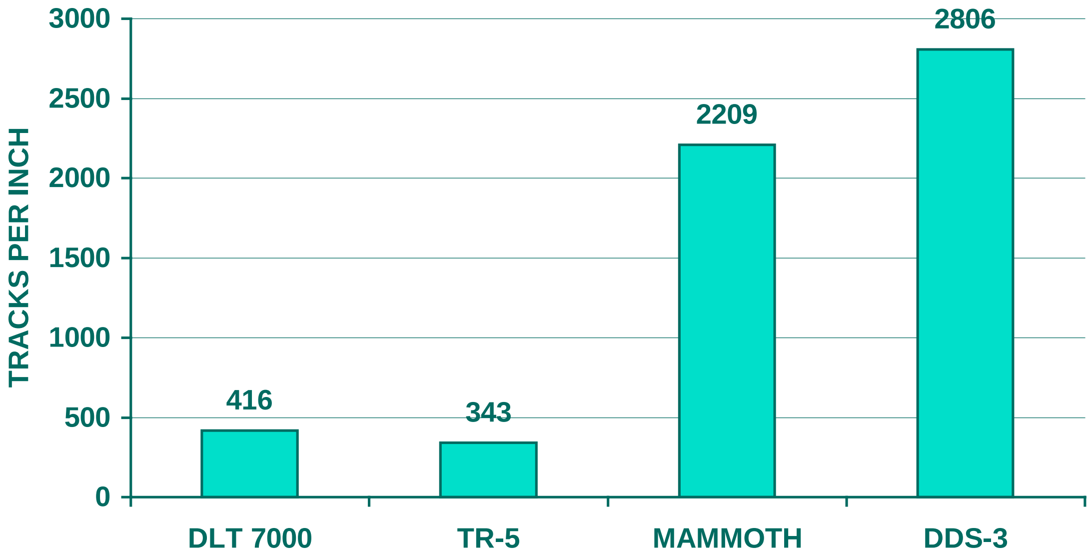

Figure 5 – Track density

Unlike helical technology, current linear technology does not control the position of the head on the track and instead relies on a narrow read head to wander on a very wide track. Head positioning only occurs at the beginning of the track. Linear tape can add a tracking servo provided the off-track wandering is slow compared to the high speed of the tape. Developing a servo to control the position of the head while writing tracks will also be difficult because the write head will need to be positioned relative to the previously written track. This will require the addition of a feedback mechanism to sense the position of the previously written track. Tracking servo has always existed on helical scan technology tape drives. With the slow tape speeds and short tracks, helical scan technology drives can easily increase the track densities further while still providing high data reliability. Adding tracking servo will be difficult and will add complexity and cost to linear technology.

As track densities increase, so does the signal interference caused by the adjacent tracks. Helical scan technology can easily implement heads with different azimuth angles to minimize the signal interference between adjacent tracks since the heads read and record data in only one direction. Because linear technology records data in both directions, it can implement different azimuth angles only by adding heads for each azimuth or pivoting the heads to a new angle at the end of each track. Both methods increase the cost and complexity of the technology.

Helical scan technology will lead linear technology in advancing capacity through the use of thinner media, higher format efficiency, increased linear bit density, and increased track density.

Advancement in Performance

The performance or transfer rate of a tape drive can be improved by increasing linear bit density, increasing the format efficiency, increasing the number of heads, and increasing the head to tape speed. Increasing the format efficiency and linear bit density to advance the performance follow the same arguments as advancing the capacity, which are clearly in the favor of helical scan.

By using multiple heads in parallel both linear and helical scan technologies can increase the transfer rate. Implementing parallel heads in linear technology is more difficult because of the requirements for read after write. In helical scan technology, read after write is accomplished easily with the existing read head. In linear technology the heads must be mounted in a write-read–write configuration to allow for read after write in serpentine recording. By configuring the heads this way, the read head will follow a write head in either the forward or reverse direction. So for each additional track, three heads must be added for linear technology instead of only two for helical scan technology.

Increasing the head to tape speed for linear technologies requires the tape speed to increase, since the heads are stationary. The increase in tape speed will force linear technology to increase the motor size and increase power consumption. The higher tape speed will also increase the already long start/stop times. Higher tape speed will put more stress on the tape and will also make a tracking servo more difficult to implement.

Increasing the head to tape speed in helical scan technology only requires increasing the rotational speed of the scanner in which the heads are mounted. This requires no increase in power, has no effect on start/stop times, and does not increase the tension on the tape.

There is no end in sight for the increasing capacity and performance demands for tape products. Both linear and helical scan technologies will continue to increase their capacities and performance to meet this demand. But because of the inherent advantages of helical scan technology over linear technology, helical scan will advance faster and at a lower cost.