DIGITAL DATA BASES ON OPTICAL VIDEODISCS

by

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Abstract

Optical videodiscs were developed as a low cost means of distributing video programs. The high density and random access playback features lend the medium to data retrieval. Further, the optical disc itself can be used as a data base of images and the inclusion on data is a natural extension. Applications are discusssed. Characteristics of the videodisc channel are examined and modulation and error correction scheme are recommended.

I would like to thank IBM for sponsoring this research.

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Chapter 1: The Optical Videodisc

As video becomes an increasingly important medium, new technologies develop around it. One important such innovation is the optical videodisc. A light source, usually a laser, is used to read microscopic pits in the disc from which the video signal is recovered. There are two types of optical videodisc systems: transmissive and reflective. The reflective system developed by Philips is by far the most common and was used in this research. Magnavox, Pioneer and MCA/DiscoVision all market and industrial players compatible with this format.

Video signals in the U.S. conform to the NTSC standard. An NTSC signal contains both image (intensity, hue, saturation) and sync (horizontal and vertical) information. On the disc, source video and two audio signals are frequency modulated to produce the composite spectrum shown in figure 1. This FM signal is then limited, converting it to Pulse Width Modulation (PWM) and modulates the laser on and off during disc mastering.

Using a photo-etching process, the laser creates a spiral track of microscopic pits in a finely polished glass master. Program material starts at the inner tracks and spirals out to the edge. The disc surface is metalized and is used as a master from which injection molded copies are produced. These copies

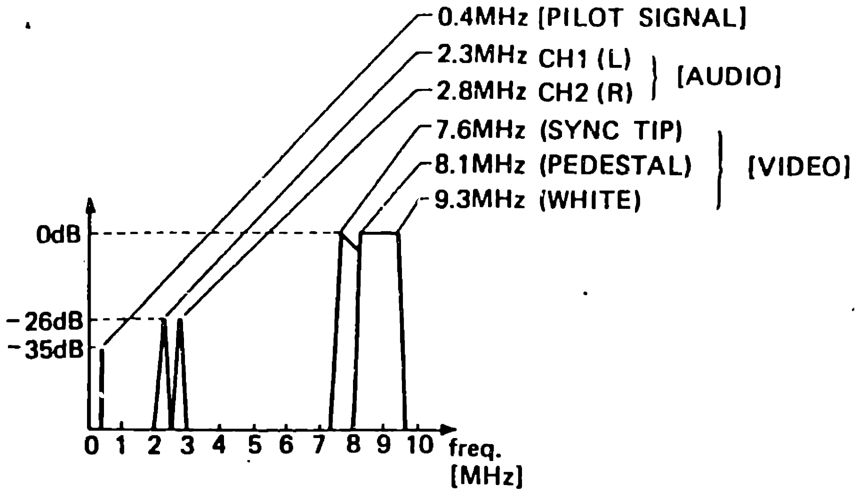
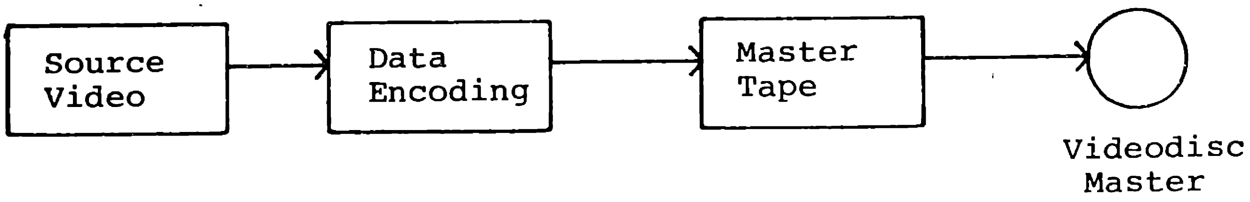
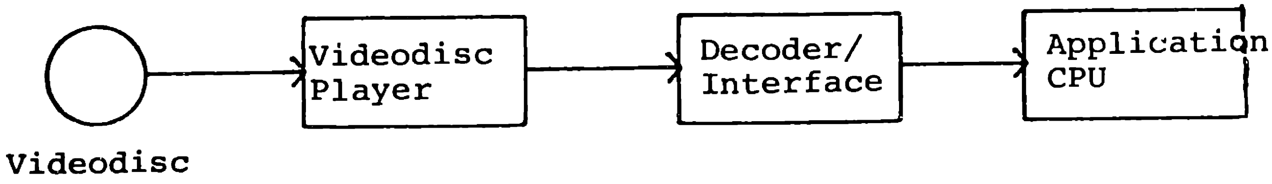


Figure 1

Composite Video Spectrum



Mastering Chain



Playback Chain

Figure 2

are coated with a reflective material. Two such discs are glued together with the reflective sides in the middle to form a videodisc. The the clear outer plastic layer protects the disc from scratches and dirt after production.

An optical videodisc player basically reverses the modulation chain. A laser in the player is focused through the outer plastic surface onto the reflective layer below. The reflected beam is detected by a set of light sensitive photo diodes. Any noise on the plastic surface, such as scratches or finger prints, are out of focus on the diode array. The relatively large point spread function of the surface noise acts to low pass filter such noise. A FM signal is recoverable from zero crossings so what we are interested in is the transitions between the reflective surface and the less reflective pits. Changes in reflectance are then reconstructed as the limited FM signal. The audio and video channels are bandpass filtered and detected to recover the original program material. Internal player circuitry performs time base correction based on color burst and horizontal sync phase.

There are two varieties of videodisc format. On a CAV disc, one revolution of the disc contains one frame of the video signal. NTSC video displays 30 frames per second and hence a CAV disc spins at 30rps or 1800rpm. This also means that the linear velocity increases as the read optics move out to the edge. Because the vertical retrace intervals on adjacent frames line up, still framing is accomplished by backing up one track at that time and replaying that frame. Backing up once per field yields reverse and skipping a track becomes fast motion. Slow motion is achieved by playing each frame a few times and then moving to the next one.

Not only do the vertical retraces line up radially, but any radial slice repesents the same portion of each video frame. Blemishes on a disc that effect adjacent tracks also effect the same place on the screen of adjacent frames. This will be important when we discuss encoding formats.

The other flavor is Constant Linear Velocity, or CLV, and as the name implies the disc speed is regulated such that the surface of the disc is moving past the read optics at a constant speed regardless of where the optics are positioned. Of course this means that the disc spins more slowly as the optics move toward the outer edge. CLV discs can hold up to 60 minutes of program material but cannot take advantage of the search or still frame features of the player. This format is designed for movies and other programs where playing time per side is more important than random access or still framing.

Chapter 2: Optical Videodisc Applications

The Videodisc medium offers some interesting new features. First, both video and audio signal quality is improved over home video tape. The optical videodisc provides for 4.2MHz video bandwidth and 20KHz stereo sound. Mass production costs of discs are less than tapes because discs are in a series of steps whereas videotapes are serially recorded. Thus, the videodisc plays an analogous part to the vinyl album. Currently in the audio market, good quality pressings out perform most tape decks as far as bandwidth and signal to noise ratio. Pressing records as opposed to recording tapes also has its cost advantage. This in no way makes the cassette tape deck obsolete. Its usefulness, as with video tape, lies in copying hard-to-get material, recording broadcast programming for later playback and home production.

In addition, optical videodiscs are resistant to scratches and surface noise, making them good for repeated or continuous use. The use of light to read the disc, as opposed to a contact stylus, makes still framing possible. Although some form of still image display is available on some video tape and contact disc models, most are not designed for prolonged viewing without degrading the source. In the case of home video tape, the video head eventually wears out the tape surface. Similarly, capacitive videodisc systems will damage a disc's tracking groove if still framed for more than a few minutes.

Linked to the optical videodisc's ability to single frame is perhaps its most interesting feature. The MCA/DiscoVision 7820 and Pioneer VP-1000 players can be instructed to search to a specified frame. All frames on the disc have a frame number encoded in the vertical retrace period. (This is an example of other efforts to include digital data in a video signal and is discussed further in chapter 4). Coupled to a computer, the videodisc becomes a data base of images and sequences of images. Similar systems have been attempted using video tape players with marginal success. [12] Long search time and poor still framing ability are some of tape's failings. Although a videodisc player cannot yet match the performance of a computer disc drive, it lies somewhere between the two. Interfaces have been constructed for the Interdata 3220 to be able to control both the MCA and Pioneer players in the lab. The MCA players have an end to end seek time of about four seconds. In addition, they provide single frame display, slow forward and reverse, and auto-stop. The auto-stop function plays from the current frame to a specified frame number and stops. As work here continues, the computer/player interface will be refined and features such as continuous frame number reading will be implimented.

In a graphics lab, one quickly realizes the value of memory. An image stored in a frame buffer for display might be comprised of 640 x 480 pixel values, each representing the color of a point on the screen. Each pixel might be one byte. Hence a good quality display might consume 250,000 bytes. Such an image would be of potentially better quality than one derived from an NTSC signal. An NTSC image is equivalent to about limented.

In a graphics lab, one quickly realizes the value of memory. An image stored in a frame buffer for display might be comprised of 640 x 480 picture elements, or pixels, each representing the color of a point on the screen. A good quality display might use one byte per pixel and hence consume 250,000 bytes per image. Such an image would be of potentially better quality than one derived from an NTSC signal. Given the following estimations,

NTSC Bandwidth: 4.2 MHz
Nyquist Sampling: 8.4 samples/sec
Bits per sample: 7
Image signal time per line (discarding sync): 53 usec
Lines per image: 484

we can assume 188,000 bytes per image. This is still significant and when viewed in the light of a videodisc's capacity for 54,000 images, it is substantial.

A single side of a videodisc has then been changed from a half hour of movie type entertainment to an intelligently controlled video access system. An early experiment with videodiscs here at the Architecture Machine Group yielded a disc known as the Slideathon. Slideathon is a collection of slides from the Roach Architecture Library and many individuals' travels. Comprised of 54,000 slides, it would otherwise occupy 54,000 pages in a book (of many volumes) and be over 8 feet thick.

A more sofisticated application was implimented in connection with the Mapping By Yourself project [5]. The concept was to allow the user to get to know his way around a city. A film team went to Aspen, Colorado with a 35mm movie camera mounted on top of a van. They drove up and down all of the streets in town, filming one frame every ten feet. Then all turns at all intersections were similarly filmed. Next, 35mm slides were shot of all buildings and some included an in depth slide tour. For example, pictures may be taken of a restaurant's dining room and menu as well as its head chef and specialty dessert. All film was edited and transfered to videodisc. The resulting disc is a data base with which the computer can take the user around town under his control.

Briefly, the Travel program works as follows. Two videodisc players are used such that one is being viewed while the other one is anticipating the next sequence and seeking to it, known as staging. For example, you are travelling east on Main Street. Upon reaching an intersection, the computer notes that you have not taken any action and so continues to play through the intersection. The user then indicates that he would like to turn right at the next intersection. Under program control, the other disc player searches for the starting frame of the desired upcoming turn. This frame number comes from a data base contained in the computer. When the interection is reached, display is cut to the other player and you make a right turn onto Monarch Street, after which the 'south on Monarch Street' sequence is shown. The user also has the option to vary speed

and direction (forward or reverse) and to stop. He may also stop and touch a building on the screen. A touch sensitive display indicates to the computer where the user touched and that information plus a digital data base is consulted and the front view of the desired building is searched to and displayed. If that building has a slide show associated with it, the user can ask to see it. Thus the combination of the videodisc and the computer allows dynamic insertion of building facades and user controlled routes.

To familiarize you with Aspen, you could watch a video tape of someone else's ride through town, stopping at where he thought you might like to see, but the Travel program provides for a large, general and flexible data base that you can use to fit your needs and interests. Another area where interaction is important is education. The idea of programmed learning courses and tutored texts work by periodically testing the reader and reviewing (or repeating) material not understood. Personalized Movies is an attempt to provide a much more interactive learning environment [6]. The videodisc provides the source of lessons, diagrams and short illustrations. The first project was a Bicycle Repair Manual. The program starts with a still frame of a bicycle. Touching a component on the bike causes the the player to play a sequence, with sound, on the removal and adjustment of that part. If at any time the user is not sure about a particular procedure or tool, he may stop the lesson, and touch the item in question for more detail.

One could just sit a watch the whole disc, but maybe you already know how to use an adjustable wrench. So, by interacting with the computer, you effectively create a movie as you watch that is taylored to your knowledge and experience.

Above are just a few examples of what videodiscs hold in store for the future. The combination of videodiscs and computers seems promising. But in order to organize, access and control 54,000 frames, there must be some sort of description of what's where. For example, in Travel the computer has to know what the starting and ending frame numbers are for the right turn from Main to Monarch. Given that there is visual data for each turn and street and every building in Aspen, the digital data base that must accompany that disc becomes quite large. In Bicycle, touching different items on the screen initiate different sub-lessons. The computer must know where things are on each frame.

In each of these cases, although the data bases are large, if a particular frame is being displayed, then only a particular portion of the data base is useful at that time. For example, in the bicycle manual, areas of the current screen directly indicate bicycle sub-lessons. Similarly, the disc address of slide shows for the buildings in Aspen are needed only for the subset of all buildings currently in view. By replacing the picture information at the top and bottom edge of the screen with encoded digital information, the video and digital data bases combine into one medium. This data base expands to include full frames of encoded text for computer display, program code, or any other useful data. As we will see, there is research being done in the area of pure data storage and retrieval on optical discs. But the goal here is to provide a low cost, NTSC compatible system for storing both visual and numeric data.

Chapter 3: Associated Efforts

The television industry has developed a large system of distibution for its programming. Recently, the wideband video channels in radio communications, cable systems and recording media have been recognized as a means of digital and textual communication.

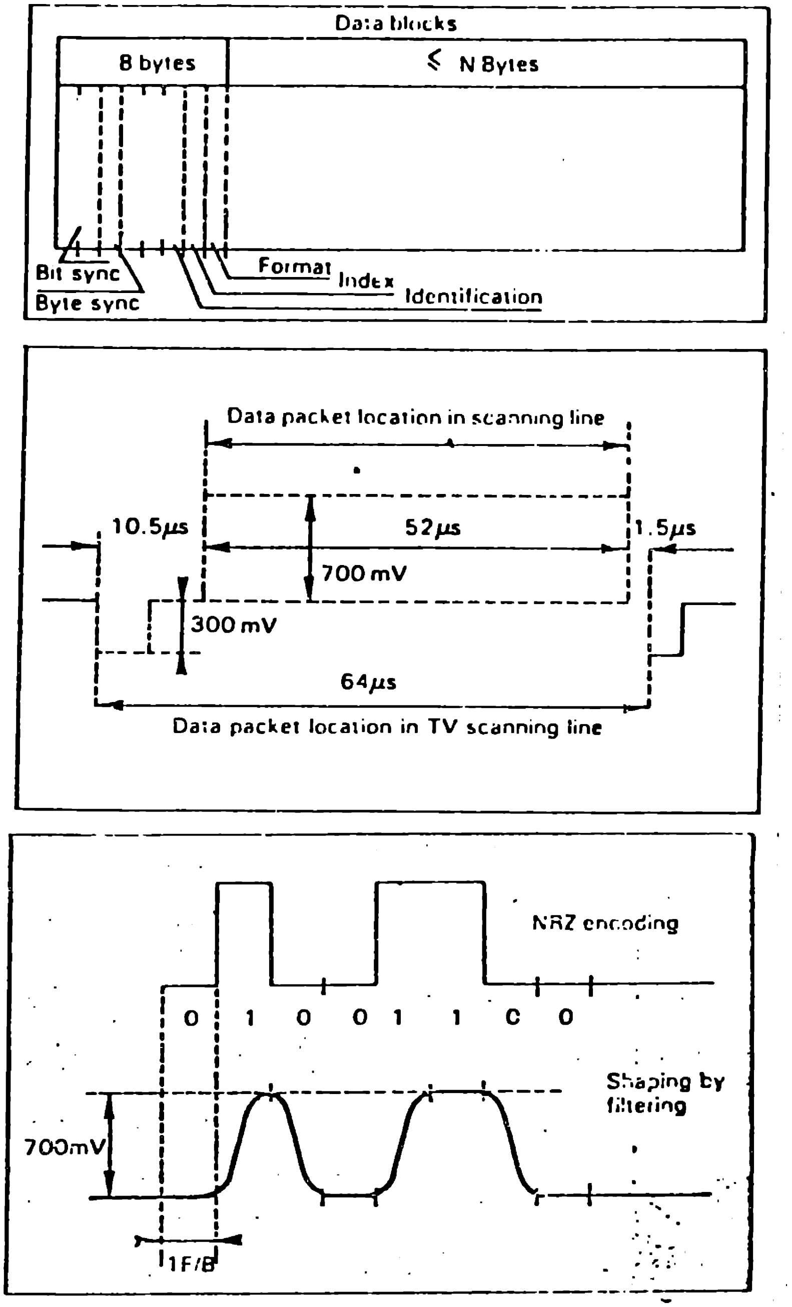
A great deal of progress has been made in Europe. Two systems exsist for the inclusion of text and/or graphics to be encoded into a broadcast channel. The UK standard is Teletext, in which text is encoded into the signal during the vertical blanking interval [9]. This text could be subtitles either for the

deaf or in a foreign language. It could also be independent of the video program such as program listings, magazines articles, or phone directories. Such information is transmitted repeatedly and intellegence in the home receiver can select the desired sections for display. The result is a trade off between data density, variety of available material and access time.

Another such system is the French Antiope Videotex [8]. Videotex describes a format of header, clock and data and also defines character code functions. It allows for color text and graphics display and overlay (for subtitling). Many countries in Europe have adopted the Videotex standard and adapted it for their particular broadcast systems. The bit signalling frequency used in France is 6.203MHz while the value recommended by the Swiss PTT is around 5MHz and the value experimented with on the M-NTSC standard (USA, Japan, Canada) is 4.2MHz. The Videotex in France is used both on phone lines for interactive use and in conjuction with TV broadcast systems; the latter is called Didon. Data is encoded as shown in figure 3. It includes two bytes of bit sync followed by a sync byte, header and data in NRZ format. In the case of the NTSC television system, Videotex yields 20 useful bytes per line. At one line per field, the average useful data rate becomes 9600bps.

An interesting difference between Antiope and Teletext is in the formatting of a line. Given an unrecoverable error in a line, either system will wait for that line to come around again and retry. But if the error is due to some intersymbol modulation, it is likely to fail again. The Antiope system includes a Format field in each header desribing how the characters are arranged in that line. The use of a non fixed format increases the chance of recovery from intersymbol modulation errors. The trade off here is that if the Format field can not be read, the whole line is undecodable.

Similar systems are under development around the world including the Canadian system Telidon and Closed Captions here



Antiope Packet Format

<u>Figure 3</u>

in the US. The Closed Caption system is being critisized by the CBS network as being inflexible and incompatible with other systems. Currently the Closed Caption system can only display monochrome text and is intended for deaf viewers.

With the advent of cable TV, both signal quality and number of available channels will increase dramatically and data communications will become a large part of that industry. Hopefully a standard will emerge that is flexible enough to satisfy the requirements of broadcast, cable and recorded video, including the optical videodisc.

As a point of interest, note that there are systems that encode digital information into NTSC for storage and retrieval. These systems take advantage of exsisting technology in the video domain for high density, high bandwidth, low cost and compatable equipment. The Corvus Systems, a firm marketing Winchester type disc drives for small systems, also sells a product called the Mirror which encodes data from the disc for backup onto videotape cassette, thus getting double duty out of your videotape unit. But home videotape provides poor bandwidth and fidelity compared to videodiscs or even broadcast TV. The Mirror uses a 1.1MHz bit clock and employs parity checking, CRC codes and redundancy to recover errors.

Another example of spinoff technology from the video industry stems from the optical videodisc itself. Originally designed by Philips, the optical videodisc was intended to be a vehicle by which MCA could market movies and other video programming at a reasonable production cost. Currently, Philips is taking the optical disc and developing it for the computer industry as a data storage device outside the video domain. Their DRAW (Direct Read After Write) system will allow archiving and other "write once", long term and high density storage applications. Similar work is being done in digital audio which encodes a 16 bit linear A-to-D code on a small optical disc.

The first example of data encoded into video for optical discs is part of the videodisc system itself. The number of each frame is encoded on the disc once per field in a baseband bi-phase-mark modulation. The 40 bit code contains sync and parity check bits and is stored at a rate of 1 usec per bit.

Chapter 4: Encoding Schemes

In order to determine an effective encoding scheme, the various distortions that limit data rates and accuracies must be studied. R. W. Lucky, in his discussion of data transmission limitations [7], divides signal impairments into two categories - deterministic and random. Deterministic impairments are predictable in advance and include imperfect compansion and multipath reflections. Lucky also notes that predictable distortions can be dealt with effectively using adaptive filters, self clocking codes and other such means. Videodiscs suffer from varying disc speeds (it's only mechanical) but an internal time base corrector uses signals from timing tracks adjacent to the program track to reduce timing errors to 10ns per line [3]. The pre-mastering process can introduce intersymbol modulation but this can also be taken care of by careful recording technique. Filtering or even adaptive filtering at mastering time can be used to satisfy the Nyquist criterion. This is more of consideration for the encoder/modulator and the reader is refered to Lucky, page 159.

Gaussian noise and impulse noise are random. A report by the SMPTE Study Group on the Video Disc [14] measured video signal to noise ratios of between 25dB to 40dB. Assuming the standard video bandwidth of 4.2MHz, we can apply Shannon's theory [13] of channel capacity.

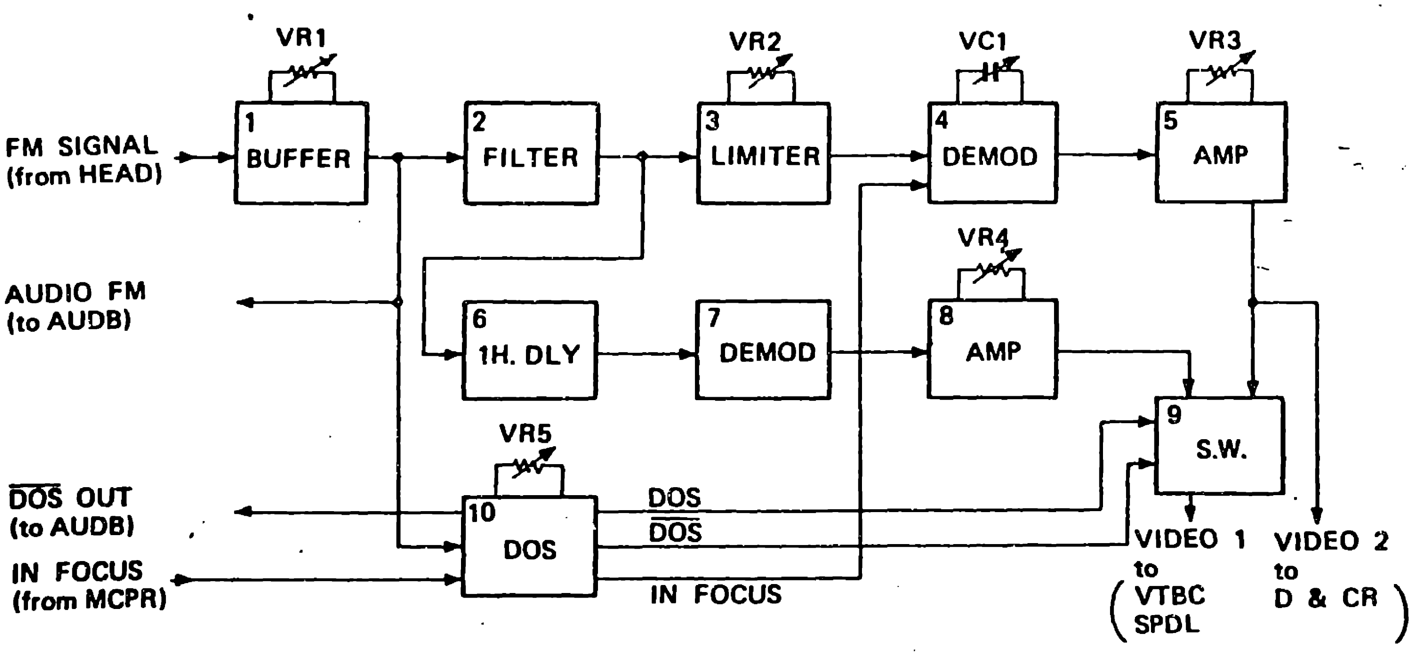
$$C = W \log_2 (1 + S/N)$$

W represents bandwidth and S/N is signal to noise power ratio

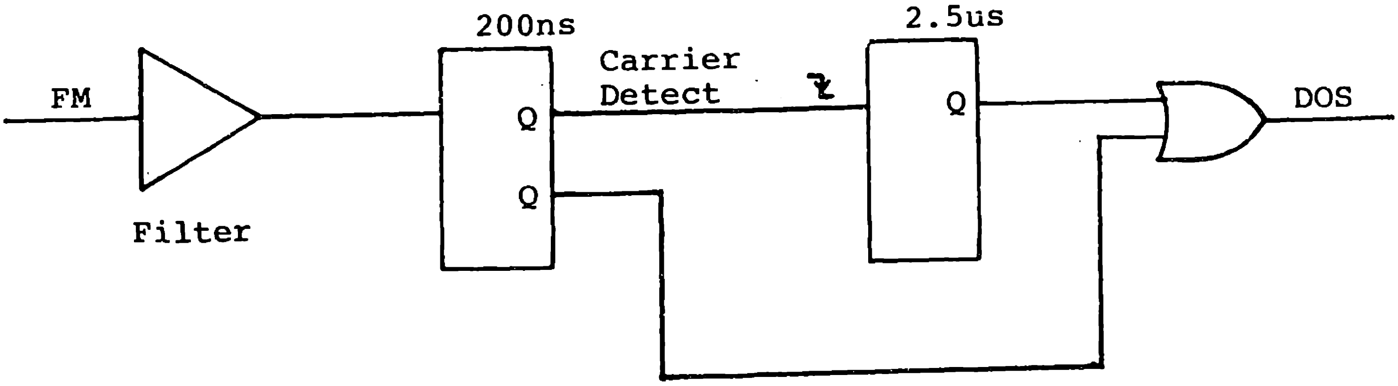
yielding C, the channel capacity in bits per second. From our values above, capacity ranges from 35Mbps to 56Mbps. From Nyquist's theorum that a channel of bandwidth W is defined by 2W samples per second, it would seem that Shannon, or we, have made an error. The solution is that in order to approach the rates that Shannon's theory indicates, each sample must contain more than one bit of information. For example, one of four possible signal levels could be used to represent two bits. This technique is directly affected by signal to noise ratio. Most communications channels do not get very close to their Shannon limit and unfortunately, there is no acompanying algorithm to determine the scheme that would yield that data rate, none the less it provides a useful upper bound on channel capacity.

But by far the most frequent cause of error on discs are dropouts. Dropouts are flaws in the disc's reflective surface such as tiny holes or scratches. A dropout could be a result of a flawed master, in which cases all discs from that pressing would have the same defect. The manufacture of blanks and the stamping process itself are also to blame. Dropouts range in size from microscopic to as large as 1.5mm across. Unlike additive Gaussian noise, dropouts are impulse noise sources that are independent of the data modulation technique used and effectively yield a signal-to-noise ratio of zero.

Current video players must also address the problem of the dropout. Figure 5 is the block diagram the video demodulator board from the MCA 7820 player and is representative of videodisc player design. There are three signal paths from the FM signal. (2-3-4-5-9) is the main signal path and (2-6-7-8-9) for a path that is one horizontal line delayed. The dropout sensor (DOS) circuit monitors video carrier and controls the output switching stage (9). While carrier is present, the main video path is routed out for display. As long as (11) continues to be retriggered, carrier detect (CD) remains true. Approximately 100ns after loss of carrier, CD goes false forcing DOS OUT true. The output switch (9) is then switched to delayed video to be displayed. Because of signal delay time in the demodulation path, the demodulated dropout reaches the switch after it has changed and settled, thus smoothly substituting the image from two scan lines above over the dropout. The length of



(a) FM Demodulator



(b) Detail of Dropout Sensor

Figure 4

a dropout is extended 2.5us by (12) so that the end of the dropout can propagate through the filter/ demodulation section after which the video is switched back to the main path. The FM signal from the optics is often noisy with sperious triggerings of (11), but (12) protects DOS from these.

Dropouts in FM SIGNAL were observed with a occiliscope ranging from 280ns (one cycle) to 4us. Good FM was a .6v p-p signal. Dropouts tended to cause FM SIGNAL to deflect away from the ground, often outside the .6v p-p range. As expected, a dropout has little or no reflectance and, rather than attenuating the FM SIGNAL, it removes it. Not all dropouts are holes and there are distorted sections that occasionally trigger the carrier detect one-shot. An interesting thing to note is that in still frame mode, the player spirals out one rotation (i. e.frame) and skips back a track during vertical blanking. As the optics move between tracks, FM SIGNAL attenuates to zero and returns, a process that takes about one line time (60us). Care must be taken not to include this line in any encoding or error analysis schemes.

A prototype model of a disc-to-data decoder was modified to accumulate statistics about dropouts. The details of the board are discussed in chapter 6. On command from the host processor, an Interdata 7/32, the decoder waits for a specified line and clocks NRZ data bits into local memory for subsequent transmission to the host. Using a phase locked loop, the bits were sampled at twice the color subcarrier frequency (7.16Mbps). An MCA 7820-Model 2 was modified to bring carrier detect out to the decoder board as a TTL signal. Still using using sync and color burst from the player's video out, data (CD) was clocked at 7.16Mbps or 144ns/bit during non-blanking time. A Panasonic WJ-4600A Special Effects Generator was used to generate necessary sync signals including subcarrier regeneration. The GenLock feature of the unit provided stability in that it would lock to video from the player but once locked, changed slowly and was not sensitive to glitches or lost syncs. For example, if dropouts have destroyed color burst on two consecutive lines, the second line will not be able to recover and will send a strange and undefined signal at burst time. The GenLock circuitry determines that it cannot lock to this and continues regenerating subcarrier until it finds a good burst. The same is true for missing sync pulses or large negative going pulses that often get detected as sync. This feature is mandatory on a project such as this where data is accessed by counting sync tips from from the top of a field.

Given that we can compensate for signal corruption during sync time, we can think of the remaining signal as the communication channel of interest. There is a tendency to think of a frame as a two dimensional array as displayed on the screen, but that is an arbitrary and perhaps misleading model. There is no relationship between the same position in different lines except that they are displayed above one another on a monitor. A frame is actually one dimensional: time or better yet angle around the disc. Extending that model, the other index is frame number, corresponding to radius. This is useful since dropouts can extend across tracks.

In order to do analysis over many frames, the player must be under computer control. The 7820 Model-2 supports a UEI, or Universal External Interface. It allows an RS-232 port from the Interdata to issue commands and to request status to insure things are the way they should be.

Test programs were developed to search to a start frame and accumulate dropout statistics for some number of frames. CD was sampled by the data decoder board one line (400 samples) at a time. Appendix A contains the observed data and resultant histograms. From this information, we will choose a worst case error pattern and develop an appropriate error recovery scheme.

Out of 1600 frames, an admittedly small sample, the worst frame exhibited between 260 and 270 dropped out bits. There are 480 line x 400 bits per frame, or 192,000 bits per frame. That is 1 error in 711 or 0.142% bit error rate, worst case. The longest single dropout was 96 bits long. But judging from the non-dropout length distribution, or distance between dropouts, dropouts are frequently closely spaced. Hence, if those small spaces were ignored, the largest possible dropout could have been 270 bits. Our error correction should be able to correct 270 bad bits in the chosen encoded block size.

Chapter 5: Error Correcting Codes and Modulation

Using the dropout statistics as an approximation of error behavior, an error correcting code can be selected. Other criteria include encoding cost, decoding cost, expected unrecoverable error rate, data density (bit clock rate) and decoder speed. There are many trade offs to be examined and most are dependent on the application. Since one goal is to provide data supplimental to visual images as they are viewed, our encoding block size should be small, no more than 5 percent of the screen or 24 lines. Since "proof reading" discs after production is impractical, it is important to keep the error rate down. Even after an error is detected on a disc, it cannot be patched and must be discarded. Assuming our application calls for 24 lines per frame, a reject rate of one error in 100 discs might be reasonable. Due to the publishing nature of the disc, i.e. the discs are decoded many more times by many more people than they are encoded, encoding cost becomes less important. Lowering decoding cost is attractive because it would make available large information bases to relatively small, inexpensive computing systems.

Codes exist designed for correcting random or burst errors. Busrt codes are more efficient, but require a minumum number of good bits between error bursts. As we have seen, the separation between dropouts varies widely hence a burst code is not appropriate. Random bit error correction codes need large code words to combat error bursts and are therefore inefficient and expensive. One method to reduce the effects of dropouts is interlacing. A set of code words are generated for a block and are arranged in rows. Then each column is recorded effectively separating the code bits. If there are n code words then a dropout of n or less will affect only one bit in each code word and data will be recovered. The farther apart the bits are, the bigger the dropout tolerance is. The trade off is in smaller and smaller code words resulting in less efficiency.

Sufficient interlacing reduces the problem down to the aggregate dropout probability. Both BCH and Reed-Solomon codes are very effective but are slow and expensive to implement. Binary polynomial multiplication and division is required for error correction and hardware decoding times run about 5usec per bit. This scheme could become attractive in the future as VLSI and other technology gains speed.

Cyclic codes offer a good combination between power, speed and cost. Golay is a cyclic (23,12) code that can correct any three bit errors. It is relatively easy to implement and can run faster than the 7.14Mbps rate of incoming data. Using our mean error rate estimation of 0.142%, there is a 3% chance that more than three errors will befall a given 23 bits. Clearly a more powerful code is needed.

Maximum Length Sequence codes can tolarate up to a quarter of a code word to error and still recover. On the other hand, code word length grows exponentially with message length and soon gets out of hand. A (255,8) encodes 8 bits in each line but can correct for 63 bits worth of dropouts. Brute force may not be the answer here.

Most codes grow in efficiency with increasing code size. But decoding time and cost go with them. One Step Majority Logic Decodable Codes are easily and quickly decodable with hardware but again size becomes a problem after n=1057. If the task of decoding could be broken into subtasks, a smaller amount of circuitry could be used iteratively to decode data, sacrificing time for cost. Peterson suggests a product code as a method of controlling both random and burst errors [10].

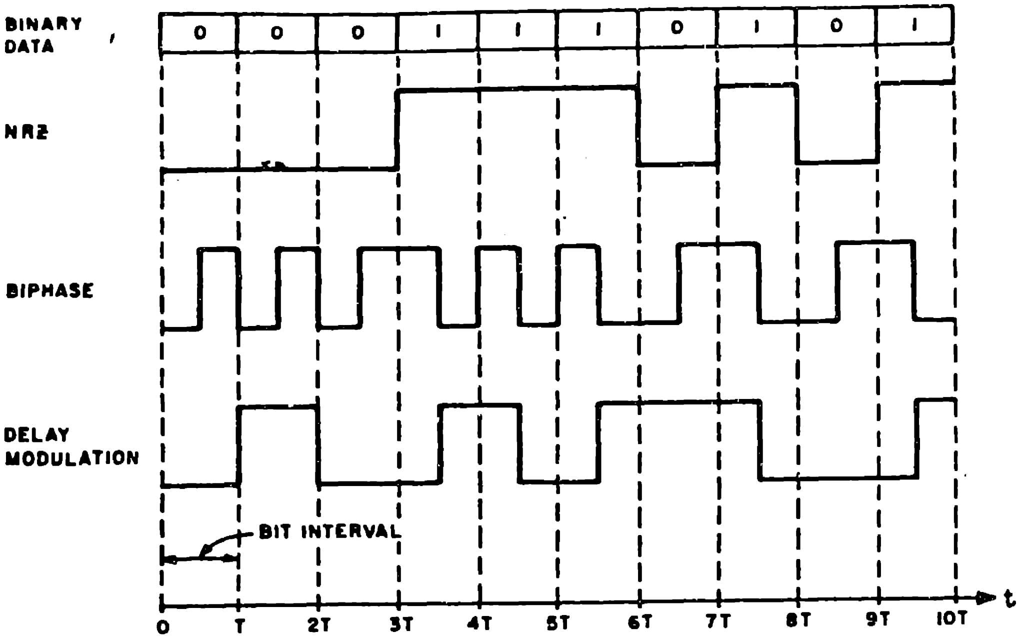
A product code is implemented by arranging the message in a matrix and performing row-wise encoding on all rows, followed by column encoding. Now a 1-Step Majority Logic Decodable Code of more reasonable size can be considered. A (73,45) code will correct 4 errors and detect 8. Arranging the message to be a 73 by 73 bit square of 5329 bits, this packet fits in 15 lines and contains 2025 bits or about 250 bytes. Row or column code words have a 10% chance of losing more than 4 bits. But errors not corrected by the first code are tried by the second. The fact that we can detect as well as correct errors can also be used to correct some errors. If after applying both decoding schemes, there remains some bad received words, the points of intersection of two detected bad words can be complimented to further enhance data recovery.

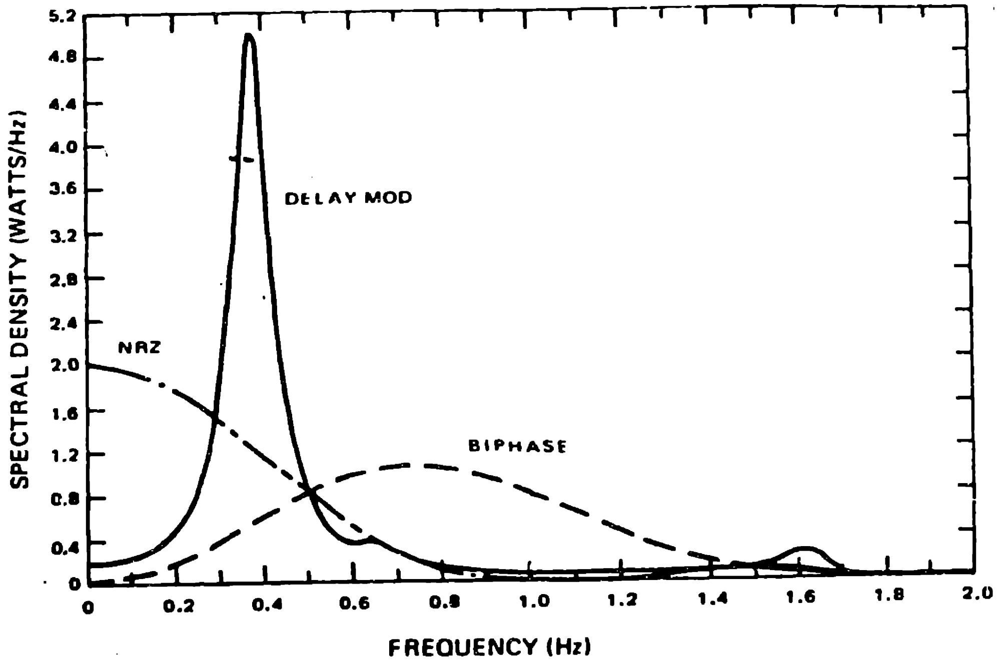
The final touch is to apply what was mentioned above as interlacing to our product code. Consider a(i,j) to be the finished 73x73 code word. The bits can be selected in an order that maximizes the distance between bits that were encoded together. The transmitted stream has the form a(1,1), a(2,2), a(3,3) ... a(73,73), a(1,2), a(2,3) ... a(72,73), a(73,1), a(1,3) ... a(71,72), a(72,73).

The hardware necessary to decode such a scheme starts with a 5329 bit buffer. Incoming bits from the demodulation section are distributed appropriately in the buffer after which error correction can begin. Starting with the orientation that was performed second during encoding, apply the cyclical correction algorithm. If the decoding finishes with no unrecoverable errors, the data is passed to the computer interface. If in fact there were unrecoverable errors, the next round of decoding is performed perpendicularly to the first. If this does not fix all errors, then the intersection of uncorrectable code words is used to find possible bad bits. The sequence is repeated until either all errors are corrected, nothing changes during a full pass or the circuit reaches some maximum number of passes. The Majority Logic Decoder requires a 28 bit shift register, 23 exclusive OR's, and a nine input majority gate (16 four bit adders). A sequencer similar to the Am2911 would be useful to control the flow of data and control. The cost of the decoder is kept down yet little time is lost if all errors are corrected on the first pass. Addition correction time is spent only on very bad blocks.

Peterson and others mention that cyclic product codes, although more effective than a one of the cyclic codes alone, it is very difficult to define the resultant correctable space of codewords. This will remain to be seen in future test discs. Certainly a large cyclic code guarantee a lower error rate than an equally sized product code, but we must first wait for technology to produce 4000 bit Majority Logic Decoders.

The next concern is modulation technique. Three common baseband schemes are NRZ, Bi-sync, and Delay Modulation (or Miller encoding). Of the three, the latter two are self clocking and DM features a longer minimum pulse size than





One sided power spectral densities

Figure 5

Bi-sync. A strong arguement can be made for either, and NRZ was chosen for the first implimentation. The choice between NRZ and DM becomes the choice between a self-clocking code and a color subcarrier clocked code. One reason NRZ was chosen is because decoder circuitry is simple and the NTSC signal provides a very stable clock. Also the board then serves the dual purpose of sampling not only an encoded signal but any signal, including the player's internal Carrier Detect.

In order to take full advantage of the disc capacity, the dropout compensator that detects loss of carrier and substitues alternative material must be defeated during data lines. This entails a control line from the board to the player and would be easy to implement.

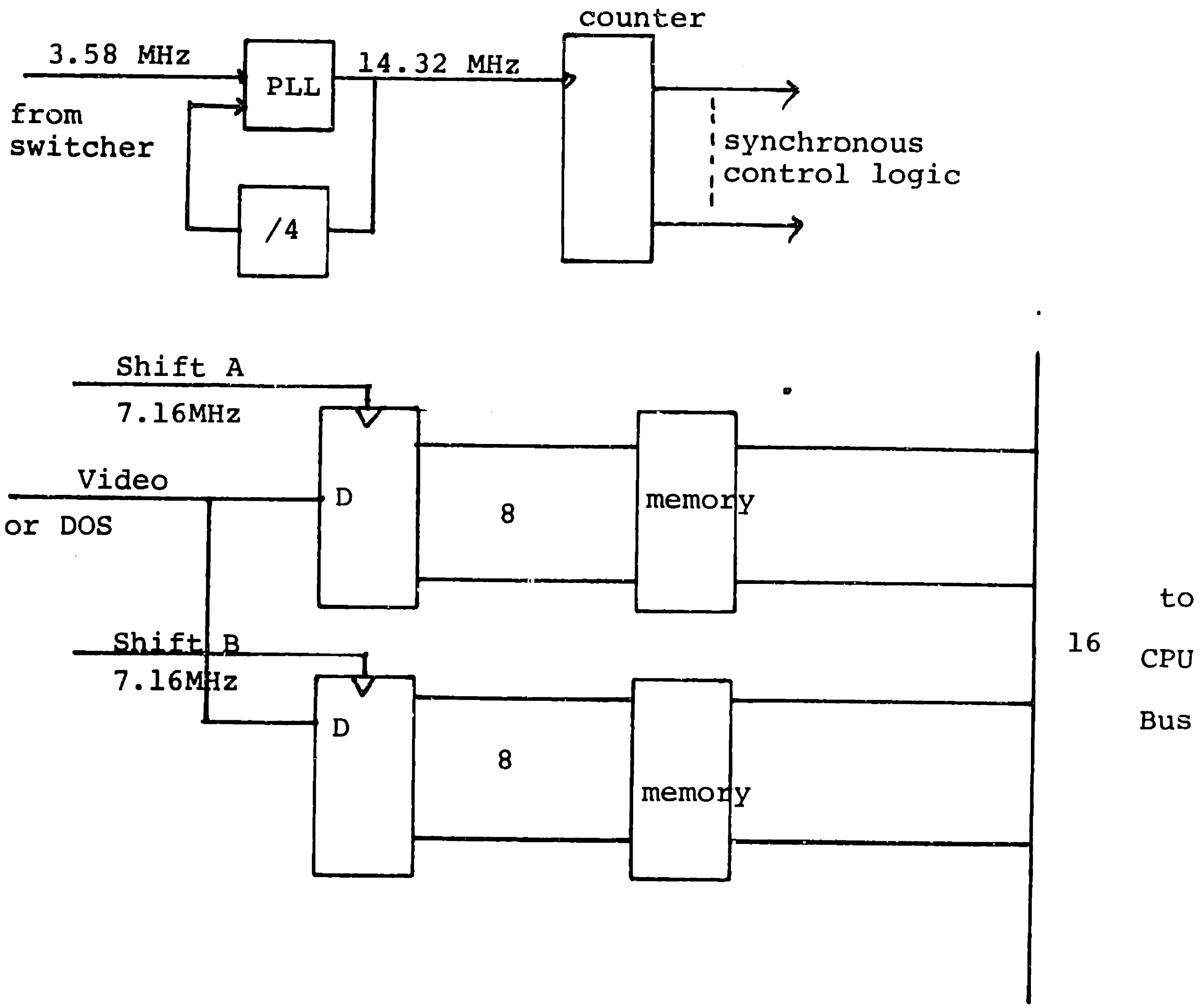
An alternative modulation scheme is Miller or Delay Modulation. Signal level changes during a "1" bit time and between two adjacent "0" bit times. This would enable the decoder board to process the demodulated video directly without the internal TBC, releasing that to process the image with dropout compensation, etc.

Chapter 6: Recovery Implementation

The prototype digital data decoder board (DDD) was built as a tool for data gathering and to begin to address some of the problems to be faced in the final design. Figure 6 is a block diagram. It operates as a peripheral to an Interdata 7/32 processor and receives commands to read data from a particular line. When the line comes around, it demodulates NRZ, the clock being synced to twice the subcarrier frequency. Received data is stored in local ram memory until requested by the host.

The video front end begins with the Panasonic mixer. As shown, the mixer accepts Player Video Out and GenLocks to it, providing the decoder board with composite sync, vertical drive, blanking and regenerated color subcarrier. Serial Data into the decoder can be selected from Player Video Out or Carrier Detect. A Phase Locked Loop is used as a frequency multiplier [16] to generate a system clock at 4 x s.c. Half this rate, or 2 x s.c., becomes the bit clock to the shift registers. The PLL turned out to be one of the trickier sections to make work reliably. A type 564 PLL was used but PLL's with greater stability will be included in future designs.

Double buffering in the input section allows bits to be clocked and shifted while the previous byte is being written to



Data Path Block Diagram of Decoder Board

Figure 6

local ram. A subcarrier phase adjustment on the mixer serves as a framing adjustment for the shift clock.

As it stands, the host/decoder interface is slow and straight forward. The host writes a line number to the DDD and that sets the DDD to read in that line next time it by. When the DDD's Busy status bit goes low, the operation is done and raw data can be read from the DDD, one word per request. In a final version, the decoder board should either perform DMA to pass decoded blocks or maintain on board memory shared by the decoder and the system bus. Refering back to comment made in chapter 2, applications such as Travel often only need access to a small portion of a very large data base at a time dependent upon what it is they are viewing at the moment. If the computer did not have to request each block read and decode but instead the DDD continueously updated memory with the data from the most recently viewed frame, a memory window into the disc's large data base results. In addition to off loading the CPU somewhat, it has other uses in program and system design. Consider the Travel program with data on disc. If each frame contained information describing what action to take given any of the user's possible actions, then the Travel program is merely an interpreter and the disc contains the program which we are driving through.

The Majority Decoder can decode a packet in about the same time it takes to read one in, because they are similar shift and gate types of operations on the same number of bits. But decoding cannot start until a whole block is read in and can be un-interlaced. If the block is badly dropped out, that data access time goes up. If the block is unrecoverable, the DDD indicates that to the CPU and processes the next frame. Many data bases have additional error recovery due to redundancy. Travel is a good example. Every frame on a particular city block heading a certain direction all have the same right turn start frame number. This type of recovery is best left to the application software.

Chapter 7: Applications

The optical videodisc shows great promise for success, not only for its technical achievement of data density, but also for the wide acceptance of the Philips standard by all reflective videodisc manufacturers.

Acheiving the same broad standard in a data encoding format is less likely, in view of the different requirements in density, mastering cost, playback cost and reliability for a given application. Reasonable trade offs have been attempted here aiming for a low cost decoder, 16 bytes per line and close to real time decoding. A block size of 15 lines gives the user choice between one or two packets of data acompanying a frame of image or 10K bytes of data consuming a frame. A large part of the cost lies with the sub-mastering of the data onto video.

A large, fast computer system is needed to present data to an encoder board at rates fast enough to make a sub-master in real time. Other wise, bursts of video can be recorded and the tape backed up and re-synced. Such equipment is expensive and so a reduced data rate format is needed for installations that desire to make their own discs on 3/4" helical videotape recorders. The clock rate could be slowed down by a factor of 4 with little modification of the decoder circuitry. This is an attractive alternative to storage,of text with pictures (i.e. newpapers, magazines, research articles) for easy access and extended life.

Decoder cost is not as dependent upon that rate because still frameing means that even with very slow data processing equipment, if the data can be clocked into local memory, it can be processed at leisure. At the proposed rate, a small user with a videodisc player (<$1000), a decoder board (<$1000), and a home computer (<$1000) programs like Travel and Bicycle become a reality in the home, office or school. The disc is expensive to make if all you want is one, but in quantities the price drops to under $10 per side. This introduces the concept of data publishing. Since the small user cannot make discs himself for a reasonable cost, he must rely on the commercial market to provide him with useful data on disc. A full disc, being 500 million bytes without images, might contain yellow page listings with advertisements.

Currently, the only people doing substantial research into the topic of digital data on videodisc is neither the DP industry nor the videodisc manufacturers themselves but the potential end users. Hopefully much fruitful research will will result and a useful flexible standard is developed and implimented. In the end marriage between videodisc player and the computer must be consumated by the combination of video and data.

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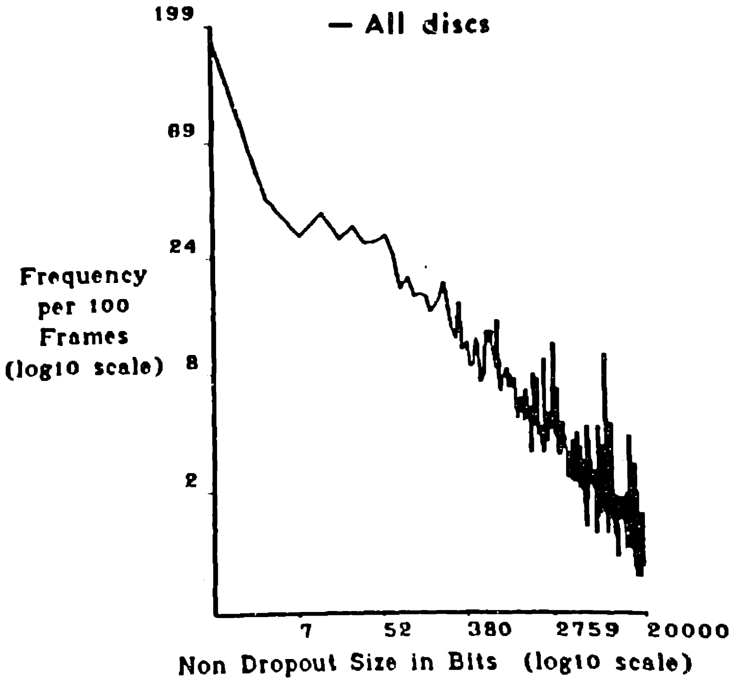
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24
8
2
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7
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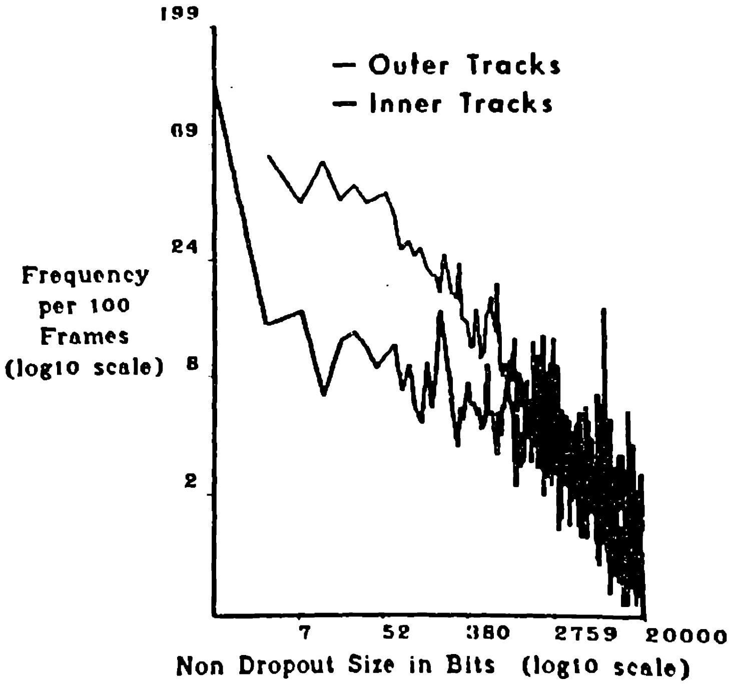
380
2759
20000
Non Dropout Size in Bits (log10 scale)


— Outer Tracks
— Inner Tracks
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24
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380
2759
20000
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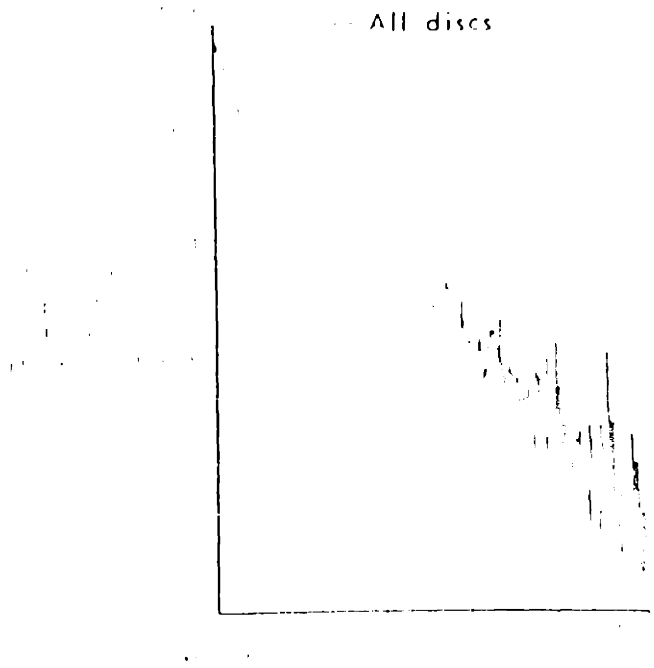
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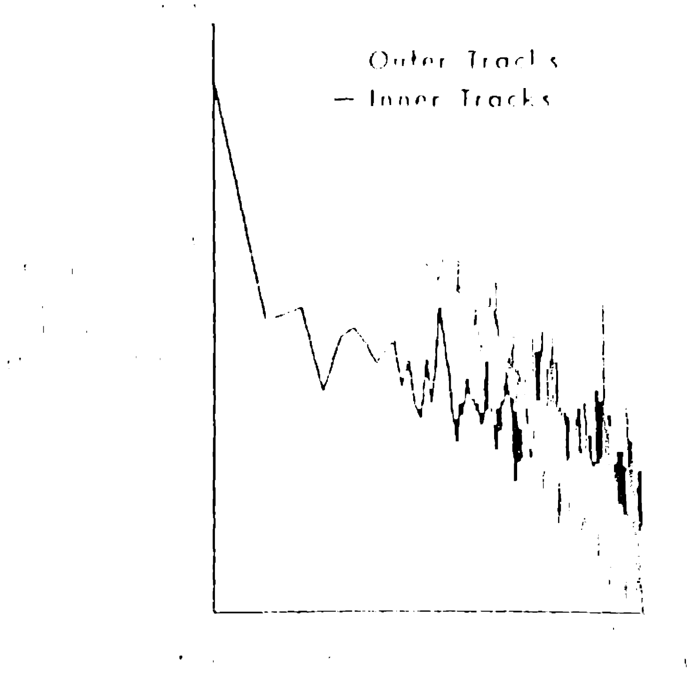
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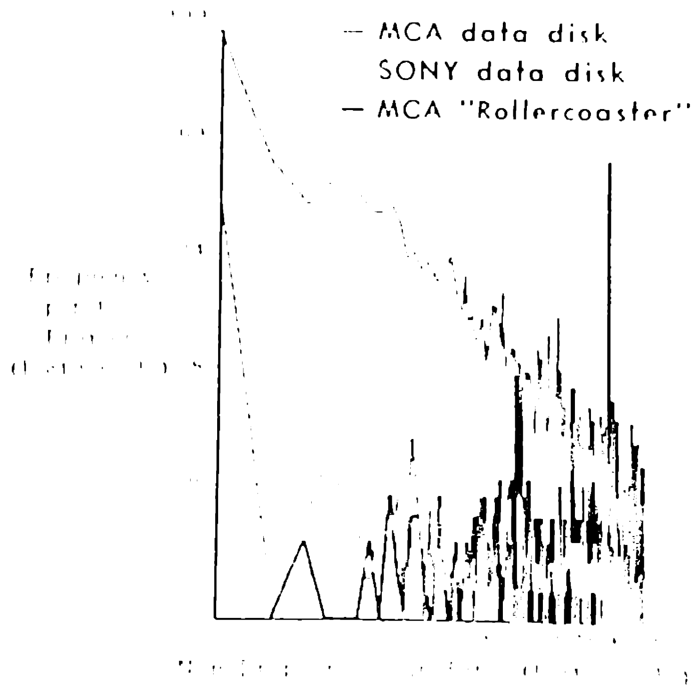
Inner Tracks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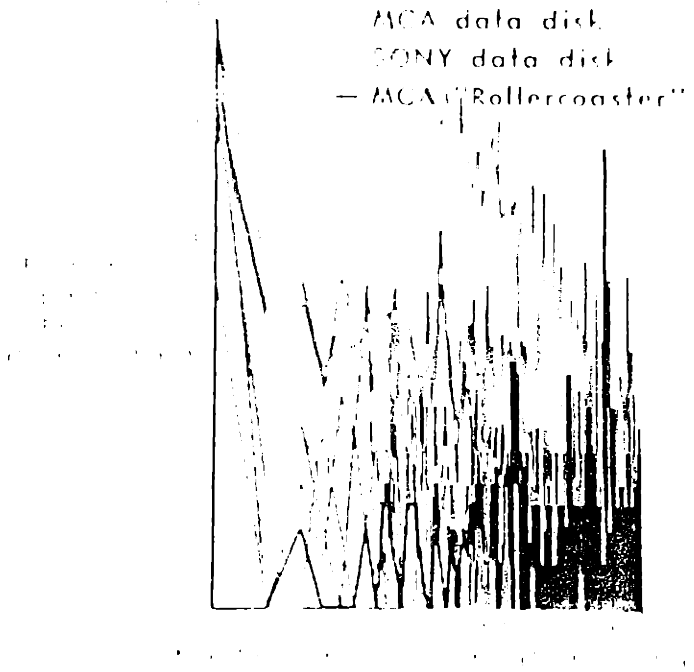
SONY data disk
— MCA "Rollercoaster"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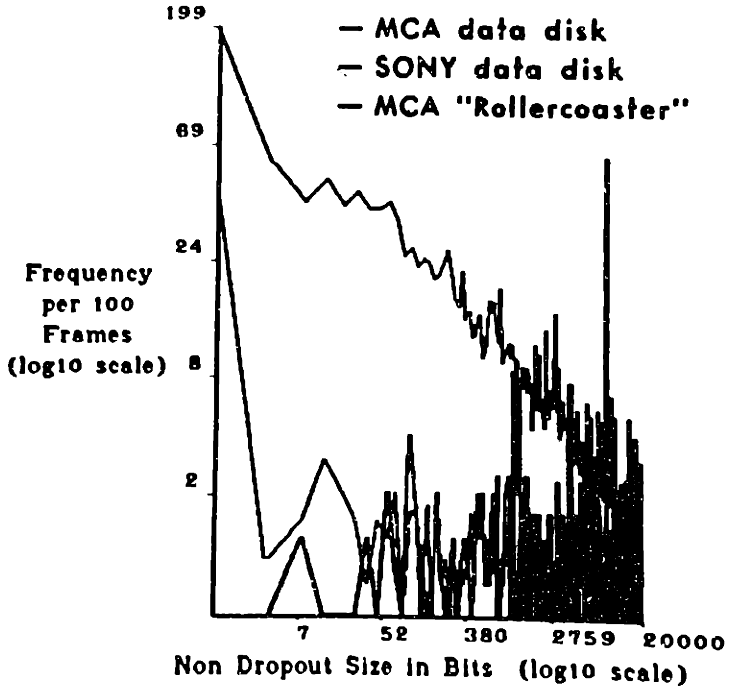
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Frequency per 100 Frames (log10 scale)
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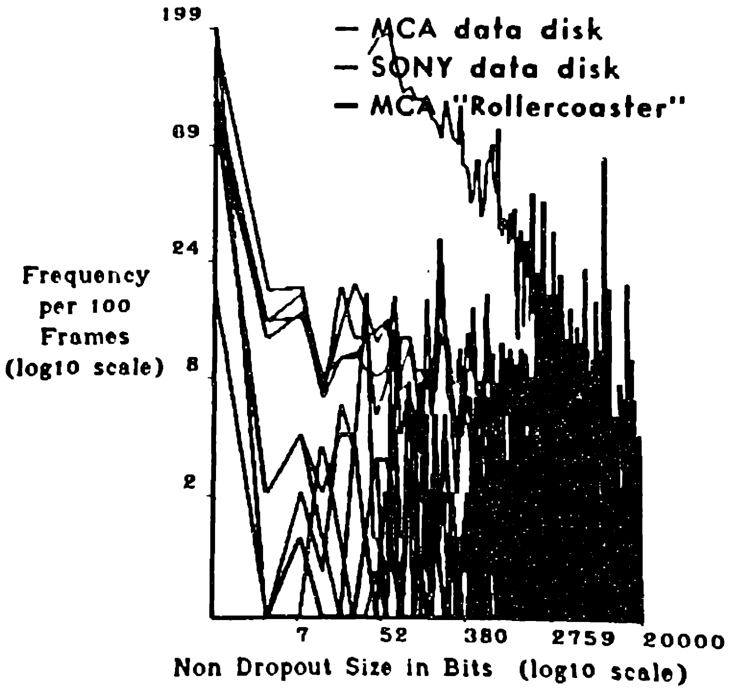
Non Dropout Size in Bits (log10 scale)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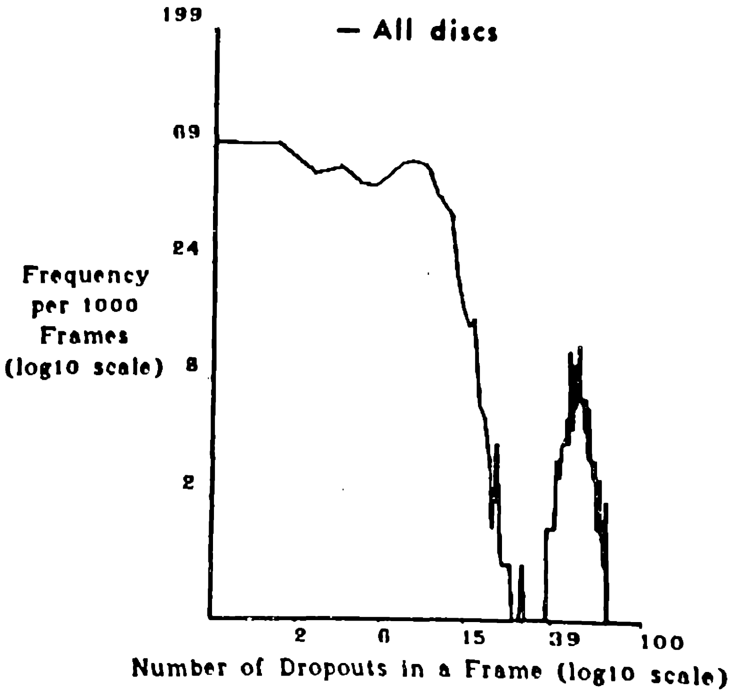
Non Dropout Size in Bits (log10 scale)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39
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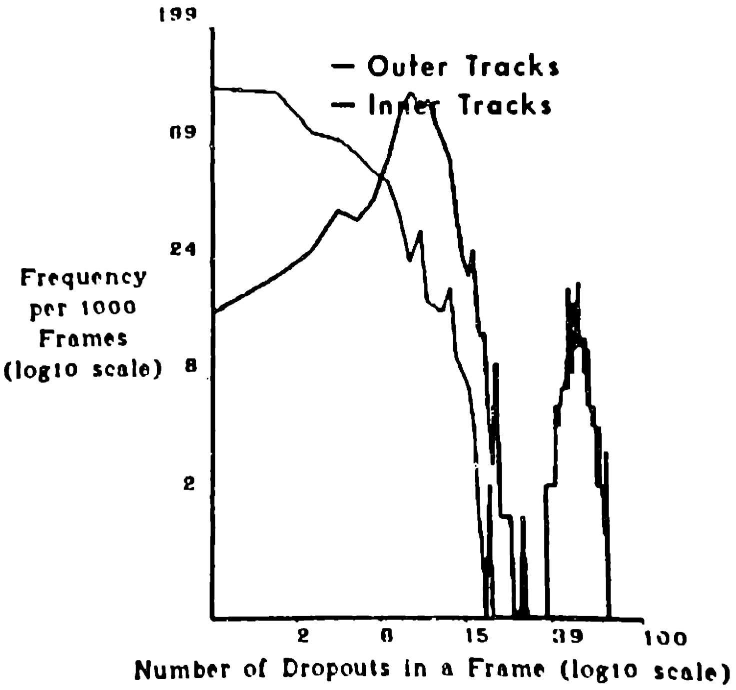
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— Inner Tracks
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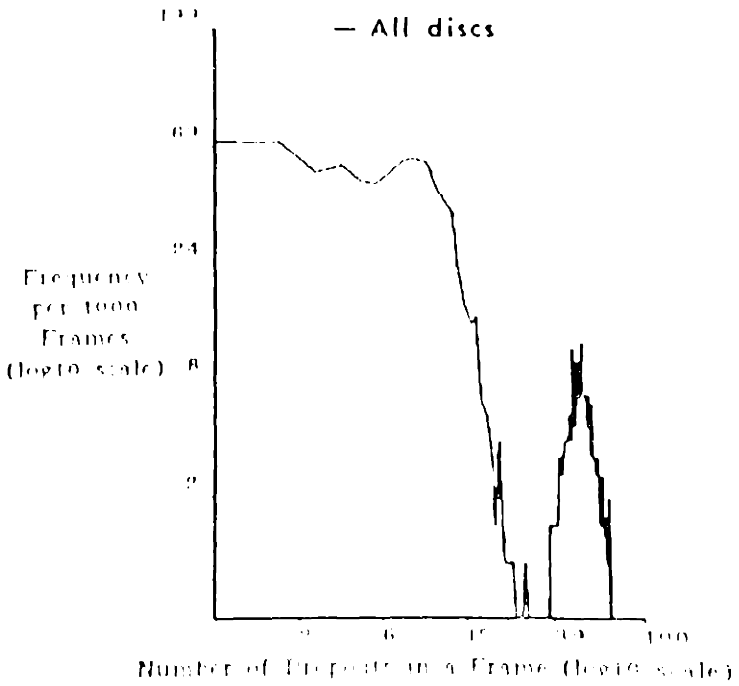
Number of Dropouts in a Frame (log10 scale)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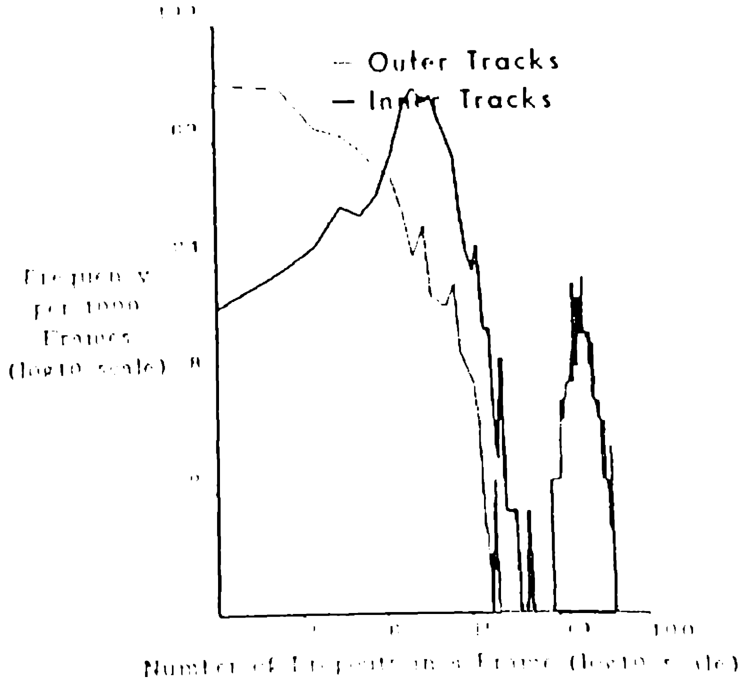
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— Inner Tracks
Frequency per 1000 Frames (log10 scale)
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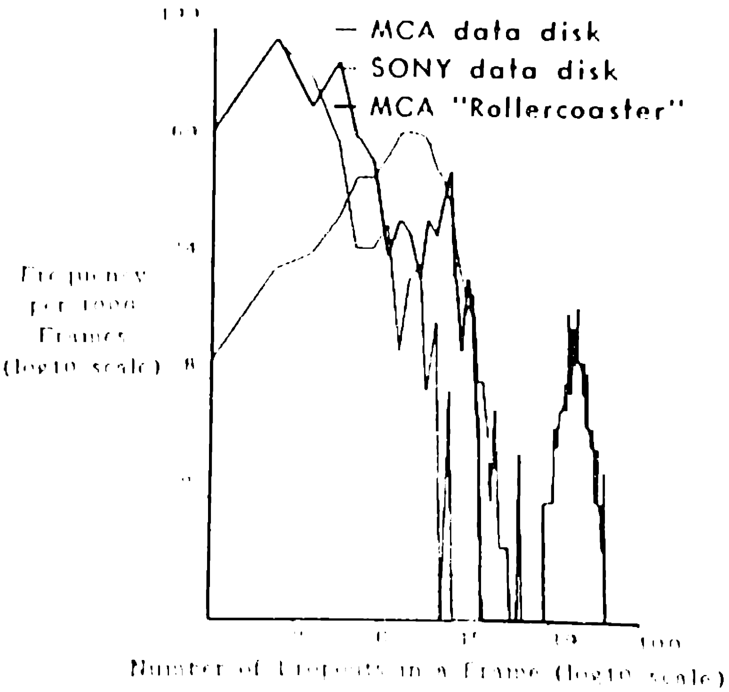
Number of Errors in a Frame (log10 scale)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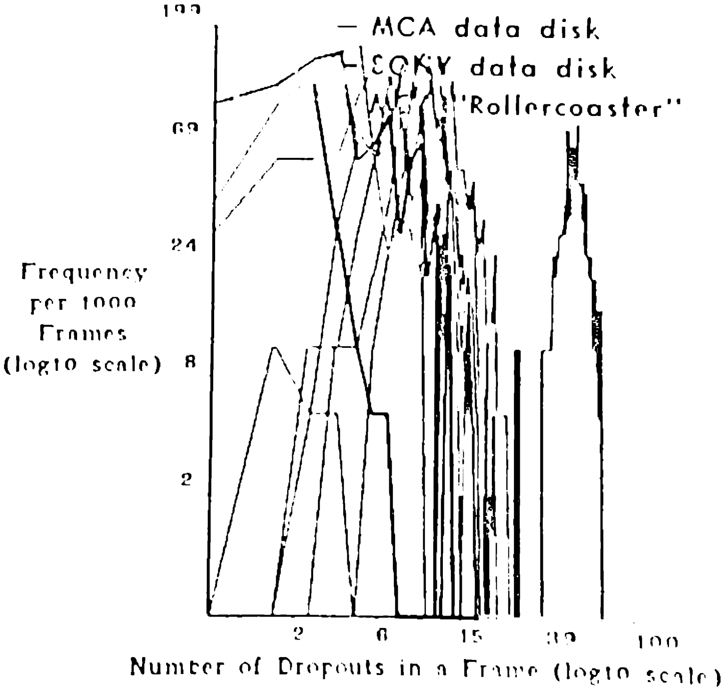
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"Rollercoaster"
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6
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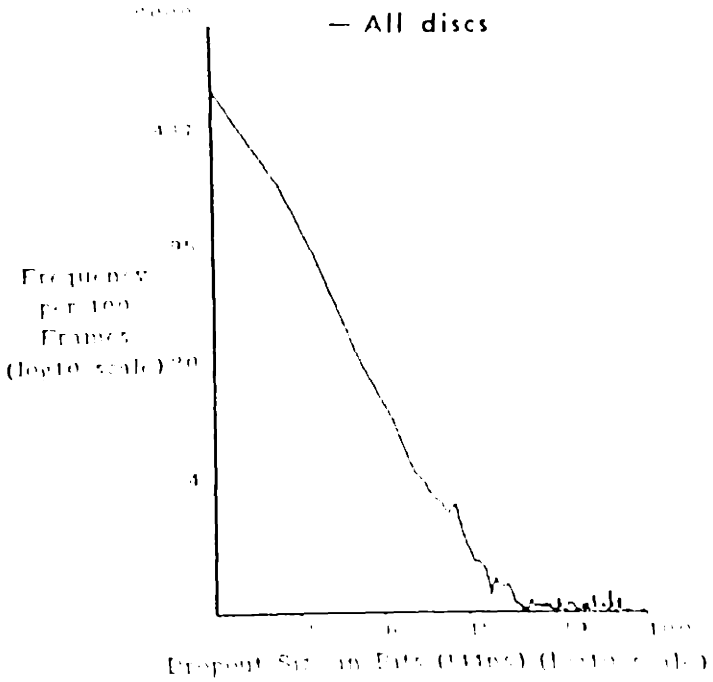
Number of Dropouts in a Frame (log10 scale)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Frequency per 100 Frames (log10 scale)
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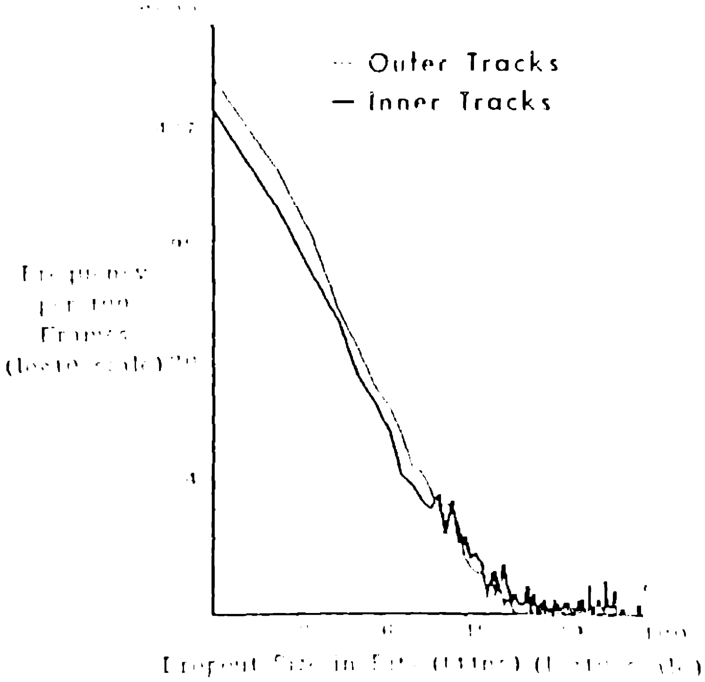
Outer Tracks
— Inner Tracks
Frequency per 100 Frames (log10 scale)
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Dropout Size in Bits
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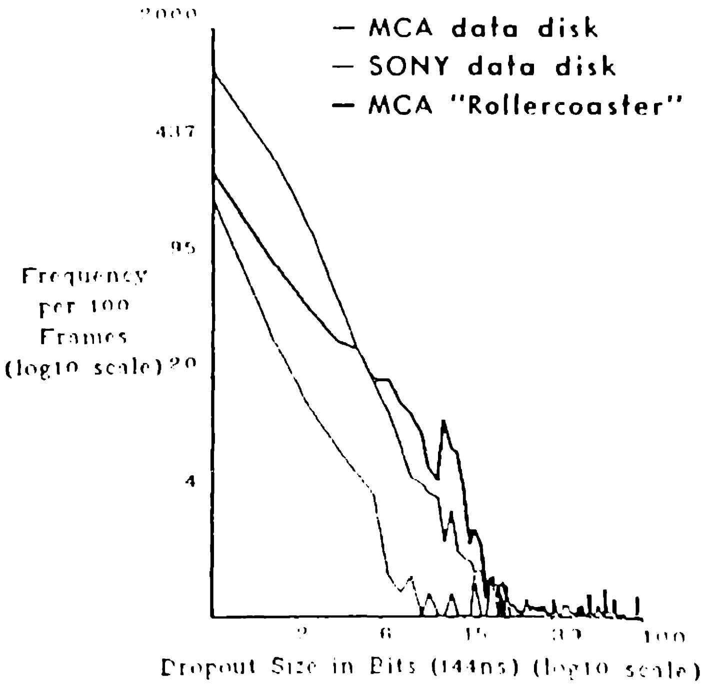
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437
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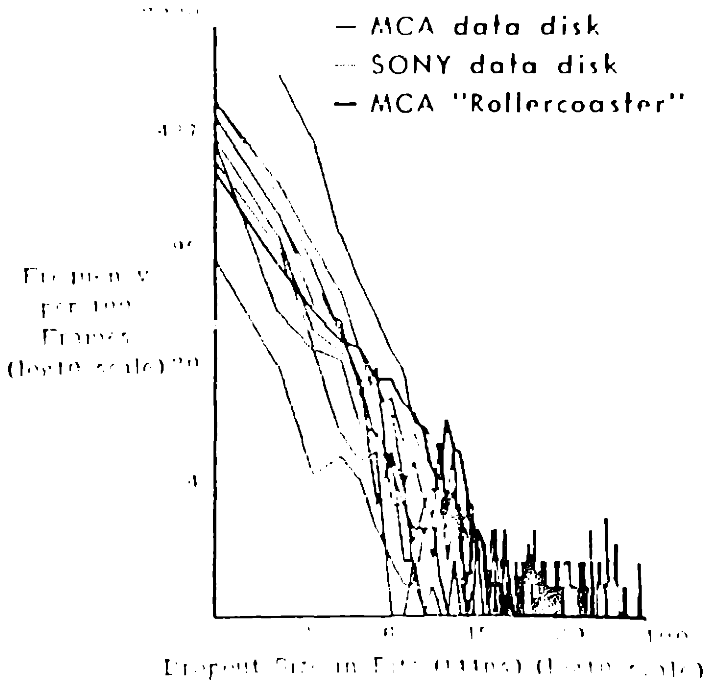
Frequency per 100 Frames (log10 scale)
20
4
2
6
15
33
100
Dropout Size in Bits (144ns) (log10 scale)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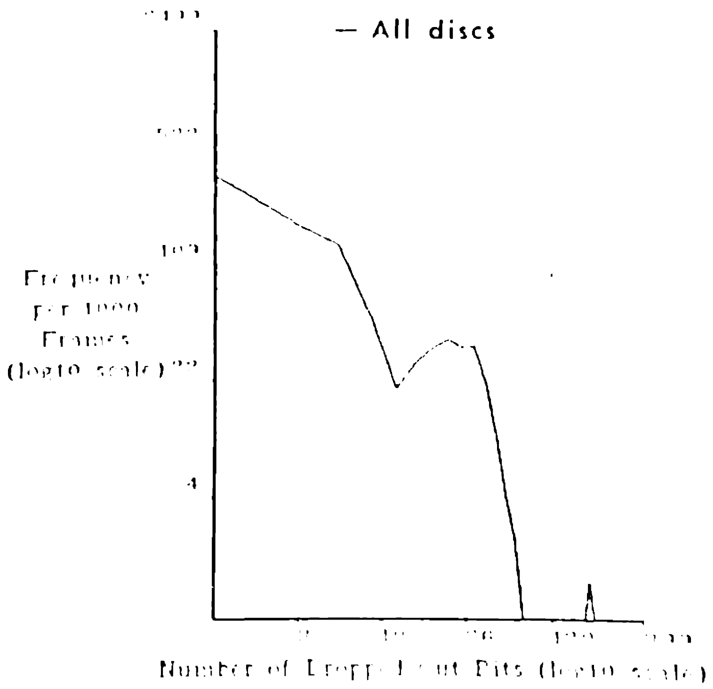
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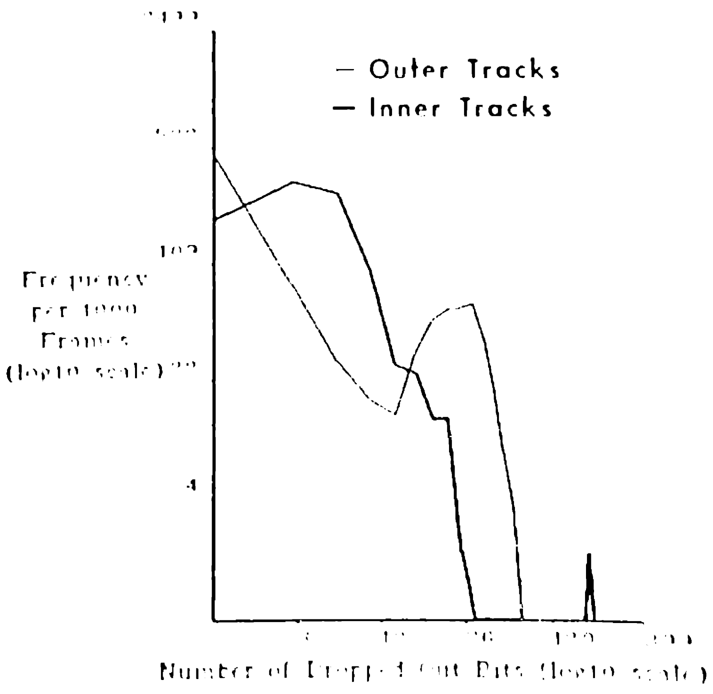
Number of Dropped Out Bits (log10 scale)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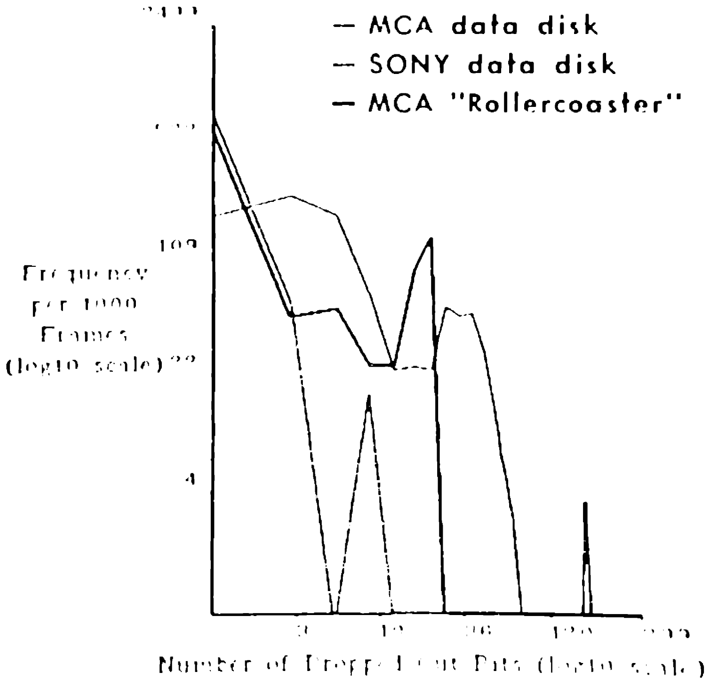
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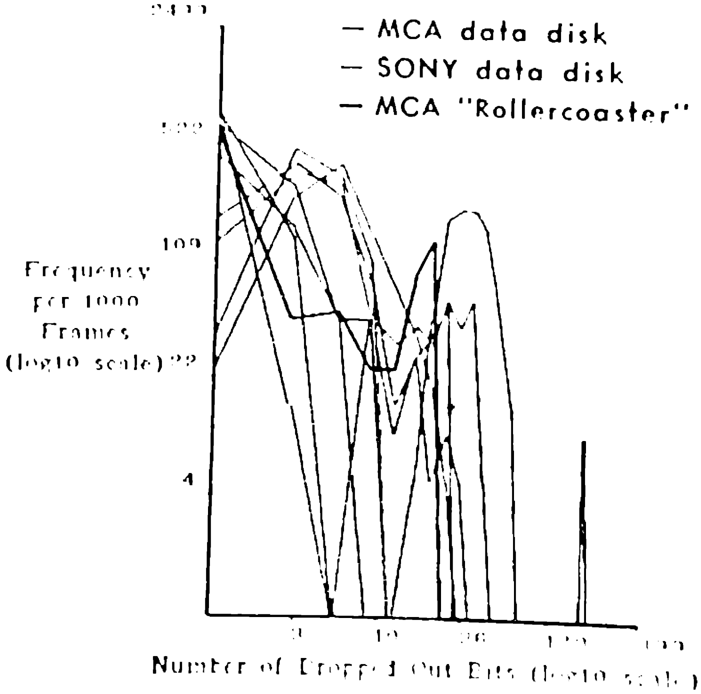
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