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THE SONY SDDS SYSTEM
DIGITAL SOUND ON FILM DELUXE

BY

JOHN F. ALLEN

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FIRST IN DIGITAL STEREO

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Of the three major digital film sound processes now in use, Sony Dynamic Digital Sound (SDDS) is the most recent to be introduced. While many, I confess myself included, have believed that Sony's long delay in bringing their system to market would severely handicap their prospects, this $40 billion dollar company is off to an impressive start. Both from a technical and marketing point of view, SDDS has rapidly launched itself into a prominent position with commitments for installations in over 2500 theatres and an increasing number of film titles.

From the beginning, SDDS was conceived by film mixers and post-production engineers at Sony Studios as the kind of premium sound recording format which they would ideally like to use for motion pictures. Lead by post production executive vice president, Michael J. Kohut, Sony's team felt strongly that they wanted to develop an eight channel format which revived the practice of using five full range speakers behind the screen (left, left-center, center, right-center and right). Since this was announced, there has been considerable controversy about the true benefits of five screen channels versus the more common three (left, center and right). Throughout these discussions and in the face of much skepticism, Sony has never wavered in their desire to regain the qualities five screen channels brought to 70 MM presentations prior to 1977. Since then, subwoofer and stereo surround channels have been substituted for the left-center and right-center channels, leaving only three full range screen speakers. Sony engineers wanted to have it all. By adding the stereo surround and subwoofer channels to five full range screen channels, a new eight channel film-sound release format was born.

Originally, five screen channels were used in large 70 MM theatres with screen widths often exceeding 50 feet. Since few modern screens are this wide, Sony has been questioned about the relevance of five speakers behind today's generally smaller screens. As it turns out, this concern has been premature and misplaced. More about this later.

In addition to eight channels, other SDDS design goals were: placing all the digital information on the film, a high degree of data redundancy, full on-board digital processing for the equalization and fader control stages and a "minimum" of digital audio compression. After several years of painstaking work, a few false starts (digital

sound on film isn't easy) and an investment of around $20,000,000.00, SDDS is here and worth listening to.

DIGITAL COMPRESSION

Ever since Sony and Phillips pioneered in the development of the digital compact disc, virtually everyone has become spoiled by the CD's qualities of low noise, low distortion, as well as a total absence of wow, flutter clicks and pops.

Professional digital recording is always accomplished with a "linear" system. In a linear system, all the digital data is recorded, stored and used for playback. Each second of sound is divided into a number of samples. Professional recorders use a sampling rate of 48,000 per second, while CD's employ a sampling rate of 44,100. All of these samples are equal in time. Each sample is then measured and stored as a "word" of ones and zeros. The number of bits in this word determines the dynamic range capacity of the recording. Compact discs use a 16 bit system for a theoretical dynamic range of 96 dB. Eighteen bit systems have a theoretical dynamic range of 108 dB and 20 bit systems; 120 dB.

Sony's SDDS system is an eight channel, 20 bit system with an initial sampling rate of 44,100 Hertz. Each of the eight channels is a full frequency bandwidth channel. In other words, even the subwoofer information is recorded on a full range channel, rather than one limited to 200 Hz or so.

Eight 20 bit, 44,100 Hz samples multiplies out a staggering 7,056,000 bits of information per second. This divides into 294,000 bits per frame of a motion picture film running at 24 frames per second. By way of comparison, this is five times the data stored on a compact disc and far too much information to be reliably printed and read from a release print. In order to store digital soundtracks on motion picture prints, therefore, one must carefully find a way to balance the amount of data which can be reliably printed and retrieved from the film, with a compressed or reduced data recording which can be reconstructed upon playback to sound as much like the original as possible. Ideally, there should be no audible differences or unpleasant artifacts.

ATRAC

Compressing digital data should only be done when there is no other choice. It is considered a last resort when one simply cannot store all the original data, due to space or other limitations. Designers of digital film systems must learn how to determine which audio information is heard by human hearing and which is not due to a variety of circumstances and hearing characteristics.

Sony's digital audio compression scheme is called Adaptive Transform Acoustic Coding, or ATRAC. First introduced in Sony's mini-disc consumer products, ATRAC processing begins after the audio information has been completely converted to digital in its linear form. ATRAC's task is to mathematically represent the digital data in a form with 80 percent fewer bits. Employing non-uniform algorithms, the sound samples are first split into three bands and then analyzed for frequency content, amplitude as well as time. If a quiet sound is close enough in frequency to a louder one, ATRAC calculates if the quieter sound would be audible. If it is found that the quiet sound is quiet enough as well as close enough in frequency to the louder sound so that it would be masked and thus made inaudible, the ATRAC system will discard the inaudible sound, reducing the data required to store that moment of audio. Further data reduction is made possible by evaluating the amount of time various sounds persist. A background wind noise, for example, changes very little over time and so it can be allotted relatively fewer data bits. A gunshot or other short duration event is allocated lots of bits due to the rapidly changing nature of this kind of sound.

These and other combined operations result in a five-to-one compression ratio. Where one second of digital audio once required 7,056,000 bits, it is now stored with approximately 1,411,200 bits. Since the SDDS soundtrack has a capacity of 2,460,000 bits per second, there is plenty of capacity left to store redundant digital audio, synchronization and error correction information.

The consumer version of ATRAC has not been entirely well received. Indeed the mini-disc demonstrations I have personally witnessed have been disappointing, as the compressed digital recordings displayed rather obvious colorations of the sound. Sony representatives who were present acknowledged that this is the case. In another test, a low level signal was applied to only one channel. The mini-disc's ATRAC processor generated a very audible noise which alternated between channels, a most bizarre effect. Though these effects may be unimportant in the least critical consumer applications which the mini-discs are intended for, such effects are hardly acceptable for a professional system.

Sony has insisted all along that their professional SDDS ATRAC system is free of these artifacts. Indeed, this version does seem to be superior in every way to the consumer version. None of the SDDS presentations I've heard has revealed any of the noticeable problems I had heard previously. It's important to distinguish between these two versions of ATRAC lest anyone be confused by some of the consumer reviews.

SOUND ON FILM

SDDS stores their digital information on both sides of the film, at the outer edges beyond

the perforations. Each of the 2,460,000 bits available per second is 24 by 24 microns in size. Printing this exclusively in the film's cyan layer provides the sharpest resolution. The tracks are designated "P" for the track on the picture side, and "S" for the track on the soundtrack side. Of course, SDDS prints carry the normal stereo analog optical soundtracks.

The "P" and "S" tracks are not synchronized with each other. While the "S" track is synchronized with its associated picture frame, the audio on the "P" track is placed 17.8 frames ahead of the picture. When data corruption occurs, recovery is greatly facilitated by the fact that some redundant information is available from an location 17.8 frames away; well ahead of the problem area. This also means that when major trouble with the digital data occurs, rather than switching to the analog soundtrack, the SDDS system first defaults to its own digital backup data. Most errors are corrected with eleven stages of Reed-Solomon error correction, including the redundant data which was read and stored 17.8 frames earlier. Under more severe conditions, all the channels designated for the left side of the theatre can be summed and played through the left side speakers, played as a group. The same is true of the right side channels. This level of digital error correction is called digital concealment. The analog track is used only then as a last resort after two digital backup modes.

THE THEATRE PROCESSOR PACKAGE

The SDDS package consists of the processor itself, a dual camera penthouse reader and a finished multi-conductor control / video cable. The penthouse installation is straight forward utilizing adaptor plates for the various projectors. The dual camera reader needs no adjustment, as it is adaptive and self-calibrating. The light source has been updated with a large array of 12 red light emitting diodes (LED's). These are configured in an array four diodes across and three high. When the red light of these diodes is focused on the SDDS soundtracks, the cameras see only the cyan colored digital data. The LED's are pulsed at a rate controlled by the film speed as it is pulled through the reader's sprocket. The film speed detected by this sprocket is also used to determine the clock rate of the entire SDDS digital decoding chain. As an added feature the LED's are off when there is no film movement, ensuring their already long life expectancy of 10,000 hours is used entirely for actual digital data recovery. Using such a large array of diodes provides more than enough light for the cameras without pushing anything. An unexpected benefit of the LED array has been an increase in the reader's immunity to film scratches due to the increased diffusion of such an over-sized light source. All this greatly improves the accuracy of the data acquisition, reducing errors where they are the most difficult to overcome.

The video cameras in the penthouse are charged coupled devices (CCD's), similar to those in Sony's television cameras. The data is "photographed" as it passes in front of the reader. Once actually read from the film, the data is sent through a tracking and data recovery stage. The video is enhanced and processed to further distinguish the actual digital data from any imperfections which may be on the film. Once accepted as genuine digital information, the bits are sorted into the actual data blocks they represent.

The recovered data is then sent to the error correction stages described earlier. The corrected data (still a single stream of bits containing all eight channels of digital audio) is sent to a "first-in, first-out" memory buffer where the appropriate delay is added to synchronize the digital sound with the picture and further provide the additional delay required for the surround channels. The total delay available is five seconds.

DIGITAL SIGNAL PROCESSING

The next stage is a series of digital signal processor (DSP) blocks. These handy devices can be used for a variety of purposes. Rather than incur the expense of designing and manufacturing a multitude of designated circuits, DSP's are very versatile devices which can be programmed to perform different things. The SDDS processor uses DSP's to separate the error corrected data stream into the eight individual channels of ATRAC encoded digital audio. The ATRAC encoding is then deciphered and reconstructed into an eight channel 20 bit 44,100 Hz digital recording.

One unique SDDS processor feature is its ability to mix down the eight channel soundtrack to a six or four channel playback format for those theatres which lack eight channels of speakers and amplifiers. In addition to these mixed down formats, there is also a six channel format called "7.1". This substitutes the wide-band left-center and right-center signals with the subwoofer signal. The subwoofer speakers still receive their normal information. This idea is especially useful in reducing the load on the subwoofers if they are found to be inadequate, presuming the other speakers are capable of the additional bass output. SDDS is thus compatible with virtually all the current true stereo playback formats found in today's theatres. However, as with any digital format the theatre's amplifiers and speaker systems must possess the dynamic range required of digital sound, something virtually no theatre systems can really claim.

EQUALIZATION AND SETUP

Sony's SDDS system is the first to employ on board 1/3 octave equalization in the digital domain. Digital equalization can be done well or poorly. Done well, as Sony has here, digital equalization can improve the clarity of the sound by reducing the slight loss encountered when analog audio is passed through all the circuitry of a 27 or 32 band

analog equalizer. Since digital equalization is accomplished mathematically instead of through such circuitry, the resulting sound can be noticeably cleaner. The final SDDS DSP stage is used to set output levels. Here again, this is done entirely in the digital domain. In the long run, this should prove to provide a far more stable channel to channel balance than typical of analog processors. Only after all processing is accomplished in the digital domain, is the data actually converted into analog audio signals and sent to the power amplifiers.

A COMPUTER TO SETUP A COMPUTER

In essence then, the SDDS processor is a computer. It must, therefore, be programed by a computer. There are on-board adjustments, but they are very slow and difficult. The processor is best serviced with an external laptop computer. The requirement for an expensive computer, which (it must be understood) does nothing whatsoever by itself to improve the sound quality, has raised questions from field technicians, myself included. (My field luggage and tools already weigh 121 pounds.) Large service organizations will need to equip their technicians with a laptop. Ultimately, some multiplexes may be required to keep one on the premises in case the processors need to be frequently moved from house to house. However, since there are sound quality benefits to all digital processors, portable computers must become a fact of life in motion picture theatres just as they have in other professional audio applications. As the software improves, theatre technicians will quickly become familiar with computerized setup procedures.

Unfortunately, the initial programing provided to setup the SDDS processor is, in my opinion, frustrating and time consuming. No audio adjustments are presently possible when the film is running. Some technicians may find this software difficult to use, particularly in the short time periods one is often allowed to perform installations, prior to the day's first matinee. SDDS has agreed that their early setup software is imperfect and they are working to upgrade it. To their credit, they have actively sought advice from field technicians on how the software might be improved. Already, a more efficient and simpler version is promised for early 1995.

The actual on-screen display the SDDS setup program provides to perform the adjustments is wonderfully elegant and simple. It's getting to it that's unnecessarily complex. Technicians using the early software to install SDDS with for the first time should allow plenty of extra time to learn how to deal with this cumbersome program. Future installing software promises to be much easier.

THE ALL IMPORTANT SOUND QUALITY

As always the final judgment of any sound format is done by listening. Any sound-on-

film soundtrack, of course, faces the fact that release prints lack the proper space to store the soundtrack in its original master form. Composite sound-on-film release prints have historically required that the sound record be compromised in order to fit it in the small space available. For example, we have lived for years with the restricted dynamic and frequency range of analog optical soundtracks. Even the magnetic soundtracks used for 70 MM prints are compromised by print to print, and sometimes reel to reel variations. The requirement for individual picture magnetic preamplifier alignment, its often uneven results, cumulative print ware, magnetic head ware and the projector's inability to properly pass the film past the pickup heads without constant azimuth deviations, have all impacted 70 MM presentations everywhere. Digital sound-on-film also requires some compromise in the form of digital compression such as described above.

With all this in mind and several exposures to the SDDS system, both in Sony's screening room and in theatres, I think I can fairly state that the SDDS system may be the best sound-on-film recording format I've encountered. When played over loudspeaker systems capable of the full dynamic range SDDS demands, the sound is at all times clear, dynamic and effortless. There is never a sense that one is listening to a digitally compressed recording employing masking techniques, such as was evident during Sony's consumer mini disc demonstrations.

One of the selections in the SDDS demonstration reel is a music only section from HOOK. This is especially useful since anyone can and should listen to the same music and orchestra on the soundtrack CD (Epic # EK48888). Being as familiar with this John Williams score and its sound as I am, it would have been easy to hear any degrading effects the ATRAC SDDS system might introduce. Remarkably, I detected none. This selection may be the most compelling demonstration of the sonic success of the SDDS system even if it doesn't contain the most dynamic material or a single word of dialog.

FIVE SCREEN CHANNELS VS. THREE

I have also had the opportunity to more fully experience the benefits of installing five full range screen speakers. Up until recently, I have been solidly behind the use of five screen channels in theatres with screens over 40 feet wide. To my surprise, however, the use of five speakers behind smaller screens is also valid and effective. This is particularly evident in Sony's screening room with just a 12 foot screen. Five speakers provide the seamless wall of sound, which stereo is supposed to be, with a greater sense of depth and listening satisfaction than one experiences with only three speakers behind the screen. Exhibitors installing SDDS should strongly consider implementing the full eight channel system wherever possible.

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