DIGITAL AUDIO SIMULATION DEVELOPMENT FOR SONAR TRAINERS

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The application of digital simulation techniques for audio simulation in sonar training devices has overcome many limitations of analog simulation. It has succeeded in providing higher fidelity, better recognition of sounds, greater reliability, smaller size and, in many cases, lower costs.

The use of a general purpose digital computer with a digital audio simulator in training systems is an example of the application of advancing technology producing superior performance with a reduction in complexity and cost.

Audio simulation of sonar sounds must duplicate the sounds of operational sonar equipment with a realism as high as practical. Digital simulation is a natural approach to overcome the analog audio generators problems of adjustment, switching control, maintainability and cost. Digital circuitry also conserves power, logistics, size, and in addition offers the key to realism and fidelity through circuit flexibility that is necessary for complex sonar trainer applications.

Basic theory supports the fact that any waveform can be reproduced if sampled at a rate consistent with tolerable error. High speed digital circuits offer a technique for producing discrete sound elements which can be summed for audio simulation.

The simulation of discrete sounds must be correlated to several trainer functions. These functions include (1) sound sources, (2) sonar response, both bandwidth and mode of operation, and (3) total problem environment including own ship. To achieve this goal many analog audio models were required.

The goal of good audio simulation and the requirement for audio models implies a somewhat tacit assumption. This assumption is that the most realistic way to simulate a complex audio source for trainer applications is to model its sound generating properties rather than to reproduce its effects from storage. An example of the latter is manipulating a recorder and adding desired trainer variables. By modeling the sound source, flexibility and therefore realism can be more easily effected.

The required audio effects of vehicles, sea life, and environment that must be simulated can be cataloged into four major categories.

1. Own ship's active sonar sounds
2. Problem vehicle sounds
3. Biologic sounds
4. Ambient and/or system noise

These major interacting categories can be further analyzed to characterize the specific sounds expected as well as ultimately suggest a method of simulation. For example, the first category, Own Ship's Active Sonar Characteristics, requires demodulated transmitter sounds with appropriate reverberations and echo returns. Therefore, the method of digital simulation would be the generation of sine waves modified for transmitter pulse width and frequency, target doppler (if applicable), random scattering, and absorption.

The second category, Problem Vehicle Sounds, are typically propeller and machinery sounds which can be simulated by modulating noise for screw beats and sine waves for major machinery natural frequencies. Saw tooth waveforms are used for torpedoes and vehicles which contain many harmonics in their audio spectrum.

The third category, Biologic Sounds, are as diverse as the variety of sea life that exists. The more prevalent sounds, however, are porpoise, whale, and shrimp which have been modeled and implemented with appropriate sine wave and noise modulation.

The last category, Ambient and System Noise, is characteristically broadband noise that is band-limited to the specific sonar response. Typically this sound is simulated with digitally created white noise and filtered with operational hardware to achieve the proper spectral response.

These above techniques were used to some extent in the early analog simulators. However, their control and ranges were major limitations for realistic audio simulation.

At this point we have developed a method of sound generation in which implementation involves a software/hardware impact. If we assume a straight digital-to-analog conversion, several simultaneous output channels would require full time computer utilization for appropriate frequency response. By analyzing each source to be created it was found that an external sound generator could be controlled by the main trainer computer which would achieve the desired audio response. It was also found that many of the sound sources had common origins, and multiplexing and arithmetic circuits could be time shared in the external processor.

The resultant trainers therefore contain one or more audio processors which accept modeled envelope instructions from the main trainer computer. These instructions are converted to sounds which the processor generates until modified by a new instruction. This allows small computer transfer time requirements and keeps the main trainer free for problem calculations and model generation. The transfer time is typically less than 5 percent of cycle time, and the internal sound instruction set up from internally stored models is around 30 percent for a two-channel system.

In taking a closer look at sound modeling, several techniques have been used to analyze a desired source into manageable form for reconstruction employing digital techniques. One technique uses a spectrum analyzer with time integration to determine the major or fundamental frequencies inherent in a specific sound source to be simulated. Another technique performs high speed sampling, followed by digital compression, and internal storage of the simplified model in a table for subsequent processing and output formatting.

Other techniques also have been applied. Unfortunately some of them fall in the class of "If it works, use it; however, modify it until it sounds right." There are many examples of these expediencies in all simulation equipment, yet the analyses behind these approaches leaves something to be desired. Many times a closer look reveals a simplified model or the key elements necessary for a difficult simulation problem.

Of the two analytical approaches above, the spectrum identification is best suited for simulating long period repetitious-type sounds that contain identifiable frequency components. The second approach involving sampling is best suited for a short term audio burst with no apparent frequency stability. A mix of both approaches is required for most audio simulation.

A porpoise is an example of sine wave generated sounds. Frequency versus time and amplitude versus time are sampled and stored in look-up tables. This tabular model is outputted at random intervals if a porpoise is in the problem. Clicks and several sine tables are required for the total porpoise model, including diving and surfacing movements, effecting total porpoise simulation for trainer applications.

The porpoise-generated instructions from the computer are outputted every 10 milliseconds and contain amplitude, frequency, and change of frequency. The external processor takes these 3 values and converts them by way of stored sine tables to digital values to be summed with other converted instructions for subsequent conversion to analog levels. A series of 10 millisecond instructions comprise a typical porpoise whistle or squeal.

Propeller cavitation is an example of a short term audio burst without specific frequency components. To simulate this effect the actual speed of the vessel is converted to shaft rotation which determines the amount of time and how often the cavitation occurs as the blade sound wave front radiates toward own ship's sonar receiver. The instructions from the computer activate the appropriate number of shafts in the problem and transfer "on-off", and "amplitude" values to the audio processor. The "ON" instruction is converted to a period where the amplitude is multiplied by white noise and the off time is multiplied by zero to achieve simulation of propeller cavitation with turn count or speed characteristics.

By use of digital techniques to generate both sine and modulated noise, the audio special processor can be packaged on conventional logic panels with integrated circuits. Approximately 500 standard IC's are required for a dual channel sonar trainer. This is typical for a trainer capable of simulating sounds of four vehicles, six biologics, two target echoes, four torpedoes, two ambient noises, two shrimp beds and two reverberation sources, all independent and operating simultaneously in real time. These capabilities can be expanded by adding processors as modular blocks if more sources are desired.

Digital audio development like any other development program has uncovered areas which need more answers, more refinement, including quantitative and qualitative correlation standards. One side effect of our development produced equipment which could enable us to break into the computer-to-processor interface. This capability enabled us to modify and manually adjust the transfer function in real time to more effectively evaluate the stored model and find discrepancies in an authentic spectral response. Spectral analysis itself has proven a great tool for audio simulation. This is believed to be essential for any audio simulation verification.

In summation, the progressive approach to digital audio simulation has been geared to provide a cost-effective sonar sound simulator for trainer applications. Both hardware and software have been used in three trainer designs to date with a minimum of redesign. The development has led to improved and expanded capabilities with emphasis on compatibility between hardware and software implementation. Future effort will continue correlation of authentic and simulated vehicle sounds for better simulation. Also, models can and will be refined with analysis of noise modulation and noise modeling which will expand and define new applications.

ABOUT THE AUTHOR

MR. G. A. MANN is Principal Development Engineer at Honeywell Marine Systems Division where he is currently responsible for systems and checkout engineering of trainer systems. Previously, he was responsible for project development to digitally simulate breadboard audio for training systems. Mr. Mann received his B.S. in Physics from the University of Redlands. He has also taken graduate courses in Computer Design and Programming, and Business Communication at Chaffey College. Mr. Mann was formally a senior Project Engineer for data display terminals at Conrac Division of Conrac Corporation. He has also been a Staff Member of the Engineering Department at Earth Sciences, a division of Teledyne, responsible for specification and interface compliance at the project level. Design experience included system design with digital applications. Mr. Mann was also responsible for test equipment design and creation of test procedures at the system and subsystems level. He was instrumental in the computer analysis and testing of a math model project performed for the Lincoln Laboratory at MIT. At Lockheed Aircraft Corporation, he was responsible for the acquisition of data from jet aircraft and satellite recorders. Mr. Mann was previously group leader responsible for the Thor-Agena ground station equipment at Vandenberg AFB and error analysis of the Polaris Missile test equipment at the Sunnyvale facility.