PAT FLANAGAN

Dolphin Project

One of the special features of this section is the article on Listening, Incorporated which appeared in the July, 1967 issue of Analog Magazine. Written by Pat Flanagan when he was Vice-President in charge of research for Listening, the article is actually an Annual Stockholder's Report -- which attracted much attention because the Science-Fact had come to read so much like Science-Fiction. Also enclosed is the face sheet of one of the U.S. Navy Reports Pat co-authored while at Tufts University. The Multipath Delay Line described by the report was used in the Man-Dolphin Computer to synthesize and analyze data.

A STUDY OF ACOUSTICAL MULTIPATH SYSTEMS

SECTION IV

DELAY LINE

By

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and

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A STUDY IN ACOUSTICAL MULTIPATH SYSTEMS

SECTION IV

DELAY LINE

4.1 INTRODUCTION

Acoustical delay lines of many varieties (mercury, quartz, glass, wire) are in use. (See Bibliography on Magnetostrictive delay lines in "IRE Transactions on Electronic Computers" 1961, p.285). One interesting variety, a nickel wire driven by an electromagnetic signal, is capable of producing electrical signals along its length. Among the many applications of this nickel wire delay line, the Whitehouse Correlator, developed by Dr. Harper Whitehouse, USNOTS, Pasadena, California, is typical and suggested to us applications to acoustical recognition problems, including localization synthesis and dolphin pulse structure synthesis. The torsional stress wave generated by the device has a velocity producing a delay of 9.0 microseconds per inch which seemed particularly useful for applications in the 0-400 microsecond region of localization.

The delay line was developed under the direction of the U. S. Naval Ordnance Test Station, China Lake, California: Contract N123(60530)-52397A and was used on this project by permission.

$$R(s) = F(s) \sum_{n=0}^{M} a_n \epsilon^{-s\tau_n} \quad \ldots\ldots\ldots\ldots \quad (9)$$

and the transformation $T(s)$ constructed

$$T(s) = \sum_{n=0}^{M} a_n \epsilon^{-s(\tau_M - \tau_n)} \quad \ldots\ldots\ldots\ldots \quad (10)$$

the resultant signal $P(s)$ is given

$$P(s) = R(s)\, T(s)$$

$$= F(s) \sum_{j=0}^{M} a_j \epsilon^{-s\tau_j} \sum_{k=0}^{M} a_k \epsilon^{-s(\tau_M - \tau_k)}$$

$$= F(s) \epsilon^{-s\tau_M} \sum_{j=0}^{M} a_j \epsilon^{-s\tau_j} \sum_{k=0}^{M} a_k \epsilon^{+s\tau_k} \quad \ldots\ldots\ldots \quad (11)$$

The result is the original signal delayed by τ_M and modified by the product of sums. The product of sums can be represented as follows:

$$\sum_{j=0}^{M} a_j \epsilon^{-s\tau_j} \sum_{k=0}^{M} a_k \epsilon^{+s\tau_k} = \sum_{n=0}^{M} a_n^2 + \text{cross terms} \quad \ldots\ldots \quad (12)$$

$$\text{cross terms} = \sum_{k=0}^{M} \sum_{j=0}^{M} a_k a_j \epsilon^{-s\tau_k} \epsilon^{+s\tau_j} \quad j \neq k$$

In this product, the cross term result for $j \neq k$ can be given as follows:

$$\sum_{x} a_x \left(\epsilon^{-s\tau_x} + \epsilon^{+s\tau_x}\right) \quad \ldots\ldots\ldots\ldots \quad (13)$$

THIS IS A COPY OF THE 1966 LISTENING, INC. ANNUAL REPORT WRITTEN BY PAT FLANAGAN, VICE-PRESIDENT IN CHARGE OF RESEARCH.

This is a fact article.
It is, in fact, the legal annual report of a genuine corporation, Listening, Inc., a privately owned stock corporation, closely held, and—sorry about that!—with no stock for sale.

Annual Report

The research work Listening, Inc. is actually carrying out, however, sounds so much like some of our more advanced science fiction that when I got this annual report, it seemed necessary to publish it to let the readers see what's actually being done now!

Analog Science Fact/Fiction
July 1967

LISTENING
INCORPORATED

INFORMATION
COMMUNICATION
KNOWLEDGE

19 December 1966

6 Garden Street
Arlington,
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- ► Color Sonar
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Imagine sitting by the seashore and listening to the waves. If you can, now imagine that the sound of waves along the shore is talking to you. The sounds might say, "In front of you is sandy, sloping beach, but far over to the right is an outcropping of rock, and there is a quiet cove on the left." And you might also imagine that, whatever the weather, the waves speak of those same features. One time in a loud, wild voice, another time in a soft, gentle voice, but always of the same shore.

Now can you imagine wind in a forest, and the sounds tell of leaves and branches, of large and small trees, and of the brush and forest floor. The sound from the floor is a quiet sound, the trunks of the trees are columns of whispers, and the leaves are a flutter and rustle of sound. Again, no matter the weather, whether rain or wind, the sounds tell of the same forest, and the voices may change but the message is the same except as the seasons change the character of features of which the whispers comment.

These are not merely romantic imaginings; they are facts for the observing. Doesn't your kitchen sound like your kitchen, and your living room sound like your living room? Isn't the office of one character to be heard and the neighborhood bar another? Not by reason of the sounds of voices, footsteps, and movement alone, but by reason of what the rooms do to the sounds which fill them. Movie sound men have been aware of this for decades, and always tape silence on the set, for dubbing if necessary. Inescapably, each feature of our environment modifies the sound of nature in its own way, which we may hear, if we listen.

Now think of the human vocal tract as a room of mobile walls, and that the shape and substance of the room can be heard when filled with sound. And this whether by whisper, shout, or song. Or by a buzzer, a belch, or an electronic reproduction of a train. Isn't it clear that the particular sound is of lesser importance than what the structure does to the sound? We may say that sound is *transformed* by the vocal tract, and that the resultant sound carries the marks of having been there.

Consider that sound is transformed by its environment, then if it were possible to create an inverse to the environmental transformation, we would have a picture of that environment. We at Listening are learning how to do this.

We are rapidly becoming expert at information, communication, and knowledge in the recognition and synthesis of acoustical signals and environmental characteristics.

The following is a summary of Listening activities and products resulting from our specialized knowledge in the field.

Pat Flanagan beside steel "Ear" used to Listen under water. Ear is an array designed to be used in conjunction with the human computer.

Dolphin Communications Program

One of Listening's current activities is the establishment of verbal communications with the species Tursiops Truncatus, or Dolphin. This work is being performed under contract with the U. S. Naval Ordnance Test Station, China Lake, California. At present we have two dolphins located in a lagoon, near the University of Hawaii facility on Coconut Island off of Oahu, Hawaii. We have a language of eighteen words in use between man and dolphin at this time.

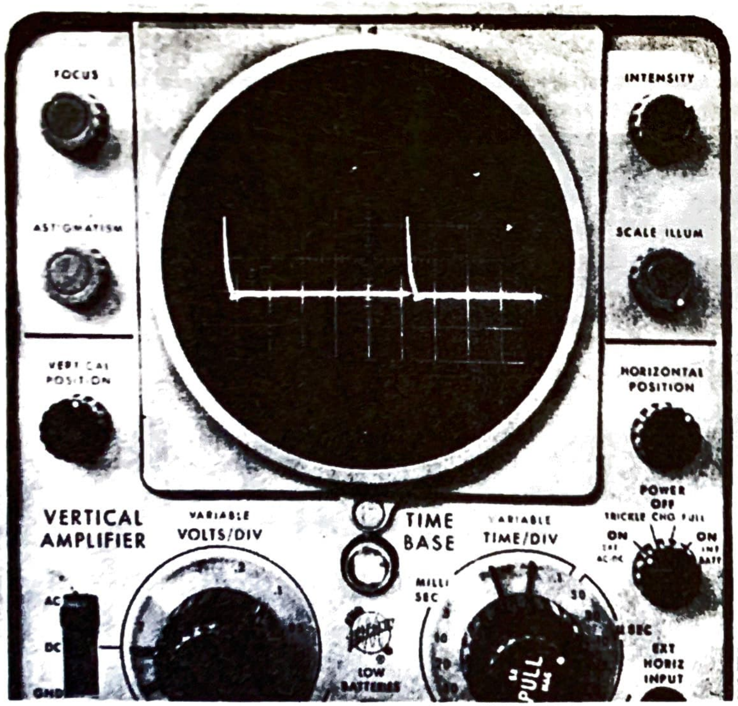
Man-Dolphin Translator

One of the products evolving out of the program is a translator to detect human speech forms and translate them into a whistle language using sounds normally used by Dolphins. The translator's mate, the DMT (Dolphin-Man-Translator) performs the reverse function, making sounds like human speech from dolphin whistle inputs.

Sondol

The *Sonic Dolphin* is an acoustical generator that produces pulses very similar to those produced by Dolphins in echo location and recognition when darkness or muddy water prevents the use of vision.

Sondol has been tested by human subjects and shows potential as an aid to the blind in sensing his environment and to the scuba diver for perception in murky waters. With practice, anyone with normal



hearing can find his way around in total visual darkness.

The unique feature of the Sondol is the use of the human computer as a readout device.

A trained diver with practice should be able to identify objects accurately under water at distances up to three hundred yards.

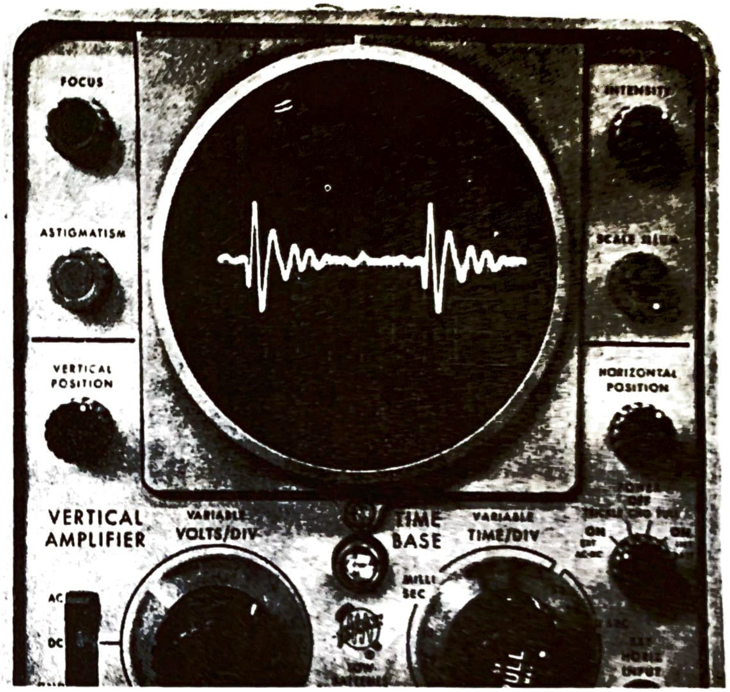
Spatial Localization: Ears

Research by Dr. Dwight Wayne Batteau, President of Listening, has resulted in a most unusual product, the ear.

Dr. Batteau's research under Navy contracts into the phenomenon of human spatial sound localization has revealed that the pinna, or external ear, is a very delicate computer-steered array which produces transformations on incoming sound fronts. These transformations are then used to compute sound source location in space.

We have three main products as a result of this research.

A. Air-Ears: These are two microphones mounted in molds of human pinnae and spaced approximately the width of the human head to produce a binaural pickup. Tape recordings made with the "ears" retain the localization trans-



formation and position is readily identified when the result is listened to using headphones. If the eyes are shut, one is seemingly magically transported to the locale of the recording. Vertical, horizontal, and distance of sounds is preserved—not just the left or right as in recordings made with bare stereo microphones.

One of the most interesting uses for the ears is in the recording of conferences or lectures. In this application, the location of the speakers is preserved and the ability to put attention on different people is retained; for example, if two or more people are talking at one time, one can listen selectively to any one person without interference from the others.

Recordings made in this manner could be played through many times in order to "hear" everyone. The ability to pay attention selectively is called the "cocktail party effect." If the same recording were made with bare microphones, the voices would all have the same "location" and would result in confusion of speakers.

B. Underwater Ears: The underwater ears are stainless steel ears eleven inches in size designed for localizing and recording underwater. The exact location of sounds under water $\pm 8°$ can be identified in real time by a listener. The locations can be recorded permanently on tape or disc and listened to later . . . as previously—azimuth, elevation, and range are easily identifiable.

C. Location Synthesis: As a result of ear research we can program a computer to take any sound and produce variable transformations on it to give any chosen subjective "locale." Possible uses for this computer are many, among these are exotic spatial music, not only stereo, but up and down and distance as well.

One of the problems of building a space station, be it outerspace or innerspace, is that personal orientation is lost in the use of intercoms or radio communications.

With localization computation, the various people could be given synthetic positions and thus retain proper orientation to each other. If Joe calls you over the radio, you know instantly that Joe is behind you and below you to the right at an angle of 45° and about thirty feet away. Without the system, you would have no idea where Joe is located.

Phoneme Detector

In the development of the Man-Dolphin Translator, it became necessary to recognize various speech patterns electronically. Part of this system is a Phoneme Detector which recognizes the various "marks" or features given vocal pulses by the vocal tract.

The Phoneme detector coupled with a vocal pulse detector and a fricative detector—also Listening devices—and appropriate logic could enable verbal control of machines in any area requiring speech recognition.

Square Wave Speech Generator

A rather unusual development is the DDCS which converts human speech into square waves which are completely recognizable. The device offers potential as a ninety-five percent efficient modulator to radio transmitters, hearing aids, hydrophone drivers (for speech under water), an easy form for scrambling and unscrambling, and for use in speech synthesizers and recognition equipment.

Neurophone

The Neurophone is a radio transmitter designed to produce the phenomenon of hearing electrically without mechanical vibration. The device was invented by Pat Flanagan in 1959 and was widely reported in leading magazines.

Mr. Flanagan has sold development rights to Listening, Inc.

The Neurophone is being marketed by Listening as a research instrument to qualified institutions interested in working with the phenomenon.

Spectrum Analyzer

The MSA-1 is a real time spectrum analyzer originally designed to print out an analysis of dolphin whistles. Thirty filters are used to construct a thirty point spectrum diagram on electrically sensitive paper.

The analyzer can be tailored to fit any spectrum up to 100KHz, and can be changed by the replacement of filter cards.

Color Sonar

Color Sonar is an active sonar system developed by Dr. Batteau to give a variable color readout to aid in identification of objects under water regardless of distance.

The property of the materials of which an object is made to reflect sound of different frequencies with different efficiency is called "acoustic coloration." This is the physical property made use of in Color Sonar. In order to present significant differences in material or object coloration, the acoustical spectrum is translated into a visible color spectrum to produce a color photograph, or to present color distinguishability to an observer.

In this manner, the difference between a whale and a submarine would be easily recognizable due to different color readouts.

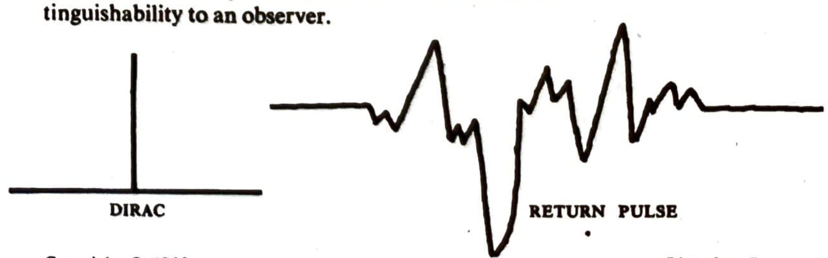
Computer Recognition of Environments

When a Dirac pulse is transmitted into a reverberant environment, the features of the environment transform or filter the pulse such that the return signal contains a "picture" of the environment. See Diagram.

Our work in computer recognition programming will soon enable us to take a "picture" with a sound pulse, create an inverse, and draw a binocular 3-D picture of that environment with the computed information.

Sound pictures taken under water would enable man to "see" and identify details of objects previously impossible to recognize by any other method but raising them to the surface.

The sound picture system coupled with Color Sonar would enable recognition of type of material at the same time.



LISTENING COMMUNICATIONS OFFICE
6 GARDEN STREET, ARLINGTON, MASSACHUSETTS
LCO TECHNICAL LETTER OF 23 JANUARY 1967

Pat

TECH HAT
LCO MASS
LCO HAWAII

BOX CAR GENERATOR

It has become obvious in my attempts to remove the vocal pulse that a nearly perfect "Box Car" or step function circuit be made.

After much labor and trying of ten circuits, the circuit in figure one was created. This circuit is unique in that the storage capacitor is driven by a nearly zero impedance source. The circuit is extremely effective. The circuit is unique in that the sampling trigger Q5 turns on a highly linear amplifier consisting of Q1 through Q4, the storage capacitor is driven directly by a complimentary emitter follower arrangement.

When Q5 is off, the impedance seen by the storage capacitor is extremely high, consisting of reverse biased transistors and diodes.

This also makes a very good "gate" - the closed loop gain of the output stage is unity.

VOCAL PULSE EXTRACTOR

Figure 2 represents a unique scheme for extracting the vocal pul -

The use of a "tuned" circuit in the first stage assures the opening wavefore to always start in the same direction.

This signal is then differentiated, and passed a pair of zero crossing detectors, one is set to detect negative crossings, the other - positive crossings.

The outputs of these detectors are used as triggers to "Box Car" both signs of the incoming wave.

The "Box Cars" are then added, and the resulting sum should contain the first peak, and very little of the following wave.

This signal can then be further processed to remove all but the vocal pulse.

Figure 3 is a detailed progression of "AH".