From Torpedo Fire Control to Sonar at Librascope
by
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Librascope made a business decision in the late 1960's or early 1970's to try to expand its very successful surface ship and submarine torpedo fire control business into the sonar arena. This seemed like a natural thing to do since -- fire control -- the process of aiming and steering a torpedo to a target is based on -- sonar -- the detection and measurement of sounds made by a target vessel. It was argued that an integrated sonar and fire control system designed and built as one system could be optimized to perform better than two systems developed separately with an interface between them.

The bridge between sonar and torpedo fire control, called Target Motion Analysis (TMA), had traditionally been part of torpedo fire control and therefore an area of Librascope technical expertise. TMA computes a target's location, course, and speed from sonar measurements. These values are then used to aim and steer a torpedo.

Sonar technology was undergoing significant changes around 1970. This was due to technical innovations in commercial oil exploration using low frequency sound and long straight line arrays of hydrophones towed behind a research vessel. The U.S. Navy extended these innovations for use in submarines and for strategic purposes.

In order to try to exploit this new technology, Librascope invested in the development of a Sonar Display Research Laboratory (sometimes called the Blue Room because of its blue carpets and drapes) and an adjacent Sonar Signal Processing Laboratory. The story of the display laboratory is the subject of a separate article.

By the time I joined Librascope, during August of 1972, the company was pursuing projects related to development of passive sonar signal processing and corresponding target localization processes. Soon after my arrival, the company learned that the Navy was planning in the not too distant future to issue a request for proposal (RFP) to contract with one or more corporations to build ETASS (Escort Towed Array Sonar System) and SURTASS (Surveillance Towed Array Sensor System) towed arrays. ETASS was to be a tactical array deployed in the Navy surface ship fleet whereas SURTASS was to become part of the U.S. naval strategic surveillance capabilities. Librascope made the decision to make a considerable investment in order to prepare to respond to the RFP.

The company funded effort began with a study to specify an array suitable to examine passive detection and localization techniques. Two topics drove the study; acoustic noise studies and processing to support target triangulation and explore the feasibility of wave front curvature ranging similar to the PUFFS (Passive Underwater Fire Control Feasibility System) sonar system aboard the USS Haddock SSN-621 at the time.

To gain experience with towed array acoustic data, Librascope accepted a contract below the expected cost with the Naval Ocean Systems Center, San Diego to analyze self noise data from USS Dolphin SS-555. The purpose was to garner experience with such data and enhance our corporate qualifications for the RFP. That project provided valuable background for planning our company funded towed array project.

The result of the towed array study was a decision to purchase a 2010 foot long towed array with three apertures from Seismic Engineering in Houston Texas. At the forward and after ends were apertures designed with hydrophone spacing based on 1,000 Hz. In the middle of the array was an aperture populated for 100Hz. These apertures enabled tests and studies throughout the passive processing band under consideration for both the surface and submarine arrays, and enabled some data reduction opportunities consistent with surveillance systems.

Figure 1 below, shows the Librascope Towed Array aboard the Research Vessel R/V Harris which was made available to Librascope under a Navy/Industry Cooperative Research and Development (NICRAD) agreement with the Naval Sea System Command (NAVSEA). In addition, a data recording system was rented from the U.S. Underwater Sound Laboratory in New London, Connecticut.

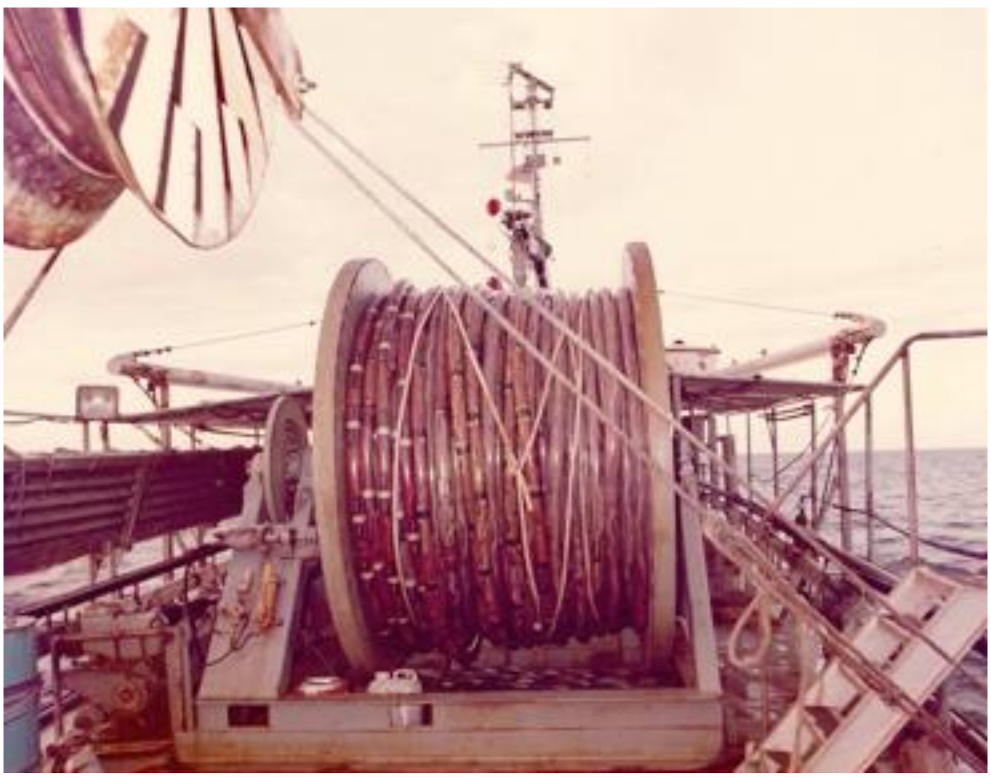

Figure 1 - Librascope Towed Array

Another important decision was made to purchase two acoustic pingers compatible with the U.S. Navy's Atlantic Undersea Test and Evaluation Center (AUTEC) range off Andros Island in the Bahamas. The pingers were acquired to provide definitive data to measure towed array motion. What became known as the “Singer Pingers” were the first of their kind and subsequent to our sea test were rented to the U.S. Navy.

Figure 2 shows the pingers that were installed in the towed array. The upper tube was a battery pack, the second tube is the electronics and the transducer is shown at the bottom of the figure. The pingers were installed in a short segment of the towed array and controlled from the laboratory aboard ship.

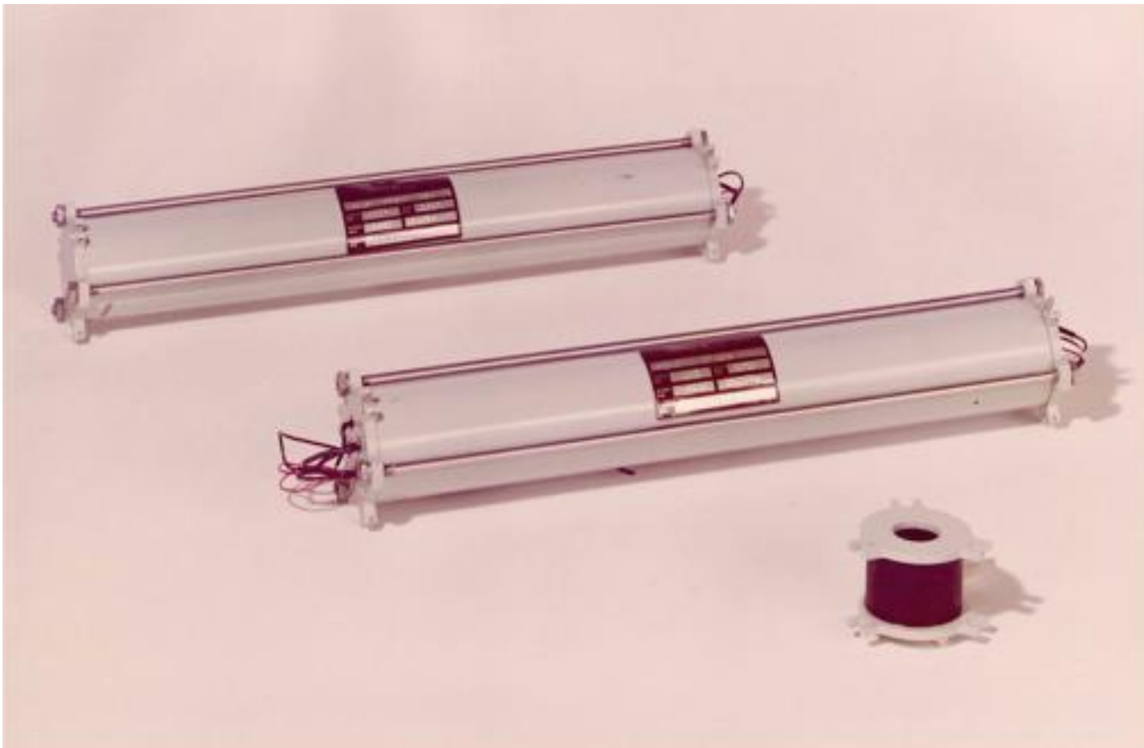

Figure 2 - One of the Singer Pinger Assemblies
From top: Battery, Electronics, Transducer

The towed array had, I think, 72 acoustic channels that required amplifiers to interface with signal analysis tools on the ship and the data recording system. The amplifiers were designed by Librascope's Don Holyoke and were manufactured by Librascope. This was the first Librascope manufacturing production run that used the newly acquired Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) system.

Our towed array was hard wired. Hence the number of acoustic channels recorded at any time was limited by the number of conductors in the tow cable. The array was designed to permit recording any two apertures at a time. Changing the configuration required retrieving the array far enough to permit changing plugs in one of the modules. That was a time consuming period so the test plan allocated day one to recording the low frequency aperture at the center of the array and the aft high frequency array.

Figure 3, shows the rack of amplifiers and the test equipment used aboard R/V Harris during the sea test.

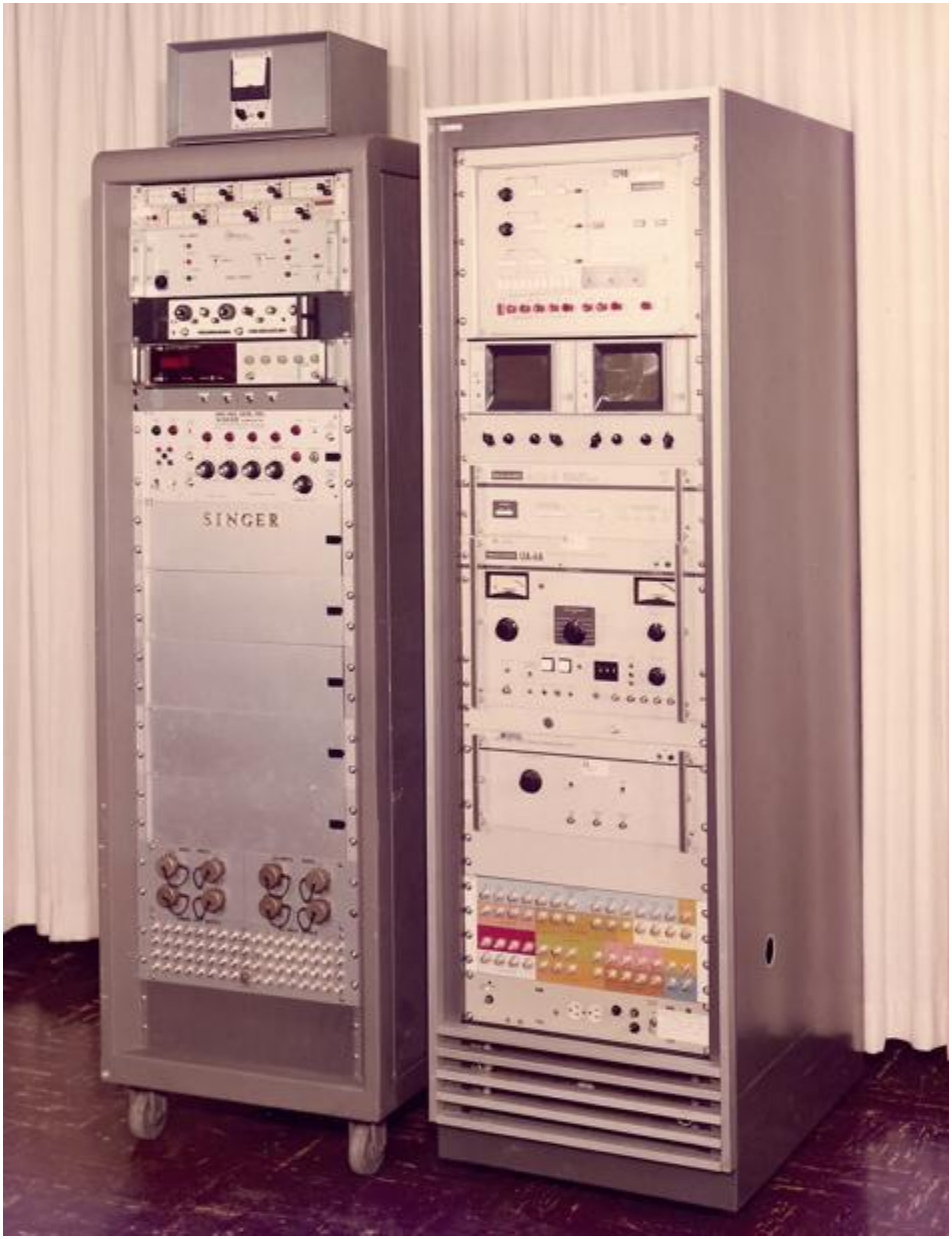

Figure 3 -- The Acoustic Amplifiers and Test Equipment

After the towed array was manufactured and ready for a sea test it was shipped to the U.S. Naval Research Laboratory's acoustic test facility at Bugg Spring, Florida near Orlando.

Bugg Spring is a small lake with a perceptual depth that enabled an acoustic aperture to be suspended vertically and ensonified with a close by test projector. Figure 4, shows one of the two high frequency (1,000 Hz) acoustic apertures suspended to be tested in the lake.

Figure 4 - Suspended High Frequency (1,000 Hz) Acoustic Aperture

In addition to the Bugg Spring tests, three hydrophones identical to those in the towed array were tested at various hydrostatic pressures in the laboratory in Orlando to determine the sensitivity of the sensors so that accurate calculations to convert voltages to in sound pressure level were possible.

As an aside, LCDR David Bolka of Nave Sea became interested in the Librascope project because of the thoroughness of the calibrations done to prepare for the sea test. David Bolka became one of the youngest Commanders in the Navy when he was deep-selected for promotion two years later.

In Figure 5, Darrel Forest is wiring the connection box that attached the tow cable to the electronics in the laboratory space. I have forgotten exactly how many conductors were present in the tow cable; however I do recall it was very expensive and far exceeded the cost of the acoustic array! I also remember with embarrassment that the box that housed the connections Darrel was making was omitted in the PERT Chart Ernie Pool required me to develop for the project! Fortunately Don Holyoke rescued me and found the box at a LA vendor.

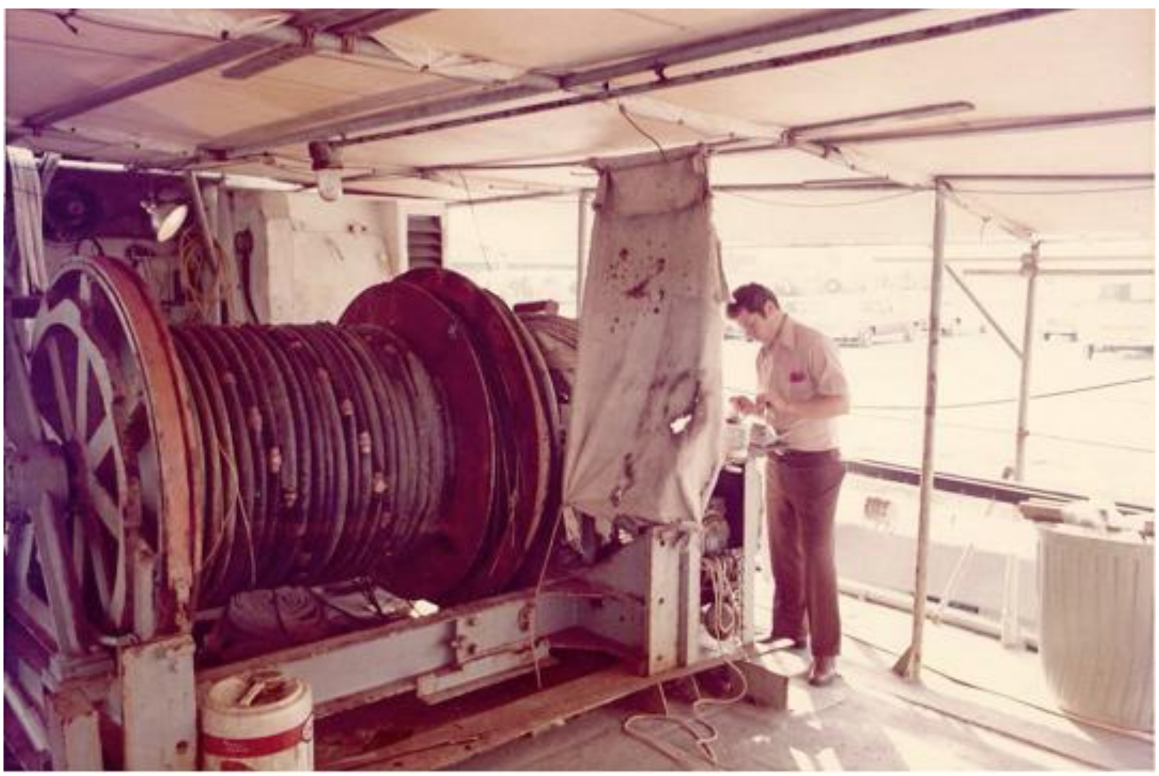

Figure 5 - Darrel Forest Wiring the Connection Box

Figure 6 below, shows Librascope's corner of the laboratory space aboard R/V Harris. The rat's nest of cables on the floor connected the array to our amplifiers and provided them to the data recording system rented from the Underwater Sound Laboratory. Their system is the rack with the tape recorder at top with a sheet of paper attached.

Figure 6 – Librascope Space aboard the R/V Harris

Figure 7 shows the array being deployed during the sea test. The task took quite a while because in addition to 2000 feet of acoustic array there was the vibration isolation module to reduce strumming of the array and the tow cable. Handling of the array was carried out by contractors that supported the Underwater Sound Laboratory sea tests and the R/V Harris. I have long forgotten company names; however remember well the professional capabilities they provided. We were also supported by a technician from Seismic Engineering. We were aboard R/V Harris on the AUTEC range during early December of 1973.

Figure 7 – Deployment of the Librascope Towed Array

The results of the sea test were substantial and were valuable during the writing of the ETASS/SURTASS proposal during summer of 1974.

Figure 8, is a summary of the date attained during two days on the AUTEC range. The data summary indicates which apertures were recorded and the objective of the test runs.

LIBRASCOPE TOWED ARRAY PROGRAM

DATA SUMMARY MATRIX

5 DECEMBER 1973

RUN	TIME (MIN)	CPA (YDS)	SPEED (KTS)	△BRG (°REL)	TGT (Hz)	PURPOSE
1	60	5567	6.1	S 74-154	NOISE PLUS 100 250 1000	BEARING ESTIMATES @ LOW SPEED HF & LF ARRAY
2	13	844	6.0	S 10-122	NOISE PLUS 100 250 1000	BEARING ESTIMATES @ HIGH S/N HF & LF ARRAY
3	26	1630	9.0	S 28-170	250 1000	BEARING ESTIMATE WITH ARRAY MORE SHALLOW
4	27	4268	8.2	P 50-137	250 315 1000	SHORT RANGE BEARING EST. AHF ARRAY
5	29	5569	9.0	S 68-133	93,105, 215	SHORT RANGE BEARING EST. LF & AHF ARRAY RUNS 3, 4, 5 RANGES WERE VARIED TO LOOK FOR LLOYD MIRROR EFFECT
6	24	1032	15.0	P 0-162	93, 105, 215	HIGH SPEED SELF NOISE EVALUATION

6 DECEMBER 1973

RUN	TIME (MIN)	CPA (YDS)	SPEED (KTS)	△BRG (°REL)	TGT (Hz)	PURPOSE
1	15	990	5.4	P 35-154	1000	TRIANGULATION RANGING @ HIGH S/N RATIO
2	24	1457	5.6	S 28-129	200	±5° SNAKE COURSE FOR ARRAY MOTION
3	19	3853	5.5	P 63-119	95,200, 475	TRIANGULATION RANGING EXCELLENT RUN
4	17	4856	8.6	P 59-119	95,200, 475	TRIANGULATION RANGING LOST R/V HARRIS TRACK FOR PART.
5	25	1101	2.5	S 46-140	800 TO 2000 Hz NOISE -3 dB/OCT.	BROAD BAND BEARING ESTIMATES
6-A	28	1212	2.6	S 27-180	200 475 1000	ARRAY MOTION AND END FIRE SENSITIVITY
6-B	24	OPENING END FIRE			200 475 1000	OPENED @ 6 KTS FOR PROP LOSS AND LLOYD MIRROR EXPT.
6-C	31	540° CIRCLE FOR ARRAY DYNAMICS				

Figure 8 – AUTEC Range Data Collection Summary

Figure 9, shows an interesting picture that depicts motion of a towed array relative to the tow ship. It was the first data of its kind when we reported it. The solid line was the track of the R/V Harris. The dotted line is the position of the after pinger more than two thousand feet behind. What is clear is the towed array “cuts the corner” when the tow ship maneuvers. While this was not a surprise, these data made it clear that Librascope could locate two places on the towed array during our tests.

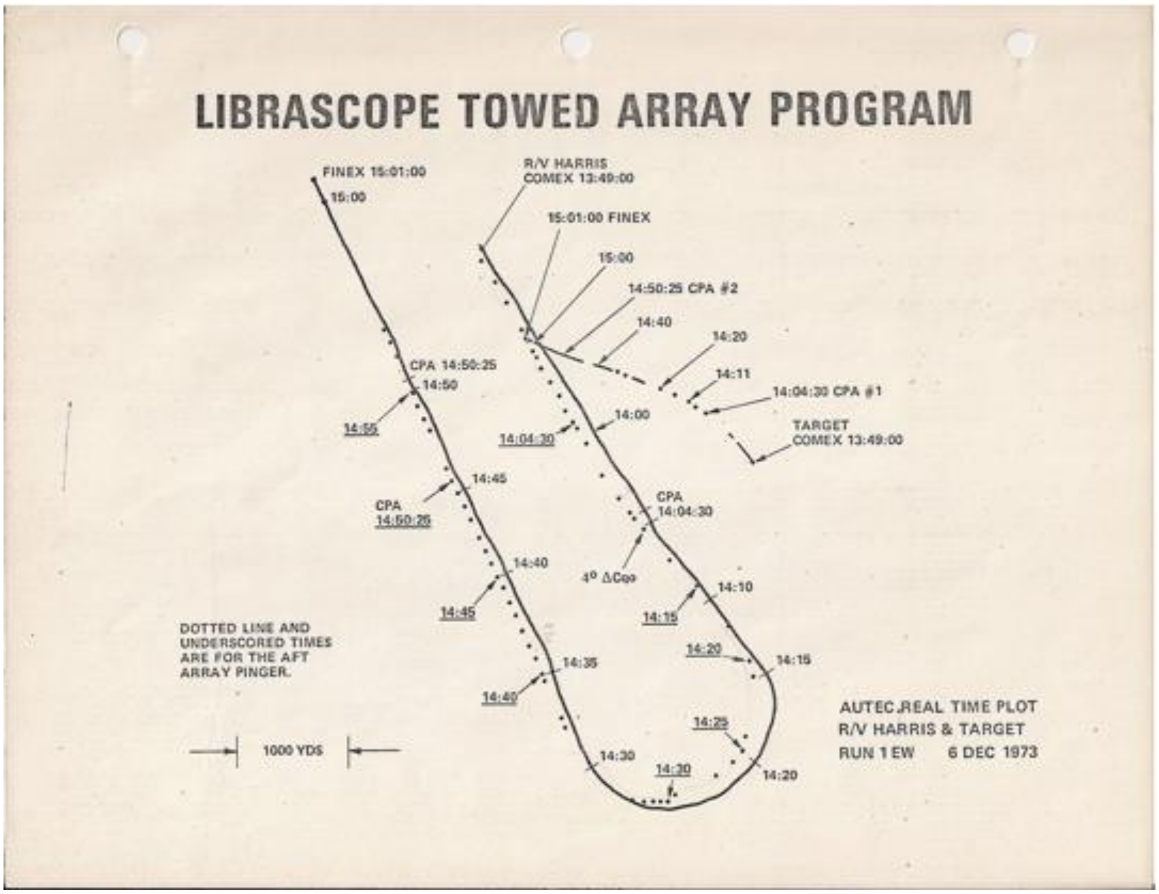

Figure 9 – Towed Array Motion Tracking

Shown to the right of the ship’s track is the position of the acoustic target providing signal for the array to record.

Figure 10, is another example of what we could observe using the towed array pingers. The solid line is the course of the towed array measured by drawing a line between the forward and the after pinger. The data are all in AUTEC range coordinates. The triangle and dot data are the headings of the forward and after pingers measured by measuring the slope of the line connecting positions measured a few seconds apart of the individual pingers. These data provided some insight to the issue of establishing the heading of the towed array and the positions of the apertures that are required to estimate target bearings from acoustic data.

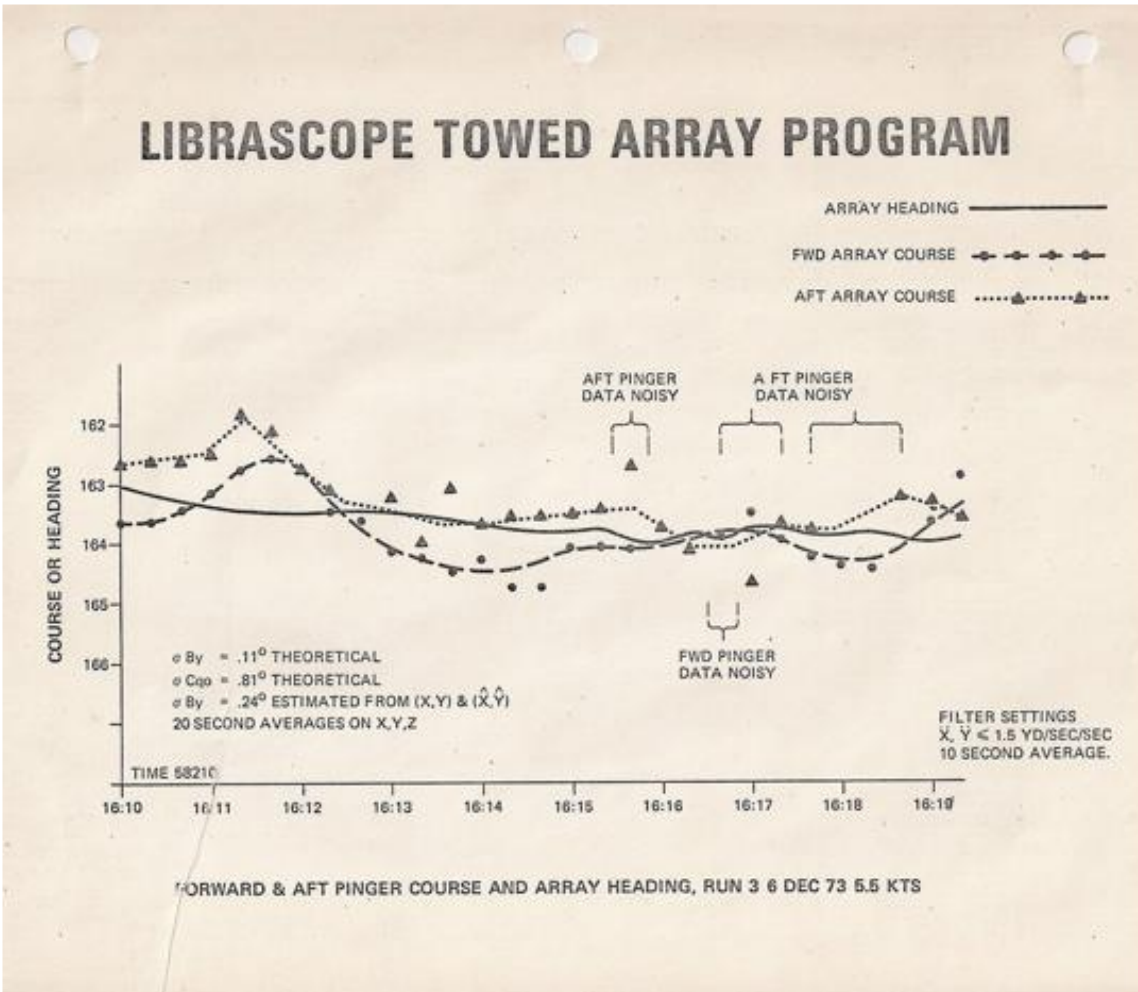

Figure 10 – Towed Array Heading and Course Data

Figures 11 and 12, show the bearings estimated using a narrow band estimator to track tones in the target's signature. Figure 11 is for a 200 Hz. tone and Figure 12 is for a 475 Hz. tone. The bearing estimates were made using an algorithm developed by Librascope's Dr. Fred Smith. Shown on the two figures are the standard deviations of bearing error versus signal to noise ratio. The circled X's are measured from sea test data and the dots are theoretical calculations. I suspect the simulated data are from Fred's work, although we also had much help from George David who was lead engineer for the Librascope Sonar Signal Processing Laboratory.

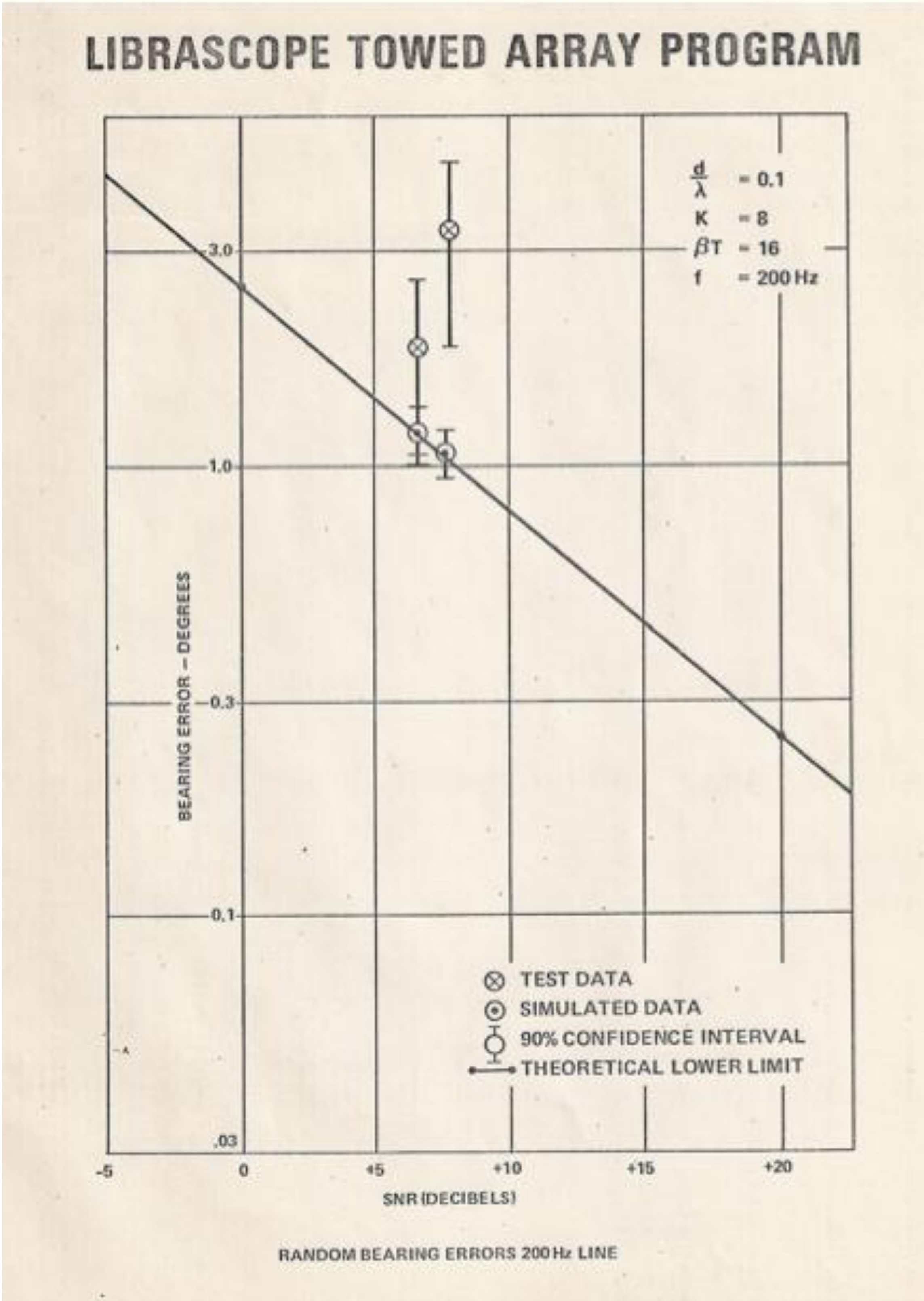

Figure 11 – 200 Hz Tone Data

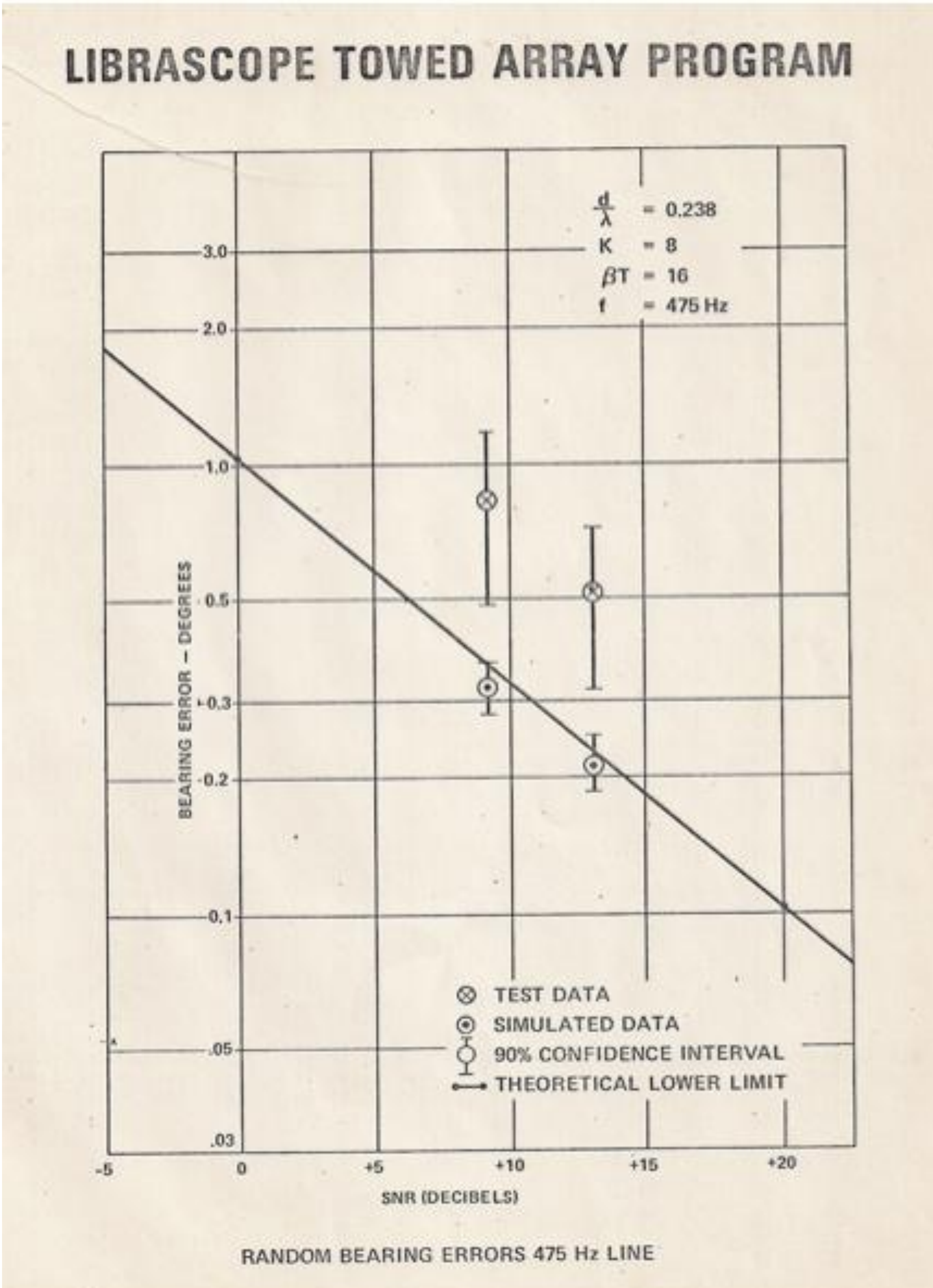

Figure 12 – 475 Hz Tone Data

I left Librascope late in August of 1974 and do not have the final report of the sea test prepared by Fred Smith. I did have a draft I wrote but gave it to one of the engineers at Naval Underwater System Center (NUSC) in support of localization work during the mid 1980’s. I donated the report because it clearly demonstrated Librascope was on the right track with respect to tactical towed arrays.

Comparison of the array Librascope towed at sea and the TB-29 towed array in the submarine fleet today is interesting. Maybe once again Librascope was on the cutting edge of technology.