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SONOBUOY MILS (SMILS)

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Summary

The purpose of this paper is to describe a new technique for locating missile impact positions in the open ocean using Navy sonobuoys. Figure 1 shows a typical Navy ASW sonobuoy, an air-dropped, expendable VHF radio that relays the underwater acoustic signals received on a hydrophone beneath it to an aircraft overhead. This missile impact location system has the advantages of being low cost, portable and capable of high accuracy. Basically the sonobuoys monitor the hydroacoustic signal of a missile impact on the ocean's surface and use fixed ocean bottom transponders as a geodetic reference for the sonobuoys. Heretofore we have used aircraft dropped sofar charges as an acoustic tie between the surface sonobuoys and the ocean bottom transponders. Impact accuracy in this sonobuoy system of 0.1 NM is possible. In the future, with a little more hardware development, the use of active sonobuoys will eliminate the need for the sofar charge reference tie and the upgraded SMILS will have an accuracy of 250'.

Today's MILS

The present Missile Impact Location System commonly known by its acronym MILS was installed in the Atlantic and Pacific ten years ago by Western Electric. It is a fixed system using passive hydrophones, long submarine cables and shore recording facilities. Two basic MILS systems are used.

For missile tests targeted to the broad ocean areas or BOA, a sofar charge is carried by the missile. This charge contains 1/2 to 4 lbs of explosive that is detonated as the missile sinks to 3000' or 4000' depth. The sofar signal is monitored by distant hydrophones and the missile position determined by a standard ranging calculation. Figure 2 shows a classical sofar signal plus a short 4% section of the actual ray paths between source and receiver. The characteristic sharp ending of this sofar signal facilitates an accurate ranging calculation for missile impact location. If a high sofar position accuracy is required, the sofar transmission velocities to each of the MILS hydrophones must be measured within a few hours of the missile test. This is done by dropping a series of sofar charges at a nearby bottom transponder benchmark.

When greatest missile impact accuracy is required, the missile is aimed to impact over a circular array of ocean bottom hydrophones adjacent to an island. Figure 3 shows the MILS hydrophones at Ascension. Phones 31 to 36 form such a target array. Their water depth is 10,000'. These phones actually monitor the acoustic energy radiated by the missile impact splash overhead. For the short hydroacoustic transmission distances involved in this target array, straight rather than curved ray paths may be used for calculations and the MILS system accuracy is essentially the accuracy with which the bottom array can be located and surveyed. The remaining hydrophones in this figure are at about 3000' depth and are for monitoring distant sofar charges.

These ten year old MILS systems do not meet all of the requirements for testing new missiles particularly in the open ocean. Often a desired open ocean impact area is not surrounded by the fixed MILS hydrophones required for accurate position calculations. The installation of new MILS phones required for adequate coverage is expensive, lengthy and often politically impractical. The systems poor high frequency response is inadequate to identify or monitor small sofar charges or to separate closely spaced re-entry body splash signals.

Sonobuoy MILS - SMILS

The sonobuoy MILS or SMILS as we have used it, is based on three well-developed hardware or phenomena. The first is the Navy's Lockheed Electra anti-submarine warfare aircraft known as the P3 with its multi-channel sonobuoy underwater listening system for detecting submarines. This aircraft has long legs. For an impact area 1000 miles offshore the P3 can transit at 380 knots, install sonobuoys for one hour and remain on station for six hours. The Navy's Mk 41 sonobuoy is shown in more detail in Figure 4. It's output rf power is one watt. There are 31 rf channels available. A P3 could normally carry 60 but could carry 200 sonobuoys. This sonobuoy has a three hour operating life but a $25 modification extends this to nine hours. The Navy buys such sonobuoys by the hundred thousand each year at a cost of about $100 each. The only modification we make to this P3-sonobuoy weapons system is to turn the aircraft sonobuoy receivers down 34 db to prevent signal overload. We are monitoring loud transient signals not distant submarines.

The second well-tested hardware that we are using is the ocean bottom transponder that was developed by Bendix for AFETR 6 or 8 years ago. These serve as the permanent mid-ocean benchmark for our sonobuoys. Once installed these transponders last for 2 or 5 years, depending on utilization. They may be replaced as their batteries weaken without another expensive localization survey. These transponders are energized by a ship's 16 kc echo-sounder and respond at 9 to 12 kc. A surface vehicle may re-occupy such a mid-ocean benchmark with 50' accuracy. The benchmark must, of course, be initially located on the surface of the earth using an accurately navigated surface ship.

The third phenomena on which this SMILS system is based is reliable sound propagation thru the surface wind-mixed layer of the ocean. The presence or absence of this surface layer and its propagation effects are the crux of the destroyer echo ranging attempts to detect submarines. Propagation thru this layer have been studied for 50 years and is well known. Propagation thru this surface "wave guide" is illustrated in Figure 5. The SMILS propagation path is reliable and excellent inversely in proportion to the destroyer echo ranging problem being difficult. We have monitored missile splash signals through this duct at ranges to 20 miles. This surface duct is very common except during calm summer seas. Typically, it always exists in the North Pacific west of Vandenberg and in the tradewind areas east of the Caribbean and off Eniwetok or Kwajalein. Except after a storm it would not exist during summer months east of Cape Kennedy. Without a surface mixed layer, splash signal propagation paths to sonobuoys are by ocean bottom-bounce rather than a surface duct and the sonobuoy MILS system accuracy is seriously degraded.

Specifically we have monitored HARP upper altitude sounding vehicles as they impacted or splashed on the ocean surface off Barbados. Figure 6 shows the 16" launch gun at Barbados. A 5" gun was also used. These HARP sounding vehicles climbed to 300,000' or 400,000'. Figure 7 shows a HARP vehicle in its launch sabot ready for loading in the 16" gun. The vehicle muzzle launch velocity was as high as 4000'/sec and the ocean surface impact velocity as high as 3000'/sec. Their impacts off Barbados served to simulate the acoustic splash signatures of future missiles. Figure 8 is the splash signal of a HARP vehicle from the 16" gun on an omnidirectional sonobuoy. Figure 9 is from 5" gun launches. Our practice has been to drop sonobuoys in concentric circle about a datum sonobuoy at the predicted impact position. Our Navy P3 had 8 or 12 sonobuoy receivers and a 14 channel one inch instrumentation tape recorder. Barbados is in a steady tradewind area, a surface mixed layer was reliably present for all our tests there. We recently commenced using the Navy Mk 41 sonobuoys shown earlier. This sonobuoy has the additional advantage of a vertical line hydrophone array with a 10 db rejection against the bottom reflected signals. This produced splash signals as shown in Figure 10.* This horizontal directivity facilitates identifying the acoustic signals coming in horizontally in the surface duct and discriminates against vertically incident signals such as ocean bottom reflections.

For an actual missile test the sonobuoy pattern shape and dimension would be determined by the missile, by the accuracy of the aircraft navigation and the uniform reliability of the surface duct.

SMILS Error Estimates

The one sigma error estimates for today's SMILS are shown in Figure 11. You will note it's a combination of several calculations. Just before and after the missile splash the Navy P3 aircraft scatters 8 to 12 sofar thru the sonobuoy net. These sofar positions are calculated by the BOA MILS. This is actually quite a precise calculation since the sofar detonation times are available from the sonobuoys. These scattered sofar drops serve two purposes. The first is to provide the basis for calculating the relative sonobuoy pattern just before and just after impact. The aircrafts DR drop positions of the sonobuoys are only good for a rough first quick-look splash calculation. An upgraded sonobuoy pattern is needed for refined calculations. The second purpose is to get one of these sofars near the actual missile splash. The relative positions of a splash and a sofar one mile apart can be calculated with 100' accuracy if they are surrounded by sonobuoys 5 to 10 miles away. Hence that nearby sofar, located by the BOA MILS served to locate the missile splash. Since the splash and sofar are not simultaneous events, the drift of the sonobuoys reduces this relative spacing calculation accuracy to about 400'. Two hours before and after the missile test the RIS will drop a sofar calibration series in the transponder array to calibrate the BOA MILS and hence to precisely locate the P3 dropped sofars. The total system accuracy of this sonobuoy MILS if we are rms all of the error numbers of Figure 11 is about 1/10 of a mile one sigma.

To get a greater sonobuoy MILS system accuracy and to give us a capability in areas not monitored by the fixed hydrophones of the ocean MILS we are modifying an active Navy sonobuoy so that it will energize the bottom transponders once per minute in a SMILS system with errors shown in Figure 12. The bottom transponders will then serve to locate the other sonobuoys at the time of the missile impact eliminating among other errors the sonobuoy drift error just mentioned. Assuming the bottom transponders at this future data have been located with 100' geodetic accuracy, the accuracy of this improved system is better than 250' geodetic. This accuracy calculation was calculated in more detail by Convair's Paul Morenz in a computer study. His final accuracy estimate was 169 feet one sigma for an impact centered over a bottom transponder array located to 50' geodetically.

Other Proposed MILS

In recent years several new missile impact systems have been proposed utilizing bottom hydrophones connected to various types of surface radio buoys. Such a radio buoy MILS would eliminate most capital costs of new fixed MILS systems of todays type. A MILS using an ocean bottom hydrophone has a higher potential system accuracy than our sonobuoy MILS but the electrical conductor from the surface to the ocean floor is a very rough technical problem that has never been solved. The electrical conductor may be feasible on the drawing board but it has never been demonstrated in the rough open oceans.

SMILS Advantages and Disadvantages

The big advantages of our sonobuoy MILS over these proposed systems are the lack of any permanent hardware located at the ocean's surface and the low development cost. The negligible capital expenditures required by SMILS is particularly attractive with today's Viet Nam funding problems. For complicated missile tests, SMILS can expand its sonobuoy network to say 24 sonobuoys, something that is impossible with bottom sensors driving anchored buoys. The 10 to 2500 Hertz frequency bandwidth of the sonobuoys is more than adequate for timing requirements. The SMILS disadvantages include need for aircraft in the impact area and a somewhat more complicated MILS data reduction program.

Acknowledgements

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* Not available at time of publication

Figure 1

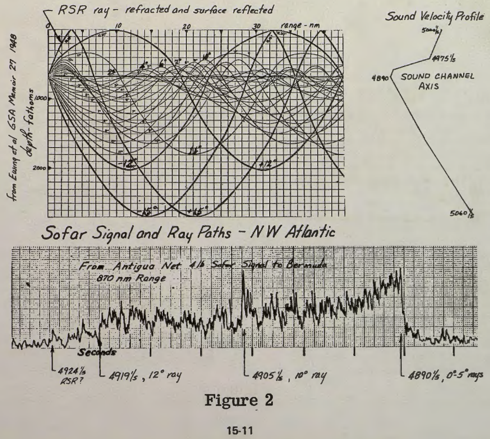


Figure 2

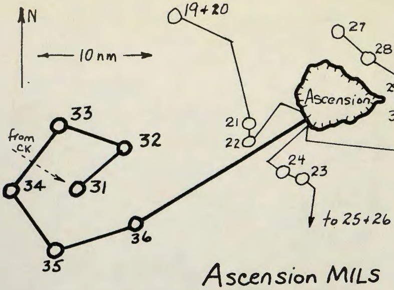


Figure 3

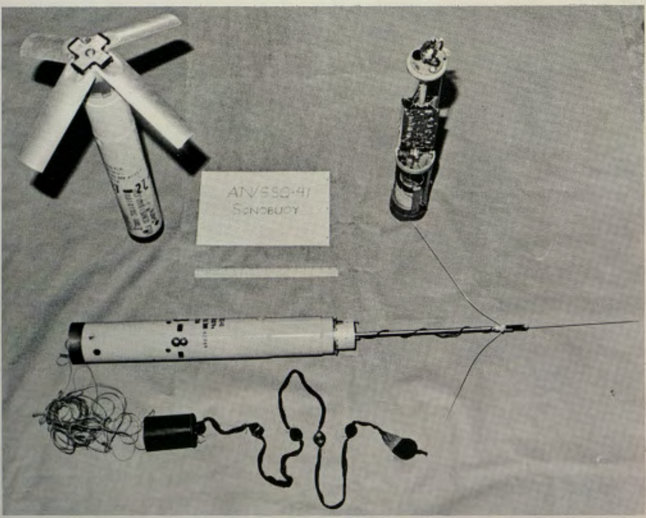
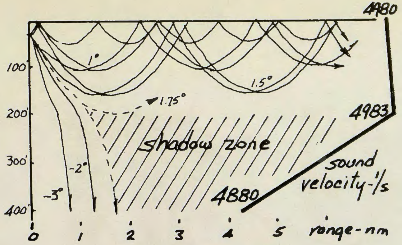


Figure 4



propogation in 200' surface duct or layer from 25' source

Figure 5

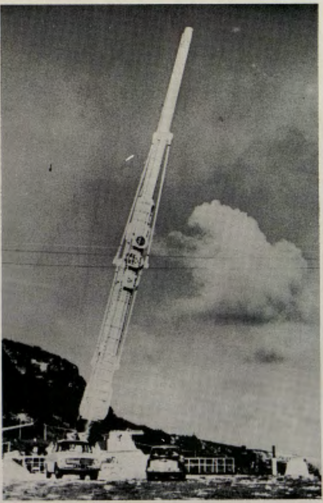


Figure 6

Figure 7

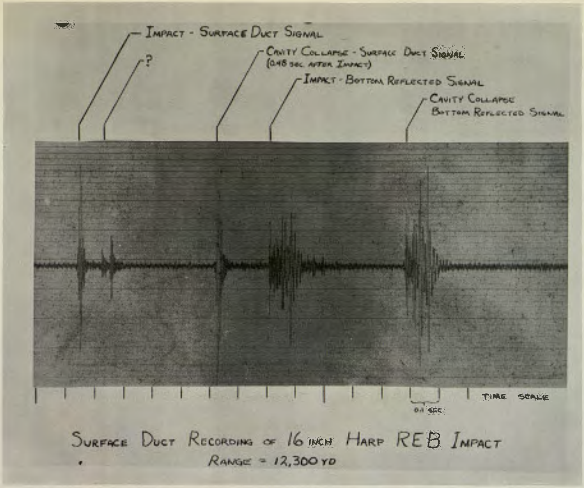


Figure 8

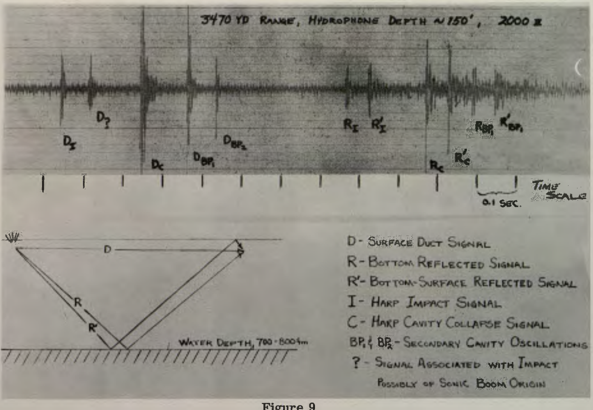


Figure 9

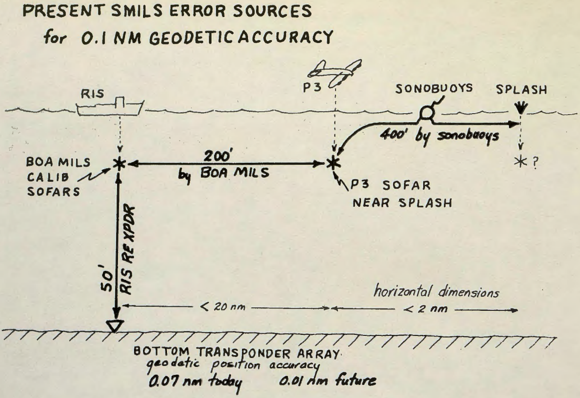


Figure 11

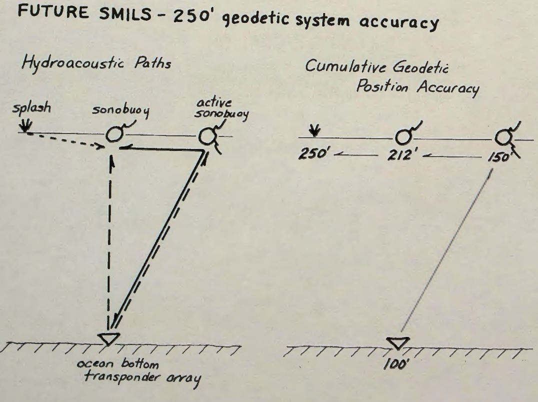


Figure 12