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Edwards Street Laboratory  
Yale University  
New Haven, Connecticut

Technical Report No. 9  
ESL:570RKW:Ser 077  
12 August 1952

Report on the Use of the Mk 6 Acoustic System  
(Audio Reception System M-21)  
for Sound Ranging

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ABSTRACT

Ranging experiments, using blasting caps as sound sources and an array of four hydrophones of a Mk 6 Acoustic System installation at Fishers Island, have demonstrated that passive sound ranging is entirely practicable and that quite precise location of the sound source is possible, limited principally by the precision with which the hydrophone locations are known.

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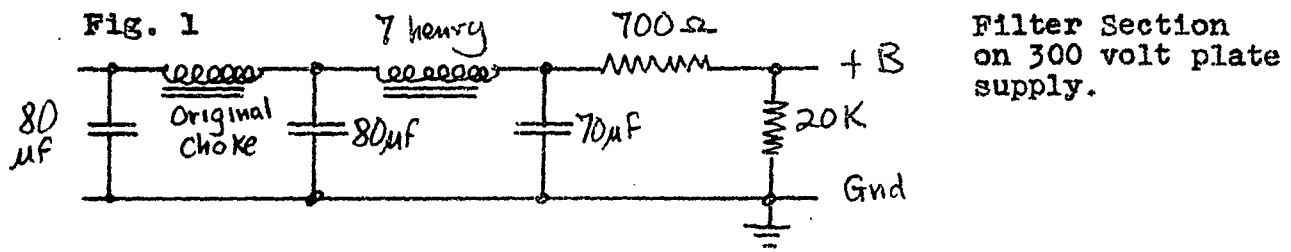
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Report on the Use of the Mk 6 Acoustic System  
(Audio Reception System M-21)  
for Sound Ranging

In a previous report, Ref (a), a description was given of work with Mk 6 Acoustic System installations at both Yorktown and New London (Fishers Island) carried out by Yale Harbor Protection Project personnel.

The present report is an extension of Ref (a) and describes experiments in sound ranging using the Fishers Island installation.

In preparing to carry out ranging tests with the Mk 6 system, it was found that considerable work on the circuits was necessary. As a result of faulty manufacture some servicing of a routine nature was needed, but of more basic concern is the fact that the design of both the power supply and the audio amplifier leaves something to be desired. The power supply, in particular the 300 volt plate supply for the amplifier, is inadequately filtered with the result that the hum level is much higher than need be tolerated. The audio amplifier is so highly microphonic that acoustic feedback from the loudspeaker mounted on the same chassis causes regeneration even at low gain settings. A simple additional filter section removed the first difficulty; but no attempt was made to repair the amplifier, since this would have required an extensive change in the layout.

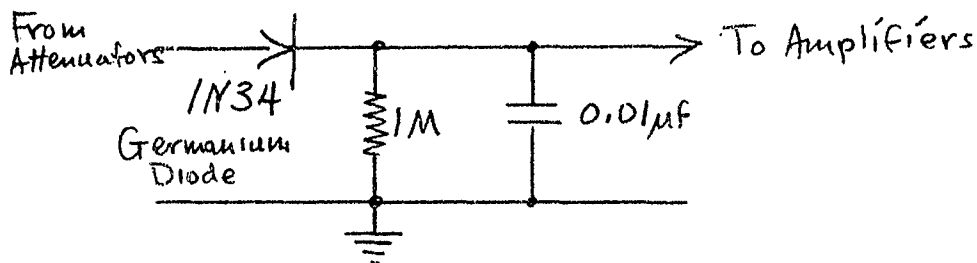


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However, the loudspeaker was placed at a more remote point, and some slight improvement resulted.

In the actual ranging tests, the audio amplifier and recording apparatus associated with the equipment were by-passed. Instead, a high speed (125 mm per second) pen recorder and four separate amplifier channels, all manufactured by the Rahm Instrument Company, were used. Of course, three channels would have been sufficient under ideal conditions for ranging purposes. Immediately after the attenuators on the shore based equipment an integrating device with a time constant of 0.01 seconds was inserted.

Fig. 2 Integrating circuit



This circuit provides an envelope of frequencies above 100 c.p.s. The rectifier-filter circuit was required, because the frequency response of mechanical recorders is necessarily limited, whereas a large amount of the energy in noises of interest is associated with higher frequencies than those to which the recorder would respond. The device proved very effective in giving clean, sharp recordings of the wave fronts.

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The Fishers Island hydrophone cables were terminated in a cable hut at the shore, as noted in Ref (a), and the circuits completed to the Harbor Entrance Control Post, Mount Prospect, via pairs in existing telephone cables. An overland cable run of about one mile was required. Since the underwater cable sheaths were presumably exposed to the sea, and since the sea constitutes the return circuits for the hydrophones, the cable sheaths were bound together at the cable junction box (where the seaward cables and the telephone cables interconnect), and connected to the junction box and to one side of each of four telephone cable pairs leading to the HECP.

It was found, however, that an unduly high 60 cycle hum level existed when the equipment was placed in operation. As a first step, it was decided to determine whether the 60 cycle pickup was in the shore cables or in the seaward cables. It was soon discovered that the cable sheaths did not constitute an adequate ground or connection to the sea return. Accordingly, a length of tinned copper braid was immersed in the sea near shore and used as a grounding point. The hum level was then reduced to an entirely acceptable value, somewhat less than that generated by the shore equipment itself.

It was not practical to have mine drops made in New London harbor for these tests, so the sounds to be ranged upon were produced by firing small fulminate of mercury blasting caps at points which were established by transits on shore. The tests showed that with

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the integrating circuits described, time differences could be measured with quite sufficient accuracy. In fact, it appears that inaccuracies in ranging will reside almost entirely in uncertainties as to hydrophone positions and as to the velocity of sound in sea water. With regard to the first uncertainty: the positions of the hydrophones must be known to within a few feet or accurate ranging will evidently be impossible. The four phones which were installed in New London harbor were sighted in by taking angles between known points with a sextant on board the boat which was laying them. The present tests have shown that this method is insufficiently accurate. Furthermore, as is usual with the Mk 6 systems, the hydrophones were installed approximately along a straight line between 500 and 1000 yards apart. Our experience indicates that for ease of plotting, and even for maximum accuracy when the results are to be calculated, the phones should be placed in triangular arrays, since this usually results in more sharply defined intersections of hyperbolae. Better methods for accurately positioning hydrophones should be one of the results of further ranging work being carried on at Jamestown, R.I.

A statement of exactly what accuracy can be obtained would be of interest, but unfortunately the positions which were given to us for two of the four hydrophones appear to be considerably in error. However, the hyperbolae plotted from the time differences between the other two phones invariably passed within 20 yards. It is safe to assume that had all data been calculated for positions rather than plotted on charts (1/20,000) this error would have been much

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smaller. The size of the error also reflects two other things: the inaccurate positioning of hydrophones and the crudeness of our base line on shore. To have gone to great lengths with the latter in these initial tests would have been wasteful in the light of the former. The time differences could be measured to 0.001 seconds which corresponds roughly to five feet. There is no reason why, assuming adequate knowledge of hydrophone positions and sound velocities, sound ranging with existing Mk 6 apparatus could not be almost as accurate.

Of major concern, of course, are questions of constant monitoring and of resolving several splashes in close succession. These problems are under consideration and it is hoped that suggestions will be shortly forthcoming.

It is interesting to observe that, in spite of the irregular performance of the hydrophones as mentioned in Reg (a), the results on sound ranging are entirely satisfactory. The very sharp wave fronts obtained through the use of the integrating circuit seem to lend promise to the idea of an automatic system for receiving and storing time-difference-of-signal-arrival information.

Accordingly, plans are being made to construct an electronic time-measuring device based upon digital computing techniques. Such a device has the virtue of being always alert, responsive to time differences much shorter than necessary for this purpose, and of being adaptable to entirely automatic operation. This device will be described elsewhere. Preliminary study indicates, however, that such a device is the ideal answer to the need for constant surveillance and constant and continuous alertness.

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Reference (a) HPP Technical Report No. 7  
(HPP:570:Ser 052 dtd 28 April 1952  
"Experimental Study of Mk 6 Acoustic System  
for Mk 51 Controlled Mines" by  
Andrew Patterson, Jr.

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Fig. 3. Photo of sample recorder trace resulting from reception of blasting cap explosion (underwater) on four hydrophones of Mk 6 Acoustic System.

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