Army Operational Research Group Memorandum No. 266
The Possibilities of New Uses of Radar with Artillery.

(Minutes of Meeting held at A.O.R.G. on 5th February; 1944)

Brigadier Schonland (Chairman) asked Colonel Paterson to outline the problems to be discussed.

Colonel Paterson A.5. Shell, burst and splash all give radar echoes. Is the observed position the real position? Probably not for the burst, possibly not for the splash, but more information is needed.

It would help if the echo could be increased when being used for calibration and reduced when auto-following is being employed. This seems to require different types of ammunition for the two purposes.

Shell echo measurements allow the muzzle velocity to be found. They also give a means of locating trajectories of shells, mortar bombs and rockets. Equipment which gave this information might be very important in the field for counter battery purposes. It might even replace sound ranging and flash spotting. Accurate measurements of range and angle of sight or range and time on air bursts might be used for "trial shooting" in A.A. gunnery and "witness point shooting" in field artillery. Radar might also be used by field artillery for correction of fire during an engagement, and might replace optical methods by ranging on the air burst.

Anti-Aircraft Shell Burst

Col. Weston, Ordnance Board. Fleet observations had led to trials by H.M.S. "Excellent" on the actual positions of burst and splash and the positions given by radar equipment.

Lt. Cmdr. Roche of H.M.S. "Excellent". The true position was found by cine-theodolite and the radar records obtained by N.T. 283, a 50 cm A.A. equipment. With bursts at about 3,000 yards and 4" shell, the radar range gave a bias of +60 yards; with 4. 5" shell the bias was +135 yards.

Col. Weston. The Ordnance Board were laying on trials next month with both 50 cm. and 10 cm. Radar.

(1) To repeat the observations of H.M.S. "Excellent" using a 4.5" gun with angles of sight of 10 and 50 degrees and with bursts at various ranges up to the maximum range at which a strong echo could be observed.
(2) To explode shell statically to determine whether the position bias was observed under these conditions.
(3) To repeat the Anson Shoot 1500 yards, 20° Q.E, 3000 yards, 10° Q.E. and 3000 yards, 50° Q.E., 20 rounds each repeated on three different days using 3 different calibres.

Cine-theodolite and visual observations would be made. The radar screen will be photographed with a cine-camera taking 16 frames per second.

The present view was that the "throw forward" bias effect varied with the calibre of the shell but not with the range or the angle of sight; more information was however required.

Brigadier Schonland asked whether any variation of bias with frequency had been observed.

H. M.S. "Excellent" said that there appeared to be less bias with 10 cm. equipment than with 50 cm.

Professor Cockcroft said that more "throw forward" would be expected to be observed on a shorter wave length and a general discussion suggested that the cause of the bias might be the growth of the burst.

Dr. Kempton, A.D.R.D.S. pointed out that the reflection was not from a simple surface but either from a mass of ionised gas or a flight of shell fragments.

Professor Cockcroft suggested that photographs should be taken at high speed with G.L. Mk. III during the Ordnance Board trials and H.M.S. "Excellent" agreed that the tube showed very complicated disturbances.

Dr. Shire A.D.R.D.E. asked how accurately the radar calibration had been tested to find whether any of the results might be caused by changes in such calibration.

H.M.S. "Excellent" said that tests had shown high accuracy of calibration as tested by the standard naval routine.

Dr. Kempton suggested that the echo from a square pulse would not be of very definite position as the burst would spread over a distance and the operators would probably choose the final stage of a quick set of changes.

Professor Cockcroft thought that the high speed photographic records should clear up the facts.

Col. Paterson hoped that the results would show how consistent were the operators' observations so that their likely errors could be ascertained.

Major Robarts, S.A.A.A. said that observations on 3.7" shells using GL Mk. III had shown a similar positive bias of about 110 yards (corrected for set bias) at ranges of 4000 and 8000 yards. The average errors of observing the burst was estimated as 20 to 30 yards.

Lt. Col. Chignell A.A. Cmd. said that the A.A. Cmd. - A.O.R.G. trials showed a varying bias of from 100 to 300 yards. The variation appeared to have no correlation with range or time of flight. A good observer usually obtained consistent results on one day but varied from day to day. A.A. Cmd. were however looking on the method only as a quick check for the correction of gross errors; a few rounds being fired when the alert sounded.

Further experiments were proposed in collaboration with A.O.R.G.

Dr. Craik, Cambridge Psychological Laboratory, suggested that operators would show errors of anticipation.

Lt. Col. Chignell replied that photographs of the C.R.T. showed that the error of the operator's cursor was perhaps 40 yards.

Col. Paterson asked what positive bias was likely owing to the time required for the echo to form and Lt. Cmdr. Roach said that .H.M.S. "Excellent's" records showed this was small and of the order of 10 to 20 yards.

Dr. Kempton said that the problem was analogous to that of ranging on a ship, say 100 yards long and giving an echo from a sloping deck.

Dr. Taylor, A.D.R.D.E. thought that 50 cm. radar showed the echo from ionised gas whereas 10 cm. probably recorded most of the echo from fragments.

Col. Paterson asked for an estimate of likely accuracy on a burst if the positive bias were eliminated.

A.A. Cmd. thought 25 yards by photographic recording of the trace and 50 yards by visual observation. A fix of this accuracy would be of great value to A. A. Cmd. and might provide a check for meteorological data and lead to improvement in the accuracy of this information. Dr. Shire suggested that a delay screen on the C.R.T. might help.

H.M.S. " Excellent" said that special ammunition would probably be wanted when auto-following was in use and Col. Paterson thought there might be difficulties near the crossing point when using automatic following.

Dr. Shire expected 30 to 40% increase of echo on passing from the S to the K band but even then the echo from the burst was not likely to equal the echo from a bomber so that there should not be trouble with auto-following, especially as shortening the pulse width would reduce the likelihood of the set following the burst.

Shell Splash

Col. Weston, Ordnance Board were trying to improve the echo from a shell splash by putting various substances between the blunt nose of the shell and the ballistic cap. A 2 oz. exploder gave improved echo. Various dyes were tried but gave no special radar effect. Dipoles in the ballistic cap were said to have shorn 20% improvement on 10 cm. Large scale trials were proposed. Extra explosive in the cap gave some effect on 50 cm. but little, if any, on 10 cm. Visual photography of the splash of 4" and 4.5" shells showed that splashes reached their maximum after 1 second and persisted for about 4 seconds, the splash often rising to 200 feet. I.C.I. had carried out experiments with 10 lb. charges at various depths and found no delay in the radar build-up.

Lt. Cmdr. Roach said that a 275 set at Llandudno could follow 4.5" shell to the horizon.

Major Varley, A.O.R.G. said that with the K band, C.A. set, the echo on the tube seems to build up as quickly as the splash observed through binoculars. Even in high winds the splash could be observed on the screen and on one occasion there appeared a drift for 300 yards down wind from a 15" shell at 36,000 yards - no visual check was possible at this range.

C.A.S. said there appeared to be a positive bias of 15 to 30 yards on a 6 inch shell where the width of the splash was probably 20 yards.

There was a great advantage in having the burst at the same height as the gun itself so that it would be helpful if radar could observe ground bursts.

Dr. Kempton said that some radar sets should show two out of three ground bursts and further improvement was hoped from experiments now being carried out at A.D.R.D.E.

Major Stephenson said that one of the reasons why H.A.B. shoots were not used more frequently was the difficulty in deploying and surveying 3 O.P's. By radar methods only one O.P. would be required.

Lt. Col. Taylor disagreed. The gun positions had in any case to be surveyed and the extra work for setting up the 3 O.P's was not great. The objection to the use of H.A.B. was that groups of rounds had to be fired for each range and for each charge. He thought that radar for unseen air bursts would be of great value and it might help meteor observations by ranging on the meteor balloons using a theodolite for angle.

It was also suggested that in cloudy weather a G.L. III could give range and angle, though with less accuracy. Echoes could be got up to 20000 feet by fitting a dipole on the balloon. The Navy are making meteorological observations by observing balloons with the NT 275.

Muzzle Velocity Measurements

Col. Paterson said that the present methods were

(a) R.D. camera
(b) Photo-electric cell with chronograph

The British P.E. Equipment measured the velocity over 100 feet and an Australian one had a base only 10 feet long. This latter equipment was stated to work at Q.E's up to 70 degrees.

The chief drawback of these equipments for coast artillery was that they had to be in front of the gun. Radar apparatus could be used while actually engaging the enemy.

Dr. Taylor said that A.D.R.D.E. were developing a K band field set to give muzzle velocity to 1 in 300 by C.W. Doppler measurements over the first 50 feet.

Lt. Col. Taylor said that the present accuracy of measurement of muzzle velocity was to 5 - 10 f.p.s. but the value for a gun varies from day to day. The R.D. camera is slow to use and gives some troubles; hence the field radar set might be very helpful.

Trajectories of Projectiles

Col. Paterson said that the problem of locating enemy mortar positions had been given much attention. Trials were being carried out on the use of radar.

Dr. Kempton stated that the A.D.R.D.E. early experiments showed that GL Mk. III would detect the mortar shell only in the first and last parts of its trajectory and when it was at right angles to the beam.

More recently the American 584 and airborne sets with a P.P.I. showed also only the beginning and end of the flight but would do so up to angles of 40° from the line of fire.

Ground clutter often hides the first few hundred feet.

22nd February, 1944.

(signed) S R Hamby (?)
for Superintendent A.O.R.G.

EEB

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Dr. Craik