An H2S Ground Mapping Radar Project

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Aircraft navigation took a major step forward during WWII with the introduction of H2S ground mapping radar in 1943, prior to this navigation was a hit and miss affair using Sextant and stopwatch. But now even in poor weather a recognisable plan view of the ground over which the aircraft was flying could be viewed on a radar screen.

Having been given an Indicator Unit 184, the principal viewing unit from an early H2S it was decided to try to produce a PPI (Plan Position Indicator) picture on its screen. From a descriptive Air Publication (AP2276A) it appeared a daunting task as even the most basic system had a minimum of 12 units of which I had one, the first task was to obtain some circuit diagrams and learn how it all worked. Books like "Echoes of War" and "The Bombers Eye" were useful as they provided great detail as to how the equipment was developed and used. Two VMARS members came to my aid with circuits and a technical manual, and a visit to The RAF Museum, Hendon permitted me to examine a mountain of documentation, the only trouble was the more I read the more difficult the project seemed!

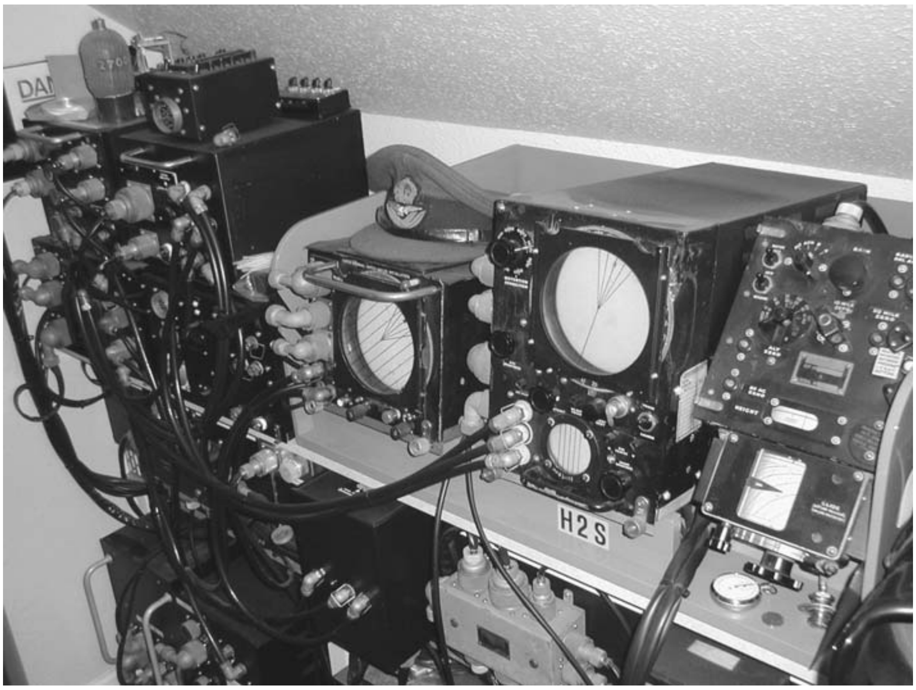

Fig 1 Principal units. Waveform Generator 26, receiver, simulators, Indicator Units 182, 184 and Switch Box 207. Under the table the PSU and Modulator 64

Getting Started

To try and build up my enthusiasm I decided to get the valve heaters to light up in the indicator, and here was the first problem. H2S installations are powered from a central power unit (Power Unit 280). In a large aircraft like a Lancaster where the radar units are scattered about low voltage heater supplies are not distributed, instead the radar supply of 80v @ 1600Hz is sent to each unit where a step-down transformer produces the necessary low voltages. Because the indicator unit required a number of different heater voltages it was deemed easier to produce the correct 80v high frequency mains rather than try changing the transformer to a standard 50Hz one. This was a sensible approach, as looking at other circuits this problem would manifest itself again as every unit contained a unique multi-winding heater transformer.

Fig 2 Main power supply consisting of an 800W rotary inverter.

Powering Up

In service the radar would be powered by an engine mounted generator, the voltage being controlled by varying the DC excitation using a carbon pile regulator, frequency was determined by the RPM of the engine which could vary greatly, giving rise to the term 'Frequency Wild Generation'. A transistorised inverter using a toroidal transformer was made and powered by my main 28VDC supply, this gave 120W at 80V/1500Hz, and when connected was more than adequate to light up the heaters. Not a great achievement but it was a great boost to see all the valves and tube heaters glowing. By now I had acquired a large 250v 50Hz ex RAF PSU which gave 300v and 1500v EHT, and a Waveform Generator 26 (WFG). Things started moving!

Progress

A glance at the circuit of the Waveform Generator (WFG) will show that this is the radar's video mixer and clock, radar is a sequentially operated device, operated by numerous time-related pulses and waveforms, the WFG is the device where they are generated and distributed. If this project was to be a success this above all other units had to work correctly.

The WFG was in good order for its age, a few valves missing and some of the wax caps cracked but sadly both range switching relays had been removed. The first job was to replace the relays, change the capacitors and valves and check the resistor values, of the rubber insulated wire only that coloured yellow had perished and so was replaced. Using the mains PSU and 1500Hz Inverter the WFG was powered and set up with an oscilloscope using the pictures in the manual for reference, we were getting somewhere at last.

Now was the time to decide which of the numerous marks of H2S to base my project on. Between 1943 and 1945 H2S went from a Mk.I to a Mk.IIIG, mark IV already developed but not in service, together with all the Coastal Command versions of H2S known as Air to Surface Vessel radar (ASV). One of the problems I was to encounter would be compatibility of units between Mk No's, unfortunately there was no RAF stores to order equipment from, it was the luck of the draw what units were available from rallies etc. My WFG was a No.26 from H2S Mk.II, the Indicator Unit 184 was compatible and I had the circuits and interconnection diagrams available, A Mk.II it would be.

Connecting Up

Standard connectors in use at that time were 'Jones' and 'Williams' the latter known as 'W' connectors, other than on the GEE tuning units I have not seen many Jones plugs used in radar, but 'W' connectors abound. These connectors were made in numerous styles from single pole to (rarely) 25 pole. Chassis versions were only made as male and it is not uncommon to find lethal voltages on exposed pins, as the most basic H2S installation had approximately 80 connectors finding sufficient was to become another problem.

By now I had acquired an Indicator Unit 182 (Fishpond) which was used in some H2S installations as an 'add on' to detect attacking night fighters, a modulator 64 and the two main interconnection junction boxes. On aircraft rubber insulated wiring was used inside a woven tinned copper sheath which was earthed to provide screening. This was not deemed necessary and cables were made up using 16/02 PVC wire in a PVC sheath, black wire was used throughout.

By now sufficient hardware was available, the PSU had been modified to be remotely controlled, all units had been interconnected and tested, and no smell of burning or expensive bangs were noticed. A green trace appeared on the lower (Height) tube on the indicator unit, but there was still another item required before a PPI trace would appear. Radar works by measuring the time delay between a transmitted pulse and the reception of an echo, a PPI is produced by causing a radial line to be drawn on the face of the tube, commencing at the same time the transmitter fires. If the antenna rotates and the position of the line drawn on the tube is made to rotate in step, and the reception of an echo causes a bright blip to appear on the screen a map like presentation of the ground over which the aircraft flies will be presented. The centre of the screen will be the aircraft and the top of the picture will (usually) represent the aircraft heading.

A Working PPI

In H2S the Sine and Cosine voltage vectors applied to the scan transformers, which were required to rotate the trace, were produced by mechanically coupling a sin/cos resolver to the aerial drive gearbox. A scanner assembly was now needed, but despite all enquiries none were available. This is not surprising, as most collectors will have noticed it is often easier to obtain major units than ancillaries such as junction boxes, trays and aerials etc. It is surmised that on scrapping an H2S equipped aircraft the scanner would not be removed, and would disappear as scrap into the melting pot. So now another decision had to be made, to try and go the whole way and make up a working installation or add some simulation? Up to this point several years had elapsed and the availability of equipment was almost non-existent. Some units obtained, like the Indicator Unit 182 and Switch Box 207, were new, whilst the Modulator 64 was complete, but in poor condition; so poor that I almost scrapped it. I still required a Transmitter, receiver and another WFG to drive the Fishpond.

One of the other factors to be taken into consideration was where could I mount a radiating radar aerial, what would it see and what would be the effect of 10kW of R.F. be on my neighbours electronic devices? I should point out that one of my neighbours is an International Airport. So the die was cast and at this point I decided to add some simulation in order to progress the project.

Success at last, sitting in the workshop watching the trace rotate, the screen glowing a ghostly green, magic. The aerial simulator was simply a small geared 12v DC electric motor rotating at 60RPM its shaft coupled by a piece of rubber sleeving to a sin/cos resolver whose rotor received the sawtooth from the WFG. Now was the time to connect Fishpond.

Fig 3 Aerial simulator. This was an early model using a Sin/Cos pot,later replaced with a resolver.

Fishpond

Whereas the PPI on the Indicating Unit 184 was used by the navigator for mapping, the presentation on the Indicating Unit182 was observed by the radio operator and was designed to view the hemisphere under the aircraft from which attack by night fighters might be expected. A problem was that when the navigator optimised the contrast on his PPI, the picture faded on Fishpond, sometimes with dire consequences. This was corrected by the introduction of a WFG type 43. At this point things were looking good, an improved aerial simulator had been made incorporating a microswich, which operated every revolution to put a heading mark on the screen, the diagram for a WFG43 obtained and a copy WFG made and incorporated. Whilst the new WFG worked well the Fishpond PPI was poor, their was jitter on the range rings and these were thick and poorly focussed. Now my visit of years before to Hendon again paid off as amongst the piles of documents copied was a file containing modifications, and one of these was for the rectification of my problem!

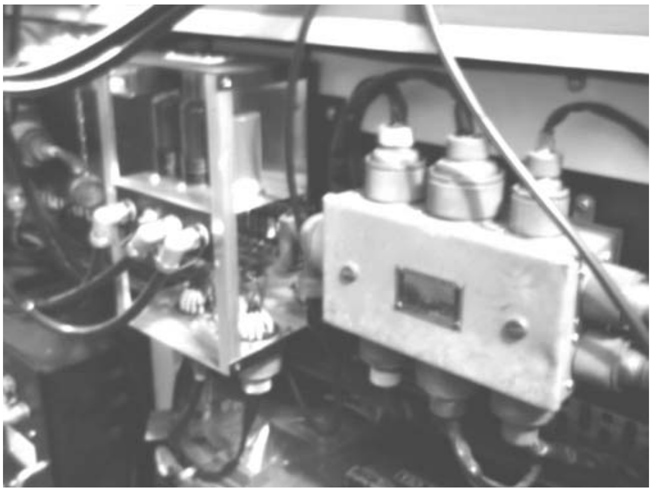

Fig 4 Waveform Generator 43, a copy was made from drawings obtained from Hendon. On the right is one of the two system junction boxes.

A Proper Picture

The system was now well and truly up and running, The PPI displayed a rotating trace with heading and adjustable range marker, on the height tube (lower tube) calibration strobes were present and were adjustable and the Fishpond displayed range rings on demand. The Switch Box 207 had been incorporated to control the power unit,

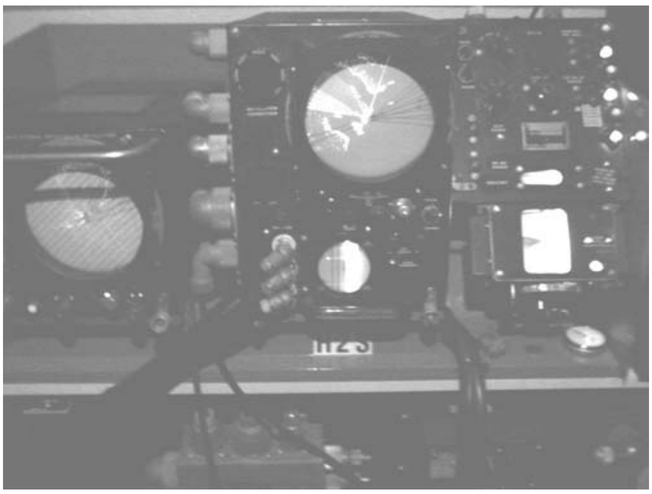

Fig 7 A PPI simulated picture on the Indicator Unit 184. Such is the low light output of the CRT, a VCR517, the picture was taken in almost total darkness.

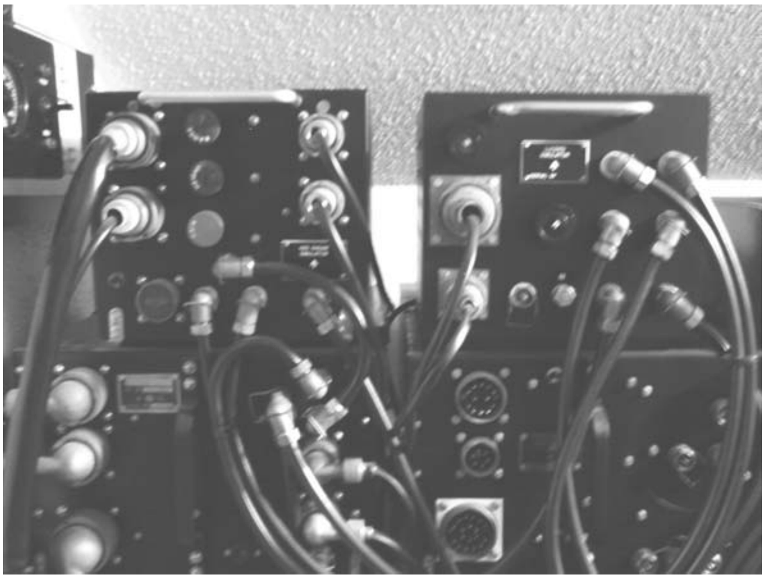

Fig 5 Top left the video simulator containing the aerial resolver, video amplifiers, range marker and noise generator. Top right, the Lucero simulator and Beacon and BABS pulse generators.

Fig 6 Hewlett-Packard 1333A X-Y display, this is a high brightness medium/short persistence indicator for medical purposes used as a video converter. The tube contains the Photodiode.

range selection, aerial rotation and markers. A Lucero simulator had been made and by switching this into circuit beacon range and BABS (approach) information could be selected to appear on the height tube, both devices early examples of today's ILS/DME. A receiver had been obtained and although in place was not fully in use, as its functions were being simulated. What else was there to do?

Years before I had worked on a Cossor 787 radar, a facility of which was an electronic map overlay on the PPI. The principle was simple, a slave unmodulated PPI rotated in synchronism, and through a series of lenses shone through a glass map plate upon which a map was printed (similar to a 35mm film negative). Light which went through the clear parts of the map plate were detected by a 931A Photomultiplier, and after processing fed into the display PPI video, where mixing with the received echoes produced a composite map/echo display.

A Hewlett-Packard 1333A X-Y display was to hand and after slaving it from the aerial simulator gave a rotating trace. By sellotaping a miniature map painted with black enamel on a piece of acetate onto the face of the HP 1333A, and using op-amps and a Photodiode, a suitable level video output was available. This was fed into the video mixer in the WFG26, and lo and behold a map of Rotterdam appeared by magic on my screen.

You would have thought I would be satisfied by now, but no, the picture displayed was too perfect, where was all the noise. A simple video frequency White Noise generator was made and its output mixed with the map video, by setting the levels the land masses appeared grainy and noise was present on the dark parts of the PPI, a rubbish picture but true to life.

What Next

During the course of my research I came across a Trainer Type 54. Consisting of a modified H2S, which produced lifelike displays, this device could be coupled to a Link trainer where a pilot and navigator could work together to hone their operational skills without leaving the ground. The radar installation was a standard H2S using a modified Indicator Unit 162 and without the transmitter. Instead a crystal transducer was made to rotate above a specially prepared glass map in a tank of water, the crystal being exited with 2kW pulses at 13.5MHz, this frequency being the I.F. of the receiver.

Ultrasonic waves would propagate through the water at a scale speed. The glass map was left polished to represent water, sandblasted to represent land and features such as cities and towns were represented by gluing graphite granules to the map face. Ultrasonic echoes received by the crystal were fed directly into the I.F. strip of the receiver and processed and displayed in the usual way. Unfortunately no details of the crystal transducer are available, experiments have been carried out using an old medical ultrasounding device but this has proved unsatisfactory.

Fig 8 Indicator Unit 162, this was an earlier simpler display than the 184. When a crystal transducer can be made to work, this will form the heart of a Trainer Type 54 simulation.

Acknowledgements

Finally my thanks go to VMARS members John Roper and Colin Baker who over the years have provided me with information, advice and encouragement not to mention numerous bits and pieces, and to whom I am indebted.

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Here's a bit of nostalgia from the adverts pages of *Short Wave Magazine*, October 1947 issue.

If anyone is wondering what these prices represent in today's money, then £52 10/- is now worth £1,370, and £75 is worth £1,958. No wonder so many post-war amateurs decided to make their own, or re-use the mountain of surplus equipment.