Moonshine

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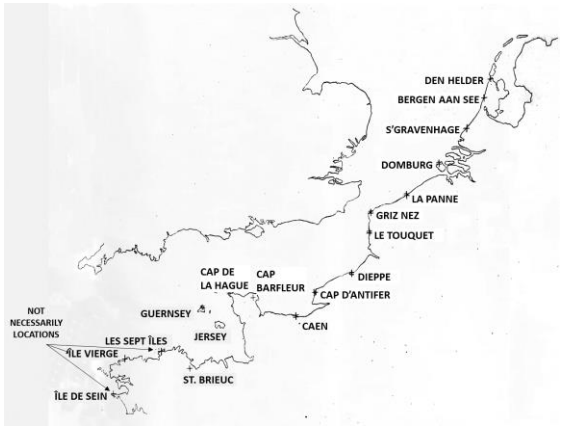
The first radar countermeasures

- From 1936 Britain had expended huge efforts into the development of radar and by 1941 had many systems in service.
  - Ground-based Air Defence, Early Warning, Coastal Defence etc.
  - Naval radars
  - Airborne radars – ASV and AI
- In 1941 radar countermeasures were low priority.
- Then on 12th February 1942, German battlecruisers Scharnhorst and Gneisenau escaped up the English Channel on under cover of a heavy jamming attack against British radar – the “Channel Dash”.
- The Radio Countermeasures Division at TRE, led by Robert Cockburn, were able to establish radar countermeasures as an essential war requirement.
- The first jammers were airborne
  - Mandrel barrage noise jammer and Moonshine pulse jammer

Military situation in 1942



[UK National Archives AVIA 26/287]

- RAF attempting to gain air superiority over France.
- Enemy had two costal chains of air defence radars covering France and Low Countries.
- Each site had one or more Freya long range air defence radars and a shorter range Würzburg fighter control radar.
  - Sites identified from signal intercepts and aerial reconnaissance
- Desire was to spoof the Freya systems using airborne jammers, to divert enemy fighter defences to intercept false bomber raids.

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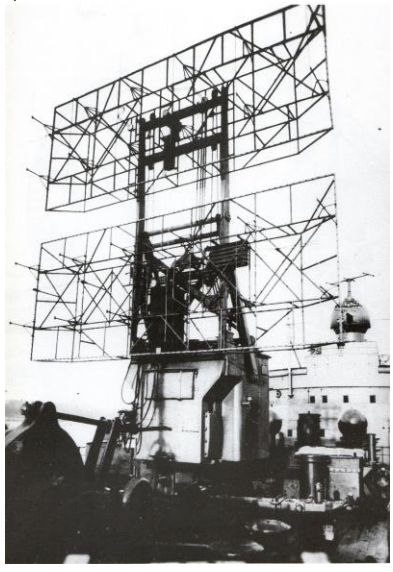
Freya, Würzburg-Riese and Würzburg



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Freya and Würzburg

- Freya long range air defence in 1942
  - Radar frequency in 119.5 – 128 MHz band (bandwidth 0.5 MHz)
  - PRF 500 or 1000 Hz.
  - Antenna gain ~13 dB (estimated from air photographs; separate tx and rx arrays)
  - V polarisation
  - Power estimated from intercepted signals 5 – 50 kW
  - Range 120 miles against fighter aircraft.
- Würzburg radars, used for gun laying
  - 53 cm (570 MHz)
  - Range 35 miles against fighter aircraft (70 miles for Würzburg-Riese)
  - Not being jammed so jammer aircraft had to stay outside its detection range

Jammer radar equation

- Pulse-repeater jamming
- A pulse jammer needs to replicate the power density received at the radar from a real target. The jammer ERP only has to be a factor k less than radar ERP

$$P_j G_j \approx P_r G_r \frac{\sigma}{4\pi R^2} = k\, P_r G_r$$

- If σ = 100 m^2 and R = 35 miles, it can be seen that $k \approx$ -86 dB.
- Freya 10 kW peak power with 13 dB gain; jammer with 3 dB antenna gain only requires peak tx power of 0.5 mW.
  - Less power required at longer ranges
- Even with significant feeder losses, jammer power of ~mW required.

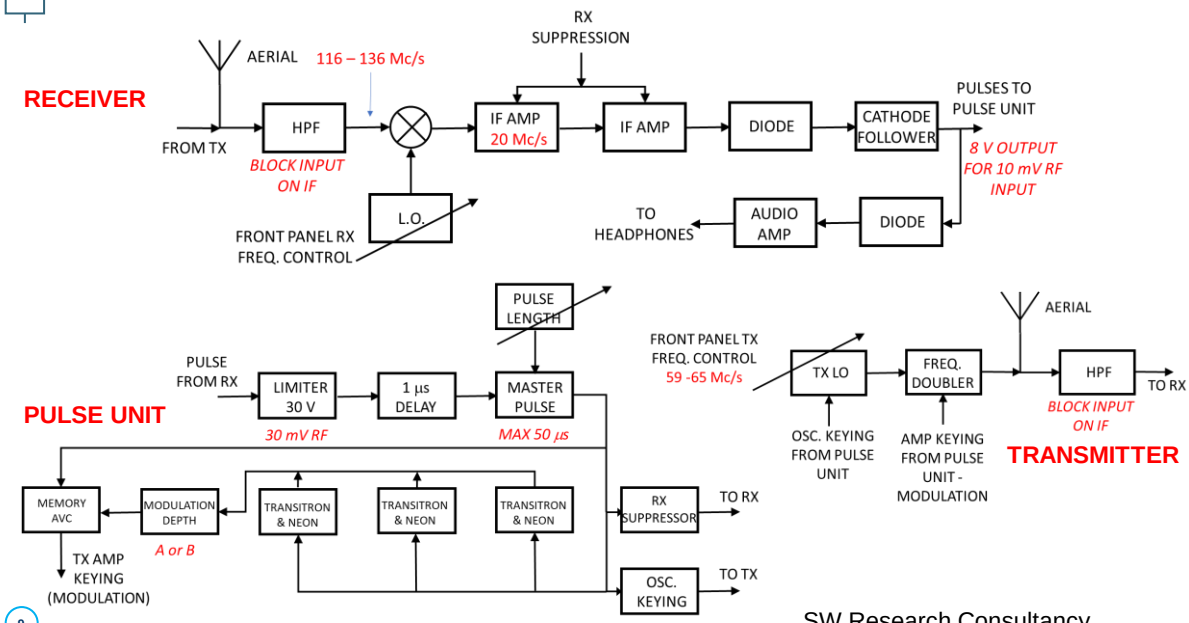
Moonshine

- Calibration flights were made to establish the signal levels received by an airborne receiver at different heights and ranges.
- Estimated that a receiver with vertical λ/4 dipole would observe a maximum signal of 30 mV at desired minimum range of 35 miles
  - Signals detectable beyond 100 miles.
- Retransmitted jammer pulses should have amplitude proportional to the received pulses.
- It was estimated that a signal gain of 34 dB (voltage gain of 50) would be required to replicate the return from a fighter aircraft.
- 30 mV received, with 1.5 V transmitted, represented maximum required power of 30 mW at the antenna.

Moonshine concept

- The aim was to fit Moonshine equipment in a group of aircraft to fly at about 10,000 ft towards to enemy air defence systems
- Each Moonshine receiver covered about 1 MHz bandwidth, pre-set before take-off, so 8 or more (one in each aircraft) were needed to cover the Freya band of 119.5 – 128 MHz.
- Received signals within the pre-set band of an individual equipment triggered a modulation unit, which generated an extended pulse of up to 50 μs duration with amplitude proportional to received signal.
- This extended pulse was used to modulate the transmitter, also on a pre-set frequency, approximately the same as the receiver frequency.
- Signal transmitted through a λ/4 dipole

Block diagram



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Boulton Paul Defiant

- In 1942 Mandrel and Moonshine were fitted to a Special Duties Flight (later to be known as No. 515 Squadron) of Boulton Paul Defiant aircraft, under the control of 11 Group RAF Fighter Command.

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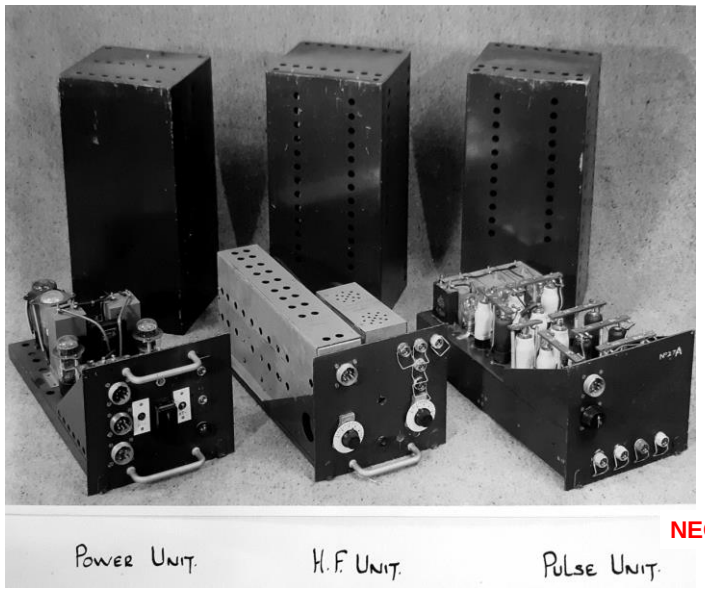
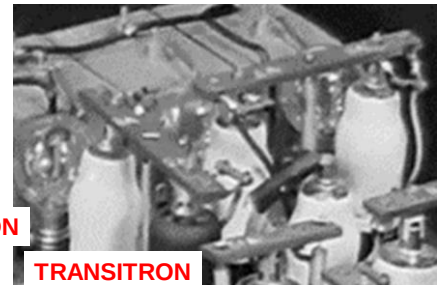
Moonshine boxes



[UK National Archives AVIA 26/287]

- Moonshine was built in 3 boxes, each 9 in × 8 in × 18 in, with a total weight of 74 lb (33.6 kg).
- Power consumption was 180 W from a 1500 c.p.s. generator



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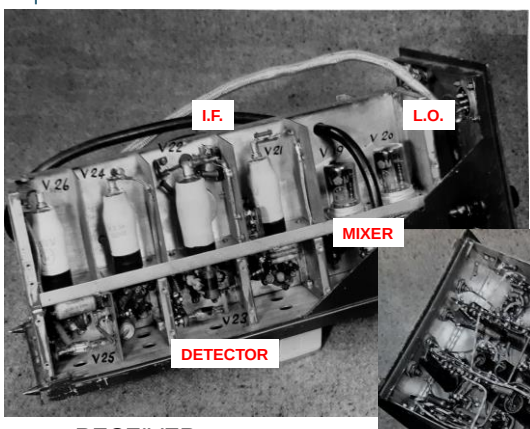
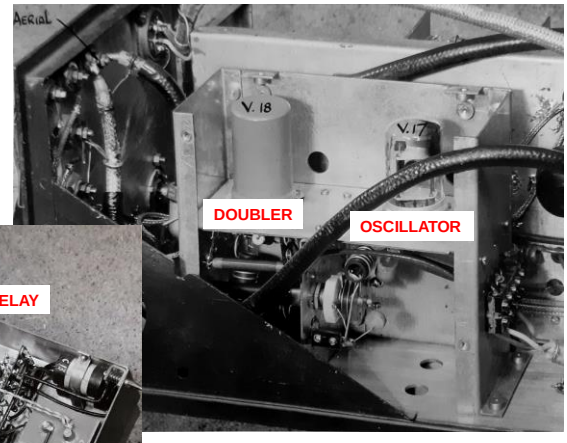
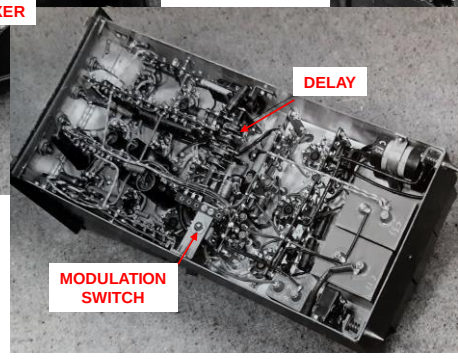
Hardware



RECEIVER



TRANSMITTER



PULSE UNIT

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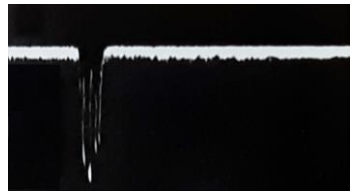
Moonshine response in radar

2 mile A

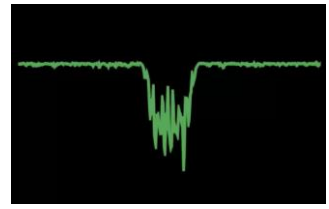


2 mile B

Real aircraft; ~30 spitfires in 5 mile raid.

5 mile A

5 mile B



Simulation

Visualisations of Moonshine responses of different range extent and modulation depth (A or B)

[UK National Archives AVIA 26/287]

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Operational success

- Moonshine was very successful in spoofing Freya during 1942.
  - Enemy fighter squadrons were scrambled to meet phantom threats, allowing real raids to proceed with reduced threat.
- To counter this jamming, the Germans increased the spread of Freya frequencies and further Würzburg-Riese were introduced.
- The equipment was refitted to Beaufigher aircraft but the requirement to jam Freyas in this way was no longer required after April 1943.
- Mandrel would continue to be important to protect bomber raids over Germany.
- Work was started on a 55 cm version of Moonshine in 1943, but this work was discontinued at that time. Some of the advanced ideas from this work would be taken up in 1944 in the US version of Moonshine.

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New operational requirements

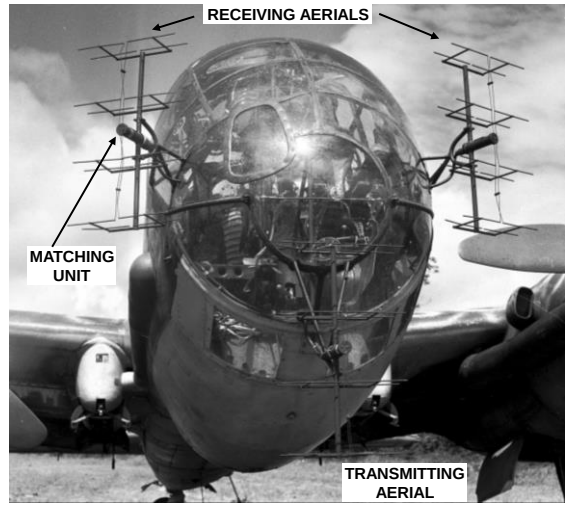
- To support of the deception activities leading up to Operation Overlord (D-Day) in 1944, it was determined that a naval jammer was needed to spoof enemy airborne maritime surveillance aircraft.
- Now the threat would usually be a single airborne radar, rather than multiple Freyas on different frequencies, so that the Moonshine equipment could be tuned by an operator to the required frequency.
- The aim was to create the impression of large numbers of ships crossing the English Channel.
  - Used simultaneously with aircraft dropping Window barriers to simulate a large moving ship convoys in ground-based radars.
- The same systems would be successfully used later in 1944 in support of Operation Dragoon, the allied invasion of southern France.

Naval Type 660 jammer

- The naval version of Moonshine was called the Type 660.
- The main threat was the FuG 200 Hohentwiel radar, fitted to German maritime reconnaissance aircraft, operating in the frequency band 540 – 590 MHz.
  - There was a subsidiary threat from the Lichstenstein S radar (75 – 85 MHz) and also a concern that the Germans may have been using captured British ASV Mk. II systems (176 MHz).
- The naval 55 cm version of Moonshine operated on a similar principle to the airborne system, but with operator control and no AVC memory circuit (due to problems of multipath fading of received and transmitted signals)

FuG 200 Hohentwiel

[World War Photos]



Ju 188 [MRATHS]

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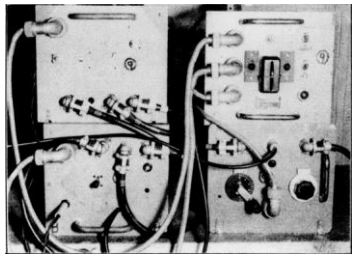
Harbour Defence Motor Launch



Type 660

- 540-590 MHz and 75-85 MHz systems were fitted Harbour Defence Motor Launches.
- Two antennas, one at either end of the boat, were used to reduce fading.
- US Army personnel were specially trained to operate the equipment.
  - Threat radars had to be identified by ear and Tx and Rx tuned to match them.
  - FuG 200 Hohenwiel had a 50 Hz PRF, which would have been distinctive, allowing discrimination against ground-based Würzburg etc.

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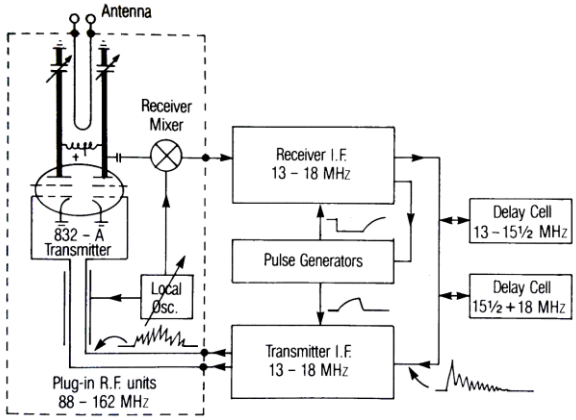
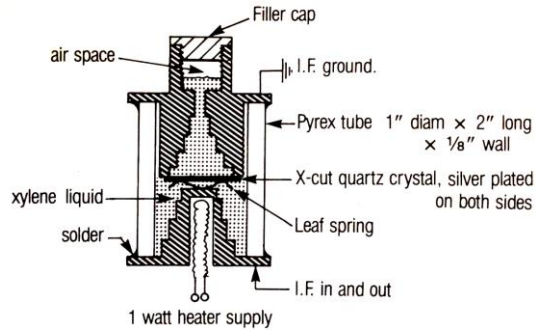
Further developments

- By the end of 1944, Moonshine equipment was stated to be available covering the following bands:
  - 540-590 Mc/s (TRE equipment)
  - 75-85 Mc/s (TRE equipment)
  - 88-168 Mc/s in three bands (USA equipment)
- The US equipment was AN/APQ-15, intended to protect against Japanese radars in the Pacific war.

AN/APQ-15

- The AN/APQ-15 was the first true repeater, with signals mixed down to IF, modulated in a crystal delay line, then mixed back to the original frequency for re-transmission





S. Dodington, "The Development of 'Moonshine' in the US in World War II", in *Radar Development to 1945*, R. Burns, Ed., Peter Peregrinus, London, 1988, pp. 410-415

- British Moonshine equipments were built in small numbers by TRE.
- First used in aircraft (ARI 5515) to confuse Freyas and later on naval vessels (Type 660) to confuse airborne maritime reconnaissance aircraft.
- Very effective when first used, resulting in changes to enemy equipment and tactics
  - Freya frequency range increased.
  - FuG 200 Hohentwiel introduced ability to rapidly tune to another frequency
- In response, work was underway at the end of the war to introduce panoramic jammer receivers, with motorised tuning.
  - Rapid identification of new signals and automatic tuning to match their frequency.
- Work had also started on methods to identify radars from their emissions.
- The work continues…