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Battle of the Beams

Dr Carlo Kopp

Pathfinder He-111H bombers of the elite KampfGruppe 100 wing were the first to deploy the Y-Geraet radio navigation aid to mark targets for other Luftwaffe bombers.

Knickebein transmitter ground station. Many were built along the coast of occupied Europe.

The modern term NavWar (Navigation Warfare), much like Electronic Warfare in general, is commonly perceived as a 'new' or 'modern' development, characteristic of recent times. Nothing could be further from the truth, as both have their origins during a period almost 70 years past, the German Blitz campaign of bombing raids against Britain in 1940.

After Germany's failed attempt to subdue Britain by daylight bombing of population centres, the German effort shifted to night bombing where underdeveloped airborne radar allowed for much lower sustained loss rates in bombers. As effective as the Spitfires and Hurricanes of Fighter Command may have been in daylight, the murky black was not their domain.

The principal impediment to night bombing, and indeed all blind bombing during this period, was the absence of airborne ground-mapping radar and mostly, precise navigational aids. The Luftwaffe, one of the great innovators of this period, sought to overcome this problem. The starting point was the introduction of the Lorenz blind landing system, termed the Ultrakurzwellen-Landefunkfeuer or LFF. The Lorenz system operated at 38 MHz and was used to permit an aircraft to align itself for a long final descent under blind conditions. A radio transmitter with three antennas was installed near the runway threshold, and these antennas would transmit a pair of overlapping beams. One was modulated with a series of dashes, one with a series of dots. The Luftwaffe equipped many of its bombers with Lorenz receivers. If the aircraft was aligned with the boresight of the beam the pilot would hear a steady tone in his headset, if he was left or right of the centre of the beam, he would hear either dots or dashes. The Lorenz system was a tremendous innovation for the period and ultimately led to modern Instrument Landing Systems (ILS).

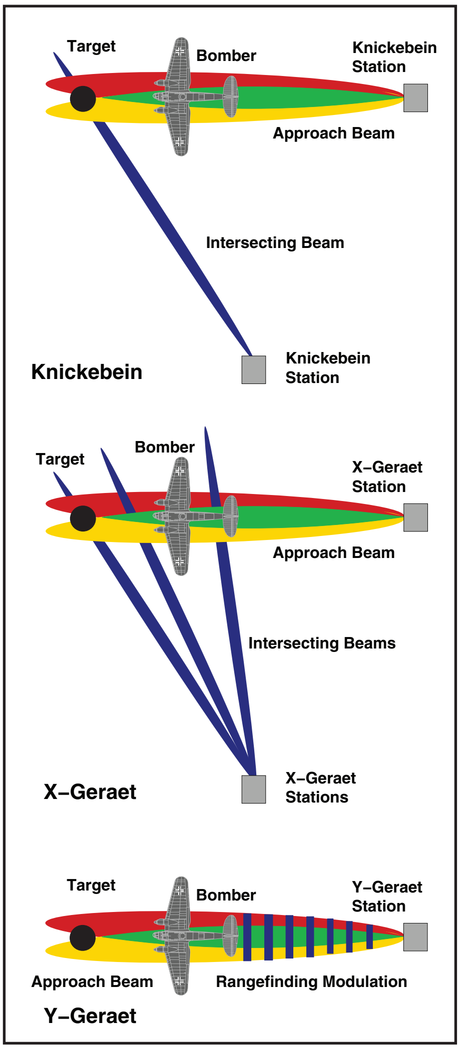
What the Lorenz system also offered was a navigation aid for blind bombing, exploiting the same suite of receivers in a bomber aircraft.

The Knickebein system, named after a magical raven in German mythology, was an enhanced Lorenz system using a much larger directional, steerable, antenna system built to produce a much narrower 0.3 degree wide beam over a much greater range. The Knickebein system pointed two beams at the target, the bomber would fly down the middle of the 'approach' beam, which was aligned to pass over the target, and drop once the intersecting beam was crossed.

Using already installed Lorentz landing receivers, the Knickebein was a covert installation. It was complemented by the more advanced Wotan I or X-Geraet (X-device), developed by Dr Hans Plendl, which used multiple Lorenz style transmitters to fix bomber position, operating between 66 and 75 MHz. The bomber would fly along the middle of the 'approach' beam, which was aligned to pass over the target, then cross multiple intersecting beams to alert the pilot to his distance from the target. The first of these was 50 kilometres from the target, and told the pilot to precisely align down the middle of the 'approach' beam. The second intersecting beam was at 20 km distance, and told the navigator to start a special clock with two independent hands, one of which started rotating at this point. The third beam intersected at 5 km from the target, and was used to start the second hand on the clock. When the two hands of the clock aligned, an automated bomb release was triggered electrically. The X-Geraet required precision flying and precision alignment of the beam transmitters, mounted on steerable turntables, but provided accuracy which was unheard of during that period.

KampfGruppe 100 was formed in late 1939, equipped with 25 specially equipped pathfinder He-111 bombers. After Dunkirk, the Luftwaffe constructed a series of Knickebein and X-Geraet stations in Holland and France.

The British were warned of Knickebein and X-Geraet as early as November 1939 when the 'Oslo report' a package of technical intelligence material produced by an anti-regime scientist in Germany, was received. By 1940, captured diaries, notes, bomber navigator logs and interrogation of shot down Luftwaffe crews confirmed the worst fears of Britain's technical intelligence community. The German blind bombing aids were real and effective.
To confirm what the Luftwaffe was up to, the RAF formed the first ever Electronic Intelligence (ELINT) unit, equipped with three obsolescent Avro Ansons fitted with suitable radio receivers. After numerous attempts to detect the Knickebein beams, success was achieved in June 1940 when a 400-500 metre wide beam was detected, exhibiting the expected modulation behaviour at 31.5 MHz.
Operation 'Headache' was subsequently launched to defeat the Knickbein system. The first defensive measure adopted was the installation of ground based noise jammers operating at the Knickbein frequencies. These were built from modified hospital electro-diathermy units used for cauterising wounds.
The second measure was the requisitioning of available Lorentz landing system transmitters, to be relocated as jammers for use against Knickebein. With low power levels these could interfere with the signal, but not enough to achieve the aim of 'bending' the beam to push the bombers off target.
Further effect was invested into ground based warning receivers, to establish which of the many Knickebein frequencies were being used on a given day. By July that year these were established at a number of coastal radar sites.
The centrepiece of the British Electronic Counter Measures (ECM) effort was however 'Aspirin', a high power transmitter which emulated the signals from the dot modulated lobe of the Knickebein. This had the effect of confusing German pilots, who even when centred in the Knickbein beam would hear the dots emanating from the Aspirin jammer.
Authoritative UK sources, such as Alfred Price, indicate that the British never progressed to the use of an in-phase deception repeater jammer to 'bend' the beams, despite this being a widely held belief today. What the British did achieve was large scale incoherent and unsynchronised jamming to interfere with the pilot's ability to use the beams.
Price argues, and reasonably so, that accidental 'beam bending' could have occurred many times, when the distances between a bomber, the aspirin jammer and the Knickebein site on the continent were such that the dots aligned in time when received by the bomber. Another possibility Price argues for is that there would have been times when the German pilots tuned to the Aspirin jammer rather than the weaker Knickebein signal from the continent. Price cites one anecdotal story told apparently by a captured Luftwaffe crewman of a bomber flying a full circle attempting to track the Aspirin signal.
By October 1940 the British had deployed fifteen Aspirin jammers to frustrate the Knickebein system. The stakes were high.
Estimates of the accuracy of the Knickebein suggested that it was capable of putting a 300 m x 300 m box around an intended target, which when saturated with bombs from a mere 40 aircraft would put the bombs down on average 17 metres apart.
By August 1940, the Luftwaffe had brought KG.100 into the fray, using the more advanced and accurate X-Geraet. Twenty He-111Hs bombed a Birmingham factory tooling up to build Spitfires at night, and eleven bombs hit the factory buildings, which was unprecedented accuracy for a night raid.
Code-named 'Ruffian' by the RAF, the system was detected at 74 MHz, producing similar modulations to the Knickebein. The mean error of the X-Geraet was determined to be of the order of 120 metres (cf GPS C/A at 30 metres worst case).
The British built the 'Bromide' jammer, using radar hardware, to defeat the X-Geraet system. While the Bromide equipment was being developed, KG.100 conducted no less than forty raids using X-Geraet. These raids were essentially an 'Opeval' to determine the limits of the system and to develop tactics. KG.100 started dropping incendiaries, a tactic to mark targets for a larger bomber force. This was the origin of the pathfinder technique later used by the RAF to obliterate German cities.



On the 6th November the RAF had an intelligence windfall when a KG.100 He-111 bomber force landed on a beach near Bridport. British deception jamming of a German beacon in France led the Heinkel off course to fuel exhaustion. Unfortunately, a clumsy attempt to salvage the Heinkel by the Royal Navy sunk the Heinkel in shallow water, but the British recovered the waterlogged X-Geraet receivers.
The devastating raid on Coventry was subsequently led by KG.100 using the X-Geraet, with an approach beam sent from Wese on the Cherbourg peninsula, and intersecting beams sent from a site in Calais. The first four Bromide jammers deployed by the British proved ineffective, as their modulation was not matched to the X-Geraet and was rejected by the filters in the KG.100 receivers. Once KG.100 'lit up' Coventry, over 400 bombers from other units converged to drop 450 tonnes of bombs on the city.
Analysis of the captured X-Geraet receivers allowed the British to modify the Bromide jammers and ensure newly built jammers were effective. By November 19 the KG.100 raid on Birmingham was ineffective, as Bromide worked. The RAF's problem was not having enough jammers to cover the whole of Britain. London, Southampton and Sheffield were attacked successfully.
By early 1941, the X-Geraet was losing effectiveness, along with Luftwaffe command confidence in the system.
The Luftwaffe was, however, deploying a third radio bombing aid also designed by Dr Plendl, named Wotan II or Y-Geraet. Y-Geraet used a similar but automated scheme for bomber heading tracking, but used a beacon transponder arrangement for measuring range between the Y-Geraet station and the bomber. Not unlike a 'back to front DME', the Y-Geraet station operators could track the bomber's position and send by radio course corrections to the pilot.
The Luftwaffe was less fortunate with Y-Geraet than with the previous two systems. The British requisitioned a mothballed experimental BBC television transmitter at Alexandra Palace in North London, and adapted it to rebroadcast the Y-Geraet rangefinding signal. Labelled the Domino, the Y-Geraet jammer was soon followed by a second installation at Beacon Hill near Salisbury.
The RAF was effectivley performing 'range gate stealing' jamming attacks on the Y-Geraet, to completely compromise the range measurement achieved by the Germans. The German ground station receiver would lock on to the Domino jammer instead of the Y-Geraet transponder on the bomber, and the British could then manipulate its range measurement.
The Domino jammer proved effective, and in the first two weeks of March 1941 only 20 per cent of Y-Geraet raids resulted in commanded bomb releases. Three Heinkels were shot down in early May and the RAF recovered the Y-Geraet receivers. They quickly determined that the automated mechanism for measuring the bearing error in the beam was susceptible to continuous wave jamming, which crippled the bearing analyser circuit.
Time had run out for the Luftwaffe, and with the buildup for Barbarossa, the invasion of the USSR, the KampfGruppes were redeployed east and the Battle of the Beams was won by the British.
The Battle of the Beams is generally acknowledged to have been the first modern effort at electronic warfare, and was characterised by the Luftwaffe not attempting to seriously improve the jam resistance of their systems, but rather by deploying newer and more advanced systems. It remains an excellent case study of how the game of technical intelligence gathering and analysis is played, and how pivotal it is to success in modern warfare.

Further Reading: Price A, Instruments of Darkness, Peninsula Publishing, 1987.