16. TACTICAL EMPLOYMENT OF ACTIVE COUNTERMEASURES

Electronic Jammers. At its best Carpet could conceal its aircraft up to a few miles of the jammed Wurzburg. But it was not always at its best. Early employment was of pretuned sets, and they often suffered a frequency change after takeoff. Expansion of the Wurzburg frequency range at that time would have made it necessary to carry five jammers in a bomber to ensure complete coverage, and there weren't that many Carpets. It required nice calculations, too, to know when to turn Carpet on, for the jamming was stronger than the plane's echo at outlying ranges, and when turned on before the radar could get an echo from the plane, simply gave the enemy an extra early warning. In figure 17, the top drawing shows aircraft moving in undetected under protection of Carpet jammers carried in the first two planes of the formation. The inset shows the effect on the Wurzburg radar scope. In the lower drawing the jammers were turned on too late and the first plane was beginning to show on the Wurzburg scope (first inset). In the second inset, the skilled radar operator had built up the blip by adjusting the gain.

Improved models of Carpet and improved techniques met the Wurzburg modifications. The AN/APT-5 had the same power as Carpet III, but could barrage or spot-jam up to 1,200 mc if frequencies got that high. And the AN/APT-4, with about 40 times the power output of Carpet I, could jam the Wurzburg down to one sixth the range obtained against Carpet I.

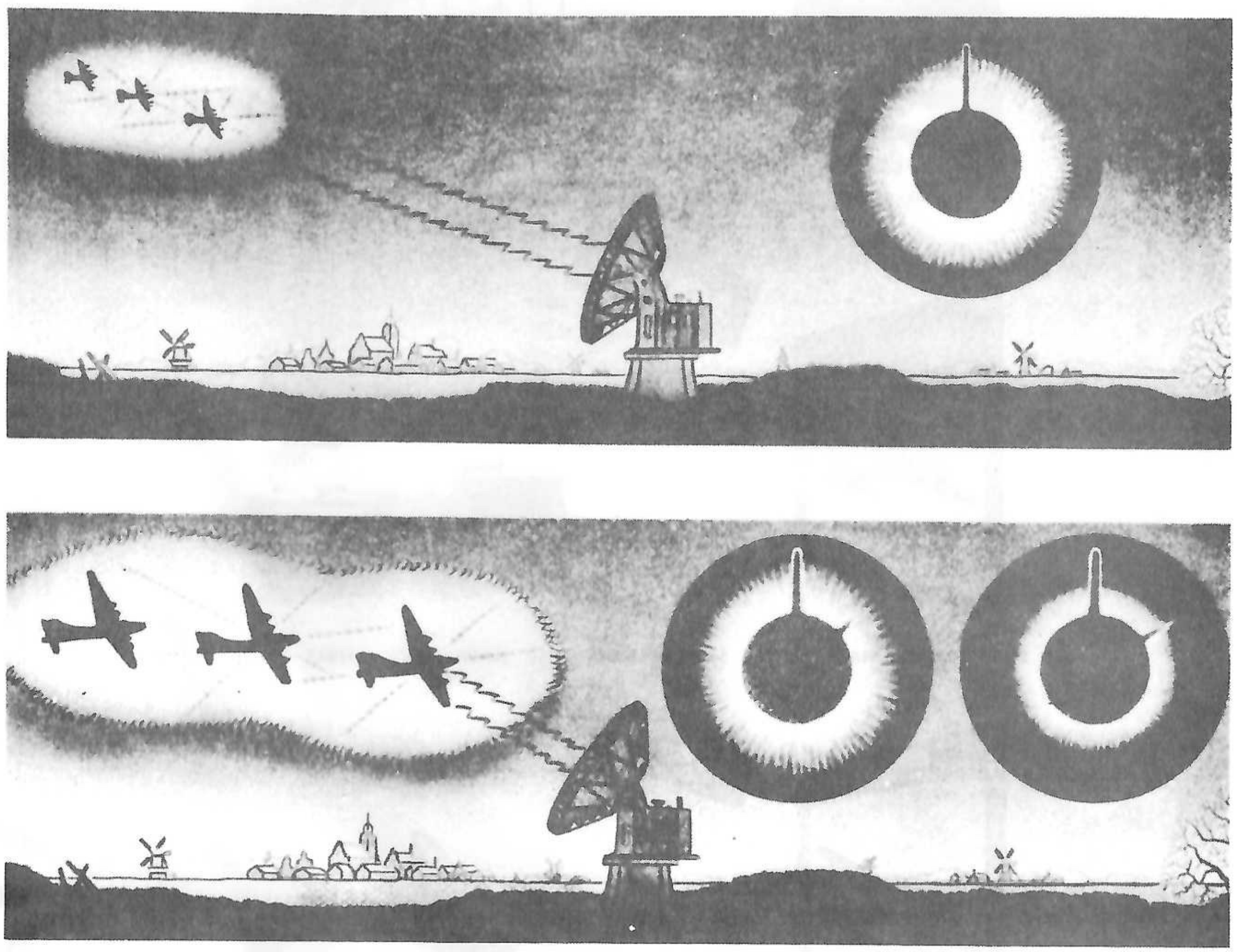


Figure 17. Tactical employment of Carpet jammer, World War II.

Instead of barrage jamming with transmitters pre-tuned, previously effective against the Wurzburg narrow frequency band, Allied planes now used spot-jamming with Carpets tuned in the air against exact Wurzburg signals as detected by an airborne radar search receiver known to operators as the "Blinker." This technique was described and illustrated (fig. 18) in Radar for November 1944:

> As barrage jamming is analogous to shooting with a shotgun, spot-jamming is like shooting with a rifle. The rifle is Carpet I and its sight the "Blinker" search receiver -- Wurzburg serves as the rabbit. The jamming procedure amounts first to detecting the GL [gun-laying] signal with the search receiver (sighting the rabbit), then tuning the jammer to that signal (drawing a bead and firing). If the Wurzburg changes frequency when the jamming starts (rabbit starts to run) the operator can follow with the receiver and still fire effectively.

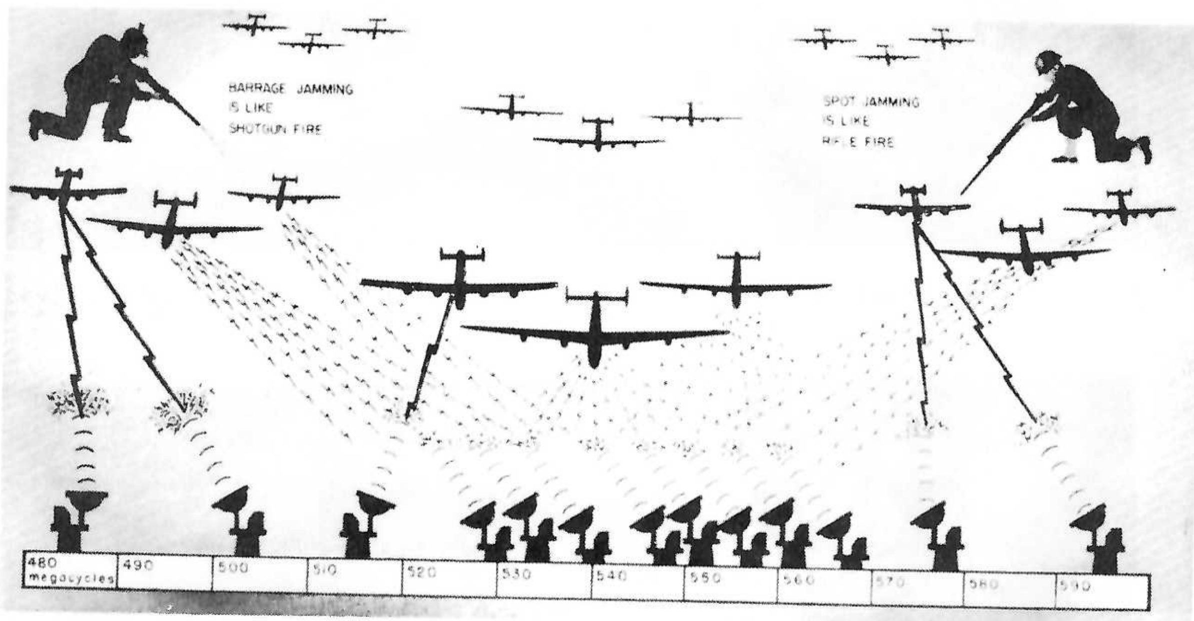


Figure 18. Barrage and spot-jamming, World War II.

Owing to shortage of equipment and trained operators, an all-out program of spot-jamming was not feasible, but a combination of barrage and spot-jamming with Window reduced flak losses sharply in one bomber group from two and a half percent to less than half of one percent.

Confusion Devices. Another field of employment came under the head of diversionary tactics. The Allies soon saw that Window, Chaff, Rope, and similar confusion devices were useful for "spoofing" as well as jamming. Electronic jammers also could be used, in a more limited way, to confuse the enemy. The mere appearance of jamming on radar scopes was an indication of some type of action. The trick was to mislead the enemy about where this action was going to occur.

The first known enemy use of Window for deception was at Bizerte, 6 September 1943 (fig. 19). Early warning radars reported 200 aircraft attacking, but Allied fighters could find nothing. Actually, less than 50 planes are believed to have participated. Flying in low to avoid early radar detection, they climbed sharply near the coast, released their Window (the Germans called it Dueppel) in one big cloud, and then changed course for the target. A well-trained operator could often see through Window and nullify such simple tactics, successful on this occasion because of the surprise.

Against early warning radar, Window could be used to confuse the enemy's alerting system and split fighter strength. A few planes might spread Window to simulate a large rendezvous, while the actual formation met elsewhere. Or, as in figure 20, a few planes might sow

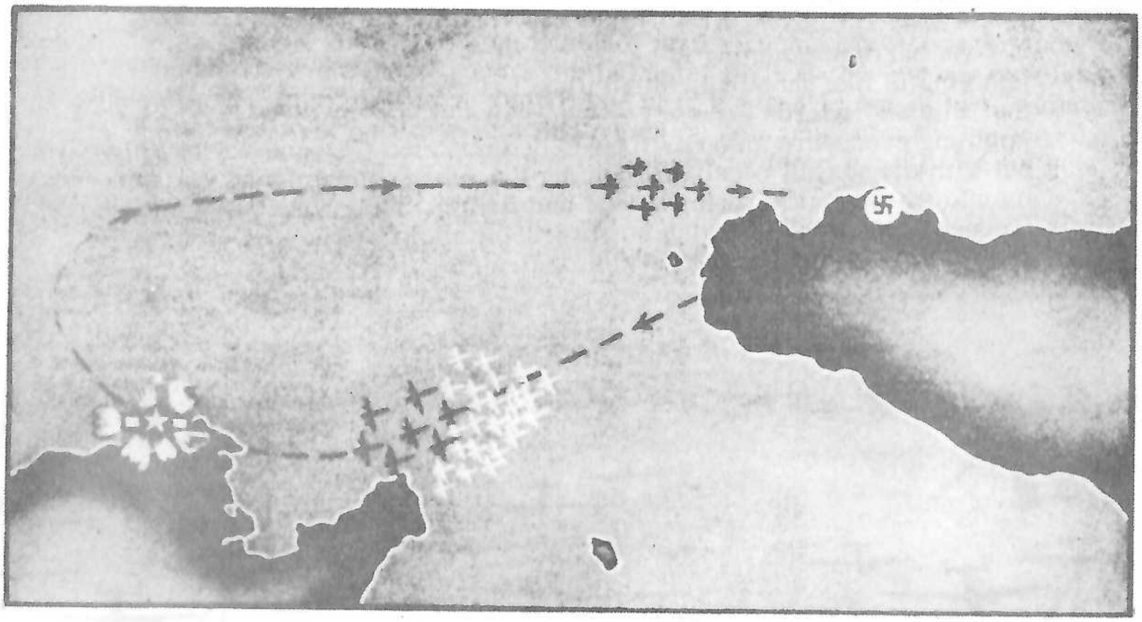


Figure 19. First known enemy use of Window for deception: Bizerte, 6 September 1943.

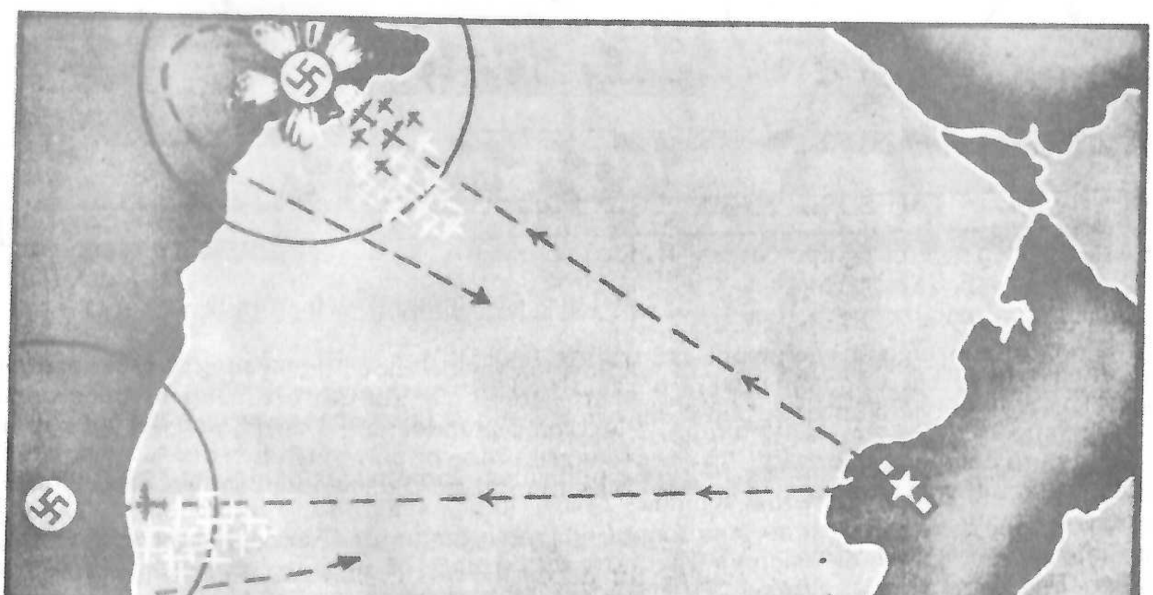


Figure 20. Window used to simulate diversionary raid.

a lane of Window along a possible route of attack to simulate a raid, while the main striking force was passing through another lane of Window to the actual target. The rings around the target indicate the range of the enemy radar. Both lanes would appear the same in enemy scopes, and it would be difficult to distinguish between two fake raids, a real raid and a diversion, or two real raids. Against the airborne radar of an enemy fighter, Window could be used to cover evasion tactics of an attacking or retreating force (fig. 21). Use of Window against GCI radars to cover an actual formation is shown in figure 22.

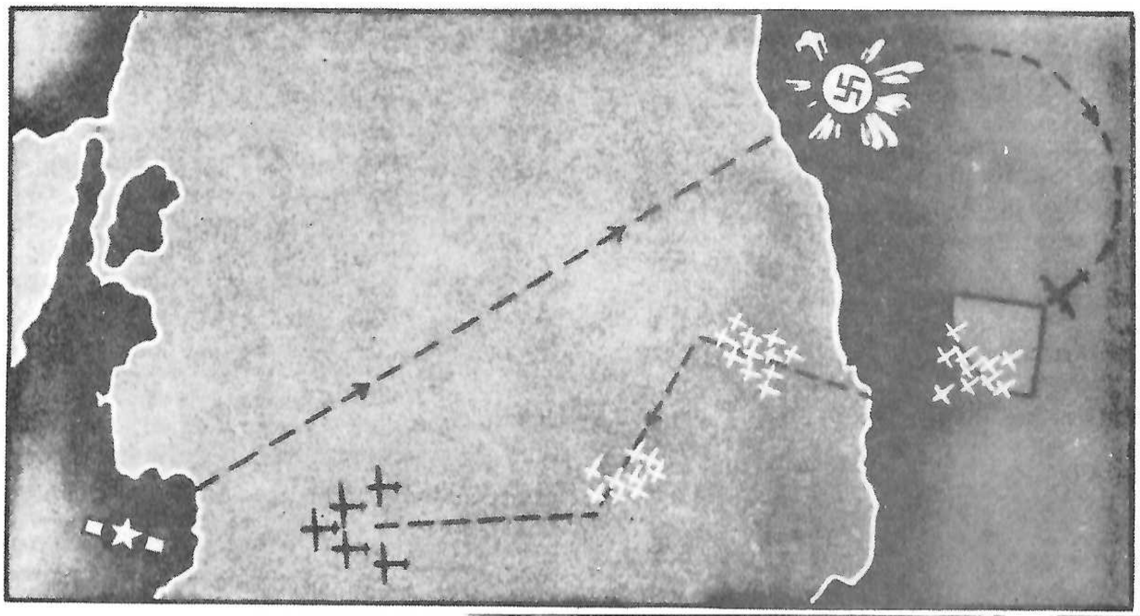


Figure 21. Window used to cover evasive action.

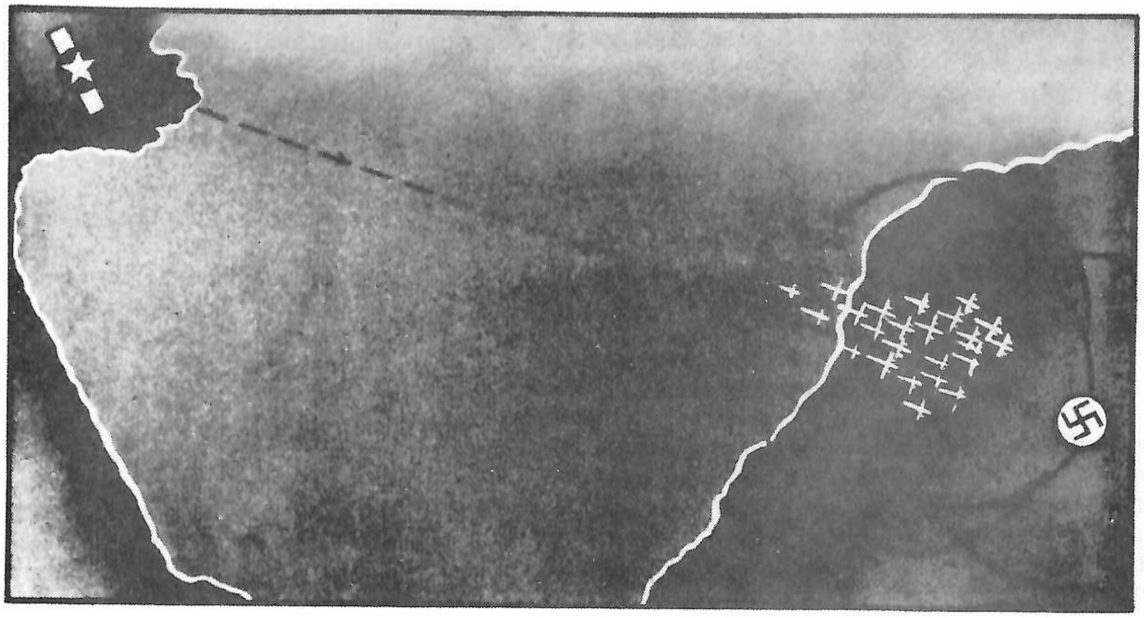


Figure 22. Window used against GCI to cover formation.

Some knowledge of the opposing radar and precise handling of the confusion device were necessary to successful employment of these ruses. Good training in detection could nullify, or at least minimize, such tactics. But the surprise effect was sometimes sensational. An intelligence report described the reaction of a German GCI officer to a flight over his area:

> The officer-in-charge was mad with rage and declared he would prefer to be bombed by 100 aircraft rather than submit to that flood of paper. He is supposed to have detected 700 machines without having been able to locate one.

17. FERRETS AND GROUND ECM UNITS

The United States was not slow to recognize the importance of training specialists in the new techniques and tactical employment of ECM. The Joint and Combined Chiefs of Staff had recommended four new types of units for ECM operations -- investigational, jamming, deception, and maintenance. Since it is necessary to know something about an enemy's radar capabilities in order to counter them, early emphasis in this country was placed on training and outfitting search units. Next in importance were units trained and equipped to jam the radars identified by the search units. The British had acquired their intelligence of German radars by any and all means -- underground channels, photo reconnaissance, commando raids, electronic intercept. In the United States, the Signal Corps and the Army Air Force collaborated in outfitting and operating search aircraft known as ferrets.

Early in 1943 two USAF lieutenants, fresh out of a new ECM course in radar school, undertook a passive countermeasures mission. Photo reconnaissance had revealed a probable Japanese radar installation on Kiska, in the Aleutians. Confirmation was needed, and so was information on how to knock it out. The two lieutenants were assigned to get the information. Theirs was our first ferret mission (fig. 21).

Ferret I was a B-24 with bomb bays rebuilt to house the latest investigational equipment. In a series of sorties with this aircraft, the two lieutenants found the signal and homed on it, logged the station's frequency, power, and pulse repetition frequency (PRF), provided data for checking its coverage, and were able to indicate how bombers could approach it with least risk of detection.

Shortly afterward the challenge offered by German radar in the Mediterranean was accepted by six more ECM lieutenants in three ferret-equipped bombers. Their mission was to locate and investigate all radars along the Mediterranean from Spain to Crete -- a tall order, for they found a radar installation on an average of every 30 miles.

Working in close cooperation with these Air Force ECM crews were Signal Corps ground units whose mission was also to detect radar signals and either jam them from the ground or provide the necessary airborne countermeasures equipment. The First Signal Service Platoon (Special) was organized and equipped to jam the Japanese radars on Kiska during the invasion of the island, but sudden Japanese withdrawal robbed the platoon of its target. In the Mediterranean, however, this same unit, working with a British ECM team, supported the ferret aircraft by active as well as passive countermeasures. Based on a mountain top in Corsica, they spotted and analyzed radar beams emanating from the coasts of southern France and northern Italy, and helped guide Allied aircraft sent to bomb out the coastal installations. In addition to radar search sets and radio direction finders, the unit was equipped with Mandrel and Dina jammers which were put to good use neutralizing the remaining enemy radars during the invasion of southern France. A signal service battalion, the 3103d, rendered similar service during the Normandy invasion. In the Pacific, two specially equipped and trained ECM units, the 3153d Signal Service Company and the 3144th Signal Service Platoon, supported combat operations.

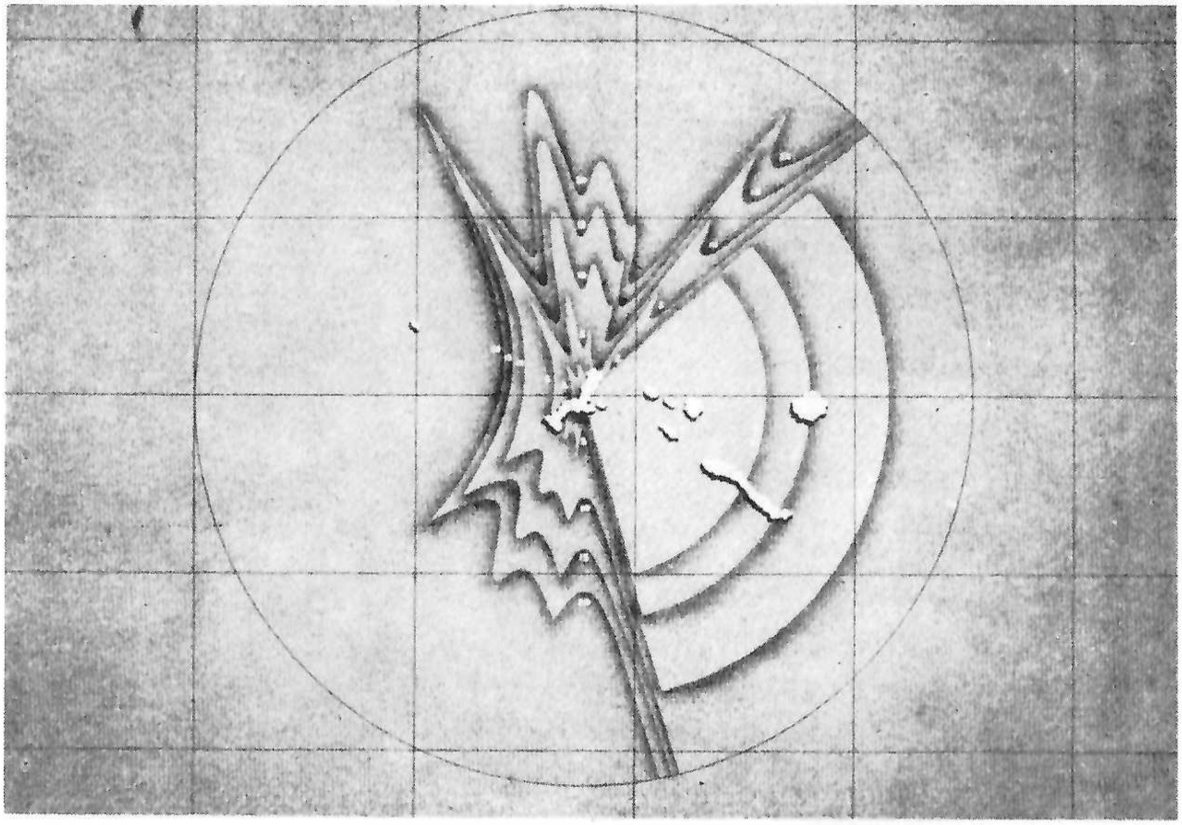


Figure 23. First ferret mission: Kiska.

The success of early ferret operations started a new trend in passive countermeasures. Trained ECM officers planned the missions, operated the special equipment, and were responsible for tactics, maintenance, intelligence, and interpretation. From information gained in flight, the ECM officers constructed shadow maps for use in laying out paths of approach to circumvent enemy radar coverage and in devising specific countermeasures.

The men selected for these hazardous and highly responsible missions were intensively trained. Graduates of communications schools, most of them had taken a six-month course in radar fundamentals and electronics at Harvard or MIT, followed by practical radar training with airborne radar equipment, and a four-week course in ECM.

In addition to flying ferret missions, ECM officers frequently modified or built equipment, developed antennas, tested captured equipment, and made new installations. Their aircraft, equipped by the Signal Corps, bristled with antennas and were the most crowded of aircraft. In 1944 a B-24 might carry 20 antennas. Its equipment could provide data on locations, frequencies, and ranges of radar and cw stations, and on signal power, pulse widths, and VHF frequencies. In addition to navigating and standard radar equipment, it might carry, in a special ECM room in the rear bomb bay, a panoramascope with an S-27 receiver, an S-28 receiver and audio oscillator, a pulse analyzer, an AN/APR-4 receiver, and an AN/APR-2 autosearch receiver. ECM equipment on a B-17 might include audio oscillators, oscilloscopes, AN/APR-4 receivers, Mandrel jammers, Carpet jammers used to force Wurzburgs to change channels so the alternate channels could be detected, and a tape recorder for received audio signals. But changes were frequent, since theater requirements gave varying emphasis to various equipment combinations. One piece of equipment designed by the Signal Corps specially for ferret operations was much in demand by the close of 1943. This was the AN/APA-17, a radar direction finder which covered the frequency band from 25 to 1,000 mc.

In the South Pacific, early in 1944, Ferrets 7 and 8 patrolled from Australia to Borneo, detecting radar targets for American bombers, and supporting naval operations against Japanese shipping. Because of the vast distances involved, the first ferret missions against the Japanese mainland in mid-1944 were accomplished aboard B-29 strike aircraft on routine bombing missions. One of these aircraft carried close to a ton of radio and radar equipment (fig. 24) leaving the crew hardly enough room to draw a deep breath, and its antenna array

Figure 24a. Electronic equipment for early ferret aircraft. Not shown are power supplies, cabling, control boxes, and numerous other parts.

created as much resistance as a strong headwind. An ECM observer, equipped with an AN/APR-4 search receiver and an APA-11 pulse analyzer, would catalog the enemy frequency spectrum and pinpoint the radars as the B-29's headed for the target. By the end of the year the Japanese early warning net across North China and Japan had been plotted in this manner bit by bit. The results revealed that the Japanese had radar of only low usefulness compared to German installations. There were no confirmed intercepts above 220 megacycles.

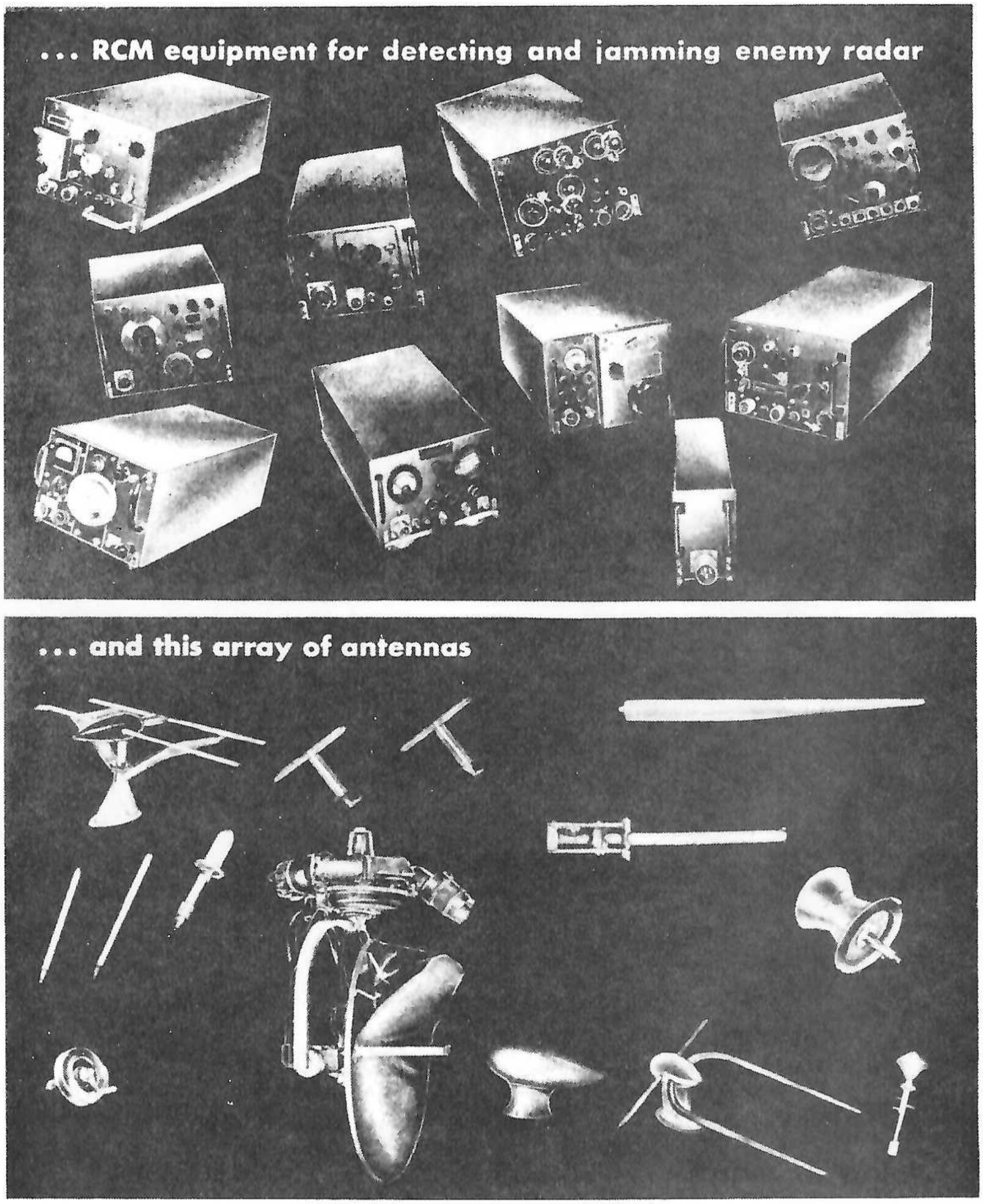


Figure 24b. Most ferret aircraft carried at least four of the RCM (radar counter-measures) equipment, plus all the other equipment shown on these two pages.

This kind of search activity went on into 1945 from bases in China and the Marianas, but when the distances narrowed five specially equipped B-24 Ferrets were crash-built for use against the mainland of Japan. Fitted with all the latest ECM equipment, and designed for comparative comfort, the new Ferret had an insulated ECM room five and a half feet by eight and a half feet that boasted such luxuries as dull green walls, posture-type chairs, eye-level dials, gasoline and electric heaters, electric fan, electrically heated suits, and felt-based rubber matting. The cutaway drawing (fig. 25) shows electronic installations.

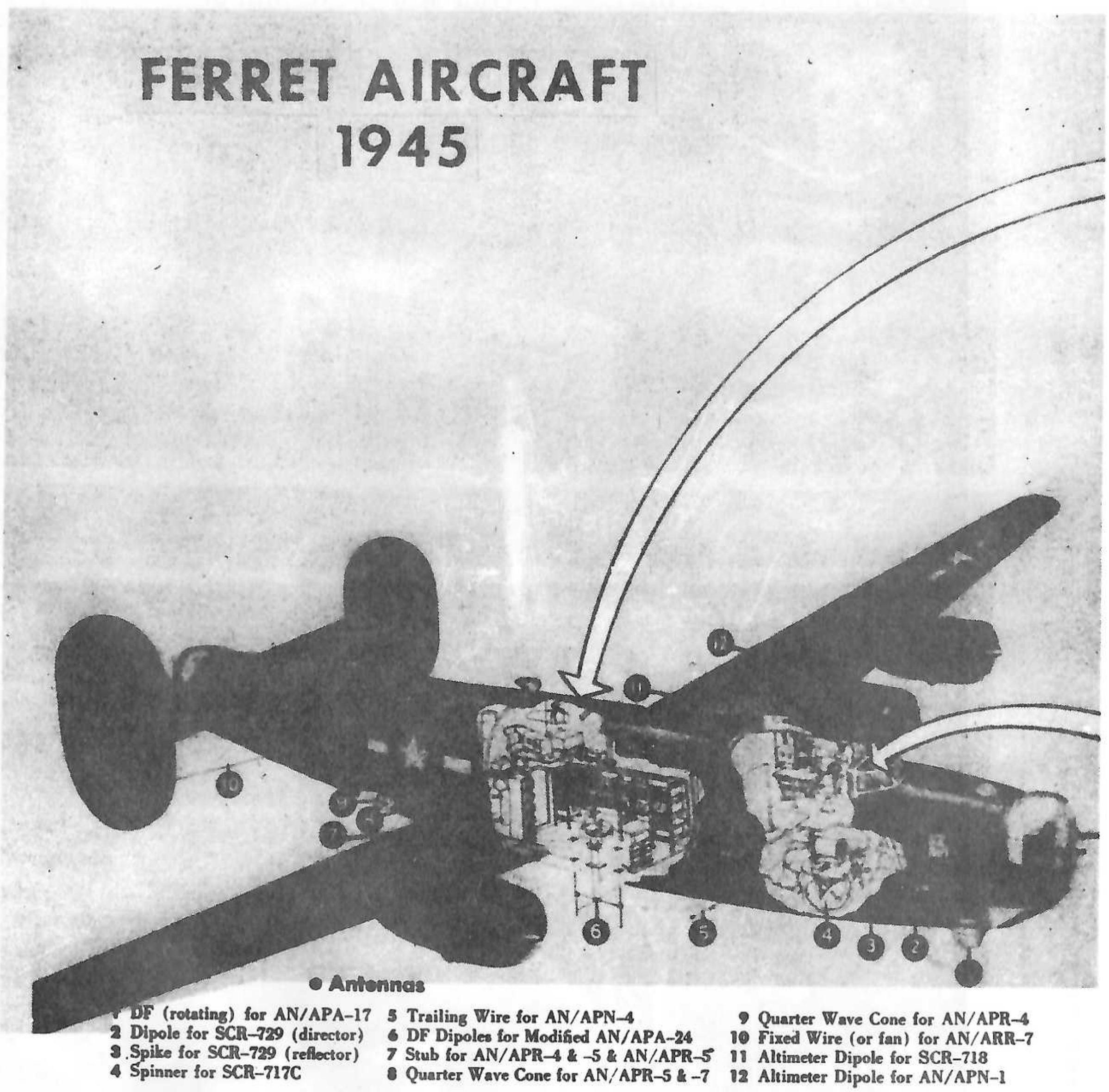
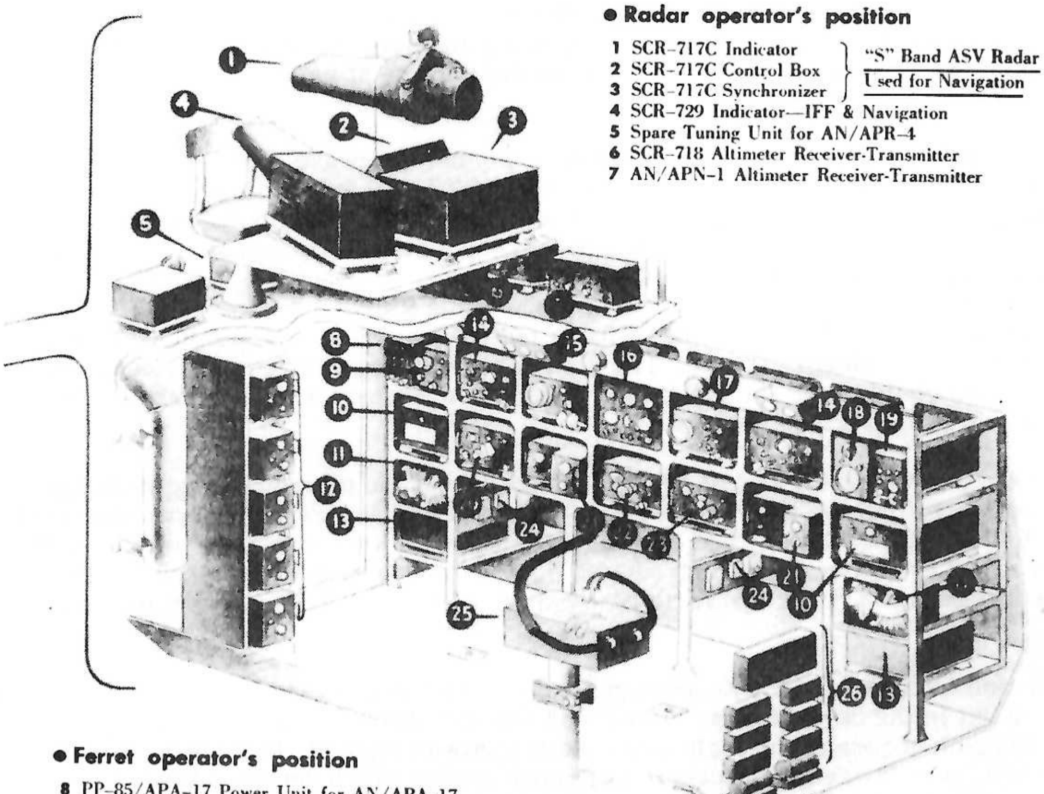


Figure 25. Ferret aircraft, World War II, showing electronic installations.

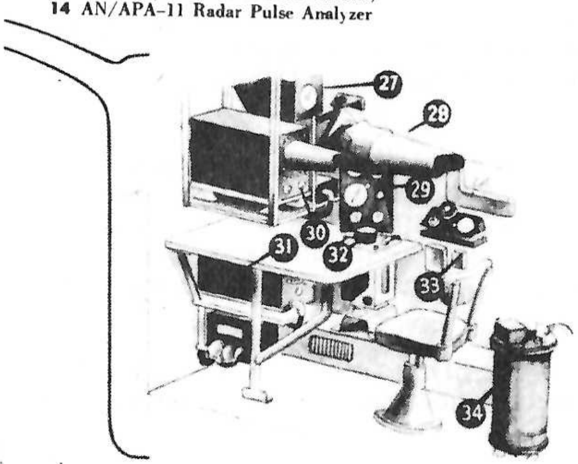


• Radar operator's position

1 SCR-717C Indicator
2 SCR-717C Control Box
3 SCR-717C Synchronizer } "S" Band ASV Radar Used for Navigation
4 SCR-729 Indicator—IFF & Navigation
5 Spare Tuning Unit for AN/APR-4
6 SCR-718 Altimeter Receiver-Transmitter
7 AN/APN-1 Altimeter Receiver-Transmitter

• Ferret operator's position

8 PP-85/APA-17 Power Unit for AN/APA-17
9 AN/APR-7 Radar Search Receiver—1000 to 3000 Mc.
10 AN/APA-23 Tape Recorder (u/w Search Receivers)
11 Antenna Switching Assembly SA-23/AR
12 Spare Tuning Units for AN/APR-4
13 AN/ANQ-1 Wire Recorder (Audio)
14 AN/APA-11 Radar Pulse Analyzer
15 AN/APA-17 Indicator—Radar DF 25 to 1000 Mc.
16 Instrument & Switch Panel
17 AN/APA-10 Panoramic Adaptor
18 AN/APA-24 (Mod.) Indicator Radar DF
19 PP-32/AR Power Unit (u/w Search Receiver)
20 AN/APR-5 Radar Search Receiver 1000 to 6000 Mc.
21 AN/APR-4 Radar Search Receiver 400 to 4000 Mc.
22 AN/ARR-7 Radio Search Receiver 550 Kc to 28 Mc.
23 AN/ARR-5 Radio Search Receiver 28 to 143 Mc.
24 Interphone Jack Boxes
25 AN/APA-24 (Mod.) DF Radar 85 to 450 Mc.
26 Special Interphone Amplifiers



• Navigator's position

27 Fluxgate Compass Indicator
28 SCR-717C Indicator
29 Instrument Panel
30 AN/APN-4 Indicator
31 AN/APN-4 Receiver } Precision Navigation
32 SCR-718 Altimeter Indicator
33 Interphone Jack Boxes
34 SCR-717C Radio Frequency Unit

Figure 25 (contd). Ferret aircraft, World War II, showing electronic installations.

18. ANTI-SUBMARINE WARFARE

While the Allies, on the offensive in the air, were devising countermeasures to neutralize German defensive radar, the situation at sea was just the opposite. With a fleet of nearly 700 U-boats and an average daily toll of 16,000 tons of shipping sunk, the Germans in 1942 were striking their heaviest blows at Allied capability to wage war. Concurrently the Allies were defending their vital shipping of men and materiel as best they could by radar-equipped aircraft and ships, and the Germans were devising countermeasures.

At the start of the U-boat menace in 1939 the only British defense consisted of convoy escorts and short-range planes. Installed in a few of the aircraft were some handmade, near-sighted, longwave, air-to-surface-vehicle (ASV) radar sets called the Mark I. Aboard the convoy ships was a non-radar device called Asdic for spotting submerged submarines. Neither was effective against the German tactic of attacking on the surface at night and escaping without submerging under cover of darkness.

Late in 1940 the British tried a surprise weapon -- another longwave, short-range radar, the Mark II, known in the United States as SCR-521. At 1,500-3,000 feet altitude, the Mark II could detect surfaced submarines at 8 miles. These sets were installed in both ships and aircraft. They met with moderate success, driving the U-boats from the British shores and out to sea, where short-range planes could not follow.

The Germans now initiated their famous wolfpack tactic, pouncing on whole British convoys loaded with lend-lease in the North Atlantic. The British scraped together a squadron of long-range Liberators which could range far out on patrol, and armed them with the Mark II, but the best defense was still by surface vessels.

When we entered the war at the end of 1941 the character of the unequal struggle changed. The U-boats turned their attention to American coastwise routes. At first our ships, unarmed and unescorted, died like flies. In May and June of 1942, U-boats sank over 200 vessels in the U. S. Atlantic strategic area alone. But then came a series of countermeasures and counter-countermeasures that seesawed back and forth between the opposing forces, slowly working to Allied advantage.

In June the British introduced a 5,000,000-candlepower searchlight designed to keep U-boats from surfacing at night in the Bay of Biscay. Used with the ASV Mark II, these searchlights made it possible to bomb accurately at night after the target was sighted. In August the U-boats countered with Metox, a radar search receiver of French design which detected Mark II longwave pulses in time for the U-boat to submerge. But the Allies had not been idle. A USAF unit known as the Sea-Search Attack Development Unit (SADU) had been activated in June. It was equipped initially with eleven B-18's, in which were installed microwave radars (SCR-517). It also had two British-loaned B-24's fitted with early British microwave sets known as DMS-1000 and with the first airborne plan-position indicators. SADU's primary mission was to develop microwave tactics and techniques, but it also flew emergency missions. In its first month of life, under the operational control of the Navy, it sank and damaged four U-boats, and made 18 sightings.

With the Mark II now neutralized, and the Germans as yet unable to detect the new microwave radar, 14 new DMS-1000's were crash-built at a U. S. Laboratory and rushed into British service. By the end of 1942 other microwave sets, the AN/APS-2, the SCR-717, and the British Mark III, were coming to the rescue. By March 1943, more than 50 percent of the aircraft assigned to the first U. S. Antisubmarine Army Air Command were equipped with radar, many of them microwave.

Meanwhile the U-boats had virtually deserted the West Atlantic and were moving east. In March the death struggle began with the heaviest wolfpack attacks and prodigious sinkings. But the better-equipped Allies, with aircraft-radar teams and support groups, including escort carriers, struck back so vigorously that the U-boats were largely driven from the North Atlantic. In May and June alone nearly 100 U-boats perished.

The survivors stole back to their bases and were fitted with an improved search receiver, the Naxos, and then were afraid to use it for fear of revealing their position. They tried radar decoys -- a balloon and a buoy -- with varying success. They gained a temporary advantage, late in 1943, by using the Schnorkel, an airvent that permitted the U-boat to remain submerged while its batteries were charging. But improved Allied devices followed in quick succession, and the U-boats threat subsided. In August 1944, the Allies were able to report a total of more than 500 U-boats sunk.

It was said that just before the Germans surrended, one of their foremost scientists was developing an improved anti-radar material for Schnorkel -- a very wide-band wave-absorbent material to cover the spectrum from about 100 to 15,000 mc. The scientist applied for a patent on this material but was told he would have to wait until Germany won the war.

19. D-DAY SUPPORT AND DIVERSIONARY TACTICS

By D-Day much more sophisticated diversionary tactics were ready for use. These have been described in numerous historical studies of World War II, and are discussed in more detail under the heading, "Cover and Deception," elsewhere in this series of information sheets. Here we are concerned principally with the active ECM and electronic deception used to screen the Allied landings in Normandy and southern France.

About two months before D-Day, in a propaganda broadcast to England, the Nazis bragged about their defenses. They had several cumbersome names for radar, but in this broadcast they used the name of an instrument for sounding water depths. "Echolot" came from "echo" and "lot" (a plumb or measuring device).

> Anglo-American attempts to destroy the effectiveness of the German electric pylons /they announced/ have failed completely. Pylons function according to the echolot process... night fighters employ the same methods. In fact, the whole of Germany is enveloped by a close network of echolots so that each single enemy machine, let alone formation, is under constant observation. By these means German defenses can operate with extreme rapidity and effectiveness.

How did it happen, then, that on 6 June 1944 some 6,000 Allied ships began landing troops on the Normandy coast before the Germans even knew they were there?

The Allies were well aware that, on D-Day minus 2, the coast of northern France presented a solid radar front, with major German stations every 10 miles. Allied photo-intelligence and search operations had detected, between Brest and Calais, 6 Chimneys and 6 Hoardings for long-range early warning; 38 Freyas for medium-range early warning and night fighter control; 42 Giant Wurzburgs for night fighter control, coast gun control, and use against low-flying aircraft; 17 Coastwatchers; and one Small Wurzburg for each flak battery.

The actual count was probably much higher. In his book, Triumph and Tragedy, Winston Churchill estimated that there were at least 120 major German radars in 47 stations along the 250-mile coastline from Guernsey to Calais.

Figure 26 shows the main pattern of coastal and inner radar lines, approximate locations of major installations forming the pattern, the outward range of the coastal system, and the full coverage of the inner system, as known to the Allies two or three months before D-Day. The map is not intended to show every German radar station.

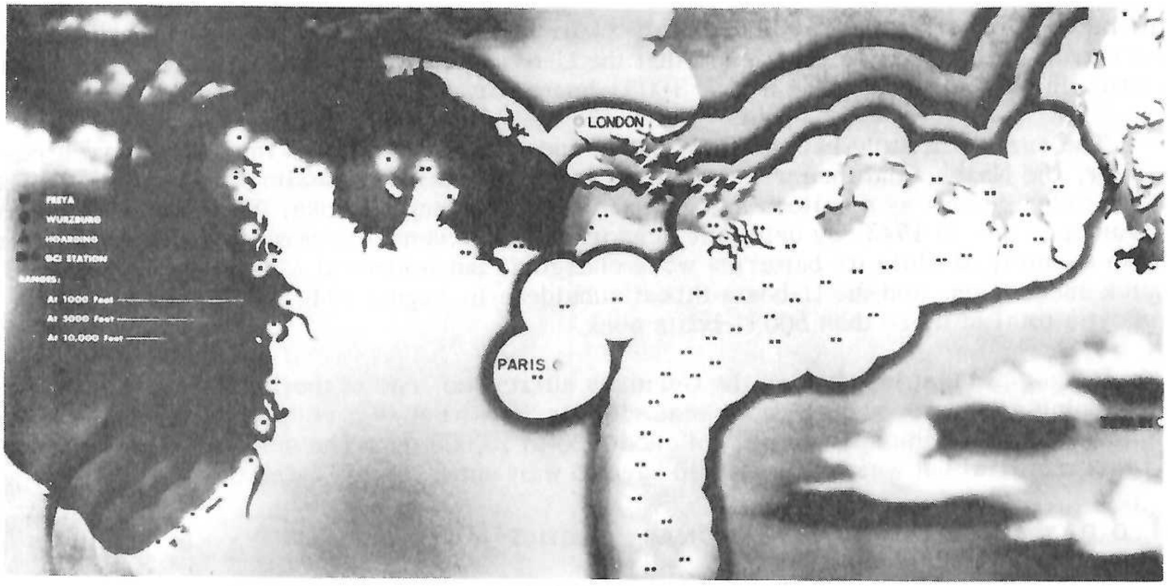


Figure 26. German radar defense system: Spring, 1944.

In the last analysis, a bomb is the best countermeasure. This, at least, was the Allies' opening gambit against the German radar defenses. On D-Day minus 1 the coastal system had been reduced, by a blistering attack with bombs, rockets, and machine guns, by 82 percent. According to a subsequent report, only one site remained operational within gun range of incoming invasion ships and its reports were ignored because uncorroborated. In all, more than 190 installations were knocked out, including the system of jamming stations which the Germans had augmented after the successful escape of the Scharnhorst and Gniesenau.

It was the job of ECM to take care of what was left of the inner defenses and to confuse the enemy as to the exact area of the projected landings. On the night preceding D-Day, U. S. Air Corps squadrons fitted with Mandrel (anti-Freya) jammers, patrolled for five hours at 18,000 feet above the south coast of England, screening the concentration and approach of airborne forces to the French coast (fig. 27). Meanwhile, British aircraft carried jammers and dropped Window and dummy parachutists inland from the Dover-Calais area, confirming the Germans in their opinion that this would be the site of the main landings, and diverting most of the German fighter aircraft to that area. At widely separated points, small craft approached the French coast carrying reflectors and towing aluminum-painted balloons to create radar echoes like those of major warships, and Window was dropped over them to simulate large convoys. Other diversionary raids by only a few ECM-equipped aircraft simulating a large-scale airborne invasion succeeded in drawing off numerous German fighters east of Cap d'Antifer, just above Le Havre, while the real threat existed west of the Cap. Many fighters that were initially deployed well back of the invasion area remained in ignorance of the area of attack because the American communications jammer Air Cigar effectively jammed their radios.

The invasion fleet, equipped with 600 items of ECM equipment for use against gun-control radar, succeeded in approaching well within radar range before German coastal shelling began.

This large scale jamming of German radio and radar by both U. S. and British forces in a relatively small area was coordinated by a combined countermeasures advisory staff. An operational ECM staff also functioned before and on D-Day to make immediate decisions on and changes in the ECM equipment when necessary.

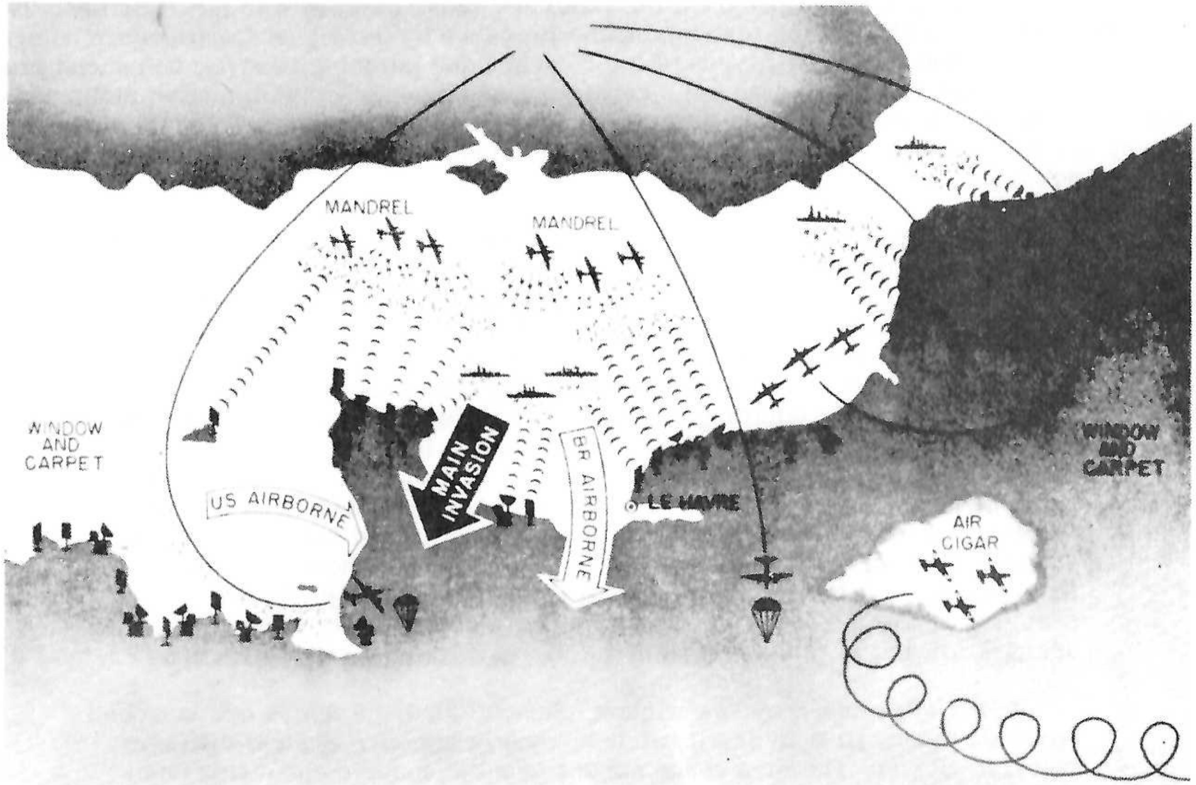


Figure 27. Allied ECM pattern for the Normandy invasion.

In southern France, the Allied invasion force made use of even more complicated diversionary tactics, and more U. S. ships carried ECM equipment. A successful naval feint toward the Toulon area was supported by an abundance of balloon reflectors, rocket-borne Window, and jamming equipment. Minelayers and even PT boats carried jamming transmitters.

A second diversionary force, consisting of a few British gunboats carrying balloon-supported reflectors and jamming transmitters, simulated a large convoy approaching the region of Monaco. Although a fairly obvious fake, this action succeeded, as planned, in gaining a tactical advantage for the Allies.

The main assault forces were supported by an airborne Mandrel screen similar to the one used in Normandy. Ships also carried Carpets and Rugs to jam Coastwatchers, Freyas, and Wurzburgs. Listening posts reported that five out of six Coastwatchers went off the air, and the rest were neutralized.

20. COMBAT TRAINING

ECCM. In the summer of 1944, numerous radar sets guarding a control area extending hundreds of miles seaward from our east coast were reported jammed to saturation. This scare gave place to embarrassment when investigators discovered that it wasn't jamming at all, but interference among our radar sites. The radar operators had neither recognized the symptoms nor made corrections. The investigator's report included a recommendation for anti-jamming training on operational sites, specifically "visits of demonstration crews equipped with training devices to simulate jamming or, if possible, actually to jam certain stations so that operating crews may gain experience in anti-jamming techniques."

Late the previous fall, officers of the Technical Liaison Division, OCSigO, had initiated such an anti-jamming training program for radio and radar operators in Great Britian. The courses, complete with training texts and films prepared by the Signal Corps, were designed to improve operation through all types of interference and jamming likely to be encountered under combat conditions. A mobile unit, consisting of a van packed with motion picture projectors, audio equipment, and code practice equipment, travelled about Great Britian establishing several unit schools and demonstrating the latest enemy jamming to about 2,000 operators a month.

In 1944, a similar U. S. training unit popularly known as the Anti-Jamming Medicine Show toured all the way from Brisbane to the north coast of New Guinea, meeting with rapt response from radar operators of all services. The unit consisted of a weatherbeaten aircraft commanded by a Navy lieutenant with two Air Force lieutenants and an Australian crew. The aircraft was fitted with one Dina and two Mandrel jammers, a Navy practice jammer called the CXCD, an Australian-built practice jammer covering 150 to 250 mc, two ARC-1 Navy intercept receivers, one portable jamming simulator for lecture purposes, and several varieties of Window. A contemporary account of the demonstration follows:

> The next morning the Hudson took off on its first demonstration flight, while on the ground the radar operators huddled around several SCR-268-A scopes. This was electronic jamming. During the two-hour demonstration they sweated and fumed, trying to track through the noise. At first the job seemed impossible, but by the time the run was over they were catching on, seeing through the grass and railings.
>
> In the afternoon they saw window. Several kinds of chaff were launched from the plane, first in small batches, then in big ones to show different tracking effects. The men at the scopes found themselves profiting from their noise-jamming baptism. The window symptoms were different, but the general idea was the same. They did tracking that afternoon that would have sent them yelling for the maintenance man 24 hours earlier.

One valuable by-product resulted from the Medicine Show demonstrations: they detected faulty radar setups and showed commanders the importance of improvements. In New Guinea, for example, six SCR-248's were pitted against the Medicine Show, but they didn't have a chance. They were bunched within a six-mile radius, and all were operating within plus or minus 1/2 megacycle of the same frequency. The vulnerability to jamming of this geographical and frequency deployment had previously been brought to official attention. But it was not until ranking officers of the command, invited to attend the electronic jamming demonstration, saw all six of their radars knocked out by one Dina transmitter, that serious attention was given to changes in siting and frequency assignment.

ECM. Training in active and passive ECM was tied in with combat preparations in all theaters. During 1944, with their perimeter contracted, the Germans had a picket fence of gun-laying radar and heavy AA batteries defending the heart of the Reich. Allied countermeasures had to be tailored to fit, and many new techniques and expedients were field tested against a similarly defended target, the Ploesti oil fields. Intensive electronic warfare preceded and accompanied the raids on this strategically important target. Days were spent log-checking, flying ferret missions to pinpoint German radar installations and detect their operating frequencies, and making maps of all target areas to show gun-laying and AA installations. Training kept pace.

At Gioia, in southern Italy, the 1044th Signal Battalion set up a school popularly known as the Radar City Music Hall, where all incoming officers and men were trained in the use of electronic countermeasures. Operators learned to locate German signals on the "Blinker" and to jam on the proper frequency. It was hard to distinguish on the earphones between the high pitch of the small gun-laying Wurzburgs (3,750 cycles per second) on which jamming was concentrated, and the low pitch of the giant GCI Wurzburgs (1,875 cycles per second). The Germans did not make it easier. Jammed on one frequency, they would shift two or three megacycles. Or they would camouflage the GL Wurzburg by putting it near the frequency of the GCI Wurzburg. Operators were trained to expect these dodges.

Lacking enough Carpets to protect pathfinding aircraft, the ECM people developed the chaff bomb, which consisted of a flare-case packed with chaff. Cordite was detonated by a mechanically timed flare fuze to expel the chaff at 25,000 feet. P-38's, flying at 30,000 feet, preceded the lead groups and dropped the bombs at nicely calculated 8,000-foot intervals. This vertical screening was not as complete as horizontal screening, but it caused confusion on Wurzburg scopes.

The real need, of course, was for more Carpets. After the capitulation of Ploesti, a Rumanian officer told an Allied ECM delegation that many Carpet missions had completely jammed his Wurzburg at all GL control distances.

As the Allies advanced, other ECM delegations moved in to investigate captured radar installations and report on German developments. In November 1944 a new narrow-beam radar, making use of the first German-made PPI scope, was discovered partially installed in Belgium. This type of technical intelligence gave the Allies a vital advantage in devising new countermeasures and training operators in their use. So the Wizard War went on.

21. PROXIMITY FUZES

Another American development during World War II that is pertinent to the subject of electronic warfare was the variable-time (VT) proximity fuze. A weapon, rather than a countermeasure, it nevertheless qualified for the role of a counter-countermeasure against the German buzz-bombs and long-range rockets launched at England during the last phases of the war. For the Germans had countered the Allies' electronic jamming capabilities by designing these missiles with magnetic, gyro, and clockwork controls that were immune to jamming. The only defense against them was to destroy them at their launching site or shoot them down.

Before the development of the proximity fuze, antiaircraft fire was tragically inefficient. Shells fuzed to burst on contact required a direct hit; time-fuzed shells required complex calculations, all subject to error. Enemy aircraft could upset these calculations by evasive action. And while the V-1 and V-2 bombs were incapable of evasive action, they were small and very fast, and therefore difficult to hit.

Projectiles with proximity fuzes are detonated automatically by proximity to the target. A fuze setting is not required before launching, and perfect directional accuracy is not essential. Proximity fuzes may be of five types: electromagnetic, electrostatic, acoustic, photoelectric, and infrared. The electromagnetic variable time (VT) fuze was the first type developed and is the type most generally used today. Others, particularly the acoustic and infrared types, may be encountered in the future.

The VT fuze is used on spin-stabilized projectiles, such as artillery and antiaircraft artillery shells, and on fin-stabilized projectiles, such as bombs, mortar shells, rockets, and guided missiles.

Because of the problems involved in minaturizing and ruggedizing vacuum tubes for use in spin-stabilized projectiles, the first radio proximity fuzes were developed for bombs and rockets. The British were working on such fuzes in 1941, trying to fit into the head of a 3-inch rocket a tiny radar set which would explode a projectile when it passed near a target. But it was not until the NDCR concentrated the efforts of United States scientists and production methods on the project that real progress was made. In April 1941, six bombs containing proximity fuzes were successfully tested, and in May a basic design was produced for a radio proximity fuze for shells. In November of the same year a development contract was concluded for pilot production and preparation for full-scale production. In January of 1943, our Navy was using VT-fuzed shells with outstanding success against Japanese aircraft. And in the autumn of the same year, when the British were warned by secret intelligence that the Germans were preparing to attack them with robot bombs, our Office of Scientific Research and Development (OSRD) began at once to design new devices to counter this threat.

When the first V-1 bomb, or buzz-bomb as it was popularly called, fell in England, the problem of shooting down bombs flying at 350 mph had already been solved. The British were in possession of three remarkable inventions, all developed in the United States: the VT-fuze, the SCR-584 microwave early warning radar set, and the M-9 electrical director for AA guns. These three devices, used in combination with barrage balloons, improved antiaircraft defense to such an extent that, in the last four weeks of V-1 attacks in England, the percentage of buzz-bombs destroyed increased from 24 percent to 79 percent. On the last day of the attack, of 104 detected by early warning radar, only four reached London.

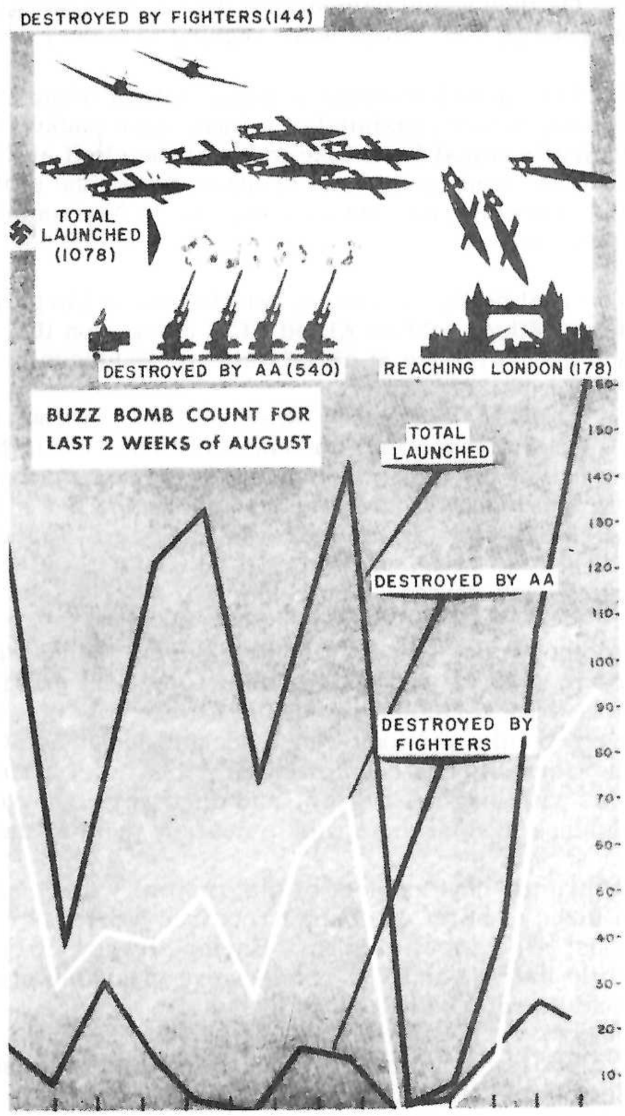


Figure 28. The VT-fuze against the V-1 bomb.

For fear of duds revealing the secret device to the enemy, use of the VT-fuze was at first limited to firing over water. But in December 1944, during the Battle of the Bulge, it was at last released for use against ground troops. The effect was devastating. An officer from General Patton's headquarters saw a German infantry company caught by a barrage of VT-fuzed shells while they were executing a river crossing. There were no survivors.

General Patton himself made the most penetrating observation about the new weapon. "When all armies get this shell," he wrote, "we will have to devise some new method of warfare."

Perhaps the General was visualizing today's electronic warfare.

Section IV. EW TODAY AND TOMORROW

22. COLD WAR

Communications jamming became not only a weapon but a basic strategy of the Cold War when, in 1948, the USSR started jamming Voice of America (VOA) and British Broadcasting Company (BBC) Russian language broadcasts. Protests to Moscow and to the United Nations against this peacetime jamming brought the countercharge that the VOA and BBC broadcasts constituted psychological warfare against which the USSR had "the right and duty... to paralyze the aggressor... " VOA broadcasts to Communist China have also been jammed since 1958.

It was not until 15 September 1959, the day Khrushchev arrived in the United States, that the USSR jammers were silenced. Upon his return to Russia they resumed, though on a more limited scale.

This jamming operation has been enormously costly to the Russians. VOA broadcasts are relayed to and retransmitted from points in Europe and North Africa on about 16 different frequencies in both the shortwave and broadcast bands. Some 85 transmitters are used. To jam these diverse frequencies and blanket the high transmitter powers, the USSR uses an estimated 1,500 transmitters at 300 sites in Russia and 750 transmitters at 90 locations in satellite countries. The specially designed jamming transmitters can shift frequency rapidly and jam effectively at powers up to 1,000,000 watts. It has been estimated that the initial cost of the system was near $250,000,000 and its operating cost about $185,000,000 a year. Nevertheless, some VOA broadcasts do get through.

We can expect this tremendous jamming potential to be turned to military advantage in case of war. We can also anticipate comparable proficiency in non-communications jamming by a nation as technologically advanced as the USSR.

23. PRESENT TRENDS

What can we do to counter this potential threat? The answers are to be found in better communications training, especially in the field of communications security; more intensive research and development and faster procurement in the fields of ECM and ECCM equipment; and improved awareness of the vital importance of planning new and better tactics and techniques in our program of electronic warfare.

Most of today's countermeasures are airborne. One plane in each formation carries, instead of a bomb load, an ECM pod to jam radar-guided missiles and cause them to feed back false information to their guidance systems. A small electronic jammer can obscure range data by sending out spaced pulses at the same length, frequency, and pulse repetition rate as the enemy radar, thereby simulating actual target echoes. The technique of range pull-off, created by a slow shift in frequency of the ECM pulses, simulates a change in target range. False directional information is provided by strong spurious pulses when the target is in one or more of the side lobes of the enemy radar's receiving antenna.

Counter-countermeasures to defeat these techniques consist of rapid frequency changes, varying pulse lengths, and identifiable modulations of the radar transmission.

But this is only one facet of an increasingly complex pattern. To name only a few of the new developments of significance in electronic warfare, the future will see increasing use of reconnaissance and communications satellites, radar-absorbing materials, and infrared detection devices.

During World War II the Germans, and later the United States and Great Britian, used infrared in active surveillance systems, typified by the sniperscope which permitted an infantryman or tank gunner to see his target at night.

The Germans used infrared detection devices against Allied night bombers to supplement radar and to counter Allied chaff. They also experimented with infrared for airborne interception and developed an antiaircraft missile having an infrared homing system. The Allies used infrared guidance with several glide bombs. One of these, known as Felix, saw service in the CBI theater toward the end of the war.

A more recent development, the Sidewinder missile, proved the value of infrared guidance systems once and for all in an aerial engagement between Nationalist and Communist China jet fighters over the south China coast. The accuracy of the Sidewinder, with an infrared homing device in its nose, was impressively demonstrated in this one engagement alone. Although numerically inferior, the Chinese Nationalist force, armed with the Sidewinder missile, achieved a 30-to-1 victory over the Communists.

Infrared also has potential military applications in the areas of secure voice communications, map-making, countermeasures and deception, and detection of stellar radiation in daylight (which suggests its use in automatic celestial navigation systems). Because of its flexibility, some authorities predict that infrared, within the next decade, will largely replace radar for missile guidance, target detection, and mapping.

What is the status of ECM and ECCM in these new fields? There is always scope for ingenuity. Let our closing paragraph give you a few hints on what we are doing and what we could like to do.

24. FUTURE TRENDS

We are currently spending from five hundred to six hundred million dollars a year on electronic warfare equipment and systems for electronic reconnaissance, surveillance, countermeasures, counter-countermeasures, and training simulators. This figure may increase to close to a billion dollars by 1970. In FY 62, jammers, decoys, ferrets, and other ECM equipment have accounted for over 200 million of these dollars. In the past, the largest percentage was spent for aircraft EW equipment, but emphasis is expected to change radically in the next five years, from aircraft to missiles and spacecraft. Much passive electronic surveillance now being conducted by aircraft will be performed by space vehicles. Communication satellites will carry their own ECM and ECCM equipment. Active ECM devices will be increasingly built into ICBM and IRBM warheads.

We must assume that our adversaries are following a similar course. Consequently, while we are developing these systems we must also plan our defense against them. Adequate defense against space vehicles is absorbing much R&D effort today. Physically enormous radar systems needed for early warning and surveillance have proved feasible, and so have the necessary data-gathering systems. Missile flight paths can be predicted and the orbits of satellites established to help provide successful defensive interceptions. The relative inability of such systems to maneuver is also an advantage to the defense.

These characteristics must be considered in planning our own offensive systems. We need effective countermeasures to neutralize defense radars and enable successful penetration of an enemy's defenses. We can use chaff or similar confusion devices to great advantage because, in the nearly complete vacuum and weightlessness of Space, such particles of lightweight radar-reflective material will form a cloud around the space vehicle and move with it until re-entry. Heavier particles can be introduced to screen the re-entry. Balloon decoys shaped like satellites or nose cones are also practical. Radar-absorbing materials for aircraft and re-entering space vehicles return very weak radar echoes, serving much the same purpose as sound-absorbing ceilings in a soundproofed roon.

Active jamming equipment is not expected to be appreciably larger or more powerful than that in use today. Defensive radars, at least in the near future, will improve their performance by coupling increased radar power with greater antenna and receiver sensitivity. Since the echoes will be weak, jamming power can also be weak. Expendable communications jammers are being developed, and long-range scatter-jamming systems.

Many problems remain to be solved, however, in these and other ECM areas. In passive countermeasures we need better direction-finding antennas, including those designed to meet the rigorous environmental requirements of satellites. We also need automatic passive ECM systems and digitally programed receivers. Among the more stubborn problems in active ECM are those relating to more sophisticated radar design and techniques, better means of evaluating vulnerability of new radar systems to countermeasures, and more realistic training devices.

The major problem is time -- and how best to use it. We hear of the missile race and the space race, but little is said of perhaps the most urgent race of all -- the EW contest. More like sword-play than a race, EW by its very nature consists of lightning thrusts and parries. The temper of the steel and the skill and alertness of the adversaries are of supreme importance in the contest. Even the slightest momentary advantage on either side could change the future of our planet.

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Glossary

A-scope -- A type of radar indicator that presents the range of a target as the distance along a horizontal time base. Time is measured from the instant the radar pulse is transmitted to the instant the echo from the target is received. Signals appear as vertical deflections on the horizontal time base.

Acquisition radar -- Search radar. A radar used to search a designated area so as to detect the presence of targets.

Antenna beam width -- Angle measured between the directions on either side of the beam axis of a directional antenna at which the radiated power level is one-half of maximum.

Antenna directivity -- Extent to which the antenna can focus the radar beam.

Antenna gain -- Measure of the concentration of energy of a directional antenna in a particular direction as compared with a standard dipole antenna. Thus, antenna gain is a measure of the effectiveness of a directional antenna.

Antenna radiation pattern -- A graphical representation of the radiation of the antenna as a function of direction. Pattern cross sections are normally given in both vertical and horizontal planes.

Artificial glint -- Artificially produced glint that is intended to make the tracking radar antenna slew back and forth rapidly from wingtip to wingtip or from nose to tail of the aircraft being tracked instead of slowly wandering about the aircraft. This condition may be accomplished by mounting antennas called blinkers on the nose, tail, and on the wingtips of the aircraft.

Automatic tracking -- A system of radar tracking in which the tracking mechanism automatically follows a target that has been selected or locked on.

B-scope -- A type of radar indicator that presents range and azimuth information, on which the signal appears as a bright spot on a rectangular scanned area. Range is measured vertically, and azimuth is measured horizontally.

Barrage jamming -- Broadband frequency coverage jamming intended to jam a number of opposed radars. Barrage jamming is accomplished by one or more broadband frequency coverage jammers or a number of spot jammers tuned to adjacent frequencies so that continuous coverage is provided over the broadband.

Battery acquisition radar -- A search-type radar, the function of which is to detect or to acquire assigned targets in the area of responsibility of a gun or missile battery.

Blind speeds -- Certain critical moving-target speeds, relative to the wavelength of the radar signal, at which there will be cancellation or attenuation of echo signals from the target by the radar's coherent MTI system.

Blip -- Echo indication on a radarscope.

Burn through -- Condition in which the echo return from a target can be seen through jamming on the radarscope.

Carcinotron tube -- An electron tube that can be used in the production of fast swept-frequency jamming. The tube permits rapid frequency changing at extremely fast rates, over very wide frequency ranges, at moderate power output.

Chaff -- Electronic countermeasure material composed of narrow, short strips of metallic or metallic-coated material capable of reflecting a radar signal.

Clutter -- Undesirable indications on radarscopes that are caused by natural unintentional interference resulting from the returns from terrain features, precipitation, clouds, etc. Returns from chaff are sometimes referred to as clutter.

Coherent MTI -- An MTI system that utilizes a reference oscillator that is locked in phase to the transmitted pulse (coherent oscillator). The phase of the reference oscillator signal is compared with the phase of signal returns to detect moving targets in the presence of clutter.

Coincidence detection -- ECCM technique accomplished by comparing video from two successive interpulse intervals and detecting only those video signals having the same time relationship in the two intervals. Interference suppressor (IS), least voltage coincidence detector (LVCD), and rabbit trap are three of the terms commonly used in reference to coincidence detection.

Conical scanning -- A type of antenna beam scanning in which an offcenter antenna lobe is rotated about the axis of a parabolic reflector, describing a cone in space about the axis of the reflector.

Corner reflector -- Confusion reflector made up of a number of plane surfaces of rigid reflecting material, such as metal mesh or sheet metal, that are connected together in many different ways to make up three-dimensional reflectors with a number of facets or faces. This reflector is designed to reflect any intercepted radio wave directly back to its source, regardless of the orientation of the reflector.

CW jamming -- Jamming accomplished by the transmission of unmodulated RF signals at or close to the frequency of the radar to be affected.

Decoy -- Any of several types of large confusion reflectors used for a particular deception application.

Defense acquisition radar -- A search-type radar, the function of which is to detect targets in the area of responsibility of an area defense system.

Duty cycle -- Ratio of pulse duration time to pulse-repetition time, which is the same as the ratio of the pulse average power (power averaged over one pulse-repetition time (prt)) to the pulse peak power.

Echo -- The portion of the energy of a transmitted pulse which is reflected back to the source by a target.

Expanded sweep -- An enlarged or magnified portion of a cathode-ray tube sweep.

Fire control -- The determination and regulation of the firing of guns or missiles.

Gate grabber -- A deception technique intended to cause a tracking radar to lose the target it is tracking by attracting the range gate to a strong deception signal.

Gated MTI -- A system that provides for MTI operation over a selected area of radar coverage and normal radar operation over the remainder of the area of coverage.

Grass -- Random spike-like deflections on a deflection-modulated radarscope, caused by noise.

Ground clutter -- Undesirable target indications on radarscopes caused by signal returns from the ground or from objects on the ground.

Homing -- Following a course directed toward a point.

Identification friend or foe (IFF) -- A system used with radar for distinguishing between friendly and enemy craft.

IFF transponder -- A receiver-transmitter which transmits reply signal automatically when the proper interrogation is received.

J-scope -- A modification of the type A indicator (A-scope). The time sweep produces a circular range scale near the circumference of the cathode-ray tube face. Signals appear as radial deflections of the time trace. Range, but no bearing information, is indicated.

K-scope -- A modification of the type A indicator (A-scope) which is used for aiming a double-lobe (lobe switching) system. A horizontal or vertical time trace is used, and the signal appears as a double deflection of the time trace with the ratio of amplitudes indicative of the error in aiming.

Kite -- Balloon supported decoy used in airborne operations.

L-band -- Band of frequencies between 390 and 1,550 megacycles.

Lobe switching -- A form of antenna scanning in which the direction of maximum radiation or reception is periodically switched in turn to each of two or more directions. Lobe switching may be used for accurate direction finding.

Moving-target indication (MTI) -- A wide variety of techniques utilized for the purpose of detecting moving targets in the presence of ground clutter and clutter from chaff and precipitation. This is accomplished by discrimination against the clutter.

Null -- Zero signal indication.

Panoramic receiver or adapter -- A receiver that permits observation on a cathode-ray tube indicator of signals within a wide-frequency range. An accessory to convert a conventional receiver into a panoramic receiver.

Parabolic reflector -- Highly directional antenna reflector, a cross section of which is in the shape of a parabola.

Polarization -- A term used in specifying the direction of the electric field component of a radio wave as radiated from a transmitting antenna.

PPI (PPI scope) -- A type of radar indicator presentation where the sweep rotates in a circular manner, pivoted at the center point of the indicator tube face. The signal appears as a bright spot with range indicated by distance from the center of the tube face and bearing by its radial angle.

Pulse modulation -- The process whereby an RF carrier is modulated by a signal consisting of recurrent pulses in which the duration of the pulse is short compared with the interval between the pulses. In pulse modulation, the creation of a high-power pulse followed by a relatively long waiting period before the next pulse is formed results in a high peak-to-average power ratio.

Pulse-repetition frequency (prf) -- the number of pulses per second.

Pulse width -- The time duration of a pulse as measured at the half-power points.

Rabbits -- Unintentional interference signals on the radarscope that result from the operation of other nearby radars.

Radar diplexing -- A method for utilizing two identical radar sets with a single antenna, in which the radar sets transmit and receive simultaneously.

Radar duplexing -- A method for utilizing two identical radar sets with a single antenna, in which only one of the radar transmitters is permitted to fire into the antenna at a given time, while the other transmitter operates in a standby condition into a dummy load. Radar duplexing may also be known as radar duoplexing.

Resolution, azimuth -- The angle or distance by which two targets at the same range must be separated in azimuth in order to be distinguished by a radar set.

Resolution, range -- The distance by which two targets on the same bearing line must be separated in range in order to be distinguished by a radar set.

Rope -- Confusion reflector consisting of a single, long strip of reflecting material or a number of small reflectors placed end to end and held together by a suitable supporting material.

S-band -- Band of frequencies between 1,550 and 5,200 megacycles.

Side lobe -- A portion of the radiation from a directional antenna, other than the main lobe.

Spoofing -- Form of transmission deception accomplished by a pulse-repeating tactic that results in a series of false target indications on the radarscope that may appear in line with and at greater range than the echo from the target from which the deception signal is being transmitted. These false target indications may also appear at false azimuths.

Spot jamming -- Narrow-band frequency coverage jamming intended to jam on specific opposed radar. Generally, the frequency coverage of spot jamming is confined to a band of frequencies no wider than that necessary to cover the bandpass of the opposed radar, and may consist of only the radar transmitter signal frequency.

Staggered prf -- A technique used to overcome or counter the MTI blind speed problem, in which the pulse-repetition frequency of the radar is periodically switched in turn to each of two frequencies.

Straw (wheat straw) -- Strips of reflecting material cut to lengths somewhat longer than chaff. The length of straw causes it to lack mechanical rigidness, giving it the appearance of stalks of grain after threshing.

Strobe -- An intensified sweep on a PPI or B-scope that results from certain types of interference.

Sweep and lock (lock-on) jammer -- Jammer that searches for a radar signal by continuously tuning through a wide band of frequencies (sweeping). When a radar signal is picked up, the jammer locks on the radar frequency and transmits at the radar frequency.

Swept-frequency jamming -- The process whereby the frequency of a transmitted jamming signal is continuously swept over a certain broad band of frequencies. The band swept may be up to 1,000 megacycles wide.

Transmitter peak power -- The maximum value of the transmitted pulse in a pulse radar system.

Video integration -- Technique in which the video from each interpulse interval is delayed and added to the video from the next interpulse interval. This results in discrimination against signals that do not have the same time relationship with respect to the transmitter pulse during successive interpulse intervals. This technique is effective against nonsynchronous interference.

Window -- Small reflecting items, commonly made of metalized paper or foil, dropped from aircraft to create false signals on the radarscope. Chaff is the term most commonly used for window.

X-band -- Band of frequencies between 5,200 and 10,900 megacycles.

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