Naval Radar

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Few developments had a greater impact on the war at sea than radar. By September 1939 the British Royal Navy, United States Navy and German Navy had all tested and begun installing radars in their ships while the other major navies had active research underway to develop shipboard sets

Some radar basics:

Radar displays: Initially radar displays consisted of a horizontal base line on a cathode ray tube (CRT). A target appeared as a vertical deflection of the base line. Range was determined by the location of the deflection along the base line. Bearing was a bit more complicated. The radar pulse was in the form of a tear drop with the point at the radar set. This lobe might be fairly narrow and might be fairly wide. The bearing was at or near the center of the lobe. Since the target would only appear when the radar was pointed at it bearing was not as simple as range. This meant for tracking it was necessary to hold the radar on the target. In 1942 the plan position indicator (PPI) was introduced. "(B)y mid 1943 this made possible a presentation of the tactical scene surrounding the ship by continuous rotation of the antenna array at a constant rate and rotating a radial line on the CRT in synchronism, the presence of targets being indicated by a brightening of the line. . . Now all targets appeared, and each antenna rotation refreshed the picture." This greatly simplified navigation and in the context of fleet air defense provided the ability to track multiple targets all at once. The PPI display is what most people think of when they think of radar.

Radar types, broadly speaking, were divided into two types: search and fire control. There were two types of search sets: surface and air. Fire control sets were developed for many purposes, the three most important being main battery, secondary battery and heavy machine gun.

U. S. Radar

In 1937 USS *Leary* (DD-158) was the first U. S. warship fitted with a radar. By the time of Pearl Harbor all U. S. ships of cruiser size or larger were either fitted with radar or scheduled for such fitting.

Type	Wave Length	Power Output	Range (nautical miles)	Main Function	Remarks
CXAM		5 kw	50 nm (aircraft) 12 nm (ship)	Air search	Large ships A-scope
SA		1950 w	40 nm (aircraft)	Air search	Initial contract January 1942. Destroyer size ships A scope; PPI later
SC		SC & SC 1 1500	SC 30 nm bomber; SC 1,	Air search	First tested in June 1941 on USS *Somers*. No height finding

		w, SC 2 & SC 3 2500 w	2 & 3 75 nm		capability Destroyers and larger SC & SC 1 A scope, SC 2 & SC 3 PPI. Bearing error 2 degrees at 100 nm (7 miles)
SE			12 nm large ship; 8 nm destroyer; 4 nm surfaced submarine	Surface search	A scope
SG		50 kw	Battleship: 22 nm; destroyer: 15 nm; bomber @ 500' 15 nm	Surface search	First tested in May 1941 on USS SOMERS. First installed in a fleet unit in April 1942, USS AUGUSTA. First USN microwave radar. First to use multicavity magnetron. Follow on types: SE, SF, SJ, SO, SP, SS & ST. Destroyers and larger. First with PPI
SJ			Maximum reliable range 5 miles	Surface search	Search and Fire control for submarines.
SK		3500 watts	100 nm on bombers	Air search	Modified SC receiver with CXAM type antenna and PPI scope. Initial contract April 1942. Best US air search radar from 1943 to end of war. Bearing error 2 degrees at 100 miles (7 miles). SK-2 exceeded performance expectations in battle. Large ships. A and PPI scopes
SL			20 nm large ship	Surface search	Small ships PPI scope
SM				Fighter control	Also known as CXBL. Could give height information and because of definition of scope presentation gave good information as to composition and vertical formation of attackers. First CV equipped with this system was CV 16. By June 1944 all carriers had this equipment.
SO			8 nm large ship	Surface search	PT boats PPI scope
SP				Fighter control	
SR				Air Search	

SS				Surface search	
SU				Surface search	
Mk 3 FC		2.2 kw	8 nm destroyer 14 nm battleship	Main battery f.c. 6" guns or larger	Mk 34, 35 & 38 directors
Mk 4 FD		2.4 kw	17 nm on large aircraft; 8 nm on destroyer; 12 nm on battleship	Dual purpose f.c. 5" guns	Mk 33 & 37 directors
Mk 11		1.7 kw	Varies 5-7 nm depending on mark and mod.	3 nm on planes	Automatic weapons A scope
Mk 12				Dual purpose f.c.	Mk 37 director Similar to Mk 4
Mk 13				Main battery f.c.	Mk 34, 38 & 54 directors
Mk 22				Height finder	
Mk 28					

British Radar

In August 1938 HMS *Sheffield* was fitted with a Type 79Y radar. *Rodney* followed in October.

Type	Wave Length	Power Output	Range (nautical miles)	Main Function	Remarks
271	10 cm	5-90 kw	10-25 nm	Surface warning	First microwave set. Beginning in May 1941 fitted in hundreds of ships. Very successful.
272	10 cm	5-90 kw	10-25 nm	Surface warning	Variant of 271 used in destroyers and cruisers.
273	10 cm	5-90 kw	1-25 nm	Surface warning	Variant pf 271 used in cruisers and battleships.
275	10 cm			Main gunnery large ships	Replacement for 284
276	3 cm			Surface warning	Used in few destroyers between 1943 & 1945 as 272 replacement
277	10 cm	500 kw	25-35 nm	Combined air and surface warning	First set with PPI height finder, performance not very good,

				height finder	first fitted late 1943
79	7 meters	70 kw	60 nm	Air warning	First British air warning set. First used by *Sheffield* in August 1938
279	7 meters	70 kw	100 nm	Air warning with barrage predictor	First widely used air warning set. Supplanted by 281
280	3.5 meters			Air warning/AA ranging	Adaptation of Army model, used on old cruisers in 1940-41
281	3.5-4 meters	350 kw	120 nm	Air warning	Most widely used air warning set in use during WWII on large ships. First fitted in 12-40 to *Dido*
282	50 cm	25 kw	3.5 nm	Close range AA gunnery	First fitted in early 1941 in *Prince Of Wales*
283	50 cm	25 kw	8.5 nm	Blind fire AA barrage for main armament of large ships	Came into use in late 1942. All cruisers and battleships
284	50 cm	25 kw	10 nm	Main battery large ships	Very successful gunnery set for main armament for large ships. First fitted in *Nelson* in June 1940
285	50 cm	25 kw	8.5 nm	Long range AA gunnery	Variant of 284, successful surface and air warning set for small ships as well as long range AA.
286	1.5 meters			Air and surface warning set	Naval version of RAF ASV set. First fitted in autumn 1940. Poor performance. First mark had non rotating aerial
290	1.5 meters			Air warning	First fitted in early 1941. Intended as replacement for 286 but supplanted by 271 and 272
291	1.5 meters		35 miles	Air warning	Widely used successful set for small ships throughout the war. First used at end of 1941
293	10 cm	500 kw	12.5 miles	Air and surface target indicting	First fitted in late 1943
294	10 cm	500 kw		Combined air and surface warning height finder	Replace 277
295	10 cm	500 kw		Combined air and surface warning height finder	271-3 replacement introduced in 1945
298	3 cm			Surface warning	

Japanese Radar

In 1928 Professor Yagi became famous as one of the developers of the "Yagi antenna", a mainstay for radar antennas. In spite such an early success Japanese radar development was a mixture of fits and starts. However, in the navy's overall opinion radar did not seem to offer many offensive possibilities.

Type	Wave Length	Power Output	Range	Main Function	Remarks
21	1.5 m	5 kw	Max. 90 mi. Effective. 40-60 mi.	Air search	First version installed in battleship *Ise* in May 1942. Most BB, CA, *Akitsuki* class DDs and CVs eventually received this equipment. A Scope. Bed spring/mattress antenna
13	2.0 m	10 kw	Max. 90 miles Effective 30-60 miles	Air Search	A Scope. Entered service in 1944.Most ships, including small escorts carried this equipment. Ladder antenna.
22	10 cm	2 kw	Max. 35 miles Effective 10-20 miles	Surface search	First version installed in battleship *Hyuga* in May 1942. A Scope. Most surface ships including small escorts eventually received this equipment. A late model (22-4S) was being developed for surface fire control. Horn antenna (2: one transmit one receive)

German Radar

German experiments into the potential of radar started quite early. In 1938 *Admiral Graf Spee* became the first warship outfitted with radar.

Type	Wave Length	Power Output	Range	Main Function	Remarks
FuMO 21	368 MHz		14-18km		Destroyers
FuMO 22	368 MHz		?		Capital ships
FuMO 23	368MHz		?		Capital ships
FuMO 24/25	368MHz		15-20km		Capital ships, destroyers
FuMO 26	368MHz		20-25km		Capital ships
FuMO 30	368MHz		6-8km		Submarines
FuMO 61	556MHz		8-10km		Submarines Hohentwiel-U
FuMO 63	556-567 MHz		12-20km		Hohentwiel-K
FuMO 81	3300MHz		20-30km		Survey set, *Prinz Eugen,* destroyers, S-Boats, Berlin-S

FuMO 213	560MHz		40-60km		AA Gunnery
FuMB 7			passive		Timor
Palau			passive		
FuMB 3			passive		
FuMB 4			passive		Sumatra
Seetakt					

Italian Naval Radar with Enrico Cernuschi

Before the war Italian research paralleled that of other countries, but Italy entered the war with no ships equipped with radar.

RDT 3	1,5 m	15 kilowatt 500 Herz impulse	108 miles against aircraft	Air search	Prototype completed on Oct. 1939. Too cumbersome to be used on ships; mattress antenna
EC 3 bis	72 cm	5 kilowatt 500 Herz impulse	6 against sea targets 16 against aircraft	Sea and air search	Prototype tested successfully on April 1941; that same set is fitted on *Littorio* on Aug. 1941; removed on May 1942 for improvements
EC 3 ter "Gufo"	60 cm	10 kilowatt 500 Herz	8 (fitted on a destroyer) or 16 on a battleships against sea targets; 43 miles against aircraft	Sea and air search	Introduced since September 1942
RDT 4	1,5	50 kilowatt 500 Hertz	113	Air search	Based on land for air warning. Produced from 1942
G III	65-80 cm (it could change	10 kilowatt	16 miles against sea targets; 24	Sea and air	Prototype tested on August 1943; series set

	automatically working frequencies to avoid enemy jamming)	500 Hertz	miles against aircraft	search	introduced by the German navy in the Mediterranean Sea on 1944

France with John Jordan

In 1934 a crude radar was installed on the liner *Normandie*. At the beginning of the war the Marine Nationale was still experimenting with various equipment.

MN

DEM*	2 meters	60 w	37-50km (aircraft) 10-25km (ship)	air search	Prototype in *Richelieu* May 1941; display (A-scope equivalent) added August. Further prototypes in *Jean Bart, Strasbourg, Algerie* and *Colbert* 1942. In the standard installation, there were separate antennae for transmission and reception to port and to starboard. Accuracy ±50m range, ±1-2° bearing.

DEM = *Détection Electro-Magnétique.* Note that this is simply the equivalent of RDF or Radar; there were no model numbers as there was no series production. The dipoles, reflectors, transmitters and receivers were developed by radio specialists Sadir-Carpentier; the display by the Compagnie des Compteurs. A decimentric radar was under development at the time of the occupation of Southern France.

Russian Radar with Stephen McLaughlin

Though they conducted useful experiments before the war the Soviet navy had no working radars when war came to Russia.

Designation: Redut-K
Date: 1940
Purpose: Air search
Wavelength: 74 Megehertz/400cm
Power: 50 kW
Range of observation: 64.8m / 120km
Error in range: +/-1,500m
Error in direction: +/-7 degrees

Designation: Redut-K
Date: 1940
Purpose: Air Wavelength: 74 Megehertz/400cm

Power: 50 kW
Range of observation: 64.8m / 120km
Error in range: +/-1,500m
Error in direction: +/-7 degrees.

Based on a unit designed for use ashore. Only one example was mounted aboard ship, on the Black Sea Fleet cruiser *Molotov*. Reportedly proved very valuable in giving air raid warnings when the ship was in port; didn't get much use at sea.

Designation: Giuis-I
Date: 1944
Purpose: Air search
Wavelength: 214 Megahertz/140cm
Power: up to 80 kW
Range of observation: up to 25m / 46km with target at an altitude of 5,000m
Error in range: +/-1,100m
Error in direction: +/-5 degrees

Manufactured during the war; only three sets were delivered to the navy, and were mounted on the destroyers *Strogii*, *Gromkii* and *Rianyi*.

Sets delivered as part of Lend Lease, or used aboard ships loaned to the USSR:

British:
Type 79
Type 242 (on destroyers delivered to USSR)
Type 243 (on Battleship *Royal Sovereign*, loaned to USSR)
Type 251 (on *Royal Sovereign*)
Type 252 (on *Royal Sovereign*)
Type 271 Mk. IV
Type 273
Type 281
Types 286 and variants
Type 291
Type 291v
Type 291w (for submarines)

American:
ABK-7 (aboard cruiser *Milwaukee*, loaned to USSR)
SK
SG
SF-1
SL
SO-13search

Doctrine Development During the War

One striking aspect of radar development is how Allied and Axis doctrine diverged once war was underway. Prewar exercises showed that radar transmissions were detected by target ships well before the sets received return echoes. This indicated that radar silence was as important as radio silence. In fact as late as HMS *Illustrious'*s arrival in the Mediterranean in 1940 radar sweeps were restricted to once an hour. It soon became apparent that this was impractical and the ban was lifted. The Axis, however, never fully lifted that restriction.

The first radar directed fighter interceptions took place during the Norway campaign in the spring of 1940. By later standards these was crude. The carrier HMS *Ark Royal,* which lacked radar throughout her career, was accompanied by the radar equipped HMS *Sheffield.* Using flags or Morse she passed information on unidentified contacts to an officer on the bridge of the carrier. He had a table on which he plotted the two ships locations together with the location of the unidentified contacts as well as his own fighters. Using this crude method he passed the information on to the fighters who then calculated the vector to the target. His problem was compounded by the fact that the radar being used only had an A-Scope so it had to either continuously track the one raid or search for others switching back and forth between tracking and search. This problem would eventually be solved with the introduction of the PPI scope. From this crude beginning the Royal Navy began the development of a radar doctrine that led to what eventually became the Combat Information Center (RN Action Information Centre). One of the great cooperative ventures of the war was the sharing of radar secrets between the RN and USN.

The narrow focus of the Axis navies on radar as a surface gunfire aid can be seen in the variety of radars on the newly commissioned HMS *Prince of Wales* and the German battleship *Bismarck* when the two ships met. The British ship was equipped with a wide variety of radar equipment; two main battery fire control radars, four dual purpose fire control radars, four pom pom fire control radars, a surface search radar and air search radar together with a variety of electronic countermeasures equipment. The fire control radars were fitted to their directors while the search sets were on the mast(s) so they could sweep around 360 degrees on a continuous basis. By contrast the German ship's three radars were all fitted to the directors and were restricted in their search by the train of the directors. The director motors were not suited to the continuous use implied in a search radar. This method of mounting radars continued in the German and Japanese navies for much of the war. In the latter case cruiser radars were mounted on the mast.

During the 1944 Battle of the Philippine Sea the US carriers were fitted with SK (1 or 2) and SC (late model) air search as well as a SG surface search set. The carriers also had fire control radars for their 5-inch guns. The battleships and cruisers had similar outfits. In the Imperial Japanese Navy the carriers were fitted with type 21 and 13 sets while the battleships and cruisers added the type 22.