WESTINGHOUSE MICROWAVE SYSTEMS AND TECHNOLOGY

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ABSTRACT

The first knowledge of the impending Japanese attack on Pearl Harbor was obtained by a Westinghouse surface radar. Unfortunately, the information was not utilized. Microwave systems at Westinghouse began in 1929. From then to early 1996, Westinghouse radar and EW systems excelled on land, sea, air and space -- from World War II through Desert Storm. That proud tradition has been continued by Northrop Grumman and Lockheed Martin.

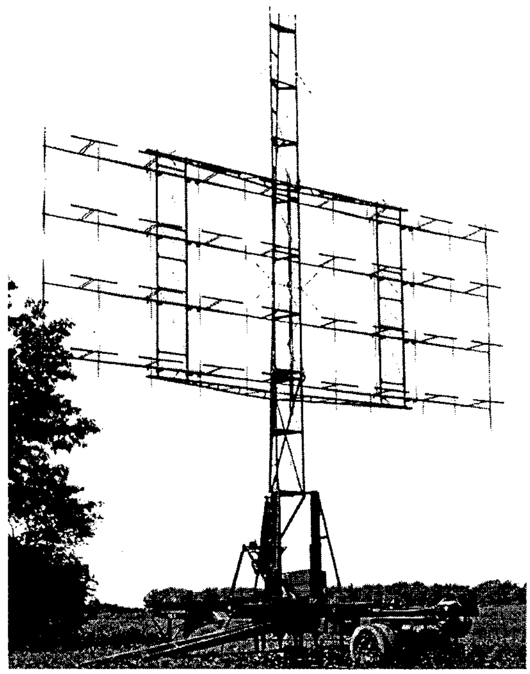
INTRODUCTION

Almost all of the work on Westinghouse microwave systems occurred in Baltimore, but the earliest activity took place in Pittsburgh. In late 1929, G. Ross Kilgore generated ultra short waves using a split-anode magnetron, eventually reaching a wavelength of 1.6 cm. By 1933, it proved possible to measure Doppler signals from moving automobiles and railroad cars.

From World War II to Korea, through the Cold War, Vietnam, and Desert Storm, Westinghouse radars and EW systems set a standard of excellence in every theater, and on the variety of platforms used by the Military. Radars were used also for commercial air taffic control and the manned space program. That tradition of excellence has been continued by Northrop Grumman and Lockheed Martin.

SIGNIFICANT SURFACE RADARS

• *SCR-270/271* - On December 7, 1941, an SCR-270, located at Opana near Pearl Harbor, and operated by Private Joseph L. Lockard, gave an early warning of the impending Japanese attack. This was the first ground-based radar equipment made for the Army Signal Corps. The long range aircraft warning radar stayed in action throughout World War II.



• *SCR-584* - A mobile, anti-aircraft gun control radar, designed by the MIT Radiation Laboratory. The 584 picked up aircraft 40 miles out and aimed a battery of four 90 millimeter guns. This radar aided fighters to knock down 90 percent of the V1 "buzz" bombs.

• *MPS-20* - A 5-megawatt, stacked beam S-band ground-based radar made for the Air Force. The MPS-20 pioneered technologies new for the time -- printed circuits, Moving Target Indication (MTI), Electronic Counter-Countermeasures (ECCM) and frequency agility.

• *FPS-27* - Served the Air Force as their air defense surface radar until 1971, when it was upgraded (to the FPS-27A) with hybrid receiver and digital processing techniques - including digital MTI and biphase coded pulse anti-clutter transmission.

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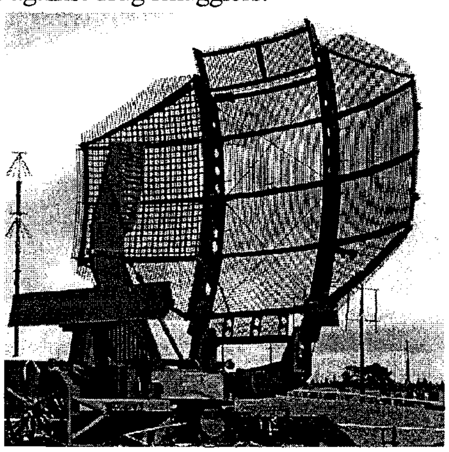
• *TPS-43* - Starting in 1967, this highly successful S-band ultimately spawned 12 generations. Wally Hoff began a long involvement with the 43 during the transition from the D to the E series. The TPS-43E, 1975, had modifications which included: magnetic core memory replaced by integrated circuits, quartz delay replaced by light weight, low cost Surface Acoustic Wave (SAW) devices, and low noise RF receiver traveling wave tube amplifiers replaced by solid state integrated RF receivers. Further, the TPS-43E was expanded to a version employing an Ultra-low Sidelobe Antenna, the TPS-43E (ULSA). This derived from technology developed on the AWACS program. This outstanding 3-D tactical radar essentially became the TPS-75 in 1987.

• *TPS-70* - This 3-D, S-band radar, 1982, utilized technology from the TPS-43, but was modified with a slotted array low sidelobe antenna, which greatly enhanced ECCM performance. The TPS-70 has served as the primary sensor for the Caribbean Basin Radar Network, where, in addition to military applications, it can be used against drug smugglers.



• *TPS-63* - A highly reliable 2-D, L-band tactical radar, which automatically detects small, fast, low-flying targets during severe weather and over adverse terrain.

• *TPS-27* - A mobile version of the l- band FPS-27, that provided the entree into Air Traffic Control.

• *ARSR-3* - The first of a new generation of on-route air traffic control systems, and one of the first minimally attended radars. The ARSR-3 was actually two cross-connected radars using the same antenna. In the diplex mode, each of the two L-band transmitters operated at a slightly different frequency to improve aircraft detection. Through the use of circular polarization superior weather clutter cancellation was obtained. Dick Linder is often called the "founding father" of this program.

• *ARS-9* - This S-band ATC radar was the first to simultaneously provide calibrated weather and aircraft data.

• *ARSR-4* - Started in 1988, this L-band, unmanned, 3-dimensional radar is used for both air defense and ATC.

• *SR-3* - The SR series were the Navy's shipboard radars. The L-band SR-3 was installed on destroyers in 1945 for high-angle search.

• *SPS-58* - The Navy's L-band point defense radar system could distinguish high-speed, low-flying targets from sea or ground clutter. With detection to the horizon, maximum early warning was received.

SIGNIFICANT AIRBORNE RADARS

• *ASB-1* - The activity that led to over 20,000 UHF search radars for carrier-based aircraft began in the autumn of 1941, with an order for 25 model radars (in secrecy).

• *APQ-35* - This 1946 system was composed of three separate radar sets, all X-band. With these radars, the -35 provided search, track and tail warning for the Douglas F-3D "Skyknight" night fighter, which saw action in the Korean War. The APS-21 was a search radar with a range of 52 miles. The tracking radar, APG-26B had a lock-up range to four miles. For tail warning, the APS-28 had a detection range of four miles.

• *Aero-13* - This 1950s X-band system was the first radar configured in a cylindrical shape.

• *DPN-53* - This X-band terminal seeker for the BOMARC missile marked the start of pulse Doppler radar. In 1953, work was begun at Westinghouse on pulse Doppler radar for a wide range of applications led by Harry B. Smith. The ultimately highly successful work required advances in Stable Local Oscillators (STALO), high PRF, spurious signals suppression, improved Transmit/Receive (TR) tubes and more.

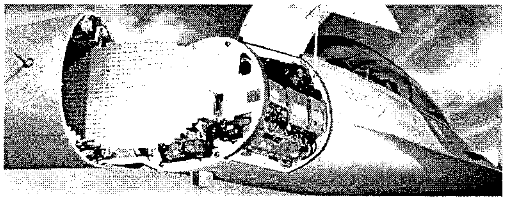
• *APG-59* - An X-band multi-mode fire control radar for the AWG-10 Missile Control System. This 1960s system was installed on the F-4J aircraft. Heavily involved, especially on the air-to-ground modes, was Noel Longuemare.

• *APQ-120* - Used on every Air Force F-4E aircraft to provide target information for weapon delivery. The APQ-120, considered the first solid state radar, was an

X-band pulse radar that used a tunable magnetron as the power amplifier in the transmitter; the rest of the system used transistors.

• *APG-66* - This mid-1970s radar, developed for the F-16A/B was derived from an internal program called WX. The system has eleven air-to-air modes and sub-modes through which it detects and tracks airborne targets.

Key technology features for the APG-66 included:
- Broadband slotted array antenna
- Passive receiver protection
- Digital Signal Processing (DSP)
- Single channel monopulse



• *APG-68* - This fire control radar is an advanced APG-66 for the F-16C/D. The DSP was replaced with a Programmable Signal Processor (PSP). This increased the number of modes and functions. A dual mode transmitter provided increased detection range by adding a high PRF velocity search mode.

Airborne Radar Firsts

- Automatic angle and range acquisition radar
- Pulse Doppler fire control radar system
- Digital range, multi-target track-while-scan
- Ultra low sidelobe antenna
- Digital, coherent on receive Doppler
- All solid state radar (including transmitter)
- Forward looking, synthetic aperture radar
- Low sidelobe, electronic scan array

AIRBORNE PHASED ARRAY RADAR

The radar dream in the 1960s was for a solid state, active aperture phased array system. This required higher speed silicon ICs and better gallium arsenide microwave devices than existed at that time. So, first came passive arrays; these used electron tube microwave sources and silicon IC controlled ferrite phase shifters.

• *EAR* - The Electronically Agile Array was a program to develop advanced concepts for a phased array radar for the B-1 bomber. The phased array antenna of the EAR system could change the shape of its beam electronically using 1,818 separate radiating elements. What the Air Force desired was a radar development that would lead to a radar system to replace five existing radars, to aid in long range bomber penetration. The five radars to be replaced by one system were: ground mapping, air-to-air, automatic terrain following, terrain avoidance and weather mapping.

• *APQ-164* - The Offensive Radar System (ORS) for the B-1B bomber is an X-band phased array, multimode, digital radar.

• *APG-77* - This active aperture, phased array X-band radar for the F-22 aircraft was started in the mid-1980s with work on a program named Ultra Reliable Radar (URR). To prepare for the F-22 radar, a joint venture was formed with TI, the URR associate contractor. The active electronically scanned antenna meets the requirements of extreme bandwidths, high efficiencies, low antenna sidelobes and radar cross-section, rapid beam agility, and adaptive sidelobe and mainlobe jammer cancellation. With precise T/R modules the radar system can provide simultaneous multimode and multifunction operation, low observability, enhanced electronic counter-countermeasures (ECCM), and ultra-high reliability with predictions of >10,000 hours MTBF.

AWACS

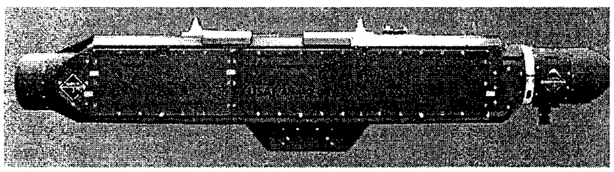
The APY-2 is an S-band pulse Doppler radar for the E-3A AWACS. This radar contains 598 line replaceable units, 919 multi-layer printed circuit assemblies of 550 different types, over 1000 cable assemblies, and 77,000 electrical parts - for over 600,000 total parts. In March 1977, the first AWACS aircraft was delivered at Tinker Air Force Base. This system provides long-range surveillance of high or low flying aircraft, while a maritime mode can detect moving and stationary surface ships. It represents a significant advance over early radar, which did not have a look down capability. The system provides an instant overview of more than 100,000 cubic miles.

OTHER RADAR ENVIRONMENTS

The Fire Control Radar (FCR) on the U.S. Army's AH-64D Longbow Apache attack helicopter is mast-mounted and operates at 35 GHz. Add to the radar the fire-and-forget Hellfire modular missile system, and the result is the most combat effective helicopter in the world.

The NASA Gemini program was planned as a phase between the one-astronaut Mercury program and the three-astronaut Apollo mission to the moon. The purpose was to refine techniques that would be needed to reunite the Lunar Lander with the Apollo Spacecraft after the lunar landing. To this end, in 1961, Westinghouse embarked on developing and producing the first space radar. The Gemini rendezvous radar enabled the two-man Gemini capsule to successfully maneuver to another space vehicle.

ELECTRONIC WARFARE



Westinghouse activities in Electronic Warfare (EW) began in the mid-1950s. By the early 1960s, after several programs including the B-70 Defensive Subsystem (ALQ-24), the desire to add a countermeasures capability to existing aircraft expanded the work on external stores configurations (pods). About this time, Southeast Asia was heating up.

• *ALQ-66* - The Molecular (integrated circuits) Pathfinder Receiver provided technology that led to several Quick Reaction Capability (QRC) EW programs.

• *QRC-272 Peanut Pod* - To locate hostile radiators, communications and radar.

• *ALQ-101* - This pod was used on at least seven different aircraft types. It grew out of the QRC-335, which itself was and outgrowth of an early 1960s program 669A – penetration aid for manned aircraft.

• *ALQ-119* - This series offered full frequency coverage to provide protection in three microwave bands. Also, it was the first EW system to utilize digital waveform generators.

• *ALQ-131* - A highly modular pod, available in 16 basic structural configurations. Flightline reprogramming was demonstrated in the mid-70s on the ALQ-131 – the first EW system to have this feature. This became a requirement on all later systems.

• *ALQ-153* - A rear-looking, pulse Doppler radar or tail-warning system.

• *ALQ-165 or ASPJ* - This is an internal ECM system, because the military was never completely happy with pods. Their flexibility and adaptability were virtues; however, they took up a weapons station. The ASPS was developed and produced by both Westinghouse Electronic Systems and ITT Avionics.

During Operation Desert Storm, no aircraft entered hostile territory without self-protection equipment. More than 700 Westinghouse ECM systems were employed to protect a variety of platforms. Over 75 percent of the U.S. Air Force tactical aircraft were protected by Electronic Systems' ECM systems and the ALQ-153 was employed to provide missile warning for the B-52 aircraft. Aircraft equipped with the ALQ-131 Block II pods flew more than 9000 missions without a plane being downed by enemy fire. Further, the high reliability of the equipment was demonstrated by the fact that no aircraft missed a mission due to the unavailability of Westinghouse ECM.

TECHNOLOGY

Advances in active devices and other components are usually required to realize advances in radar systems. System software is equally vital. As early as 1943, with radar moving to higher frequencies, pioneering work on aluminum doped silicon detectors took place in Baltimore. In 1957, a microwave tube facility was established in Baltimore to enhanced TR tube development. One year later, a semiconductor facility was also established at the Air Arm Division. As computers became increasingly necessary in radar systems, major software activities were launched. Early Westinghouse work on gallium arsenide was important for the mixers and Keyed Oscillator (KO) deck of EW systems, such as the ALQ-119 and ALQ-131. This led to the development of Monolithic Microwave Integrated Circuits (MMIC) for active aperture.

All of these system and technology advances over the years are the result of efforts by dedicated men and women.