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USAF Security Service SIGINT post at Marienfelde, Germany, in the early 1960s.

Hot Radios In The Cold War

The Race For The First Microprocessor-Controlled, Digitally Synthesized VHF-UHF Radio

by Terry O'Laughlin

Thirty years ago, before the Berlin Wall fell, German women spun the dials on hundreds of Watkins-Johnson (WJ) receivers deep in a windowless, secure US Air Force surveillance site, searching for signals from the Communist Eastern Block. The women wore parkas and gloves to ward off the cold, their eyes glued to the spectrum monitor searching for signals, their ears clamped in headsets listening for targeted communications.

Twenty-five years ago, a US Navy ship studded with antennas trawled in tight loops at undisclosed Western Pacific locations. Below deck, amid racks of signals intercept (SIGINT) equipment covering almost DC to daylight, the same WJ receivers ferreted out communication intercepts (COMINT).

On the other side of the world, modified light armored vehicles (LAV) rumbled across the desert with US Marines scanning the spectrum on two of the same WJ receivers, one coupled to WJ direction-finding (DF) gear searching for suspicious transmitters.

These are just three applications out of the thousands where WJ radios were used in the Cold War. Official histories of SIGINT activity rarely mention WJ or any other specific radio manufacturer. Even DRS Technologies, which owns the former WJ Gaithersburg, Maryland facility that produced these radios, maintains a distance from this glorious past. No story has ever been printed about this particular radio and its applications. Until now...

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Starting From The Rubble

On June 28, 1962, the US Air Force established a monitoring post using mobile platforms on a hill in Marienfelde, Germany, near Berlin. Records are sketchy, but the electronic intercept (ELINT) mission apparently used Collins AN/MLQ-24 panoramic microwave receivers. The site grew quickly with construction of permanent buildings beginning in October, 1965.

The hill at Marienfelde was artificial, created by women right after World War II. The first years after the war were brutal in Berlin. Most able-bodied men were dead or prisoners, heavy machinery was non-existent, even trucks and horses were rarities. Corpses, both human and animal, rotted under the unmovable debris. Clean water was scarce and sanitation non-existent. Starving women and children gathered dandelions, acorns, and chickweed trying to survive in the unspeakable conditions. Aid under the Marshall Plan did not arrive for several years, first reaching France in May, 1948.

Eventually, the occupying forces put 60,000 women to work clearing the streets and dismantling unsafe buildings. Known as Trümmerfrauen (rubble women), they cleared the rubble by hand, pushing carts and pulling down walls with hand winches. Bricks and stones that could be salvaged were cleaned for reuse. They moved the rest, often by handcart, to several locations outside town, one of which was Marienfelde. They were unpaid. Their only reward was extra food rations.

Marienfelde was on Diedersdorfer Weg, near where the street once dead-ended at the Death Strip of the Berlin Wall. It was directly visible from the East German guard towers. WJ staff visiting in those days, recall looking out with binoculars from the antenna tower and seeing a Communist soldier staring back at them. This close proximity made Marienfelde ideal for Cold War SIGINT reception.

Mission Needs Drive Innovation

Marienfelde was continuously modified as SIGINT missions evolved, and the number of missions expanded dramatically during the Cold War. Matthew M. Aid, writing in *Secrets of Signals Intelligence during the Cold War and Beyond*, found that the United States built 70 SIGINT stations by the early 1960s. In *Body of Secrets*, reporter James Bamford notes the U.S. eventually had "over 2,000 intercept positions around the world."

"SIGINT had achieved a preeminent status within the intelligence community" according to Aid. It supplanted what NSA director William O. Studeman derisively called "historically less productive intelligence means."

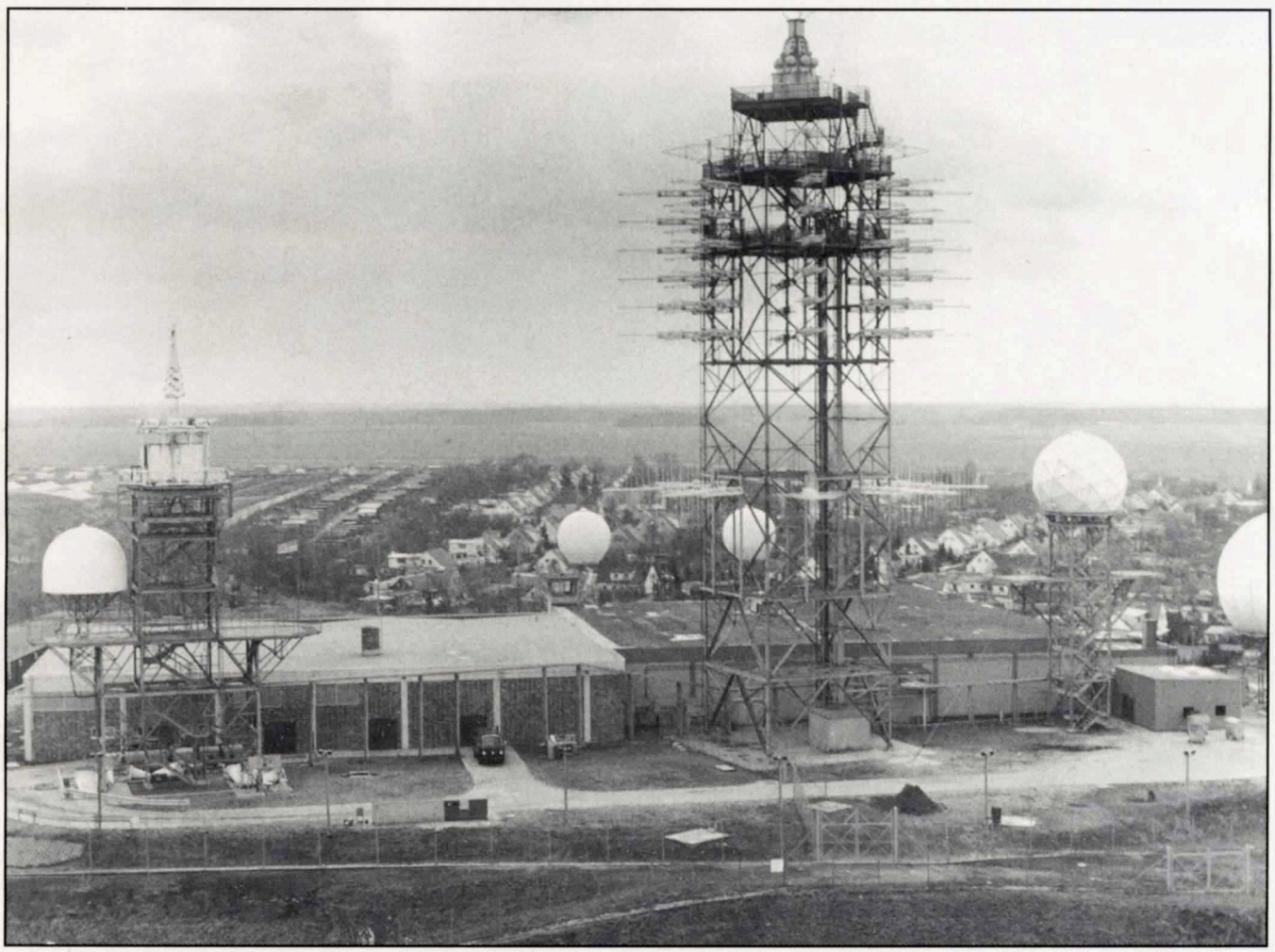
The voracious appetite for SIGINT created a perfect environment for development of increasingly sophisticated VHF, UHF, and microwave receivers. To expand the amount of incoming intelligence, Congress regularly provided millions of dollars to various agencies for improved SIGINT equipment.

On The Technological Frontier

From its introduction in 1964, the Communication Electronics, Inc. (CEI) RS-111 was very popular for SIGINT work (see *Pop'Comm*, June 2008). Thousands of these manually tuned receivers were sold and used at sites all over the world.

In early 1969, CEI introduced the revolutionary RS-160 Pan Man scanning system. Its ability to display large swaths of spectrum enabled quick visual scans for interesting activity. Their varactor tuners opened the door for scans and sweeps controlled by the Digital Equipment Corporation PDP-11 computer.

The expanded SIGINT opportunities presented by computer-controlled receivers whetted the Department of Defense's (DoD) appetite for digital VHF-UHF receivers with internal microprocessor control and frequency synthesizers. In 1975, they requested proposals for a receiver with scan, step, and mem-



Marienfelde SIGINT listening post in 1978.

ory capabilities as well as the same basic feature set of the RS-111, which had 30 to 1000 MHz coverage, a spectrum monitor and fit in 5-1/2 inches of rack space.

Successful applicants would be given $60,000 to develop a prototype. WJ managers estimated development costs of $1 to 2 million. The prototypes would be submitted for examination, and the best prototype would then receive additional funding for a small production run. If the first production run was acceptable, the next order would be for 500 receivers and the real paycheck.

Only two companies, the WJ CEI division and the Ralph E. Grimm Co. (or Regco) were seen as viable candidates, and they were given one year to develop prototypes. It was an epic competition.

Let The Battle Begin

Ralph Grimm had created CEI and personally mentored many of the staff with whom he was competing. Grimm had sold CEI to the California-based WJ early in 1967, staying in charge as manager. When development costs swamped profits in 1974, WJ reorganized and reduced his role to Vice President of Engineering.

Unhappy in a secondary role within the facility he created, Grimm left the CEI division effective May 30, 1975. He started Regco as an engineering design firm, much like Allen Clarke, his mentor, had started Clarke Instruments (see *Pop'Comm*, June 2009).

Grimm successfully recruited a few CEI division employees and leased space from Racal Communications in their Rockville, Maryland, plant where they were building RA-6217 and RA-6772 receivers. Grimm's first products were accessories like speakers and spectrum displays that Racal fabricated for Regco.

Regco and WJ battled for business right from the start. In Regco's favor, Grimm had a sterling reputation and scores of carefully nurtured contacts. But at this point, his skills as a teacher, mentor, and manager worked against him. At WJ's CEI division he had left behind a healthy facility with many excellent engineers. The competition reached the point where, in May 1976, WJ took Grimm to court over a sole source receiver contract he had won. The judge sided with Regco.

A Mission Orientation

At CEI, one of the engineers sequestered for this project had logged many hours developing custom versions of the RS-111 receiver. He was well aware the DoD bought radios to complete intercept missions. To accommodate the mission-driven intelligence consumers, he argued for a flexible platform, a receiver reconfigurable without resoldering or chassis modifications.

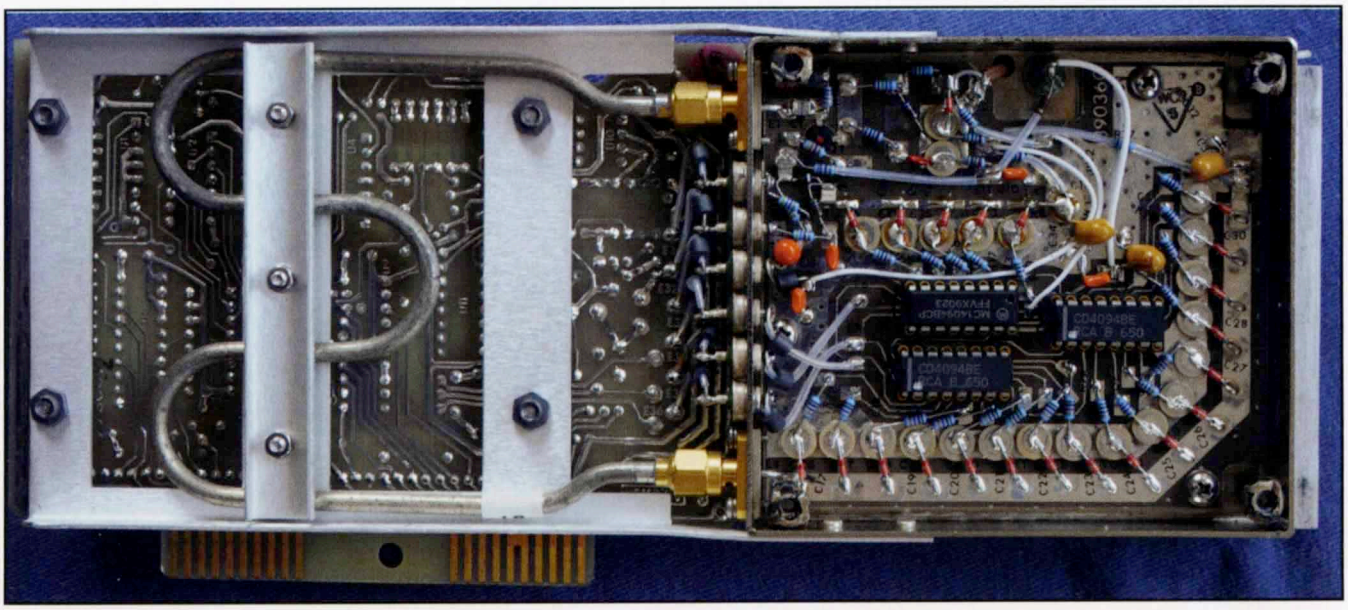
The new receiver was developed with a compartmented warren of card cages, each with extra slots. The main chassis was studded with wire wrap sockets whose long spikes allowed connectors to be plugged in anywhere. The front panel used switches with snap on buttons so labels could be changed as needed. The rear panel was saturated with prepunched connector openings and reconfigurable BNC connectors.

Bumps In The Road

Developing the first microprocessor-controlled, synthesized VHF-UHF receiver turned out to be an extraordinarily difficult task. Circuit demands easily exceeded the specifications of available components. Neither WJ nor Regco had a workable receiver at the end of the contract period. Both companies were granted 30-day extensions.

USNS Observation Island bristling with antennas and loaded with receivers.

Watkins-Johnson's original WJ-8617 prototype. It was the world's first microprocessor-controlled, synthesized VHF/UHF radio. (Photo courtesy DRS Technologies)



The first LO synthesizer from the WJ-8617B. The length of the unusual tuned coaxial transmission line on the left was changed by the switching diodes on the right.

Near the end of the extension, WJ still did not have a functional radio. The engineering director told the staff to focus on completing the front panel and fill the rest of the card slots with untested prototype boards. In this way they could demonstrate the radio's look and feel while saying they just had to iron out a few bugs.

This facade, christened "WJ-8617," was presented to the contracting officer's technical representative (COTR). He was able to spin the tuning knob and see the frequency display change and click switches to change indicators on the otherwise nonfunctional radio. The gamble paid off as the COTR had no antennas or headphones. He was impressed enough to contract with WJ for the initial run of 50 receivers.

Into Uncharted Waters

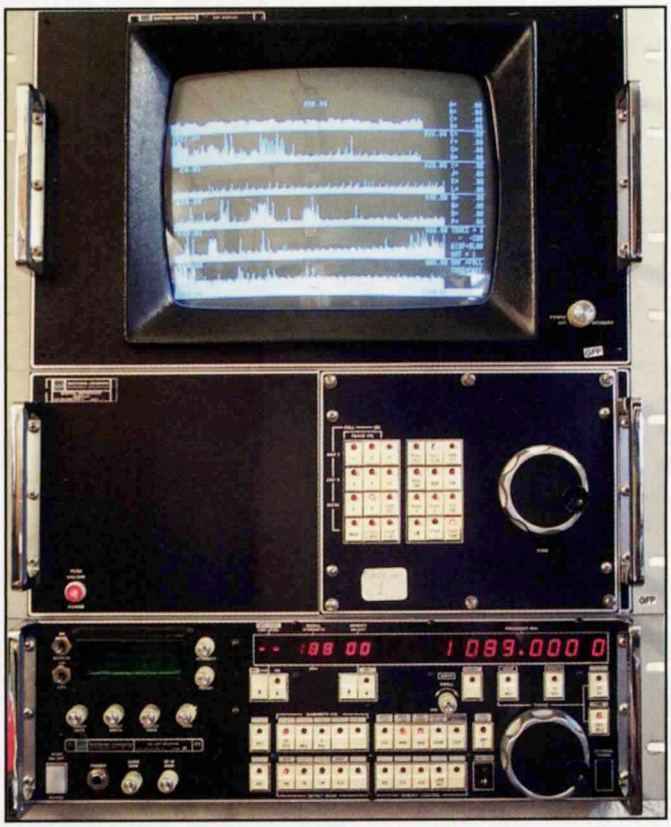
Winning the contract pushed WJ out of the frying pan and into the fire. They had six months to deliver 50 radios and they didn't have a working prototype. Close to one third of the circuit boards had to be discarded and redesigned. In addition, the prototype was designed for 500 MHz to be extended later by a plug-in module. The agency wanted 1000-MHz coverage right away.

Designing a frequency synthesizer to generate 572 to 1052 MHz was extraordinarily tricky. At these frequencies, the only divide by 4 logic chips on the market ran extremely hot (much like an overclocked CPU in a modern PC). By delicately juggling finicky components and design constraints, the synthesizer engineer completed a working prototype.

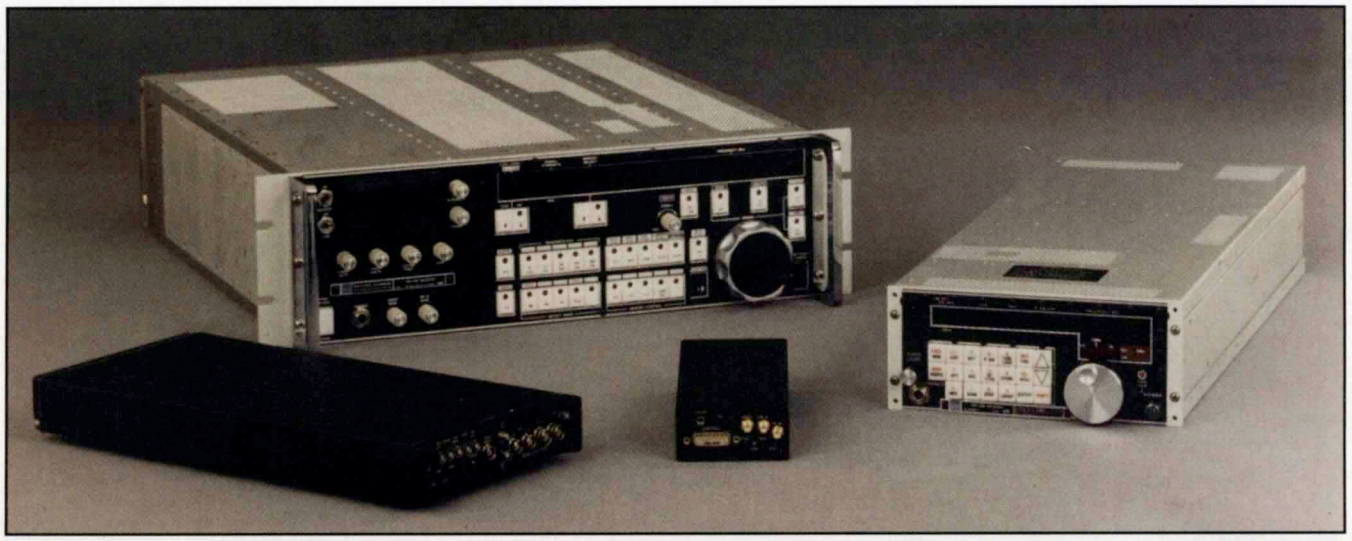
With the deadline fast approaching, the project manager decided to rush the prototype into production before it was adequately tested. An initial run of 25 was delivered to the government in 1977. Almost immediately, WJ received complaints about a defective FM detector. The FM quieting was only -20 dB for the special FM signal targeted in the government's current mission.

The project engineer knew the FM circuit was good. It had been developed, ironically, by Ralph Grimm, years earlier and successfully used in many receivers. Working through the radio, the synthesizer engineer concluded the 1st LO was noisy. Its sensitive 100 MHz/volt voltage controlled oscillator (VCO) didn't need much provocation to produce noise.

WJ had backed itself into a corner. In most respects the radio functioned well, but it was not suitable for the mission. There was too much internal noise to catch the elusive signal. All 25



A WJ-9195 Rapid Acquisition Spectrum Processor using a WJ-8618B-2 (assembled and restored by the author).



A WJ-8617B and its modern descendants (left to right), a Miniceptor, Microceptor, and WJ-8615P receiver. (Photo courtesy DRS Technologies)

units were returned, but not before the DoD sent one to Dr. Ulrich Rohde, of the German electronics firm, Rohde & Schwarz, for testing. Rohde reported it was the worst design he had ever seen. Bill Kunz, who replaced Grimm as CEI division manager, ordered production halted.

Regco Nips At The Heels

Meanwhile, Regco continued developing its own design, the RG-5500, in the hope of securing future contracts. Grimm was a gifted engineer, but was reluctant to incorporate unproven components into his designs. For the digital circuits, he simply hired young engineers. Regco engineers ably designed functional circuits, but controlling the radiated noise from jagged square waves was not an art taught in engineering schools. WJ's experience in this area helped them prevail.

In the heat of the battle, Grimm had a heart attack and died on September 12, 1978, at the age of 54. Regco completed development and contracted with Racal to produce the RG-5500, but it never sold well. After Grimm's death, Regco limped along, becoming a subsidiary of Racal and developing the now rare RG-5540 and RG-5545A receivers before disappearing.

Producing A Hit: The WJ-8617B

WJ was in the hot seat. It had invested an enormous sum in the WJ-8617 and had only $60,000 to show for it. The company wouldn't receive another dime if it didn't deliver a product satisfying the customer.

The synthesizer engineer started out by requesting a spectrum analyzer. Amazingly, CEI designed dozens of commercially successful receivers, some well into the microwave region, without spectrum analyzers. With synthesizers, this was no longer possible. WJ purchased a Hewlett-Packard 141T with the hot, new HP-8554B plug-in, one of the first to be reliable over 1 GHz.

After many long nights away from his family, the engineer realized he had to design a completely new synthesizer. Phase lock loop (PLL) components were crude in the mid-'70s. Phase detectors were fidgety, op amps were noisy, and VCO chips hadn't been invented. The options for creating low noise PLL circuits were limited. The solution he developed, adding a digitally switched transmission line is, to my knowledge, unique in the history of communication receivers.

By itself, a transmission line did not have the requisite Q, meaning the bandwidth was wide relative to the frequency. But if the transmission line is tuned to harmonic multiples, the bandwidth stays the same as the frequency increases, narrowing the effective selectivity. Adding a transmission line to the VCO dramatically quieted the oscillator phase noise and reduced its voltage sensitivity to 12 MHz/volt. The new circuit improved the FM quieting to -55 dB, more than enough to satisfy the customer.

Monkeys On The Production Line

There was one hitch. Tuning a transmission line to exact multiples of a 1/4 wavelength between 572 and 1052 MHz required incredibly precise construction. The digital circuit controlled the length by switching 16 PIN diodes spaced 3/8 of an inch apart. Tiny dimensional variations in construction required a unique switching pattern for each radio.

Initially, it took eight hours to find the switching pattern for each radio by hooking it to a PDP-11 that switched the 16 diodes as though controlled by monkeys let loose on a keyboard. When the correct sequence was discovered, it was burned on an EPROM and the radio could ship. As production continued, patterns emerged that cut the search time to five hours.

Quality control on the production line revealed that the handwork of assembler Anna Lowe, a post World War II German immigrant, was so precise, only three sets of EPROMs were needed to properly tune her synthesizer circuits. Thereafter, she was the only assembler entrusted to construct this circuit.

Radios Out The Door

The prototype WJ-8617 was repackaged and sold as an "A" model. Contracts for a dozen variants were underway in 1980. They worked well, except on the mysterious FM signal once avidly sought by the government. After introduction of the "B" model, sales skyrocketed. By 1985, over 30 variants had been ordered. Total sales eventually reached into the thousands.

Released in four models, WJ-8616, WJ-8617, WJ-8618 and WJ-8619, only the WJ-8617 and WJ-8618 are common. The WJ-8616 is somewhat rare, and less than a dozen remote-control WJ-8619 units were manufactured.

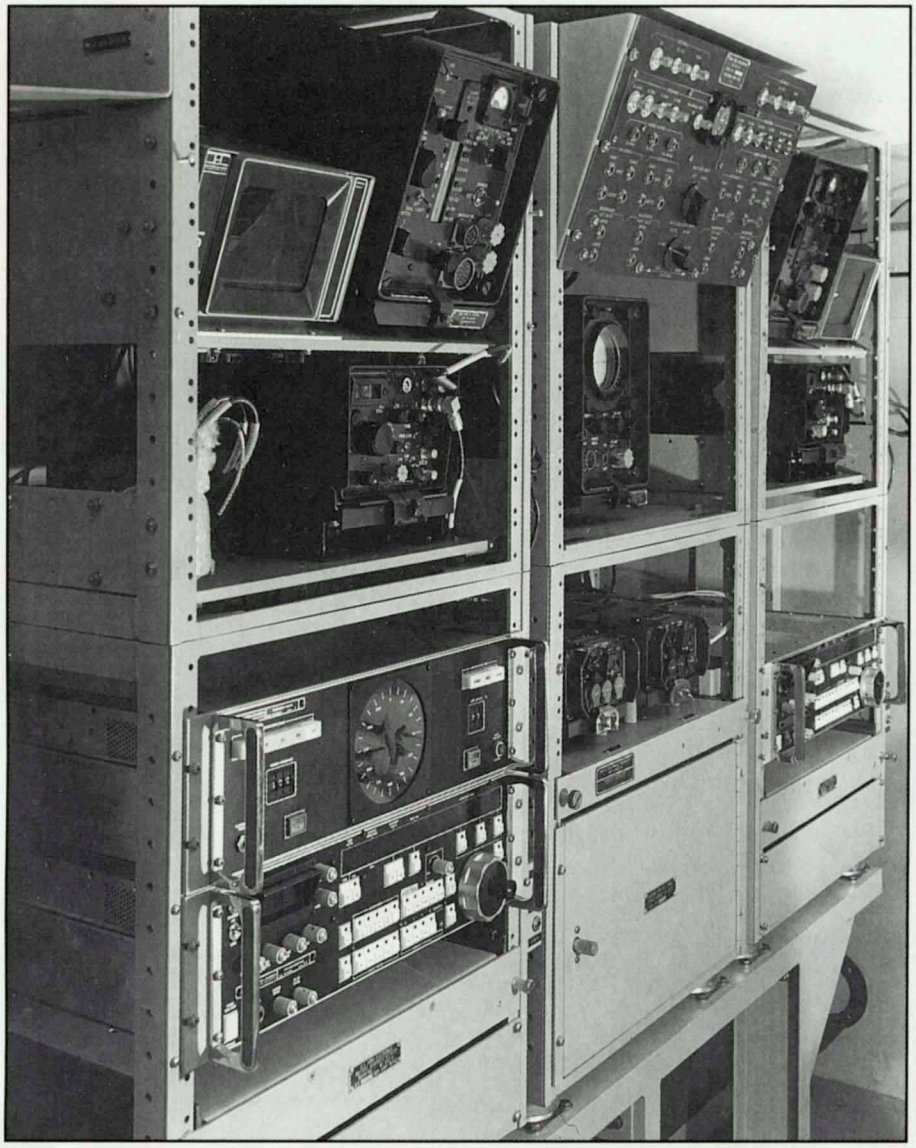
The WJ-8618 is a Tempest version of the WJ-8617. They were sold only to the U.S. government. Everyone else received the non-Tempest version. The main difference is better shielding and bypassing on the input and output connectors in the Tempest version. Much greater variations exist within each model. For example, the WJ-8617B(S1) has a different processor and control architecture with more flexibility than the WJ-8617B.

In all, there are 59 variants of the WJ-8617 and 35 variants of the WJ-8618; and within these variants, there were additional special orders. Many cards and circuits are identical across all versions, but many are unique and work only in specific radios. Distinguishing one variant from another can be challenging. Repair and configuration of these radios can elude even experienced radio technicians.

A full discussion of the variations found in these radios is beyond the space available in this magazine. A few additional details can be found on the author's website, http://waktins-johnson.terryo.org.

Cold Warriors

The WJ-8618B receivers at Marienfelde ran 24/7 every day of the year. The



An AN/TRQ-32 Teammate with two WJ-8616A receivers, WJ-8971 DF unit, PD-602-6 panoramic displays and pairs of R-1444 and R-1518 receivers. (Photo courtesy DRS Technologies)

The Watkins-Johnson WJ-8617B, widely used throughout the Cold War.

room was kept at 55°F to enhance the reliability of the radios. Between transmissions, the cold aluminum tuning knobs were in constant use, leading the German women to ask visiting WJ engineers for a heated tuning knob.

Pictures of Marienfelde are rare as any passerby with a camera was likely to be stopped and their film confiscated. Surprisingly a photo appeared in a WJ catalog from the 1980s. The equipment was removed in 1991 and the base was closed in 1992. All 14 buildings were razed in 1996. Most of the activity there remains unknown.

The missions of the *USNS Observation Island*, one of the two Missile Range Instrumentation Ships that are part of the 26 ships in Military Sealift Command's Special Mission Ships Program (www.msc.navy.mil/inventory/ships.asp?ship=133), are as closely guarded as those at Marienfelde. The ship is well known for its role in development of the Polaris missile and as a platform for the Cobra Judy radar. Very little official information is available on its activities from the mid-'70s through the '90s. By the time WJ engineers boarded her in the 1980s to work on the WJ-8618B receivers, she was based in the Pacific Ocean. Not much else is known from this period.

Near the end of WJ-8618B(S1) production, the radio was installed in a modified LAV christened the Mobile Electronic Warfare Support System (MEWSS). The Marine Corps accepted delivery of 12 of these in 1989. *Jane's Military Communications* says "MEWSS provides targeting information to the battlefield commanders." Various configurations of this vehicle were still in use within the last 10 years. A MEWSS Facebook group shows one with a WJ DF antenna onboard a Landing Craft Air Cushion off the coast of Somalia in 2001. Other information is scarce.

In Perspective

The first WJ-8617B sold for approximately $20,000 without options. Fully tricked-out versions from the late '90s cost over $50,000. Records are classified, but WJ engineers believe around 7,000 were made. If you do the math, this is clearly a successful product. The DoD may occasionally buy overpriced toilet seats, but as we have seen, they will not pay for mass production of inadequate radios.

In the late '70s, Dr. Rohde scorned the WJ-8617A. Even with this inside peek at the competition, Rohde & Schwarz needed several years to introduce a radio with comparable circuitry. Despite ample evidence to the contrary, their website still claims the ESM-500, introduced in 1980, was "the world's first radio surveillance receiver that had fully microprocessor-controlled functionality."

If you are contemplating a used radio in this series, *caveat emptor*. Like a used Ferrari, very few people can handle the setup, operation, and maintenance of these complex radios. If you can't fix it yourself, there are few repair options in the United States and almost none overseas. But if you get your hands on one, you will be operating a vital part of Cold War history. These radios served their country in countless obscure corners of the world.

The author wishes to thanks DRS Technologies for access to its Watkins-Johnson archives.