NAVAL COMMUNICATION STATION AT WHEELER MOUNTAIN, WASHINGTON

by
C. E. Williams *and* V. C. Marsolan,
Electronics Engineers, Puget Sound Naval Shipyard

The establishment of a primary v-l-f transmitting station to afford maximum coverage in North Pacific and Alaskan areas has been under consideration by CNO for several years. Upon receipt of CNO authority, the Bureau of Ships, in August 1946, directed that Commander, Puget Sound Naval Shipyard proceed with surveys for determination of the most suitable and practicable site in the Pacific Northwest. A preliminary survey of Alaskan areas showed that construction and maintenance costs for such a radio station in that area would be excessive, that transportation of materials and fuel would be difficult and involved and that full-time operation could not be depended upon.

The projected station is to be established primarily for v-l-f "FOX" broadcasts on frequencies between 14.5 and 26.2 kc, using either dual 500-kw units for independent or simultaneous operation on separate antenna halves, or with maximum power of 1000 kw. The basic requirements for the siting of such an installation are as follows:

1—Reliability of communication and control circuits to district headquarters.

2—Accessibility to highways for logistic support and the availability of primary power sources.

3—Sufficient area in a valley between mountains to permit erection of 10 catenary spans 6000 to 8000 feet in length (at maximum heights) across the valley and to construct the transmitter and helix buildings.

4—Effective radiation of high power from the catenary spans at the specified frequencies.

5—Availability of land and economy of construction.

6—Location distant from centers of population, to avoid radio interference with other services.

7—Suitability of site for underground construction if eventually required.

A survey of the Northwest was carried on in the fall of 1946 for the selection of a site which would meet the above requirements. Within a radius of 100 miles of the district headquarters in Seattle there are more than 100 valleys with sufficient depth to accommodate the catenary antenna system, but of these, less than half could meet the requirements of accessibility to highways and primary power sources. Detailed surveys were made at about forty tentative sites and, after evaluating the merits and demerits of these, it appeared that the Wheeler Mountain site would be the most satisfactory; this site was so recommended by Commander, Puget Sound Naval Shipyard, to the Bureau of Ships. Representatives from the Bureau visited the proposed site in March 1947 and were pleased with the site's possibilities. Following endorsement of the proposed site by the Bureau of Ships, CNO approved the location subject to confirmation of the electrical properties of the area by suitable tests.

The Wheeler Mountain site is located in the foothills of the Cascade Range, approximately 50 miles airline from Seattle and 11 miles from Arlington, the nearest town. The area map, figure 1, shows the Puget Sound basin, the location of cities, towns, highways and the Wheeler Mountain area. The transmission path from the Wheeler Mountain site to seaward traverses 20 miles of lowlands to salt water and thence to sea over Puget Sound, the Straits of Juan de Fuca or the Straits of Georgia. A minimum area of 7000 acres is required to accommodate the installation and associated facilities.

The chief feature of the site is the valley cross-section and mountain slopes which permit erection of the catenary antenna between north anchorages on Wheeler

FIGURE 1—Navy Communication Station at Wheeler Mt., and proposed v-h-f/u-h-f communication links.

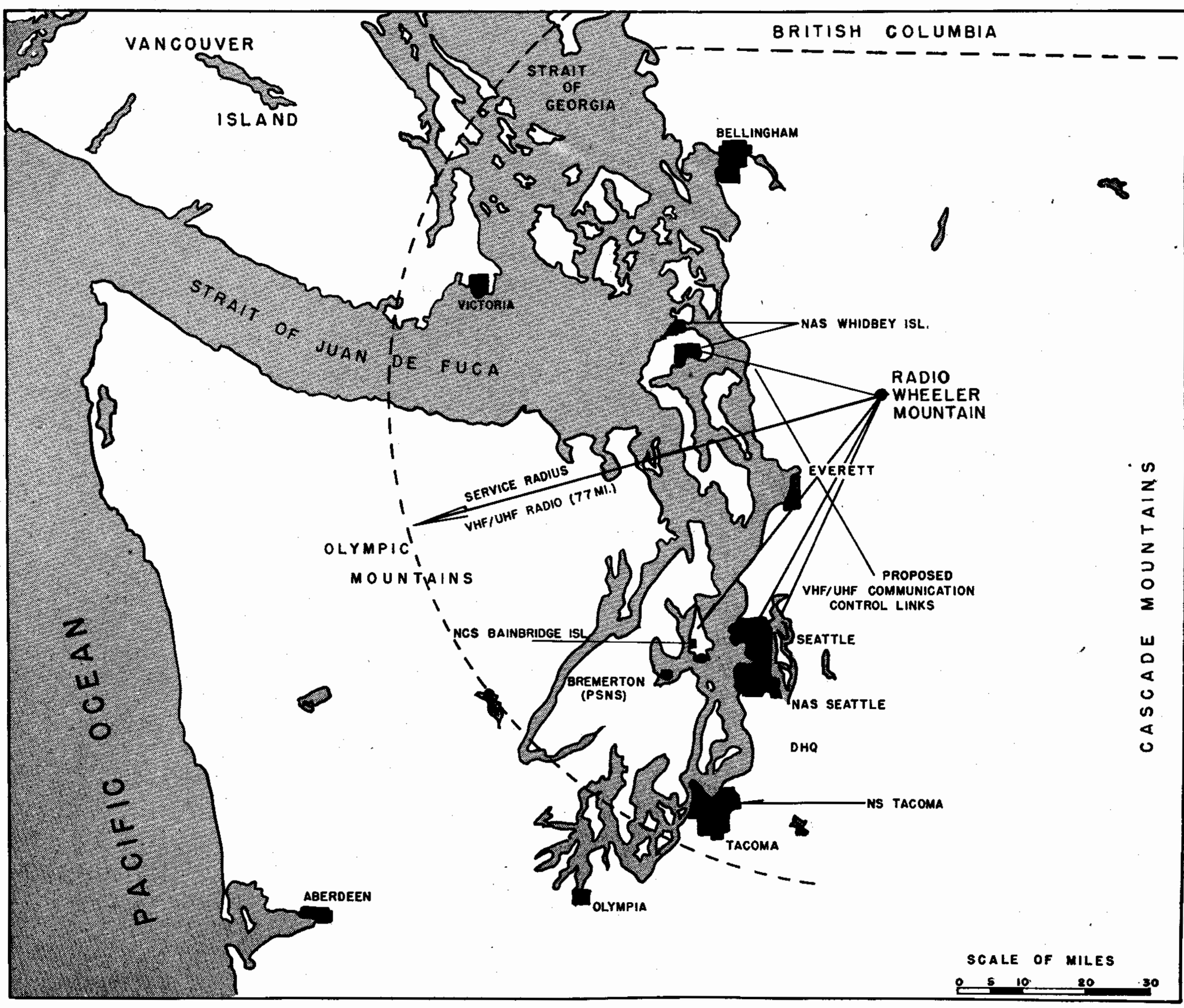

FIGURE 2—Jim Creek Valley, with Wheeler Mt. on left and Blue Mt. on right.

Mountain at elevations averaging 2788 feet above sea level, and south anchorages on Blue Mountain at average elevations of 2626 feet; Jim Creek in the valley is at an average elevation of 735 feet. This results in a mean difference between valley floor and anchorage sites of 1972 feet and, by use of 200-foot towers to be erected at each anchorage, the average height will be increased to 2172 feet.

Figure 2 shows the valley antenna area, with Wheeler Mountain at the left and Blue Mountain in the right foreground. The antenna area is generally clear of merchantable timber, having been partially logged off on the Blue Mountain side and on the lower portions of Wheeler Mountain, and burned off at the upper elevations. In order to prepare the antenna area for erection of antenna spans and the installation of a buried ground system considerable clearing of underbrush and vegetation will be necessary, as well as removal of debris and fallen timber which would be a fire hazard. A typical logged off area, such as prevails on Blue Mountain, is illustrated in figure 3.

Figure 4 shows the face of Wheeler Mountain. The six northern anchorages will be located just above the upper patches of exposed rock and within the present timber. Adequate foundation for all towers and structures is insured by underlying rock which is close to the surface or is exposed in most locations.

An abundant water supply is available at all times from Jim Creek which flows through the site, from numerous smaller creeks and springs on the mountain sides, and two large lakes which serve as a reservoir and feed Cub Creek—a tributary of Jim Creek—which enters Jim Creek near the area to be used for residential and service buildings. The residential and service building areas will occupy approximately 100 acres of land immediately adjacent to the west end of the main valley. The ground in this area is partially cultivated, with some grazing land and the remainder covered with alders, maples and second growth fir, hemlock and cedar. Because of its setting in the foothills, with abundance of natural life, wooded areas, lakes, streams, and ample land for cultivation, yet within 30-minute travel time from Everett, a city of some 32,000 population, this station when completed, should prove to be very appealing to service personnel who enjoy outdoor life.

Very extensive and detailed surveys have been conducted to facilitate planning of the station in general, and in particular the antenna-ground system. Because of the lack of topographical survey data upon which to base the antenna span locations it was necessary to conduct a complete survey of all the valley area and at possible anchorage positions, involving about 2000 acres, most of which lie in heavily-wooded areas or on precipitous mountain slopes.

In order to determine the radio-electrical properties of the antenna site, a single wire antenna was erected at a typical span position, with a temporary ground system on the mountain slopes and in the valley. Following this, measurements were made of the antenna characteristics and of field intensities throughout the north-western part of Washington and out to sea through the Straits of Juan de Fuca. A more complete description of the test antenna, ground system and transmitter and the ground measurements follows.

Ground resistance measurements were conducted in the antenna area by the following methods:

1—By obtaining the value of resistance between each pair of driven rods (electrodes) spaced 100 feet apart and arranged in form of an equilateral triangle and computing the ground resistance from the formula $R_X = \frac{R_1 + R_2 + R_3}{2}$. Values of resistance were obtained with a ground megger and with a Navy Model OJ 1000-cycle bridge.

2—By use of a ground megger and four electrodes spaced 100 feet apart in a straight line. In this method the value of resistance obtained from the megger is proportional to the voltage drop between the two inner electrodes directly in the path of a current flowing between the two outer electrodes. From this data the ground resistivities in ohms-per-cubic-meter were computed.

3—By measuring directly the current and voltage in a 60-cycle alternating current circuit consisting of an a-c generator, step-up transformer and a pair of No. 6 bare copper wires 100 feet in length separated 10 feet and buried 20 inches deep.

In general, results of methods (1) and (2) were in agreement and in some instances were proportionate. For example, where a high ground resistivity was encountered there was also a high value of resistance between electrodes. Because of the inaccessibility along the mountain slopes only three tests employing the 60-cycle method were performed. Values of resistance obtained by this method varied from 100 ohms in the valley floor to 175 ohms along the mountain slopes. With the 4-rod ground electrode method, a resistance of 367 ohms per cubic meter was typical of the valley.

The location selected for the test transmitter was more than a mile from the nearest abandoned logging road in the valley; thus it was necessary to construct an access road and to clear and grade a small area for the mobile equipment, power units and temporary housing. Additionally, old logging roads were opened up and extended to the top of Blue Mountain, the south anchorage of the test span. A swath was cut in the timber across the valley between the two anchorages. A temporary road was cut to the 1250-foot level on Wheeler Mountain, from which point the antenna tail cable was hauled by hand to the 2700-foot level and secured. The antenna, comprised of a single span of No. 6 Copperweld (40%) wire, 4500 feet in length with a No. 10 harddrawn copper vertical downlead at mid-point, was assembled on the ground. Steel tail cables completed the remainder of the span which totaled 7520 feet. The antenna was then hauled into position

FIGURE 3—Blue Mt., looking up from the 1500-foot level and showing nature of the terrain and logged-off areas.

by using the winch on a bulldozer on Blue Mountain. At a working tension of 1500 pounds this afforded a "T" antenna with a physical height at the center of approximately 1500 feet.

Although the ground conductivity was fair, a ground system was installed for the test transmitter. It consisted of a grid of 10 bare copper wires extending approximately 3000 feet up each mountain slope beneath the test antenna and 5 similar wires extending 2500 feet up and down the floor of the valley along Jim Creek. Ground rods were driven at the ends of each conductor and at many points in the vicinity of the test transmitter.

At the test site two temporary cabins were assembled for shelter of mechanics and test personnel, and a Model MBS communication unit was brought in for maintenance of communications with the mobile units used for measurements of field intensities. The 200-watt v-l-f test transmitter was housed in a surplus trailer formerly used as an airfield portable control-communication unit. Power was obtained from either of two 5-kw power units. The facilities described are illustrated in the accompanying photograph, figure 7.

Two Model OG field intensity measuring units enclosed in light wooden structures on flat body trucks were driven to various points within range of the transmitter, where measurements were made on 15.0, 15.55, 19.4 and 28.0 kc. Additionally, one of the Model OG field intensity measuring units was removed from a truck and placed on board a seagoing tug for observing field intensities down the Straits of Juan de Fuca and off the West Coast. Messrs R. H. Berkheimer and V. C. Marsolan, Electronics Engineers, supervised these operations.

FIGURE 5—A typical winter scene at Jim Creek.

The purposes of the field intensity measurements were to determine the effective heights and the radiation resistances of the test antenna at various frequencies and to secure information on signal attenuations resulting

FIGURE 4—Location of six northern anchorages and v-h-f site (indicated by arrow).

from the character of the surrounding terrain. Moderate attenuation of signal strength was experienced in the mountainous areas of the Cascade and Olympic Ranges, especially at the highest frequencies; in the other areas the attenuation was negligible. Typical values of effective height and radiation resistance of the test antenna derived from these measurements are as follows:

Freq. (kc)	*Effect. Hght. (meters)*	*Rad. Resist. (ohms)*
15.5	201	.173
19.4	205	.278
28.5	213	.622

Characteristics of the test antenna were measured with a Navy Model OH impedance bridge at frequencies of 25 to 75 kc. A General Radio Signal Generator, 0 to 40 kc, was employed in conjunction with a Model RAK-4 receiver as a detector and the decade box of the Model OH impedance bridge to measure characteristics of the antenna at the lower frequencies of 14.5 to 25 kc. The results of the latter method were substantiated by the direct substitution method of inserting resistance and reactance between the output of the test transmitter and the antenna.

Data obtained from field intensity observations and from the characteristics of the test antenna furnished essential information for the design of the final antenna and ground system by the contractor.

The plans presently being prepared by RCA Communications provide for an antenna system which will, in all probability, exceed in size any antenna previously constructed. It will consist of 10 catenary spans averaging 7550 feet in length, with a minimum length of 5640 feet and a maximum length of 8740 feet. The lengths of the active radiators in the flattop array will vary between 4000 and 5500 feet and the average separation between radiators in each of the 5-wire sections will be 360 feet. The separation between the antenna halves will be in the order of 800 feet.

The span conductors will be stranded cables; each conductor will be composed of 37 strands of No. 7 Copperweld, extra high strength (total diameter approximately one inch), insulated from steel tail cables by 2100-pound insulators. Although these spans have a calculated breaking strength of 89,000 pounds, sufficient sag will be allowed to maintain the working tension at or below 45,000 pounds when loaded with ½-inch of ice and a wind pressure of 8 lbs. per foot of projected area of span cables. The horizontal feeders from the transmitter to the terminals of the vertical downleads will consist of hollow conductor cables 0.920 inches in diameter. The feeders will be supported by 125-foot steel towers at the junction points of the vertical downleads. Additional antenna height will be gained by installation of 200-foot steel towers at anchorage positions.

The v-l-f transmitting equipment (figure 9) comprises a Type AN/FRT–3 high-power v-l-f dual 500/1000-kw radio transmitter incorporating the latest developments in electrical features and circuits which are especially designed by RCA-Victor Company to fulfill the military and technical requirements of the Naval service for a shore-based radio station. Two 500-kw radio-frequency sections are arranged symmetrically about the center line of a U-shaped equipment area to afford an unobstructed view of all indicating instruments, local controls, and equipment sections of the transmitter proper from the operator's supervisory console position.

The design of the transmitting enclosure features the latest developments in industrial styling. Each section compartment is totally enclosed in aluminum shielding, bolted to aluminum structural members. Electrical interconnections are enclosed in shielded metal raceways and terminated at appropriate terminal boards. A fabricated steel enclosure containing instruments, controls, observation windows and access doors provides an outer wall facing the operator's console. A color scheme based upon a harmonious combination of light and

FIGURE 6—Blue Mt. slope, showing standing timber that will be removed from the antenna area.

dark cobalt blue trimmed in stainless steel enhances the attractiveness of the entire transmitter.

Units of the transmitter proper, the watch operator's supervisory console and the master frequency bay are located on the operating level or the main deck of the transmitter building. In the lower story directly below is the machinery area containing cooling equipments, power equipments and utility spaces. Unit assemblies such as rectifiers, exciters and high-power amplifier elements are designed as self-contained and self-supporting units of welded or formed sections supporting vertical chassis-type panels with surface mounted components. This method of construction, evolved from the broadcast transmitter field, provides great flexibility and ease of maintenance combined with minimum space requirements. Since this type of construction lends itself to modern production methods, considerable economy is realized.

Basically, the electrical features of the transmitter consist of duplicate oscillator units, each containing a simple master oscillator held in step with an extremely stable master frequency control system; F.S.K. with provision for a deviation of plus or minus 25 cycles is included. Following the oscillator stage is a duplicate exciter chain of untuned stages requiring no adjustment over the operating frequency range of 15 to 35 kc. These stages drive either or both power amplifiers through a driver transformer system which requires no adjustment.

The duplicate 500-kw power amplifiers are driven by either of the duplicate exciters to maintain correct instep phasing of the output currents. Each power amplifier consists of an untuned grid filter-network, bias supply, two water cooled tubes in push-pull, and a plate tank circuit having individual variometers and a balanced bank of fixed oil-mica capacitors with a selective switching arrangement for obtaining optimum Q over the frequency range. Energy is transferred to the antenna system through an output coupling inductance and antenna helix apparatus associated with each of the duplicate power amplifiers. Each antenna output system is resonated by means of a remotely controlled motor-operated variometer and is separately shielded to permit grounding of either antenna system without disturbing the operation of the other.

The transmitter power-amplifiers are designed to deliver 1000 kw of power into the ten-span catenary antenna, and the calculated radiated power output is expected to be approximately 400 kw at 14.5 kc, increasing to 600 kw at 35 kc.

The main transmitter building will house the AN/FRT-3 transmitter and associated equipment, offices, two helix rooms and other facilities. The transmitter and control consoles will occupy a space 60 by 80 feet with 20-foot ceiling height on the second floor. Two rooms about 75 feet square and 75 feet in height located directly back of the transmitter will house the antenna coupling and loading circuits. The transmitter will be air conditioned, with blowers, heat exchangers, circulating pumps for both pure and raw water for cooling vacuum tubes, etc. located immediately below the transmitter spaces. Provision will be made for maximum utilization of low temperature water from Jim Creek

FIGURE 7—Test transmitter site.

CONFIDENTIAL

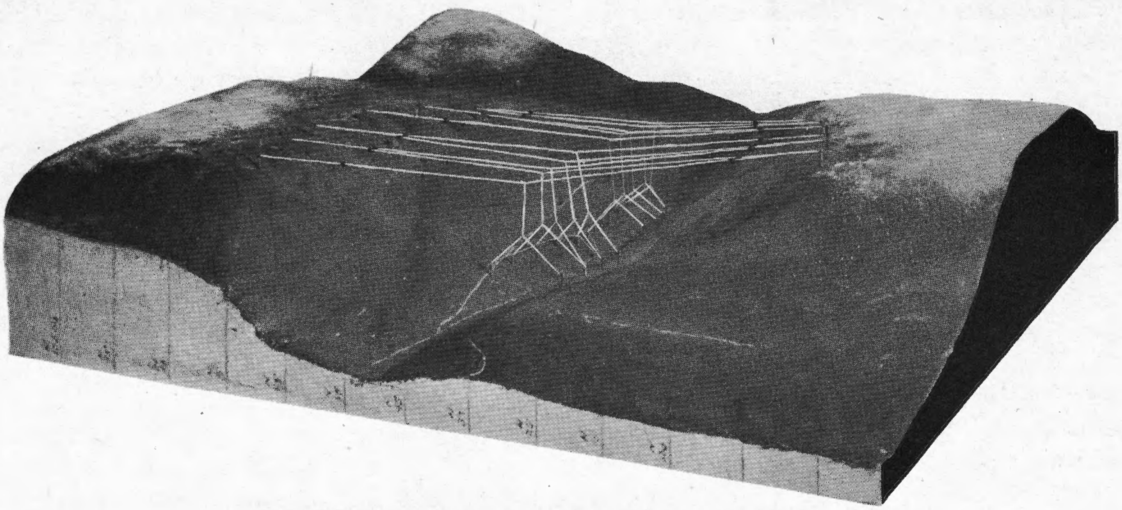

FIGURE 8—Preliminary mock-up of proposed antenna.

for cooling purposes. Included on the lower floor will be electrical and mechanical shops and the main rectifier transformers and electrical distribution system for the building. Provisions will be made for testing facilities, vacuum tube and small parts storage, and offices on the upper floors. The structure will be completely fireproof with special provision for bonding and grounding of all metallic materials because of the high intensity radio-frequency field in proximity to the antenna and feeder system.

All major power sources in the Northwest operate into a common distribution net, thus the combined generator capacity exceeds 3,000,000 kva, at the present time. For operation of the Wheeler Mountain Station, primary power probably will be obtained from the nearest feeder which is about 11 miles distant, and delivered via a new high-tension line to a substation within the reservation. This substation will have a capacity of 3,000 kw with provision for transferring the station load to auxiliary generating units, which will be capable of carrying the full station load continuously. These standby units will be in duplicate; thus there will be installed two 2500-kva diesel-driven generators for supplying the transmitter plate rectifier and keying loads, and two 600-kva diesel units for supplying vacuum tube filaments and general station loads, about 300 kw of which will be for lighting and general utilities.

Although construction of the v-l-f transmitter has been underway by RCA-Victor for over a year, and site surveys and tests are practically complete, the major part of the program, which is the development of the site, is just beginning. An initial construction appropriation of $4,000,000.00 is now available and an additional sum of $3,000,000.00 is expected to follow. These funds will be used for construction of roads to the antenna anchorages, erection of steel towers, clearing of 2,000 acres in the antenna area, grading of building sites and improvements to Jim Creek channel, building of bridges, dams, water and sewage systems, and construction of buildings. Because of the high potential gradient in the antenna field and large ground currents in the area, special attention must be given to the type of building and electrical construction to avoid creation of fire hazards or injury to station personnel. In addition to the main transmitter building previously described, the building program calls for construction of a diesel electric power plant, shop and service buildings, storehouses, barracks, quarters for married employees, recreation building and outdoor facilities, garages for trucks, cars and special station maintenance equipment, and a fire station. This will be followed by installation of the radio ground system and construction of the main antenna. This project including equipment will ultimately involve an expenditure of close to $10,000,000.00.

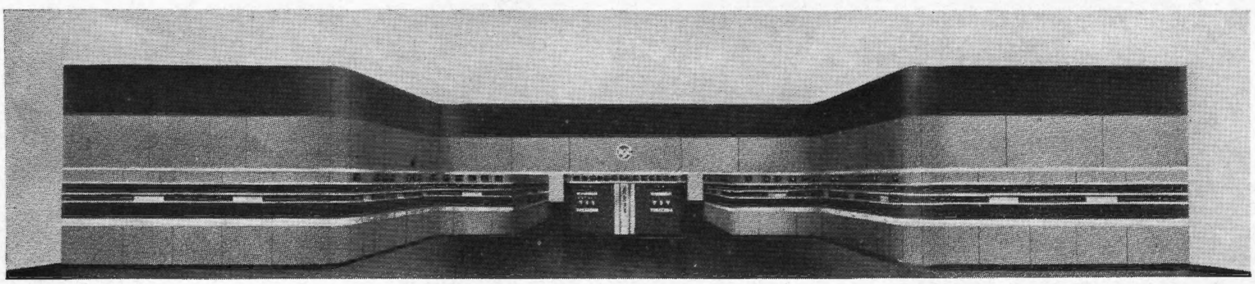

FIGURE 9—1000-kilowatt v-l-f transmitter.

RADIO WHEELER MOUNTAIN

PROPOSED RADIO RELAY CENTER

by
J. M. PATERSON,
Electronics Engineer, Shore Section, Puget Sound Naval Shipyard

Primarily the new Navy Communication Station, Wheeler Mountain, will be a high-powered very-low frequency transmitter station. The site, however, is also admirably suited for use as a focal point or relay center for radio links operating at frequencies limited to line-of-sight transmissions. The proposed site for the relay station is at an elevation of approximately 3000 feet and offers satisfactory radio transmission paths to nearly every Naval activity in western Washington. Its proposed location is one mile north and 2400 feet above the low-frequency transmitter building. The presently planned facilities will be reached by a branch from the access road to the antenna anchorages on Wheeler Mountain; the equipment will be housed in a concrete building.

The basic communication control link network proposed for Radio Wheeler Mountain is outlined on the location map, figure 1, of the preceding article. The present v-h-f repeater station at Paine Field, which links the Naval Air Station, Whidbey Island, with the Naval Air Station, Seattle, would be replaced by the relay center at Radio Wheeler. New links would be established from Radio Wheeler to the Navy Communication Station, Bainbridge Island, and to the Thirteenth Naval District Headquarters, Seattle. An extensive system of terminal equipment would provide the means for interconnecting as many voice, teletype, telegraph, or control circuits from the remote stations as may be required. At least a portion of the control and switching system would be operated automatically from remote stations.

The terminal equipment and operating spaces are to be so designed that new radio links may be easily incorporated into the basic network when the need arises. This feature will be extremely valuable in the event that the acquisition of additional sites for Naval activities become necessary, for it will greatly reduce the problem of communication with these sites.

The same feature which makes Radio Wheeler Mountain a good site for a Communication Control Link Relay Center also makes it a good site for a Ship-Shore Radio Relay Station. No present Navy-controlled reservation in the Puget Sound area even approaches the elevation offered by this site. Innumerable islands and peninsulas in Puget Sound introduce a very serious shadow effect on signals originating from stations at lower elevation. The extent of shadow effects on signals from Radio Wheeler will be less because the intervening land areas are relatively insignificant in elevation. A dependable service radius of 77 miles is anticipated for this station, based on the accepted method of computing v-h-f coverage and taking into consideration refraction of waves at very high frequencies. The approximate area over which reliable coverage can be expected is indicated by the arc shown on figure 1 of the preceding article on the Wheeler Mountain Station.

To further utilize the height advantage offered by Wheeler Mountain, the eventual installation of a long-range air surveillance radar station is contemplated at a site which will be set apart from the v-h-f/u-h-f relay center to reduce the likelihood of interference to radio circuits. A means of providing remote control and of repeating the indications to remote plan position indicators via radio link will be required. Remote stations would probably be located at Naval Air Station, Seattle, and Naval Air Station, Whidbey Island, where present radar equipments are extremely limited in range by heavy ground return from surrounding hills and obstructions. This project will be one of the later phases of development of Radio Wheeler Mountain.

Type of Approach	Last Month	To Date
Practice Landings	8,332	211,298
Landings Under Instrument Conditions	201	9,097