RADIO TRANSMISSION CHARACTERISTICS IN OREGON OF MEDIUM AND VERY-HIGH COMMUNICATION FREQUENCIES

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FOREWORD. The use of radio as a medium of communication by police departments, fire departments and other emergency services whose activities involve the protection of the public health, life, and property has become widespread. It has become such an important factor in the field operations of such services that their efficient functioning without radio communication would now be a virtual impossibility. In recognition of the importance and requirements of the various emergency services, the Federal Communications Commission has allocated for their exclusive use a large number of channels in the medium and very-high frequency portions of the radio spectrum.

Early systems were established by municipal police departments for the purpose of rapidly dispatching mobile units to the scene of a crime or accident. Such systems usually comprised a central station transmitter, operating in the medium frequency portion of the spectrum between 1.6 and 2.5 megacycles per second, over which information intended for the receiver-equipped cars was "broadcast". History records many instances of a criminal being caught in the act of commission of a crime because of the rapid response of a "prowl" car to the alarm. Prior to the installation of one-way radio dispatching systems, it was necessary for a patrolman "walking a beat" to call his headquarters for instructions at a prearranged time or in response to a visual call signal.

The users of one-way dispatching systems soon became aware of the fact that two-way communication between the mobile units and their headquarters was necessary to make the system completely effective. It was found that the operator of the mobile unit sometimes missed a call because he happened to be out of his car at the scene of an accident or because the car was located in a noisy or weak-signal area when the call was transmitted. Frequently an ambulance or assistance was needed, making it necessary for the officer to locate a telephone to call his headquarters.

Because of the necessarily restricted antenna height available for mobile applications, mobile transmitting equipment was developed which operated in the very-high frequency portion of the spectrum between 30 and 40 megacycles per second. By locating the headquarters receiver at some elevated site overlooking the city, it was found possible to receive satisfactorily signals from mobile units operating within all, or a major portion of the area protected.

The advantages of two-way radio communication with mobile units were very evident to many emergency services. New systems were installed almost as rapidly as equipment became available, until the assigned channels became fully occupied and finally overcrowded. Interference between adjacent areas became a serious problem, even when the interfering transmitters were operating on adjacent or alternate channels. The state of the art did not permit the design of receivers sufficiently selective to reject off-frequency signals of high intensity. During certain periods of the solar cycle, particularly during the summer months, it was found that the refracted sky-wave interference between areas separated by a distance of 1500 to 2500 miles became very severe.

The introduction to the art of the technique of frequency modulation provided a partial solution to the interference problem because of the well-known "capturing" effect of a signal having an intensity exceeding that of another signal on the same frequency. The fact generally is conceded that it is possible to design a frequency modulation receiver having an inherently greater sensitivity than a comparable receiver of amplitude modulated waves. Because of this and other factors, it was found that the dependable service range of a mobile unit employing frequency modulated equipment frequently exceeded that of its headquarters station using medium frequency amplitude modulated equipment. Because of the differences in propagation characteristics of the medium and very-high frequency waves, the range of the mobile units was more consistent throughout the diurnal and seasonal cycles.

The headquarters station equipment, as well as the medium frequency mobile receivers operated by some agencies had reached the state of obsolescence through years of use during the development of the art. It was an obvious and natural step to replace the obsolete equipment with frequency modulated very-high frequency units. Following such replacement, the user usually found that he possessed an efficient communication system. The interference problem due to the overcrowded condition of the available channels, however, became generally worse, partially because of the installation of additional systems and partially because of the increased severity of the sky-wave interference due to the refraction phenomena accompanying the solar cycle during the years 1940 to 1948 inclusive.

Techniques and components developed during World War II have made practicable the use of the very-high frequencies in the 150-160 megacycle band of the radio spectrum. Many systems have secured relief from interference by replacing their 30-40 megacycle amplitude modulated equipment as it reached obsolescence with frequency modulated equipment operating in the 150-160 megacycle band. Often, more complete coverage of some areas is secured by the higher frequency systems due to the differences in propagation characteristics, which tend to eliminate or alleviate by operation in the 150-160 megacycle band the weak-signal areas encountered in the 30-40 megacycle band.

The Oregon State Highway Commission installed a one-way dispatching radio network in 1936 to provide communication with mobile units operated by its field engineers and maintenance personnel and those operated by members of the Department of State Police. The system operates on the medium frequency channel of 1706 kilocycles. The majority of the approximately 200 mobile units are equipped only with receivers, however, 25 of them are equipped with transmitters operating on the medium frequency channel and 10 with amplitude modulated transmitters operating in the 30-40 megacycle band.

The experience gained through the use of the equipment since

1937 has indicated that very satisfactory one-way service is provided over large areas by the medium frequency equipment. For reasons that will become apparent in the following discussion, the further attempt to use the medium frequency channel for mobile transmitters has been abandoned.

The obligation to the travelling public of the Oregon State Highway Commission and the Department of State Police to provide safe highway travel demands that the field personnel and the administrative staffs coordinate their efforts during emergency situations. Such coordination is impossible without adequate and dependable communication. To achieve this result, it is tentatively planned to equip each mobile unit which now has only a receiver installed in it with a mobile transmitter.

The recent trend of thought of communication engineers has been directed toward the higher frequencies to such an extent that many of them have condemned the medium frequency bands as being useless and obsolete. The problem involved in providing dependable two-way radio communication between mobile units and their headquarters stations in a city is quite different from that encountered in covering a large state. Satisfactory state-wide very-high frequency systems have been installed in several eastern states; however, the area involved in such systems is in many cases less than that of one of the counties in the state of Oregon. In addition to the greater areas over which communication must be effected, the terrain of the state of Oregon is generally unfavorable for the satisfactory propagation of very-high frequency energy.

It has been found that the propagation of waves in the very-high frequency portion of the spectrum over rugged terrain can not be predicted with a reasonable degree of accuracy. A wide variation of service areas has been experienced with equipment operating in both the 30-40 and 150-160 megacycle bands in different sections of the United States. Each band has exhibited desirable and undesirable characteristics. In order that the proper choice of operating frequency for the proposed mobile units could be made, it was decided that a survey of the state would be conducted, using equipment operating on each of the two available very-high frequency bands. The data thus obtained have been correlated with the known characteristics of the existing medium frequency system for the purpose of comparison and evaluation.

MEDIUM FREQUENCY COMMUNICATION NETWORK. The nucleus of its present radio network was installed by the Oregon State Highway Commission in 1936 and was placed in operation during the early part of 1937. It was proposed that the system be used jointly by the Highway, Police and Forestry Departments, with particular priority placed on the Police usage.

The contract for furnishing and installing the equipment meeting published specifications was awarded to the Collins Radio Company, Cedar Rapids, Iowa. Radiotelephone equipment included in the contract were three Collins Type 20C 1000 watt transmitters, one each of which was installed at Klamath Falls, La Grande and Salem, and seven Collins Type 150C 50 watt transmitters installed at Astoria, Bend, Burns, Coquille, Milwaukie, Roseburg and The Dalles. Four Collins Type 18F 10 watt transmitters were installed, one each at Baker, Eugene, Grants Pass and Pendleton. Ten Collins Type 18F 10 watt mobile transmitters, equipped with dynamotor power supplies and all accessories were furnished but not installed.

Antenna structures furnished by the contractor included eight 120 foot self-supporting steel tower radiators and associated ground radial systems, which were installed at Burns, Coquille, Klamath Falls, La Grande, Milwaukie, Roseburg, Salem, and The Dalles. Other antennas erected comprised horizontal one-half wavelength current-fed wires, supported between wooden poles 65 to 90 feet high.

Receiving equipment furnished by the contractor was manufactured by the Radio Corporation of America for general and amateur communication usage, identified by the type number ACR-175, and was continuously tunable from 550 kilocycles through the higher "short wave" bands.

Service tests of the completed radiotelephone network were commenced early in January, 1937. It was evident very soon thereafter that satisfactory inter-station signals could not be received during daylight hours from many of the stations. The signal intensity of the 50 watt stations was particularly low, indicating a need for greater transmitter output powers. The Federal Communications Commission authorized, upon application, the modification of the seven 50 watt transmitters to permit somewhat greater areas to be served by the stations involved. The modifications required simply the replacement of the high-voltage power transformers with larger units, thereby increasing the output power to 100 watts.

A substantial improvement in signal strengths was noticed upon completion of the modifications in June, 1938; however, the continued use of the system indicated a need for higher-powered transmitters at several stations having large service areas in which the coverage to mobile units was found to be inadequate. Consistently dependable communications between even the 1000 watt stations at Salem, La Grande, and Klamath Falls was found to be impossible because of the variable factors affecting sky-wave propagation of energy at the operating frequency.

The Rules and Regulations of the Federal Communications Commission prohibit the use of State Police radiotelephone stations primarily for the purpose of handling point-to-point, or inter-station messages; however, such stations are permitted to intercommunicate within their good service ranges provided that no interference is caused to the mobile service and, further, that messages requiring radiotelephone relaying to reach the addressee are not handled. The Commission has allocated a group of channels in the 2.8 and 5.2 megacycle portion of the spectrum for the use of state police radiotelegraph stations, by which means it is expected that point-to-point traffic will be handled. Interstate radiotelegraph networks, comprising one "Interzone" station in each cooperating state system, have been organized to facilitate the coordination of the various agencies.

Intrastate radiotelegraph networks comprise two or more "Zone" telegraph stations.

The successful operation of a State Police organization requires that all members in the field be kept informed of immediately important events. The further increase in transmitter powers necessary to provide consistent point-to-point communication was economically unsound. It was decided that Zone radiotelegraph equipment would be installed at those key stations having consistent radiotelephone contact with all other stations in their respective local areas. Federal Communications Commission regulations prescribed, at that time, that an operator holding a license of Second Class or higher be stationed at each 1,000 watt transmitter. Because of their key locations, high-powered radiotelephone transmitters, and the presence of qualified technical personnel who could readily obtain radiotelegraph operator licenses, it was decided that the Salem, La Grande, and Klamath Falls stations would be equipped with auxiliary radiotelegraph transmitting and receiving equipment.

The signal strength of the 100 watt transmitter installed at Milwaukie was found to be insufficient to override the high noise levels encountered in the metropolitan area of Portland by the mobile units. The Collins Radio Company representatives were consulted regarding the availability of a suitable replacement transmitter. It was determined that the 500 watt Collins Type 202BA-10 transmitter would meet the specifications and, in addition, provide equipment necessary for use as an Interzone radiotelegraph station, since it was designed for operation on any one of ten selected channels, with integral means for rapidly changing the operating frequency and type of emission. The 100 watt Collins Type 150C transmitter originally installed at Milwaukie was replaced with a Type 202BA-10 unit in February, 1939, resulting in complete coverage of the mobile service area and establishing the nucleus of a Zone/Interzone radiotelegraph network.

The 100 watt Collins Type 150C transmitter installed at Bend was replaced with a 500 watt Collins Type 202B transmitter in March, 1939. This equipment is similar to the Type 202BA-10 transmitter installed at Milwaukie except that it is designed for operation on a single frequency. The 100 watt transmitter removed from the Bend station was then installed at Pendleton, replacing the 10 watt unit, which was moved to Meacham. A 120 foot self-supporting steel tower, identical to the eight towers furnished as a part of the original system, was erected at Medford and the 100 watt transmitter removed from Milwaukie was installed at Medford in May, 1939.

Many inquiries were being received by the Highway Commission from the travelling public regarding snow and road conditions over the Santiam and Wapinitia passes during the winter months. Reports of the field personnel stationed in these areas were usually received by mail, since direct communication was effected by means of a Forest Service telephone system, which was often out of service during the stormy seasons. To provide reliable contact with these points, two 50 watt composite radiotelephone transmitters were designed and constructed in the maintenance shop at the Salem headquarters station by department technicians. Because of the fact that commercial power was not available at these remote locations, the transmitters were equipped with dynamotor power supplies. One of the transmitters was installed in January, 1940, at the Santiam Junction Maintenance Station, located at the junction between highways US-20 and Oregon 222 in the Cascade Mountains. The second unit was installed at Government Camp in May, 1940.

Three radiotelegraph transmitters having rapidly-operating frequency changing mechanisms and output powers of 250 watts also were designed and constructed in the Salem shop. The transmitters were equipped to operate on any selected one of four frequencies: 2804, 2808, 5140, or 5195 kilocycles. One frequency in each of the two bands was designated as a "calling" channel and the other as a "working" channel. The use of the radiotelegraph equipment, which was placed in service in July, 1940, permitted reliable contact to be made between zones at all hours when radiotelephone signals were weak. Messages addressed to stations other than the Zone stations were relayed by radiotelegraph between the Zone stations and then re-transmitted to the designated addressee by radiotelephone.

Further changes were found to be necessary to provide more reliable coverage to the mobile units in some areas. The Type 150C 100 watt transmitter originally installed at Roseburg was replaced with a Type 150S-2 250 watt unit in July, 1940, and was moved to Eugene, where it replaced the Type 18F 10 watt equipment in September, 1940. A 500 watt General Electric Type 4G3A2 transmitter was purchased and installed at Medford in December, 1940, replacing the Type 150C 100 watt unit which was moved to John Day and placed in operation in January, 1941. The 10 watt Type 18F transmitter removed from the Eugene station was equipped for portable operation and installed at Austin, where it was used to communicate primarily with the John Day station. The Austin installation was originally intended to be of a temporary nature, but the need for reliable communication during the stormy winter months has demonstrated the advisability of maintaining the station at that location.

Upon the completion of the Willamette Highway, Route 58, a third composite 50 watt transmitter was constructed and installed at Odell Lake in November, 1940, to provide a means of keeping the travelling public informed as to weather and road conditions in the vicinity of the Willamette Pass.

Further expansion and development of the radio network was halted by World War II, during which time the system demonstrated its usefulness as a vital link in the national defense organization. Following the end of hostilities, nine composite 250 watt transmitters were purchased from the State of Maryland, which replaced its 1698 kilocycle amplitude modulated equipment with frequency modulated very-high frequency transmitters.

An extensive expansion program incorporating these units has been planned and partially completed. The 10 watt Type 18F transmitter at Baker was replaced with a composite 250 watt transmitter in November, 1947. A second 250 watt transmitter was installed at Ontario and placed in operation in February, 1948. Application has been filed with the Federal Communications Commission for a Construction Permit authorizing the installation of the third composite 250 watt transmitter at Arlington.

It is proposed that five of the remaining six units will be used to replace the 100 watt transmitters presently installed at Astoria, Coquille, Eugene, The Dalles, and Pendleton. The sixth will be installed at Newport. The 100 watt equipments removed from these stations will be placed in service at Tillamook, Grants Pass, Odell Lake, Blue Mountain Pass on Highway US-395 near the Oregon-Nevada border, and Redmond. The 50 watt transmitter removed from Odell Lake will be installed at Corvallis and two portable stations incorporating the Type 18F transmitters removed from the Baker and Grants Pass stations will be disposed temporarily at Seneca and Chemult.

It is intended that the primary service area, as referred to in the following discussion, shall be interpreted as being that area in which consistently reliable signals can be received by mobile units having normal receiver sensitivity, as is encountered in practice. The primary service areas of all stations comprising the network have been determined by experience, obviating the necessity of comparing actual measured field intensities. The observed maximum service ranges of stations having equal output power have been compared and found to be approximately the same in all cases, irrespective of the location of the station.

The primary service area data thus obtained have been reduced to graphical form and are shown as areas concentric with the transmitter location on the maps of Figures 1, 2 and 3.

The coverage obtained with the stations as originally installed is shown in Figure 1. The incomplete degree of service is immediately apparent by inspection.

The map of Figure 2 shows the primary service areas covered following the completion of the first period of expansion prior to the beginning of World War II in 1941. It is evident that numerous gaps existed between individual areas. Coverage of the heavily-travelled arterial highways US-30 and US-99 is shown to be very inadequate, as is service along the Oregon Coast Highway, US-101. As shown, a mobile unit operating along the Columbia River Highway, US-30, will be virtually isolated from the radio communication standpoint between Bonneville and a point near Pendleton, with the exception of the area in the vicinity of The Dalles. Likewise, dependable signals will not be received between a few miles south of Baker and the Oregon-Idaho state line at Ontario.

Figure 3 is a map showing the expected coverage of the network after completion of the current expansion program. Coverage along the arterial highways is indicated as being virtually complete. The shaded areas shown represent the service ranges obtained or predicted under the most unfavorable conditions experienced or anticipated. Average coverage is actually in excess of the primary service areas shown, providing substantially usable signals throughout a large part of the mobile service regions.

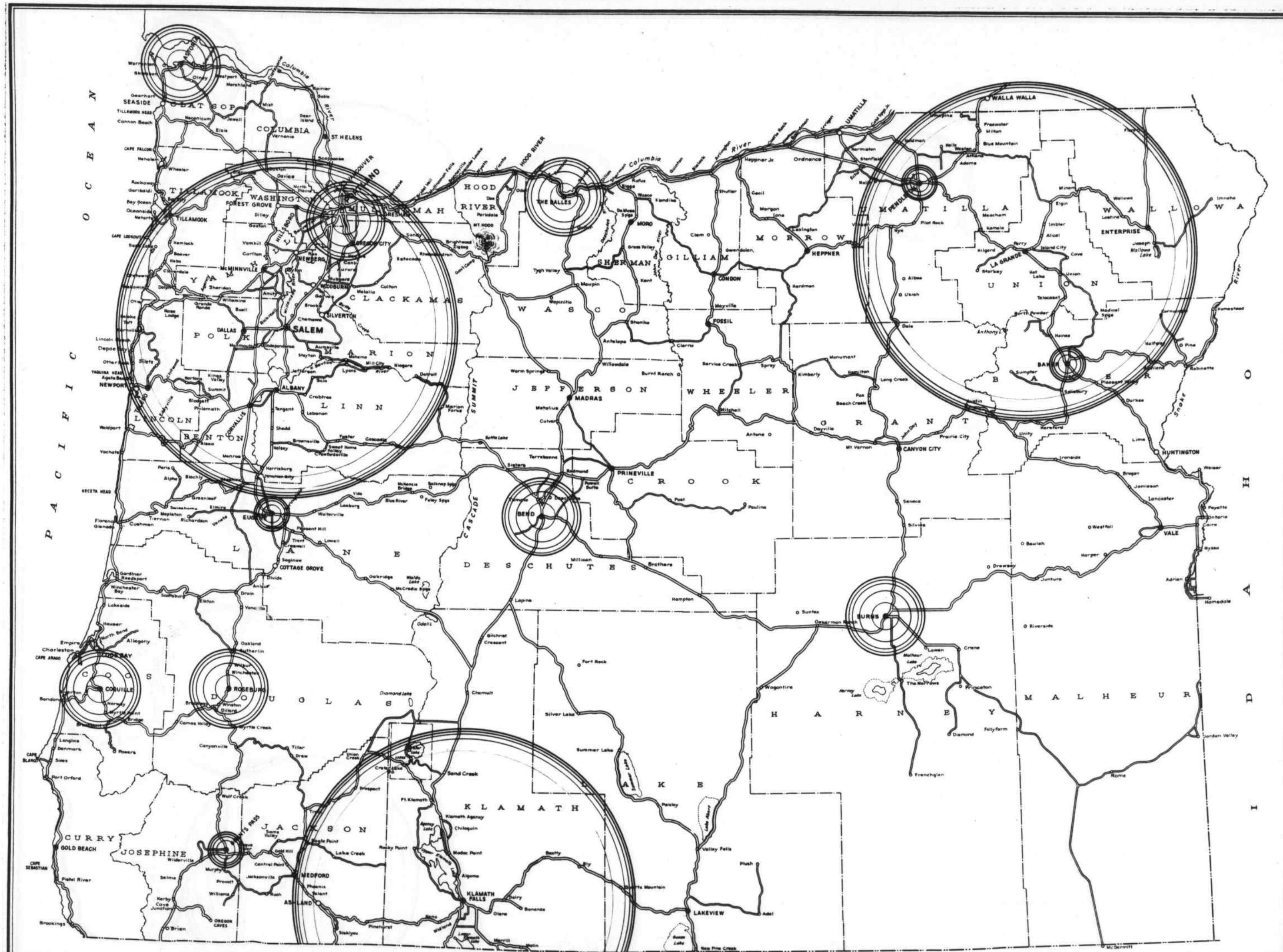

Figure 1. Primary service areas of radio network stations in 1937.

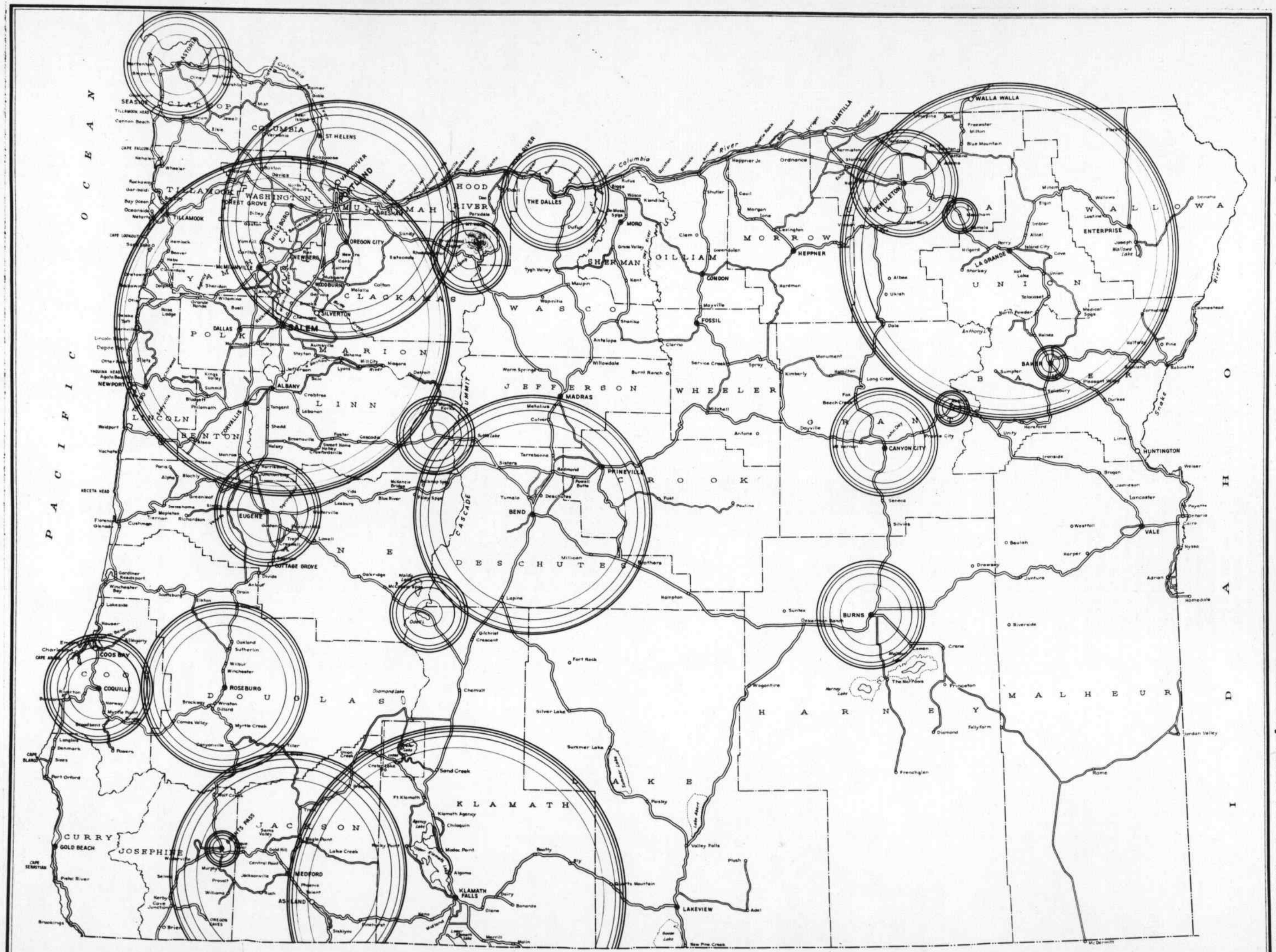

Figure 2. Primary service areas of radio network stations in 1941.

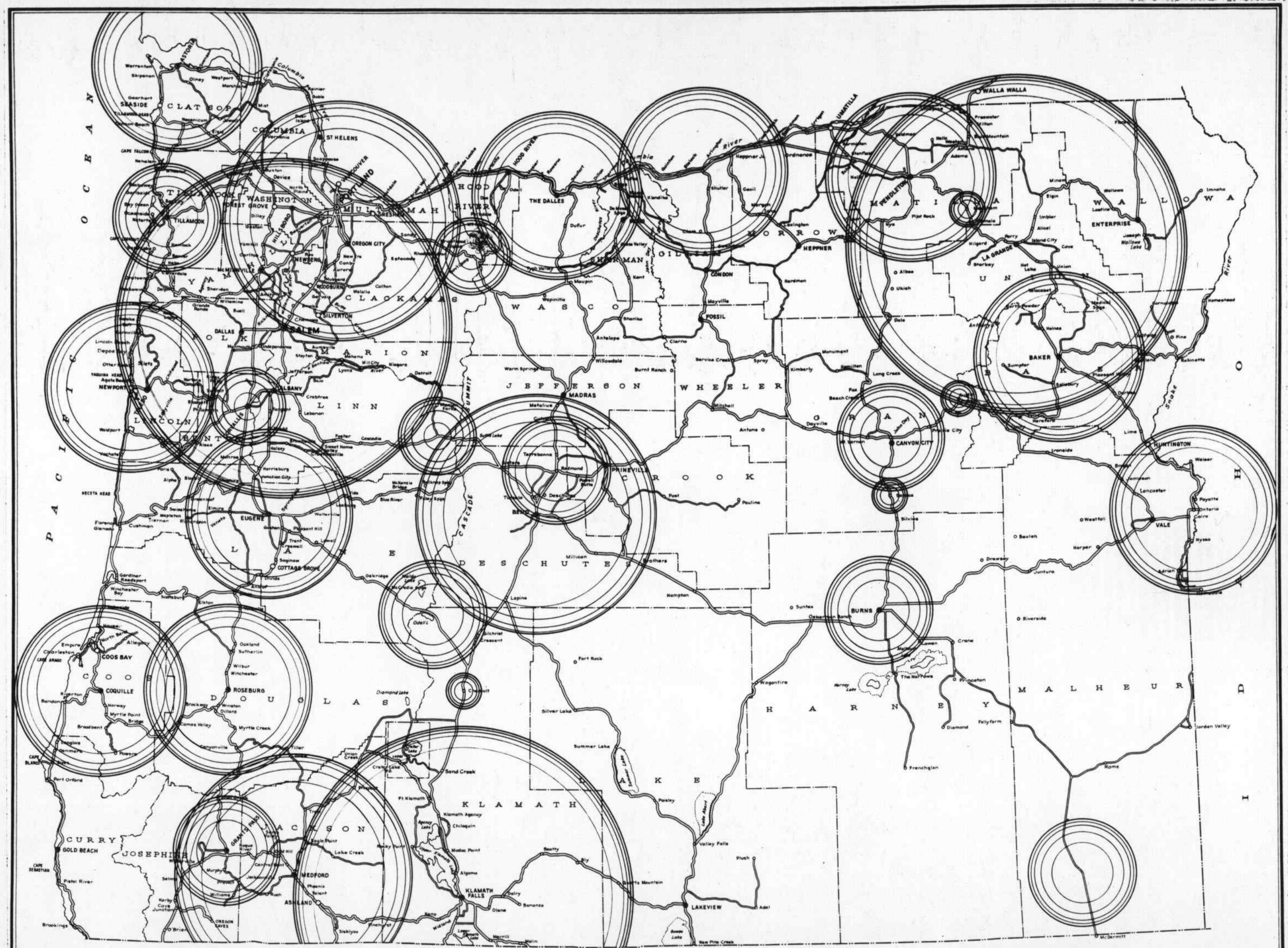

Figure 3. Service areas of network expected following proposed expansion.

RECEIVING EQUIPMENT. The RCA Type ACR-175 receivers installed as original equipment in all stations of the network proved to be unsatisfactory in several respects, although they were reasonably well designed considering the state of the art. The selectivity was found to be insufficient to reject adjacent-channel signals during those hours of darkness when conditions were favorable for the good propagation of sky-wave signals. The variable-tuning feature was undesirable because of the frequent detuning by accidental mechanical shocks and because of the inherent frequency drift due to thermal and humidity changes. As a means of partially solving the tuning problem, hourly equipment tests were scheduled to permit each operator to adjust his station receiver. Occasional bursts of noise would cause the operator to decrease the volume control setting to a point where a call could not be heard.

The Radio Manufacturing Engineers, Peoria, Illinois, announced in 1940 the development of a receiver designed expressly for fixed-frequency services. The RCA Type ACR-175 receivers were replaced with these newly-announced units, modified to specifications and designated RME Model SPD-13. They were found to be extremely selective and sensitive. Freedom from frequency drift was insured by the incorporation of a quartz crystal local oscillator frequency controlling element. A Carrier-operated "squelch" circuit caused the receiver to remain quiet in the absence of a received signal.

Immediately after the installation of the new receivers the network acquired a high degree of reliability. It was found that satisfactory point-to-point communication could be maintained during the greater part of the average day and the use of the Zone radiotelegraph equipment was abandoned.

The high radio noise intensity characterized by the increasing use of electrical appliances and industrial machinery forced the removal of the station receivers at Salem, Bend, La Grande, Medford and Klamath Falls to remote locations having low ambient noise intensities. In such installations, the audio frequency output of the receiver is transmitted at a low power level by means of metallic circuits to the station, where it is amplified to the power level required to operate a loudspeaker. A further improvement in the performance of the radio network was effected by these changes. It is expected that similar installations will be made at the majority of the stations within a period of several years. Further refinements in the receiver circuits have been introduced which tend to increase the overall effectiveness of the equipment.

One of the problems resulting from the removal of the receivers to remote locations was the adjustment of the operating threshold of the squelch circuits. Adjustment during periods of high ambient noise intensity resulted in loss of effective sensitivity during more quiet periods. An automatic squelch threshold circuit was designed and installed in the receivers which causes the loudspeaker to become operative only when a signal having an intensity exceeding the noise level is received.

MOBILE EQUIPMENT. Ten Collins Type 18F 10 watt transmitters, equipped with dynamotor power supplies, were furnished under the original installation contract. These units were installed in snowplows and other maintenance vehicles, which were equipped with sectional antennas having a length of 25 feet. It was necessary for the operator to stop the vehicle, put the separate antenna sections together and fix the antenna in a heavy-duty socket provided on the vehicle before making a transmission. The range was very limited and, because of the inconvenience involved, the mobile units were seldom used and were subsequently removed from the heavy equipment.

It was evident that a more efficient and practical antenna system would have to be designed before effective use could be made of the medium frequency mobile units. A series of experiments was undertaken, using a passenger car for a test vehicle, and the relative effectiveness of a number of antenna systems was determined.

A single-turn loop, comprising an insulated wire extended longitudinally over the top of the car from the front to the back bumper, with the car body completing the circuit, was tried. Very strong signals were received from the vehicle when it was in the vicinity of the receiver due to the strong induction field; however, the radiation field proved to be very weak and the signal intensity decreased rapidly as the vehicle moved away from the receiver. Marked directional properties characteristic of loop antennas were observed and the system was discarded as unsatisfactory.

A "top-loaded" antenna[1] developed for mobile use by the United States National Park Service and Stanford University was tested and found to provide a comparatively efficient radiator, having a measured power gain of 12.2 decibels as compared to a base-loaded vertical whip antenna of the same length (1, p. 32). This antenna comprises an inductor and capacitor elevated above the vehicle by a vertical, tubular metal supporting member, which is insulated from the vehicle and energized by the transmitter. Construction and mode of operation is similar to that of a conventional sectionalized tower as used in broadcast engineering practice. The inductance of a coil, which is electrically connected in series between the supporting member and a short whip, is adjusted so that its reactance is very nearly equal, at the operating frequency, to that of the combined capacitive reactances of the short whip and a shielding tube placed coaxially around the coil. When the antenna is so adjusted, the current antinode appears along the supporting tubular member, which is the principal radiating element.

The tuning operation was found to be a very critical procedure, since it was necessary to adjust the inductance of the coil by removing wire one-half turn at a time in order to reach the optimum tuning point without decreasing the circuit Q by the addition of end-effect or eddy-current losses. The properly adjusted top-loaded radiator was found to produce an effective service range of approximately 15 miles when energized by a 10 watt mobile transmitter.

It was felt that a more powerful mobile transmitter would be required to provide a satisfactory answer to the mobile communication problem. An experimental mobile transmitter having an output power of 40 watts and incorporating "instant heating" filament tubes was designed and constructed in the Salem shop and was installed in the test vehicle. The effective service range produced by this unit was found to be 25 to 30 miles, as would be predicted by simple calculation.

A series of measurements was made to secure data for plotting the relative field strengths produced by the mobile unit in the Salem area. A Hallicrafters Model SX-17 receiver, installed at the Salem station, was used as the measuring instrument. The signal strength meter integral with the receiver and scaled in "S" units of 1 through 9, in accordance with amateur radio practice, was calibrated in terms of microvolts input to the receiver antenna terminals by the use of a General Radio Model 605 Standard Signal Generator. From experience, it had been determined that a signal producing a deflection of S5, corresponding to an input voltage of 8.6 microvolts, represented a limit below which communication was not consistently reliable because of variable local noise conditions. The power ratio between S unit intervals in the range between S5 and S9 was found to be reasonably linear, averaging approximately 6 decibels. For the sake of convenience, the standard scale readings were recorded during the tests.

The test vehicle, equipped with the 40 watt transmitter and top-loaded antenna, was driven over highways extending very nearly radially from Salem and a large number of test measurements were made. Identical routes were covered from three to five times during different hours of the day and over a period of several weeks. The data secured were plotted for each radial line and an average reading determined.

The average measured relative field strengths produced by the test vehicle are shown on the contour map of Figure 4, in which the contour intervals represent a power ratio of approximately 6 decibels. Police patrols operating from the Salem headquarters station cover that area bounded by the towns of Aurora, Valley Junction near Grande Ronde, Corvallis, Albany, Mill City and Molalla. As can be seen, usable signals were received from all boundary locations with the exception of Mill City, a fact which contributed to the decision to install additional mobile transmitters operating on the medium frequency channel.

Further investigation of the antenna problem led to the development of an improved method of base-loading a vertical whip radiator (2, pp. 24-25) which provided an antenna having a higher radiation efficiency than the top-loaded type without the mechanical disadvantages of the latter. It was found that the antenna current increased as the L/C ratio of the parallel-resonant lumped-element circuit connected between the antenna and ground was increased, becoming maximum when the only capacitance shunting the loading inductance was that of the antenna whip plus the stray capacitance of the circuit. The reason for the observed effect was obvious upon consideration, since the circulating current in the parallel-resonant circuit was being divided between the shunt loading capacitor and the distributed antenna and stray capacitances combined in inverse

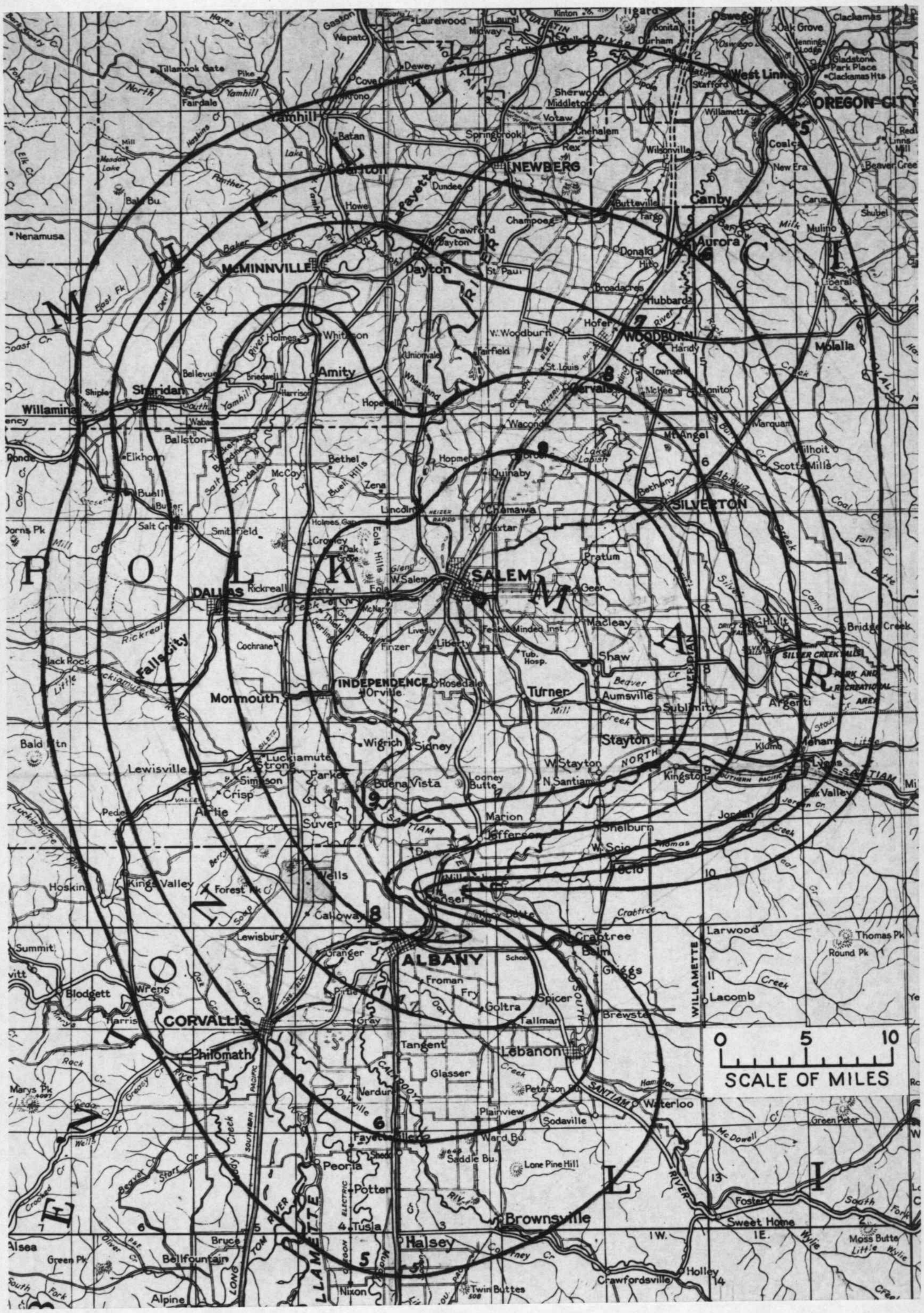

FIGURE 4. Average Daytime Field Strength Contours Produced by a 40 watt Mobile Transmitter Energizing a Top-loaded Radiator. Contour intervals approximately 6 db.

proportion to their respective capacitive reactances.

Coupling of the transmitter to the antenna was effected by means of a flexible coaxial transmission line having a nominal impedance of 72 ohms and connected to the low-impedance end of the loading inductor, between ground and a tap approximately 5% of the total number of turns from the grounded end of the coil. The position of the excitation tap was determined by experiment, being that point which provided a resistive termination at the transmitter end of the transmission line.

A 9 foot vertical whip antenna was base-loaded by means of the improved system, being tuned to resonance by adjusting the number of turns in the loading inductor, a method identical to that used for adjustment of the top-loaded antenna. The antenna current, measured at the base of the vertical whip, was found to be 1.2 amperes. The current at the base of the top-loaded radiator was found to be 0.5 amperes when energized by the same 40 watt transmitter. Field tests of the improved base-loaded system indicated that a substantial improvement in radiating efficiency had been effected, the field strength being increased approximately one S unit (equivalent to a power gain of 6 decibels) throughout the area shown in Figure 4.

In order to simplify the tuning procedure, which was necessary only at the time of initial installation of an antenna, various types of powdered-iron cores were inserted into the loading inductor, being mechanically variable along the axis of the coil to permit adjustment of the reluctance of the circuit. An adjustable, $1\frac{1}{2}$ inch diameter solid core of either Stackpole Type G2 or Aladdin Type 560 material 2 inches in length was found to provide a satisfactory tuning medium when used with an inductor 2.25 inches in diameter and 3.1 inches long, close-wound with 73 turns of #18 enamelled copper wire and tapped for excitation 4 turns from the grounded end.

Experience had indicated that a whip length of 9 feet was too great to eliminate the frequent striking of overhead wires, trees and other objects. The antenna length was decreased to 7 feet without appreciable difference in the radiated field strength and was adopted as a standard size.

The measured voltage gain of a 7 foot vertical whip, base-loaded by means of a variable-reluctance inductor, was found to be 11:1, corresponding to a power ratio of 20.8 decibels, as compared to the same whip without the loading means.

The 40 watt experimental mobile transmitter was redesigned to provide a model for the production of permanent units, and a total number of 19 identical transmitters were constructed and installed in patrol cars operating in the Klamath Falls, Medford, Roseburg, Eugene, Coquille and Salem areas. The consistent communication ranges of the units during daylight hours varied, according to the receiving conditions as affected by local noise in the respective areas, but were found to be comparable to that experienced in the Salem area.

During evening and nighttime hours, the mobile unit operators found that often they were unable to contact their base station beyond a distance of 10 or 12 miles from the station receiver. The increased background noise in the station receiver due to the sky-wave propagation of distant atmospheric disturbances contributed to the difficulty. Interference effects between sky-wave and ground-wave components of the radiated signals were observed, causing severe fading. It was found that polarization effects became very pronounced during this period; switching the station receiver input from a balanced-line horizontal doublet to an unbalanced "T" antenna permitted satisfactory reception of a signal that could not be heard when the doublet antenna was used. It was found that the Medford and Roseburg units could communicate with the Salem or Eugene stations more easily at night than with their own base stations. Obviously, such effects are undesirable in an emergency communication system, which must be capable of providing reliable communication between the headquarters stations and their mobile units at all hours of the day and night.

Difficulty is sometimes experienced by those fixed stations separated by distances of 45 to 55 miles, such as Milwaukie and Salem, due to the "skip distance" effects which prevail under those conditions favorable for good sky-wave propogation. The higher power output of the transmitters at stations so separated reduces the difficulty to that of the annoyance factor caused by fading.

INTERFERENCE. The State of Oregon has been very fortunate in having had allocated for its use the 1706 kilocycle channel, since it is effectively a clear channel excepting during some hours of the night. Adjacent-channel interference was experienced with the initial equipment; however, the installation of the more selective RME SPD-13 station receivers has completely eliminated such difficulty. Some signals of relatively low intensity are received during the night from other systems located in the eastern part of the United States and operating on the same channel, but the interference produced is insignificant.

The wartime installation and subsequent use of LORAN networks in the 1800 to 1900 kilocycle band has resulted in some interference of a serious nature, being particularly troublesome at those stations situated west of the Cascade Mountains. Because of the inherently steep wave-front characteristics of the emissions produced by LORAN transmitters, keying sidebands are evident in the 1706 kilocycle channel. The addition of highly effective peak-limiting noise silencers to the station receivers affected has reduced the interference from this source to a tolerable point, although the keying transients can be heard during night hours.

A rather unusual type of interference became evident after the assignment of the 1240 kilocycle channel for the operation of broadcast stations KFJI in Klamath Falls and KWIL in Albany. A modern superheterodyne receiver tuned to 1240 kilocycles has a local oscillator frequency in the vicinity of 1700 to 1710 kilocycles, depending upon the accuracy of alignment and station selection. The signal strength radiated by a local oscillator is sometimes very appreciable, having been heard and identified at a distance of three miles from the station receiver at Salem. This type of interference proved to be particularly troublesome at Klamath Falls, where the noise level is high and the only broadcast stations that can be received satisfactorily during daylight hours are those operating locally. The Klamath Falls station receiver was relocated to a site near the wartime Marine Barracks facility, several miles north of the city, in order to solve simultaneously the local oscillator heterodyne and noisy power transmission line interference problems.

VERY-HIGH FREQUENCY SURVEY. In order to determine the effectiveness of equipment operating in the very-high frequency bands of 30-40 and 150-160 megacycles per second, it was decided that the locations representative of terrain likely to be encountered in all parts of the state would be surveyed with actual mobile equipment.

Manufacturers' representatives were contacted to ascertain the availability of suitable equipment with which to conduct the tests. Two mobile transmitter-receiver combinations, adjusted for operation on a frequency of 154.49 megacycles, were made available for use through the courtesy of Motorola, Incorporated, while two mobile combinations operating on a frequency of 33.14 megacycles were generously provided by the Link Radio Corporation. It was felt that these equipments were representative of the well-engineered types commercially available.

The 154.49 megacycle equipment furnished comprised two Motorola Model FMTRU-30D Transmitter-receiver combinations. The transmitter unit was rated to deliver 30 watts of narrow-band frequency modulated energy to the antenna, which comprised for mobile use a one-quarter wavelength (19 inch) vertical spring steel wire, mounted centrally through and insulated from the top of the test vehicle. The receiver unit was designed to have an overall sensitivity such that 20 decibels of noise quieting was produced by an input terminal voltage of 1 microvolt.

The equipment operated on a carrier frequency of 33.14 megacycles comprised one Link Model 35-UFM transmitter, one Link Model 50-UFM transmitter and two Link Model 11-UF receivers. The transmitters were rated to deliver to the antenna 35 watts and 50 watts respectively of narrow-band frequency modulated energy.

The mobile antennas used on the frequency of 33.14 megacycles throughout the tests were of the one-quarter wavelength vertical whip type, supported along the left rear side of the test vehicle by means of a rugged tripod frame. A portable, knock-down "ground plane" antenna was tested and found to provide less signal strength than the mobile type, probably because of some difference between the operating frequency and the resonant frequency of the only available antenna of that type. For the sake of convenience, it was decided to use the mobile 33.14 megacycle antennas for surveying purposes, with the reservation that decided improvement in the results secured could be effected through the use of a properly designed antenna of the coaxial or ground-plane type, either of which is unwieldy and difficult to install temporarily.

A coaxial antenna, connected to the 154.49 megacycle transmitter-receiver combination by means of flexible coaxial transmission line was used at the fixed or base station whenever possible. Because of its small physical dimensions, installation of such an antenna on a high tree or other object was not usually difficult. It was felt that the results provided by the use of the external coaxial antenna would be representative of those which might be expected with a permanent installation at the same location.

Since highways US-30 and US-99 constitute the heavily-travelled traffic arteries across the State of Oregon, it was felt that the installation of a new mobile communication system would logically be started along these routes. It was decided, therefore, that these highways would be surveyed throughout their lengths, so that an accurate appraisal of the station equipment requirements could be made.

The equipment was made available for several weeks during the months of December, 1947, and January, 1948, and because of other committments of the manufacturers it was necessary to complete the tests at the earliest possible date. It was unfortunate that the survey was necessarily conducted during that part of the year when many of the sites selected as being desirable for receiving locations were not easily accessible by automobile. Considerable difficulty was experienced throughout the tests due to mud, snow and rain. The tests in the vicinity of The Dalles were conducted during the 24-hour period having the heaviest total rainfall that had been recorded in the history of the Weather Bureau.

The survey procedure was practically identical for each location tested. One vehicle having both 33.14 megacycle and 154.49 megacycle equipments installed in it was stationed at the location selected for the base station, which was usually an elevated and reasonably accessible point. The other vehicle, also having equipment operating on both channels, was driven over the roads and highways in the area to be surveyed. Test calls were made at one mile intervals by the mobile unit and verified by the base station. The actual test calls were of short duration so that the operation of both channels could be compared under identical conditions and from the same locations.

The base station receivers were each equipped with indicating instruments to measure the limiter grid currents produced by the received signals. At the beginning of the survey, limiter grid current readings, which are an index of the relative signal field intensities, were recorded. The frequency of the test calls, usually averaging one test call on each channel per minute, posed a difficult recording problem for the base station operator. After gaining experience, it was found that the receiving operator could describe the signal strength by estimating the signal-to-background noise ratio present in the receiver. Signal intensities were subsequently recorded in five degrees of quality; i. e., SATURATED, defined as having sufficient intensity to produce complete limiting and eliminate all except inherent receiver noise, SLIGHT NOISE, MODERATE NOISE, SEVERE NOISE, AND CLIPPING. The latter condition referred to the intermittent closure of the carrier-operated squelch circuits due to lack of sufficient received signal intensity.

ASTORIA AREA SURVEY. The survey was commenced at the western end of highway US-30, at Astoria, on December 19, 1947. Inspection of the topography in the vicinity of Astoria disclosed that the most logical choice for a receiving site was easily accessible by automobile and also would be available for use as a permanent location if it should prove to be satisfactory. The site chosen was near the base of the Astor Column, at an elevation of 595 feet above mean sea level. The monument area is the property of the City of Astoria, which offered the use of the location for the survey and eventual permanent installation if desired. Power and telephone circuit facilities were available at the site.

The base station vehicle was parked near the caretaker's quarters, upon which the external antennas were erected. The 154.49 megacycle coaxial antenna was fastened to a pole and raised to a height of 30 feet above the ground. A portable, knock-down "ground plane" antenna, resonant at a frequency somewhat higher than 33.14 megacycles but the only one available, was also erected on a pole and raised to a height of approximately 25 feet above the ground.

Two test vehicles were used in the survey at this location; the 154.49 megacycle transmitter for the standard test vehicle had not been delivered when the test was conducted, so the Motorola representative furnished and operated his personal automobile, in which such equipment was installed. The 33.14 megacycle equipment had been installed in the standard test vehicle prior to the test.

Test calls were made at intervals of one mile, or whenever an easily identified check point had been reached, the leading vehicle making the first test from a chosen location so that the following unit would be able to test from the same point without the necessity for stopping either vehicle.

Along highway US-101, solid signals were received on both frequencies from Astoria south to the tunnel through Arch Cape, at Milepost 36.6, slight noise appearing on 154.49 megacycles in the vicinity of Cannon Beach. No signals were received on 154.49 megacycles from the Arch Cape Tunnel to the Nehalem River Bridge, although contact was established intermittently, with moderate to severe noise and frequent clipping, on 33.14 megacycles.

After reaching the Nehalem River bridge, the vehicles returned north by way of Oregon Route 53 to the Necanicum Junction with Oregon Route 2. The 154.49 megacycle signals were heard intermittently along this section, with severe noise and clipping generally, becoming saturated at the Coast Range Summit, 3 miles south of Necanicum Junction. The signal strength on 33.14 megacycles was sufficient to produce excellent signals, with slight to moderate noise, from all locations along Route 53 with the exception of a short section between Mileposts 3 and 4, immediately south of the Coast Range Summit, where the background noise became severe.

Upon reaching the Necanicum Junction, the vehicles turned east on Oregon Route 2. The 154.49 megacycle unit was heard with solid signals to a point near Elsie, at Milepost 20, beyond which clipping and severe noise became evident. Contact was lost at Milepost 23, 3 miles east of Elsie. The 33.14 megacycle unit was received with excellent signal strength and slight background noise to a point 7 miles east of Elsie. The vehicle encountered a severe snowstorm at that point, and, because of the late hour and inclement weather, it was decided to return to the base station at Astoria. The signal strength at the turning point indicated that the limit of satisfactory communication had not yet been reached.

After the vehicles had returned to Necanicum Junction, the effectiveness of the 33.14 megacycle ground plane antenna was checked. The test vehicle stopped and made a test call, during which the limiter grid current reading at the base station receiver was recorded. The ground plane antenna at the base station was then disconnected from the 33.14 megacycle equipment and the mobile whip was connected in its place. Another test call was made and the antenna tuning of the base station receiver was readjusted, after which the grid current reading was again recorded. It was found that the mobile antenna produced a higher grid current reading than the external ground plane antenna that had been used throughout the test period previously described. The difference between the resonant frequency of the antenna and the equipment operating frequency was thought to be the reason for the unexpected results.

On the following day, the test vehicles travelled east on highway US-30. The signals on both channels were saturated from the base station east to Bradley State Park, beyond which noise appeared on each frequency. The 33.14 megacycle signals were moderately noisy at Marshland, acquiring severe noise and clipping beyond that point, while the 154.49 megacycle signals were understandable, with moderate to severe noise, to a point 2 miles west of Clatskanie, at Milepost 67.

As a result of the tests in this area, it was felt that the coverage secured on either channel would be adequate to provide satisfactory service, but that the results obtained on 33.14 megacycles indicated that more complete coverage would be provided by the lower of the two frequency bands. Since good coverage was obtained from the site chosen, which was desirable for other reasons previously mentioned, it was felt that the permanent installation should be planned on the basis of these factors.

PORTLAND AREA SURVEY. The experience of several of the users of very-high frequency systems in the metropolitan area of Portland was considered in the search for the best receiver site. It was decided that the top of Mt. Scott, southeast of the City, offered the greatest possibilities as a base station location.

Prior to the undertaking of the general survey, the Link Radio Corporation representative had made a preliminary survey of highways US-30 and US-50 east from Portland on a frequency of 33.14 megacycles, using the equipment which was later made available for use in the general survey. The tests were witnessed by the writer and the data secured are included in the following discussion in the same manner as if they had been made during the general survey. The conditions under which the preliminary tests were made were identical to those following, with the exception of the fact that a permanently-installed coaxial antenna, owned by the Portland General Electric Company and a part of their 30-40 megacycle system equipment, was used at the base station instead of the mobile whip antenna.

On December 20, 1947, the base station was set up on the northwest edge of the top of Mt. Scott, at an elevation of 1,170 feet. The 154.49 megacycle coaxial antenna was erected on a pole and raised to a height approximately 20 feet above the ground. The 33.14 megacycle equipment was not available for use during this test, but the areas involved had been covered previously by the preliminary survey.

Along highway US-50, the signals produced on both channels were solid with little noise from Portland east to Government Camp, at Milepost 54.6.

A considerable amount of apprehension was felt concerning the possibility of adequately covering the Columbia Gorge along highway US-30. All fears were dispelled, when it was found that the signals produced on either frequency were solid from Portland east to Milepost 55, becoming intermittent with severe noise and clipping between Milepost 55 and the Mitchell Point Tunnel at Milepost 61. No communication was possible from along the highway east of Mitchell Point; however, contact with the base station was established on 33.14 megacycles from a hill top in Hood River.

As would be anticipated by inspection of the terrain, the area from Portland south to Salem along US-99E was covered with solid, saturating signals on both frequencies. The test vehicle was not driven farther south than Salem for the survey in this area, although it is expected that satisfactory signals would be received on both channels to Albany.

On December 22, 1947, the base station was again set up at the same location, but with the 33.14 megacycle equipment installed. The 154.49 megacycle coaxial antenna was again erected at a height of 20 feet and the mobile antenna was used on 33.14 megacycles throughout the test.

From Portland west on highway US-30, solid signals were received on 154.49 megacycles to the top of the hill immediately west of Rainier, at Milepost 52. Because of the fact that the elevation of the highway dropped very rapidly beyond that point, it was expected that the signal strength also would drop very rapidly and the test vehicle returned toward Portland. The signals on 33.14 megacycles were solid to Little Jack Falls at Milepost 45, becoming intermittent with severe noise and clipping between Little Jack Falls and Rainier. Contact could not be established from the business district in Rainier on 33.14 megacycles, although weak signals with moderate to severe noise were experienced when the test vehicle was on the south approach of the Longview Bridge.

The test vehicle returned toward Portland from Rainier, turning southwest at St. Helens and taking a gravelled road toward Vernonia. Contact was maintained on both channels from St. Helens to a point 26 miles west of St. Helens, beyond which 154.49 megacycle signals were not received. The 33.14 megacycle signals were saturated from St. Helens to near the junction with Oregon Route 47 at Pittsburg.

Slight noise appeared at Pittsburg, rapidly becoming severe and clipping. Contact established intermittently between Pittsburg and Vernonia, with severe noise generally throughout the section.

Test calls were made from a 500 foot hilltop near Vernonia, the location being that selected by the local Power Utility for their station site. Contact with the base station on Mt. Scott was established on both channels, the 33.14 megacycle signal having slight noise and the 154.49 megacycle signal having moderate background noise.

Intermittent communication was maintained on 33.14 megacycles from Vernonia to Glenwood Junction, at which point contact was again established on 154.49 megacycles. The vehicle was driven west on Route 2, with solid signals being received on both channels to the summit of the Coast Range at Milepost 27, 3 miles west of the Clatsop-Tillamook County Line, in Clatsop County. This was the turning point reached when the Astoria area was surveyed, indicating that a good coverage safety factor would be provided along Route 2. Slight to moderate noise was evident on each system, with the 33.14 megacycle signals having greater apparent strength. At Milepost 27, it was determined that the 154.49 megacycle signal strength dropped rapidly beyond the summit, while that of the 33.14 megacycle signal showed evidence of remaining usable for a somewhat greater distance. The test vehicle was turned around at Milepost 27 and the return trip to Portland was started. The signals became quiet on both frequencies when the Sunset Tunnel was reached, becoming saturated between Forest Grove and Portland.

The results of the survey of the Portland area indicated that satisfactory coverage could be secured on either frequency, with the 154.49 megacycle channel providing slightly greater range along the western end of the district on Highway US-30 and the 33.14 megacycle channel having greater coverage in the mountains and valleys west of Portland along Route 2.

The receiving site chosen was found to be excellent, providing greater coverage from a single location than is now provided by an existing 30-40 megacycle system in the same area with three widely separated receiver installations energizing loudspeakers at the central control point. Because of its ideal situation with respect to the surrounding terrain, including the metropolitan area, Mt. Scott may prove to be undesirable for a receiving site. Being a natural location for the installation of very-high frequency systems, particularly the commercial frequency modulation broadcast and television services, the problem of spurious responses and receiver desensitizing by high intensity radio frequency fields may become so serious as to overcome the advantages of the site. Several very-high frequency systems are now installed there; the addition of others may prove to be mutually detrimental unless the systems are all well engineered.

THE DALLES AREA SURVEY. The base station was installed January 5, 1948, on the top of Seufert Hill, near the Civil Aeronautics Administration's radio range station east of The Dalles, at an elevation of 1,200 feet above mean sea level. The 154.49 megacycle coaxial antenna was erected on a pole and raised to a height of 14 feet above the ground. The mobile whip was used as the antenna for the 33.14 megacycle equipment.

The test vehicle was driven on highway US-30 from Portland to The Dalles after the base station had been set up, and test calls were commenced in the vicinity of Cascade Locks, in accordance with a prearranged schedule. Contact was first established on 33.14 megacycles near Viento, the signals becoming solid, with slight noise, at Milepost 55. The 154.49 megacycle signal was first heard at Milepost 55, where it immediately became solid, with slight background noise.

The unit travelled east past The Dalles and the signals on both frequenies were solid to the John Day River at Milepost 122, on the Sherman-Gilliam County line, beyond which no contact was possible on either channel. A large amount of "swinging" was noticed on both frequencies between Mileposts 108 and 118--first one would become completely quieted while the other developed noise, then the situation would be reversed suddenly. Communication quality signals were received generally along this 10 mile section, although some clipping was evident on 154.49 megacycles.

In order to investigate the behavior of the very-high frequency waves in rolling terrain typical of that found in central eastern Oregon, the mobile unit was driven south from The Dalles along highway Oregon 23 to Maupin, along US-50 to its junction with US-97, and north on US-97 to its junction with US-30 at Biggs. Both channels provided solid, saturated signals from The Dalles to the Tygh Valley Ridge at Milepost 27. Communication was impossible on either frequency in the 10 mile canyon section between Mileposts 27 and 37, after which 33.14 megacycle signals were solid to Maupin Junction. The signals on 154.49 megacycles were not heard until Milepost 38 had been reached, after which they were solid to Milepost 65. No further contact was made on 154.49 megacycles between Milepost 65 and US-97, or between US-97 and Biggs on US-30. Contact on 33.14 megacycles, however, was solid throughout the remainder of the route with the exception of some degree of clipping in the town of Maupin and a total absence of signal in a 2 mile canyon section between Mileposts 8 and 10 of US-97 near Biggs.

The results of the survey in the area of The Dalles indicated that the most complete coverage would be secured by the use of the lower frequency. The total lack of signal in the canyons near Biggs and Tygh Valley Ridge posed problems that could be solved by the use of automatic repeater stations, properly located; however, the use of such repeaters would not at the present time be economically justified.

ARLINGTON AREA SURVEY. A study of the topography in the Arlington area indicated that the general region around the airport would be the highest and most readily accessible location for the base station. The airport elevation is approximately 850 feet above mean sea level and about 600 feet above the town and highway. The base station was set up near the Administration Building on January 6, 1948, and the 154.49 megacycle coaxial antenna was fastened to the top of a 40 foot wooden antenna pole.

Before the external 154.49 megacycle antenna was connected to the equipment, the tests were made on US-30 west of Arlington to compare the results secured when the mobile antennas were used on both channels. The test vehicle was contacted at Rufus, near Milepost 116, on 33.14 megacycles, and intermittent communication was maintained from Rufus to the John Day River, Milepost 122, where the signals became solid and quiet. The 154.49 megacycle signals were not heard until the unit had travelled to Milepost 130, 9 miles east of the John Day River, after which solid signals were received.

The area east and south of Arlington was covered by the test vehicle by following highway US-30 east to Ordnance, turning south on Oregon 207 and driving to Lexington, going from Lexington to Heppner via Oregon 74, then following highways Oregon 207 and Oregon 206 to Condon, returning to Arlington on Oregon 19. The 33.14 megacycle signals were solid from Arlington to 11 miles east of Boardman, after which they were not heard until the Umatilla-Morrow County line, 17 miles north of Lexington, was reached. The 154.49 megacycle contact was solid from Arlington to 11 miles east of Arlington, at the junction of highways US-30 and Oregon 74, after which none was made until the Umatilla-Morrow County line was reached. Solid coverage was obtained on 33.14 megacycles between the County line and a point 3 miles south of Lexington, beyond which intermittent contacts were made from selected points along the highway between Lexington and Condon, usually from those points having a high relative elevation with respect to nearby terrain. Solid, saturating signals were received from Condon to Arlington on 33.14 megacycles, with the exception of a 2 mile section in Olex canyon, between Mileposts 6 and 8, from which contact was impossible. The 154.49 megacycle signals were intermittent between the County line, 17 miles north of Lexington, and Condon, with contact being established from selected high points generally. Signal strength was excellent when contact was possible--signals either were very strong or were entirely absent. Solid coverage was secured from Condon to Arlington, with the exception of the Olex canyon, where a 3 mile section between Mileposts 6 and 9 was found to be "dead".

On the following day, a second test run was made from Arlington east on US-30, with the coaxial 154.49 megacycle antenna erected on the top of a 75 foot airway beacon tower, located at the west end of the airport. Coverage was found to be greatly improved and signals were received without breaks from Arlington to the Morrow-Umatilla County line, 3 miles east of Irrigon.

The decided improvement in coverage effected by the relocation of the 154.49 megacycle antenna indicated that a probable improvement would also be obtained on 33.14 megacycle, which provided substantially greater coverage under comparatively equal conditions. The beacon tower site is an excellent one for the location of equipment, since, in addition to its physical prominence, telephone and power facilities are available at the tower.

PENDLETON AREA SURVEY. In order to secure adequate coverage of the section in the Blue Mountains, between Pendleton and La Grande, it was decided to locate the Pendleton receiving site at the airway beacon on Emigrant Hill, near Milepost 250 on US-30. The base of the

75 foot beacon tower is elevated approximately 3,550 feet above sea level. Because of the long distance from Pendleton, which can be seen easily in the valley below Emigrant Hill, it was planned that automatic radio repeater circuits would be installed between the permanent terminal point in Pendleton and the remote equipment location.

The tests were commenced on January 8, 1948, according to a prearranged schedule. The mobile unit used as the base station at Arlington delayed departure until the Pendleton base station could be established. Test calls were commenced by the mobile unit at Boardman, where the 33.14 megacycle signals were excellent, having only slight background noise. The 154.49 megacycle signal was very intermittent and noisy from Boardman. The test vehicle turned around and headed west, testing every mile to check the signal strength. The 154.49 megacycle signals were heard, although very noisy and intermittent, to 6 miles west of Boardman, while the 33.14 megacycle communication was solid with slight noise to Milepost 162, 9 miles west of Boardman, with the signal gaining background noise rapidly thereafter. Clipping became evident at Milepost 159, 12 miles west of Boardman, and the vehicle turned around and headed for Pendleton. On the return trip, the 33.14 megacycle signals were solid with little noise from 9 miles west of Boardman to Pendleton, while those on 154.49 megacycles became solid one mile east of Boardman, remaining quiet from that point to Pendleton.

The highway from Pendleton to Walla Walla, Oregon 11, was surveyed January 9th, with the 33.14 megacycle channel providing solid and near-saturation signals from Pendleton north to the Washington-Oregon state line. The higher frequency became intermittent and contacts were very noisy in the area between Weston and Freewater, with contact impossible from many locations. Contact was established with the base station from Freewater and from the state line, however.

A test was made along US-395 with a vehicle having only the 154.49 megacycle equipment installed in it. Solid signals were received from Pendleton to the summit of Battle Mountain, at Milepost 39.8, approximately 30 airline miles south of Pendleton. Intermittent contact was maintained between Battle Mountain and Milepost 45.6, 4 miles north of Ukiah. On the return trip from near Ukiah to Pendleton, the vehicle turned west on Oregon 74. Tests revealed that solid coverage obtained from the junction of Oregon 74 and US-395 to 3 miles west of the junction, with intermittent contacts being made from that point to 11 miles west of the junction. Solid signals, with occasional moderate noise, were obtained between 11 miles west of the junction and Lexington, with saturated signals from all points between Lexington and Pendleton. The 33.14 megacycle equipment was not available for use in surveying this route.

The survey unit was driven east on US-30 and solid signals were received on both channels from the base station site to a point 3 miles east of Kamela, at Milepost 270.8. A rapid decrease of the signal intensity on 33.14 megacycles was noticed between the summit of the Blue Moutains, Milepost 266.8, and the end of the service radius, 3 miles east of Kamela. Contact was established from an overpass at Milepost 274.7, 7 miles east of Kamela, on 154.49 megacycles, although the signal strength was very low. Communication was again established on both channels from a Highway Department rock stockpile site at Milepost 276.2, 8.4 miles east of Kamela.

MEACHAM AREA SURVEY. A Highway Department maintenance section station, located at Meacham, was selected as the next base station site from which to conduct a survey. The mobile antennas were used on both channels at the base station, which was established on January 10, 1948. The coverage east from Meacham was found to be extremely limited, with signals on 33.14 megacycles being solid only to the summit and those on 154.49 megacycles becoming intermittent at Kamela. Further tests from Meacham were abandoned thereafter, since a greater range was secured from the Pendleton remote site on Emigrant Hill.

REPEATER SITE SELECTION. It became apparent that a second automatic radio repeater installation would be required to provide communication with the Emigrant Hill site, La Grande station, and mobile units operating in the area between them. The stockpile site at Milepost 276.2, from which point communication with the Emigrant Hill base station had been established on both channels, was a logical first choice for a repeater location. The base station was established at that point, using mobile antennas on both frequencies, and it was found that solid communication was secured between Meacham and La Grande on 33.14 megacycles and between the Blue Mountain summit and La Grande on 154.49 megacycles.

LA GRANDE AREA SURVEY. The base station was transferred to

La Grande and set up in the yard of the Highway Department equipment shops, since a heavy snowfall made access to elevated points near the city very difficult. The mobile unit was in communication with the base station on 33.14 megacycles throughout the test run from La Grande to the proposed repeater site at Milepost 276.2 on US-30, although moderate to severe background noise prevailed between Milepost 280, 6 miles west of La Grande, and the repeater site, from which strong signals were received. The 154.49 megacycle signals became very weak, with severe background noise in the region between 3 and 6 miles west of La Grande, between Mileposts 284 and 281, respectively. Contact was not established west of Milepost 281 until the proposed repeater site was reached, where signals with a moderate amount of background noise were received.

Inspection of the rim of mountains surrounding La Grande led to the determination to continue the survey from the Highway Department shop yard, where a 120 foot steel antenna tower, used as a radiating element for the existing medium frequency transmitter, was available for use as a permanent antenna support. Since it was felt to be undesirable to put the station out of service during the survey by using the tower as a temporary antenna support, the base station was established on a small hill located immediately west of the hospital and having an elevation of 2,750 feet, which is the approximate elevation of the top of the steel tower. The coaxial 154.49 megacycle antenna was erected on a wooden pole about 20 feet above the ground level, while the mobile antenna was used with the 33.14 megacycle equipment.

The tests were made January 11, 1948, using two separate mobile units, one of which was equipped for operation on only the higher frequency. This vehicle travelled along Oregon 82, northeast from La Grande toward Minam. Solid signals, with very little noise were evident between La Grande and the summit of Minam Hill, beyond which contact was impossible. Upon returning to La Grande, the high-frequency unit followed US-30 south from La Grande to Union, turning on Oregon 203 between Union and Baker. Signals were received between La Grande and the Baker-Union County line, beyond which point the tests were discontinued because of lack of time.

The mobile unit equipped for operation on both channels followed US-30 between La Grande and Baker. Excellent signal strength was observed on 154.49 megacycles throughout the route with the exception of the canyon section between Union and 4 miles south of Union. Contact was impossible in this canyon; however, it was later discovered that the transmitter was improperly adjusted, resulting in somewhat subnormal performance. The 33.14 megacycle signals were fully quieted between La Grande and Milepost 310, 8 miles south of Union, but became intermittent and noisy between Milepost 310 and Baker. Communication was established from the business district of Baker, although severe background noise was present.

The results of the survey in the La Grande area indicated that satisfactory coverage could be obtained with either channel if the antenna were to be mounted on the 120 foot steel antenna tower at the Highway Department shops, although the performance of the lower frequency was definitely superior along US-30 north of the city. As was shown previously, an automatic radio repeater station would be required to provide complete coverage of the latter section. Since communication was established on both channels between the repeater site and the Emigrant Hill and La Grande base stations, a repeater station would permit communication to be maintained between a mobile unit in the Kamela-La Grande section and either the Pendleton or the La Grande base station. Because of the fact that this section is a particularly important and dangerous part of the highway system during the stormy winter months, it is probable that the expenditure of a sum sufficient to install a repeater station would be justified.

BAKER AREA SURVEY. The mobile unit arrived in the Baker area during a severe snowstorm January 11, 1948, making it necessary to choose a site for the base station that was not optimum for a permanent station. It was found that the "Hillcrest" residential district was the only reasonably elevated point accessible. The elevation of the base station, which utilized the mobile antennas on both frequencies, was 3,550 feet.

The mobile unit which was travelling along Oregon 203 between Union and Baker and which was operating on 154.49 megacycles only was first heard at Pondosa, on the Union-Baker County line. Signals were very strong from that point to Baker, with the exception of along a short section in the vicinity of Salt Creek, where the signal became very weak and noisy.

After the base station was established, the mobile unit which had remained in La Grande and served as the La Grande base station started south along US-30. Solid communication was maintained on 33.14 megacycles between La Grande and Baker, although rapid variation of the signal intensity was observed. The 154.49 megacycle signals were heard for the first time when the vehicle reached Milepost 293, 5 miles south of La Grande, after which moderate to severe noise was encountered until Union was reached. No communication was possible between Union and North Powder. Signals were again heard, with slight to moderate and occasionally severe background noise between the railroad overpass at Milepost 310.5 and North Powder, south of which the signal strength increased and the noise disappeared.

Because of the severe weather, the tests were discontinued for the balance of the day. The following day, January 12th, an attempt was made to locate the base station near the Baker reservoir, situated at an elevation of 3,800 feet on a hill immediately northeast of the Highway Department office, where the medium frequency transmitter was located. After some difficulty had been experienced, the base station was established and US-30 south of Baker was surveyed. Mobile antennas were used again on both channels. It was found that solid signals were provided on both 154.49 and 33.14 megacycles between Baker and Pleasant Valley, which is 11 miles south of Baker, but that contact was impossible on either frequency beyond Pleasant Valley.

The reason for obtaining such an extremely short range was difficult to understand until a topographical map was secured and studied, since the hill appeared to have visual coverage of the highway for many miles south of Baker. A rough plot of the profile of the terrain between the base station site and Pleasant Valley showed that very high intervening mountains proved to be a definite limitation to coverage south of Baker.

The base station was again established on "Hillcrest" the following day, January 13th, to determine the communication range from Baker east on Oregon 86, toward Richland. It was found that the 154.49 megacycle signals extended from Baker to 17 miles east of the junction with Oregon 203, while the 33.14 megacycle frequency provided communication from Baker to a point 19 miles east of the junction, with intermittent contacts established for 3 miles thereafter.

The results of the Baker area survey revealed that further investigation of the site location problem is necessary. It is likely that the results secured by the use of medium frequency mobile equipment will be superior to those provided by that operating on a very-high frequency.

ONTARIO AREA SURVEY. The topography of the area in the vicinity of Ontario is such that there are no natural sites suitable for the location of a very-high frequency antenna. It was decided that a permanent installation would involve a high supporting mast located at the Highway Department maintenance section headquarters. The base station was set up in the headquarters yard, using mobile antennas on both frequencies.

Along US-30, from Ontario north toward Huntington, the 154.49 megacycle signals were solid from Ontario to a point 15 miles north of

Ontario, while the 33.14 megacycle signals extended to a point 20 miles north.

West of Ontario, the 33.14 megacycle signal intensity was sufficiently great to provide fully quieted reception between Ontario and Vale, with consistent contacts being made between Vale and a point 14 miles west of Vale on US-20. The 154.49 megacycle signals were quiet from Ontario to 1 mile west of Vale, becoming intermittent and noisy thereafter and disappearing entirely 3 miles west of Vale. Contact was effected from the summit of a hill 12 miles west of Vale.

The signal intensity of both systems was very low along US-28 from Vale northwest toward John Day. Contact was lost on 154.49 megacycles only 2 miles northwest of Vale, while the 33.14 megacycle signals were copied to a point 5 miles northwest, becoming intermittent and noisy thereafter.

Although somewhat greater ranges of communication would be expected if the antenna height were to be increased, it is doubtful that an extension would be appreciable for any reasonable increase in antenna height because of the limiting terrain in the area surrounding Ontario. The use of the lower frequency definitely is indicated in this region by the superior results produced.

The Ontario area was the final section of highway US-30 to be surveyed. Following the completion of the tests in that area, further coverage surveys were deferred for a few days because of previous committments on the part of the manufacturers for the use of their mobile equipment.

MEDFORD AREA SURVEY. The tests were resumed January 21, 1948, with the objective being the survey of highway US-99 throughout its length.

The base station was established near Medford, on a very prominent peak known as Roxy Ann. The city of Medford, which held the title to the property, had previously indicated that permission to install equipment permanently would undoubtedly be granted if the site proved to be advantageous. The base station vehicle was driven almost to the top of the mountain and the 154.49 megacycle coaxial antenna was fastened in a tree top at a height of approximately 35 feet above the vehicle. The mobile antenna was used with the 33.14 megacycle equipment.

The coverage along US-99 south of Medford was excellent on both channels, with fully quieted reception being the usual case until the summit of the Siskiyou Mountains was reached. The 154.49 megacycle signals became intermittent south of the summit, while the 33.14 megacycle signal strength remained sufficiently high to permit excellent communication to be maintained as far south as the California state checking station near Hilts. No attempt was made to continue farther south into the state of California, since there was neither any desire nor any need to provide service into that area.

Along US-99 west of Medford and north of Grants Pass, solid contacts were made on both channels as far north as the summit of Sexton Mountain, with the 33.14 megacycle signals being somewhat more consistent.

The results of the tests indicated that a permanent installation on Roxy Ann would be highly satisfactory, providing service not only to the Medford area, but also to the Grants Pass region.

ROSEBURG AREA SURVEY. A hill situated immediately east of the State Highway Department's Roseburg office and having an elevation of approximately 800 feet above the highway was chosen as the most logical location for a very-high frequency installation, since it would require only very short lines for power and audio frequency connections with the headquarters office. A road extending part of the way to the top of the hill was negotiated with difficulty, and it was found to be impossible to drive more than one-half of the way to the top. A secondary hill, jutting out from the selected point and roughly 400 feet above the highway became, of necessity, the base station site for surveying purposes. Mobile antennas were again used on both frequencies.

Along US-99 south of Roseburg, the 33.14 megacycle signals were solid, with very slight noise, to a point near Myrtle Creek, where severe background noise was encountered. The signal intensity increased south of Myrtle Creek for a distance of 4 miles, after which the signal became noisy but understandable as far south as Canyonville. The range of the 154.49 megacycle equipment was limited approximately to 4 miles north of Myrtle Creek, with severe clipping and noise occurring beyond that point.

North of Roseburg, excellent signals were received on both channels as far north as Sutherlin, beyond which moderate to severe noise was evident. The range of the 154.49 megacycle equipment was restricted to Yoncalla, while communication was maintained on 33.14 megacycles as far north as Drain.

Oregon 42 was travelled by one mobile unit which had 154.49 megacycle equipment only installed in it. Completely quieted signals were received between Roseburg and near the summit of Camas Mountain. Communication was maintained to a point several miles west of Camas Valley, although the background noise became very severe near the end of the run.

It was felt that a permanent installation on the top of the 800 foot hill originally selected would provide adequate service for the Roseburg area, although some doubt remains about extension of the range south of Canyonville because of the deep canyon in that area. The lower frequency provided decidedly superior communication in the Roseburg area along those routes where comparative tests were conducted.

EUGENE AREA SURVEY. The base station was installed January 23, 1948, on Judkins Point, immediately south of US-99 and approximately one-quarter mile southeast of the Highway Department District Maintenance Office, where the medium frequency station equipment is located. The elevation of the vehicle, which used the mobile antennas on both frequencies for the test, was approximately 700 feet above mean sea level and 250 feet above average terrain.

Consistent communication was maintained on 33.14 megacycles along US-99 from Eugene to 3 miles south of Cottage Grove, while contact with the mobile unit on 154.49 megacycles was lost a short distance south of Cottage Grove.

It was desired to provide communication along Oregon 58 in the direction of Oakridge. It was found that excellent signals were maintained on 33.14 megacycles from all points between Eugene and near the steel bridge at West Fir junction, west of Oakridge. The 154.49 megacycle signal commenced to clip 5 miles east of Dexter and became impossible to understand 9 miles east of that town.

Because of a limited amount of time, it was necessary to forego the survey north of Eugene on US-99; however, it was felt that the coverage would be adequate in that direction. Subsequent experience has confirmed that prediction. The lower frequency channel provided definitely superior results in the section east of Eugene and somewhat better results along US-99 south of Eugene.

SALEM AREA SURVEY. Because of the fact that the headquarters of the state departments involved is in the Salem area, the maximum amount of coverage that could be secured was desired. An inspection of topographical maps disclosed that the most elevated point near Salem was Prospect Hill, located approximately 8 miles southwest of the city at an elevation of 1,150 feet above mean sea level. The crest of the hill was not accessible by automobile; however, construction of a very-high frequency station on a nearby hill by the American Telephone and Telegraph Company was underway and the site was accessible. Permission was obtained to make use of one of the wooden poles which had been erected, for the purpose of supporting the 154.49 megacycle coaxial antenna. The 33.14 megacycle mobile antenna was used on the lower frequency. The elevation of the latter radiating element was approximately 1,000 feet, while the 154.49 megacycle antenna was mounted 60 feet higher.

The mobile unit was driven south along US-99E December 16, 1947, and test calls were made on both frequencies at intervals of one mile. The 154.49 megacycle signals were excellent, with fully quieted reception the usual case and with occassional slight noise, from Salem to Eugene. The 33.14 megacycle signals were quiet between Salem and Albany, beyond which the background noise became moderate to severe in intensity. Between Junction City and Eugene a considerable degree of clipping was experienced.

The vehicle returned to Salem via US-99W. Along that route, the 154.49 megacycle signals were consistently strong between Monroe and Junction City, while some noise was evident on 33.14 megacycles in the vicinity of Benton-Lane Park. North of Monroe, the conditions became reversed and the background noise on 154.49 megacycles became severe, while the 33.14 megacycle communication was excellent. The higher frequency propogation improved near the Naval Air Station south of Corvallis and the background noise disappeared.

December 17, 1947, the mobile unit began tests on 33.14 megacycles at Milwaukie while driving toward Salem on US-99E. Consistent contacts were effected along all parts of the route with the exception of a short section between Fallview, near Oregon City, and Coalca railroad siding, where severe noise was introduced.

Upon arrival at Salem, the vehicle travelled west on Oregon Route 22, north at Ricreall on US-99W 3 miles north of McMinnville, and north on Oregon 47 to Gaston. Signals on both frequencies were solid, with occasional slight noise, between Salem and McMinnville. Severe noise was noticed when the mobile unit was driving through the business district of McMinnville. Moderate to occasionally severe noise was present throughout the route from McMinnville to Gaston; however, contacts were made each time the base station was called.

The return trip was made via Oregon 18 to Valley Junction and Oregon 22 to Salem. The signal intensity on both frequencies was high throughout the section.

The choice of frequencies to be used in the Salem area was definitely in favor of the 154.49 megacycle channel, since the coverage of the latter south of Salem was decidedly superior. It is probable that a permanent installation on Prospect Hill would require an automatic repeater station because of the long distance between the control point and the very-high frequency site.

FINAL SELECTION OF OPERATING FREQUENCY. A review of the results secured by the use of 33.14 and 154.49 megacycle equipment in representative sections of the state of Oregon showed that the lower frequency provided generally superior coverage, with the higher frequency performing more satisfactorily in the Willamette valley south of Salem. The selection of a channel in the 30 to 44 megacycle band was definitely indicated to provide the degree of state-wide service required by the Oregon State Highway and Police Departments.

It is a generally accepted fact that the amount of interference due to anomalous propagation decreases rapidly as the operating frequency is increased above 40 megacycles per second. An inspection of the Maximum Usable Frequency charts released by the National Bureau of Standards revealed that such interference is present very seldom, and then for only short periods of time.

The Frequency Allocation Committee of the Associated Police Communication Officers, Inc., was contacted to determine their recommendation. It was found that the 42.94 megacycle channel had been tentatively reserved for use by the Oregon State Police under the national allocation plan formulated by that committee. Accordingly, formal application was submitted to the Federal Communications Commission, which authorized the installation of mobile transmitters operating on that frequency.

Temporary receiver installations have been completed at Astoria (near the Astor Column), Portland (Mt. Scott), Salem (antenna mounted on top of the steel antenna tower at the medium frequency station), Eugene (Skinner's Butte), Roseburg (steel antenna tower), and at the Marine Barracks near Klamath Falls. The operation of 75 mobile transmitters since January 1, 1949, has shown that the choice of operating frequency was proper. The communication range obtained at each location has equalled or surpassed that indicated by the initial surveys.

It is expected that permanent installation of equipment on a state-wide basis will be commenced at an early date.

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