FCC RESEARCH & DEVELOPMENT: 1938-1980

Milton C. Mobley, Retired FCC Assistant Chief Engineer

This history is dedicated to George E. Sterling and his many years of leadership in communications, as Chief, Radio Intelligence Division, Chief Engineer and Commissioner of the FCC, and to the memory of Charles Ellert, first Chief of the Laboratory Division. It was my privilege to work for and with these outstanding members of the engineering profession.

INTRODUCTION

Recent engineering graduates probably do not realize the conditions existing in our profession 50 years ago. Instrumentation now readily available did not exist, and what was manufactured was rather primitive. Instrumentation was non-digital; automated data recording was on paper charts requiring manual data reduction. The state of the art in instrument stability was rather poor; it required far more careful use than now necessary. Only one principal U.S. manufacturer of RF measurement equipment existed.

Until the early 1920's, the main U.S. government interest in communications was in application of the marine safety provisions of the Berlin Treaty of 1912, issued to promote maritime safety after the sinking of the Titanic (Figure 1). Initially, this was a responsibility of the Bureau of Marine Inspection and Navigation (BMIN) of the Department of Commerce. During that period, U.S. ship radio installations were typically leased from a concern such as RMCA or Mackay, licensed to a lessor and often operated by its personnel.

Ship transmitters were most often of the spark type, with some Poulsen arcs. Spark transmitters required careful adjustment to minimize emission bandwidth (which became broader as loading increased). Kolster of the BMIN developed the Kolster Decremeter to be used to determine the bandwidth. While the Poulsen was essentially a continuous wave (CW) device, it also had a disadvantage, in that the arc could not be keyed on and off, but rather had to be keyed by shifting the frequency to some other frequency during the space intervals of the keying. It was, however, rather popular with operators, because it required a continual supply of pure ethyl alcohol to the arc chamber. Shore stations often used Alexanderson alternators, a rotating machine that could generate RF up to at least 500 kHz. Early receivers used crystal detectors, requiring skill in selecting a "good spot" on the open galena crystal for optimum sensitivity. Later ones were of the regenerative type, and radiated a signal at the selected frequency while operating.

In 1927, because of the advent and fairly rapid spread of AM broadcasting, responsibility for all radio communication was transferred to a new agency, the Federal Radio Commission (FRC), which established inspection districts, with offices at major ports and some large inland cities. Some BMIN personnel were transferred to the Federal Radio Commission.

After the 1928 International Radiotelegraph Conference, frequency allocations from 10 kHz to 50 MHz were issued by the FRC. Provisions for television broadcasting were made in January 1929; the only system then experimentally usable was the Baird, which employed a rotating disk with a spiral of lenses in front of a lamp. In January, 1940, Kenneth Norton presented a statement on "Ultra-High Frequency Propagation" at a television hearing; this was a theoretical study of the predicted field strength versus distance of 50 MHz for transmitting antenna heights ranging from 30 to 10,000 feet and a receiving antenna height of 30 feet.

The Communications Act of 1934 replaced the FRC, and took over its personnel. It had wider responsibility than the FRC -- jurisdiction over all interstate wire and radio communications, but not equipment standards. These were added later. In those days, the staff of the Washington office was quite small; most of the FCC staff were Radio Inspectors and associates assigned to various Field Offices. The Chief Engineer had the responsibilities of the present Executive Director, and supervised most of the staff other than those immediately serving the Commissioners and the Secretary. In the beginning, the legal position was that all non-governmental use of the spectrum required licensing.

BALTIMORE FIELD BUREAU OFFICE, 1938

My first assignment as a radio inspector was to the Baltimore office of the FCC, as one of four inspectors to the then new Marine Safety Watch. This division was established to provide information on the general conduct of marine radio communications, including safety operations (which had and still have priority over routine communications). My recollection is that there was at least one similar operation at another field office. In the Baltimore case, it was in a building at Fort McHenry, also occupied by the Field Office and Monitoring Station. The Inspector in Charge then was Charles A. Ellert (later the first Chief of the Laboratory Division). One reason for the choice of Baltimore was that the bay opening to the south offered a good propagation path to the tropical areas; often at night, signals from the Brazilian and African coastal stations were heard clearly.

The Monitoring Station facilities included a frequency standard dating from about 1929, physically about as large as a small power substation, and a few receivers. Oscilloscopes of the day were limited in frequency response, so that modulation observations were made by coupling receiver intermediate frequency (IF) output to the deflection plates instead of the normal input amplifier. The office had one signal generator, a vehicle equipped to locate high frequency (HF) RFI (with a loop direction finder), and a second vehicle equipped with a Western Electric field strength meter. This was large and heavy enough that it was

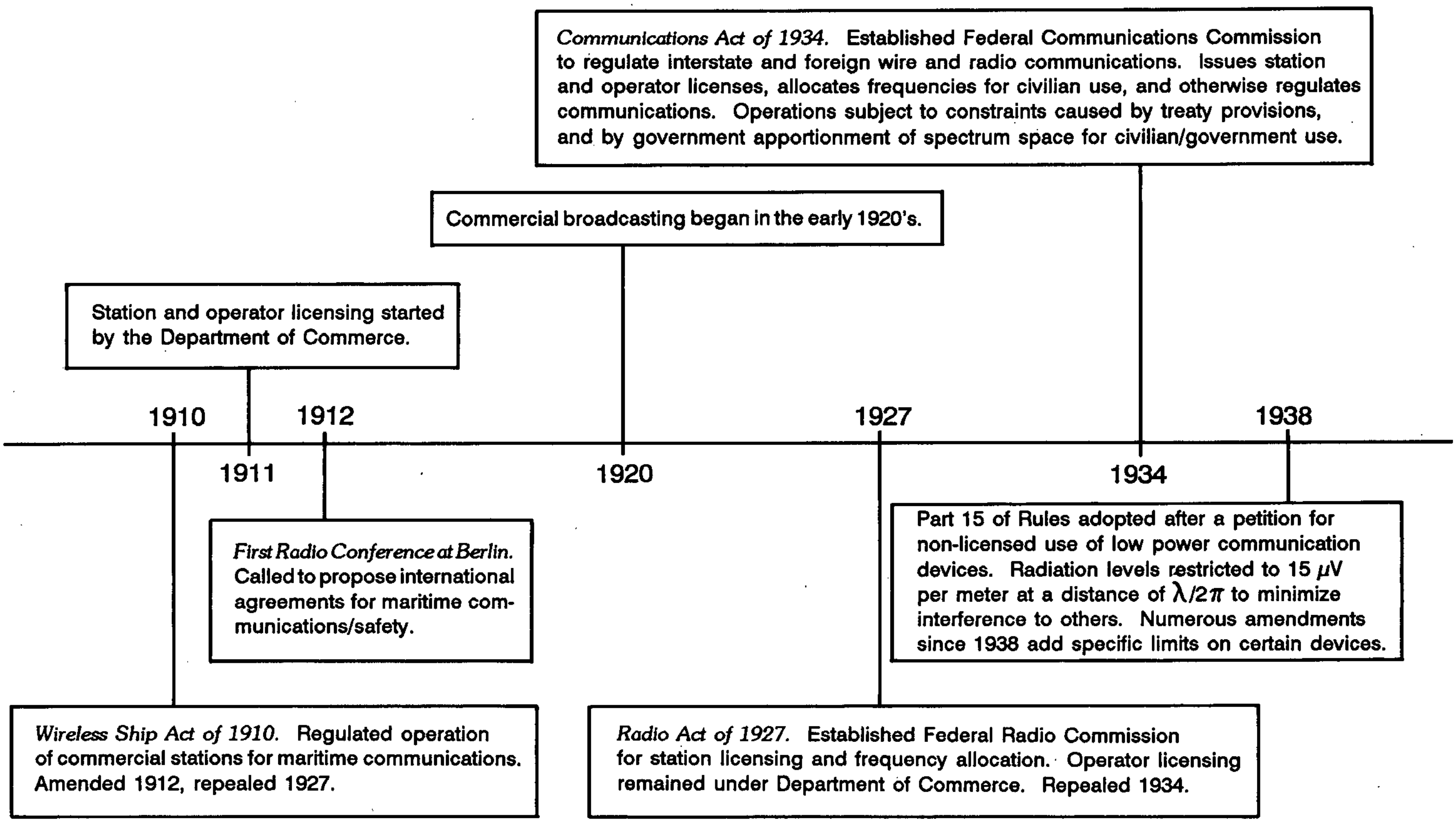


Figure 1. History of the Federal Regulation of Civilian Communications.

not portable, but had to be used as mounted in the vehicle (a Packard Limousine with a wooden body). Receivers then on hand extended to only about 30 MHz.

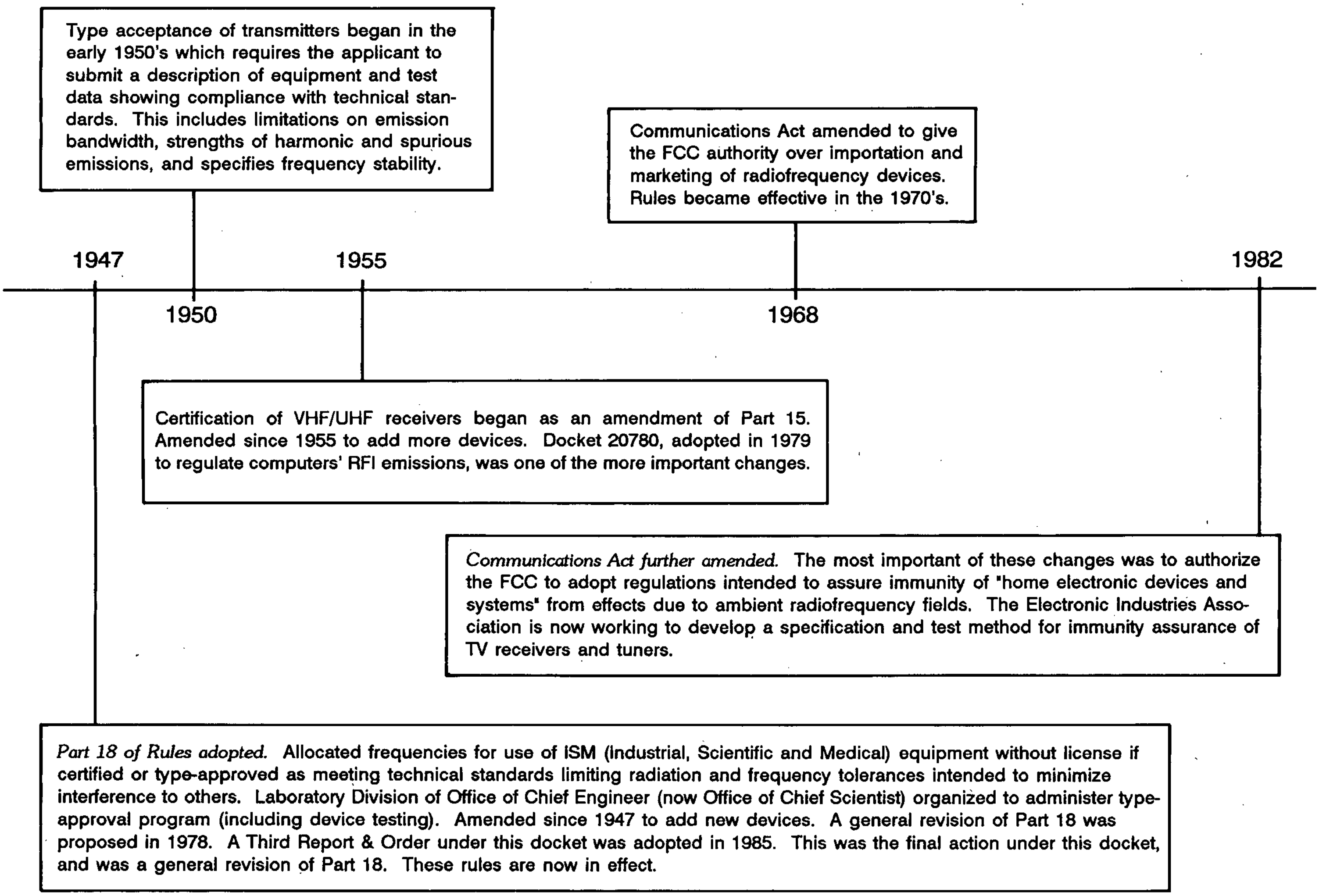
Before 1940, operations of the office mainly comprised inspection of ships entering the port (typically on a monthly basis for routine inspection, and yearly for a detailed inspection), yearly inspections of radio stations located in the district, monitoring of station frequencies, location of RFI sources, and the Marine Watch.

Unlike the present organization, the several Radio Inspectors on the staff were assigned from time to time to any and all of these operations. This incidentally widened their professional experience and tended to keep the staff informed of technical advances.

Frequency allocations were extended up to 300 MHz in 1937.

RESEARCH & DEVELOPMENT, 1938-1940

In 1938, to implement the provisions of Public Law No. 97, enacted in May, 1937, a rulemaking was proposed to improve maritime safety communications. One element of this was to require an automatic means for receiving a distress signal (an Automatic Alarm Receiver, which was to respond to a series of consecutive 4-second dashes transmitted by the ship in trouble). A second part was to require an automatic device which could key the transmitter with the automatic alarm dash signal. Another element was to determine the power level needed for effective communications (at 500



kHz) from ship main transmitters. Section 354(d) of PL 97 required that "The main installation shall have a normal transmitting and receiving range of at least 200 nautical miles ... by day under normal conditions and circumstances."

Two specimens of automatic alarm receivers were obtained for test by the Baltimore office. E. W. Chapin, (later second Chief of the Laboratory Division) conducted extensive technical tests of these devices. One element of the specification was that they have no or very rare response to any signals other than the intended alarm signal. For this reason, they were, after the earlier tests, installed with the equipment of the Marine Watch. This afforded an extended period of operation, with the monitoring staff present, to verify any response to the actual alarm signal. In later rulemakings, a similar period of on-the-air operation was required for the same purpose; alarm indications being correlated with distress reports.

As a third element, the Baltimore office was directed to make a study of ship antenna characteristics and performance, and to provide equipment for the measurement of atmospheric noise, a major limiting factor in medium frequency (MF) communications. The objective of this study was to collect data to enable FCC determination of the power level necessary for effective ship communications at medium frequency. The assessment of necessary ship transmitter power required data on antenna effectiveness, useful transmitter power output, and limitations due to typical levels of atmospherics.

At about the same time (I do not recall the rulemaking), a decision was made to collect data on overland AM broadcast propagation over the full 11-year sunspot cycle.

Commercial equipment directly suitable for these purposes did not then exist. Measurement of antenna parameters required development of a portable device including a power oscillator, with a coupling network capable of feeding RF current to the ship antenna as installed, and an integral dummy antenna, so that the apparent antenna resistance and capacitance could be measured. As the apparent antenna resistance included losses, the effective resistance was determined separately by measurement of field strength over sea water at one mile distance, with a known amount of current through calibrated RF ammeter to the antenna. Useful transmitter power output could then be calculated. From the statistics of the antenna parameters from the many ships that were measured (at Baltimore and other ports), the transmitter power necessary for a given field strength could be determined. The rulemaking eventually determined that an effective radiated power (ERP) of 200 watts was the minimum level to satisfy the requirements; due to antenna losses, this actually meant that the transmitter had to develop about 1000 watts minimum.

As a corollary to this, the sensitivity of ship automatic alarm receivers needed verification to determine the field strength necessary for their operation. For this, a special signal generator was developed. It had a calibrated RF output coupler that was isolated from ground so that it could be connected in series with the connection from the ship's antenna to the alarm receiver. This measurement, together with data on the effective height of that ship's antenna, enabled calculation of the minimum necessary field strength. This author believes that the advent of the vertical antenna in recent years, with generally higher losses, has probably worsened the effectiveness of marine safety communications at 500 kHz. Apparently this has been ignored by the FCC.

For measurements of atmospheric noise (a major limiting factor in communications effectiveness), marine receivers (including RCA-AR67, a superheterodyne type just coming on the market) were modified for noise recording. This involved changing the receiver's automatic gain control characteristic to enable measurement of average and peak noise levels, plus a mode that recorded the number of noise peaks occurring in a given interval. As the peak and average detector circuits included a 10 mFd capacitor in the circuit, and some types of these had too low a leakage resistance, a great deal of investigation was required to find a capacitor type suitable for the purpose.

After extensive testing at the Baltimore office, the modified receivers were installed on merchant ships. A second receiver modified to record the level of selected broadcast stations also was installed. The equipment included a signal generator used both for receiver gain calibration and for other tests. The latter included extensive testing using the signal generator as a transmitter to provide typical messages in the presence of measured levels of atmospheric noise, for copying by a competent operator at the time. These messages (with added noise) were also recorded so that they could be used to replicate the original tests.

Installations of this type were placed on several ships.

The results of these extensive measurements were presented to the Commission at the Ship Power Hearing [#30539] on November 14, 1938. Charles A. Ellert, Kenneth A. Norton and Ross Bateman were the principal speakers. Readers should note that less than two months were required for equipment development, a little longer for the voyages and field measurements, and about the same time for data analysis and preparation of the report, a relatively short time for such a fundamentally important project.

For the broadcast propagation measurements at Baltimore, a small building was built on a plot leased to the FCC at the Montebello Hospital in Baltimore. It was equipped with one of the marine noise measuring receivers, and with several more Hammarlund Super-Pro receivers, also modified for signal recording, and with chart recorders to record the data. These were all coupled to a vertical antenna; the effective height of this (about 10 meters) being measured after completion of the installation. Small air conditioners then being non-existent, the building was ventilated by a thermostatically controlled fan. For stability over the yearly changes, the internal temperature of the building was set to about 120 degrees, and the receiver HF oscillators were changed to crystal control.

Similar installations were made at Atlanta, GA, Grand Island, NE, and Portland, OR. The receivers for these were modified at Baltimore. There were 26 different transmission paths.

These installations were operated from 1939 through 1958 (several years more than one 11-year sunspot cycle). The recorded data for each day was analyzed to determine the median value of field strength for the hour centered at two hours after sunset for the midpoint of the transmission path. This was correlated with the numbers of sunspots for that day. This data was taken into account in the rulemaking that determined the necessary geographic spacing for stations on the same channels.

The early calibrations of the receiving antennas were carried out by Charles Ellert or E. W. Chapin of the Baltimore Field Office. After the inauguration of the Radio Intelligence Division, Mr. Chapin continued the calibration work and acted also as a technical adviser. Personnel of the Field Engineering Bureau conducted the actual operation and maintenance. George Waldo and Harry Fine of the Research Division, OCE took an active part in the data analysis.

I was fortunate enough to work on the task of equipment development, and escape most of the drudgery of chart analysis.

Petitions were filed in 1938 by parties desiring to sell low-power communications devices that could be used without having to be individually licensed. The two types that were the subjects of those petitions were: 1) A record player containing a low-power oscillator modulated by the signal from the phono pickup and radiating via the associated power lines; and 2) an AM receiver that had the tuner separated from the audio system and coupled thereto by inductive coupling from a horizontal radiating loop at IF frequency. Some research was carried out by the Baltimore Office to develop test methods. The level of radiation from the wireless record player was found to be affected greatly by the type and configuration of the power wiring of the building. This had less effect on radiation from the proposed receiver. The result was that there was a decision to set up a special elevated open-wire power line to enable measurement under controllable circumstances. A similar line was used later at the FCC laboratory in field tests of certain cordless telephones that used carrier current for transmission from the base unit to the portable unit.

RESEARCH & DEVELOPMENT, 1940-1945

In the summer of 1940, President Roosevelt directed the FCC to develop a capability for control of clandestine communications within the U.S. This resulted in the establishment of the Radio Intelligence Division (RID). A new Routine Division assumed the other responsibilities of the former Field Service.

Most of the younger radio inspectors of the Field Division were reassigned to RID. Many new employees were recruited, mostly from those holding commercial and amateur radio licenses. At Baltimore, Mr. Ellert was placed in charge of an immediate training program, covering direction finding (DF) work, both mobile and fixed, and other aspects of the RID activities. A temporary HF/DF (of the elevated-H type originally developed by Adcock in England) was set up on the grounds of the Montebello Hospital (this was made by Roger Phelps, previously assigned to the Philadelphia Field Office) and used in this training. Similar training took place concurrently at other locations, there being several hundred new employees.

Equipment for RID, consisting of cars, receivers, transmitters, etc. was contracted for, and started arriving in the fall of 1940. Several cars were equipped at Baltimore, and were used initially in the DF training. Sites for monitoring stations, both primary and secondary, were being located. When the site was chosen at Allegan, the building had been used as a school the previous spring, and the teacher was under contract for the 1940/41 year; as part of the property deal, the FCC agreed to hire her as a secretary.

In the case of Baltimore, site selection was narrowed to three possible ones: a site near Aberdeen, MD (soon after taken over by the Army); one at what is now BWI Airport (really too sandy for good ground conductivity as needed for DF purposes); and the one that finally became the Laurel Monitoring Station. This was taken over in February 1941; repairs and improvements to the road and building started immediately. At that time, the surrounding area was farmland, with a few houses and 1 small store in the Guilford Village nearby. By April monitoring was under way.

While I had originally been assigned to the secondary station at Towson, I never even went there, but worked at the Baltimore office until the Laurel property was obtained, after which I transferred, soon being detailed to a laboratory activity.

RID R&D

The ordinary directional loop antenna is susceptible to error due to horizontal polarization of the observed signal, commonly present in signals propagated through the ionosphere. For these signals, the most effective device then available was of the Adcock type(developed originally circa 1917 in England). This had vertical dipoles at the ends of a horizontal boom, which were rotatable in the horizontal plane about the center of the length of the boom. Transmission lines were along the boom from the dipoles to its center, and connected so that signals arriving simultaneously at the dipoles were cancelled, thus giving nulls at right angles to the axis of the boom. In this design, with careful attention to details and balance of parameters, the DF is unaffected by horizontal polarization.

The first Laurel HF/DF was a portable Army Adcock that had very poor performance. I was assigned the task of developing another, also of the Adcock elevated-H type. The first of these was installed south of the monitoring station building.

Measurements made on the HF/DF enabled development of an improved model which featured a tuner with coils switched to any of several frequency bands from 1.5-30 MHz. I should note that the most useful instrument in these tests was a grid-dip meter which readily showed the frequencies of various resonances and the effectiveness of changes in the coupling to the tuner. Except for a signal generator and some frequency meters (of the calibrated oscillator type), this was the main RF measuring device at the station at the time.

The first version had open transmission lines exposed to the elements; the second version had these enclosed in the hollow boom that supported the dipoles. The equipment was mounted on an elevated house about 8 feet by 8 feet, about 15 feet above ground. The first one of the second type used a battery operated receiver; later ones used AC power from underground supply lines through decoupling chokes. Heat in winter was delivered via a wooden duct from a heater at ground level.

We manufactured about 125 of this second model; some of them were transferred to OSS or the military for use out of the country. The wooden house for the device was locally constructed. All primary monitoring stations and some of the secondary stations were equipped with them. I made about 50 of the tuners; the remainder were contracted for with a small Baltimore manufacturing company.

I made many trips to other sites to verify performance of and readjust these Adcocks. When better materials became available after the war, the horizontal boom of these HF/DFs was replaced with one made of plastic tubing. Later on, they were modified for remote control. The design continued in use until the advent and installation of the Wollenweber direction finder in the 1960s.

(The same Baltimore company also manufactured for RID some units of aperiodic (wideband) receivers, designed to report the presence of RF emissions without regard to frequency. I do not recall who on the RID staff did the initial development of these receivers.)

Three commercial HF/DFs became available in 1942/43. One, using shielded loops mounted coaxially at the ends of a metal boom, originally developed by UAL for its inter-continental flight services before the war, was installed. It turned out to have errors due to horizontal polarization effects that could not practicably be eliminated. This was mainly because the loops were unbalanced instead of being balanced to ground.

A second system, Type DAJ, made by ITT (developed by Henri Busignies) was made available by the U.S. Navy. This had four arrays, each having monopoles located at the corners and center of a square area, connected by underground coaxial cables to goniometers within the monitoring station. We installed it in the field south of the monitoring station now occupied by the Wollenweber DF. While accurate, this system had a crucial flaw, in that the amplifiers used to couple the monopoles to the coaxial cables were severely affected by intermodulation. The Laurel system was not so badly impaired, but the one at Santa Ana, CA had intermodulation components only a kHz or so apart throughout the rated range. The Navy had several of these systems installed, generally in locations where the RF ambient did not cause difficulty.

Later, another paired loop type was made available for test, a Navy Type DAB. Like the UAL version, it also had problems with horizontal polarization, but these were traced to the arrangement of the loading coils used as an accessory in tuning the loops, and were practically eliminated by modification of the circuit arrangement.

So far as I know, the FCC never used any DAB's, but some were used when the U.S. Coast Guard started setting up its HF/DF network, expected to be needed as transocean civilian air travel increased post-war. I was involved in the planning of this system, as a Lt.(jg), USCG(R), in the CG HQ in Washington. As it happened, the reliability of aircraft improved so much that the expected need for a CG HF/DF system as an adjunct to Air-Sea Rescue did not occur, and the CG terminated the HF/DF program near the end of 1945.

Collateral activity at Laurel RID included training many groups in DF and other investigative techniques, including several from South America. The building at the lab known as "The Schoolhouse" was set up for that purpose originally. Transmitter hunts were carried out locally as part of the training. Several hundred people attended these courses.

ROUTINE R&D

The construction of the Cape Cod building (that later housed the FCC Laboratory) was one of several funded by Congress in 1940, expected to be used as monitoring stations (Allegan, Kingsville, Powder Springs and Santa Ana having buildings of the same design). It was started in mid-summer 1941 and finished around the end of that year. Routine Division monitoring activities were transferred there from Baltimore, with Tom Cline and Willmar K. Roberts as the initial technical staff. Jules Dietz was assigned later.

Part of the work then was non-RID monitoring (frequency measurement, modulation monitoring and compliance with other rules).

The regenerative receivers then widely used in ships for communications were known to radiate signals at the frequency they were tuned to, strong enough that submarines could use their DF equipment to locate the ship even though it was not transmitting. The rules were amended to limit receiver radiation by limiting the available power level at the receiver antenna terminals, effectively outmoding the regenerative types. Initially, use of marine receivers by commercial vessels was prohibited except in cases of distress, pending availability of approved types. Type approval was required for the new types of receivers, and manufacturers had to submit test samples to the Routine Lab for testing.

A test method and test fixture were developed for this purpose. The main problem with this measurement was that the receivers typically had high input impedance so that several could be connected in parallel to the same antenna. A meaningful measurement of available power required proper matching of the measurement instrument to the receiver impedance.

The USAF had developed the "Gibson Girl" portable distress transmitter for its plane crews to use in the event that they were forced down in an over-ocean flight. The prewar regulations for commercial ships had required them to have at least one lifeboat equipped with a permanently mounted emergency transmitter, (usually battery-operated), capable of use by non-technical personnel. Later on, ships were also required to have portable emergency transmitters. Like the USAF type, these were powered by a hand-cranked generator.

Approval testing of these transmitters was assigned to the Routine Laboratory staff at Laurel. This included testing to see if the devices would float as required without damage; one sank in testing. Later models were tested by the FCC Laboratory after it began operation in 1946.

Roberts and Dietz also conducted research into appropriate monitoring methods and equipment for VHF emissions, as the use of the spectrum had gradually extended upward from the pre-war usable limit of about 30 MHz (that limit was mainly due to lack of suitable tubes and techniques). Armstrong's experiments in New Jersey and his invention of the super-regenerative receiver had helped materially in opening up that part of the spectrum.

Research was also conducted into the levels of co-channel interference in the AM broadcast band, with the resulting data being used later to help in setting criteria for co-channel station separations. Although there had been well-known theoretical propagation criteria (developed in the Technical Research Division of the Washington office of the FCC by K. A. Norton and other noted experts), radio propagation in the real world included some unforeseen conditions having serious effects, such as causing the signal from a station to extend far beyond the predicted distances, resulting in interference within the normal service areas of other stations on the same channel. This activity included performing listening tests with variable levels of co-channel interference, as well as recording distant stations.

POST-WAR LABORATORY

In early 1946, the Commission directed that a Laboratory Division be established in the Office of Chief Engineer, to occupy the Cape Cod building previously used by the Routine Division for monitoring. The first Chief of the Laboratory was Charles Ellert (previously Travelling Supervisor in RID), with W. K. Roberts as his assistant. I had just been released from Coast Guard service, and was among several others (former servicemen and former RID personnel) assigned to the Laboratory. Concurrently, the Laurel Monitoring Station was turned over to the Field Bureau.

Within a few months, Mr. Ellert resigned to enter into a partnership that became Kann-Ellert Electronics, a parts distributorship, in Baltimore. His replacement was E. W. Chapin, previously assigned to EIC, Baltimore.

In 1946, I was temporarily detailed to the Watson Signal Laboratories, Ft. Monmouth, NJ to work with Dr. G. W. Kenrick on development of receivers for measurements of atmospheric noise in the Arctic, which was at the time a matter of concern to the military. Fortunately, this did not involve any need for me to travel there in the winter.

The rulemaking that developed into Part 18, covering ISM equipment, was then being developed. As one part of that proposal provided for type approval of medical diathermy equipment, there was an immediate need for test facilities.

One lot of surplus military material donated to the Laboratory included three SCR-270 radars (approximately 100 MHz), three other radars (type not now recalled, but operating at about 200 MHz), and three others (operating at about 400 MHz). This lot comprised 10 or 20 freight cars of material, which was hauled to the Laurel site while decisions were made as to its uses.

The SCR-270 employed a large antenna that rotated on top of a 100-foot metal tower. The tower top, rotating mechanism and controls of one radar were used in the construction of the large turntable now in the "Diathermy Range" south of the Cape Cod building. Although the drive motor has been replaced with a later variable-speed type, the range is still functional for its original purpose. It also has been used for measurements of the radiation patterns of many radio equipped vehicles, for the FCC and other government agencies.

Part 18 was adopted in 1947 to regulate the use of ISM equipment (RFI from diathermies had been a major problem to licensed communications before 1940). Type acceptance for various types of transmitters began in the mid-1950's. Part 15 was amended about 1955 to limit RFI from receiving devices (RFI from garage door opener receivers and TV/FM receivers had become a problem). In that period, these were voluntary standards for the manufacturer; they were changed to compulsory standards in the 1960's.

Another facet of the Part 18 rulemaking was its limitations on frequency instabilities of diathermies, etc. The idea of the spectrum analyzer had been proposed (a development based on the Panoramic receiver), but they were not commercially available to any appreciable extent. In 1946 Roberts developed a version of a spectrum analyzer intended specifically for diathermy frequency measurements, with markers set at the Part 18 frequency variation limits. This device was used for at least the next twenty years. In 1950 he constructed a general purpose unit for FOB use.

When Part 18 was adopted, petitions for reconsideration of the emission limits were filed. Petitioners claimed that to develop a practicable diathermy that would comply with Part 18 and at the same time be therapeutically effective was impossible. To refute this, I was assigned the task of designing and constructing one for the 27 MHz band. This was accomplished, and the device was taken to the AMA in Chicago, where it was subjected to tests of medical effectiveness. Tests included both a measurement of the amount of energy developed in a test sample of water in a given period of time (approximately 200 watts being required) and a measurement of actual clinical practice by applying it to the thigh of a test volunteer. The design of this diathermy was covered in a paper by Chapin, Roberts and Mobley, published in IEEE Proceedings around 1950.

As a further experiment, the RF generator was used as a transmitter with a different coupling network, to determine how much attenuation of harmonics was reasonably practicable. Findings concluded that simple means could reduce them to more than -100 dB, although to measure these levels on harmonic frequencies required filter usage at the input of the measurement equipment to attenuate the fundamental frequency. (This technique has since been recommended in various measurement procedures.)

Early in the organization of the Laboratory, a decision was made to include a calibration facility for its RF measurement equipment as well as that used by the Field Bureau (this continues in the present Instrumentation & Standards Branch). Irl Ball (previously at Allegan and Puerto Rico), Albert Craig and Joseph Hanyok were the first ones assigned to this effort. Nearly 2,000 instruments have been calibrated for Laboratory and FOB use since it began operation.

Due to increases in laboratory activities in connection with type approval of equipment, the two-story brick building at the rear of the laboratory site was constructed in 1948, under GSA supervision. About 1955, the one-story annex was added to this building, under FCC contract. The initial use was to house the Instrumentation Calibration facility.

One problem encountered with calibration was that all of the early VHF field strength meters marketed after WWII used balanced RF cables to connect them to the antenna, rather than coaxial cable as is the present practice. Suitable broad-band transformers to convert an unbalanced signal source to an unbalanced field intensity meter (FIM) input were not available until after the advent of ferrite and other transformer components. Roberts modified a Measurements Model 80 signal generator (then a modern type) to provide an attenuator with dual oppositely-phased outputs, for calibrating these FIMs. It was used until the obsolescence of all of the balanced input FIMs took them out of service.

Another calibration problem arose in standardizing the output level of RF signal generators. Power meters suitable for the purpose were not available. The laboratory constructed a calibration device using a bolometer for this purpose. If I remember correctly, this device was designed by Roberts.

A problem with later models of FIMs was that the dipole antennas were generally not constructed so as to provide a proper impedance match to the nominal 50 ohm coaxial cable. About 1955, Roberts developed an improved design of a dipole mount with integral matching transformer (reported in IEEE Proceedings, circa 1955, patent applied for about that time). This design has been used exclusively for measurements by the Laboratory and Field Operations Bureau, and is being commercially marketed.

Proper calibration of field strength meters that use loop antennas requires the use of a standard loop balanced to ground, with a known current through it, so that the strength of the field at a given distance can be accurately calculated. A setup for this was installed in the "Schoolhouse"; as a wooden building without aboveground wiring, it was suitable for the purpose. Preliminary tests were made in 1947 in an open field with the measuring equipment at ground level and elevated some 3 meters aboveground, and these results compared with those measured in the "Schoolhouse" to verify that it was equally acceptable for the purpose. Improvements in the method were made in 1953. In 1973, because of the planned construction of the new laboratory building, a study was made to determine how much separation might be needed from its metal structure to the site of the concrete block structure intended to be the location of this facility. As further verification, after the construction of the new laboratory building in 1975, similar comparative tests were made in the Loop Building and the "Schoolhouse." The coupling transformers used with the standard loop were replaced with wideband types featuring improved characteristics.

In the early 1950's, international proposals to require the use of a specific distress signal for small craft, like a radiotelephone equivalent to the radiotelegraph autoalarm were under consideration. Three competing systems were proposed. The U.S. proposal was for modulation with a tone of about 1300 Hz, modulated by a tone of about 15 Hz. The second proposal was for two alternating tones. I do not recall how the third one worked. Equipment to generate the U.S. tone proposal was designed by Lawrence Middlekamp at the laboratory, and several sample units were constructed. These used vacuum tubes in their circuitry. In 1951, a truck was outfitted with receiving equipment, and one each of the three proposed tone selectors. Arrangements were made with the Coast Guard to have the test signals transmitted by one of their vessels at intervals while on patrol between West Florida ports, with the receiving truck on an island near Cedar Key, Florida. This test period lasted for one month. A similar test was conducted on Lake Michigan, with the receiving truck at the lakeside facility of the Coast Guard at Port Huron, MI. The reports on these tests were submitted for consideration in making the final decision on the international radiotelephone distress signal.

Beginning in 1951 and ending about 1965, VHF/UHF recordings of distant TV signals were conducted at various FOB sites over selected propagation paths. About 50 crystal-controlled special receivers were constructed or readjusted by the laboratory for these purposes. Where needed, antennas also were constructed and calibrated for these installations. Mr. Chapin and I made about 30 trips to these locations to verify performance of the installations. The installations were operated by local Field Bureau personnel.

Data was sent to the Research Division for analysis.

In the middle 1950s the proposals for color TV involved three incompatible systems. One, proposed by CBS, and first used in medical seminars, used a rotating disk with colored sectors. Another, submitted by RCA/NBC, at first used three kinescopes with color filters to project a color picture on screen. I do not recall how the third was said to operate. While there was an initial decision in favor of the CBS system, it required an electric motor to turn the disk. A copper shortage existed at the time due to the Korean War and the decision was set aside.

By the time the shortage had ended, RCA/NBC had developed the present type of picture tube, and proposed what is now the NTSC color TV system. The laboratory worked on several projects connected with these systems, including one that used frequency modulation for the TV signal, rather than amplitude modulation. Demonstrations of the two systems were carried out at a building near the Mall in Washington, and also at the FCC Laboratory, the latter being attended by all of the Commissioners. This soon resulted in acceptance of the RCA/NBC version as the national standard. One element in the decision was that the color transmissions were compatible with the black/white TV receivers, then widely used.

Interference to aviation communication frequencies from local oscillator radiation of TV and FM receivers became a problem in the 1950s. The laboratory set up its first VHF measurement range, on the site now occupied by the present main building. Similar ranges were being installed by others typically for measurements at a 100-foot distance. As an aid to correlation of measurement results, a HF transmitter (originally used in tanks in WWII, and therefore especially rugged in construction) was used as a test sample at the laboratory and several other sites, and the data reported to an IEEE committee for comparison. This particular transmitter was selected because it was known to have poor harmonic suppression. This was the first approach to the method now described in ANSI STD C63.5 for open area site qualification.

In 1955, the laboratory constructed and equipped the first of the mobile units intended to make field observations of TV transmission quality to be operated by FOB personnel. Most of the measuring equipment and accessories were constructed or modified for improved performance by the laboratory staff; Lawrence Middlekamp did much of this work. The first unit was based at the laboratory for technical support. Sydney Lines was the first engineer to use this; Raymond Day was his successor. Another unit was constructed for use on the West Coast, and each of these was replaced by later models as improved technical equipment became available.

Another early project was the development of equipment for automatically checking on the occupancy of RF frequencies. This required the construction of two special chart recorders, using a modified Hammarlund Super-Pro receiver mechanically tuned over a selected band, or part of a band. The chart was about 15 feet in length. Tuning from one end of the band to the other took about ten minutes, with a short mark being made on the recorder trace for every unoccupied channel (or vice versa, if desired). At the end of the run, the tuning mechanism retraced at much higher speed, to the beginning. This action repeated, with the chart trace being displaced sideways to separate the second and later traces from the first. These recorder units were mounted in a truck, and HF occupancy measurements were made at several locations.

As a further modification of this equipment, VHF converters were added to the system, so that observations of VHF communications channel occupancy could be made. This equipment was used for periods of about a month each, at Chicago, New York, Laurel, and some other locations.

The post-war expansion of VHF TV, and the advent of UHF TV brought about a need to set standards for co-channel separations in distance, and address issues such as adjacent channel separations, etc.

Part of this investigation entailed comparative measurements of the effective coverage of selected co-located VHF and UHF stations (of which few existed at the time). Similar measurements were made on other UHF stations. The selection was made primarily to give data on a wide range of terrain types. A vehicle (Pontiac coupe) was equipped with a 30-foot manually operated mast (for measurements at 10 feet, and 30 feet, where possible). The receivers used were modified (VHF) or made (UHF) at the laboratory, and the antennas were calibrated there, by the three-antenna comparison method.

Surveys were made at Champaign/Urbana, IL; San Francisco, Fresno, and Los Angeles, CA; South Bend, IN; Baton Rouge and New Orleans, LA; Salisbury, MD, Miami, FL; and Harrisburg, PA. New Orleans was typical of flat country with dense forests, and semi-rural in usage; Champaign/Urbana was country with some hills and little forestation, generally rural in usage; Fresno was flat, nearly desert country, and (at that time) rural in usage; Harrisburg was rather hilly in part and mountainous in part, and generally suburban in usage; and the Los Angeles/San Francisco locations were mountain sites with very hilly surroundings, generally urban in usage. The co-located stations were, at that date, about the only instances of those situations.

At Champaign/Urbana, I worked with Adolph Andersen of the laboratory staff; in California, Miami, Maryland and Louisiana, I was assisted by engineers of the local FCC offices. At Harrisburg, Mr. Chapin, Joe Hanyok and I took turns in the survey (with a delay due to a heavy snowstorm that isolated Chapin in York, PA for three days). Overall, we put some 30,000 miles on the car in this project.

All of the survey radials were run from within a few miles of the transmitter to as far as a measurable signal could be recorded at a 10-foot antenna height. Where possible, segments of the radials were repeated at a 30-foot height. Some of these 30-foot height segments were many miles long, as at New Orleans on the bridge across Lake Ponchartrain.

Another UHF project involved setting up a 400 MHz radar transmitter on top of Dan's Mountain (approximately 3000 feet of elevation) southwest of Cumberland, MD, with its antenna aimed at the Laurel site. There the companion receiver was set up to record signal level variations. Although the Laurel site is about 1500 feet below the line of sight to Dan's Mountain, a signal was measurable most of the time the transmitter was operating. This was due apparently to "knife-edge" diffraction on a narrow sharp-topped ridge at Cacapon, WV. Signal variations due to atmospheric conditions also occurred, particularly when inversions happened along the path. The transmitter was fitted with a sampler and recorder for monitoring its power output (the tubes used degraded noticeably over a month or so), and the receiver was fitted with a motor-driven capacitor to vary its frequency to assure that the somewhat unstable transmitter frequency was within the receiver passband much of the time. The transmitter was operated unattended; laboratory staff went to the site periodically to check on its operation and to reset the recorders, etc. This project continued for about a year (until the supply of transmitter tubes was exhausted).

A later modification of the VHF/UHF recording program occurred when the FCC was operating the experimental UHF transmitter on the Empire State Building in New York. Recorders were set up in the north Philadelphia suburbs, at the home of Roger Phelps (then Engineer in Charge, Philadelphia FOB). A second group was set up at Laurel Monitoring Station. In addition to the UHF receiver, each of these also had receivers for recording signal levels on VHF Channels 5 and 7. A special problem arose at the Laurel site; the ambient signal from the Washington Channels 5 and 7 was far greater than that from the New York stations. The solution to this problem was unusual: for each channel, one antenna was aimed at New York and one at Washington. The attenuated signal from the Washington antenna was phased to cancel the part of the Washington signal picked up by the New York antenna. As the respective frequencies of the visual carriers of the two stations on each channel were offset, the bandwidth of the recorder was then set to about 1 kHz, so as to separate the desired remote signal from the undesired local signal. To compensate for slight frequency instabilities at the transmitters and in the recording receivers, the frequency of the receiver's first local oscillator (crystal) was varied periodically over a small range (experimentally chosen) so as to keep the desired remote signal within the receiver bandwidth without approaching the frequency of the Washington station carrier. These VHF/UHF recorders were operated until the use of the New York transmitter was terminated.

At the beginning of the UHF project, in 1961, the laboratory was assigned the task of calibrating antennas and measuring equipment used by the Commission's contractor (who was to make surveys of comparative VHF/UHF signal quality within 25 miles of the Empire State Building). Part of the work included construction of dipole antenna sets of the Roberts type and calibrators for the Smith portable VHF/UHF field strength meters (purchased under a separate contract). This project included installing UHF/UHF TV receivers at a number of selected locations in New York City and suburbs. As an aid in the selection of suitable receivers, the laboratory conducted tests on receivers of ten manufacturers plus some converters and separate tuners. After the decision on the selected models, the laboratory conducted sampling tests of the 125 receivers delivered for use in the project.

The laboratory also equipped a Corvair van (with an air-erected 30-foot antenna mast) to be used by the Research Division (then in the Washington office) for measurement of VHF/UHF signal levels, along selected radials beyond 25 miles from the Empire State Building. This van was equipped and although the operating personnel was given instructions in its use, they did not fully appreciate the problems of driving around with a mast above the vehicle until it had been damaged a few times by running into obstructions.

In 1973, Congress appropriated funds for the new laboratory building. It was completed in 1975, and operations transferred there. The type acceptance processing, formerly in the Washington office was transferred to the laboratory.

To include detailed statistics on types and numbers of research and equipment approval projects would make this article unduly lengthy. In the period 1946 to 1980, several hundred research projects, concerned with proposed communication systems, propagation, interference problems, etc. were undertaken. Many studies have been made on the performance of devices on the market; one of the most notable of these was the evaluation of 50 TV receivers for susceptibility to intermodulation. In that period, several thousand devices were tested for type approval or certification. Approximately 1100 CB transmitters were evaluated in a short period when the new CB rules were adopted; the FCC had promised industry that all applications filed by a certain date in November would be processed by the following January 1st.

From the beginning, senior members of the laboratory staff have worked with industry groups on the development of equipment standards and test methods. They also took part in U.S. delegations to many international conferences. This is a continuing activity. ■

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