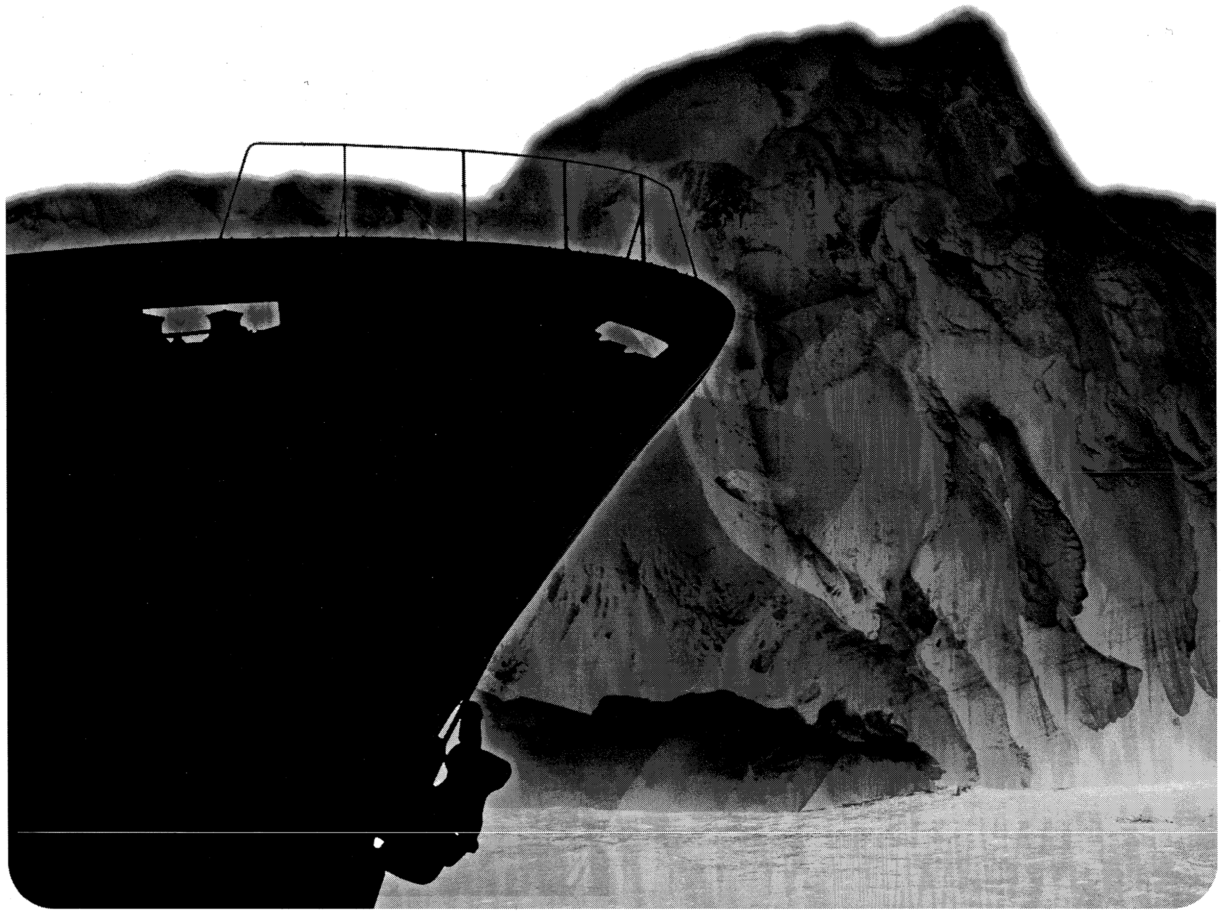
PROCEEDINGS OF

THE RADIO CLUB OF AMERICA, INC.

Founded 1909, New York, U.S.A.

Fall 1997



Titanic Tragedy Spawns Wireless Advancements

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Plaque Dedication to Fred Link – Pg. 21

Historic Connections – Pg. 27

The Advent of Thin-Film Manufacturing – Pg. 37

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THE RADIO CLUB OF AMERICA, INC.

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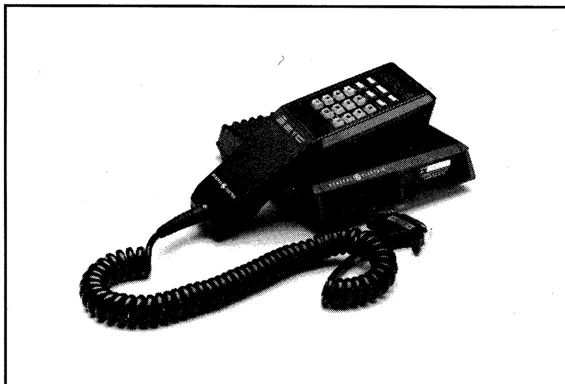

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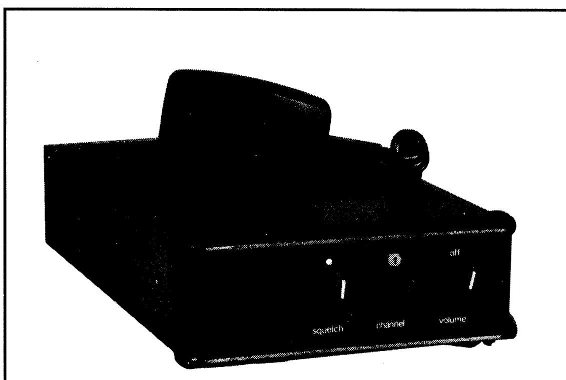

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Jane Bryant, **Proceedings** *Editor*

The Past, the Present, the Future

The advent of personal communications services (PCS), with more than 55 markets online, signifies the power of wireless communications. Wireless has changed the way we work, communicate and live. The future for the radio communications industry appears limitless as new spectrum and applications are opening the doors to entrepreneurs who are devising ways to make communications better and better. In addition, diverse applications are on the horizon such as digital camera technology married to phones and more content delivered via wireless.

All of this is truly amazing and would not be possible without the ingenuity and dedication to wireless communications of the radio pioneers. This issue of the *Proceedings* takes all of this into account with a mix of editorial highlighting the past and today's accomplishments.

The RF engineers of the past have paved the way for the next generation of radio enthusiasts to enter an exciting and booming wireless industry. The opportunities for tomorrow's engineers are incredible. There exists vast opportunities for engineers with RF capabilities, as the shortage across America continues.

Hiring good RF engineers continues to be a major challenge for wireless communications companies. In spite of this challenge, continuous inroads are being made in RF technology by today's engineers.

Today's achievements are made possible by innovators and leaders like Fred Link, who played a significant role in contributing to wireless' role in war and public safety communications. Our *Proceedings* features on "The Father of the Police Radio" and "Plaque Dedication to Fred Link" depict a time when radio communications was becoming king. Perusing these articles provides a taste of how the radio advancements of the past shaped the developments of today.

The critical importance of wireless communications can be seen in "*Titanic* Tragedy Spawns Wireless Advancements," which describes the tragic happenings of the magnificent *Titanic* and how improvements in radio came about after this maritime disaster. It is unfortunate that it took the sinking of this large ship and the loss of lives to change radio communications processes.

We feature arc transmitter technology in our article on "Historic Connections." This article summarizes what nuclear science owes to the development of arc transmitter technology.

The present and the future are depicted in "The Advent of Thin-Film Manufacturing." This article describes how superconductive electronics are enabling improvements in call handling at cell sites as wireless communications components based on the low-loss property of HTS thin films can provide significant performance benefits as well as significant size and weight reductions for filter

Continued on page 35

By Ray Minichiello

Titanic tragedy spawns wireless advancements

The tragedy of the RMS *Titanic* — loss of life numbering 1,500 passengers the night of April 14, 1912 — was a great tragedy that seems even greater when one considers that all 2,205 *Titanic* passengers might have been rescued if just a couple of things had happened differently. Nothing is gained, however, by living in the world of "if only." Tragedy often breeds progress, and in the case of the *Titanic,* this proved to be true.

Little has been said of the circumstances of the *Californian*, a passenger ship that was within sight when the *Titanic* struck the iceberg that caused it to sink. The *Californian* failed to acknowledge the distress flares of the *Titanic* or to turn on its wireless. The passenger ship *Carpathia*, 58 miles southeast of the stricken *Titanic*, responded to the distress call and rescued 705 passengers in lifeboats. The other 1,500 passengers had succumbed to the cold sea.

The sinking of the "unsinkable" *Titanic* shocked the world. The pride of the White Star Line, the *Titanic* was the sister of the RMS *Olympic*, which had already enjoyed great success and acceptance by the travel industry. The *Olympic* had also set a speed record for the round trip from England to New York.

The *Titanic's* sinking generated an opportunity for many to profit on the meager details available. Most details were available through the late David Sarnoff, the Marconi wireless operator, atop the Wannamaker Building in New York City. Sarnoff handled traffic without relief for several days with the ship *Carpathia* and the shore station at Glace Bay, Nova Scotia. Sarnoff's tenacity and loyalty during the period of uncertainty catapulted him to fame, and later he became president of Radio Corporation of America.

News released to the media by the Marconi Wireless Company was often distorted, and the sensationalism often overshadowed the enormity of the tragedy. The book publishing industry joined the bandwagon and capitalized on the distress of the survivors and the family members of those lost at sea. One book in particular, *The Sinking of the* Titanic *and Great Sea Disasters,* published within weeks of the disaster, was pedaled door-to-door with a profitable success.

Even the cinema, in its infancy, capitalized by producing animated films of the *Titanic*, including such scenes as passengers' struggles and fights to find space on the limited number of lifeboats. By the moral standards of 1912, the animation exceeded human tolerance.

Since the *Titanic's* sinking, stories, books, documentaries and films have emerged with variations of the facts. The fascination about the *Titanic* continues to attract the human soul. The latest resurrection is the movie, *Titanic,* due for release Dec. 19, 1997. This movie, by 20th Century-Fox, is a $200 million extravaganza representing most accurately the events taking place prior to, during and following the *Titanic* disaster.

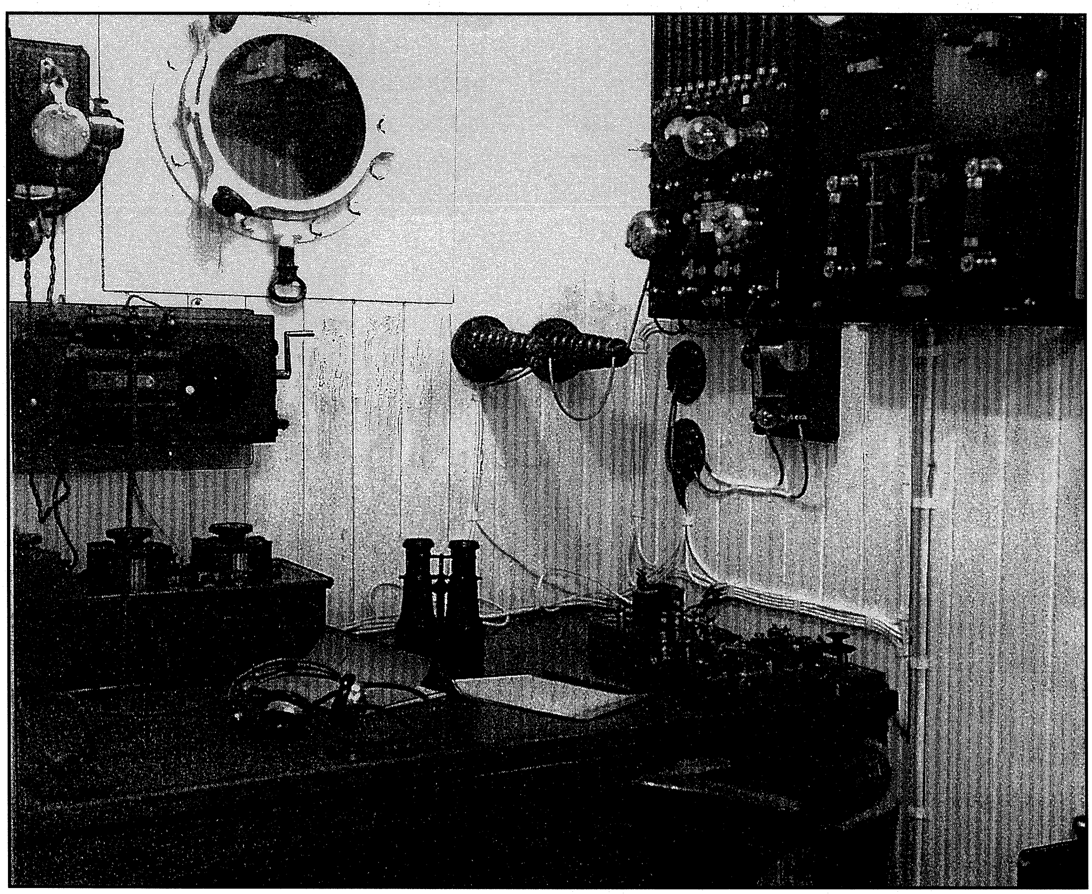
No money was spared in the research and presentation of historical facts, or the re-creation of scenery depicting the ship including the grand salon and, of course, the replica of the wireless room that played a most important role in the rescue of the 705 passengers.

The movie goes into extraordinary detail to include replicas of the motion picture cameras of the 1912 period, to depict the filming of passengers gathered at the pier to embrace one another for the last time and extend a wish for a "bon voyage" before embarking on the *Titanic*. The reproduction accuracy of the wireless room and its equipment will be testified to when the original wireless room is lifted by Titanic Inc. and delivered to the Marconi Museum in Bedford, NH, for evaluation and display. Titanic Inc. and its president, George Tulloch, are the salvage contractors given sole rights to the recovery of any and all of the *Titanic* lying 12,000 feet at the bottom of the sea. Artifacts already recovered and restored by Titanic Inc. are currently on display in Memphis, TN. The exposition moves on to Atlanta for opening Nov. 19, 1997.

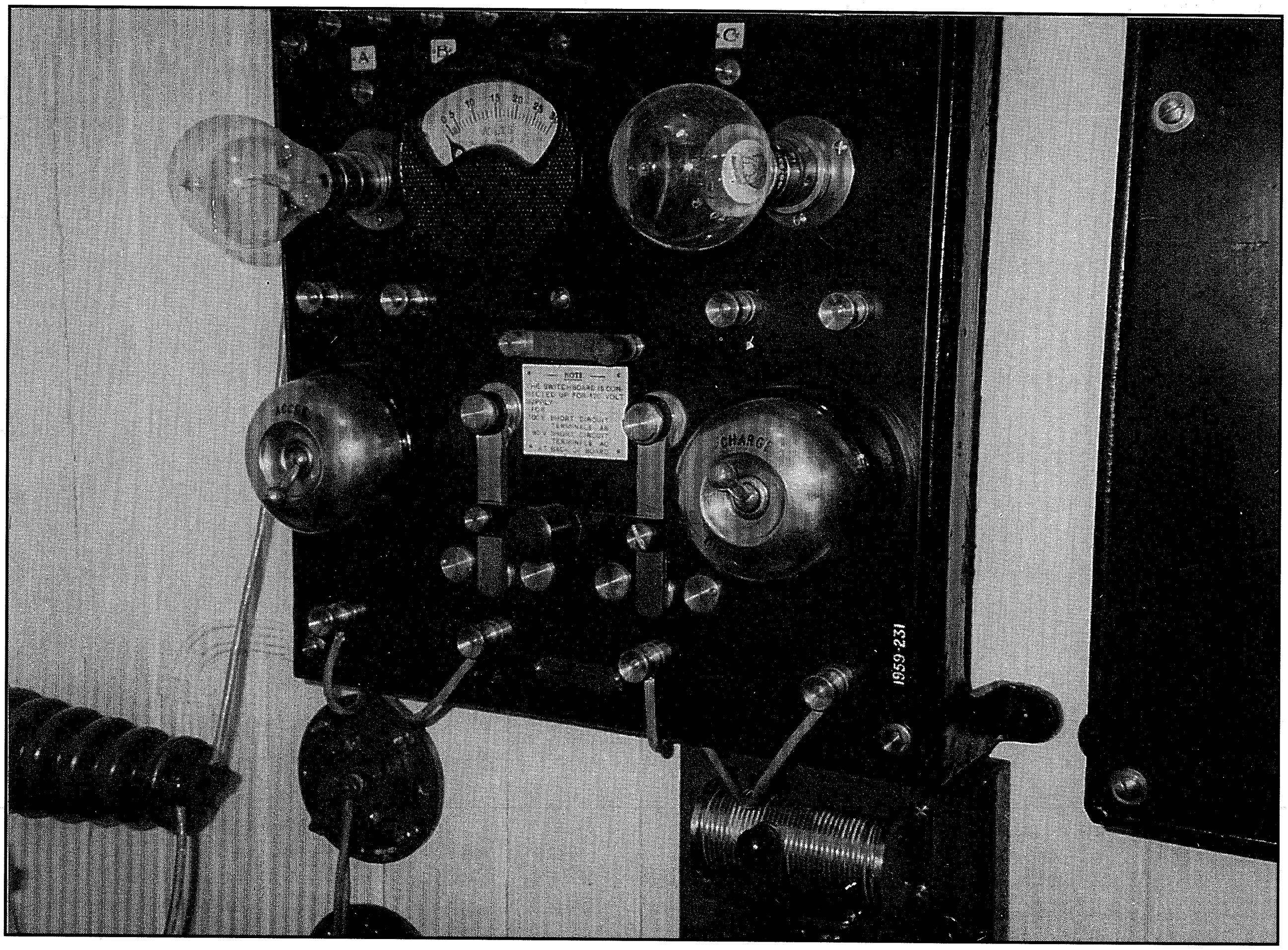
The Wireless Room

The importance of the *Titanic*'s wireless room after striking the iceberg can best be described by the beginning of events on the evening of April 14, 1912. The night was clear, and many stars were visible. The sea was calm. For the North Atlantic to be so smooth was a sailor's dream. The *Titanic's* captain, E.J. Smith, apparently saw his opportunity to go full speed ahead in an attempt to break the ocean-crossing record of its sister ship, *RMS Olympic*. Lookouts were posted in the crow's nest to watch for icebergs ahead.

Prior to the collision of the *Titanic* with the iceberg, two wireless messages warning of an iceberg field ahead were received by Jack Phillips and Harold Pride, the Marconi wireless



Titanic wireless room replica.



Switching panel, from generator to emergency battery.

operators aboard the ship. The most critical report was received at 9:40 p.m. from the ship *Mesnaba,* stating the ice field position at 42 25' N, 50 30' W. The *Amerika,* too, had sent a wireless message earlier, at 11 a.m., advising of the ice field at the same coordinates. These reports were posted but not acted on by Capt. Smith or his first officer. Disaster was imminent.

At ll:40 p.m., a lookout shouted the report of "iceberg dead ahead!" repeatedly. The bridge attempted evasive action but struck the iceberg on its starboard side, ripping through the hull a length of nearly 300 feet. The *Titanic* suddenly was no longer invincible. Having lost its sealable bulkheads, it was unable to remain buoyant at its bow, and within only 150 minutes following the collision, the bow submerged. Then at 2:10 a.m., in a final gulp, the stern rose up to an angle of almost 60 degrees, lurched, and began its descent to the ocean's floor.

The chain of events that followed would, by today's standards, be declared incredible, and lawless. One must be remember, however, that the rules and regulations governing safety at sea had not yet been adopted for this rapidly growing industry. The period of the early 1900s was one of rapid growth of the luxury liner popularity. The wealthy pursued the first and second class staterooms, and great numbers of European immigrants crowded the third class facilities. Also, the countries with shores touched by ocean travel ports, lacked expedient communications to review, foresee and call for international regulations.

Communication by wireless had just emerged. It was a scant 17 years after Guglielmo Marconi discovered an application for Hertzian waves, and only 15 years following the formation of "Marconi's Wireless Company Ltd." in Chelmsford, England. The installation of wireless on ocean-going vessels began in the early 1900s, but the objective was profit from transmissions of messages, mainly commercial, to compete with the established overland wire service already in place. Thus, the *Titanic*, as were other ocean liners, was equipped with Marconi wireless systems primarily for the commercial handling of message traffic. The wireless operator's responsibility was to transmit and receive messages known as "MarconiGrams." These included stock exchange quotations, and business, private and news messages. Wireless for signaling distress was incidental. The multitude of non-passenger ships had no reason to be equipped with wireless. The implementation of wireless as a means of safety at sea was remote. The absence of regulations governing both safety at sea and wireless use contributed to the *Titanic* disaster.

To understand the role of wireless on the night of April 14 is to understand the primitive stage of wireless technology of the period. To begin with, the generated signal of the spark transmitter was blunt and broad. The spectrum it occupied was, for example, all of today's broadcast band and then some. The lopsided theory of the period demanded brute force power for the signal to reach a magnetic detector or a galena crystal receiver; these, too, were broad in reception. Selectivity as a specification for receivers and bandwidth for transmitters was yet to be an established criterion. Hence, during close-proximity operation of stations, whoever hit the air first occupied almost the entire spectrum, denying others within close range the ability to communicate unless a tuned circuit (more of a wave trap) was employed to minimize the interfering signal.

The precise frequency of the *Titanic* and *Californian* transmitters at the time of the incident is not known; nevertheless, whatever the separation, the poor receiver selectivity and the closeness of the two vessels allowed but one transmitter operation. Herein, the lack of regulations, as well as the lack of procedures governing wireless operators, resulted in the inevitable blow to the *Titanic*.

Aboard the *Californian*, the wireless operator, Cyril Evans, turned on his wireless to dispose of his routine traffic. Because of the close proximity of the two ships, however, the *Titanic* operator advised Evans to "shut up" as he was interfering with traffic to Cape Race, a shore station. Evans complied. Being the lone operator on the *Californian* and having worked a long day, Evans retired for the night — another unfortunate occurrence for the *Titanic*.

The *Californian*, just 10 miles from the *Titanic*, found itself in the same ice field earlier in the evening, at 11 p.m. Wisely, the captain of the *Californian* had ordered his ship to a halt, preparing to wend its way out in daylight.

The *Titanic* struck the iceberg at 11:40 p.m., less than a minute following its sighting by the lookout, but the "CQ/D" (General Call/Distress) was not initiated until 12:15 a.m., 35 minutes later.

The *Californian* first officer observed white flares shot into the sky from the *Titanic* but unfortunately assumed these to be shooting stars. He also thought of the possibility that these flares were part of a celebration aboard the *Titanic* because arbitrary discharge of flares, white or colored, was not regulated. The first officer's uncertainty nevertheless prompted him to use the Morse Light Signal Lamp aimed at the *Titanic*, but he received no response.

The *Californian* did not attempt to send a wireless inquiry to the *Titanic*. Because of this one failure, the fate of the 1,500 lives was doom. Evans, the *Californian*'s wireless operator, had already retired, and no attempt was made to awaken him to assume his post at the key of the wireless station. It was, indeed, one imbroglio after another.

The scene now changes. (For graphic representation of ship locations, please refer to Figure 1.) Fifty-eight miles to the southeast of the *Titanic* was the *Carpathia*. The wireless operator, Thomas Cottam, was preparing to retire when, by

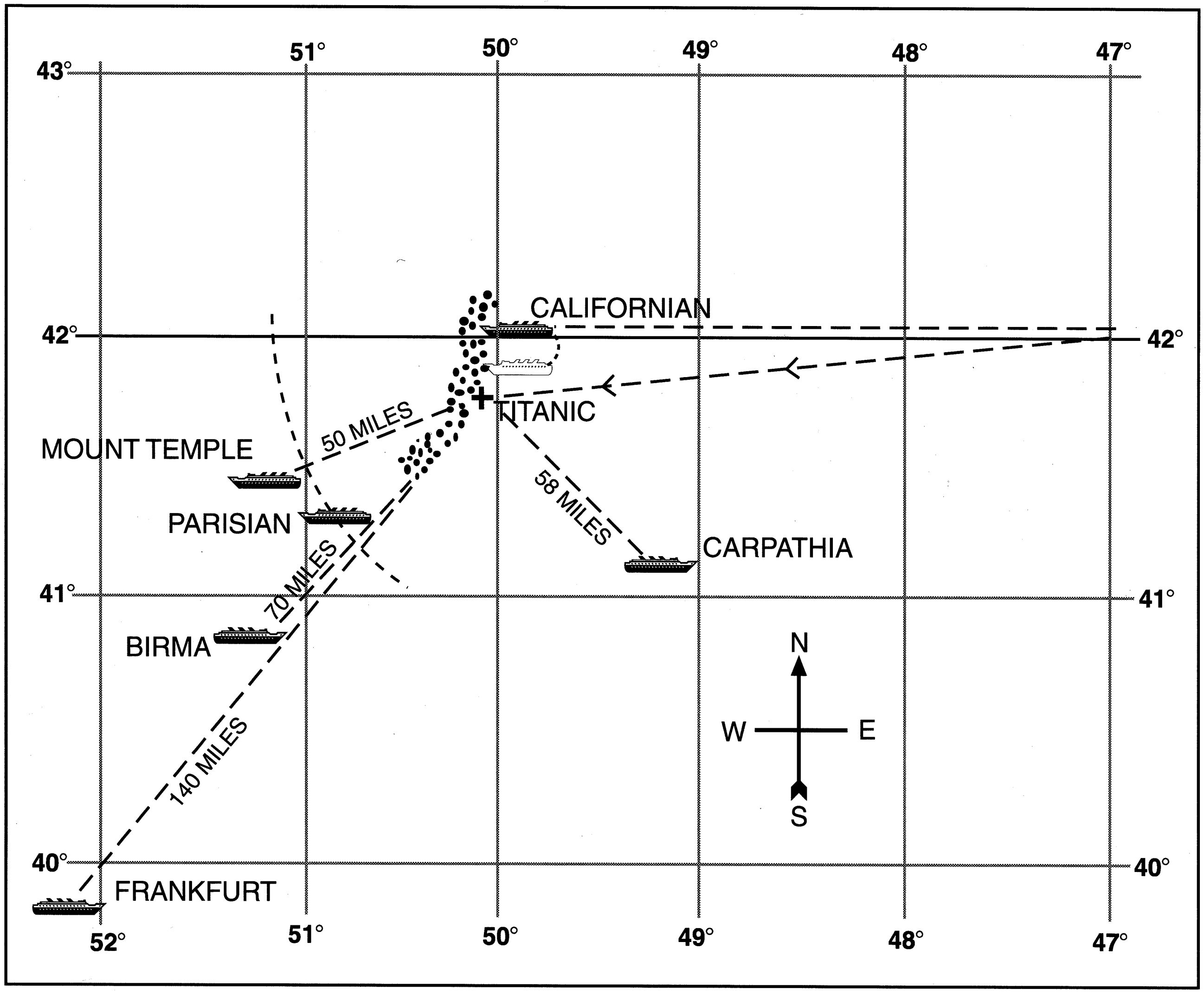
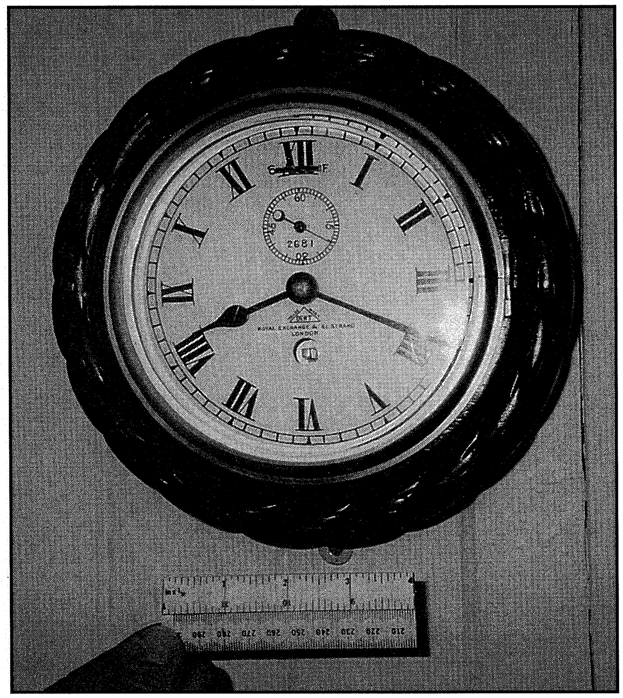


Figure 1. The Titanic*, the ice field and nearby ships.* Titanic *struck iceberg at 11:40 p.m., April 14, 1912; CQD sent at 12:15 a.m.*

chance, he initiated contact with the *Titanic* to advise its operator that Marconi station at Cape Cod was attempting to contact him. The response from the *Titanic* was prompt, with an urgent message naming itself in distress and requesting aid. The *Carpathia* turned its course 140 degrees and headed for the *Titanic*. Although there were many ships in the area, including the *Frankfurt* 140 miles away, that heard the "CQD" and were racing toward the *Titanic*, the *Carpathia* arrived at the scene first, at 4:15 a.m. On arrival, there was no *Titanic*, only emptiness, except for the lifeboats containing 705 passengers. By 8:30 a.m., all survivors were picked up.

One can only imagine the *Californian* crew's despair when in the morning they were told that the *Titanic* sank during the night. They were there, a few miles away, but the last to know.

The details of the *Titanic*'s sinking are well documented by the minutes of the inquiries of both the United States and Great Britain. The most significant result of the disaster investigations was the call for an International Radio-Telegraph Convention to convene in London on July 5, 1912, for the purpose of establishing regulations and procedures governing wireless services aboard ships and ship-to-shore. Attended by 65 countries, the convention was a



Wireless room clock, spring wound, built as a replica of the original including all the markings.

Replicas of motion picture cameras of 1912 vintage. They were used in several scenes, filming passengers prior to boarding the Titanic.

success. Regulations and procedures were enacted, some of which are still in effect today. Among these is the "SOS" as the universal call for distress as it was determined to be the simplest form of signaling to replace "CQD." The "Q" signals were an outcome of that meeting.

The first conference, "Safety of Life at Sea" convened in London on Nov. 12, 1913 and was attended by 65 countries. This conference was the turning point of communications as we know it today. Sweeping regulations were put into effect governing all ships at sea, whether motor-propelled or wind-propelled. Ocean-going ships carrying passengers to foreign ports were mandated to be fitted with a wireless installation. Further, the wireless station was to be manned 24 hours a day. The wireless room became the focal point on board all vessels having to abide by all the new rules, regulations and laws, establishing safety of the ship and passengers as the first priority. This was a departure of wireless from its previous role as mainly a dispatcher of commercial traffic for profit. The value of wireless on board was now self-evident.

The "Safety of Life at Sea" conference was concluded Jan. 20, 1914. It was determined that all countries having ocean-going vessels were culpable for inadequate safety regulations on its vessels. The conference emphasized the necessity for a united action to revise the old laws and adapt them to the new conditions. The benefit of these new regulations apply to this day. This conference ended the "free-for-all"period on the high seas. Regulations were made concerning the number of lifeboats required on board, life jackets, procedures, and officer and crew responsibility. It was agreed, too, that three ships from the United States and England would be dispatched to the North Atlantic to serve as an ice patrol to advise other ships by wireless of iceberg locations. On-board lighting was also part of the overhaul. Morse Light and other signaling methods, including rules governing the discharge of flares, were revamped.

There might not have been any loss of life if the *Titanic* had not been operating by the archaic regulations established in 1894. Although the ship was certified to carry 3,500 passengers and crew, the lifeboat capacity on board was for 1,200. In accordance with England's old Board of Trade Regulations, the *Titanic* was indeed in compliance with the required number of lifeboats. The rules set forth 18 years earlier stated, "Sixteen lifeboats shall be carried for ships 10,000 tons and over." The *Titanic* was a 46,000-ton vessel! The number of lifeboats was determined by tonnage, not by number of passengers. The *Titanic*'s 16 lifeboats and four rafts were barely capable of supporting 705 passengers. One of the lifeboats capsized during its launching, causing those who occupied it to lose their lives.

Although the *Titanic* was magnificent in construction, referred to as a floating castle, the investigation of the *Titanic* tragedy revealed a great number of inadequacies. These included improper bulkhead design, navigation judgment errors, lack of emergency procedures, an improperly trained crew and a host of other acts of negligence.

In all its bungling, the *Titanic* and its 1,500 passengers lost at sea became the catalyst for the examination, re-evaluation and the implementation of new marine regulations. It has been more than 85 years since the tragedy of the *Titanic*, yet we continue to rejoice in 705 lives saved.

Marconi's Inquiry

Guglielmo Marconi promptly went to the dock to greet the arriving survivors on the *Carpathia* and to interrogate his employee, Harold Bride, the wireless operator. It was but a few days later that the survivors presented Marconi a solid gold medal, in gratitude for his wireless installation on board the *Titanic,* which is credited for saving their lives. Without wireless on board, all 2,200 passengers might have perished, leaving behind a terrible mystery to haunt us forever.

A tragedy can sometimes give birth to a greater acclamation that possibly would never occur otherwise. This is the legacy of the *Titanic* disaster. The news of the *Titanic* was closely followed by everyone. What better projection of the word "wireless" could there be, as the news media carried the disaster story day after day for months? The mystique of the word "wireless" gave birth to a new generation of operator aspirants, together with need for accelerated manufacture of wireless equipment to meet the demands for ship and shore installations.

Marconi recognized the need for operator training and established Marconi Wireless Schools throughout the world, including in the United States. The new regulations requiring wireless on board all ocean-going vessels made it necessary for Marconi to step up production to meet the need. In Oct. 1912, Hugo Gernsback also grasped the opportunity to be a wireless supplier and formed the Electro Importing Company on Fulton Street, New York City, mailing out 200-page catalogs. Lower Manhattan developed into the mecca of wireless manufacturing companies and supply houses. The radio amateur, already experienced in wireless, greeted a new flock of enthusiasts eager to join this elite group of pioneers, thereby further expanding the user market. The advent of the vacuum tube, 201A, developed a few years later, justified the sophisticated term "radio."

The tragedy of the *Titanic*, occurring when it did during a period of slow growth of a new industry, was responsible for the jump start of the wireless, radio and electronics industry that today provides the greatest number of jobs in the history of civilization.

About the Author

Ray Minichiello, P.E., (W1BC) is chairman of the Guglielmo Marconi Foundation, U.S.A. Inc. and the U.S. National Marconi Museum. He is also Director, Fellow and Life Member of the Radio Club of America, Inc.

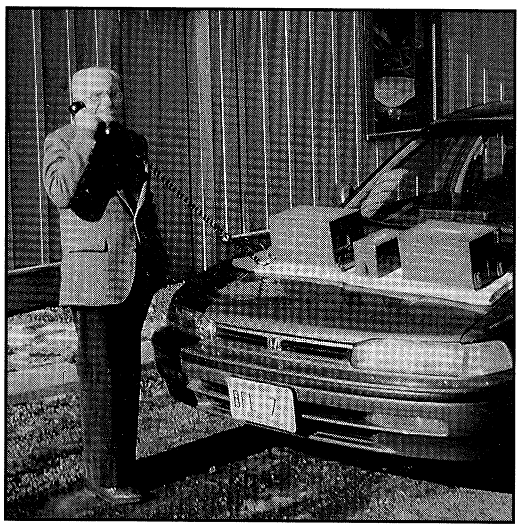
Photo credit: Terry Reed

By Dean Hammond

The Father of the Police Radio

About two-and-a-half years ago, while traveling around the country in search of a 1941 Ford Connecticut State Police car featured on the cover of the *Saturday Evening Post* 50 years ago, I happened upon several new friends. All are great people from various walks of life, but none is so interesting as a man who shares his year of birth with the Connecticut State Patrol (CSP), the first state police department in the country.

For the first two years of friendship, we knew each other personally only by our voices on the phone and a quick hello on a Christmas card. I learned a lot about him from others and from books and magazine articles at the library. He is not only my friend but the friend of every police officer, soldier, fireman, explorer, pilot, sailor and everyone who has ever relied on the two-way radio for assistance. He has many titles. "Father of Land Mobile Radio" and "Father of the Police Radio" are the two most noteworthy.



Fred Link tests out the radio outside of Rathskeller Pub, Frenchtown, NJ.

At age 92, Fred Link still refers to the gift he gave to the CSP as "my baby." His baby is now 56 years old. It has grown up and has had many offspring of its own, but when I last checked, you could see most of great grandfather's characteristics in today's youngsters. Several original family members still reside in Connecticut. The last one (a radio tower) I visited stood proudly at the top of Chestnut Hill Road in Killingworth, CT, where nothing has changed during the last half-century.

The first child was given its name eight months before delivery, on March 7, 1940, by the Federal Communications Commission (FCC). The name was W1XTJ. The father listed on the certificate is F.M. Link, and the scheduled delivery date was Nov. 7, 1940, in Hartford, CT.

The FCC prescribed only that the baby not interfere with other frequency families that lived in Hartford's surroundings. The baby was small in comparison to those today, only being 25 watts.

W1XTJ grew up fast. Within a year of its birth it had 10 brothers and sisters. They are all relatives of the family we know today with the surname of KCA782. All of the family has remained healthy, except for a new transmitter or two. Their tower heights have shrunk, and they have become more sophisticated, but they still have an active career.

In the first minute of the first conversation I had with Fred, he made it quite clear how proud he was to have his first "baby" in Connecticut. The next hour was spent praising the baby's mother, former Commissioner Edward J. Hickey and the Connecticut State Police.

Over the years, Fred has returned to Connecticut to visit his extended family on many occasions. One of his fondest recent memories was the dedication in 1987 of a bronze plaque at 100 Washington St. that reads "*A major advance in police radio occurred in 1940, when the Connecticut State police begain operating a two-way, frequency modulated (FM) system in Hartford. The statewide system developed by Daniel E. Noble of the University of Connecticut, and engineers at the Fred M. Link Company greatly reduced static, the major problem of the AM system. FM mobile radio became standard throughout the country following the success of the Connecticut system.*"

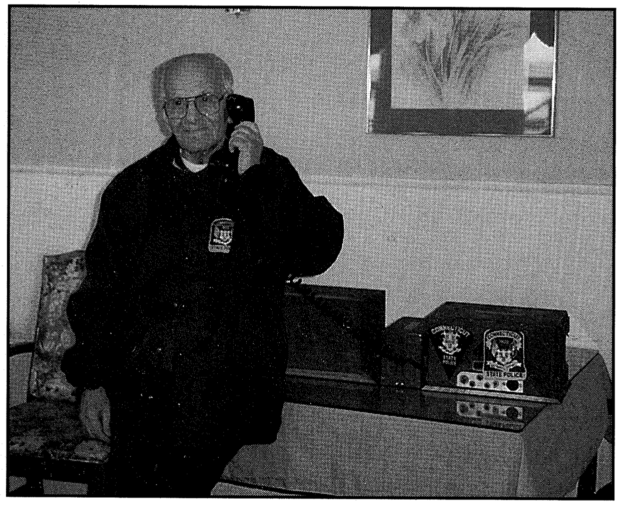
Fred has been eager to return again to Connecticut, and I have been eager to visit his farm in Pittstown, NJ. Because of his health, it made more sense for me to bring Connecticut to Robin Hill Farm than for Fred to venture north. On a beautiful day in January 1997, I transferred the Link radio from the trunk of the 1941 cruiser and headed to New Jersey.

Robin Hill Farm is a large horse farm where Fred and his wife, Mildred, have lived since 1960. It is a western New Jersey town near the Pennsylvania line. The countryside of rolling hills, small villages and farms is much like eastern Connecticut. Fred has been having some difficulty getting around lately, and finds things easier at the nearby Valley View Manor.

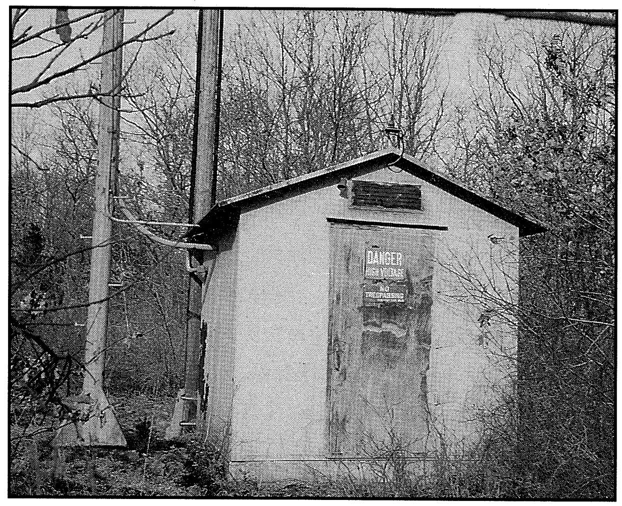
Upon arrival at Robin Hill, I was given a tour of the grounds by Frank, the farm manager. Besides keeping their own horses and boarding several others, the Links rescue horses destined for the slaughterhouse. Inside the comfortable ranch house, one is quick to realize that it is the home of someone special. Congratulatory tributes and letters of praise from several U.S. presidents blanket the walls. Certificates of accomplishments and lifetime achievement plaques are visible from any point. This is the home of the man whose powerful amateur short-wave station, W2ALU, made history in maintaining radio contact with Admiral Byrd as he explored the South Pole. It is the home of a man, who along with John B. Knight, constructed the first TV transmitter ever to air a scheduled program. This man's radio equipment was largely responsible for the Allied success in the second World War. This is the home of a citizen who three times returned from retirement to assist his country and the radio industry. This is the home of the man best known as the "Father of the Police Radio."

Valley View Manor is down Cook's Cross Road from Robin Hill Farm. Mildred and I were driven the short distance by Carlos Hudson, the Links' good friend who was visiting from Mexico. Everyone at Valley View was eagerly awaiting our arrival — none more so than Fred. I was thankful that I had remembered to transfer the radio into the trunk of Carlos' car because everyone wanted to see the "radio that Fred built." Despite having to cope with the typical problems of age, Fred smiled from ear to ear as I set up the three units that constitute the trunk-mounted radio in the social hall. The staff was most impressed in learning how Fred's radio revolutionized the industry and was a major factor in winning many battles of the second World War. Here, 50 years after the war, Fred was standing shoulder to shoulder with veterans who owed their lives to the Link radio and Fred Link.

Over lunch at the Rathskeller Pub in Frenchtown, NJ, Fred, Mildred and Carlos outlined Fred's career and the history of the FM two-way radio. Fred had a keen interest in electronics and radio from an early age. He first obtained his radio license at age 14, with the call letters "3BVA," while in pursuit of a Boy Scout merit badge.



Fred Link at Valley View Manor with radio.



Original Link Tower on Chestnut Hill Road, Killingworth, CT.

Two-way radio communications had been around since the early '20s, but it was unreliable, restricted to short distances and subject to automobile ignition noise and atmospheric static interference. It used AM (amplitude modulation), which is radically different from FM (frequency modulation). In the mid '30s, Maj. Edwin Howard Armstrong of the U.S. Army Signal Corps had developed a new theory in radio transmissions that would eliminate static. Static was a problem that had been wrestled with since the days of Thomas Edison, and it was believed by most at that time to be incurable.

Prof. Daniel E. Noble of the Connecticut State College (now the University of Connecticut, or UCONN) set out to prove Armstrong's theory to be valid. At about the same time (1938), the Connecticut General Assembly, at the request of Commissioner Hickey, appropriated $120,000 for a state police radio system. Nothing was mentioned as to what type of equipment should be used, or how the system should function. The Big Three in radio transmitters, Galvin Manufacturing (shortly after to be renamed Motorola), RCA and General Electric were thinking of proposing a one-way AM system with a limited two-way system in hopes of winning the Connecticut contract.

Noble and Armstrong were confident that the two-way FM statewide system could be a success if given a chance. They turned their attention to Fred Budelman of Link Radio, who had some insight about FM from what he had read and from what he knew about the two engineers, Noble and Armstrong. The three collaborated and convinced Col. Hickey that, given the chance, they could surpass anything imaginable in the world of two-way radio communications. Link was in hot pursuit of the Big Three.

For the next 12 months, Link employees battled technical radio problems in their New York City loft factory. (Incidentally, the loft was shared by Bill Lear of the aviation industry, who, with Fred, was experimenting with a radio transmitter that could fit into a small aircraft instrument panel.)

John Balint was an early and long-time employee of Link. He is credited with coining the term "squelch" during the testing of the Connecticut radio. Because of FM radio mechanics, there is a continuous intercarrier noise of hiss. Previous two-way radios only had two controls — on-off and volume. "Volume" and "on-off" are words small enough to engrave over a knob, but not "intercarrier noise control." At a meeting called to tackle this problem, it was Balint who suggested "squelch." Although Link is proud of his radio, Balint is proud of naming the squelch and of other contributions he made to this radio.

As the glitches were being worked out in the New York loft and on the Storrs campus, men and machinery were at work on Avon Mountain, CT. There, it was decided, was the highest centrally located point in the Station "H" area suitable for a tower. A small structure to house a transmitter was built, and the telephone company connected it with lines to the third floor of the new headquarters at 100 Washington St., Hartford, CT.

A 1939 Ford Tudor was chosen as the surrogate mother. As in every other aspect of police work, the cop on the beat had an important part to play in getting this new technology from the drawing board to the streets. Trooper Edward Sheeler is one of the many unsung heroes when it comes to the radio development. He logged more than 20,000 miles in survey activities. Hour after hour, day after day, W1XTJ traveled about Hartford county giving its location to HQ. It was apparent from the first day that the Connecticut Department of State Police had a healthy child.

As the days passed, W1XTJ wandered one mile at a time farther from HQ. It made its way to Danielson and Westport, Canaan and Groton. It is said that Hickey spent most of his time on the third floor and became uneasy when the "kid" did not answer quickly. When the colonel was addressed on the radio, he chose a simple title, "1HQ." The engineers and department heads left no stone unturned in their testing of the new radio. Commissioner Hickey wrote in the January 1941 issue of *FM* magazine that "the results obtained were successful beyond our highest expectations, as complete two-way coverage was secured over the entire Hartford patrol area, which in some instances, involved a talk-back range of 25 miles."

An important factor of the system was the overlapping of service by each station. If one station could not receive or transmit to a mobile unit, in most cases another station could. Or if one station failed completely, other stations could take over the duties. The system also made it possible for a mobile unit to become a temporary base if necessary.

F.M. Link Radio Company, in the meantime, had begun production of additional units, which were immediately installed in Hartford patrol vehicles as the units became available. Just as quickly as the experiment proved a success, the FCC authorized Connecticut to continue on to the next phase. Towers began springing up all over the state. The so-called assembly line was located on the fourth floor of 125 West 17th St., the loft shared with Lear. Up to this point, Link Radio was primarily involved in the manufacturing of AM police radio receivers, using rights and tooling owned by American Bosch, a subsidiary of the German company, Robert Bosch. Link said that he purchased American Bosch with the encouragement of the U.S. government, which was nervous about German ownership of American radio manufacturing facilities after World War I. The network of distributors that came with American Bosch and its affiliation with Graybar helped Link Radio to expand.

Nevertheless, it was in the midst of the Depression, and business was slow. Link had to send his people out to find home radio repair jobs to keep the company afloat. Balint was Link's 13th employee when he joined the company just prior to the Connecticut job. Radios were wired by hand, one at a time. Besides becoming friends with Link, I've had several fun-filled and interesting years chatting with and meeting such important radio pioneers as Balint.

He remembers well the enthusiasm on West 17th St. following the Connecticut experiment — "Jubilation." Lear had just made a bigger name for himself also and was moving his operation out of the city. That gave Link the entire fourth floor for the Connecticut project and several military projects that had developed. As soon as the last orders for AM sets were filled, Link Company employees immediately began work on the new FM sets for other Connecticut stations. At first they could put out about

20 sets a week, the same as before with AM. Connecticut needed 225 mobile units and 10 base stations. Meanwhile, back in Connecticut, it was decided to put each station on line, one by one. The Beacon Falls station was about to move to a new home in Bethany, and seeing that the nearby ridge on Peck Hill was the most suitable place for a tower, Station "I" was the next offspring.

It is the opinion of retired CSP Lt. Angelo Buffa, who graduated from the patrol's academy in 1938, that the two-way radio was the greatest improvement ever made for both the department and the men. "First of all, the radio got us off the motorcycles and into the patrol cars," Buffa said in a January 1997 interview.

"In the patrol car, the radio was like having a partner. It was a link to the troops. It has saved many a life over the years," he said. Buffa has only praise for Hickey in this and other advancements the department made during his watch.

As Balint wrote in his Spring 1996 *Proceedings* article, "Squelch": "Good news travels almost as fast as bad news, so in the spring of 1940, we received a visit from a captain in the one and only 'mechanized cavalry' division, later to become the 'First Armored Division'... He had heard about the Connecticut state project and wondered if the FM sets would do better than the AM sets in tanks." Captain Williams had $3,000 in his maintenance budget and was to be competing in maneuvers (in Kentucky) in two months. He needed radios that could fit in place of one ammunition rack on six tanks that would be in that competition. The "cavalry" was bringing six tanks to Madison Square Garden for a horse show in a few weeks, and it Williams hoped that Link could accommodate him. Finding a front row seat for Hickey at the Garden would surely guarantee six Connecticut sets to be pulled off the assembly line, modified slightly and made ready for the mechanized cavalry. What went in the tanks at the horse show was a best-kept secret. The story goes that the tank crews remained in the tanks to become accustomed to the new radios even as they made their way south by freight train. Budelman, chief engineer of Link Radio, was dispatched to rendezvous with a base station, probably the one intended for Bethany barracks. He realized after arriving in the "war zone" that he had forgotten his tuning tool, and he had to improvise using a mess knife. After "extensive" communication training at the horse show and on the southbound freight train, Williams' division was ready to meet the enemy. His tanks literally ran circles around the other units and won the war games.

The high caliber of Williams' division should not be underestimated; however, the captain gave all the credit to the superior form of communications his tanks possessed. The U.S. military realized it was about one year behind Hickey's Connecticut troops in communications, which resulted in a major shakeup. Williams was promoted to major (and later colonel), and as a result of his foresight, the military was better prepared for what the country would be facing the following year. In the fall of that year, the mechanized cavalry converted to an armored corps of two armored divisions and a separate tank battalion. The recommendation was made that the cavalry be equipped with new FM radios such as those being used by the CSP. Just as the two crystal-controlled channels used in the patrol cars could be switched, the same switch could be used between the battalion and company frequencies.

Three weeks after the attack on Pearl Harbor, a tank battalion with these radios was sent to the Philippines for use by forces under Gen. MacArthur's command. These were the first FM radios ever used in combat and were stamped "Fred Link Radio Co., New York City." ("Profile," *Communications* magazine, September 1983.) It was an uncommon practice to include manufacturer identification on military equipment. Because of the urgency, the radios were pulled from the manufacturer (Link) and immediately installed. The Link logo and name can be seen on a battlefield unit pictured in *From Tom*

Tom to Electron, a book published by Link Radio in 1950.

Link went on to develop other revolutionary radio equipment for the military. Ironically, Col. Williams was the first to use the Link ANTRAC (short for Army-Navy transmitter and receiver combination) radio at the U.S. First Army's signal officer on D-Day in Normandy. The first-of-its-kind equipment allowed radio communications from beach command posts to be relayed to, or from, any phone in England. As in Normandy, it continued to be a vital weapon for Allied victories during the Battle of the Bulge and future encounters as the troops pushed across Europe.

As was reported in the November 1987 *Proceedings* article, "Land-Mobile Radio Milestones," page 11: "All of this grew out of the pioneering use of FM radio by the Connecticut State Police, the courage of Commissioner Edward Hickey, the foresight of Professor Noble, and the capabilities of Fred M. Link, his chief engineer Fred Budelman, and the personnel of Link Radio Company."

Meanwhile, on 17th St., the entire fourth floor had been taken over by F.M. Link. The state police and highway patrol departments from Ohio, Maryland and North Carolina had dispatched representatives to Connecticut to check on the new child for themselves. Orders for new radios quickly followed those inspections, and the Link company had to expand again, taking over the third floor, then the second, and then started climbing up from the fifth. In 1943, Fred Link purchased the eight-story building, and it became known as the Link Building.

As the four of us chatted over lunch, it became obvious to Fred, Mildred and Carlos that I was looking for the whole story behind the Link radio, and that I was not there merely to pay tribute to a great guy. After returning to Robin Hill Farm, we sat down in Fred's library and looked at old pictures and researched books regarding the radio. Mildred scribbled down names and phone numbers of other important people. One such person was Gaetano J. "Tom" Amoscato, a president emeritus of the club, who was Fred's Connecticut representative for many years. With his help, with help from others and with material from Fred himself, I put together this history of police radio. Up until the 1930s, AM radio was primarily used for broadcasting entertainment. In 1935, a group of police departments throughout the country formed the Associated Police Communications Officers association (APCO) to give police departments a collective voice before the FCC when lobbying for more frequencies specifically for police. In the 1992 book about Motorola Service Stations, *Critical Connection,* written by Kathi Ann Brown and published by Motorola University Press, the author writes: "...[P]olice departments weren't the only ones waking up to the potential of non-commercial radio." Galvin Manufacturing "found itself sharing the market with several brand name competitors — General Electric, RCA, Federal and the talented Fred M. Link of Link Radio." Galvin's first FM set was introduced about one year after Link's.

Motorola had problems from the day that first set rolled off the assembly line, but not with the equipment. Noble had left his college position in Connecticut to spearhead Motorola's drive into the FM two-way radio field. "He transformed Motorola's product line almost overnight," said Paul M. Galvin, Motorola's founder in *Critical Connection*. The problem was that Galvin's customers were dissatisfied with the service they were getting. Galvin turned to Fred Link for answers. *Critical Connection* quotes Link as saying that Galvin said to him, "Look, we're doing something wrong. If you, with your limited financing and a one-man show, can drive my people in the field crazy to compete against you, what are we doing wrong?"

Fred said he told Galvin that Link Radio only sold radio equipment to customers who had licensed technicians on hand to service it. In Connecticut, those technicians were led by Sydney

Warner, the CSP's radio supervisor. After consulting with Link, Galvin quickly called together his top management and followed Link's advice. He instructed them to sell only to customers who had a high-level maintenance team in place. That says a lot for Fred and his love for the industry. Although making a living was important, his every move was made to ensure that the industry went ahead even if it were to the benefit of his competitor.

Competition became greater after the War, and Fred realized that he could do more for the industry and his country in the consulting field. The words and stories above give an account of Fred's first 50 years as "Father of the Police Radio" and his "Connecticut Baby." The story of his second 50 years in radio is equally astonishing, but it will have to wait for another day.

Several years after reading *Critical Connection*, Fred dropped a note to a friend, a note that I believe best states Fred's feelings over the years, *pride*. As Fred wrote, "Frankly, when I first saw this book, I was flabbergasted by the praise the Galvins gave me...as being the foremost competition they were forced to try to beat...I hope this book will make a lot of my friends understand a lot more about my status in this industry..."

Yes, it did, Fred.

About the Author

Dean Hammond is a retired officer of the CSP. After retirement, he became actively involved with that organization's academy alumni association, CSPAAA. He acquired a 1941 Ford and outfitted it in every detail as it had been featured on the cover of the March 24, 1945, *Saturday Evening Post.* Those details included having the original license plate year and number, the old uniform on the trooper, the same police articles lying on the rear window deck and an original Link antenna. His travels took him to the North Carolina home of Max Bloodworth, retired radio technician, who donated an original Link mobile unit to the project. Herb Elmers, retired CSP technician, put the unit into working condition. It is believed to be the only functioning unit in existence. In those travels, other original Link equipment was found, and it has been donated to the CSP museum.

Hammond has a degree in political science and business from East Carolina University. Until becoming involved in this museum project, he knew little about radio electronics — not that he knows much more, three years later. The tower site in his troop area was located on the top of Winchester Mountain. It was accessible only by a foot path. When emergency repairs were needed during the night, troopers accompanied the radio technician on foot for safety. Hammond followed the path and watched as repairs were made. Twenty years later, he watched and took pictures as that tower was dismantled, a road was installed, and a new microwave tower was erected.

By Don Bishop, **Proceedings** *Editor*

Plaque Dedication to Fred Link

Fred M. Link, president emeritus, was honored in Middletown, CT, on May 19, 1997, and a ceremony was conducted to rededicate a plaque sponsored by the Institute of Electrical and Electronics Engineers (IEEE).

Rededication ceremony

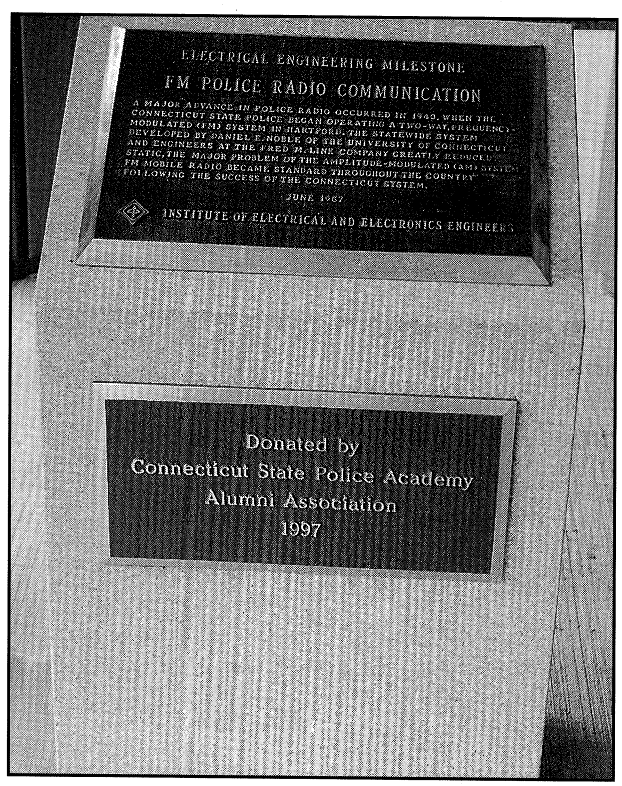
The plaque recognizes the 1940 statewide, two-way FM police radio system developed by Daniel E. Noble of the University of Connecticut and engineers of the Fred M. Link Company, New York.

The plaque originally had been dedicated on June 25, 1987 at State Police Headquarters in Hartford, CT. Relocated to the Department of Public Safety headquarters in Middletown, the plaque has been mounted on a stone monument donated by the Connecticut State Police Academy Alumni Association. It reads:

ELECTRICAL ENGINEERING MILESTONE—FM POLICE RADIO COMMUNICATION

A MAJOR ADVANCE IN POLICE RADIO OCCURRED IN 1940, WHEN THE CONNECTICUT STATE POLICE BEGAN OPERATING A TWO-WAY, FREQUENCY-MODULATED (FM) SYSTEM IN HARTFORD. THE STATEWIDE SYSTEM DEVELOPED BY DANIEL E. NOBLE OF THE UNIVERSITY OF CONNECTICUT AND ENGINEERS AT THE FRED M. LINK COMPANY GREATLY REDUCED STATIC, THE MAJOR PROBLEM OF THE AMPLITUDE-MODULATED (AM) SYSTEMS. FM MOBILE RADIO BECAME STANDARD THROUGHOUT THE COUNTRY FOLLOWING THE SUCCESS OF THE CONNECTICUT SYSTEM.

Lt. Col. Matthew Tyszka, commanding officer of the State Police Office of Administrative Services, conducted the rededication and the



A close-up of the IEEE milestone plaque at the entrance to the Connecticut Department of Public Safety headquarters in Middletown.

ceremony to honor Link.

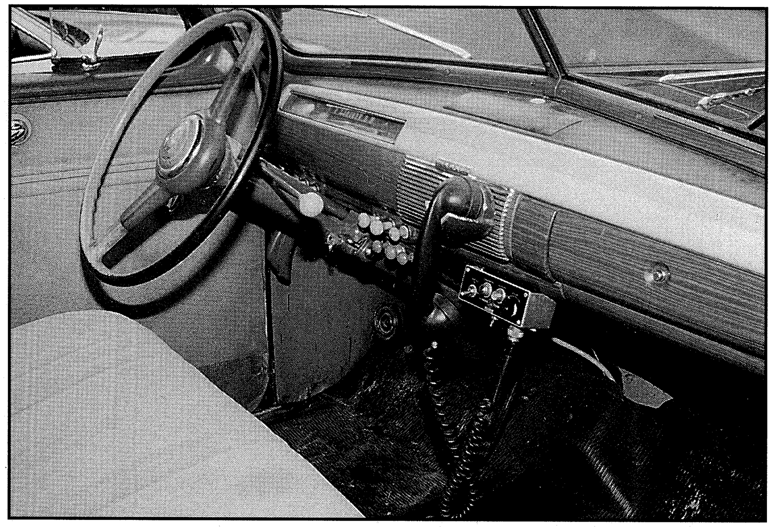
He explained that the Connecticut General Assembly had appropriated $120,000 in 1939 to establish a radio system for the state police. Because it used a new technology, two-way FM radio, it was the first of its kind in the world. "Connecticut became the pioneer in the use of FM two-way radio for public safety communications," Tyszka said. "Although the hardware for our system has been replaced several times over the years, the same lowband FM technology and system configuration is still being used by us today."

"Lowband" refers to the 30–50 MHz range, the lower part of the "very high frequency" or VHF band. In the 1930s, these frequencies were known as "ultra-high frequency" or UHF. At the time, making equipment work reliably at those frequencies was no small challenge, and it depended in part on the use of crystal-controlled transmitters and receivers.

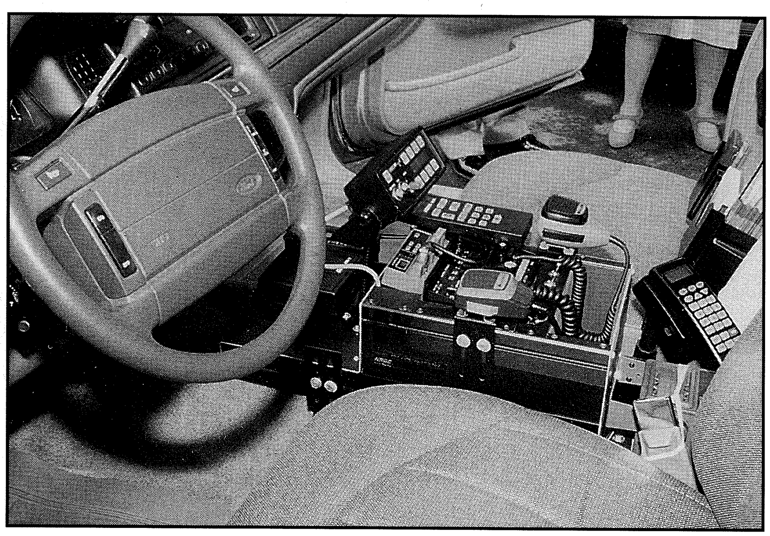
In 1940, the state police had 290 troopers who answered 15,000 calls for service. "Today, we have 1,000 troopers who respond to more than 500,000 incidents every year using the very same radio system," Tyszka said.

Posing in front of the Connecticut Department of Public Safety building in Middletown are, from left, State Police Lt. Col. Matthew Tyszka; Carlos Hudson; Joanne Link Sotres; John E. Balint; J. Dean Hammond; Raymond C. Trott, P.E.; and Don Bishop. All except Sotres and Hammond are Radio Club members.

The trunk of a 1941 Ford sedan that J. Dean Hammond restored to duplicate a 1945-era state patrol vehicle includes trunk-mounted Link Radio equipment that is in operating condition on the Connecticut State Police VHF frequency that has been in use since 1939.



With the radio equipment hidden in the trunk, the passenger compartment of the 1941 Ford sedan shows only a radio control head and a handset.



A state patrol vehicle in use in 1997 has much more electronic equipment on the console in the passenger compartment, including radio controls and microphones, radar controls and a cellular handset.

The Connecticut Telecommunications System (CTS), consisting in part of a microwave network that is mostly built and a trunked radio communications system that is yet to be put out for bid, will replace the lowband VHF radio system. "Inventions such as digital voice, channel trunking, simulcasting and mobile computers were not even dreamed of by engineers in 1940," Tyszka said. "The Connecticut State Police will once again become a pioneer in the telecommunications industry by integrating all these marvels into one seamless system."

CTS is expected to benefit the public with more efficient service. More importantly, state troopers will be safer and better equipped to fight the modern criminal, assist the public and increase their patrol time, Tyszka explained. "They will be confident that their calls for assistance will be heard."

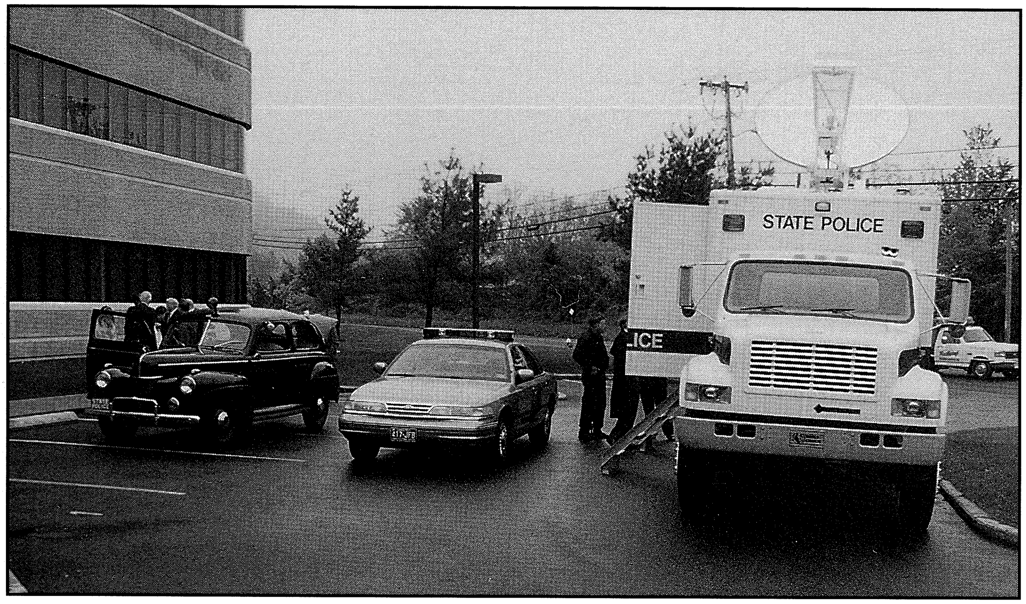
Squelch

The IEEE plaque mentions how FM helps to overcome static. FM receivers are quiet when they pick up a signal, also known as a carrier. Unfortunately, they are noisy when the signal stops unless a circuit is used to block the noise. At first, the noise was known as intercarrier noise, denoting the noise heard when one unit stops transmitting and before the next one starts.

Col. Tyszka recognized a member of the audience, John E. Balint, and pointed out that it was Balint, as the Link company's receiver engineer, who devised the circuit that stops intercarrier noise. Because "intercarrier noise" is too long of a name to stencil onto a radio panel next to the control knob, Balint coined the word "squelch" to signify the circuit. "All of us who use the radios owe a debt of gratitude to John Balint for saving us the strain of listening to noise between transmissions on the FM radios," Tyszka said.

Honoring Link

Tyszka handed a plaque to Joanne Link Sotres, Link's daughter, for her to present to Link "on behalf of the men and women of the Connecticut State Police." Link was unable to attend.



These vehicles represent steps in communications progress. At the left, the 1945-era police vehicle. In the middle, a modern state police patrol vehicle. At the right, one of two disaster recover vehicles designed to restore communications breakdowns resulting from man-made or natural disasters.

The plaque reads:

PRESENTED BY THE CONNECTICUT STATE POLICE

MR. FRED LINK

IN HONOR OF HIS OUSTANDING CONTRIBUTION TO THE SAFETY AND EFFICIENCY OF THE TROOPERS OF CONNECTICUT IN 1940. HE PIONEERED AND DEVELOPED THE FIRST LAW ENFORCEMENT MOBILE F.M. TWO-WAY RADIO SYSTEM IN THE WORLD FOR THE CONNECTICUT STATE POLICE.

PRESENTED THIS 19TH DAY OF MAY, 1997

Sotres said the following:

"I want to thank everyone, first of all, on behalf of my father, who would have very much enjoyed seeing everyone here.

"The next thing I want to do is, just for a moment, to take you back — you're talking about 1940. I was six years old. I remember my father, bounding up the stairs, three at a time. I remember Carmen Cavalero every Sunday on the record player. I remember also that the minute you said dinner was ready, he disappeared into some place that no one ever found, and he did that up to the recent time.

"As far as his being a father — I had half a father. This was not due to communication. It wasn't because he was dedicated and he wasn't being a good family man or something.

"He was a mutant. He had a Phillips-head screwdriver in one hand, all the time. He was a half-person. You only saw legs, sticking out behind a television set. Because we didn't watch television. He, of course, was involved in television as well as mobile communications. We didn't *watch* television. We *adjusted* television. That meant he got behind the television set with his Phillips-head screwdriver, and we sat in front and told him when it was okay. It was never okay for long.

"The other thing was, families like to say, 'Oh, they're close; they're together.' That wasn't the way it was in my family. In my family, you were handed what they called a walkie-talkie, and you were told to go as far away as you could, while you could still hear it. That's how we spent the afternoons on Sunday. And we played a little softball, too.

"Basically, our lives were taken up with some form of communication and some form of electronics. It's an experience that I wouldn't trade for the world," Sotres concluded.

Speaking on behalf of the Radio Club of America, Raymond C. Trott, P.E., its president, gave the following remarks:

"It is indeed an honor for me as president of the Radio Club of America to speak at this dedication to Fred Link.

"This recognition of Fred's contributions is not only to the public safety mobile radio industry, but also for his and Dan Noble's assistance in helping the State of Connecticut become a leader in two-way mobile communications in 1940.

"As president of the Radio Club of America, I would like to pay tribute to the man who, as president of the Radio Club of America for nearly a quarter of a century, helped make the organization the foremost communications society in the world.

"You may not know that the State of Connecticut had a part in the early days of radio, back in the pioneering days. In 1921, six or seven members of the Radio Club of America built a transmitter that made the first transatlantic radio message, which took place from Greenwich, Connecticut, to Scotland. There is still a plaque down in Greenwich, a marker, which commemorates the event.

"Today, the state still is acknowledging the importance of statewide communications by forging ahead with state-of-the-art technology which will improve the reliability of their communications, add many efficient operational features and, most importantly, increase the safety of the field officers and the people of Connecticut.

"Thank you, State of Connecticut, Fred Link and Dan Noble, for taking the reins in the development of public safety radio as we know it today," Trott concluded.

Joanne Link Sotres, Fred Link's daughter, with the plaque to be presented to Link.

Other guests

Tyszka acknowledged several other guests in the audience. Among them were Connecticut State Representative Linda Orange, who serves on the legislature's public safety committee. Also in attendance was Deputy Commissioner George Luther of the Police and Fire Division of the Public Safety Commission. Raymond Minichiello, P.E., came to the dedication as chairman of the Guglielmo Marconi Foundation of Bedford, NH, and gave Tyszka a plaque for the State of Connecticut that represents the foundation's Pioneer Award. I attended the dedication representing the Radio Club in my role as a director and as editor of the *Proceeedings,* and also as editorial director of *Mobile Radio Technology.*

Equipment display

A tabletop display of early state police radio communications equipment just inside the front door of the headquarters building gave visitors a chance to see part of the evolution of the technology. Robert DiBella assembled the display. He used equipment from his own collection, with the exception of the Link radio equipment, which is owned by the state police. Included is the first public safety hand-held radio purchased in the state of Connecticut in 1967. DiBella made the purchase for the state and now owns the unit. He also acted as an assistant to Tyszka in making the arrangements for the dedication.

In the parking lot were three vehicles representing additional steps in the communications evolution.

Retired state trooper J. Dean Hammond

Continued on page 49

By W.J. Byron, W7DHD

Historic Connections

What Nuclear Science Owes to Arc Transmitter Technology

The San Francisco Peninsula (Silicon Valley) is well-known to all who have or have had an interest in things electronic and nuclear. One of the joys available occasionally to a historian is the discovery of a special connection, one that can be presented in narrative style and that reveals some of the characteristics of the momentous cooperation between two scientists. Two men figure prominently in this story. They are Dr. Leonard Fuller and Dr. Ernest O. Lawrence, and their story begins in the early part of the century, around 1918.

VLF radio propagation was used successfully in the application of radio for commercial use. It had surpassed what had been used commonly by the news media and for regular business telegrams — the wired telegraph systems. Several transmitter types were in use, however. All were successful, but only one has a bearing on this story — the arc transmitter.

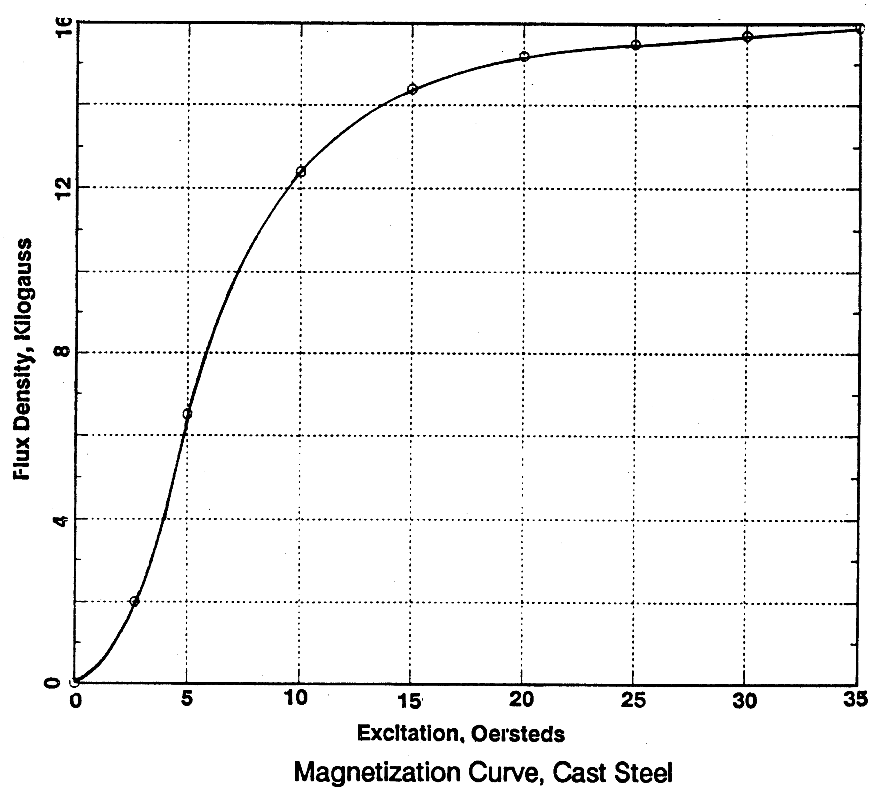


Figure 1. Magnetization curve for cast steel. All the arcs and the Lawrence 36-inch cyclotron are composed of cast steel.

The only U.S.-licensed builder of the "Poulsen Arc," the Federal Telegraph Co., was based in Palo Alto, CA. Leonard Fuller was chief engineer from 1912 until June 1919, when he accepted an unsolicited offer from Ohio Insulator Co. His duty was to be assistant manager. Fuller was not interested in administering to what Federal Telegraph had become — a message-handling organization, albeit a *worldwide* message-handling organization.

Arc transmitter development had come to a halt. The future was to be in high-vacuum tube technology. In either case, high-voltage RF insulators had to be developed to accommodate state-of-the-art high-power transmitters. A few years later, high-voltage 60 Hz insulator development would be required, too. Arc transmitters, by the way, were operating at megawatt power levels at the time of World War I.

When the war terminated in 1918, one of its consequences was the subsequent termination of a military contract with Federal to equip both ends of a communications channel with the AEF (American Expeditionary Force) in France. Accordingly, four sets of cast-steel magnetic components were built. Two were shipped to France as complete transmitters, and two sets were stored on company property in Palo Alto. Those would have become necessary parts of the two-transmitter arc station projected for North Carolina, the U.S. end of the Bordeaux circuit.[1]

Arc transmitters require a magnetic field, which is necessary for the physical behavior of the arc. In order for the transmitter to function properly, the arc must be extinguished *within each and every RF cycle.* During each hiatus, a magnetic field "blows out" (removes) the residual ions from the gap. The higher the power, the higher the magnetic flux requirement. Higher frequencies also require higher magnetic flux. Figure 1 shows that the saturation flux for steel is about 16 kilogauss. The flux required for operation at shorter wavelengths, say at 10 km, was close to cast-steel magnetic saturation. Steel is quite permeable; even ALNICO-5 saturates at 20 kilogauss.

The station (named "Lafayette" and with the call sign LY) at the Bordeaux end of the circuit was nearly complete at the armistice. The U.S. government then canceled the contract, and the arcs were scheduled for disposal. The French were interested in having the station completed for their own use, and the U.S. Navy became the prime contractor for finishing the station. It was finished in December 1920.

The antenna was supported by eight 860-foot high triangular self-supporting steel towers, each only slightly shorter than the Eiffel Tower, than the tallest man-made structure in the world. It produced receivable signals out to a distance of 12,000 miles — halfway around the world. VLF antennas require vertical polarization, which is accomplished by using electrically short verticals equipped with huge top hats and base-loading coils. They were combinations of top-and-base-loading, and in the arc transmitters of that vintage, *the antenna composition determined the operating frequency.* The tall antenna masts mentioned previously supported the large Bordeaux top hat.

The transmitters operated until the early days of World War II. The only reason for the "hurry up"

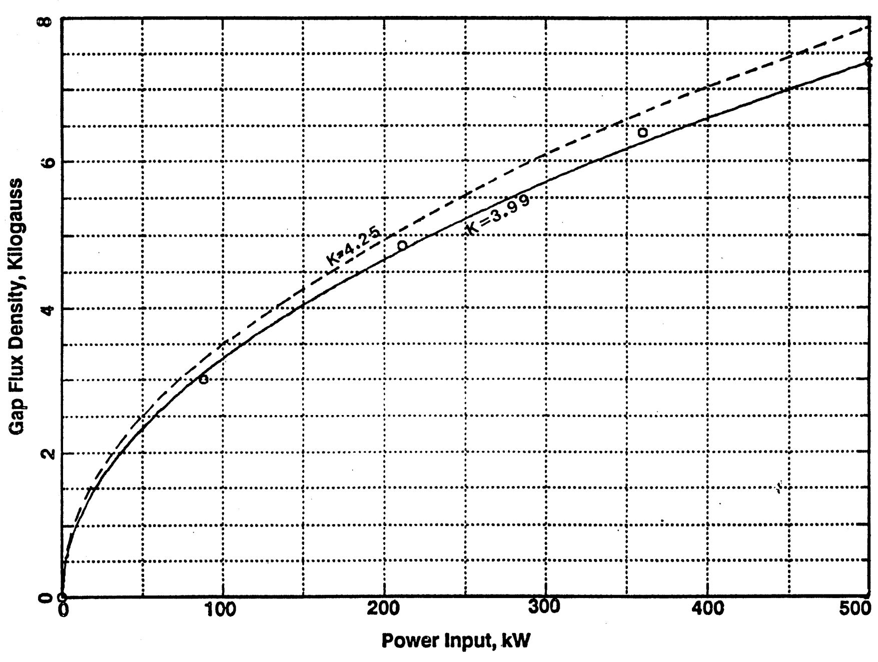


Figure 2. Arc transmitter characteristics, kerosene, at a wavelength of 12,100 meters.

in 1918–1920 was that, although the French would rather have installed an alternator of their own design, it was not ready yet. The arcs operated at an input of 1,000 kW — many times the power of any other type of transmitter.

Arc transmitters exhibited an intrinsic efficiency of exactly 50%, so the Bordeaux transmitters emitted 500 kW. They were the most powerful transmitters in the world until the Malabar (Java) arc transmitter came on-line a few years later. It operated at an input of 2,400 kW, and was built by the Dutch. It operated until the mid-1920s. The only transmitter design capable of such power levels was that of the arc, and it remained true for the next decade.

Arc transmitters of that vintage still hold the "record" for input power. Figure 3 is of one of the two converters destined for France — one of the actual machines. Large arc converters were operated in pairs, one operating, the other down for cleaning.

Figures 1 and 2 show the magnetization curve for cast steel and an example of the internal magnetic flux required for arc operation. The figures give an indication of the capability of the magnetic circuit. Fuller was the first (and only) engineer who accurately determined the "whys" of arc technology. He alone was responsible for the elevation of transmitter power to the megawatt range. That investigation was performed using one of the Navy's 500 kW transmitters. It's not germane to this article, but a much better description of arc technology may be found in Reference 2.

The steel castings, two sets of which were in Palo Alto, weighed about 50 tons (total weight of the nine machined castings per transmitter.) Accordingly, they were manufactured in "pieces," each one of less than the maximum allowable shipping weight by the railroads. Those castings remained on Federal Telegraph Co. property (later on city

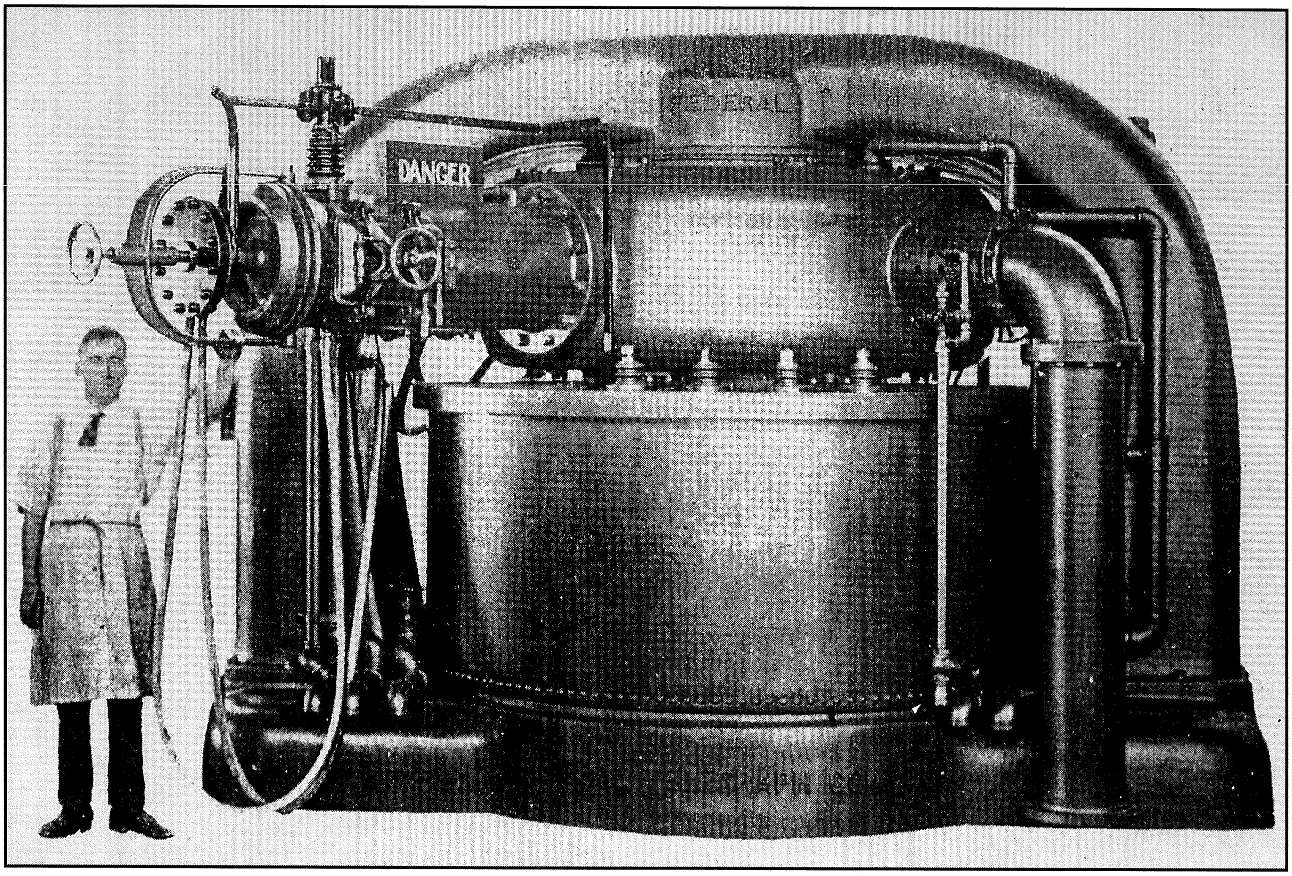


Figure 3. One of the two 1-megawatt arc transmitters sent to France. They became station "LY" at Bordeaux.

property) from 1918 until about 1930.

Fuller was now with Ohio Insulator Co. He was to head the development effort for high-voltage insulators required by new distribution systems in California, which were the highest-voltage standard transmission lines in the world at that time. Several years had lapsed, during which time Federal was bought by ITT/Mackay Radio. Lawrence was in Berkeley. Fuller joined the faculty at U.C. at Berkeley at the University's request; he was to establish an Electrical Engineering Department. It was in this capacity that he became acquainted with Lawrence.

University of California at Berkeley

The Physics Department at the University of California at Berkeley was busy, as were most others, investigating various aspects of atomic nuclei. One of the most effective tools for the research was laboratory-induced nuclear disintegration, ("atom smashing"), accomplished by bombarding nuclei with high-energy ions. The ions were accelerated, usually by linear accelerators, a linear device that functioned in a manner similar to that of electron acceleration in a cathode-ray (oscilloscope) tube. The major differences were size, energy and polarity. There were accelerators nearly a mile long.[3]

Lawrence and Dr. Stanley Livingston were studying the possibility of generating high-energy ions by means of the cyclotron. The name (cyclotron) came later, but I use it to describe the activity, and to give the unit a name. The investigation devolved into a search for a rather large electromagnet needed to contain the ions within the device.

The design was simple in concept but difficult to accomplish. The process is described in Figure 4. The heart of the cyclotron is a pair of metal chambers shaped like a pill box cut in half along one of its diameters. The two halves are hollow, D-shaped elements, called "dees" or "Ds." The inner edges are separated from each other and are parallel. A source of ions, usually protons (hydrogen nuclei), is located at the center between the Ds.

High-frequency alternating voltage is introduced to the halves. The potential between the Ds is caused to alternate rapidly, some millions of times per second, so that the field is directed first to one and then to the other. Because of the electrical shielding of the internals of the Ds, the space within each is a region of zero electrical field.

The two Ds are enclosed within — but insulated from — a larger cylindrical metal container from which the air has been evacuated, and the

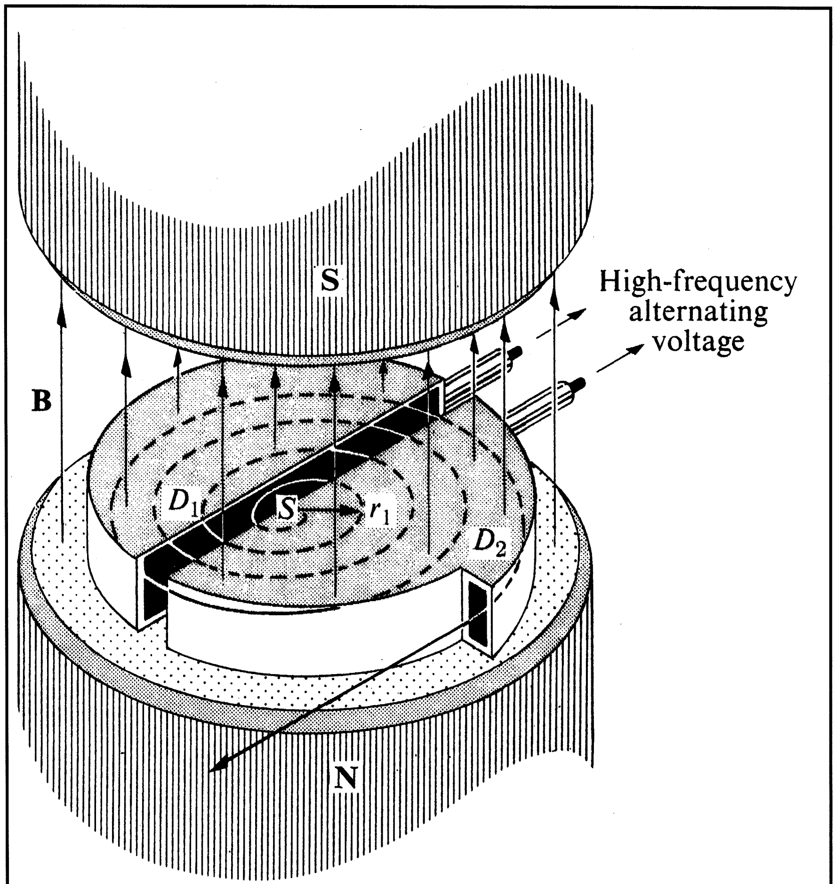


Figure 4. Isometric drawing to describe the cyclotron principle.

whole assembly is placed between the poles of a powerful electromagnet that provides a magnetic field *within* the Ds. Its direction is perpendicular to the plane of the Ds.

Now when a deuteron (or proton) appears in the center, it is accelerated toward the instantaneously negative D. Within the D, however, it follows a circular orbit until it emerges at the gap. At this time (assuming synchronization), it is again accelerated into the other D but now orbits around in a larger radius because of the added energy (velocity) it acquired as it crossed the gap between the Ds. The orbit of any ion then would resemble the track on a phonograph record.

At the final orbit, the ion is "straightened out" by an electrode (not shown in the figure), and it emerges so that it can be directed to a target, usually some *heavier* atom. Ions that possess several million electron-volts energy are obtained. The significance is the construction of an accelerator contained in a room vs. an accelerator hundreds or thousands of feet long. The development of the final cyclotron is the result of many experiments, and the acquisition of a large electromagnet.

There is a faculty dining room at the university, which was frequented by both Fuller and Lawrence. It was at lunch one day when Lawrence volunteered that he would like to acquire a large electromagnet. He, of course, had no idea of the two magnet cores residing in Palo

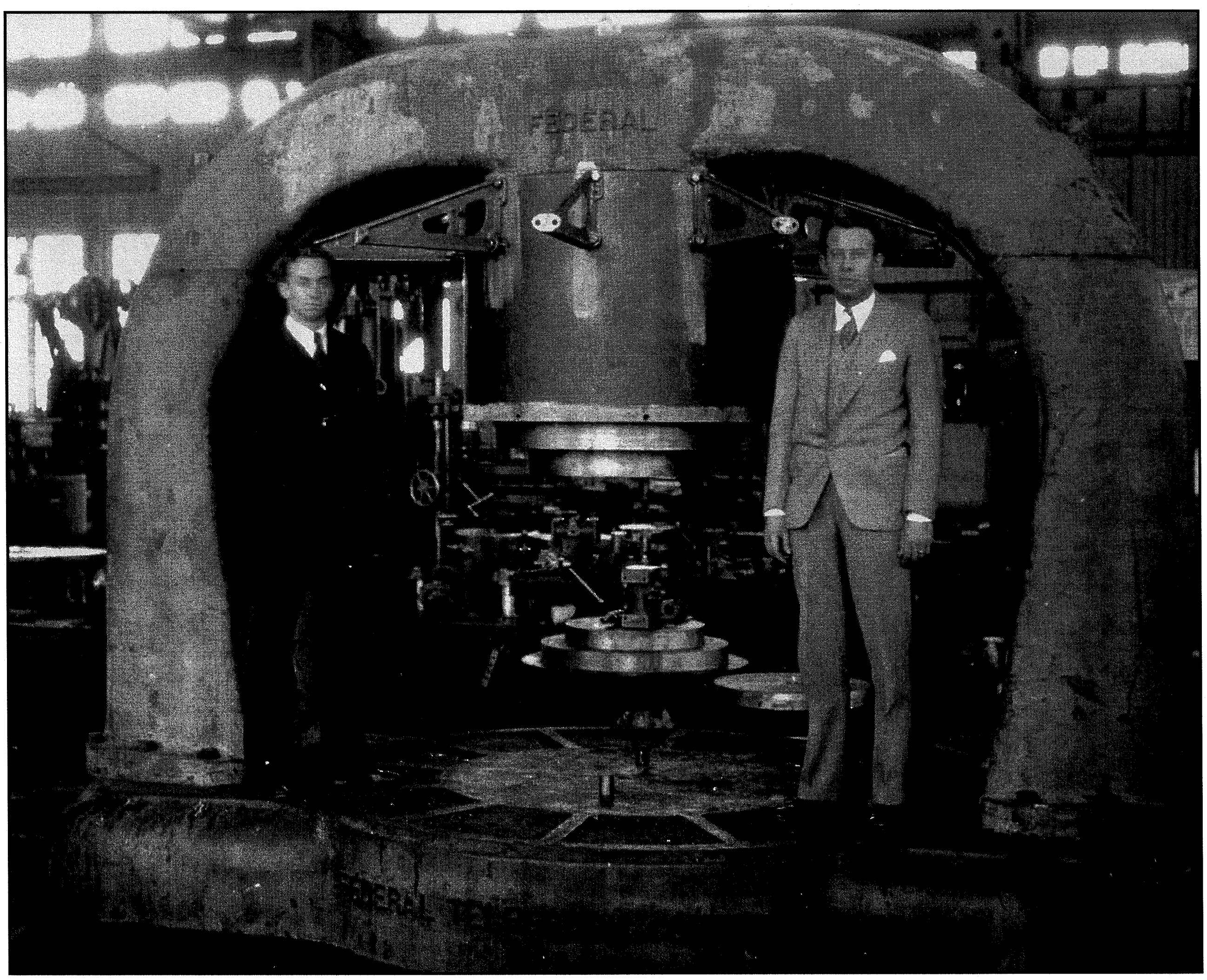


Figure 5. The Lawrence cyclotron during construction. On the left is Livingston, and on the right, Lawrence.

Alto. Furthermore, it was following the depression, and school funds were tight. Leonard Fuller was involved in many important, and largely unpublicized, events in scientific and engineering history. *This* one was to have consequences neither of them could fathom at that time.

Fuller indicated that he might be able to help, and the conversation was left there, for the moment. As was mentioned earlier, Federal Telegraph Co., later ITT/Mackay Radio, had possession of the two remaining sets of magnet components. Nobody worried about their being out in the open, unguarded. They weighed tens of tons each, so were pretty safe from possible theft!

Fuller arranged by telephone for Mackay to donate those magnets, one set to Lawrence at Berkeley, and one set to Stanford University, which apparently could not accommodate them at the time. They remained on what became Palo Alto city property and were sold as scrap metal *to the Japanese*. Fuller, knowing that the several transmitting tubes and other components would be needed, arranged for them to be given to Lawrence. Therefore, components of the RF source for the Ds also came from Mackay.

Figure 3 is one of the actual converters sent to France. Notice its size and shape. You will see it reflected in all of the cyclotron pictures, with one important difference. The magnet coils were both above and below the center line in cyclotron service, but the magnet coil is on only one side (the bottom) on the arc converters.

Neither of the unassembled steel cores had windings on them, nor were there any stored on federal property. Fuller told Lawrence that the university would have to purchase the copper, but that Fuller could arrange for the coils to be formed by Mackay. The windings,

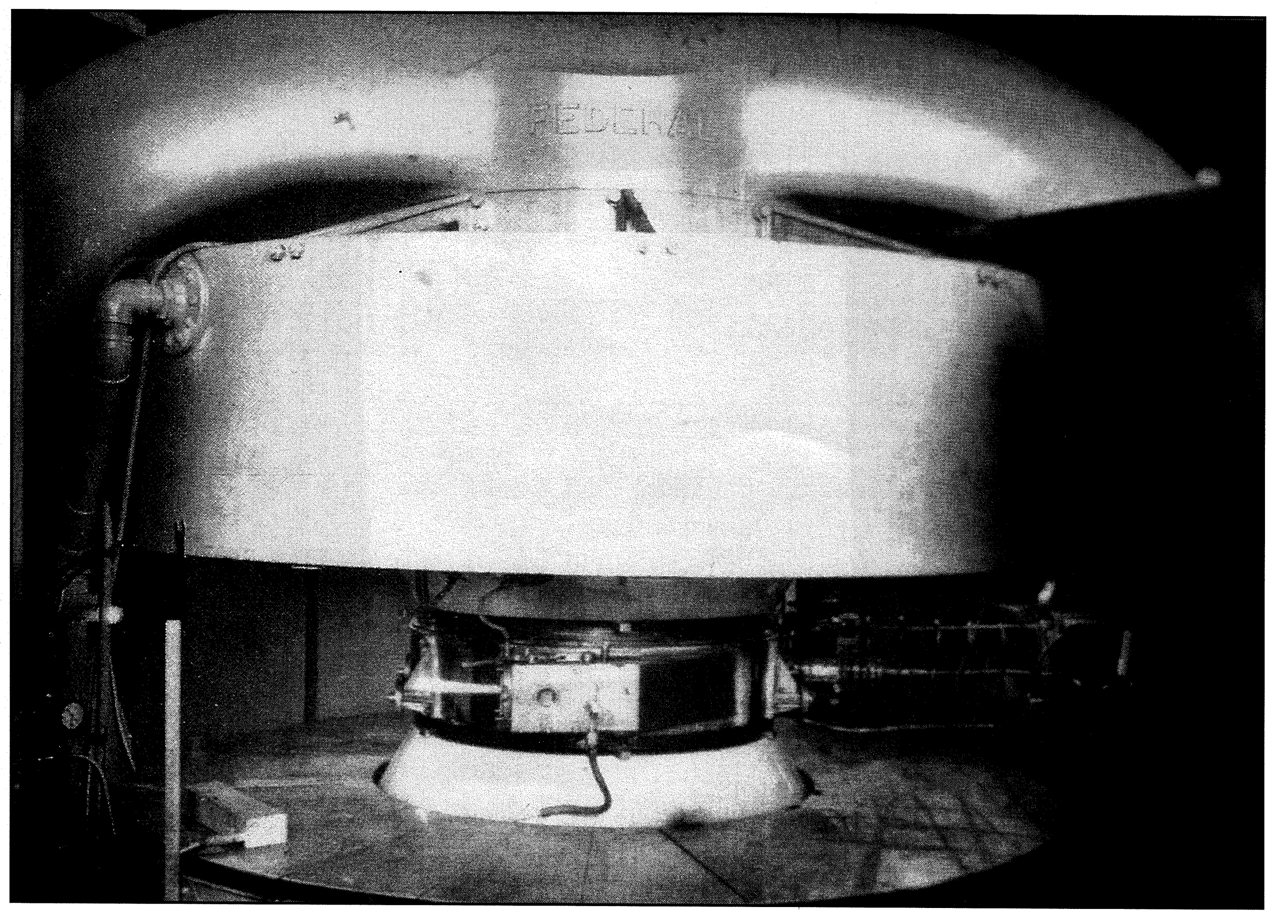


Figure 6. The Lawrence cyclotron in operation. Note the ionized air emanating from the box in the center.

Leonard Fuller.

incidentally, were copper straps, 1.25" wide by 0.25" thick. In both the arc and cyclotron, the coils required oil cooling. The copper accounted for perhaps 10 tons of the total finished weight.

The detailed behavior of electromagnets is not easily determined. One must know all about the magnet: its shape, path length, permeability, flux and, in this case, the requirements of the pole gap — that part of the magnetic circuit not conducted by the steel or iron. One advantage of dc electromagnets is that they can be modeled. Small-scale models were built and tested, and the results could be extrapolated with very little error. The scale model for the large arc could be contained in a volume of about 1 cubic foot and could be lifted easily by one hand.

The pole pieces in the megawatt arc transmitters had to be built so that the flux would be concentrated into a volume of only a few cubic inches. The poles, therefore, were reduced progressively in size so that they resembled the business-end of a large blunt artillery projectile, with a smaller flat section on the ends. From a flux-control standpoint, a smooth gradual curved slope would be desirable, but from a machining standpoint, it was much easier to do it in a series of conical sections.

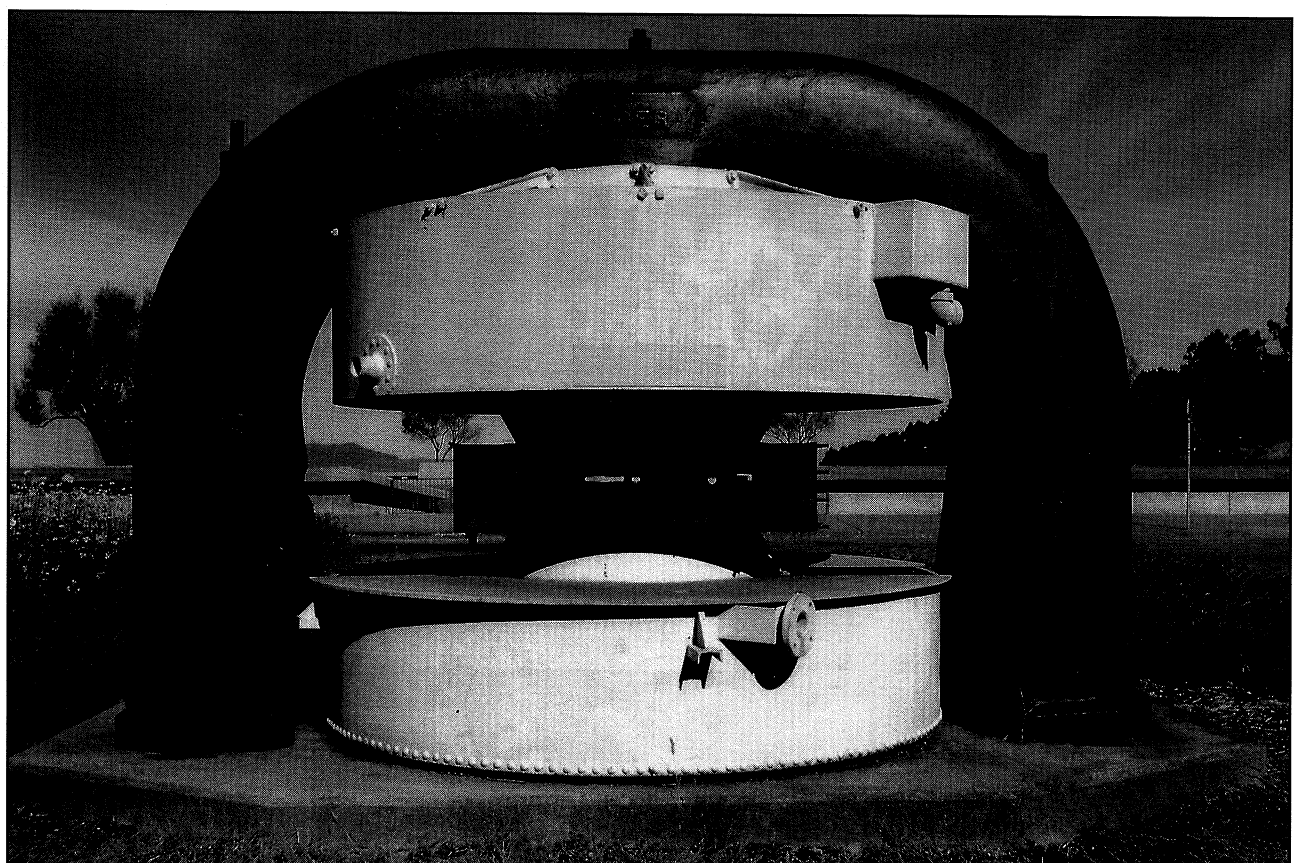


Figure 8. The Lawrence cyclotron as seen today outside the Lawrence Berkeley Lab Museum.

The cyclotron would require large, flat, parallel circular pole pieces. After battling flux-shapes in the arcs for a number of years, Fuller probably was the best engineering consultant available. He worked with Lawrence in the overall design of the magnet plus its pole pieces, which produced a vertically aligned magnetic flux of uniform density all over the face of the poles. There is no intent here to denigrate any part of Lawrence's previous work with magnets. He knew his way around them. He, along with Livingston, had built several small cyclotron prototypes at Berkeley. Enough prior work had been done with the concept that the success of a larger one was virtually assured, and that led to this quest.

The physics world was agog at the limitless prospects of artificially induced radio activity. Not for the activity alone, but also for the methods of inducing it, and for the results of experiments that produced it. Lord Rutherford, in his Cavendish laboratory, had pointed the way. He employed alpha emission from radium for his experiments. There just is not enough radium in the world to support the number of labs and experimenters engaged in the research. Furthermore, the tedious nature of Rutherford's techniques discouraged most physicists.

Simple calculations revealed to Lawrence (and others, too) that one microampere of electrically accelerated light nuclei would be more valuable than the world's total supply of radium — if they could be accelerated to the level of a million electron-volts. This puts the efforts expended by Lawrence, et al, in the proper light and leads us to the completion of the 36-inch cyclotron. What evolved in a few short years were ion beam currents in the ampere range and energies in the tens of millions of eV. They were made possible both by the linear accelerators and the cyclotrons.

Connections are difficult to categorize. For example, the linear accelerators were products of Merle Tuve, Ernest Lawrence's boyhood chum. He and Tuve both built and flew gliders and built an early radio transmitter. Tuve was the first to reflect radio pulses from the atmosphere, a study that led directly to the invention of radar. So at the time Lawrence was ushering the use of the cyclotron, Tuve was building linear accelerators.

Lawrence had come to Berkeley in 1928, after he left Yale. He had earned his Ph.D. there; his doctoral thesis was on photoelectricity. He came to California even in the face of friends' belief that he would quickly "go to seed" in "the unscientific climate of the West." Things proved different; during Lawrence's tenure, Lawrence Berkeley Laboratory produced no fewer than seven Nobel Laureates, including Lawrence, for the cyclotron.

Lawrence tended to avoid filing patents in his name (those in which he did, the usual $1 royalty was assigned to the U.S. government). He invented the "Chromatron" color TV tube. Most of us did not know that. Of most important national significance, however, is his development of the large-scale mass spectrometer, the "Calutron," by which kilogram quantities of pure ^{235}U, the only isotope (of three) that is fissionable by thermal neutrons, could be obtained. That is how we obtained the material for the Hiroshima weapon.

The Berkeley cyclotron, shown being constructed in Figure 5, and shown operating in Figure 6, was used occasionally for medical research. The staff placed temporary white-walled enclosures around the machine to make it more like hospital-related equipment. Lawrence also invented and developed what became known as the Sloan-Lawrence million-volt X-ray. It was in time to treat his mother, who had been diagnosed with inoperable cancer. She recovered and outlived her son by 21 years.

Acknowledgments

I am greatly indebted to the Public Information Department of the Ernest Orlando Lawrence Berkeley National Laboratory, particularly Mary Padilla. Information on Lawrence used for this

article came from "A Biographical Memoir for Publication by the National Academy of Sciences," by Luis W. Alvarez. Even Lawrence's Berkeley biographer is a Nobel Laureate. Alvarez is also the father of the "extinction-by-asteroid" theory of the dinosaurs' disappearance. It is now widely accepted as being the most probable scenario.'I also thank the late Hank Olson, W6GXN. He is the one who found the outdoor exhibit that has the original cyclotron.

Researching individuals such as Lawrence and Fuller, particularly Lawrence, places a would-be historian and biographer in a difficult position. So much is available that it becomes a chore to select "proper" subjects. A full-fledged biography of Lawrence would be several hundred pages long.

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About the Author

William J. (Bill) Byron was born in the same year that spark transmitters were banned (1923). He never heard a spark signal, and is not sure of ever having heard an arc signal either. History, particularly that of radio, is a continuing interest.

He was in the Field Artillery in WW II, serving in the United States and Europe. His main occupation has been in the nuclear field, doing engineering research and development in reactor-safety instrumentation and in control design. After doing reactor-plant startups — on four continents — for nearly 20 years, he spent five years at Princeton University, before retirement, on the Tokamak project. He was educated at Carnegie Institute of Technology (EE) and at Michigan State University (Physics). Byron has been an amateur operator for 40 years. He is a member of the Radio Club of America, an AWA member and a life member of SOWP and ARRL.

The Past, the Present, the Future... continued from page 3

subsystems in cellular and PCS base stations.

As our industry continues to grow, we need to encourage young men and women to enter the world of RF. Without good engineers, advancements will taper off. Who knows what the stories of tomorrow will be in terms of RF accomplishments and the women and men behind them. One thing is sure, however, if we continue to promote the excitement and positive attributes of being a part of the wireless industry, people will seek out opportunities in radio and build their communications visions of the future — just as the radio pioneers we highlight in this issue have done.

Article ideas and publicity items for the Spring *Proceedings* should be directed to Jane Bryant, c/o McQuerterGroup, 8201 Greensboro Drive, Suite 1000, McLean, VA 22102.

By Jane Bryant

The Advent of Thin-Film Manufacturing

In the radio communications industry, many pioneers have paved the way to better methods of communicating via their innovations and designs. In today's wireless markets, superconductive electronics are enabling improvements in call-handling at cell sites.

Superconductors are materials that undergo a transformation at reduced temperature, which gives them unique electrical properties, including the ability to carry electrical currents without any resistance. Without resistance, electrical signals are not dissipated in the form of heat, so all manner of electrical and electronic devices and components become far more efficient.

Microwave components are currently being made using high-temperature superconductors in two distinct ways. Thin-film technology can be used to make planar circuits for microwave applications, including filters, resonators, delay lines and others. In order for these devices to work well, the superconducting material must be of very high crystalline quality.

An alternative approach, thick-film manufacturing, involves taking copper microwave components, such as resonant cavity filters, and coating them with a paste of superconductor precursor material that is then fired on to form a ceramic superconducting coating. The crystalline quality of the resultant material provides the low-loss benefits of superconductors.

This article reviews the history of superconductors and takes a closer look at the inroads being made in thin-film manufacturing, as innovative thin-film manufacturing is making substantial contributions to the radio communications industry. Thin-film manufacturing consists of thin-film deposition technology and the same photolithographic processing techniques that are at the heart of the semiconductor industry. Superconducting films are made by vacuum deposition techniques like sputtering, pulsed laser deposition and co-evaporation. These techniques, for the most part, were first developed for other industries. Sputtering, for example, is used to put coatings on razor blades.

The Discovery

The first superconductor, mercury, was discovered in 1911 by a Dutch physicist named Kamerlingh Onnes, who won the Nobel Prize for his work. Over the succeeding decades, many other superconductors have been discovered. In 1986, IBM scientists K. Alex Mueller and Georg Bednorz discovered that a LaBaCuO compound they synthesized in their laboratory reached superconductance at a temperature higher than 30° K, breaking a 20-plus-year-old record. They, too, were awarded the Nobel Prize.

Within a year of their discovery, related materials were found that superconducted above 90° K. Within two years, the record temperature was more than 120° K. New superconductors continue to be discovered.

The origin of the superconductivity was a mystery for nearly 50 years following the original discovery, until the theory of John Bardeen, Leon Cooper and Robert Schrieffer (the BCS theory) was published in 1957. In that theory, a state of matter was proposed in which electrons in a superconductor form "Copper pairs" that cooperate to avoid the collisions and interactions within a metal that lead to ordinary resistance. This pairing up can only occur when the temperature is low enough that the ordinary thermally induced motions of the electrons are reduced sufficiently.

In high-temperature superconductors, there are sufficient differences in observed behavior that the BCS theory does not seem to apply. As a result, many theoretical physicists are hard at work trying to explain the phenomenon. An idea currently in fashion is that high-temperature superconductors (HTS) are the first "d-wave" superconductors to be discovered.

Whatever the mechanism may turn out to be, no theory yet has been devised that predicts which materials will be superconductors and at what temperature.

So far, only theories exist to explain why a material superconducts. Fortunately superconductor manufacturers do not need to know the origin of superconductivity to use superconductors.

1986's Finding

Until 1986, the highest temperature at which any material was known to superconduct was 23 degrees above absolute zero. Most of the more than 6,000 known superconductors enter the superconducting state at temperatures well below this value. However, in 1986 a new class of superconducting materials was discovered and, in the years since, a number of superconductors with critical temperatures above 77° K (Celsius degrees above absolute zero) have been identified. The significance of this temperature is that it is the boiling point of liquid nitrogen, an inexpensive and commonplace coolant.

Prior to the discovery of these "high-temperature superconductors," superconductivity required the presence of liquid helium, a costly and difficult-to-use cryogenic liquid.

The Cooling Process

Thousands of superconductors have been discovered during the decades. Some are mundane elemental metals such as tin and lead; others are exotic, multilayered ceramic materials with acronyms such as TBCCO. All of them behave as ordinary conductors until their temperature is lowered to a "critical temperature."

For the case of ordinary lead, this occurs only 7 degrees above absolute zero!

High-temperature superconductors can be cooled into the superconducting state by immersing them in liquid nitrogen, which is available nearly everywhere because of its routine use in medicine, food processing and other industries.

In addition, a mechanical refrigerator can cool superconductors. Low-temperature or cryogenic refrigerators are commercially available from a variety of manufacturers because they are widely used in the semiconductor processing industry. Refrigerators based on the Gifford McMahon cycle are designed to run for a year without mechanical failure.

Although there are thousands of superconductors known, only a handful have been found to have the combination of physical and chemical properties that make them suitable for most applications.

Wireless Applications

Microwave filters made from superconductors have the advantage that the tradeoffs between filter selectivity and filter efficiency that exist with conventional materials do not apply to superconductors. Ordinary filters are increasingly inefficient (the signal is wasted in the form of heat) as they are made more selective (more filter stages or poles). Superconducting filters have extremely low insertion losses even when they are made with a large number of poles. Thus, better filters become practical when they are made from superconductors.

Because of the increasing losses in copper, conventional filters are limited to no more than nine poles. One wireless superconductor manufacturer, Conductus, has made cellular filters with as many as 19 poles. In addition, thin-film superconducting filters are much more compact than the resonant cavity filters currently used in base stations. Those filters can be as long as 3 feet.

The low-loss properties of superconductors are extremely beneficial in passive electronic components in which increased efficiency leads to enhanced signal strength, improved signal resolution and reduced component size and weight. Examples of passive components enhanced by superconductivity include communications filters, which can provide extraordinary frequency sensitivity while maintaining excellent efficiency because of the inherent low losses of the materials.

Superconductors can provide unequaled performance in a compact package.

Resistance

There is truly no resistance to direct current (dc) in a superconductor. Thus, if one induces an electrical current in a ring of superconductor, it will flow forever. At typical microwave frequencies — in the cellular band, for example — the resistance of a superconductor is perhaps one thousandth of that in the best ordinary conductor.

For most practical purposes, this is as good as zero. It is certainly low enough to make superconducting radio frequency components the best in the world.

Cellcom Trial

Earlier this year, Conductus and Cellcom, a cellular carrier that operates about 100 base stations in rural and urban areas in Wisconsin and Iowa, completed a trial of the manufacturer's ClearSite receiver subsystems. The results point to performance benefits associated with superconductive electronics, including consistent improvements in call handling at the sites.

According to Cellcom, the carrier observed decreases in dropped-call rates in the range of 20 percent on the cell sites that were upgraded with Conductus ultra-low-noise front-end receivers.

The Future

No one knows whether the future holds room-temperature superconductors. If a real room-temperature superconductor were to be discovered, the next question is whether it would be a material that lends itself to being fabricated into useful things. Most superconductors do not, and the ones that do have taken years to develop.

Conclusion

Wireless communications components based on the low-loss property

of HTS thin films could provide significant performance benefits as well as significant size and weight reductions for filter subsystems in cellular and PCS base stations. In these applications, microwave filters made using thin-film superconductor technology have the ability to provide extraordinary frequency selectivity while maintaining excellent efficiency because of their inherent low insertion losses. HTS narrow-band notch filters and bandpass filters could also significantly reduce signal interference in base station receivers with minimal signal loss. The problem of so-called "A-B interference" is an increasing concern for cellular service providers and highly-selective and efficient superconducting filters may provide an effective solution to the problem between wireline and non-wireline operators. In high-density urban areas, reducing A-B interference would allow for increased channel reuse and improved call quality.

On the transmit side, conventional power combiners, which combine the signals to be transmitted by the base station, lose about half of the radio-frequency power between the

Continued on page 49

By Don Bishop, **Proceedings** *Editor*

Book Review

Valley Voices *by John Russell Gilchrist*

John Russell Gilchrist's book is impressive for what it includes and disappointing for what it omits. The book offers historical details — one might even say minutia — about radio stations in the Chicago area. To be more precise, stations in the Fox Valley, hence: *Valley Voices.*

The accounts of the earliest radio station operations really appealed to me, as did the histories of high-power Chicago AM stations that I began listening to in Denver 30 years ago and 850 miles away, and that I still listen to from a distance of 400 miles in Overland Park, KS. With respect to these histories, the minutia about people involved in these operations bring some human drama to what otherwise could be dry, technical descriptions. I learned of people connected with pioneering radio facilities that I had not previously known about and learned more about some people who performed on stations I already was familiar with. These portions of the book were the most entertaining.

What's odd, though, is that the book has no index. The only organizational aid is the table of contents, which is arranged by geographic area. Unless I missed it, the book does not define the geographic area of the Fox Valley. An index and a map would have been helpful. Embedded text references such as "See WQAT" are difficult to use for lack of an index, a map or a call sign reference list.

Another odd aspect is that, apparently, Chicago is not in the Fox Valley. Several Chicago station histories are included by virtue of the stations' transmitter locations, many of which evidently are in the valley. Transmitter location is a strange basis for selecting which stations to include, but I say hurrah for that, anyway, because a book strictly about smaller and lesser-known stations would not have been as interesting.

Although these peculiarities do not detract much from a first-time read, they limit the book's utility as a reference work.

The book includes some descriptions that will not be found anywhere else, such as stations that had only a brief existence in the early days of broadcasting; low-power FM stations operated by school districts; and a few unlicensed AM and FM stations that made a mark and that launched some broadcasting careers before being closed by federal authorities.

Read *Valley Voices,* and you'll know more about Chicago radio than most people who live there and many who worked for stations there. As someone who has listened to Chicago stations for many years, I enjoyed the book.

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Plaque Dedication to Fred Link... continued from page 25

brought a 1941 Ford sedan that he has restored to duplicate the way the state police configured such vehicles for patrol use in 1945. The vehicle is equipped with a Link transmitter, receiver, antenna and control head as it originally would have had.

A current patrol car that was on display is equipped with a lowband VHF radio and other electronic equipment that the state police expects to replace with an upgraded trunked radio system.

Also on display was one of two disaster recovery vehicles with the capability to restore CTS communications breakdowns resulting from natural or man-made disasters. CTS itself consists of about 53 microwave relay sites. Among other capabilities, the network will replace the telephone lines that now connect the various lowband VHF base stations. Those base stations will be replaced later with an 800 MHz trunked, two-way simulcast radio system with voice, data and video capabilities. Mobile data terminals will allow troopers to make motor vehicle inquiries, wanted persons and missing persons checks from the vehicle without calling the dispatcher.

The disaster recovery vehicles use a variety of systems to establish communications, including satellite links, microwave interfaces, spread-spectrum terrestrial links, telephone interfaces, cellular interfaces, interoperational frequency radio interfaces and an 800 MHz trunked system with a backup site controller. The main purpose of the vehicles is to substitute for the fixed CTS microwave sites.

About the author

Don Bishop (LF) is editor of the *Proceedings* and a director of the Radio Club of America. He is the editorial director for *RF Design* and *Mobile Radio Technology* magazines, and conference program chairman for International Wireless Communications Expo and RF Design Conference & Expo.

The Advent of Thin-Film Manufacturing... continued from page 39

channel amplifiers and the antenna. To counteract this effect, ultra-linear power amplifiers that are difficult to produce must be used. For emerging PCS systems, which will have lower output power requirements compared to the existing 800 MHz cellular systems, these amplifiers could potentially be substituted with the use of lower-cost HTS power combiners. Also distortion originating in these amplifiers could be eliminated by a low-loss "clean-up" filter.

Tests of these filters are ongoing at various laboratories, at selected manufacturers of cellular equipment and at operating cellular base stations.

About the author

Jane Bryant (F) is editor of the Proceedings and a director of the Radio Club of America. She is editorial director at McQuerterGroup, a public relations, marketing and advertising firm that specializes in wireless and telecom and represents Conductus, which provided information for this article.

The U.S. NATIONAL MARCONI MUSEUM

Bedford, New Hampshire

The Guglielmo Marconi Foundation, U.S.A., Inc. & The U.S. National Marconi Museum is located in the historic district of Bedford, New Hampshire, marking the town's link with Bedford, England, where Marconi spent much of his childhood. The exhibits follow with equipment, literature, audio-visual presentations - the development of radio communications from, "Spark to Space". Displayed is early Marconi wireless equipment together with the progression of radios up to the current cellular telephone exhibit. Included too, will be displays of early medical RF therapy, broadcast, amateur, mobile two-way radio and personal communication system products.

An important aspect of the 14,000 square foot building is its John Frey Technical Library, containing thousands of radio communication periodicals some in a series dating from 1920. All the publications are indexed by subject, author, date and publisher, cataloged on CD-ROM that can be accessed by Internet on the library computer. The shelves also hold hundreds of engineering, text and reference books. The visitor to the museum will enjoy browsing through historical literature.

There is a restoration room for repair of vintage radios, a machine shop and a facility room for educational lectures to school groups, and for meetings of electronic oriented organizations. Plans are underway to house a 100 watt FM broadcast station in the educational section of the FM band, with emphasis in its programming of world scientific news.

Since the Museum is education oriented, the Marconi Legacy Fund has been established to provide scholarships to students in the pursuit of studies related to the art of radio communications. Your donation of vintage - and - modern electronic equipment, surplus to your needs, will be most welcome to benefit the Marconi Legacy Fund. As the Marconi Foundation is a non-profit corporation, all donations will be acknowledged for personal and tax records.

For more information of how to contribute equipment, participate in the Marconi Legacy Fund, or joining the Marconi Foundation, please contact:

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