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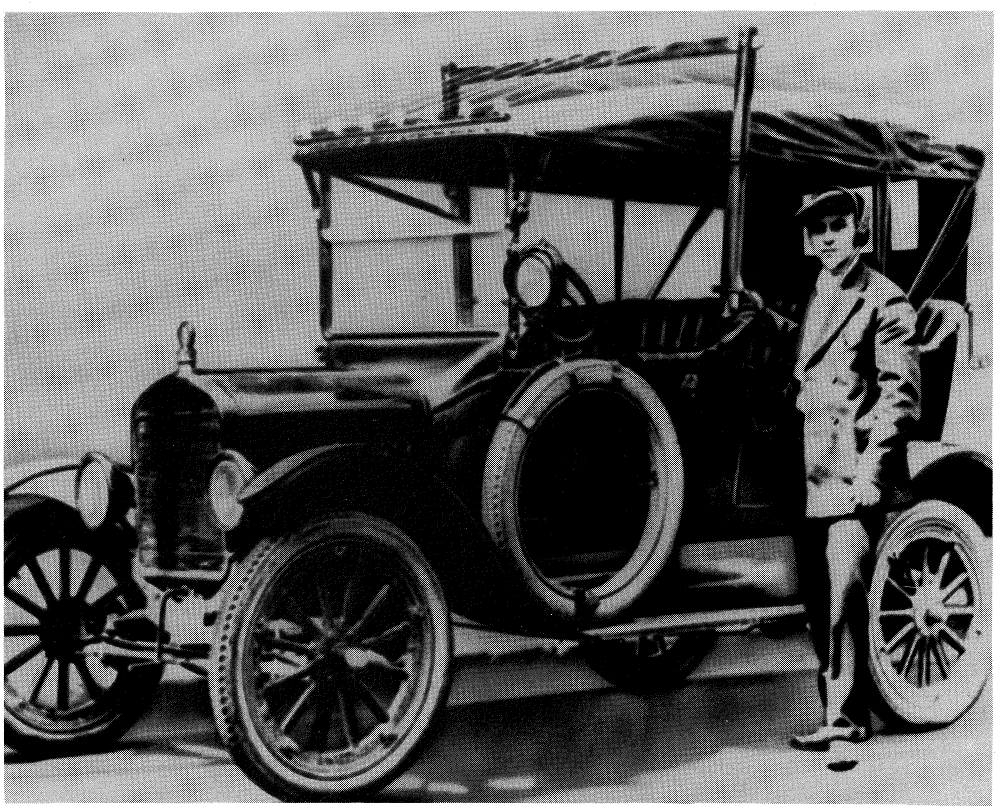


Antenna wires were strung along the roof of the first Detroit police radio car in 1921. (Courtesy of Dr. James E. Brittain)

THE RADIO CLUB OF AMERICA, INC.

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

The Radio Club of America, Inc.

324 SOUTH 3rd AVENUE, HIGHLAND PARK, N.J. 08904

Price $2.50

Organized for the interchange of knowledge of the radio art, the promotion of good fellowship among the members thereof, and the advancement of public interest in radio.

CONTENTS

Guest Editorial

Seldom in recent years have the achievements of our members been recognized as they have been in 1987 with the acclaim by the IEEE Milestone Awards.

The IEEE Center for the History of Electrical Engineering under the leadership of Dr. Ronald R. Kline (F), and the IEEE History sub-committee chaired by Dr. James E. Brittain (F), were empowered to honor significant achievements in the history of mobile radio communications and did so with the designation of three events as Mobile Radio Milestones.

The first recognized the actions of the Detroit Police Department, in 1928, to use radio communications between a dispatcher and a moving vehicle. The second identified the giant step taken by the Bayonne, NJ Police Department in 1933 in their use of the first "two-way" radio communications between fixed stations and vehicles and between two-or-more patrol cars; and the third acknowledged the leap in techniques in 1939 when the Connecticut State Police adopted FM radio for their state-wide operations.

Members of The Radio Club of America played vital parts in each achievement. The late Robert Batts (F) was a student at Purdue University when he designed a reliable receiver which made possible the Detroit radio dispatching system, and then he went on to help the Indianapolis Police Department set up their radio operations. The significant Bayonne, NJ two-way AM system pioneered yet another milestone in its use of frequencies in the 30-40 MHz bands and all of this was developed by Frank A. Gunther (LF) who then was Chief Engineer of Radio Engineering Laboratories, Inc. (REL).

The third Milestone designation to the Connecticut State Police Radio System came as recognition to the invention of FM radio by the late Major Edwin H. Armstrong (F) and the development of a workable FM mobile radio by the Fred M. Link Company (later Link Radio Company) many of whose employees are or have been members of The Radio Club.

The Radio Club of America extends its conratulations to the IEEE Center for the History of Electrical Engineering for its work of honoring achievements in the history of electrical and electronics engineering, and to Dr. James E. Brittain and Dr. Ronald R. Kline for their support of the nominees for the Mobile Radio Milestones. We recognize and acclaim the accomplishments of members of The Radio Club in bringing to fruition the dreams of better communication.

Fred M. Link

LAND-MOBILE RADIO MILESTONES

"The early history of land-mobile radio communications is a history of police pioneering." wrote Professor Daniel E. Noble, 26 years ago.

In 1983, The Institute of Electrical and Electronics Engineers (IEEE) believed that it was time to honor significant achievements in the history of electrical and electronics engineering. To do so, they established the Electrical Engineering Milestones program.

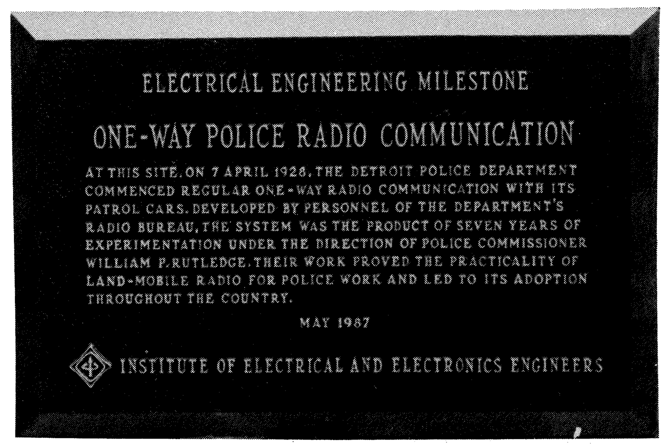
Three pioneering achievements in land-mobile radio were selected as Milestones marking three breakthroughs in the history of mobile radio prior to World War II. The first occurred in Detroit on April 7, 1928 when that city's police department commenced one-way radio communications with its police cars on a permanent basis. The feasibility of two-way police communications was demonstrated five years later by the Bayonne, N.J. Police Department. The third pioneering achievement marked the introduction of frequency modulation in 1939.

Each Milestone selection was supported by detailed documentation requiring extensive research in libraries, archives, and of government records. It required interviews with individuals who were participants or who had extensive knowledge of the achievement and could be substantiated.

An IEEE History sub-committee chaired by Dr. James E. Brittain (F) had the responsibility of evaluating the nominations for Milestone Awards originating with the Southeastern Michigan, North Jersey, and Connecticut Sections of the IEEE in conjunction with the IEEE Vehicular Technology Society. This was somewhat unusual in that three land-mobile radio milestones were considered simultaneously.

The sub-committee consisting of Dr. Brittain, Karle S. Packard and Thomas Aprille received and evaluated the nominations during July 1986 and recommended approval to the full IEEE History Committee in August 1986. The approval of the History Committee was confirmed by the IEEE Executive Committe and the Center for the History of Electrical Engineering, under the direction of Dr. Ronald Kline (F), undertook responsibility for dedication ceremonies. Each of the IEEE Sections that intiated a nomination then became responsible for planning and hosting the dedication ceremony at which a plaque was placed at a public site in the vicinity of where the achievement occurred.

This paper is, then, a tale of three cities.



Plaque recognizing Detroit Milestone.

DETROIT 1928

To a person of vision, the need for direct communication with moving police cars was clear. One such man who refused to accept repeated failures in his attempts to establish radio communications with moving police cars was Commissioner William P. Rutledge, of the Detroit Police Department. In 1921, four years after the city had pioneered the use of autos for police patrols, Commissioner Rutledge purchased a Western Electric 1-A 500-watt broadcast transmitter and, for a period of six years, tried to develop a system to provide satisfactory voice communications with moving cars. Their point of failure was in the receivers.

Both radio-telegraphy and voice transmission were tried but the basic problem of receiver instability and lack of sensitivity limited the coverage. With each year, new approaches were tried but all were failures. The accumulation of frustration became so great that, in 1927, the station was shut down and the radio room locked.

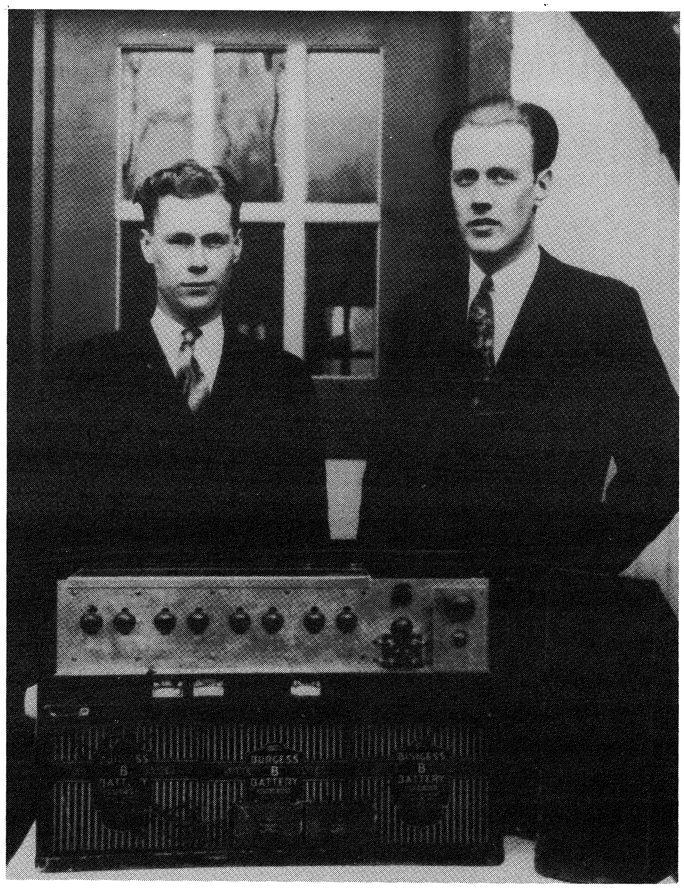
During the six-year period, there were seven license changes ordered by the Federal Radio Commission. In 1922, the police were assigned a provisional commercial license KOP on 360 meters. According to the rulings in 1922, KOP was required to provide broadcast entertainment during regular hours, with the police calls interspersed as required. Finding suitable performers for the broadcast programs was difficult; consequently, the police band was given notable workouts.

Although Commissioner Rutledge closed down the Detroit police radio station in 1927, he did not give up. Convinced that the automobile had given the criminal an advantage in speed that could not be overcome by police dispatched by telephone, he desperately sought an answer to the problem of obtaining reliable and efficient receivers.

During the Summer of 1927, a young student from Purdue University, Robert L. Batts (F), was working at a radio parts store in Detroit. One of his customers was a young Detroit motorcycle policeman named Kenneth Cox. The two frequently discussed the possibility of making a radio receiver work in a police car.

Batts had been using a superhetrodyne receiver with a loop antenna in a truck for tracking radio interference. To him, the problem of car reception seemed simple. When he returned to school, that Fall, he and Cox continued to communicate via the mails, and Batts sent suggestions and sketches for the construction of a police radio receiver.

Later that Fall, Cox told Commissioner Rutledge that he could make a radio work in a police car, and built a breadboard model cushioned with foam rubber. He deliberately dropped the receiver on the floor of Rutledge's office to show how rugged it was — it still worked. Cox received an assignment from Commissioner Rutledge to develop the receiver, and he began a campaign immediately to entice Batts back to Detroit.



The "Batts" receiver, with the designer, Robert Batts on the left, and Patrolman Kenneth Cox on the right.

Batts returned to Detroit as a patrolman since this was the only way that he could be paid by the police department. The Western Electric 1-A transmitter was rebuilt from a self-excited unit to a crystal-controlled MOPA, and moved to the Harbormaster Building located on Belle Isle in the Detroit River. Batts started designing the new receiver around the newly invented screen-grid tube.

The receiver consisted of three stages of tuned radio frequency amplification using type 322 tubes, a tuned 200-A detector, a 201-A first audio amplifier transformer-coupled to a 112-A output tube. Copper shielding of the RF and detector sections, and locked tuning capacitor adjustments contributed to electrical and mechanical stability.

Heavy duty 135 volt "B" batteries were used, and a 6 volt storage battery mounted on the car's running board provided the "A" power. The "A" battery drain was 1.1 amperes and it was necessary to switch the storage battery every four days. Two seven-passenger cars referred to as Cruisers were equipped with the newly-designed receivers.

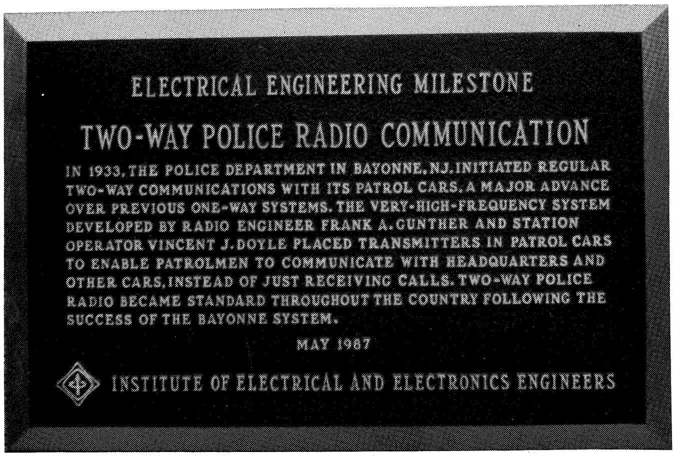
On April 7, 1928, the Detroit Police Department commenced one-way radio communications from its dispatcher to its patrol cars. It was the first of the breakthroughs in the history of mobile radio. The project had begun seven years before when Commissioner Rutledge authorized the setting up of an experimental station and predicted that "the wireless telephone will being a new era to police work."

Pending a request to the FRC for operation on 200 to 250 meters, the base station went on the air under the call W8FS on 150 meters on April 7th — and the system worked! The receivers stayed tuned and reception was satisfactory all over the city.

The building of a better receiver, the locating of the base station at a high and noise-free location, and the devising of a better antenna system contributed to the success of the system that proved the practicability of land-mobile radio.

By the end of the year, using the receivers designed by Batts and constructed by the radio station staff, eight cruisers had been outfitted and credited with 551 arrests. A short time earlier, the first broadcast to a radio-equipped harbormaster boat had been made.

The pioneering of the Detroit Police Radio System was the beginning of land-mobile radio communications, and it drew world-wide publicity. Several cities added equipment during the next two years and, in 1931, the State of Michigan installed a 5 kilowatt transmitter in Lansing. The growing recognition of the utility of police radio was documented by the Federal Radio Commission's report of one year's operation in 50 police departments which found that one arrest resulted from every ten calls; that in large cities, radio dispatched police recovered $250,000 worth of stolen property every day; and that the average time to get police to the scene of trouble was three minutes from receipt of a phone call.



Bayonne Milestone Plaque.

BAYONNE 1933

By 1933, the desirability of "two-way" communications was emerging. The decided advantages were self-evident.

It was clear to many engineers that one-way police radio, operating in the frequency range of 1.5 - 2.5 MHz, had numerous limitations:

1. The limited available spectrum could not allow frequency assignments for all of the communities that eventually would require police communications.
2. Long-distance skip common to the frequencies at night and due to propagation factors such as Sun-spot cycles caused severe interference between even the few cities then using one-way radio.
3. Heavy static caused by lightning often interfered with transmissions of emergency messages.

In 1932, the FRC had begun assigning experimental licenses for operations in the then VHF band (30-40 MHz), and this offered the possibility of two-way communications within the same band.

Edwin Howard Armstrong's (F, and president of The Radio Club 1916-1920), least-known discovery, the super-regenerative circuit, turned out to be the genesis of successful communications at the VHF frequencies. The circuit's characteristics were:

1. Extremely sensitive
2. Very simple circuit requiring few tubes thus having a low battery drain
3. Excellent automatic volume control action important in mobile operations
4. High immunity to static generated by spark pulses (ignition noise)
5. Poor selectivity which facilitated searching for a transmitter in the uncrowded frequency bands and which permitted the use of simple transmitters with few tubes, low battery drain, and poor frequency stability.

In the early 1930's, Radio Engineering Laboratories, Inc. (REL) of Long Island City, NY had a staff of enthusiastic and active Amateurs who had developed a line of 56 MHz transmitters and receivers for the Amateur fraternity. The equipment was used successfully to communicate to and from automobiles and aeroplanes. This led to the assembly-ing of a workable two-way mobile radio system which, in 1931, was demonstrated at the New England Police and Fire Chiefs Convention, in Providence, RI.

Also during the early 1930's, REL was supplying portable radio telephones to Radio Station WOR, of New York. Through their chief engineer, Jack Poppele (LF), WOR pioneered the field of remote pickups. A few of these included the attempt to couple a U.S. Navy blimp to the tower of the Empire State Building, and transmission from planes of aviation pioneers such as Clarence Chamberlain and Amelia Earhart.

Through Jack Poppele, the REL engineers met Charles Singer (F), engineer-in-charge of WOR's transmitter, and Vincent Doyle, one of the operators. During a visit to the transmitter in Kearney, NJ, the REL group demonstrated their two-way radios by talking from their car to the REL plant in Long Island City.

Doyle then mentioned that both he and Singer lived in Bayonne, NJ and that he would attempt to set up a demonstration to that city's police department. A successful demonstration lasting several weeks followed, and plans were developed to secure the first experimental license from the Federal Radio Commission specifically for a two-way police radio system.

The application was filed on October 7, 1932 with Vincent Doyle listed as Operator-in-Charge using Commercial License First Class, New York issue 8376, dated April 6, 1932. Frank A. Gunther (LF and president of The Radio Club 1956-1957) was listed as Chief Engineer responsible for the technical statements. Shortly thereafter, Doyle applied to the Bayonne Police Department for a position and became the first police radio officer for a two-way radio system, with the rank of Lieutenant, on May 19, 1933.

On February 21, 1933, The Board of Commissioners of the City of Bayonne, NJ had received bids for the furnishing and installing of:

1. Transmitter and receiver for Police Headquarters
2. Receiver for residence of the Police Chief
3. Nine transmitters and receivers for Police Cars
4. Two extra receivers for stationary installations
5. An extra transmitter and receiver for Police Cars

REL was awarded the order for supplying and installing all equipment at a cost of $4,990.

The construction permit had been issued by the FRC on December 12, 1932 and by March 1933, Lt. Vincent Doyle was on the air with the first two-way police radio system. The system installation was completed on July 31, 1933 when nine police cars were equipped with super-regenerative receivers and non-crystal controlled MOPA transmitters using a pair of 210's in the final. The station was operated on the temporary experimental license W2XCJ.

A radio milestone is cited

By WILLIAM KLEINKNECHT
ADVANCE STAFF WRITER

In 1933, the site of a police vehicle with a long antenna mounted on the rear and an officer talking to himself in the front seat may have perplexed a few residents of Bayonne, N.J.

But mobile two-way radios would soon be employed by every major police department in the country, a bit of progress due in large part to the work of Frank Gunther.

Gunther, a longtime New Dorp resident, and the radio he pioneered were honored yesterday in Bayonne, the little-heralded birthplace of the same two-way radio that now saves lives every day around the globe.

Bayonne Mayor Dennis Collins and others were on hand at the dedication of a bronze plaque commemorating what the Institute of Electrical and Electronic Engineers (IEEE) has deemed a milestone in communications.

"It was great that there is somebody around who was alive at the time," Gunther joked yesterday. "At most of these things, everybody who was involved is dead."

As the chief engineer of Radio Engineering Laboratories in Long Island City, Gunther was in charge of installing the two-way radio system for the Bayonne Police Department.

At the time, many big-city police departments were using one-way radio in their patrol cars, but the equipment for a two-way system was considered too bulky for use in vehicles.

But the advent of high-frequency systems allowed Radio Engineering Labs to develop equipment small enough to place in automobiles. The company chose the Bayonne police because the Federal Radio Commission would not have allowed such revolutionary technology in private hands.

Gunther says the two-way system, whose bulky vacuum tubes were housed in the trunks of the patrol cars, created quite a sensation among Bayonne police officers and anyone else who laid eyes on it.

"Everyone who saw one of our demonstrations was baffled," Gunther recalled yesterday. "Most people didn't even know what a microphone was in those days."

Within two years, he said, many other New Jersey cities began use of the two way system, and both Radio Engineering Labs and Gunther's career grew along with the phenomenon.

"It was a real takeoff for me," he said. "I spent the rest of my life at the company. I finally became president."

Gunther, 79, retired from the Radio Engineering Labs in 1970, but he remains on the board of directors of the firm's publically traded parent company, Dynamics Corp. of America, in Greewich, Conn.

The dedication yesterday of the plaque in Bayonne's Fitzpatrick Park, near City Hall and Police Department, was one of three achievements being designated as Electrical Engineering Milestones by the IEEE.

Also being cited are the Detroit Police Department's use of one-way radio in 1928 and the introduction in 1940 of FM radio by the Connecticut State Police.

IEEE Milestone Event, Bayonne, New Jersey, May 1987.
Left: Mayor Dennis P. Collins
Right: Frank A. Gunther (L.F.)

The World's First Public Demonstration of Two Way Mobile Radio, Bayonne, New Jersey Police Department — 1932. Left to Right: Frank A. Gunther, Chief Engineer - REL; Robert Hertzberg, Editor Radio Section N.Y. Sun; Charles Srebroff, President - REL; Lt. Vincent Doyle, Bayonne Police Dept.; William McDonald, Editor - Radio Retailing; and Keith Henney, Editor - Electronics. Note: Hand microphone in Lt. Doyle's hand and Vertical antenna forward of windshield on car.

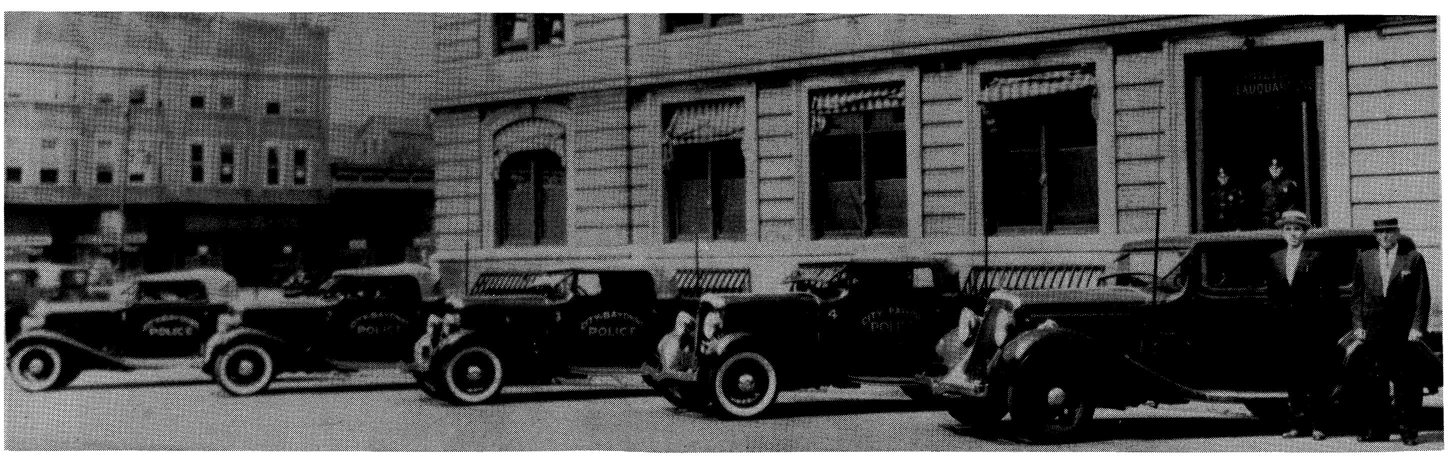
On October 14, 1933, *The New York Sun* published a news article over the by-line of Robert Hertzberg (F) which began:

"The main shortcoming of present police radio alarm systems — the inability of officers in patrol cars to talk back directy to their headquarters — has been overcome completely in a simple but very spectacular two-way communication system installed recently by the Police Department of Bayonne, New Jersey. Not only can the patrolmen talk directly to the dispatcher, but they can also communicate directly between themselves. The extreme value of an arrangement of this kind as a means of combatting and preventing crime is self-evident and the effectiveness of the system has been demonstrated quite thoroughly during the five months that it has been in operation."

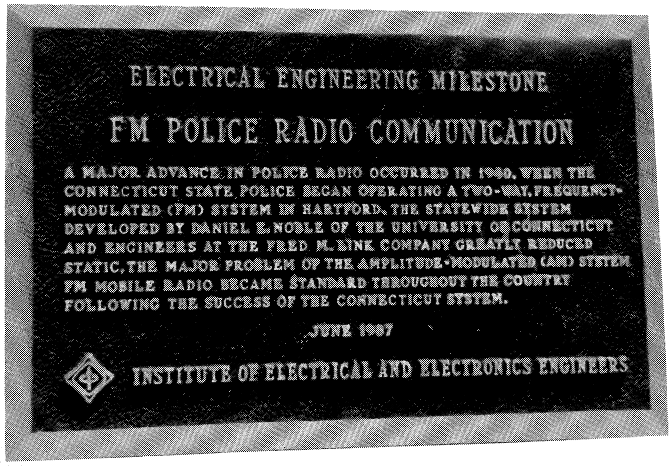
Thus the first of many accolades was bestowed upon two-way police radio.

During its early years of operation, the Bayonne two-way system was demonstrated to hundreds of visitors from all parts of the World. Many other cities quickly followed in adopting the REL two-way police radio systems and, during 1933 and 1934, the following communities installed systems: Eastchester, NY; Peoria, IL; Jersey City, NJ; Elizabeth, NJ; Bethlehem, PA; Union City, NJ; South Bend, IN; Harrison, NY; Long Beach, CA; Springfield, OH; Atlantic City, NJ; Kansas City, KS; Quincy, MA; Brookline, MA; Harrisburg, PA; Deal, NJ; Margate, NJ; Ventnor, NJ; Pleasantville, NJ; Rockland County, NY; and the FBI. In addition, the Lehigh Valley Railroad installed the first two-way railroad radio, and the New York State Conservation Department installed the first two-way aircraft radios.

Because each of those systems performed with reliability, the first steps had been taken in the two-way radio field.



Five of the nine Bayonne Police patrol cars equipped with two-way mobile radios. The two officials at the right are Public Safety Director Jerome J. Brady and Deputy Chief of Police Daniel J. Kilduff.



Bronze plaque Connecticut State Police Headquarters, 100 Washington St., Hartford, CT.

HARTFORD 1939

The Communications Act of 1934 set up the Federal Communications Commission and the law gave the new agency powers which had formerly belonged to several other government departments, including the Federal Radio Commission. On October 13, 1937, the new FCC issued Order No. 19 which allocated 29 channels in the 30.58-39.9 MHz band to police departments. This order was a milestone in the development of two-way police communications. The use of crystal control for transmitters and receivers became universal and, in 1938, the FCC established the maximum frequency tolerance of 0.05 percent on frequencies above 30 MHz.

Two-way communications were standard procedures for municipal police radio systems but state police still were operating one-way broadcast services. It remained for Colonel Edward J. Hickey, Commissioner of the Connecticut State Police, to establish the first two-way state police system in the United States. The success of the Connecticut system started the nationwide switch from AM to FM operations.

In 1939, Daniel E. Noble was Assistant Professor of Electrical Engineering at the University of Connecticut. During that July, he was asked to assist the Connecticut State Police in developing a state-wide radio system. The statement of the requirements did not specify whether one-way, two-way, intermediate frequency, very-high frequency, amplitude modulation or frequency modulation was to be employed, but it was understood that the use of FM for the system would be investigated thoroughly.

The State of Connecticut is approximately 90 miles long by 60 miles wide with very hilly terrain over the entire area. Hills vary in height up to 2400 feet and the elevation changes are often precipitous. For police operations, the state was divided into ten troop units with each operating from its own headquarters.

Dr. Noble's studies resulted in a proposal that the system:

1. Use very-high frequencies and frequency modulation;
2. Locate the fixed transmitter and receiver sites at high, noise-free elevations near the centers of each patrol area;
3. Use 250 watt base station transmitters for each patrol area, remotely controlled from the area troop headquarters;
4. Use two frequencies: 39.4 MHz for the fixed transmitters, and 39.18 MHz for the mobile transmitters;
5. Use a maximum two-way communications distance of 24 miles from the selected fixed station transmitter sites; and
6. Be designed with a generous safety factor to assure reliable communications.

Mobile FM equipment was designed to conduct proving-out tests and to survey proposed transmitter sites. At the beginning of the tests, conventional field-strength surveys were used but then abandoned in favor of listening surveys when it was found that strong ignition noise made the interpretation of field strength measurements impossible in terms of intelligibility of received signals.

Since no FM emergency service equipment was commercially available at the time that the design of the system was undertaken, the development of special apparatus became the first requirement. To facilitate the construction of new test equipment, the services of the Fred M. Link Company were enlisted. Since the company already had built specialized amplitude-modulated mobile radios, it was necessary only to introduce the new FM circuit requirements in order to produce units that were satisfactory both electrically and mechanically.

The transmitter modulator circuits which proved to be most effective were an adaptation of the original circuit of Major Edwin H. Armstrong which had been used successfully by Dr. Noble in the University of Connecticut's experimental FM transmitter W1XCS, placed in operation in 1938. The adaptation to the single tube phase shift modulator was devised by Glen Musselman (F), of REL.

The shift from AM to FM was a radical step. The use of FM, or more properly PM (phase modulation), permitted the transmissions to operate within the 40 KHz bandwidths permitted in the very high frequencies.

The designs of the transmitters were based upon the modulation requirements introduced by the average male voice with the greatest mean power in the region between 500 and 1000 Hz, and with a substantial reduction in power above 1000 Hz. The mobile transmitters used a frequency multiplication of 32 following the phase modulator output which had a maximum deviation of 12,800 Hz; the transmitter output was 25 watts with a six volt storage battery drain of 23 amperes.

The receivers were triple-detection superhetrodynes with double crystal control. The essential design elements were:

1. 40 KHz band pass.
2. Sufficient gain so that the fluctuation noise in the first converter circuit would saturate the second limiter.
3. Sharp audio cutoff beginning at 3000 Hz.
4. Sensitive squelch action with a high degree of carrier-to-noise discrimination.

While the sensitivity of the receivers was not known because of the uncertainty of the calibration of signal generators below one microvolt, the indications were that sensitivities in the order of one-quarter to one-half microvolt were obtained.

The first FM two-way mobile radio installations were characterized by exceptional reliability and range of communications as compared to the usual AM installations. While the police pioneered the development of the first practical mobile radio systems, the engineers of the radio communications industry carried out a continuous program of refining the equipment designs in order to increase spectrum loading. As spectrum crowding developed bringing the inevitable interference problems, the needed reduction of transmitted spurious radiation, the reduction of receiver spurious responses, and a substantial improvement in receiver selectivity followed. Additional refinements reduced transmitter noise, introduced instantaneous deviation control, and provided receiver design to minimize desensitizing and intermodulation interference.

The change from AM to FM did not alter the physical characteristics of mobile equipment significantly. The transmitter still was a combination of frequency multipliers and a power amplifier, with the phase modulator of the FM unit substituted for the amplitude modulator. The receiver became a double-conversion superhetrodyne with RF and IF amplification but with the addition of limiters and a frequency detector which differentiated the FM from the AM unit.

Forty KHz was used as the bandwidth chiefly because of the stability factors in VHF design. Narrower bands now are used beneficially and resulted from improved circuitry which solved the drift problems. Narrowing the bandwidth of the receiver generally increases the FM reception range because of reductions in noise peaks.

An additional characteristics of FM reception should be mentioned. Since the volume received depends upon frequency deviation rather than upon carrier level, an FM system possesses the quality of perfect AVC action. A user may travel over hilly terrain and, as long as the signal level does not drop below the fluctuation noise level, there will be no noticeable change in reception accompanying the wide changes in RF level at the receiver input. That effect alone greatly improved reception over that encountered in the AM systems to provide more reliable service over a much greater area.

Fred Link with exhibit of 1939 Link Radio equipment from Pioneer Installation for Connecticut State Police.

A unique feature of the Connecticut State Police Radio System was the use of the roof-top antenna. A quarter-wave tapered rod was mounted on a conical spring and fastened to the middle of the car roof. A 34 ohm coaxial cable connected the antenna to the transmitter and receiver.

The successful operation of the Connecticut system may be traced to two factors. The use of FM in a conventional installation with the receivers located at the barracks and thereby close to highways and other noise sources, could not have produced a satisfactory system. The engineering layout which specified a high, quiet base station location near the center of each patrol area contributed greatly to the effective operation of the system. With high, quiet receiving locations, it was possible to maintain signal levels from distant mobile units great enough to exceed the fluctuation noise threshold of the receiver and saturate the limiter properly.

The original installation of the Connecticut system was made at Hartford to prove out the system. The transmitter was located on Avon Mountain at an elevation of approximately 900 feet above sea level. The coaxial antenna was supported by an 80 foot steel pole. For many weeks, two-way communications were carried on with mobile units over the entire state. From extreme distances, it was necesary to pick a hill or other favorable location free from obstructing hills, for talking back from mobile units. A deep valley or a location behind a shielding ridge was regarded as unsatisfactory for talkback over long distances.

The overlapping of service areas was an important design factor. While it was possible for the single station at Hartford to provide some coverage over the whole state, each of the several patrol area stations could serve all or a large portion of an adjacent area. Therefore, if one or more area stations should fail, the areas could be served by the nearest available station. This coverage safety factory insured continuation of service when it was most needed during emergencies which prevented operation of one or more base stations.

The effects of a strong signal wiping out a weak signal in the FM system were used in the Connecticut system to permit simultaneous operation of several base stations without interference in the area of the stations. By employing 39.18 MHz for the mobile units and 39.5 MHz for fixed stations, a base station in an area could transmit to its assigned mobile units without preventing the reception of mobile transmissions by the other barrack units.

The success of the Connecticut State Police Radio System was due to the foresight of Dr. Daniel E. Noble; the progressive attitude and support of Commissioner Edward J. Hickey of the Connecticut State Police; of Sidney Warner, State Supervisor of Radio Maintenance, for his effective engineering assistance; Edward Sheeler for his 20,000 miles of survey activity; and of Fred M. Link (LF and president of The Radio Club 1969-1987), and his chief engineer, Fred Budelman, for their contributions to the development of the specialized equipment.

The success of the Connecticut State Police Radio System has long reverberated in the field of mobile radio communications. The great 1937 flood of the Ohio River inundated Louisville, KY and troops from Fort Knox were called for flood duty, particularly for maintaining communications. Amateur radio provided yeoman service during the emergency and Mr. Robert Lavielle who operated a radio store in Louisville catering to the Amateurs, also represented F.M. Link Radio Inc. He suggested to personnel of Fort Knox that perhaps FM radio should be investigated for military services.

While vehicular radio had come into general use in police vehicles, the military was afflicted with problems that did not affect others. One of the worst was "track static", the static electricity generated by the friction of the sections of rubber-faced tracks used on tanks and combat cars. Others were breakage of antennas, the need for the use of headphones within the crash helmets used in tanks, and the problems of ignition interference.

Each year, the troops went on maneuvers — to Ft. Oglethorpe, GA., Fort Riley, KS., Plattsburg, NY., and to Louisiana. During these maneuvers, the radio equipments worked well when the vehicle's power plants were off but were next to useless when the armored vehicles were in motion. The communications always came into criticism and it became apparent that amored vehicles could never be tactically-controlled until an adequate means of communicating amongst themselves could be developed. Also, a system had to be developed that would allow two-way communications from a Division Commander down through the chain of command to the moving armored vehicle in combat.

Colonel Roger B. Colton (later Lt. General) was in command of the Signal Corps Laboratories at Fort Monmouth, NJ. He was anxious to develop better communications for the whole army and, in November 1939, he brought a pilot model of an FM police set built under an Armstrong license by REL to Fort Knox.

During the following Spring, Fred Link visited Louisville, KY where his agent, Mr. Robert Lavielle, brought Mr. Link to see the new kind of army at Fort Knox. He took a ride in a tank and operated the radio equipment — the old SCR-193. At the end of the ride, Mr. Link was amazed and dismayed that the Mechanized Cavalry were still struggling with such obsolete equipment.

That Summer, the Mechanized Cavalry travelled to Plattsburg, NY for its encampment and maneuvers. The engineers of REL were invited to give a series of demonstrations of the two-way FM radios upon the recommendations of Lt. David Talley (LF) (later Lt. Colonel). The operations of the base station and six mobile units were completely successful.

After its encampment at Plattsburg, the Mechanized Cavalry unit visited the World's Fair in Flushing, NY and, again, Mr. Link visited the unit and made a study of their communications equipment. There, came the first news of Hitler's invasion of Poland.

Shortly thereafter, while the Mechanized Cavalry was on maneuvers near Shreveport, LA, Dunkirk fell to the German Panzer divisions, and a new wrinkle in the Cavalry's maneuvers was the introduction of the police type FM radio equipment manufactured by the F.M. Link Company and later designated the SCR-298. These sets were used by the umpires in simulating artillery fire.

When an Artillery unit started simulated firing, an umpire would broadcast the map coordinates of the artillery target and other details of the assumed fire, and the nearest umpire would proceed to that spot, inform the troops that they were under fire, and assess casualties based upon the fire information and actions of the troops after the announcement.

In late 1940, the Mechanized Cavalry was converted to an armored force consisting of an armored corps of two armored divisions and a separate tank battalion. In the absence of adequate radio communications equipment, Captain Grant A. Williams (F) (later Colonel) visited New York and met with Fred Link and arranged to purchase six sets of the new FM equipment similar to that being used by the Connecticut State Police. The men met with Major Edwin H. Armstrong to confirm the decision to use FM radios. The design was similar to that designated as Type III consisting of two receivers — one to monitor the battalion frequency and the other to monitor the company frequency; and with a crystal-controlled transmitter switchable between the battalion and company frequencies.

Mr. Fred Budelman, Chief Engineer of the Fred M. Link Company, travelled to Fort Knox with the radios and, together with Robert Lavielle, made the first installations and tests in the maintenance shops of the 141st Signal Company. The tests were remarkably successful, so much so that a decision soon was made to buy sufficient equipment to outfit three tank battalions.

Personages present, from left to right: Comm. Edward J. Hickey - Connecticut State Police Commissioner; Col. Roger B. Colton, Director Signal Corps Laboratory; Major James O'Connell, Deputy Director, Fort Monmouth; Sydney Warner, Radio Supervisor, Connecticut State Police; Major Edwin Armstrong, Inventor of FM, etc.; Major Soules; William Marks Ch. Civilian Eng.; Ft. Monmouth Capt. Langer; William Hessel; E. Townley and two other unidentified civilian engineers from Ft. Monmouth. Tropper Schailer, Connecticut State Poilce on far right.

It was known that these initial designs were not rugged enough for tank usage and combat service, and that they did not have the flexibility to completely meet tactical requirements. They were designated the SCR-293 for the complete set, and the SCR-294 for the mounting base and a single receiver; to be used a training aids.

Shortly after Christmas 1941, Williams was informed that a tank battalion was to be sent to the Philippines to reinforce General MacArthur, but that there was no standard radio equipment to equip them. As a last resort, a decision had been made to use the SCR-293/294 sets which had been received shortly before and used on the maneuvers. This was done and the tanks were shipped out; a month or so later, the battalion was captured with other American troops at Bataan shortly after the SCR-293's became the first FM radios to be used in combat.

Colonel Williams was assigned to duty in the European Theatre of Operations as Signal Officer of the U.S. First Army and, there, was first to use tactically in combat the Link AN/TRC-1,3,4 which enabled the integration of radio into wireline telephone and telegraph networks. Two excellent stories on the use of the ANTRAC radios have been published in the *Diamond Jubilee Yearbook* of the Radio Club of America.

The equipment was used within 72 hours after the landing of troops in Normandy on D-Day, for telephone and teleprinter communications from a beachside terminal near the First Army command post through a relay on the Isle of Wight thence to Middle Wallop and through their switchboard to any phone or teleprinter in England.

Again, during the Battle of the Bulge in December 1944, with lines cut and snow and ice impeding their rebuilding, the ANTRAC radios enabled the Army Commander to keep contact with his Corps and Divisions, and to make tactical dispositions to resist the attack.

For a third time, after the U.S. Armies had crossed the Rhine and were dashing at full speed to meet the Russians, the ANTRAC was the only means fast enough to keep the Army network functioning.

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 Dan Noble, and the capabiities of Fred M. Link, his chief engineer Fred Budelman, and the personnel of Link Radio Company.

THE SESQUICENTENNIAL OF THE TELEGRAPH

by Donald K. deNeuf, WA1SPM (M 1972, F 1974)

With 1987 being the 150th anniversary of the development of the electromagnetic telegraph, the pioneering work of 1837 of Charles Wheatstone and William Cooke in England and of Samuel F.B. Morse and Alfred Vail in the United States will be recounted in detail in other publications.

The telegraph radically changed the conduct of business transactions, military campaigns, diplomacy, and many other aspects of life. But there were happenings that were, perhaps, minor in stature that occured and will be looked at again in this article.

THE MORSE TELEGRAPH CLUB

During the 1960's, a group of seven telegraphers formed the Alfred Vail chapter of the Morse Telegraph Club. Each year, they operated a coast-to-coast hookup over donated facilities of the Western Union Company on the Saturday nearest to Samuel Morse's birthday, April 27th.

The late Commander E. J. Quinby (M 1959, F 1963, L 1976) and the other six members each paid $20 a month for the privilege but their activites also included use of a party line leased from New Jersey Bell whereon they kept their touch on the key with the Morse code which had provided the communications nerve pulse of the world.

The members ranged from one who built a radio transmitter in 1908 to one who put up the first chain of radio towers for 2,500 miles up the Amazon. One was born in a sod house on the Santa Fe Trail at a time when the telegraph was opening up the West.

The annual trans-continental messages originated at many locations. One year, the terminal was at the home of the late Stuart Davis (M 1955, F 1975) in Union, NJ. Davis, a retired Postal Telegraph operator, maintained the country's only telegraph museum in his home. A bachelor and physically handicapped, Davis had been a Morse code buff since childhood and a lifelong collector with hundreds of historical telegraph instruments, inventions, documents, books and posters in his collection.

Another year, the terminal was at the Vail barn in Morristown, NJ in which Samuel Morse sent the first Morse code message in 1837 to his co-worker Vail. Ten years later, the first telegraph line from Washington reached Newark, NJ and Ezra Cornell began building the future Western Union network. Morse code clicks broadcast the news over the wires. Men hung around telegraph offices for the baseball scores. The larger offices were besieged for election returns. They were the source of war news, stock quotations, race results.

Stuart Davis liked to relate the story of the abilities of some of his contemporaries: "One wire chief who wrote in a very tiny hand was asked, 'How many words can you put on a (telegram) blank?' He replied that he didn't know but 'I can copy a ten word message in the space of a postage stamp.' "

"Some bragged of how many words they could stay behind the sender, and so it went. Finally, another wire chief spoke up 'I'm not the fastest operator around here but I can copy a message in French with one hand and one in English with the other, at the same time.' "

"The Chief Operator went to the traffic department and returned with a message from the Montreal duplex in French, and one in English. The wire chief was provided with pencils and pads. The two messages were sent at usual hand key speeds. He made perfect copy of both! Amid cheers and slaps on the back, the Superintendent sent out for hamburgers and near-beer (Prohibition, you know), and the rest of us got back to work."

"As the Old Timers told us young squirts 'We handled the business about as fast as the machines, and we were a lot more reliable.' "

Ed Quinby's home, a former coach house located in Summit, NJ, was even fuller than Davis's museum home, but he had another hobby. He and Mrs. Quinby couldn't live on the ground floor because he tinkered and she played music there. The floor was home to a thousand-pipe, four-manual organ.

Quinby had other interests, too. He was part owner with his son and a friend of the last of the Mississippi River sternwheelers, the *Delta Queen,* and spent much time playing the calliope aboard the boat. His backyard was taken up by still another hobby; he was a historian and author on interurban trolley lines and built a three-foot scale model of the plush green interurban cars upon which he had worked as a motorman and conductor during World War I.

He almost was rejected for that job when he told them of his previous experience — as a motorman on a New Jersey amusement park roller coaster at the age of 18. "It was a Summer job while I was going to City College in New York. They had built and used electric power to speed it up and down. I remember the Irishman who taught me. First, he told me the safety rules but, he added: 'To keep your job here and be a success, you gotta scare the livin' bejesus out o' the passenger.' "

He had learned Morse code while attending a military academy and was one of a group of boys who built a quarter-mile telegraph line. "We found Morse very useful when we had our exams. We used to have inkwells with iron lids in our desktops, and whoever knew an answer would tap it out in Morse on his inkwell lid."

The telegraph messenger boy then was a American tradition. Telegrams were handed personally to top business executives. Steel magnate Andrew Carnegie got his start as a Western Union delivery boy, and recommended it as a way to get ahead:

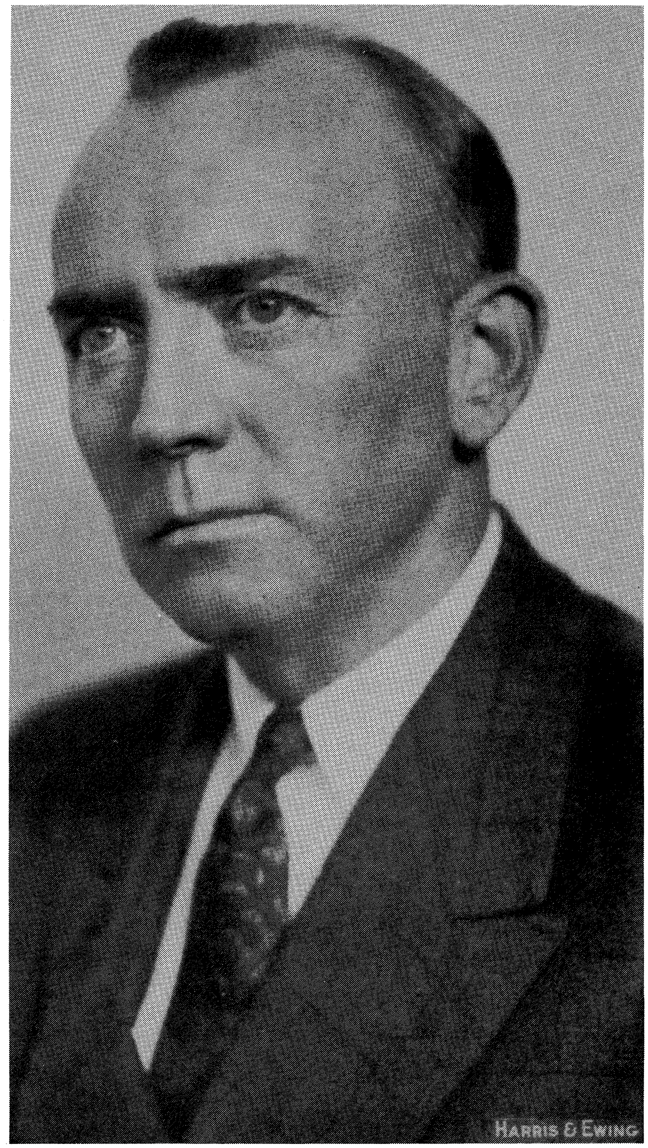
"A messenger boy in those days had many pleasures. He met very kind men. I do not know a situation in which a boy is more apt to attract attention which is all a really clever boy requires in order to rise."

That world lived on for the members of the Morse Telegraph Club in their Vail Chapter: Paul F. Godley (M 1920, F 1926, H 1964); Clarence Pfeifer (M 1956); Edward Dunne; Thomas Barry; and Preston Baldwin. Many adopted the world of radio.

Paul Godley is best remembered in the history of radio for a different kind of trailbreaking. Born in 1889 in a sod house on the old Santa Fe Trail, he learned the Morse code by age 7 when his brother and a classmate set up a telegraph line in Le Grande, IA. He was 16 when he got his first job as railroad and a Western Union telegrapher at a railroad station in Malinta, OH. "The railroad was short of telegraphers. When the superintendent interviewed me and I told him my age, he said, 'Well, you could be 18 in this emergency.' There weren't enough telegraphers and a good one could get a job at any time and any place. A lot of them just wandered around and never stayed anywhere very long. They used to be called 'boomers.' They'd get drunk after payday and forget to show up, so they'd get fired and wander on."

He got a contract, later, with the Brazilian government to put up a chain of radio communication towers up the Amazon River to the Bolivian and Peruvian borders in 1913 and 1914. "The boats used to anchor in the middle of wide spots in the river, so as to be out of reach of Indian poison arrows," Godley recalled.

But his different kind of trailbreaking came in 1921. "Up 'til then, all radio was long wave, and short waves were considered useless. The long waves had a lot of static and I noticed that it was particularly bad under the tropical conditions in Brazil. A year after I got back, I developed a very sensitive short-wave receiver. In 1921, at Androssen, Scotland on the Firth of Clyde I showed that transoceanic radio by high frequency short waves could work by receiving from station 1 BCG in Greenwich, CT. About three years later, long waves began to be abandoned." The story of that first trans-atlantic short wave message is told in detail in the 1 BCG Commemorative Issue of The Radio Club's *Proceedings* of October 1950.



THE MAN WHO RECEIVED THE MESSAGE

Paul Forman Godley who received the signals in Scotland and copied the epoch making message sent by 1BCG. His scientific knowledge, long experience and exceptional operating ability were largely responsible for the success of the transatlantic transmission.

CROSSING THE HUDSON

While Morse was a professor of painting and sculpture at New York University, he conceived the idea of using electromagnetism to communicate via electric currents. He had no capital and his first telegraph was a theoretical but impractical Rube Goldberg sort of invention. The messages were sent by spelling out the words in type-like beads with points which interrupted the current. The receiving end was a pencil which the electromagnets swung from side to side across a band of paper, with the message being read from the peaks and valleys of the line.

One of Morse's NYU students, Alfred Vail, brought Morse to see Judge Stephen Vail, his father. The Judge was convinced that the invention might work after he scribbled a message whch Morse sent to Alfred inside the barn; it read: "Patient waiters are no losers." Judge Vail then backed Morse and his son, financially.

Alfred Vail worked to simplify telegraphy into the dot and dash system, and then showed Morse that it could be "read" by ear. After a demonstration telegraph line was built from Washington to Baltimore in 1844, the Magnetic Telegraph Company was formed and extended the line in 1846 and 1847 from Philadelphia to Newark where messages went to New York by train to Jersey City and thence by ferryboat across the Hudson River.

A rival, the Baines Chemical Telegraph Company, using a Scottish patent, ran a line up to Fort Lee, NJ and tried to lay a cable under the river, but the cable was broken by a ship's anchor before it could be used.

Finally, a 310-foot tower was built atop the Palisades at a cost of $10,000 with a wire to a telegraph station in the Washington Heights home of naturalist James Audibon. Eventually replaced by an improved underwater cable, the tower broke at least three times by 1856, but the trouble with local residents were even worse.

Pioneering telegraph lineman James D. Reid, writing his memoirs in 1897 in a book called *Telegraph in America* recalled: "As soon as the line was complete to Fort Lee, our sorrows began. The glass insulators, as they glistened in the sunlight, were splendid marks for boys and rifle shooters, and they went down by the dozen. Sometimes riflemen would try to split the wire." To finish it off, "One night rain fell through a cold atmosphere and froze on the wires. Wind came up and 40 miles of copper wire went down as by a breath, each length broken short at the pole." The bare copper wire was replaced by iron.

Ezra Cornell, who had tried to lay a cable from Fort Lee in 1845, started a telegraph line from Piemont, NY two years later. It was parallel to the Erie Railroad being built by Eleazer Lord. In 1851, an Erie Railroad superintendent in a train waiting for another train to pass, discovered that he could use the nearby telegraph to check ahead on the oncoming train. When it became apparent that the telegraph could save sidetrack waiting time, the Erie bought Cornell's telegraph line and train dispatching by telegraph was born. Four years later, the Erie Railroad telegraph — later Western Union — was opened to commercial business in the cities served by the Erie.

TOM EDISON, TELEGRAPHER

History tells us that when Thomas Alva Edison was 15 years old, he saved the life of a child who had been playing on a railroad track. The child's father, a telegraph operator, rewarded young Edison by giving him lessons in telegraphy. For the next five years, he was a roving telegraph operator working in various cities throughout the United States and Canada. He preferred to work on the night shift where he could more easily carry out experiments.

At one wayside telegraph office, he was required to send an identification signal to the dispatcher every hour. So that he could devote attention to more interesting things, Edison devised a clock mechanism which could transmit the signal automatically. It worked perfectly. His employers did not appreciate the experiments especially when Edison put the telegraph lines out of commission, or when he fell asleep because he was so tired.

THE INCREDIBLE INDO-EUROPEAN TELEGRAPH

By 1860, commercial and diplomatic pressure was increasing for telegraph service between the United States and Europe but, at that time, engineers felt that a telegraph line lying at the bottom of the Atlantic Ocean was technically impossible. In 1842, Samuel F.B. Morse had transmitted telegraphy over a short section of insulated wire laid in New York Harbor. The first attempt to establish electrical communications by submarine cable on a commercial basis was in 1850 when a cable was laid between England and France. It broke down shortly after communications were established and much yet had to be learned about insulations and electrical phenomina.

As a result of the thinking of the engineers, Western Union planned a vast project for the running of an open wire telegraph line crossing the United States, Canada, Alaska, and then Siberia to European capitals. The Russian link had been started in 1860 with a two-wire overhead line on poles extending from Moscow through Siberia to Vladivostok — a distance of nearly 7,000 miles. The Great Northern Telegraph Company, an early Danish firm, apparently worked closely with the Russian Telegraph Administration in providing technical know-how.

Great Northern wanted to connect its lines with the trans-Siberian circuit to provide a route between Europe and the Orient. They were building telegraph lines in China and laying a submarine cable between Vladivostock and Nagasaki, Japan to bring their objective into reality. The European — Far East service was opened for public traffic in 1872.

Before the Western Union plan had progressed very far, a workable transatlantic cable was laid in 1865 by Cyrus Field, and which performed satisfactorily a year later. While the International Morse (or Continental) code had been adopted at the Berlin conference in 1851 for submarine telegraph cables, the dots and dashes were of the same duration but of different *polarity*. Dots were formed by applying positive potential to the cable, and dashes by applying negative. Spacing was achieved by grounding or "earthing" the cable.

With the cancellation of the Alaska — Siberia open-wire link shortly after the Atlantic cable began to provide service, attention in Great Britain turned to the desperate need for telegraph service between London and India to assist in the building of the Empire. A submarine cable had been laid through the Mediterranean and the Red Sea to India but it suffered so many failures and interruptions that it was virtually useless.

Attempts were made to bridge the gap through the Russian telegraph system to the Persian (now Iranian) border and there to connect into an existing Aden — Karachi circuit. However, the maintenance of the line in Persia was so poor that satisfactory operation seldom was realized, and the mish-mash of facilities caused many delays because messages had to be repeated manually at many points by operators unfamiliar with the language used.

In 1867, the German company, Siemens, offered a plan for a new system under a single management, to pass through the Anglo-German cable thence through the Prussian-Persian lines to connect, at Teheran, with a system administered by the British-India Authority. The automatic repeater, introduced in the United states in the early 1860's, would be used.

The Indo-European Telegraph Company Ltd. was formed to construct and operate the line which was completed early in 1870 after the solving of the many construction and logistic problems. Intermediate stations between London and Calcutta incldued Lowestaft, Emden, Berlin, Thorn, Warsaw, Jitomir, Odessa, Kertch, Suchum, Tiflis, Julfa. Teheran, Bushire, Jask, Karachi,and Agra. The circuit consisted of two 6 mm diameter wires carried on some 70,000 poles. Spruce poles were used in Poland, oak poles in southern Russia, and iron poles in the Caucasus and Persia.

With the exception of a break between 1914 and 1921 due to World War I, the line provided realiable, efficient and very profitable service for almost 60 years. The overhead line was more than 11,000 kilometers in length — more than a quarter of the Earth's circumference. It was a magnificent monument to Siemens and their associates who not only overcame tremendous construction and operating problems but, frequently, almost unbelievable diplomatic and nationalistic stubborness and resistance.

Incidentally, while the Western Union facility via Russian America and Siberia was aborted, a fantastic plus developed from its efforts. Western Union president Hiram Siblen urged the purchase by the United States of Russian America, from Russia; the U.S. did so for $7,200,000. This became Alaska and, eventually, the 49th state of the Union. It was, perhaps, the greatest land bargain in history: about two cents an acre!

The building of the open-wire telegraph in India was noted for curious as well as difficult problems. The early system used the "needle" type telegraph wherein polarity changes in current cause a magnetic needle in the receiver to swing right or left to indicate the dots and dashes of the International Morse code. One historical record of the system says: "In the first place, it was discovered that the air in India is in a state of constant perturbation of the strongest kind, so that the instruments there went into a high fever and often refused to work. Along the north and south lines a current of electricity was constantly passing which threw the needles out of gear, baffling the signallers."

"Moreover, the tremendous thunder storms ran up and down the wires often melting the conductors; monsoon winds tore the teak posts out of the sodden ground; the elephants and buffalos trampled the fallen lines into kinks and tangles; the Delta aborigines carried off the timber supports for fuel and the wires or iron rods on them to make bracelets and to supply the Hindoo smitheries; the cotton and rice boats kedging up and down the river dragged the sub-aqueous wires to the surface."

"In addition to these graver difficulties were many of an amusing character. Wild pigs and tigers scratched their skins against the posts in the jungle, and porcupines and bandicoots burrowed them out of the grund. Kites, fishing-eagles and hooded-crows came in hundreds and perched upon the line to see what on earth it could mean and, sometimes after a thunderstorm when the wires were wet, were found dead by the dozens, the victims of their curiosity."

"Monkeys climbed the posts and ran along the lines, chattering and dropping an interfering tail from one line to another which tended to confound the conversations of Calcutta. Parrots with the same contempt for electrical insulation, fastened upon one string by the beak and another by the leg; and in one village, the complacent natives hung their fishing lines to dry on them."

"In 1856, there were four thousand miles of telegraph wire stretched over India; some upon bamboo posts which bent with the storms and thus defied them; and some in the Madras Presidency, upon monoliths of granite — these, during the Mutiny, proving their worth ten times their cost."

Perhaps present day wire chiefs — or their current equivalents — can look back in history with some satisfaction that the "good old days" had just as many or more headaches then, as they suffer today.

(Editor's Note: Don deNeuf is widely recognized as a lucid writer of vignettes of history. In 1986, he was awarded the prestigious Ralph Batcher Memorial Award by The Radio Club "for contributions in preserving the history of radio communications through his writings and publications of articles." He is a frequent contributor to the publications of the Antique Wireless Association, The Royal Naval Amateur Radio Society, Society of Wireless Pioneers, and other communications societies. The Radio Club'd Diamond Jubilee Yearbook includes Mr. deNeuf's tribute to the late William S. Halstead in the paper "Man of the Renaissance".)

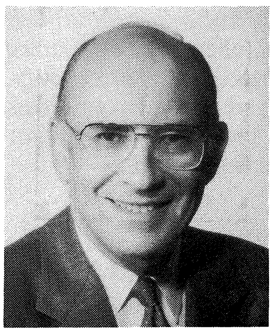
HONORS AND AWARDS 1987

ARMSTRONG MEDAL
William W. Eitel

Awarded in recognition of his major contributions to the design and manufacturing of high-powered radio tubes.

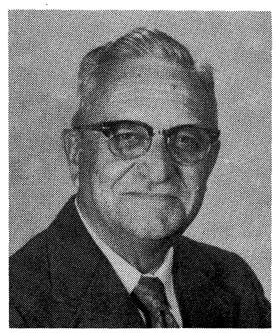
ALLEN B. DuMONT CITATION
Kenneth A. Hoagland

Awarded for his role in television research and development.



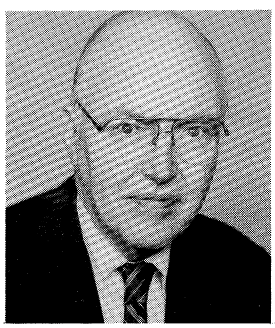
SARNOFF CITATION
William J. Weisz

Awarded in recognition of his achievements in advancing electronic communications.



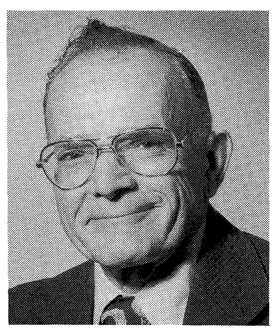
RALPH BATCHER MEMORIAL AWARD
Dr. John D. Ryder

Awarded for his documentation of radio history, and for his achievements in the field of higher education.



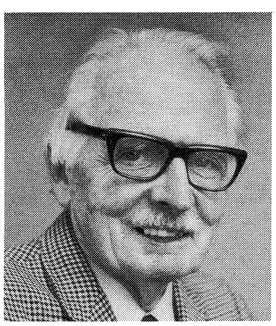
BUSIGNIES MEMORIAL AWARD
Renville H. McMann, Jr.

Awarded for his work in developing professional broadcasting equipment.



PIONEER CITATION
Edward Sieminski

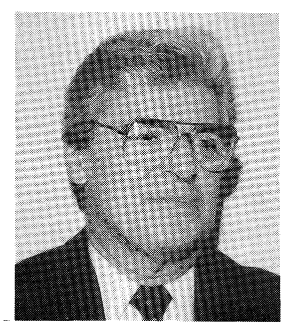
Awarded for his active support of our Club and the communications industry for more than a half century.



LEE deFOREST AWARD
William Storm Halstead*

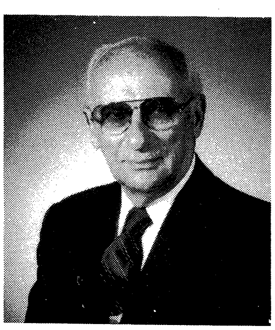
Awarded for his contributions to radio communications and the art of multiplexing.

*Awarded posthumously



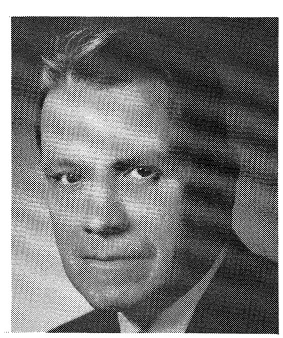
PRESIDENT'S AWARD
Gaetano (Tom) Amoscato

Awarded for his dedicated support of the Club.



FRED M. LINK AWARD
Frank A. Gunther

Awarded for his pioneering achievements in the development of two-way police radio communications.



SPECIAL SERVICES AWARD
John W. Morrisey

Awarded for his distinguished services to our Club.

FELLOWS - 1987

The following members are elevated to the Grade of Fellow in The Radio Club of America in recognition of their achievements in furthering the goals of the Club, and are here Cited:

Steven L. Aldinger, Vice President Sales and Marketing — Celwave RF Inc., Marlboro, NJ, for contributions to land-mobile radio antenna systems.

Ronald H. Ammeraal, Western Area Manager — Sinclair Radio Laboratories, Inc., Riverside, CA, for antenna systems design and installation, and work in fields of technical training.

Gene A. Buzzi, President — Omnicom, Inc., Tallahassee, FL, for leadership in the field of public safety communications, spectrum management, and spectrum utilization.

Donald Christiansen, Editor-in-Chief — *IEEE Spectrum* and *IEEE The Institute,* New York, NY, for distinguished contributions in the fields of publishing and journalism.

Mark E. Crosby, President — SIRSA, Inc., Rosslyn, VA, for leadership in land mobile radio.

John H. DeWitt, Jr., Consulting Engineer — Nashville, TN, for outstanding accomplishments of antenna design, electronic applications, and in the field of astronomy.

Alan M. Dorhoffer, Editor — *CQ Magazine,* Hicksville, NY, for contributions in the field of publishing of Amateur radio periodicals.

Les M. Ettinger, President — Tele-Path Cor., Fremont, CA, for pioneering work on Earth stations for satellite TV reception.

Dr. Robert Lee Everett, Consulting Engineering — Washington, DC, for activities in originating and implementing high-powered HF broadcasting antennas and the techniques that utilize their novel characteristics.

Dr. Robert E. Fenton, Professor — Dept. of Electrical Engineering, Ohio State University, Columbus, OH, for research on communications, and guidance and control aspects of highway automation; and leadership in IEEE Vehicular Technology Society.

Michael T.N. Fitch, Chief — Private Radio Bureau, FCC, Washington, DC, for accomplishments in policy and rule making for private radio services; and for activities at international radio conferences.

Otis S. Freeman, Vice President and Director of Engineering — Tribune Broadcasting Company, New York, NY, for innovative pioneering developments in TV broadcasting.

Augustine J. Gironda, Publisher — Mamaroneck, NY, for contributions in the publishing of Amateur radio periodicals and support of Amateur radio organizations.

Ms. Arlene Harris, Vice President — DYNA, Chicago, IL, for leadership and innovation in the cellular radiotelephone and high-capacity radio paging industries.

Charles W. Herrin, Retired manufacturing and marketing executive — Redwood City, CA, for contributions in the field of specialized mobile radio servies and products.

Loren F. Jones, Retired Educator and Engineer — Philadelphia, PA, for contributions to broadcast engineering, and for wartime services in radio and radar fields.

John J. Kelleher, Consultant — Silver Spring, MD, for activities in the areas of international radio spectrum planning and utilization for satellite systems.

Dr. Ronald R. Kline, Professor — Dept. of Electrical Engineering, Cornell University, Ithaca, NY, for contributions in the preservation of the history of radio and electronics.

John D. Lane, Esq. Attorney — Artis, Hedrick and Lane, Washington, DC, for legal guidance of APCO programs.

Charles N. Lynk, Vice President and Director of Mobile Research Motorola, Inc., Fort Worth, TX, for developments in mobile radio transmitter, receiver and systems design.

Dr. Peter Mailandt, President — Decibel Corporation, Dallas, TX, for leadership in the field of specialized communications hardware and their applications.

Ian M. McKenzie, Managing Director — Philips R.C.S., Ltd., Cambridge, England, for leadership in mobile radio production, and in the support of Australian industry policies.

Charles S. Moody, Jr., Corporate Communications Manager — Central Fidelity Banks, Inc., Richmond, VA, for achievements in the design and development of large communications systems, and major contributions in wartime radio services.

Joseph Y. Nasser, Jr., Director of Emergency Management and Communications — Volusa County, FL, for leadership as President of APCO and as Chairman of the National Safety Planning Advisory Committee.

William L. Ordway, Telecommunications Planner — Santa Ana, CA, for extensive activities in telecommunications planning and design, especially in the field of cellular radio.

William H. Sayer, Consultant — Hemet, CA, for innovative pioneering achievements in early UHF television transmitter design.

Michael S. Schwartz, Vice President, Operations — Amcell, Inc., Atlantic City, NJ, for contributions in the design, construction and marketing of paging and cellular radio services.

Anthony K. Sharpe, Engineering Manager — Philips R.C.S. Ltd., Cambridge, England, for development of radio paging products and systems and, specifically, for leadership in establishing the POCSAG paging standards.

T. Shimomura, Executive Vice President — OKI Telecom, Fair Lawn, NJ, for his special contributions leading to the successful coordination of Japanese and American ideas and programs that have resulted in an excellent joint-venture program in the U.S.A.

Dr. Eric D. Stoll, Consulting Engineering — Teaneck, NJ, for contributions to the development of broadband directional AM antennas, digital communications systems, high-speed and high-density tape recorders, and fault-tolerant computer systems.

Edward S. Talley, Manager of Telecommunications — Grumman Corporation, Bethpage, NY, for contributions to computer-assisted design and manufacturing systems.

Jay W. Underdown, President, — Spectrum Resources, Inc., st. Charles, MO, for achievements in the field of consulting engineering on public safety communications systems.

Gordon V. West, Radio Columnist — Costa Mesa, CA, for contributions to electronic journalism and radio Amateur education.

William C. Willmot, Retired - NASA J.F.K. Space Center — Merritt Island, FL, for services as Emergency Services Officer and Alternate Frequency Manager, and for educational work in Amateur radio communications.

Maurice Zouary, Executive Vice President — Movietronics Corp. of America, Inc., New York, NY, for long-time support of Dr. Lee deForest as the inventor of sound-on-film motion pictures.

PRACTICAL NOTES ON SURGE PROTECTION

by Al Gross (M 1977, F 1980, L 1978)

The May 1987 issue of The PROCEEDINGS carried an authoritative treatise titled "Electromagnetic Pulses: Theory, Threats, and Defenses" written by Lt. Claudius E. Watts, IV.

In this article, Mr. Al Gross (LF), father of Citizens' Band Radio, writes of his work as a consulting engineer in matters pertinent to the analysis and documentation of electromagnetic interference (EMI), radio frequency interference (RFI), sources of other destructive energy.

This paper was prepared as a sequel to Lt. Watt's thesis and discusses the treatment of transients for protection of electrical and electronic equipments. It has been written as a compendium for the lay person and as a guide post for the application of good practices. (Ed. note)

INTRODUCTION

To design transient surge protection into electronic equipment and connectors, it's helpful to have some understanding of:

- where the surge come from;
- what their waveforms and energy levels look like;
- where the test standards came from; and
- what "their" waveforms and energy levels look like.

Electromagnetic interference, experienced by electrical and/or electronic equipment and that may affect its normal operation, can be classified as follows:

1. Discrete-frequency continuous signals such as those from radio, television, and radar;
2. Wideband continuous signals such as from automotive ignition systems, electrical power switchgear, and corona discharges from electric power transmission components and high lines; and
3. Non-recurrent impulse signals commonly referred to as transient surges such as those generated by the sudden release of stored energy in electrical storms, and electrostatic discharge.

The random nature of this third group of interference signals makes it difficult to predict their presence and to measure their amplitudes, duration and energy content. Consequently, a statistical evaluation is often used by engineers and equipment designers to predict their nature and frequency of occurrence.

High technology microcircuits are particularly vulnerable to damage from exposure to this group of impulse signals. The complexity and density of circuits on a single microchip therefore requires telecommunications, data processing and control equipment engineers to devote attention to transient surge suppression, if there is to be uninterrupted operation of vital networks, without loss of data or control functions.

Suppression of transient surges at their various sources external to equipment and signal lines, is not practical. Protection from surges has to be provided by inserting a suppression device between the source and the susceptible circuits or equipments. Further, practical considerations dictate that shunt protection where the surge suppressor is connected in parallel with the sensitive circuits or at entry to the equipment, is almost universally employed.

To date, the silicon p-n diode has generally been regarded as the most suitable device with which an engineer or equipment designer could provide secondary surge suppression. However, it has been limited in its application by its surge power rating.

Two fundamental aspects of transient surge suppression are:

1. Sources of transient surge interference and the levels actually experienced in practice. Comprehensive protection can only be provided through precise knowledge of surge sources and a quantitative assessment of the amplitude, pulse width, waveshape and frequency of occurrence of the transient surges; and

2. Performance requirements of suppression devices should have as little effect as possible on the normal operation of the circuist that the devices are intended to protect. In the past, the level of transient suppression of both RFI and EMI, and the interference with normal circuit operation, have been a compromise at best.

SOURCES OF TRANSIENT SURGE INTERFERENCE

Transient surges affecting the normal operations of electrical and electronic equipment have both natural and man-made causes. They can be propagated by radiation, conduction, or a combination of both.

LIGHTNING

Thunderstorms can develop from local convection currents caused by heating of air near the earth (heat storms), or as a result of the impact of advancing cold air on a mass of warm moist air (frontal storms) which may extend for several hundred miles. Heat storms are non-regenerative owing to the cooling effect of the associated rainfall to earth, while frontal storms are regenerative in nature through long time movements of the large air masses involved.

Lightning discharges take place in various forms. In order of descending frequency of occurrence these are: inter-cloud discharges; downward-directed discharges that fail to reach the earth; and discharges that develop in a general upward direction from the top or side of a charged cloud. Ball, ribbon and pearl lightning are less common. Of the various lightning discharges, the cloud/earth discharge has been studied in detail, largely because of its having the greatest impact on life.

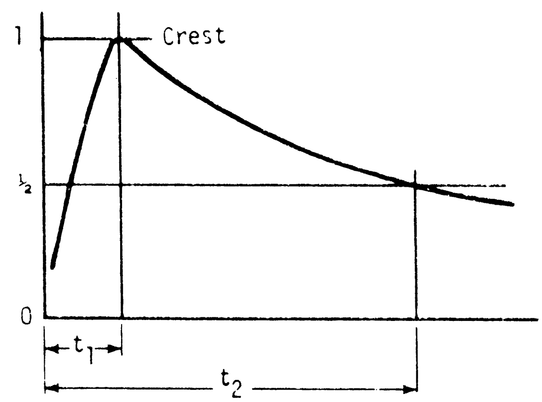
As a thunder cloud develops from a rising mass of moist air, a redistribution of electronic charges occurs such that the main volume of the cloud becomes negatively charged and its upper surface positively charged. Usually there is also a small pocket of positive charge near the leading base of the cloud. However, with the majority of the cloud base being negatively charged, this results in a positive charge being induced in the earth ground immediately below the cloud.

The normal earth-discharge commences in the negatively-charged region of the cloud and follows the formation of an ionized column of air beneath the cloud. The discharge does not take the most direct path down the ionized column to earth; instead it moves in a series of steps — guided by pockets of the charge — down a succession of branch paths which offer the least line of resistance to earth ground.

The path to earth ground is completed either by a continuation of the above process or through meeting a positive leader originating from the earth ground, such as tall buildings, poles or trees. With the path complete, a positive charge flows upward from earth ground into the charged cloud. It is the first positive return stroke that constitutes the main lightning stroke, and is the cause of the thunderclap which derives from the very sharp and large rise in temperature of the air around the discharge. The first return stroke involves peak currents of 1,000 to 100,000 amperes with rise times of the order of one microsecond and is responsible for most of the destructive effects of lightning. Earth discharges in frontal storms are of greater magnitude and frequency than in heat storms.

Direct lightning strokes are responsible for considerable damage to overhead lines and above-ground equipment. Underground cables, on the other hand, are virtually immune to damage by direct stroke but, in common with overhead lines, are subject to lightning induced voltage/current surges which can be propagated along the cable into sensitive equipment. However, while a direct lightning stroke can comprise a discharge of around 100,000 amperes, cable borne surges impressed on equipment are significantly attenuated by the resistivity of earth ground (which, for example, could be natural soil or a concrete footing), line impendance, and conductor sharing.

A lightning surge is normally characterized as a double exponential waveform (Fig. 1). It is defined by a fast rise time to its peak value; a decay time (from zero time to half-peak value); and a peak value expressed as either a voltage or current at a specified source impendance. In the United States, 8 by 20 microseconds and 10 by 1,000 microseconds current waveshapes are used. For some applications, 1.2 by 50, and 8 by 50 microseconds are also employed.



(Fig. A)

Thunderstorms and lightning activity in an area where equipment is to be located are factors to take into account when considering the level of electrical surge protection required.

In addition to earth/cloud discharges, transient surge suppression must also take account of the more frequent inter-cloud discharges, since the electro-magnetic (EMI) field associated with such discharges are capable of inducing surges into power, telephone and control lines. Inter-cloud discharges, although having leader strikes, do not have intense return strokes; the dispersed charges in a cloud offer greater resistance to a return current flow than earth ground so that the charge is dissipated by gradual leakage.

ELECTROSTATIC DISCHARGES (ESD)

An electrostatic discharge from a charged person with a finger extended toward a metal equipment cabinet, can be characterized by a peak voltage up to 15,000 volts and a discharge current of several amperes having rise times of approximately 10 nanoseconds (10×10^{-9} seconds). The discharge current can take several paths through the equipment to earth ground as, for example, through an integrated circuit or along supply lines on a circuit board which, at the high frequencies involved, can create significant voltage drops. A further path may be along signal leads between cabinets. In consequence, although the energy in static discharge pulses is only in the milijoule (milliwatt) range, fast logic circuits remote from the point of discharge can be switched, thereby causing malfunctions or total damage.

In addition to the human body, other sources of electrostatic discharges are dielectric materials such as may be used for packaging, and plastic wrap materials. Contact electrification occurs when certain dissimilar materials are brought together and then separated. Free electrons from one material are captured by "traps" in the second material so that each material acquires an equal and opposite charge.

Fictional electrification occurs in parallel with contact electrification and the effects can either enhance or oppose each other. Friction between materials results in local heat and mechanical stress which creates new free electrons and "traps". As with contact electrification, the materials involved become charged through the free electrons lost by the one material being captured by "traps" in the other material.

In practice, people can become charged from friction between the soles of their shoes and a carpet, or their clothing and chair fabric. The maximum level of charge attained will be one of equilibrium determined by such factors as the person's self-capacitance; relative air humidity; environmental temperature; skin moisture; the materials and contact pressures involved; carpet thickness, resistivity and dielectric constant; rate of walking; friction generated; and, to an extent, the distance traveled or period over which friction occurs.

With regard to electrostatic discharge from a person, for example, through a metal cabinet to ground, there are three characteristics to consider. A human body is likely to have a self-capacitance of the order of 100 picofarads (.0001 microfarads) and a mutual capacitance to ground (a conducting floor) dependent upon the contact area with the carpet, and carpet material and thickness. Mutual capacitance values of 120 to 150 picofarads (.000120 to .000150 microfarads) are considered reasonable. The internal resistance of the human body presents a low source impedance (about 100 ohms) to the discharge, particularly when the skin is moist. In dry conditions, skin resistance can raise the source impedance to approximately 10,000 ohms.

Electrostatic discharges having peak voltages up to 40,000 volts have been measures where extreme conditions particularly favored static generation.

POWER SUPPLY

While power supply overvoltage surges associated with normal load switching operations and fault currents (such as fuse failure on D.C. power distribution systems) can be impressed upon sensitive computers, telecommunications and control equipment directly through the power supply leads, voltage surges deriving from the power supply can also be produced on communication lines and enter sensitive equipment. These transient surges can occur through direct contact with the power supply (such as from supply cables falling across the telecommunication lines), electromagnetic (EMI) coupling, or large power-system-fault currents flowing through the common ground connections, thereby producing significant voltage drops. The transient surges will last from a few microseconds to a period equivalent to several power supply cycles. The possibility of surges arising from intentional abuse or damage to power distribution systems and equipment should not be overlooked.

To protect equipment against these transient surges, and in particular prolonged surges which can be a source of ignition, it is good practice to employ a form of fusing. To provide protection against transient voltage surges of short duration and low current, a transient surge suppressor is required. The suppressor employed should have the necessary rating to absorb these transient surges and this may avoid unnecessary fuse operation through premature failure of the transient suppressor.

NUCLEAR EXPLOSION (NEMP)

A small percentage of the energy liberated in nuclear explosions such as atomic, hydrogen or neutron, is contained in the prompt gamma radiation emitted. Interaction from this radiation with atmospheric atoms and molecules produces free electrons which separate (at almost the speed of light) from the ionized atoms creating an intense electromagnetic field.

The resulting transient surges induced on exposed lines, cables and equipment have rise times on the order of 10 nanoseconds to 100 microseconds. Transient voltage surge peak values of around 1,000 volts have been reported, but this value will depend on size of the nuclear explosion and how far the point of the induced surge is from the explosion. Atmosphere explosions will result in greater electromagnetic fields than those created by ground explosions.

MAXIMUM PROTECTION

The main purpose of a transient surge suppressor is that it should consistently hold the equipment line operating voltages at non-destructive levels while overvoltage transient surge conditions prevail. To meet this requirement, the equipment line specifications must take into account the possible or intended operating environment by way of quantitative information of the nature and frequency of transient surges that may be encountered. Accurate transient surge data is difficult to come by other than by field tests because of the random and unpredictable nature of surges and source of generation, both from source location and time interval frequency.

EFFECT ON CIRCUIT PERFORMANCE

The requirements of a transient surge suppressor for minimum effect on circuit performance are as follows:

1. Its turn-off state characteristics should not affect the circuits or line it is protecting; for example, not having excessive leakage current.
2. Quick recovery immediately following the transient surge pulse.
3. The rated operating temperature range should be equal to or greater than that of the circuit or line it is protecting.
4. The response time should be compatible for use with the latest in modern circuit designs.

In the event of transient surge suppressor failure, it should be to an evident fail-safe state. The energy within a voltage transient is not infinite and thus will decay when shunted by the transient surge suppressor reflecting some energy back to the source or distributed impendance. In case of a severe, abnormal transient beyond the maximum ratings, the transient suppressor will initially fail "short" thus tripping the system's circuit breaker or fuse while protecting the entire circuit.

Transient surge suppression can be built into connectors, by using silicon p-n junction devices mounted to the connector contact. This technique offers the following advantages:

1. Excellent clamping ability (such as sharp breakdown, low slope resistance and long-term voltage stability).
2. Wide operating temperature range.
3. Very fast response time.
4. Good average power dissipation.
5. Fail-safe to short circuit.

The silicon p-n device conducts when the transient voltage surge reaches a value sufficient to cause avalanche multiplication. The transient is shunted through the bi-polar silicon device to the connector shell. Typical response time of the transient absorbing suppressor clamping action is better than 1×10^{-9} seconds.

Transient surge suppressors are suitable for protecting electrical and electronic circuits from 1,000 to 5,000 volt lightning surges with 1.2 by 50 microsecond and 10 by 1000 microsecond *voltage* waveforms, or 8 by 20 microsecond to 10 by 1,000 microsecond *current* waveforms.

A transient surge suppressor is normally selected according to the reverse "Stand-Off Voltage" (V_R) which should be equal to or greater than the DC or continuous peak operating-voltage level. The stand off voltage level has a value specified by the suppressor manufacturer slightly below the breakdown voltage (BV) and is the recommended normal maximum operating-voltage of the circuit to be protected so as to avoid significant reverse power dissipation in the surge suppressor under non-surge conditions.

Maximum clamping-voltage (Vc) is the maximum peak voltage appearing across the transient surge suppressor device when subjected to the peak pulse-current in a one millisecond time interval. The peak pulse voltages are the combination of voltage rise due to both the series resistance and thermal rise.

A design rule of thumb for determining the transient suppressor clamping-voltage (Vc) is to multiply the nominal breakdown-voltage (BV) by a (clamping) factor of 1.45 to ensure that the voltage rating of the particular circuit is greater than the clamping voltage of the suppressor. This type of transient suppressor requires the designer to ensure that the suppressor clamping voltage exceeds the normal maximum DC supply voltage in the circuit, otherwise the suppressor will remain permanently in the conducting state following a transient surge.

REVERSE LEAKAGE CURRENT (Ir)

The reverse leakage current (Ir) of a transient suppressor under steady state stand-off condition is normally stated at the stand-off voltage (V_R) and at a lower breakdown-voltage (BV) value.

PEAK PULSE POWER (Pp)

To determine the proper transient surge suppressor device according to the peak pulse power, certain mechanical constraints will apply when the suppressor device is to be designed onto a connector pin. The peak pulse power determination can be accomplished by knowing the source impedance and the maximum transient surge voltage. Once the maximum peak pulse current (Ipp) is known (and if its value is less than the maximum Ipp), use the maximum clamping voltage (Vc) to calculate power for worst case design. However, the physical size of a transient suppressor to be mounted on a pin within the connector housing will limit the peak pulse power capability of the device.

PEAK SURGE CURRENT (Ipp)

To determine the appropriate maximum peak transient surge (non-repetitive) current for a suppressor, a designer may use as reference the following formula:

$$Ipp = \frac{Pp\ max \quad (Watts)}{BV \times 1.45}$$

where BV = nominal breakdown voltage

and 1.45 = clamping factor

The above information may be taken from data books published by manufacturers of silicon transient suppressor devices.

CAPACITANCE

The capacitance within the transient surge suppressor device is a function of the silicon chip physics and the applied electrical conditions. This characteristic is listed for a transient surge suppressor device in the manufacturer's data book.

RESPONSE TIME

The response time for p-n silicon transient voltage surge suppressors is characterized by their phenomenal surge handling capabilities, extremely fast response time (1×10^{-12} seconds) and low series resistance R_{ON}). Therefore, the silicon surge transient surge suppressor effectively provides immediate shunt with negligible or no overshoot.

Surge and transient suppression are the main ingredients in electromagnetic compatibility (EMC) for electrical and electronic systems, equipments and components.

No single suppression device is the total panacea to intercept and suppress unwanted destructive surges and transients. At best a reasonable measure of suppression and protection can be provided by careful selection of devices available from a variety of manufacturers.

Where applicable, the use of high and low pass filters in conjunction with surge and transient suppressors can be designed into systems and equipments. Inductive and capacitive (LC) networks are used in radio and audio frequency filters with surge and transient suppression devices as part of the network. Most manufacturers provide application notes illustrating various schemes using their devices in system and equipment designs.

Gas-filled spark gap devices can be used in a variety of suppression circuits and are capable of intercepting and shunting energy levels up to 20 KV with burnout energy threshold levels in the order of 10^3 Joules. The power transmission and switchgear industry continue to use spark gaps and surge coil inductors to arrest over-voltage surges and transients. Power utility research groups are conducting extensive tests on metal oxide varistors (MOV) for application to high-voltage transmission systems and switchgear.

Terminal protection devices for the engineer are included in Table A. A list of device types with characteristics is included as Table B.

TABLE A

Terminal Protection Devices (TPD)

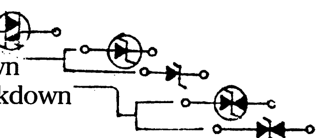
Purpose: To reduce transient and surge signal voltage to a safe level. The TPD will alter the pulse frequency spectrum because much of the incident energy is reflected. The reflected energy must be dissipated elsewhere.

Summary of Nonlinear TPD

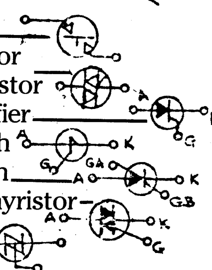
a) Spark Gap
   1. Air gap/carbon block
   2. Gas tube
   3. Arrestor/gas tube

b) Varistor
   1. M.O.V. Metal Oxide Varistor
   2. Silicon carbide varistor

c) Semiconductor
   1. Rectifier
   2. Bipolar forward
   3. Reverse breakdown
   4. Bidirectional breakdown



d) Semiconductor, Thyristor
   1. Unidirectional Diode Thyristor
   2. Diac Directional Diode Thyristor
   3. SCR Silicon Controlled Rectifier
   4. SUS Silicon Controlled Switch
   5. SCS Silicon Controlled Switch
   6. TRIAC Bidirectional Tride Thyristor
   7. SBS Silicon Bilateral Switch



Important Parameters (Insertion Effects)

Shunt Capacitance (C_T) (specified by manufacturer)
Leakage Current or
Standby Impedance (specified by manufacturer)
Turn-on Time
Current Capability
Turn-off
Device Polarity
Temperature Dependence
Damage Threshold

TABLE B

DEVICE TYPES	CLAMPING OR FILTERING THRESHOLD	CIRCUIT APPLICATION	DISADVANTAGE
Varistor MOV	3-1500V	Power, A.F.	Hi. Capacitance
Semiconductors:			
Forward Diodes	0.1-07V	R.F., A.F.	Lo. Burnout Energy
Breakdown Diodes	1-200V	Power, A.F.	Hi-Capacitance
Spark Gaps:			
High Speed Gaps	400-20KV	R.F., A.F.	Hi. Cost
Arrestors using High Speed Gaps	400-20KV	Power	Hi. Cost
Filters:			
Ferrite Bead Chokes	RF	Power A.F.	Ineffective Protection due to D.C. Saturation
Feed Thru Capacitors	RF	Power, A.F.	Dielectric Failure
General RLC Networks	D.C., R.F., A.F.	Power, R.F., A.F.	Impedance Mismatch

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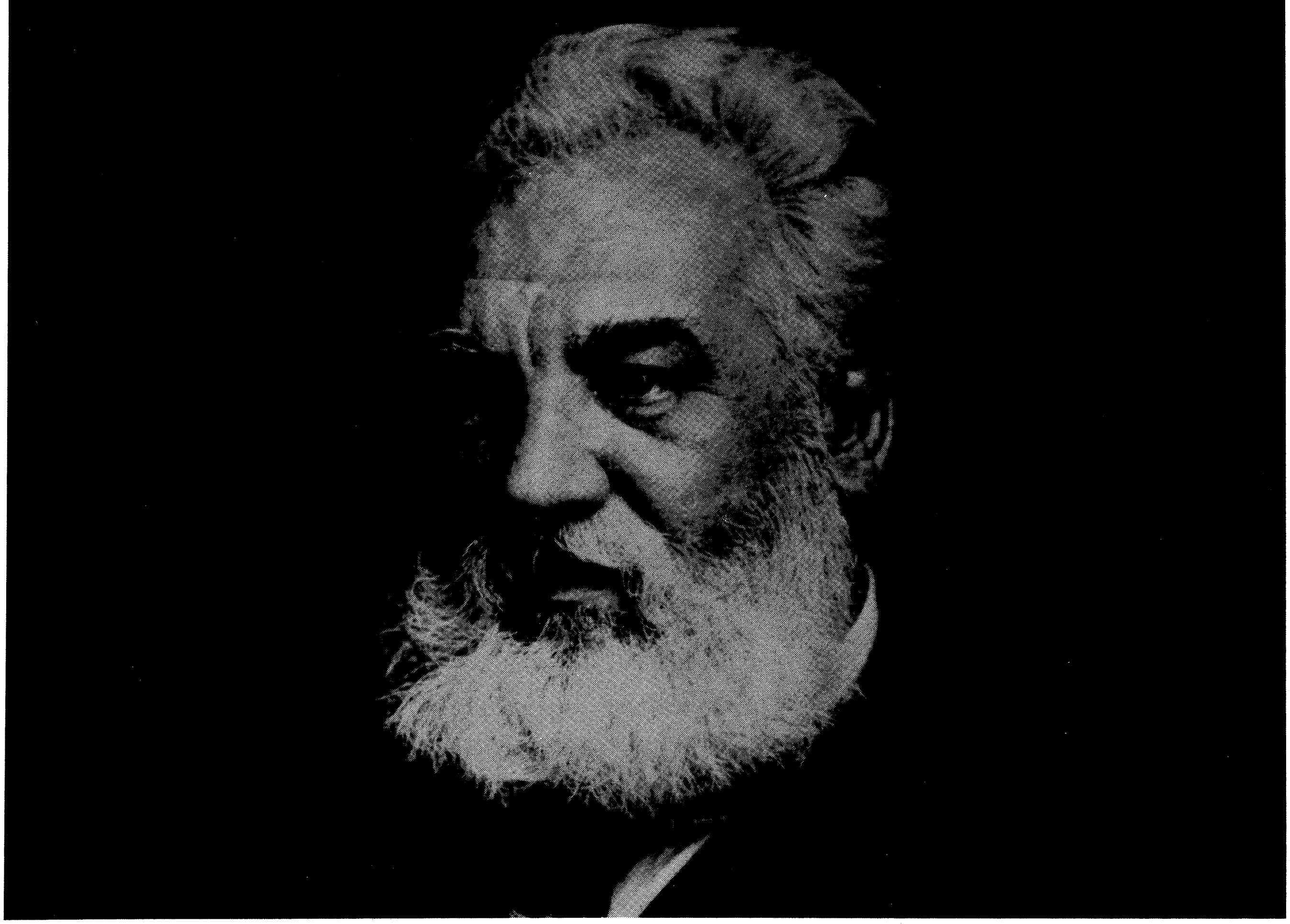

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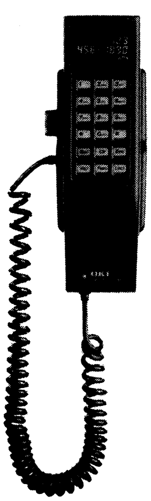

In fact, working together with the company that Alexander Graham Bell helped create, Oki designed and produced the world's first cellular telephone—back in the mid-1970s.

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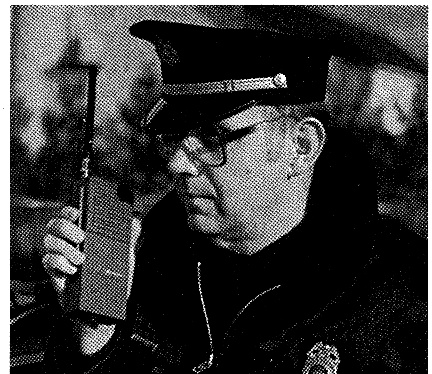

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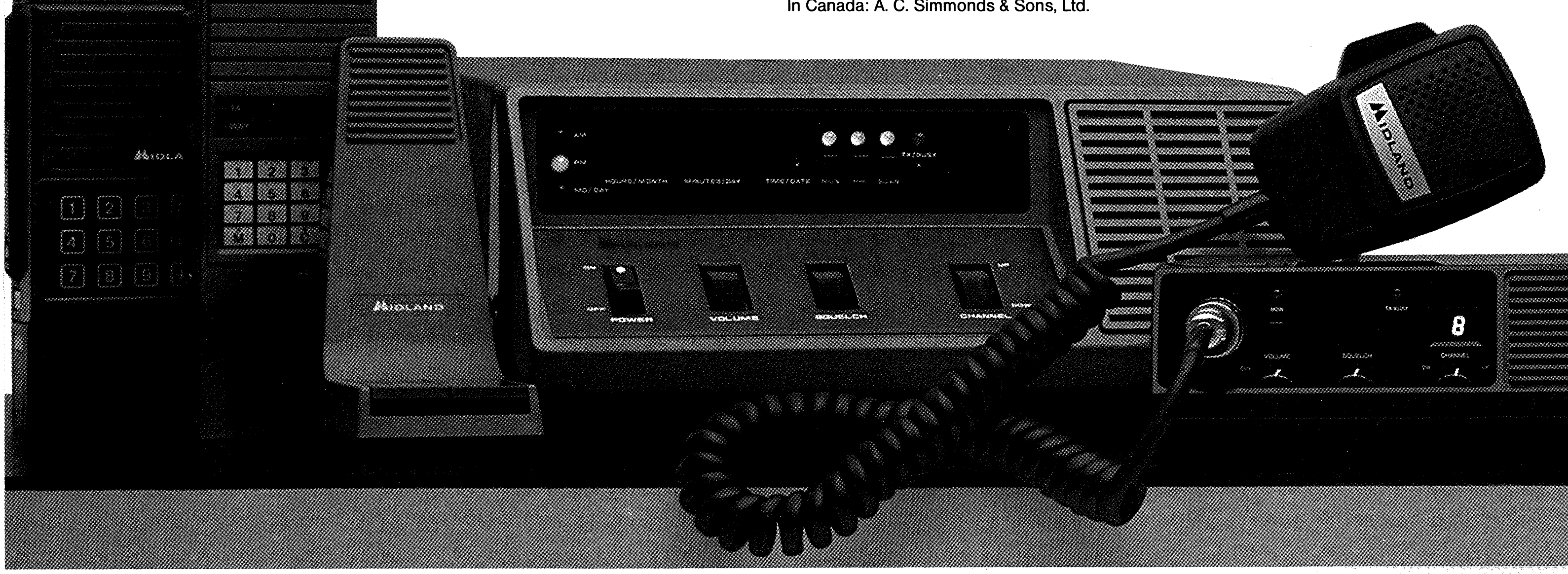

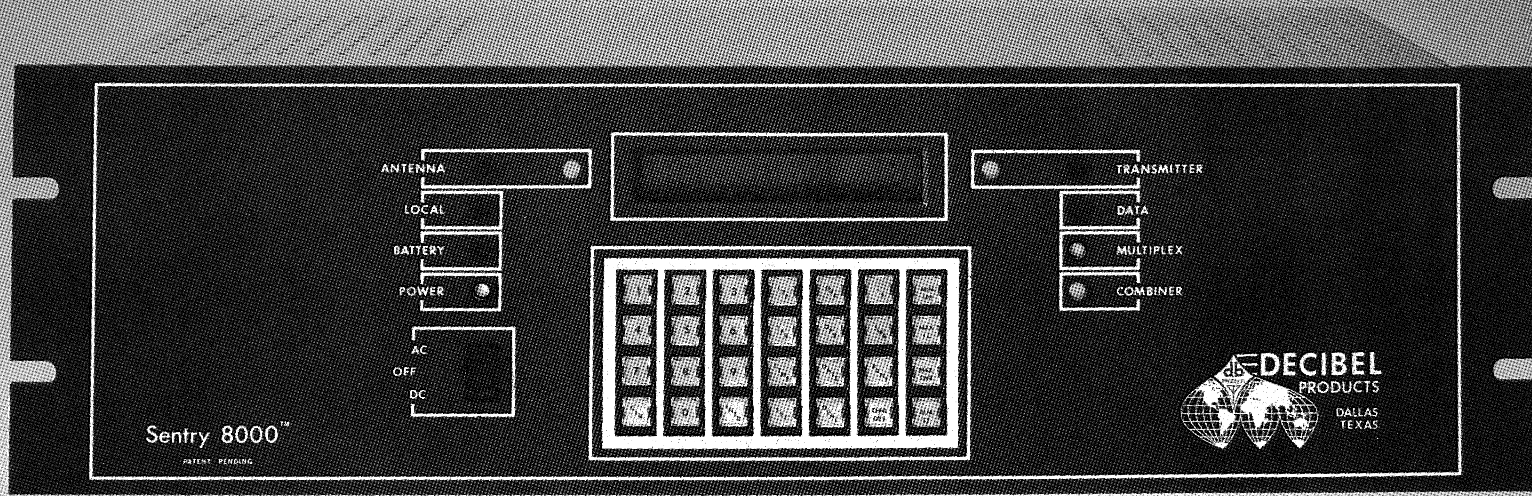
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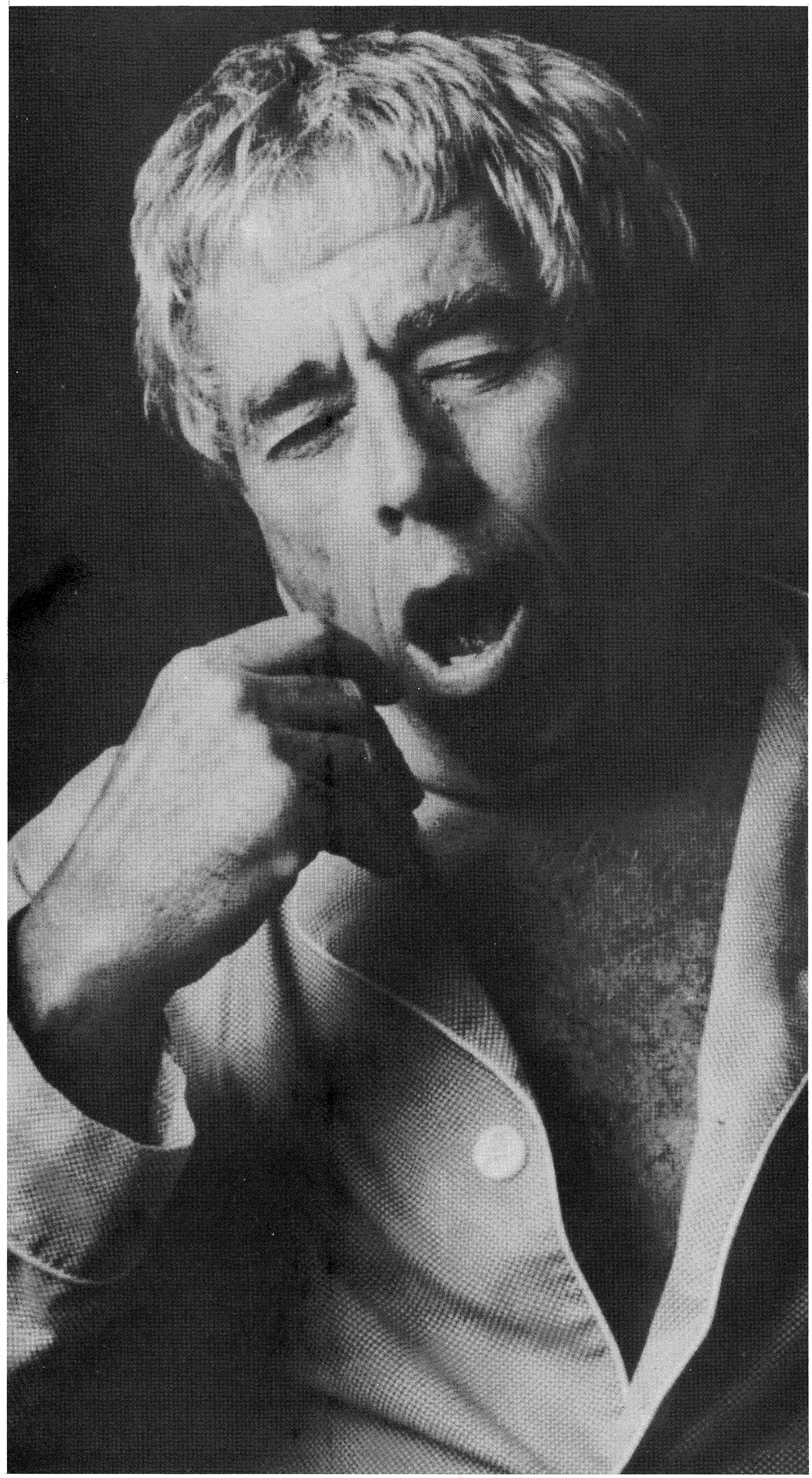

E.F. Johnson believes it's time to change some attitudes about the 2-way radio market.

For too many people, the two-way radio market is one big yawn.

GE and Motorola. Motorola and GE.

But what they overlook is that for over 63 years, there's been an alternative. A better alternative. A radio company that offers more reliable products backed by the most experienced national dealer service organization in the business. And a longer history of radio innovation and refinement than either.

That company, as you've guessed, is E. F. Johnson.

Since 1923, we've been pacing the industry with the latest in product developments. Our trunking system is recognized as the standard in the industry. And the rest of our radios aren't far behind.

You'll find we have the largest nationwide network of locally owned dealers and factory-trained technicians, providing service, inventory and expertise right in your area.

You'll find a company that's large enough to handle the biggest jobs in the field, yet flexible enough to be responsive to smaller, customized projects.

We're not into washers, dryers, refrigerators or stereos. So our name isn't always on the tip of your tongue. But when it comes to two-way radio, we're beginning to look less and less like a challenger, and more and more like the leader.

To learn more, or to arrange for a custom demonstration of E. F. Johnson equipment, look in the Yellow Pages for the dealer nearest you, or call 1-800-247-8343.

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