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THE RADIO CLUB OF AMERICA, INC.

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THE RADIO CLUB OF AMERICA, INC.

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CHANGES - AN EDITORIAL

This is a time of changes.

The cover is an indication. For the first time since Volume 61, Issue Number 2, of November 1987, we do not have a picture on our cover. One reason is that we had none relevant to the papers published in this issue. Our president, Mr. Fred M. Link, suggested listing the contents on the cover. This had been done for many years during the early issues of *The Proceedings*.

A more formidable change in the operations of the Club will result from the actions of the Board of Directors in deciding that the terms of office of the President, Executive Vice President, and Vice President should be limited to one year, commencing in 1992. A related change establishes a pattern of succession -- beginning in 1993 -- the presidency will be filled by the preceding year's Executive Vice President, and that chair will be filled by the preceding year's Vice President.

Elections will be held each year for a successor Vice President; also for the Vice President/Counsel, Secretary, and Treasurer. Each of these officers may succeed themselves in office but the President, Executive Vice President, and Vice President may serve one term only and are ineligible for re-election to the same office. Seven Directors will be elected each year to serve a two-year term.

This marks the end of an era. The term of office of the incumbent president, Fred M. Link, began on January 1, 1969; it will end on December 31, 1992. In the period 1969 - 1991, the Club's membership has increased from approximately 500 members to the current 1,103. The Club has celebrated its 75th anniversary. Sections have been formed in California, Florida, Texas, and Washington, DC., and plans are underway for new Sections in New England and Southern Texas.

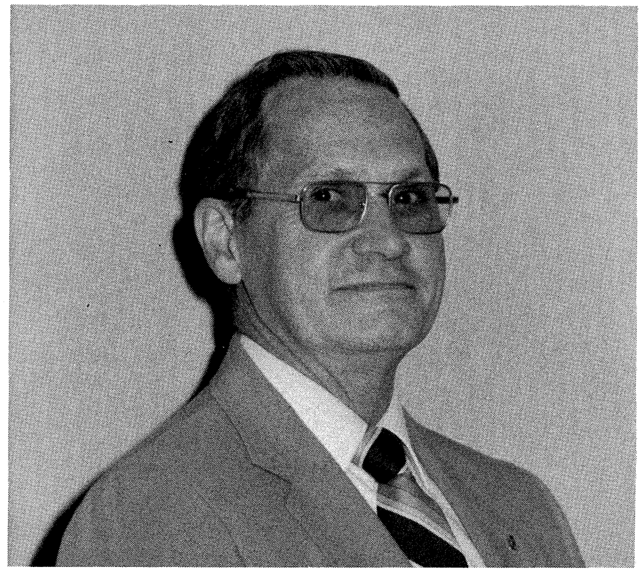
This, then, has been a period of growth reflecting much of Fred Link's personal efforts. His successors will have a tough goal to meet.

The new organization effectively establishes the Office of the Presidency wherein the three officers occupying the offices of President, Executive Vice President, and Vice President now form a team to direct the future of the Club. It will be a team that will look to you, our membership, for help and directions -- **and changes**.

THE SUMMER THAT NEVER WAS

by **William R. Gary, P.E., K8CSG** (F)

Despite the millions of words written and spoken in the media about the Exxon Valdez oil spill, cleanup, effects, etc., hardly anything of significance has appeared describing the utterly fantastic telecommunications work and the people who accomplished it. It was an epochal event -- a challenge of stern proportions, well and successfully met. Bill Gary was there, and tells about it here. - Ed.



William R. Gary, P.E.

"Never in the history of the petroleum industry, and possibly in telecommunications, has so much been done in such a remote location by so few people in such a short period of time."
Bob Black, March 13, 1990

INTRODUCTION

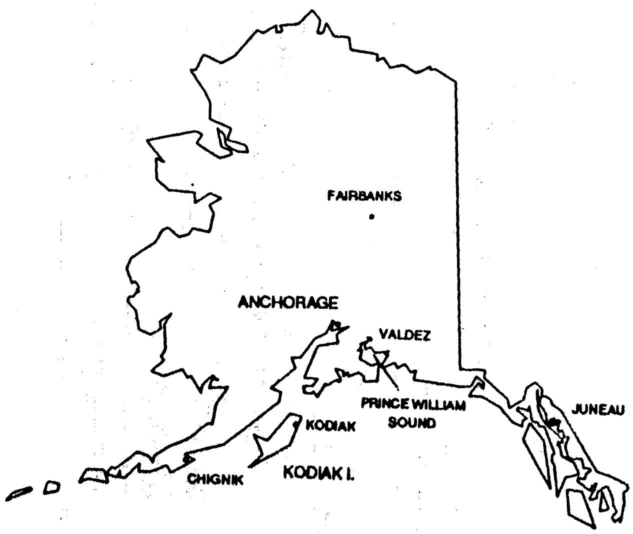
Shortly before 10:00 PM on March 23, 1989, the tanker *EXXON VALDEZ* slipped its moorings at the Valdez Terminal of the Trans-Alaska Pipeline. Guided by a harbor pilot, the 970- foot behemoth glided through Valdez harbor and into "the narrows", the mile-wide entrance to the deep-water, ice-free port chosen years earlier as the tanker-loading facility to serve companies producing crude oil on the North Slope of Alaska. Over seven thousand similar voyages had been completed without mishap since operation of the pipeline and terminal began.

This trip was to be different -- very different. After leaving the narrows and dropping its pilot at Rocky Point, the tanker sailed southwesterly into Prince William Sound. Rounding Busby Point, skipper Joe Hazelwood gave maneuvering instructions to the second mate, Gregory Cousins, and went to his stateroom to complete some paperwork. For reasons still unexplained, the *EXXON VALDEZ* struck Bligh Reef, rupturing eight cargo tanks and impaling itself firmly on the rocks. Millions of gallons (250,000 barrels) of Prudhoe Bay crude oil poured from the ship, creating the worst oil spill ever in United States waters. Of vital importance was the nearly 1,000,000 barrels of crude oil remaining aboard the tanker. In what is recognized as an out standing feat, Exxon managed to offload the remaining crude oil without additional spills. This was accomplished in a matter of days, despite the risk that the *EXXON VALDEZ* might break up and sink during this critical operation.

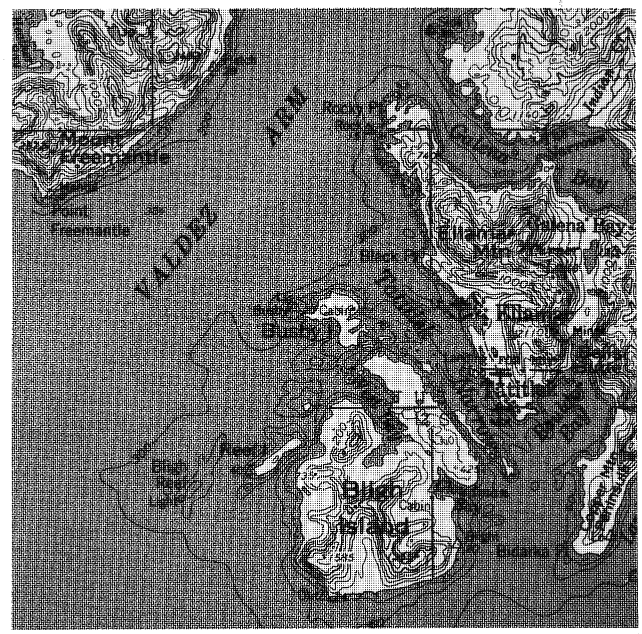
Exxon mobilized over 11,000 people, 1,500 vessels and 84 aircraft to clean and treat hundreds of miles of Alaska shoreline. These numbers have been widely quoted in the various news media. Millions of words have been written about the oil spill, its effects upon the Sound and its environment, Exxon and its efforts to contain and then to clean up the oil, and many tangential facets of the spill.

Relatively few words have been written about one aspect of what was to the be the largest news story of the year. What has been overlooked, generally, is that the massive cleanup effort described so often, so extensively and sometimes so inadequately, could not have taken place without telecommunications.

Throughout the massive 1989 operations, two lives were lost -- a probably intoxicated seaman fell overboard and drowned, and a shipboard food-handler died in an accident unrelated to cleanup activities.



Alaska



Location of *EXXON VALDEZ* Accident

The mobilization, movement, coordination and supply of the cleanup armada, all with the high degree of safety, could not have been accomplished without the complex telecommunications system that was constructed solely for that purpose.

Some 230 people, rarely more than 35 at any given time, were mobilized to build, operate, maintain -- and eventually remove -- one of the most unique telecommunications systems ever built. Starting from just a handful of small radios and a few ordinary telephone lines, the Exxon Valdez Project communications system grew to over 4500 radios in less than three months. The system used every kind of suitable technology available for the unique environmental and operating conditions faced by the cleanup effort. The system functioned well -- very well, in fact. Although constructed hastily and for summertime use only, this large, complex system enabled cleanup workers and supporting staff to communicate effectively in an area essentially lacking in normal infrastructure, e.g., telephones, power, roads, etc.

This is a story that begged to be told. It is a story of how modern technology and equipment blended with immense human effort. Not unlike many other cleanup workers, telecommunication engineers and technicians labored through seemingly endless eighteen-hour days. Men and women were separated from families for weeks at a time. Fortunately, the worst injury suffered by a telecommunications employee was the strained back of a shipboard radio operator -- despite construction work that was conducted on craggy mountain tops where helicopters could sometimes only hover while men and equipment were unloaded.

Throughout the long days of Alaska's Summer, the work went on -- and on -- and on. Except for a few brief periods at home, key people kept at the task. For many, 1989 will long be remembered as ***The Summer That Never Was.***

FIRST DAYS

How do you describe the experience of a lifetime?

This story began with the grounding of the *EXXON VALDEZ*, an event which dominated the news in Alaska and other parts of the world for weeks, then months, and continued into 1990 and 1991 as Exxon returned to the beaches of Prince William Sound and the Gulf of Alaska. Here is how the telecommunications story began on that fateful day in late March, 1989.

March 24 -- *12:28 AM*

Captain Joseph Hazelwood radioed the Coast Guard in Valdez that the *EXXON VALDEZ* had "fetched up" aground in the vicinity of Bligh Island. He reported that the tanker was hard aground, with ruptured cargo tanks leaking crude oil into Prince William Sound. "It looks like we'll be here for a while," said Hazelwood. The Port of Valdez was closed two minutes later.

Alyeska, the company responsible for operating the Trans-Alaska Pipeline and the Valdez terminal, was notified of the accident. Emergency centers in Valdez and Anchorage were quickly activated; the first communications technicians reported for duty in just over an hour. As the seriousness of the spill became more apparent, Alyeska communications personnel were called in, including some who had planned to enjoy a long Easter weekend.

3:23 AM

Bligh Reef, upon which the tanker ripped open her belly, lies some twenty-five miles south of Valdez. Coast Guard personnel from Valdez arrived, boarded the *EXXON VALDEZ* and calculated that nearly six million gallons of oil had leaked from the damaged cargo tanks.

Alyeska began to implement its oil spill response plan, including preparation of a large barge for deployment into Prince William Sound. A portable UHF repeater and portable handheld radios were placed in service on the barge, and an Alyeska technician was assigned to the barge as it prepared to move toward the *EXXON VALDEZ*. Alyeska also asked Alascom to provide emergency assistance. Alascom, the major statewide communications company, had a portable satellite earth station as well as permanent earth stations in Valdez, Anchorage and other critical locations in Alaska.

8:00 AM

Don Derryberry (M 1990), an Exxon senior-level telecommunications engineer, was already enjoying an expected three-day holiday weekend, working in his Houston garden. Derryberry is a veteran of over thirty-five years in radio communications, much of it in the maritime field, and had completed over seven years of service with Exxon when the fateful call from Exxon Shipping Company arrived.

10:30 AM

Bob Black (M 1971,F 1976), a Coordinator for Exxon Telecommunications, was remodeling a bathroom in his Houston home. The telephone call he received at 10:30 AM interrupted Black's project, one which he would not finish for many months. Although he would not realize it for days, possibly weeks, the *EXXON VALDEZ* would present the greatest challenge of his thirty-five years in Exxon telecommunications.

EXXON VALDEZ

11:30 AM

Alascom equipment departed Anchorage by truck for the ten-hour drive across icy roads to Valdez. By mid-afternoon, additional technicians arrived in Valdez to augment the one-man resident Alascom staff. Alyeska technicians, working with Copper Valley Telephone Cooperative, were installing telephones in the Valdez Westmark Hotel conference room. This was to be the first Command Center for attacking the spill.

9:00 PM

Trucks carrying the earth station and associated equipment arrived safely in Valdez, too late to be deployed until the next day. Alyeska and Alascom selected Reef Island, overlooking Bligh Reef and the stricken tanker, as the site for the portable earth station.

March 25 --

Saturday morning dawned relatively warm and sunny, the air filled with the sounds of helicopters and fixed-wing aircraft constantly arriving and leaving Valdez airport. People were beginning to flood into Valdez via every means of travel possible -- oil company officials, engineers and technicians, government officials, news reporters and contractors of various kinds. Everyone knew that the spill was a big one -- and that it would not go away quickly.

7:00 AM

Six Alyeska and Alascom employees left Valdez via helicopter for Reef Island. Their first task was to clear three to four feet of snow from a 30' x 75' site for the portable earth station. When they finished, hours later, they had uncovered sloppy muskeg. Plywood cribbing had to be installed to keep the satellite equipment from sinking into the ground during the Spring thaw.

In Anchorage, the Oil Spill Response Team assembled for briefing and distribution of special equipment. At 7:30 AM, Don Derryberry took possession of twenty-seven pieces of equipment to be used for Exxon's initial oil-spill response communications facilities.

Arriving in Valdez at 9:00 AM, Derryberry went to the Exxon Command Center (ECC) in the Westmark Hotel. His first action was to order a key telephone system to replace the twelve individual telephones in the ECC. Simultaneously, he had an Exxon contractor locate the special Oil Spill Response communications equipment which had been shipped from Hawaii. With all of the Exxon equipment located and moved to an apartment serving as bedroom and shop, Derryberry and Bill Laxson (North Slope Telecom) made plans for Sunday's work; new radio batteries were placed on overnight charge.

4:00 PM

Using an Army National Guard Skycrane helicopter flown in from Anchorage, Alascom deployed 12,000 pounds of truck-mounted Satcom equipment.

March 26, Easter Sunday -- *6:00 AM*

Derryberry and contractors began installing a UHF control station at the ECC in the Westmark. Alyeska and Alascom employees returned to Reef Island to clear more ground.

Noontime

The Skycrane delivered the portable module containing the earth station's electronic equipment, Alyeska's Portable Communications Module (PCM) and a diesel power unit. Shortly after noon, the sturdy Skycrane roared in above Reef Island's trees once more, this time to deliver the trailer-mounted satellite antenna. Technicians quickly completed interconnections, and dial tone was available on Reef Island. About the same time, Derryberry turned up the Exxon UHF repeater, providing radio communication between the ECC, the *EXXON VALDEZ* and the existing limits of the spill.

Helicopter At Reef Island

1:00 PM

During the helicopter lifts to Reef Island, technicians had been busy preparing to install a multichannel UHF terminal on the *EXXON VALDEZ*. This involved a four-hour trip by fishing boat from Valdez to Bligh Reef. The electronic equipment was hoisted onto the tanker by crane, while technicians climbed aboard via seventy-five feet of swinging rope ladder.

Onshore, Derryberry and Laxson were installing Marine VHF and aircraft VHF stations at the ECC. Alyeska was moving to install a high-gain antenna to extend the range of the marine VHF station at its PCM on Reef Island. By Sunday night, telephone communications were working from Valdez to Reef Island, and radio communications linked the island to vessels mobilized in Prince William Sound to fight the oil spill.

March 27 --

Technicians who had spent an uneasy night sleeping aboard the *EXXON BATON ROUGE*, which was lightering crude oil from its sister tanker, returned to the *EXXON VALDEZ*. Still unknown was the full extent of damage to the ship, and its list was more pronounced than the night before. By midday, the nervous technicians had two more telephone lines working from the ship to Valdez via Reef Island; others were established shortly afterward, enhancing the vessel's single-channel INMARSAT link and its HF radio.

Valdez, Alaska

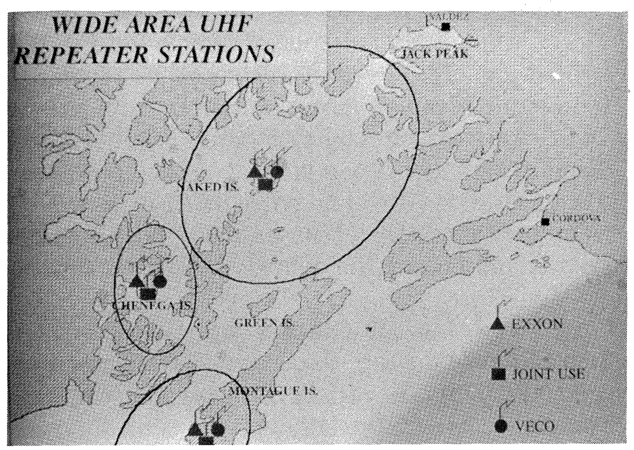
During those hectic first days, Valdez changed from a small town of 3000 people to an international communications center. The flood of incoming people doubled the population almost overnight. Hotel rooms were completely filled; all rental cars were in use; restaurants even ran out of food. Funded by Exxon, Copper Valley Telephone Cooperative doubled it's central-office capacity; Alascom increased its long-distance circuits from 24 to over 200. In such hectic conditions, the initial communications facilities were installed and placed in operation -- all in roughly three days encompassing an Easter weekend.

But all of this was just the beginning. Learning that the Exxon Command Center was to be relocated, Don Derryberry wearily picked up his hat and began to plan the installation of a telephone system in the new facility.

SHIFTING INTO HIGH GEAR

As the Exxon Command Center (ECC) was relocated from the Westmark Hotel to the nearby Royal Center, a 100-line telephone switch was quickly installed to serve the rapidly growing cleanup organization. The rapid growth in demand for telecommunication services is illustrated by the need to replace the first switch with a larger, 300-line machine -- within days. This switch was able to meet service requirements for roughly two months; it was replaced with a 450-line switch in early July.

Exxon's Chris Cooper, a former Alaska resident, arrived on April 2 to help Derryberry. When local manpower resources proved inadequate, Exxon began rounding up available radio technicians from the Texas/Louisiana Gulf Coast. These technicians, accustomed to working long hours under demanding conditions, were undeterred by the pressures to install radio systems in Prince William Sound. Cooper, Derryberry and North Slope Telecom's Bill Laxson designed a wide-area, multiple-repeater UHF radio system to be used by all cleanup participants in Prince William Sound.



Prince William Sound

The system consisted of three major repeater sites -- Naked Island, Chenega Island and Montague Island. Each site was to be equipped with three repeaters, forming three distinct radio networks. One network served the Exxon management team; one served VECO, the contractor selected to perform and oversee cleanup activities; a third, the Joint Network, was designed to provide radio service to agencies of the Federal government, including the U. S. Coast Guard, agencies of the State of Alaska, and similar groups. Eventually, three separate radio control centers were established, one for each network, with deliberate overlap of abilities to communicate via the various nets.

Exxon's Dave Lerten (M 1988), a veteran of telecommunications installations and operations in diverse parts of the world, was dispatched to Valdez on April 12. Lerten focused on the need for a defined relationship with Exxon's primary cleanup contractor, VECO, and various governmental agencies involved in the effort. The agreement which evolved provided that Exxon would not only coordinate all telecommunications services for the project, but would also provide the equipment needed by all participants. This control of that vital facet of the overall operation proved to be highly successful.

After Lerten's visit, Exxon management decided that the magnitude of the oil-spill cleanup project required the on-site presence of a senior member of telecommunications management. Bob Black, a veteran of nearly thirty-five years of Exxon service, was dispatched to Valdez on April 17. The management plan included a three-week rotation of Black and Dave Newman (M 1990) as alternating onsite managers of Telecommunications and Computer Services (T&CS) for the Valdez Project.

During his first tour of duty in Valdez, Black defined the T&CS organization and its relationship to overall management of the oil-spill cleanup. T&CS reported directly to Exxon's O.R. Harrison, General Manager of the project. This arrangement also was vital to the success of the telecommunications effort, enabling problems to be quickly resolved at the critical management level.

Another of Black's initiatives was the acquisition of human resources. Technicians were recruited from a variety of sources, including companies which regularly provide such services to Exxon. Engineering resources were obtained from Exxon's internal staff and from outside contractors. Exxon uses a number of outside sources for project management and engineering services; these were quickly brought into play. The author was involved in planning, engineering and management support from late April through the end of the 1989 operations, and subsequently in 1990 and 1991.

SUPPLIERS

The superb support provided to Exxon by its suppliers was sometimes little short of amazing. For example, a supplier of 450 MHz handheld radios was asked late on a Friday to ship 350 units. The manufacturer mobilized an ad hoc workforce during the weekend, assembled and tested the radios, and had them on an Alaska-bound aircraft by Sunday afternoon. One of Exxon's suppliers of combiners and duplexers consistently responded with overtime work schedules to supply the more than 75 cavity packages required by the project. At one point early in the project, Exxon had virtually bought the entire national supply of VHF marine antennas in the United States. Exxon people resorted to calling small dealers who might have one or two antennas in stock which could be shipped to Alaska. A major radio supplier called Exxon at one point and poignantly asked *"Please don't order any more radios for at least ten days!"*

LOGISTICS

This is a brief description of some of the logistics challenges, reflected by the kinds and quantities of equipment used in the project:

* >4500 radios all types, of which there were ≈ 2500 UHF portables, 600 mobiles, 1200 marine portable radios, 60 repeaters (3243 radios were purchased from one manufacturer)
* >75 duplexers
* 30 HF radios -- backup in many cases
* 5 PBXs
* 27 key systems
* 150+ FAX machines
* >450 PCs
* 4 microwave links
* IMTS package with three nodes, 22 channels and over 30 remote terminals

Exxon Telecommunications was uniquely positioned for just such an emergency. The Division functions within Exxon as a largely self-contained entity with worldwide responsibilities, purchasing its own equipment and processing its own invoices. This enabled the unprecedented volumes of materials and equipment to be procured in unbelievably short intervals. One of the keys to this critical success is Leon A. Spencer (M 1987)). A veteran of 15 years with Exxon Telecommunications, Lee is a repository of literally encyclopedic knowledge of equipment, technology and resources. From their offices in Houston, Lee and Jim Mancuso performed daily magic in locating and expediting the shipment of the equipment needed in Alaska. Mancuso later went to Valdez where he eventually "turned out the lights" for telecommunications, in October.

The logistics system was relatively simple. Each evening, Black or Newman convened a meeting of key staff in Valdez. Often gulping dinner simultaneously, engineers, technicians and supervisors decided what was needed next. A nightly FAX message was prepared and sent to Houston, describing the types and quantities of equipment and material needed. At one meeting, over $350,000 of material was ordered in less than two hours.

Spencer and Mancuso were able to begin working East Coast sources as soon as they arrived at the office in Houston. Over and over, by the end of a day they had located, ordered and coordinated air shipment of much of the material on the nightly FAX communique. Quantities of 200-300 handheld radios, 100 or more mobiles and antennas, tens of FAX machines, batteries, accessories, repeaters, cavities and the like appeared, seemingly like magic, in Valdez within mere days from the FAX requests. Every operation of this type has its unsung heroes -- Lee Spencer (KB5OG) and Jim Mancuso exquisitely filled that role throughout the summer.

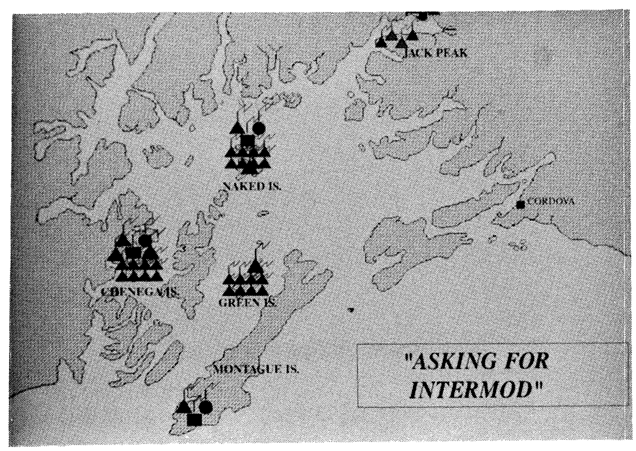
Exxon's Lillian Canouet became the guardian of the logistical paperwork. Lillian kept track of the invoices and shipping dates for all of the telecommunications materials, modes of shipment, estimated arrival dates and the like. Her daily FAX messages enabled the Valdez team to develop its plans around the expected arrival of materials. It was not unusual for equipment to be requested by Valdez, located and purchased by Houston, shipped by a vendor, delivered to Valdez and installed in less than a week.

With all of the many parcels of equipment arriving in Anchorage, another tracking and expediting mechanism was required. Virtually all telecommunications material shipped to Alaska went first to Anchorage via air freight. Exxon's agent and long-time provider of telecommunications support, North Slope Telecom, Inc., (NSTI) received and logged everything. Since material sometimes was destined for Seward, Homer or Kodiak, as well as Valdez, NSTI employees separated materials appropriately and shipped them to their appropriate destinations.

The logistical chain -- simple in concept -- was more complex in operation than one might expect. Without the smooth functioning of the system, however, many things that went right would inevitably have gone wrong.

RADIO FREQUENCIES AND LICENSES

The wide range and complexity of radio systems required an unusually large number of discrete radio frequencies -- over 200 of them. Coordinated by Exxon's June Riddick, forty Special Temporary Authorizations (STA) were obtained from the FCC -- each within 24 hours of the request. The FCC could hardly have been more supportive. STAs were obtained for HF marine, VHF aeronautical, VHF marine, UHF business, 450 MHz IMTS, satellite and microwave frequencies. During one of the evening planning sessions, discussion centered on how many 450 MHz frequencies would eventually be needed. Someone suggested, a bit facetiously perhaps, that Exxon should simply apply for the entire 450 MHz Business Radio Service band. The request was made -- and promptly granted. Later, when it became apparent that telephone service exceeding the INMARSAT system's capabilities was needed, the FCC authorized Exxon to implement 22 IMTS channels via three hubs located in Prince William Sound --on Common Carrier frequencies.



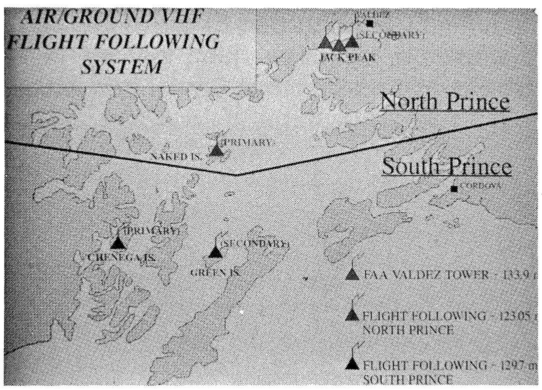
Prince William Sound
UHF Repeaters & IMTS Systems

It has been said -- accurately -- that these unique authorizations could not have been granted anywhere else in the United States. What made the various systems necessary -- a virtual absence of telecommunications facilities in Prince William Sound -- also made the grants possible. Essentially, there were no other users to worry about.

Since the cleanup operation often resembled a military one, organizations and logistics followed suit. Radio networks were established to support the organizational structure along group and sub-group lines. This resulted in a complex UHF frequency plan, a plan which seemed to be constantly changing to meet shifting requirements. The final Frequency Plan exceeded twenty typewritten pages which defined nearly fifty different channel plans for the multi-channel radios used.

RADIO SYSTEMS

Due to the virtual lack of existing facilities in the area, Exxon was faced with providing a complete communications infrastructure in an extremely short time. In addition to the wide-area UHF repeater system, flight-following radio systems were installed for use by the FAA and Exxon in managing the fleet of aircraft and its operations. Prince William Sound was divided into North Prince and South Prince, with separate aeronautical frequencies provided for each section. Additionally, air-to-ground facilities were established in Valdez, Seward and Homer on the Kenai Peninsula, and on Kodiak Island and its surrounding waters.

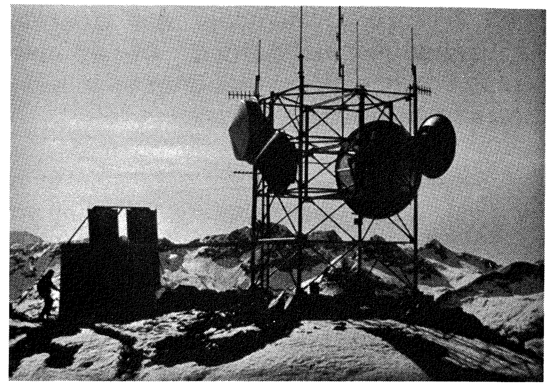


Prince William Sound

Initial control links for mountain top repeaters and air-to-ground stations were provided by 450 MHz links. Exxon and the State of Alaska Communications Division jointly expanded an existing State microwave link from Valdez into PWS via Jack Peak to provide additional control links. It subsequently became necessary for Exxon to construct a separate 2 GHz microwave system from Valdez to Jack Peak, Naked Island and Chenega Island to provide radio control and telephone channels, and to reduce the potential effects of catastrophic failure. This system was conceived, designed, purchased and installed in approximately two weeks -- considerably faster than a typical microwave system.

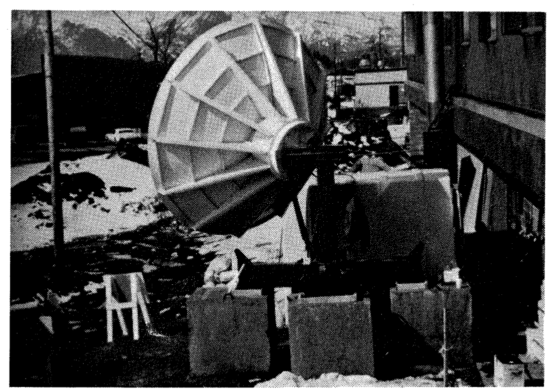
SATELLITE COMMUNICATIONS FACILITIES

Small Ku-band satellite terminals were installed on Knight Island and Perl Island during part of the summer. These also provided control channels for HF, marine, UHF repeater and



Jack Peak

air-to-ground radios serving critical areas. Later, one of the Ku-band stations was installed on Green Island to provide dial tone to the IMTS terminal installed there late in the summer. In addition, a semi-permanent satellite link, using a 12-foot dish in Valdez, was established to provide a broadband link to Houston for telephone and data circuits for the operation. INMARSAT service was used extensively as described below.



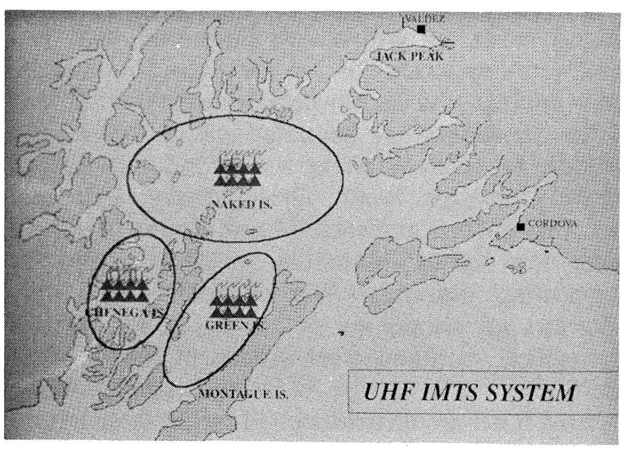
Exxon Command Center - Valdez
12-foot Satellite Dish

TELEPHONE SERVICE ON THE WATER

In approximately six weeks, Exxon created sleeping facilities for 5000 people "on the water" aboard vessels of all kinds and sizes. In addition to leasing cruise ships for the purpose, Exxon also leased for short periods U.S. Navy vessels for service as floating command centers and hotels. Each of these major vessels required the installation (and subsequent removal) of an INMARSAT terminal and stabilizing gyroscope, VHF marine and UHF mobile radios, air-to-ground radios on vessels with helipads, and FAX machines.

The sixteen Exxon-owned L-band INMARSAT terminals immediately swamped COMSAT's Santa Paula West Coast INMARSAT terminal with traffic. It became obvious that additional capacity was needed. COMSAT managed to reposition a satellite to serve a small, temporary earth station set up by Exxon's contractor at Santa Paula. Using this link, four private-line satellite telephone circuits were established to Valdez to serve heavy-traffic Exxon INMARSAT terminals. With INMARSAT costs running $10 a minute, monthly bills of over $500,000 were not unusual.

Facsimile (FAX) was one of the genuine surprises of the entire operation. The demand for FAX machines seemed insatiable, with over 150 units eventually deployed. The popularity of FAX and Exxon's ability to provide service also presented a small dilemma. All too often, vessels within sight of each other were detected exchanging FAX messages via INMARSAT -- at a cost of $20 a minute -- when there were small courier vessels idling alongside!



UHF IMTS System

Naked Island

As the shipboard telephone traffic exceeded the capacity of the satellite systems, Exxon explored alternatives for expanding telephone capacity in PWS. One of the more unique ideas was to use a tethered blimp as a platform for a radio system supporting IMTS equipment. Brushed aside by some as impractical, the idea survived several days of planning before the coverage limitations created by steep mountains and shading of work areas killed it. The problem was solved by installing one IMTS terminal on Naked Island, another on Chenega Island, and eventually a small terminal on Green Island. Multiple sites were needed for the same reason that the blimp idea failed -- shading and coverage limitations. The IMTS facilities effectively solved the problem of providing telephone service to vessels. In another probable first, the Green Island IMTS terminal was linked to Valdez via satellite -- an interesting system topology for IMTS service.

HF RADIO

Since HF radio is widely used in the Alaska fishing industry, many of the vessels leased by Exxon for the project were equipped to operate on marine HF frequencies. This became one of the tools used, especially in the early phases of the project and in the Gulf of Alaska waters which the wide-area UHF systems did not completely cover. As the VHF and UHF systems were deployed, HF radio became primarily a backup mode of communications due to poor summertime propagation and the activity of the fishing fleets and normal users.

RADIOS USED

In the early days of the project, the need for a large number of handheld radios was recognized. Early estimates of "several hundred" units were a bit low, since the ultimate number reached nearly *3500*!

Two basic kinds of portables were needed -- VHF marine and UHF. Several kinds of marine radios were ultimately used as field experience indicated those which could not survive the unusual operating conditions. The basic UHF handheld issued was a six-channel unit, most of them a single model. A few other types were used for special requirements or when the "standard" radio was not available. The handhelds delivered 2 to 4 watts, which proved to be adequate for most applications.

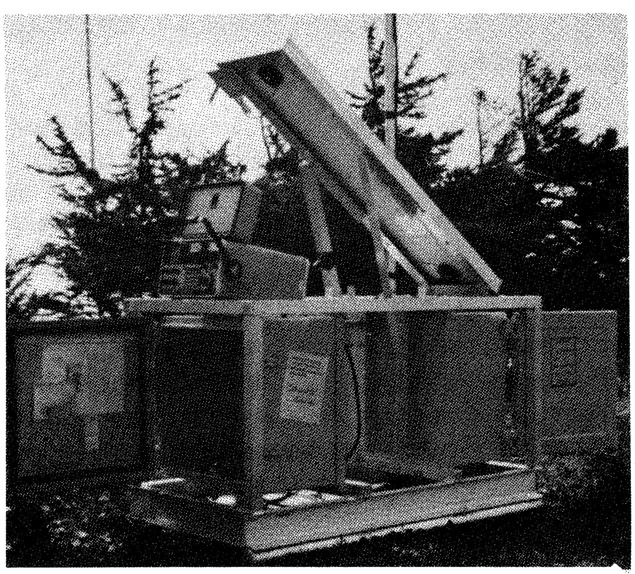
The 450 MHz radios were all computer programmable for assigning frequencies, tone-squelch frequencies, etc.

Small, compact mobile radios were used. The majority of the mobile units were installed aboard vessels and powered from either vessel battery-power or auxiliary-power units installed with the mobiles. These radios were also computer programmable.

HF radios were conventional multichannel marine units, 12vdc-powered, delivering 100-watts. Some were equipped with external, automatic antenna tuners to accommodate needs for occasionally changing frequency. Onshore, these units were frequently placed on a mountain top and remotely controlled from a Command Center in town.

GAP-FILLER REPEATERS

The mountainous terrain and distances in operational areas of the cleanup presented challenging radio coverage problems. The most effective solution became the ubiquitous *gap-filler* repeater. These gap-filler repeaters were originally designed by Exxon's Lee Spencer, and Lockard & White engineers in concert with IWL Communications, the fabricators, for use in the mountainous desert of North Yemen.

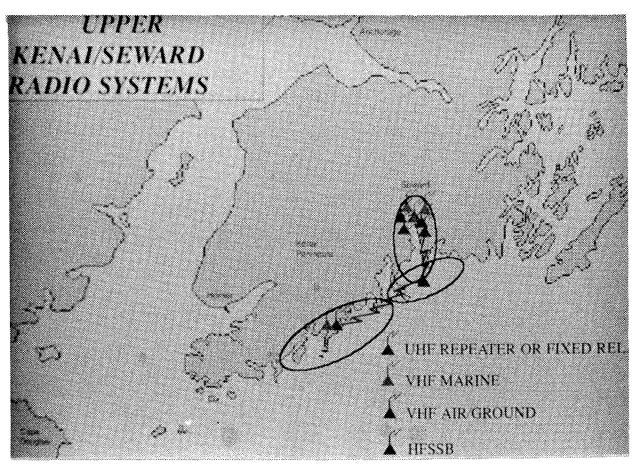


Gap-Filler Repeater

Constructed with lightweight aluminum frames and weatherproof containers for batteries and radios (two handhelds connected back-to-back), these solar-powered packages can be easily deployed by helicopter. On occasions, these units were flown into sites where the helicopters could not even land, but merely hovered near the ground. Engineers and technicians unloaded the gap-fillers, set up the antennas, oriented the solar panels and weighted the bases with sandbags to resist stiff mountain winds. The gap-fillers were configured in different ways depending upon requirements. One popular arrangement provided crossband operation between ordinary 450 MHz frequencies and VHF Marine Radio channels. For merely extending the reach of 450 MHz repeaters, gap-fillers with back-to-back 450 MHz radios were frequently used. The gap-filler packages were absolutely vital to the success of the operation.

GULF OF ALASKA SYSTEMS

When the *EXXON VALDEZ* grounded on Bligh Reef, few people suspected that splotches of leaking crude oil would find their way over five hundred miles to Chignik on the Alaska Peninsula. Unfortunately, the southwesterly movement of free oil far exceeded the expectations of many. In addition to contaminating the rugged shores of Knight, Chenega, Smith, Green, Perry, Latouche and other islands in Prince William Sound, it moved along the Kenai Peninsula to Kodiak and its neighboring islands. The oil spill left its ugly footprints on shorelines of the Kenai and Alaska Peninsulas, contaminated waters of the Shelikof Strait, and found its way as far as Chignik. Along the way, it left ample evidence of its perverse nature as it seemingly avoided entire stretches of beaches and fouled others nearby.



Gulf of Alaska Radio Systems

As the oil moved along the Kenai Peninsula, Exxon established field offices at Seward and Homer. Exxon technicians based in these offices helped Valdez plan the deployment of repeaters and base stations at strategic locations on the Kenai coast. Due to the rugged terrain, it became necessary to rely heavily on the gap-filler packages for such remote sites as McArthur Point, Gore Point, and others. Temporary stations installed on Rugged Island, at the mouth of Resurrection Bay, provided the links back to the Seward office from the coastline repeaters.

At Homer, a substantial radio site was established on Diamond Ridge overlooking the town and Kachemak Bay. UHF links were established to outlying stations and repeaters in the Chugiak Islands, Barren Islands, and others.

KODIAK ISLAND

Few people expected that leaking crude oil would reach the shores of Kodiak Island. The 350 miles of water and land between Kodiak and Bligh Reef seemed to offer a more than adequate buffer. In this expectation, the small contingent of cleanup people initially assigned to Kodiak required rather modest telecommunications support. Before the oil spill cleanup operation was phased down in September, these simple facilities had mushroomed into a unique, complex telecommunications "blanket" covering most of Kodiak, its neighboring islands, surrounding waters and parts of the Alaska Peninsula.

Kodiak is a rugged, mountainous island lying south of Cook Inlet and adjacent to the head of the Alaska Peninsula. The island, 100 miles long and 60 miles wide, consists mostly of mountains and narrow shorelines punctuated by numerous inlets and bays. Snow-capped mountains rise to 4500 feet and are creased by deep valleys. Through the valleys flow streams which feed the bays and inlets, and provide homes for spawning salmon. Much of the island is occupied by the Kodiak National Wildlife Refuge, home of the famous Kodiak bear. One can rarely fly Kodiak skies without spotting bald eagles, bears and other fascinating forms of wildlife. Viewed from a helicopter flying low over the Karluk river, a massive salmon run is a truly awe-inspiring sight.

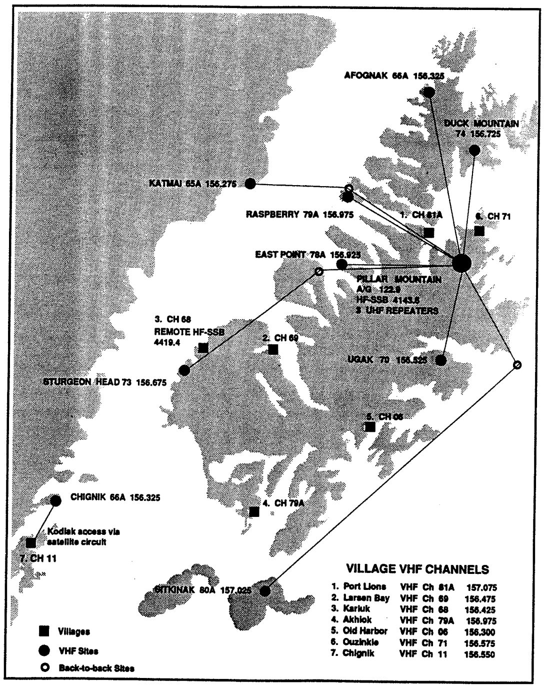
To the north of Kodiak lie Raspberry, Afognak, Shuyak and several lesser mountainous islands, bereft of people except for a small handful of tiny fishing villages. To the southwest lie the less rugged Trinity Islands, i.e., Sitkinak, Tugidak and Sitkalidak, similarly remote and noted mainly for their scenic beauty and a Coast Guard communications site on Sitkinak.

The city of Kodiak, perched precariously on the northeast corner of the island, is one of the largest fishing ports in the nation. With a population of around 6000, Kodiak has more people than the remaining population of the island. Sprinkled along the shores of the island and its bays are 20 to 30 small fishing villages, some of which are homes to small canneries like the one at Larsen Bay. "Cannery row" in Kodiak, however, is where most of the annual catch is processed for world markets. The villages range in population from less than 100 people to larger towns of over 300 or so.

Across the Shelikof Strait, 20 to 30 miles wide, lies the Alaska Peninsula reaching Westward toward the Aleutian Islands chain. At times, the often peaceful appearing strait harbors some of the worst weather and seas of American waters -- and some of its best fishing. Overlooking the strait on the mainland lie national parks, wildlife refuges, mountains (up to 10,000 feet high) of the Aleutian Range, and the Katmai volcano. Down the peninsula, 120 miles from the southwest corner of Kodiak Island, is Chignik Bay and the village of Chignik (pop.179).

Oiling of the beaches in the Kodiak area was erratic. Long stretches of beach had no oil; various areas had spotting and tar balls; still others were victims of blobs of chocolate-brown mousse, oil-saturated kelp, and free oil which simply washed up with the tide -- and stayed.

Early indications hinted that Kodiak might escape with a relatively limited cleanup effort. When the operation on Kodiak began, local VHF marine and HF-SSB marine radios provided the primary means of communications. Local fishing boats and their crews were pressed into service to begin removing oil, mousse, kelp, oily rocks, wildlife carcasses and the like from the beaches. The wife of a Kodiak fisherman used her marine HF-SSB base station at her home in the town of Kodiak to serve as a clearing house of information and provide coordination communications with the boats around the islands. In the beginning, this was the extent of cleanup communications in the entire Kodiak Island area.



Kodiak Island Radio System

It quickly became clear that better communication was needed between the Kodiak Command Center and fishing vessels offshore around the islands and up in the bays cut deeply into the mountainous shorelines. VHF marine radios are commonly found on the fishing vessels, but the rugged terrain made VHF communications even from the top of Pillar Mountain impossible in many locations.

A combination of radio equipment and techniques enabled communications to reach, eventually, into virtually every nook and cranny of the Kodiak area shorelines. From remotely-controlled UHF stations on Pillar Mountain, special cross-band gap-filler repeaters translated the mountain-top UHF signals to the VHF marine band and vice-versa. Even after the success of these innovations, critical spots remained where communication was needed. The solution to these problems was the use of both translator-repeaters and conventional repeaters, all linked back to Pillar Mountain and then to the Kodiak Command Center. Using combinations of these various systems, plus HF-SSB stations deployed in major villages, Kodiak and its surrounding islands became completely "wired" for radio communications. An additional double-hop arrangement across the Shelikof Strait linked Kodiak with vessels along the shoreline of the Katmai National Park near Cape Liktugitak. These innovative installations were the work of three young Exxon engineers, W.C. "Kip" Gary (WD5DLZ), John Brogan and Frank Shearer, and North Slope Telecom's Tom Aho. Tony Smaker (KL7AF), long-time resident of Kodiak and a local electronics entrepreneur, provided valuable support throughout the cleanup operation.

The control stations on Pillar Mountain were connected to various agencies in Kodiak and the Kodiak Command Center via a complex web of wireline and carrier facilities provided by Telephone Utilities of the Northland (TUN). TUN also provided the active bridges required to interconnect all of the control lines and the various locations. This enabled the Kodiak Command Center and the agencies to talk directly to fishing vessels along the shores of the islands and inland waterways, and to the aircraft supporting their operations. The same techniques were also applied to similar problems along the Kenai Peninsula in the Homer and Seward areas.

TELEPHONE SYSTEMS

Radio provided vital communications in many phases of the cleanup operation. However, as discussed earlier, telephone systems were hastily installed in administrative headquarters, logistics centers, field offices and the like. Exxon planned and provided all of the telephone facilities for cleanup agencies and contractors, in addition to its own offices. These facilities ranged from single-line installations to key systems in small offices and wildlife treatment centers to state-of-the-art digital switching systems of various sizes. The switch in the Valdez Command Center was replaced twice -- once only days after the first system was installed. Such was the pace of many activities in the early days of the cleanup.

Alaska, with its vast area and modest population, is a natural environment for satellite communications systems. The state's well-developed Satcom systems provided trunks and tielines interconnecting Exxon's various offices and work centers. The sheer volume of traffic, however, forced Exxon to install its own satellite terminal in Valdez to provide telephone and data circuits connecting to Exxon's networks in Houston and the lower-48 states.

The support of local telephone companies in Alaska -- Copper Valley Telephone Cooperative, Anchorage Telephone Utilities, and Telephone Utilities of the Northland -- was outstanding throughout the cleanup operation.

COMPUTER SERVICES

The first people to arrive in Valdez brought their own computers with them to begin planning and coordinating the cleanup work. As the workforce grew, the demand for computer resources presented a challenge in itself. Equipment was purchased locally, shipped from Houston and obtained from other diverse sources. Recognizing the potential problems associated with this growth, Exxon's telecommunications group took over management of computer services. An extensive network of data circuits, controllers and LANs evolved over the months of the operation. Laptop and desktop PCs, eventually over 450, even found their way onto the larger vessels alongside the telephones, radios and FAX machines. Many of the PCs were linked to Houston via the satellite facilities for office-automation applications and services.

PEOPLE

Throughout the summer, Exxon employees and contractors came and went -- in all areas of the operation. The telecommunications function benefited from the relative continuity of being managed alternately by Bob Black and Dave Newman (N5DN). Projects like this, however, must have other continuity factors to be successful. Two Alaskans provided the glue that often seemed to hold it all together for most of the Summer.

Bob Hansen, owner of a radio and electronics business in Anchorage, left the business in the hands of his staff, to spend most of the summer in Valdez. Bob managed the Exxon Radio Shop which was established in Valdez. Bob's major role was coordinating the installation work in the field. During the Summer, he managed an ever changing array of bench and field technicians in the frenetic work.

Debbie Webster served as the maestro of the telecommunications office in Valdez. Employed as a contract secretary, she quickly became de facto office manager. It takes a very special person to be able to work long days, week after week, to constantly answer the telephones of several engineers and managers, tend the FAX machine, sort out questions and decide who can answer them, and keep track of the housing accommodations of an ever-changing, mobile group of telecommunications people. Debbie also provided the cheerful humor often needed in a severely overcrowded office. Mother of two youngsters, Debbie occasionally took a day off -- days which are vividly remembered as those which usually did not go as well as they might had Debbie been there.

As counterpoint, none of the telecommunications group will ever forget *The General* -- Exxon's Everett Bradley. Owner of a great, dry wit, "General Bradley" not only performed his work in an exemplary manner -- he managed to keep everyone laughing during what was very serious business.

The Telecommunications and Computer Services group used over 230 people during the Summer -- 60 Exxon employees and ~170 contractors. Rarely were there more than 35 working at a given time. These people came from all over the United States. Many came with experience of working in numerous foreign countries, often under demanding circumstances. Others were recruited in Alaska where it seemed everyone wanted to participate.

Many had never met before; others had crossed paths time and again in various parts of the world. New friendships were formed, old ones renewed. There was clearly a spirit of camaraderie, fed by the drive to accomplish impossible goals in short periods of time. Some people served only one tour in Alaska; others came back again and again. Virtually all agreed that this was a unique experience, the kind that perhaps comes but once in a lifetime. In a rare coincidence, a father (the author) had the unique opportunity to work with and rewardingly observe the performance of his own son in the telecommunications project.

Far too numerous to tell here, the inevitable "war stories" arose. Some will be told and retold for years at industry conferences and chance meetings. Some are outlandishly funny, others poignant. Many reflect the very best in people working under stress -- and succeeding.

CONCLUSION

Approximately 11,000 people were eventually involved in the 1989 cleanup activities, with 235 on the first day. There were over 800 by the end of the first week! To support this army of workers, Exxon bought or leased 1500 vessels and 84 aircraft. Exxon also acquired enough floating boom to encircle Manhattan Island three times!

The object was to clean up as much of the 258,000 barrels of spilled oil as possible. The oil threatened or damaged over 3700 miles of Prince William Sound's shoreline -- 100 miles of very badly oiled, 150 miles with medium impact and 250 miles lightly impacted. Outside of the Sound, there were 700 miles of affected shoreline. The vast telecommunications effort was devoted entirely to the support of this incredible challenge.

All of the radio and telephone systems used in the Valdez Project were designed, fabricated and installed in extremely short periods of time. In April, no one would have dared to forecast that it was remotely possible. But it was done. It was done by an unusually talented, dedicated group of engineers and technicians, drawn from a wide range of sources, often working eighteen hours a day.

Those of us engaged in telecommunications choose this line of work for various reasons. Perhaps the most compelling reasons are that we enjoy electronics and the art of communicating, and are challenged by the varied requirements of the companies and operations which we support. Another frequently-mentioned reason is that the work often takes us into interesting parts of the world. There it becomes even more challenging because of different cultures, geography, topography and, certainly in the Alaska work, weather conditions and the intense pressure to get impossible things done quickly. ***The Summer That Never Was*** included all of these factors -- and more. This telecommunications project was an incomparable success because its people were *determined* to make it so!

AUTHOR'S NOTE --

I first arrived in Valdez in the evening of April 29. Perhaps a harbinger of countless days and events to come, the weather was chilly and foggy, with intermittent drizzle falling on snow-capped mountains. It was a pattern typical of Valdez weather -- something we were to experience and wrestle with throughout the summer.

Months later when I left Valdez on October 11, morning awoke with bright stars in a clear, dark sky. As the sun emerged, it glinted from new snow covering the tops of towering mountains surrounding Valdez, sparkling brightly against a gorgeous sunrise and bright blue skies.

This story is dedicated to those who devoted a piece of their lives to the work in Alaska. We fervently hope that beautiful October morning is a harbinger of better times to come in The Great Land.

- W.R. Gary, P.E., K8CSG

William R. Gary (M 1982,F 1984) has devoted over forty years to the art and science of telecommunications. He received his Bachelor of Electrical Engineering degree from the University of Louisville (Kentucky) Speed Scientific School in 1953. Following graduation, he devoted 33 years to telecommunications engineering and management in the domestic natural gas and international oil industries. During those years, he also served two tours of active duty with the U.S. Army, retiring from the Army reserve as a Major (Signal Corps) after 21 years of service. He is a Fellow of The Radio Club of America, a Past President and Honorary Member of the Energy Telecommunications & Electrical Association (ENTELEC), a Senior Member of the IEEE, a Registered Professional Engineer, and an Honorary Member of the International Communications Association (ICA). Radio communications is also his hobby; as W4URF and K8CSG, he has long been an avid DXer and is a member of the ARRL DXCC Honor Roll. Following more than four months of consulting service to Exxon in Alaska during 1989, he returned to Alaska during 1990 and 1991 to provide additional support.

Mr. Gary is a Vice President and Partner of the telecommunication engineering firm of Lockard & White, Inc., and is Executive Editor of **ENTELEC News.** Natives of Kentucky, he and his wife Petey live in Houston, Texas. Their children, all grown, reside in Longview, TX, Kingwood, TX, Tulsa, OK, and Curacao, Dutch West Indies.

PROTECTING YOUR INTELLECTUAL PROPERTIES

by **Thomas R. Morrison, Esq., (M)**
Morrison Law Firm, Mt. Vernon, NY

RCA member Tom Morrison, former W2IST, is a patent attorney in Mount Vernon New York. His firm, Morrison Law Firm, publishes a monthly newsletter covering items of interest about the legal protection of ideas. So many RCA members are involved in new product development and the management of high-technology business that we have asked Tom to give us excerpts from his newsletters for publication in our Proceedings *from time to time.*

Thomas R. Morrison, Esq.

Intellectual property (a stuffy way of saying patents, trademarks and copyrights) is protected by law in the U.S. and in most other countries.

Let's look at a copyright. A copyright protects "original works of authorship" including literary, dramatic, musical and artistic. The protection covers published and unpublished works, and gives the owner the exclusive right to do and authorize others to do the following:

- reproduce it;
- prepare derivative works based upon it;
- distribute copies or phonorecords of it (this includes giving it away); and
- perform or display it.

While infringing a copyright is illegal -- there are exceptions. "Fair use" permits copying parts of work for criticism, news, etc. A "compulsory license" permits limited use. (You have to pay a fee, and obey certain rules.)

You can't protect some things such as works that are not fixed in a tangible form, such as: a dance that is not notated or recorded, or an improvised speech or performance that is not written or recorded. A computer ROM or PROM may qualify as a literary work.

It takes very little originality for a written work to be entitled to copyright protection. But there is a limit. A court has now ruled that the arrangement of names, addresses and numbers in a telephone book cannot be protected from copying.

You also can't protect titles, names, short phrases and slogans, familiar symbols or designs, mere variations of typographic ornamentation, lettering, or coloring, mere listing of ingredients or contents.

NOTES ON INNOVATION

SUE IF YOU WANT TO, BUT NEVER THREATEN

To take a case to court, there must be an "actual controversy". That means, an actual conflict between the parties. If you own a patent, you can sue an infringer. But, if you threaten an infringer with an infringement action, the infringer can sue you in federal court, asking the court to declare the patent invalid, or that you do not infringe.

You can avoid giving the infringer the option of filing a declaratory judgment action. If you do not threaten, he cannot sue. So it is a good rule to never threaten an infringement suit. You can sue when you are ready, but do not threaten beforehand.

There is good reason to avoid giving an infringer an excuse to file a "declaratory judgment" action. For one thing, you avoid letting the infringer choose the timing of a court action. For another thing, you avoid letting the infringer choose the court in which the action will be held. In a country as large as the United States, your expenses in a court action can be very different if the court is 3,000 miles away rather than in your own city.

WHAT TO DO WITH A PATENT INFRINGEMENT LETTER

Suppose, one morning, your mail contains a letter charging you with infringement of a U.S. patent. What do you do? The following are steps you should follow:

Acknowledge the letter immediately. Tell the writer of the letter that you will respond soon. This will prevent rash action (it may avoid him filing a lawsuit) and is evidence of good faith on your part.

Have your patent counsel begin a study of the patent to see whether the claim of infringement is valid.

Have engineering and marketing look for invalidating prior art (publications or patents published more than one year prior to filing date of the infringed patent.)

Have engineering consider "design-around". Sometimes, a simple design change avoids infringement. If you make the change, the patent owner can then sue only for past infringement.

Appoint one in-house person to coordinate the investigation. That gives outside and in-house people one contact point.

Find out something about the patent owner: Does he sue? Is he resolute? Can he fund a lawsuit? Answers to these questions show how seriously to treat the notice of infringement.

From the very beginning, consider settlement. At every stage, consider settlement. Defending a lawsuit is expensive, and its outcome is always uncertain. The only ones who seem to benefit are the lawyers.

UNPATENTABLE DESIGNS GET PERPETUAL PATENT-LIKE PROTECTION UNDER TRADEMARK LAW

You have a successful product on the market. Somebody copies it. You can stop them.

Court decisions now hold that a unique product design (a product's "trade dress") can be protected from copying. This is true, even if the product cannot be patented, or registered as a trademark.

This is even better than patent protection. It never expires. It lasts as long as you produce the product. A utility patent expires after 17 years.

The legal theory comes from trademark law. The thinking goes that, a product with a distinctive appearance gives the appearance "secondary meaning". In trademark parlance, something has secondary meaning if the public associates the appearance of the product with a particular source. Allowing a second party to make a similar product could lead to confusion or mistake.

You can protect your unique product (particularly in California and New York courts). But if you see a unique product, copying it could bring you trouble.

NEW TRADEMARK LAW PERMITS FILING WITH "INTENTION TO USE"

You can now apply to register a trademark based on your intention to use it. This is new, and a big benefit.

Formerly, you had to use a trademark before you could register it. Until use, you could not develop legal rights in it. Large investments went down the tube when a trademark later was found to be unavailable.

Now, you apply for registration when you decide you intend to use a trademark. Your application triggers the Trademark Office into deciding whether the mark is registrable. You obtain priority rights from the date of application. If the Trademark Office turns you down, you have lost very little.

This lets you plan your future trademarks with some certainty.

You still must use the mark before registration is completed. Use must be bona fide commercial use -- token use is not enough. That is, you must ship commercial quantities of the goods bearing the mark. How much is commercial quantities? That depends on the goods themselves.

On deciding that a trademark is registrable, the Trademark Office holds up registration until it gets an affidavit of actual use. Proof of actual use is due within six months after a notice of allowance. The time for filing proof of use can be extended for additional periods of six months, up to a total of 24 months, at a cost of $100 per extension.

DESIGN PATENTS ARE EXCLUDE FROM "EXPERIMENTAL USE" EXCEPTION

A statutory bar prevents you from applying for a patent.

Ordinarily, you are barred from patenting a product that is in public use more than one year before you apply for a patent. There are some exceptions.

If the public use was required to perfect or test the product, courts have decided that this "experimental use" does not trigger the time for a statutory bar. It is crucial that the invention owner not receive any money for the goods and that the invention owner have access to data from the experimental use.

This does not apply to design patents. The embodiment, exhibition and observation of a design are the only uses possible for the subject of a design patent. Therefore, there can be no "experimental use" of a design.

FLEXIBLE U.S. PATENT PRACTICE UNKNOWN IN OTHER PLACES

You can claim anything you disclose in a U.S. patent application, even if you don't do it when filing. You can even add more disclosure and, if your application is rejected, you can force the patent office to consider new claims and arguments. This makes our patent practice fairer, and leads to better patents. Most foreign countries do not go so far.

One rule -- for this to work, some version of the original application must still be pending.

DIVIDE AND CONTINUE

DIVIDE - Suppose you claim more than one invention in a patent application. You may be forced to elect the claims describing one invention you want to pursue. You don't give up the remaining claims, though. You can file a divisional application to claim the other inventions. As long as you file the divisional application before the parent case issues, or is abandoned, it is awarded the benefit of the original filing date. You may have more than one invention left over to file in a divisional application. You can do this, and later file another divisional application, as long as any part of the original application (or any divisional application) is still pending.

CONTINUE - You file a continuation when you are not able to get what you want in a patent application. You can amend, add claims, and give new arguments. It costs a filing fee, but a continuation requires the patent office to consider our amendments and arguments.

C-I-P A continuation-in-part is a new application that contains some matter from a pending application, plus new matter. The original matter is given the benefit of its parent's filing date -- the new matter is given the benefit of its actual filing date.

STRONG PATENTS - These things give us the flexibility to gives our clients the strong patents they deserve.

COPYRIGHT ON INSTRUCTIONS KEEPS OUT GRAY GOODS

A novel approach uses a copyright on label instructions to keep out gray goods.

Gray goods are goods being imported from a foreign country that carry an authorized trademark, and that should not be imported into the United States. The law has not been kind to those trying to stop importation.

Goods were shipped from the U.S. to a foreign country, and then consigned back to the U.S. against the wishes of the manufacturer. The manufacturer filed an application for copyright registration on the instructions on the labels. A New Jersey federal court decided that permitting importation would infringe the copyright. The result -- goods are barred. A cute trick -- and it worked.

YOU CAN PROTECT YOUR TRADE SECRETS

It happens all the time. An employee quits and goes into competition. That may be OK, except he takes your customer list with him. Is this legal? No.

A court will not take away a person's right to make a living. But it won't permit theft of your property either. Your property includes the secrets you have developed to give you a business advantage. Besides customer lists, they include design data, drawings, formulas, among others.

You have to sue to correct the problem. A court may prevent the culprit from using your secrets, require return of all objects taken, and even require the bad guy to pay to advertise his evil deeds.

If you are going to do something about theft of your secrets -- don't wait. If you delay, a judge will say "You took your time, why should I rush."

Remember -- if it's not a secret, you cannot protect it. You need procedures. You must control visitors in your place (visitors passes help). Keep sensitive items in closed areas, and instruct your people in handling confidential information. A written employment agreement is a good idea.

Do these things, and you have a good chance of enforcing your rights in your trade secrets.

SERVICE MARKS FOR SERVICE BUSINESSES

A trademark has to do only with products, right? Wrong.

A service mark protects service businesses, like this law firm. The picture of our office, is a registered service mark. We always print a notice of registration (An R in a circle) alongside it? That is an international trademark notice.

Always put the registered symbol alongside your mark (product or service). It is important. If you do it, an infringer is liable for damages from the instant he infringes. If you don't, you have to give him actual notice before he begins to be liable for damages.

Using the R symbol when your mark is not registered is against federal law.

PATENTS CAN BE RE-EXAMINED

You make a product that seems to infringe somebody's patent. You can ask the Patent Office to examine the invention again, to see whether it is still patentable. This procedure costs a lot less than an infringement suit in federal court and, if the invention is unpatentable, you can't be sued.

YOU CAN AGREE TO SHARE A TRADEMARK

It happens all the time. You start selling widgets under a trademark. Then, you find another user of the same, or similar, mark on goods that are similar to yours. What do you do?

Lots of times, two users do no harm to each other. Why fight?

You agree with the other user that there is no likelihood of confusion. You both register for concurrent use of the mark. This makes a lot more business sense than having a conflict.

EMPLOYER HAS RIGHTS IN INVENTION MADE WITH HIS RESOURCES

Your employee invents a gang-busters widget. Do you have any rights to the invention?

Sometimes YES, and sometimes NO. (The lawyer's usual answer.)

A written agreement settles this problem before it begins. If you don't have one, three rules apply:

ONE - An engineer is hired to invent, and directed to invent. His inventions, in the field for which he is hired, belong to you, even with no written agreement.

TWO - An inventor who works at home, using his own time, equipment and materials, owns his invention. You get no part of it.

THREE - An inventor who uses your time, equipment and materials owes you "shop rights". You get a non-exclusive, royalty-free right to use the invention. This seems fair.

METHOD CLAIMS COVER UNPATENTABLE GOODS

Suppose you make a widget, one that everybody has made for years. Can't patent it, you say -- well, maybe you can -- in a way.

You can patent a method of doing something, like a better way to make your unpatentable widget. If anybody uses your method in the US, it infringes your patent.

But using your method patent in a foreign country doesn't infringe because the power of a US patent stops at the shoreline. Can the foreigner just ignore your patent and sell his goods here? Nope.

Congress responded to the screams of frustration, by (you guessed it) passing a law. Now, if your prosaic widget is made overseas using your US patented method, the widget infringes when it is sold or used in the United States. Pretty nifty.

COMEUPPANCE FOR REFAC

"Comeuppance" is a quaint American word that captures the feeling of what is happening. It means, receiving proper punishment for one's evil deeds. Refac is an American company that uses patents, and the US courts, like a blackmailer. Their basic tactic is to buy or license a number of patents in a technical area (e.g. liquid crystal displays). Then, they assume that anyone in that business must be an infringer. Finally, they charge everyone in the business with infringement. If they cannot get a license agreement, they sue. In some cases, they sue more than one-thousand companies at the same time.

Defending a patent infringement action costs so much that many companies decide it is cheaper to pay for a license, rather than defend the lawsuit.

U.S. courts are becoming tired of being an instrument of such blackmail. Sanctions are now being imposed on Refac for filing frivolous lawsuits. Most recently, a New York court found that Refac did an illegal thing in a lawsuit against Lotus Development Corp. Refac took a 5% interest in a patent in exchange for a promise that it would sue at least two alleged infringers. Under US law, this is a NO-NO.

PRODUCT SHAPE GETTING EVEN GREATER PROTECTION

Product shapes continue to get stronger protection. We do not have an industrial design law, but the trademark-like protection of product appearance gives more protection than industrial design protection could possibly do. The Trademark Trial and Appeal Board has now decided that the shape of the Motorola radio transceiver should be registered as a trademark. This is better than an industrial design registration -- trademarks never expire.

DO-IT-YOURSELF IN THE PATENT OFFICE:

Edison Used To Do It. Why Not You?

When Edison needed an idea for one of his products, he studied issued patents to find out what other people had done. Then, he built on and "invented around" the inventions of others on his way to 1000-plus patents of his own. Edison had the best private library of U.S. patents in the world -- you can see how extensive it was in a visit to the Edison Museum in Orange, New Jersey.

Patent attorneys do searches for $600 - $700 to tell you whether your invention has already been patented. But you can do your own patent search. It is easy. And it is FREE. Not only that, but you get much more out of a search you do yourself than one you have a professional do.

How Can You Get More?

All you get from the patent attorney is copies of patents that may kill your invention. What you don't get are ideas that may help you refine your invention, or get around the fact that somebody has already invented your baby. But when you look through 200 or 300 patents that are relevant to your invention, you will see dozens of other ways to do part of what you are trying to do. You can pick up these ideas and combine them with your own ideas and improve your own invention. Sometimes the idea you came in with is not patentable, but before you leave, you find other ideas that drive you off in a more fruitful direction.

You Don't Have Edison's Library, So How Do You Go About Doing A Search?

Many public libraries, including the New York Public Library, have bound volumes of U.S. patents in patent-number order. These are mostly worthless for doing a search.

An efficient search needs the patents organized by class and subclass so that, once you find out where your invention can be found, a short search leads you to the information you want.

The place to search is the United States Patent and Trademark Office in Crystal City, in Alexandria, Virginia. The public search room is open six days a week, 8 AM to 8 PM weekdays, and all day on Saturday. The public is welcomed.

How Do You Get There?

That is the easy part. Crystal City is just across the railroad tracks from Washington National Airport. There is a bridge over the tracks. In good weather, you walk through the airport parking lot, turn left past the old FAA buildings, over the bridge, and there you are. Crystal City is also on the Washington Metro. You can take the subway from Washington National Airport, or you can take Amtrak to the Washington station, and catch the Washington Metro there.

Then What Do You Do?

You get an ID badge from a guard at the door, and you are in. Inside, look for copies of the *Manual of Classification* chained to beat-up old writing desks. Look up your invention alphabetically, and note the class and subclass. You have to use a little imagination to find your invention -- the classification system is made up by committees of bureaucrats, and you know how screwed up they can be. If you have trouble finding your invention, ask somebody. The room is filled with professional searchers. ask any one of them -- they are almost always glad to give a newcomer a hand.

Once you have your class and subclass, you go into "the stacks". The stacks contain over 10,000,000 patent copies, arranged by class and subclass. The identifying numbers of classes and subclasses are printed on signs in the aisles. Pull out the one or two "shoes" containing copies of the patents in your class and subclass, take them to a reading desk, and start searching.

When I search, I scan the patents for those that seem to be relevant, but I don't spend the time then to do a complete analysis. Instead, I list the numbers of all patents that seem interesting. Then, when finished, I go to the order window and order copies. These are shipped in a few days. If you are in a hurry, you can make copies on a coin-operated photocopy machine.

The following is a separate story:

CONGRESS HAS THE WRONG IDEA

Congress and the President have completely missed the whole idea of the patent system.

The U.S. Constitution tells Congress to set up a patent system for the improvement of science and technology. The Constitution thinks that the idea of patents is to benefit **the public**. Congress thinks that it is to benefit **the inventor**.

So, in the interest of "cost recovery", Congress has decreed that inventors pay whopping big filing fees for a patent application, and just as whopping fees when a patent issues. To add insult, they charge whopping so-called "maintenance fees" every four years. If you do not pay the maintenance fees, the patent lapses.

The result is the death of the private inventor. Edison could not have paid these fees. He could not have been a professional inventor. Only rich corporations can pay the fees.

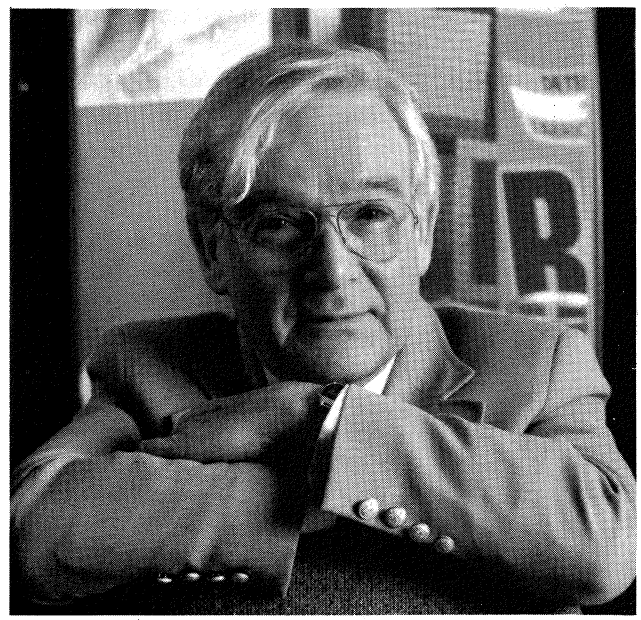
I have a proposal. The government should not charge the inventor a fee for giving us his technology. Society should pay him a bonus for his contribution to science and technology.

But then, Congress never asks my advice when it makes laws.

THE ACADEMIC INVENTOR TODAY

by **William F. Schreiber, Ph.D.**
Professor of Electrical Engineering, Emeritus
Massachusets Institute of Technology

On November 9, 1990, Columbia University through its Center for Telecommunications and Information Studies of the Graduate School of Business, presented a conference in recognition of the 100th anniversary of the birth of Edwin Howard Armstrong. Dr. Schreiber, of the MIT Research Laboratory of Electronics, was the keynote speaker at the luncheon. The title of his talk was The Role of the Academic Inventor in Today's Information Business Environment *from which this paper was prepared.*



Dr. William F. Schreiber

INTRODUCTION

I am pleased to have been asked to speak to you today about the academic inventor on this special day honoring Edwin Armstrong. Although I am no latter-day Armstrong, he is definitely one of my heroes.

Last month, I received the David Sarnoff Gold Medal from the Society of Motion Picture and Television Engineers. No one has suggested that I am following in his footsteps, but he is also one of my heroes.

It is a tragedy of modern times that these two became enemies instead of collaborators. Both were giants, although very different from each other. Our country needs both kinds, and we also need a business climate in which two such different people can work together to contribute to the welfare of the nation.

I had always wanted to build things but, after two years in industry, I concluded that I ought to be a scientist instead and so applied to many graduate departments of physics. Harvard wisely placed me in what is now the Division of Applied Science where I decided that it was, after all, intellectually respectable to design useful products and processes rather than do pure science.

After receiving the Ph.D., I spent six years in Hollywood at Technicolor Corporation, and then went to MIT from which I retired earlier this year. For 40 years' effort, all of which was spent in the broad area of image processing, I have completed three major projects; I am still working on the fourth. They all involve some advance in the state of the art, some useful products and, I like to think, some good science as well.

As I try to explain to my students, image processing is an application area. The reason the field is worth working in is that society has a need to have its images processed and is therefore willing to spend money on development and deployment.

Image processing is not an abstract science (although abstract science may be useful in getting the work done) and it is not a mere academic exercise. We try to develop devices and systems that not only exhibit some principle but that successfully perform some service that is needed and for which there is a market. I have found that academic work of this kind can make important contributions to the education of scientists and engineers. They learn to seek solutions to problems rather than finding problems that can be solved with the specialized knowledge that they may already possess.

Goal-oriented research also motivates students to seek careers on the economic front lines where our country needs them. The best people do the best work, and so I am very proud that many of my former students, as good as any in the world, are helping to design the best American products.

After Harvard, I spent six years in the "real world" at Technicolor Motion Picture Corporation, trying to develop a video bandwidth-compression system that would facilitate video tape recording, which had not yet become practical. It turned out that it was not the best approach but I did learn a lot about color that was to be useful later, and also learned something about running R&D projects.

SOME EXPERIENCES AT MIT

Naturally, I am best acquainted with the experience of the academic inventor from my own work at MIT. During that period, aside from the technology itself and the pleasures of working with such good students, I think I have learned something about the academic inventing process and the equally important, but more difficult, task of transferring its product into the marketplace. Neither is easy and neither happens by chance. I shall briefly sketch each development to see if some principles may emerge.

The Associated Press asked us to develop a new system for transmitting pictures to newspapers to replace the obsolescent mechanical drum scanners then in use, and to computerize the process of receiving, editing, and transmitting Wirephotos throughout the world.

We developed what the AP called the "Electronic Darkroom," and installed it at AP headquarters in New York about 1970. It was probably the first computer-based image processing system to go into commercial service.

We also developed the first cheap laser scanners and recorders, with which AP eventually replaced all of its facsimile equipment. The economic potential of such recorders seemed obvious, so the MIT office in Tokyo arranged for me to visit nearly all of the Japanese companies that might be interested.

One company in particular, then the largest Japanese manufacturer of plain-paper copiers, was quite intrigued by my suggestion that they use a laser scanner to write onto the drum of their copier so they could use it for computer output. I made two visits and we exchanged a number of letters. Finally, I received a letter from the managing director saying it was a great idea and they were already doing it. We had succeeded in transferring the technology, which is now commonplace, but the experience indicated that we had something to learn.

Some of my colleagues at that time were developing a reading machine for the blind. One of our AP acquaintances deeply wished to start a company, and he convinced us that the optical character recognition portion of the machine could make a good product for driving typesetting machines in the newspaper industry.

We got some money from a venture capitalist, hired a group of recent MIT graduates, made a machine and found that, indeed, there was a market. OCR became a viable technique for computer input.

Building on some of the laser scanner technology from the AP project, we then developed the first electronic process camera to prepare pictures for printing. We never made much money from this company so we sold it to AM International. It is still in existence making excellent products that sell quite well in Japan. This was a much better experience in transferring technology, and showed the very important role of students.

We then took a project from a large gravure printing company to develop a computer-based prepares system for color printing. With our students, we designed and built a complete system and installed it in a printing plant in Providence. It was intended to show not only the feasibility of making printing plates directly from computer storage, but to demonstrate that the number-crunching capability of computers could be used to enable an operator without years of experience to do successful color editing.

Here our intention was nothing less than to revolutionize color printing, long an esoteric art. We were a few years ahead of our time, and the landmark MIT patent in this field has been languishing. However, with the increasing use of color in desktop publishing, it appears that this development will now come into its own. Here, we failed completely to transfer the technology at the time, but eventually industry caught up and MIT is now likely to reap some of its benefits.

HIGH-DEFINITION TELEVISION

Since 1983, we have been working on high-definition television, funded by a consortium of American companies. Just because we had analyzed the problem of developing and installing a completely new TV system from the standpoint of benefit to the country rather than benefit an individual company or industry sector, we took a path that turned out to be much more productive than that of most other groups.[1] This approach has recently been endorsed by the FCC. Our correct analysis of the problem gave us a head start of several years so that we are now a contender in the contest being held by the FCC to select an American transmission standard. The terms of the contest require delivering a complete hardware system for testing, for which we originally had no money.

Two years ago, the Defense Advanced Research Agency (DARPA) decided to support HDTV as a means of strengthening the industrial base, particularly in visual displays and signal processing. Of the $10 million to be spent, we were awarded $1.5 million, enough to deliver a very good military system to DARPA but not enough to deliver and support a winning HDTV system for FCC competition.

Now we are trying hard to raise additional funds, and are learning more every day about what it takes to transfer this kind of technology when the industry in question would rather not have it or, if it must make the enormous changes that HDTV will require, would rather do it on its own terms. (There is some parallel here with the Armstrong-Sarnoff battle, when RCA wanted to push television rather than FM radio, not realizing that both could be profitable.)

THE ACADEMIC INVENTING PROCESS

Rapid industrial development has been a principal factor in raising the standard of living. While industrialization has always brought with it some unwanted side effects, it has generally been true that nations with a vigorous industrial sector were most secure and had the best-off populations. Much of the development, of course, is done by industry itself. However, there have always been many areas in which possible profits were too far off, or even doubtful, to entice the private sector into making the required investments. In some cases, government has provided the money and, in certain others, academia has undertaken the task.

Ideally, strong companies with a long history in specific areas find it profitable over the long run, to establish on-going research and development activities together with a cadre of well trained, well equipped, and well paid engineers and scientists. While not every project leads directly to a successful product, the new knowledge gained in the underlying science and technology makes it possible to develop lines of products that serve to strengthen the company year after year.

Examples are the development of modern solid-state electronic components at Bell Laboratories, the virtual invention of color television at the RCA Laboratories in Princeton, and the development of synthetics such as nylon at DuPont. In such a climate, it is possible to develop expertise of a special kind that simply cannot emerge from short-term undertakings. as an example of a very specialized process, I remember reading a very long article in the *Bell System Technical Journal* about soldering, indispensable even today in making printed circuit boards. The author had spent his entire professional life studying the underlying physics and the means by which soldering could be made cheap and reliable. A much larger effort, still bearing fruit, has been carried out for decades by Kodak to learn how to make better photographic film.

The ideal industrial development process does not work out for everything. Particularly in today's business climate, we find an increasing reluctance to make the investments in R&D required to lay the groundwork for products that will not produce profits within a very few years. Industry tends to give up whole areas of activity of questionable profitability even if they are vital to long-term survival.

A glaring example is the nearly complete loss of the domestic consumer-electronics industry. Electronics is well on its way to becoming the largest of all industries in its own right, and it also underlies many other industries. It supports the semiconductor industry. Consumer electronics, such as the VCR, has become the technology driver of the entire industry. Countries that give up TV receivers are likely to be inadvertently giving up industrial competitiveness itself.

In the academic environment, there is little worry about short-term profits and much more interest in the underlying science. Professors need not be concerned about protecting the profits of individual companies and are less inhibited by current views in industry. They are generally free to

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[1] Until recently, it was the virtually unanimous opinion of U.S. broadcasters that any HDTV system must be compatible with today's NTSC receivers. However, the real issue is service to those receivers during the transition period; no one has ever proposed to black them out. The use of a compatible signal format for this purpose so constrains the design of new systems that it is not possible to get good enough performance. The FCC has now ruled that the HDTV system is to be entirely independent of NTSC, and that current receivers are to be served for an interim period by simultaneously broadcasting in both old and new formats.

chose long-term goals and to stick with lines of research longer. They usually do not have to convince so many people as industrial scientists in order to get started. All they need is time, ideas, students, and money. While the last is certainly indispensable, much less of it is needed than in industry.

At a place like MIT, finding well qualified students to work on industrial projects is easy. Many of our students come to MIT already motivated to do work that produces a tangible useful result. Even in competition with our more theoretically inclined colleagues, we never fail to find excellent students to work on such projects. Many of them know that this kind of experience at the university is very good preparation for industrial employment later.

Equipment is harder to come by, but I have found that this is not an insurmountable obstacle. Combinations of gifts, deep discounts, occasional grants by MIT from its own pocket, and sponsor support usually provides most of what is really needed. We have also built, primarily by students, a considerable amount of specialized research equipment -- the experience of doing this also being a valuable educational experience.

Money is by far the hardest thing to find even though, by industrial standards, we don't need very much. For example, our HDTV project has never spent in one year as much as it costs to produce one hour of prime-time programming! For small projects, we can often bootleg the support. Faculty and students do not punch time clocks. If we don't need new equipment, and can find enough fellowship students (MIT always has a lot of NSFs and students with industrial fellowships) who are interested in doing theses in an area, quite extensive projects can be carried out. For example, this is the means by which we worked on adaptive image enhancement.

There seems to be an unlimited amount of money available from industry to support work in imaging systems. One has to work to get it, and it is harder to find money for projects that do not have an immediate market application, but the support can be found. Whenever there is an ongoing project, even if it has particular short-term goals, it is usually possible to pursue some ancillary investigations of more general interest. My own laboratory was entirely supported in this manner for more than 20 years.

Most academic research work is supported by DoD, NIH, NSF, NASA, FAA, DoT, and virtually every other federal government as well as many state government agencies. The government usually takes a longer-term view of its needs than does industry.

In these days, when many voters have come to believe that the government never does anything right, it is well to remember that much of this government support for research and development has been spectacularly successful. Without it, we would not have the strong computer, semiconductor, or aircraft industries. Radar, the atomic clock, biotechnology, and many pharmaceuticals owe their existence to government funding. On a less innovative level, massive direct government investment in industrial infrastructure, most of it which was turned over to the associated companies virtually cost-free after World War II, played a large part in the U.S. domination of the world economy for several decades thereafter.

In comparing academic with industrial research, the question often arises as to whether it is possible to find enough experience and skill in academia to produce systems that will be practical in the real world. This is rarely a question in more "scientific" areas such as gene splicing, but it always comes up in system design such as high-definition television.

What I have found is that the academician is much more likely to take a fundamental view and to ask questions such as "What is the problem?" and "What are the possible solutions?" and "What is likely to be the effect on the rest of the industry?" and "What will be the effect on other industries?" and "What will be the effect on the trade balance?" than the industrial system designer who is primarily motivated by making money for his company.

In addition, particularly at a place like MIT, each faculty member has available to him at least some advice and comment from a large group of colleagues with diversified experience and knowledge. Finally, in the course of numbers of projects that involve interaction with sponsoring companies and seeing systems go from ideas to products, one cannot help but learn a great deal about what is practical and what is not.

EXPLOITING ACADEMIC INVENTIONS

This is the hard part, and I cannot pretend that anyone has found a completely satisfactory solution. What we have found are several methods that work under particular conditions.

The most common methods of technology transfer are publications and sending out our students. Both methods tell the world what we have done, but our students also know how to do it, and are highly valued. Through all the ups and downs of our economy over the last 30 years, none of my students has ever had the slightest difficulty finding a job. Right now, our group has become the main source of Ph.D.- and MS-level graduates who have had significant experience in TV-related research. We have so many of our graduates spread around in the industry that, in the FCC competition, we are likely to win even if we lose.

A number of universities have now organized themselves to do a better job of technology transfer and, in the process, to try to increase their income from the developments in their laboratories. Such income can be used for any purpose and is therefore highly valued. In spite of raising tuition much faster than inflation (although not as fast as health care), the cost to MIT of providing education is still double the amount charged.

The economic squeeze on the research universities is getting much worse as government support in many fields is decreasing. At the same time, more money is needed for student support as tuition inflation makes it more difficult for families to bear the entire burden. We never have enough money.

It takes money and organization to turn ideas into products and to get them to the market -- and the universities have neither. The two methods that are used are licensing to existing companies, and starting new ones around the technology. At MIT, about 10% of the 70 or more licenses issued per year involve startups. In those, MIT often participates in the startup process and may even take equity in the company in lieu of royalties. It also sometimes acts as a catalyst in establishing cooperation between the startup and an existing large company.

Some MIT developments have been easy to license and are very lucrative. The invention of the magnetic core storage device and the first successful synthesis of penicillin and of vitamin A were of obvious value. It is much more difficult to interest companies in HDTV systems. Here we are dealing with today's short-term outlook and also with competition from internal developments that have in-house champions who would rather lose with their own system than win with someone else's.

Not long ago, I heard a luncheon address by an eminent TV broadcasting figure who said that there was no point in universities inventing television systems since no one would put any money into them. Perhaps he was right; time will tell.

At that time, most of the work directly funded by broadcasters was going into receiver-compatible systems that deep-enough thought would have shown can never achieve sufficiently good performance to be successful in the marketplace. Actually, broadcasters correctly concluded that HDTV was more of a threat than an opportunity and so had little interest in promoting its development. This is also a short-sighted view since the only alternative to competing with HDTV delivered by non-broadcast means such as cable and VCRs, is to go out of business.

The alternative to licensing existing companies is to start new ones. There is now a thriving venture-capital industry to provide the needed funds. Quite naturally, these groups work very hard to choose projects with a very high probability of success, and that will return their investment many times over within a few years. There has been a lot of activity in biotechnology with its promise of very high profits, and in software developments where the entry price is very low.

Venture capital plays a very important role in our economy, having been responsible for many of the rapidly growing high-tech companies such as DEC, Apple, and Intel. However, in many cases, the result is a small company that, even if highly profitable to the venture group and the principals, is too weak to stand on its own, and is soon sold. Today, the purchaser is often a Japanese or European company; this is a prime method by which a significant portion of American inventiveness moves overseas. From the standpoint of the country as a whole, it would be much more advantageous if more venture capital came from strong U.S. companies rather than from investors primarily interested in short-term profits.

Another characteristic of startups on the university scene is that they often take faculty away. While this is often good for the company, it deprives the faculty of just those members who would best serve an important sector of the student body. From this standpoint, licensing schemes that permit faculty to share royalties and thus motivate them to stay teaching are better.

A final possible source of support for technology transfer is the government itself. It is generally not available unless there is a clear military need. In addition, it contravenes current philosophy that holds that we must not have an industrial policy; the government should not pick winners and losers. Actually, of course, we now have and always have had an industrial policy. The policy consists of the sum total of government actions that affect industry, including taxes, regulation of security markets, procurement policy, science policy, and foreign policy. The current *de facto* policy is to get out of manufacturing -- which is a recipe for poverty.

Unfortunately, U.S. industry is becoming less willing and less able to provide the investment funds required to support product development more than a few years ahead. If one accepts the need to have a vigorous industrial sector to maintain our security and our standard of living, it is clear that something must change.

Either the laws and practices of the federal government that have created the short-term view must change or the government itself must become a source of needed funding. Those who dislike the second alternative ought seriously to consider the first. In the absence of any action whatsoever, we can look forward only to a continued erosion of our industrial strength and, with it, our slipping from the first rank of nations.

CONCLUSIONS

Academic inventing is very appealing to a small fraction of today's university faculty. At its best, it is an effective source of new products and processes, usually of a kind not very likely to emerge from industrial laboratories. It gives the involved faculty members the experience needed to be better mentors of their students. In addition, it is an effective means of motivating students to become proficient in design and to go to work on the economic front lines. It can also provide some additional income to the universities, thus helping them to produce highly educated and innovative scientists and engineers who are so valuable to industry. In a time of increasing competitiveness, this is a useful way to help tilt the scales back in the direction of a strong manufacturing sector which is indispensable to the nation's welfare.

More work is needed in providing the modest funds required for academic R&D that is closely related to industrial needs. Even more important is devising means to improve the transfer of the fruits of university research to industry. More consideration ought to be given to the role of government in this process, particularly as companies become less interested in long-range investment.

JULY 14, 1991

Bid for new superconductor patent denied

United Press International

The U.S. Patent Office has rejected the University of Houston's claim to have developed the first superconducting material that works at normal temperatures.

In a preliminary ruling on what is likely to prove a legal battle over commercial rights to one of the most significant scientific breakthroughs in recent years, the agency disallowed a patent claim by the university and scientist Paul Chu, The Houston Post reported.

The decision, if not reversed by a federal court of appeals, leaves at least three other parties in competition for the patent on a pure form of a compound called 1-2-3.

Normal temperature superconducting materials have been hailed as a stunning scientific and technical breakthrough. Until recently, superconductivity could only be achieved at very low temperatures, a fact that ruled out most practical applications.

But 1-2-3, and other compounds developed subsequently, open the door for the use of superconductivity in a variety of applications ranging from magnetically levitated trains to high-speed computers.

American Telephone & Telegraph Co. appears to be the lead contender for the coveted patent.

THE WIRELESS PERSONAL COMMUNICATIONS REVOLUTION

Adapted from a forthcoming article in *IEEE Communications Magazine*

by **Theodore S. Rappaport, Ph.D., N9NB (F)**
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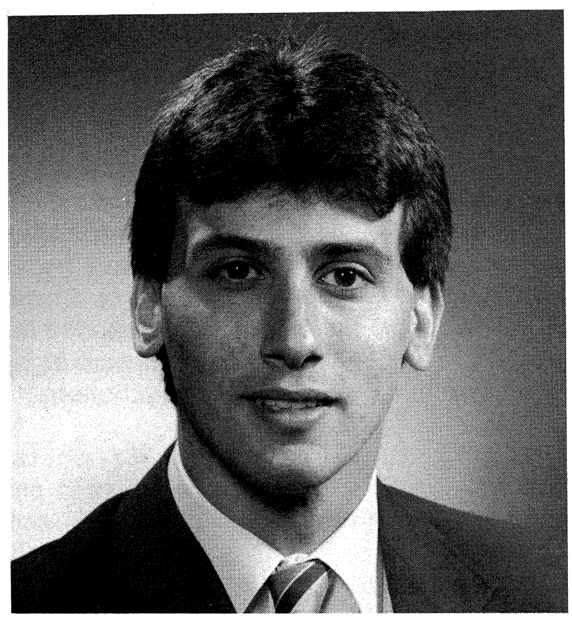
Virginia Polytechnic Institute and State University

ABSTRACT

It is quite likely that wireless communication systems will, before the end of this century, provide ubiquitous voice and data communications to a significant number of citizens in the developed nations of the world. The societal changes that will be brought about from wireless personal-communication services are going to be profound. This paper provides an overview of how rapidly the wireless communications field is growing, and highlights major activities around the world that are making wireless personal communications a reality. The paper concludes with a discussion of propagation and system design research at Virginia Tech aimed at properly designing emerging high-density personal-communications systems.



Dr. Theodore S. Rappaport

I. INTRODUCTION

Over the past three years, interest in wireless communications has been nothing less than spectacular. Cellular radio systems around the world have been enjoying 33% to 50% growth rates. Many paging services have been gaining customers at the rate of 30% or more per year and, within the last two years, there has been intense research and development aimed at commercializing new wireless communication services called Personal-Communications Networks (PCN).

The first wide-scale adoption of a wireless personal-communications system was in citizens' band (CB) radio during the late 1960s and early 1970s. While it was a victim of its own success due to an instant and uncontrolled saturation of the radio spectrum, the staggering acceptance of CB radio was a clear indication that consumers wanted an inexpensive, portable means of communicating. A more modern wireless device that has enjoyed widespread popularity is the cordless telephone. By now, it is likely that over 65 million cordless telephones will have been sold in the U.S. alone (it is estimated that almost half of the cordless phones sold have been discarded or are not used).

The convenience of portable telecommunications offered by a device as simple as a cordless phone is clearly in demand and, while the design solutions for an ubiquitous wireless communications network will be tremendously complex, all market indications show that the consumers wish to have a small device, similar in size to a cordless phone, that would allow them to make and receive phone calls wherever they are. The idea behind wireless personal-communications networks (PCN) is to make communications truly personal so than anyone can place a call to anyone else. Much like the stereo Walkman™ or the lap-top computer, PCN will permit truly ubiquitous access no matter where the location of the user is at the time of access.

These days, the terms PCN and PCS (Personal Communications Services) are often used interchangeably. PCN refers to a concept where a person can use a single communicator anywhere in a large geographic area -- perhaps someday the world. PCS refers to a service which may not embody all of the PCN concepts but is more personalized (i.e. lightweight terminal, better performance, more flexibility and user options, etc.) than a present-day cellular telephone.

SOME EXAMPLES OF DEMAND

Data that support the premise that wireless personal communications is emerging as a key, wide-sweeping technology that will dramatically impact our society can be found from numerous sources including trade journals and government agency reports throughout the world. As an example, in the U.S., there were over 5.4 million cellular telephone users as of March 1991.[18] This compares with 25,000 users in 1984, and 2.5 million users in late 1989.[1] It is clear to most industry experts that the Cellular Telephone Industry Association's (CTIA) 1989 projection of 10 million U.S. cellular users by 1995 will be exceeded in late 1992 (!), and that cellular radio carriers are enjoying exponential increases in service subscriptions.

This demand for mobile/portable telecommunications is a world-wide trend and is particularly acute in Europe. For example, cellular telephone in Sweden is already enjoying a 5.4% adult market penetration,[18] and market penetration has been increasing by more than 0.1% per month. Finland, Norway, and France have been experiencing similar growth rates. Although no spectrum has yet been allocated to emerging personal-communication services (PCS) in the United States, industry analysts are projecting annual revenues to be between $33 billion and $55 billion by the year 2000.[17]

In the United Kingdom, viewed by many as the leading country for PCS initiatives, three major companies are investing hundreds of millions of dollars to install an infrastructure that may eventually allow citizens to use small 10mW portable terminals to place and receive calls in populated areas throughout the country. At worst, PCS will provide relief for users which operate in the 900 MHz U.K. cellular markets and, at best, will offer customers the ability to use a single wireless communications unit for home, office, or automobile -- thereby obviating the need for a traditional wired phone to the home. Two of the three companies involved: Microtel, and Unitel, are actually consortia consisting of many leading telecommunications companies from all parts of the world.. The third U.K. Personal Communications Network (PCN) service supplier, Mercury, is the leading non-wire-line service provider of England's present analog cellular system. These PCN companies are expected to become some of the biggest advertisers in the U.K. throughout this decade, as they strive to pioneer and market the revolutionary PCN service.[19]

The pervasiveness of PCN will be made available by an immense infrastructure of low-power, suitcase-sized base stations that will provide portable subscribers with wireless access to the local telephone loop in populated areas. PCN hopes to be able to offer wire-line communication quality using radio as a transmission medium.

Base stations will be placed on lamp-posts, roofs and ceilings of buildings and concourses, and in other locations where people congregate. Backbone links which connect PCN base stations to other PCN base stations and to the public switched-telephone network (PSTN) will be supplied by one of two methods: either via the existing telephone wire or fiber plant, or via line-of-sight microwave links.

Of course, the wide-scale deployment of such an extensive high-grade wireless telephone system will require engineering tools and techniques and antenna designs that allow rapid and accurate propagation prediction and system design. The radio coverage of each base station will intentionally be limited by low transmitter power, so that frequencies can be reused many times within a few city blocks. Depending on regulatory decisions by the British Post Office, PCN could compete directly with wired residential telephone service in the U.K. Thus, it is conceivable that customers could bypass the telephone company and use a single PCN terminal for communications at home, office, or in the car.

In the U.S., over 50 experimental licenses have been issued within the last year to regional Bell operating companies (RBOCs), non-wireline cellular service providers, manufacturers, cable companies, and new start-up companies hoping to pioneer PCN service. To increase the competition and development time of new wireless technologies and services, the FCC has created a special incentive called the "pioneer's preference", that offers the exclusive use of reallocated radio spectrum to companies that first demonstrate new technologies or concepts for PCN or other new wireless services.

Many of the U.S. PCN experimenters have filed petitions for rulemaking at the FCC requesting new dedicated or shared spectrum for PCN services, and hope to secure an advantageous position through pioneer's preference. Industry and government experts view the demand for wireless personal communications to be so great that the FCC has indicated that underutilized portions of the radio spectrum could be subject to reallocation in order to accommodate consumer demand.

Several good tutorial articles that describe the impetus and technological challenges behind cellular radio and PCN can be found in the August and September 1990 issues of the *IEEE Communications Magazine*. The different second-generation standards that are emerging around the world are described in several invited papers in the May 1991 issue of the *IEEE Transactions on Vehicular Technology* which features digital cellular technologies. As indicated in the *VT* special issue, it is conceivable that 50 to 75 million subscribers could be using wireless systems for personal communications by the mid-1990s. This is corroborated by a recent Morgan Stanley report that predicts cellular and PCN systems will achieve at least 12% market penetration in many developed countries by the end of the century.

RECENT EVENTS IN THE WIRELESS INDUSTRY

In large U.S. markets like Los Angeles and New York, where hundreds of thousands of users can access the cellular radio spectrum, the 832 cellular analog-FM voice channels are unable to accommodate the number of users, and methods to improve capacity and cellular system design are desperately needed. For those not familiar with cellular radio, in each market (i.e. city) there are two cellular service providers: the wire-line provider, called the B channel provider; and the non-wire-line, or A channel provider. Each of the two service providers are allocated 416 duplex voice channels in a 25 MHz spectrum allocation. Each voice channel is comprised of a 30 kHz base-to-mobile link and a 30 kHz mobile-to-base link.

Over the past four years, numerous standards have been proposed for digital cellular radio communication interfaces throughout the world. Digital modulation offers improved spectral efficiency and simultaneously offers better speech intelligibility for a given carrier-to-interference ratio (C/I). More importantly, digital modulation accommodates powerful digital speech coding techniques that further reduce the spectrum occupancy of voice users. With digital transmission formats, service providers will be able to offer customers additional features such as dynamically-allocated data services, encryption, etc.

In early 1990, CTIA and the Telecommunications Industry Association (TIA) approved Interim Standard 54, which specifies a dual-mode cellular radio transceiver that uses both analog FM (the present day U.S. Advanced Mobile Phone System, or AMPS standard), and a linearized $\pi/4$ Differential Quadrature Phase Shift Keying modulation format with a Code Excited Linear Predictive (CELP) speech coder (called the U.S. Digital Cellular, or U.S.D.C. standard).[20] The U.S.D.C. standard offers roughly three times the capacity improvement over AMPS by providing 3 voice channels which are time-division multiplexed (TDMA) on a single AMPS 30 kHz FM voice link.

With further speech coding improvements, six times capacity is likely to be achieved by 1994. The dual mode equipment will allow a graceful transition from analog FM to digital cellular, since cellular operators will be able to change-out analog channels to digital channels depending on their geographical capacity demands. In this manner, customers with analog phones will be assured service in any market until some announced time in the future. A rural cellular carrier that does not suffer great capacity demand would be likely to stay with AMPS for as long as possible, probably several years (mid-1990s), while a metropolitan operator would likely change out AMPS for U.S.D.C. more rapidly (within 2 years).

It is interesting (and also a bit troubling to those who invested a great deal of time and money in developing the IS-54 Standard and who plan to abide by it) that since introduction of the U.S.D.C. Standard IS-54, many vendors have introduced their own competing standards which are incompatible with it,[20] and now virtually all major cellular radio service providers are conducting field trials to evaluate new, competing standards, so it is unclear if U.S. digital cellular radio systems will be completely compatible throughout the country, even though this was the major goal of U.S.D.C.

In contrast with U.S.D.C., the European digital cellular system (called Group Special Mobile, or GSM) was developed for a brand new spectrum allocation in the 900 MHz band. That is to say, GSM was developed to ensure that a single access and equipment standard would be used throughout the

European continent. Unlike U.S.D.C., which hoped to make a seamless transition of America's analog system to digital, GSM was developed from scratch and made pan-European compatibility its primary objective.

Today, in most European countries, the cellular system and standards are already unique to the individual countries. In fact, at the time of writing, a cellular phone that works in France cannot be used in England. GSM operates in new spectrum at 900 MHZ dedicated for use throughout Europe. Details of the GSM specification are given in [21,25] and equipment will be available to the pan-European community by the time of publication of this article.

GSM is the world's first TDMA cellular system standard, and uses a constant envelope-modulation format to gain power efficiency (constant envelope modulation allows more efficient class-C power amplifiers to be used) over spectral efficiency (constant envelope modulation has a larger bits per Hertz of RF occupancy than does linear modulation). GSM uses an equalizer and slow-frequency hopping to overcome multipath effects which cause intersymbol interference and, thus, irreducible bit-error rates. As the world's first digital cellular radio standard that has been adopted by a large market, GSM is viewed as a front-runner for early implementation of PCN throughout the world. Depending on the success of U.K. 1800 MHz PCN initiatives, GSM equipment could be implemented on a world-wide scale if spectrum allocations are made available in other countries.

In February 1990, just after CTIA adopted IS-54, Qualcomm, Inc. proposed to CTIA the use of spread-spectrum and sophisticated base station signal processing to offer capacity improvements ten times greater than AMPS (see the paper by Gilhousen, et. al. in the May 1991 *IEEE Transactions on Vehicular Technology* special issue on Digital Cellular Technologies). Major cellular radio service providers and manufacturers have steadily supported Qualcomm as they develop prototype spread spectrum cellular phones that will be ready by mid-1992.[22] Work conducted two decades ago[26], and more recently [29], confirms that spread-spectrum holds great promise for accommodating huge capacity with simple frequency management although the capacity is highly dependent on radio path loses within the service area. Of course, higher capacity means higher revenues and less churn (loss of customers) for cellular service providers, so the Qualcomm proposal received immediate attention.

Today, many U.S. companies such as PCN America and Omnipoint Data are looking at the viability of spread spectrum to overlay on existing point-to-point microwave users such as utility companies, banks, and public safety users, in the 1850 - 1990 MHz band. The concept behind overlay is that low-power spread spectrum PCN service could be offered directly on top of existing terrestial microwave systems that do not have such a great degree of capacity demand and have not been engineered to take full advantage of the spectrum.

References [23] and [24] discuss the concept behind overlay, and some techniques that could be used to minimize interference between existing and new users. Recent propagation measurements to test the levels of interference caused by PCN subscriber units to existing fixed microwave users were presented in [24] and more recently have been detailed in a report submitted on June 14, 1991 by PCN America to the FCC, as part of its experimental PCN license.

Presently, major telecommunication companies are researching the effectiveness of overlay systems from a capacity standpoint. If a sufficient grade of service could be offered through spectrum sharing between new wireless service providers and existing line-of-sight microwave licensees, then the FCC would be able to instantly accommodate market demand for wireless cellular/PCN without a major new spectrum allocation. The fear, of course, is that there could be an unsatisfactory degradation of service to both the existing microwave users and the overlaid PCN users. The overlay concept is being tested by numerous companies in the U.S. under the FCC experimental license program, and the FCC has, as of yet, not made a decision on their position on the matter.

The cable industry also has been watching the sudden growth in cellular/PCN throughout the world. Cable companies have a massive RF network installed throughout populated regions, and it is obvious that telecommunication services could easily be offered over the existing cable plant. In fact, PCN base stations could easily be installed in residential areas by splicing existing cable runs and tapping on the base stations mounted on lamp posts or inside buildings. Indeed, several U.S. cable companies are presently conducting experiments to determine the feasibility of PCS using the cable plant. When one realizes that U.S. cable operators already have spectrum allocated for microwave feeds in the 2 GHz and 13GHz bands, the possibility of utilizing the cable spectrum for PCN services instead of point-to-point feeders presents a lucrative new business opportunity for the cable industry.

For local loop, or premises applications, which merge voice and data, Bellcore[15] and the European Technological Standards Institute (ETSI) have proposed digital TDMA standards that offer between 400 kilobits per second (kbps) and 1100 kbps rates in office and residential environments. While the wide spread deployment of such standards will likely rely on new dedicated spectrum for the services, significant engineering manpower has been devoted to develop the standards, and a great deal can be learned from the research.

Bellcore's system exploits the slow time-varying nature of indoor channels and uses antenna polarization diversity to improve link performance between a base station (port) and mobile terminal (portable). Bellcore's proposal limits the data rate to 450 kbps based on an extensive measurement program that determined worst case multipath channels in a large number of buildings, houses, and cities.

Bellcore's approach minimizes the complexity and battery drain of the portable, since power-hungry adaptive equalizers can be avoided. Also, Bellcore's system uses a novel over-sampling demodulation technique that allows a receiver to lock coherently onto the incoming modulation with only a couple of bits of overhead. Reference [15] provides additional details about the Bellcore system, and [21], [25], [34], and [35] provide additional information about ETSI and the DECT standard.

EDUCATION AND RESEARCH FUNDING IN WIRELESS COMMUNICATIONS

The burgeoning wireless communications industry has created an interesting problem for wireless manufacturers and service providers throughout the world. Because the field of cellular radio and personal communications is changing so rapidly, and since the field involves system concepts seldom taught at universities, wireless companies are having difficulty finding entry level graduates with sufficient education to make an immediate contribution in research or design. In particular, a large number of universities presently do not offer undergraduate or graduate courses on the topics of mobile radio propagation or wireless communication system design.

Consequently, recruiters are forced to "raid" competing companies for more senior personnel, and resign themselves to spending 6 months to 2 years to train new graduates in the art and science of mobile and portable radio. In an informal survey of some of the largest cellular radio companies in the U.S., the author has learned that engineers with knowledge of mobile radio propagation change jobs often, and are in extremely high demand. Particularly in the past two years, since cellular radio has enjoyed 50% annual growth rates and new digital systems have been proposed and tried, engineers with experience in cell site design or computer simulation expertise in mobile radio propagation, traffic modeling, antenna design, and digital signal processing have been highly sought after by the wireless industry.

The Mobile and Portable Radio Research Group (MPRG) of the Virginia Polytechnic Institute and State University (Virginia Tech) is a new group within the university's Bradley Department of Electrical Engineering. Founded in the Spring of 1990, it is conducting basic and applied research in the areas of radio propagation measurement and prediction, communication system design using measurement-based propagation models, and simulation of various digital modulation, diversity, and radio equalizer techniques.

The group's mission is to develop analysis tools and computing techniques for emerging personal communication systems, while providing quality research opportunities to graduate and undergraduate students. Also, MPRG is providing opportunities for technical interchange. As an example, an EE graduate student lecture series in the Fall of 1989 featured key researchers from the cellular radio industry, and the first Virginia Tech Symposium on Wireless Personal Communications, held during June 1991 in Blacksburg, VA featured 18 invited talks and panel discussions by industry experts over a three-day period, and was attended by 175 people from 22 states and 9 countries. The necessity for academic research groups like MPRG becomes clear when one realizes the enormous, yet sudden, activity in the wireless field, and the growing demand for young graduates who can make immediate contributions to a very dynamic field.

Federal funding for wireless communications has been limited in the United States. The National

Science Foundation has shown little interest in funding experimental or theoretical work applied to wireless communications. It is ironic, though, that an NSF-sponsored project at Purdue University in the mid-1970s provided the first study of a spread spectrum cellular radio system[26] -- a study that created interest in spread spectrum access approaches for cellular radio communications which now, nearly 20 years later, are being extensively commercialized by numerous companies. During the Summer of 1991, however, NSF awarded Rutgers University with a cooperative University/ Industry center. Rutgers' Wireless Information Network Laboratory (WINLAB) is working on network and access solutions for third-generation wireless personal-communication systems, and was the first U.S. academic laboratory formed for wireless personal communications education and research.

The Defense Advanced Research Projects Agency (DARPA) is funding projects to develop small, low-powered wireless devices, and is supporting technology development for rapidly deployable local-area communication systems. New designs and fabrication technologies range from advanced silicon integrated circuits to software tools for propagation prediction and simulation. The knowledge base, resulting technologies, and system design tools from these projects will not only improve the U.S. military capability but also has relevance to the U.S. consumer wireless personal communications industry, as well.

It is worth noting that, in contrast with the U.S. government agencies, the European, Canadian, and Japanese governments have made substantial funding commitments to research laboratories and university programs focusing on wireless personal communications and related technologies. For example, in Europe, the RACE program (Research and Development in Advanced Communications in Europe) has committed over $100 million per year to the European Community during the period 1987 - 1992.[27]

A significant portion of those funds have been spent on collaborative industry/university research in wireless communications, with the goal of concurrently expanding the knowledge base and pool of technical experts. RACE appears to be yielding big dividends. The European community is widely recognized as the world leader in creating and accepting new digital cellular radio system techniques (recall that many European countries presently enjoy more than a 5% cellular market penetration, compared with around 3% in the U.S.), and it is where the concept of personal communications was first put into wide scale practice. Casual conversations with researchers across the worlds indicate that over 50 European Ph.D. students are tackling dissertations dealing with antennas and propagation for emerging wireless personal communication systems. And this doesn't include other areas of PCN such as modulation, coding, diversity, and system design!

In Canada, numerous iniatives are underway to encourage academic participation in research for wireless personal communications. The Telecommunications Research Institute of Ontario (TRIO) program is enhancing the technological competitiveness of Canadian industry through university/industry partnerships in telecommunications research. TRIO was founded in 1987, and has grown steadily. In 1991, the Ontario province and Canadian industry will provide over $6 million dollars for university communications research in Ontario. A significant portion of those dollars are being spent for mobile and satellite stems research for wireless personal communications.

The mobile and satellite systems program supports over 50 graduate students at five universities, and involves about 20 Canadian communications companies. Other Canadian provinces are also providing research support for regional; universities active in wireless personal communications. On a federal level. The Canadian Institute for Telecommunications Research (CITR) was established in 1989, and is providing research grants to universities throughout Canada. CITR's budget is over $4 million annually (overhead is waived on CITR funding) and is focusing on two major thrust areas: broadband communications and wireless communications.

As an example of CITR projects in the antennas and propagation area, research is investigating propagation and diversity techniques for indoor wireless communications at millimeter waves, fading issues for 20 - 30 GHZ personal satellite communication systems, and new cellular system design techniques. Universities involved with CITR wireless research include Carlton University, Concordia, Ecole Polytechnic, Laval University, McGill, Queens, Simon Frazier University, University of British Columbia, University of Calgary, University of Ottawa, University of Toronto, University of Victoria, the University of Waterloo, and the University of Western Ontario.

Japanese research programs in wireless personal communications abound, and there are numerous universities which are active in the area and are making fundamental contributions. As an example, Kyoto University has been a major contributor in the wireless communications field and has an active graduate program in propagation and communication systems design. Federal funding for academic research in Japan often involves interaction with industrial laboratories.[27] It seems clear that most federal governments view the tremendous impact that wireless communications will make on the world's economy, and are hoping their investments will result in new technologies and a body of experts who can engineer and develop new wireless personal-communications systems.

RESEARCH AT VIRGINIA TECH's MPRG

Early efforts to obtain government funding from the National Science Foundation failed, but industry response has been excellent and, after one year, twelve major wireless companies (including Bell operating companies, major radio manufacturers, and computer manufacturers), DARPA, and the FBI have provided a funding base in excess of $1 million. Collaborative research products with Purdue University, Northeastern University, and the University of California at San Diego have provided cross-fertilization of ideas and knowledge, and is helping to make the U.S. approach to wireless communications research more synergistic.

At MPRG, students receive an educational experience that provides them with a solid understanding of the theory and practice of mobile radio communications and emerging personal-communication systems. At the same time, they are tasked with developing and validating analyses, models, and research tools for the wireless industry. These tools help transfer knowledge from the MPRG laboratory into industry and academia. In 1990, the first year of MPRG, five MS-EE students graduated with expertise in RF filter design, indoor radio-propagation measurement and prediction, adaptive noise-cancellation techniques, and urban radio-propagation prediction.

Presently (1991), there are fifteen graduate and five under-graduate MPRG students pursuing degrees with an emphasis on wireless communications. As a result of student theses, several analysis and simulation software tools have been developed for internal use, and also are being used for research and development by a number of companies and universities. An EE graduate course dedicated to the topic of cellular radio and personal communications was offered in the Spring of 1991 and enjoyed an enrollment of 34 students, making it the most popular graduate course in the EE curriculum at Virginia Tech that term. Senior elective courses in radio wave propagation and satellite communications also are popular EE courses at Virginia Tech.

While the research and educational mission of MPRG concerns itself with more than just propagation, the group received its first research contracts in the area of propagation measurement and prediction, and continues to maintain an active program in this area. There is extreme interest in and demand for propagation measurements and models for the proper design of emerging wireless services such as PCN, and more powerful site-specific channel modeling techniques and tools are needed.

However, the U.S. wireless industry often finds conducting their own measurements and propagation research to be a time consuming and expensive task, and many industrial players view it as an expensive luxury which involves high-priced consultants. MPRG has emerged as a sensible and cost-effective alternative since it has an established equipment arsenal and provides research expertise in the area of propagation measurement and prediction. By pooling resources in an Industrial Affiliates Program, MPRG is generating useful tools and basic propagation models that can be shared by all affiliate members, and the resulting value of the research is much greater than the cost to an individual member. All results are published so that the entire research community benefits from the knowledge base.

Here, we briefly present some of the basic parameters used to describe multipath-channel characteristics, and show results from propagation measurements in urban, microcellular, and indoor channels. These measurements involve wide-band characterizations where a very short RF burst is sent and the echoes are received, as well as narrow-band (CW) characterizations that measured signal fading over large temporal and spatial spans.

As shown subsequently, antenna experiments have revealed that polarization can dramatically reduce the multipath time-delay spread and the fluctuation of delay spread in mobile channels. Results presented in this article are not meant to be interpreted as definitive work in mobile radio propagation. On the contrary, it is hoped that this article will spark interest and ongoing discussions in propagation modeling and prediction for personal communications.

II. PROPAGATION MEASUREMENT AND PREDICTION

A large part of MPRG research has dealt with measuring, and then statistical modeling, the path loss and time dispersion of multipath radio channels. Measurements and models have been made in many different environments:

a) traditional urban cellular radio channels with base station heights exceeding many tens of meters [1,2];

b) urban cellular radio channels with lower antenna heights, on the order of 15 - 20 meters [2]; and

c) in-building channels within sports arenas, factories, office buildings [3,4], and open-plan office buildings.[5]

Also, impulsive noise measurements have been made inside many types of buildings at three bands between 900 MHz and 4.0 GHz,[28] including two of the license-free Industrial, Scientific, and Medical (ISM) bands.

For urban mobile-radio channels, it has been reported that the coherence bandwidth (the bandwidth over which the received signal strength will likely be within 90% of any other frequency from the same source) is between 10kHz to 500 kHz.[6] Consequently, to sufficiently resolve multipath components (in the time domain) that cause frequency-selective fading, a channel sounder for urban channels should possess an RF bandwidth several times larger than the maximum coherence bandwidth.

This thinking led us to use a 500 ns probing pulse (4 MHz RF bandwidth) in [1] and [2]. For indoor measurements, we have used probes that have durations on the order of 5ns, thereby providing measurements that span over 400 MHz and which resolve individual multipath echoes to about 1.6 m separation distance. (The baseband pulse is DSB modulated so there is a bandwidth expansion factor of 2 at RF. Thus, the baseband complex envelope has a 200 MHz resolution bandwidth.)

We use time-domain techniques rather than swept-frequency techniques since it is easy to identify the location and intensity of reflecting objects in the channel. This information is vital for successful development of site-specific propagation models that can recreate the channel-impulse response. Our measurement systems are easy to assemble, test, and deploy, and provide instantaneous channel measurements with excellent time-delay resolution. Post detection integration is employed to improve the signal-to-noise ratio of the measured power-delay profiles. Our approach, though, requires slightly more peak power than the direct-sequence systems used in [7], [8], and [9], for a specified coverage distance. However, MPRG has developed a direct-sequence, spread-spectrum system which is being used in new measurements. Broadband, discone, Yagi, and helical antennas have been used to ensure no pulse spreading is attributed to impedance mismatch.

Figure 1 illustrates important parameters that indicate multipath dispersion in mobile radio channels. The rms delay spread (σ_τ) measures how spread of the channel power-delay profile about the centoid, and the excess delay-spread (X dB) indicates the maximum excess delay at which multipath energy falls to X dB below the peak received level. These parameters are useful measures for comparing different multipath channels and have been used in the past to approximate bit-error rates for digital modulation schemes without equalization.

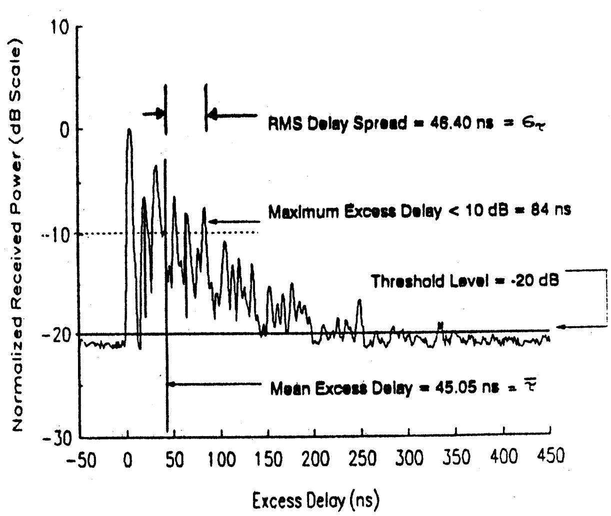


Figure 1

Historically, time-dispersion parameters such as σ_τ for ionospheric channels were computed by using a temporal average of the channel impulse response during a time period over which the channel appeared wide-sense stationary.

In mobile systems, however, the time variation of the impulse response is due primarily to motion, so the parameters may be computed over a spatial average during which the channel appears wide-sense stationary.[9, 30]

Particularly in indoor channels, individual multipath components fade very little between two fixed terminals or terminals moving along a small area.[31,32] Statistical processing on an extensive indoor propagation data base showed that individual multipath components fade in a log-normal sense over small temporal and spatial intervals, with a standard deviation of only a couple dB. Simultaneous CW measurements showed that the narrowband fading between two fixed terminals is Ricean, but the CW fading can be either Ricean, log-normal, or Rayleigh when the receiver is moved over a small area.

Deep fades of individual multipath components are primarily due to shadowing as a terminal is moved, or results from the phasor sum of unresolvable multipath components within a resolution cell. Knowledge of the channel time-dispersion to temporal-dispersion resolutions much greater (smaller duration) than the bit durations of a communication signal, and how the time dispersiveness changes over space, is important because these factors determine the instantaneous bit-error floor which occurs because of data smearing. By performing the time convolution of transmitted data bits with accurate spatially (time) varying impulse response models, it becomes possible to predict burst errors and conduct real-time system design experiments using computer simulation instead of prototype hardware.[33]

Historically, path loss has been found to be closely linked to the separation distance between transmitter and receiver, so a simple model for the path loss at some distance r from a transmitter can be expressed as

$$P(r) = P(r_o)(r_o/r)^n \qquad (1)$$

The exponent n in (1) represents the best-fit (in a mean square sense) average-power law at which signal power decays with respect to a free space measurement at r_o, the close-in reference distance. Measurements have shown that field measurements are generally log-normally distributed about the average-distant-dependent power law given in (1), independent of r.

Figures 2 and 3 show different time dispersion and path loss results from urban multicellular measurements reported in [2]. The measurements were made through several existing cellular markets in Germany using a 500 ns probing pulse and existing cellular base station antenna heights which ranged from 20 to 93 m in height.[2]

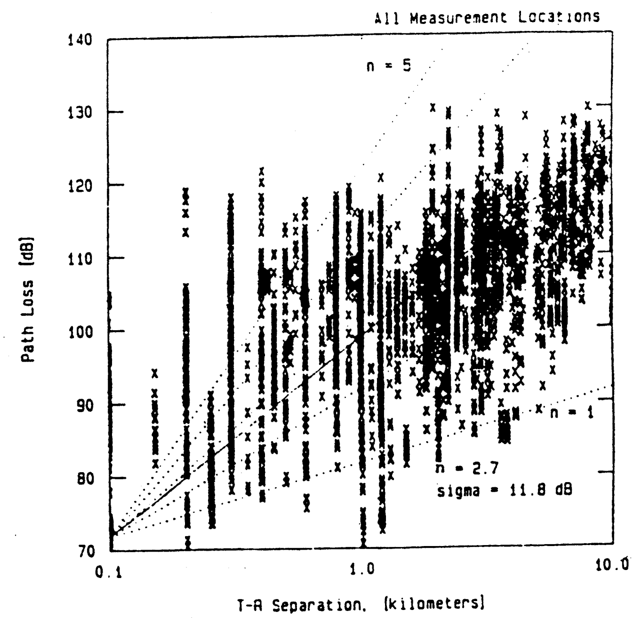


Figure 2

Data in Figures 2 and 3 assume r_o is 100 m. Using the assumption that path loss is log-normally distributed about the mean-power law, the standard deviation σ in dB completely specifies the distribution of received power as a function of distance. For a best-fit path loss exponent, σ will be minimized over the entire scatter plot. Reference [29] shows the selection of the close-in reference distance is important for system design considerations and capacity analysis. The close-in reference distance is a leverage point about which a best-fit mean-path-loss exponent extends from. Historically, a reference distance of 1 km was used as early land-mobile systems strived to provide coverage over tens of kilometers.

However, emerging microcellular systems will cover deliberately smaller regions so that spectrum reuse can be employed more extensively in a specific market. By diminishing the size of the radio cells, more users can be accommodated within a given spectrum allocation and, consequently, capacity can be increased at the expense of more base stations and infrastructure. Thus, path-loss models must use a close-in reference distance that is several times smaller than the distance to the most distant user within a coverage zone.

We have shown using field measurements that the value of the path loss exponent can change depending on the free space reference distance chosen, which indicates that simple d^n path loss models are subject to interpretation of the close-in leverage point selected. For microcellular and PCN systems, reference distances on the order of 1 - 100 m are appropriate.

MPRG research has focused on measuring indoor and microcellular channels and developing models for such channels, since it is our belief that outdoor environments and street-level systems will serve the largest number of wireless users in the decades to come. Extensive indoor propagation measurements have been, and continue to be made, with the goal of deriving site-specific modeling approaches and installation tools based on the physical descriptions of building interiors.[5,13]

Along the way, we have used statistical modeling procedures[10] to reproduce, on a personal computer, extensive propagation measurements given in [13] so that research can focus on indoor radio communication system designs using realistic computer-generated impulse responses.

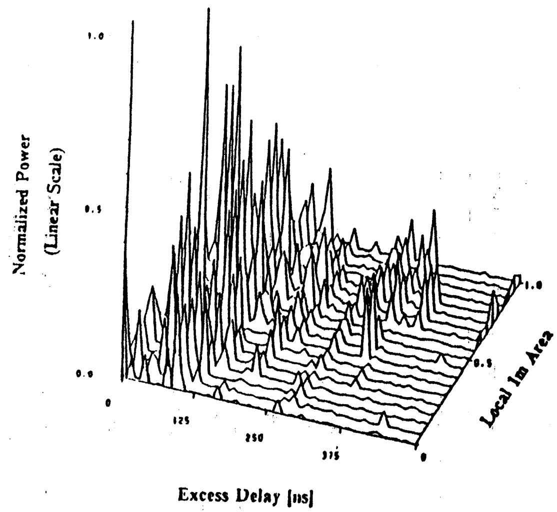
	Antenna Height (m)	n	σ(dB)	Maximum T-R Separation (km)	Maximum RMS Delay Spread μs	Maximum Excess Delay Spread (μs) (10 dB)
Hamburg	40	2.5	8.3	8.5	2.7	7.0
Stuttgart	23	2.8	9.6	6.5	5.4	5.8
Dusseldorf	88	2.1	10.8	8.5	4.0	15.9
Frankfurt (PA Bldg.)	20	3.8	7.1	1.3	2.9	12.0
Frankfurt (Bank Bldg.)	93	2.4	13.1	6.5	8.3	18.4
Kronberg	50	2.4	8.5	10.0	19.6	51.3
All (100 m)		2.7	11.8	10.0	19.6	51.3
All (1 km)		3.0	8.9	10.0	19.6	51.3

Important Channel Statistics for the various base locations and the entire data set.
From Seidel, Rappaport and Singh, *IEE Electronics Letters 9/26/90*

Figure 3

Also, more recent measurements[3,4], and measurements reported in the literature[14] have been used to generate, on a computer, impulse response and path loss measurements in traditional partitioned office buildings, and soft partitioned (Herman-Miller office partitions) office buildings.

The statistical channel models are useful for determining, through simulation, irreducible bit error rates, modulation performance, diversity implementations, and robust equalization methods. The propagation simulator, called SIRCIM (Simulation of Indoor Radio Channel Impulse response Measurements), is a valuable research tool for MPRG communications research, and is also being used by 30 companies and universities. The models used in SIRCIM are detailed in [10]. While similar in nature to the SURP simulation program used for urban radio propagation[11], SIRCIM is based upon measurements made over



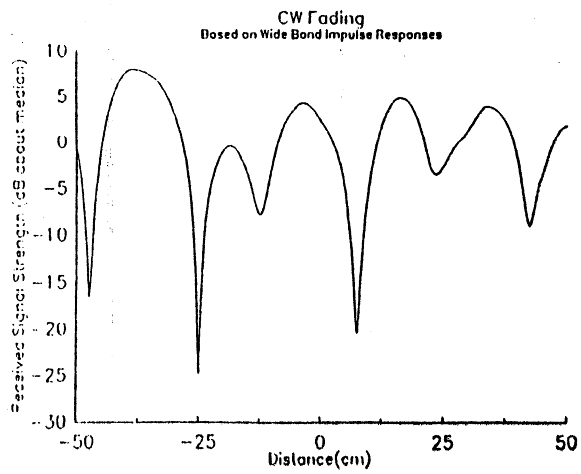
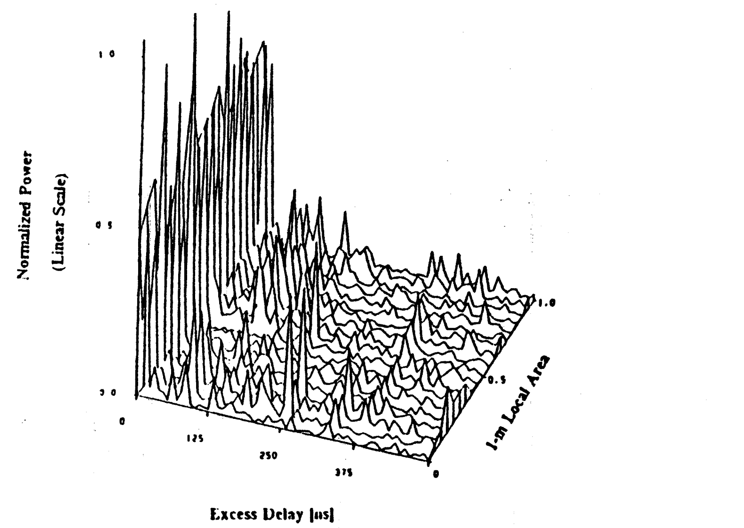


Figure 4. These waveforms are examples produced by SIRCIM. SIRCIM provides the user with data files that contain Amplitudes, Phases, and time delays of the channel impulse response, and computes fading statistics, large scale path loss, best fit exponent and standard deviation. User can specify building type, topography (LOS or OBS), and T-R separation distance. SIRCIM is based on extensive measurements made in over ten different buildings.



EXAMPLE OF SIRCIM OUTPUT IN LOS OPEN PLAN BUILDING

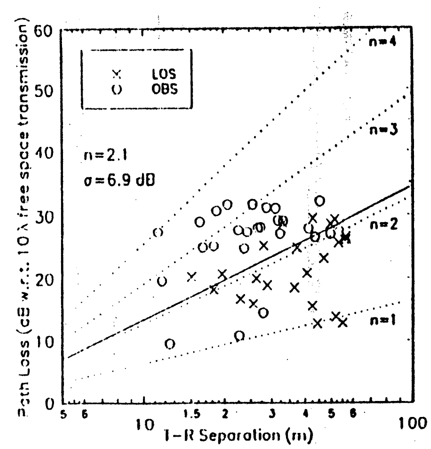


Figure 4A. Additional examples of output generated by SIRCIM. All data are stored on disk for later use in analysis or simulation.

small-scale distances, and thus allows synthesis of the phase of individual multipath components based on the Doppler shift and a random scattering model. By computing the spatially-varying phasor sum of multipath components, SIRCIM recreates CW fading envelopes identical in nature to those measured in the field. MPRG plans to update the software as more measurements become available, as as user experience dictates.

A useful result from [3] is that propagation characteristics are very similar at both 1.3 GHz and 4.0 GHZ, which means that SIRCIM models (based on measurements at 1.3 GHz) will hold up to at least 4.0 GHz, and probably at somewhat higher frequencies. At the time of this writing, MPRG measurement capabilities are limited to frequencies below 4.0 GHz, although new measurement equipment is being purchased for measurements up to 30 GHz.

Typical examples of data produced by SIRCIM are shown in Figure 4. Data files that contain the amplitude, phases, time delays, and path loss for individual multipath components are produced by SIRCIM and written to disk for later use in bit error simulation. These files may then be used to test bit error rates and system designs without prototype hardware.

Narrow band measurements have shown how the path loss exponent, and the deviation about the best-fit average path loss model, can be affected by building type, or location within a building. Table 1, extracted from [5], indicates that in different building types, the floors can offer different values of attenuation. Figures 5 and 6 present measured attenuation factors for various obstacles in indoor environments.[4,5] In [5], a simple two-parameter statistical model was developed to model the loss due to each partition or each wall encountered between a transmitter and receiver located within a building.

Figure 7 shows a scatter plot of path loss measurements made on three different floors of two different buildings, and the predicted path loss based on the simple model in [5]. The agreement between measured and predicted path loss is very good for the most part, and has an overall standard deviation of 4 dB. A standard deviation much greater than 10 dB usually results when only distance (and no site-specification information) is used to predict signal strength from a data base of several different types of buildings. For measurements in Figure 7, the transmitter antenna was mounted 1.8 m above ground, and the receiver was located at desk height, slightly shadowed by movable office cubicles (soft partition) and obstructed by concrete walls. Using a very simple model that assumes 1.4 dB loss for each cubicle wall and 2.4 dB for each concrete wall (the walls did not span the entire floor), and free space propagation everywhere else, it was possible to closely predict signal strength contours.

	FAF(dB)	σ(dB)	# Locations
Office Building 1 :			
Through 1 floor	12.9	7.0	104
Through 2 floors	18.7	2.8	18
Through 3 floors	24.4	1.7	18
Through 4 floors	27.0	1.5	18
Office Building 2 :			
Through 1 floor	16.2	2.9	40
Through 2 floors	27.5	5.4	42
Through 3 floors	31.6	7.2	40

Table 1a

	n	σ(dB)	# Locations
All Buildings :			
All Locations	3.14	16.3	646
Same Floor	2.76	12.9	501
Through 1 Floor	4.19	5.1	144
Through 2 Floors	5.04	6.5	60
Through 3 Floors	5.22	6.7	58
Grocery Store	1.81	5.2	89
Retail Store	2.18	8.7	137
Office Building 1 :			
Entire Building	3.54	12.8	320
Same Floor	3.27	11.2	238
W. Wing 5th Floor	2.68	8.1	104
Central Wing 5th	4.01	4.3	118
W. Wing 4th Floor	3.18	4.4	120
Office Building 2 :			
Entire Building	4.33	13.3	100
Same Floor	3.25	5.2	37

Table 1b

It is possible to account for obstructions when computing coverage zones. The following tables provide representative attenuation factors for obstacles, based upon extensive measurements by Virginia Tech MPRG personnel

	Loss (dB)
Concrete Block Wall	13
Loss from One Floor	20 - 30
Loss from One Floor and One Wall	40 - 50
Fade Observed When Transmitter Turned a Right Angle Corner in a Corridor	10 - 15

Figure 5a

Shadowing Effects of Common Factory Equipment

	Loss (dB)
2.5 m Storage Rack with small metal parts (loosely packed)	4 - 5
4 m Metal Box storage	10 - 12
5 m Storage Rack with paper products (loosely packed)	2 - 4
5 m Storage Rack with paper products (tightly packed)	8
5 m Storage Rack with large metal parts (tightly packed)	20
Typical N/C Machine	8 - 10
Semi-automatic Assembly Line	5 - 7
0.6 m square Reinforced Concrete Pillar	12 - 14
Stainless-steel Piping for cook-cool process	15
Concrete Wall	8 - 15
Concrete Floor	10

Figure 6

	Loss (dB)
Light Textile Inventory	3 - 5
Chain Link Fenced-in Area 20 ft. high containing tools, inventory and people	5 - 12
Metal Blanker, 12 square feet	4 - 7
Metallic Hoppers which hold scrap metal for recycling, 10 square feet	3 - 6
Small Metal Pole, 6 inch diameter	3
Metal Pulley System used to hoist metal inventory, 4 square feet	6
Light Machinery, <10 square feet	1 - 4
General Machinery, 10-20 square feet	5 - 10
Heavy Machinery, >20 square feet	10 - 12
Metal Catwalk/Stairs	5
Light Textile	3 - 5
Heavy Textile Inventory	8 - 11
Area Where Workers Inspect Metal Finished Products for Defects	3 - 12
Metallic Inventory	4 - 7
Large I-Beam, 16-20 inches	8 - 10
Metallic Inventory Racks, 8 square feet	4 - 9
Empty Cardboard Inventory Boxes	3 - 6
Concrete Block Wall	13 - 20
Ceiling Duct	1 - 8

Figure 5b

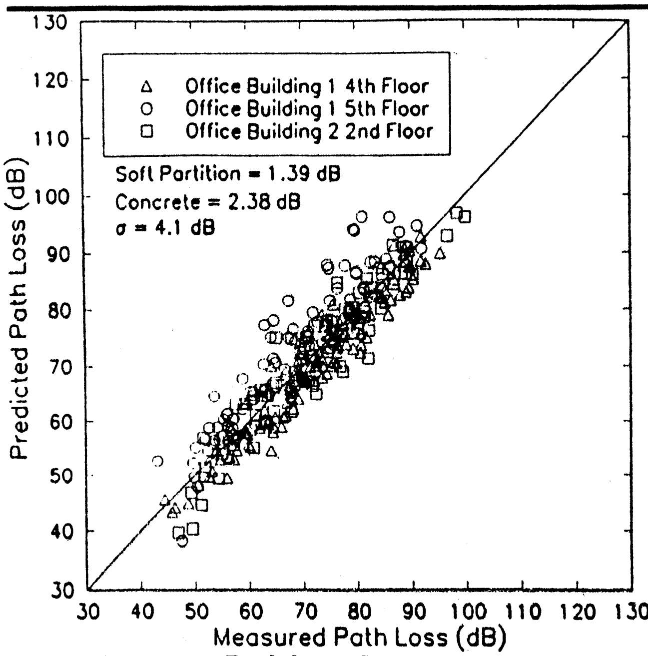


Figure 7. Path Loss Measurements

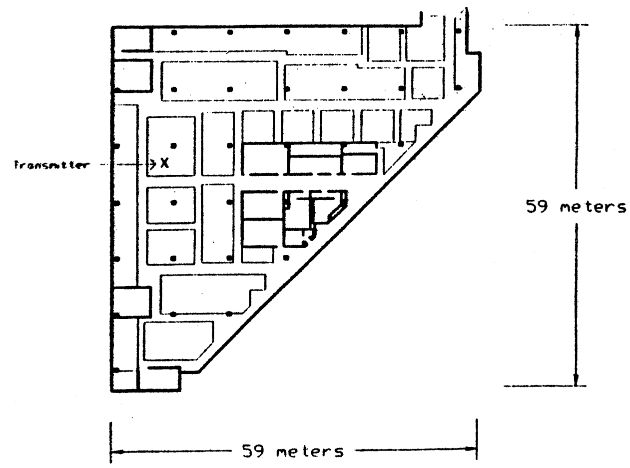


Figure 9. Open Plan Office

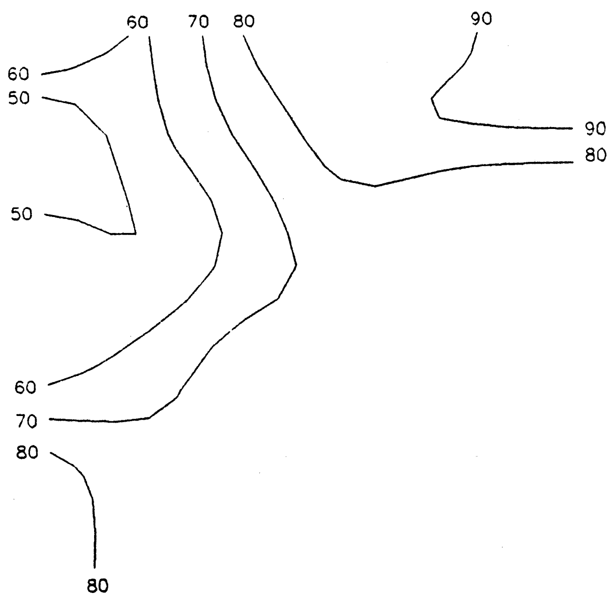


Figure 8. Measured Path Loss Contours

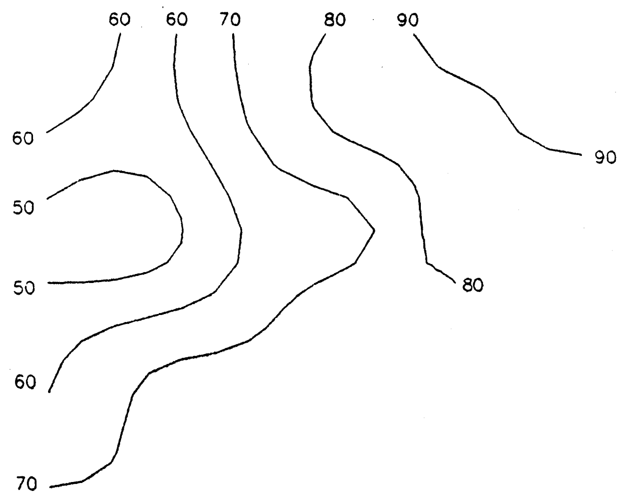


Figure 10. Predicted Path Loss Contours

Figures 8 to 10 illustrate how the simple site-specific attenuation model can accurately predict coverage throughout the work space. Figure 9 shows a schematic of a typical 59 m X 59 m open plan office with movable cloth partitions and concrete walls. Dark lines in Figure 9 denote concrete walls that extend from floor to ceiling. Lighter lines represent 2.0 m tall soft partitions. Figures 8 and 10 can be overlaid on Figure 9, and show measured and predicted signal strength contours based on the site-specific model in [5]. A simple distant-dependent path-loss model would provide circular contours of equal radius about the transmitting antenna. Although this modeling work is preliminary, it shows us that simple descriptions about the building topography could be used to predict coverage areas and interference zones with much better accuracy than models used today.

MPRG researchers are continuing measurements that will aid in developing accurate site models. These models will then be incorporated into an automated system-design tool that will optimally locate base stations for minimum interference and, consequently, maximum capacity. MPRG is working to exploit knowledge of propagation environment to improve and automate system installation without measurements.

Work in [4] has shown that antenna polarization can play a big part in reducing the delay spread (i.e., improving the bit-error performance). In [15], Cox describes the Bellcore UDPC system as using polarization diversity to open the eye in digital modulation techniques. Our work [4] shows that, indeed, polarization diversity can be used to select the best channel at a particular location.

Our work also shows that circularly-polarized (C-P) directional antennas, when used in line-of-sight channels, can provide a much lower delay-spread than linear-polarized antennas with similar directionality.[4] Figure 11 shows how the rms delay spread changes as a mobile receiver is moved over a 2.5 λ track. The identical track was transversed using omni-directional and directional linear-polarized antennas, and directional circular-polarized antennas.

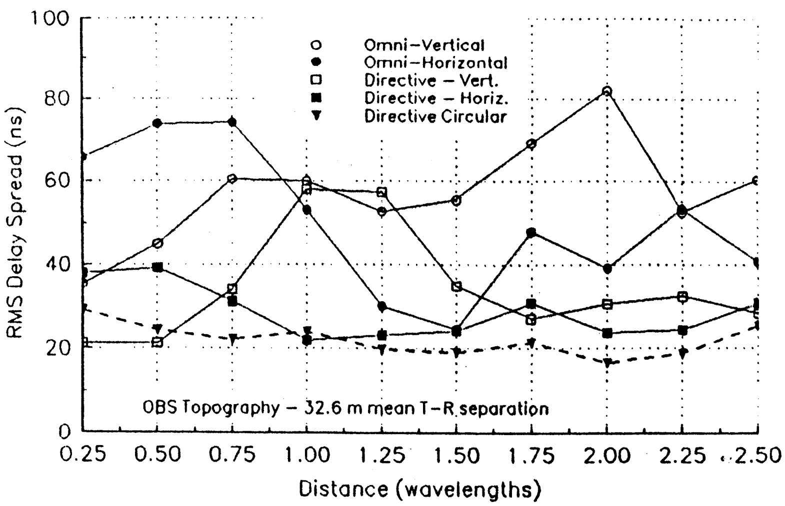


Figure 11.

Variation of rms delay spread along a 2.5 λ track for omni and directional antennas. Gain of omni antenna was 1.5 dBi; gains of linear directional and CP directional antennas were about 10 dBi. Frequency = 1.3 GHz.

Note that the C-P helical antenna offers much less delay-spread than do the L-P omni or Yagi antennas. Also, directional antennas reduce the delay-spread when compared with omni antennas. We have also seen this on cross-campus links which illuminate several buildings at a time.

In outdoor links especially, it appears that when aligned off-axis, directional C-P antennas offer much more multipath resistance than linear-polarized antennas. The multipath reduction is likely due to cancellation of odd-bounce multipath, and offers a significant performance gain since it reduces the time dispersion of the channel. Further, this finding indicates an accurate propagation prediction tool must consider polarization effects.

MPRG is conducting additional wide-band measurements up to 30 GHz around campus to provide data for building-penetration loss, floor-to-floor loss for different shaped buildings, the correlation of signal strengths over small distances, and the importance of antenna pattern and polarization on system design, to reveal additional modeling parameters.

Referring back to Figure 2, there is a large amounts of scatter about the best-fit, indicating that surrounding buildings have a large impact on the measured-path loss between a transmitter and receiver. Site-specific propagation models that predict, with good accuracy, the shadowing losses and the diffraction effects in urban canyons are needed for system design, and good progress is being made by numerous researchers throughout the world. A recent paper shows the viability of ray tracing and shadowing for accurate propagation prediction for microcellular systems[16], and unpublished work at MPRG shows that, in fact, only a few rays and simple diffraction methods can be used most of the time to get surprisingly good prediction (within 3 dB) of measured signals in microcellular environments.

III. CONCLUSION

The wireless personal communication age is coming soon. This paper has attempted to put in perspective some of the recent trends and events that are shaping the wireless personal communications revolution. The paper also gave insight into research and educational activities at Virginia Tech, and pointed out some of the tools and techniques used to characterize radio propagation. New models for propagation prediction will lead to appropriate spectrum allocations and robust system designs.

One area of research that is of great importance but was not mentioned above is environmental safety. Perhaps more important than research aimed at developing wireless personal communications; good, objective, in-depth experiments must be performed jointly and immediately by engineers and medical scientists to determine health risks associated with continuous and pulsed microwave radiation. While standards exist, it is unclear if those standards actually represent safe levels for humans. If a cause and effect relationship exists between cancers and microwave radiation, this must be made known immediately and the physical mechanisms must be learned to combat radiation at microwave frequencies that will be near our bodies and all around us. We must be certain that the wireless personal-communications age will be an environmentally-safe age as well.

IV. ACKNOWLEDGMENTS

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MAKING IT IN THE U.S.A.
A CASE HISTORY

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INTRODUCTION

This paper describes the design of a high-volume consumer RF product for manufacture in the United States. Discussed in this paper are the design techniques employed, and the experiences and results of the design effort. The item was to compete with established products being produced in the Pacific rim.

The subject of this paper is a video cassette recorder accessory device that allows the broadcast of television signals over a short range. This device is for the purpose of transmitting program material from one source, typically a video cassette recorder, to one or more television receivers within a home. The product operates within the frequency range of 902 MHz to 928 MHz and is approved under the provisions of part 15 of the FCC rules and regulations.

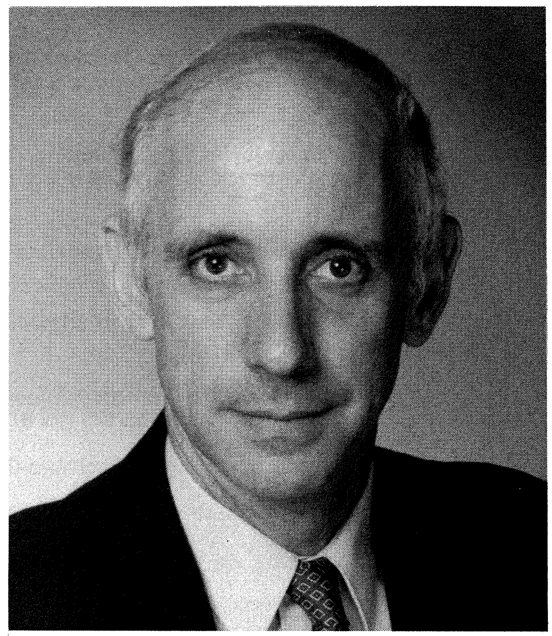
Other than those imposed by part 15 of the FCC rules and regulations, there were no restrictions placed on any part of the design. Cabinets, features, packaging, performance; any aspect of the product was to be considered in the design. The electrical design probably had more effect on the overall cost and competitiveness than any other facet of the project. This paper deals with the electrical design of this product.

The product consists of a transmitter and one or more receivers. Usually, a consumer purchases one transmitter and receiver. All reference throughout this paper to the "video broadcaster" refers to the usual configuration of a set of one transmitter and one receiver.

EARLY PLANNING AND INVESTIGATION

One of the first tasks undertaken in the design of this item was to evaluate current competing products to establish areas where improvements could be made and competition could be established.

Similar products were purchased and their performance evaluated. The units were dissected, parts counted and costed, the number of internal adjustments were counted and rough schematics traced.



Dr. Albert D. Helfrick

It was determined, and to no one's surprise, that not even one of our potential competitor's units could be copied and made in the United States, and be cost competitive with imports. What was required was a superior design.

In the case of some competitive products, making a superior design would be simple. These were, primarily, designs employing labor-intensive techniques such as hand-mounted components, intricate shielded enclosures, many tuning adjustments and so on. Interestingly, these units were those with the lower retail prices.

The more sophisticated video broadcasters used modern techniques such as surface-mount components, simpler shields, fewer adjustments and offered more features. These more sophisticated units provided the benchmark for our design.

From the design team's experience with off-shore factories, we knew that many imported items have an extremely high labor content. There also is a widely accepted opinion that RF circuits require labor-intensive construction such as shields, hand-wound coils and a large number of trick adjustments. Because of the significantly lower labor costs in some Pacific-rim countries, many products employing even this high-labor content construction are profitable.

SETTING THE GOALS FOR A SUCCESSFUL DESIGN

The design criteria for the video broadcaster involved the following goals, in their order of importance:

1. Minimum assembly labor
2. Minimum test time
3. Maximum yield
4. Minimum parts count
5. Minimum parts cost

The order of importance will tend to vary depending on the product involved. As an example, an item that would have a high material cost rather than labor cost would not benefit from a further reduction in labor. The list shown represents an order of importance for a typical electronic product. As technology provides more complex integrated circuits, the number of active component parts would decrease while the labor either remains the same or increases. This would have an effect on the order of importance.

Although there has been phenomenal advances in integrated circuits in the RF region, a lot of RF tasks are still done in the classic way. One excellent example of this is filters. Most RF filtering is done with discrete inductors and capacitors, with either element being variable for critical filters. The existence of a filter in a design implies considerable labor. The parts are often not machine inserted, and the variable parts require some sort of test procedure to be adjusted.

Although there may be some valid arguments to re-order items 3, 4, and 5 in the list, it is well established that items 1 and 2 are at the top of the list for RF devices.

MINIMIZE ASSEMBLY LABOR

To meet the first criterion, assembly labor can be minimized through the following techniques:

1. Designing the electronics so that the vast majority of components are machine assembled;
2. Reducing the number of sheet-metal parts;
3. Reducing the number of screws, clips and other fasteners; and
4. Reducing the number of hand soldering operations.

1. Machine Assembly

Item 1 is a very large factor. Not only can a machine place parts at a rate far exceeding that of an assembler, many modern surface-mount machines are capable of pretesting the components for orientation, electrical parameters, and placement accuracy.

In the early stages of the design, there was some study to evaluate relative cost of surface-mount vs. through-hole technology. It was found and verified by some recent articles in the trade journals, that the cost of surface-mount technology may be slightly higher than through-hole technology mainly due to the high cost of surface-mount placement machines. There is some cost disadvantage for some surface-mount components while, on the other hand, there is a significant advantage for many.

Not all components were available in surface-mount packages at the time of the design of the video broadcaster. The number of parts being added to the surface-mount list grows daily but there will always be some parts not available as surface-mount components.

There may be a cost premium for a surface-mount part relative to through-hole parts and the temptation to save cost by using a through-hole part must be considered very carefully.

A situation arose in the design of this device involving a quartz crystal. As it turned out, the surface-mount crystal was significantly more expensive than the conventional HC/18 can with wire leads. It was decided to provide a surface mount pad layout on the printed circuit board and to surface solder the conventional HC/18 crystal in anticipation of a more affordable surface-mount crystal becoming available.

The more generic surface-mount parts such as 74HC logic, and standard linear ICs such as op-amps, tend to have the lowest prices due to the greater amount of industry competition. In many cases it is more economical to perform a task using a larger number of generic parts rather than one unique part.

The frequency synthesis of the video broadcaster's oscillators is an example of a larger number of generic ICs being less expensive than a smaller number of unique chips. The frequency synthesizer could have been reduced to a total of three chips using a sole-sourced synthesizer chip. However, this part was not available in a surface-mount version and was not multiple sourced. Therefore, it was deemed prudent to use a design with generic parts in spite of the fact that seven chips were required. The cost of the seven chips, after careful shopping, was less than the cost of the three-chip design. This is in addition to the peace of mind from having a practically inexhaustible supply of parts.

Because the video broadcaster operated in the 915 MHz region, the use of chip components was a significant advantage. The video broadcaster used microstrip techniques and the surface-mount chip components are especially suited for this frequency range. No special microwave parts were used but great precautions were taken to insure that components were evaluated for specific circuit locations and that new vendors would be evaluated before loading their parts onto the surface-mount assembly machine.

The estimated average cost of assembly for a surface-mount component is $0.03 per part which is about the same as for a conventional through-hole part. However, when the suitability of the chip components to the 915 MHz range is considered, the advantage of the surface-mount technology was overwhelming and was chosen as the basis of this design.

Most likely, for some applications, the older through-hole, wave-soldered assembly technique would prove to be more cost effective and would be the obvious method of choice. Each application requires it's own analysis.

2. Reducing Sheet Metal Parts

Sheet metal parts, the subject of Item 2 of the list of priorities, are notoriously expensive. It is not so much the expense of a fabricated part but the expense of handling those parts after they are received. Sheet metal parts are such items as brackets, cases, and, particularly for RF devices, shields. They must either be soldered in place, screwed down, tabs bent, clipped, or some other type of hand operation employed. Thus, sheet metal parts add to the tasks under items 3 and 4.

Some sheet metal parts are unavoidable, such as shields. However, the amount of shielding can be kept to a minimum by lowering signal levels to prevent radiation, decreasing sensitivity to minimize the effects of signal ingress, and making tight, compact circuits. In the video broadcaster, microstrip techniques were used with a very large ground plane area to contain the RF fields and minimize undesired radiation.

When shields are required, they should be as small as possible and made from one piece of stock. Also, remember that shields need not be made from brass or copper and do not need to be thick. In the video broadcaster, the shields were fabricated from .005" tin-plated steel with solder tabs which were inserted into the board like a component. The shields had small holes to allow access to the enclosed circuits for tuning.

.3. Reducing Fasteners

In addition to being applied to sheet metal parts, fasteners are found on plastic parts, machined parts, purchased components, etc.

The expense of fasteners is the labor required to apply these fasteners. Clips and speed nuts are preferable to screws and nuts but the use of minimal fasteners is the ideal.

When applied to product cases, fasteners can be minimized by using cases that dovetail, have slots for mounting printed circuit boards and other parts, etc.

The video broadcaster uses a two-piece, injection-molded plastic case with a rear panel that fits into slots on the upper and lower halves of the case. The printed circuit board nests into four bosses and the entire assembly is fastened with four self-tapping screws. The decorative front panel is fastened with an adhesive backing. Although the circuits are quite different, the video broadcaster transmitter and receiver use the same case but with different graphics on the front and rear panels.

Another very useful technique for reducing the number of fasteners is the use of printed-circuit-board-mounted controls, connectors and switches. There are two significant advantages to this; first, the controls, connectors and switches may be wave soldered and save labor and fasteners. Second, the electronics assembly may be wholly contained on one PC board and thus fully tested before it is installed in the case.

4. Reduce Hand Soldering

Reducing hand soldering is a matter of choosing the right components. Hand soldering is usually associated with the larger components of an electronic circuit board. In many cases, items that were hand soldered may be replaced with items that may be wave soldered. Some really clever component designs are allowing more of the larger components to be surface mounted which opens up the possibility of complex assemblies requiring neither hand soldering nor wave soldering.

One of the more common hand soldering tasks is the connection of wires to a printed circuit board to connect to power supplies, front panel components or other externally mounted parts. Ideally, wires should be eliminated. In addition to an expensive manual soldering job, the wires must be cut, stripped and tinned before soldering.

REDUCE TEST TIME

Immediately following assembly labor in the list of design goals; test time is a significant cost factor for two reasons. First, not only is labor involved, it is at a higher skill level than assembly and, thus, is more costly. More employee training is required in addition to a test fixture and test equipment. These last two items, fixturing and test equipment, can be particularly expensive when RF is involved.

Test procedures usually imply that something must be adjusted. A variable circuit element is generally much more expensive than a fixed element. As an example, a variable resistor, i.e. a potentiometer, costs about as much as 25 fixed resistors. Furthermore, to the component cost must be added the expense of a test technician and all the needed equipment to set the adjustment to the correct setting.

In the case of the video broadcaster, the oscillators were synthesized for the three operating channels using a phase-locked loop. This required the inclusion of seven ICs in the receiver and another seven in the transmitter. This was offered as a feature to the consumer and some of the cost was justified by that. In the competitive unit in which the frequency was set by a varactor voltage, three potentiometers were provided to set the three operating frequencies. The cost of the three potentiometers was about one-third the cost of the ICs required to implement the phase-locked loop. When the cost of setting those three potentiometers to the correct frequency is considered, the cost of the phase-locked loop becomes much less significant.

Automatic test equipment is another method of reducing test time. Providing test points that allow internal measurements while the unit is in a test fixture greatly reduces test time.

Some tests, particularly those required of RF systems, are notoriously expensive. On such test is any sort of swept-frequency test. In one competition video broadcaster, RF amplifiers were made from transistor and matching networks, whereas, in the domestic design, MMICs were used without tuning. Expensive sweep testing was required to adjust the coils of the matching network to provide the necessary gain. From a parts cost viewpoint, the transistor amplifiers with their impedance-matching networks were less expensive. However, from an overall cost standpoint, once the hand inserted coils and the swept-frequency RF tuning were considered, the transistor amplifiers were much more expensive.

To design an electronic circuit that requires less testing and, ideally, no adjustments, implies a design that is tolerant of normal variations in component values.

Typical design techniques to achieve this is to design circuits where the gain is set by feedback rather than device gain, operating circuits in saturation where the signal level is a function of power supply voltage rather than device gain, etc.

It is important to perform extensive analysis whenever a circuit cannot be adjusted for component parameter variation. Computer analysis such as Monte-Carlo analysis is very important in high volume designs. It is necessary to operate at such narrow profit margins that even a small number of rejects could prove disastrous.

MAXIMIZE YIELDS

If any subassembly or final assembly fails to meet the acceptance specifications, that part must be either repaired or discarded. The further along the production process the item is, the more costly the repair or discarding will be. Thus, it is necessary to perform as much evaluation as possible early in the assembly process.

Repair is to be avoided at all cost. If a subassembly has to be discarded, it is best if the subassembly has the minimum amount of parts installed. If repair has to be performed, it is most easily done when the circuit is of minimum complexity.

However, as it was explained previously, the test time should be minimized as it is expensive. The least expensive and very effective test is performed by the surface-mount assembly machine before a component is installed. As an example, consider a resistor that is discarded for an out-of-tolerance value before being installed. The cost of this part is less than one cent. Consider now if the resistor were installed but was caught at a subassembly test. The test technician may take one minute at a cost of about $0.75 plus the penny for the resistor. But, if the first test that identifies the out-of-tolerance resistor is the final test, it may take a test technician 5 minutes to locate and replace the bad part and now the cost is $3.75 plus the penny for the resistor.

Testing can be enhanced by the use of test points which may be provided for a bed-of-nails check for low frequency or DC checks. Certainly for the 915 MHz frequencies involved in the video broadcaster, the bed-of-nails will not provide an accurate result.

The DC parameters of RF circuits, while operating, may be measured through a test point if a series resistor is provided to offer isolation from the test pin to the high frequencies. The addition of a resistor results in an unused component under normal operating circumstances. However, the cost of the resistor and it's placement is of the order of $0.037 which means that 135 resistors cost as much as one 5 minute repair job.

MINIMUM PARTS COUNT

One requirement of a successful product is a clever design. A clever design is one that performs the maximum functions from the minimum components, is easy to assemble, requires very little or no testing or adjustment, and so on. How clever a design is, is not measurable and is an intangible. However, sufficient engineering talent along with ample time and support must be provided if there is to be any hope of a clever design.

There are several good reasons to design electronic circuits that use a minimum of parts. First, the fewer parts the less the parts cost. This statement is not always true. Obviously an expensive part that replaces a few very inexpensive parts does not support a lower parts cost. When the parts being minimized are similar parts such as resistors or ceramic capacitors, then making a reduction in component parts has a significant effect. There is a lot of overhead associated with component parts. They must be purchased, stocked, loaded on to the surface-mount assembly machine, tested and finally placed on the printed circuit board.

Below is a tabulation of the parts count in the video broadcaster compared to that of the competition:

RECEIVER	Imported Unit	Domestic Unit
Capacitors	45	50
Resistors	26	49
Potentiometers	2	0
Inductors	28	7
Transistors	6	4
ICs	2	11
Diodes	5	7
Crystals	0	1

One of the first observations is that the domestic units have more parts by about 10 percent. Although this is true, further investigation is necessary. First, the domestic unit offers more features and performance. This means that the unit does more with only a ten percent increase in components. One significant difference is that the transmitter and receiver local oscillators are synthesized. This saves some test time as the receiver local oscillator and transmitter oscillator do not have to be adjusted using an expensive spectrum analyzer to spot the oscillator frequency. The phase-locked loop is most evident in the integrated circuit count of the two units and the existence of two quartz crystals in the component count. When a standard crystal is used such as a watch crystal, or color-burst crystal the cost can be low.

Notice, also, the domestic unit has no potentiometers as compared to a total of seven for the pair in the imported design. As previously explained, these are usually expensive parts.

One very important observation is the significant number of inductors used in the imported unit. Many of these are hand-wound air-core inductors that must be tuned by spreading the turns. It is not the cost of the inductor that is significant, but the fact that it must be tuned. The imported unit had more than four times the number of inductors that the domestic unit has. Not every inductor was tuned, on either the domestic or imported units. But, the difference in adjustments -- either inductors or other adjustments -- on the new design is one-fourth that of the competition. A printed filter using microstrip techniques was used on the domestic unit while a lumped filter was used on the imported unit as one example of saving inductors.

TRANSMITTER	Imported Unit	Domestic Unit
Capacitors	48	51
Resistors	32	46
Potentiometers	5	0
Inductors	15	3
Transistors	7	4
ICs	2	12
Diodes	5	5
Ceramic Filters	1	1
TOTALS	229	251

If the component list of the product includes a large number of different parts, many more purchases must be made of smaller quantities. In addition, it is necessary to load more parts on to the surface-mount machine. The goal for cost effective parts requirements is to use the minimum number of parts and to use as many common parts as practical.

In the video broadcaster, every bypass capacitor is of one value. Furthermore, the same value is used for coupling, even in applications where this common value is much larger than necessary. The use of a smaller capacitor may save a small amount but would be more than wiped out by the increased cost of introducing a new part.

PARTS PROCUREMENT

When designing for low cost, engineers must be involved with the early parts procurement process. If the product has potential for very large volume, such as a consumer item, the purchasing process must be very aggressive. Those engineers who have not been involved with high-quantity production, particularly those whose experience is primarily involved with high-rel, low-quantity RF circuits, will be absolutely amazed at the real cost of some familiar items when the quantity is over a million pieces.

First, always design around multiple-sourced components. In the design of the video broadcaster, the phase-locked-loop synthesizer was originally designed around a single-chip synthesizer which was sole sourced. The design was extremely compact and elegant. However, the manufacturer could name its price for the chip and should the chip supplier ever develop a production glitch the broadcaster would be doomed. Although the new synthesizer design used seven chips, three were the same, and the chips were common 74HC items.

The new synthesizer design resulted in two strong bargaining tools when shopping for low prices, common parts and high quantity. What resulted was a circuit with almost four times as many ICs but no worries about price or an available supply.

There was one basic rule followed in the design of the video broadcaster. Whatever the quoted price of a component part, it was never low enough. The quantities involved in the video broadcaster were sufficiently high that quotes could be made directly from the factory at very competitive prices.

CONCLUSION

There is an unfortunate irony in the chronicle of the video broadcaster. Although it was our sincere desire to manufacture a consumer item in the United States, many of the internal components are of foreign origin. Even the components bearing U.S. manufacturer's logos are assembled in foreign lands. Many major items are of domestic origin such as the plastic cases, panels, and the printed circuit board. However, there is even strong competition in this area from foreign suppliers. All those involved in this project would like to see competitive domestic components available, particularly in surface-mount components. On the other hand, the most value added was from domestic sources.

There were no new, unexplored techniques used in the design of the video broadcaster. All of the techniques discussed in this paper have been available for some time. Being competitive is a matter of using modern techniques, a clever design, and a good deal of common sense.

Dr. Albert D. Helfrick is a Fellow and Secretary of The Radio Club of America, and a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE). He is the president and owner of Helfrick and Associates, Inc., an engineering consulting firm. His firm has been involved in the design of several consumer devices using RF technologies, as well as a number of commercial/industrial products. He holds a BS in Physics, an MS in Mathematics, and a Ph.D. in Applied Science. He is a Registered Professional Engineer in the State of New Jersey.

Recent texts written by Dr. A. D. Helfrick:

Electrical Spectrum and Network Analyzers, Albert Helfrick, Academic Press, 1991.

Modern Electronic Instrumentation and Measurement Techniques, Albert Helfrick and William Cooper, Prentice-Hall, 1990.

Elektrische Messtechnik, (German language edition of *Electronic Instrumentation and Measurement Techniques, third edition*), VCH Verlagsgesellschaft, Albert Helfrick and William Cooper, 1989.

Modern Aviation Electronics, Albert Helfrick, Prentice-Hall, 1984.

Practical Repair and Maintenance of Communications Equipment, Albert Helfrick, Prentice-Hall, 1983.

Two other books are out-of-print, and a second edition of *Modern Aviation Electronics* is in preparation.

RADIO PIONEER - FRANCIS H. SHEPARD, JR., P.E.

The business card introduces him:

F.H. Shepard, Jr., P.E.
Consulting Engineer

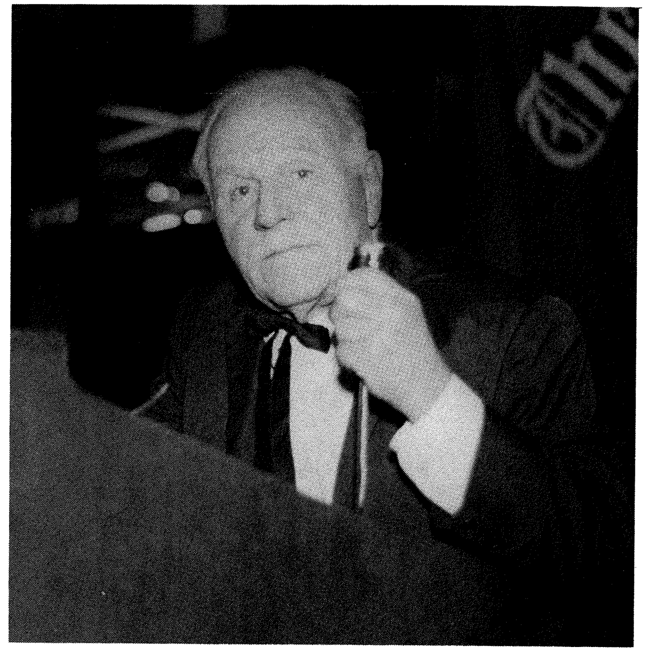
Following graduation from Yale University's Sheffield Scientific School, he began his career as an engineer working with Dr. Elmer Sperry during the early 1930s. There, he developed a chopper-stabilized DC amplifier using a gold-plated microphone as a chopper. The amplifier and a thermocouple mounted on a 60-inch parabolic reflector were used to detect heat radiated from ships at sea beyond the horizon.

While with Sperry, Shepard developed a relaxation-oscillator type fathometer; in turn, this led to later work at RCA on burglar-detection alarms. The failure of sonic-alarm systems to work in fur vaults had caused panic amongst furriers. By substituting a radio-frequency relaxation oscillator, the alarm could be adjusted to the point where it would not quite relax (squag); since the amplitude of the oscillations became sensitive to load and that load changed in relation to the standing-wave pattern, the oscillation amplitude would change to activate an alarm.

In later years, the issued patent on the high-frequency relaxation oscillator was declared expired and out-of-issue. Shepard was asked whether he had any undue interest since, unbeknownst to Shepard, this patent covered the proximity fuze which was to play a vital role during World War II.

Sometime about 1935, William S. Hinman of the U.S. Bureau of Standards visited the RCA applications lab and brought a Diamond-Dunmore-Hinman radio sonde. The radio sondes were sent aloft attached to balloons, to obtain weather information from the upper atmosphere. The radio transmitters used a relaxation oscillator that was frequency-controlled by variable resistors to indicate temperature and humidity conditions.

The D-D-H circuit used a pentagrid converter, and was unstable. The Bureau of Standards wanted RCA to improve the tube's stability. Shepard informed Hinman that this was impossible, and suggested a relaxation circuit based upon his (Shepard's) fathometer and burglar alarm. A prototype circuit with a relaxation oscillator modulating the rf transmitter, using a filamentary twin-triode tube, was put together at RCA, and tested.



Francis H. Shepard, Jr., P.E.

When Hinman returned to Washington, he phoned Shepard and said that he almost got fired for changing the circuit but, he said, exhaustive tests by the Bureau's engineers confirmed the performance of the circuit and it was adopted.

Later, when Hinman became Director of the Bureau of Standards, he told Shepard that, over the years, the radio sondes had been used all over the world as the principal means of studying and predicting the weather and, while they were now using more modern tubes and circuit layouts, the basic circuit had never been changed.

The development of weather instruments at the Bureau of Standards was funded by the Julian P. Frieze Company. A summer student employed at the Bureau imported some British technology and so possibly the first production applications of the printed circuit board was accomplished in the United States.

Dr. Sperry had developed the gyro compass and the earth-inductor compass; in turn this led to the development of automatic ship steering and aircraft autopilots. The late General Jimmy Doolittle was, then, a Sperry test pilot.

The work on feedback at Sperry led to Shepard being retained by the Brown Instrument Company and the Bristol Instrument Company. Those companies were using self-balancing potentiometers together with dash-pot, thermal-delay bridges, etc. to stabilize steam power plants. Shepard's work was to simplify and improve the controls using vacuum tubes and electronic circuits.

That experience led Shepard to be retained by the Fire Control Division of the Frankfort Arsenal, at Philadelphia, where he designed and built a clutch-operated fuze-setter servo, and its stabilizing electronics. He also designed and built the prototype servo electronics to control the Vickers hydraulic drive on the 90mm and 105mm anti-aircraft guns. This servo operated with dead-beat response: no velocity, acceleration, or rate-of-change of acceleration lags -- for precision tracking, and for slew control between targets even though the hydraulic drives suffered limits together with lags of velocity, acceleration and rate of change of acceleration. The servos were interfaced with the Bell Labs M-9 Director. Later, these servos were used on the U.S. Navy's 40mm anti-aircraft guns, and their 40mm quads..

In connection with his work regarding fuze setter and power-drive gun servos, Shepard overheard a discussion of a problem of recording the pressures of propellant powders inside gun barrels. He suggested a peak-reading amplifier that would store the peak reading. Immediately, he was commissioned to build such an amplifier which resulted in a "peak-pressure meter." The U.S. government subsequently ruled that all military missile propellants be batch tested and approved. Shepard manufactured and supplied these peak-pressure meters to the various arsenals and suppliers of propellants.

During an assignment to The Baldwin Locomotive Works, Shepard observed the shock-wave straightening of large locomotive castings. This led to a better understanding of metal fatigue and the need to control impact forces. Sometime later, he observed the use of delay-line control of radar pulses; together with the knowledge of the use of shock waves, he designed a system to control the impact forces in high-speed printers through the use of mechanical delay-line hammers.

In 1950, this led to a fixed-price contract to build a high-speed (30 lines per second) printer to be used to print ballistic tables at the Aberdeen Proving Grounds. Subsequently, Shepard Labs manufactured a 120-column printer for the U.S. Navy to maintain their inventory of spare parts.

Printers were supplied to Stanford Research Labs, the Bank of America, National Cash Register, General Electric and others for use with the first electronic machine accounting systems. Printers also were supplied to the Radio Corporation of America for their BISMAC computers which were in use by the New York, Travelers, and Metropolitan Life Insurance companies. For military applications, printers were supplied as part of Sylvania's *Moby Dick* project for the U.S. 7th Army stock control centers in France and Germany, and through IT&T to the U.S. State Department in Washington, DC.

Two printers installed at the U.S. Army Automotive and Tank Command, in Detroit, averaged over one million lines of print per day for 7-1/2 years without downtime for repairs. When this particular BISMAC was then retired, the University of Ohio acquired it and operated the printers without any reconditioning.

Since Shepard retained title to the ballistic-hammer patents, he licensed-to-manufacture the Radio Corporation of America, the National Cash Register Company, General Electric, British Tab, English Electric, Standard Elektrik Lorenz, Olivetti, and others.

IBM executives and engineers spent several weeks of study at Shepard Labs on the pretext that they wanted to purchase or take a license. A bit over a year later, Bernard Greenblatt presented a paper before the IEEE on how the ballistic hammer made possible the chain printer.

Needless to say, to protect his licensees, Shepard had to sue IBM for patent infringement. After years of so-called discovery and several weeks in court, Shepard won the suit.

The U.S. Navy was using the Sperry-Draper inertial navigation system on the Polaris submarines. What was needed was a printer to fit into a limited-size bulkhead and which would interface with the computers to keep a running log of the operations. Within ten weeks of the order, Shepard delivered a 30-line-per-second printer complete with special interface logic. The Navy was concerned whether the system could operate at 50° C. maximum temperature; Shepard said it would. How sure could he be when his best environmental test equipment was his wife's hair dryer?

Shepard explained that the germanium transistors used in the circuitry, were the components most sensitive to heat. Then he put a hot soldering iron against the transistors; when the circuits started to falter , he removed the iron and touched the transistor with spit. It sizzled -- so it passed the test. The Navy accepted the test, initially; however, they later ran their own heat tests.

Over the years, the 50 or more systems supplied by Shepard had a record of 26,000 hour mean time between failures, according to Navy records. Shepard Labs received a letter of commendation from Admiral W.F. Radborn.

In 1975, Shepard was retained by the Realty Industrial Corporation (William S. Gubelmann) to develop an electronic version of a word-processing system. Previously, Gubelmann had applied for a patent on an electro-mechanical justifying typewriter but which had been found too complicated for economical manufacturing.

Using a Remington Selective typewriter, Shepard developed a servoed carriage with a proportional-character scope display, installed a many-page memory which could be edited, and loaded or unloaded from tape cassettes, or over a phone line via an RS-232 two-way phone interface. Realty Industrial Corp. processed patents on the system and licensed Sperry Remington.

Engineers at R.C.A., had ben given an assignment to make an efficient Class B audio power tube. The then existing tubes were plagued by distortion caused by non-linear grid impedance. Efforts were being made to correct this by using a variable-pitch and spaced grid. At lunch one day, while the engineers were discussing the problem, Shepard remembered a student inspection trip wherein a steam hammer was being demonstrated by an operator. So skilled was he that he could smash the crystal of a watch without damaging its mechanisms. This was mechanical feedback involving the operator.

Shepard suggested that the engineers should forget about the tube's distortion and work for its efficiency. They should make a governor whereby the tube would control its output in accordance with its input somewhat like the control of a flyball governor on a steam engine. Shepard took a ribbing from the engineers with "Shepard will fix it like a steam hammer."

In the lab, Shepard hooked up a circuit using plate-to-grid feedback and added voice-coil feedback involving phase control of the signal. It was a stable circuit upon which RCA obtained a patent some time before Arthur Black of Bell Labs released his treatise on feedback.

While at RCA, Shepard designed and built a vacuum-tube voltmeter which later was marketed as the RCA Voltohmist. Later, he was retained by Ballantine Laboratories where, applying the techniques developed at the Frankfort Arsenal, he developed the peak-to-peak voltmeter.

An assignment in 1940 by the Telautograph Company to update their equipments brought the recommendations that the systems be deigned to operate by carrier currents over power lines, through telephone lines, and over any communication circuit. Their reaction was that this was too costly to undertake. Shepard then sold the idea to the U.S. Army Signal Corps who worked up a specification and bid request for portable systems. Since Telautograph would not bid, permission was granted to Shepard to bid on his own account, and he received the contract. From that, he developed a clutch-servoed pen with rectangular coordinates operating with a portable handheld transmitter. Operating from four derived functions, it enabled information to control above-normal writing speed with a bandwidth of six to ten cycles per second.

Shepard's experience with radio sondes, servos, printers, etc. resulted in a contract with the U.S. Bureau of Standards to supply material and services in accordance with instructions from the contracting officer. The contract lasted several years.

One of the first assignments was to review a problem of the U.S. Treasury in Chicago where the Treasury was recording the sale and redemption of Series E Saving Bonds. The procedure was to hand record each bond into a giant ledger which then was copied onto one of 270,000 rolls of microfilms. In order to find information on a sale or redemption, the files were searched via IBM punched cards. The Treasury spokesman stated that the IBM cards were stored in arsenals around Chicago, that there were then 61,000 tons of cards, and that this was getting slightly out of hand.

One of the group from the Bureau of Standards suggested the use of a doughnut memory in which one thousand 20-inch magnetic disks arranged in doughnut form could be selected and read for the information stored on two million IBM cards. Under the Bureau of Standard's contract, Shepard designed and constructed the mechanics and electronics of the device, which operated with a mean access time of one second.

Another assignment was the development and prototyping of a clutch-operated antenna servo that would stably track a target within a couple of mils on the Kingfisher, the second guided missile developed for the U.S. Navy, even though the missile would pitch and yaw at a two-to-five second rate. The prototype was tested and adopted. There followed the applying of missile- stabilization servos to mechanical, clutch operated under-wing actuators.

It became apparent that, with all of the electronics and servo power required, a reliable source of electric power was needed. Batteries were too heavy, and generators using slip rings or commutators would not work at high altitudes. Shepard resolved the problem by designing and constructing a 2,000 cycle self-regulating alternator without slip rings operating from the almost infinite power available as a bleed from the missile's main jet.

The solution to the problem came out of a snow storm during late 1940 that knocked out power to his home for 17 days. No heat - no lights - only misery. Recalling that an induction motor driven over synchronous speed would feed power into the line, Shepard connected a 1/3 horsepower motor to the engine of his lawnmower. Nothing happened when first started. To magnetize the armature, he connected his car battery. A short power surge then again nothing.

When the motor's speed exceeds the line frequency, the line is a leading load so Shepard added capacity across the motors output and again applied the car battery. Now, there was power generated for a little longer. Then, after connecting 180 microfarads across the motor, voltage rose to 150 volts at a frequency of almost exactly 60 cycles. No amount of throttle on the Briggs and Stratton would increase the voltage or frequency. The motor became saturating -- self regulating at 150 volts and 60 cycles.

Based upon his experience, Shepard designed and supplied five 2000-cycle induction generators. The Raymond Engineering Company was commissioned to build 25 more. During a visit to Raymond, Shepard was amazed at the general state of euphoria amongst the employees. It seems that on the previous day, Albert Einstein had come to visit his nephew, a tool maker, and had talked to everyone individually at their level of understanding. Even the cleaning woman came away enriched by the conversation -- the sign of a really great man.

The Kingfisher missile also needed a proximity fuze so Shepard designed a one-tube superregenerative circuit using magnetic modulators powered by the 2000-cycle output of the induction generator. The circuit could be arranged to select or sweep any desired range. This resulted in a contract with the U.S. Navy to supply a range-only radar. When this was accomplished, the Navy decided to classify the project so Shepard had to sit idly by and watch other engineers develop magnetic radar modulators.

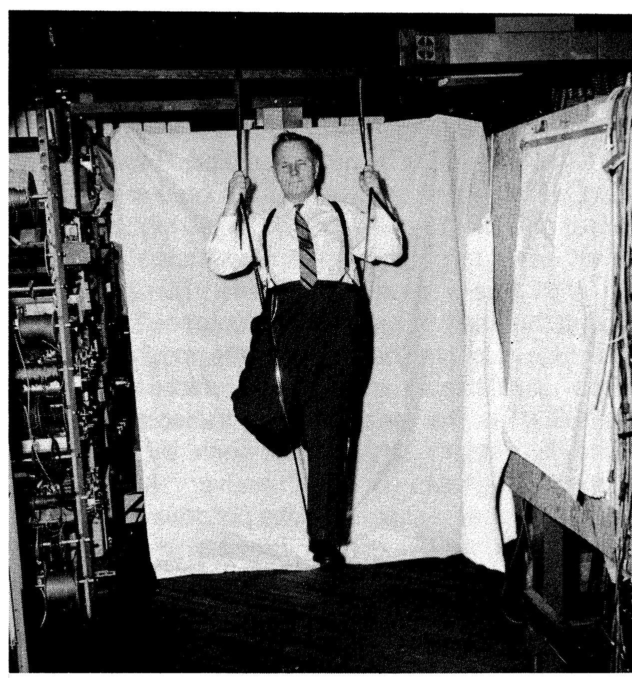
The success of the Kingfisher radar-operated fuze resulted in a study contract with the U.S. Army Signal Corps in which Shepard demonstrated that superregeneration with gated-pulse reception would have the same selectivity and information bandwidths and, hence, the same noise factor as the best of the traditional radio circuits. This technology was used on the Signal Corp Moon Radar Project.

Discussions with personnel of the Bureau of Standards regarding wear of magnetic clutches led to the concept of the magnetic-dust clutch which Shepard designed and built the prototype model. Further discussions on how aided-tracking was used on the Kingfisher antenna servo and missile stabilization brought the question: "Why wouldn't this work on a clock?" And so the self-adjusting clock was invented, to be used in almost every auto until the quartz-controlled clock was introduced.

Shortly after V.E. Day, Shepard was commissioned to set up the industrial-electronics session at the first IRE convention following World War II. The session was scheduled for a Saturday morning in the grand ball room of New York's Astor Hotel. As the session began, there was no projector and none of the speakers would address the meeting without the use of their slides. As master of ceremonies, Shepard began to talk about how the program was organized. He complained that IRE papers contained too much math. He asked why they could not explain the solutions in English words and revert the math to an appendix. "Many of us," he said "do not understand math, and mathematicians will not accept the math without doing it themselves."

Every time that Shepard tried to call on one of the authors to take over (without slides), he was refused, the audience would applaud and would not let him sit down. This went on until well into the afternoon when a projector finally was obtained.

In the audience were several engineers from DuPont. Shortly after the session, Shepard was contacted and retained by DuPont. The company scheduled him for regular visits to their Applied Physics Labs, in Wilmington, DE, to the rayon division in Buffalo, the petroleum products division in Penns Grove, NJ, the film-products division in Parlyn, NJ, and the Remington Arms division in Bridgeport, CT.



Testing Splices in 35mm DuPont Kronar Film

DuPont had recently developed a new Kronar super film. This film was stable and strong by virtue of being grain-oriented by stretching during manufacturing. The only problem was that no known adhesive would stick to it and splicing by thermal bonding destroyed the grain orientation and, thus, its strength.

Shepard resolved the problem by developing a dielectric heating machine whereby the film could be heated, bonded, and quickly quenched to prevent disruption of the grain orientation. He demonstrated that 35mm Kronar film spliced on his machine would support his weight, then over 200 pounds.

During the 1930s, Shepard's wife, a coloratura soprano, wanted recordings of her voice. He bought the best equipment affordable at the time -- an RCA recorder that engraved an acetate disc. It worked but the higher-pitched notes distorted horribly while the middle tones were masked by background noises.

Asking himself the question "How does the human ear handle its range of sound without apparent low-level noise or high-level distortion?", and studying the Bell Labs' Fletcher-Munson curves showing the characteristics of the human ear, it became apparent that these curves could exist only if the response of the ear was non-linear.

He replotted the curves and found that the ear had infinite sensitivity for very small signals yet never saturated on loud signals. The ear would generate odd harmonics (3rd, 5th, 7th, etc.) in descending order in the same percentage of total sound , regardless of the fundamental's amplitude. The unique property of of this nonlinear curve is that the ratio of fundamental to harmonic tones remains substantially independent of the amplitude of the fundamental over a range of many decibels.

So on to the next question "How do we make an amplifier behave like the human ear; i.e., approach infinite gain for low-level signals while never saturating on signals thousands of times greater?" The answer: "It is simple. Bias a vacuum tube at the peak of its transconductance curve, and introduce positive feedback to the extent that the output oscillates at an inaudible, micro-volt level." Feedback at the peak of the transconductance curve is positive while excursions off the peak become progressively degenerative. A pentagrid converter tube was ideal for this purpose.

Shepard designed a circuit wherein the gain of the specific bias point was raised to infinity by positive feedback. Signal excursions off the peak reduced gain-excursions beyond the transconductance to less than one -- actually reducing the gain -- then, without saturation, expanding the input signal that it could handle. With the circuit, Shepard could shout into the microphone while clearly recording conversations thirty feet away.

Shepard built and demonstrated a hearing aid; it showed phenomenal results. A friend whose hearing had been damaged in an auto accident, had never been aware of nerve deafness until after the accident. Sound became completely incomprehensible, and the best hearing aid then available gave little help and caused an emotional strain. The non-linear hearing aid gave instantaneous comprehension even when dishes were clashed and paper was rattled, and when words were whispered or shouted.

The Maico Hearing Aid Company became the first licensee under the patents. Maico then arranged for Shepard to present a paper before the American Otological Association.

To demonstrate the excellence of his hearing aid, Shepard demonstrated the unit to Zenith by pounding a sheet of steel while a conversation was going on. The only person who understood the conversation was the one wearing his hearing aid.

Zenith manufactured hearing aids using the same non-linear 1R5 pentagrid converter tube as used in the demonstration. John Howland, of Zenith's legal and patent department, told Shepard that when the government stopped all non-military electronic production during World War II, Zenith had already manufactured and sold more hearing aids than the rest of the industry combined during the time that they had made hearing aids. This developed because the Zenith hearing aids did not require individual fitting for persons with damaged hearing and nerve deafness. Since the units had only a volume control and a slightly-adjustable tone control, they could be sold over the counter. . This allowed the buyer to avoid the necessity of coping with "dealers" pushing features of competing aids.

During the development of the hearing aid, it became obvious that small radios having miniature speakers could be made to deliver to the human ear, the apparent low frequencies that the speakers could not physically radiate. Church organ builders had, for centuries, keyed the third and fifth harmonic organ pipes to simulate the sound of a pipe too large to fit into the organ. So what was needed in the radios was a distorting amplifier having a specific type of non-linearity. Shepard found the answer in a tube in which the peak of transconductance exhibited in the negative region.

This non-linear characteristic built into small radios extended their apparent frequency response in the low frequencies by odd harmonic generation, and the high frequencies by intermodulation beats with white noise and/or orchestration. It generally is not realized that, through the intermodulation of high frequency signals with orchestration or white noise in music, the brain miraculously interprets this intermixture as high-frequency tones that cannot be differentiated from pure tone inputs.

The high-frequency response was augmented by increasing the coupling of two IF transformers, and controlling the roll-off resonances of the speaker and cabinet. However, a serious problem arose: the cabinet and speaker resonance normally built into these sets stuck out like a sore thumb. Shepard resolved that problem by developing circuitry using positive current feedback in combination with negative voltage feedback. It was so effective at controlling the speaker and cabinet resonances that it was impossible to locate those resonances by ear using an input from a variable-frequency audio signal generator.

Resolving those problems enabled Shepard to license Zenith, Motorola, RCA, Admiral, Majestic, Belmont, Emerson, Stromberg-Carlson, DeWalt and others; also included were suppliers of radios to Sear Roebuck & Company. License fees for use of the patents were set at three cents per set. For each licensee, Shepard worked with the licensee's engineers to incorporate the circuits into their current products.

In 1980-81, Shepard was retained by the Breeze Corporation to develop a 3-phase motor drive for use on helicopter hoists being supplied to Sikorsky for use on the Navy's Lance program. A simple forced-commutation means was developed, whereby SCRs could generate frequencies from zero to plus-or-minus that of the power line; the inverter would brake an overhauling load and feed a limited amount of power back into the AC power line. Patents were assigned to Shepard.

During the early 1980s, Shepard developed and patented a unique self-compensating inverter that would drive one to four 40-watt fluorescent lamps, or one or two 100-watt 8-foot lamps without adjustment. A modified version would drive 1,000 watt mercury vapor or sodium arc lamps. Recent requirements that all ballasts present a high power-factor to the AC power line led to the development of a high-power-factor means which would feed power to or from a DC voltage with minimal loss. The device should work on 3-phase motor drives, and Shepard currently is bread-boarding such a drive. The circuitry uses six low-cost 7400 IC chips and six power transistors to drive over 1,000 watts into 3-phase motors. Only four power transistors are needed to drive an open-delta circuit. Initial tests indicate that an overall efficiency of 80 percent is feasible.

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Shepard became a member of The Radio Club of America in 1936, was elected to the grade of Fellow in 1942, and to Life Membership in 1970. He served many years in Club offices which have included: Director, 1944 - 1951; Recording Secretary, 1951; Corresponding Secretary, 1952 - 1953; President, 1954 - 1955; Secretary 1971 until 1985 when he was elevated to the status of Secretary Emeritus.

Shepard was awarded The Armstrong Medal in 1969, and The Pioneer Citation in 1988. He was elected to the grade of Fellow in the IEEE in 1969 "for contributions in the field of high-speed printers and electronic instrumentation."

He was a founding member of The Armstrong Memorial Foundation, and held membership in the Institute of Radio Engineers (IRE), and in the American Society of Mechanical Engineers.. He holds patents on more than 100 inventions, and is a Licensed Professional Engineer.

He has a philosophy: Inventing isn't hard -- just build upon what you've already learned.

1940 - A DEMONSTRATION OF FM RADIO

by **William H. Smith, W3GKP**
Recording Secretary
Washington Radio Club

MINUTES OF REGULAR MEETING OF WASHINGTON RADIO CLUB
January 13, 1940

The first regular meeting of the Washington Radio Club of 1940, held on Saturday evening, January 13, at 8:00 PM in the National Museum Auditorium, witnessed the largest attendance at a regular meeting of the Club in its history. Over six hundred persons -- many from out of town, including a large number of notables in the radio field -- were in attendance.

The meeting included a demonstration, the first in history outside of New York and the New England states, of the new system of frequency modulation invented by Major Edwin H. Armstrong, of Columbia University. Also the feasibility of multiplexing with this system was demonstrated. This was the first public demonstration of multiplexing with this system.

The principal speaker was Major Edwin H. Armstrong, known throughout the world for his work in connection with the regenerative, superregenerative, and the superheterodyne circuits, and now the inventor of the revolutionary system of frequency modulation.

The actual demonstration of the system was handled by Stuart L. Bailey, of Jansky & Bailey, prominent consulting radio engineers, Washington, D.C., and licensees of High Frequency Broadcast Station W3XO, located in Georgetown, D.C. This station was the first in this part of the country to be licensed to use this system. Mr. Bailey will be remembered as having previously spoken before the Club.

Certain ultra high fidelity electrical transcriptions (flat to about 9500 cycles), furnished especially for the occasion by the Associated Music Publishers, Inc., formed part of the demonstration.

In order to show the extremely high fidelity characteristics of the system, an experienced radio announcer and three musicians performed in a studio specially created for the demonstration at 1219 Wisconsin Avenue, N.W., Washington, D.C. Concerning this portion of the program, the official organ of the broadcasting fraternity, the National Association of Broadcasters Reports, dated January 19, 1940, at page 3973, stated "The reproduction of the live talent was so life-like that it evoked spontaneous applause from the audience, even though they were only hearing the artists through a loud speaker."

The multiplexing portion of the program was accomplished by transmitting a high fidelity musical program and two ultra audio (21,000 and 23,000 cycles) simultaneously. The ultra audio tones actuated an electronic typewriter supplied by the International Business Machine Corporation, at the rate of 100 words a minute. The original of the letter transmitted is attached. A dozen or more carbon copies were made of this letter at the same time as the original.

The meeting was opened at 8:15 PM by President Fred W. Albertson of the Club. After a few words of welcome of the Washington Radio Club, "the oldest radio organization in existence," to the special guests of the Club, including the Washington sections of the Institute of Radio Engineers and the American Institute of Electrical Engineers, the Baltimore section of the Institute of Radio Engineers, the Baltimore Radio Club, and the Greenbelt Radio Club, he presented Major Armstrong as an outstanding amateur, and contributor of more outstanding inventions to the radio Art than any other single individual.

President Albertson pointed out that in checking over some of Major Armstrong's applications to the Federal Communications Commission for the Major, he was "pleased to note that he listed as one of his qualifications to carry out radio research that he had been a 'ham' since 1906."

Major Armstrong, as an introduction, stated that he was proud to be a "ham" and that it was entirely fitting that the first public demonstration of this new contribution to the Radio Art should be a meeting of the oldest radio club in existence.

For about an hour, Major Armstrong outlined the history and nature of his invention, its advantages over the conventional amplitude modulation and how, in his opinion, it would revolutionize the radio telephone service, particularly standard broadcasting. Portions of his talk were illustrated by slides.

A few of the advantages of frequency modulation over amplitude modulation which were pointed out are:

1. Freedom from QRN and all forms of QRM. This means extremely low noise levels.

2. Feasibility of very high fidelity (30 to 16,000 cycles used in the particular demonstration).

3. Practicability of wide dynamic range.

4. Usability of a small fraction of the signal strength necessary for amplitude modulation.

5. Wide consistent range of transmission at higher frequencies (43.2 megacycles used in this demonstration); many times the distance to the horizon.

6. Efficiency in the operation of transmitting equipment.

7. All transmission, in effect, at 100 per cent modulation.

8. High powered stages of transmitters operating Class C.

9. No modulator necessary with its reserve power of four times the carrier power.

10. Riding of the gain control unnecessary, and no off the air because of over-modulation on peaks.

11. Total elimination of cross-talk, heterodyning and ordinary QRM between stations operating on the same channel.

The President, following Major Armstrong's talk, introduced Stuart L. Bailey. There followed a technical description of Station W3XO, which is located in Georgetown, D.C. and licensed to operate on 43.2 megacycles with 1000 watts, using the Armstrong system of wide-swing frequency modulation with a maximum band width of 200 kilocycles. This description was illustrated by slides.

The actual demonstration of frequency modulation in operation was then presented. Reception was from time to time on several different receiving sets located on the stage of the auditorium, including a receiving set manufactured by the Radio Engineering Laboratories, built especially for frequency modulation, and a new Model 480-M Stromberg-Carlson Telephone Manufacturing Company all-wave broadcast receiver.

A large, wide-response Weight high-fidelity loud speaker, supplied through the courtesy of the Yankee Network, Inc., was used with the R.E.L. receiver. Although an outside antenna was available, reception was on a small dipole antenna located on the stage of the auditorium.

Absolutely no interference of any nature whatsoever was experienced during the demonstration. It is interesting to note that a year or so ago another demonstration was attempted in this same auditorium, using an ordinary amplitude modulated broadcast receiver with a rather elaborate outside antenna. Because all of the equipment of this building is operated on direct current, it was found impossible even to receive the local broadcast stations without considerable interference, and the demonstration was abandoned.

The first portion of the program consisted of the following:

"Hail, Hail, The Gang's All Here,"
an Associated electrical transcription by the All States Band.

Station identification announcement by Dwight Rorer, formerly of Station WPEN, Philadelphia, and WSNJ, Bridgeton, New Jersey, who announced all of the following selections:

"Macushla," an Associated electrical transcription;

"Washington Post March," a World Broadcasting System Band recording;

"Alice Blue Gown," an Associated organ electrical transcription.

After the mechanical reproduction of the program, Mr. Bailey described the studios of the station constructed especially for the occasion. He pointed out that the telephone company wanted the prohibitive sum of over Two Hundred and Thirty Dollars for a high fidelity line from one of the local broadcasting station's studios for this occasion, making it necessary to construct studios near the transmitter. The live talent portion of the program demonstration was also announced by Mr. Rorer and was presented as follows:

Piano Solo, "The Polish Dance" (Scharwenka) by Maestro Arturo Papalardo, formerly director of the Manhattan Opera Company and nationally known artist;

Vocal Solo, "My Hero" by Olive Harris, lyric soprano of Alexandria, Virginia, artist of Maestro Papalardo; (Offenbach)

Piano Solo, "The Apache Dance," by Maestro Papalardo;

Vocal Duet, Romberg's "Auf Wiedersehn" by Olive Harris, soprano, and Dwight Rorer, baritone, accompanied by Maestro Papalardo.

Mr. Bailey then gave an outline of the particular advantages of frequency modulation in multiplex operation, with a description of how it was to be done in this demonstration. He pointed out that along with a high fidelity broadcast program there might be transmitted at the same time, without mutual interference, a second such program or perhaps a facsimile program, or both. It was shown how binaural transmission was very feasible with frequency modulation.

Then followed an Associated electrical transcription, selections from Verdi's "La Traviata" by the Associated Symphony Orchestra. At the same time that this was being received a radio typewriter, similar to a typewriter, located on the stage of the auditorium, received a letter dated January 13, 1940, addressed to the Washington Radio Club and signed by Walter S. Lemmon, Director of the Radiotype Division, International Business Machines Corporation. The original of this letter is attached. (It contains the autographs of Major Armstrong and Mr. Lemmon). Following the receipt, it was read to the meeting by President Albertson.

The President introduced Professor C.M. Jansky, Jr., senior member of Jansky & Bailey, an outstanding radio engineer, and a former "ham". Professor Jansky figured prominently, the President said, in the early days of broadcasting in formulating our present rules and standards of allocation, and is eminently qualified to present the advantages and disadvantages of the new system in allocation.

Among other things, Professor Jansky pointed out that two powerful stations operating on the same frequency, both using frequency modulation, would not interfere with each other, as we now understand interference, at any point within their service area. Halfway between the two stations, one or the other station would be heard but never both, and a slight change in the location would eliminate one and bring in the other.

He stated that instead of a ratio of desired to undesired signal strength of 20 to 1 necessary to good reception with amplitude modulation, a 2 to 1 signal strength ratio was adequate with frequency modulation. Professor Jansky predicted that frequency modulation would soon replace much of our present amplitude modulation, and that the advantages of frequency modulation were so great and so numerous that its adoption could not possibly be suppressed.

Major Armstrong was again presented to the meeting by the President. He showed a number of slides demonstrating the magnitude of even the present adoption of this new system. He showed pictures of his own 40 kilowatt station operating on 42.8 megacycles at Alpine, New Jersey, W2XMN; of the 50 kilowatt 43 megacycle Yankee Network transmitter, W1XOJ, now under construction on Mt. Asnebumpskit, near Paxton, Massachusets, 2 kilowatts of which have been in operation for some time rendering a broadcast service to the entire New England district; of the 43 mile 250 watt 132 megacycle relay transmitter which carries programs from Boston to the top of Mt. Asnebumpskit; of the amateur station of Carmen R. Runyon, Jr., W2AG -- now licensed as W2XAG and W2XCR -- in Yonkers, New York, at which amateur station much of the original research on frequency modulation was carried on. Many other slides were shown.

At the conclusion, the meeting was thrown into a question and answer forum, at which time the audience directed their questions to Major Armstrong, Professor Jansky or Mr. Bailey. The President finally was forced to cut off the discussion because of the lateness of the hour.

The meeting finally adjourned at 11:30 P.M.

On concluding the meeting, President Albertson thanked all those who had contributed to making the meeting a success. Special appreciation was expressed to Major Armstrong and his two engineers, Mr. James Day and Mr. John Bose, who had been in Washington for days before working on the demonstration; to Professor Jansky and Mr. Bailey and their gang of engineers, including Mr. Oscar W.B. Reed, Vice President of the Washington Radio Club, Ronald H. Culver, another member of the Washington Radio Club, and Mr. George Lohnes; to Walter S. Lemmon, Director of the Radiotype Division of International Business Machines Corporation and his two engineers, Messrs. Lawrence and Holt, who had been in Washington for a week working on the details of the demonstration; to Paul DeMars, Chief Engineer of the Yankee Network, Inc., to Mr. Ray H. Manson, Chief Engineer of Stromberg-Carlson Telephone Manufacturing Company for equipment; to Professor Franklin M. Doolittle, of Station W1XPW and WDRC, Hartford, Connecticut, for slides; and to the announcer and musicians, Dwight Rorer, Maestro Arturo Papalardo and Olive Harris, for their work in connection with the live talent portion of the demonstration.

The Auditorium was packed to over-flowing with more than six hundred persons. A list of all of the out-of-town guests would be impossible. A few of those who came to Washington especially for the meeting from great distances are as follows: Dr. Eugene C. Woodruff, State College, Pennsylvania, President of the American Radio Relay League; Walter Bradley Martin, Roslyn, Pannsylvania, Director of the Atlantic Division of the American Radio Relay League; Dr. Greenleaf Whittier Pickard, Boston, Massachusets, noted radio pioneer; Professor Franklin M. Doolittle, of Stations W1XPW and WDRC, Hartford, Connecticut; Mr. Italio Martino, Chief Engineer, WDRC, Hartford, Connecticut; Mr. Paul DeMars, Chief Engineer, the Yankee Network, Boston, Massachusets; Mr. Walter Damm, Manager, Station WTMJ, Milwaukee, Wisconsin; Mr. Kenneth Sliker, Chief Engineer, WHBC, Canton, Ohio, and the Ohio Broadcasting Company, and Mrs. Sliker; Mr. Mortimer L. Burbank, Manager, Station WJAR, Providence, Rhode Island; Mr. Thomas C. Pryor, Chief Engineer, Station WJAR, Providence, Rhode Island; Mr. Cecil D. Mastin, Manager, Station WNBF, Binghamton, New York; Mr. Clifford Harris, Chief Engineer, Station WIP, Philadelphia, Pennsylvania; Mr. Beverly T. Whitmire, Manager, Station WFBC, Greenville, South Carolina; Mr. Maurice Levy, Assistant Chief Engineer, Stromberg-Carlson Telephone Manufacturing Company; and Mr. Fred Allman, Manager, District Office, Graybar Electric Company, Richmond, Virginia. Mr. Allman had a dozen or more individuals with him from southern Virginia and North Carolina.

The Washington Sections of The Institute of Radio Engineers and The American Institute of Electrical Engineers, the Baltimore Section of The Institute of Radio Engineers, the Baltimore Radio Club and the Greenbelt Radio Club were specially invited to the meeting of the Washington Radio Club. Through the courtesy of these organizations, notices concerning the meeting were carried on their individual meeting announcements. President Albertson, in person, extended an invitation to the Baltimore section of The Institute of Radio Engineers and the Greenbelt Radio Club.

Fred W. Albertson, Esq., P.E., W4BD (LF) practiced law for 40 years in Washington, DC with the law firm of Dow, Lohnes, & Albertson. From the late 1930s until his death, the firm handled many legal matters for Major Edwin Howard Armstrong, including many of his exasperating problems with the Federal Communications Commission. With Albertson being a licensed broadcast engineer as well as a lawyer -- and a "ham" -- he proceeded with most of the contacts with the FCC and other regulatory agencies.

Now retired for 20 plus years and living in Key Biscayne, FL, Albertson continues to operate his amateur radio station W4BD. He has been a "ham" for 67 years. He was elected to the presidency of the Washington Radio Club in 1939.

THE AMATEUR RADIO SINGLE-SIDEBAND STORY

by **John C. Geist, N3BEK** (M)

Returning to Amateur Radio after a 33 year "sabbatical", I was amazed at the great improvement resulting from the use of single-sideband modulation. More than amazed -- flabbergasted! No power wasted in an rf carrier, no power modulator, no heterodyne interference.

I remember listening to the 75-meter phone band while visiting Ed Hill, W3FEG,[1] *in the early 1950s. It was practically as bad as CB at its peak with the addition of heterodyne whistles spread across the band.*

In 1980, I went on the air with a station consisting of a sold-state transceiver, an "antenna tuner" and an inverted-L (Marconi) antenna. With my out-of-date experience, the convenience, frequency agility and operating effectiveness of this simple setup were indeed astounding. I thought I was in heaven. The performance of this modest but modern station prompted me to investigate the AM-to-SSB revolution in Amateur Radio technology. The result is this **Single-Sideband Story.**

John C. Geist

BACKGROUND

In a single-sideband, suppressed-carrier transmitter, a carrier frequency is amplitude modulated with the signal to be transmitted. The carrier and one sideband are removed from the modulated signal and only the remaining sideband is transmitted. The receiver is designed to have a bandwidth just wide enough for the one sideband.

In order to recover (detect or demodulate) the original modulating signal, a signal of the same frequency as the original carrier signal must be reinserted into the received signal. This is the same function accomplished by the beat-frequency oscillator (BFO) in CW reception. The 1985 *ARRL Handbook* lists the following advantages of single-sideband, suppressed-carrier modulation:

Spectrum conservation.
More talk-power for a transmitter final stage (of equal peak output power.)
Elimination of carrier interference.
Reduction of multipath distortion.

The single - sideband, suppressed - carrier system was in use in the 1920s in both commercial radiotelephone and multichannel carrier telephone systems. The U.S. Air Force switched to SSB for long-distance communication for its improvement over conventional AM. The submarine underwater carrier telephone developed during World War II used SSB after tests proved that AM was unusable for that application.

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[1] Ed Hill is a ham-radio friend whom I met in Rehoboth, Delaware, in 1935. He has been active in Amateur Radio continuously since 1934. He was on SSB with a Central Electronics SSB exciter in 1954, and became acquainted with Wes Schum, founder of the company, through on-the-air sideband contacts. Ed had the thrilling experience of running some sideband tests with Generals Curtiss LeMay and Hap Arnold while they were airborne over Washington, DC taking signal-strength measurements through touch-and-go landings. He has a cherished QSL from "Curt" and "Hap."

The 1943 edition of Terman's *Radio Engineering Handbook* states that the reinserted carrier must be within ten Hz of the original carrier at the transmitter -- a formidable challenge for radios continuously tunable through 30 MHz. Clearly new concepts in rf circuit design would be required. Careful tuning of a modern receiver with digital frequency read-out shows that 10 Hz is undectable, + or - 50 Hz is quite acceptable, and that + or - 75 Hz is usable for amateur communication.

The World War II ban on amateur radio was lifted on November 15, 1945. The return to the ham bands was nearly instantaneous. Operation was strictly prewar: a few crystal frequencies, call CQ, and tune the band for an answer. Soon the HF bands were overloaded. Heterodynes were overwhelming.

In 1946, the ARRL technical staff made comparative tests of AM versus narrow-band FM. It was clear that FM was not a solution to the problem of over-crowding in the HF bands. George Grammer, Technical Director of ARRL, reporting the results of the tests in the February 1947 issue of *QST* stated: "The only solution to the question of enough space for 'phone eventually must be the adoption of single-sideband, suppressed-carrier techniques." He concluded: "...but would require such a complete overhauling of our transmitting and receiving methods that it is not likely to come about overnight." He was right on both counts.

GETTING STARTED

The first Amateur Radio SSB QSO took place on the 75-meter band in September 1947 between Oswald G. Villard operating the Stanford University club station W6YX, and G. Wagener, W6QVD. The results of the early experiments with SSB were reported by W6QYT in the January 1948 *QST*.

Within three months of the original test, at least eleven stations were experimenting with home-built sideband transmitters on the 75- and 20-meter bands. In the January 1948 *QST*, the editor took the position that the initial experiments proved the practicability of SSB/SC "as we're calling it", for Amateur Radio and they "point the way toward the most significant development that has ever occurred in amateur telephony..."

In the same issue, Byron Goodman, Assistant Technical Editor, presented a "primer" article entitled "What is Single-Sideband Telephony?". In the May 1948 *QST*, W2KUJ, Don Norgaard with the General Electric Research Laboratory, emphasized the advantages of SSB in an article entitled "What About Single-Sideband?".

In what turned out to be ambiguous wording,Norgaard seems to have claimed a 12 db advantage for SSB over AM.[2] In the January 1954 *QST*, an article entitled "The AM Equivalent of SSB", George Grammer, in questioning Norgaard's claim succeeded in further confusing the issue and then concluded "...the fact is that, power gain or no power gain, single-side sideband is capable of working rings around a.m. stations of much higher power." Norgaard made a significant contribution to the adoption of SSB with his article in the June 1949 *QST* explaining how combining phase-shifted carrier and modulating signals would generate single-sideband, suppressed-carrier signals without the use of narrow-band rf filters.

A flurry of articles promoting SSB appeared in *QST* during the early 1950s. These included instructional material, sideband-generator design, and information on sideband reception. SSB on-the-air activities were reported several times each year. Coast-to-coast, and east coast to Europe and New Zealand contacts were reported in 1950.

At the start of 1953, there were about 300 side-banders on the air.[3] Collins Radio Company used advertisements in the last three 1954 *QSTs* to promote single - sideband, suppressed - carrier modulation.

The first WAS, WAC, and DXCC SSB-awards were announced in 1956. Sideband articles continued to appear in *QST* throughout the 1950s and '60s but, after 1954, reporting of on-the-air activities was discontinued and the promotional and instructional articles were scarce. This new technology to amateur radio was established, but it was entering a long period of slow acceptance.

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[2]From the 1985 *ARRL Handbook*, page 9-5: "... at the risk of resurecting an old controversy, the overall advantage of SSB is on the order of 12 db." (power gain of 16). The 1987 *Handbook* reduces the advantage to a more reasonable 9 db. My number is 7.8 db.

[3]From the October 1954 *QST*, "Fifty Years of ARRL", page 75.

EARLY DIFFICULTIES

Through most of the 1950s, the lack of receivers designed for single-sideband hindered its use. SSB transmitters were designed specifically for the application but the only receivers available were the superhets designed for AM -- mostly commercial sets. The major shortcomings of the available receivers were: inability to keep both the VFO and BFO tuned to their precisely correct frequencies; the annoying pumping or thumping as the AVC (AGC) (attack too slow, decay too fast) tried to follow the sideband envelope; and the low level of the BFO output for strong signals -- equivalent to over modulation with its characteristic distortion and wide band splatter. There were many on-the-air references to "slop-bucket modulation" and "Donald Duck" audio which often led to emotional exchanges between AM and SSB advocates.

Successful reception required disabling the AVC, reducing the signal with the rf-gain control, and tuning the BFO for maximum intelligibility. Although some operators never were able to achieve acceptable SSB reception, many did. In time, the amateur community came to accept that when the transmitting and receiving equipments were properly adjusted and properly operated, SSB was capable of producing clean, intelligible communication-quality audio.

CONTINUING PROGRESS

An article in the April 1953 *QST* described the design of a complete SSB receiver. Thousands of amateurs had built the tuned-rf, regenerative-detector, audio-amplifier receivers that had become standard before World War II. Few, however, were capable of building a sophisticated superheterodyne.

The sidebanders continued to rely on commercial AM/CW receivers which were improved year after year, to provide easier tuning of and better audio quality from SSB signals. In the May 1953 *QST*, the late Murray G. Crosby (F), W2CYS, explained the product detector as a method of SSB demodulation superior to the conventional diode AM detector. This feature soon was added to some of the commercial CW/AM/SSB receivers, but they still were all-mode sets rather than ones designed specifically to take maximum advantage of SSB.

In 1958, the following fondly-remembered manufacturers were building equipment for SSB: Collins, National, Hammarlund, Hallicrafters, E.F. Johnson with the Viking line, Heath with a line of home-assembly kits, and Drake -- a newcomer, that year.

Wes Schum, W9DYV, founder of Central Electronics, gave SSB the initial impetus with his phasing sideband exciter. Unfortunately, the phasing circuits were inherently complex and required precision adjustment. It was recognized that the circuitry could be simplified if the unwanted sideband could be removed by a simplified passive filter. Also, the selectivity of conventional receiver IF amplifiers using tuned circuits, could be improved by substituting steep-skirt, flat-bandpass filters. In the February 1953 *QST*, Ben Roberts, W0IEU, of Collins Radio, explained the concept of the mechanical filter making use of the magnetorestriction phenomenon to provide sharp bandpass characteristics. Magnetorestriction mechanical filters were used in the Collins 75A-3 Receiver.

In late 1953, Collins introduced the famous S-Line transmitter and receiver using mechanical filters. The filter was a key improvement in amateur radio equipment designed specifically for single-sideband communication. But something even better was to come: the multipole quartz-crystal filter. The November 1961 *QST* carried a product review of the McCoy 9 MHz fixed-tuned, single-sideband crystal filter with a nearly-flat, 3 MHz pass band. That brief *QST* review may have been the initial announcement to the amateur community of this important technical advance.

THE BREAKTHROUGH

In late 1957, Collins Radio introduced the KWM-1 SSB Transceiver for the 20, 15 and 10 meter bands, advertising it as "The First Mobile Transceiver."[4] The KWM-1 was reviewed in the April 1958 *QST*. The reviewer recognized the technical achievement represented by the transceiver with the following comments: "...the KWM-1 may well mark the end of an era and the beginning of another. This unit is more than another piece of gear; it could be a way of life (in amateur radio)." "...we haven't been describing just a receiver or just a transmitter, we have been describing a **STATION**!" Unfortunately, as was other Collins equipment, the KWM-1 was priced out of the range of most Radio Amateurs.

In October 1959, Collins launched an extensive advertising campaign for the new KWM-2 Transceiver for 160, 80, 40, 20, 15, and 10 meter bands -- "Systems Engineered for Mobile and Home Operation."[4] This was not just advertising hype. In the transceiver, for the first time, the overall amateur radio station was integrated into a coordinated system. Previously, in both home-built and commercial equipment, the receiver, transmitter, and auxiliary functions were treated separately with little, if any, attention to overall station control functions, and operating convenience and effectiveness.

Sideband was a natural for transceiver design. Because power modulators were not required, it was practical to put the transmitter, receiver, and a single power supply in a single case of reasonable size and weight -- and more reasonable, of course, if the one power supply was put in a separate case. With the transmitter and receiver in the same case, it became easy to use one tunable VFO to set the frequency for both transmitting and receiving.

The transmitter and receiver were automatically on the same frequency by tuning a single dial. Further savings were realized by designing the circuitry to use common band switching, low-level amplifiers, bandpass filters, and carrier oscillator for both transmitting and receiving.

The transceiver brought a new method of operating to Amateur Radio. It no longer was necessary to tune the band to look for an answer to a CQ; with the transmitter and receiver locked on the same frequency, stations in contact would always be operated on the same frequency. For the first time, amateur-radio operators experienced true frequency agility. It was a chicken-and-egg situation: SSB made the transceiver practical, and the transceiver made SSB universally attractive.

Art Collins, W0CXX, (F) founder of Collins Radio, and General Curtiss LeMay were instrumental in converting the U.S. Air Force to SSB. It is clear that by the introduction of the SSB HF transceiver and the preceding development of the Collins S-Line, Art Collins also was instrumental in moving Amateur Radio into SSB communications.

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[4]The KWM-1 and KWM-2 were 175-watt PEP input, vacuum tube transmitters with ganged tuning of rf stages to provide single-dial tuning. There were sparate controls for tuning the output circuits of the transmitter final-amplifier tubes.

The other manufacturers of amateur radio equipment soon followed Collins into the potential transceiver market. A product review in *QST* referred to the "transceiver craze." By that time, Swan had entered the competition. Initially, the emphasis was on mobile operation. Soon, it was realized that the transceiver would become the standard for all HF and VHF amateur radio communication. These manufacturers, as a group, brought the price of transceivers down to the affordable range of many more amateurs.

The 1960s seem to have been a decade of consolidation in which the use of SSB grew steadily. Most, but not all, of the equipment advertised in *QST* was designed primarily for sideband. Even so, AM hung on tenaciously. In the mid-1960s, a product review of an AM-VHF set commented: "Sideband has not yet taken over VHF; there is still lots of AM operation on the VHF bands."

Some manufacturers continued to "sell" AM. But after the mid-1960s, it was clear that the AM supporters were fighting a losing battle. In addition to the old-line companies, a number of new manufacturers entered the SSB-transceiver market. Only a few of the new ones left a lasting memory. Drake and Swan entered early. Ten Tec entered the field modestly in September 1969. Atlas was introduced in 1974 and gained good acceptance for a few years.

The Signal One transceiver was always a mystery to me and, after reviewing the *QST*s carrying its ads, it still is. It seems to have been far ahead of the competition technically but priced two-to-four times higher. In one advertisement, the Signal One was described as "not a new transceiver, but a new Integrated Station" for the 160 through 10 meter bands with 300 watts input, two VFOs, untuned rf stages, single-dial tuning, and IF shift.

Signs of things to come: advertisements for the Johnson Viking line were discontinued at the end of 1966; in 1968, Heath replaced National on the inside back cover of *QST*; that same year, a company called Spectronics started advertising the Yaesu transceiver; there was no indication that it was manufactured in Japan.

In 1968, the June *QST* editorial discussed "appliance operators", National disappeared from *QST*, and Hammarlund disappeared in 1970. In January 1970, Yaesu replaced Heath inside the back cover. By 1970, one message was screaming from the pages of *QST*: after introducing the KWM-2

Transceiver, Collins advertised the same series of equipment in the same series of advertisements month after month, year after year. There was no indication of any changes in the Collins equipment while the competition was continually adding technical refinements.

THE LAST ACT

Information on transistors began appearing in *QST* during the 1960s. Transistors were used in the equipment described in many of the construction articles and, by the late 1960s, most commercial transceivers were built with solid-state electronics excepting for the power stages of the transmitter.

In the last half of the '60s, information was presented on the design and use of powdered-iron toroidal coils. The stage was set to integrate the technologies of SSB, narrow-band rf crystal filters, solid-state electronics, toroidal rf transformers, and digital control circuitry into an all solid-state, digital-frequency-readout transceiver with untuned rf stages, crystal-controlled frequency synthesis, and microprocessor control. This very significant technical achievement took place gradually over a number of years.

Japanese manufacturers took the lead in the introduction of digital control and "bells and whistle" features. In the early 1980s, they dominated advertising in *QST* with the rapid introduction of new models and, in the process, captured the U.S. amateur radio market. One by one, the U.S. manufacturers had been dropping out of the picture: Hallicrafters in 1976; Hy Gain/Galaxy and Henry/Tempo in 1977; Atlas in 1978; Swan in 1980 and, finally, Drake and Collins [5] in 1984. Ten Tec and Heath were the only U.S. manufacturers left[6].

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[5]As a subsidiary of Rockwell International, Collins returned in 1979 with the updated KWM-380 Transceiver. It was basic state-of-the-art but did not include the operating features being offered by the competition. The Rockwell ads were discontinued in 1984.

[6]The enigmatic Signal One Transceiver, technically updated and renamed "Mil Spec 1030" continued to appear in *QST* until 1986.

RECAPITULATION

The conversion from AM to SSB was preceded by AM-FM comparison tests conducted by ARRL and the report on these tests by George Grammer in which he concluded that Amateur Radio would eventually convert to sideband. Amateur activity toward that end started with the first SSB QSO in September 1947. Acceptance of single-sideband, suppressed-carrier moduilation by the amateur radio community was built on a series of technical improvements: i.e., the product detector, improved AVC, crystal-control of the reinserted carrier frequency, the narrow-band rf crystal filter, and the concept of combining the transmit-receive functions into a single transceiver.

It also had overcome an entrenched reluctance to leave the tried-and-true amplitude- modulation technology. By 1970, single-sideband, suppressed-carrier modulation was the normal mode for amateur radio HF communication. The AM-to-SSB conversion was complete.

The move to sideband, however, was only part of a much larger revolution: SSB, VHF-FM, FM repeaters, solid-state electronics, digitaltechnology, appliance-like transceivers, and the shift from American to Japanese manufacture. Both equipment and operating practice had undergone drastic changes. In some respects, Amateur Radio had become a different hobby. By about 1983, it had completed a thorough technical revolution, and the next technical advance was underway: the marriage of Amateur Radio and computers, and the move into Packet. But that is another story.

ACKNOWLEDGEMENT

Thanks to Jack Salin, W3FKT, Wayne Shaffer, W3QAN, and Jack Sobel, W0SVM, who supplied information and, especially, to Ed Hill, W3FEG, who checked the story for accuracy.

THE HERITAGE OF OLD ACOUSTICS: CARRIER AND SIDEBANDS

by **Kaye Weedon (M)**

The Remarkable Resonator

For the past century, little attention seems to have been given to the Helmholtz resonator which the inventor described in a mathematical paper of 1859, and in his famous book.[1]

Figure 1 shows its design: a spherical glass vessel with a short neck and circular opening.

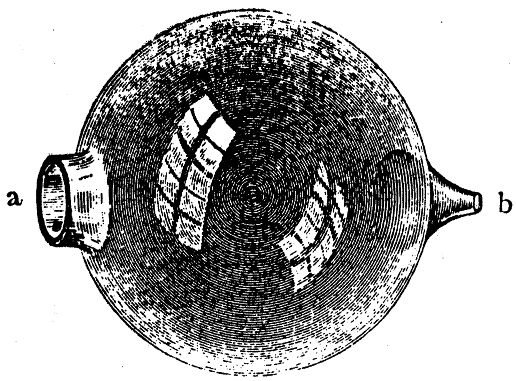

Figure 1. The Helmholtz Resonator

The absence of sharp corners and the high polish of the glass gave the spherical Helmholtz resonator the lowest air friction losses and, therefore, a very high Q.

The neck was carefully ground until resonance at the desired frequency was achieved. Opposite was a nipple which fitted into the listener's ear, the other ear being closed by a stopper. The hard and smooth glass inner walls gave minimal air friction and, of all possible shapes, the spherical was the optimal one.

For these reasons, the resonator provided a remarkably selective listening device. We have to turn to the modern electromagnetic wave cavities in order to appreciate the small losses of the Helmholtz acoustic resonator.

According to Terman,[2] such cavities were introduced in radio by W.W. Hansen in 1938. Terman quotes the case of two copper-walled cavities, one in the shape of a cube, the other a sphere. The cube had a Q of 24,000, the sphere 28,000. Although no measurements are known, we

Kaye Weedon

may conclude by analogy that the glass resonator had a Q which was hundreds of times greater than any passive electrical circuit could be made to have at similar audio frequencies.

Mayer's Experiment

In 1875, Mayer[3] published an acoustical experiment which is shown in Figure 2.

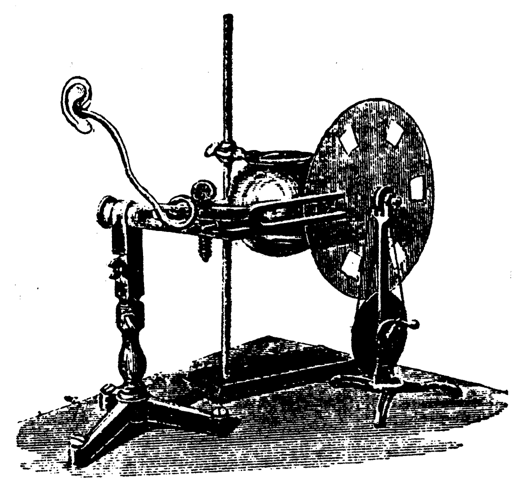

Figure 2. Mayer's Apparatus

A shutter wheel was rotated close to the mouth of the resonator. This interrupted the resonance excited by a vibrating tuning fork. Mayer did not interpret his observations in terms of the side frequencies.

A Helmholtz resonator was tuned to a frequency f_c.

The experimenter listened via a rubber tube; the other ear was closed by an ear plug.

In front of the mouth of the resonator was placed a revolving disc with a series of apertures. A steel tuning fork vibrating at f_c was held close to the disc, whereby the sphere resonated.

This resonance was, however, interrupted at a frequency f_m when the disc was turned at a certain speed. By hindsight, we know that the side frequencies ("side bands") were produced at $(f_c - f_m)$ and $(f_c + f_m)$. Mayer had presented a very early modulator. However, since his apparatus was very sharply tuned to f_c, he did not observe $(f_c - f_m)$ and $(f_c + f_m)$. Mayer did not interpret his observations in terms of the side frequencies.

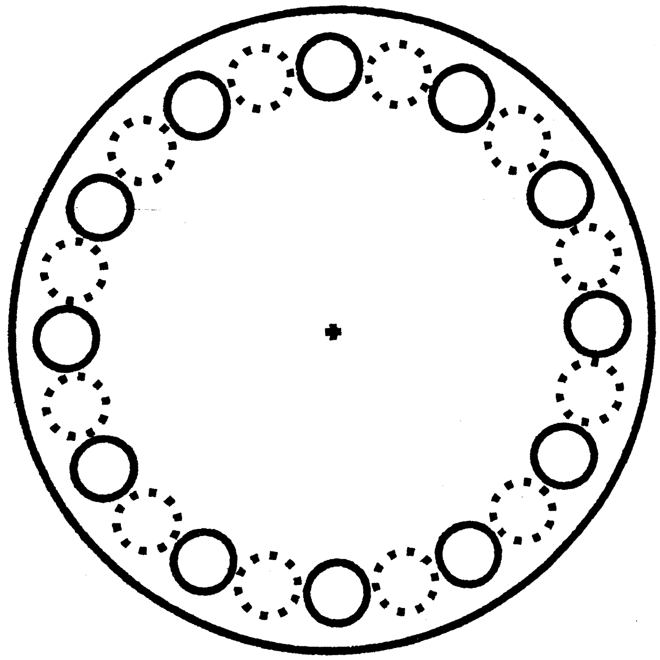

Figure 3

A wall in the laboratory was pierced by a ring of large holes. A sector shutter was rotated in front of them. The experimenters listened with two resonators, one held to each ear. A harmonium behind the wall was sounded at a frequency midway between those of the resonators. The side frequencies were heard simultaneously.

Carrier f_c and Side Frequencies $(f_c - f_m)$ and $(f_c + f_m)$ expressed mathematically by Crum Brown and Tait.

Lord Rayleigh, in a paper of 1880[4] and his "Theory of Sound",[5] stated that the correct explanation of Mayer's experiment was that given by Crum Brown and Tait in 1878.[6]

A wall or partition was pierced by a ring of large apertures through which issued a tone of frequency f_c from a harmonium (or an organ pipe) behind the wall. A sector disc revolved in front of the apertures, interrupting the sound at frequency f_m.

The side frequencies $(f_c - f_m)$ and $(f_c + f_m)$ were heard by the use of two different Helmholtz resonators, one held to each ear. The tone of the harmonium was chosen midway between the frequencies of the resonators and $(f_c - f_m)$ and $(f_c + f_m)$ were heard simultaneously. The high selectivity of the two listening resonators suppressed this middle or carrier frequency f_c.

Crum Brown and Tait, both skilled mathematicians, made use of a well-known trigonometric formula[7] for the product:

$$\cos a \cdot \cos b = 1/2 \cos(a - b) + 1/2 \cos(a + b) \qquad \text{Eq. 1}$$

and stated that the resulting sound was given by:

$$(1 + \cos 2\pi f_c t) \cdot \cos 2\pi f_c t = \cos 2\pi f_c t + 1/2 \cos 2\pi(f_c - f_m)t + 1/2 \cos 2\pi(f_c + f_m)t \qquad \text{Eq. 2}$$

Helmholtz Was First

Helmholtz described very briefly an experiment involving interrupted sound (or modulation).[1]

A cylindrical cavity of brass had a top surface with a central aperture while the bottom was pierced by a circular row of holes (Figure 4).

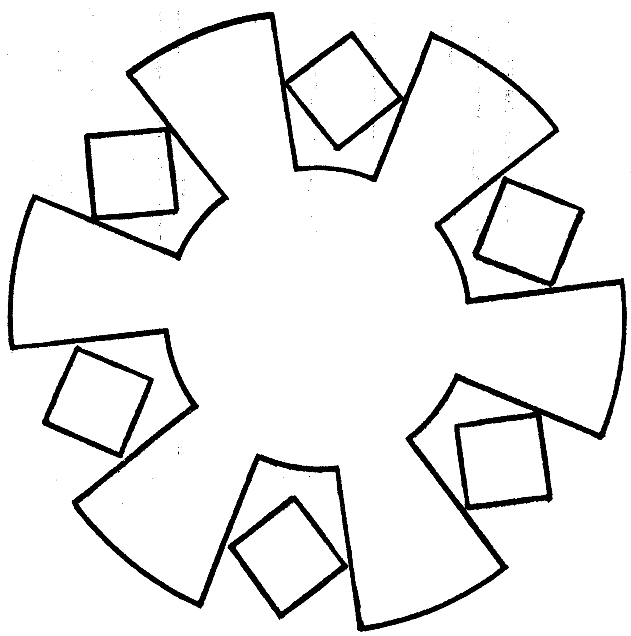

Figure 4

A shutter was rotated next to the bottom of a brass cylindrical resonator. This was sounded in resonance with a tuning fork. The shutter wheel interrupted or modulated the resonant tone. At sufficiently high values of the modulating frequency, Helmholtz observed the side frequencies by the unaided ear.

Close to the bottom of the resonator there revolved a disc with a similar row of holes. A sound source in the shape of a steel tuning fork was held close to the opening of the resonator which was tuned to the fork frequency f_c and, therefore, resonated.

However, this resonance was interrupted (i.e., modulated) by the rotating disc to give the frequency f_m. When the disc was rotated fast enough, Helmholtz heard the resultant side frequencies $(f_c - f_m)$ and $(f_c + f_m)$ simultaneously with unaided ears. He applied another trigonometric formula[7]:

$$\sin a \cdot \sin b = 1/2 \cos (a - b) - 1/2 \cos (a + b) \qquad \text{Eq. 3}$$

and stated the expression for the resulting sound to be:

$$(1 - \sin 2\pi f_m t) \cdot \sin 2\pi f_c t =$$
$$\sin 2\pi f_c t - 1/2 \cos 2\pi(f_c - f_m)t + \cos 2\pi(f_c + f_m)t \qquad \text{Eq. 4}$$

The date of the Helmholtz experiment has not been ascertained but may have been around 1865.

Applying the Modern Computer

Equations alone convey little meaning unless illustrated. We must do what previous generations could not: plot Eq.2 and Eq.4 by computer. Figure 5 shows computer plotted graphs for Equations 2 and 4. (They are identical so that a single plot is sufficient.)

To Conclude: The early workers in acoustics showed mathematically and by experiment what was to take decades to be re-discovered in radio engineering: a modulated carrier frequency equals a carrier flanked by upper and lower "sideband" frequencies.

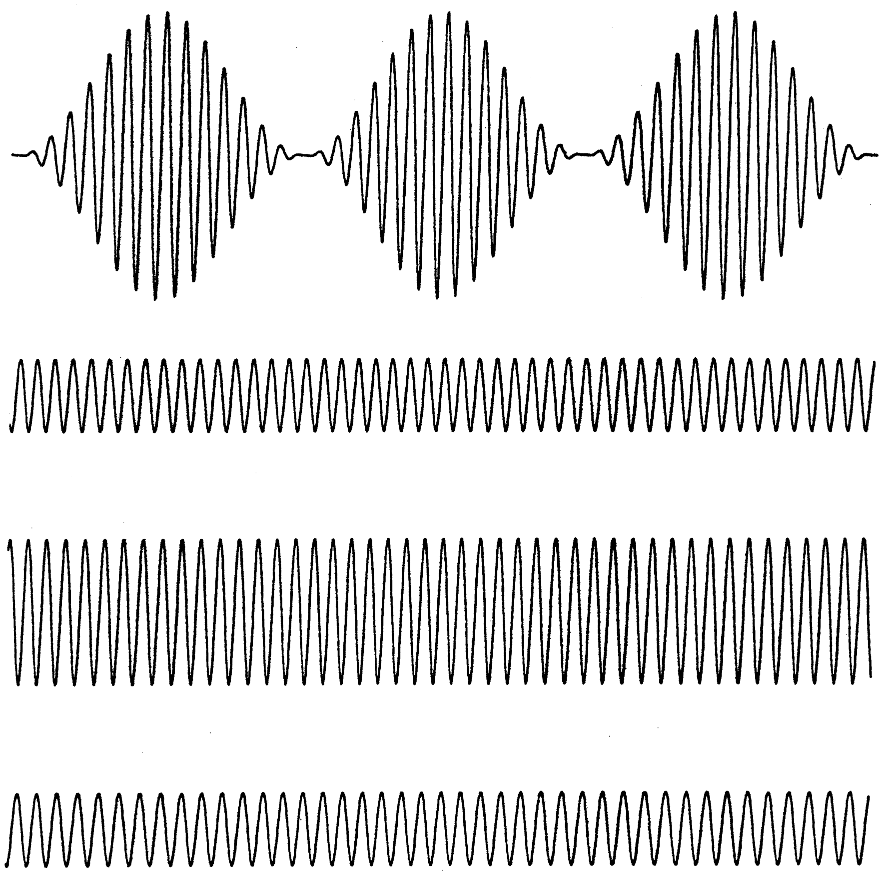

Figure 5.

The graph at the top shows a carrier modulated 100% with a sine or cosine envelope (left hand side of Eq. 2 and 4.)

Below: Upper sideband $(f_c + f_m)$
Carrier f_c
Lower sideband $(f_c - f_m)$

(Right hand side of Eq. 2 and 4.)

WHO WERE THEY ?

Hermann L.F. Helmholtz, (1821 - 1894). The productive genius of several sciences. Professor at Bonn University, later at Heidelberg. Biography in *Sensations of Tone*, 1954.

Alexander John Ellis, (1814 - 1890). Best known for his studies of phonetics and English dialects.

Alfred Marshall Mayer, (1836 - 1897). Professor of physics at the Stevens Institute of Technology, Hoboken, NJ.

Lord Rayleigh, (1842 - 1922). Professor of experimental physics at Cambridge University; one of the most versatile physicists ever. Biography in *Theory of Sound*, 1945.

Alexander Crum Brown, (1838 - 1922). Professor of chemistry at Edinburgh University, along with **Peter Guthrie Tait**, (1831 - 1901). Professor of physics.

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James E. Brittain, Ph.D. (F) for pointing out the existence of *Sensations of Tone,* 1954, later found to be still available,

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To **Amund Kjellstad** who produced Figure 4, and made various copies, and

To **Hans J. Weedon** who made plots of Eq. 2 and Eq. 4.

Mr. Kaye Weedon was born during 1907 in Christiania (Oslo), Norway. He graduated in 1931 in communication engineering then worked two years in radio factories. For a number of years, Weedon was employed in the photographic inporting house of J. L. Nerlien A/S, as Chief Engineer responsible for the sales of a variety of technical equipment. These included the "MUFAX" facsimile machines which enabled the Norwegian government to distribute weather charts to all airfields; also 52 newspapers were supplied with the Fairchild Scan-A-Graver machines which produced plastic printing "blocks" made on the spot from photographs. In 1969, he joined Kodak of Norway as a consultant to management until retirement in 1977. He is a contributor to the publications of the Norsk Teknisk Museum of which he is a Member for Life; also, he is an Honorary Member of the Norwegian Acoustical Society. His lifetime hobby has been research and writing about the History of Technology, especially in the fields of radio and vacuum tubes. One of his longer papers appeared in a 1980 volume of **Volund** *with the title of* "Breakthrough in Electronic Tube Devices; The Introduction of High Vacuum," *which discusses the works of Gaede, Coolidge, Langmuir, Houskeeper, van der Bijl, and others. Weedon was awarded the Houck Award in 1983 by the Antique Wireless Association (AWA).*

BOOKS THAT YOU MIGHT ENJOY:

EMPIRE OF THE AIR

by **Thomas S.W. Lewis, Ph.D.** (M)
Professor of English, Skidmore College

Tom Lewis' latest book, *Empire of the Air*, is a story of three men: Edwin Howard Armstrong, a genius who found a way to send signals loud and clear around the world; Lee de Forest, a flamboyant and ambitious scientist whose invention of the Audion laid the foundation of modern electronics; and David Sarnoff, a Russian immigrant who rose from a telegram delivery boy to communication czar as head of the Radio Corporation of America.

The narration has the stuff of real drama. It fills you with a sense that you are reading about a complex web of relationships and emotions that inevitably came into play between the three men who are, indeed, the men who made radio.

Told with clarity and intelligence, the book shines more light on the personalities of each man and their relationships than anything that has been published in years. The building of the world of radio was a strange blending of dreams and mundane work, and Dr. Lewis has explained it.

The book is something of a cliffhanger. Richer than the usual non-fiction; it is closer to a novel. Like a novel, it tells the narrative about three men's lives over a half century and is punctuated by acts of genius and treachery, idealism and betrayal. The subject is fascinating; the book a remarkable piece of craftsmanship in itself. Here is a real writer and chronologist at work.

The book will be a *Book of the Month* selection in January and the story will be told in a special two hour TV program to be presented over the Public Broadcasting System on January 29, 1992, and later on a radio program over American Public Radio stations. We eagerly await the TV and radio presentations.

This is a book I wish I had written. (Ed.)

352 pages, 32 pages of illustrations, 6 x 9 inches, with index, Harper Collins *Publisher*, New York, $25.00. May be ordered from the publisher at 1-800-331-3761. Visa, Mastercard or American Express cards are accepted. Please mention code #X0011 when ordering.

DON C. WALLACE

by **Jan David Perkins, N6AW** (M)

This recent biography about the late legendary Don Wallace, W6AM (M 1981,F 1981,L 1981), chronicles the life and achievements of that remarkable individual. More than just a biography, the author intertwines the personal life of Wallace and the history of Amateur radio.

Wallace's first experiment with a radio receiver on the West coast occurred when the Junior Wireless Club was being formed on the East coast. He built a spark-gap transmitter and made his initial contacts two years before the Department of Commerce began to issue licenses.

The book traces the birth and development of Amateur radio and the way it was impacted by the Great Depression and two World Wars. Wallace would be the radio operator for President Wilson on the voyage to the Versailles Peace Conference, win the 1923 Hoover Cup for the best home-built Amateur radio station, and put up 16 rhombic antennas on 120 acres that would form the largest non-commercial antenna farm in the world. With that station, Wallace achieved the top position on the ARRL DX honor roll in 1957, and occupied it for most of the next 28 years.

After the Viet Nam war, Wallace and the author became close friends. During their frequent meetings, Wallace related the stories behind his many certificates and awards, and of his early experiences in Amateur Radio. Perkins began to record the stories on a cassette recorded and, from that source, the biography of Wallace and the history of early radio was preserved. This book contains much of that information.

The book also contains appendices filled with vintage information such as early call-sign district maps, Morse and Continental code tables, etc.

Illustrated (200 photographs with 24 in color), 320 pages hardbound, 8½ x 11 inches with 16 appendices, glossary, bibliography, and index. The Vestal Press, Ltd.,Vestal, NY, publishers. $29.95. Radio Club members may order directly from the author for $25 plus shipping and handling ($3.00 U.S. or $5.00 overseas); limit one per person. Write to Jan D. Wallace, N6AW, 524 Bonita Canyon Way, Brea, CA 92621.

DON'T KNOW WHAT TO DO WITH YOUR SURPLUS ELECTRONIC EQUIPMENT?

by **Arch Doty, K8CFU** (LF)
Director & Chairman of The Legacy Fund Committee

Most members of The Radio Club owe their success to close associations with some aspect of electronics. Oftentimes, this has resulted in the accumulation of unique, historic or interesting pieces of electronic equipment. The true "Pack Rats" in the collection of equipment are, of course, the many Club members who are Amateur radio operators.

Regardless of where the equipment came from, or what its intrinsic or historical value may be, the persistent question (most often voiced by wives) is: "What should we do with all of this stuff?"

The Legacy Fund of The Radio Club may provide an answer.

The Legacy Fund was set up by the Club's Directors so as to consist of invested assets whose income (from dividends or interest) is used to partially pay the day-to-day operations of the Club.

Assets for this Fund come from gifts and bequests made by members of the Club, and from other individuals or organizations. The financial goals are that when the income from the Fund is sufficient to pay the operational costs of the Club, then other sources of income may be used exclusively to support scholarships and other types of grants that would be in the best interests of the electronic community.

The operational costs of the Club, exclusive of the scholarships awarded by the Grants-in-Aid Committee, are minimal since all of the Club's activities are handled by volunteers. Even the traveling expenses relating to attendance at the meetings of the Board of Directors are borne by the involved member.

A feature unique to The Legacy Fund is that donations to it may be in the form of electronic or other equipment of historical interest, or of potential value to The Radio Club. Such gifts of equipment may be made at any time, or as a bequest in a will. In either case, the donation will garner the benefits of your making a gift to the Club -- a tax-exempt organization operating under the provisions of Section 501(c)(3) of the Internal Revenue Code of 1954.

An excellent example of a gift of equipment was the donation made several years ago by Dr. Thomas T. Goldsmith (LF), formerly Vice President of Engineering of the Allen B. DuMont Laboratories, Inc. He gave the Club a number of the early DuMont television sets together with a wealth of data, films and other materials documenting the activities of Dr. Allen B. DuMont and the DuMont Laboratories. The Club is making arrangements for the permanent public exhibition of this collection of irreplaceable historic equipment.

Another prominent member has added a codicil to his will specifying that all of his Amateur radio equipment and related electronics should be sold at the time of his death, and the proceeds given to The Legacy Fund.

Two members have commenced periodic donations to the Fund, thereby spreading their contributions over a number of years while their earning powers remain at their best. One has chosen to make cash donations; the other chose to donate the computer system upon which this publication is composed.

The goal of the Board of Directors and the members of The Legacy Fund Committee is to establish the equivalency of an endowment fund similar to that which supports our leading colleges. Such endowments permit an organization to maintain excellent standards regardless of fluctuating economies. In our case, the earnings of The Legacy Fund will stabilize the dues structure while permitting greater services such as improved publications.

Gifts of various types may be made to The Legacy Fund of The Radio Club of America, as follows:

1. Donations of electronic or other equipment of significant historical interest, or of practical use to the Radio Club of America.

To make arrangements for evaluations (for tax purposes), shipments and final disposition of such donations, please communicate with:

Mr. Arch Doty, Chairman
Legacy Fund Committee
Radio Club of America, Inc.
347 Jackson Road
Fletcher, NC 28732
phone: (704) 684-5871

2. A bequest in your Will to The Radio Club of America of cash, securities, or radio equipment of historic or intrinsic value.

It is recommended that you arrange with your attorney for such a bequest to be included in your Will. The codicil language used by one member in making his bequest was:

> **"I give and bequeath to the Radio Club of America, Inc., New York, so much of my electronic equipment as it may desire to have or use, the remainder of such equipment to be sold by my Executor and the proceeds thereof given to the Legacy Fund of The Radio Club of America."**

Please advise Arch Doty, Chairman of the Legacy Fund Committee if you are arranging a bequest to the Club.

3. By an immediate individual or corporate gift of cash or other negotiable assets. Such gifts may be made in the name of the donor or any other person or organization.

Gifts of this type may be sent -- marked "Legacy Fund", please -- directly to:

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For further information, please communicate with the Chairman of The Legacy Fund Committee.

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A PRACTICAL APPROACH

by **Dr. Albert D. Helfrick, P.E., (F)**

This text fills a gap between texts covering the theoretical aspects of spectrum and network analysis, and the instruction book of a spectrum or network analyzer. It is a source of practical information together with a complete description of the fundamentals and techniques of spectrum analysis.

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If you are a practicing engineer working in the fields of signal processing and communications, and seek to develop a thorough knowledge of spectrum analysis, then you will find this book to be an invaluable reference source.

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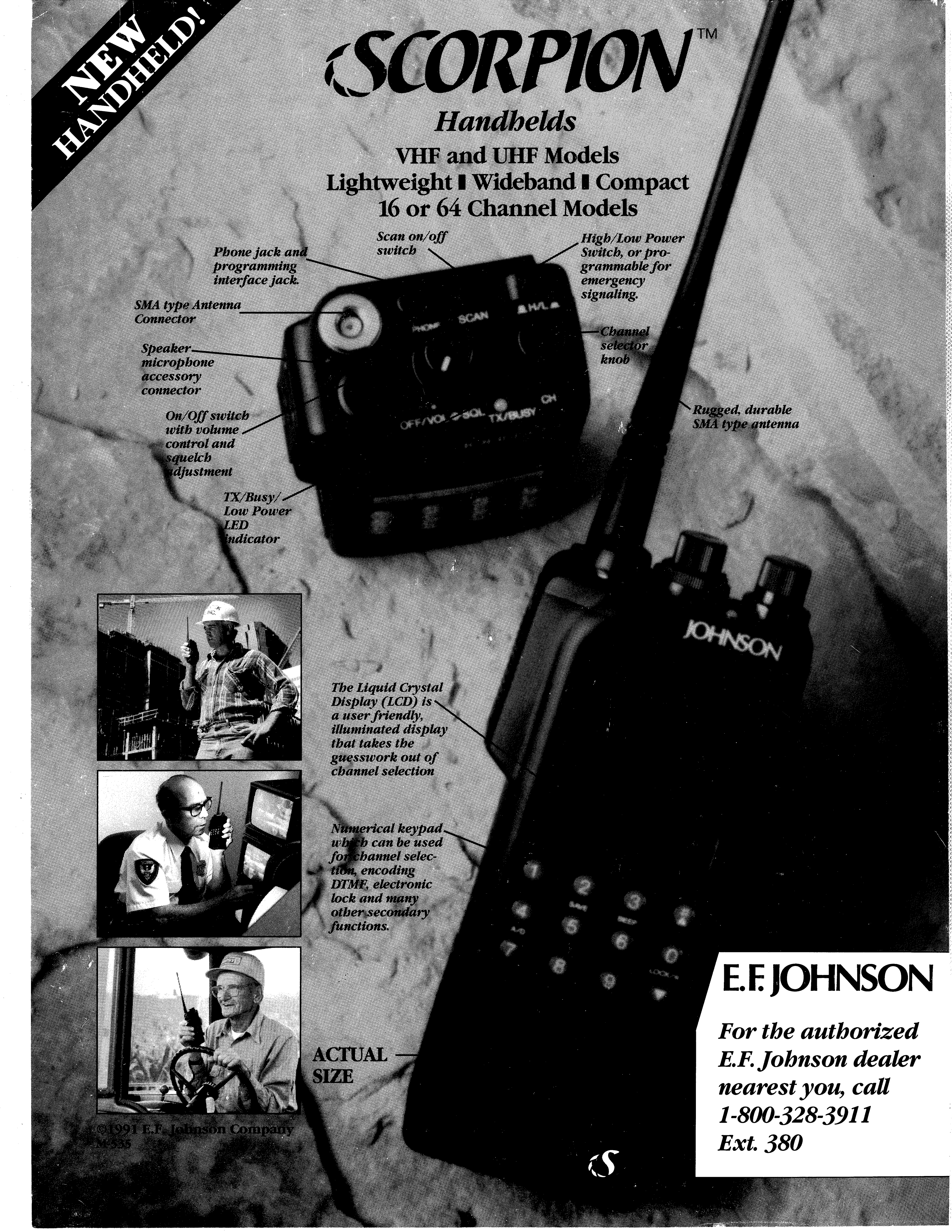
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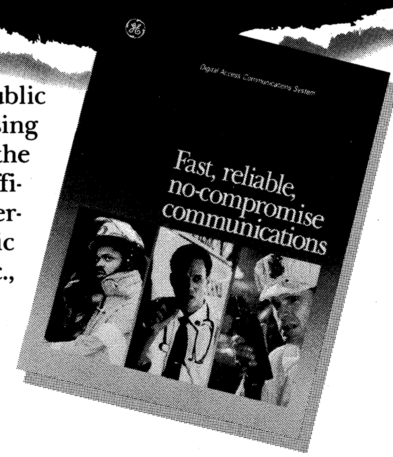

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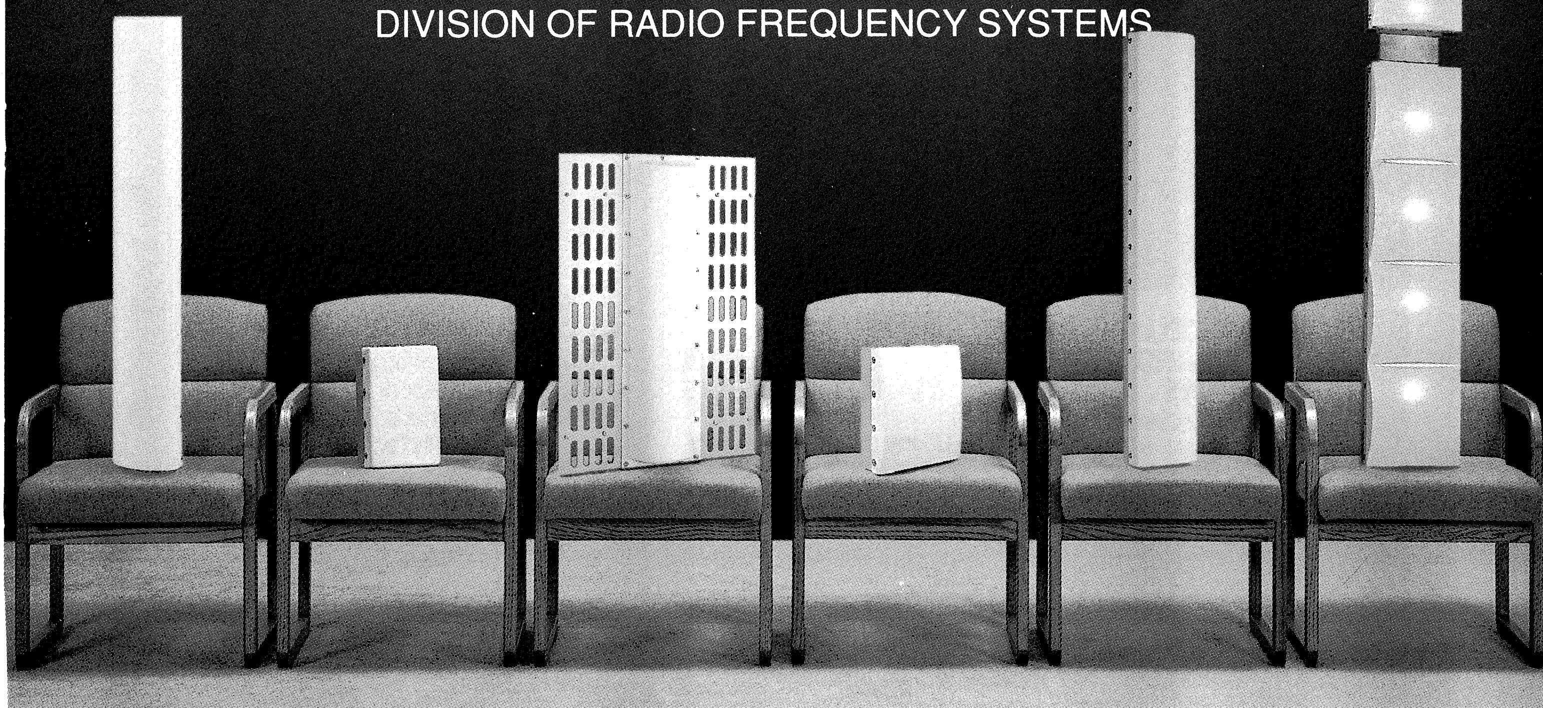

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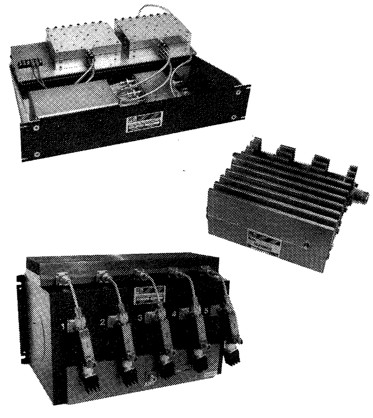

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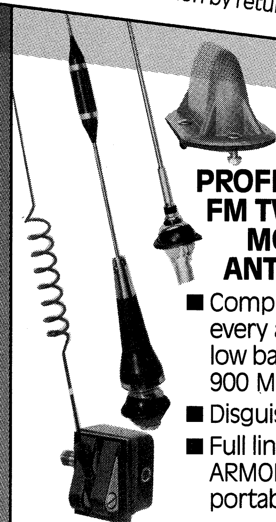

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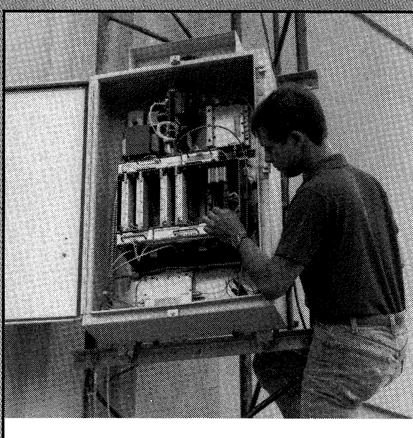

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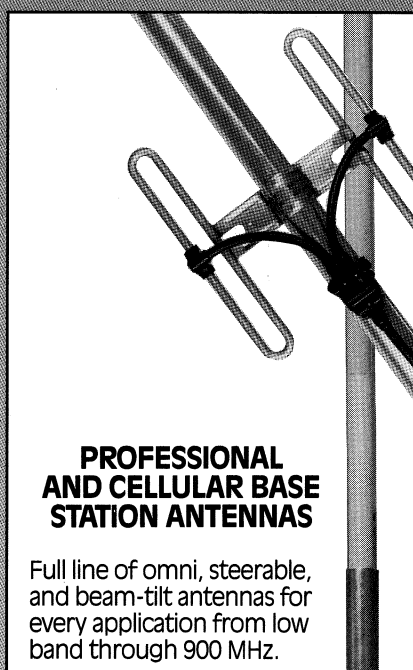

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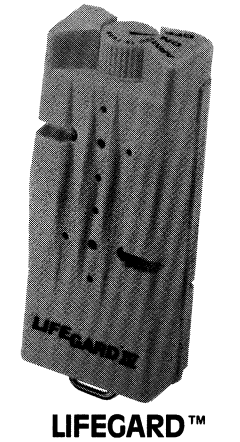

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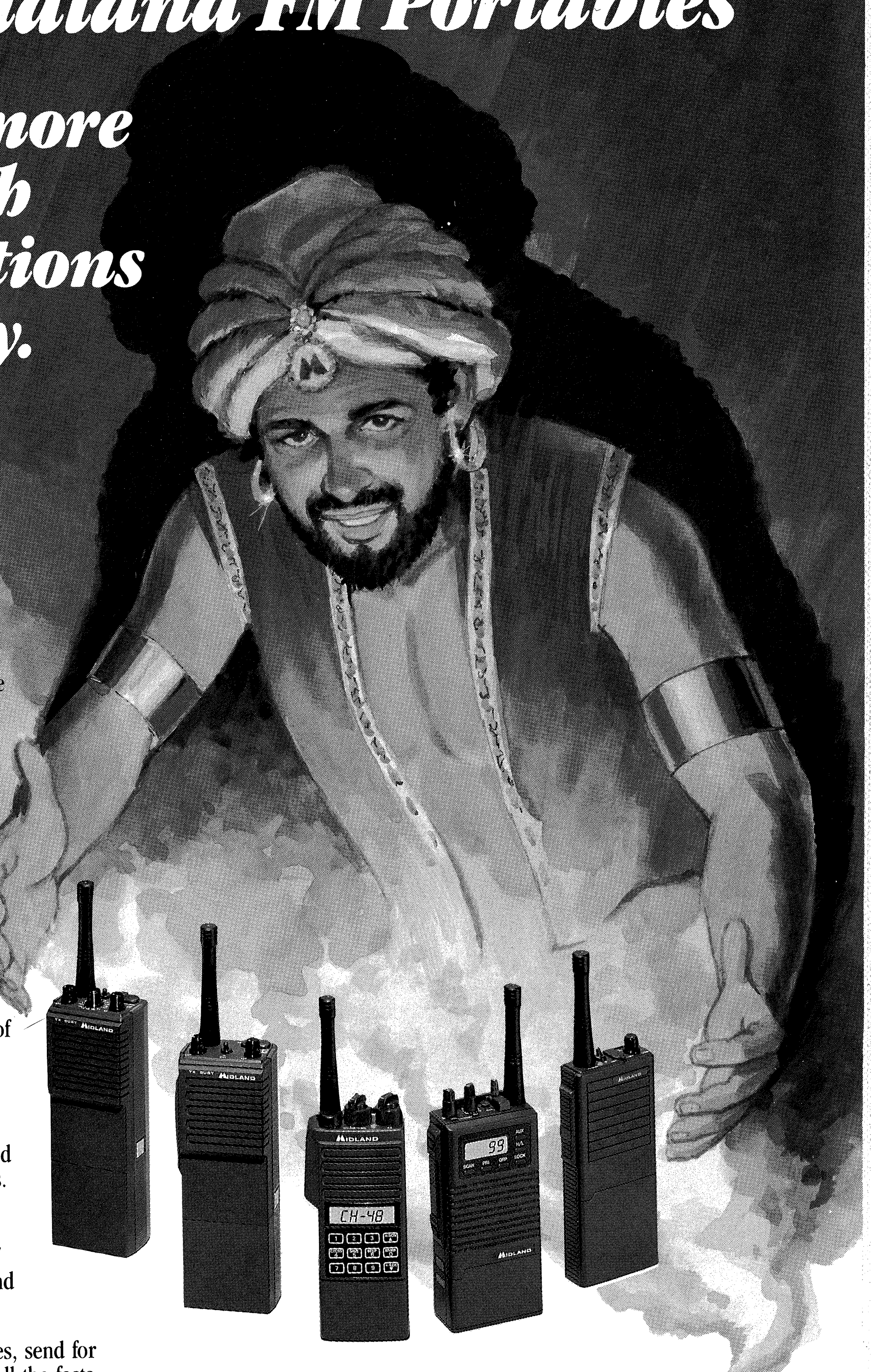

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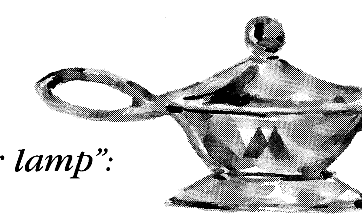

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