Proceedings of

The Radio Club of America, Inc.

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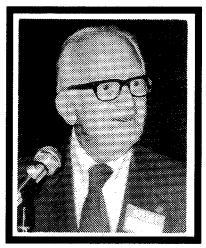
Founded 1909

The Radio Club of America

FOUNDED 1909

EXCELLENCE IN BROADCASTING



Jack R. Poppele 1898-1986

JACK POPPELE BROADCAST AWARD

Presented to

FOR HIS LONG TERM CONTRIBUTIONS TO
RADIO BROADCAST IMPROVEMENTS

PRESIDENT

SECRETARY

DATE

THE RADIO CLUB OF AMERICA, INC.

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

THE RADIO CLUB OF AMERICA, INC.

45 South Fifth Street, Park Ridge, NJ 07656

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The Jack Poppele Broadcast Award

The Board of Directors have approved the establishment of The Jack Poppele Broadcast Award which is to be granted for the first time during the 80th Anniversary Awards Dinner held on November 17, 1989. The award to Mr.Leonard Kahn is in recognition of his long-term contributions to the improvements of radio broadcasting.

Jack Poppele became a member of The Radio Club in 1941; was elevated to the Grade of Fellow in 1942, became a Life Member in 1970, and an Honorary Member in 1985. He served with distinction as Vice President in 1967 and 1968 and as a Director in 1965-67 and 1969-83; he was elected to Director Emeritus for Life in 1983.

He was awarded the Sarnoff Citation in 1974 "for Significan Contributions to the Advancement of Electronic Communications." His career spanned the entire history of broadcasting and he was an early advocate of AM radio stereo broadcasting. President Eisenhower appointed him to the position of Director of The Voice of America, U.S.I.A.

He was an outstanding pioneer whose contributions have brought pleasure and enlightment to many.

Editorial Opinion

THE WAY WE LOOK

This issue of *The Proceedings of The Radio Club of America, Inc.* is being prepared in its entirety on a computer using its word-processing facilities, by members of The Radio Club. It has been quite an undertaking.

Perhaps to be honest, we should say that the advertisements were not prepared on our computer but rather supplied to us by the advertising agencies. The text material, however, was prepared on the Tandy 1000-TX computer donated to the Club some months ago by **Mr. Jay Huckabee,** W5EPJ **(F)**.

The text was prepared in three locations and since the equipments and software were dissimilar, each article was prepared in the ASCII format on a floppy disk then sent to our Treasurer, **Dr. Eric Stoll,** K2TO **(LF),** who converted from the ASCII format to the *WordStar 2000* format which matched the software used by your editor.

Here, a decision was made to emulate the layout used by the *IEEE Spectrum* and *The Smithsonian* but using the Helvetica type faces available in our H-P printer. We tried other layouts as well as the Courier type face that's built into the software, but made our decision based upon the ease of reading the final drafts.

We're still experimenting. We'd like to acquire a scanner so that we could convert photographic material, line drawings, and other graphics into the language of the computer. That would eliminate the halftone photographic work now being done by our printer. And we think that it would save us more money.

Yes, we're saving by doing the "typesetting" on out equipment. The printer currently is charging $ 70 an hour to convert typed or handwritten documents into dummies that then must be proofed, and cut-and-pasted. That's expensive, too.

We're not trying to deprive a typesetter or his boss of well-earned profits but, after all, The Radio Club is not a wealthy organization. We're trying to keep the dues structure to a reasonable scale so that it won't be burdensome to anyone, particularly our retired members.

WHAT ELSE ?

This layout of *The Proceedings* developed from experimentations in the last few issues of *The Newsletter*, and there'll probably be more experiments. Our goal is to have a format that looks professional and that supports the excellence of the papers that we publish.

There is a further goal. During December 1990, we shall be commemorating the centennial of the birth of Major Howard E. Armstrong. One project will be the publishing of a "year book" edition of *The Proceedings* having a hundred or more pages. Of course, that will take a lot of work by our members.

The material to be included is being obtained from many sources. We'd like to be able to reprint all of the papers presented at the early Radio Club meetings by Armstrong and then published in the early issues of *The Proceedings*, but we're not having much success in obtaining those early issues.

Our plea to members for help in searching out articles written by or about Armstrong, has helped. **Robert M. Morris**, W2LV **(M)** sent along an unpublished paper presented by Dana M. Raymond, Esq., Armstrong's attorney, in 1974 on the occasion of the 10th Anniversary of the New England Wireless and Steam Museum. It gives an insight into a part of Armstrong's life that we haven't seen before.

Alan S. Douglas (M) has offered help through the writing of a paper defining the conflicts between Armstrong and deForest over their patents.

Dr. Hugh G. J. Aitken, W1PN **(F)**, has granted permission to excerpt parts from his book *The Continuous Wave*.

The Antique Wireless Association through **Bruce Kelley**, W2ICE **(F)**, has granted permission to reprint a paper presented at an AWA Conference in 1971 which describes the field tests of the Armstrong FM system which were made from the Empire State Building during 1934 and 1935.

We're continuing to solicit papers, photographs, or articles such as newspaper cuttings which will help to tell the story of Armstrong's life and achievements. If you have access to any, please write to us. Thanks.

WHITHER GOETH THE CLUB ?

From its founding in 1909, The Radio Club has functioned under a Constitution and a set of By-Laws drawn up by the membership. The Constitution seldom is amended and an affirmative vote of two-thirds of the membership is required to make a change. The By-Laws which cover the nitty-gritty of the day-to-day operations requires only a majority vote of the Board of Directors to effect a change.

If you're interested in the two documents, you'll find the text of each in the *Diamond Jubilee Yearbook,* and in the 1986 Membership Directory. Both are excellent documents that have served the Club well over these 80 years.

We're now reviewing each to see whether the Club might be improved through amendments or additions to the Constitution or By-Laws. We'd like to see our Sections become more active and thereby benefit those members who find it difficult to attend the Club's annual meeting with its technical seminars and award dinners. Maybe lowering the Section membership requirements from 15 to 10 persons might help, and that can be changed in the By-Laws.

There are plans to publish a new Membership Directory during 1990. It probably will be issued in July and cover the membership through June. Advertising will be accepted. Like other directories, the Radio Club Membership Directory is an item that is saved and frequently referred to - thereby making it a particularly good place to put a message that will be read over a long period.

We'd like to increase the size of *The Proceedings* to include more and longer items. Because of the diversity of professions and interests of our members, it sometimes is difficult to find papers that interest everyone, but that is our goal. In failing to find articles of general interest, the solution lies in publishing more papers that might be of specialized interest with the goal of covering as many areas of electronic communications as may be possible.

With the excellent trade journals, Amateur radio publications, and other specialized magazines, we must find a niche that is somewhat different. The ideal would be to duplicate the successes of the early issues wherein new developments and inventions such as those of Armstrong, et al., were discussed.

WE NEED YOUR HELP

This is an exciting time to be associated with the field of electronic communications. Almost daily, announcements are made of new techniques, new equipments, and improved services. Each contribute to the prosperity of the individual and the nation.

We want to tell your story of what's happening. We have two "mouthpieces": *The Proceedings* and *The Newsletters,* where we can let the World know about you. We're not very good about publishing hype pieces sent out by public relation departments but we might excerpt something about you if it relates to radio or other forms of communications.

Besides telling your story, we're ready to help you to give a scholarship to some youngster who might become another wizard. Many of us, alone, cannot do much to help the schooling of someone other than our own kids but when our few dollars are co-mingled with those from a few dozen others, there's usually enough to do some good.

That's the purpose of the Club's Grants-in-Aid Fund. It began in 1977 when **Capt. William G. H. Finch, USNR (ret.), D.Sc., P.E.,** a Life Fellow and Director Emeritus of the Club, made a gift of $ 10,000 to the Club to establish a scholarship fund. That nest egg has grown to over $ 175,000 through prudent investments and contributions from other members. The latest large donations were in the sum of $ 10,000 each from **Alfred H. Grebe, Jr. (F)** in memory of his father, and from the family of the late **Jack Poppele (H)**.

But for every such large contribution, there have been a hundred smaller ones - those of five or ten dollars sent when someone paid their dues. Those are important because they quickly add up to a significant sum, and because someone has thought for a moment of how they could help someone else through the Club's teamwork.

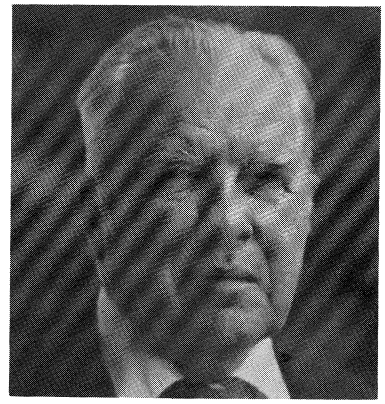
And so, Friends, you now have an idea of what's on my mind as we put this issue of *The Proceedings* to bed. It'll be in your hands in a few days and we'll be working on the issue for next May together with the advanced articles for November 1990's issue dedicated to Armstrong.

Thanks for listening

JWM.

Tutorial on MAGNETIC RESONANCE IMAGING

By **Jerry B. Minter (LF)**
Director Emeritus

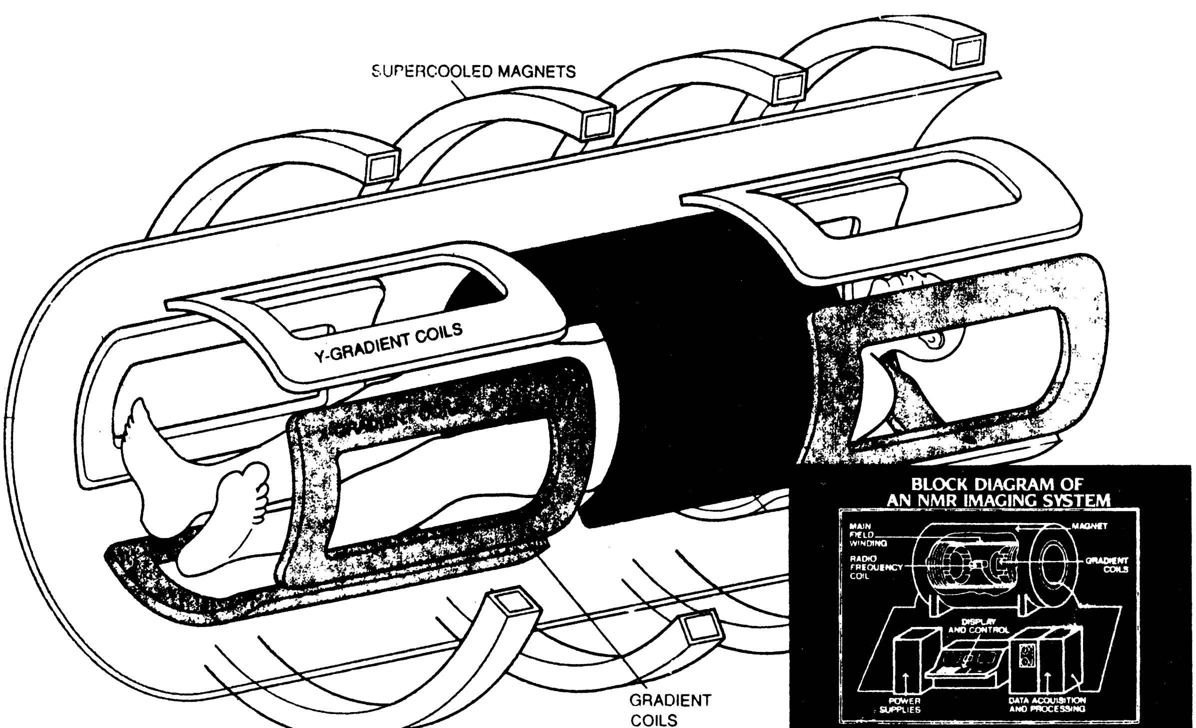


Magnetic Resonance Imaging was originally designated as NMR for Nuclear Magnetic Resonance Imaging; however the general public misunderstood the use of the "nuclear" term, so a change was made to MRI and occasionally to just MR.

For many years magnetic resonance of atomic nuclei has been used in chemical analysis of biological samples. The resonant characteristics of atomic nuclei in a magnetic field were discovered in 1946 by two different research efforts under the direction of Purcell at Harvard and, simultaneously, by Bloch at Stanford. These two scientists were jointly awarded the Nobel Prize for Physics in 1952.

In 1971, Damadian wrote a technical paper noting the differences in relaxation times between tumors and normal tissue. In 1972, Damadian was issued the first patent on MR scanning (US patent #3,789,832). Dr. Damadian is founder and president of FONAR Corporation.

In 1972, Lauterbur demonstrated how the MRI signals could be converted into images by means of a particular reconstruction method. Much progress has been made by Philips, General Electric, Fonar, Resonex and many others in refining the display technology. For example, it is now common place to synchronize the timing of the rf pulses with the heart rate to reduce blurring from heart motion.



Superconducting magnet is the most critical part of a high-field MR system. generating the static field required for the polorization of the nuclei. The computer is also crucial, controlling the overall operation of the scanner. It provides the pulse-timing information for the gradient and radio-frequency transmitter coils. It also switches on the preamplifier and the receiver circuitry during the time when data is being acquired from the spinning nuclei in the body. Finally, the computer reconstructs the data to form cross-sectional pictures of internal body structures.

The nucleus of an atom is made up of protons and neutrons. Since the atomic particles are grouped in pairs that rotate in different directions, atoms with an even number of protons and neutrons tend to cancel their external magnetic fields.

Fortunately the nuclei of Hydrogen, Sodium and Phosphorous do exhibit a weak external magnetic field as the result of their rotation or spin. These nuclei also can be made to precess when disturbed by a synchronous magnetic pulse of rf at their natural resonant precession frequency.

The process of precession is exhibited by a spinning top when it is starting to lose momentum. In the case of the nuclei spin disturbance, the precession or axis of rotation wobble occurs in the high frequency region from 20 MHz to about 100 MHz when a dc magnetic initial polarizing field is about 1.5 Tesla or 15,000 Gauss. Since the signal levels are very low in amplitude, the magnetic resonance equipment must be shielded from stray rf fields such as from FM broadcast and television stations which are located in this part of the frequency spectrum.

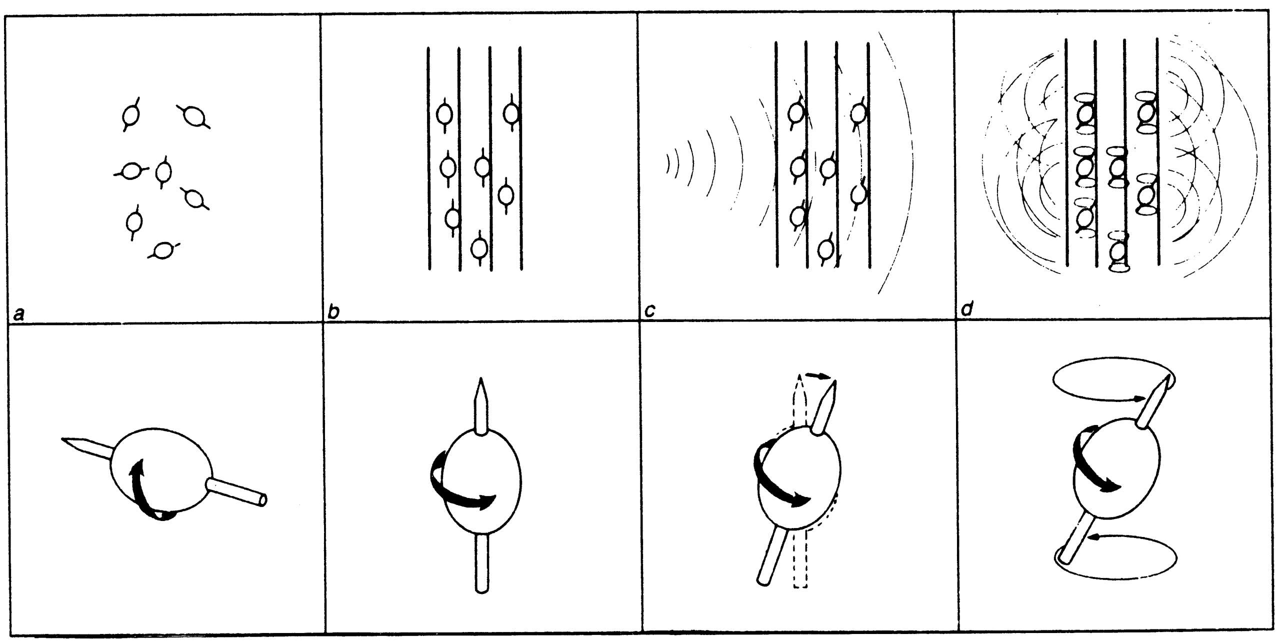
From Figure 1a, it can be seen that the various nuclei are randomly oriented in the absence of any external magnetic field. When a strong steady state or dc magnetic field is applied, Figure 1b indicates how the various nuclei align their respective rotation axis with that field.

1. *Sequence of events in MR observation. Randomly oriented nuclei tend to align with an applied magnetic field, and are shown releasing electromagnetic energy after excitation with radiation at their Larmor frequency.*

When a magnetic force is applied to these aligned nuclei perpendicular to the direction of the dc field, the axis of the nuclei are tilted away from the aligned equilibrium direction and will go into precession around the direction of the dc field. The frequency of this precession is called the Larmor frequency and is given by: $\mathbf{f} = \mathbf{kB}/6.28$ where **B** is the magnetic field strength, and **k** is the gyromagnetic ratio, which is a constant for each type of nucleus.

This perpendicular force is applied by a pulsed radio frequency signal at the Larmor frequency. The duration and strength of this rf pulse can be adjusted to tilt the axis though any angle from the aligned equilibrium position as shown in Figure 1c.

As the result of axis displacement the nuclei absorb energy. As soon as the rf pulse ceases, the nuclei will start to reorient back to the original dc magnetic field. During this reorientation the absorbed energy is emitted in the form of a weak radio signal that can be detected by a suitable antenna. (See Figure 1d.) The time constant associated with this return of a group of nuclei is known as the longitudinal or spin-lattice relaxation time, **T1**. Since the precise value of the local magnetic field strength varies due to the presence of neighboring atoms, the nuclei begin to precess at slightly different frequencies. Therefore the nuclei begin to fall out of phase with each other, so that, though still rotating, they rapidly assume random orientations of their respective axes. Consequently the signals emitted from the nuclei interfere with one another, which causes a rapid decrease in the received radio signal. The time constant associated with this transverse or spin-spin relaxation time is called T2.



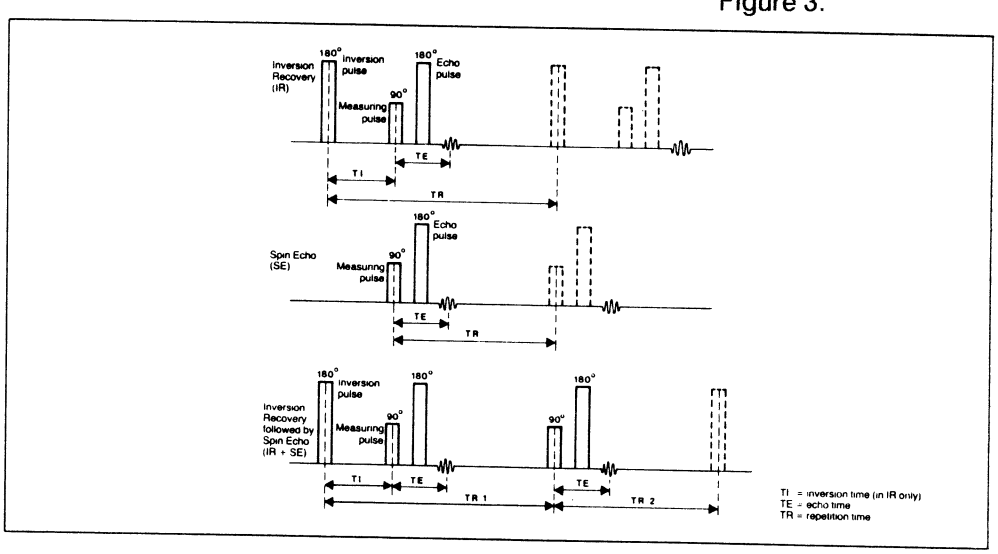
This shift of the Larmor frequency in the presence of neighboring atoms is known as the chemical shift. Therefore to sum up, the significant parameters associated with MRI are: the proton density; the spin-spin relaxation time **T2**; the spin-lattice relaxation time **T1**; and the chemical shift. The first three parameters are important for image construction while the chemical shift of the Larmor frequency is used in MR spectroscopy to identify the presence of various water/fat compounds.

Figure 2 lists the relaxation times in milliseconds at 0.5 Tesla (5,000 Gauss). Greatly increased relaxation time is characteristic of tumors. Unfortunately MRI is not yet proven reliable to identify which tumors are malignant. Other techniques such as radioactive isotopes and SPECT (single proton emission computer tomography) are available to identify the presence of malignant tumors.

2.T1 and T2 Relaxation times (ms) at 0.5 tesla

	T1	T2
Fat	200	130
Bone with marrow	220	50
Yellow ligament	350	25
Skin	400	25
Connective tissue	420	20
Scar fibrosis	500	30
Muscle	600	70
Disk protrusion	730	50
Glioma cyst fluid	2100	1100
CSF	3500	2600

3. *Time Intervals in pulse sequences. The 'square' pulses represent the bursts of RF employed as pulses to cause inversion, re-phasing or to allow measurement. The oscillating signals represent the MR response signals.*



In order to secure data for the production of images, it is necessary to utilize several variables, for example, the repetition rate of the rf pulse, **TR,** must be varied as well as the duration and strength of the rf pulse. Of course the proper radio frequency must be used to select which nuclei is to be observed. Since Hydrogen is present in the body fluids and yields a stronger signal response than some of the other nuclei, it is used frequently for MRI. Figure 3 shows some time sequences. The rectangular forms represent the rf pulses which are applied perpendicular to the dc magnetic field. The oscillatory forms represent the weak MR response signals which are usually detected by the same antenna which transmitted the rf pulses.

Each MR imaging sequence yields a signal whose strength depends on all three parameters: proton density; **T2**; and **T1**. By using different imaging sequences the effect of each parameter can be emphasized. The imaging sequences which are frequently used are:

SPIN ECHO SEQUENCES

In this imaging sequence the influence of **T2** is maximized together with the basic proton influence. If a short **TR** time is used, the resulting excitation is started before re-magnetization is completed and **T1** influence is also introduced into the image signal.

INVERSION RECOVERY SEQUENCE

An inversion (180 degree) pulse is applied a short time before the signal excitation pulse. Prior inversion of the magnetization introduces a large **T1** influence in the image signals, which are measured in the same way as the spin echo imaging sequence. The reconstructed image thus contains a **T1** contrast superimposed on the proton density and **T2** contrast. The Inversion Recovery sequence and the Spin Echo sequence can also be combined to a Mixed sequence as shown in Figure 3.

FAST FIELD ECHO IMAGING

MRI with useful quality can be obtained in only a few seconds using this technique; however, there is a trade-off in contrast and signal-to-noise ratio. The contrasts generated are dominated by proton density and T1.

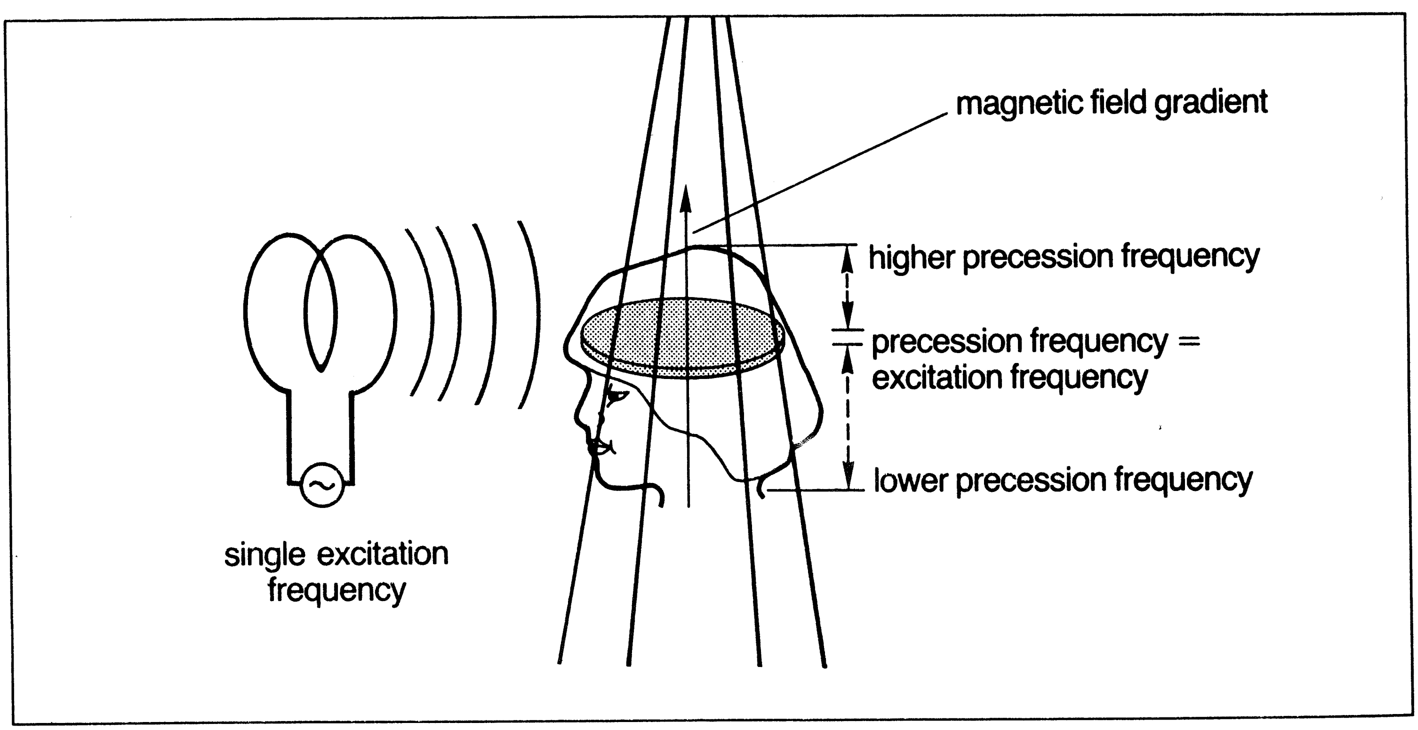
DISPLAY TECHNOLOGY

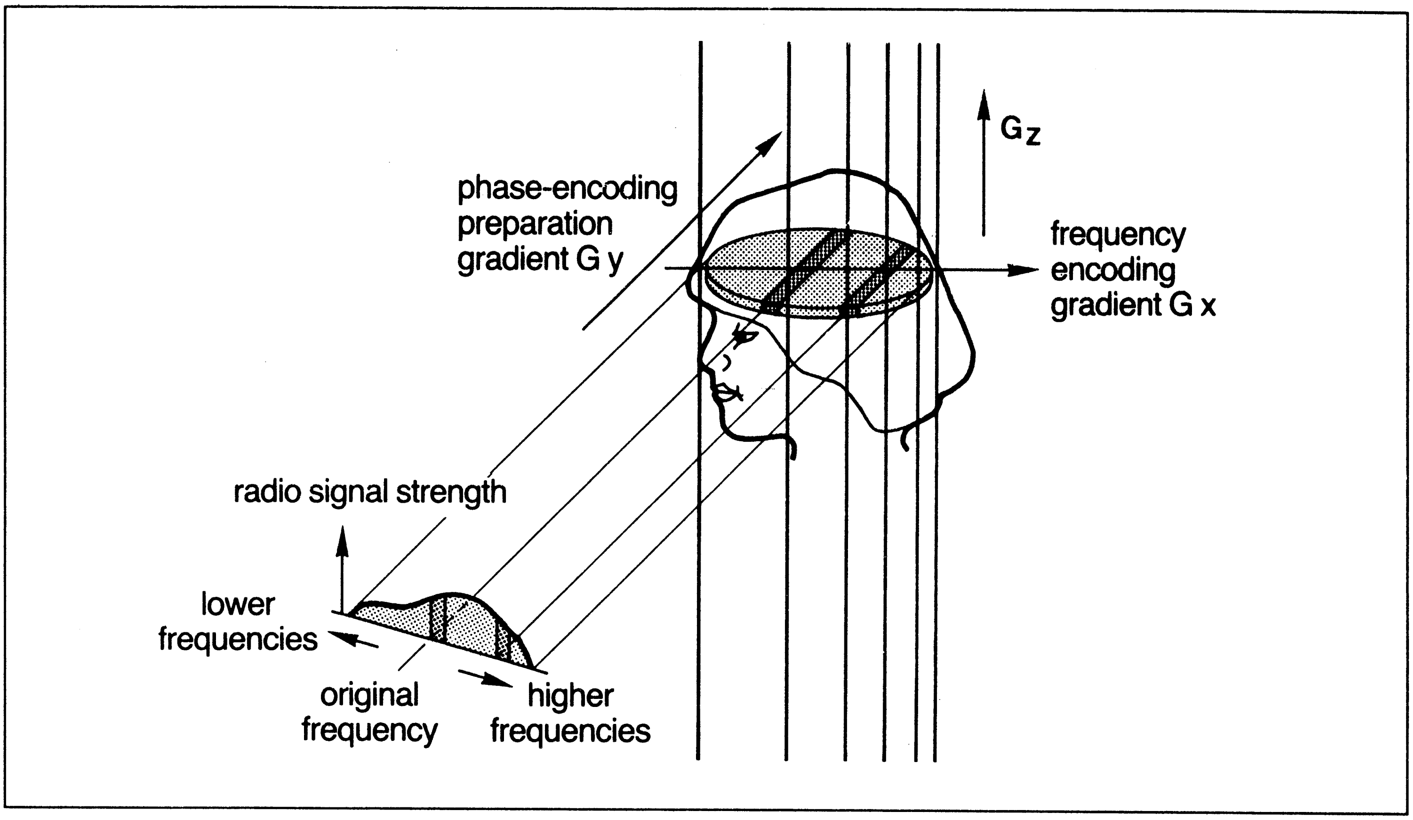
In order to determine location of the image in the body, a particular slice must be isolated for detailed examination. To select a slice, a relatively weak magnetic field gradient is applied in such a way that the homogeneous dc field is slightly reduced at one edge of the desired slice and slightly increased at the other edge. (See Figure 4.) This means that the Larmor frequency increases as the field strength increases along the magnetic field gradient. Only in the selected slice does the Larmor frequency match the rf excitation frequency. In this way the slice to be imaged contains a narrow band of precession frequencies, the thickness of the slice being varied by the field strength.

TWO DIMENSIONAL IMAGING

After excitation of the selected slice, a second magnetic field gradient is applied at right angles to the first. (See Figure 5.) The resonant frequency in the selected slice varies along the direction of the second gradient; a frequency analysis of the emitted signal then shows where the various components of the signal originate along the direction of this gradient. This process is repeated N times, however, with increasing strength of gradient providing a full spatial detection of the selected slice. In this way, sufficient data are acquired for reconstruction of an NxN pixel image by a computer program performing two-dimensional Fourier transformation. The concept of gradients can be physically illustrated by visualizing a perfectly flat surface which is exactly perpendicular to the Earth's gravitational force. On this surface we place a perfectly round ball. If we create a slight gravitational gradient by gentle tilting of the surface, the ball can be made to roll in a desired direction, subject, of course, to the reaction by its momentum as a result of its mass.

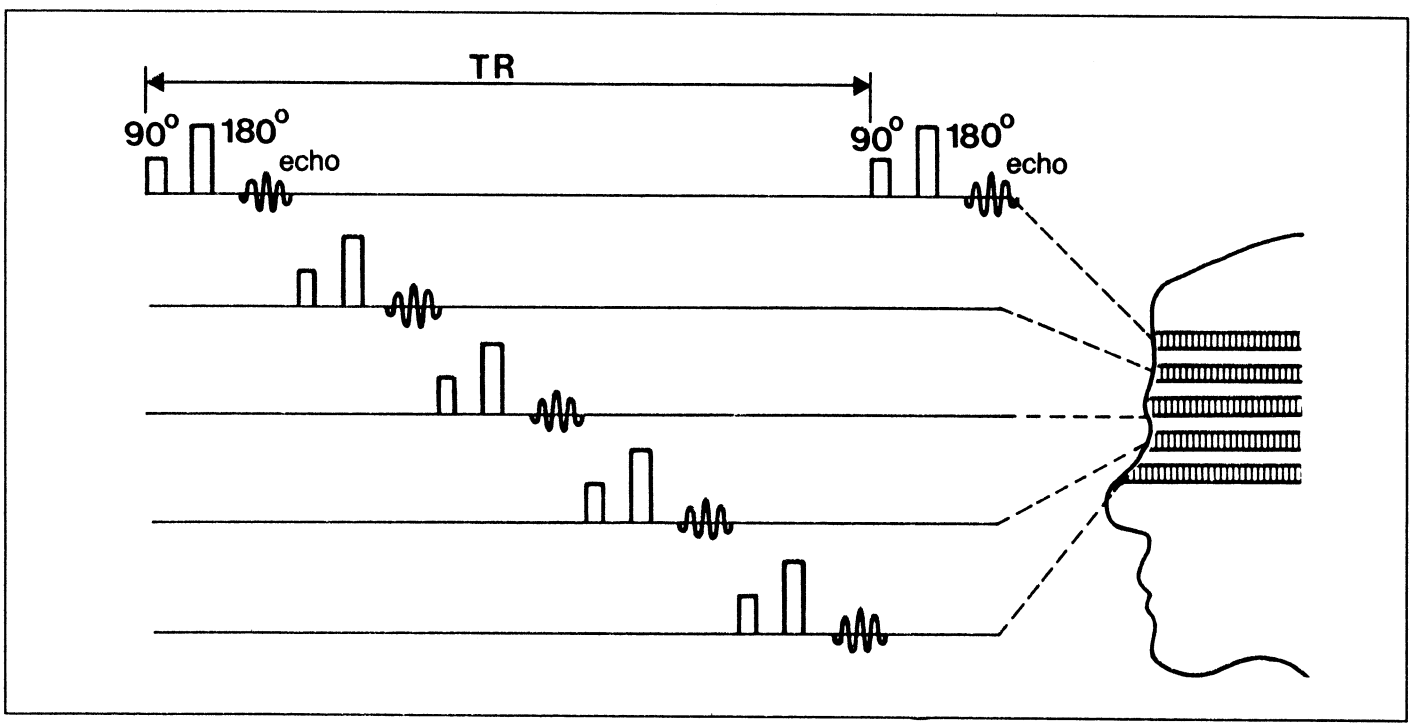
4. *Selective excitation of a single slice. In view of the field gradient, nuclei in plane with a Larmor frequency matching the frequency of the excitation pulse are the only ones excited.*





5. *2-dimensional Fourier imaging. Spatial information is encoded, in one direction by frequency and in the orthogonal direction in the plane by phase, by the application of gradients Gx and Gy respectively.*

6. *Multiple slice technique. In the time TR, required for return to equilibrium by the first excited slice, other slices are measured in a suitable order.*



MULTIPLE SLICE IMAGING

Figure 6. The waiting time in every measuring cycle for each slice can be used for excitation of other slices. This enables the excitation of several slices rapidly one after the other, so that data can be acquired from a number of slices prior to repeating the imaging sequence in the first slice. In this way, images can be acquired for a number of slices in a time similar to that required for a single slice. Three-dimensional imaging can be obtained by storing a series of two dimensional image slices on tape or disk and later combining the series into a volumetric three-dimensional presentation. Since the data is stored in digital form, these volumetric images can be rotated about any axis at any angle in any plane for detailed study prior to surgery. In addition to using shades of gray to illustrate varying densities, color can be tagged to certain shades by the computer to further accentuate the contrast. This color can be related in significant ways: for example, red can be used for blood flow, yellow for fatty tissue, etc.

Since this tutorial is intended to inform the members of The Radio Club of America about MRI, it is worth noting that essentially induction fields are utilized rather than radiation fields. From Maxwell's fundamental equations, we know that the "near field" and the "far field" are both present from the usual dipole radiator. The near field drops off inversely as the square of the distance while the far field drops off inversely as the distance. The two are equal at approximately one-sixth the wavelength. In a pure far field in space (air), the electric and magnetic vectors are equal in magnitude and at right angles in direction. Their vector cross product, of course, is the direction of propagation.

In power and audio transformers only the induction field is present, except for stray capacitance (which can be shielded out). This means that in working at wavelengths of several meters, the body-to-antenna spacings will be much less than one-sixth wavelength, so the induction or near field will be involved. Therefore, only loop-type antennas will be useful for measuring the MI signals. Proper electrostatic shielding and balance of these antennas will reduce stray pickup of broadcast signals. Also the use of narrowband tuning with phaselock technology can perhaps be utilized to reduce noise, since the frequencies are quite specific.

Many different antennas have been made up for special applications; for example, see Figure 7, which shows a knee coil used by Philips Medical Systems. Perhaps some of the specialized winding technology that has been developed for CRT yokes could be applied to these unique antenna designs. One problem in particular is the use of the same antenna for transmitting and receiving the signals a requirement well known to the designers of radar antenna diplexers.

7. *Knee coil: wrap around surface coil type.*

The location of the MRI presents problems of weight, stray dc magnetic fields, shielding from rfi, etc. The use of cryogenic technology also complicates the operation of those units having magnetic fields above 0.3 Tesla (3000 Gauss).

The non-invasive operation of MRI allows it to be used in most cases without any damage to tissue unlike the case for the extensive use of x-rays. However care must be taken to restrict MRI use on patients with implanted cardiac pacemakers and other electronic implants. Large metal prosthetics with appreciable magnetic permeability must also be avoided.

The stray dc magnetic fields can erase credit cards, cause print-through in magnetic data tape and make it necessary to consider nearby magnetic material which may move. For example, in a certain location the MRI was directly below a parking garage for the hospital with resultant disturbing eddy currents induced in the normally steady dc field of the MRI. Perhaps use of the old Helmholtz Coil technique could be applied to reduce the stray dc field from the MRI magnet assembly.

In general, more time is required to make a full body scan with MRI than with a computerized axial tomography (CAT) scan. This extra time plus the cost of investing large sums to acquire and operate the cryogenic system run up the patient cost for the use of MRI. In spite of these high costs, MRI does provide valuable diagnostic data not obtainable by any other known means.

Video tape recordings of the MR images with color tags dynamically illustrate the visual results not possible on the printed page. Such tapes are becoming available from several sources. One particular source is: Dynamedia Inc., 2 Fulham Court, Silver Spring, MD 20902 (301-649-3447).

Thanks for much of the above material to Philips Medical Systems, Shelton, CT.

AN OVERVIEW OF MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging lets doctors take three-dimensional pictures of the body organs using a radio-magnetic field that surrounds the patient. The pictures are unlike anything available from other diagnostic tools that rely on X-rays or ultrasound. This new state-of-the-art diagnostic system which uses radio waves rather than radiation to create images of the human anatomy, may represent the most significant advance in medical technology since the discovery of the X-ray.

The Magnetic Resonance Imager consists of three components: a large superconducting magnet; radio waves; and a computer. The system creates a magnetic field that is 25,000 times that of the Earth's. When a patient is centered in the magnetic field, the hydrogen atoms of the body align with the magnetic field. A series of radio-frequency waves is introduced causing the hydrogen atoms to emit faint signals which then are computer processed into images. Because the system is non-invasive, it offers fewer risks than some diagnostic alternatives and, in some cases, may reduce the need for lengthy hospitalization.

During the MRI scan, the patient is bombarded with magnetic waves from an 18,000 pound magnet and the response of atoms deep within the body is recorded by computers and transformed into a picture.

Magnetic resonance spectroscopy (MRS) can be used to examine the bioenergetics of human skeletal muscle continuously and non-invasively. Application of this new technology has already improved understanding of the metabolic changes that accompany muscular exercise.

Advances in magnetic resonance imaging (MRI) are making it possible for injured athletes to return to the field sooner. Traditional X-rays produce images of bones while MRI provides clear images of the soft tissue surrounding bone including tendons, ligaments and cartilage, sites of many sports injuries. MRI is considered superior to X-rays, CT, and arthrograms in diagnosing runner's knee, herniated disk, shin splint, tennis elbow, torn cartilage, damaged ligaments and other sports injuries according to one sports medicine specialist.

The MRI is particularly useful in examining soft tissue such as cartilage and tumors; it also is amongst the best ways of studying the brain or spinal cord. Because of this new technology, it often is possible to more readily diagnose lesions in the brain, spinal cord and musculo-skeletal system without subjecting the patient to interventitive procedures. It is thought that some day MRI may visualize and quantify chemical changes in diseased cells and thus contribute to the actual detection of life threatening illnesses.

ONE MAN

A Short Story of Samuel N. Harmatuk

Samuel N. Harmatuk

Sam was born in New York City during February 1910 of Ukranian-Russian immigrant parents. His father died in the 1918 flu epidemic, and Sam was reared by his mother who was the prototype single parent.

Sam graduated from Stuyvesant High School, then attended New York University where he played water polo, was a member of the fencing team, graduated with a degree in mechanical engineering with an aeronautical major and was a Guggenheim scholar. He began flying about 1927 and became an Air Corps Reservist; he already was a radio Amateur and furthered his education in the radio field with extension courses and constant study.

Sam joined the New York City Fire Department circa 1936 and had considerable experience as a fire fighter in some of the most active units in lower Manhattan.He was called for active military duty a few days after Pearl Harbor, trained in Tucson and went to Australia. There, he became an executive officer of a B-24 bomber squadron which was active in New Guinea and throughout the South Pacific. He ended the War in Japan with the rank of Lieutenant Colonel.

With peace, he returned to the NYC Fire Service, was promoted to lieutenant and later to captain. He was detailed to a newly formed Radio Research unit along with the late Art Meyerson. Together, they designed and developed the first portable VHF radios used in the New York Fire Department. The first tactical use of these units was at the time of the crash of the B-25 bomber into the Empire State Building. They were the only means of communication between the ground and upper floors of the building. These now are displayed in the N.Y.F.D. Museum.

The Fire Department was in need of an improvement of its radio communications capability. The then existing system had been installed in the mid 1930's and consisted of a 1630 KHz AM transmitter in Long Island City, and several dozen mobile units operating in the 30 MHz band and used chiefly by the marine division and some administrative officials.

Harmatuk was assigned the task of developing a specification and systems design for equipment able to handle the dispatch and operations traffic of all five boroughs in the greatly increasing activity of the Fire Service.

With the limited portion of the spectrum in the 150 MHz band then available to the Fire Service, it was essential to design equipment that could operate at only 30 KHz separation in order to provide the operational autonomy for the borough dispatch centers and to cope with the enormous increase in activity which had risen a full order of magnitude in little over a decade.

The greatest difficulty lay not so much in the technical area -- although the required frequency stability and receiver selectivity represented major advances -- but in countering the pressures of manufacturers who attempted to denigrate the specifications as being "visionary and impractical". Suffice to say that in a very short time, the FCC mandated the narrow band and stability requirements confirming Harmatuk's foresight.

The proof of his vision lies in the fact that the Fire Department system endured and maintained its efficiency for over a generation without substantial modification while most systems became obsolete in half that time.

He retired from the Fire Department at age 65 and from the Air Force Reserve at the mandatory retirement age for Colonel. He continued flying gliders here and in Europe well into his 70's.

He joined The Radio Club in 1957, was elected to the Grade of Fellow in 1961, and became a Life Member in 1970. He served as Vice President from 1971 to 1979, then became a Director. In 1983, he was elected to Director Emeritus for Life by the Board of Directors.

Sam Harmatuk died on July 23, 1989 after a lengthy illness and was interred in the Veterans Cemetery at Pinelawn, as was his wife, Lee, who had predeceased him by some 16 years. He is survived by his son, Paul, of Austin, TX and daughter, Barbara Vyden, of Beverly Hills, CA and by four grandchildren.

He should be remembered together with a few similar-minded cohorts as one who fought politicians and vendors of questionable integrity who were interested solely in the short-term results. We could use more of his kind!

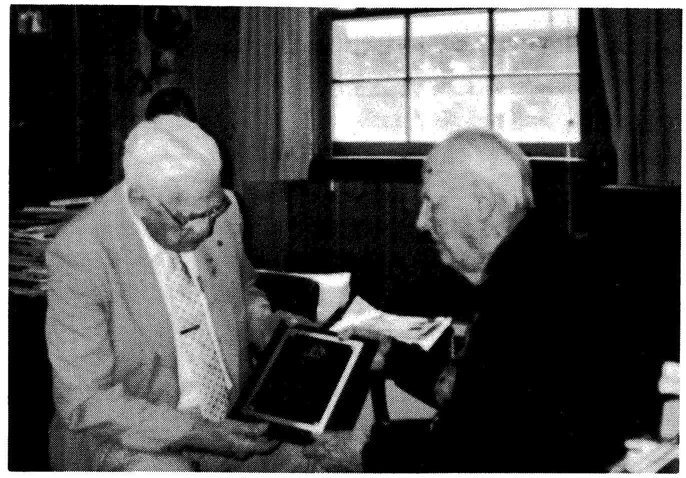
-Nicholas J. Reinhardt, P.E.

RADIO PIONEER - DR. HAROLD H. BEVERAGE

In 1938, the second Armstrong Medal was awarded to Dr. Harold H. Beverage (M 1920, F 1926, L 1971, H 1983) for his outstanding work on wave antennas. The presentation was made at The Radio Club's 29th Anniversary Banquet held at the Engineers Club in New York City, on November 4th. The citation read:

> *In recognition of his pioneer work on wave antennae and his continued work in this and other phases of the radio art, the award of the Armstrong Medal by The Radio Club of America is made to Harold Henry Beverage.*
>
> *Almost from boyhood he has been actively interested in all phases of radio, his first amateur station having been built in 1910. As a radio engineer and under the tutelage of Alexanderson, he rapidly made a name for himself in the development of radio transmission.*
>
> *To both the amateur and professional worker his name has been immortalized in the Beverage antenna, the precursor of wave antennae of all types. His later work in the development of spaced diversity antenna systems is of outstanding importance in present day radio communication. His knowledge of the phenomena involved in the operation of antennae of all types is profound.*
>
> *The successful use of long distance short wave signals through all types of interference is basically due to his work in the optimum utilization of space power.*

Today, The Armstrong Medal of The Radio Club and the Medal of Honor of the Institute of Radio Engineers are framed together in his home at Stony Brook, NY. They are in good company with the Liebmann Memorial Prize of the IRE (1945), the Lamme Gold Medal of the American Institute of Electrical Engineers (1957), the Marconi Gold Medal of Honor of the Veteran Wireless Operators Association (1974), the Pioneer Award of The Radio Club of America (1976), and the IEEE Centennial Medal (1984).



Another award was made on April 18, 1989 when George Apfel (F and Director)) presented Dr. Beverage with the Quarter Century Wireless Association President's Special Award citing Beverage for his significant experimentation and development of practical long-wire antenna systems for lower frequency communications.

At age 95, Beverage recalled that while still a boy in North Haven, Maine, he wound a tuning coil and added a crystal detector and headphone to serve as a wireless receiver. At age thirteen, he made an unannounced trip to Boston precipitated by the fascination that ships far at sea could communicate with land, and motivated to see firsthand the equipments that made this possible. Aboard a docked freighter he met a wireless operator who demonstrated his equipment and encouraged Beverage to consider a similar occupation.

His first amateur radio station was built in 1910 around a transmitter using an Electro Importing Company one-inch spark coil driven by some cast-off batteries obtained from a local boat-shop owner. He used the call letters HB. The antenna used two wires suspended between 60 foot masts, with a lead-in wire from the center.

While in North Haven High School, he was hired by the Knox Telephone Company as a maintenance man for North Haven where there were about sixty subscribers including two party-lines each with eighteen members. A defective line often required a long search for the trouble which sometimes turned out to be caused by some old lady who placed her metal-framed spectacles on top of the hand-cranked signaling magneto and, in turn, short-circuited the line.

In 1907, Beverage bought an alto horn and joined the town band. Every Monday night brought rehearsals. There was a need for another trombonist so his grandmother, proud of her grandson's interest in music, bought him a slide trombone.

His music made college possible through the supplemental funds earned in playing with a group of musicians and earning five dollars for a Saturday night's performance. At the University of Maine, he set up a wireless station using the call sign UM. Of the hours spent at the station, perhaps the most memorable occurred on April 14, 1912 when he copied signals from the S.S. Titanic on her maiden voyage. The next day, he copied signals from the S.S. Carpathia, the first ship to reach the Titanic after she had collided with an iceberg and sunk.

Beverage graduated from the University of Maine in 1915 with the degree of Bachelor of Science in Electrical Engineering. Two offers of employment were available: Lowes Theaters invited him to play trombone in their theater orchestra for the sum of $22 a week ; General Electric was prepared to pay him $11.20 a week. Beverage accepted G.E.'s offer and spent the next year testing motors, transformers and generators.

At that time, Dr. E. F. W. Alexanderson was recognized as one of the most promising scientists in communications. A native of Sweden, he had joined General Electric in 1901. In 1916, Beverage presented himself to Dr. Alexanderson and suggested that he needed someone on his staff who was versed in radio propagation and receiver system development to design a receiver to go with a transmitter incorporating Alexanderson's high-frequency alternator

Soon, Beverage was taken into the laboratory where he found that Alexanderson often would present his staff with six or more problems and then return two hours later to see how many had been solved.

In 1918, the war with Germany made it increasingly evident that control of communications would be a major factor in determining the winner. Beverage was given his first major assignment: to assist in developing the Alexanderson barrage receiver system intended to provide a defense against the German reception of American signals.

The resulting barrage receiver required two antennas, each two miles long and laid on the ground. The antenna system solved some of the problems of interference by the Germans that plagued the French Army.

The first barrage receiver was installed by Beverage and his associates about four miles north of NFF, a powerful transmitting station at New Brunswick, NJ, where a 200-watt Alexanderson alternator was in use. A ground antenna was extended two miles northeast and two miles southwest from the receiver. The extremely strong signals from NFF were readily balanced out and eliminated; at the same time, signals from MUU, in England, were received.

The U.S. Navy became interested in the results and requested that a similar system be installed near Bar Harbor, Maine. In laying out the system, Beverage found an interesting phenomena. In setting up the station, he found that the signals from Europe were excellent on the northeast wire but only static was received on the southwest wire. From field tests, he decided that ground wires were uni-directional and received signals from the direction in which they were pointed. It suggested to him the idea of an aperiodic uni-directional antenna. At this outpost in Maine, the principle of the Beverage wave antenna was born and, at a later date, served as a basis for his first patent.

Because the receiver/antenna system was unidirectional, it could be aimed to receive signals from the U.S. forces and, by simultaneously transmitting a barrage of interference, the Germans were prevented from copying the messages.

The wave antenna became widely used at very low frequencies of 10,000 to 30,000 Hz. A principal value was in the elimination of static from lightning storms, one of the major problems which troubled such low-frequency equipment.

Marconi's discovery in 1926 that short-wave radio signals could travel long distances during daylight hours made the wave antenna largely obsolete. Short wave radio systems were more economical since the long-wave antennas were extremely costly, but short waves were far from perfect. Their most serious drawback was the tendency to fade in Northern regions because of the Sunspot ionization of the atmosphere.

Shortly after World War I, Beverage received a "pink slip" dismissing him from General Electric. The U.S. Navy had been urging domestic corporations to make provisions to keep valuable radio patents in the hands of American companies. As a result, GE joined with Westinghouse Electric and Manufacturing Company to form the Radio Corporation of America. Dr. Alexanderson was named chief engineer.

Beverage recalled that upon receiving the "pink slip" he went to Dr. Alexanderson and asked why he had been fired. Alexanderson replied, "You fired? Oh, I forgot to tell you; I had you transferred to RCA."

For the next two years, Beverage was in charge of radio reception systems including receivers, antennas and radio propagation studies of high frequencies. At the RCA Research Center at Riverhead, Long Island, the first full-scale Beverage antenna was erected: a six-mile long wire extending southwest from Riverhead. By cutting the wire at intervals and inserting a receiver, the test team found that the European signals increased while at the same time static from the southwest decreased. They also found that the losses in the wire were high as it lay on the ground.

The obvious answer, they determined, was to erect the antenna on poles to increase the velocity and decrease the attenuation, and an antenna on poles was constructed. For the first time it was possible to receive a wide band of frequencies without adjustments to balance out the static and interference from stations south of Riverhead.

These antennas soon were erected all over the world. The late Paul F. Godley (M 1914, F 1926, Hon. 1964) used the wave antenna at his station at Ardrossan, Scotland with great success in picking up amateur radio stations throughout the United States including 1BCG operated by members of The Radio Club of America. Godley had heard Beverage's amateur radio station 2BML at Riverhead and attached Beverage's name to the new invention; from that time on, the wave antenna was referred to as the Beverage antenna. The first written account of the Beverage antenna was published in the November 1922 issue of *QST* magazine under the title "The Wave Antenna for 200-Meter Reception."

In 1921, America, England, France and Germany wished to establish radio communications with Rio de Janeiro and Buenos Aires. Since insufficient traffic existed to warrant four stations, an agreement known as the AEFG Consortium was reached to share a single facility. Beverage was selected to head an expedition to Brazil to determine whether it would be possible to establish communications directly with South America.

The first tests were made at Cabo Frio located about 75 miles east of Rio. It was found that heavy static in the afternoon made communications with Rio impossible. Consequently, the equipment was repacked and shipped to Recife, Pernambuco. After repeated delays in clearing through Customs, Beverage was advised to give 100 milreis to Senhor A and 50 milreis to Senhor B, etc. He did. It worked.

At Recife, the tests were excellent in the receiving of signals from Europe and the United States. Recommendations were made to the AEFG Consortium that a permanent relay station be built in Recife to transfer strong signals to Rio and Buenos Aires The recommendation was adopted and a station was built by the French.

In 1927, Beverage and Harold O. Peterson, of RCA, found that diversity reception, a combination of several antennas, minimized fading. Marconi had continued his experiments on wavelengths below 200 meters from his station in Poldhu, Cornwall, England and the signals sent from there were measured at the RCA facility in Riverhead. By 1924, the Poldhu transmitter had been adjusted to transmit on 32 meters and those signals were heard both at night and during the day, contrary to all theory.

The atmospheric static which interfered with long waves practically disappeared on the shortwaves; however, these were interrupted by rapid and random fading. Based upon such data, Drs. Beverage and Peterson combined signals from three aperiodic antennas spaced about 1,000 feet apart in a triangle, but in a manner independent of phase. This resulted in a steady signal. To further reduce fading, they combined antennas with opposite polarities. This technique known as polarity diversity reception, still is used in satellite reception to compensate for the effect of the ionosphere on polarization.

By 1929, Beverage had been made chief research engineer in charge of the reception laboratory at Riverhead, the transmitting laboratory at Rocky Point and the terminal facilities in New York City. He had become recognized as an outstanding engineer in radio research. In 1938, the University of Maine, cognizant of the magnitude of his work, conferred upon him the honorary degree of Doctor of Engineering. That same year, he received the Armstrong Medal from The Radio Club of America.

Beverage remains proudest of his participation in World War II. As an expert consultant to the U.S. Secretary of War, he worked on projects in North Africa, Italy, and Britain.

An early assignment took him to Labrador, the departure point for many bombers flying to the England. Several had been lost on the Greenland ice cap because pilots could not find the airfield in Greenland during bad weather. In an effort to improve communications, Beverage recommended the use of low frequencies in lieu of the unreliable high frequencies. He knew that high frequencies were unreliable in the far North, sometimes fading out for days during the magnetic storms.

He was told that low frequencies had been tried but could not be heard; a horizontal dipole with a balanced input to the receiver had been used. Beverage then laid out a few hundred feet of wire and proved that low frequencies were coming through as predicted.

He spent weeks checking the installation at Prestwick, Scotland which was the terminal of the bomber route, and Beverage antennas were installed at all locations; they had a real advantage in that no towers were required and, if destroyed by enemy action, could be replaced rapidly. Solid communications between all airfields on the North Atlantic bomber route were secured. For his valuable services, Dr. Beverage received the Signal Corps Certificate of Appreciation.

He was given his most important assignment when he arrived in London two weeks before D-Day, June 6, 1944. The job was to provide communications to direct air support for the invasion of Normandy. He proceeded to visit the 9th Tactical Air Force in Uxbridge where the radios were on a common frequency with the U.S.S. Ancon where an admiral and a general were to control the entire operation of getting troops ashore at Omaha Beach. It was planned that when troops made it ashore, they would have portable transmitters enabling them to enter the communication net and ask for air support. The commanding general at Uxbridge would reply in a coded message to the U.S.S. Ancon stating the number of bombers assigned and their time of arrival.

Uxbridge was experiencing trouble in getting information through. Beverage gave the following account of the situation:

> "We found that a vertically polarized antenna was being used similar to the one on the Isle of Wight overlooking the English Channel. The propagation of vertical polarization over seawater is excellent. Uxbridge, about forty miles over land in the direction of Omaha Beach in France, presented a different problem. The ground wave over land is very poor on both vertical and horizontal polarization. The only solution appeared to be the use of sky wave with horizontal polarization, and many days were spent supervising the change to sky wave. I was worried whether, with the change, signals to and from the U.S.S. Ancon and the troops ashore would get through. On D-Day, I was briefly confused as all frequencies had been changed to confuse the Germans but was greatly relieved when I soon knew that all had performed as planned."

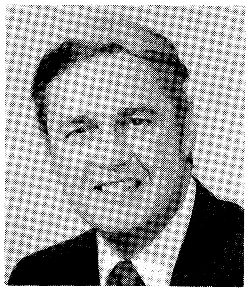
As a result of his work, Dr. Beverage was honored with the Presidential Certificate of Merit signed by President Truman.

Beverage remained with the Radio Corporation of America until his retirement in 1958 at which time he held two positions: Vice President for Research in Communications, and Director of Radio Research. One of his protege was a promising young scientist, the late George H. Brown, Ph.D. (M 1985, F 1986) who was awarded the Armstrong Medal at The Radio Club's 1986 Annual Awards Banquet.

Honors continued to come to Dr. Beverage. He was made a Fellow of the American Association for the Advancement of Science, and a Fellow of the American Institute of Electrical Engineers. He is listed in numerous *Who's Who* publications.

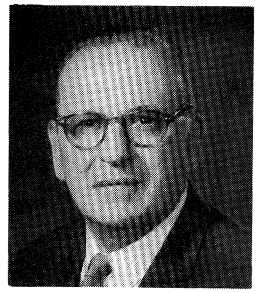
Dr. Harold H. Beverage joined The Radio Club in 1920, was elevated to the Grade of Fellow in 1926, became a Life Member in 1971, and was awarded the distinguished Honorary Membership in 1983.

HONORS AND AWARDS 1989



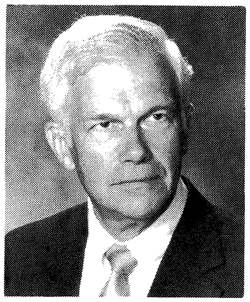
SARNOFF CITATION
William E. Endres

Awarded in recognition of his significant contributions to the advancement of electronic communications.



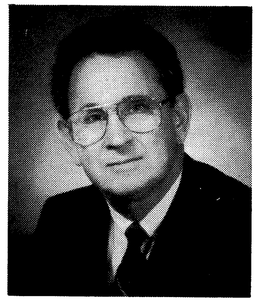
PIONEER CITATION
Capt. William G. H. Finch, USNR (Ret.)

Awarded in recognition of his pioneering in facsimile, radio color-picture transmissions, and radio teleprinter inventions and developments.



JACK POPPELE BROADCAST AWARD
Leonard R. Kahn

Awarded in recognition of his long term contributions to the improvements of radio broadcasting.

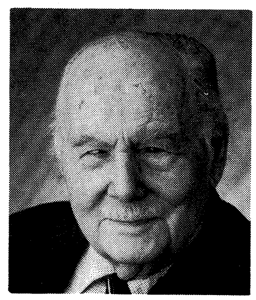


FRED M. LINK AWARD
Mal Gurian

Awarded for his significan contributions to the development and advancement of land mobile radio communications.

RALPH BATCHER MEMORIAL AWARD
James E. Brittain, Ph.D.

Awarded in recognition of his work in preserving the history of radio and electronic communications.

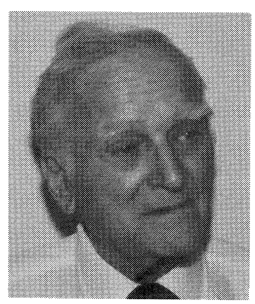


BUSIGNIES MEMORIAL AWARD
Avery G. Richardson

Awarded in recognition of his contributions to the advancement of electronic communications for the benefit of mankind.

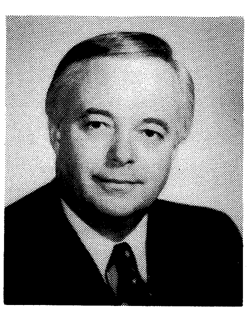
ALLEN B. DuMONT CITATION
Kenneth A. Chittick

Awarded for his leadership in the design of television receivers and development of compatible color television standards.



LEE deFOREST AWARD
Fred Shunaman

Awarded for his long-time friendship with Dr. Lee deForest.



SPECIAL SERVICES AWARD
Eric D. Stoll, Ph.D., P.E.

Awarded for his outstanding success in computerizing the records ans fiscal reports of The Radio Club of America.

PRESIDENT'S AWARD
Joseph R. Sims, P.E.

Awarded for his substantial contributions to the success and development of The Radio Club of America.

FELLOWS - 1989

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

Jack G. Beverly - for leadership in the development of control and dispatch systems for public safety radio systems.

Aldo A. Bottani, Jr. - for pioneering work in developing over-the-horizon TV systems and design criteria for cellular radio telephony systems.

Raymond L. Collins - for leadership in the manufacturing of specialized mobile radio products in the fields of antennas and RF power monitoring.

Ms. Mercy S. Contreras - for leadership in the publication of periodicals related to mobile and cellular radio communications.

David N. Corbin - for innovative designs of radio communication systems.

David M. Crawford - for early research in color television maintenance procedures and publications.

Leonard F. Davis - for developing international standards and marketing procedures for paging and mobile radio communication products.

Theodore R. Faust - for early work in commercial airlines communications, and for critical developments in night vision and guided missile power supplies.

W. H. Galpin - for distinguished services in military communications, and educational and engineering work on antenna, filter and multicoupler systems.

Dr. Albert Helfrick, P.E. - for leadership in the design of precision instrumentation systems, and for authorship of text books, articles and conference papers on communication subjects.

Col. Arthur D. Hendricks - for distinguished services in military communications and in the U.S. diplomatic services, overseas petroleum operations and Amateur radio communications.

Lt. Gen. William B. Hilsman - for outstanding leadership in military communications, computer usage and information systems, and for post-military services in providing digital radiotelephone systems.

Kenneth A. Hoagland - for leadership in the development of cathode-ray tubes for specialized applications, and in the development of electronic image sensing devices.

William S. Hoovler - for innovative development work in inter-facing subway communications with public safety surface radio systems.

Lt. Col. Robert J. Howell - for distinguished accomplishments in the U.S. Air Force communications services, intelligence operations, and electronic warfare.

Fred J. Huber, Jr. - for research and marketing of innovative radio communication products.

David Hubertz - for contributions in land mobile radio communications in areas of private dispatch systems.

Duane L. Huff - for systems engineering and design of anti-ballistic missile defense radar systems, phased arrays, and high-power radars, and studies in cellular radio development.

Reuben A. Isberg, P.E. - for contributions to the engineering aspects of television broadcasting, including the development of the video recorder and for pioneering the use of television in educational activities.

Joel I. Kandel - for innovative designs in local government public safety land-mobile and maritime radio systems, and in digital applications for communications.

Seymour Krevsky - for contributions to classified electronic warfare systems, leadership in IEEE sections and societies, and publication activities.

Howard L. Lester - for early work in radio and television broadcasting, the development of mortar and artillery locating radar and high-brightness TV projectors, and for contributions to Personal Radio Communication Systems and cellular radio telephony.

Robert W. Maher - for contributions in the legislative field as Director of Research for the House Sub-committee on Health and the Environment, and Special Assistant to the President.

Roy E. Place - for distinctive leadership in the marketing of land mobile radio and paging products.

Ms. June Poppele - for distinguished services to The Radio Club of America, Inc.

Edward J. Reichler - for responsible activities in the development of Southern California antenna sites, and service to the mobile radio communications industry.

John W. Reiser - for activities in the international standardization in the transmission and antenna fields of AM, FM, short-wave, and TV broadcasting.

Stanley Reubenstein - for distinctive services in the supplying of mobile radio products, and in the activities of professional and Amateur radio organizations.

Warren Struven - for development of critical monitoring and computer-controlled systems at Stanford Linear Accelerator Center, and the design of its "leaky feeder system" for VHF and UHF underground communication systems.

Frederick G. Suffield, P.E. - for contributions to early military and commercial airline radars, and Stratovision television system.

Derek Turner - for early surveying and establishing of radio repeater sites in Northern England and Scotland, and for the designing of special radio circuits for police, fire brigades, and municipal facilities.

Harry Vorperian - for contributions toward the development of specialized and classified military equipments.

Col. John G. Webb - for contributions in the effective use of radio communications in World War II, and for unique designs of mobile radio systems for commercial applications.

Robert W. Weir - for early work in closed-circuit television and for leadership in the manufacturing of high-quality antenna systems.

Ralph O. Williams - for the preservation of the history of radio through the Atwater-Kent Museum at Orient, NY, and for work in the design and operation of missile guidance systems.

Walter B. Williams, - for pioneering in the field of public safety radio and, specifically, with the *IEEE-Milestone* Police Radio System of the City of Detroit.

Jan A. Zachariasse - for distinguished leadership in several branches of radio including the application of electronics within the fishing industry, and for his leadership in the United Kingdom, Europe, Australia, and South America in the cellular radio field.

THE CENTENARIAN AWARD

Mr. Hugo Cohn is an unusual person. He celebrated his 102nd birthday on November 26, 1989 by attending the 80th Anniversary Banquet of The Radio Club, a week earlier.

At age 102, Mr. Cohn is the oldest living member of The Radio Club of America and, to commemorate the achievements during his tenure, the Club's Board of Directors established The Centenarian Award. It is to awarded to any living member of the Club upon achieving the age of 100 years.

Hugo Cohn became a member in 1939, was elevated to the Grade of Fellow in 1953, and became a Life Member in 1971. He is a graduate of Columbia University's School of Engineering Class of 1909 with a degree in Electrical Engineering. A year later, he established COVIC Electric Company to perform electrical contracting.

His company manufactured early dental X-ray equipment and refined the arc welding equipment used during World War I. In 1922, he founded Radio Receptor Corp. which manufactured crystal radio sets and AC-operated battery eliminators. During the 1930's, he pioneered the manufacturing of aircraft radio beacons and navigational equipment and, during World War II, the company developed and built blind landing and IFF beacon systems. That work continued after the war until, in 1957, Radio Receptor was merged with General Instrument Corp., and Mr. Cohn retired to become a management consultant for the Tennessee Valley Authority and other clients. Between 1969 and 1984, he was active as a volunteer with the New York City Department of Aging. He continues to study and to keep abreast of the new technologies in the electronics industry.

We salute Hugo Cohn for a job well done, a life well lived, and the distinction of being the first recipient of The Radio Club's Centenarian Award..

FUTURE HIGH CAPACITY PUBLIC SAFETY RADIO TECHNOLOGY

by Chandos A. Rypinski (F).

INTRODUCTION

Often it is said that additional frequency space is needed for the public safety dervice organizations in the larger cities. This presentation agrees with the assertion that more capacity is needed, but goes further to say that eventually so much more capacity and capability is needed that there also must be new technology and new administrative methods. The blending of new technology, achievable spectrum use, and acceptable organizational structure is a challenge which eventually must be met. A workable technology and organization for this new order of communication is described. Those involved in the core of the business must prepare for eventual adaptation to changed modes.

Much more can be done when large blocks of users of radio spectrum work cooperatively rather than autonomously. Technical changes also require changes in deep-seated administrative policies. In addition, there must be changes in the way that radio systems are designed, marketed and administered.

PRESSURES FOR CHANGE

Change is not motivated by the simple existence of a better technology but by real needs for greater operational capabilities and better cost factors. The present "archipelago" of independent systems will not be able to cope with trans-jurisdictional crime perpetrated by those with a complete understanding of its weaknesses. Throwing money at the existing system will not sufficiently improve its effectiveness but, instead, will increase the negative consequences of the absence of a common system design. Some of the motivating factors are as follows:

More Services

All local government and dispatch services would get improved services from greater use of non-data communication. Fifteen years ago, non-voice input-output devices were pushbuttons and lights More recently CRTs and printers have been used with moderate acceptance. Now, facsimile graphics transmission, with far more versatility and security than any previous non-voice method, can be provided--but it needs high rate digital transmission.

The ability to send pictures, maps and legal document to and from operating units by radio and in secure form will be highly valuable.

A further capability will be voice-messaging where a unit can send a message to a dispatcher whether or not the dispatcher is free at the moment of transmission. Queued messages would appear on a display with prioritization to improve the probability of quick handling of urgent traffic. This will avoid ambiguity between congestion of radio channel capacity and that of dispatch staffing. It also is possible to integrate sign-post type of vehicle location into the system at a slight additional cost.

More Capacity

More capacity does not necessarily mean more voice channels. Very often lack of dispatcher capacity is interpreted as insufficient radio channels. What may be needed is more processing capability using a selection of radio channels, the quantity of which is independent of the number of dispatcher chairs.

It must be recognized that a large fraction of all traffic is dispatch orders and status reports which can be handled with datagrams requiring only milliseconds of air time for each. (A two-way broadcast data channel could well support a few thousand operating units.)

Broadcast mode can be very valuable to a public safety system. The unplanned use of the broadcast mode greatly reduces its value when a large fraction of the messages are irrelevant and become noise to the monitoring stations. It is possible to filter traffic centrally so that it is received and displayed or heard only by stations where relevance is possible. If the status and location of units is valuable to all units, that should be a prepared broadcast, transmitted securely by datagram to a printer or facsimile device. It should not be provided by chance monitoring of dispatch orders.

Very large increases of system capacity are available from the effective use of the non-voice communication methods and the selective use of broadcast matter.

Universal Access and Standards

A ridiculous situation now exists with respect to management of mutual-aid between agencies because of the nonexistence of adequate interagency communications. It is as bad as an army where each company or platoon can choose from a wide variety of weapons using non-interchangeable ammunition. There are many parts of California where communications after an earthquake can only be obtained using Amateur Radio operators and equipment. Such ad hoc arrangements cannot possibly furnish enough capacity.

It is possible to have all local government radio equipment mechanically identical and manufactured in quantity. Administrative subdivisions and local frequency plans could be controlled by firmware or downloaded software that would make it possible to set up temporary area-wide channels as needed without physical change in the units. Also, it is possible to do these things in such a way that the undetected theft of a unit radio does not give a monitoring capability for more than a few hours.

This type of communication must be designed to standards cooperatively defined by users, manufacturers and regulators. The Federal Government does have administrative entities that are capable and authorized to undertake such matters. A poor reason for failing to advance in this area is the non-cooperation of manufacturers whose positions depend upon the existing structure of customers, marketing channels and technology.

Standards are sometimes seen as opening a USA market to the volume manufacturers and new suppliers to the vehicular market. The economic and operational benefits to the public and the public safety community are too great for continued resistance for this reason.

Shift to Personal Sized Radio

More and more communications are seen as addressed to individuals rather than to a vehicle or piece of equipment. While it is possible to use a personal radio in a vehicular system, the capability exists only because of the large signal margins provided to cover shadowed areas and overcome interference.

It is also possible to partially cover the interiors of business and public buildings from outside vehicular radio systems. Eventually, interior radio systems will be of a design specific to that need. Such personal radio systems will be characterized by many more access points (equivalent to base stations), much closer geographical spacing of access points, transmitter powers in the range of 1 to 50 milliwatts, the inclusion of data messaging functions beyond simple voice, and support from a good cable communication network with far more capabilities for integrated voice and data. The advantages from reduced transmitter power requirements in personal radios are many.

Frequency Reuse Strategy

Design with "cellular" methods requires a frequency reuse strategy, and a method of predicting signal-level and signal-to-interference level as a function of location. It becomes increasingly difficult to predict performance as the range of the base station becomes smaller and where signal levels depend more on the position of nearby obstacles than on distance.

Cellular design is usually based on a single illumination point for an area which may be circular, an irregular polygon, or an approximation of a "pie-shaped" sector. The cellular methods are two-dimensional at any given place. The station that moves from floor to floor in a tall building or in a parking garage is not taken into account. An attempt should be made to confine a cell to one floor of an office building. Cells also can be defined as the combined coverage of many illumination points if certain technical problems from "simulcasting" are overcome.

The multi-site defined cell may be thought of as a "distributed antenna" for a common broadcast, and a diversity receiver. At the edge of such a cell, the distance-related decrease in signal level is much more rapid than for a single-site illuminated cell. Therefore, fewer frequencies are required for continuous coverage by avoiding traditional cellular assumptions on handoff and reuse distances. It is possible to multiply the capacity of each channel by as much as the reuse factor is reduced, for the same spectrum efficiency.

For example, these factors may be compared for a small cell and a multiple antenna system, as follows:

Factor	Cells	Multiple Antenna
Reuse Factor	24	4
Channel Bandwidth	1	6

The reuse factor is the total number of different frequency sets necessary for continuous coverage with low but not zero interference probability. Different plans have crowded this factor down to 12.

There also are asymmetrical plans wherein the groups do not all have the same number of channels thereby permitting a larger number of groups. The number must be higher the more closely spaced the co-channel sites are spaced, and 24 is a fair number for cell radii of less than 3000 feet cell.

Spectrum Access

It is possible for the technical strategies advocated to be used in the present 900 MHz band with great benefits. Because of the intensive existing use, it is desirable to sustain the possibility of use of microwave frequencies in the range of 1.2 to 3.3 GHz.

The central fact is that there are no suitable unassigned frequency bands. Access must depend upon co-use of frequency space for many years. A speculation is that the urban demand for low band microwave point-to-point systems could decrease as a result of wider availability and greater capacity of optical fiber and new public network links.

The FCC should be viewed as having fully committed that which it has to award. The problem is with the competitors who were there first but may not have the highest priority from an economic or public interest point of view. The competitor to be avoided is the US government with its extensive claims to frequency space and little inducement to give up anything already committed.

Co-use, if possible, depends upon system designs with low power transmitters and short radio paths.

There are technical reasons for this type of design, but an important part of the political justification is much more intensive use of the spectrum as compared with its existing use. Any proposed technology must be positioned to have the probability of success in a contest for use of the frequency spectrum.

COMMON MEDIUM VOICE-DATA RADIO SYSTEM DESIGN

It may be helpful to the comprehension of the nature of a future system to put down specific numbers with the understanding that they are not a choice or recommendation. Some example characteristics of a possible future radio system are as shown on Table I:

Table I: Example Characteristics of Possible Future Radio Systems

Operating frequency:	0.805 - 3.300 GHz.
Duplexing:	Frequency Division-- 45 MHz separation at 900 MHz., and proportionally for higher frequencies, 500 KHz in each direction.
Channel data rate	800 KHz in each direction
Channel bandwidth:	1 MHz -- one channel for each direction
Derived channels:	20 per channel
Derived channel payload:	32 Kbs
Segmentation:	64 octet payload segments sent once per 16 milliseconds
Nominal radio path length:	1200 feet maximum
Nominal Transmitter Power--	
Peak per unit transmitter	20 milliwatts over 0.8 msec
Peak per fixed transmitter:	20 milliwatts over 16 msec
Services:	One-way connectionless packet data Voice messaging Two-way simplex voice Two-way duplex voice

The system is formed from a duplex channel of 800 Kbs in each direction further subdivided into virtual channels of 32 Kbs payload bundled in segments of 80 octets of which 64 are payload. The system frame period of 16 milliseconds is divided into 20 equal time slots of 800 microseconds to produce time division multiplexed channels usable either for one-way or two-way and for packet or voice.

Given a radio range limit of 1200 feet with margin for minor obstacles, the design of the system must be such that all points in a service area get coverage from at least two sites, and most points from three or four sites.

Likely sites for access points are street intersections and the inside of entrances to high-usage buildings. The range can be stretched for unobstructed paths like stadiums for sporting events, and it must be reduced for penetration of walls in buildings.

A public-safety cell is now defined as a traffic entity so that handoff is not normally a required function. The boundaries conform more closely to political or administrative subdivisions. The typical communication will begin and end while the unit station is within one coverage cell even if the predominant access point changes during a communication.

A further major feature differentiating this plan from a cellular system is the provision for one-way communication. If acknowledgment or receipt is required, that is done by application-level software sending an appropriate return message and not by setting up a two-way connection and releasing it. A great deal of the broadcast and status-reporting, non-voice traffic may be unidirectional without an acknowledgment requirement.

The data rate of 32 Kb/s may contain a forward error correction code which would reduce the throughput to 60-75% of the medium rate to obtain bit-error-rate probability smaller than 1×10^{-6} when used for packet data.

With this overview, it may be interesting to describe some of the underlying design details and calculations.

Radio Plan

The central point of the radio system plan is the use of overlapping coverage from multiple, closely-spaced radio-access points each transmitting identical information. This, functionally, is the same as one transmitter with power dividers and cables to many antennas. This arrangement works identically to a distributed antenna system.

A necessary system property is a modem technology which, with multiple signals of near equal level but with slightly varying time of arrival, will avoid cancellation effects preferably summing the energy of all received signals. Discussion of these methods is not taken up in this presentation.

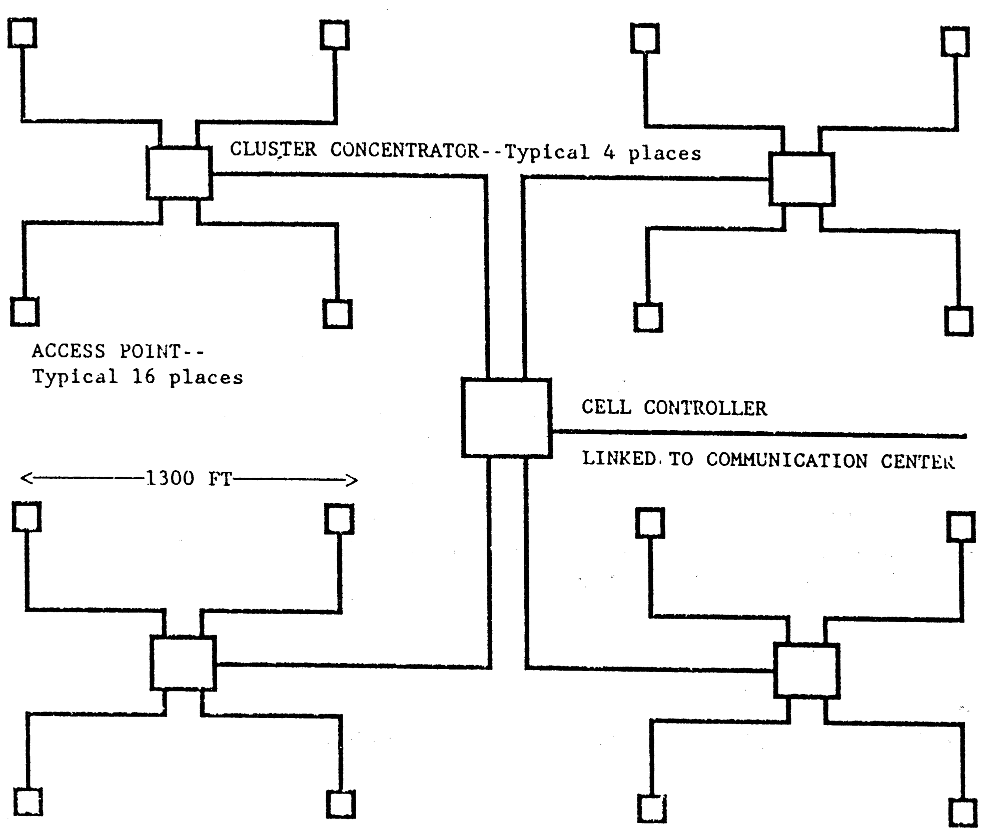


Figure 1. Layout of 16 Point Radio Access Network

Figure 1 shows 16 access points where each cluster of 4 antennas is supported by a common intermediate concentrator. More imaginative schemes are possible depending greatly on fitting the design to local needs. The preferred long distance medium is optical fiber.

Actual systems in high density urban areas might have 64 illumination points per square mile (650 ft. average spacing) with entirely irregular positioning. In less urbanized areas (1300 ft average spacing), 16 illumination points per square mile might serve.

Assuming that an administrative area is one square mile, one system would supply 20 channels of 32 Kb/s per square mile. More capacity would require more channel groups at each access point, or a division of the area into smaller cells. (Less capacity would result from increasing the coverage area for one cell.) Capacity could be measured by the number of channels of access or the aggregate bit rate of those channels per square mile of land area.

Less capacity might not result in an economic solution. A better answer would be to increase the size of the user group until the available capacity is more efficiently utilized.

Because radio coverage can be fitted to the served area (like lighting with many fixtures), interference limitations will become a minor factor. Overlap between different systems will exist in a very small part of the total coverage. Since coverage is far easier to predict and measure than is signal-to-interference, radio system design will be easier and more accurately forecast.

Table II: Required Transmitter Power

Free space loss between isotropic antennas: (32.44 + 20 log F (MHz) + 20 log D (km))	- 82.5 dB at 900 MHz and 350 meters	
Fixed Station antenna gain less cable loss:	9.5 dB all gain in vertical pattern	
User Station antenna gain less cable loss:	1.0 dB	
NET LOSS BETWEEN ANTENNA TERMINALS:	**72.0 dB**	
Thermal noise in 1 MHz bandwidth: Pn = K T B (terminated))	$.004 \times 10^{-12}$ watts =	**-114.0 dBm**
Receiver noise figure:	9.0 dB	
Demodulation margin:	9.0 dB	
Error rate margin:	13.0 dB	
Fade margin:	24.0 dB	
NET REQUIRED RECEIVE LEVEL:		**- 59.0 dBm**
NET REQUIRED TRANSMIT POWER:		**+ 13.0 dBm**

Reference Propagation Loss Calculation

The required transmitter power is estimated initially from the calculation shown above.

This calculation shows that each time the operating frequency is doubled, the required power increases 6 dB. This is because the directivity of the antennas is assumed fixed and the same for all frequencies. Usually, there is more antenna gain at higher frequencies, but not here. Also, more fade margin is necessary for an obstructed path as the operating frequency increases. For these reasons and others, 900 MHz is attractive, 1.8 GHz is usable, and 3.6 GHz is far more difficult.

Frame Structure

At a medium signal rate of 0.800 Mbs, the following dimensions are used:

1 Second	=	62.5 frames		
1 Frame	=	20 time slots	=	16 milliseconds
1 Frame	=	1,600 octets		
1 Time slot	=	80 octets	=	1 segment + 8 octets OFF time
1 Segment	=	72 octets	=	1 payload + 8 overhead octets

The Access Point and the User Station both transmit using 20 time slots with 64 octets of payload.

The aggregate of all voice samples and packet data segments are sent in blocks of 64 octets corresponding to the number of samples taken (128) in a time interval of 16 milliseconds; however, the samples for one slot must be transmitted in 0.8 milliseconds of air time. (Voice is encoded at a rate of 32 Kb/s.)

Regular Slot Structure

Each time slot is formatted as an 80 octet interval, as shown in Figure 2, which is autonomously operated and for each segment (also sometimes called a "row") of packet transmission. The format of all transmission intervals is similar whether packet or isochronous, as shown in Table III for the mobile-to-base direction. In the base transmit direction, the first four octets are additional synch rather than OFF.

Table III: Format of Transmission Intervals

Octet #	# Octets	Function
0-3	4	Synchronization
4-10	7	Label, Access Control, Parity
11-74	64	Payload
75	1	Off transition
	76 octets	Xmitter ON interval
	4	Xmitter OFF interval
	80 octets	

Four octets would use 40 microseconds of air time corresponding to 40,000 feet of propagation time. This could be a fundamental limiting dimension on design factors which contribute uncertainty or delay. One octet of apparent OFF time is an absolute requirement at the Access Point receivers.

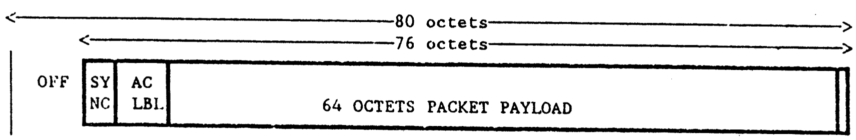


Figure 2. Regular Time Slot/Segment Structure

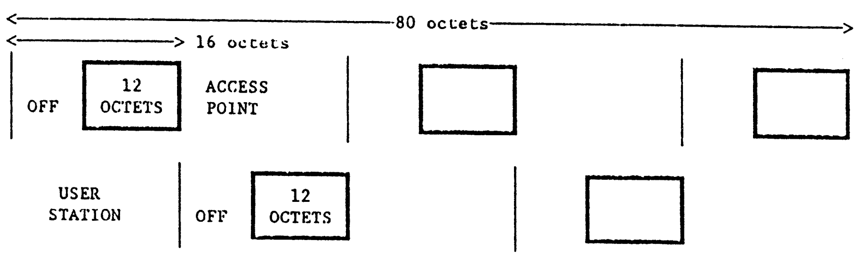


Figure 3. Access Request/Grant Sub-segment/Sub-slot Structure

Access Mode Slot Structure

Access mode divides each normal time slot into subsegments of 16 octets each as shown in Figure 3. The assignment of octets is the same as for a normal slot except that the payload is omitted. The 7 label and access control octets are the payload.

Table IV: Access Mode Format

Octet #	# Octets	Function
0-3	4	Synchronization
4-10	7	Label, Access Control, Parity
11	1	Off transition
	12 octets	Transmitter ON interval
	4	Transmitter OFFinterval
	16 octets	x 5 sub-slots = 80 octet slots

Access Protocol

This subject is critical to the design of the system. It controls the dead time between consecutive uses of a service, and the time lost from contention is determined by the way the access protocols reacts to simultaneous attempts to use the system.

Rather than propose a fully explained protocol or a thorough analysis of the alternatives, a summary of one possibility is described.

The access process uses subsegments of 16 octets including the 4 octet OFF interval. It is possible to ping-pong three transmissions from the Access Point and two from the User Station within the duration of one 80 octet time slot. This procedure is used for access with contention resolution for the first use of both data and voice channels.

Access to each segment (also called "row" or "cell" in other contexts) is regulated by the AC field within the 7 preamble overhead octets.

Once the slot space is allotted to either a fixed or mobile user of the Access Point, the sender is the sole occupant of the time slot until finished.

The Access Point transmits a marking corresponding to one of the following states within the AC field of each segment:

1. "available for use" marking in subslot 1 of each vacant segment
2. "busy" marks a segment and then starts a packet transmission in the payload space with a preamble in packet or isochronous format.
3. "busy continuing" marking for a further segment of a packet already started
4. "busy ending" marking for the last segment of a packet already started.

A User Station may request slot access when the status "available for use" of the segment is broadcast in the 1st Access Point subsegment. A request is made in the 2nd subsegment, and it is granted or refused in the 3rd subsegment. Retry is conditionally permitted in the 4th subsegment, and may be granted in the 5th. Once a User Station receives a grant of access, the next packet can start at the beginning of the payload in the next regular segment.

Traffic and Capacity

It is easy to describe capacity in channels, but it is necessary to describe it terms of the number of units supported. No previous experience with pure voice systems is applicable because of huge differences in the use of air time. To make an estimate, the air-time usage of one unit for one hour in seconds duration of a 32 Kb/s channel will be imagined as follows:

Unit Station Transmitting:	Seconds.
Voice conversation mode:	12
Voice message mode:	12
Status reporting--data:	1
Acknowledgments--data:	2
Data base requests--data:	1
Air time in sec/hour/unit:	28
Air time in min/hour/100 units:	47

The dimension for voice conversation mode must be averaged over a large number of units where usually there is little or no ordinary voice conversation, but occasionally there might be a long one. Conversations of 300 seconds (100 seconds transmitting time) might happen 4 times an hour in a fleet of 100 units. This corresponds to 4 seconds per unit. At least a traffic provision for this possibility is justified. Eight seconds is added for short conversations.

Twelve seconds of unit transmitting time is actual speech time in one direction. The measure is unrelated to connection time in telephony, but would correspond to about 36 seconds of telephone conversation.

One second of data channel time is enough for at least 100 ordinary short data messages. The load from data is very low.

Base Station Transmitting (100 units):	Sec.
Voice conversation mode:	1200
Voice broadcast mode:	150
Voice message mode:	300
Acknowledgments--data:	100
Data base reports--data:	300
Facsimile transmission--data:	300
Data broadcast:	5 0
Total air time sec/hour:	2400
Total air time min/hour:	40

Three hundred seconds of data channel time at a rate of 2,500 ASCII characters per second (considering FEC) is a lot of text (3,000 double-spaced typewritten pages).

To transmit a typical facsimile page, a speed improvement of 2/1 over existing machines could be expected (10 seconds). The facsimile channel time allocation is 30 pages per hour.

This estimate suggests that at 65-75% air time utilization, one 32 Kb/s channel would support 100 units, and that 20 channels would support at least 2000 units.

This amount of capacity may be unremarkable by current FM voice standards; however, far more capacity, many new services and far greater margin for unusual peak loads are provided by the assumptions.

The high degree of utilization is entirely feasible, because the store-and-forward modes enable efficient queueing, and the delay is short because the usage and messages are short. A quick assumption is that delay rarely exceeds the length of the average message: 6 seconds for voice and 10 milliseconds for data.

Geographic Capacity

It is unlikely that any public safety organization would reach a geographic concentration of 2,000 units per square mile even including ambulances, fire, highway maintenance and all relevant politicians; but it is not impossible for sporting events, riots, political conventions and parades. There are several choices:

(1) A smaller number of channels per group
(2) Greater area per cell
(3) Inclusion of a larger user group

The first two possibilities are technical. The last and economically preferrable solution is partly political.

The technical possibility which is *not offered* is increasing the range of each access point. Increase of the area per cell can only be done by using more illumination points in a common system. Greater range has too many difficulties starting with increased transmitter power.

Hardware

The largest gain in function and lowered costs will come from identical units. Channel plans and service configuration must be downloadable software. It may be easier to visualize the system with some description of the hardware that might be used:

The **personal unit** should in some versions resemble a cellular telephone in that there is an integral keyboard and display. The simplification that would result from reducing required transmitter power from 1.7 watts to 0.02 watts, is very large. It is less obvious, but *simplex only versions would be even simpler,* avoiding the duplexing filter and most of the associated 50% power loss. It also not be obvious that the cost of a radio is affected by the fractional bandwidth of the channel. Channels which are too narrow relative to the operating frequency cause spectrum waste in guard bands for crystal frequency and band-filter variations. Also the conversion scheme can be simplified for wider IF bandwidths. The low cost of consumer radio is in great part due to easing the technical requirements by appropriate choice of fractional bandwidth and adjacent channel interference conditions.

The **vehicular unit** could be electronically similar to the personal unit excepting that it is divided into an RF unit which is part of the base of the antenna, a processor unit with handset and speaker, and a keyboard, a display, and a printer where the printer might be a receive-only FAX device with 5" wide paper roll. Extension connectors might provide transmission access for accessories such as a scanner for transmitting finger prints or driver's licenses, or a still-frame video camera.

The **fixed access-point radio** is not easy to forecast because it depends greatly on the conditions of installation. The access-point radio probably will be in two parts where there is an up-down converter built into the base of the antenna, and a processor unit close to the power source, and at working level in the structure on which the antenna is supported.

Either unshielded telephone pairs or optical fiber cables can be used for the link to a **cluster concentrator** serving 4 to 16 access points. The cluster concentrator is probably linked by fiber optic cable to a **cell controller**.

It may be necessary to carry each receiver channel separately to the cluster concentrator where the received data message is decoded one segment at a time. The segment is forwarded to the cell controller only if it is apparently error free and not a duplicate of a segment already committed to transmission. Buffering at this point is dimensioned for 64 octet payloads.

ECONOMIC ESTIMATES

The cost of the large number of access points is a major consideration. A first estimate is that the cost is the sum of the following items:

(1)one street light on its own post
(2)electronic equipment and antenna
(3)installed, 2000 feet of one of the following media:
a) dual twisted pair telephone cable
b) dual optical fiber with transducers
(4)allocated cost of a 1/n part of shared and common equipment

The electronic equipment, at a few thousand dollars, might be a minor part of the installed cost. Rather than justify a particular number, an installed cost of $25,000 per site will be assumed arbitrarily, and economic feasibility estimated from there.

An average of 16 sites per square mile and a system of 20 square miles with 2000 units wil be a further provisional assumption. The immediate result is $8 million or $4,000 per served unit. A city of 20 square miles might have a population of 0.5 million, and so the cost could be put at $16 per inhabitant. This is a method of economic measurement and not a conclusion.

It is important to notice that the cost is not sensitive to the capacity of the radio system. Whether the radio is wideband or narrowband would make only a few percentage points of difference. Therefore:

> **The total cost of a fixed system that served 40,000 units in 20 cells would not be materially different from one serving 2,000 units in one cell 20 times larger (where both systems use the same number of access points). The best economic solution is to combine all possible services into a common system.**

What may not be obvious is that this capital cost for the fixed network is lower than that for the cellular telephone service.

CANDIDATES FOR CO-USE OF PUBLIC SAFETY FIXED NETWORK

The first candidates for co-use of this system are all of the arms of local government which use the city streets. Some of these are:

- Ambulances
- Fire departments
- Street departments
- Local government administrations
- City transit system busses
- Sanitation departments
- City-owned power and water utilities

The next set of candidates for co-use are public service entities which may be independent of the city-owned radio access network. Examples are:

- County Sheriff and corresponding public safety services
- State functions including freeway maintenance services and highway patrols
- Hospital emergency support services
- Ambulances

There is a possibility of offering access service to dispatch type private users, but this is too provocative and political to press further. What is clear is that there is an economic incentive for a common system for the largest possible definition of an affinity group of users. Without this, there is no possibility of an order of magnitude increase in the capacity of the private system portion of the radio spectrum.

Shared Cost Allocation

It should also be understood that a system of this type can provide automatic usage records for allocation of costs or billing of shared cost. Carried to the limit, radio access is a shared municipal service available to an eligible type of user, and that user buys his own approved type unit station equipment and pays periodic and usage-based charges for the service.

Capacity Allocation

There is a temptation to divide the available channels among possible user groups. That should be resisted. Eventually, multiple access methods will result in all users having electrical access to all channels. The selective addressing will limit all users only to the relevant traffic access determined by the system administrators. What is to be divided is not channels but address space and use time.

CONCLUDING SUMMARY

By reducing the coverage of one base station site from a typical radius of 5-10 miles to 0.25 miles or less (and now renamed "Access Point"), the required transmitter power is reduced from 100 watts ERP (base stations) and 3-10 watts (mobiles) to less than .05 watts (peak); and this greatly simplifies personal radio design. Using multiple rather than single low-power access points provides coverage by site selection rather than by overpowering to fill shadows. The frequency re-use factor can drop to 4 where it might be 24 for a conventional cellular system with small radius cells.

Accepting a common form of digital transmission has great advantages in increased capability for necessary non-voice communication services which greatly reduces air-time requirements per station.

With this type of system, the cost of the fixed network is almost independent of radio bandwidth. The system can be designed for the largest feasible bandwidth which, in this case, is thought to be 1 MHz for 800 Kb/s. This change from conventional frequency division channelization disposes of most of the fixed network per channel equipment costs. Channels are defined by time slots and logic circuits. This change causes site cost to be relatively unaffected by the number of channels it supports. Compared with a cellular system, the advantage in increased spectrum utilization may be estimated as follows:

Gain from reduced geographic spacing:
$(6/0.25)^2 = 576$
Same considering 16 cochannel sites:
$576/16 = 36$
Gain from reuse factor reduction:
$24/4 = 6$ and $6 \times 36 = 216$
Loss from greater bandwidth/channel:
$25/(1000/20) = 0.5$
$0.5 \times 216 = 108$

The plan shown has about 100 times the spectrum utilization per channel provided as compared with a small cell telephone system, and more when compared with a longer range private system at 900 MHz.

This advantage would be increased by a factor of 2 to 5 when the gain from replacing voice with 24 Kb/s data and from avoidance of waste of half of a duplex connection with one-way information is also considered. Technically, a system of the type described, might furnish the entire dispatch communication services required in a city as a specialized common carrier. No rooftop or mountain top sites would be needed. No long distance interference would occur in unusual meteorological conditions.

The cost per mobile station for the fixed network service might be 10% of that of a cellular subscriber, based on 40% of the allocated capital cost and 4 times the channel loading. Obviously, there could be great resistance to this type of plan because the money saved is already being spent somewhere. But this economy and increase of service capability is the reward for adopting a common personal radio dispatch system standard supported by a national consensus of users and suppliers. For our own economic survival as taxpayers and service purchasers, I hope that this type of communication technology can evolve in the next decade.

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Chandos A. Rypinski is President and Chief Technical Officer of LACE, Inc. (Local Area Communication Equipment) of Petaluma, CA. He is a Fellow of The Radio Club of America, a Senior Member of the IEEE, and recipient of the IEEE Centennial Medal for contributions to vehicular radio technology.

BUSINESS LISTINGS

Ronald H. Ammeraal, Sinclair Radio Laboratories, Inc., 400 South Ramona, Suite 212-B, Corona, CA 91719, 714-737-2120

Gaetano (Tom) Amoscato, Amtol Radio Communications Systems, Inc., 150-47A 12th Road, Whitestone, NY 11357, 718-767-7500

Donald B. Arnold, Commonwealth Communications Industries, Ltd., 602 Lickinghole Road, Ashland, VA 23005, 804-798-9128

Aldo A. Bottani, Telecommunications Consulting Services, 281 Seton Hall Drive, Paramus, NJ 07652, 201-265-7797

Gene A. Buzzi, Omnicom, Inc. – Communications Engineering, 325 John Knox Road, Suite E-204, Tallahassee, FL 32303, 904-386-3180

Richard W. Ehrhorn, W4ETO, Ehrhorn Technological Operations, Inc., 4975 North 30th Street, Colorado Springs, CO 80919, 719-260-1191

Les Ettinger, Tele-Path Corporation, 49111 Milmont Drive, Fremont, CA 94538, 800-292-1700, 415-656-5600 (CA)

Larry R. Evans, Integrated Management Systems, 9805 Horton Road SW, Suite 100, Calgary, Alberta, Canada T2V 2X5, 403-255-9630, 403-243-9482 (FAX)

John A. Facella, Motorola Communications – International Group, 1301 East Algonquin Road, Schaumburg, IL 60196, 312-576-0486

Joseph J. Fairclough, WB2JKJ, The Radio Club of Junior High School 22 N.Y.C. Inc., P.O. Box 1052, New York, NY 10002, 516-674-4072

William J., Hotes, President, Telocator, 2000 M Street NW, Suite 230, Washington, DC 20036, 202-467-4770

Eric A. Jacobson, Publisher, Intertec Publishing Corporation, P.O. Box 12901, Overland Park, KS 66212

R. W. Johnson, P.E., W6MUR, Spectrum Measurement Corp. (RFI Test Lab), 2820 Grant Street, Concord, CA 94520, 415-687-7620

Leonard R. Kahn, Kahn Communications, Inc., 425 Merrick Avenue, Westbury, NY 11590, 516-222-2221

Antoinette P. Kaiser, STI-CO Industries, Inc., 36 Letchworth Street, P.O. Box 97, Buffalo, NY 14213-0097, 716-881-3287

James K. Laffey, The Warner Group Management Consultants, 5950 Canoga Avenue, Suite 600, Woodland Hills, CA 91367, 818-710-8855

Richard P. Meyer, Esq., Meyer, Faller, Weisman and Greenburg, P.C., 4400 Jenifer Street, Suite 380, Washington, DC 20015, 202-362-1100

Maryanne Micchelli Conte, WFAN Sportsradio, 1372 Broadway, New York, NY 10018, 212-869-6660 x257

Wayne H. Morris, BBL Industries, Inc., 2935 Northeast Parkway, Atlanta, GA 30360, 404-441-6464

Paulla A. Nelson-Shira, Pandata Corp., 2175 South Jasmini, No. 211, Denver, CO 80222, 303-756-0690

John J. Nevin, Quintron, One Quintron Way, Quincy, IL 62301, 217-223-3211

William L. Ordway, Cellular Strategies, 2042 Inwood Lane, Santa Ana, CA 92705, 714-544-2404

Mark A. Plagens, President, National Communications Stores, P.O. Box 2854, Conroe, TX 77305, 409-539-2854

Joseph J. Pomparelli, RPC – Radio Page Communications, 102 Centre Boulevard, Suite J, Marlton, NJ 08053, 609-985-1500

Thomas R. Poor, Communication Enterprises Inc., 2315 Q Street, Bakersfield, CA 93301, 805-327-9571, 805-327-2732 (FAX)

James G. Prestwood, Jr., Prestwood Communications, 1445 Greene Street, Augusta, GA 30910-0189, 404-722-1111

Jack Reichler, Meridian Communications, 23501 Park Sorrento, #213A, Calabasas, CA 91302, 818-888-7000

Alvin Reiner, Federal Communications Commission, 7435 Oakland Mills Road, Columbia, MD 21046, 301-725-1585, 301-344-3411

Francis J. Rodriguez, M.S., Spectrum Management, Western Union Corporation, 1 Lake Street, Upper Saddle River, NJ 07458, 201-818-5922

Theodore Rykala, P.E., Communication Consultant, 33247 Cloverdale, Farmington, MI 48024, 313-478-6994

Herschel Shosteck, Herschel Shosteck Associates, Ltd., 10 Post Office Road, Silver Spring, MD 20910-1192, 301-589-2259

Larry Steckler, President, Gernsback Publications Inc., 500-B Bi-County Boulevard, Farmingdale, NY 11735, 516-293-3000, 516-293-3115 (FAX)

J.C. (Jim) Stratt, Vice-President, General Manager, Sinclabs Inc., 85 Mary Street, Aurora, Ontario, CANADA L4G 3G9, 416-773-1994

William Torbick, W. Torbick & Associates, 226 Ivy Lake Drive, Forest, VA 24551, 804-525-7246

Edward F. Weingart, Vice-President Engineering, Metro One Cellular Telephone Co., 87 West Passaic Street, Rochelle Park, NJ 07662, 201-587-8000

William A. Wickline, P.E., President, Kathrein Incorporated, 26100 Brush Avenue, #319, Euclid, OH 44132

CROSS REFERENCE

Amtol Radio Communications Systems, Inc.,
- Gaetano (Tom) Amoscato

BBL Industries, Inc.
- Wayne H. Morris

Cellular Strategies
- William L. Ordway

Commonwealth Communications Industries, Ltd. - Donald B. Arnold

Communication Consultant
- Theodore Rykala, P.E.

Communication Enterprises Inc.
- Thomas R. Poor

Ehrhorn Technological Operations, Inc.
- Richard W. Ehrhorn

Federal Communications Commission
- Alvin Reiner

Gernsback Publications Inc.
- Larry Steckler

Herschel Shosteck Associates, Ltd.
- Herschel Shosteck

Integrated Management Systems
- Larry R. Evans

Intertec Publishing Corporation
- Eric A. Jacobson

Kahn Communications, Inc.
- Leonard R. Kahn

Kathrein Incorporated
- William A. Wickline, P.E.

Meridian Communications
- Jack Reichler

Metro One Cellular Telephone Co.
- Edward F. Weingart

Meyer, Faller, Weisman and Greenburg, P.C.
- Richard P. Meyer, Esq.

Motorola Communications - International Group - John A. Facella

National Communications Stores
- Mark A. Plagens

Omnicom, Inc., Communications Engineering
- Gene A. Buzzi

Pandata Corp.
- Paulla A. Nelson-Shira

Prestwood Communications
- James G. Prestwood, Jr.

Quintron
- John J. Nevin

RPC - Radio Page Communications
- Joseph J. Pomparelli

Sinclabs Inc.
- J.C. (Jim) Stratt

Sinclair Radio Laboratories, Inc.
- Ronald H. Ammeraal

Spectrum Measurement Corp. (RFI Test Lab)
- R. W. Johnson, P.E.

STI-CO Industries, Inc.
- Antoinette P. Kaiser

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- Les Ettinger

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- Aldo A. Bottani

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- William J. Hotes

The Radio Club of Junior High School 22 N.Y.C. Inc. - Joseph J. Fairclough

The Warner Group Management Consultants
- James K. Laffey

W. Torbick & Associates
- William Torbick

Western Union Corporation
- Francis J.Rodriguez, M.S

WFAN Sportsradio
- Maryanne Micchelli Conte

RADIO CLUB OF AMERICA PROFESSIONAL DIRECTORY

GAETANO (TOM) AMOSCATO
Communications Consultant
150-47A 12th Road
Whitestone, NY 11357
718-767-7500

ARMANDO COURIR I4AIJ (I1AIS-9A1AIJ)
Land-Mobile Systems Consultant
Via E. Barsanti, 8
50127 Florence, Italy
39-55-4381265

GARY EISENBERG, WB2EQX
Communications Through 2-way Radio
460 West 35th Street
New York, NY 10001
212-736-6500

ROBERT I. ELMS, P.E.
Land Mobile & Telemetry Consulting Engineer
72 Smithtown Road
Budd Lake, NJ 07828
201-691-9067

WILLIAM E. ENDRES
Television Security System
145 Main Avenue
Clifton, NJ 07014
201-473-8822

ERO E. ERICKSON
Business Radio Comm. Consultant
5622 West Diversey
Chicago, IL 60639
312-889-7654

R. JAMES EVANS
Comms. Consultant, Land Mobile
2803 Southwood Drive
East Lansing, MI 48823
517-351-3252

W.G.H. FINCH, P.E.
Fax and Record Communications
3025 Morningside Blvd.
Port St. Lucie, FL 33452
407-335-5147

MILTON R. FRIEDBERG
Management Consultant
2537 Claver Road
Cleveland, OH 44118
216-382-4070

HARRY S. GARTSMAN, W6ATC
Military Avionics, ASW & ECM Systems Consultant
9921 Sunset Blvd.
Beverly Hills, CA 90210
213-273-1995

ALAN W. HALEY
Land Mobile Consultant
319 Tacoma Ave., N.#608
Tacoma, WA 98403
206-272-8310

CHARLES HIGGINBOTHAM
Land Mobile Consultant
85 Aspen Meadows Circle
Santa Rosa, CA 95409
707-539-8638

JACK HOFELD
Communications Consultant
P.O. Box 422
Virginia City, NV 89440
702-847-0723

R.W. JOHNSON, P.E., W6MUR
FCC/VDE RFI Measurements
2820 Grant Street
Concord, CA 94520
415-687-7620

LEONARD R. KAHN
Communications Consultant
425 Merrick Avenue
Westbury, NY 11590
516-222-2221

JOEL I. KANDEL, KI4T
Communications Consultant
5463 SW 92 Avenue
Miami, FL 33165
305-596-9373

BRUCE M. KARR, KA4MET
Public Safety Communications Consultant
4727 E. Alamos, #116
Fresno, CA 93726
209-292-2024

JAMES A. LANG, P.E.
Telecommunications Consultant
24591 Summerhill Court
Los Altos, CA 94022
415-948-5914

FRED M. LINK
Communications Consultant
Robin Hill
Pittstown, NJ 08867
201-735-8310

LOREN McQUEEN
Communications Consultant
2633 South Bascom Avenue
Campbell, CA 95008
408-377-2900
FAX 408-569-7684

JAMES MANN
P.O. Box 340
Agoura, CA 91301
818-889-6666

STUART MEYER, W2GHK
Land-Mobile Radio Consultant
2417 Newton Street
Vienna, VA 22181
703-281-3806

RAY MINICHELLO, P.E.
Communications Consultant
33 West Water Street
Wakefield, MA 01880
617-245-4640
800-225-4438

JACK REICHLER
Antenna Sites So. California
23501 Park Sorrento #213A
Calabasas Park, CA 91302
818-888-7000

JOHN J. RENNER
Advanced Technology
P.O. Box 1608
Arlington, VA 22210-0903
703-532-2155

THOEDORE P. RYKALA, P.E.
Communications Consultants
33247 Cloverdale
Farmington Hills, MI 48024
313-478-6994

F.H. SHEPARD, JR., P.E.
Consulting Engineer
16 Lee Lane, Countryside
Summit, NJ 07901
201-273-5255

CARL E. SMITH, P.E.
Communications Consultant
8200 Snowville Road
Cleveland, OH 44141
216-526-4386

JAMES L. STEVENSON, NCE, IEEE
Communications Consulting Engineer
P.O. Box 340
North Branch, MI 48461-0340
(313) 688-2633

ERIC D. STOLL, Ph.D., P.E.
Communications Consultant
117 Hillside Avenue
Teaneck, NJ 07666
201-836-2351

DAVID TALLEY, W2PF
Telecommunications Consultant
10275 Collins Avenue, Suite 1533-S
Bal Harbour, FL 33154
305-868-4131

RAYMOND C. TROTT, P.E.
Land Moble/Microwave Communications Consultant
1425 Greenway Drive #350
Irving, TX 75038
214-580-1911

WOULD YOU LIKE TO BE INCLUDED IN THE PROFESSIONAL LISTING?
Contact STUART MEYER
2417 Newton Street
Vienna, VA 22181
703-281-3806