Proceedings of

The Radio Club of America, Inc.

Volume 59, Number 2

November, 1985

Founded 1909

THE RADIO CLUB OF AMERICA, INC.
c/o Fred Shunaman, 324 South 3rd Avenue, Highland Park, NJ 08904

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

The Radio Club of America, Inc.

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

Price $2.50

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

THE AWARDS OF THE RADIO CLUB

The ARMSTRONG MEDAL, initiated 1935, the initial recipient being Major Edwin H. Armstrong.

Bestowed by the Board of Directors of the Radio Club of America upon any person within its membership who shall have made, in the opinion of the Board of Directors, and within the spirit of the Club, an important contribution to Radio Art and Science.

The SARNOFF CITATION, initiated 1973, with initial recipient being the Honorable Barry Goldwater.

Established by the Board of Directors to be given annually to a Club member for Significant Contributions to the advancement of Electronic Communications.

The ALLEN B. DUMONT CITATION, initiated in 1979, the initial recipient being Dr. Thomas T. Goldsmith, Jr.

Bestowed by the Board of Directors of the Radio Club of America upon the person who has made important Electronic Contributions to the Science of Television.

The RALPH BATCHER MEMORIAL AWARD, initiated in 1975, with the initial recipient being William H. Offenhauser, Jr.

Presented annually to a member who has assisted substantially in preserving the history of radio and electronic communications.

The RADIO CLUB PIONEER CITATION, initiated in 1975. The initial recipient was Ernest V. Amy, a Founder of the Club.

Designated by the Board of Directors to be given annually to senior members who have contributed substantially to the success and development of the Club, or to the art of Radio Communications.

The PRESIDENT'S AWARD, established in 1974. The first recipient was Dr. George W. Bailey.

For unselfish dedication to the support of the Radio Club of America.

The HENRI BUSIGNIES MEMORIAL AWARD, established in 1981. Wm. H. Foster was the first recipient.

For the advancement of Electronics for the benefit of mankind.

The LEE deFOREST AWARD, established in 1983. D.E. Replogle was the first recipient.

In memory of the many contributions of Dr. Lee deForest to the radio communications industry.

BANDWIDTH EFFICIENT TECHNOLOGY

A Report on the Art

Dr. Gregory M. Stone

by Gregory M. Stone
Fellow, R.C. of A

It is now sixty-three years since that historic first trans-atlantic short wave message via 1BCG and those pioneers: Grinan, Amy, Armstrong, Burghard, Cronkhite and Inman earned the tributes paid them here today.

Now, instead of utilizing short waves for trans-atlantic communications we routinely employ geo-synchronous satellites carrying voice, data and wide-band video signals.

With our ever-increasing technological development, the need for efficient transfer of information via radio frequency has placed great demands upon our spectrum resource, to a point where spectral congestion is a serious concern. In response to the recognized scarcity, governmental regulatory bodies in this country and abroad are attempting to develop a posture that fosters the efficient use of our spectrum resource.

Unfortunately, as with most shortages, spectral congestion is of our own creation. Thus it is incumbent upon us, the radio scientists and engineers, to propose techniques that permit the more efficient usage of radio frequency spectrum. This suggestion is by no means new—numerous authors have addressed this very issue. Consider the following quotation:

> "It is a well known fact that in carrier wave transmission it is necessary to provide for the efficient transmission and reception not only of the carrier frequency itself but also for a band of frequencies of width depending upon the frequency and character of the signal itself. This necessity is becoming more and more a serious consideration as the severity of wavelength regulation and the necessity of sharp selective tuning are increased. In view of these facts, a great deal of inventive thought has been devoted to the problem of narrowing the band of transmission frequencies."[1]

Obviously, much of the above content is applicable to our situation today, yet it was written by John R. Carson, and published in the December 1922 issue of the *Proceedings* of the IRE, one year after the 1BCG transmission.

As I view the situation, an apparent disparity exists between what the technological art permits and how we choose to apply or mis-apply it. In this paper we will discuss bandwidth efficient technologies, where we are today, and the general future trends, including our need for governmental regulations (or lack thereof) which promotes the development and exploitation of bandwidth efficient technologies.

The Issue of Efficiency

Bandwidth efficiency may be viewed in terms of an integration of the information capacity parameter of a channel and its communications efficiency. For example, while bandwidth efficiency is generally concerned with the information (Nyquist) capacity of a channel in bits per second per cycle per second, (bps/cps); it cannot ignore Shannon's work, which generalizes the signal-to-noise needed for a given error rate (E_b/N_o). In this context several technical criteria determine the ultimate bandwidth efficiency of a given technology. These criteria include: the information coding/formatting or compression employing various quantizing techniques; the base band and radio frequency modulation systems used, i.e. linear versus non-linear; the type of channel coding employed; physical characteristics of the channel such as its noise statistics, signal distribution and propagation law; the efficiency of the discontinuity (aerial) system employed and by the performance of the detection/demodulation system.

Information Formatting (Compression)

At present, information compression may be effected through amplitude and frequency domain processing. Since the 1930's amplitude processing, specifically syllabic amplitude compression/expansion or companding, has been employed for noise reduction and decreasing the linearity requirements of transmission circuitry.

Today, with the advent of integrated circuitry, we are able to utilize amplitude companding in mobile and handheld portable radio sets at 2-1 and 4-1 ratio syllabic rates. The future promise of amplitude companding is not predicated upon fixed law devices but, as Dolby and dbx have long contended, the most promise for noise and dynamic range reduction is through the use of adaptive equalization in conjunction with adaptive amplitude companding with ratios as high as 8-1.

In the frequency domain, the delta modulation codec is in common usage in such diverse applications as military communication networks and land mobile voice privacy systems. At data rates of 10.0 kbs, delta modulation systems employing a continuously variable slope (CVSD), are able to convey intelligible voice. However, CVSD at a 10.0 kbs data rate requires a 25.0 kc/s channel if a non-linear radio frequency modulation is used such as FSK; or if QPSK in a linear transmission medium is employed, the 10.0 kbs data rate could be accommodated in a 5.0 kc/s channel. Still, in terms of bandwidth efficiency, digital voice transmission must be effected in bandwidths less than even 10.0 kc/s. To achieve this reduced data rate transmission for voice, the use of voice coding or vocoding is necessary.

Since Dudley's work in the 1930's with the spectrum channel vocoder, technology has developed to a point where natural sounding synthetic speech may be derived at bit rates as low as 2.0 kbs in systems employing linear predictive speech coding (LPC) in conjunction with vector quantizing. Similarly, intelligible speech may be transmitted at data rates of 1.2 kbs for LPC without vector quantizing and 600 bps with vector quantizing although speaker recognition is seriously compromised. With today's CMOS LPC processors, discounting any vector quantizing improvement, speech at quality levels consistent with marginal toll quality circuits may be conveyed at a 3.0 kbs rate, which is easily supported in a 2.5—5.0 kc/s channel, depending on the modulation system employed.

We view the application of linear predictive coding either with or without vector quantizing, as essential elements in bandwidth efficient transmission systems comprised of combined voice and digital data networks. And, as LPC is a digital technique, an encryption algorithm such as DES may be applied, resulting in private, narrow-band digital voice.

Also under the frequency domain classification but in the analogue world, is the Harris frequency compandor which effects voice band width compression through discarding non-essential voice energy/spectral components. Intelligent voice may be transmitted in a 1.6 kc/s frequency band width although articulation suffers somewhat.

Modulation

Both base band and radio frequency modulation may be classified in terms of envelope characteristics, ie. constant envelope or non-constant envelope. The difference is obvious; constant envelope modulation conveys information only in the frequency or phase domain while non-constant envelope modulation utilizes both frequency/phase and amplitude domains for information transmission. In terms of efficiency, those techniques that employ both phase and amplitude terms generally are capable of higher data rate capacity but require a linear transmission medium. Constant envelope modulation does not require a linear medium for transmission but must be heavily filtered to minimize spectral spreading which compromises its data capacity.

Under the constant envelope classification we find the following types of modulation which hold promise in terms of band width efficiency: Firstly, M-ary Phase Shift Keying or PSK may be used. If two phase levels are used the designator is 2-PSK or bi-phase; with four phase states, 4-PSK, Quadrature Phase Shift Keying or QPSK, and eight-phase states 8-PSK; In terms of "narrow band" constant envelope modulation three types are most promising: Tamed Frequency Modulation, Minimum Shift Keying and Guassian Minimum Shift Keying. With Tamed Frequency Modulation the binary waveform is processed in a specific premodulation filter consisting of a three-tap transversal filter and a Nyquist-3 low-pass filter which acts to control spectral spreading, with a modulation index of 0.5 the TFM waveform has an efficient spectral power density. Minimum Shift Keying or MSK, is a binary frequency modulation which is essentially a derivative of Frequency Shift Keying except that the modulation index for MSK is set at 0.5, with a frequency shift equal to 0.25 times the bit rate. When a premodulation filter is applied to MSK, such as a Guassian low pass, the resultant waveform is Guassian Minimum SHift Keying or GMSK. With any type of premodulation filtering, such as that employed in TFM or GMSK systems, out-of-band emissions are reduced at the expense of increased intersymbol interference. However, as the above techniques are constant envelope, they may be efficient in terms of bandwidth utilization where they permit saturated non-linear amplification without increased out-of-band emissions, thus permitting close channel spacing. To fully exploit the advantages of TFM or GMSK, fairly advanced coherent or synchronous detection and processing is needed for reasonable BER vs E_b/N_o values. [2 3 4 5 6]

In terms of non-constant amplitude modulation, the most promising is a hybrid of 4-PSK and 4-ASK or Quadrature Amplitude Modulation. In this process, (QAM) information is conveyed through four distinct phase and amplitude states requiring a linear transmission medium. With coherent detection and advanced processing, QAM is able to transmit almost 75% more information in a given channel than an equivalent QPSK waveform.

Of course, systems that utilize the amplitude domain for information are susceptible to device and channel non-linearities/variations and corrective measures must be taken to remove the amplitude and phase perturbations. The following discussions on linear transmission and detection/demodulation will shed some light on means presently available to permit QAM usages under previously hostile conditions.

With any digital modulation system, the issue of bit error rate (BER) performance versus the signal-to-noise quantity E_b/N_o cannot be ignored. Even the most promising bandwidth efficient modulation is not practically relevant if its moderate to low SNR performance is not consistent with mobile radio applications. To improve the E_b/N_o performance, sophisticated channel coding may be employed but only at the expense of information rate and/or bandwidth. In addition, channel anomalies such as amplitude and phase distortions must be corrected for, to permit accurate data demodulation. This issue is non-trivial, for as BER's of 10^{-7} may be attained at 10.0 dB E_p/N_o with high level modulation, in an infaded environment, with Rayleigh fading and random FM that value may be reduced to 10^{-3} or worse.

Radio Frequency Transmission

Until the development of practical digital radio frequency power amplifiers, even digital modulation had to be conveyed through analogue devices. In the case of constant envelope modulation such as frequency or phase, non-linear and efficient Class-C amplification may be employed. However, as non-constant envelope modulations are capable of higher information transfer rates, a linear radio frequency amplification and transmission medium is needed. (A very good case can also be made for the transmission of such modulations as QPSK via linear techniques as bandwidth efficiencies are improved and filtering is made far more versatile.)

With renewed interest in single sideband modulation and linear amplification/transmission, the prospects for efficient voice and digital data transmission in narrow channels, ie. 4.0 or 5.0 kc/s, is quite favorable. To effect this bandwidth efficient usage, the radio frequency up conversion and final amplification circuitry must have very low in and out of band intermodulation and sideband noise levels consistent with linear practice. Fortunately, several techniques are available, and with modern techniques the up conversion process is no longer of concern at frequencies in excess of 1,000.0 MC/s (1.0 KMC). Power amplification does pose some very real difficulties as linear devices in both the VHF and UHF ranges are typically low power and exhibit low conversion efficiencies. The most promising solution to low distortion power amplification at the VHF and UHF frequencies is through the application of Envelope Elimination and Restoration, developed by Leonard Kahn in the early 1950's, combined with modulation feedback of the Polar Loop or Cartesian types proposed by V. Petrovic, of the University of Bath, United Kingdom.

The linearity of a modulator or amplifier may be improved through the application of negative feedback and if the feedback contains only the modulation information of the amplified signal, and assuming that the amplifier bandwidth is much wider than the highest component of the feedback signal, large amounts of feedback may be used while maintaining amplifier stability. This feedback arrangement involves resolving the modulated radio frequency signal into orthogonal components and applying feedback. Therefore, any two orthogonal paramters may be used; yet when these are expressed in polar or cartesian form, feedback implementation is easily achieved.[7 8 9 10]

In the 150 MC/s frequency range, transmitters employing polar form feedback, based upon Envelope Elimination and Restoration, have been developed exhibiting 40-45% conversion efficiency with intermodulation products down, 60 dB 3rd order and higher order down 70 dB, or more.

Cartesian feedback in conjunction with the Weaver form of single sideband generation has been successfully constructed that suppresses unwanted sideband emissions by more than 60 dB in conjunction with third order intermodulation suppressed to a like amount. The importance of the Weaver modulator is that it lends itself well to McGeehans Transparent Tone In-Band (TTIB) coherent phase reference scheme, covered later in this paper. Stevenson [11] recognized this in his development of Digitally Processed Multi-Mode modulation (DPMM) which also utilizes the Weaver method of single side band generation and demodulation. DPMM is discussed in the next section.

As frequency increases, transmitter linearity and conversion efficiency decreases; with the application of Envelope Elimination and Restoration, Weaver sideband generation and polar or cartesian feedback, efficient linear modulators and amplifiers may be produced at frequencies well above 1,000.00 MC/s, if strip line and other precision technology is applied.

Detection/Demodulation

We have previously discussed the need for coherent/synchronous detection and demodulation to achieve high information rate transmission with minimal bit error rates in narrow, ie. 4.0-5.0 kc/s channels. But, in the mobile environment, coherent detection is complicated by Rayleigh fading and random frequency modulation due to doppler. Therefore, signal processing is needed that removes the amplitude and phase perturbations from a fading signal and provides a solid coherent reference for digital data and voice demodulation.

The most common approach involves the use of feed forward automatic gain control (FFAGC) for amplitude fading (flutter) correction and tone above band signalling to provide automatic frequency control, permitting automatic receiver tuning and reliable squelch performance in single sideband systems.

However, FFAGC only acts as an amplitude flutter corrector and is unable to correct for random frequency modulation and phase distortion due to doppler which previously was referred to as "irreducible error".

In the late 1970's and early '80's Dr. Joseph McGeehan and Andrew Bateman, of the University of Bath, United Kingdom, developed feed forward techniques that corrected for both amplitude and phase perturbations present in the received signal envelope propagated through a multipath environment. In addition, the tone above band pilot system was succeeded by a Transparent Tone In Band (TTIB) system which provides correlation fading statistics between the information channel and coherent reference pilot.

McGeehan's phase and amplitude perturbation correction system is refered to as Feedforward Signal Regeneration or FFSR and not only provides for the simultaneous removal of phase and amplitude fluctuations but also the reference pilot is regenerated as a single frequency component, thereby making the extraction and removal of the system reference tone an easy process.[12] For feedforward techniques to be effective, unambiguous information describing the magnitude and phase of the multipath induced distortion must be extracted. This fading information has been shown to be contained within a bandwidth of twice the Doppler frequency. Therefore, providing there is adequate separation between the pilot tone and its neighboring information components, it is possible, by suitable filtering, to separate the Doppler spread pilot from the spread audio components, without spectral smearing.[13]

The Transparent Tone In-Band (TTIB) pilot carrier system affords the desired mechanics to implement FFSR successfully at frequencies up to at least 1,000.00 MC/s (1.0 KMC). With TTIB, the baseband signal from 300 to 3000 cps is split into two approximately equal frequency segments, ie. 300-1700 cps and 1700 to 3000 cps. The upper frequency band is translated up in frequency an amount equal to twice the maximum anticipated multipath spreading plus an allowance for imperfect filtering. At

900.0 MC/s (33cm) a notch width of 0.3 kc/s would be adequate for anticipated vehicle speeds of up to 160 km/hr. The audio baseband would then be segmented: from 300—1700 cps; and from 2000 to 3300 cps. The second half would be translated up in frequency and extend from 31000 to 4400 cps. A pilot tone centered at 1850 cps would then be inserted. The total transmitted band width, in the above example, would be 3300 cps. It is then important to understand that TTIB trades off transmitted bandwidth for the notch width, yet without the resulting coherent phase reference, FFSR would become prohibitively complex and costly. In addition, TTIB is ideally suited for coherent digital data demodulation as the system conveys the needed phase information on the pilot tone, for PSK, at the original carrier frequency, precluding the need for the complex carrier reconstruction techniques necessary in conventional PSK systems.[14 16]

A second technique for the coherent transmission and detection of digital data was developed by F. Davarian and is refered to as a tone calibrated technique. In Davarian's system, Manchester coded Pulse Code Modulation is employed, as a spectral null exists at the center of the occupied band width, permitting insertion of the pilot or calibrated tone, without frequency translation needed in TTIB. Davarian claims that the bandwidth efficiency of the tone calibrated technique is considerably better than that of MSK, as his system permits the use of non-constant envelope signaling. [16]

The much promoted Digitally Processed Mutli-mode Modulation or DPMM, developed by Stevenson, is another candidate in the bandwidth efficiency arena. DPMM utilizes the Weaver method of side band generation and detection. As all processing is conducted through digital means, the distortion levels on both transmit and receive should be quite low. DPMM also employs a pilot in a TTIB configuration, for AFC etc. [17]

A final comment should be made with respect to detection and demodulation: while the above techniques afford a high degree of practical correction for amplitude and phase errors, digital signal processing based upon statistical autocorrelation holds promise in terms of detection of signals at and below the noise floor and for interference rejection.

Future of Bandwidth Efficient Technology

In a recent interview Fred Link made the remark that the frequency synthesizer was one of the most significant developments in radio. The future viability of bandwidth efficient technology is dependent upon the cost effective application of not just frequency synthesis but other "advanced" technologies such as large scale integration (LSI) and very large scale integration (VLSI). Already, in the United Kingdom, Plessy and Consumer Microcircuits, Ltd. are in the process of integrating the McGeehan FFSR and TTIB techniques. Domestically, Stevenson et al are in the planning states of implementing DPMM and LSI or VLSI form. Many if not all of the past technical impediments such as size, power, consumption, stability are non-existent with presently available technology. Just in the area of LPC, Texas Instruments has released a CMOS LPC processor which is applicable to mobile and portable usages where size and power consumption are important.

In the area of radio frequency components, microwave integrated circuits (MIC) and now monolithic microwave integrated circuits (MMIC) are within the range of applicability to top-of-the-line mobile products. In fact, to successfully implement such efficient techniques as EER and Polar or Cartesian feedback at microwave mobile frequencies, advanced stripline and MIC technology is required.

So too, will the application of digital signal processing (DSP) increase not only in context of FFSR but also LPC with vector quantizing. The advances in information formatting and channel coding will no doubt be derived from progress in DSP technology.

With today's technology, we can transmit digital voice at information rates of 3.0 kbs while maintaining speaker recognition and preserving syllabic articulation. And, that 3.0 kbs data rate can be easily supported in a 3.0 to 5.0 kc/s channel depending upon the modulation system employed.

As for analogue voice, if single sideband suppressed carrier transmission is used, the same channel bandwidth stated above for LPC is applicable. If Harris frequency companding is applied, the transmission bandwidth is reduced to 1.6-2.1 kc/s, which can be supported in a 2.0—2.5 kc/s channel.

And, we are not neglecting digital data communications. The application of high level digital modulation techniques is now consistent with bandwidth efficiency. TFM, GMSK, M-ary PSK and QAM all are available today for high performance data transmission. Assuming a 5.0 kc/s channel, data rates of 4.8 kbs are easily achieved and 9.6 kbs is feasible with the existing art. In October 1984, Plessy went public with its proposed digital voice/data system for application in 5.0 kc/s channels in the United Kingdom's recently released Band III. Plessy proposed data rates of 4.8 kbs, which rivals the highest speed presently in use domestically, with frequency modulation and 25.0 or 30.0 kc/s channels. [18]

To achieve efficient transmission of analogue and digital information existing technology must be applied. I see no scientific barriers in place and as was stated in the beginning of this paper, the inefficient use of spectrum is of our own creation; the governmental regulators, in theory, act as trustees of our spectrum resource. Regulations must not impede the development and application of bandwidth efficient technology, yet must be cautious not to favor one over others with equal or greater promise.

List of Sources Consulted

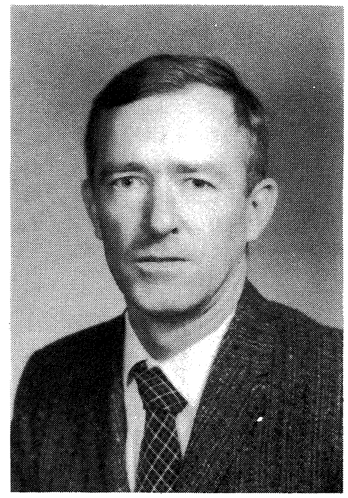
1. Carson, John R., NOTES ON THE THEORY OF MODULATION, *Proceedings of The Institute of Radio Engineers,* Vol. 10, No. 1, Feb. 1922
2. Bellini, Sandro, et. al., NONCOHERENT DETECTION OF TAMED FREQUENCY MODULATION, *IEEE Transactions on Communications,* Vol. Comm-32, No. 3, March 1984
3. Elnoubi, Said, et. al., ERROR RATE PERFORMANCE OF NONCOHERENT DETECTION OF DUOBINARY CODED MSK AND TFM IN MOBILE RADIO COMMUNICATION SYSTEMS, **IEE Transactions on Vehicular Technology,** Vol. Vt-30, No. 2, May 1981
4. Goode, Steven H., A COMPARISON OF GAUSSIAN MINIMUM SHIFT KEYING TO FREQUENCY SHIFT KEYING FOR LAND MOBILE RADIO, *IEEE Vehicular Technology Society, Conference Record,* May 1984
5. Murota, Kazuaki, et. al., GMSK MODULATION FOR DIGITAL

(Continued on page 22)

THE YAGI-UDA ANTENNA

by James E. Brittain
(Fellow, R.C. of A.)

Light on a little-known bit of technical history



Dr. James E. Brittain

The Yagi-Uda antenna and its directional characteristic have long been known by members of the Radio Club of America. Less well known, at least outside Japan, is the fascinating story of the invention of this antenna and the related research in short-wave communication initiated by Hidetsugu Yagi at Tohoku University in the 1920s. The centennial of Yagi's birth that will be observed January 28, 1986 seems a highly appropriate time for a retrospective assessment of the career of Professor Yagi and the antenna named for him and his younger colleague, Shintaro Uda.

Hidetsugu Yagi (1886-1976) was born in Osaka at the time that Heinrich Hertz in Germany was engaged in his pioneering experiments in the generation and propagation through the air of high-frequency electromagnetic waves. Thus Yagi was born at the dawn of the wireless age and, before his death in 1976, he witnessed the creation of wireless communications systems capable of sending television pictures to Earth from the vicinity of Saturn, approximately a billion miles away. He received an engineering degree from Tokyo University in 1909 and continued his education in Europe where he did research under the direction of Heinrich Barkhausen in Germany and J. A. Fleming in England. Barkhausen was the Director of the Division of Weak-Current Engineering at a technical college in Dresden and was the co-inventor of a positive-grid high-frequency oscillator that was employed by Yagi and Uda in the 1920s.[1]

During his stay in Germany, Yagi did research on resonant transformer circuits of the type used in wireless transmitters. He wrote a technical paper on his findings and submitted it to Professor Barkhausen in June 1914 for possible publication. The outbreak of the first World War a few weeks later forced Yagi's hurried departure to England, leaving behind his experimental data. He later published the theoretical section of the paper in the *Proceedings* of the Institute of Radio Engineers in 1917.[2] In England, Yagi worked with Fleming until 1916. Fleming had been the first to employ the vacuum diode in a wireless receiver.[3] Yagi retained an interest in the vacuum diode and later encouraged the diode experiments of Okabe that culminated in the discovery of the split-anode magnetron.

Before returning to Japan, Yagi came to the United States where he spend some time with George W. Pierce (1872-1956) at Harvard University. Pierce was known for his research on crystal rectifiers and had been named the first Director of the Cruft Laboratory at Harvard in 1914.[4] He taught classes in wireless telegraphy and was the author of the book *Principles of Wireless Telegraphy* published in 1910. Yagi may have gaind some insight into the possibilities of directional antennas from conversations with Pierce or from Pierce's book. The book contained a chapter on directive antennas that included a brief discussion of the directivity of two or more vertical monopoles. However, the use of parasitic elements was not mentioned.[5] While in the U.S., Yagi joined the Institute of Radio Engineers which meant that he would have access to its *Proceedings* when he returned to Japan. During 1917, he submitted two manuscripts to the editor of the *Proceedings.* The first paper was based on his resonant transformer research in Germany. Yagi's second paper, published in 1918, compared tone production in wireless telegraphy using AC and DC sources applied to a variety of spark gaps. By the time the paper was published, he was listed as a professor of electrical engineering at Tohoku Imperial University in Sendai, Japan.[6]

Telecommunications Research at Tohoku

Not surprisingly, Yagi took advantage of what he had learned from Barkhausen, Fleming and PIerce by selecting wireless communication as a focus for research. Under Yagi's influence, several other members of the EE faculty at Tohoku and advanced students including Shintaro Uda soon became participants in a collective research effort. According to Uda, both the area and the scientific approach to research that Yagi introduced were unique among engineering faculties in Japan at the time.[7] The Saito Gratitutde Foundation, a private foundation created in Sendai by Z. Saito, provided significant financial support for the group research effort under Yagi's leadership. At least eight individuals in addition to Yagi participated in the telecommunications research at Tohoku in the early years. The perceived need for low-power communication links between Japan's many islands or ship-to-shore provided an additional stimulus in the direction of short-wave wireless systems.

After graduating in electrical engineering at Tohoku

University in 1924, Shintaro Uda joined the faculty as a lecturer and became an active member of the research group headed by Yagi. Uda was born on June 1, 1896 in Toyama Ken and later received his doctorate in engineering at Tohoku in 1931. As one of his first projects, Uda designed a vacuum-tube triode oscillator that operated at a wave length of about 440cm. Experiments with this oscillator as a transmitter led to the invention of the Yagi-Uda antenna during 1925.

Invention of the Yagi-Uda Antenna

In his initial experiments with the short-wave oscillator, Uda employed a single-wire resonant loop antenna and observed the directive radiation that it produced. In an effort to produce a more directive beam he tried placing a parasitic loop tuned below resonance near the driven loop. The idea for this arrangement apparently was stimulated by an investigation of loops of various shapes by the absorption method carried out by one of Uda's classmates as a thesis under the direction of Yagi.[8] The next step taken by Uda constituted the essence of the invention of the Yagi-Uda antenna. He tried the substitution of vertical metal rods for the parasitic loops and found that the field intensity as measured in a preferred direction increased with the number of parasitic rods. Uda then began a comprehensive investigation to determine the effect on antenna directivity of changes in length, spacing and geometric arrangement of the parasitic elements of the newly invented antenna.

Yagi and Uda gave the first published report on the new antenna in a jointly-authored paper entitled "Projector of the Sharpest Beam of Electric Waves" that appeared in the Proceedings of the Imperial Academy of Japan in February 1926. The paper included a theoretical analysis of a vertical dipole antenna and its interaction with a parasitic rod located in the proximity.[9] Uda disclosed further information on the antenna in a paper published in March 1926 in the *Journal* of the IEE of Japan.[10] This paper included experimental data obtained using three parasitic rods in combination with a brass rod that was driven as a half-wave dipole. In the April 1926 issue of the same periodical, Uda published a second installment in what became a lengthy series on the beam system under development at Tohoku University.[11] He suggested that an antenna containing three reflector rods be called a "trigonal reflector" if used with a transmitter or a "trigonal collector" if used with a receiver. A diagram in this paper showed the parasitic reflecting rods located at the corners of an isosocles triangle with a base length of one wave length and a height of a quarter wave length. He stated that the antenna performance could be further improved by adding two additional reflecting rods along the sides of the triangle. In July 1926, Uda published the results obtained using what he called a "polygonal reflector" antenna that used nineteen reflector rods.[12] Fourteen additional rods had been added to the five rod trigonal arrangement with the added reflectors located in straight lines that formed an included angle of sixty degrees. He reported that the antenna pattern was quite similar to that of a parabolic reflector antenna.

Professor Yagi applied for a Japanese patent on a directional antenna with parasitic elements in January 1926 and for a U.S. patent in September 1926. The patent described complex circular array antennas that employed a vertical dipole at the center with parasitic elements arranged around the circumference of one or more concentric circles. In addition, each parasitic element consisted of two collinear segments that could be connected to act as a reflector or unconnected to act as a director. Yagi explained that a directional beam could be produced by a specific combination of reflectors and directors and that the beam could be made to rotate around the main antenna in a manner similar to a light beam from a rotating light house. He included examples of preferred radiation in six or eight directions depending on the number of parasitic elements used. His most complicated arrangement used thirty-two parasitic elements situated on three concentric circles. He stated that the direction might be altered by means of relays or push button devices. One claim of the Yagi patent covered a linear array with one active element and a plurality of parasitic directors. The U.S. patent issued May 24, 1932 and Yagi assigned it to the Radio Corporation of America.[13] According to Uda, the circular array covered by the Yagi patent was intended for use as a radio beacon to aid ship or airplane navigation.

Despite several publications in Japan during 1926, it seems probable that American radio engineers did not learn the details of the Yagi-Uda antenna prior to the Third Pan Pacific Science Congress that convened in Tokyo in November 1926. John H. Dellinger, Chief of the Radio Division of the National Bureau of Standards, was among those who heard a joint paper by Yagi and Uda entitled "A New Electric Wave Projector and Radio Beacon" that was presented at the Tokyo meeting. Bureau of Standards engineers later used a Yagi-Uda antenna in an experimental limited visibility landing system for air craft reported in 1930.[14] Shortly after the Pan Pacific meeting, Uda submitted a paper to the *Proceedings* of the IRE in March 1927 entitled "High Angle Radiation of Short Electric Waves."[15] This paper gave a relatively complete disclosure of the characteristics of the "new wave projector developed by the author" including the nomenclature used by the Japanese engineers to describe the antenna. After describing the "trigonal reflector," Uda explained that the addition of several parasitic director elements along a line in front of the reflector caused the beam directivity to be "remarkably improved." He suggested that the plurality of directors be called a "wave canal" and that the combination of the wave canal and trigonal reflector be called a "wave projector." He mentioned that the antenna pattern had been obtained by means of a crystal detector and microammeter that were mounted on a pair of wood poles and moved by a pulley. He stated that it had proved necessary to read the meter from a distance using a telescope since the "observer's body causes a remarkable effect on the field distribution." During 1927, Uda published six more installments of his long series of work-in-progress reports on short-wave beams in the *Journal* of the IEE of Japan.

The dissemination of information about the short-wave research at Tohoku University was facilitated greatly as the result of a visit to the U.S. by Professor Yagi early in 1928. He gave talks to members of the IRE in New York City, Washington, D.C., and Hartford in February. Yagi also made a trip to Schenectady where he spoke to a group at the GE Research Laboratory. His disclosure of the Okabe split-anode magnetron to the GE radio electronics specialists led them to develop quickly a 400 MHz magnetron that was tested along with a Yagi-Uda antenna by E.S. Darlington and others at GE during the summer of 1928.[16]

Yagi also contributed a paper that summarized the recent achievements of the Sendai team that he directed that was published in the *Proceedings* of the IRE in June 1928.[17] In the first section of the paper, he reviewed briefly the design characteristics of the wave projector including the effect of varying the height above the earth of sending and receiving antennas. He mentioned also the circular array radio beacon antenna of his still pending patent. He stressed the advantage of using several parasitic directors and reported that the received power had been found to increase almost in proportion to the square of the number of directors in the wave canal. In the second section of his paper, Yagi discussed the Okabe magnetron that had been used to generate strong oscillations at a wave length of around 40cm. Yagi concluded his paper by giving credit to both Uda and Okabe "to the ingenuity of both of whom the successful development of the beam system is mainly due." In turn, J.H. Dellinger of the Bureau of Standards commented on Yagi's paper that he was convinced "was destined to be a classic." Dellinger praised Yagi for having done "exceptional fundamental work" and for presenting "a series of principles which will unquestionably guide much of the further development."

Uda and his colleagues carried out propagation experiments at 4.4 meters from November 1927 to November 1928. Their transmitter was situated on the roof of the laboratory in Sendai and a portable receiver was taken to remote sites. They achieved satisfactory reception at a distance of 65km using two Cymotron 202 triodes rated at five watts. With more powerful Radiotron UX 852 tubes rated at 75 watts, they reached a distance of 135km with the receiver atop a 365 meter hill in October 1928. The Yagi-Uda antenna was used throughout these experiments.[18] During this period Uda also investigated the effect of placing a metallic sheet instead of a rod between the transmitter and receiver. He found that it acted as either a reflector or as a director depending on its dimensions. He also experimented with glass tubes filled with solutions such as sulphuric acid or salt water, again located between the transmitter and receiver. His data indicated the effect of changing the length of the liquid column and the conductivity of the solution.[19] Uda's research on the wave canal was extended to the use of up to 30 director elements and to antennas that used two or three parallel lines of wave canals. These experiments convinced him that multicanal wave projectors were no better than a single canal so that the single canal was preferable because of its comparative simplicity.[20]

Decimeter Wave Communication

In 1929, the Tohoku University group begam an investigation of wireless communications at wavelengths below one meter. Both the Barkhausen-Kurz oscillator and the Okabe magnetron were available as transmitters, but they found the crystal detector to be unsuitable as a receiver due to low sensitivity. An important breakthrough in receiver design was made by Shintaro Uda when he made the unanticipated discovery that a Barkhausen tube could be used as a regenerative detector with good sensitivity. Although the Armstrong regenerative receiver long had been known, Uda was the first to discover the effect in a Barkhausen oscillator. He developed a three-tube receiver for use over the range of 40 to 80cm. The new receiver, when used in conjunction with the Yagi-Uda antenna. extended the range of practical communications from a few meters to several km. He first used a Cymatron UF-101 as the first stage detector-amplifier and later substituted a Cymotron UX-199. Subsequently, Uda adapted another Armstrong invention, super-regeneration, by using a Barkhausen tube in the super-regnerative state, controlled by a quenching oscillator operated in the one to three MHz range. This gave a further increase in receiver sensitivity and stability.[21]

Uda reported on his new ultra-short wave receiver and related communication experiments in two papers published in the *Journal* of the IEE of Japan in 1929 and in a paper in the *Proceedings* of the IEE of June 1930. His receiver also was demonstrated at an international meeting in Brussels in 1930 and still exists in a museum in Tokyo. In his IRE paper entitled "Radiotelegraphy and Radiotelephony on Half-Meter Waves," Uda reported successful communication at distances of up to 30km. He stated that the wave projector antenna had "proved to be astonishingly advantageous in concentrating and collecting the wave energy at these short wave lengths." He mentioned that both the transmitting and receiving antennas had consisted of reflectors and eleven director rods. He disclosed that the transmitter had used up to seven Barkhausen tubes operated in parallel but that the output still was less than produced by the Okabe magnetron oscillator. Uda concluded that the experiments had shown that reliable wireless communication at half-meter wave lengths could be achieved at a distance of over ten km. He asserted that "there remains no question of the possibility of the practical application of these extremely short waves."[22]

The 1930 volume of the *Proceedings* of the IRE that included Uda's paper contained also papers by ten other Japanese authors. This suggests both the increasing scale of Japanese telecommunications research and the effective entry into the international wireless fraternity. Several of the Japanese researchers who published in the IRE periodical were affiliated with the Ministry of Communications Laboratory in Tokyo while others were at various universities. An overseas edition in English of the Journal of the IEE of Japan was initiated in 1937 and continued until 1941.

Uda and his colleagues experimented with communication at an even shorter wave length of 17cm in 1931. Special tubes obtained from France that were designed to minimize interelectrode capacitance were used in the transmitter. The circuit was tuned by sliding a metal disc along a single metal rod that was connected to the grid. Uda constructed a super-regenerative receiver similar to the one used earlier at 50cm for reception at 17cm. He reported these tests at a meeting of the IEE of Japan held in April 1931.[23]

Early Short-Wave Communication in Japan

The Yagi-Uda antenna received its first commercial application in Japan in 1933 when a government radio telephone link was inaugurated between Sakata and

Tobishima Island, a distance of 40km. The preliminary tests that set the stage for this system were carried out by the Tohoku University group in cooperation with the Sendai Branch Office of the Japanese Ministry of Communication. Uda constructed radiotelephone sets suitable for two-way operation at wavelengths between 2 and 10 meters. He employed the abrupt change in noise level in the super-regenerative receiver when a signal was detected to actuate an automatic calling device. One of his colleagues proposed that this effect be named the "Uda Phenomenon."[24] Radio sets using the calling device were manufactured subsequently by the Nichiden Denpa Company in Sendai. The Uda-designed equipment was used for communication tests between a fixed station location near Sendai and a mobile station on a ship during 1931 and 1932. The possible use of the system on fishing boats was investigated at the request of the Fisheries Research Institute at Watanoha in 1932. The screening effect of small islands, polarization of the antennas, and variation in transmitter power were among the variables investigated during these tests. Success in the wireless relaying of telephone calls carried by wire from Sendai to Sakata to a station on Tobishima Island persuaded the Ministry of Communication to establish a permanent VHF link between Sakata and Tobishima in 1933. The Uda system also was employed in August 1932 for on-site coverage of a boat race. Reports on the race from a boat were transmitted by VHF to a radio broadcasting station in Sendai and broadcast throughout the country.

Epilog

In November 1951, E.S. Darlington, by then a Major in the U.S. Air Force, visited Professor Yagi, whom Darlington had not seen since Yagi's visit to the GE Research Laboratory in 1928. Darlington learned that Yagi's home in Tokyo along with his library and thirty years of research data had been destroyed by a fire bomb raid in April 1945. Yagi stated that it had taken four or five days for his books to be finally consumed by the fire. At the time of his interview with Darlington, Yagi was a consultant to the Japanese government on the formulation of television standards and the planning of Japan's technological rehabilitation. At about the same time, the Yagi Antenna Company, Ltd. was organized with Yagi as its president.[25] Yagi was awarded Japan's Order of Cultural Merit in 1956 and the Poulsen Medal by the Danish Academy of Science in 1958.

Shintaro Uda did further work on the theory of the Yagi-Uda antenna after the war and was co-author with Y. Mushiake of a book entitled *Yagi-Uda Antenna* published in 1954. He became interested in the traveling-wave tube around 1950 and worked with K. Kamiryo in research on the device until he retired from Tohoku University in 1960. During the years 1955-1958, Uda conducted microwave propagation tests in India while serving as a UNESCO expert. In 1960 he joined the faculty at Kanagawa University and began research on the laser with M. Hasegawa.[26]

The telecommunications antenna that has been the subject of this essay became commonly known as the Yagi antenna sometime after Yagi's visit to the U.S. in 1928. Yagi himself credited Uda for having done much of the experimental research on the antenna. Available documentary evidence makes it quite difficult to determine the extent of Yagi's intellectual contribution to the conception, analysis and development of the antenna but he clearly orchestrated the joint efforts of the research team that included Uda. It would seem therefore that the use of the name Yagi-Uda antenna in recognition of the contributions of both men to the development of short wave communication systems of which the antenna was a key element is quite appropriate.

Both Yagi and Uda are held in high esteem by those who have followed in their footsteps among Japanese electrical engineers. It seems to the author that a significant virtue of Japanese culture is the respect and honor given to ancestors, senior family members, and professional predecessors. It is a virtue that Americans and in particular members of the telecommunications fraternity might well emulate. Professor Yagi once wrote that "it is not a man but a brute who is not grateful to one's parents or others."

Notes

1. See a biographical note on Barkhausen in *Proceedings* of the IRE, Vol. 18 (1930), p. 1275. See also *A Century of Honors* (IEE Press: New York, 1984), p. 47.
2. Hidetsugu Yagi, "On the Phenomena in Resonance Transformer Circuits," *Proceedings* of the IRE, Vol. 5 (1917), p. 433-446.
3. See the biographical sketch on Fleming in the *Dictionary of Scientific Biography,* Vo. 5, p. 32-33.
4. See the biographical sketch on Pierce in the *Dictionary of Scientific Biography* Vol. 10, p. 604-605.
5. George W. Pierce, *Principles of Wireless Telegraphy* (McGraw-Hill, NY, 1910), p. 297-298.
6. Hidetsugu Yagi, "On the Possibilities of Tone Production by Rotary and Stationary Spark Gaps," *Proceedings* of the IRE, Vol. 6 (1918), p. 323-344.
7. Unpublished reminiscence by Shintaro Uda entitled "My Memories of Early Days in Connection with Studies in the Field of Microwaves." I am indebted to Professor Gentei Sato of Sophia University for providing me with a copy.
8. *Ibid.*
9. Shintaro Uda, *Short Wave Projector: Historical Records of My Studies in Early Days* (Copyright 1974 by Shintaro Uda). From a copy provided by Professor Sato.
10. S. Uda, "On the Wireless Beam of Short Electric Waves," Part I, *Jour.* IEE of Japan, March 1926. I have used an English abstract provided by Professor Sato.
11. Ibid., Part II, April 1926.
12. Uda, *Short Wave Projector,* p. 26.
13. H. Yagi, U.S. Patent No. 1, 860, 123, "Variable Directional Electric Wave Generating Device," issued May 24, 1932. Also see Uda, *Short Wave Projector,* p. 32-35.
14. Uda, *Short Wave Projector,* p. 52-53.
15. S. Uda, "High Angle Radiation of Short Electric Waves," *Proceedings* of the IRE, Vol. 15 (1927), p. 377-385. See also *Short Wave Projector,* p. 35-44.
16. W.C. White, "Some Events in the Early History of the Oscillating Magnetron," *Jour.* Franklin Institute, Vol. 254 (1952), p. 197-204.
17. Hidetsugu Yagi, "Beam Transmission of Ultra Short Waves," *Proceedings* of the IRE, Vol. 16 (1928), p. 715-741. See also a reprint of this paper with editorial notes in *Proceedings* of the IEEE (May 1984), p. 635-645.
18. Uda, *Short Wave Projector,* p. 53-59.
19. *Ibid.,* p. 18-21.
20. *Ibid.,* p. 28-29.
21. *Ibid.,* p. 61-69. See also Uda, "My Memories of Early Days."
22. S. Uda, "Radiotelegraphy and Radiotelephony on Half-Meter Waves," *Proceedings* of the IRE, Vol. 18 (1930), p. 1047-1063.
23. Uda, *Short Wave Projector,* p. 81-85.
24. *Ibid.,* p. 102.
25. W.C. White, "Some Events," p. 197-204.
26. Uda, *Short Wave Projector,* p. 145-146 and 149-176.

RADIO CLUB OF AMERICA PROFESSIONAL DIRECTORY

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

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

ERO E. ERICKSON
Business Radio Comm. Consultant
3009 North Cicero Avenue
Chicago, IL 60641
312-685-6641

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
305-334-5147

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

HARRY S. GARTSMAN, W6ATC
Military Avionics Systems Consultant
9921 Sunset Blvd.
Beverly Hills, CA 90210

CHARLES HIGGINBOTHAM
Land Mobile Consultant
7757 Conservatory Drive
Sarasota, FL 34243
813-355-1813

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

ALLAN E. HOLT
Radio Career Consultant
3007 Pacific Avenue, Suite 3
Virginia Beach, VA 23451
804-481-5621

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

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

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

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
TELEX 346354 (C AND C CMPL)

JAMES MANN
2-way Radio Equipment
P.O. Box 340
Agoura, CA 91301
213-889-6666

F. STUART MEYER, W2GHK
Sr. Past President IEEE-VTS
c/o E.F. Johnson, Suite 907
1601 N. Kent Street
Arlington, VA 22209
703-525-6286 (O) 703-281-3806 (H)

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

JACK R. POPPELE
TV-CATV-CCTV Multi-Media Consulting
145 Main Avenue
Clifton, NJ 07014
201-473-8822

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

JOHN J. RENNER
Advanced Technology
3426 North Washington Blvd.
Arlington, VA 22201
703-525-2664

ULRICH L. ROHDE, Ph.D., SC. D.
Communications Consultant Frequency Synthesizers & Wideband Feedback Amplifiers
52 Hillcrest Drive
Upper Saddle River, NJ 07458

THEODORE P. RYKALA, P.E.
Communications Consultant
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

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

WOULD YOU LIKE TO BE INCLUDED IN THE PROFESSIONAL LISTING?

Contact STUART MEYER
Suite 907, 1601 N. Kent St.
Arlington, VA 22209

Office: 703-525-6286
Home: 703-281-3806

Citations to New Fellows

Herbert Becker, W6QD, *Los Alamitos, CA.*
Contributions in early communications magazine publishing and Amateur Radio organizations.

Andy Bower, K1NZW. *Regional Manager, Repco, Inc., Niantic, CT.*
Numerous achievements in the mobile radio distribution field.

James E. Brittain, *Georgia Institute of Technology, Atlanta, GA.*
Eminent historian—extensive contributions to the history of radio science and technology.

James W. Campbell, *Santa Ana, CA.*
Contributions in early FM and PM land mobile receiver design.

Donald M. Christie, *Austin, TX.*
Achievements in the field of innovative production techniques in communications equipment.

Donald R. Cook, *Fresno, CA.*
Pioneering in the development of radio common carrier and paging systems.

Theodore J. Cohen, K4XX. *Executive Scientist, ORI, Inc., Alexandria, VA.*
Extensive literary contributions in the fields of propagation, RFI and solar activity.

Norman R. Coltri, *Director of Communications, New Jersey State Police.*
Contributions in the field of Public Safety communications, especially frequency management.

Jack Daniel, *Jack Daniel Co., Cucamonga, CA.*
Early refinement of community repeaters, multicouplers, cross-band couplers and remote control.

La Neil Eitel, WA7LUN, *Dayton, NV.*
Achievements in Amateur high-speed radiotelegraph reception; contributions in support of OSCAR and AMSAT.

William Endres, *President, Tele-Measurements Inc., Clifton, NJ.*
For contributions in communications, closed-circuit TV and teleconferencing systems.

Charles English, *President, APCO, Cary, NC.*
Leadership in public safety organizations and communications.

Lester M. Fisher, *Collins/Rockwell International, Dallas, TX.*
Work in the microwave field, with special reference to waveguide filter and multiplexing systems design.

Robert S. Foosaner, *Chief, Private Radio Bureau, FCC.*
Leadership as Chief of the Private Radio Bureau of the FCC.

Marvin Grossman, W8AZO, *Antenna Specialists, Cleveland, OH.*
For contributions in the fields of public safety, industrial and land transportation radio systems.

Steven Gumport, M.D., WB2RVU, *NYU Medical Center, New York, NY.*
Numerous contributions to science and technology, and services through the Medical Amateur Research Council (MARCO).

Fred Hamer, *E.F. Johnson Co., Waseca, MN.*
For the implementation of 800-MHz wide area and ribbon specialized mobile radio systems.

Leo M. Himmel, Sr., *Association of American Railroads, Washington, D.C.*
Leadership in railroad communications design and management.

Henry B. Kreer, *President, Stevens, Kirkland, Kreer, Inc., Chicago, IL.*
Development of citizen participation in highway safety as founder and executive director of REACT (Radio Emergency Associated Radio Teams).

Charles M. Lewis, W4BV, *Treasure Island, FL.*
Long-term leadership in product line management and marketing in the fields of broadcasting, communications and computers.

Alfred J. Mello, *City of Providence Communications Dept., Providence, RI.*
Contributions in the field of Public Safety radio communications and spectrum management.

John Mitchell, *President, Motorola, Inc., Schaumburg, IL.*
Industry leadership and direction of one of radio industry's top organizations.

Ralph W. Muchow, *Elgin, IL.*
Distinguished and extensive contributions in preserving the history of radio and communications.

Merle B. Parten, K6DC, *San Carlos, CA.*
More than 40 years contributions in military and civilian radio.

Joseph Pavek, *Hopkins, MN.*
Contributions to preserving the history of radio communications.

Richard Plessinger, *Miami Valley Radiotelephone, Hamilton, OH.*
Pioneer in paging and radio common carrier and leader in industry organizations.

Edward Rich, N0AA, Washington, D.C.
Achievements in the field of weather satellites.

W.B. Sloop, W4AAE, *Raleigh, NC.*
Long-time service in the public safety communications field.

Lester G. Schimpf, WA2FTR, *Holmdel, NJ.*
Contributions in military, semiconductor and two-way radio.

Houston H. Stokes, *University of Illinois, Chicago, IL.*
Contributions in econometric software development.

Gregory M. Stone, WB9PHA, *Sachs-Freeman Associates, Lake Bluff, IL.*
Numerous contributions in the spectrum conservation and general communications technologies.

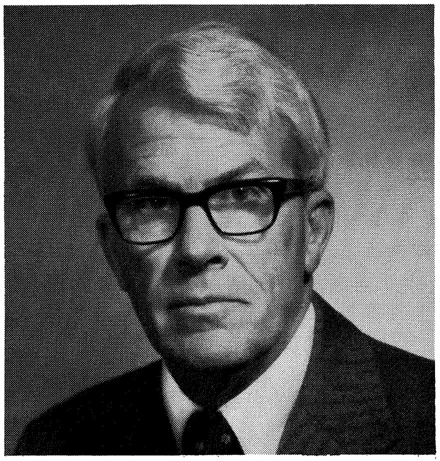
Donald L. Stoner, W6TNS, *Stoner Communications, Merver Island, WA.*
Early contributions toward amateur satellites; achievements in low-cost single sideband equipment.

Earl T. Van Stavern, W4NXP, *Commonwealth Communications Industries, Ltd., Ashland, VA.*
For his pioneering efforts in developing radio common carrier and paging interface terminal equipment.

William A. Wickline, WA8WBO, *Vice President, Katherine Corp., Cleveland, OH.*
Leadership in specialized antenna systems and development in the VHF, UHF and microwave frequencies.

Anthony F. Yellin, W2EDA, *Manager, Ebasco Services Inc.*
Responsible for creation and implementation of training programs in tropo-radio communications systems.

SARNOFF CITATION



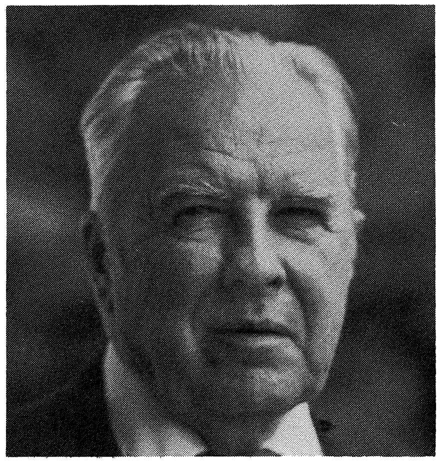
Dana Atchley

Dana Atchley, Jr. (M 1970, F 1983) who receives this year's Sarnoff Citation, was born in New York City in 1917. He graduated from Harvard with a B.S. degree in 1940, and went to work for Sylvania. During the greater part of World War II he served on the staff of the Director of the Naval Research Laboratory in Anacostia, DC.

After the war he rejoined Sylvania, and in 1947 joined Tracerlab, Inc., a manufacturer of radio chemicals and nuclear instruments. Leaving Tracerlab in 1951, he joined the staff of United Paramount Theaters (later American Broadcasting Co.) as a technical coordinator responsible for ABC's early investments in the electronics industry. ABC purchased a 50% interest in Microwave Associates, and Mr. Atchley was elected its President in 1952. He served as Chairman of the Board of Directors from 1969 through February 1978 when Microwave changed its name to M/A-COM, Inc. He is now Chairman Emeritus of that company.

Mr. Atchley is a Life Member of the IEEE and a Fellow of the Radio Club. He holds several FCC licenses and has been an active amateur since 1933, with the call W1HKK until 1968, since then W1CF. He is a founder/director of the Anorexia Nervosa Aid society of Massachusetts, and is one of the two owners of FM Station WMVY on Martha's Vineyard.

BUSIGNIES AWARD



Jerry Minter

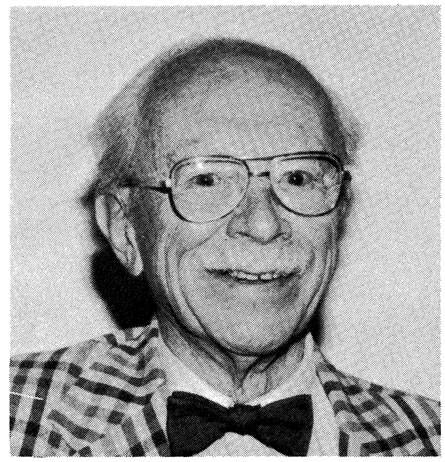
Jerry B. Minter, (M 1942, F 1944, L 1975), recipient of the Henri Busignies Memorial Award, was born in Texas in 1913. He received the B.S.E.E. degree from M.I.T. in 1934. In 1935 he joined the Boonton Radio Corp. (Boonton, NJ) developing bandpass transformers. In 1939 he and a few associates organized Measurements Corp., and was Vice President of that company until 1953, when he resigned to devote full time to Components Corporation, of which he has been President since 1946.

Special scientific satellite instrumentation designed and patented by Mr. Minter has been used extensively by NASA, AEC and NRL. Technical fallout from this high-reliability electronics is now being sold by Components Corp. in the computer and other fields. Since 1965 he has also been active in the application of specialized TV equipment to the medical field.

Jerry is a Life Fellow and Past President of the Radio Club, as well as of the Audio Engineering Society. He is a member of the American Society for Metals and the Society of Motion Picture and Television Engineers. He is a Life Fellow of IEEE, and currently active on the North Jersey Award Committee. (He also founded the North NJ Section of IEEE.)

His services to the Club have been outstanding. Besides being President twice, Director several times, his last term running from 1970 to the present (now Director Emeritus), he has also worked almost continuously on committees, particularly those concerned with nominations or awards.

LEE DEFOREST AWARD



Austin Cooley

Austin G. Cooley (M 1971, F 1973, L 1983), who receives the Lee de Forest Award for 1985, was born in Seattle February 9, 1900. He received a B. Sc. from M.I.T. in 1924 and earned the E.E. degree from the University of Alaska in 1973.

He was a radio operator at Port Walter, AK, in 1916, and was in the U.S. Navy in 1918 and 1919. He then operated on West Coast ships, and at an M.I.T. experimental station 1921 to 1923. He was operator on the McMillan Expedition (schooner Sachem) in 1926, and worked with Western Union from 1927 to 1935. He then joined Times Facsimile Corp., where he remained until 1959, developing his facsimile techniques.

Mr. Cooley received an award from the IEEE "for his contributions to facsimile transmission methods." Other awards include the Certificate of Appreciation from the War Department, the Marconi Medal of the Veteran Wireless Operators Association, and a scroll from the Air Transport Association. He was inaugurated into the Nevada Inventors' Hall of Fame in 1984. He is a Fellow of the IEEE and member of the Society of Motion Picture Engineers and the Armed Forces Communications and Electronics Association.

ALLEN DuMONT CITATION

John Morrisey

John Morrisey (M 1973, F 1979, L 1983), recipient of the Allen B. DuMont Citation, joined General Electric after graduation from Georgia Tech, and was assigned to a study of high-vacuum techniques; later he was sent to Buenos Aires. In 1941, he started work for RCA at the Harrison tube plant. He transferred to NBC in 1942, and was sent to Europe as a war correspondent. In 1945, he returned to the States to report on the founding of the United Nations in San Francisco.

When the TV freeze was lifted in 1951, Mr. Morrisey joined the Allen B. DuMont Laboratories to become sales manager of the International Division. Here, he became involved in technical writing, publishing several articles on subjects relating to TV and radio broadcasting in journals dealing with overseas communications.

With the demise of DuMont Labs, he joined Collins Radio as assistant director of the International Division, and, in 1961, was recruited into ITT to become Director of industrial products marketing in the Latin American Division. Since retirement, he has engaged in consulting engineering work.

Mr. Morrisey has been a member of the Club's Executive Committee since 1977 and a Director since 1980. He is well known to many members as the Editor of the Club's Diamond Jubilee Year Book.

PIONEER CITATION

George Connor

George Connor (M 1936, F 1942, L 1971), who receives the Pioneer Citation for 1923, was born in Hoquiam, WA in 1903. He received his education at the University of Wisconsin. In 1925 he joined RCA Service in Chicago, and in 1926 became assistant manager of the Technical Service Department of Brunswick-Balke-Collender of the same city. From 1934 to 1968 he was with Sylvania Electric Corp., in positions ranging from radio tube engineer to Senior Vice President, Sylvania Electric Products Co., Batavia, NY. He became a Fellow of the Radio Club in 1942, and is a member of the IEEE, the Photographic Society of America, the American Association for the Advancement of Science and the Electronic Industries Association. He retired from Sylvania in 1968 and is now living in Ocala, FL, where he is active in our Florida Section.

Ramsey McDonald, W4OHD (M 1970, F 1972) of North Palm Beach, FL, died Sunday, October 6, 1985. Mr. McDonald was a pioneer in mobile radio, developing two-way transmission and reception for the police department of Richmond, Indiana, in 1937, at a time when the mobile units in a police radio system carried only receivers.

RALPH BATCHER AWARD

Donald Fink

Donald Fink (M 1934, F 1940, L 1973), recipient of the Ralph Batcher Memorial Award, was born in New Jersey in 1911. He received a B.S. in Electrical Communications from M.I.T. in 1933, and an M.Sc. (EE) from Columbia University in 1942. He joined the staff of *Electronics* magazine, where he remained (with a three-year leave of absence during World War II) until 1952, the last six years as Editor-in-Chief.

During the war he was an expert consultant on radio navigation and radar for the Office of the Secretary of War.

In 1952 he became Director of Research for Philco. In 1956 and 1957 he was Editor of the *Proceedings* of the IRE, and was President of the Institute in 1958. From 1958 to 1975 he was General Manager of the IRE-IEEE.

Mr. Fink was the author of the first authoritative book on television *(Principles of Television Engineering,* 1940). He wrote at least four other books on the subject, as well as works on radar and computer science, and was co-author, with John D. Ryder, of the monumental *Engineers and Electronics* (IEEE Press, 1984). He also edited a number of other works, including McGraw-Hill's *Standard Handbook for Electrical Engineering* and *Electronics Engineers' Handbook.*

Mr. Fink is a Fellow of the IEEE and the British IEE, as well as of the SMPTE.

President's Award

Fred Shunaman

Fred Shunaman, (M 1968, F 1972, L 1983), recipient of the 1985 President's Award, was born in 1901, in Leominster, MA. Moving with his parents to Saskatchewan in 1912, he became interested in radio through a number of Gernsback booklets that fell into his hands. In 1923 he built the first radio he ever saw, and heard radio for the first time when—after a week of unsuccessful attempts—he succeeded in tuning it in to the local station (some 60 miles away). Later, after building numbers of sets for the neighbors, he became the local service technician, and in 1927 "went professional," working for a number of years in radio repair shops or operating his own, in Saskatchewan, New York, San Francisco and Shanghai.

Later he sailed as radio operator on the tankships Niobe and Prometheus, operating for Standard Oil of New Jersey. In 1942 he went to work for Hugo Gernsback, becoming Managing Editor of *Radio-Electronics* (formerly *Radio-Craft*) and continuing with Gernsback for 23 years. In 1972 he became Executive Secretary of the Radio Club of America, a position he still holds.

He is the author of two books, *Test Instruments in Electronics Servicing* and (with Leo Sands) *101 Questions About Hi-Fi and Stereo,* and edited *From Spark to Satellite,* by Stanley Leinwoll. He has also written numerous articles in *Radio-Electronics* and other magazines.

MODERN TELEPHONE SWITCHING SYSTEMS

by David Talley
(Fellow, RC of A)

In current telephone systems, telephones in customer homes and offices are connected by 2-wire connectors (pairs in cables) to the local switching center or central office, which is usually designated an End or Class 5 Central Office. This switching center handles all outgoing and terminating calls from and to its subscribers (customers). It also routes calls destined to telephones outside its own service area. These calls may be sent over interoffice trunks to other nearby switching centers, or over toll-connecting trunks to a Toll Switching Center for calls to distant points. Fig. 1 illustrates a representative local telephone network.

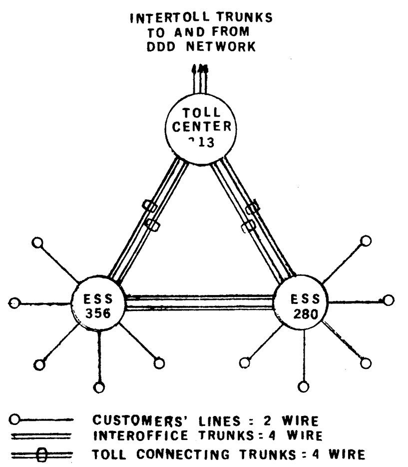


FIG. 1 - (CLASS 5) END OFFICE SWITCHING NETWORK

Central offices initially used electromechanical switching equipment, such as step-by-step, panel, and crossbar apparatus. They were designed for a total capacity of 10,000 lines, numbered from 0000 to 9999. Therefore, four digits had to be dialed to reach the desired telephone number. Moreover, each switching center was given a 3-digit office code. Thus, in a large city or metropolitan area, it was possible to reach any one of about 5,980,000 telephones by dialling 7 digits.

(Note that the numbers 0 and 1 are not used for the first digit of the office code. They are used for the middle digit of the Area Code to enable the central office switching equipment to distinguish between local and long-distance calls.)

Telephone Switching Systems

Electronic switching systems ESS were first placed in service by the Bell System in 1965. They have now replaced about half of the electromechanical switching systems used for handling local calls. An important advantage of electronic switching is its very high switching speed. For instance, several milliseconds are normally required in electromechanical offices for operation of relays to perform switching functions. In contrast, electronic devices in ESS offices complete such functions in a few nanoseconds.

The early electronic systems of the Bell System (No. 1 ESS and No. 1A ESS) utilize analog switching concepts because speech signals are in that waveform. Analog signals may be represented by voltage or current waveforms that continually vary in voltage or current magnitudes, corresponding to the signal's amplitude variations. These analog signals are transmitted and switched on a two-wire basis (for both directions of transmission) by the central office equipment.

Digital signals from computers, and also the pulses from rotary dials, can be considered as trains of minute square-wave pulses. These streams of pulses and spaces (no pulses) in a

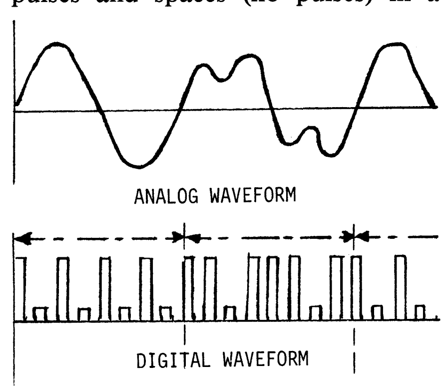


Fig. 2: Typical examples of abalog and digital waveforms

given time represent speech and other analog signals, which have been encoded into a series of binary numbers. Digital transmission and switching normally require two wire-pairs, one for each direction of transmission. Fig. 2 depicts waveforms of analog and digital signals.

Analog speech and tone signals must be converted to the digital format for digital electronic switching as well as transmission purposes. This conversion is typically accomplished by sampling and time-division techniques, employing the 8-bit per sample method of the pulse code modulation (PCM) process.

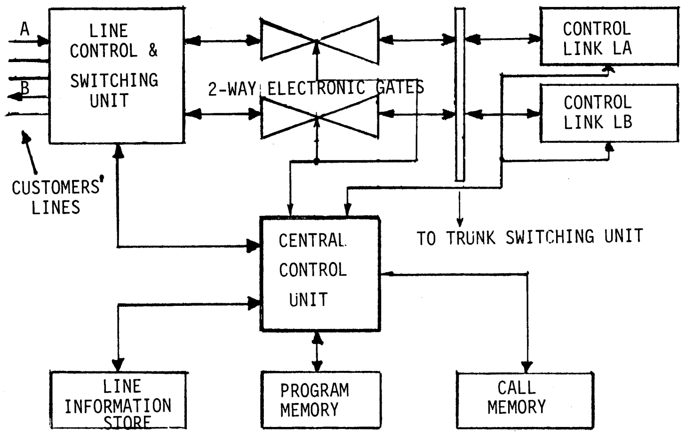


Fig. 3: Circuitry of TDM system applicable to small central office.

Analog Systems

Analog electronic switching systems may be classified as *Space Division* and *Time Division Multiplex* (TDM) Both use similar means of line and trunk scanning stored program control (SPC) call store memory and central logic functions. However, different control and transmission procedures are employed in handling calls.

In space division operations, an individual metallic 2-wire path is established through the switching equipment between the calling and called line, also between the called line and the selected outgoing trunk, and from the incoming trunk to the called line terminal.

In contrast, the TDM method employs a common transmission path that is time-shared by all connecting lines and trunks. TDM switching is performed by a series of high-speed electronic gates. Fig 3 is a simplified block diagram of a TDM electronic switching system applicable to PBX installations and small central offices. Assume that an intraoffice connection has been established between calling line A and called line B. Both lines will be periodically connected (but not simultaneously) to the common transmission path by their respective two-way electronic gates acting in sequence with their assigned time slots.

There were many difficulties in adapting the TDM process to the high calling rate and traffic volume needs of large switching offices. These factors led to the development of Space Division means for analog electronic switching systems. Fig. 4 illustrates the primary elements of Space Division electronic switching as used in the Bell System's No. 1 and No. 1A ESS, the GTE No. 1 EAX, and equivalent systems of other manufacturers.

The selected paths through the aforementioned switching network, which interconnect customer lines and trunks, consist of metallic contacts or crosspoints inside reed capsule type switches termed "remreeds" or "correeds." They do not make or break circuits in which current is flowing. These metallic switches, however, can carry the 20-Hz ringing current (75-90 V ac) to ring telephone bells. Unfortunately, LSI circuits and other currently available "chips" cannot handle such voltages. Thus, other means are used for interfacing customer lines with digital electronic switching systems, as later described.

Digital Systems

In analog electronic switching systems, the central processing unit (Central Control) can perform only one task at a time when processing a call. Moreover, the vulnerability of Central Control to outages of other essential ESS elements requires that it and other major components be duplicated. These factors limit the traffic-handling and expansion capabilities of analog ESS operations. Furthermore, there is a growing need for switching networks to carry both voice and non-voice (data) traffic.

The foregoing requirements can be more effectively accomplished by digital switching techniques, without adversely affecting the cost or performance of present voice-traffic operations. For example, inexpensive microprocessors and large-scale integrated (LSI) circuits or "chips" can now provide substantial quantities of memory circuits and greatly increased processing speeds at lower costs.

Likewise, memory and processing facilities can be furnished in numerous small units throughout the digital ESS. This feature also permits higher processing speeds, and better reliability can be attained. Thus, improved microprocessor technology makes it feasible to employ the "distributed control" concept in place of the present Central Control processing method used in most analog ESS for End or Class 5 central offices that directly serve customer lines. The "distributed control" method enables almost all call control functions to be handled by outside microprocessors. For instance each microprocessor can control a limited portion of the digital ESS operations.

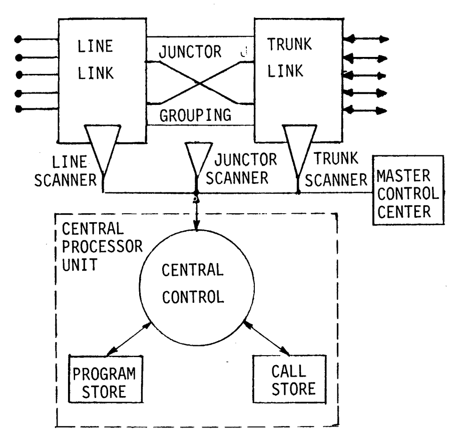


Fig. 4: Space division switching circuit

Likewise, each microprocessor can be associated with a particular small group of customer lines. Thus, a failure in the functioning of the microprocessor will harm service to only a few customers, and will not affect Central Control operations of the entire digital ESS.

Digital ESS centers also have larger line terminal capacities and can han-

dle considerably more busy-hour calls than analog ESS offices. The analog No. 1 ESS was initially designed for a maximum of 65,000 terminals and 110,000 busy-hour calls. The improved No. 1A ESS has a capacity of 128,000 line terminals and 240,000 busy-hour calls. Present designs for the GTD-5 EAX digital ESS are 150,000 lines and 360,000 busy-hour calls. It is understood that the new No. 5 ESS is designed to handle 250,000 customer lines and probably about 600,000 busy-hour calls.

Interface Requisites

Toll trunks served by the digital No. 4 ESS are derived from either analog FDM carrier systems or digital PCM (T1) carrier facilities. Thus, they already have 4-wire transmission paths and can interface directly with the digital ESS office. Customer or subscriber lines, however, connect to their central offices over 2-wire analog cables which carry both directions of transmission. Consequently,

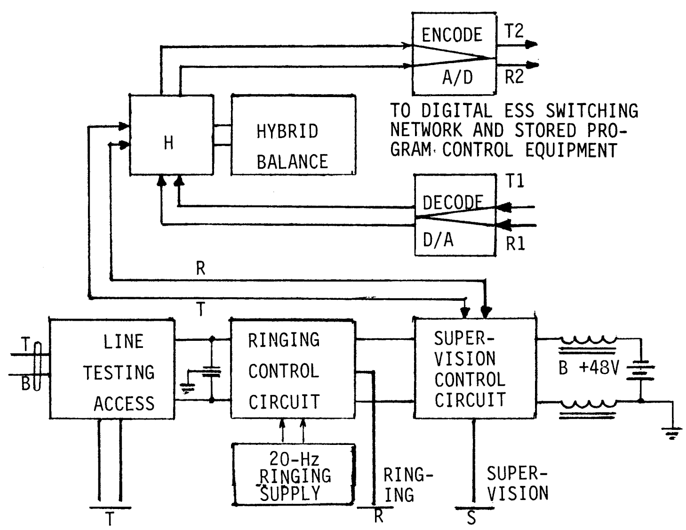


Fig. 5: Circuit of a standard subscriber line interface

each customer's line will need a line interface circuit in order to function with the 4-wire paths in digital ESS offices.

A typical subscriber's line interface circuit for this purpose comprises the following hardware components and circuits. These seven essential functions are known colloquially by their Bell System's acronym, BORSCHT:

B—48-V battery supply to power the customer's line equipment.

O—Overvoltage protection device to protect against induced voltages from power lines and lightning strikes.

R—Ringing circuit to apply 20-Hz ringing current to ring customer's bells, and to disconnect the ringing current when the telephone is answered.

S—Supervision of the customer's line to detect off-hook and on-hook conditions, dial pulses and disconnections.

C—Codec equipment, which consists of A/D (analog to digital) encoder and D/A (digital to analog) decoder.

H—Hybrid transformer and balance network circuit to interface the customer's 2-wire line with the 4-wire digital switching network. An active hybrid circuit employing integrated circuits is now superseding the hybrid transformer.

T—Testing access to customers' lines. Relay contacts are currently used to interrupt the T and R contacts, pending the development of improved "chips" for the purpose.

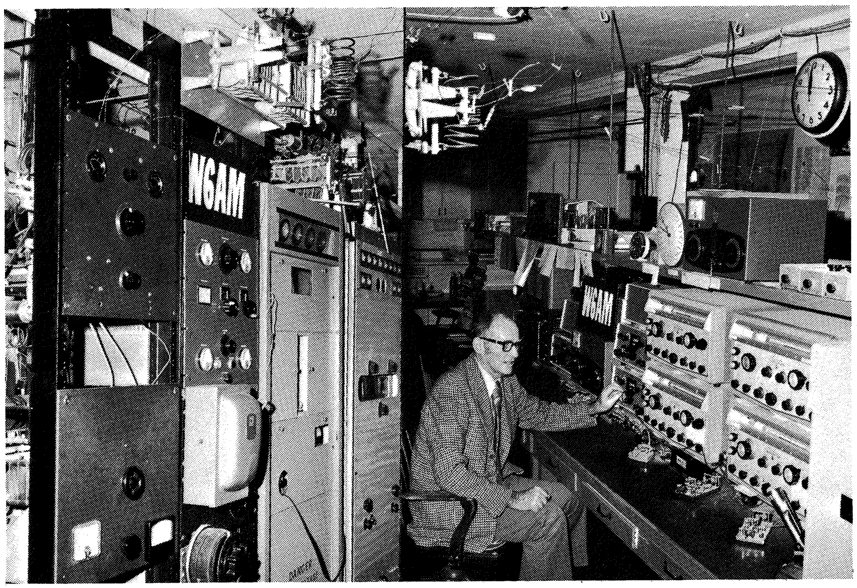
A simplified BORSCHT circuit for subscriber line interface is presented in Fig. 5. The nomenclature in it refers to the above-referenced lines.

The use of digital telephones with existing 2-wire lines necessitates providing the aforementioned "BORSCHT" functions, thereby greatly increasing costs compared to using present analog telephone sets. Moreover, a 4-wire line would be needed to the digital ESS office in addition to a local power supply (See B in Fig. 5) at customers' premises. Therefore, for these and related economic reasons, subscriber line interface circuits (SLIC) are provided as integral parts of Class 5 (End) digital ESS offices. The SLIC, under control of its microprocessors, can furnish the above-mentioned BORSCHT facilities for customers served by digital ESS centers. It is more economical, however, to provide the analog-digital conversion (A/D and D/A) and other BORSCHT features at remote terminals (line-concentrator units) which are located in various communities. This arrangement, which can serve numerous customers at substantial cost reduction, employs the "distributed control" concept of the digital ESS, as previously described.

The remote terminal is controlled and monitored by its microprocessors. Status data (on-hook, off-hook) conversation, and dial pulses or tone signals detected by the microprocessors, are transmitted together with associated identifying data to the central processor unit (CPU) in the Digital ESS office. Whenever a status check or other processing action is necessary, the CPU immediately notifies the microprocessor in the pertinent remote terminal.

The number of remote terminals needed depends on the customer concentration in the community or service area of the digital ESS office and the class of service—business or residential. In this connection, a "pair-gain" method employing the 24-channel PCM digital (T1) carrier system and designated SLC-96, has been developed by ATT-Bell Laboratories. It connects remote terminals directly to the digital switching equipment in digital ESS end offices, and can serve from 24 to 96 analog customer lines, depending upon the required concentration. Each customer's line interfaces with a channel unit that functions in a similar fashion, as shown for the BORSCHT circuit in Fig. 5. Analog signals from customer's line are converted to PCM digital signals by the channel units and then multiplexed into 24-channel digital signals by the microprocessors and associated integrated circuits. The digital signals from a customer's line are assigned to a specific time-slot in order to differentiate it from the other 23 PCM signals that are being multiplexed. Communication between time assignment units in remote terminals and the digital ESS are provided by a two-way data link, which also handles alarms, customer line test data, and PCM T1 line projection switching.

Wallace, King, Pass On



Don Clare Wallace, W6AM (L 1981, F 1981), became a "Silent Key" on May 25, 1985 at the age of 86. His pioneering work in radio communications covered a span of 75 years. Don accomplished many exploits, particularly in the early days of radio. He became a CPO in the Navy at the age of 19, and served as the Chief Radio Operator to President Woodrow Wilson on the USS George Washington enroute to and from the Versailles Peace Conference. He was in charge of 35 radio operators on this presidential yacht. They included Harold Beverage (M 1920, F 1926, L 1971, H 1983). In 1923, Don was awarded the silver Hoover Cup by the Secretary of Commerce, Herbert Hoover, for the design and construction of 9ZT, the best amateur radio station at that time.

Don was born in Belview, Minn. and his family moved to California in 1905. He received his first Amateur Radio operator's license and call 6OC from the Bureau of Navigation, Department of Commerce, in 1912. He subsequently passed the First Class Radiotelegraph license examinations and, as a teenager, served as a radio operator on ships sailing up and down the Pacific coast.

In 1926, Don Wallace obtained the W6AM call sign. From 1926 to 1960, Don traveled throughout many of the western States as a radio manufacturer representative. He always carried a portable transceiver with him to keep in touch with hams around the country.

At the end of WWII, Don purchased the 120-acre Palos Verdes site near Long Beach from Press Wireless. This site contained over 100 poles supporting various rhombic antennas used for worldwide radio communications. He rearranged this "antenna farm" into a set of nine rhombic antennas, each about 1,000 foot long. They were organized to radiate the RF signals from either end, providing eighteen different directions of coverage. With these facilities, W6AM was able to communicate with radio hams in 365 countries (as classified by the ARRL for DX contests). Moreover, W6AM continued to remain on the top of the DXCC Honor Roll of the ARRL since 1955.

The composite photograph shows Don Wallace at the operating position of W6AM. His many achievements will long be remembered by the Amateur Radio fraternity, particularly by those involved in DX competitions.

Frank King (M 1909, F 1926, L 1926, H 1972) "the first member of the Club", died September 3, 1985, at age 93. He was a member of the Boys Aero Club, which became the Junior Wireless Club in 1909. In 1911, the Junior Wireless Club reorganized as the Radio Club of America, with Frank as its first president.

His radio career began in 1906, when he set up his first station, "FK" at his home in New York City. In 1911, with the help of George Eltz, he built and operated the first amateur telephone station in the United States, using an arc transmitter.

In 1912, Frank presented to the Club a design for a membership pin. It has been in use ever since.

Graduating from Columbia with an E.E. degree in 1917, he joined the Armed Forces in 1918. He organized and was Officer in Charge of the first U.S. Aircraft Naval Radio Laboratory, later serving in France and at Naval Headquarters in Washington.

In 1928 he joined with Ernest Amy and Julius Aceeves in the engineering firm of Amy, Aceeves and King. The company's office was Club headquarters for nearly 40 years.

He remained active to an advanced age, and attended the Club's Annual Banquet in 1980, where he received the Pioneer Award.

the first "belt-mounted" 80-channel mobile.

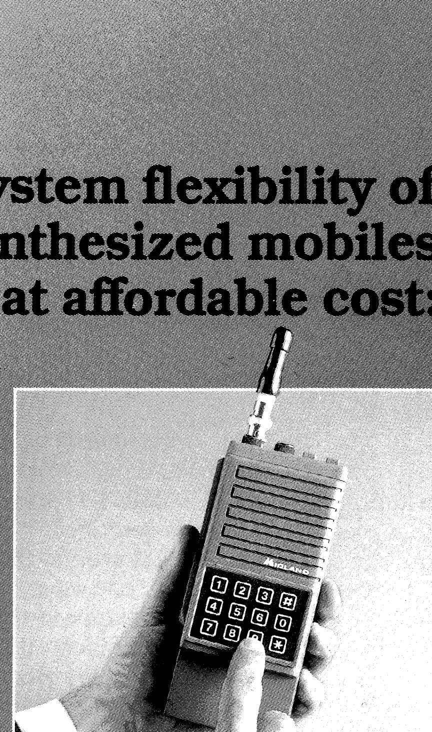
Now, the system flexibility of today's best synthesized mobiles in a portable radio at affordable cost:

the Midland SYN-TECH™ portable

▪ Reprogrammable E/PROM-controlled CMOS microprocessor ▪ 5/2 Watt switchable RF output ▪ DTMF keypad option (with or without ANI) ▪ Reprogrammable CTCSS and channel scan options ▪ Reprogrammable TOT and busy channel lockout ▪ True "jerk-and-run" mobile converter ▪ International specifications.

Find out how easily you can put mobile capability on your hip, or in your grip. Call Midland LMR Marketing, toll-free:

1-800/MIDLAND
(1-800/643-5263).
Ask for Ext. 1690



MIDLAND LMR
LAND MOBILE RADIO

1690 N. Topping • Kansas City, MO 64120
Telex: 43-4045 Cable Address: MICO
In Canada: A. C. Simmonds & Sons, Ltd.

Mahlon Loomis—Discoverer of Radio

Mahlon Loomis was a prominent Philadelphia dentist who held U.S. and British patents, circa 1854, on a mineral plating process for making false teeth. Almost forgotten is the fact that he had another U.S. patent (129, 971—July 30th 1872)—the first issued for "Aerial Telegraphy"—14 years before Heinrich Hertz demonstrated electromagnetic waves. Hertz's experiments were repeated throughout the world. Very little—usually nothing—appears about Loomis in textbooks.

The *Washington (DC) Chronicle* issue of November 1, 1872 reported that Loomis conducted experiments with "kites covered with fine, light gauze of cooper wire held with a tether of the same material." A sketch was drawn in 1865, by Dr. Loomis, depicting Cohocton Mountain and Boerse Deer Mountain—14 miles apart—in the Blue Ridge Mountains of Virginia—with kites flying from the top of each mountain. A handwritten caption below the sketch reads "Sent Signals by 'Aerial Telegraph' between these two stations by elevating a kite on each mountain, the tether of which was a small copper wire, attached to a galvanometer, each end lying in water. Signals were perfect during the cloudy part of the day. Elevation about 1,500 feet."

The essential part of the patent material indicated "... The utilization of Natural Electricity . . . by suitable conductors . . . relying upon the disturbance produced in the two electro-opposite bodies of earth and atmosphere PRODUCING COMMUNICATIONS WITHOUT AN ARTIFICIAL BATTERY OR THE FURTHER USE OF WIRES OR CABLES TO CONNECT THE OPERATING STATIONS . . ."

In 1926, a book entitled *Radio Theory and Operations* by Mary Texana Loomis was published by The Loomis Publishing Company of Washington, DC. Mary—said to be a distant cousin—says on page 256 (italic mine): "... and although *no* transmitting *key* was made us of, nor any *sounder* to *voice* the *message*, yet they were just as *exact* and *distant* as any that ever travelled over a metallic conductor . . . and . . . it is evident that Dr. Loomis also used the *telephone,* although research has not yet disclosed exactly how he did this."

On May 21, 1872, Congress listened to a long speech relative to the "Loomis Aerial Telegraph Bill" requesting an appropriation of $50,000. The principle of operation of the Aerial Telegraph was described: "... causing electrical vibrations or waves to pass around the world as upon the surface of some quiet lake, one wave circle follows another from the point of the disturbance to the remotest shores so that, from any other mountain top upon the globe, another conductor, which shall pierce this plane and receive the impressed vibration, may be connected to an indicator, which will mark the length and duration of each vibration; and indicate by any agreed system of notation, convertible into human language, the message of the operator at the point of the first disturbance." Congress denied the request; calling the whole idea "absurd."—*Don deNeuf*

BANDWIDTH EFFICIENT TECHNOLOGY

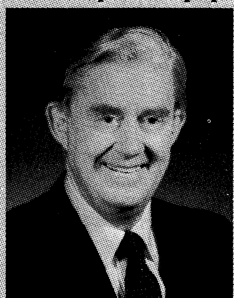
(Continued from page 6)

MOBILE RADIO TELEPHONY, *IEE Transactions on Communications* Vol. Com-29, No. 7, July 1981

6. Chung, Kah-Seng, GENERALIZED TAMED FREQUENCY MODULATION AND ITS APPLICATION FOR MOBILE RADIO COMMUNICATIONS, *IEE Transactions on Vehicular Technology,* Vol. Vt-33, No. 3, Aug. 1984
7. Petrovic, V., REDUCTION OF SPURIOUS EMISSION FROM RADIO TRANSMITTERS BY MEANS OF MODULATION FEEDBACK, *IEE, Second Annual Conference on Radio Spectrum Conservation Techniques,* 6-8 Sept. 1983
8. Petrovic, V., et. al., REDUCTION OF INTERMODULATION DISTORTION BY MEANS OF MODULATION FEEDBACK, *Colloquim on "Intermodulation—Causes, Effects and Mitigation",* 09 April 1984, Digest No: 1984/37 Professional Groups E8 and E12, United Kingdom
9. Petrovic, V., et. al., THE DESIGN OF VHF SSB POLAR-LOOP TRANSMITTERS, *IEE Conference on Equipment and Systems,* 20-22 April 1982
10. Petrovic, V., VHF SSB TRANSMITTER EMPLOYING CARTESIAN FEEDBACK, *IEE Communications 84, Conference Publication Number 235*
11. Stevenson, Carl R., AN IMPROVED MODULATION FORMAT AND SIGNAL PROCESSING SCHEME FOR ACSB SYSTEMS, *IEEE Vehicular Technology Society Conference,* May 1984
12. McGeehan, Joseph P., and Bateman, Andrew J. THEORETICAL AND EXPERIMENTAL INVESTIGATION OF FEEDFORWARD SIGNAL REGENERATION AS A MEANS OF COMBATING MULTIPATH PROPAGATION EFFECTS IN PILOT-BASED SSB MOBILE RADIO SYSTEMS, *IEE Transactions on Vehicular Technology, Vol. Vt-32, No. 1,* February 1983
13. McGeehan, et. al., ibid
14. McGeehan, Joseph P., and Bateman, Andrew J., PHASE LOCKED TRANSPARENT TONE-IN-BAND (TTIB): A NEW SPECTRUM CONFIGURATION PARTICULARLY SUITED TO THE TRANSMISSION OF DATA OVER SSB MOBILE RADIO NETWORKS, *IEE Transactions on Communications, Vol. Com-32, No. 1,* January 1984
15. Bateman, Andrew J., and McGeehan, Joseph P., DATA TRANSMISSION OVER UHF FADING MOBILE RADIO CHANNELS, *IEE Proceedings, Vol. 131, pt.F, No. 4,* July 1984
16. Davarian, F., HIGH PERFORMANCE DIGITAL COMMUNICATIONS IN MOBILE CHANNELS, *IEEE Vehicular Technology Conference,* May 1984
17. Stevenson, Carl R., NARROWBAND DPMM MODULATION IS 'BACKWARD COMPATIBLE' WITH FM, *Mobile Radio Technology,* Nov. 1984
18. *Electronics Times* (UNITED KINGDOM), 4 October 1984

IN 1933, FDR WASN'T THE ONLY ONE MAKING RADIO HISTORY.

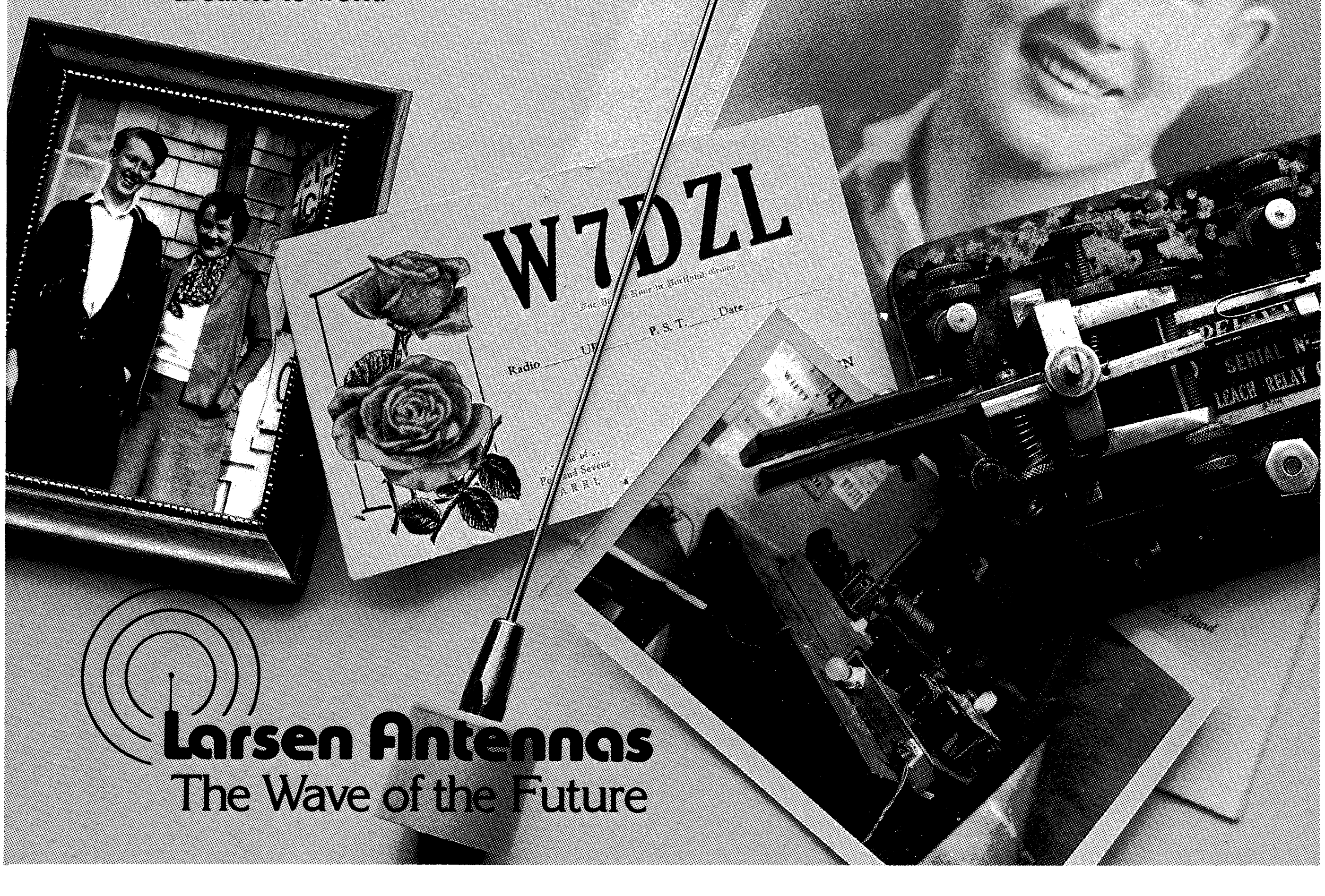
While the country gathered around the radio to listen to President Roosevelt's fireside chats, Jim Larsen was already working on a converter to pick up police calls on the family radio. When he found that he could



pick up ham signals too, he was soon roaming the air waves as W7DZL, or "Dizzle," to his fellow hams.

A perfectionist even then, he kept taking his radios apart and rebuilding them, and designing antennas to go with them... each time making improvements and each time thinking of more improvements to make.

Now after 50 years as a ham operator, Jim keeps reaching out further — both as an antenna designer, and as an amateur. Because although his call sign has since changed to K7GE, and his QSL cards include nearly every country, he's still dreaming up more improvements...and putting his dreams to work.



Larsen Antennas
The Wave of the Future