Proceedings

SPRING 2016

2015 AWARDS BANQUET

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INSIDE

Silicon Valley's Influence on Radio Evolution

Intelligent Structural Health Monitoring

A Look Back: RCA 100 Years Ago

Birth of the FM Car Radio

2016 Banquet & Tech Symposium Details

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CONTENTS

From Your President 4
From the Publications Chairman 4
2016 Banquet to Feature Nobel Laureate 5
A Personal View of Silicon Valley: The Central Role of Radio 7
Intelligent Structural Health Monitoring 15
2015 RCA Fellows Address 19
Save the Date! 107th Banquet & Awards Presentation 22
2015 Technical Symposium Slides Available 22
Seeking 2016 Technical Symposium Presenters 22
Lord Kelvin, the Atlantic Cable and the Origins of Signal Shaping 23
IEEE Offers Free White Papers 31
RCA 100 Years Ago 32
Call for Papers & Editorial Comments 34
It's Time to Honor the Distinguished and Deserving 35
RCA Awards Nomination Form 36
RCA Fellow Nomination Form 37
Motorola's First Broadcast FM Auto Radio – The Motorola FM-900 38
IEEE Announces New REACH Education Program 43
NYU Speeds Development of 5G and Makes Software Open to All 44
AWA Museum Expansion & 2016 Convention 45
Hamvention Volunteers Needed 46
Fresh Content on the RCA Website 46
Youth Activities Update 47
Support RCA by Donating Your Frequent Flyer Miles 47
Book Review | Sprague Electric:
An Electronics Giant's Rise, Fall, and Life After Death 48
Book Review | Tesla, Revisited 51
2016 Banquet Sponsorship Form 55
RCA Financial Report 56
Business & Professional Directory 57
Event Calendar 60
Welcome New Members! 62
Silent Keys 62
Is Your RCA Membership Current? 63
Shop Amazon & Help RCA 63

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FROM YOUR **PRESIDENT**



As your 2016 president, I'm honored to have the opportunity to lead the oldest, most prestigious group of wireless communications professionals in the world, and am committed to helping RCA evolve to remain relevant for generations to come. One of my goals is to increase member engagement and value. We are working to find new, fresh ways to help you connect with your fellow members and the larger wireless community. While we are looking forward, we remain strongly committed to preserving and honoring the past. I encourage you to let me know your thoughts on this important topic.

Dayton Hamvention is just around the corner on May 20-22, and this year RCA will be highly visible at the show. We are looking forward to connecting with old friends and reaching out to new, potential members to share the value of belonging to RCA. We hope to see you at one or more of the following!

- **RCA Booth** (North Hall NH0225) and the Youth Booth (North Hall NH0226) Stop by to say hello or sign up to staff the booth on behalf of RCA. ***Please contact Colleen Ayers at colleen@radioclubofamerica.org if you would be willing to volunteer at the RCA booth.***
- **Youth Forum** organized for the 29th year in a row by RCA member Carole Perry: Saturday, May 21, 9:00 am – 12:00 pm
- **Instructor's Forum** organized by Carole Perry – for teachers, instructors, or anyone leading a youth group for kids using ham radio: Friday, May 20, 10:30 am – 12:00 pm
- **Contest University**, the **Top Band dinner**, the **Contest Super Suite** and the **Contest Dinner**, all at the Crowne Plaza downtown

RCA would not be what it is today without the involvement of our dedicated and accomplished members. One of my favorite parts of the year is meeting to honor these incredible individuals at the **RCA Awards Banquet**. We are now taking nominations for RCA awards and Fellows, to be honored at the banquet. See pages 36 & 37 for the nomination forms, and take some time to nominate a deserving colleague.

I am thrilled to announce that our 2016 Banquet, returning to its traditional home at the New York Athletic Club, will feature Keynote Speaker Dr. Joe Taylor, K1JT, an American astrophysicist and Nobel Laureate. Securing a speaker of this caliber is a testament to RCA's reputation and standing in the wireless community. It will be an event not to miss – make your plans now to join us on November 18!

The **2016 Technical Symposium** will once again deliver stellar programming to help you stay ahead of the curve in the field of wireless communications. We are currently looking for presenters willing to share their knowledge. See page 22 for details on how to submit a presentation.

Thank you for your continued involvement in RCA! Please help us spread the word!

TIM DUFFY, K3LR, President
The Radio Club of America, Inc.

FROM THE **PUBLICATIONS CHAIRMAN**



This Spring 2016 issue of the *Proceedings* brings you exciting news about our initial plans for the 2016 Banquet and Awards Ceremony and the Technical Symposium. As we return to the New York City Athletic Club, we anticipate a fantastic event anchored by our first-ever Nobel Laureate! Joe Taylor, who received the Nobel Prize in Physics in 1993 for discovering the first binary pulsar system nearly two decades earlier, is this year's keynote speaker. We encourage all of you to make your plans early for attending and meeting your fellow RCA members.

This issue includes a broad array of articles spanning early milestones in electronics to current hot topics. We encompass the Atlantic Cable to FM car radios, the origins of Silicon Valley and the latest in tower structural health monitoring for the 21st century. This issue also introduces a new column: 100 Years Ago at RCA. Our illustrious club started in 1909 and the *Proceedings* began publication in 1913. What better way to measure our progress than to regularly revisit a few of our early activities and milestones? Our Voices of Tomorrow column written by our young authors will return in Fall 2016.

We are indeed honoring the past and staying committed to the future. As we strive to further expand the *Proceedings*, we invite each of you to contribute articles, news stories and ideas for future content. We welcome your comments, recommendations and suggestions on ways to further improve the *Proceedings*. Please offer your support and contributions, and feel free to contact us.

We look forward to seeing all of you in New York City this November.

DAVID BART, KB9YPD, Editorial Director and Chairman
RCA Publications Committee

RCA 2016 BANQUET TO FEATURE NOBEL LAUREATE **JOE TAYLOR, K1JT**



Professor Joe Taylor, K1JT
(Courtesy Office of Communications, Princeton University)

RCA is thrilled to announce that Joseph Hooton Taylor, Jr. will be featured at the 2016 Banquet and awards ceremony. This is the first time that RCA will be welcoming a Nobel Laureate, and our members will not want to miss this incredible opportunity.

"Joe," a Princeton University Professor, is a lifetime amateur radio operator. He and Russell Hulse received the Nobel Prize in Physics in 1993 for their discovery in 1975 of the first binary pulsar system. Professor Taylor will speak about topics of interest to RCA, including comments about the recent historic discovery of gravitational waves announced February 11, 2016. This announcement, made by the Laser Interferometer Gravitational-Wave Observatory (LIGO) and the VIRGO Collaboration, confirmed Albert Einstein's theories about the existence of gravitational waves 100 years after they were first published.

A pulsar, or pulsating radio star, is a highly magnetized, rotating neutron star that emits a beam of electromagnetic radiation. This radiation can be observed only when the beam of emission is pointing toward Earth similar to the way a lighthouse can be seen only when the light is pointed in the direction of an observer. This behavior is responsible for the pulsed appearance of the emission. Neutron stars are very dense, and have short, regular rotational periods. This produces a very precise interval between pulses that range roughly from milliseconds to seconds for an individual pulsar. Pulsars are believed to be one of the candidates of high and ultra-high energy astroparticles.

In 1974, Taylor and Hulse discovered for the first time a pulsar in a binary system. This pulsar orbited another neutron star with an orbital period of just eight hours. Einstein's theory of general relativity predicts that this system should emit strong gravitational radiation, causing the orbit to continually contract as it loses orbital energy. Observations of the pulsar soon confirmed this prediction, providing the first-ever evidence of the existence of gravitational waves. In 1993, Taylor and Hulse received the Nobel Prize in Physics for their discovery.

Joe was born in 1941 in Philadelphia, but grew up in Cinnaminson Township, New Jersey. He became an amateur radio operator as a teenager in the 1950s. Today, he continues to be an active ham and is likely to be on the air participating in several contests each year. In 2001, he authored the weak signal processing suite WSJT that is widely used for Earth-Moon-Earth and meteor scatter communication modes.

Joe received a B.A. in physics at Haverford College in 1963, and a Ph.D. in astronomy at Harvard University in 1968. He went to the University of Massachusetts at Amherst, eventually becoming Professor of Astronomy and Associate Director of the Five College Radio Astronomy Observatory. His thesis work was on lunar occultation measurements. In November 1967, the first pulsar observation was made by Jocelyn Bell Burnell and Antony Hewish, about the time Joe completed his Ph.D. Joe then began studying pulsars after finishing his graduate studies at Harvard. He immediately went to the National Radio Astronomy Observatory's telescopes in Green Bank, West Virginia. Since then, he has worked on all aspects of pulsar astrophysics. In 1975, Joe and Hulse made their own discovery during a survey of pulsars made at the Arecibo Observatory in Puerto Rico. In 1980, he moved to Princeton University, where he was the James S. McDonnell Distinguished University Professor in Physics, having also served for six years as Dean of Faculty. He retired from Princeton in 2006.

Joe has continued to be an expert on the measurement of binary pulsar properties because these phenomena provide a stringent test of Einstein's general theory of relativity, and of the existence of gravitational waves. Binary star systems lose energy and slow down because they radiate their energy. The rate of energy loss can be computed using various theories of general relativity.

Joe Taylor first obtained his amateur radio license as a teenager, which led him to the field of radio astronomy. He is well known in the field of amateur radio weak signal communication and currently has the call sign K1JT (previously K2ITP, WA1LXQ, W1HFV, and VK2BJX). He mounted an expedition in April 2010 to use the Arecibo Radio Telescope to conduct moon bounce with amateur radio operators around the world using voice, Morse code, and digital communications. He wrote several computer programs and communications protocols, including WSJT ("Weak Signal/Joe Taylor"), a software package and protocol suite that utilizes computer-generated messages in conjunction with radio transceivers to communicate over long distances with other amateur radio operators. WSJT is useful for passing short messages via non-traditional radio communications methods, such as moon bounce and meteor scatter, and other low signal-to-noise ratio paths. It is also useful for extremely long-distance contacts using very-low power transmissions.

Joe was among the first group of MacArthur Fellows. He has served on many boards, committees, and panels, co-chairing the Decadal Panel that produced the report Astronomy and Astrophysics in the New Millennium that established the United States' national priorities in astronomy and astrophysics for the period 2000-2010. He was a guest of honor in the 2009 International Physics Olympiad. His many awards include:

- Heineman Prize of the American Astronomical Society (1980) (inaugural)
- Fellow of the American Academy of Arts and Sciences (1982)
- Henry Draper Medal of the National Academy of Sciences (1985)
- Tomalla Foundation Prize (1987)
- Magellanic Premium (1990)
- Albert Einstein Medal (1991)
- John J. Carty Award for the Advancement of Science of the National Academy of Sciences (1991)
- Wolf Prize in Physics (1992)
- Nobel Prize in Physics (1993)
- Karl Schwarzschild Medal (1997)
- World Radiocommunication Conference (WRC-12) Address (2012)
- International Telecommunication Union (ITU) Gold Medal (2012)
- ARRL Centennial Presentation (2014)

The Radio Club of America would like to particularly thank RCA President Tim Duffy for his role in inviting Professor Taylor to join us at the 2016 banquet. We look forward to seeing everyone in November for this rare and very exciting opportunity.

Observations of the pulsar discovered by Taylor and Hulse soon confirmed Einstein's prediction, providing the first-ever evidence of the existence of gravitational waves. In 1993, they received the Nobel Prize in Physics for their discovery.



Nobel Laureate Joe Taylor, K1JT, addresses an audience at the ARRL National Centennial Convention
(Rick Lindquist, WW1ME, photo, courtesy ARRL)

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A PERSONAL VIEW OF SILICON VALLEY: THE CENTRAL ROLE OF RADIO

By David B. Leeson, Ph.D.

EDITORS NOTE: Dr. David Leeson was the keynote speaker at the 106th Radio Club of America Banquet and Awards Ceremony in November 2015. Based on his own personal experiences, he discussed the role radio played in developing a high-tech culture for Silicon Valley. Later, Dr. Leeson spoke on the origins of the SLAC National Accelerator Laboratory in a March 2016 panel discussion for the IEEE Silicon Valley Technology History Committee. PowerPoint slides from both of these presentations have been generously shared with RCA members on the RCA website. The following article by Dr. Leeson is a summary of his RCA banquet speech.

When I was invited to give last November's welcoming keynote presentation to the Radio Club of America's first-ever West Coast meeting, I thought to introduce three paths for understanding Silicon Valley: its regional advantage, radio's central role in its emergence, and some of my own illustrative personal experiences here. As background, I have worked here for half of Silicon Valley's hundred-year history. I came to Stanford for my Ph.D. from 1959-1962, later found a position in a local defense startup, and then founded and managed California Microwave from 1968-1993. Since then, I have been a Stanford consulting professor, investor and business owner.

REGIONAL ADVANTAGE

I focused first on the regional advantages that have made Silicon Valley different, and in many ways uniquely more flexible and effective, than other established or emerging industry regions. Second, it seemed to me that a focus on the significant role of radio technology (as opposed to semiconductors) in Silicon Valley evolution would resonate with RCA members whose own backgrounds are in communications. Last, I wanted to say a few words about my own personal experiences in founding and building a microwave company that drew on both my industry and amateur radio background. I would like to leave you with my own view of the "secret sauce" that underlies the unique success of Silicon Valley.

The mystique of Silicon Valley is grounded in the story of newly founded companies that grow out of nowhere by forging new approaches, starting from scratch to become both very successful and fabulously rewarding investments for their founding group, and even for later staff and investors as well. The fact is that most startups do not succeed. But although earth-shaking successes are a very minute fraction of the companies that have been formed here, they have become household names around the world, creating legends that entice investors to continue venture investments imagining their own El Dorado.

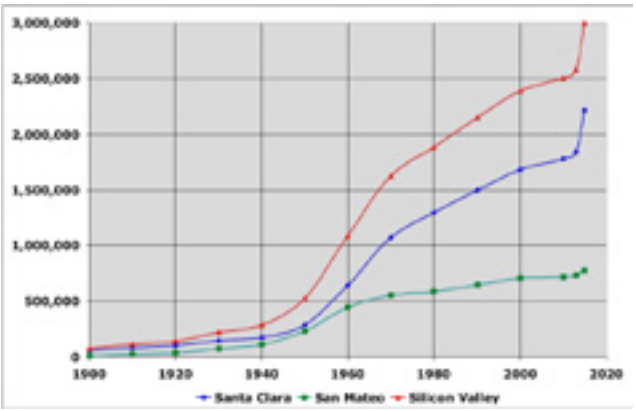


Fig. 1. Population growth in Silicon Valley.

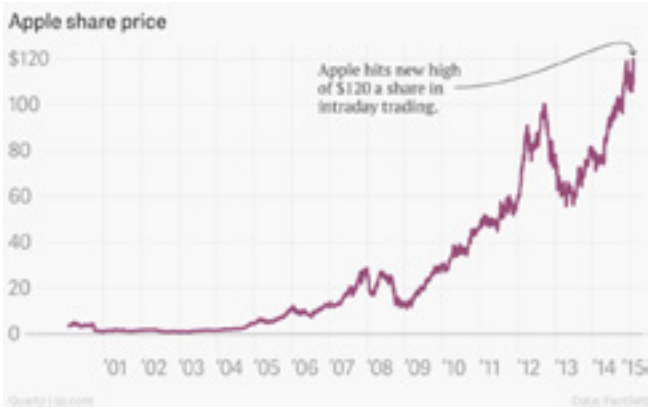


Fig. 2. Apple's share price.

Things get founded and grow bigger faster here. Many generations of products and companies have thrived. Why? What is the secret? Organizations and regions typically become more rigid and institutionalized as they succeed and mature, so how has this region avoided that? Can it be expected to continue?

I want to focus particularly on the many product, organizational, economic and political life cycles through which this region has been able to reinvent itself over and over again. That has driven a forty-fold increase in population since 1900, shown in Fig. 1. A famous example is the dramatic rise in the capitalization of Apple, shown in Fig. 2, to become the most valuable company in the world and a symbol of Silicon Valley.

The early history of what would become known as Silicon Valley has been well studied. The simplistic popular view is that the regional technology history began with the arrival here of William Shockley and semiconductors in 1955, followed by many spinoffs of the "traitorous eight."

Instead, as detailed in the Fall 2015 issue of this journal, the real story goes back at least to the beginnings of radio.[1] Wireless communication was of critical value to the shipping companies of the port of San Francisco and then the U.S. Navy, both of which wished to avoid foreign ownership or monopoly pricing from elsewhere. Both Stanford and radio were young when the first wireless technology venture was founded here in 1909 by Cyril Elwell, fresh out of the university himself. Although both the university and the local radio industry were small and regional by the time of World War II (WWII), the seeds of the present were planted.

THE DEFIANT WEST

During the pre-WWII period, the shackles of the radio monopolies of the large eastern companies, such as RCA and AT&T, were broken by what has been termed the "Defiant West."[2] This regional collaboration to find ways around the patents was led by local small businesses under leaders (and radio amateurs) such as Ralph Heintz, Charles Litton, Sr., William Eitel and Jack McCullough and by Stanford inventors William Hansen, Russel H. & Sigurd F. Varian, Frederick Terman and William Hewlett.

So let us turn now to identify the combination of regional advantages that arose to make Silicon Valley uniquely more flexible and effective than other established or emerging industry regions. The roots of the regional advantage have been identified as the conjunction, all within easy travel, of advanced technology, entrepreneurial culture and venture finance. The addition of favorable climate and plenty of open land, plus the influx after WWII of both federal funding and trained veterans, further fortified the character of the region. Even events so remote as the Gold Rush and the railroad fortunes left a freewheeling spirit of risk-taking and the regional wealth to make risky investments. One interesting carryover from the 1870's to today, is California's unique law that enables employees to change jobs freely: "…every contract by which anyone is restrained from…a lawful profession, trade, or business…is void." The success of early radio, vacuum tube and microwave companies provided examples of payouts that encouraged further venture investments and of successful individuals willing to mentor and sponsor new entrepreneurs.

A key source of technology and technologists has been Stanford, a university that emerged onto the world stage from a regional level through its willingness to consider practical problems to be as worthy as academic ones. Also, since early in its history, Stanford faculty have been alert to finding opportunities to mentor and invest in promising students and their ideas, and they have been instrumental in the founding of many of the pioneer firms in each wave of Silicon Valley development.

The entrepreneurial culture I found here has been based on willingness to share equity, to permit youth to manage, and to promote the benefits of collaboration over vertical integration and strict proprietary secrecy, concepts less commonly found elsewhere. Silicon Valley, perhaps reflecting its Old West heritage of migrating settlers, places much greater reliance on youth in management as shown in Fig. 3. It is considered admirable to leave a job with a mature firm and take a risk, even if you fail. The idea of patiently working their way up over decades through a traditional corporate hierarchy is foreign to this area. And, because there are many entrepreneurs who are willing to try their hand, there is also a vigorous venture capital industry that has struck gold enough times to be willing to invest in a new idea.

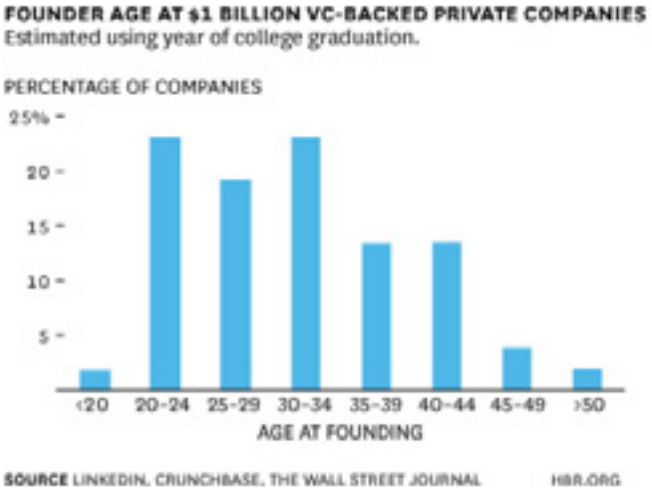


Fig. 3. Founder ages at $1 Billion venture capital backed private companies.



Fig. 4. Prof. Frederick Terman.



Fig. 5. Russell Varian and W. W. Hansen with Model C klystron.

In many cases, companies here have been founded and run by entrepreneurs who would be considered much too young to manage anywhere else. It is not uncommon for startups to be founded and managed by youthful entrepreneurs, a number whom were told, as I was, "You're too young to manage." Others, including the founders of Apple, Google and Facebook, were too impatient even to have any interest in the corporate climb.

Silicon Valley has uniquely promoted the use of equity to allow employees to be owners. Employees view themselves as owners, and certainly are treated that way in startups. This fosters an organizational culture that will not tolerate indifference or neglect. In addition, the regional practice for startups to use existing support infrastructures eliminates the costs and compound risks of the vertical integration found elsewhere.

A final critical component has been the turnover in new technology life cycle phases that open opportunities for new ventures. The key for a successful startup is to have freedom from the overhang of conflicting priorities that bedevils an existing company that has become too rigid and bureaucratic.[3] Life cycles in which product classes become commodities cause mature companies to run down, but the culture here has managed to foster repeated product cycles: radio and tubes, radar and countermeasures, microwave tubes and accelerators, integrated circuits, computers, networks, mobile devices, and applications. Somehow, the older companies do not get in the way of the new ones. When companies succeed here and their products become commodities, a newer category of product typically arises that existing companies view either as unpromising, too limited, uninteresting to their largest customers, or outside their competence. A few of their key people have the vision to see the opportunity, and depart to capitalize it, finding ready legal and financial support. Even if only one in a hundred persists, or perhaps one in a thousand becomes a really big success, that is enough to give hope to investors.

Attempts by established companies from other regions to install local entities that can tap into the Silicon Valley culture have, by and large, not done well. The experience of Xerox and its famous Palo Alto Research Center is a well-studied example.[4] The culture of Silicon Valley has also proven persistently difficult to export to areas with other cultures that may not share its 100-year history.[5]

I should mention at this point the valuable role of a large traditional defense contractor, Lockheed Missiles and Space, which was the largest employer in the area for many years. Lockheed provided both a ready refuge of retreat from startup failures and a source of technologists, and also made major contributions to Stanford. Another question often arises, "Why didn't Silicon Valley grow near the University of California in the East Bay region?" I believe the answer lies in a lack of industrial spinoff opportunities from the nuclear science of E. O. Lawrence there, plus the fact that the public University of California was state funded, so professors there had far less incentive to seek the types of outside funding that brought the private Stanford to its present standing.[6]

THE RISE OF STANFORD

The long interrelationship with Stanford is a key source of regional strength. Regional industry and the university have grown up together from the early vacuum-tube days, through microwave and radar, to semiconductors, computers, mobile communications, the Internet and its applications. So an important factor in the blossoming of Silicon Valley was the emergence of the modern Stanford from a prewar struggling regional university to become an internationally recognized research institution. In a nutshell, Stanford got big through

its connection with radio, with amateur radio occupying a significant educational role. Radar and countermeasures brought corporate, and then federal, funding to Professors Frederick Terman (6AE), shown in Fig. 4, and William W. Hansen (6CSY).

During the Great Depression, politically conservative Stanford would not accept funding from the New Deal, and it fell into difficult financial straits. The invention by young Hansen of the microwave resonator in 1935 led directly to its application in the breakthrough invention of the microwave klystron by Hansen and the Varian brothers (shown in Fig. 5) in 1937. This led to the offer by Sperry Gyroscope of funding in return for shared patent rights. In a remarkable coincidence that cast a long shadow over future events here, this funding included $1,000 for a patentable idea donated by Charlie Litton (6AO). The funding was earmarked for Terman, then the sponsor of Stanford's amateur radio club, to bring his student David Packard (9DRV) back in 1938 for postgraduate study at Stanford. After graduating, Packard had gone east to take the only job he could find during the Great Depression. He rejoined his classmate William Hewlett, still at Stanford, who that same year would patent the audio oscillator on which the Hewlett-Packard Company would be founded a year later. In that close community of colleagues, Packard's graduate research was directed by Russell Varian, with guidance from Charles Litton, shown in Fig. 6.

Hansen and his protégés, graduate students John Woodyard and Edward Ginzton, also developed, patented (with Terman) and published new fundamental types of antennas. They combined these with the klystron to develop the first microwave blind-landing systems and Doppler radar. At the outset of WWII, Terman, Hansen and their colleagues were called east to lead wartime efforts on radar and countermeasures. As a result, they became well known to their corporate and government sponsors, who agreed after the war to fund a new Stanford microwave laboratory for Hansen and an electronic radar countermeasures laboratory for Terman. In a parallel development during WWII, Eitel and McCullough's company, EIMAC, and Litton's company both grew so that between them they dominated the supply of vacuum tubes for the radar effort.

At Stanford, the postwar discovery of nuclear magnetic resonance by Bloch and Hansen, the invention by Hansen of the traveling wave electron accelerator and the development in his laboratory of the megawatt klystron led directly to the funding and construction of the famous two-mile Stanford Linear Accelerator and its many successors. The microwave countermeasures and vacuum tube companies that spun out of these laboratories, including Varian Associates, became the venture successes that encouraged the widespread investments in the next industrial phase, the Silicon era.

During that postwar period, despite the influx of big federal research contracts, Stanford was still suffering financial problems. The university owned 8,000 acres, but was unable to sell any land under the terms of its original land grant. The idea arose to develop excess land by leasing the land to shopping centers and other retail uses. But as his company succeeded and grew, Russell Varian arranged to rent land closer to Stanford. Fred Terman was both a Varian director and a member of the university's land committee, and he saw the great mutual benefit of attracting additional technology companies to locate nearby, providing rental fees, tuition, research funding and jobs for graduates. From this came the concept of the Stanford Industrial Park, which proved to be the incubator and direct predecessor of Silicon Valley. As the saying goes, the rest is history.

THE ROLE OF RADIO

But what about radio? Radio has been central to Silicon Valley both before and since the semiconductor period that is popularly thought to represent the regional origin. From its beginnings in maritime communications, radio and wireless products have been central to all but integrated circuits and computers among the Silicon Valley product eras, including:



Fig. 6. Charles Litton at his glass lathe.

- Prewar radio and vacuum tubes
- WWII radar (2,000,000 tubes)
- Microwave tubes and countermeasures
- Particle accelerators
- Silicon and Moore's Law
- Computers
- Networks
- Cellphones and Wi-Fi
- Applications of the infrastructure.

From the early era, wireless and radio have come full circle to modern wireless. Today, there are more connected wireless devices than the population of the earth.

MY JOURNEY TO SILICON VALLEY

Let me turn now to some brief recollections about how I came to be in Silicon Valley, after which I will conclude with some comments on what might be expected to come in the future.

I have been smitten by radio since I first witnessed amateur communications when I was four years old, and I have been an active amateur licensee for more than sixty years. I was taught to fix radios by a kindly shop owner, beginning when I was thirteen. By fifteen, I was a licensed amateur, and while still in high school I designed and built my own transmitter, kilowatt amplifier and antennas. The diagnostic skills I learned in those days have served me well ever since, and form an important part of what I have tried to pass on to my students.

Los Angeles in those days was heaven for a teenage radio ham, and our club, the Pacifico Radio Club, shown in Fig. 7, was composed of hams my age who were devoted to an annual national radio competition, which we won outright to the chagrin of our elders. The lessons in project management and leadership were a wonderful start for my eventual career, and have been another element of my teaching.

Amateur radio in those days was the original maker culture, and I benefited. At one point, I read a science-fiction article that pointed out the great energy and cost efficiency advantages of communications as compared to transportation (zero-rest-mass particles vs. finite-rest-mass particles). My plan for a career in radio was confirmed.

While I was in college, I consulted for various professors and outside electronics firms. Hughes Aircraft Co. was local and was run by radio amateurs whom I was able to approach. So as soon as I was eighteen and could be insured, I signed on to work summers and vacations as I progressed through school.

The innovative ionospheric work of Professor O. G. Villard, Jr. attracted me to Stanford for my doctoral studies. Villard, an active radio amateur himself and the faculty advisor of the Stanford Amateur Radio Club (W6YX), had worked with Terman during WWII and was influential at Stanford. The informality and vigor of Stanford and the area attracted me from first sight. Once there, I designed special equipment and circuits for Prof. Villard's projects, and gradually became aware of the unique career possibilities that the region offered. I had seen nothing comparable at either Caltech or MIT. In recognition that Hughes had provided a fellowship for my degree work, I returned to Los Angeles when I received my Ph.D. in 1962. My design and project work at Hughes over the next two years in Doppler radar and space satellites was a valuable education that shaped the rest of my career.

By the time I was twenty-seven, I was an ambitious, well-published engineer. Inquiring about my prospects for promotion at Hughes, I learned it would be years before I could be considered for a management position. In 1964 I decided to leave and look for a position back in the Stanford area, but in my search I was told by larger companies that



Fig. 7. My early days in amateur radio.



Fig. 8. Prof. O. G. (Mike) Villard.



Fig. 9. Our company founders in 1968.



Fig. 10. David Packard.

they needed engineers, not managers, or that I did not fit their culture.

Fortunately, my Stanford mentor, Prof. Villard, shown in Fig. 8, directed me to a recent startup of which he was a board member, Applied Technology, which had spun out of Stanford's countermeasures lab. That clicked for me until the rapidly growing company decided a number of us were too young, and began to bring in our former supervisors from larger companies. Spinoffs ensued, and after Applied was acquired, I left in 1968 to found my own company at age thirty-one.

It was a revelation to me that, with the sponsorship and encouragement of Prof. Villard, my founding team of five could put together a concise business and financial plan, and receive almost overnight funding in the Stanford area. In a jaw-dropping event, after hearing just a brief outline of my proposal while we were traveling east on an airplane, Villard pulled a blank check from his briefcase, signed it and gave it to me, telling me not to put in more than a quarter million dollars. That was a lot of money back then, nearly half of our funding plan in a single stroke! Years later I asked him if he thought it was a big risk, and he replied that he was confident it would work out, and that he had done well.

With that as seed capital, the rest was raised almost overnight. Venture capital in those days was quite personal, and not the institutionalized business it has become. Referred by Villard, I would go to the home of a potential investor, outline my proposal and typically receive a check on the spot. By the time I arrived at the next investor, word had spread by telephone and the scene was repeated. We allocated our initial ownership among three groups, Stanford professors such as Villard and Terman, individual venture inventors and ourselves, believing that none of the founders, shown in Fig. 9, should have a free ride. We raised only that single round with no expectation of more, and within the first year received contracts by which we became profitable almost immediately.

I had the opportunity to meet David Packard, shown in Fig. 10. I attended a dinner at his house, and I saw his strategic clarity, management style and personal informality as examples to emulate. After the dinner he took us all out to his garage to show how well his new drill press worked. Packard said that if it had not been for amateur radio, "the Hewlett-Packard Company would never have come about."[7] Also, he told about a meeting at which a speaker said that management's responsibility "is to the shareholders — that's the end of it." Packard said he objected, citing responsibilities to employees, customers and community.[8]

I greatly admired Packard's approach. Our strategy at California Microwave was to build "a decent honest success" through radio infrastructure products that relied on our unusual qualifications in low-phase-noise signal sources. We pursued a conservative financial strategy and were able to fund our growth by reinvesting our profits.

We grew both through our own products, and then also by investing in startups that we could coach and which would serve the same customers that knew us. Almost all the new outfits succeeded, at which point we acquired them under our initial funding agreement. Our products eventually included radar and associated test systems, terrestrial microwave radio links, satellite earth stations, defense avionic systems, unmanned intelligence drones, and Wi-Fi, examples of which are shown in Fig. 11. Through membership on standards bodies and industry associations, I was able to apply my amateur-radio experience in obtaining FCC approval of propagation beacons to promote the acceptance of the new regulatory framework for unlicensed wireless networks.

In 1971, the technology journalist Don Hoeffler was looking for a name for a series of articles in the industry weekly Electronic News about the many semiconductor companies that had been created by then. At the suggestion of an acquaintance, he titled it "Silicon Valley USA," as shown in Fig. 12, and it stuck. So, in a sense, "Silicon Valley" actually came to me.

By 1972 we were sufficiently established and profitable to go public, and ultimately, by meeting our customers' stringent needs for performance and reliability, we provided a handsome return for our initial investors and our employees. When I retired twenty-five years later, I left a going enterprise

with a staff of 2,000, satisfied that I had met my personal objectives and was financially able to enjoy a subsequent career at Stanford.

SOME OTHER ANECDOTES

Along the way, I experienced some additional interesting events that offer insight into Silicon Valley and its culture. When our company had barely been founded, my standards-committee colleague at a government lab approached us with an opportunity to solve a serious Doppler radar problem for him. He was willing to sponsor us if we could help him. Since we had little else to do just yet, we turned right on it. When the government people came to survey our little company, we asked our relatives and friends to come in and create something of a Potemkin village, first appearing to work in the assembly area, then moving to a conference room, and finally sharing lunch with the government folks. I would guess they saw right through us, but they were satisfied that with their coaching we were ready to move out immediately, and could do the job.

Once we had begun to succeed on the initial contract for instrumentation, the opportunity expanded to include work on the radar itself. In order to test the radar, with typical informality we took it upon ourselves to use as our target the very large fruit-can shaped water tower of a nearby packing plant (the area was still agricultural then). It had not occurred to us that the Navy planes flying over that tank on their way to landing at nearby Moffat Field would not appreciate being illuminated by military radar. A vehement telephone call from the authorities strongly recommended that we discontinue our use of that target. We did!

Much later, a telling incident involved an opportunity to provide a larger East Coast company with satellite equipment that we had been building for other major customers. They arrived for a meeting, heard our presentation about our gear and toured our facilities. They went home, and promptly awarded the contract to another company that we felt offered a less capable product. When we inquired why, we were told, "Well, you were not serious or respectful, you did not wear suits and ties." What a distressing example of an inter-regional disconnect with our informal culture!



Fig. 11. California Microwave products.

While we were building California Microwave, I was also active in my hobby as an amateur racecar designer and driver. Over the years, as I learned what it takes to win, I was afforded many strategic and project lessons that enhanced my ability to manage our business, as well. Some of these lessons included:

- Strategic segmentation:
  Do not compete where you cannot win
- Projects:
  Put show-stoppers first, to avoid unlikely investments
  No last-minute changes without recovery time
  Rely on checklists and mnemonics
  Expect failures, know and practice diagnostic discipline
  Components must work individually first
  Integration takes more time than expected.

One interesting outcome of my racing was a lesson I learned from using one of Intel's new digital watches as a stopwatch. It failed when most needed, and I later complained about the inconvenience of its failure to Bob Noyce, then a colleague on Stanford's Engineering Advisory Board. He laughed heartily, telling me his own had cost him a whole lot more, and that its "$15 million reputation" was brought up whenever someone suggested that Intel move into a consumer business. I often used this story to remind myself that we were best adapted to the discipline of infrastructure requirements.

ETHERNET AND UNLICENSED WIRELESS

To conclude, let me say a few words about future radio possibilities. The field of unlicensed wireless,


Electronic

New York, N.Y., Monday, January 11,

SILICON VALLEY U.S.A.

This is the first of a three-part series on the history of the semiconductor industry in the Bay Area, a behind-the-scenes report of the men, money,

Fig. 12. "Silicon Valley U.S.A".

which includes Wi-Fi and Bluetooth, required a milestone change in the regulation of radio. From the very beginning, radio was licensed to avoid interference. With limited spectrum, this restricted development.

The effect of Moore's Law to so greatly reduce integrated circuit costs has favored the economics of digital computing and communications. The inventors of Ethernet were informed by their personal experience with amateur packet radio. The packet concept guaranteed errorless digital data transmission. For a time, amateur packet radio was the largest packet network, and proved packet contention could work.

With input from industry and universities, the FCC and other regulatory bodies accepted the concept of packet contention methods for new unlicensed spectrum. This has spread rapidly to include cellular telephony and computer networking, including wideband backhaul applications.

With more and more demand for mobility, radio continues to be the key to the future. New frequency allocations will be developed to carry the expected load. The developing "Internet of Things" is actually radio-centered, and the concept of nanodevices in quantities of trillions is yet another step requiring radio and related technologies.

Last, the serious question arises whether the Silicon Valley model can still function. Industry, academia and venture capital have become more institutionalized. Companies no longer share information so readily. The region is experiencing high land and building costs, unaffordable living costs and transportation gridlock. Some of the industry's leading companies can feel the pressure of their products becoming commodities.

But it seems there is still no limit on the new young entrepreneurs with novel ideas, and venture capital is still alert to take advantage of fundable proposals. I do not think I can answer the question about the future, but it will be interesting to watch it arrive. In any event, it has been a great fifty-year adventure for me in the hundred-year history of Silicon Valley.

ABOUT THE AUTHOR



David B. Leeson is a consulting professor of electrical engineering at Stanford University. He was for twenty-five years the founding chairman and CEO of California Microwave, Inc. He holds degrees from Caltech, MIT and Stanford.

Leeson is a Life Fellow of the IEEE, and received its Cady Award for his seminal work on phase noise. He is the author of widely cited journal papers and a book, and was a member of IEEE standards committees for wireless networking and frequency stability. His professional interests are microwave communications, entrepreneurism and history. He was a sports-car race driver and is an avid radio amateur (W6NL). He is the faculty advisor and license trustee for the Stanford Amateur Radio Club (W6YX).

For RCA members, Dr. Leeson has provided a complete copy of the slides for this speech and also for a related one at the IEEE. The PDF files for these presentations are located on the RCA website at http://radioclubofamerica.org.

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THE RADIO CLUB OF AMERICA, INC.

INTELLIGENT STRUCTURAL HEALTH MONITORING

Mark S. Allen & David G. Brinker
Co-Inventors
March 2016, Peoria, IL, USA

EDITOR'S NOTE: Mark S. Allen and David G. Brinker are the co-Inventors of a tower-mounted sensor for providing "smart" continuous health monitoring of vertical tower structures. One of the inventors, Mark Allen, provided a technical discussion about the invention, "Tower Structural Health Monitoring for the 21st Century," at the 2015 RCA Technical Symposium. We are grateful to the inventors for authoring their first publication about their invention and its application and sharing it with RCA.

OVERVIEW

In today's 21st century environment, communications infrastructure has taken on a new importance with regard to personal communications, emergency communications, entertainment, and business. Communications infrastructure in many cases requires vertical structures such as towers and poles to hold antenna systems and related equipment to facilitate such systems.

In the U.S. marketplace, there are several major wireless carriers that in many cases operate duplicate infrastructure for competitive purposes. This becomes very clear to anyone who has observed two or three towers on the same corner. These entities operate their towers in accordance with their own specifications and certain government regulations, such as those imposed by the Federal Aviation Administration (FAA) concerning lighting and marking of such towers. Consequently, there is little consistency throughout the marketplace regarding how such structures are designed, erected, and maintained over their service life. The Telecommunications Industries Association (TIA) is accredited by the American National Standards Institute (ANSI) to develop voluntary, consensus-based industry standards for a wide variety of Information and Communication Technologies (ICT) products, including towers and other structures that are relevant to this article.

The inventors identified a need for employing new and emerging technology to add an element of health monitoring to these types of structures. Health monitoring for vertical structures has many of the same benefits of monitoring one's personal health. In many cases, early indicators, if properly detected, are precursor warning signs of more catastrophic events. It seemed a logical progression to the inventors.

The remainder of this article will discuss more specifically the methodology employed in the inventors' monitoring system and the underlying technology that supports its operation.

GOALS OF MONITORING

Obviously, as with any complex system, early detection of impending issues is certainly more desirable than a reactive stance. To accomplish this, the inventors set forth the following key goals.

- First-tier design goals for the system included: continuous health monitoring of the structure; determination of the amplitude and frequency of vibrations; correlation of the structure's displacement coincident to wind velocity and direction; verification of wind gust performance factors; and generation of a reporting system for unusual behavior
- Second-tier design goals for the system included: short- and long-term trend analysis to track the responses of the structure; early detection of structural issues; electronic detection of additions and deletions from the structure; electronic detection of unauthorized activity on the structure; mitigation of vibration-related phenomena, e.g., vortex shedding; and assistance with forensic investigation of failures.
- Third-tier design goals centered on an attempt to maximize tower assets for the owners. These goals included: allowing design engineers to examine actual versus predicted performance; providing an alternative to traditional "tower

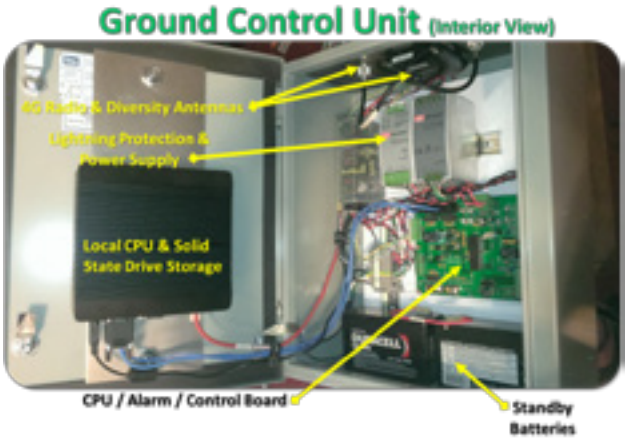


Fig. 1. Interior view of the ground control unit.



Fig. 2. David Brinker analyzing the system architecture.

mapping"; allowing designers to focus on displacements versus calculated forces; allowing designers to investigate true drag and shielding factors of a tower with its appurtenances; allowing engineers to determine the percentage of overall structure utilization "loading"; assisting with engineering decisions concerning placement of appurtenances on the structure; and gathering historical performance information for new designs.

In a hypothetical example, where a large tower operator has numerous monitored structures within the path of a storm, this detection system will be highly predictive of where repair resources should be allocated. By examining post-storm data from a large group of structures, dispatch priorities for repair easily can be established. Structures with permanent deformations, slack guy wires, or other issues can be identified. Such identification allows management to dispatch capacity-restrained resources to the most critical sites first. Such ability helps to prevent further damage and catastrophic failure, and enables the application of critical maintenance operations.

SYSTEM ARCHITECTURE

The structural health monitoring system consists of several operating components:

- A tower-mounted sensor array
- A wind velocity and direction detector
- Integral cabling
- A ground control unit (GCU)
- A connection to the Cloud
- A user-accessible dashboard from a browser
- Short-, intermediate-, and long-term data storage capabilities in the Cloud

The design goals of the tower-mounted sensor were as follows:

- Detection of lateral displacements
- Detection of twist, sway, and rotation
- Detection of dominant frequencies of structural displacements
- Integration with other sensor types (e.g., ice detectors)
- Correlation of site and area weather data
- Utilization of specific mathematical algorithms unique to this purpose
- Intermediate- and long-term trend analysis
- Output of alarms as defined by the user

The inventors encountered significant design challenges during the alpha and beta testing of the structure health-monitoring system, as well as during the pre-production hardware development. The major challenges encountered were as follows:

- Fixing or determining a point in three-dimensional (3D) space without references
- Determining how to filter incoherent noise out of the fundamental sensors
- Designing an algorithm family to determine movements
- Developing an electronic design:
  - with zero self-generated electromagnetic interference (EMI) emissions
  - that can operate in areas of extreme radio frequency (RF) fields
  - that will withstand multiple lightning strikes
  - that will accommodate a wide variety of installations
- Developing a mechanical design that will withstand the elements of nature



Fig. 3. Project development team meeting.



Fig. 4. Exterior view showing the tower mounted sensor.

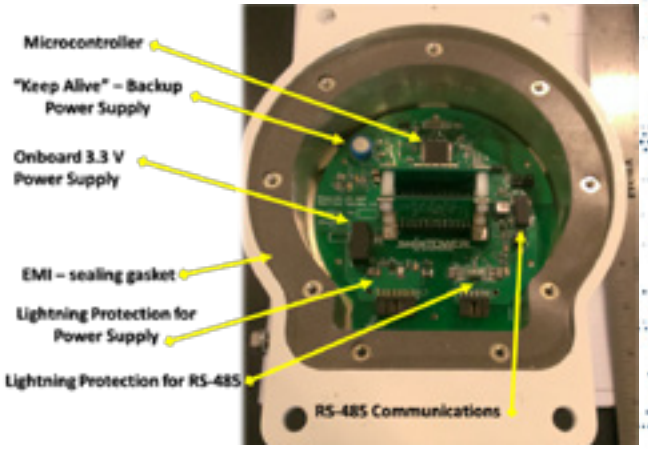


Fig. 5. Interior view showing the sensor components.

THE TEAM

After discovering the numerous unique challenges inherent in designing this completely new technology, the inventors determined that a multi-disciplinary team was required in order to have a chance at a successful design. Ultimately, the team consisted of: a physicist; mechanical engineer; structural engineer; civil engineer; RF engineer; electrical engineer; software engineer; digital signal processing expert; and a sensor fusion expert.

It took some time to search out the required talent and bring them onboard. Initially, the widely varied disciplines required of the team did not coalesce very well. We divided the project into specific sections and built sub-teams to address each of the key problem areas. This methodology was borrowed from Robert Oppenheimer, who employed the same strategies during the Manhattan Project that developed the first atomic bomb. So, we divided tasks into subtasks, thus attacking the overall problem from multiple fronts.

Eventually the sub-teams began to coalesce and outputs from each of them in turn were combined, with the eventual result being working prototypes.

Project management of such a widely diverse set of disciplines proves to be quite challenging as well as rewarding.

THE PRODUCT

The heart of the entire project was the development of the tower-mounted sensor. This sensor had several unique design criteria that had to be met without exception by the design team. The key features of the sensor were as follows:

- High voltage and current protection for lightning strikes
- RF-protected circuits and connections
- Ability to function under severe weather conditions
- Internet (or intranet) access/administration/updates
- Secure (encrypted) data transmission and storage
- Backup of key data
- Simple to install, low cost, scalable
- Remote upgrades as products evolve

The sensor is based around the Inertial Measurement Unit (IMU) using MEMS (micro-electro-mechanical systems) technology.

This solution uses a miniature, surface-mounted, high-performance IMU and Attitude Heading Reference System (AHRS). The device combines a 3-axis accelerometer, a 3-axis gyroscope, and a 32-bit processor into a miniature surface-mounted module.

The sensor with algorithms and special filters calibrates for scale, noise, drift and bias inherent with MEMS technology, and outputs the displacements, twist and sway of a structure.

TESTING FOR ROBUSTNESS

Both the inventors and the design engineers became very concerned about the sensors and the GCU being robust enough to survive an environment that most anyone would call hostile to electronics. With sensors mounted at or near the top of the tower, they would be subject to numerous lightning strikes, which occur in the normal course of nature. Additionally, the sensor most likely would be surrounded by both transmit and receive antennas; consequently, the sensor electronics would need to survive exposure to extremely high RF fields. At the same time, the electronics could not generate any emissions that could be received on the receiving antennas mounted in close proximity to the sensor. The designers also were concerned about whether the GCU would be able to survive whatever surges came down the interconnecting cables from the tower, plus any line surges that may originate on the alternating current (AC) power supply lines.

The only way to verify this performance was through extensive laboratory testing. The design team selected the National Technical Systems (NTS)

Lightning Discharge Testing & Survivability
FAA DO-160 Standards
Injection Point Pickup Sensor Detail

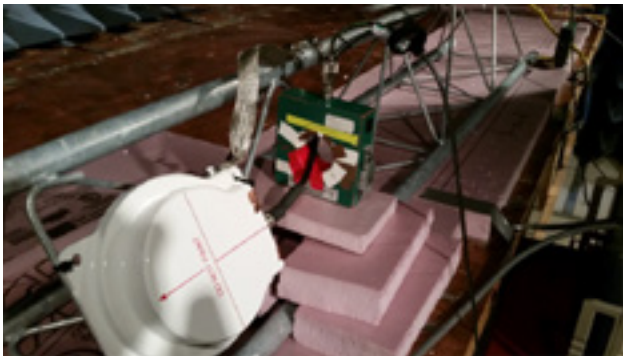


Fig. 6. Lightning discharge testing and survivability.

High RF Field Exposure Testing

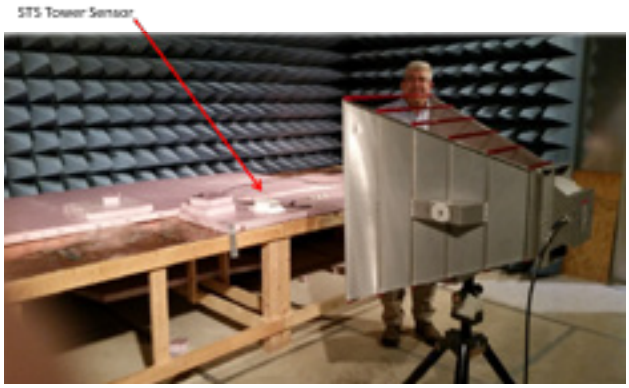


Fig. 7. Exposure testing.

facility in Rockford, Illinois, as its testing laboratory of record. NTS was selected because this facility is fully accredited for DO-160 measurements. Additionally, this facility specializes in the survivability of aircraft electronic systems in the same environments that the designers anticipated for their sensors, especially lightning and high RF fields.

The expertise that NTS brought to the testing regime was invaluable. Key vulnerabilities of design were detected and, with the assistance of NTS engineers, were corrected. In the end, the sensor and GCU were deemed acceptable by virtue of the fact that they would survive multiple lightning strikes and electrical surges, while at the same time accepting a variety of high RF fields, without generating any measurable emissions.

PROJECT SUMMARY AND CURRENT STATUS

At the time of this writing, the designers have Phase 1 production-ready hardware designs available to be built in quantity. This applies to both the tower-mounted sensor as well as the GCU. The physicists are still fine-tuning the specific algorithms and filtering required for the system. Additionally, the user interface in the form of an Internet-based dashboard, together with the alarm reporting system, are being finalized. It is the designers' belief that the system will be commercially available on the market by late 2016. Finally, the designers have applied for, and are awaiting final award of, patents on this technology.

ABOUT THE AUTHORS



Mr. Allen (W6PC) began his radio career in 1966, in Texas with an early interest in radio broadcasting and land mobile communications; in the years following he received his 1st Class Radiotelephone from the FCC and a Bachelor of Science in communications and electrical engineering.

With his roots in land mobile radio, Mr. Allen was the Vice President of Engineering and Chief Engineer at E.F. Johnson Company in Waseca, MN, Vice President & Chief Engineer of Titan / Datron World Communications, now part of L3 Communications, San Diego, CA, Executive Vice President and subsequently President of SUNAIR Electronics, Fort Lauderdale, FL. He has developed and overseen development of hundreds of product developments for the land mobile, military and government marketplace. He has several US patent applications in process.

Today, Mr. Allen is Vice President of ROHN™ Tower Company in Peoria, IL. & Principal with SmarTOWER Systems, also Peoria, a Senior Member of IEEE and a Senior Member of SBE for more than 35 years, Life Member of ARRL. Additionally Mr. Allen is a Fellow in The Radio Club of America and is currently serving on the Board of Directors.



David G. Brinker is Vice President of Engineering for the Rohn Products LLC., Peoria, IL. Dave is actively involved in numerous professional organizations including the American Society of Civil Engineers, the Telecommunications Industry Association and the International Association of Shell & Spatial Structures. He has over 35 years of experience in the design and construction of self-supporting latticed towers, guyed masts, pole structures and their foundations and is a registered Professional Engineer in 48 states.

2015 RCA FELLOWS ADDRESS

John Wright

EDITOR'S NOTE: John Wright spoke on behalf of the 2015 Class of Fellows inducted at the 106th Radio Club of America Banquet and Awards Ceremony. Each year RCA inducts those who have made outstanding achievements and contributions to the art and science of radio communications, broadcast or the Radio Club of America. The following text presents Mr. Wright's acceptance speech. Biographical information about Mr. Wright is located at the end of his comments.

Good Evening, I am John Wright, and I am greatly honored to be here this evening to speak on behalf of the 2015 Radio Club of America Fellows.

The definition of a "Fellow" is a member of a group of learned people who work together as peers in the pursuit of mutual knowledge or practice. For those here this evening, it is our continual pursuit of envisioning, improving, innovating and educating in virtually all aspects of modern voice and data communications that brings us together as Fellows.

I have often been asked how I became interested in radio communications. For me, the answer was simple: It was a roll of 16 gauge magnet wire, a diode (or crystal), a 47k resistor, and a "ceramic" earphone. Yes, the basic parts of a crystal radio set.

While I was only 8 years old at the time, it was my first of many self-made kits that continued over the next several years (and yes, I still build things even today), but the fact that I could listen to a local AM radio station on something I built myself started my interest in radio technology that lasts even today.



John Wright, N6RPD at the 2015 RCA Banquet and Awards Ceremony with Margaret Lyons, 2003 RCA Fellow.

I suspect that it was no different for those who started this organization of radio pioneers over 100 years ago. It was in 1907, that a group of small boys who were so interested in flying that they formed the Junior Aero Club of the United States. In conjunction with their experiments in aviation, these youngsters had, for some time, also been interested in what was then known as "Wireless." This new idea of sending messages without wires had proved itself so fascinating, that they found themselves actually devoting most of their spare time to tinkering with wireless apparatus. Two years later, these members called a special meeting of the Aero Club, for the purpose of forming a new club, with wireless telegraphy and telephony as its main interest. This meeting was held in New York City on January 2nd, 1909 where it was unanimously decided to form a new organization to be devoted entirely to Wireless. Thus, the Junior Wireless Club Limited was founded. By 1911 the interest in amateur radio was beginning to grow by leaps and bounds and at a special meeting on October 21st, 1911, it was unanimously decided to change the name from JUNIOR WIRELESS CLUB LIMITED to THE RADIO CLUB OF AMERICA. This was in fact the birth of today's Radio Club of America, nearly 104 years ago.

In the last 104 years, wireless communication has change immensely, and new technologies and continued innovation were the keys to a whole new wireless world.

While the first wireless radios used Amplitude Modulation (AM), it was in 1935 with the invention of Frequency Modulation (FM) that improved audio quality would change wireless communication as we knew it. FM eliminated the need for large AM transmitters and resulted in radio equipment which required less power to operate. This now made the use of transmitters in vehicles more practical.

I know that there are several documented milestones in the wireless field that are noteworthy, but it is the innovation of the transistor that caused the world of wireless communication to again leap forward. Bell Laboratories developed the first transistor in 1948 which enabled electronic equipment, including the radio, to be miniaturized. But it was not until October 1954 when the first consumer transistor

radio was sold, the Regency TR1. It was a scant five inches high and used four germanium transistors. I consider this to be the start of the consumer portable radio era, when the general public would become mobile forever after.

Shortly after the development of the transistor, the next great innovation came in 1952 from the British radio engineer Geoffrey Dummer who proposed to integrate a variety of standard electronic components in a monolithic semiconductor crystal. A year later, Harwick Johnson filed a patent for a prototype called an integrated circuit (IC), further reducing the physical size of communications devices.



2015 RCA Fellows recognized at the 106th Banquet and Awards Ceremony: (left to right) Arnold Hooper, K4AHH, William Waugaman,WA3OJG, Michael Schmidt, Ray Novak, N9JA, John Wright, N6RPD.

Another milestone in communications was the invention of the mobile phone. Actually, one of the earliest fictional descriptions of a mobile phone can be found in the 1948 science fiction novel Space Cadet by Robert Heinlein. The protagonist, who has just traveled to Colorado from his home in Des Moines, receives a call from his father on a pocket telephone. Before going to space he decides to ship the telephone home "since it was limited by its short range to the neighborhood of an earth relay office." Ten years later, an essay by Arthur C. Clarke envisioned a "personal transceiver, so small and compact that every man carries one." He wrote: "the time will come when we will be able to call a person anywhere on Earth merely by dialing a number." Such a device would also, in Clarke's vision, include means for global positioning so that "no one need ever again be lost."

The mobile phone actually became a reality in the United States when engineers from Bell Labs began work on a system to allow mobile users to place and receive telephone calls from automobiles, leading to the inauguration of mobile service on 17 June 1946 in St. Louis, Missouri. Shortly thereafter, a wide range of mostly incompatible mobile telephone services were offered to the consumer, which had limited coverage areas and only a few available channels in urban areas. But the introduction of cellular technology, which allowed re-use of frequencies many times in small adjacent areas covered by relatively low powered transmitters, made widespread adoption of mobile telephones economically feasible.

Prior to 1973, mobile telephony was limited to phones installed in cars and other vehicles. Motorola was the first company to produce a handheld mobile phone. On 3 April 1973 when Martin Cooper, a Motorola researcher and executive, made the first mobile telephone call from handheld subscriber equipment, placing a call to Dr. Joel S. Engel of Bell Labs. I am not sure what was said on that first call, but I suspect it would have been almost as famous as Mr. Bell's "Mr. Watson – Come Here – I want to see you." The prototype handheld phone used by Dr. Cooper weighed 2 ½ lbs. and measured 9 inches long, 5 inches deep and 1 ¾ inches wide. The prototype offered a talk time of just 30 minutes and took 10 hours to re-charge.

On March 13, 1984, someone paid $3,995 to buy the Motorola DynaTAC 8000X (and you think your new iPhone was expensive), which was the very first handheld cellphone — that was 31 years ago. At the time, a handheld portable phone was considered a gimmick, a "look what I got!" expensive toy with rather dubious utility. Today, there are an estimated 6.8 billion cellular phones in use worldwide, and that number is growing rapidly.

Wireless communications continues to evolve. Today's wireless technology is literally all around us. There is Wi-Fi, fast 4G LTE access points on smartphones, and Bluetooth, running in everything from mobile printers and earpieces, to home security systems. Soon there will be WiGig, High-Speed Wireless Wi-Fi Hot Spots, known by the technical spec 802.11ad. This new Wi-Fi protocol will connect at theoretical speeds of 10Gbps using the 60GHz radio band. Bluetooth Smart, which is the

same technology as Bluetooth, offers a short-range wireless technology that has a distinct advantage over existing Bluetooth. While both connect over a similar 30-foot range, Bluetooth Smart is not constantly sending out a signal, and it uses less power. And, Cognitive radios, wideband digital radios with dynamic spectrum management, attempts to make the best use of the available spectrum by detecting areas of it that are unused and rapidly switching to use them.

I suspect that often the consumer does not realize that their modern communications devices, cellphones, Wi-Fi and Bluetooth connected devices, and others are actually nothing more than miniature wireless radio transmitters and receivers. While the technology continues to evolve, and new devices are created, it is that same basic RF theory that continues to be the basis for our ability to communicate wirelessly today and into the foreseeable future.

So what will be the next great innovation in wireless communications? Who knows, maybe it will start out as something as simple as a roll of wire, a diode, a resister and an earpiece. I suspect it will come from that same spirit of innovation, sense of discovery, and enthusiastic curiosity that those young boys had in 1907 which will continue to drive us in the future.

On closing, I would like to congratulate the other Fellows being honored tonight, and thank the Radio Club of America for this great honor, and leave you with this one last thought: The Stone Age did not end because man ran out of stones…It is our ability to imagine, innovate, and create without boundaries that makes us unique. Let us all continue to pursue our passion, know no limits, and dream as big as our founding fathers did 104 years ago.

ABOUT THE AUTHOR



John Wright, N6RPD, is the Immediate Past President of the Association of Public-Safety Officials (APCO) International. He is a Governing Board Member of the National Public Safety Telecommunications Council (NPSTC) and Past President of the California Public-Safety Radio Association. He retired from the City of Riverside (California) Police Department with over 37 years of service managing the city's Public Safety Communications Center (combined Police/Fire/EMS 9-1-1 Center). He is a recipient of the APCO International RF Technician of the Year award. He served as Radioman 2nd Class - US Navy in the Vietnam War.

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LORD KELVIN, THE ATLANTIC CABLE AND THE ORIGINS OF SIGNAL SHAPING

By David and Julia Bart

September 2, 2016 marks the 150th anniversary of the first successful Atlantic telegraph cable that linked the old and new worlds. It also successfully established a new way to think about signal shaping.

THE ATLANTIC CABLE

Many books and articles have explored the dramatic history surrounding the Atlantic Telegraph Cable, which successfully established the first electrical communications link between the old and new worlds 150 years ago, in 1866.[1] The Atlantic Cable linking Trinity Bay, Newfoundland with Valentia, Ireland stands as one of the greatest technological achievements of the 19th century, often equated with the 20th century's first moon landing. From those two points, further land and submarine cables reached New York, Washington and London. The cable stretched nearly 2,100 miles across the Atlantic Ocean at a depth frequently more than two miles from the surface to the ocean floor.

Both the United States and Great Britain funded portions of the project with the majority of cost borne by public shareholders. For the public, the success of the 1858 and 1866 expeditions were greeted with days of celebrations and parades in major U.S. and British cities; the President and the Queen exchanged greetings by telegram; and scientists and engineers marveled at their accomplishment. In the days of wooden ships and iron men, the impact of this achievement could not be overstated. Today, this achievement is all the more remarkable when viewed as a precursor to the Internet and worldwide global communications.



Figure 1. Portion of the title page from The Atlantic Telegraph 1865 by W.H. Russell, Illustrated by Robert Dudley. (Standard Edition, 1865, Day & Son Limited)

The American entrepreneur, Cyrus Field, spearheaded efforts that spanned more than 14 years and ultimately cost more than $12 million, approximately $150 million in today's currency. Key scientific and engineering contributions were made by Sir William Cooke, Sir Charles Wheatstone, Michael Faraday and Professor James Clerk Maxwell. Samuel F.B. Morse and Professor William Thomson (later known as Lord Kelvin) each spent significant time working onboard the ships to address the major engineering problems facing the project.

The Atlantic Cable project would require more than 50 transatlantic voyages made by hundreds of U.S. and British sailors, engineers and electricians on 13 ships in five major attempts before achieving success. (Dibner, 1959; Burns, 2007a) The attempts in 1857 and 1858 involved the two largest warships in the world, the USS Niagara and the HMS Agamemnon. The 1857 expedition ended in failure when the cable snapped as it was being released from onboard the ship.

A second attempt in 1858 also failed. In a third attempt during July and August 1858, the Niagara and the Agamemnon successfully laid the first operable transatlantic cable, using more than 340,500 miles of wire for the cable and its armor sheathing, enough to go 13.6 times around the world and 1.4 times the distance between the earth and the moon. (King, 1925) The project's team of scientists, electricians and engineers onboard ship was enormous for the time, with 33 men just handling the cable. (Mullaly, 1858) Unfortunately, the 1858 cable failed after only three weeks. The failure ultimately was attributed to high signaling voltages that "burned out" the line. (Incredibly, for all its faults, sections of the 1857 cable were retrieved accidentally—after more than 100 years—

TABLE 1. ELECTRICIANS AND ENGINEERS ONBOARD THE 1858 ATLANTIC CABLE EXPEDITION SHIPS

Staffing	USS Niagara	HMS Agamemnon
Primary Electricians:	C.V. De Sauty	Prof. William Thomson
	J.C. Laws	Mr. Bartholomew
Primary Engineers:	William E. Everett	Charles Bright
	W.H. Woodhouse	Samuel Canning
		Henry Clifford
TOTAL COMPLEMENT:		
Chief Electricians	2	2
Cable Operators	4	4
Gutta Percha Joiners	1	2
Cable Splicers & Assistants	4	3
Total Electrical Department	11	11
Ship/Cable Engineers and Assistants	5	6
Total Complement	16	17

Note: Based on Mullaly, 1858; Bright, 1908; Thompson, 1910.



Figure 2. Section of 1865 Atlantic Cable. (Prescott, 1892)

from the bottom of the North Atlantic, and were found to be still capable of conducting electric current. (Carter, 1968)

A fourth attempt was made in 1865. At that time, the largest ship afloat was the bankrupt steamship, the Great Eastern. The story of the SS Leviathan, renamed the SS Great Eastern, constitutes its own epic tale encompassing revolutionary engineering, construction by brute force, and the iron will of its designer, Isambard Kingdom Brunel. At the time of its launching, 50 years before the RMS Titanic, it was the heaviest object ever moved by man. It was more than five times larger than the next biggest ship in the world, and would not be surpassed until the building of the RMS Lusitania. It could carry 10,000 troops from England to Australia and return without refueling, and was one of the first ships to use both side wheel and screw propellers for propulsion. (Dugan, 1953)

In 1865, the Great Eastern was refitted to carry more than 500 crew and provisions, more than 8,000 tons of coal, and more than 2,700 miles of cable weighing in excess of 5,000 tons. The new cable was nearly four times as bulky and almost twice as heavy as the 1858 cable, based on design changes recommended by Professor Thomson and the Chief Engineer Charles Bright. Nevertheless, the 1865 cable broke in mid-ocean, leaving the expedition with another failure.

A fifth attempt in 1866, again using the Great Eastern, finally brought success. The expedition that year not only succeeded in laying a fresh cable, but also recovered the broken 1865 section from the ocean floor and attached it to a new portion laid in 1866, completing a second line. By September 1, both the new 1866 and the repaired 1865 cables were completed, becoming the first successfully operating Atlantic cable connections between Ireland and Newfoundland, a distance of nearly 2,100 miles. The 1866 cable operated successfully until 1872, and the restored 1865 cable operated until 1877. By then, both cables had been rendered obsolete. They were functionally replaced by a new 1873 Anglo-American Telegraph Company cable made by Telcon, and by the 1874 Direct United States Cable Company cables made by Siemens Brothers. (Telcon, 1950; Scott, 1958; Fagan, 1975; Glover, 2007)

The cable project spanned the terms of four U.S. Presidents (Franklin Pierce, James Buchanan, Abraham Lincoln and Andrew Johnson) and a significant part of Queen Victoria's reign. It demanded new technologies and new science to overcome unforeseen obstacles and the rigors of the North Atlantic. The new science of undersea oceanography was developed, in part, to determine how to lay the cable on an unexplored ocean floor more than two miles (2,600 fathoms) below the surface. The cable project stimulated many inventions including: the mirror galvanometer; new cable designs; new types of propeller and steamship technologies; new designs for hydraulic pumps and onboard winches; stronger and more durable types of insulation and wire rope; and dynamometers and hydrometers.

Even the adoption of standard units of measurement in electricity (watt, volt, ohm, ampere) stem from four years of study by a committee of inquiry and a scientific commission assembled to study the failure of the 1858 cable.[2] The eventual success of the cable project revolutionized communications, reducing correspondence times between London and Washington from more than three weeks to just 10 hours. It provided a permanent link between Europe and the Americas, and helped establish a worldwide communications network that would facilitate management and control of the British Empire. (Smith and Wise, 1989; Hunt, 1997; Smith and Wise, 1989; Bart, 2008)

TABLE 2. COMPARISON OF 1858 AND 1865 ATLANTIC CABLE CONSTRUCTION

Item	1858	1865
Manufacturer	Gutta Percha Co. (core) and Glass Elliot & Co.	W.T. Henley Telegraph Works (Irish shore end) and Telegraph Construction and Maintenance Company Ltd.
Contractor	Atlantic Telegraph Company	Atlantic Telegraph Company (Anglo-American Telegraph Company after March, 1866)
Conductor	7 Copper Wires (1 Center, 6 Surrounding)	7 Copper Wires (1 Center, 6 Surrounding)
Weight of Conductor	107 Lbs. Per Nautical Mile	300 Lbs. Per Nautical Mile
Base Coating Layer	None	Chatterton's Compound
Insulator	3 Layers Gutta Percha	4 Layers Gutta Percha Alternating With Layers of Chatterton's Compound
Weight of Insulator	261 Lbs. Per Nautical Mile	400 Lbs. Per Nautical Mile
Padding Layer	Jute Yarn (Hemp) Soaked With Compound of Stockholm Tar, Pitch, Boiled Linseed Oil & Common Bees Wax	Jute yarn (Hemp) Soaked With Preservative
External Protection (Armor)	18 Strands of Charcoal Iron Wire (each strand composed of 7 wires) Wound Spirally Around The Core, No. 14 Gauge	10 Solid Wires (each wire surrounded by Manila Yarn soaked in a preservative compound) Wound Spirally Around The Core, No. 13 Gauge
Outer Covering	Compound of Tar, Pitch & Linseed Oil	Part of Armor Strands
Cable Circumference	2.00"	3.53"
Cable Weight In Air	2,000 Lbs. Per Nautical Mile	3,575 Lbs. Per Nautical Mile
Cable Weight In Water	1,340 Lbs. Per Nautical Mile	1,400 Lbs. Per Nautical Mile
Deepest Section Laid	2,400 Fathoms (14,400 Feet)	2,400 Fathoms (14,400 Feet)
Length Laid	2,036 Nautical Miles	2,538 Nautical Miles (1,214 Nautical Miles Laid In 1865, Completed In 1866)
Maximum Communication Speed	2-3 Words Per Minute	8-10 Words Per Minute
Transport Vessels	HMS Agamemnon & USS Niagara	Great Eastern

Note: Based on Thomson, 1865; Munro, 1895; Murray, 1902; Telcon, 1950; Finn, 1980; Hearn, 2004; Burns, 2007b; and Glover, 2007.



Figure 3. Specimens of the Atlantic Cable. Left pair 1858. Middle Pair 1865. Right Pair 1866. Each pair includes 1-main cable and 2-shore ends. Bottom section includes recovered 1865 cable, model grapnel and grapnel rope used in recovery. (Courtesy Bill Burns, Science Museum, London. See http://atlantic-cable.com/Cables/1858-66Atlantic/)



Figure 4. Professor Thomson at Age 35 Reading A Letter From Fleeming Jenkin, circa 1859. (King, 1925)

TABLE 3. KELVIN'S U.K. PATENTS IN TELEGRAPHY AND ELECTRICITY

"Telegraph":	Instruments and Apparatus	9
	Current Regulation and Testing	3
"Electrical":	Measuring Apparatus For Current	6
	Measuring Apparatus (Other)	8
	Current Regulation	3
	Measurement and Recording Apparatus	6
Total		35

Note: Based on Kelvin's U.K. Patent Application titles noting the "Telegraph" or "Electrical" classification. Based on Thompson, 1910; Trainer, 2004 and 2007; William Thomson, 2007; Kelvin Probe, 2007; and searches on Google.com.

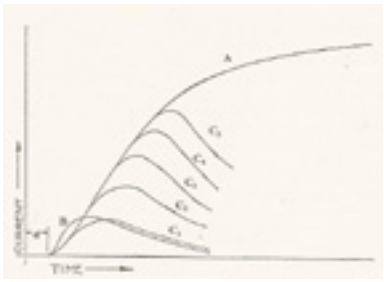


Figure 5. Thomson (Kelvin) Telegraph Signal-Arrival Curves. (Bright, 1898 and 1907)

SIR WILLIAM THOMPSON/LORD KELVIN

William Thomson is credited with many of the important theoretical and mathematical concepts that underlie the 19th century's great progress in classical physics. He established key concepts leading to the Law of Conservation of Energy, the first and second laws of Thermodynamics, and introduced "potential" and "kinetic energy" into the physics lexicon.

He established the absolute temperature scale now known as degrees "Kelvin," and was instrumental in promoting the international adoption of standard electrical measures and the metric system. He was also a public figure, renowned as an important telegraph engineer and inventor, and the scientist responsible for the success of the Atlantic Cable. Thomson used innovative mathematical approaches and analogies drawn from physics to solve many of the crucial engineering problems facing the Atlantic Cable project. He was the first person to explain the electrical theory behind the operation of land-based telegraph lines, which allowed him to conceive a new system for successful undersea telegraphy. During his lifetime, he wrote 661 scientific papers and was awarded 75 patents in the United Kingdom, the United States and Switzerland; half involved inventions in telegraphy and electrical apparatus. (Trainer, 2004; Bart, 2008)

Thomson was knighted in 1866, and in 1892 he was the first scientist in British history to be raised to the peerage, taking the name Baron (Lord) Kelvin of Largs. He was also the first scientist to be raised to the Privy Council, which occurred in 1902. Among his many honors, Thomson was Fellow and President of the Royal Society, Fellow and President of the Royal Society of Edinburgh, and recipient of

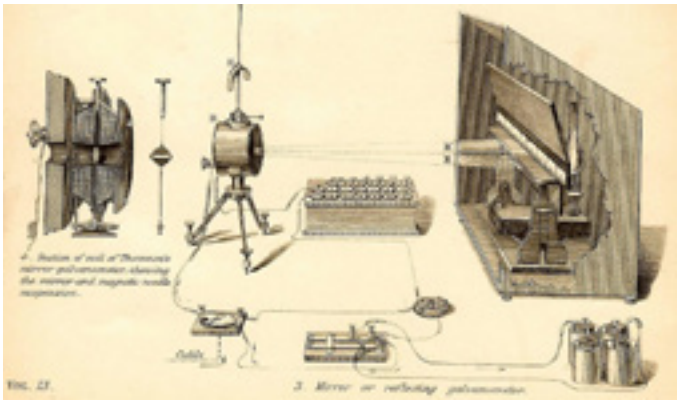


Figure 6. Submarine Telegraph Circuit Showing Thomson Mirror Galvanometer and Scale with Double-Current Telegraph Key and Batteries. (Telegraphy, Plate 2, 1885)



Figure 7. "Awaiting the Reply" in the Great Eastern circa 1866 by Robert Charles Dudley. Professor William Thomson is standing at the center. (Gift of Cyrus W. Field to the Metropolitan Museum of Art, 1892; Image 92.10.43)

the Copley Medal (the 19th century equivalent of the Nobel Prize). He was laid to rest as Lord Kelvin in December 1907, next to Sir Isaac Newton in London's Westminster Abbey. He was buried with all the pomp and honor that the British Empire could bestow on one of its most famous sons. (Bart, 2008)

THOMPSON AND STOKES

Thomson believed in the Atlantic Cable project from the outset. He was drawn into the theoretical problems facing the cable in October 1854, when Gabriel Stokes asked for his opinion on Michael Faraday's conclusions regarding the design of the cable and whether the design would limit the signal capacity. (Stokes, 1854) Stokes and others now recognized that the operation of submarine cables required a more in-depth understanding of electrical theory than landline telegraphy. By December 1854, Thomson had written a series of letters to Stokes laying out an entire mathematical theory explaining how a pulse of electricity traveled in an insulated submerged wire. In the Stokes letters, Thomson analyzed the data rate that could be achieved, and explained the feasibility and economic consequences of completing a transatlantic cable. (Stokes, 1854; Thomson, 1855a; Lindley, 2004) The Stokes correspondence marks the first time that the operation of the telegraph had been subjected to such careful theoretical analysis. (Sharlin, 1979)

THOMPSON'S LAW OF SQUARES AND SIGNAL CURVES

The scientists involved with the Atlantic Cable project soon realized that electrical signals in submarine cables behaved differently than landlines. Defining, measuring and accounting for differences in electrical resistance in underwater cables became the chief obstacle to successful long-distance submarine telegraphy.

Thomson recognized that the speed of a telegraph signal was limited by both its capacity and resistance. He calculated that the speed decreased as the square of the cable length increased for any given diameter of the core conductor. His computations confirmed the "capacitance" (the amount of stored electric charge for a given electric potential) of a cable. He found that a cable surrounded by an insulator residing in a conducting medium (e.g., salt water) acted as a form of condenser, interacting and exchanging electrical potential with the surrounding medium. Thomson devised his "doctrine of squares" to define the relationship. His concept soon came to be known as Thomson's "Law of Squares." (Thomson, 1855a; Thompson, 1909; Thompson, 1910)

According to the Law of Squares, a cable two miles long would have four times the retardation in signal strength of a cable that was one mile long, and the strength of the signal therefore would be only ¼ as strong. Consequently, for any given cable, signaling speed is inversely proportional to the square of the cable length, when holding the capacitance and resistance constant. Thomson used these relationships to define signal-arrival curves in which he could compute the arriving signal current after any interval of time following the signal transmission, based on the battery voltage, the cable resistance, the cable capacity, and length of the cable.[3] Thomson had succeeded in mathematically proving Faraday's initial theory.

However, the Law of Squares and Thomson's signal-arrival curves were not accepted immediately in scientific circles. In the debate that followed, Fleeming Jenkin and C. F. Varley proved Thomson's Law of Squares in a series of experiments in which signal speed, measured as words per minute of a standard length (8 dots and dashes), was first defined for measuring and evaluating electrical performance. (Jenkin, 1859; Bright, 1898; Cookson and Hempstead, 2000; Beauchamp, 2001) Thomson's writings, supported by Jenkin and Varley's experiments, firmly established the

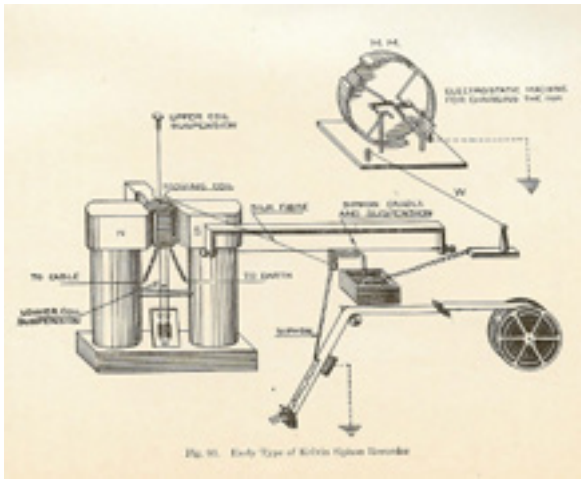


Figure 8. Operation of Early Thomson Siphon Recorder. (Submarine Telegraphy, 1921)

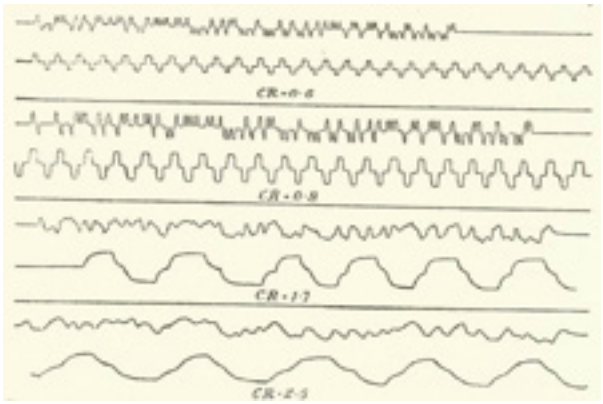


Figure 9. Siphon Recorder Signals Received Through Submarine Cables of Various Lengths. Generally, longer cables produce less sharp and well-defined signals. Signals on top are received in short cables, signals on the bottom are received through long cables. (Fleming, 1921)

crucial parameters under which a submarine telegraph system had to operate. These parameters necessitated design modifications for the 1865 and 1866 cables. Seven years after the failure of the 1858 Atlantic Cable, the 1865 and 1866 cables were now manufactured to overcome the expected retardation in signal strength that would be experienced over each cable's great length. As a consequence, the diameter of the 1865 and 1866 copper cores and the surrounding insulation were increased almost three-fold over the original 1858 cable design, in order to allow the weak currents to flow more easily. (Bart, 2008)

THOMSON'S CONTRIBUTIONS TO SIGNAL SHAPING

As early as 1848, Thomson recognized the enormous possibilities for electrical science and its potential use of applied mathematical reasoning. (King, 1925) The key lay in Thomson's unique combination of Charles Fourier's mathematical methods and Thomson's analogies concerning the theories of heat transfer and electrical impulses. Thomson described this approach in a letter to J. P. Nichol stating, "This, the first piece of physical mathematics I ever took up, has been since Fourier's time ready and quite complete for the telegraphic problems, including every practical detail—resistance in receiving instruments (radiating power of the end of a bar), imperfect insulation (loss of heat from the sides of a bar), etc." (Thompson, 1910; Smith and Wise, 1989)

Thomson was the first to describe the signal distortion that occurred on long submarine cables. His invention of the Thompson mirror galvanometer enabled weak signals to be detected.[4] Yet, despite attempts to clarify the incoming signals by varying the operators' sending practices, the electrical impulses still overlapped and became blurred. Scientists and engineers had known since 1861 that, "The most important problem to solve in submarine telegraphy undoubtedly is, how the signals may be made to follow each other with the greatest rapidity ..." (Report, 1861)

One technique for clarifying signals involved quickly applying short bursts of the opposite polarity, or a reverse signal, known as "curbing" the signal. The short bursts effectively stopped the initial current from continuing to build after it had reached an observable value, enabling a second signal to be transmitted and more clearly received shortly after the first, thereby sharpening the signal. As the signaling speed increased, the bursts of curbed current necessary to achieve clarity became almost equal in duration to the signal currents. (Dearlove, 1896; Sayers and Grant, 1897; Fitzgerald, 1899, Ash, 2001) Modifications to the Morse code also helped, but signals sent by hand still were not timed well enough to permit great increases in speed.[5] In 1875, Thomson and Jenkin developed an "automatic curb sender" to help impose accurate proportions in the lengths of the signal currents and spaces. (Ewing, 1876; Bright, 1898; Beauchamp, 2001)

Unfortunately, the Thomson-Jenkin automatic curb sender proved too cumbersome for regular work. (Dearlove, 1896; Bright, 1898) Still, Thomson's techniques for "signal shaping" would be adapted by others for use in automatic transmitters developed well into the 20th century. (Bright, 1898; Beauchamp, 2001)

LEGACIES

By 1874, 206 submarine telegraph lines had been laid worldwide, 145 still were working, and 11 more were in the course of construction; all of this activity was under the direction of 16 major companies. (Submarine Telegraphy, 1876) The Law of Squares had established parameters for successfully governing future cable design and manufacturing. Thomson's system for defining the transmission of submarine telegraph signals was so successful that

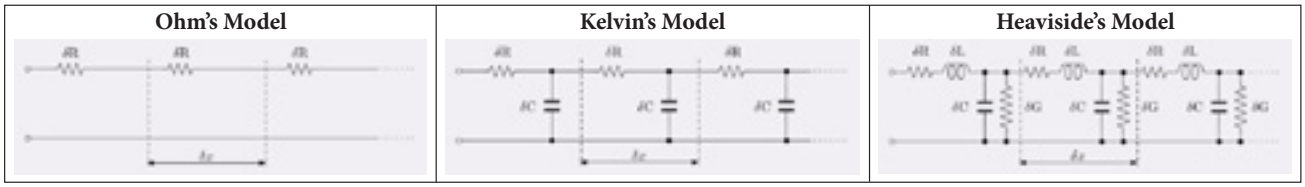


Figure 10. Three transmission line models translated into modern terms using infinitesimal elements. L, R, C and G in all three diagrams are the primary line constants. (Transmission, 12016)

there was no material change in cables designs between 1866 and 1924.

It was nearly 6o years before innovations in cable design increased the one-way speed of signals sent from transmitter to receiver. Concepts of "shielding" and "loading" the cables would not take hold until 1924. That year, Western Electric introduced an iron-nickel alloy ribbon named Permalloy, and Telcon, the Telegraph Construction and Maintenance Company, introduced its copper-iron-nickel alloy ribbon named Mu-metal. These ribbons wrapped around the copper cable cores, thereby providing the copper core with a magnetic shield. This shielding "loaded" the cable with inductance so that the signals would not become as distorted over the great lengths traveled. "Loading" the cables enabled signal speeds of 250 words per minute to be reached. Automated transmission equipment used in combination with "loaded" cables enabled transmission speeds of 400 words per minute to be achieved. (Hughes, 1928; Report, 1941; Fagen, 1975; Ash, 2001; Fouchard, 2002; Huurdeman, 2003) However, although much improved, the essence of this new design still largely depended on Thomson's original principles. (McDonald, 1937; Ash, 2001)

Thomson's ideas would have even broader implications. His mathematical analysis of the behavior of electrical transmission lines directly influenced the work of James Clerk Maxwell and Oliver Heaviside. Thomson's original 1855 diffusion model of the current in a submarine cable correctly predicted the poor performance of the 1858 Atlantic Cable, leading to the adaptations included in the 1865-1866 cables. Twenty years later, in 1885, Heaviside published the first papers that described his own analysis of propagation in cables and provided the modern form of the telegrapher's equations.

In addition to these advancements, Georg Ohm first established that resistance in a wire is proportional to its length. Latimer Clark noted that signals were delayed and elongated along a submarine cable, creating an undesirable form of distortion now called dispersion but then called retardation. Michael Faraday established that this was due to the capacitance present in the transmission line. Thomson's model incorporated resistance and capacitance, but did not use the modern concept of bandwidth. His electrical transmission limits were entirely explained in terms of the dispersion of the telegraph signals due to the capacitance effects of the undersea environment. Heaviside introduced series inductance and shunt conductance into the model, making four distributed elements in all. This model is the modern telegrapher's equation, and the distributed elements are now called the primary line constants. (Weber and Nebeker, 1994; Transmission, 2016)

Thomson's success with the Atlantic Cable made him famous. His inventions of the Thomson mirror galvanometer and the Thomson siphon recorder established him as a preeminent expert in submarine telegraphy. Indeed, Thomson's siphon recorder was the forerunner of all moving coil type instruments used in designs of galvanometers, ammeters and voltmeters. The siphon recorder also utilized an electrostatic charge to attract the ink to the paper without the pen having to touch the paper. (A second version did have the pen in contact with the paper, but used a continuous vibration to reduce friction.) The concept of using electrostatic attraction of the inking fluid would eventually form the basis for all facsimile and laser printing machines. (Munro, 1895; Murray, 1902; Thompson, 1909; Commercial Cable Company, 1915; Cameron, 1927; Green, 1970; Bart, 2008) All of these operated within a system where electrical signals with opposite polarities could travel long distances, both above and under water.

Thomson's scientific methods stemmed from two fundamental ideas that he held throughout his life, which are still vital for us today:

- First, that, "I am never content until I have constructed a mechanical model of the subject I am studying. If I succeed in making one, I understand; otherwise I do not." (Thomson, 1904).
- And second, "In physical science the first essential step in the direction of learning any subject is to find principles of numerical reckoning and methods of practically measuring some quality connected with it. I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of meager and

unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be." (Thomson, 1883).

Today, we can recognize that Sir William Thomson/ Lord Kelvin's work established the critical foundation for a modern electrical network of global communications. As the renowned mathematician P. G. Tait stated, "to you in all of these capacities is due the success of Long-line Submarine Telegraphy, with the innumerable benefits resulting from the power of practically instantaneous communication between all parts of the globe." (Fitzgerald, 1899).

[1] A number of books, articles and internet sites offer first hand and/or comprehensive accounts of the Atlantic Cable expeditions. Especially noteworthy are Briggs, 1858; Mullaly, 1858; Russell, 1865; Field, 1893; Bright, 1898, 1903 and 1908; and, Dibner, 1959. Harpers Magazine, Harper's Weekly, Frank Leslie's Illustrated Newspaper and The Illustrated London News carried extensive news coverage of all the cable expeditions. Several recent books offer a modern perspective including Standage, 1998; Ash, 2001; Gordon, 2002; Cookson, 2003; and Hearn, 2004. A comprehensive internet site with many sources is available at Burns, 2007a. See also Ho11y, 2004 for a complete bibliography of research materials. A comprehensive treatment of Sir William Thomson (Lord Kelvin) including bibliographies is included at Bart, 2008.

[2] The British Board of Trade and the Atlantic Telegraph Company established a joint committee of inquiry into the failure of the 1858 cable which issued its report in April 1861. Thomson was appointed to a five-member scientific committee to recommend specifications for a new cable. The scientific committee issued its findings in October 1863. (Report, 1861; Report, 1863)

[3] The relationships derived in Thomson's "Law of Squares" were also known in Thomson's time as the "KR Law" (K referred to capacitance and R referred to resistance). Today, the naming convention for capacitance has been changed to the letter C, and the relationships are generally known as Thomson's "CR Law". Thomson's solution is a second order elliptic partial differential equation. Thomson's equation and his inferences were later expanded by Oliver Heaviside into more a comprehensive theory about the electro-magnetic propagation of waves in electric lines. Heaviside's development of Thomson's Law of Squares would later prove to be a critical stepping stone leading to the full development of Maxwell's equations and a comprehensive electro-magnetic field theory. (Bright, 1898; Hughes, 1928; Fagen, 1975; Beauchamp, 2001; Nahin, 2002; Calvert, 2004b; Hunt, 2005)

[4] The mirror galvanometer operated on the principle that a tiny magnet made of a watch-spring, attached to the back of a minute convex mirror that hung in the center of a coil of fine wire, would move when a minute electrical signal through the coil affected the magnetic field in which the mirror was suspended. A "double-current" telegraph key had two keys which sent signals in opposite polarities as each key was depressed (one with a positive and one with a negative current). A lamp directed light onto the mirror which reflected a tiny spot of light onto a scale; and, as the mirror was deflected by the changing polarity of the magnetic field, the spot of light would move left or right, enabling a Morse code based message to be interpreted. By design, a very slight motion of the suspended mirror was optically magnified onto a visible scale which could be easily observed and recorded. Each instrument had an adjustable control magnet or group of magnets, and moveable glass rods could be used to pin the mirror and prevent its motion when not in use. Thumb-screws were used to adjust the zero position of the suspended mirror and its consequent light spot on the scale. (Munro, 1895; Bright, 1898; Thompson, 1909; Commercial Cable Company, 1915; Dibner, 1959; Green, 1970)

[5] During a series of international conferences first held in 1851 and 1854, general use of "Morse" code had been replaced by "Continental" or "International" code for most land line telegraph systems and submarine cables. Morse code continued to be used in the U.S. until after World War I. The International code replaced the arrangements of dots and dashes in certain Morse characters to enable easier and clearer identification of signals. (Prescott, 1892; Coe, 1993; Calvert, 2004a) Several additional changes were necessary for cable signaling. Rather than using pulses of equal polarity but different length for the dots and dashes, cable systems used pulses of equal length but opposite polarity. This approach enabled the signal to traverse the cable line as the signal induced an opposite charge in the surrounding water. (Thomson, 1855a; Prescott, 1892; Sayers and Grant, 1897; Thompson, 1909; Mum•o, 1895; Beauchamp, 2001)

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1866-2016 Atlantic Cable 150th Anniversary Pin. (Courtesy of Stephanie Buffum Field)

ABOUT THE AUTHORS



David Bart is Chairman of the RCA Publications Committee and a member of the AWA Board of Directors. He is also a member of the IEEE History Committee. Julia Bart is an advisor to AWA and co-author of numerous articles for AWA and RCA.

IEEE Offers Free White Paper
on Real-Time LTE/Wi-Fi Coexistence Testbed

The exponential rise in usage of mobile devices has not shown any signs of slowing down. Efforts are underway in the standardization bodies to define new ways to increase data rates and network capacity by enhancing 4G technologies and by introducing new technologies in 5G. This white paper focuses on the efforts to utilize unlicensed spectrum to improve capacity of cellular networks.

The unlicensed spectrum, specifically in the 5 GHz band, can be leveraged either using existing technologies in that band (Wi-Fi) or by modifying cellular technologies to aggregate those channels directly into the cellular PHY and MAC layer. The latter approach has led to disagreement between cellular and Wi-Fi ecosystems regarding its impact on existing and future Wi-Fi networks.

As with any disruptive technology, prototyping using a realistic test-bed is the best way to truly understand the performance trade-offs. Hence, neutral modifiable prototyping platforms that enable engineers and researchers to evaluate and compare performance trade-offs of such algorithms in realistic environments are valuable. This white paper describes such a platform based on National Instruments (NI) USRP RIO hardware and NI LabVIEW Communications System Design Suite.

See:

http://tinyurl.com/hzef52s

IEEE Offers Free White Papers
on 5G

Scenarios for 5G Mobile and Wireless Communications: The Vision of the METIS Project—The authors identified for the purpose of driving the 5G research direction and move further to give initial directions for the technology components (e.g., link level components, multinode/multiantenna, multi-RAT, and multi-layer networks and spectrum handling) that will allow the fulfillment of the requirements of the identified 5G scenarios.

Integrated Energy and Spectrum Harvesting for 5G—In this article, the authors propose a cooperative medium access control scheme for heterogeneous 5G networks that attracts cooperative sensing participants with heterogeneous energy harvesting capabilities. Illustrative results demonstrate significant energy and spectrum efficiency for 5G wireless networks.

Authentication Handover and Privacy Protection in 5G Hetnets Using Software-Defined Networking—In this article, the authors demonstrate that SDN-enabled security solutions are highly efficient through its centralized control capability, which is essential for delay-constrained 5G communications.

Challenges in 5G: How to Empower SON with Big Data for Enabling 5G—In this article, the authors demonstrate the key concepts of their proposed BSON framework through a case study of a problem that the classic 3G/4G SON fails to solve.

See:

http://www.comsoc.org/blog/tech-focus-features-5g-four-complimentary-articles-available-download

THE RADIO CLUB OF AMERICA 100 YEARS AGO (1916)

By Michael J. Clarson

This column introduces a new regular feature in the *Proceedings of the Radio Club of America*. Because RCA began in 1909, this column will highlight the world of radio that existed a century ago and focus on RCA's early history. The intention is also to include some information about the accomplishments of the Club's members.

In 1909, several members of the Junior Aero Club of the U.S. decided to form an entirely new organization, the Junior Wireless Club Limited, devoted entirely to wireless communications. Its members were mostly teenagers. The notable exception was Professor Reginald Aubrey Fessenden, a consulting engineer. Club members joined to pool their knowledge and resources to experiment with wireless communications.

In 1911, as the wireless industry was growing in a new direction, and the Club began to attract more industry professionals, the Club decided to change the name to Radio Club of America. Between 1910 and 1912, due to the enormous commercial potential of wireless communications, several regulatory attempts were made to stifle amateur radio operators. The new RCA and its members, along with industry leaders such as Hugo Gernsback—who later became a member—were instrumental in ensuring that the amateur was publicly represented, and maintained his place in this emerging technology.

In 1910, one of its charter members and RCA's first President, W.E.D. Stokes, Jr., known to his family as "Weddie," and while still a teenager, led the Club's delegation to Washington, D.C., to oppose passage of the Depew bill that would regulate U.S. radio communications. Wireless, however, was too important to continue completely unregulated, but through the efforts of RCA and people like Gernsback, amateurs and experimenters were able to maintain their place in the spectrum.

William's father worked in the family business, Phelps-Dodge & Company (yes, the "D" in W.E.D. stands for Dodge), a mining concern. This is interesting because the company became a major manufacturer of coaxial feedlines and antennas for microwave, land mobile radio (LMR) and broadcasting. He was also a proprietor of the Ansonia Hotel, where the Club held many of its early meetings. In 1915, the Club constructed a wireless station at the Ansonia Hotel so that Flag Lieutenant Frank Jack Fletcher, on the staff of the Commander in Chief, U.S. Atlantic Fleet and based at the hotel, could communicate with ships in New York Harbor. Fletcher permitted the station to be operated and manned by Club members.

By 1916, the world was at war, and the United States was still officially neutral, but wireless was changing. A triode vacuum tube was now available, known as the Audion. This $5 (which was quite a bit of money in 1916) vacuum tube was available for use in amplifiers, detectors and oscillators. Amateurs and professionals experimented extensively with these devices, and the Club members were no exception.



Radio Club of America's radio station set up to supply the U.S. Navy with communications from the Ansonia Hotel in New York City. The Navy League presented the Club with the banner in recognition of its service.

The still new *Proceedings of The Radio Club of America* published an article, *Applications of the Audion*, by Paul F. Godley. This article provided a rather extensive discussion of theory and construction that would enable the reader to understand how to use the Audion to construct receivers and transmitters on standard frequencies. This article was a "How To" guide for amateurs and professionals to construct continuous wave wireless equipment. Early wireless used damped waves, analogous to a tuning fork, where one has to keep striking it to keep the tone from dying out.

In wireless equipment, the "striking" was done by interrupting power to a spark coil. A continuous wave generator would output a tone (frequency) at a constant level as long as power was applied. The advantages were immediate and obvious. Many more stations could fit on existing frequencies. The Audion's ability to amplify also made receivers much more sensitive, thereby extending the usable range of wireless transmissions. This article was later reprinted in the August, 1915 edition of *QST*, published by the newly formed Amateur Radio Relay League (ARRL).

Also in 1916, Club member Dr. W. G. Hudson published a paper in the Club's *Yearbook* about his invention of the cleverly named Hudson Filament. Audions had a problem. They had a relatively short life because the filament would burn out. The filament in incandescent lamps would last much longer. Audions needed a filament that emitted electrons, not light. Tantalum was such a material, but it was weaker than tungsten; hence it would not last as long. Dr. Hudson's invention involved taking a thin tantalum wire and winding it around a tungsten filament, thereby solving the lifespan problem. Hudson's article had earlier appeared in the *Proceedings* in 1914.



Edwin H. Armstrong explaining the principles of super-regeneration at a meeting of the Radio Club of America at Columbia University in New York City, circa 1923.

Other papers published in the 1916 issues of the *Proceedings* included: *Portable Aeroplane and Trench Radio Sets* by William Dubilier, who later became the founder of the Dubilier Condenser Corporation; *A Modern Experimental Radio Telegraph and Telephone Station* by Alfred H. Grebe, founder of the radio station that became WCBS in New York; and several much more theoretical papers.

Prior to 1916, the Proceedings published papers by member Major Edwin H Armstrong on the *Theory of Tuned Circuits* in 1913, and in April 1915, on *The Regenerative Circuit*, his invention. This landmark circuit dramatically enhanced wireless communications. It adapted the basic Audion amplifying circuit by repeatedly feeding a small amount of the signal from the output back into the input, amplifying the signal gain by the same Audion. Amplification gain greater than 1,000 times was possible, compared to gains of only 10 times without this regeneration. Careful adjustment of the quantity of signal re-circulated into the circuit was required to maximize the amplification without causing the circuit to break into an oscillation. This important circuit was the dominant receiver circuit on the market until the 1930s, when the superhetrodyne receiver, invented by Major Armstrong and presented to the Club in 1922, supplanted it.

In 1917, upon entering World War I, the U.S. government took over all wireless communications for the war effort, but that is a story for another time.

ABOUT THE AUTHOR



Michael J. Clarson has, since building his first crystal set at the age of 8, and obtaining his Amateur License (WV2ZOW) at age 10, developed a lifelong passion for radio. The hobby spawned a career as a technician then an engineer, primarily in the land mobile industry. Mike is currently employed by Parsons Corporation, and one of his most recent projects is the design of the Public Safety radio system for the World Trade Center complex in New York City.

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CALL FOR PAPERS & EDITORIAL COMMENTS

The Proceedings of the Radio Club of America is known for bringing you a wide mix of papers, ranging from sophisticated technical material to historical surveys of subjects related to electronic communications. RCA also is known for fostering discussion and sharing the viewpoints of its members. RCA is therefore issuing a call for papers and editorial comments for publication in upcoming issues of the *Proceedings*.

The *Proceedings* is published semi-annually, and has been issued since 1914. The *Proceedings* is considered to be the first publication geared to promoting and sharing the intellectual development of all aspects of radio and wireless communications. Coverage has expanded to include relevant articles encompassing science, technology development, marketing and regulatory topics. We seek articles from knowledgeable engineers, professionals, academics and amateurs who are participating in building future applications, as well as those who want to document the history of relevant technologies.

As a fellow reader of the *Proceedings*, we would like you to author an article or editorial for publication. We welcome "early work," even if it is still in the process of being drafted. RCA offers a unique opportunity for you to get an early reaction to important work now underway in wireless communications. It is also a unique opportunity to air your views, inviting commentary and response from the membership.

We seek interesting or important technical articles, editorials and discussion pieces in any of the following areas:

- Antennas and supporting structures (i.e., towers)
- Broadband communications
- Broadcast
- Cellular telephony
- FirstNet
- Ham (amateur) radio
- Land mobile radio
- Long-Term Evolution (LTE)
- Military communications
- Regulatory topics
- Robotics
- Satellites
- Semiconductors, LED or other devices supporting wireless communications
- Any other wireless/radio technologies

Please submit an abstract (1-3 paragraphs) including the title, author(s) and contact information, a synopsis of the material to be published, and a note as to why you think the subject is interesting or important to the wireless industry. Authors of papers selected for publication in the *Proceedings* may be given an opportunity to present at one of the RCA's upcoming events, such as the annual Technical Symposium. (Note: participants are responsible for their own travel expenses to RCA events.)

Please send abstracts for articles and editorials to be published in the *Proceedings* to: John Belrose at JhDeniseB@aol.com with copies to David Bart at jbart1964@gmail.com.

Please send abstracts for potential presentation topics at RCA events to: John Facella at TechSymp2016@radioclubofamerica.org.

For general questions about RCA, an article idea or submission, please contact Colleen Ayers at colleen@radioclubofamerica.org.



IT'S TIME TO HONOR ···· THE ····

DISTINGUISHED AND DESERVING

While technology is important to wireless technology, this industry is really about the people. People who invent, create, inspire and collaborate to create the products, services and companies that make this industry one of a kind.

We are currently taking applications for two different categories of honors bestowed by the Radio Club of America on an annual basis. One is the elevation of existing members to the grade of Fellow. RCA Fellows are selected based upon their outstanding contributions and extraordinary qualifications in the art and science of radio and electronics. All Fellows will be recognized at the annual Banquet in November. The form and instructions for submission can be found on the following pages.

The Radio Club has also established eighteen awards recognizing the outstanding achievements and accomplishments of both RCA members and non-members.

Not all awards are given every year and descriptions of each award can be found on the RCA website at: www.radioclubofamerica.org/about-us/awards.

To submit a nomination, complete the form on the following pages and submit it with the instructions on the form.

Fellow and Award nominations are reviewed by the Awards Committee and their recommendations are forwarded to the full RCA Board of Directors for a final decision. Recipients are notified in advance so they can make their plans to attend the RCA Banquet and Awards Ceremony in New York City on Friday, November 18.

To submit a nomination, complete the form on the following pages and submit it in accordance with the instructions on the form.

THE RADIO CLUB OF AMERICA, INC.

AWARDS COMMITTEE

– AWARDS NOMINATION FORM –

The Club annually grants each of several major awards to members and non-members in recognition of outstanding achievement, and to provide inspiration for many people, both currently and in the future. As a member of the Club, your help in nominating and sponsoring candidates is appreciated. This form is provided to assist you in this process. In order to complete the selection process in time for the annual Awards Banquet in November, the Awards Committee prefers to receive nominations prior to August 1.

For each major award, the Awards Committee collects and evaluates all nominations then submits its recommendation to the Board of Directors for final approval by a majority of the Board.

To nominate someone for an award, please **legibly provide the information below** to the Club's Awards Committee in care of the Club's Executive Secretary in any of the following ways:

Fax:	(952) 929-1318
E-mail:	colleen@radioclubofamerica.org
U.S.P.S. mail:	4248 Park Glen Road, Minneapolis, MN 55416

A. Name of RCA award: _____

B. Is Club membership required for this award? _____

C. Full name of candidate: _____

D. Is candidate a member of the Club? _____

E. Proposed citation (between 5 and 25 words), based on why it is felt that this candidate should be considered: (to be published and announced at the presentation of the award)

_____

_____

_____

F. Attach supporting material such as an expanded explanation, a biography, a resume, and any significant published articles: (please list your attachments below)

_____

_____

_____

<u>Sponsor submitting this nomination</u>:

Full name: _____ **Phone number:** _____

E-mail address: _____ **Fax number:** _____

U.S.P.S. mailing address: _____

Date submitted: _____

The Radio Club of America, Inc.
4248 Park Glen Road, Minneapolis, MN 55416
Tel (952) 928-4651 ▪ Fax (952) 929-1318
colleen@radioclubofamerica.org ▪ www.radioclubofamerica.org

THE RADIO CLUB OF AMERICA, INC.

FELLOWS COMMITTEE

– 2016 FELLOW NOMINATION FORM –

The Club annually elevates worthy Club members to the grade of Fellow in recognition of outstanding achievement, and to provide inspiration for many people, both currently and in the future. As a member of the Club, your help in nominating and sponsoring candidates is appreciated. This form is provided to assist you in this process. In order to complete the elevation process in time for the annual Awards Banquet in November, the Fellows Committee prefers to receive nominations by the end of May of the year of the proposed elevation.

Article I of the Club's Bylaws states the following:

> Section 4: Elevation to the status of Fellow is by invitation only to those persons who have been a member in good standing for the previous five years and whose contributions to the art and science of Radio Communications or Broadcast or the Radio Club of America are deemed outstanding by the Club. Nominations for Fellow must be submitted in writing to the Awards Committee and must be supported in writing by at least two members in good standing. The Fellows Committee will report to the Board of Directors the names of all nominees for fellow, including any relevant information regarding each nominee. Invitations to persons to become a Fellow will be made pursuant to a majority vote of the Board of Directors.

To nominate an RCA member, please **legibly provide the information below by May 31, 2016** to the Club's Fellows Committee in care of the Club's Executive Secretary in any of the following ways:

Fax:	(952) 929-1318
E-mail:	colleen@radioclubofamerica.org or elaine@ecommint.com
Mail:	4248 Park Glen Road, Minneapolis, MN 55416

A. Full name of candidate: _____

B. Proposed citation (between 5 and 25 words), based on why it is felt that this candidate should be considered: (to be announced at the presentation of the award)

_____

_____

_____

C. Attach supporting material such as an expanded explanation, a biography, a resume, and any significant published articles: (please list your attachments below)

_____

_____

<u>Sponsor submitting this nomination</u>: **Date submitted:** _____

Full name: _____ **Phone number:** _____

E-mail address: _____ **Fax number:** _____

U.S.P.S. mailing address: _____

The Radio Club of America, Inc.
4248 Park Glen Road, Minneapolis, MN 55416 Tel: (952) 928-4651 Fax: (952) 929-1318
radioclubofamerica.org

MOTOROLA'S FIRST BROADCAST FM AUTO RADIO – THE MOTOROLA FM-900

By Raymond Schulenberg and Olin G. Shuler

EDITOR'S NOTE: In 2014, Raymond Schulenberg and Olin Shuler received the Radio Club of America Fred M. Link Award for "contributions to land mobile radio." The award was granted based on their involvement with the development of the first FM car radio. The Proceedings is honored to present this first-hand account of their experiences.

PROLOGUE

In the mid and late 1950s, with high fidelity coming into vogue, AM car radios still had a sound of their own. The public's ears were conditioned and trained to accept it. These radios generally were devoid of musical sounds just beyond four octaves above middle C, with the Federal Communications Commission (FCC) limit of 5000 hertz (Hz) as the highest modulation frequency allowed. The signal was capable of passing through radio receiver circuits with a 6-decibel (dB) bandwidth of 6 to 8 kilohertz (kHz) without significant loss. The most envied car radios had push-pull output stages, with bass boost and a 6 inch x 9 inch loudspeaker, sometimes rivaling the rich bass sound of the often admired Wurlitzer juke box. Bass response ruled the day. A pop music record company, Motown Records, optimized their "Detroit Sound" to match the 6 inch x 9 inch speakers on the rear-seat deck of an automobile.

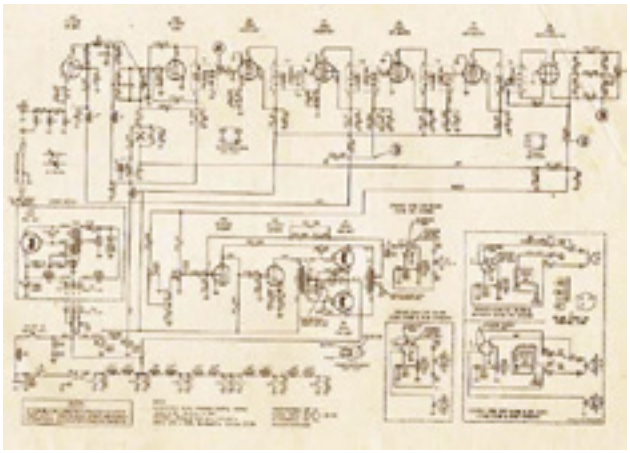
FM radio offered a superior alternative, and the public was well aware of this option. But in order to appreciate the full effect, large speakers, enclosures, and amplifiers were necessary. FM entertainment remained house bound. After World War II, FM broadcasting was moved to its present frequency location and showed promising growth—at first. In a short time, its extravagant, glamorous stepsister, television, commanded most of the public's electronic entertainment dollars. Public acceptance of FM was limited to radio phonographs in upscale console cabinets with substantial amplifiers and speakers.

New FM table model radios were disappearing from manufacturers' annual product introduction lineups. By then, many FM stations had either gone dark, or simulcast the company's AM programming. With FM radio's income stream diminishing, the medium slowly was disappearing. Radio manufacturers gave no serious thought to producing an FM car radio. Ford offered an FM converter for the Lincoln. It played through the AM radio as a dealer-installed accessory; however, it failed to gain public acceptance and was discontinued. The year was 1958.

Nevertheless, public taste for home high fidelity continued to grow, driven by musical quality available on newer records, custom labels, tape, and equipment with startling performance. The prospects for increased revenue for FM broadcasters brightened with the FCC's approval of multiplex broadcasting, bringing forth background music service in malls, offices and factories. The oncoming prospects for stereophonic broadcasting circulated in the trade journals. That promised a significant revenue advantage over AM radio. Small manufacturers were entering the auto radio scene with FM converters operating through AM car radios with their inherent sound quality limitations.

Recognizing new potential for growth in FM broadcasting, Motorola® entered the field with its first FM car radio, known as the Model FM-900. This was a complete high-performance radio with pleasing sound capability, and not a "tuner or converter." The FM-900 was designed by Motorola Distributor Auto Radio Engineering, the latter-day successors of the seminal group that first launched Motorola into the auto radio business 30 years earlier. Sold through Motorola distributors and dealers, it commanded a target retail price of $125.

In the second quarter of 1959, Ray Schulenberg was assigned as electrical design engineer to develop the FM-900, along with Bill Race as the mechanical design engineer. Herb Zeller was the design stylist. The project began.



Schematic for the FM-900.



Power supply with cover removed. Free running oscillator, selenium rectifier and RC filter. 90 volts B+.

RAY SCHULENBERG, DESIGN ENGINEER, DESCRIBES HIS ACTIVITY

FM radio was no stranger to Motorola, which had significant mobile, military and emergency radio experience. We understood the rules of the game. Utilizing existing knowledge of size and space limitations for under-dash after-market automobile radios, we determined an optimum chassis size for available locations in late model cars. Sensitivity and impeccable sound quality were the obvious goals. The question was not "What is the minimum we can get by with?" but rather, "What is the best fringe area reception, urban reception, audio power and fidelity we can we obtain?" We recognized what it would likely take to be successful and acted accordingly. Performance requirements dictated the selection of circuits and features.

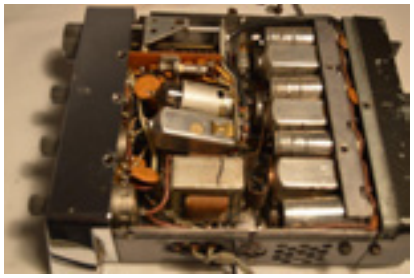
Design began in the usual classic manner with a concept chassis that was used to determine the exact layout of major components in the allocated space. Known as the "Design Model," it included permeability radio frequency (RF) tuning, a grounded-grid RF stage, converter, two intermediate frequency (IF) stages, two limiter stages, automatic gain control (AGC), full-time varicap automatic frequency control (AFC), a ratio detector, two audio stages (all vacuum tubes) and push-pull output transistors. The 90 volt B+ source for the vacuum tubes came from a small power supply, mounted separately from the radio. This was an early version of a switching power supply, using a free-running power transistor oscillator. A transformer and selenium rectifier with appropriate resistor-capacitor (RC) filtering completed the unit. Mounted out of sight, it enabled the radio to occupy minimum space on the lower lip of the dashboard.

Mechanical design engineer Bill Race and his team attended to the "mechanical packaging" inside the radio chassis. Carefully planned placement of the tuner, IF coils, tube sockets and related transformers led to a neat compact preliminary design. Unique mechanical parts were fabricated in the model shop and the first Design Model chassis came into being. Meanwhile, blueprints and production tooling details were conveyed to mechanical parts suppliers.

Radio circuitry advanced from the lab breadboard development stage, to wiring in the Design Model chassis, step by step to completion. Alignment, bench tests, and round one of optimization followed. Then, with lab performance documented as a quantified baseline, the Design Model, a speaker, a 30 inch whip antenna, a couple of tool and equipment boxes, and sometimes a lab technician, were loaded into a car. The task of field testing began.

Over a period of several weeks virtually every good or difficult reception location in the Chicago area was surveyed, covering a 60 mile-plus radius extending into Wisconsin, Indiana and Michigan. FM reception needed to be comparable to, or better than, AM. We paid particular attention in urban areas with underpasses, parking garages, and signals that reflected from large buildings. As the need for additional sensitivity and higher gain in the IF strip was realized, tube shields were added to assure stability. Heat chamber tests of the push-pull transistor output stage brought forth a more effective transistor heat sink. Each day in the field led to more hours in the lab, incrementally confirming and measuring the improvements that would be included in the design. This was followed by trips back to the field to verify the results. And then, we repeated this testing cycle. Fringe area reception and interaction of strong competing signals provided the conditions necessary to optimize AGC and AFC action. The field and lab work were interspersed with periodic project progress report meetings and demonstration trips with executives.

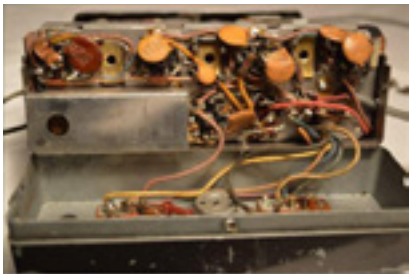
When mechanical parts containing all of the latest revisions were available from the model shop, a final



Side view with cover removed. RF deck, tuner, RF and mixer stage and 1st IF coil. The large transformer is for audio output.



Front view of the FM-900 with power supply.



Top row: 2nd IF, 1st and 2nd limiter; Middle Row: Detector and audio stages; Bottom Row: Solid state outputs and heat sink.

version of the Design Model was assembled for the latter stages of field tests. As tests progressed, with the optimizing steps quantified and included in the design, the point was reached where performance goals were met and the design was accepted for release to production. The finalized design delivered 15 watts (W) of peak audio power, with minimal distortion even at higher listening levels. Weak signal sensitivity for 10 dB quieting was less than 3 microvolts. with limiting (no background noise) observed at 10 microvolts or less. Meanwhile, design stylist Herb Zeller had created a smart-looking, chrome-plated escutcheon, a very attractive dial glass and scale, with nicely proportioned knobs. His results are best described as "very 1960!" Gorgeous!

With all revisions in place, the bill of materials and related specifications and blueprints were brought up to date. Approximately nine months after starting the project, the official release date arrived. As the electrical design engineer, I was chosen to accompany division vice president Ed Taylor to the official press conference announcement of the FM-900 at a hotel in downtown Chicago.

OLIN SHULER, PRODUCTION ENGINEER, DESCRIBES PREPARATIONS AT THE FACTORY

Basic production planning was already under way, with major equipment needs identified and acquired. The production pilot run was set for late February 1960.

Motorola's Quincy, Illinois, plant had its first exposure to the FM-900 when drawings were released and two of the official product samples were received from engineering in mid-January 1960. One was the official mechanical sample showing proper positioning and assembly of all parts and wiring. The other was the official electrical sample that demonstrated compliance with all product specifications. Meanwhile, the production engineering and the test equipment departments were readying themselves for production, with new equipment in their labs, as well as the assembly of circuit alignment/test work stations to be used in production. Then came preparation of procedures for special processes, RF and IF alignment, and testing.

The plant's industrial engineering and time-study department determined the labor content by identifying each labor step required in the wiring and assembly processes. Their documentation became part of the assembly instructions used in manufacturing. The production line was approximately 60-feet long on a steel bench with K legs and a foot rest. The workers could stand, or sit on stools with a back rest. Overhead twin fluorescent lamps provided illumination. The radios were positioned in fixtures or sometimes flat on an 18 inch wide rubber/fiber belt that moved slowly past each work station, about two feet per minute depending on the line pace. The line pace was set by the first worker on the line, starting each set on its way, cued by the periodic lighting of a 60-watt light bulb, a.k.a., the "timing light." Workers were spaced sufficiently for the supervisor to step in between them for assistance or instructions.

Ready for the production pilot run, with manufacturing preparations complete, designers Ray Schulenberg and Bill Race were present to assist the plant team. The run was assembled on a line set up for about 440 sets per day, i.e., the conditions under which it would operate after the pilot run, at production startup. This would be the first time that only supplier produced parts were used, and no parts were drawn from the "model shop." Assembly, chassis wiring and subsequent inspection activities went smoothly with few, if any, delays. The assembly was completed by early afternoon. Line workers returned to their regular production lines where they would remain until all evaluations were approved and sufficient production quantities of material were in inventory.

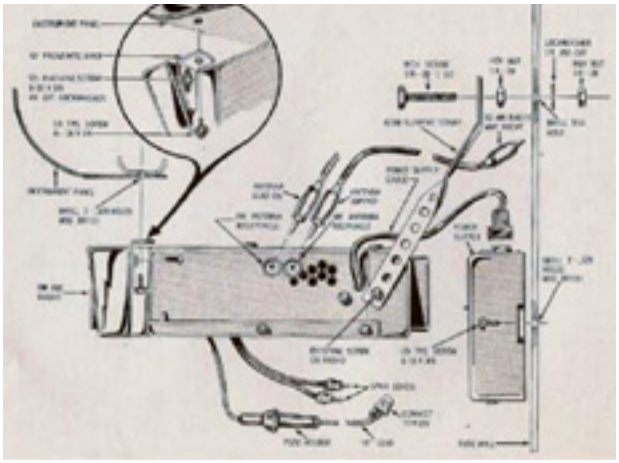
In the production test department, tuned circuit alignment and electrical tests were performed, hands-on, by production testers—while receiving training and assistance from their supervisors—under the watchful eyes of Ray and Olin. To accommodate the production volume, three identical



Bottom cover removed. View from escutcheon to rear.



Introduction in Motorola Dealer's catalog, 1960



Owner's manual installation guide.



New FM Auto Radio

OUR recent survey "FM Radios for Your Car" (December 1959) contained several reports from leading auto radio makers which stated flatly they had no plans for marketing an FM auto radio. Motorola was one of them. In spite of their former stand—or perhaps because of our article—Motorola is now mass producing the FM-900, a mobile radio that tunes 88-108 mc. This under-the-dash-installation unit can operate independently of the car's AM set. Three transistors power the hybrid circuit, which contains seven additional tubes. FM-900 shares the AM set's antenna and can be used with any 12-volt, negatively grounded ignition system. No need to sell the FM set when you sell your car. It may be moved from auto to auto, or auto to boat. Other features are AGC, AFC and $125 price.

News article announcing the FM-900. (Courtesy Modern Mechanix, June 1960)

test booths were used. Each test booth was semi-enclosed on three sides and the top, and was outfitted with new laboratory-grade test equipment. Test procedures focused on the customer-sensitive items contained in the engineering specifications. The FM-900 proved to be quite stable and easy to align. Test techs already very familiar with AM radio alignment methods adapted quickly to the FM radio testing.

With assembly and testing completed, production engineering performed electrical tests on each of the sets, recording the data to determine compliance with the roster of electrical specifications. Accuracy of production alignment was the first item checked. Then the engineering tests were made. When the data was complete, each set had met all specifications without difficulty! With minimum problems during the pilot run assembly, and full compliance with specifications confirmed, the model was approved for production.

Production began as scheduled, and in a few weeks, the production lines were running at the rated production speed, with no more than normal day-to-day issues being encountered. The FM-900 then took its place in the manufacturing schedule, rotating production runs with a group of other high-end AM sets running at about 500 units per shift for almost four years. The FM-900 was a great success. During its production life, not one electrical design change was required. This is a tribute to excellent design and component uniformity!

EPILOGUE

The FM-900 introduced FM radio to morning and evening drive-time commuters on the expressways, as well as urban and rural roads, across the U.S. This breakthrough, along with the advent of FM stereo, revitalized the FM broadcasting field. A Motorola after-market AM-FM car radio followed, and the first AM-FM factory-installed car radios appeared in 1963 and 1964. The 1963 Motorola Model R-200 Reverberation Sound for the automobile even provided "concert hall realism" inside one's car. Solid-state circuitry led the way for further development of automobile radio audio amplifiers, with power and frequency response rivaling their housebound counterparts. Loudspeaker technology and strategic placement within the passenger compartment fulfilled the mission of providing a complete high-performance radio with truly pleasing sound capability.

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(1) Personal recollections of the two authors employed by Motorola and participants in the events.

(2) *Popular Communications Magazine*, Dec. 2012.

(3) *Electric Radio Magazine*, Feb. 2013.

(4) Raymond Schulenberg and Olin Shuler. *Motorola's Introduction of The First Broadcast FM Auto Radio Motorola FM-900. AWA Review. 2015. Antique Wireless Association.*

ABOUT THE AUTHORS

Ray Schulenberg, an IEEE life member, is a retired radio design engineer formerly employed by Motorola for forty years. He designed the first broadcast FM automobile radio, along with numerous auto radios and other related products, including "Vibrasonic Sound," FM-to-AM converters and Motorola branded automobile eight track tape players. He is a member of the Radio Club of America and a 2014 recipient of RCA's Fred M. Link Award.

Olin Shuler is a Registered Professional Quality Engineer and a Fellow in the American Society For Quality. In retirement he continues as a Quality Systems Consultant. While at Motorola for over twenty years, he participated in transferring new technology from design engineering to manufacturing and provided ongoing technical support. Products included shirt-pocket sized transistor portable radios, auto radios, car radio short wave converters, three channel stereo phonographs, FM stereo radio, the eight track stereo tape player, and home quadraphonic sound using a modified eight track tape player. He is a Member of the Radio Club of America and a 2014 recipient of RCA's Fred M. Link Award. He is a past-president of the Antique Radio Club of Illinois and a member of the Antique Wireless Association. He currently holds both Amateur and Commercial FCC Radio Operators Licenses.



Olin Shuler (left) and Raymond Shulenberg (right) with the FM-900 and their 2014 RCA Fred M. Link Awards.

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NEWS ITEM

IEEE Announces New REACH Education Program

In November 2015, the IEEE History Center announced its new educational program, REACH (Raising Engineering Awareness through the Conduit of History). This is one of five signature programs of the IEEE Foundation. The goal is to raise awareness and appreciation of engineering and technology at the high school level through various multimedia-focused themes.

REACH provides a tool for history teachers to advance students' knowledge about the history of engineering and technology, and highlights the impact technology continually has on society. The REACH Academic Advisory Panel and several academic administrators are fostering strategic relationships. REACH and the IEEE History Center occupied a booth at the November 2015 National Curriculum Standards for Social Studies' national conference, in order to cultivate national interest in REACH.

REACH's first enrichment lesson resource will be designed for 9th and 10th grade world history classes, covering the history of navigation technologies with the theme of maritime navigation.

REACH intends to develop partnerships with outside partners, including history teachers and administrators, congruent museums, potential distribution outlets, production teams and animators. REACH's programs eventually are expected to include communications themes that encompass landline, radio, Internet and modern wireless modes.

Further information is available from Kelly McKenna, REACH Program Manager at k.mckenna@ieee.org.

NEWS ITEM

NYU Speeds Development of 5G and Makes Software Open to All

NYU's Research Center Founder Theodore (Ted) Rappaport (RCA Member, Fellow and Sarnoff Award recipient) announced New York University's commitment to expanding 5G cellular communications. He presented the announcement about NYU's Open-Source Channel Simulator in Washington at the FCC Workshop on Spectrum Frontiers. NYU bases the software on its pioneering measurements and modeling approaches which could cut years off development time for next-generation mobile communications.

In his keynote speech at an FCC workshop on 5G wireless technology on March 10, 2015, Rappaport announced that NYU is making its channel model simulator and measurement data free and open to all—potentially short-circuiting years of millimeter wave (mmWave) development time for companies hoping to vastly increase the transfer of data through the air.

The announcement came just days after FCC Chairman Tom Wheeler told a Senate committee that the United States will lead the fifth generation of wireless communication (5G) and quickly allocate high-frequency mmWave radio-wave spectrum—a band of frequencies that NYU WIRELESS at the NYU Tandon School of Engineering first demonstrated can help fulfill the urgent need for faster and greater wireless data capability.

The NYU WIRLESS simulator will provide the first open access to statistical spatial channel models that are based on the research group's experiments from 2011 to 2014 that showed the world that mmWave frequencies will work for mobile communication.

Already, many companies, including some corporate sponsors of NYU WIRELESS and French telecomm operator Orange, are using it. Like other channel simulators that are being developed by private companies, the simulation software allows researchers to understand the behavior and capabilities of the mmWave radio spectrum that was originally widely believed to be suitable only for indoor communication until Rappaport and colleagues at NYU WIRELESS published their pioneering radio propagation measurements, radio channel modeling, system simulation, and antenna technology research in the 2012-2013 time frame.

With the new simulator, developers of 5G cellular phones, base station infrastructure, and future Wi-Fi products will be able to use the results of four years of measurements made at new mmWave frequencies ranging from 28 to 73 gigahertz and taken in New York City and Austin, Texas. The open-source software includes real-world channel data measured throughout Manhattan and Brooklyn, and allows users to generate channel impulse responses, calculate precise time delays, locate the angles of arrival of energy in urban channels, determine received power levels, and other key technical data needed to create reliable mmWave wireless equipment and systems.

To download the NYU WIRLESS channel model simulator, and for a complete list of published resources on 5G mmWave wireless channel modeling and measurements, visit http://nyuwireless.com/5g-millimeter-wave-channel-modeling-software.

MESSAGE TO FCC: URGENCY

The race to 5G will enable driverless cars, breakthroughs in medical imaging technology, new wireless medical devices, a growing number of connected devices referred to as the Internet of Things—and it could make Wi-Fi widely available at lower cost with greater capabilities than today. Yet wireless communication has not kept pace with other computing gains, Rappaport will tell the Spectrum Frontiers Workshop organized by the FCC Office of Engineering and Technology, Wireless Telecommunications Bureau, and International Bureau.

"The demand for mobile data is forecast to continue rising 53 percent each year into the foreseeable future. Over the last 40 years, computer clock speeds and memory sizes rose by as much as six orders of magnitude. Yet communications frequencies have barely moved. The only hope to meet mobile traffic demand is to utilize much more spectrum, and opening the mmWave band will do just that," Rappaport says.

"The FCC's leadership will provide the American public with important new services and ensure that we remain at the forefront of technology development," adds Rappaport, an early proponent of the FCC's quick response to opportunities revealed by mmWave research.

His speech this morning will follow remarks by FCC Chairman Wheeler, Commissioner Michael O'Rielly, and will keynote a day-long session of presentations and demonstrations from international corporations and government.

IMPACT OF THE TECHNOLOGY

The mmWave spectrum could provide 200 times the capacity of all of today's cellular spectrum allocations, and 5G is projected to become more than 1,000 times faster than 4G.

Channel models are vital to the governing bodies setting standards, companies developing equipment that will test and manufacture the next generation of wireless communication, carriers, mobile device makers, and academic researchers.

"We are able to provide this software suite for use in link level and system level simulations because of the strong and continued sponsorship of many NYU WIRELESS industrial affiliate sponsors and the National Science Foundation (NSF), as well as the hard work of many dedicated students and faculty," says Rappaport, founding director of the research institute. Seventeen companies and institutions support the work at NYU WIRELESS, recently named by FierceWirelessTech as the world's leading academic research center in 5G.

Rappaport's announcement of the open-source channel model simulator marked the second open-source announcement this year by NYU WIRELESS. In January, it announced plans to build one of the first advanced testbeds for antennae that will be available to academic and public-sector researchers studying the mmWave spectrum. That project is supported by the NSF and collaborates with National Instruments and SiBEAM, a Lattice Semiconductor company.

RAPPAPORT AND NYU WIRELESS

Ted Rappaport holds the David Lee/Ernst Weber Chair in the Electrical and Computer Engineering Department of the NYU Polytechnic School of Engineering, as well as faculty appointments at Courant and the Department of Radiology at NYU Langone School of Medicine. NYU WIRELESS is a multi-disciplinary academic research center the Brooklyn engineering location providing a world-class research environment that is creating the fundamental theories and techniques for next-generation mass-deployable wireless devices across a wide range of applications and markets. The center uniquely combines expertise from NYU's Tandon School of Engineering, School of Medicine, and Courant Institute of Mathematical Sciences supporting the creation of new wireless circuits and systems as well as new health care solutions for the wireless industry. ***For more information, visit http://nyuwireless.com.***

NEWS ITEM

AWA Museum Expansion and 2016 Convention

The Antique Wireless Association will complete the installation of new Western Union telegraph displays in the Antique Wireless Museum by August in time for the 2016 AWA Convention. The displays include the recently donated collection from the former National Telegraph Museum that were donated in late 2014, catalogued and transferred in 2015, and installed in 2016. This historically important collection is a major addition to the museum, including many rare Civil War items, Samuel Morse's manuscript circuit diagrams, and hundreds of other items. The addition of this historically important telegraph collection follows the AWA's installation of the Voice of America Delano, California transmitting station in 2014 and 2015. The VOA station room has now been fully completed and includes wall displays that feature the history of the VOA, Radio Free Europe, the U.S. Information Agency and Edward R. Murrow. This station was originally built and installed for the VOA by Radio Club of America member Jack R. Poppele. The museum has also significantly expanded its teletype and telephone exhibits as part of its Phase II development.

The AWA Convention will be held Wednesday, August 17 to Saturday, August 20, 2016 at the RIT Conference Center in Rochester, NY. (Exit 46 of the New York State thruway (I-90), to I-390 North, to NY 253 West, and then NY 15 South.) The dual themes this year include Pre-Broadcast Wireless and Zenith Radio. Current plans include 18 presentations covering every area of communications history, plus the Flea Market and the Book Fair. The exhibits shown at the Old Equipment Contest will offer additional rare historical insights. A Welcome Pizza Party will be held on Wednesday night and the Awards Banquet will be held on Friday.

For additional information, see the AWA website at http://www.antiquewireless.org/2016-annual-convention.html.

AWA ANTIQUE WIRELESS MUSEUM

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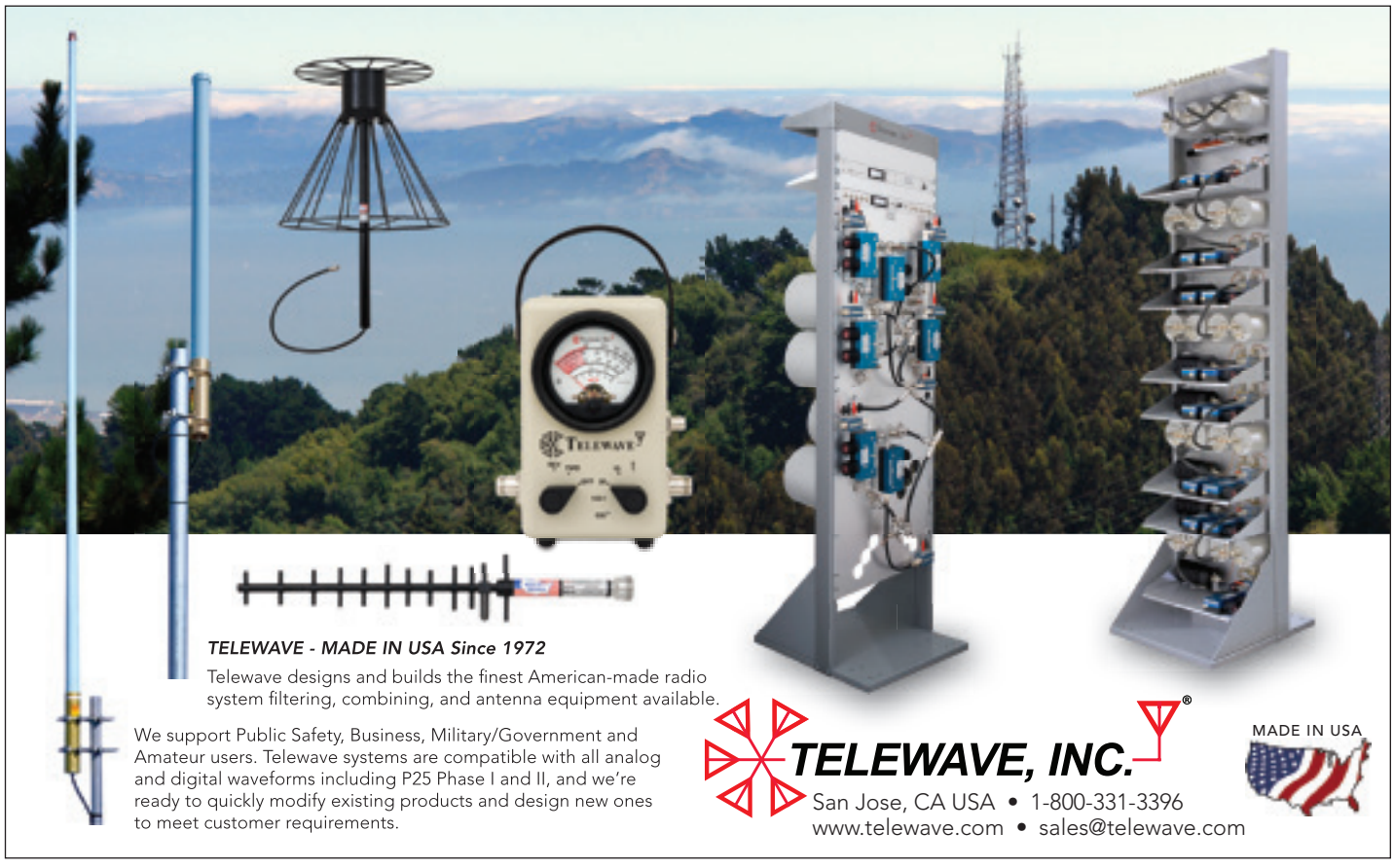
We have been hard at work refreshing and adding content to the RCA website to make it the go-to place for RCA news and events.

VISIT THE SITE FOR:

- 2015 Technical Symposium slides and videos
- Updated membership list, including email address and call sign (login required)
- Calendar of upcoming RCA and industry events
- Updated committees page
- Updated publications archive
- New products in the RCA store
- Membership, awards, and advertising forms
- Current articles about youth outreach
- And more!

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YOUTH ACTIVITIES UPDATE

Hamcation 2016 | Orlando, FL

RCA Board member Carole Perry represented RCA by hosting the Youth Forum in February at Hamcation in Orlando, FL.



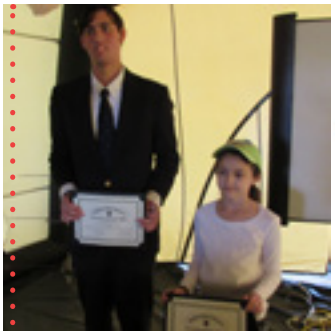
RCA Young Achiever Charles Lindsay, KJ6VCH, age 17, is the president of Suncoast High School amateur radio club.



Hope Lea, KM4IPF, age 9, spoke about her satellite radio communications.



RCA member Roger Madden showed up to support Carole at HamCation. Not pictured: RCA Treasurer, Ron Jakubowski.

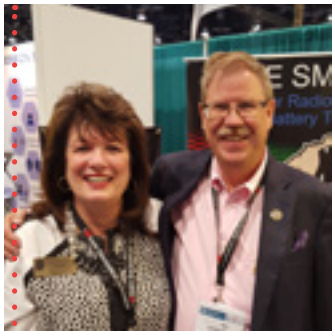


Charles and Hope proudly display their RCA Young Achiever Certificates.

IWCE 2016 | Las Vegas, NV



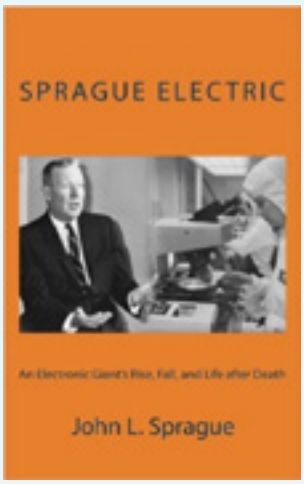
One of RCA's Young Achievers, 14 year old Rohan Agrawal, KJ6LXV, and Carole Perry, WB2MGP, at IWCE in Las Vegas in March. Rohan wowed the audience as the featured speaker at the RCA Breakfast there.



Perry with Youth Activities Committee member and RCA Director Charles Kirmuss.

Support RCA Youth Activities by Donating Your Frequent Flyer Miles

Due to the efforts of Carole Perry, the Youth Activities Program has been very successful. During the year, Carole travels all over the country to meet with people and to speak on behalf of the program. Almost all of the travel is at Carole's personal expense. You can help by donating your frequent flyer miles to the Radio Club. If you would like to participate, please contact Carole Perry at wb2mgp@gmail.com and she will assist you.



BOOK REVIEW

Sprague Electric: An Electronics Giant's Rise, Fall, and Life after Death by John L. Sprague

(CreateSpace Independent Publishing Platform, 2015)

Reviewed by Eric Wenaas

EDITOR'S NOTE: The following books have been suggested as interesting reading or as useful resources. The following review does not constitute an endorsement or recommendation by RCA. We welcome suggestions and recommendations from RCA's members regarding book suggestions to share with RCA's membership. The scope can include technical, regulatory, or other subjects. We encourage you to send your suggestions to David Bart at jbart1964@gmail.com for publication in a future issue of the Proceedings.

"Don't be Vague…ask for Sprague"—a dated but endearing slogan that appeared on the back of the ubiquitous Sprague Products Company catalog circulated to servicemen, amateurs, experimenters and industrial users for many decades during the second half of the twentieth century. The Sprague Products Company was a subsidiary of the Sprague Electric Company, which was the new name of the Sprague Products Company as of April 24, 1944. There cannot be many repairmen, antique wireless enthusiasts or ham radio operators who are not intimately familiar with the orange, blue and white catalog circulated by Sprague, or at the very least, the many Sprague capacitor lines that filled a majority of its pages.

As the title states, this book is the saga of the rise, fall and life after the existence of the Sprague Electric Company, which began with the creation of the Sprague Specialties Company in 1926 and ended when the last vestiges of the Sprague Electric Company were sold off in the early 1990s. While this book recites many historical events occurring between the founding of the company and the divestiture of its division, it is much more than a simple historical account containing facts, figures and dates. It also relates stories about the key decision-makers, details of their personal interactions, and how and why they made the decisions that shaped the destiny of the company. These stories are skillfully related by John Sprague, who was intimately familiar with the events—first as the son of the founder and CEO, Robert Sprague, then as an employee, and later as its CEO.

Author John L. Sprague divides the book into three major sections corresponding to the three major historical eras of the company—the early period when the company name was initially Sprague Specialties (1926 to 1944), the creative years when the company was renamed Sprague Electric and joined the solid-state revolution (1944 to the early 1970s), and the period of troubles, the struggle to survive, and the sale of its divisions to other entities (early 1970s to the early 1990s). Of the many historical events the author recounts, there are several that stand out. Arguably, the most important historical event of all was the invention of the variable condenser by Robert Sprague, father of the author, in his Quincy, Massachusetts kitchen that launched the Sprague Specialties Company in the first place. The variable condenser was a tapped fixed paper condenser with an accompanying tap switch that was used as a variable tone control in broadcast radio receivers that were all the rage in 1925.

While it is beyond the scope of this review to explain how Sprague's variable condenser worked or why it was unique, the reader may wish to find out by reading the original patent No. 1,675,831 entitled "Tone-Control Means." The patent filed by R. C. Sprague on May 29, 1925, which can be retrieved from Google Patent Search, has a very readable explanation of how it was used and why it was a real advance in tone control technology. The company parlayed the paper and metal-film design of this condenser into the "Midget,"—a condenser that was half the size of the standard mica condensers offered by other manufacturers of the day, and much less expensive to manufacture. Sprague was on its way to capturing the lion's share of the condenser market, which became the core business of the company.

In the second section of the book, the author describes what happened after the company decided to branch out from the company's core business of capacitors and other passive components, and pursued the transistor business. John Sprague

writes, "For Sprague this was a monumental decision, and in the minds of some, a fatal mistake." While John Sprague never reveals exactly who made the decision, one must assume that it was his father, Robert, who was CEO at the time. He goes on to explain how the solid-state device business was so different from the more familiar passive component business in terms of management style, manufacturing cost competition, and higher R&D costs. The decision to go into this business ultimately resulted in the decentralization of the management and the formation of essentially two different companies within Sprague Electric. John Sprague apparently spent a good portion of the time while he was CEO addressing this issue because he writes, "This problem of the two Sprague Electrics was never completely resolved during the remaining life of the company."

In the third section of the book, Sprague describes a sequence of events that ultimately led to the divestiture of the company's divisions, thus ending the long and colorful history of Sprague Electric as a single entity. These events consisted of a series of takeovers that would have delighted even the most discriminating corporate raider. It began late in 1976 when the General Cable Corporation made a tender offer for all the outstanding shares of Sprague Electric, a public company since June 1926. According to the author John Sprague, General Cable had acquired over 95% of the shares by March 1977, and the company found itself under new management. Sprague Electric flourished as a subsidiary of General Cable, and relations between the executives of the two companies were amicable. John Sprague rose to the position of CEO of the Sprague subsidiary in December of 1980. Then in early 1981, General Cable announced in its annual report that "discussions with Penn Central Corporation (PCC) have culminated in an offer by Penn Central to purchase for cash GK common [General Cable common stock]…resulting in GK [General Cable] becoming a wholly owned subsidiary of PCC." Sprague recalls, "Within Sprague Electric there was almost universal shock: Penn Central, the bankrupt railroad company? What did it know about electronic components?"

Adding insult to injury, Carl H. Lindner, a self-made billionaire and CEO of American Financial Corporation, accumulated sufficient stock to take over control of Penn Central in 1983. He became its chairman of the board, and ultimately he became CEO of Sprague Electric as well. John Sprague remembers that soon after Lindner became chairman of the board, he gave a briefing to the Lindner Board seeking funds for a much-needed expansion and upgrade of it silicon wafer processing facility. Just before he gave the briefing, one of the directors commented, "Well gentlemen, we have already spent a lot of money on your company, so I assume that in the future no more will be required." Upon hearing John Sprague's briefing that the needed improvements for Sprague could not be financed without additional support from the parent company, the director grumbled, "What a terrible business!" This comment presaged the divestiture of the Sprague divisions by Penn Central in the early 1990s.

Following the three main divisions of the book is an Epilog, which is actually in the form of a memoir where John Sprague reflects on experiences and memories of life with his father. John recalls two poignant life events, one involving his father and the other involving both. Labor discord in 1970 at Sprague Electric led to a strike lasting more than two months that greatly affected John's father. John writes, "I am certain that, at least in his business life, the low point for him was the 1970 ten week strike. Convinced he had made Sprague Electric a good place to work and compensated his employees fairly, he couldn't imagine that they would take such an action, endangering not just the life of the company, but also their own." The second poignant moment was an altercation John had with his father. John writes: "The argument we had over changing to a niche semiconductor strategy was one of the low points of my life. I had to convince the man I loved and respected most in the world, who starting from scratch had built one of the world's most successful passive component companies, that this time he was dead wrong. He only made things much worse by calling me a 'coward'…"

There is a very noticeable and welcome switch from the third person used in the main body of the book to the first person used in the Epilog. Use of the first person makes the memoire warmer and more personal, and it is a shame that the entire book was not written in the first person. The repeated use of "John Sprague" instead of "I" in the main body actually makes it feel like the book was written by another person and also makes it more difficult to read; for example: "At Lehovic's request, Robert Sprague's son, John Sprague, studied the patent in detail. As he did so he became increasingly excited." As a reader, I would have preferred: "At Lehovic's request, I studied the patent in detail, and as I did so, I became increasingly excited." Since many of the factual events appearing in the Epilog are also mentioned in the main body of the book, and since much of the material in main body is in fact a series of memoirs, the Epilog and the main body could

have been integrated and the first person could have been used throughout the book.

First or third person aside, the book is very interesting, quite readable and filled with information on the history and inner workings of the Sprague Electric Company that cannot be found elsewhere. For those who are familiar with the Sprague name either by using its passive components or solid-state devices, this book will augment your knowledge and understanding of the company. I highly recommend this book to anyone interested in the history of radio.

It is interesting to note that this book was produced in partnership with the IEEE History Center (IHC) Press. The IHC Press works with authors to publish books on the history of electrical and computing-related technologies, and also works with Amazon.com to publish handsome print-on-demand paperback books and Kindle versions. Prospective authors can learn about IHC Press publishing initiatives by visiting the IHC website at:

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[Note: This book review, to appear in the June 2016 issue of The AWA Journal, is reproduced here courtesy of The Antique Wireless Association.]

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John L. Sprague.
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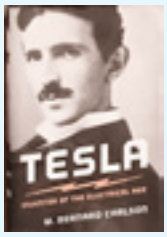
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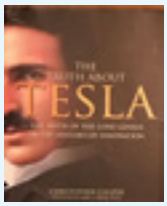
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BOOK REVIEW: TESLA, REVISITED







Inventions of Nikola Tesla by Ty Shedleski, (The Book Shed, Middletown, Del., 2015)

Tesla: Inventor of the Electrical Age by W. Bernard Carlson (Princeton University Press, Princeton. N.J., 2013)

The Truth About Tesla by Christopher Cooper (Race Point Publications, New York, 2015)

Reviewed by Nathan Cohen

EDITOR'S NOTE: The following books have been suggested as interesting reading or as useful resources. The following review does not constitute an endorsement or recommendation by RCA. We welcome suggestions and recommendations from RCA's members regarding book suggestions to share with RCA's membership. The scope can include technical, regulatory, or other subjects. We encourage you to send your suggestions to David Bart at jbart1964@gmail.com for publication in a future issue of the Proceedings.

Radio's heroes are either forgotten or overblown. Howard Armstrong is an example of the former; if we take away his contributions, we are left with the shadow of radio in a pre-digital age. Meanwhile, the myth-making opposite extreme has Nikola Tesla placed in the driver's seat of today's innovation culture, raising a brilliant, tragic, and flawed figure to a god-like icon. What should we make of this?

The facts on Tesla are impressive enough, with the spectacular success of his polyphase alternating current (AC) system—120 years later it shows no signs of being outmoded. He did work, much of it at the pioneering level, on hydraulics, lighting, motors, turbines, meters and engines. He invented vertical take-off and landing (VTOL) aircraft, albeit unrealizable as described. And he invented the simplest and most basic aspects of wireless (as we will see, not "radio") control, now enjoying a renaissance with drones and the Internet of Things.

Yet for some inventions, Tesla's "source inventor" rubric is foggy, because of overgeneralized and vague descriptions, limited embodiments, and outrageously incorrect physics therein. Today's myth origins come about chiefly from titillating newspaper interviews and ghostwritten pulp magazine articles from some 80 years ago. For reasons beyond reason, these cultural throw-aways have resurfaced (blame the Internet) and morphed Tesla into a contemporary superman. We seem to need Tesla the myth. But the greater the myth, the greater the need for sobering reality.

The greatest example of the "Tesla-is-God" assertion is his alleged invention of radio frequency (RF) wireless/radio. It is a blatant reality distortion—from an electromagnetic standpoint, Tesla's wireless system did not work as described by his patent claims, perhaps the biggest gaffe in the modern era of invention, and one that likely prevented him from a billion dollar (equivalent 2016) payday, and the Nobel Prize, both of which went to Guglielmo Marconi.

In this context, Tesla's oft-cited U.S. patent from 1897—"System of Transmission of Electrical Energy" (No. 645,576)—has twists only caught by those long-skilled in patent wording and claim construction. The patent's disclosure, its general description, does, indeed, swing to the realm of communication: resonance and passbands (that is, syntony) spoken here. But the patent claims—what Tesla was *granted* as an inventor—make the fatal and foolish mistake of marrying the equipment to a far-field propagation mechanism, indeed a wrong one, without a separate equipment patent claim breakout. Here are the key phrases, which appear multiple times, to wit:

"... causing a propagation flow ... by conduction through the earth and air strata ... receiving at a distant point ..."

The sky and the earth both as a conducting substitute for wires? For a conducting sky wave there is a heck of a lot of blanketing insulator to deal with first. Unless we ignore the fact that radio waves can propagate in a vacuum, with no actual conductors needed, Tesla was first to *describe the basic tools,* but not first to *invent*, RF communication. He received no source patents invoking RF propagation. Instead, Tesla was requiring, as described elsewhere in the patent, a breakdown of the air dielectric into a conductive (what we now call plasma) and included syntonic equipment. No wires, plenty of conductor, but no radio propagation either. To Tesla, "spark" wasn't just a mechanism to generate waves, but to conduct them, over long distances as well.

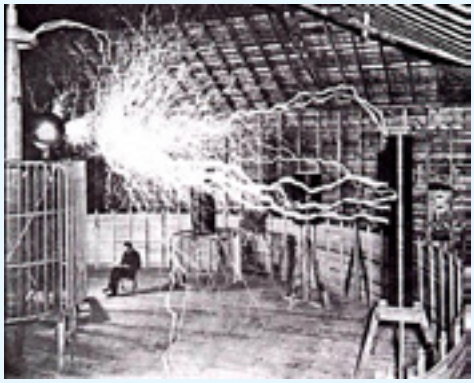
Based on his Colorado Springs, Colo., studies of lightning, where his wireless apparatus detected distant lightning strikes—through what is now known as its "QRN," i.e., RF electromagnetic interference pulses—Tesla must have surmised that lightning was *conductive* long beyond its visible distance (an incorrect hypothesis). To wit: Tesla was making an artificial lightning-tuned telegraph. Ouch! Your smart phone and Wi-Fi do not work this way. There is no "sky conduction." In contrast, the Marconi compendium of patents never invoked any form of sky conduction. From an invention standpoint, Marconi's system was different—or so it seemed.

Tesla missed the boat, but the U.S. Supreme Court revisited the debate in a 1943 decision (*Marconi Wireless Telegraph Co. vs United States*), almost fifty years after invention, that bestowed upon the post-mortem Tesla the title of wireless (radio) inventor nonetheless, through the vague phrase of "anticipated by Tesla." This often misunderstood and highly ambiguous statement refers to Tesla's *equipment*, not the propagation *mechanism*, invoking the disclosure of patent No. 645,576, but apparently not the patent claims, and ignoring the actual invention so granted and its dependence on sky conduction. "Anticipation" before a future claimed invention is, oddly, apparently not the same as saying you invented it, according to those skilled in the relevant body of law.

Since 1943, the documentation on Tesla has been scanty, hyperbolic, and often wrong. Indeed, John O'Neill's classic but fan-flavored biography of 1948, called *Prodigal Genius*, did as much to create misconceptions as to acquaint readers with some spectacular and bizarre Teslian facts. Fifty years later, enter the Internet and New Age, and suddenly Tesla is discovered and made an unlikely hero, with a devil-may-care nod to the facts.

There are plenty of facts to fall back on, and Tesla offerings in the last two years dig them out. First, there is Shedleski's compendium of Tesla patents, *Inventions of Nikola Tesla*, itself a pleasant rewind of a previous, out-of-print collection from 24 years ago. There are more than 100 U.S. patents listed. You can wrap your hands and mind around the complete Tesla with this patent compendium, and see if there is true genius afoot. You also can trace the inventive light dimming, as Tesla goes from Edison stature to occasional journeyman engineering consultant, supported partially by the Waltham Watch company. The vicissitudes of life chimed loudly for Tesla.

But the reality bites tore Tesla up. Few humans have ever seen his extremes in financial circumstances. Carlson's *Tesla: Inventor of the Electrical Age* takes the weirdness head on and provides a historian's penchant for nuggets. The basic facts don't change but the details do, and Carlson provides voluminous details on all aspects of Tesla. One key aspect of many: Tesla, while often merely portrayed as a victim, was truly one. He was shafted so many



This double exposure shows Tesla in a dangerous but bogus position, ostensibly reading poetry by the light of lightning from a huge Tesla coil.



1917: Anchored by a huge underground metallic coupling system, the Wardenclyffe tower refused to fall, and had to be dynamited for demolition.

times in business that his experience could not have been replicated today, because of more-restrictive anti-trust and monopoly laws, and more ubiquitous lawsuits.

From Carlson's tale, Tesla made fortunes and gave them up, partially due to the incompetence of others, such as George Westinghouse, who blew his early control in the AC/DC (direct current) wars, partially from Edison, who blew him off and then helped bury him with Marconi, and partially from his own supercilious and grandiose sense of how things should be done. Other fortunes were lost because of strange repugnance for … who knows what? Carlson is quick to point out that Tesla was as likely to turn down great opportunities, at least when he was famous, as to court them. Combine this with, as Carlson states, Tesla's growing obsessive-compulsive disorder (he was obsessed with the number "3"), germophobia, food restrictions (his preferred meal was the bloody drippings of a steak) and dysfunction in the human factor. These were enough to stop technology progress, ironically the one thing that kept Tesla going.

Tesla was a sick man, where the feedback of his circumstance may have aggravated his mental conditions into a pathological loop. Innovation is a tortuous path, eager to derail those weak or compromised in spirit. Certainly by the last twenty years of his life, the specter of Tesla— desperate, often broke, dubiously nurturing pigeons and escaping from people—must be one of the saddest chapter endings in American innovation, a topic Carlson takes to heart in the context of disruption, innovation, and Tesla. What a waste of a remarkable person.

While Carlson adopts an historian's narrative, Christopher Cooper's *The Truth About Tesla* takes on all comers. To Cooper, Tesla wasn't remarkable but a sometimes smarmy reinvention predicated on the work of others who were uncelebrated or kept quiet. Cooper's point of view is that innovation is a buildup of ideas and improvements, not the vision or perspicacious creation of a single genius. It's difficult to doubt Tesla's genius, but Cooper insists we dissect it. That's an interesting premise, and Cooper lavishly leads up to it by straightforwardly debunking the gross myths about Tesla (such as he was to be awarded the Nobel Prize, along with Edison), by providing excellent explanations of basic electricity, and by richly illustrating the book with a unique collection of pictures. This is a gorgeous coffee table book and a great list of "top five myths about Tesla."

Cooper uses testimony from patent and business lawsuits to give an unusual insight into the claims of Tesla as source inventor. Much is packed with facts, much is packed with dubious recollections, e.g., typical court testimony. Genius or not, Tesla does not come off well in these circumstances. But the author's point of view occasionally asserts and does not deliver. For example, Cooper leads to the premise that Tesla appropriated (consciously or unintentionally) the work of Italian scientist Galileo Ferraris, but does not provide proof. There is none. Cooper presents a sidebar suggesting that Tesla was likely gay, and a lover of pugilists. But the obsessive-compulsive Tesla apparently died a virgin and his confessed love was for a pigeon. Cooper suggests that Tesla took the inventive work of his assistant, but no proof of that exists either. Indeed, as Shedleski's compendium demonstrates, Tesla was almost exclusively a lone inventor. And the patent process deems absence of reporting co-inventors on patents with the severest penalties. Cooper leaves many "maybes" without resolution, but if that point of view is taken with some open-mindedness, the book is excellent and well worth procuring. Cooper brings us a Tesla deburred of myth and reasonably burdened with our warts of doubt.

What's missing from these three recent works is a better engineering picture of the big myth-monkey on Tesla's back: his wireless world based on his facility at Wardenclyffe on Long Island. The patent, "Apparatus for Transmitting Electrical Energy (No. 1,119,732), says little. And little is said that is newly substantive in these books. Tesla's grand project grows tiresome and we see the same mistakes about ionospheric resonances, a giant earth capacitor, lightning, standing waves, and the obvious hyperbole of global power and radio transmission, speculations merged with fact originally from Tesla's Colorado Springs experiments. Sigh.

Yet Wardenclyffe makes at least limited technical sense if you dig deep. That is, dig down. While the celebrated mushroom tower (shown in the patent and various pictures) presents the pretty part (actually a displacement current capacitive hat) of the incomplete 1901 installation, the true workings were massive, large, and went far into the earth. Tesla was trying to find and couple to lower loss resonances of earth ground that would propagate a reasonable distance by ground coupling to a large Tesla coil/transformer, along with his false premise of sky conduction.

This is not a crazy idea—in *very* modest doses. If that resonance is well below 25 kilohertz (kHz),

the wavelength of the wave may be, depending on the dielectric, up to 30 kilometers. In the near field, as is true in any electromagnetic wave, 1/r propagation dominates, and additionally strong evanescent waves, which exponentially decay, exist in the medium to roughly 1/10 of a wave distance. These will propagate power and/or information, with the RF displacement current completing the circuit. Some lossy power transmission may be done through RF ground conduction, with modestly lossy media, to distances of a *few* kilometers. Beyond that, losses are steep and fatal, as far field modes begin to dominate. Keep in mind that Tesla still did not understand nor recognize true RF propagation, but he knew how to use its effects.

One assumes that Tesla was hoping to find much lower resonances, thus scaling the distances to hundreds of kilometers. Of course, if that proved possible in the best of ground media, the size of the Wardenclyffe mushrooms would be skyscraper high. In any case, Marconi's "S" across the Atlantic, and the previously unexpected economies of scale afforded by the expanding polyphase AC power grid—Tesla's competing baby—ended the Wardenclyffe option, torn down in 1917.

So where does all this leave Tesla in contemporary terms? He was right (AC power) and wrong (RF/wireless). He was brilliant and he was borderline showman/crackpot. He was rich and he was poor. He was dynamic and he was lost.

Like it or not, Tesla was a major contributor to the modern world, and we have an obligation to accept him the way he was, and not the ways we would like him to be. There is no mystery to Tesla, but a person who did his best with what he had, and genius, by any measure, is what he had. With that, his inspiration is deserved and well worth remembering for ages hence.

ABOUT THE AUTHOR



Nathan "Chip" Cohen (W1YW) is CEO of Fractal Antenna Systems of Bedford, MA. A physicist with expertise in electromagnetics and imaging, he holds a Ph.D. in astrophysics from Cornell University. He was a radio astronomer at Harvard; MIT; Arecibo Observatory; Cornell; NASA; and Boston University, where he retired after 15 years as a professor. After 9/11 he spent a decade working with defense and government clients on counter IED antennae and other defense systems, and was security officer for the firm. An inventor since age 6, he holds 42 US and international patents along with many patents pending, on fractal antennas, real-time deconvolution; image compression; fractal electronics; invisibility cloaks; 3D printing/manufacturing, and the (recently patented) electromagnetic deflector shield. He is editor of the scholarly journal FRACTALS and Vice President of the Radio Club of America.

1) Inventions of Nikola Tesla.
Ty Shedleski.
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2) Tesla: Inventor of the Electrical Age.
W. Bernard Carlson.
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3) The Truth About Tesla.
Christopher Cooper.
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CALENDAR ▸

Visit the event calendar on the RCA website for the most up-to-date event information.

RCA EVENTS

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May 7, 2016

RCA FALL QSO PARTY
November 5, 2016

2016 RCA TECHNICAL SYMPOSIUM
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INDUSTRY EVENTS

UTC TELECOM & TECHNOLOGY
May 3-6, 2016
Denver, CO

AWA SPRING MEET & AUCTION
May 7, 2016
Bloomfield, NY

HAMVENTION
May 20-22, 2016
Dayton, OH

PCIA WIRELESS INFRASTRUCTURE SHOW
May 23-26, 2016
Dallas, TX

AFCEA HOMELAND SECURITY CONFERENCE
June 21-22, 2016
Washington, D.C.

APCO 2016
August 14-17, 2016
Orlando, FL

AWA ANNUAL CONVENTION
August 16-20, 2016
Bloomfield, NY

CTIA SUPER MOBILITY SHOW
September 7-9, 2016
Las Vegas, NV

AGL CONFERENCE
October 4, 2016
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2016 WIRELESS LEADERSHIP SUMMIT
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October 5-7, 2016
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SILENT KEYS

Silent key is a term of respect for a deceased amateur radio operator. The key in the term refers to a telegraph key, the instrument that all early amateur radio operators, as well as many contemporary amateur radio operators, have used to send Morse code. The term SK is used in telegraphy to indicate an end of transmission. Today, the term is commonly used within the radio community as a sign of respect and condolence regardless of whether the deceased was an amateur radio operator.



RAYMOND L. COLLINS
1932–2016

Raymond L. Collins, inventor, lifelong radio and communications devotee, ex-K7EQB / W6GLN, RCA Fellow, and President and co-founder of Telewave, Inc., passed away in San Jose, CA on March 15, 2016.

Ray Collins grew up in the rural Yakima Valley of Washington State, where he built and operated his own amateur radio gear, including a kilowatt amplifier. He worked for several local broadcast radio stations in the 1950's, among them KIMA-AM in Yakima WA, where he was the sales manager and also delivered commercials on-air.

Collins served 6 years in the Army and National Guard as a communications officer, and worked extensively with radio-controlled aircraft drones used for training combat pilots. Following his military service, he worked for RCA for 4 years, and then moved to Motorola for the next 16 years as a territory manager in the San Francisco Bay Area. He developed extensive knowledge of the Bay Area radio environment, and developed many contacts in the industry.

In 1972, Collins co-founded Telewave, Inc. to produce custom-built filtering and power monitoring devices which were not widely available at the time. He and Telewave quickly gained recognition within the communications industry by successfully reorganizing the well-known Mount Diablo radio site, which was plagued by interference and the inability to add new customers. Over his 44-year career at the helm of Telewave, Collin's reputation as a tireless worker, motivator, and innovator was legendary.

Ray Collins was a more than 30-year member and Fellow of The Radio Club of America, and a past president of the Communications Marketing Association. In 2015, Ray was honored to receive the Henri Busignies Memorial Award for his military service and many contributions to the field of radio communications. The dedicated staff and loyal team that Collins assembled at Telewave are pledged to continue his legacy through the company that he built.

The family requests contributions in Mr. Collins' name to The Radio Club of America, or a favorite charity.

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