Scanning the Issue

Special Issue on the Mobile Radio Centennial

A century ago, on June 3, 1898, Scottish scientist W. Thomson (Lord Kelvin) visited Italian-born British entrepreneur G. Marconi at his experimental wireless telegraph station in southern England. On that occasion, Lord Kelvin asked Marconi to send a message via his wireless telegraph; Lord Kelvin insisted on paying for this service, which, in his own words, was destined to become the first commercial wireless telegram, later known as a *Marconigram*. Later, wireless telegraphy and wireless telephony came to be known as *radio*.

How prophetic Lord Kelvin's words were. Since then, radio and the commercial use of electromagnetic waves in a broader sense has become an indispensable part of everyday life:

- electromagnetic waves power our microwave ovens;
- modern diagnostics in medicine can not be envisioned without electromagnetic waves;
- radio navigation and dissemination of precise time occurs via radio and/or the Global Positioning System;
- our knowledge of the world, our own planet, and other planets and stars is greatly enhanced by active and passive sensing and radio contacts with distant planetary vehicles;
- successful operations of special services and military operations depend heavily on diverse uses of radio and radar systems;
- the dissemination of information is effectively performed via radio broadcasting, audio, and television;
- point-to-point communications are performed via fiber optics and/or metal cables, microwave radio, and in the same way as a century ago by Marconi and others—via high-frequency (HF) radio.

We celebrate the centennial of Marconi and Lord Kelvin's experiment by describing some of the efforts of numerous individuals and companies responsible for the success of today's electronics industry, and mobile radio—also known as wireless, cellular, personal communications service, personal communications network, etc.—in particular.

Today, radio is a multibillion-dollar business, and cellular/personal telephones are becoming household items worldwide. In 1888, at the University of Karlsruhe, Germany, H. R. Hertz concluded his now famous experiments on radio and radar; only ten years after this event, in 1898, the first commercial wireless telegraph transmission was a rather minor event known only to a small group of professionals. A year earlier, in 1897, English scientist J. J. Thomson, a pupil of J. W. Strutt's (Lord Rayleigh, the Second Cavendish Professor of Physics in succession to J. C. Maxwell), discovered the electron. Another of Rayleigh's pupils, J. C. Bose from Calcutta, India, discovered a solid-state mercury coherer receiver in 1898. In the same year in Paris, Polish-born French scientist Maria Sklodowska Curie discovered thorium, polonium, and radium and showed that radioactivity is an intrinsically atomic property. Beginning in 1893, in the United States, in New York City, and along the Hudson River, Croatian-born American scientist N. Tesla experimented with wireless radio transmission. In April 1898, in Central Park, he demonstrated the first remote-control boat model. Around 1898, in the Russian Empire, near Petrovgrad, Russian scientist A. S. Popov experimented with wireless telegraphy. Siemens and Halske, then a well-known producer of telegraph equipment, was soon to become the producer of wireless telegraph equipment as well. Experiments in wireless telegraphy and in related equipment were under way in Italy, performed by the Italian Navy and with Marconi's cooperation; in France, where E. Branly developed a coherer receiver; in England by O. J. Lodge; in Germany by A. Slaby and F. Braun, and elsewhere. About the same time, Tesla claimed to have measured around the globe propagated signals at extremely low frequencies (ELF) and correctly described the earth-ionosphere waveguide frequencies; Tesla's claims, and/or measurement results, were theoretically confirmed in 1952 by German scientist Schumann; this phenomenon is now known as Tesla–Schumann resonance. Yet, the 24-year-old Marconi was one of the best radio system designers of the time; he was an expert in the practical design of wide-band antennas, crucial to the efficient transmission of broad-band radio signals generated by spark transmitters. Above all, as a hard-working chief scientist, he was the relentless promoter of his company's products and a true ambassador of radio.

Yet, all of these colossal achievements were barely noticed among other events of that epochal year 1898. In South Africa, the Boer rebellion was to explode a year later

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in the English-Boer War; in the Spanish-American War, the young American nation conquered Cuba and Puerto Rico, annexed Hawaii, and conquered Guam and the Philippines; in Geneva, Switzerland, Habsburg Empress Elizabeth was assassinated; the German statesman von Bismarck passed away.

The century of the commercial use of radio overlaps in a timely way with the American century. In retrospect, the great progress and the most successful commercialization of radio industry appeared in the United States; synergistically, excellent American communications systems have been contributing greatly to the prosperity of that country. Worldwide, the level of general prosperity is strongly correlated with the state of telecommunications, of which radio communications is a vital part.

This special issue concentrates on a narrow segment of radio communications called mobile radio. Officially, a mobile radio is a system where at least one of the users is on the move; scientifically, two users might be stationary, but the channel might be mobile, i.e., dynamic, as is the case with HF radio channels, and the overall system could be called mobile radio as well. This special issue consists of five parts. The first part consists of three papers mostly concerned with the history of radio and introductory material. The second part consists of three papers that provide an overview of satellite mobile communications, wireless multimedia communications, and millimeter-wave communications. The third part consists of two papers that address two important parts of a particular mobile radio system, i.e., digital speech coding and adaptive algorithms for code division multiple access (CDMA) receivers. The fourth part, consisting of two papers, addresses characterization and measurement challenges related to mobile terrestrial and satellite radio channels. The fifth part, consisting of three papers, discusses traffic performance, mobility modeling, security, and some aspects of wireless local loop.

We have the great pleasure of starting this special issue with two papers related to historic radio events. The first, "Marconi History," is by Corazza of the University of Bologna, Bologna, Italy, Marconi's native city. The author describes in detail some of the earliest radio experiments performed by young Marconi: the very first experiment in 1895 in Pontecchio (Bologna), Marconi's transfer to Great Britain, his maternal native land, the first experimental trials and the first commercial transmissions during the summer and fall of 1898, and his first transatlantic transmission attempt in 1901. The text is illustrated with sketches and photographs of those historic events.

The second paper, "Maxwell, Hertz, and German Radio-Wave History" is by Schwab and Fischer of the University of Karlsruhe, Germany, the place of Hertz's milestone experiments. The authors begin with a brief description of early achievements related to electricity by scientists outside Germany, i.e., Ørsted, Ampère, Faraday, and Maxwell. This is followed by a description of contributions made by nineteenth-century German scientists concentrated mostly around three university centers, i.e., Königsberg (now Kaliningrad, Russia), where F. Neumann, his pupil G. R. Kirchhoff, Bessel, Jacobi, Wichert, Wien, and others were born, studied, and/or worked; Göttingen, where J. C. F. Gauss, his younger colleague W. E. Weber, Gauss' pupil and second successor G. F. B. Riemann, and their numerous students made epochal discoveries and experiments in electromagnetism and telegraphy; and Berlin, where H. L. F. von Helmholtz, his colleague G. R. Kirchhoff, both previously at Heidelberg, and their numerous students, including Hertz, M. I. Pupin, and A. A. Michelson made colossal contributions to electromagnetism and radio. The authors then describe in detail a few different approaches in describing electromagnetism, including their own original contribution. This paper concludes with a brief description of the commercial aspects of early radio, including the rivalry between the British Marconi and German Telefunken companies.

The third paper, "Digital Cellular—Its Roots and Its Future," is by Uddenfeldt from Ericsson, Stockholm, Sweden. In the first part of his paper, the author briefly describes early cellular systems such as Nordic Mobile Telephony and Advanced Mobile Phone System (AMPS), which both are hybrid systems using digital signaling for system and maintenance purposes and limited transfer of data, as well as analog voice for communications. These frequency division multiplex access systems in the 1980's were augmented with all-digital time division multiplex access (TDMA) systems such as the Global System for Mobile communications (GSM), initiated by numerous European countries, digital AMPS in North America, and the personal digital cellular system in Japan, as well as a 1.25-MHz-wide CDMA system introduced by Qualcomm Corporation. After describing the state of the present commercial cellular/personal market and some of the ongoing research and standardization projects such as Universal Mobile Communications Systems, the author makes an educated forecast about wide-band TDMA and CDMA systems, which are expected to provide a wide range of wide-band data services in the near future.

In his paper "Satellite Systems for Personal Communications," Evans of Comsat Corporation describes the origins and evolution of mobile satellite systems such as Marisat, Inmarsat, MSAT/AMSC, OPTUS, N-star, Iridium, GlobalStar, ICO, Ellipso, Aries, and other systems. A brief description of some technical parameters is followed by a discussion on the likelihood of commercial success of various systems.

Hanzo from the University of Southampton authored the paper "Bandwidth-Efficient Wireless Multimedia Communications." The paper starts with the brief recent history of mobile communications, followed by a description of wireless multimedia concepts, sampling and coding theory, including speech and video coding, cellular concept, multiple access, modulation, and channel coding topics. An extensive list of references is also provided.

Andrisano *et al.* from the University of Bologna, in their paper "Millimeter Waves for Short-Range Multimedia Communication Systems," describe peculiarities of mil-

limeter waves around 30, 40, and 60 GHz in particular with respect to specific applications, which include intelligent transport systems, i.e., intervehicle and roadside-to-vehicle communications; wireless local area networks; and local multipoint distribution systems. A brief description of the propagation channel is followed by analysis of performance characterization, coverage and performance evaluation topics. An extensive list of references is also provided.

Speech coding, the efficient representation of natural analog speech in digital form, is one of the crucial elements for robust and efficient communication. Budagavi of Texas A&M University and Gibson of Southern Methodist University, in their paper "Speech Coding in Mobile Radio Communications," present an overview of currently important speech-coding standards; these include G.726 adaptive differential pulse code modulation at 32 kbit/s, G.729 codec based on conjugate structure algebraic code-excited linear prediction at 8 kbit/s, GSM regular pulse excitation long-term predictor at 13 kbit/s, IS-54 vector sum excited linear prediction at about 8 kbit/s, and many other advanced codecs. The emphasis is on understanding of a speech-coding problem and consequent solutions, which is followed with analysis of issues specific to mobile radio communications.

CDMA schemes are becoming the most popular access schemes for mobile radio applications, despite some potential drawbacks such as near–far sensitivity, complex power control, and spreading sequence design. In their paper "Adaptive Detection for DS-CDMA," Woodward and Vucetic from the University of Sydney review some adaptive detection techniques for direct-sequence CDMA signals. These include minimum mean square error, adaptive decorrelator, and multistage interference cancellation schemes, which might be employed in multiuser receivers. Some practical problems are briefly described, followed by suggestions for further research and a list of relevant references.

A sound technical design of mobile radio, and a vehicular one in particular, requires detailed knowledge of radio channel dynamics. In his paper "Sample Size Required in Error-Rate Measurement on Fading Channels," Bello of Bello, Inc., presents analytical and numerical results on the sample size required to achieve a specified root-mean-square error in estimating error rate for flat fading channels. Numerical results are presented for Lth order diversity reception of binary phase shift keying (PSK), differential PSK, and frequency shift keying signals and for different Doppler power spectra.

In their paper "Land Mobile Satellite Channel Measurement and Modeling," Loo and Butterworth of the Communications Research Centre in Ottawa, Canada, present an overview of channel measurement and modeling of ultrahigh frequency to Ka-band mobile satellite communications. Some of the models are applicable to geostationary orbit (GSO) and non-GSO satellite systems. An extensive list of references is also provided.

Early mobile radio systems involved a small to modest number of mobile users scattered over a small number of cells. Today, a network might consist of hundreds to thousands of cells, while the number of mobile units might run in the millions. In such an environment, networking issues, mobility, security, traffic measurement, modeling, and performance evaluation are of paramount importance. Orlik and Rappaport from the State University of New York at Stony Brook, in their paper "Traffic Performance and Mobility Modeling of Cellular Communications with Mixed Platforms and Highly Variable Mobilities," analyze some of these issues. Their approach allows computation of major teletraffic performance characteristics for cellular communications, including multiple platform types with cutoff priority for handoffs.

In their paper "Mobility and Security Management in the GSM System and Some Proposed Future Improvements," Mehrotra and Golding from Hughes Network Systems address in detail GSM signaling protocol with emphasis on mobility and security issues. To protect the user against potential eavesdropping and false authenticity, GSM has been reinforced with anonymity, authentication, encryption, and user and equipment identification.

Baugh *et al.*, in their paper "Personal Access Communications System: Wireless Local Loop and Mobile Configurations and Services," discuss interfaces and capabilities of existing and planned personal access communications systems. This system is expected to provide high-quality services such as toll-quality voice, integrated services digital network services, Ethernet connections, computer serial port connections, security alarm ports, etc.

Comments and Acknowledgment

This special issue was proposed by the first Guest Editor to the Radio Committee of the IEEE Communications Society about four years ago. It was planned to include a balanced participation from industry, system providers, and universities worldwide. We are living in very exciting and dynamic times, when an average IEEE engineer changes jobs, and companies, more often than the time necessary to conclude a special issue. This makes it nearly impossible to finalize the project at hand, especially one with a historic flavor. There have been a number of casualties, including potential Guest Editors and authors, who due to their new assignments were not able to participate as planned.

The Guest Editors wish to express their sincere thanks to the IEEE staff—J. Calder, Managing Editor, and his able assistant M. Scanlon—and to all authors and reviewers. The names of reviewers are listed in alphabetical order: D. Boudreau, J. Färjh, S. Gray, P. Guinard, R. Levine, J. Lodge, C. Mahle, A. McCree, P. Mermelstein, M. Moher, M. Sablatash, S. Tekinay, and A. Yongaçoglu.

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Andy D. Kucar *(Senior Member, IEEE) was born on the island Krk, Adriatic Sea, now Republic of Croatia.*

In 1967 and 1968, he did his apprenticeship in marine electrics and electronics on ocean liner and cargo ships. Sequentially, he worked as an Independent Contractor, Research and Teaching Assistant, Engineer, Research Associate, Project Leader, Head of Project Bureau, and since 1990 as a President. His assignments have included work in microwave laboratories developing circuits for analog and digital microwave and mobile radio systems, climbing radio towers on four continents, development and service of broadcast transmitters, participation in planning and development of fixed and mobile satellite systems, participation in domestic and international CCIR/ITU-R standards activities, participation in telecommunications projects for developing countries, development of channel simulators, Global Positioning Satellite receivers and inertial navigation system components (radio and fiber optics) for special customers, and education. In conjunction with his work, he studied electronics in Rijeka/Fiume, Ljubljana, and Zagreb, Yugoslavia, and in Ottawa, Canada. He defended four theses and acquired two federal licenses in three different languages and three different countries. During his studies, he was a Teaching Assistant in theoretical electrotechnics, radio communications, microwave circuits, radar systems, and power electronics; he also was a Research Assistant developing microwave circuits, broadcast transmitters, and analog and digital modems for terrestrial and satellite communications. In addition, he paralleled a year of business school and attended numerous Western business and leadership courses. He is an amateur ham radio operator. He has published numerous technical papers and reports, details of which can be found on his Web site.

Dr. Kucar is a member of the Institute of Navigation and the Association for Computing Machinery.

Jan Uddenfeldt *(Member, IEEE) received the Ph.D. degree in telecommunications from the Royal Institute of Technology, Stockholm, Sweden, in 1978.*

He currently is Vice President, Technology, with Ericsson Radio Systems, Stockholm. He is responsible for Ericsson's worldwide research and development (R&D) for cellular systems. This R&D is mainly carried out in more than 15 countries worldwide. He has been active in developing the digital time division multiple access cellular technology for the global system for mobile communication standard, as well as the North American and Japanese digital cellular standards.

Dr. Uddenfeldt is a member of the Royal Swedish Academy of Engineering Sciences. He received the Honorary doctor's degree from Lund University, Sweden, and was a three-time corecipient of the Eduard Rhein Technology Award.