# Some Examples of Current Industry and University High Frequency Research

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Although it is impossible to list all the research activities underway that relate to high frequency technology, this report will try to provide an overview of the types of projects being pursued, and note some general trends in research. Also remember that there are many more research activities that are indirectly related to high frequency electronics, including areas such as basic physics, chemistry and biology. We can list a few of the most active areas of research and the issues being explored:

*Wireless networks*—adaptability, capacity, expandability, interoperability...

*Antennas*—miniaturization, application-specific, mm-wave designs, embedded...

*Propagation*—mm-wave, ultra wideband, indoor, earth/space, multipath mitigation...

*Modulation and coding*—spectral efficiency, propagation-tolerant, high data rate, optical systems, ultra wideband, data compression, circuit requirements...

*Sensors*—a major research field, including biosensors, remote sensing, sensor networks, UWB imaging, integrating sensors into common devices (e.g. handsets), managing large amounts of sensor data...

*Nanotechnology*—micro electromechanical systems (MEMS), resonator structures, switching, multi-function integration...

*Device physics*—mm-wave and terahertz (THz) devices, optical lasers, modulators and detectors, low noise, high power density, improved IC processes...

*Circuit and system architectures*—software-defined radios, spatial processing, digital-RF interface...

*Future Systems*—Global networks, privacy and security, governmental communications policy....

## University Research

The Wireless Communications Networking Group (WNCG) at the University of Texas at Austin is a good example of the range of activities being pursued at several "wireless-oriented" universities.

*Modulation and Coding*—Current work includes using the space-time codes to use different levels of error protection and spatial diversity to different parts of a digital video stream. The main theme being explored is the tradeoff between the channel coding, spatial diversity and source coding to arrive at an optimum codeword based on the end user requirements and the fading channel characteristics. This scheme can be useful in wireless video communications.

*Network Management*—A set of advanced techniques known collectively as *multi-user detection* has been researched heavily over the past decade as a method of achieving the highest cumulative data rate with large number of uncoordinated users. WNCG's research attempts to put this theory to use, developing plausible prototypical system designs for existing multi-user detectors. This work covers diverse areas such as power control, channel estimation, complexity-management, and multi-carrier modulation.

*Distributed Sensor Networking*—The next generation of networking applications and technologies has the potential of embedding sensing and actuating capabilities in the network so as to support a variety of monitoring and controls applications. Some applications will require stringent quality of service guarantees. For example, one might jointly track the wind speed and the density of a given pathogen to create evolution models aimed at determining the source and/or support decision making for containing the problem.

To support a wide range of applications, distributed among a large number of users, while achieving high sensor utilization, two complementary problems are being investigated: What are fundamental characteristics and requirements of estimation and control applications drawing spatio-temporal data from networked sensors; and what types of network support and resource/traffic management mechanisms will be critical to enable wide-spread shared usage of such networks. In such networks, one can expect unpredictable bursts of traffic, network hot spots, and degradation in performance.

*Antennas and Propagation at Millimeter Wave Frequencies*—Wireless networks continue to move higher in frequency, where greater modulation bandwidths are viable. Within the next couple of decades, wireless broadband devices, capable of transmitting, receiving, and storing gigabits of data per second, will become available. WNCG researchers are exploring, through measurement and theory, the propagation characteristics at these frequencies. Work is also underway in computer-aided-design, modeling and simulation methods for predicting coverage and interference in these frequency bands of the future. This research is sponsored in part by NSF.

*Miniaturized Antenna Design*—As the size of wireless hand-held devices shrinks, the demand for miniaturized antennas is increasing. However, antenna miniaturization impacts antenna efficiency and bandwidth, two critical parameters in high data rate, low power consumption devices. Some of the projects being worked on include developing a new class of multiband, low-cost printed antennas for wireless devices operating in the 0.9 to 6 GHz range, developing compact, ultra wideband antennas for spread spectrum communications and impulse radio, and designing polarization and pattern diverse antennas in a small volume for mobile handset terminals in multiple-input multiple-output (MIMO) communication systems.

The work at this university is complemented by similar work at numerous other institutions, as well as by many other specific areas of research. Carnegie-Mellon University's Antenna and Radio Communications Group has explored areas that are good examples of research that focuses on specific applications:

*RF Distribution in Buildings using HVAC Ducts*—

An alternative method of distributing RF in buildings is to use the heating and ventilation ducts as waveguides. Waveguide loss is low, and this method may lead to more efficient RF distribution than radiation through walls or the use of leaky coax. Further, the use of existing infrastructure could lead to a lower-cost system. Experimental demonstrations have included channel delay-spread measurements and WaveLAN data transmissions between three floors in Roberts Hall on the CMU campus using duct-assisted propagation.

*Super-Resolution Focusing Using Time-Reversal Techniques*—Multipath propagation is present in both indoor and outdoor environments. Recent research has focused on using these multiple propagation paths to enhance the radio channel. The term "super-resolution" is used to refer to an improved spatial focusing of power from an antenna array beyond what is predicted by the Rayleigh criterion. An increase in scatterers in the environment should allow an increase in the effective numerical aperture of the antenna array. By using time-reversal techniques, this project strives to provide focusing of electromagnetic power at desired locations.

*High-speed Wireless Disk Drive*—The goal of this project is to develop an extremely high speed (600 Mb/s) wireless communication system suitable for hard drives within a limited range (radius less than 5m), and with extremely low transmitted power spectral density to minimize interference with existing wireless technologies. A wireless disk-drive interface can dramatically increase the convenience of many portable computing applications, and can also be used to create disk arrays.

## Sharing Research Ideas and Results

In recent years, cooperation among universities and industry has increased dramatically. Research groups investigating a particular problem may be national or international, academic-only or industry-academia partnerships.

For example, The Broadband Wireless Project within CITR (Canadian Institute for Telecommunications Research is investigating radio and network issues in outdoor broadband wireless systems, e.g. LMDS and MMDS. This project involves involves researchers from Carleton University, CRC (Communications Research Centre), l'Ecole Polytechnique, l'Université Laval, University of Manitoba, McGill University and University of Toronto. Currently, there are five industrial partners: Alcatel, Bell Canada, Harris Canada, Nortel Networks and Norsat International. Similar groups exist for many other areas of investigation.

## Industry Research

Industry research can be divided into two areas: proprietary research that targets the company's product development and manufacturing processes, and industry-wide research that involves the environment in which the company's products will operate. The best example of the latter is work on wireless networking standards such as the various IEEE 802 groups, Bluetooth, ZigBee, and all the wireless "telephone" network protocols.

We get little data about proprietary research other than announcements of performance milestones, and eventually, the information contained in the related patents. On the other hand, industry-wide research is handled publicly in standards development meetings, in sponsored university research (and the flood of papers published by professors and graduate students), and at professional conferences and forums.

Whether application-focused or basic science, research is what enables the development of new products. We encourage all research efforts, small or large, by induvuduals or at large institutions.