Communications Research Centre Canada
An Agency of Industry Canada

Centre de recherches sur les communications Canada
Un organisme d'Industrie Canada

Spectrum R&D Program

FY 2005/2006

Canada

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Spectrum R&D Program FY 2005/2006

1- Introduction

This report provides a summarized version of the final reports and presentations produced as a result of the various R&D projects undertaken by CRC under the Spectrum R&D program, sponsored by SITT/DGSE during the fiscal year 05/06. A summary description is presented for each R&D project. It includes the context of the project, the work done and the results achieved, as well as a list of the main publications produced as a result of the work. These summaries have been grouped under key topics for ease of reference. The SITT funding for the Spectrum R&D program in FY 04/05 was $336K. CRC provided $433K in O&M and $220K in funding from other sources, and the equivalent of 22 FTEs for total program funding of $2,733K.

2- Broadcast projects

B-15 Advanced techniques in DTV

DGSE: J. Dadourian
CRC: G. Gagnon, Y. Wu, X. Wang, K. Salehian, D. Prendergast, B. Ledoux, S. Laflèche, C. Nadeau, M. Guillet

This multi-year project continued during FY 05/06 to further the documentation of DTV broadcasting techniques and DTV receiver characteristics, and to initiate the consideration of a technical improvement to 8-VSB ATSC DTV system used in North America.

a) DTV distributed transmission system

CRC continued its work on the Distributed Transmission Systems for DTV by contributing a novel data transmission scheme using a CRC-developed Transmitter Identification sequence to the ATSC standard A/110: "Synchronization for Distributed Transmission Networks." This will help identify the source of in-band interference when common channels are used and could also be used for geolocation in indoor environments.

b) DTV receiver measurements

A number of 8-VSB receivers were tested at CRC, to evaluate their performance under different laboratory conditions and different scenarios of field capture. Advanced VSB (A-VSB) system backward compatibility was also tested with ATSC legacy receivers.

c) DTV indoor reception

The planned 8-VSB indoor field tests using a Single Frequency Network (SFN) could not be carried out because of delays in setting a suitable repeater in downtown Ottawa and the shutting down of the Manotick experimental DTV station. A new SFN arrangement is expected to be established in the future to conduct these tests. However, iterated-decision equalization techniques that combine maximum ratio combining from multiple receive antennas and block decisions feedback equalization have been studied to improve indoor ATSC DTV reception. This block based iterated-decision equalizer allows the equalization to be implemented in frequency domain and significantly reduces the complexity compared to the conventional decision-feedback equalizer. A patent application has been submitted for this technology.

Simulated DTV coverage of the planned Ottawa single frequency network

d) Advanced VSB proposal

CRC was involved in the evaluation and backward compatibility tests of the Samsung and Rhode & Schwarz Advanced-VSB proposal. The proposed technique can be used for synchronization of SFN, adding extra training sequences to improve the VSB reception, introducing additional channel coding for file transfer (like DVB-H), etc. The A-VSB technology has been designed for fixed, portable (pedestrian) and mobile applications. The proposal is in its early stage and has not yet been finalized for the ATSC. CRC has been studying the principles and the potential of this new technology for DTV applications. Collaboration is expected with Rhode & Schwarz to re-install a SFN in Ottawa to test A-VSB.

e) Impact of wind turbines on TV broadcasting

CRC was asked by the CBC to collaborate on a study of the impact of wind turbines on TV reception because of their usual proximity to the TV transmission sites. Some processing and analysis of data collected by the CBC was done to generate early findings, which were presented to the Spectrum 20/20 in November 2006. A three-year joint project funded by the *Fonds Québécois de la recherche sur la nature et les technologies* started in June 2006. The impact of the wind turbines on TV broad-casting will be evaluated analytically at CRC in collaboration with Laval University based on turbine models, height of the TV transmission tower and turbines, frequency of the television signal, materials used for the turbines, etc. Equalizer performance will also be studied since the performance of the equalizers in dispersive channels is likely to make a significant difference for DTV reception. Once the impact analysis is done, field tests will be conducted to verify the results from the study. The mitigation efforts will also be studied, including how to choose sites for wind turbines given existing television transmission towers.

f) Impact of unlicensed devices in the TV bands

Some tests were performed on DTV receivers to investigate the impact of the presence of unlicensed devices operating in the TV bands, as proposed by the FCC in its NPRM 04-186. It was found that the level of out-of-band emission suggested by the FCC for these devices would impact the TV reception. It was also found that presence of unlicensed devices on channels beyond N+/-1 may impact TV reception (DTV taboo channels). Some initial polarization discrimination tests between two UHF TV receive antennas separated by 10 m were done indoors and resulted in a range of 3.4 dB to 17.3 dB discrimination.

g) DTV return channel

Laboratory and field trial preparation work continued on the DTV Return Channel project throughout the year. A power amplifier for the Customer Premise Equipment (CPE) was designed and the development of a dual-band duplexer was completed, in order to complement the base station (BS) implementation at the Manotick site. Interference from transmitters in proximity of the BS was studied. The 8 MHz DVB-RCT equipment was upgraded with new software from Runcom but still did not meet all specifications. Final software updates as well as the 6 MHz version will only be available in the coming years. With the loss of the Manotick experimental DTV station, the field trials had to be scaled back to local field tests that will be conducted around CRC.

CRC contributed to the development of a Special Issue of IEEE Proceedings on Broadcasting dealing with digital television. CRC's contribution covered the Synchronized Distributed Transmission and Single Frequency Networks.

The results of the work are detailed in the following publications:

[1] W. Bretl, B. Meintel, G. Sgrignoli, X. Wang, M. Weiss, K. Salehian, "ATSC RF, Modulation, and Transmission," Proceedings of IEEE, vol.94, no.1, January 2006. pp.44-59, (Invited paper).

[2] J-Y. Chouinard, X. Wang and Y. Wu, MSE-OFDM: A New OFDM Transmission Technique with Improved System Performance, ICASSP'2005 vol. 3, pp.:865 – 868, March 18-23, 2005.

[3] G. Gagnon, W. Li, D. Prendergast, A. Vincent and Y. Wu, A Broadband Multimedia Datacasting System Using the ATSC DTV Infrastructure, Proceedings of International Broadcasting Convention 2005, Amsterdam, September 2005.

[4] S. R. Herlekar, K. Z. Matameh, H. C. Wu, Y. Wu, X. Wang, Performance Evaluation of an ICI Self-cancellation Coded Transceiver, IEEE Transactions on Consumer Electronics, vol. 51, no. 4, pp. 1110-1120, Nov. 2005.

[5] S. R. Herlekar, H. C. Wu, A. Srivastava, and Y. Wu, OFDM Performance Analysis in the Phase Noise Arising from the Hot-Carrier Effect, IEEE Transactions on Consumer Electronics, vol. 52, no. 2, May 2006.

[6] Y-T. Lee, S-I. Park, H-M. Eum, H-M. Kim, J-H Seo, S-W. Kim, B. Ledoux, S. Lafleche, Y. Wu, Laboratory and Field Test Results of Equalization Digital On-Channel Report (EDOCR), Proceedings of the NAB2005 Broadcast Engineering Conference, April 2005, Las Vegas, NV.

[7] W. Li, S. Laflèche, H. Liu, C. Nadeau, G. Gagnon, Y. Wu, and A. Vincent, Multipath and Burst Error Characterization on IP Data Transmission over ATSC DTV Channels, IEEE Int'l Symposium on Broadband Multimedia Systems and Broadcasting, April 6-7, 2006, Las Vegas, NV.

[8] K. Z. Matameh, S. R. Herlekar, H. C. Wu, Y. Wu, X. Wang, "Performance Evaluation of an ICI Self-cancellation Coded Digital Video Broadcasting Transceiver," IEEE International Conference on Consumer Electronics (ICCE'2006), Las Vegas, NV, Jan. 2006.

[9] D. Prendergast, Y. Wu, C. Nadeau, and G. Gagnon, The Integration of the Internet and Broadcasting for Rural and Remote Broadband Access, Proceedings of International Broadcasting Convention 2005, Amsterdam, September 2005.

[10] D. Prendergast, Y. Wu and B. Caron, The Convergence of Broadcasting and the Internet for Broadband Wide Area Interactive Television and Internet Multimedia Service, IEEE Radio and Wireless Symposium (RWS) 2006, Jan. 17-19, 2006, San Diego, CA.

[11] K. Salehian, Y. Wu, and B. Caron, Design Procedures and Field Test Results of a Distributed Translator Network, and a Case Study for an Application of Distributed Transmission, Proceedings of the NAB2005 Broadcast Engineering Conference, April 2005, Las Vegas, NV.

[12] X. Wang, Y. Wu, and J-Y. Chouinard, "Wireless Location Technologies and Application," accepted for publication in the EURASIP Journal on Applied Signal Processing (JASP).

[13] X. Huang, H. Wu and Y. Wu, Novel Pilot-free Adaptive Modulation for Wireless OFDM Systems, Wireless Telecommunications Symposium (WTS 2005), April 28-30, 2005, Pomona, CA.

[14] X. Wang, Y. Wu and B. Caron, DTV Transmitter Identification for Distributed Transmitter Networks and its Application in Position Location and a New Data Transmission Scheme, Proceedings of the NAB2005 Broadcast Engineering Conference, April 2005, Las Vegas, NV.

[15] X. Wang, Y. Wu and J.-Y. Chouinard, "System Design and Implementation of Multiple-Symbol Encapsulated OFDM," in Proc. IEEE VTC, pp.1043-1047, May 2005.

[16] X. Wang, Y. Wu, B. Caron and J.-Y. Chouinard, "A New Position Location System Using ATSC TxID Signals," in Proc. IEEE VTC, pp.2815-2819, May 2005.

[17] X. Wang, P. Ho and Y. Wu, Robust Channel Estimation and ISI Cancellation for OFDM Systems with Suppressed Features, IEEE Journal on Selected Areas in Communications, vol.23, no. 5, pp.963-972, May 2005.

[18] X. Wang, Y. Wu and J-Y. Chouinard, System Design and Implementation of Multiple-Symbol Encapsulated OFDM, Proceedings of IEEE Vehicular Technology Conference, May 2005, Stockholm, Sweden.

[19] X. Wang, Y. Wu and J-Y. Chouinard, A New Position Location System Using ATSC TxID Signals, Proceedings of IEEE Vehicular Technology Conference, May 2005, Stockholm, Sweden.

[20] X. Wang, Y. Wu, K. Yi, B. Tian and J. Y. Chouinard, "A Fast Synchronization Technique for DVB-H Receiver Using In-band Pilot and Cyclic Prefix," IEEE International Conference on Consumer Electronics (ICCE'2006), Las Vegas, NV, Jan. 2006.

[21] X. Wang, Y. Wu, J-Y. Chouinard and H. Wu, On the Design and Performance Analysis of Multi-Symbol Encapsulated OFDM Systems, IEEE Transactions on Vehicular Technology, vol. 22, no. 3, May 2006.

[22] H. Wu, S. Xi, and Y. Wu, New Robust ICI Estimation Using Distributive PM-Sequences in OFDM Systems, IEEE Wireless Communications and Networking Conference (WCNC) 2006, April 2006, Las Vegas, NV.

[23] H. Wu, and Y. Wu, A New ICI matrices Estimation Scheme Using Hadamard Sequence for OFDM Systems, IEEE Transactions on Broadcasting, vol. 51, no. 3, pp. 305-314, Sept. 2005.

[24] H. Wu and Y. Wu, Matrix Estimation Using Hadamard Sequences for Wireless OFDM Systems, Proceedings of the 62'nd IEEE Vehicular Technology Conference, Dallas, TX, Sept. 25-28, 2005.

[25] H. Wu and Y. Wu, A New ICI Matrix Estimation Technique Using M-sequence for Wireless OFDM Systems, Proceedings of the IEEE Globecom 2005, St. Louis, MO, Nov. 28- Dec. 02, 2005.

[26] H. Wu, S. Xi, and Y. Wu, New Robust ICI Estimation Using Distributive PM-Sequences in OFDM Systems, IEEE Wireless Communications and Networking Conference (WCNC) 2006, April 2006, Las Vegas, NV.

[27] Y. Wu and X. Wang, Transmitter Identification in Distributed Transmission Network and Its Application in Position Location and a New Data Transmission Scheme, Second International Forum of Digital TV and Wireless Multimedia Communications, Shanghai China, Nov. 4-5, 2005.

[28] Y. Wu, S. Hirakawa, H. Katoh, U. Reimers, and J. Whitaker, Global Digital Television: Technology and Emerging Services (invited paper), Proceedings of the IEEE, vol. 94, no. 1, pp. 1-7, Jan. 2006.

[29] Y. Wu, S. Hirakawa, U. Reimers, and J. Whitaker, Overview of Digital Television Development Worldwide (invited paper), Proceedings of the IEEE, vol. 94, no. 1, pp. 8-21, Jan. 2006.

B-16 Delivery of multimedia content in broadcasting

DGSE: J. Dadourian

CRC: D. Wang, G. Gagnon, L. Lu-Zhang, F. Lefebvre

This project was the continuation of work done in previous years on advanced video coding for multimedia, DTV based multimedia broadcasting, IP datacasting for mobile applications and multimedia broadcasting based on DAB.

a) Advanced video coding for multimedia

Since DCT-based video compression algorithms seem to have reached their full potential, new video codecs with high compression efficiency such as wavelet-based video coding have been investigated at CRC. Problems related to lossy wavelet-based algorithms were studied and a better algorithm was proposed resulting in more uniform quality of groups of decoded pictures and improved compression efficiency due to better wavelet coefficient coding, overlapped motion compensation and spatio-temporal motion prediction. The performance of the codec was found to be equivalent to the H.264, which is the most advanced video coding standard to date. New algorithms and techniques will be proposed to improve further the wavelet coder.

b) DTV based Multimedia broadcasting

Further to the previous year's study on the throughput, delay and error performance characteristics of IP data transmission over the ATSC DTV system, more in-depth investigations were carried out on the performance of IP data transmission in a noisy and multipath environment, as well as the error distribution at the IP level, to determine what additional forward error correction (FEC) is necessary for reliable IP data transmission in fixed and mobile environments. CRC proposed an error resilience scheme for IP data transmission over ATSC DTV channels by implementing Reed-Solomon codes at the IP layer. This approach is fully compatible with both the legacy ATSC transmission system and receivers. Tests of IP data transmission over ATSC DTV channels under AWGN and multipath showed that, in a noisy environment, the gain in terms of packet loss rate is around 0.5 dB of C/N. For multipath tests, the gains are 1.2 dB for CRC Dynamic Multipath, and from 0.5 dB to 0.8dB for single echo. It was concluded that smaller packets are more appropriate for reliable IP data transmission. Because of the steepness of the packet loss versus CNR curve of the ATSC system, performance improvement brought by the IP-FEC is limited in the case of noise, but less so in the case of multipath.

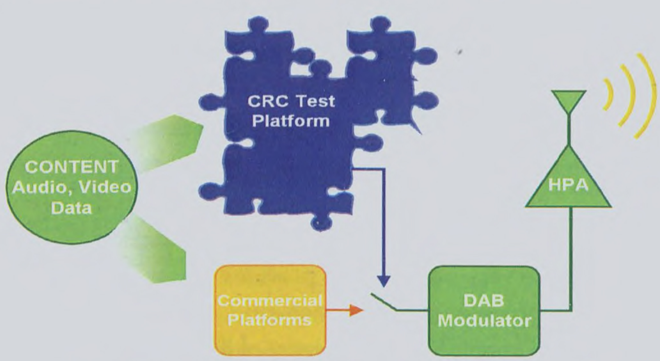
c) IP Datacasting for Mobile Applications

An IP-based file delivery platform was developed to deliver large files to the client platforms. A service announcement mechanism was also developed based on the IETF SAP/SDP protocols for automatic service discovery on the end-user side. The user-centric and Internet-like broadcast download manager proved to be very intuitive and provides a user experience that is similar to file sharing on peer-to-peer networks. On another front, new proposals and developments for the transport of IP packets were monitored in the WorldDAB Technical Committee meetings. This effort was, and continues to be, done under the Alignment TF that has the mandate of identifying an IP transport mechanism well suited for DAB. The planned report on IP datacasting has not yet been produced as DMB activities unexpectedly became higher priority in 2005. Also, important results of the WorldDAB Alignment TF are expected only later in 2006.

d) Multimedia broadcasting based on DAB

Digital Multimedia Broadcasting (DMB), which is based on the Eureka 147 Digital Audio Broadcasting (DAB) system, was developed in Korea and is operated in some countries to deliver high quality digital sound and multimedia services to fixed, portable and vehicular receivers. CRC organized and hosted the first worldwide L-Band DMB demonstrations in collaboration with ETRI, Samsung, LG Electronics and Pixtree in June 2005. Members of the Canadian broadcast industry, IC, CRTC and CBC were able to see experimental DMB services on DMB car and hand-held receivers. A mobile multimedia broadcasting (MMB) trial was organized in Montréal based on a two-year experimental license for an L-band MMB station, which will serve as a test bed for the evaluation and field trials of MMB technologies such as DAB, DMB, DAB-IP and DXB, and also as a demonstration system for local, national and international parties interested in learning more such as broadcasters, regulators, telecom and broadcast network operators, content producers, etc.

Efforts were spent on developing a DMB chain based on open source software (OSS) projects. Many encoders and decoders were evaluated and missing components were identified. A DMB content presentation platform was developed by reusing the MythTV open source personal video recorder (PVR). Two major software components were produced: a generic IP input for networked media sources and a new DMB parameters parsing library. These two components were successfully contributed by CRC to the MythTV project.



Mobile Multimedia Broadcasting transmission platform at CRC

e) Mobility improvement of DAB/DMB through dual receive antenna

The use of DAB/DMB transmission Mode IV in the 1.5 GHz band is desirable because it allows larger separation between DAB transmitters in single-frequency networks (SFN), resulting in fewer transmitters to cover the same service area and consequently lower costs for the broadcasters. However, one difficulty in using Mode IV at L-band is the performance degradation due to the Doppler effects for receivers moving at high speeds. An advanced COFDM demodulation technique based on a single receive antenna gave satisfactory performance for vehicle speeds up to about 150 km/h compared to about 100 km/h for a conventional DAB/DMB receiver in a typical urban mobile channel.

During FY 2005-06, research was conducted to characterize the performance of COFDM detection techniques based on two receive antennas. Two dual-antenna schemes were investigated. The first scheme is based on conventional differential detection (CDD) used in most DAB/DMB receivers currently on the market. The other scheme is based on the advanced COFDM differential detection technique developed at CRC. Simulation results showed that the CDD-based dual antenna receiver provides SNR gains ranging from 4 to 9 dB, over its single antenna counterpart, for vehicle speeds ranging from 4 to 93 km/h, in addition to extending the maximum vehicle speed for satisfactory audio service from about 100 to 155 km/h. The dual antenna receiver based on the CRC advanced differential detection provides SNR gains ranging from 5 to 10 dB, over the CDD-based single antenna receiver, for vehicle speeds ranging from 4 to 93 km/h. The maximum vehicle speed for satisfactory reception is extended from about 100 to 200 km/h.

The results of the work are detailed in the following publications:

[1] D. Wang, L. Zhang, and A. Vincent, "New method for reducing GOP boundary artifacts in wavelet-based video coding," IEEE Transactions on Broadcasting, vol. 52, No. 3, Sept. 2006.

[2] D. Wang, L. Zhang, and A. Vincent, "GOP-boundary artifact reduction using a new extension and sub-sampling method for wavelet-based video voding," Picture Coding Symposium 2006, April 24-26, 2006, Beijing, China.

[3] L. Zhang, "Embedded coding of the motion-compensated 3-D wavelet coefficients by concatenating spatial and temporal orientation trees," IEEE International Conference on Multimedia & Expo 2006, Toronto, June 2006.

[4] H. Liu, W. Li and G. Gagnon, "Robust IP data transmission over terrestrial DTV channels," IBC2006, Amsterdam, The Netherlands, Sept. 7-11, 2006.

[5] W. Li, G. Gagnon, H. Liu and A. Vincent, "IP over Terrestrial ATSC DTV Channels: Performance Evaluations on Data Transmission Throughput," IEEE Transactions on Broadcasting, Vol. 52, No.2, pp. 121-128, June 2006.

[6] W. Li, S. Lafleche, H. Liu, C. Nadeau, G. Gagnon, Y. Wu and A. Vincent, "Multipath and Burst Error Characterization on IP Data Transmission over ATSC DTV Channels," IEEE International Symposium on Broadband Multimedia Systems and Broadcasting 2006, Las Vegas, NV, April 6-7, 2006.

[7] G. Gagnon and W. Li, "An ATSC Broadband Multimedia Datacasting System: Implementation and Tests," IEEE Broadcast Symposium 2005, Washington, D.C., Oct. 12-14, 2005.

[8] J.-M. Bouffard, F. Lefebvre, "An IP based file delivery platform for mobile multimedia broadcasting," published in the IASTED Wireless Networks and Emerging Technologies Conference proceedings, July 2005, Banff, Canada.

[9] L. Zhang, L. Thibault and R. Boudreau, "Dual-antenna Techniques for DAB/DMB Receivers," IBC 2005 Conference, Amsterdam, The Netherlands, Sept. 8-13, 2005

B-17 In Band On Channel (IBOC) Digital Radio Technologies

DGSE: J. Dadourian CRC: R. Voyer, A. Carr, D. Camiré

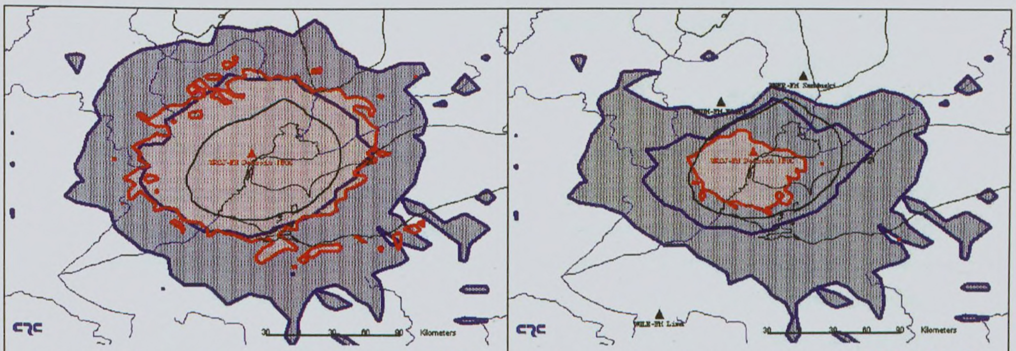
This project was established in FY 04/05 to assess the impact of IBOC on the FM band. In the U.S., the radio broadcasters decided to standardize and operate digital radio broadcasting within their FM channel allocation (in band on channel) using a technology called HDRadio. The National Radio Standard Committee (NRSC) has developed the HDRadio standard based on the technology proposed by iBiquity. The FCC has authorized the use of this technology and a number of HDRadio transmitters have been installed. This project provides technical insight on the IBOC technology, monitoring of the NRSC activities, results of simulations and opinions formulated on the basis of information available.

Relevant technical information on IBOC was gathered and assembled into a compendium in the previous year. It contains over 100 individual documents, including CRC reports, system specifications, test reports, FCC filings, white papers and technical articles. It also addresses the results of system tests and field trials in the U.S.

New functionalities were added to the CRC-COVLAB coverage analysis software in order to simulate an IBOC system and study interference scenarios to and from existing FM stations. A detailed search functionality was added to allow any FM broadcasting station in Canada (IC database) or the U.S. (FCC database) to be imported based on call sign, frequency range and/or search radius for interference calculations. A "weighing factor" was also added to the FM receiver model to allow consideration of co-channel, and first, second and third adjacent channel interference from analog and digital sources. The coverage analysis software already allowed for hybrid FM IBOC digital emission and both analog and digital reception.

Results of IBOC simulations carried out with CRC-COVLAB were presented to Industry Canada, the CRTC, Canadian broadcasters and Mexican broadcasters. In the absence of interference, the IBOC coverage corresponds to the analog FM stereo contour. However, the IBOC coverage is significantly reduced when considering the presence of neighboring first adjacent analog FM transmitters. The opposite is also true where FM stations that turn on the

IBOC signal will produce a coverage reduction for first adjacent nearby FM stations, compromising their protected contour.



Detroit Analog FM Mono and Stereo & Digital IBOC | Detroit Analog FM Mono and Stereo & Digital IBOC Considering 1st Adjacent Analog FM Stations

The results of the work are detailed in the following publications:

[1] B. McLarnon, BDMComm, "IBOC Update September 2005," September 2005.

[2] B. McLarnon, BDMComm, "IBOC Update May 2006," May 2006.

[3] B. McLarnon, BDMComm, "Coverage Extension for the FM IBOC System," V1.4, January 2005.

[4] B. McLarnon, BDMComm, "An IBOC System Compendium," V1.6, February 2005.

[5] B. McLarnon, BDMComm, "Interference Calculation Parameters for FM IBOC," February 2005.

[6] M-P. Lussier, "FCC Station Import," April 2005.

[7] M.-P. Lussier, "IC Station Import," April 2005.

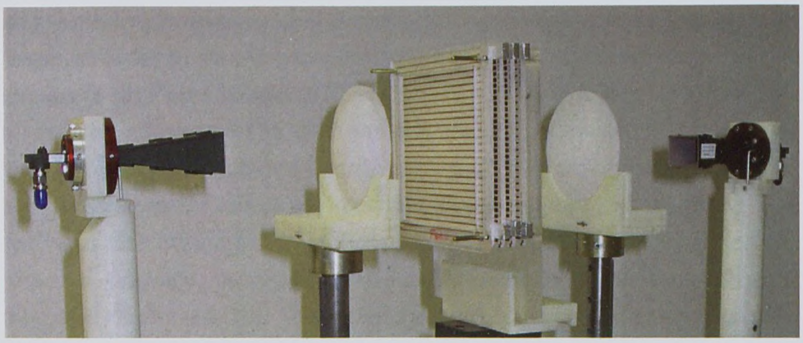
3- Satellite project

FB-09 Investigation of close-in antenna pattern suppression techniques

DGSE: R. Trenholm CRC: M. Cuhaci, J. Shaker

This project was a continuation of an investigation started in FY 02/03 on the possibility of reducing the size of the Ku-band receive antenna for the StarChoice Direct-to-Home service in the presence of small orbital spacing with a Mexican satellite (1.9°). The goal is to develop techniques to suppress radiation into regions close to the main lobe of a high gain antenna by adding a multi-layer angular filtering structure onto the aperture of the antenna.

In FY 03/04, computer simulations were conducted to determine the parameters for a 3rd order Chebichev filter with specific angular response using a cascade of frequency selective surfaces. The actual filter was designed and fabricated along with the test set-up to carry out the filter measurement. In FY 04/05, work was done on generalizing the use of this filter in cascade, as well as verifying experimentally the performance of the resulting close-in antenna pattern suppression. Four new surfaces were designed, fabricated and tested, and the results are in line with the trends observed in the simulations.



Test setup for the set of four frequency selective surfaces.

In FY 05/06, more in-depth understanding of the phase response of these frequency selective surfaces was gained to improve the design process of the Chebichev filter. It was found that the cascade of two frequency selective surfaces forms a Fabry-Perot resonator. The angular response of the multi-frequency selective surfaces was quantified in terms of the separation and tilt angle between these surfaces, in order to achieve the required close-in antenna pattern suppression. It was found that changes of 0.1 mm in surface separation resulted in significant modification of the frequency response. Such tight tolerance will lead to the need for more complex fabrication techniques. Work continued on this research project in FY 06/07 and some encouraging results were obtained. They will be described at the EMTS-07 conference in Ottawa (summer 2007) and in a report on this second phase.

The results of the work are detailed in the following report:

[1] "Angular filter study to modify the beam of a high gain antenna (Phase 1)," Jafar Shaker, CRC Technical Note No. CRC-TN-2006-001, September 2006.

4- Terrestrial Wireless projects

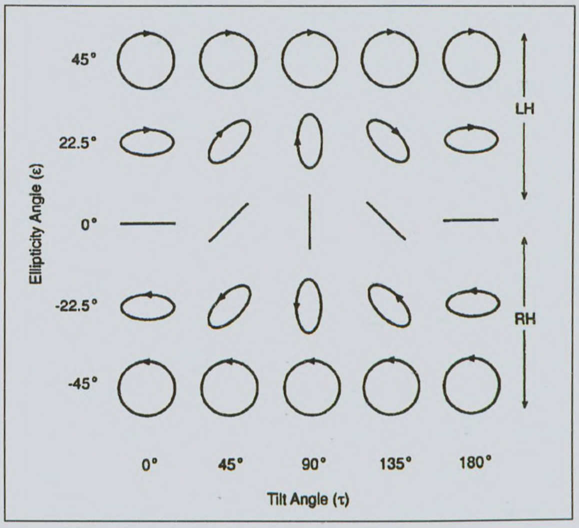
4.1- Propagation studies

T-27 Polarization Loss Model for use in Band Sharing studies

DGSE: W. Taylor CRC: D. Rogers

The ITU-R Joint Task Group 6-8-9 is considering the possibility of using antenna polarization discrimination to improve band sharing between fixed and mobile terrestrial services and broadcast satellite service. Investigation of this polarization discrimination considered the main beam as well as the non-main beam intersections between the satellite signal and the terrestrial antenna, and both linearly- and circularly-polarized satellite signals interfering with a linearly-polarized terrestrial antenna. The study considered the various factors required to establish some limits on allowable polarization-interference margins and the basic conclusions were:

- to estimate the minimum polarization loss for an incident nearly-circularly-polarized wave incident upon a "linearly-polarized" receive antenna, the tilt angles of the incident wave and receive antenna must be assumed to be collinear;
- the polarization senses of the wave and antenna must be assumed to be identical;
- the axial ratio of typical "circularly-polarized" satellite antennas ranges from 1.0 to 2.0 dB with a nominal average value of 1.5 dB;
- reasonable values of the cross-polarization discrimination for nearly-LP terrestrial receive antennas are 20 dB for typical applications and 15 dB for digital TV systems;
- with the aforementioned assumptions, the nominal minimum polarization loss that may be applied for typical "circularly-polarized" satellite signals interfering with typical "linearly-polarized" terrestrial systems is −1.7 dB. For digital TV systems, a nominal minimum polarization loss of −1.25 dB is allowable. These values are applicable within the 3 dB beamwidths of the satellite transmit antenna and receive terrestrial antenna. Less polarization loss will apply outside the antennas' main beams.



The results of the work are detailed in the following publications:

[1] ITU-R JTG6-8-9/61, "Analysis of polarization loss for circularly polarized satellite signals interfering with linearly polarized terrestrial systems" (Canada), International Telecommunications Union, Geneva, 17 August 2005.

[2] "Polarization Loss Model for Use in Band Sharing Studies," D. V. Rogers, CRC Technical Memorandum No. VPSAT 01/06, 10 February 2006.

T-25 Propagation related to 4G (2.5-6 GHz) and Public Safety at 4.9 GHz

DGSE: P. Vu CRC: R. Bultitude

This project investigated the propagation aspects related to the following two applications:

- 4G technology: propagation for mobile systems operating between 2.5 and 6 GHz (IMT2000 and beyond).
- 4.9 GHz: propagation for mobile public safety: possible range, reliability, building losses, propagation environment.

A semi-analytical technique for making accurate IMT2000/WCDMA mobile link performance (i.e. BER) predictions on measured or modeled channels had been developed in a previous Spectrum R&D project. This method can provide accurate assessment of channel response estimates and self-interference effects for high data rates and low spreading factors as expected in some 4G applications. Wideband (10 MHz) propagation data had been collected non-simultaneously at 1.9 GHz and 5.8 GHz in Ottawa in a mobile environment (35 km/h). Comparison of performance at 1.9 GHz and 5.8 GHz for WCDMA/IMT2000 was made based on measured data and predictions were confirmed concerning the increased fading (10 dB), the greater fading range, the greater requirement for channel protection and the ensuing greater costs to achieve the same performance at 5.8 GHz. It also demonstrated the trade off between the reduced spreading factors to increase transmission rates and the increased severity of self-interference.

Although the existing 5.8 GHz data was a good basis for analysis and scaling in frequency to address the use of the 4.9 GHz band for public safety, a wideband propagation measurement was undertaken at 4.9 GHz in a fixed operating scenario, where communication services are provided between a vehicle parked outside a building acting as a communication centre, and rescue crews with equipment inside the building. Transmission loss (0 to 40 dB with 14 dB median), rms delay spreads (9 to 30 ns with 16 ns median), equivalent CW envelope fading characteristics (16 over 72 measurement locations exhibited Rayleigh fading, the others were Rician with K ranging from −1 to +11 dB), and frequency correlation characteristics were measured. The results were compared with results in open literature.

Transmit vehicle and broad face of the building section where the measurements were made, showing the antenna mast elevated from the rear of the vehicle housing the transmitter.

The results of the work are detailed in the following publications:

[1] Bultitude, R.J.C., et al , "Comparison of Expected Performance on B3G Spread Spectrum Mobile Radio Links at 1.9 and 5.8 GHz Based on Propagation Measurements," Proc. 64th Semi-Annual IEEE Vehicular Technology Conference, Montreal, Quebec, Canada, September 25-28, 2006.

[2] Bultitude, R.J.C., et al , Measurement and Modelling of Emergency Vehicle-to-Indoor 4.9 GHz Radio Channels and Prediction of IEEE 802.16 Performance for Public Safety Applications, Proc. 65th Semi-Annual IEEE Vehicular Technology Conference, Dublin, Ireland, 22-25 April 2007.

T-29 Propagation Study for 4.9 GHz Public Safety Systems

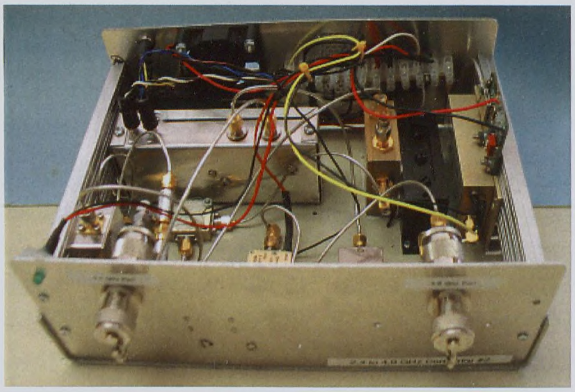
DGSE: P. Vu CRC: J. Fournier

The goal of the project was to provide analytical and practical information on the propagation characteristics of wireless systems operating in the 4.9 GHz band in support of public safety.

Three "connectorized" frequency converters (2.4 GHz to 4.9 GHz) were developed to work in conjunction with commercial off-the-shelf 802.11b/g wireless LAN equipment units to perform range, margin and link availability tests in two different environments: line-of-sight (LOS) and urban.

The line-of-sight measurements were conducted in Carp, Ontario between a vertical antenna mounted 3 m above ground level and a second antenna at 2.5 m above ground level. It was found that the maximum operational distance for a typical street level deployment is 1.4 km. GIS-based RF propagation predictions were made using TIREM, and the difference between predicted and measured levels was no greater than 4 dB.

The non-line-of-sight (NLOS) urban measurements were conducted in downtown Ottawa to emulate a rapidly deployable mesh type system at street level to provide communications to public safety organizations such as the police force, fire fighters, paramedics, etc. Three types of radio channel conditions were measured: visible LOS, building diffraction and building blockage. For visible LOS, the results showed that the maximum operational range for an urban corridor is about 720 m. In the case of building diffraction, the maximum distance is 80 m when a single building is in the way. When a client is hidden by two building corners, the quality of the received signal is poor and communication is questionable. Acceptable communication was achieved through new building constructions while no communication was possible through ~100 m of building on a 220 m link. The prediction model Pathloss 4.0 was found to overestimate the losses by some 35-70 dB and is not a valid tool for this kind of environment.



"Connectorized" 2.4 GHz to 4.9 GHz frequency converter unit

The measurement campaign and data analysis indicated that the coverage/range was small when deployed in a typical omni-directional point-to-multipoint configuration. Range extension capabilities such as higher transmit power, higher directivity and higher gain antennas and/or smaller RF channel bandwidths should be considered when implementing the regulatory framework. The EIRP limit should be determined based on the operational range needed in the various environments. Then, the expected number of users within this range and the traffic profile per user should guide the determination of the optimal RF channel size to satisfy the system requirements. This would lead to the suitable RF channelization plan in support of the regulatory framework for the introduction of public safety networks in the 4.9 GHz band.

The results of the work are detailed in the following publications:

[1] "RF Performance in the 4.9 GHz Band for Public Safety Systems," Joe Fournier, Simon Perras, et al, CRC Technical Memorandum No. TWS-TM-06-07-05, 29 August 2006.

4.2- Spectrum monitoring and interference studies

T-02 Digital Analysis System for the Integrated Spectrum Observation Centre

DGSE: D. Paskovich CRC: M. Dufour, F. Patenaude

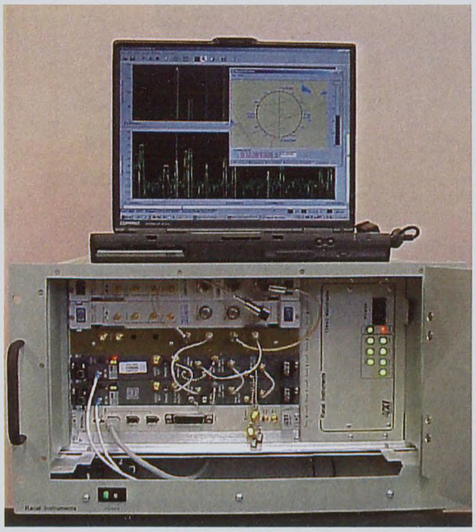
The purpose of this multi-year project is to develop and deploy the next generation of spectrum monitoring tools for the Integrated Spectrum Observation Centre. The Spectrum Explorer® (SE) software has been enhanced in the areas of direction-finding measurement and calibration, automatic modulation recognition (AMR), systems signal parameter extraction, frequency measurement accuracy, short duration signal measurements and new hardware support.

The implementation of the Spectrum Explorer® in the Integrated Spectrum Observation Center of IC was investigated and was found to only involve the addition of a data transfer interface. However, a tighter integration using "Remote Desktop" seems to be a better approach and will be implemented in FY 06/07. The possibility of using the Rhode & Schwarz FSP and FSL series spectrum analyzers as the RF front end of the Spectrum Explorer® was analyzed. Because of the competitive price of this equipment, the faster frequency sweep, the capability of broadband measurements, the extent of the frequency range (10 kHz to 40 GHz) and the better precision in signal amplitude measurement (0.5 dB), the integration of these spectrum analyzers will be a welcome improvement to the Spectrum Explorer®. It was found that the data architecture of these spectrum analyzers is essentially compatible with that of the Spectrum Explorer®. The integration work will be done in FY 06/07.

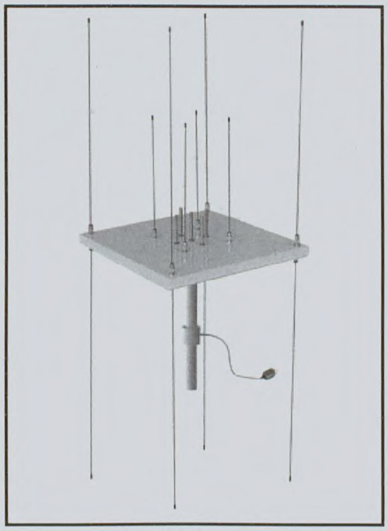
In view of implementing a smaller footprint Spectrum Explorer®, investigation was made on the SI-8614-3 Nanoceptor tuner and it was found that the required specifications are met. However, it uses a serial port for control and data interface which does not support multi-threading. Newer products from the same company seem to be more promising since they use a higher performance firewire interface.

The communication signal analyzer has been improved with the inclusion of a larger number of signal types for the modulation classifier and the capability of reporting positive and negative AM modulation indexes. Two GPS devices and their USB interface were successfully integrated to the Spectrum Explorer®.

An automatic calibration method, including software routines and switching of the noise source in the direction-finding antenna, was added to the system. This feature is now easily accessible in the software and does not require any special procedure. The phase calibration accuracy for the overall sensor is about 1° rms. The noise source and switches are typically integrated in the direction-finding antenna but a special version was developed to cover cases where access to the antenna is limited. In this case, the noise source and required switches were included in the tuner and sampler box.



Spectrum Explorer®



VHF/UHF Direction-finding antenna

Investigation continued on the design of a direction-finding antenna that would cover the range 100 MHz to 1 GHz. It was found that two antennas optimized for their specific frequency range would be required to cover this frequency range. A first demonstration antenna was built and delivered. Its precision was shown to be around 8-10° rms. More work is needed on calibration in the anechoic chamber to achieve a direction-finding precision of better than 5° rms. Some preliminary work was done on the development of direction-finding techniques using amplitude comparison rather than phase comparison for frequencies above 2 GHz. A new switching card to implement the classic Watson-Watts method was developed and will be evaluated below 1 GHz before extending the development beyond 2 GHz.

T-24 Evaluation of the Interference Potential of PLC Systems in the Frequency Range 1-80 MHz

DGSE: J.C. Brien, H. Khomusi CRC: W. Lauber, M. Zhang

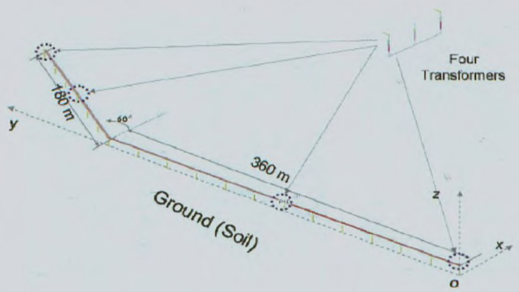
High data rate power line communications (PLC) or broadband over power line (BPL) is a new way of bringing the Internet into homes. In the past few years, methods have been developed for signals in the 1.7-80 MHz range to bypass transformers and travel on low and medium voltage (MV) power lines up to about 35 kV. However, because the signals travel on the local distribution lines and on the in-house wiring, all of these wires could form a large radiating antenna from which the signals could radiate. Some studies have predicted large increases in the background noise levels especially at

HF which could wipeout the reception of low level signals.

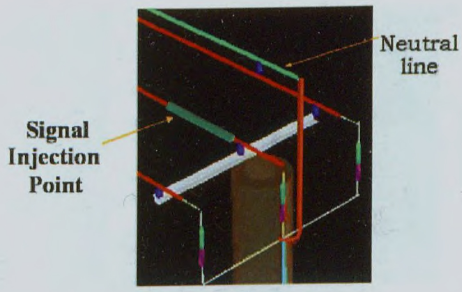
The first year of this project consisted of evaluating the proposed PLC technologies and their system architecture. A computer model of a typical medium voltage overhead three-phase power line wiring configuration was developed to characterize a real power line wiring structure with several combinations of devices, such as transformers, other conductors in the vicinity and line turns. The modeling results showed that radiation is due to signal reflections at resonant frequencies on the wires generated by impedance discontinuities, and that a limited number of very narrow specific frequencies radiate effectively from the power lines. However, 98% of the time the power lines would not radiate PLC signals in the far field.

In a region or city with full-scale deployment of medium voltage PLC service, it is expected that numerous branches, wiring configurations, transformers, appliances and loads will be joined and compounded almost at random. Cumulatively, it is highly possible for those resonant frequencies to appear at any location of the spectral range of 1-80 MHz. Such power line wirings would then become very efficient radiators.

Computer simulations continued in the second year to augment the findings and better understand the PLC signal behavior. The model for the power lines was refined with grounded transforms, an added neutral line, corner angles and resistive conductors to obtain a more realistic model of the "wire transmitting antenna." The model implemented was similar to the Amperion system using Wi-Fi to end-users. The measurement procedure set forth in the FCC Report and Order released on October 28, 2004 was analyzed in terms of the distances from the radiating wire and the signal source, and the field strength limits below and above 30 MHz.



Medium Voltage Power Line geometry with four transformer loading



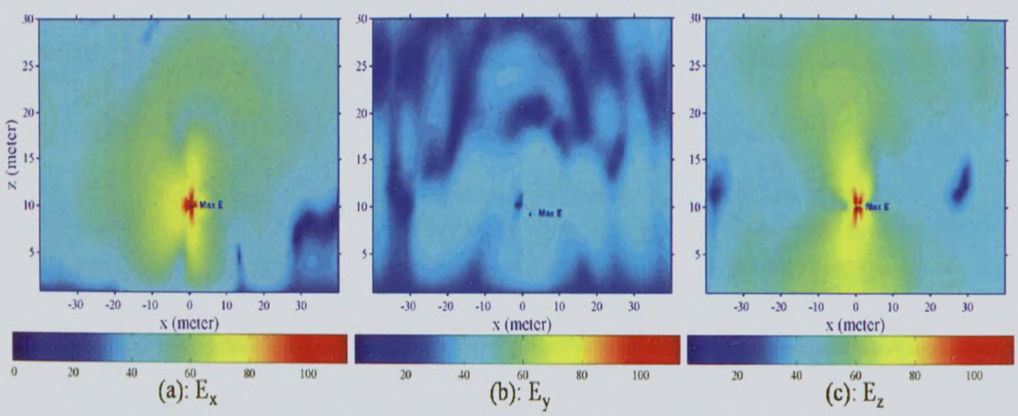
PLC signal injected at the front end of the middle line

The results supported the FCC's measurement guidelines and allowed for the development of specific comments for the measurement methodology for PLC systems in Canada. Since measurements within a wavelength of the injection point were found to miss the peak field strength by 5 dB, it was suggested to use an adjustment factor of 5 dB to estimate the true peak value from the FCC measurement methodology. Further, when measurements are done at specific fractions of wavelengths, true local peaks should be found by sweeping the distances around these points within $\lambda/10$.

It was found that the maximum field strength exceeds the FCC limit by a level that increases with frequency and reaches its maximum value at 23 MHz and then decreases up to 30 MHz. For an injected power spectrum density of −50 dBm/Hz in the 21-24 MHz range, the maximum field strength level is about 18 dB higher than the FCC limit. At 30 MHz, this value exceeds the FCC limit by more than 20 dB because of the different limit set above 30 MHz.

Simulation results concur with the FCC methodology that the field strength only needs to be measured at one antenna height (1 m above ground) below 30 MHz. However, above 30 MHz, the field strength varies significantly with height and the maximum field strength should be found by varying the height between 1 and 4 m. There is a concern about the appropriateness of using only a magnetic loop antenna to conduct the measurements below 30 MHz as specified in the FCC procedure, rather than using an active dipole antenna to directly measure the electric field. The problem comes from the fact that the magnetic dipole is calibrated in terms of the equivalent electric far-field strength. This has been shown not to hold for such near-field measurements in recent Ofcom measurements.

Reviewing the parameters of the simulated PLC systems with the manufacturers would help make these simulations more accurate. Near and far zone simulations would also need to be undertaken.



Electric field strength (dBμV/m) on the x-z cross section of the wire at 25 MHz for the third case studied measured at 147 m from the signal injection point.

The results of the work are detailed in the following publications:

[1] "Evaluation of the Interference Potential of Power Line Communication Systems (Phase II)," Ming Zhang and Wilfred Lauber, CRC Technical Memorandum No. TWS-TM-05-06-02, January 2006.

[2] "Evaluation of the Interference Potential of Power Line Communication Systems (Phase I)," Ming Zhang and Wilfred Lauber, CRC Technical Memorandum No. TWS-TM-05-02-09, January 2006.

[3] Zhang, M. and Lauber, W., "Evaluation of Interference Potential of PLC System," the 10th IEEE Internation symposium on Power Line Communications and its Application, pp. 291-296, Orlando, FL, March 26-29, 2006.

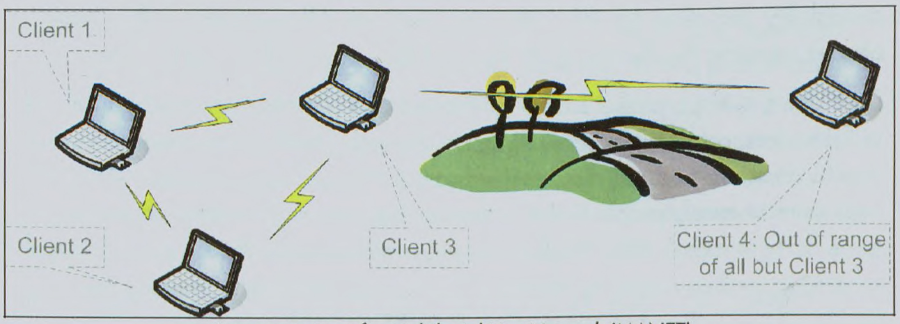
4.3- Improvement of spectrum usage

T-34 Characterization of bandwidth Requirements for wireless Ad Hoc Networks

DGSE: P. Vu   CRC: J. Fournier, L. Lamont

The purpose of this project was to clarify the bandwidth requirements for a mobile ad hoc network (MANET). Ad hoc networks support communication between adjacent nodes within a peer-to-peer network configuration. The MANET technology takes ad hoc network capabilities a step further by also enabling multiple hop wireless connectivity among mobile network nodes. This is accomplished by adding a dynamic routing capability to each node, thereby enabling them to automatically and dynamically self-organize into arbitrary peer-to-peer network topologies as determined by the relative positioning among nodes at any given time.

MANET architecture is highly effective in dealing with challenging operational conditions such as infrastructure failure, intermittent nodal connectivity, non-line-of-sight (NLOS) environments and nodal mobility. Such networks may be used to augment the functionality of commercially available Wi-Fi products where no communications infrastructure exists, and rapidly deployable, autonomous wireless networks are temporarily needed.



Representation of a Mobile Ad Hoc Network (MANET)

Practical analysis and field study using 802.11b-based ad hoc networks were conducted in order to determine the amount of bandwidth required to deploy survivable MANET of various sizes for various applications. The main challenges of a MANET architecture are the support of a dynamic routing mechanism used to maintain updated routes, and the communication between mobile nodes in the ad hoc network.

The additional bandwidth requirements of such a solution are driven by the added overhead required for the transmission of control packets, and an increase in packet collisions due to the multi-hop nature of the solution. This impact on bandwidth is quantified by performing throughput tests in laboratory conditions and outdoors, and by evaluating the support for voice over IP.

The results obtained reveal that multiple hop networking is possible using a MANET protocol such as the optimized link state routing (OLSR) protocol developed at CRC. TCP data was successfully transmitted at a rate of 4.34 Mbps over a single hop, with 0.08 Mbps transmitted over five hops. The same tests were conducted using UDP type traffic and yielded 5.02 Mbps and 0.1 Mbps respectively. The single hop rates are similar to those available from typical 802.11b systems. The added overhead of the control packet and routing mechanism was found to be negligible for a 1 hop OLSR enabled link. It is, however, not the case for links with two or more hops, as enabled by the OLSR protocol.

Theoretically, to support the multi-hop feature in a time domain duplex (TDD) system, a 50% drop in throughput is expected for each additional hop. However, results show drops of more than 60% and sometimes up to 80% in throughput. These results can also be attributed to the MAC protocol used in 802.11 (carrier sense medium access, CSMA) as well as the scaled down topology that was used to run the tests. Adding quality of service (QoS) to the OLSR protocol to select a route based on certain metrics would likely improve the throughput. For instance, routes can be selected based on bandwidth availability and allow for the data to be sent over different paths rather than always selecting the shortest path, as does the current OLSR mechanism.

Data rates, latency, packet loss and jitter values were also extracted from the test data to support single or multiple simultaneous VoIP communications. Results demonstrated that, for most scenarios, the numbers of supported VoIP calls were inversely proportional to the numbers of hops. Further work needs to be done to assess other medium access control protocols such as a TDMA scheme as well as including quality of service mechanisms to improve the quality of the VoIP communication on MANET.

The results of the work are detailed in the following publication:

[1] "Characterization of Bandwidth Requirements for Mobile Wireless Ad Hoc Networks," Joe Fournier, CRC Wiselab Report, September 11, 2006.

T-30 Investigation of adaptive frequency utilization in cognitive radio for efficient spectrum usage

DGSE: C. Cook   CRC: P. Vigneron

This project undertook the examination of the technical attributes of a cognitive radio (CR) system so that it can undertake spectrum management and interference control. An adaptive frequency-hopping (FH) technology was used as the physical modulation format. This technology is such that it emits energy at any given frequency for no more than several hundred microseconds. This serves to temporally distribute transmitted energy over the identified available spectrum, further reducing the potential interference to a given legitimate user. Most importantly, the use of adaptive FH allows many users to coexist within the same available bands, increasing the overall utilization of allocated but unused spectrum, thereby increasing the efficient use of the spectrum as a whole.

For the purpose of this study, the terrestrial wireless FH system was to operate in the midst of existing fixed UHF allocations, where licensed users may start and stop transmitting. The cognitive radio (CR) scheme measures the occupancy of the band before using it, and then chooses hopping frequencies in a pseudorandom manner. Then, other users measuring the same band occupancy obtain different hopping sequences, allowing users to coexist without requiring frequency coordination. As licensed users commence transmission, the pool of available frequencies for the FH system will be reduced, and hopping sequences will be modified accordingly.

The work consisted of developing a simulation where the spectrum is populated with typical conventional fixed frequency modulations using typical channelization and a number of CR communication links. Adaptive algorithms were used to scan the spectrum for "grey-space" (i.e., spectrum with low level of occupancy for a given time duration), then a probability-based algorithm was developed to select sub-bands deemed to be desirable for use so that appropriate frequency hopping patterns could be generated to avoid existing licensed users. Other physical layer parameters could also be adaptively adjusted such as bandwidth, number of modulated sub-bands, transmit power and system data throughput.

It was shown that by varying the number of parallel hopping sub-bands, the occupied bandwidth and the probability density of the hopping sequences, communications links could be maintained in the presence of severe interference, jamming and multi-user interference. In addition, the CR techniques allowed operation closer to sources of interference due to the increased robustness of the waveform, giving operational improvements. In high propagation loss environments, both multi-user interference and jamming are so highly attenuated that performance of the desired user is less limited by interference. The importance of accurate propagation model parameters and relative position among users was demonstrated. In a real CR system, an estimate of network propagation losses will therefore be needed to achieve better transmission reliability and better spectrum utilization

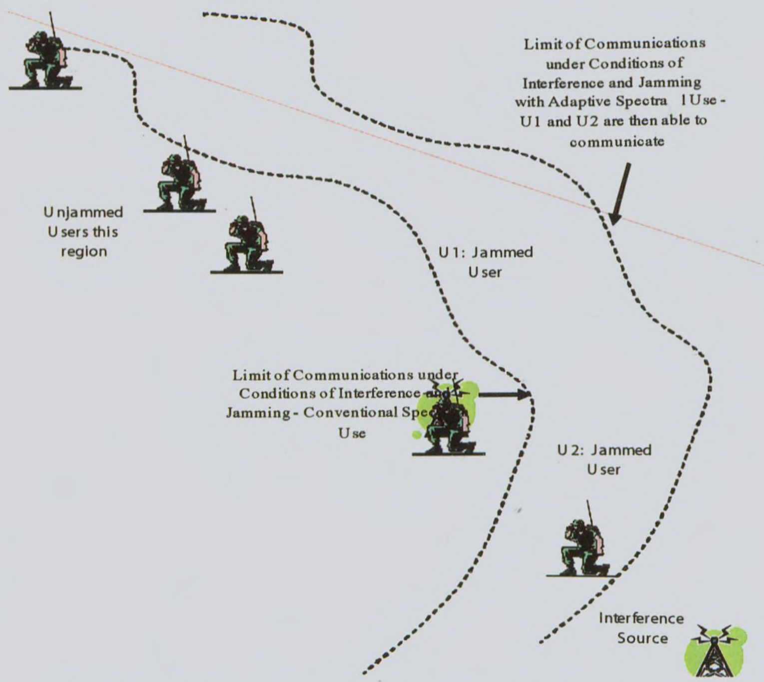


Illustration of increased interference-free coverage with adaptive spectral use

The results of the work are detailed in the following publications:

[1] "Performance of cognitive radio waveforms in a terrestrial environment with propagation loss," P. J., Vigneron, X. Tang and C. Brown, CRC Report, January 2006.

[2] P.J. Vigneron and C. Brown, "Multiband Frequency Hopping for High Data-rate Communications with Adaptive Use of Spectrum," in Proc. VTC Spring 2006, Melbourne, Australia.

4.4- Ultrawideband (UWB) Technologies

T-17 Spectral Density Shaping, Interference Mitigation, Detection, Identification and Location of UWB Signals

DGSE: S. Hanna CRC: J. Lodge, M. Sablatash

This project, continued from previous years, is in support of DGSE efforts for the development of a regulatory framework and standards for the introduction of UWB technology for short-range wireless communication. Investigations continued into the measurement techniques that will enable development of appropriate channel models for UWB signal propagation. The effects of pulse shaping, modulation, power spectral density shaping schemes and other UWB system characteristics were studied.

Mathematical theories were developed for power spectral density shaping and whitening as modulation techniques to minimize interference. The effects of propagation over models of channels were analyzed in the context of sharing with licensed systems, particularly satellite and fixed services.

Wavelet pulse shapes were investigated for their capability of mitigating interference into UWB signals as well as interference from UWB into other services. Other methods for mitigation of interference by UWB were analyzed such as the creation of a slot in the spectrum of the UWB pulse through modulation to avoid interference to a narrowband signal occupying this part of the spectrum, and at the same time, render the UWB signal more robust to the narrowband signal since it would not use this part of the spectrum to recover its signal.

CRC participated in the discussions of the ITU-R CNO TG 1/8 (meetings held by DGSE and the RABC) and contributed to the Canadian documents submitted to the final meeting of the ITU-R TG 1/8 in Geneva in October 2005.

The results of the work are detailed in the following publications:

[1] M. Sablatash and M. Sellathurai, "Wavelet pulse shapes for mitigation of interference into UWB communication systems," Proc. of the Ninth Canadian Workshop on Information Theory, McGill University, Montreal, June 5-8, 2005, pp. 367-370.

[2] Michael Sablatash, "Channel Models for Ultrawideband Wireless Communications," Proc. 2005 17th International Conference on Wireless Communications (Wireless 2005), vol. 1, Coast Plaza Hotel, Calgary, Alberta, July 11-13, 2005, pp. 83-101.

[3] Michael Sablatash, "Mitigation of Interference into OWN Signals Using Wavelets," a poster presentation for the USC Workshop on Short-Range Ultra-Wideband Radio Systems, Santa Monica, California, April 11-12, 2006.

[4] Michael Sablatash, "More Precise Channel Models, Interference Problems and their Mitigation, and Detection of UWB Signals for Spectrum Monitoring," a poster

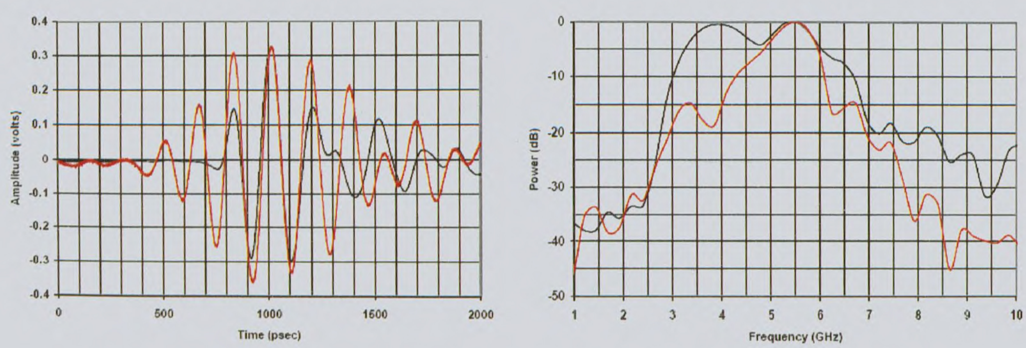
presentation for the USC Workshop on Short-Range Ultra-Wideband Radio Systems, Santa Monica, California, April 11-12, 2006.

T-36 Ultrawideband Measurements and Sharing Problems

DGSE: S. Hanna CRC: W. Lauber, A. Chubukjian

This project is also continued from previous years in support of DGSE efforts for the development of a regulatory framework and standards for the introduction of UWB technology for short-range wireless communication. CRC provided support and participated in three working groups of Task Group 1/8: 1) UWB Characteristics, 2) Impact of UWB Devices on Radio Communication Services and 3) Measurement Techniques. TG 1/8 completed its work in October 2005.

CRC developed and purchased a number of UWB sources that were used in the development and testing of measurement techniques. Development and characterization of UWB antennas was also carried out and further work was done on studying the distortion of UWB pulses by narrowband communication antennas. Gain and return loss and measurements were conducted on three commercial narrowband antennas to characterize the amount of filtering that the UWB signal will experience when going through these antennas. Two of these antennas were optimized for the 5.6 GHz band and the other one was for the 2.4 GHz band. Unlike a UWB antenna, the narrowband communication antennas were not designed to pass the full UWB signal without distortion. These antennas act as bandpass filters in the range for which they were designed, and create pulse distortion and extra oscillation in the time domain as could be seen from frequency and temporal responses of the transmitted UWB pulse. These antennas may offer additional protection to the victim communication system operating in the bands where the antenna has poor response.



Temporal and Frequency Responses of the D-Link 5.6 GHz Antenna to the Time Domain UWB Signal (Black – no antenna, Red - received signal on the D-Link 5.6 GHz antenna)

Work was done on the development of UWB monitoring devices. Since UWB is an underlay technology, most of the signals should be buried in the noise background. The range of UWB devices is about 10 m and always less than 100 m. The UWB devices should be easy to find physically, and a simple measurement device should allow a verification that they are operating in the UWB frequency allocation. Any monitoring device will need an UWB antenna that passes all relevant frequencies in the range of 3.1 to 10.6 GHz. A two-element array antenna was proposed to give unambiguous angle of arrival information for UWB signals. The monitoring device will probably not have elaborate demodulation schemes. A very high speed digital sampling scope could be used to detect these signals.

Experimental measurements were also conducted to determine the impact of UWB transmission on a 5 GHz WLAN 802.11a. It was found that a measured throughput of 7.8 Mbps (50% of maximum throughput) can be achieved with a signal-to-interference ratio of 3.5 dB, measured at the input of the receiver in the case of a conducted interference. In the case of radiated interference, the results indicated that having two UWB interference sources as close as 20 cm to the victim receiver could degrade the receiver performance significantly, depending on the received signal level. A separation of at least 0.5 m between the antennas of the victim and offending devices would ensure optimal system performance.

The results of the work are detailed in the following publications:

[1] "Ultra Wideband (UWB) Measurements and Sharing Problems," Siva Palaninathan and Wilfred Lauber, CRC Technical Memorandum No. VPTWS-TM-05-06-04, March 2006.

[2] "Experimental Study of Conducted and Radiated UWB Interference and its Impact on the Throughput of 5 GHz WLAN Receivers," Ibrahim Haroun, Siva Palaninathan and Wilfred Lauber, CRC Technical Memorandum No. VPTWS-TM-05-06-06, March 2005.

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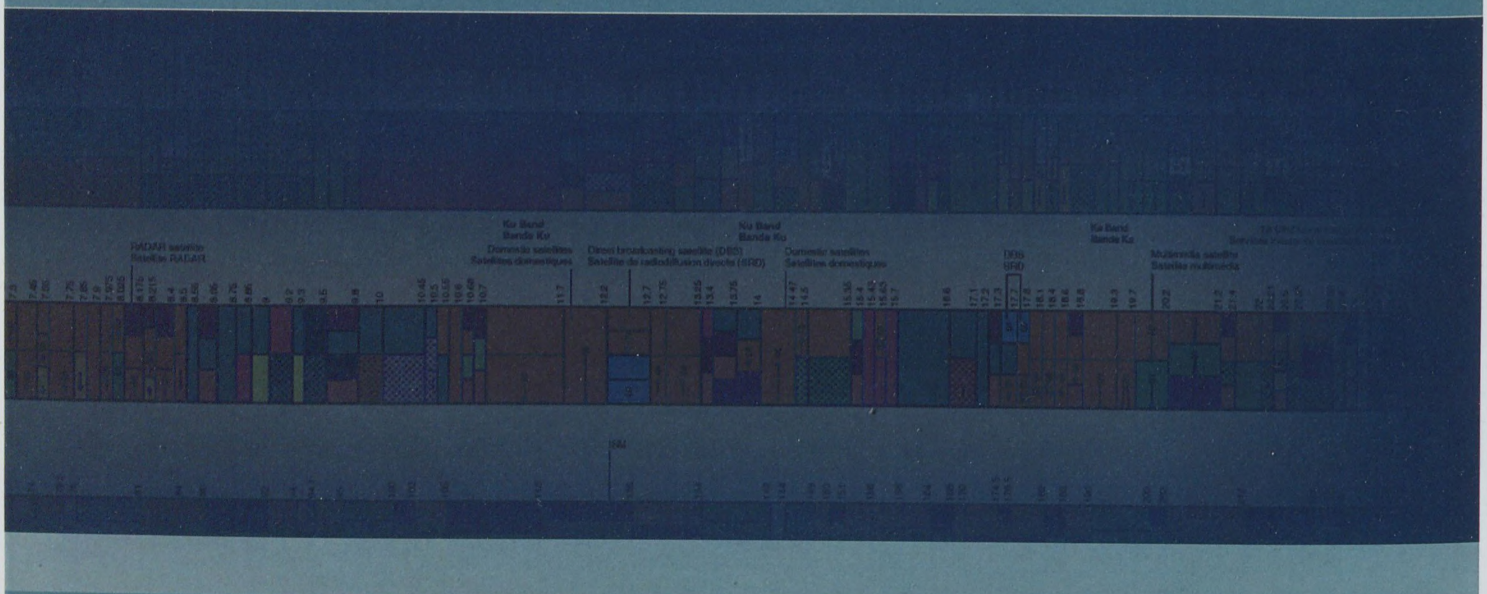
RADAR satellite
Satellite RADAR
Ku Band
Bande Ku
Domestic satellites
Satellites domestiques
Direct broadcasting satellite (DBS)
Satellite de radiodiffusion directe (SRD)
Multimedia satellite
Satellites multimédia