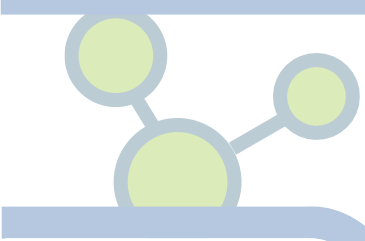
Communications Research Centre Canada
An Agency of Industry Canada

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



RURAL AND REMOTE >> BROADBAND ACCESS PROGRAM

THIRD YEAR REPORT

2004 05

Canada

CRC

"Today's technological transformations are intertwined with another transformation - globalization - and together they are creating a new paradigm: the network age."

United Nations Human Development Report, July 2001

INTRODUCTION

According to the International Telecommunication Union (ITU, January 2005), Canada is fifth in the world for broadband access penetration. However, because of its size and often sparse population, special measures need to be taken to keep apace towards reaching all Canadian citizens.

The federal government has already taken steps towards this end with the Broadband for Rural and Northern Development (BRAND) program and the National Satellite Initiative (NSI). However, once these two programs are fully implemented and the industry has expanded services where it makes economic sense, there will likely be some 1,700 communities and approximately 575 First Nations reserves that will still be left un-reached with broadband communications. This represents over one third of Canadian communities and 5% of the Canadian population. Further efforts will be needed to link these communities to the data network infrastructure.

Information on the BRAND and NSI programs can be found on Industry Canada's Broadband web site at http://www.broadband.ic.gc.ca/pub/program

Furthermore, even if a community has access to broadband, many of its residents may not. This is especially true in rural areas, where the population density beyond a central town or village may be too low to make it cost effective using current technologies.

The Communications Research Centre Canada (CRC), an agency of Industry Canada, is dedicated to developing appropriate technologies for connecting Canadians and increasing their capacity to communicate, learn and innovate via broadband technology.

In April 2002, CRC launched the Rural and Remote Broadband Access (RRBA) Program, a five-year initiative to support R&D into cost-effective technologies for bringing broadband services to Canada's rural and remote areas. Milestones of the third year of the RRBA program are detailed in this report. Information on the successful commercialization and outcomes from the program can be found in the Technology Transfer section.

PROGRAM MANDATE

Through the RRBA Program, CRC is conducting research, development and testing of innovative broadband access technologies and systems that will facilitate extension of broadband services to rural and remote areas in a timely and cost-effective manner. These broadband technologies have the potential to provide all Canadians with equitable access to education, healthcare, global business opportunities and more. These affordable technologies should allow the private sector to develop viable business cases for the provision of broadband services to Canada's under-served areas.

The RRBA Program creates synergy among CRC's various research groups; capitalizes on the existing expertise in satellite communications, terrestrial wireless and broadcasting; supports Industry Canada for the development of related policies, regulations and standards; and transfers the technology to industry once developed and demonstrated. The Program also includes participation in international standards activities with the aim of reducing the cost of broadband access equipment through large-volume manufacturing, and promoting Canadian expertise and technologies to other countries that face similar challenges.

RRBA PROGRAM ACTIVITIES IN 2004-2005

Over the past year, broadband access continued to spread in the market place in Canada and abroad. Special effort is still needed to extend broadband connectivity to un-reached communities and First Nation Reserves. Satellite communications will play a major role in this effort and the RRBA program continued its R&D work to improve open-standard satellite technologies that will be especially suited to this purpose.

In the case of the rural communities that have broadband connectivity, the access to broadband services is found to be somewhat uneven, with lower density areas clearly at a disadvantage. The RRBA program has concentrated on developing technologies that would make the extension of broadband access to less populated rural areas more cost effective. Such effort may very well provide the bridge between "making broadband widely available to communities" and "making it widely available to all Canadians".

The first major effort in this context was to try to use lower radio frequencies for their better propagation characteristics, therefore extending the reach of wireless broadband systems and hence allowing for a larger subscriber base in lower population density areas. The second effort was to actively participate in international standards setting organizations to assist the development of a broadly accepted technical standard. This would likely result in a cost reduction of the equipment through volume production, similar to what has happened with the Wi-Fi® technology.

> **"Support for regional and rural economic development will target the fundamentals -skills upgrading, support for research and development, community development, and modern infrastructure such as broadband..."**
> Speech from the Throne, October 2004

The results of the R+D projects supported by RRBA and the related R+D activities are summarized below.

> **[We foresee] a Canada where the benefits of the 21st century economy are being reaped from coast to coast to coast – on our farms, in our fishing, forest and mining industries, and in our rural communities where modern communications are helping to surmount the barrier of distance.**
>
> Speech from the Throne 2004

R+D PROJECTS

1 Terrestrial Wireless Technologies

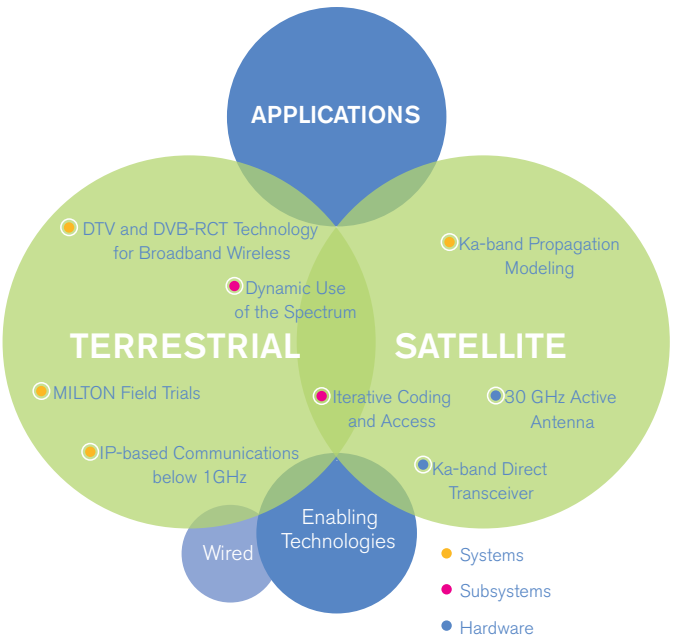
MILTON

CRC completed the development of its 5 GHz multimedia wireless access system called MILTON[1]. As a last-mile solution which can interface with optical fiber and Gbit Ethernet networks, this technology is well suited for small rural communities where the bulk of the population is within 1.8 km of the rural community centre (10 km2 area). The system is a cognitive radio network that, by using a 24-petal hub antenna, can reuse frequency up to 6 times and can reach as far as 5 km in line-of-sight conditions.

Further, a number of software pieces have been written to support the operation of the MILTON system and patents for this technology have been granted or are pending. More details on the technology can be found at the web site www.crc.ca/milton.

24-petal MILTON Hub antenna

R+D Projects in 2004-2005



1 *Microwave-Light Organized Network*

A total of 25 low gain subscriber terminals (6x6 inches) and 10 high gain terminals (14x14 inches) have been produced for various field trials. The MILTON system has been deployed for field trials in Kanata, in the western suburb of Ottawa, since September 2004.

With the hub, six terminals have been in operation without any failure. In December 2004, the Government of India made the MILTON technology a prime area of investigation for its Center of Development of Telematics (C-DOT), which purchased this technology for trials in Bangalore. CRC will also be involved in the development of an ASIC version of the MILTON technology and the integration of the Wavesat WiMax® chips for C-DOT.

WI-FI® BELOW 1 GHZ

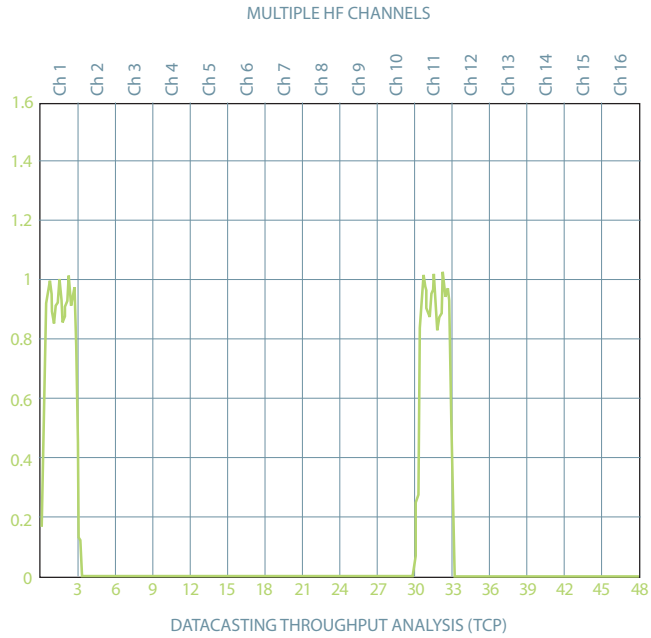
Investigations on the use of frequencies below 1 GHz for future broadband access systems continued in a view to enhancing the coverage range at low cost. Connectorized prototypes of a duplex frequency converter between the 2.4 GHz band and 700 MHz were developed. Printed circuit board prototypes were later produced. The prototypes were successfully used in a field trial where Wi-Fi® connectivity was established at 5 Mbit/s over a range of 5 km in a NLOS[2] point-to-point setup at 700 MHz. Further evaluation in the field indicated that the range of 802.11b/g WLAN seems to double in NLOS conditions and quadruple in true LOS as compared to their useat 2.4 GHz.

Antennas used for the Wi-Fi® experiment at 700 MHz

DYNAMIC USE OF SPECTRUM

Researchers continued the development of a flexible OFDM[3] modem emulator to allow for the investigation of adaptive approaches for the opportunistic use of free or under-utilized spectrum in allocated bands. The emulator, developed on a Pentium PC with high-end audio cards, is capable of adaptive modulation (from QPSK to 256 QAM), frequency agility (by turning on and off certain carriers), and spectrum monitoring functions based on the built-in FFT[4]. Most of the effort in 04/05 consisted of the integration of convolutional and turbo error-correction schemes to the modem and their testing. This technology has the potential of dynamically sensing and using the 'available' spectrum (in frequency, time and space) to provide broadband access where the spectrum is not heavily used.

CHANNEL OPERATION CONTROL POSSIBLE WITH THE OFDM MODEL EMULATOR



2 Broadcast Transmission Technologies

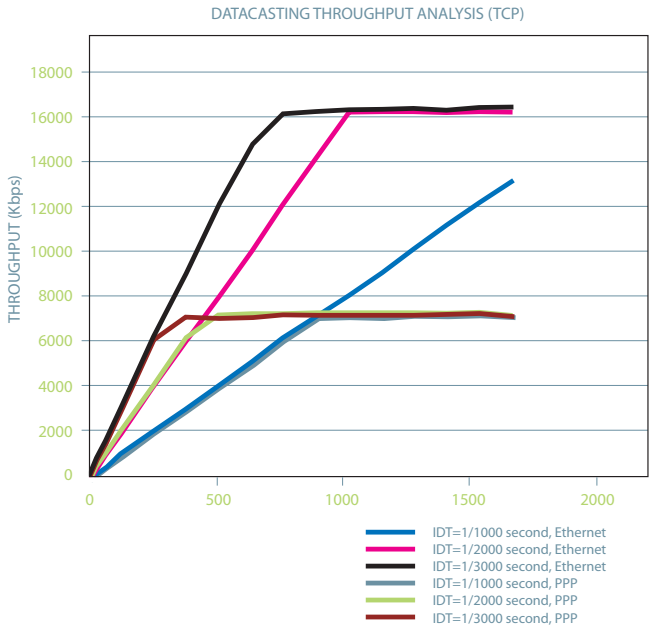
Digital television (DTV) can typically carry about 20 Mbit/s of forward broadband capacity per 6 MHz TV channel over a coverage area of up to a 70 km radius. The concept of using DTV-ATSC[5] in the forward direction and DVB-RCT[6] for the return link from the user terminals was pursued further to provide two-way, high-speed data services for RRBA application.

TRANSPORT OF IP TRAFFIC OVER DTV-ATSC

The transport of encapsulated Internet Protocol (IP) data packets over the DTV-ATSC stream was tested in the presence of RF noise to quantify the performance of IP data broadcasting services over DTV. Based on the results of these tests, optimization of the network parameters was considered to improve the performance of the system. Connectivity with other technologies such as Wi-Fi® was investigated and, as a result, a bridge from DTV to Wi-Fi® is in an early implementation stage. A number of papers and demonstrations giving the results of this work were presented at various broadcast conventions.

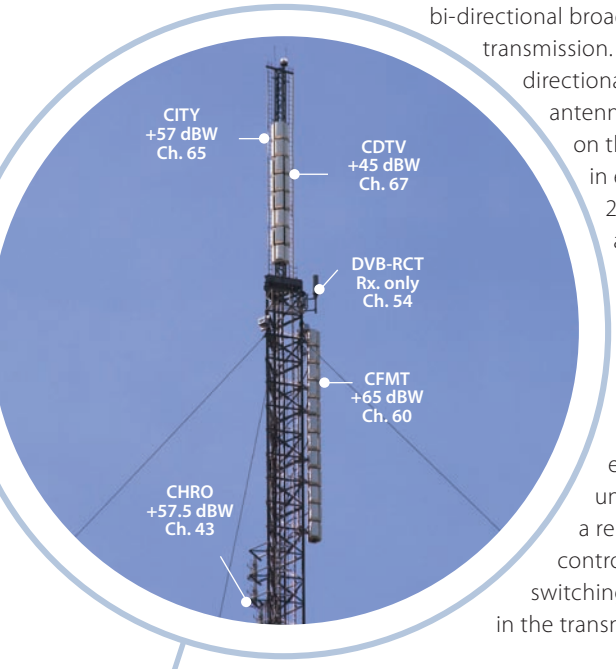
2 Non line-of-sight
3 OFDM: Orthogonal Frequency Division Multiplex
4 FFT: Fast Fourier Transform
5 DTV-ATSC: Digital Television Standard developed by the Advanced Television System Committee in the US.
6 DVB-RCT: Standard adopted by the Digital Video Broadcasting Project in Europe for the Terrestrial Return Channel

DTV-ATSC DATACASTING PERFORMANCE



ATSC-DTV / DVB-RCT FIELD TRIALS

The Manotick TV-UHF experimental station (south of Ottawa) was readied for full-scale field tests of DTV-ATSC / DVB-RCT bi-directional broadband transmission. A 5 dBi omni-directional receiving antenna was installed on the TV tower in early summer 2004 along with an outdoor RF unit that includes two switchable pre-selection filters and a low-noise front-end. An indoor unit that includes a remote gain control and failsafe switching was installed in the transmitter shelter.



Antennas on the Manotick tower

DVB-RCT EQUIPMENT ACQUISITION AND TESTING

An 8 MHz version of the DVB-RCT equipment was delivered to CRC in December 2004 and functionally tested for basic operation in the laboratory. Following some upgrades, the equipment was proven to work at the physical layer in QPSK mode. Further tests are needed to verify its operation in 16 QAM and 64 QAM modes. A 6 MHz version of the DVB-RCT equipment to operate in a normal TV channel is expected to be delivered in 2005.

NEW BROADCAST TRANSMITTER NETWORK PLANNING FOR BETTER SPECTRUM USE

As part of the transition from conventional analog television to DTV, there is an opportunity to use TV bands more efficiently. Distributed transmission networks using synchronized transmitters operating on a single channel could be implemented to carry the same programming over large areas, rather than multiple frequency-translators. This will allow for a reduction in the number of channels needed, reducing the RF spectrum needed for broadcasting and freeing up spectrum for other applications such as RRBA. To prove the concept, a single-frequency network was set up with three synchronized transmitters in downtown Ottawa and the results proved the applicability of this concept even in a harsh multipath environment.

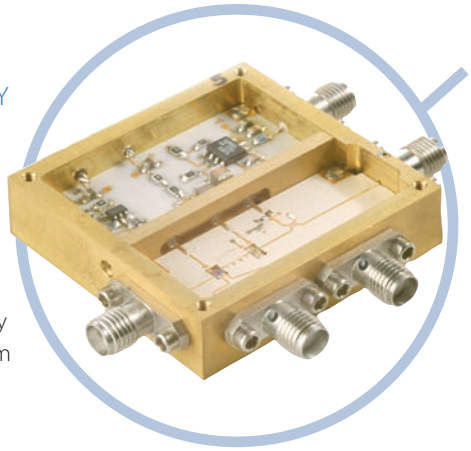
Single frequency network measurements in Ottawa

Network planning studies were initiated based on the TV Ontario Network to prove the applicability of the distributed transmission concept on a large scale. This provincial TV network uses different channels to broadcast the same program across the province and consists of high and medium power transmitters and a large number of low-power frequency-translators distributed over the territory. Preliminary results showed that common channels, available to all the locations where low-power translators are used in moderately congested areas, could be found in the DTV channel allotment plan. Such channels could be used for single-frequency networks in these areas. These encouraging results were presented to a major broadcasters' convention in the USA.

3 Satellite Broadband Access Technologies

SUPPORT FOR THE USE OF ANIK F2 KA-BAND CAPACITY

The joint CSA/CRC/industry (Telesat, EMS and COM DEV) Payload Flight Demonstration Program for Anik-F2 was completed with successful in-orbit tests in December 2004. The focus is now on preparing for R&D trials of the experimental on-board processor and providing technical support and guidance to Industry Canada's National Satellite Initiative to take full advantage of the Anik-F2 Ka-band capacity credit for Northern Canada. The DVB-RCS open standard system was selected for the use of this Ka-band satellite capacity.



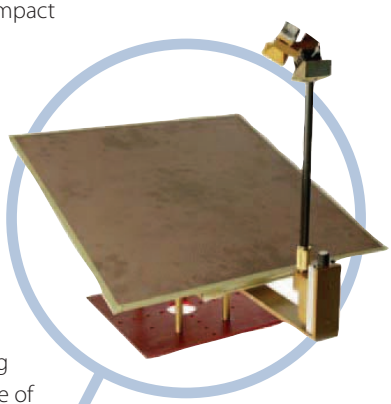
Integrated 30 GHz Harmonic Modulator with Detector Diode

IMPROVED MODULATION AND CODING FOR DIGITAL SATELLITE TRANSMISSION

During 04/05, work progressed on developing interleavers and turbo codes for forward error correction that out-perform the equivalent DVB-RCS turbo codes. An efficient soft vector decoder for block codes was recently developed and licensed to industry. Research was done on optimization of multi-user detection techniques for contention-based access to satellite broadband services based on the trade-off between relative performance, complexity and resulting latency. Also, the frequency synthesizer developed under contract the previous year was shown to meet the stringent requirements needed for operation in the DVB-RCS environment at Ka-band.

A software implementation of the DVB-S physical layer protocol, consistent with the software architecture defined for the Software Defined Radio technology, was initiated. This implementation will later be augmented to the DVB-S2 protocol and tests will be conducted.

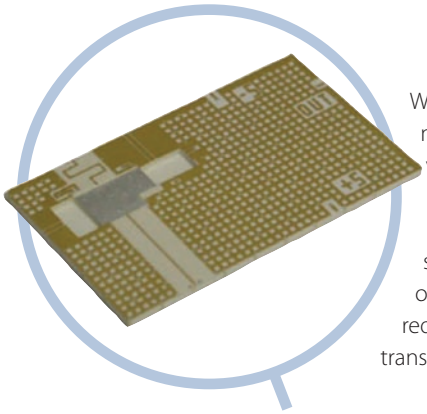
A novel 45 cm reflectarray antenna with an offset feed was designed and fabricated to accommodate the 30/20 GHz dual-frequency, circular-polarized operation. The aim of the present devopment is to use a more compact antenna structure with less feed blockage for small satellite terminals. The antenna has an equivalent gain performance, a centre-fed reflectarray, a better sidelobe level performance but a slightly degraded axial ratio at 30 GHz. This design could meet the ITU-R gain mask with respect to discriminating among geostationary satellites if the size of the antenna is greater than 70 cm.



Offset-fed 30 /20 GHz Reflectarray

KA-BAND EARTH TERMINAL TECHNOLOGIES

The direct modulator compensation was refined with a new synchronization scheme that was tested on the prototype produced the previous year. Local oscillator and image suppression exceeding 40 dB was achieved. A few combined vector modulator and detector circuits were designed, fabricated in MMIC and successfully tested in prototype form. This new technology is now being evaluated by industry for space applications. Solid-State Power Amplifier (SSPA) linearization was developed further with the completion of the AM/AM linearization prototype and the initiation of the AM/PM linearization implementation and testing.



Work continued on the miniaturization of a 30 GHz vector modulator with a coupler, amplifiers, and an envelope detector in a single package to improve overall performance and reduce the cost of direct transceiver satcom/wireless

Ka-band modulator miniaturization

communication terminals. The actual miniaturized 3-D package was implemented in Low Temperature Cofired Ceramic (LTCC) technology. Three different module topologies, corresponding to three LTCC realizations of different degree of complexity, were conceived, designed and fabricated. On the basis of device performance, one of the three LTCC design options was selected for implementation. The final module was tested and found to perform well at target frequencies. The module was also tested in the prototype direct transmitter and performed as expected.

EARTH-SPACE PROPAGATION PREDICTION

Research was conducted on the definition of a mathematical model for real-time scaling of signal fading due to dynamic meteorological conditions from one frequency band to another. Future multimedia terminals will likely consist of a DBS[7] receiver combined with a Ka-band transceiver for Internet-like access. Therefore, the use of fade depth estimation at both 12 and 20 GHz to predict the fade depth at 30 GHz on the uplink path will be of great help. Better power control could then be used at the terminal to reduce the variability of the signal level as received at the satellite.

However, validation of the model needs to be done with rain fade data measured at three different frequencies using the same technique. Steps have been taken to obtain this data from measurement with the Italsat satellite.

RRBA SUPPORT TO INDUSTRY CANADA

Technical support to the Industry Canada programs, BRAND and NSI, continued during this third year of the RRBA program. Support to the Canadian Space Agency was also provided as part of the support to the NSI program. The Spectrum Engineering and Policy groups were kept up-to-date with the advances in broadband access technologies. Presentations were made to Industry Canada, and its regional organizations, on the RRBA program, the new technologies being investigated, and on the capabilities of Wi-Fi® and Wi-Max®.

IEEE 802 STANDARDS PARTICIPATION

During 04/05, CRC participated in the activities of the IEEE[8] 802.18 Working Group through RRBA's Program Manager. This group, which deals with the Radio-Regulations aspects for the IEEE 802 Local and Metropolitan Area Networks Standards Committee, prepared comments in response to the FCC NPRM[9] 04-186 related to License-exempt Operation in the TV Broadcast Bands. As a result of the 802.18 WG work, the case for a Point-to-MultiPoint broadband access system operating in the unused spectrum in the TV VHF/UHF bands in rural and remote areas in the US was presented to the FCC. A new Working Group (802.22) was then formed to develop the air-interface standard for what is called the Wireless Regional Area Networks (WRAN).

The role of the RRBA program in this new working group is to contribute in the development of a worldwide transmission standard operating in the low-UHF range of frequencies, particularly useful in rural and remote areas because of the inherently superior propagation characteristics. This effort is aimed at developing a suitable open standard for WRAN similar

7 DBS: Direct Broadcast Satellite
8 Institute of Electrical and Electronics Engineers
9 Notice for Proposed Rule Making of the Federal Communications Commission in the USA

to the one developed under the 802.11 working group, which formed the basis for the now well-established Wi-Fi® technology. It is hoped that the adoption of the new 802.22 standard will be as widespread as the Wi-Fi® technology, leading to high volume production of low cost (commodity) user terminals.

The work of this new group began in November 2004 at which point Gérald Chouinard, the CRC program's manager was elected as the vice-chair of the group. So far, the following main contributions were provided to the work of 802.22 by CRC:

i) Reference model for a WRAN system that would take advantage of the superior propagation characteristics of the TV bands for rural coverage;

ii) Suggested WRAN Functional Requirements developed from the WRAN reference model spreadsheet;

iii) WRAN Traffic Model developed from earlier work for the BRAND program to assess the total capacity to be provided by NSI, to be used as initial estimate of WRAN traffic;

iv) Detailed study on the potential interference of WRAN to TV broadcast considering the various TV protection ratios and eventual license-exempt (LE) transmission limits;

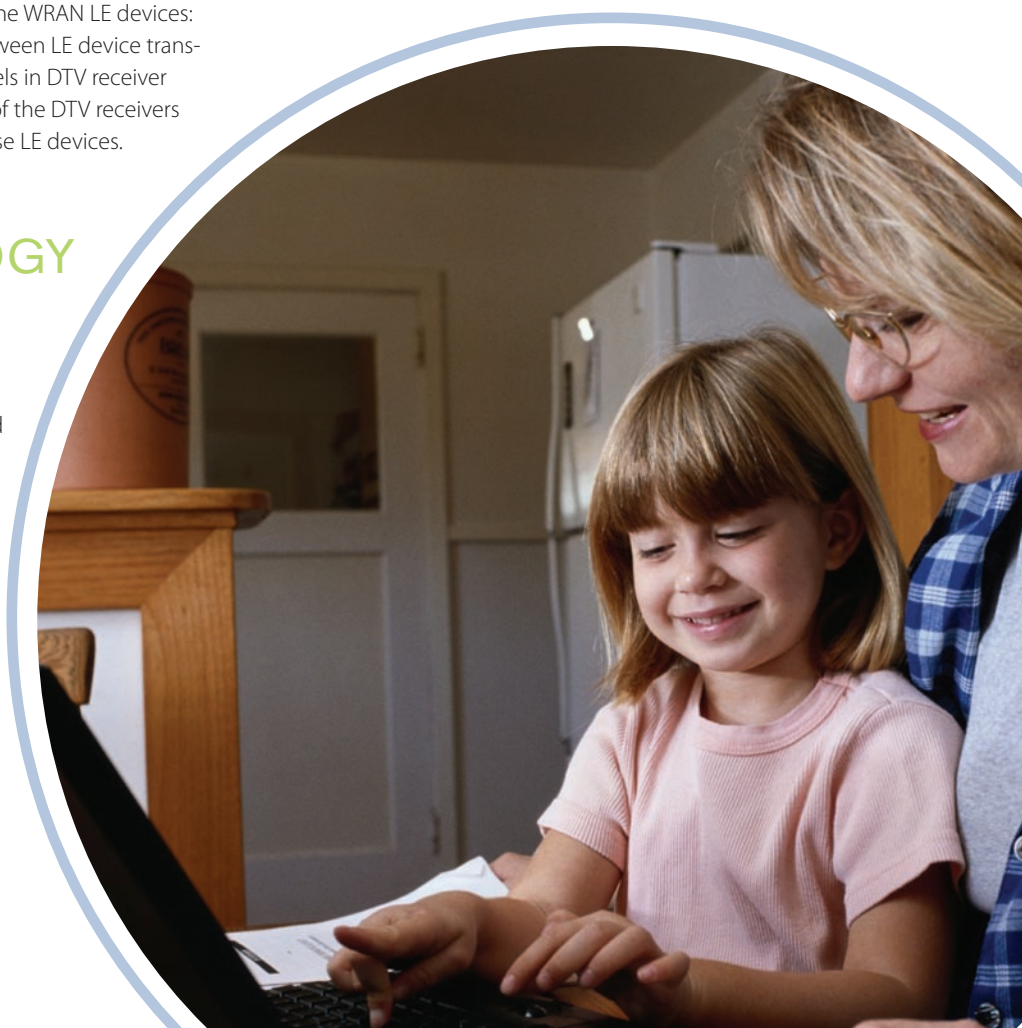
v) Out-of-band emission template for the WRAN LE devices: study of the relative importance between LE device transmission leaking into adjacent channels in DTV receiver front-ends and the de-sensitization of the DTV receivers from out-of-band emission from these LE devices.

- Over 10 NDA's were signed with Canadian companies interested in the MILTON technology.
- Some 14 technical publications and conference presentations were made on the results of the various RRBA projects carried out in 04/05.
- Two studies were carried out by CRC under contract from industry to measure the impact of LE equipment transmissions on TV and DTV receivers.
- As stated above, work began on the IEEE 802.22 standards, of which CRC is a major contributor.

04/05 TECHNOLOGY TRANSFER AND PUBLICATIONS

The following technologies were transferred to industry:

- Ka-band earth terminal technologies (direct modulator and demodulator compensation, SSPA linearization).
- Satellite capacity optimization subsystem (SCOPE) developed in 03/04.
- CRC ultra-fast turbo coding technology available on CD-ROM has been licensed to many companies.



A LOOK FORWARD

The RRBA program has addressed various related technologies, but the evolution of the situation in broadband access has confirmed that there are two main areas where CRC needs to concentrate: Ka-band satellite broadband access technologies and terrestrial wireless technologies using frequencies lower than 1 GHz to extend their coverage range in less populated areas. The program has already achieved good results in these areas and will continue focusing on them. New technologies in both of these areas will facilitate the extension of broadband access to all Canadians by making it more cost effective.

During the fourth year of the program, R&D efforts should concentrate on:

- improving the satellite broadband transmission technology at Ka-band, especially with respect to the DVB-S2 and DVB-RCT and low-cost earth terminals, as well as experimenting with the Anik-F2 Ka-band payload and support for the NSI program with installation of satellite terminals in northern Canada;
- experimenting with License-Exempt technologies such as Wi-Fi®, Wi-Max® and MILTON using lower frequencies, below 1 GHz, to verify their operation over extended coverage distances through field trials and demonstrations;
- pursuing the development of the DTV-ATSC / DVB-RCT combined technologies for carrying broadband access services, toward a full scale demonstration in 2006 using the experimental DTV station south of Ottawa, and carry out measurements to quantify the susceptibility of DTV reception to LE transmissions ;
- Actively participate in the IEEE 802.22 WG effort toward a WRAN air-interface international standard.

In addition, CRC will undertake further systems studies and take part in any spectrum related activities (policy, regulatory) initiated by Industry Canada to consider the possibility of using the lower UHF range for rural and remote broadband access. Transfer of technologies to Canadian companies will be pursued where possible so that they can deploy affordable broadband access systems in rural and remote areas in a timely fashion.

CRC will continue to participate in the IEEE 802.22 working group, which has a very aggressive schedule to provide a PHY and MAC standard to the industry by early 2008 as well as a recommended practice for proper operation of WRAN systems. This will, in turn, provide a great opportunity for CRC to actively participate in the development of this new standard for bringing broadband access to rural areas in order to:

- ensure that the technology developed for extending broadband access to the rural and remote areas will cover Canadian needs;
- allow Canadian technologies to be considered as part of this standard setting process;
- have CRC considered as a neutral site for testing the proposed WRAN systems.

Furthermore, participating in the working group will allow CRC to provide early advice to Industry Canada on the impact of the 802.22 standard on policy and regulations, and bring timely information to the Canadian industry and possible transfer of technology.

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