1. INTRODUCTION TO PROJECT « PIRATES »

1.1. Mandate

To develop the direction finding capabilities of the Spectrum Explorer as well as the necessary analysis tools required for correlating between received stations and the ALS database.

Project *Pirates* is part of the larger project consisting in the integration of the Spectrum Explorer within Spectrum Management operations.

Project *Pirates* was formerly known as " OBJECTIF LUNE " (" OBJECTIVE MOON ").

1.2. Objectives

1. To implement the integrated concept of two or more Spectrum Explorers with wideband DF antennas, synchronized through GPS, and sweeping simultaneously from different locations at high speed in wideband mode. This concept makes it possible to estimate and record the angle of arrival of all detected signals as well as to measure other technical parameters such as the signals level and the bandwidth of detected signals.

2. To develop the tools needed to estimate the location of detected radio stations using the angle of arrival data recorded by the Spectrum Explorers; to correlate the results with ALS data; to create discrepancy lists; and to map the results in MapInfo.

3. To develop automated work methods to facilitate the implementation of these new tools into operations.

4. To provide training to Spectrum Management Officers.

1.3. The Spectrum Explorer

The Spectrum Explorer was born at Communications Research Centre Canada (CRC). This unique technology, based on open software and hardware architectures, was developed by CRC researchers beginning in 1993 to assist Industry Canada in assessing the use and quality of the radio spectrum. From day one, the technology was a hit. Not only was Spectrum Explorer considerably less expensive than other off-the-shelf systems, it was also more user-friendly and significantly more flexible.

The Spectrum Explorer can support many equipment configurations, depending on system and measurement requirements. It follows a modular object-oriented approach,

which allows the straightforward use of a large number of hardware components. The Spectrum Explorer runs at high speed under MS Windows NT, Windows 2000 & Windows XP.

The Spectrum Explorer is capable of performing sophisticated spectrum monitoring measurements and analysis, including the following:

(a) Wideband Scanner

The wideband measurements include signal detection, power and frequency characterization, automatic noise floor level estimation and database recording. As an option, the Spectrum Explorer includes a Communication Signal Analyzer to identify specific signals parameters such as the modulation and the underlying communication system format.

(b) Digital Spectrum Analyzer

The Digital Spectrum Analyzer supports the same functions as a standard spectrum analyzer including markers, average calculation, front to back zoom, etc... It can also calculate the noise level in a precise manner, detect signals triggered by an alarm threshold, send signals to the Communication Signal Analyzer, and reprocess the signals from the registered database for post-analysis and support purposes.

(c) Communication Signal Analyzer

The Communication Signal Analyzer is a software module providing the real-time analysis of individual signals in great detail. Digital signals are treated by the Spectrum Explorer in order to analyze and evaluate their characteristics. The Communication Signal Analyzer includes an automatic recognition software to identify the type of modulation and a graphic interface to display the results. The types of modulation which can be recognized include CW, AM, DSB-SC, FM, FSK, SSB, BPSK, QPSK, M-PSK, M-QAM, pi/4QPSK, and 16-QAM. The system can demodulate signals using the following types of modulation: AM, SSB, FM, FSK binary, et DE-BPSK.

(d) Wideband Direction Finder

The Wideband Direction Finder is a software module that enables the Spectrum Explorer to estimate the angle-of-arrival of each detected signal while scanning at the speed of 20,000 channels per second. This software is an option of the Spectrum Explorer. When this option is used simulteneously by two or more Spectrum Explorers at different locations, the data generated by the scanning sessions can be analyzed using a geographic location analysis software to calculate and to display on a map the location of all stations detected by the Spectrum Explorers.

The Wideband Direction Finder of the Spectrum Explorer is the main tool for project *Pirates*.

1.4. Methodology

The Wideband Direction Finder of the Spectrum Explorer (SE/DF) can estimate the angle-of-arrival of detected signals. When using two or more SE/DFs at different locations, synchronized in time through GPS, we can estimate the locations of the stations which were detected simultaneously by the SE/DFs.

Each Spectrum Explorer scans a table at high speed. The table can contain many frequency bands but is limited by the frequency range of the DF antennas.

When a signal is detected, many technical parameters are recorded in a text file, such as the direction (angle-of-arrival), the frequency, the bandwidth, and the signal level.

When the scan session has been completed, the recorded data in the text file is analyzed using the software **'Location Analysis'**. This software uses the angle-of-arrival of the detected signals to calculate the location of the stations and to generate the technical parameters needed to draw an ellipse of uncertainty around each station.

The *Pirates* program working with MapInfo makes it possible to display on a map the estimated locations of the detected stations as well as their uncertainty zones. This program also displays all authorized stations in ALS.

If an ALS authorized station on the same frequency as the detected station does not appear inside or near the uncertainty zone, the detected station becomes suspect and is flagged for further verifications.

If additional verifications do not find an authorized station on the same frequency in the vicinity of the uncertainty ellipse, the detected station is added to a list of discrepancies. Spectrum Management Officers working in spectrum control have access to this list and they decide on the steps to be taken to correct these discrepancies. Based on operational priorities, one option is to open Directed Investigations.

1.5. Historic

2001

The Wideband Direction Finder of the Spectrum Explorer was used for the first time by the Quebec Region at the Summit of the Americas.

The Quebec Region of Industry Canada (SITT-Q) identified the need to develop a monitoring system which can automatically calculate the location of transmitters in order to make spectrum monitoring more automatized and more effective in urban areas. SITT-Q decided to work with CRC to develop the direction finder of the Spectrum

Explorer as well the DF antennas which will be required to meet this need.

2002

A working group was created to develop and test a system and tools of analysis which will make it possible to determine the location of stations using the direction finder of the Spectrum Explorer.

A scanning session took place in November 2002 using two sites. The following improvements were realized :

- Improvement to the synchronization of the Spectrum Explorers through GPS, making it possible for the software « Location Analysis » to use the « time stamp » during the analysis in order to determine the angle-of-arrival at a more precise time.

- Automation of the analysis with the help of MapInfo using a software executing under MapInfo.

- Adoption of the ellipse to determine the zone of uncertainty for each detected station. Circles were previously used to display the zone of uncertainty. Parameters for the ellipse are calculated by the software « Location Analysis ».

2004

CRC, in collaboration with DGSE and the Montreal office of SITT-Q, completed the development of an operational DF antenna covering 150 MHz to 1000 MHz (CRC-BD150-1000). This antenna had advanced characteristics, including the automatic calibration of the sensors and cables to prevent drifting associated with these elements. However, field testing by the Montreal office revealed that the precision of the antenna was not as good as expected. A precision of 5 degrees rms was expected but the results indicated a precision of approximately 8 to 10 degrees rms.

2005

CRC, DGSE and the Montreal office of SITT-Q continued to work on possible solutions to improve the precision of the DF antenna. The performance of the DF antenna seemed to improve when the level of filtering of the antenna calibration data was increased. It was therefore proposed to assess the DF performance of the CRC antenna through further field testing by using new calibration data with higher filtering.

2006 – CRC Tests At St-Rémi In November 2006

New field tests of the Wideband Direction Finder & Spectrum Explorer were carried out using improved calibration of the DF antenna. An error of 4.4 degrees rms was obtained

in frequency bands 150 MHz to 470 MHz and 806 MHz to 850 MHz. The results achieved by these tests justified further tests and measurements using the Wideband Direction Finder of the Spectrum Explorer. These results also confirmed that it will be possible to continue developing the project of automatically locating stations using the Spectrum Explorer.

2007

SITT-Q awards a contract to CRC for the development and construction of a new DF antenna similar to their CRC-BD150-1000 model. However, the new antenna should cover from 115 MHz to 1000 MHz, and should require two vertically mounted antennas with each antenna optimized to cover consecutive bands with reduced frequency range A system of relays inside the antenna would make it possible to automatically switch signals and calibrate the cables. Also included would be the relay control card to be installed inside the VXI chassis, as well as control and RF cables.

Other improvements achieved during the year:

- Corrections to the GPS synchronization process

- Modifications of the Location Analysis software to integrate the latest improvements on the algorithm used to analyze the data recorded by the SE/DF and to calculate the location of stations.

- Improvements to the Location Analysis software in order to calculate the maximum measured bandwidth for each detected station.

2007 – Montebello Summit

First trial at the Montebello Summit of the new QR-201 DF antenna built by CRC and covering from 100 MHz to 2700 MHz. Scanning table covering from 108 MHz to 960 MHz was used. Good results were achieved with a precision of about + or – 5 degrees rms.

2007 – CRC Tests At St-Rémi In October 2007

- The new QR-201 DF antenna was validated and calibrated using a beacon transmitter.

- Additional measurements are planned for November 2007 in Montreal to test the antenna in a real electromagnetic environment.

- The tests in St-Remi confirmed that the antenna is performing well in the band 100 to 500 MHz. However, the precision of the antenna is in question from 500 MHz to 2700 Mhz. Interaction between components of the antenna

may affect the performance of the antenna at those higher frequencies. CRC will continue research to identify and correct the source of the problem and to deliver to SITT-Q a high performance DF antenna from 100 MHz right through 2700 Mhz.

1.6. Reference Documents

This report contains many links toward documents which are stored within SITT-Q's internal document management system known as « Odyssée ». Readers who do not have access to Odyssée or to these documents can request copies by contacting Stéphane Routhier or Donald Courcy.

2. PARTICIPANTS IN PROJECT PIRATES

SITT-Q

- Stéphane Routhier — Project Leader
- Donald Courcy — Project Coordinator
- Alain Hébert — Responsible for equipment installations and set-up
- Mario Côté — Programming and MapInfo Expert
- Eddy Paul — Sites validation, execution & search of stations
- Ugo Barrette — Update of scan tables & search of stations

DGSE

- Don Paskovich — SE Coordinator for Industry Canada
- Donald Roy — Development of DLL to calculate power

As well, the CRC members listed below worked on the development of the Spectrum Explorer and the *Location Analysis* software. They also provided expert assistance and support during the measurements.

- Ernie Matt
- Martial Dufour
- Dwight Hill
- Dr. François Patenaude

We also had the pleasure of welcoming Gordon Herrmann from the Pacific Region. He came as observer during our November 2007 scan sessions.