Spring / Printemps 2006, No. 52

IEEE Canadian Review

La revue canadienne de l'IEEE

Long Lines

PIPING POWER & DATA

- Paths Beneath the Sea—50 years of Transatlantic Telephone Cable Systems
- Power Milestone—Québec's 735-kV Transmission System
- Software Process Quality
- Fiber Grating Optical Components

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IEEE Canada
The Institute of Electrical and Electronics Engineers Inc.

IEEE Canadian Review General Information

The ***IEEE Canadian Review*** is published 3 times/year as follows: Winter (to appear in April); Spring/Summer (to appear in August); Fall (to appear in December). Its principal objective is to project an image of the Canadian electrical, electronics, communications and computer engineering professions and their associated academic and business communities to:

(i) Canadian members of IEEE;
(ii) Canadian members of the profession and community who are non-members of IEEE;
(iii) The associated Canadian academic (i.e. universities, colleges, secondary schools), government and business communities.

To ensure that the ***IEEE Canadian Review*** has the desired breadth and depth, editors are responsible for screening articles submitted according to the following general themes:

1- National Affairs	4- Education	7- Computers
2- International Affairs	5- Power	8 - Electronics
3- Industry	6- Communications	

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Editorial / *Éditorial*

Eric Holdrinet SMIEEE, Rédacteur en chef / Managing Editor, Consul et délégué commercial, Consulat général du Canada à Los Angeles

S'il y a un élément qui caractérise le Canada, c'est le concept de longues lignes: 90% de la population est située dans un étroit ruban de territoire allant d'un océan à l'autre, et l'autre 10% dans des communauté rejointes en se dirigeant vers le troisième océan.

Pendant longtemps les informations et le commerce ont été transportés sur les longs rubans interconnectés de nos rivières par les voyageurs – membres des premières nations ou nouveaux arrivants qui ensemble ont personnifié l'esprit du nouveau monde.

Avec l'arrivée de l'ère industrielle, et le pays étant alors riche d'inventeurs et d'ingénieurs, il n'est pas étonnant que les innovations les plus diverses y aient été conçues pour reliées ces divers-es communauté entres elles ainsi qu'aux ressources du territoire.

Nous rendons hommage à nos prédécesseurs dans ce numéro spécial « Longues Lignes » avec deux articles historiques: un sur le cinquantième anniversaire de la téléphonie transatlantique établie par le système TAT-1, et l'autre sur la reconnaissance par l'IEEE du caractère pionnier du système de transport électrique à très haut voltage allant de la rivière Manicouagan jusqu'à Montréal.

Lors que TAT-1 augmentait considérablement le débit des communications entre l'Amérique et l'Europe, le saut quantique suivant dans ce domaine fut apporté par la fibre optique. Nous présentons ici un article technique et une revue de livre sur les composantes à fibres optiques.

Enfin, la complexité de tous ces systèmes étant de plus en plus incorporée dans une forme ou l'autre de logiciels, une méthode est ici proposée pour aider à s'assurer de la fiabilité des organisations qui développent ces systèmes, parfois à une très grande distance de leur clientèle!

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Un sondage a été réalisé récemment par l'équipe de gestion de la Revue canadienne de l'IEEE pour capture les préférences de nos lecteurs en terme de contenu et fréquence de publication, la lecture effective de la revue et sa valeur perçue, ainsi que l'intérêt pour pouvoir la recevoir sous forme électronique. Si vous avez des suggestions ou commentaires à ce sujet, nous seront ravis de les recevoir. SVP voir nos coordonnées sur la page d'Information Générale, ou à http://canrev.ieee.ca/.

If one element characterizes Canada, its the concept of long lines: 90% of the population is located in a narrow ribbon of land from sea to sea, and the remaining 10% in communities reached by going towards a third sea.

For a long time information and commerce were transported on those long interconnected lines of our rivers by the voyageurs – members of the first nations or new arrivals who together personified the spirit of the new world.

With the advent of the industrial era, and the country being rich of inventors and engineers, it is not surprising that so many innovations were made there to link those diverse communities to each other and to the territory's natural resources.

We pay tribute to our predecessors in this special "Long Lines" issue with two historical articles: one about the fiftieth anniversary of transatlantic telephony established by the TAT-1 system, and another on the IEEE's honouring the pioneering nature of the very high-voltage electrical transport system going from the Manicouagan river to Montreal.

As TAT-1 increased considerably the communications bandwidth between America and Europe, the next quantum leap in this domain was brought about by optical fibre. We present here a technical article and a book review on optical fibre components

Finally, the complexity of all those systems being increasingly captured in one form or other of software, a method is proposed to help guarantee the reliability of the organizations that develop those systems, sometimes at a very long distance from their clients!

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A survey was conducted recently by the Management Team of the IEEE Canadian Review to gather our readers' preferences in terms of contents, publication frequency, the actual reading of the Review and its perceived value, as well as the interest for receiving it in electronic format. If you have suggestions or comments about any of those, we will be happy to hear them. Please see our coordinates on the General Information page, or at http://canrev.ieee.ca/.

Dr. Ashok K. Vijh elected

President of Academy of Science, Royal Society of Canada

The IEEE Canada leadership have been delighted to learn that Dr. Ashok K. Vijh, O.C., C.Q., FRSC, Maître de Recherche at the Institut de recherche d'Hydro-Québec, invited Professor in Institut National de la Recherche Scientifique of the Université du Québec - and, most importantly for us, IEEE Fellow! - has been elected President of The Academy of Science of The Royal Society of Canada. He also becomes ex-officio a Vice-President of the Royal Society of Canada. This is our national academy founded by an act of Parliament in 1882 (see http://www.rsc.ca). Our most sincere congratulations.

Cover picture / *Photo de couverture*

Of the long lines covered in this issue, the longest would have to be the first transatlantic telephone cable, completed in 1956. Steaming into view on the right side of the cover is HMTS Monarch (4), the largest cable ship afloat at the time, which layed it. With a length of 480' and breadth of 56', it could carry 1500 nm of deep sea coaxial telephone cable and repeaters. Also shown is HMTS Monarch laying lightweight coaxial cable over the stern "V" sheave; three sheaves were fitted to its bow. Our thanks to Bill Burns of FTL Designs for permission to use these two images, downloaded from http://atlantic-cable.com/Cableships/index.htm

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Newslog Editor

Rédacteur des Coupures de presse

Alexandre Abecassis is a patent agent in Montreal at Ogilvy Renault LLP, Lawyers and Patent and Trade-mark Agents.

Alexandre Abecassis travaille à Montréal comme agent de brevet chez Ogilvy Renault S.E.N.C.R.L., s.r.l., Avocats et agent de brevets et de marques de commerce.

Send any news clippings you would like to contribute via e-mail to alexandre.abecassis@ieee.org

Veuillez faire parvenir les coupures de presse proposées par e-mail à alexandre.abecassis@ieee.org

VANCOUVER, BC, Jan. 31, 2006.
Nicer Canada has announced the launch of a hosted Voice over IP (VoIP) service combining the functionality of a traditional Private Branch Exchange (PBX) with additional value added services. With this new service, businesses are able to implement network based IP telephone systems with added flexibility since all features may be accessed via an office telephone, via home phones or via mobile phones.

EDMONTON, AB, Mar. 29, 2006
Matrikon has announced the release of a window-based alarm management software applications. This application features interactive web-reports, multi-language support, automated assessments that benchmark plant performance as well as customized profiles so that each user may customized their reports layout. This application enables an improved safety as well as an optimized plant reliability.

EDMONTON, AB, Mar. 17, 2006
Serenic, an international publisher of financial and operational software has announced that the Denver Art Museum selected their software as a new financial management software solution. This solution delivers unique and sophisticated functionalities required by not-for-profit (NFP) organizations as well as government agencies. The Denver Art Museum has a collection of over 60 000 works.

MISSISSAUGA, ON, Mar. 14, 2006
Microsoft has announced it is collaborating with Bell Security Solutions and the University of Toronto's Center for Innovation Law and Policy to develop a privacy network. This privacy network is a self-service portal where a user can search for privacy information and collaborate in permission-based online discussion forums moderated by subject matter experts from around the world. The privacy network will be managed by the University of Toronto.

MISSISSAUGA, ON, Mar. 7, 2006
Certicom has launched Certicom Security for VoIP, which is a standard-based solution for desktop VoIP handsets and mobile VoIP devices and which consist of multiple, integrated modules that implement key security protocols such as IPSec (IP Security Protocol), ssl-tls (Secure Socket Layer and Transport Layer Security) and DTLS (Datagram Transport Layer Security Protocol). It also provides the underlying cryptographic algorithms, trusted boot, secure provisioning and code signing technology, all of which are key to securing advanced applications such as IP Multimedia Subsystem (IPMS) and Unlicensed Mobile Access communications (UMA).

VANCOUVER, BC, Feb. 14, 2006
Absolute Software has announced that it has signed a limited patent licensing agreement that resolves its legal dispute with CyberAngel Security Solutions regarding Absolute's patent portfolio. Absolute Software is a leader in computer theft recovery and secure-asset tracking with more than half a million subscriptions under management.

OTTAWA, ON, Feb. 8, 2006
March Networks, a leading provider of Internet Protocol (IP)-based digital surveillance solutions has announced that one of Australia's largest banks has selected Match Networks as the standard for its enterprise wide deployment of digital video surveillance solutions. The bank will deploy the network throughout 900 branches to deliver sophisticated and centralized digital video surveillance that will enhance the safety of customers and employees, deter theft and fraud and effectively deal with case investigations.

MONTREAL, QC, Jan. 25, 2006
Nstein Technology has announced that the Software and Information Industry Association (SIIA) has named Nstein's Ntelligent Enterprise Search solution as one of the five 2006 CODiE Awards finalists in the "Best Enterprise Search Engine" category.

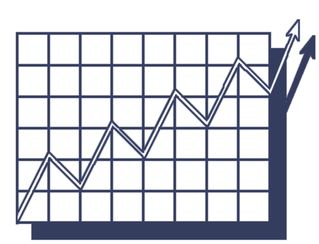
MONTREAL, QC, Apr. 20, 2006
CAE has won the prestigious Mercuriades Award in a competition organized by Quebec's largest business group. The Mercuriades competition has been organized by the Fédération des chambre de commerce du Québec on a annual basis. CAE was recognized in the "Market Outside Quebec" category. Some of the eligible activities include exports of products or services, investments, acquisitions or implementation of distribution centres or production units outside Quebec.

TORONTO, ON, Apr. 4, 2006
IBM and the University Health Network are creating a new research centre that will use a supercomputer to help discover treatments for ovarian, lung, colon and prostate cancers. The research centre will focus on analyzing protein interactions, a crucial component in understanding cancer biology, disease progression and treatment.

LONGUEUIL, QC, Mar. 21, 2006
D-Box Technologies announced that it has premiered its video game technology at the Game Developers Conference 2006 which was held in San Jose, California. Conference participants had the opportunity to try the prototype D-Box gaming chair and to play with various games.

MONTREAL, QC, Mar. 2, 2006
Matrox Graphics has unveiled the new TripleHead2Go, a palm-sized box which uniquely allows a user to add three monitors with a combined resolution of up to 3840x1024. This will enable, inter alia, an immersive experience to gamers.

OTTAWA, ON, Feb 2006
Veena Rawat, acting president of the Communication Research Centre Canada (CRC) since September 2004 has been nominated president on a permanent basis. The Communication Research Centre Canada is a research and development center in telecommunications technologies; it works extensively with IEEE on standards and recommendations.



It is with great pleasure and honour that I assume the role of Region 7 Director and President of IEEE Canada for 2006-2007. Since assuming my duties I have been busy dialoguing with members, volunteers and past Region 7 Directors to closely examine our services and increase our institution visibility to the general public. We have made significant changes to our IEEE Canada website including reorganizing the main navigation links to make it easier to search for information. I strongly encourage you to regularly visit our website at www.ieee.ca for most up-to-date news and announcements.

I sincerely thank our past President, Bill Kennedy, and his team for their hard work and contributions to the advancement of Region 7 and the IEEE. I am grateful to all members of the executive committee who have volunteered to serve our region over the next two years.

On May 05-07, 2006 I will be chairing our Region 7 Board of Directors spring meeting in Ottawa. We have arranged a session with our section chairs and other members to solicit feedback on the most important challenges facing our region. This information will be part of our goals and objectives.

The 2006 IEEE Canadian Conference on Electrical and Computer Engineering (CCECE 06) took place in Ottawa, May 7-10, 2006 (http://ieee.ca/ccece06). During the conference banquet ceremony we presented our awards for Canadian achievement in Electrical and Computer Engineering as well as for distinguished services to Region 7.

During 2006 three sections in Region 7 will be celebrating their 50th anniversary:

- Victoria Section
- Southern Alberta
- South Saskatchewan

Our hearty congratulations to these sections on their achievements. I am looking forward in being part of their celebrations.

On February 27, 2006 I was a keynote speaker at the annual meeting of Electricity Distributor Association (EDA) http://www.eda-on.ca. The presentation title was " IEEE - The Power of Collective Action".

We have been working very closely with the IEEE Job site to encourage the job advertising of Canadian companies on our website. We have made good progress and encourage you to visit our website at http://careers.ieee.org.

For the period March 03-05, 2006 I attended the Engineering Institute of Canada (EIC) annual meeting in Ottawa and was part of a team preparing vision and mission statements for EIC. Also, On May 9-12, 2006 EIC is holding its first conference on Climate Change Technology: Engineering Challenges and Solutions in the 21st Century, http://www.ccc2006.ca/. IEEE Canada is a key participant in this conference and we are grateful to our many volunteers who have contributed tremendously to the success of this conference.

We are currently dialoguing with IEEE-USA on evaluating options to extend some of their membership benefit programs to Region 7 at the same cost to our members.

It is becoming extremely challenging for Region 7 to produce a balanced budget for 2006 without incurring considerable cut backs in our services and support to volunteers. We have been negatively impacted by our strong Canadian dollar versus the US currency. In an attempt to mitigate this problem, we have had several conference-call-meetings to review options to reduce expenses. We are considering a modest increase in our regional assessment fee for 2007 to offset reduction in our revenues. At the same time, we are re-visiting our expenses line by line including the possibility of converting some of our publication from paper to electronic.

I appeal to all those members who have not renewed their membership yet to do so as soon as possible. I also encourage our members to attend our section events, seminars and special meetings as well as to consider being a volunteer.

Finally, I thank you for electing me as your 2006-2007 Regional Director and I hope to work productively with you during the next two years to serve IEEE Canada. I am also very grateful to all our volunteers at Region 7, who work hard to serve our 15000 members across this beautiful country.

C'est avec grand plaisir que j'assume le poste de directeur, Région 7 et président de l'IEEE Canada pour 2006-2007. Depuis que j'ai pris ces fonctions j'ai été occupé à dialoguer avec les membres, volontaires et ex-directeurs de la Région 7 pour évaluer nos services et augmenter la visibilité de notre institution auprès du public. Nous avons effectué des changements substantiels à notre site web, incluant la réorganisation des principaux liens de navigation pour rendre plus aisée la recherche d'information. Je vous encourage à visiter régulièrement notre site www.ieeee.ca pour les nouvelles et annonces les plus à jour

Je remercie sincèrement notre président sortant, Bill Kennedy, et son équipe pour leur travail et contributions à l'avancement de la Région 7 et du IEEE. Je suis obligé envers les membres du comité exécutif qui sont volontaires pour servir notre région lors des deux prochaines années.

Du 5 au 7 mai 2006 je présiderai le conseil d'administration de la Région 7 à la réunion de printemps, à Ottawa. Nous avons organisé la session avec nos présidents de sections et autres membres pour demander une rétroaction sur les plus importants défis auxquels notre région fait face. Cette information fera partie de nos buts et objectifs.

La Conférence canadienne de génie électrique et informatique (CCGEI) 2006 a eu lieu à Ottawa du 7 au 10 mai 2006 (http://ieee.ca/ccece06). Durant le banquet d'apparat de la conférence nous avons présenté nos récompenses pour les réalisations canadiennes en génie électrique et informatique ainsi que pour services à la Région 7.

En 2006, trois sections de la Région 7 célébreront leur 50^{e} anniversaire: Victoria,, Alberta du Sud, et Saskatchewan du Sud.

Nous plus sincères félicitations à ces sections pour leurs accomplissements. J'ai hâte de participer à leurs célébrations.

Le 27 février 2006 j'ai été conférencier principal à la réunion annuelle de l'Association de distributeurs d'électricité (EDA - Ontario, http://www.eda-on.ca). Le titre de la présentation était "IEEE - The Power of Collective Action."

Nous avons travaillé de près avec le site d'emplois du IEEE pour encourager la promotion d'emplois de firmes canadiennes sur notre site. Nous avons fait de bons progrès et vous encourageons à visiter notre site à http://careers.ieee.org.

Lors de la période du 3 au 5 mars 2006 j'ai assisté à Ottawa à la réunion annuelle de l'Institut canadien des ingénieurs (ICI) et ai fait partie de l'équipe préparant les énoncés de vision et mission pour l'ICI. Aussi, du 9 au 12 mai 2006 l'ICI tiendra sa première Conférence sur la Technologie et changements climatiques: Défis et solutions en matière d'ingénierie au 21ème siècle, http://www.ccc2006.ca/. Le IEEE Canada est un participant clé à cette conférence et nous sommes reconnaissants envers nos nombreux volontaires qui ont ont contribué énormément au succès de cette conférence.

Nous dialoguons présentement avec IEEE-USA sur la possibilité d'étendre certains de leurs programmes de bénéfices à la Région 7 au même coût pour nos membres.

Produire un budget 2006 équilibré sans couper considérablement dans nos services et support aux volontaires devient un défi important pour la Région 7. Nous avons été affectés par la montée du dollar canadien par rapport au dollar US. Pour tenter d'atténuer ce problème, nous avons eu plusieurs téléconférences pour évaluer les options de réduction des dépenses. Nous considérons une légère augmentation de la contribution régionale pour 2007, pour contrebalancer la réduction de nos revenus. En même temps, nous allons reconsidérer nos postes de dépenses individuellement, incluant la possibilité de convertir certaines de nos publications vers un support électronique.

J'en appelle à tous les membres qui n'ont pas encore renouvelé leur adhésion à le faire le plus tôt possible. J'encourage aussi nos membres à participer aux événements de sections, séminaires et réunions spéciales ainsi qu'à envisager de se porter volontaires.

Finalement, je vous remercie pour m'avoir élu Directeur régional 2006-2006 et compte travailler de façon productive avec vous durant les deux prochaines années pour servir le IEEE Canada. Je suis très reconnaissant envers tous les volontaires de la Région 7, qui travaillent fort pour servir nos 15 000 membres dans ce beau pays.

Bob Hanna, P.Eng., FIEEE, FEIC, FIEE • 2006 - 2007 IEEE Canada President

IEEE Milestone: 40th Anniversary of 735 kV Transmission System

by Vijay K. Sood

IEEE Canada Secretary, 2006-2007

In November 1965, the world's first transmission line at 735 kV was commissioned into service in Quebec. This line transported electrical power from the hydraulic centers of the Manicouagan River, in the North East of Quebec, to the load centers in the South of Quebec.

In 1955, Hydro-Québec engineers first studied how to transport hydro power from the region of Manic-Outardes in Quebec to the southern load centers of Quebec City and Montreal. By using 300-400 kV transmission lines, the world standard at the time, some 40 lines would have been needed for this task. In view of this, it was logical to consider increasing this voltage level to 500 kV. However, the jump from 315 kV to 500 kV was considered only a modest improvement to find a solution to the problem.

At this point, engineer Jean-Jacques Archambault took the initiative to consider a higher voltage level that had never been considered before. Earlier in 1958-59, he had made calculations at 700 kV with a security margin of 5%, i.e. 735 kV. However, Jean-Jacques had to persevere with this option as the European and American manufacturers of the line equipment were unwilling to build this equipment at this voltage level only for the Quebec market.

Period	Activity
From 1962-65	Construction of the first phase of the project from Manic-Outardes-Levis;
End of 1968	End of the second phase of project with the construction of the line from levis- Boucherville;
In 1970	Construction of a third line from Micoua to Laurentides sub-stations in the north of the river St-Lawrence.
In 1971	Construction of the line between Laurentides and Duvernay sub-stations.

Table 1: Construction Highlights

In August 1962, Hydro-Québec decided to take on this technical challenge and proceed with the construction, within 3 years, of the first phase of this innovative project: the line from Manic to Boucherville sub-station in the South of Montreal. Industry and consultants mobilized to tackle this, one of the world's largest construction projects.

Figure 1: Attachment of 735 kV power lines to insulators with the aid of a crane. The first-ever lines of this type linked the Manic-Outardes generating stations to the metropolitan areas of Québec City and Montréal. Photo courtesy of Hydro-Québec.

During the years 1965-85, Hydro-Québec experienced an important construction period of 735 kV lines from the huge hydraulic dams of Manicoua-gan, Churchill and James Bay. It was a pioneer in the development of a vast 735 kV transmission network. Today the division of Hydro-Quebec responsible for transmission system, Hydro-Quebec Trans-Énergie, transports some 25,000 MW over the 735 kV transmission system, which is about 5 times the amount originally planned for power handling capacity. This huge increase demonstrates the success that this company has had with the development of the transmission network over a sustained period of time.

Homage to a pioneer

Jean-Jacques Archambault is generally considered to be the father of the 735 kV transmission system, and he completed a brilliant carrier at Hydro-Quebec. He is known as an individual with great humanity and compassion by those who met him and worked with him. Before he retired from Hydro-Québec, he represented the company at all major international forums dealing with planning and transmission of electrical energy.

He was a mathematician by training and graduated from Ecole Polytechnic in Montreal in 1944. He joined Hydro-Québec in 1947 in the Planning Department. When the problem of transmission over long distances was submitted to him, he was naturally curious and studied innovative transmission systems from all over the world. After studying a proposed 600 kV system in the Bulletin des électriciens de France, he finally decided that this voltage was not practical for Quebec and he opted for 735 kV. European manufacturers were advised of this and they complied with the specification requirements to transport electrical energy with a minimum of transmission losses and noise pollution. Jean-Jacques closely followed the construction of the first phase of the line Manic-Outardes-Levis. Following this, he left for Rabat in Morocco for teaching at the Mohamed V University for a period of two years. Upon his return to HQ, he represented the enterprise as an ambassador for the transmission network at 735 kV. In 2001, he received the award from the Ordre des technologies professionals du Quebec for his achievements. His feat of transmission at 735 kV has yet to be surpassed.

Hommage à un pionnier

Jean-Jacques Archambault est généralement considéré comme le père du système de transmission à 735 kV et a accompli une brillante carrière à Hydro-Québec. Il fut connu comme une personne d'une grande humanité et compassion par ceux qui l'ont rencontré et travaillé avec lui. Avant de prendre sa retraite d'Hydro-Québec, il représentait la compagnie dans tous les forums internationaux sur la planification et transmission d'énergie électrique.

Il était mathématicien de formation et a gradué de l'Ecole Polytechnique de Montréal en 1944. Il a joint le département de planification d'Hydro-Québec en 1947. Lorsque le problème de transmission sur de longues distances lui a été soumis, naturellement curieux il a étudié les systèmes innovateurs de transmission à travers le monde. Après étude du système à 600 kV proposé dans le Bulletin des électriciens de France, il a décidé que ce voltage n'était pas pratique pour le Québec et opta pour 735 kV. Les manufacturiers européens ont été prévenus de ceci et ont obtempéré aux exigences spécifiées pour le transport d'énergie électrique avec un minimum de pertes en transmission et de pollution par le bruit. Jean-Jacques a suivi de près la construction de la première phase de la ligne Manic-Outardes-Levis. Ensuite, il a quitté pour Rabat au Maroc pour enseigner deux ans à l'Université Mohammed V. À son retour chez Hydro-Québec, il devint "ambassadeur" de l'entreprise pour les réseaux de transmission à 735 kV. En 2001, il a reçu le prix de l'Ordre des technologues professionels du Québec pour ses accomplissements. L'exploit technique que constitue la transmission à 735 kV n'a pas encore été surpassé.

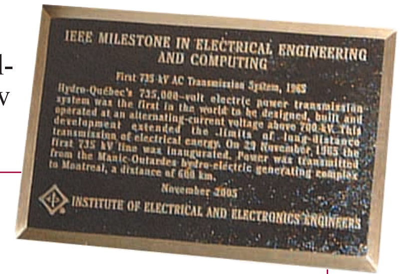
Acknowledgement

Thanks to Hydro-Quebec for providing access to its archives of the 735 kV Milestone celebrations at Montreal.

IEEE Milestone Celebrations, December 13, 2005

Hydro-Québec head office, Montréal

At the recent unveiling of the IEEE Milestone plaque on December 13, 2005, the event was celebrated with dignitaries and Hydro-Québec employees. Mme Denyse Guay-Archambault, widow of Mr Jean-Jacques Archambault, was recognized. Below is the text inscribed on the plaque:



IEEE MILESTONE IN ELECTRICAL ENGINEERING AND COMPUTING

First 735 kV AC Transmission System, 1965

Hydro Québec's 735,000-volt electric power transmission system was the first in the world to be designed, built and operated at an alternating-current voltage above 700 kV. This development extended the limits of long-distance transmission of electrical energy. On 29 November, 1965 the first 735 kV line was inaugurated. Power was transmitted from the Manic-Outardes hydro-electric generating complex to Montréal, a distance of 600 km.

Unveiling of the IEEE 735kV Milestone plaque, December 13, 2005

From left to right:Yves Filion, Président, Hydro-Québec Trans-Énergie; Thierry Vandal, Président-directeur général, Hydro-Québec; Bill Kennedy, President of IEEE Canada 2004-2005; Pierre Corbeil, Ministre des Ressources naturelles et de la Faune du Québec.

IEEE Canada representatives at the 735 kV Milestone

From left to right: Ron Potts, Vijay Sood, Gilles Baril, Amir Aghdam, Ray Findlay, Dominic Rivard, André Dupont (one of the HQ pioneers who worked on the project), Bill Kennedy, Paul Fortier, André Morin and Xavier Maldague.

Seated: Mme Denyse Guay-Archambault; Guy Monty, responsable de la construction des lignes à 735 kV.

Optical Fiber Components Obtained by Refraction Index Modulation and Geographical Formulation

By Jeffery Au[1], Thomas Bardot[2], Yassine Bouslimani[1] and Habib Hamam[1]

[1] EMAT - Faculté d'ingénierie, Université de Moncton, NB, Canada

[2] École Nationale d'ingénieurs de Brest, France.

Abstract

The Fiber Bragg Gratings (FBG) and the Long Period Fiber Gratings (LPFG) market is a result of the extraordinary development of the WDM (Wavelength Division Multiplexing) technologies. Various optical fiber components are based on the FBG and on the LPFG and used in WDM networks. They are used for optical data channel insertion and extraction, and they must handle adjacent wavelengths according to the ITU (International Telecommunication Union) standards for WDM. The limitations of FBG and LPFG are presented; in particular, FBG show a possible instability due to temperature and stress changes. The technique of combining electric arcs and geometric deformations to produce LPFG is also discussed. Due to its noticeable flexibility with respect to non-hydrogenated fiber, the electric arc technique presents a great potential for producing more stable fiber gratings by using various fiber materials. Experimental data and pictures of microstructures are presented, including biconic deformations of the modulation index due to tensile stress.

Sommaire

Le marché des réseaux de Bragg sur fibres (FBG) et les réseaux de Bragg à long pas (LPFG) ne cesse de croître suite au développement extraordinaire des technologies de multiplexage en longueur d'onde (WDM). De nombreux composants à fibres optiques utilisés dans les systèmes WDM sont basés sur des FBG et des LPFG. Ils sont employés pour l'insertion et l'extraction de canaux de données optiques et doivent supporter des longueurs d'ondes très rapprochées selon les standards de l'ITU sur les WDM. Les limitations des FBG et des LPFG sont présentées; en particulier, les FBG montrent une instabilité due aux changements de température et de tension. La technique combinant l'arc électrique et les déformations géométriques pour produire les LPFG est également discutée. Dû à sa flexibilité remarquable, la technique d'arc électrique présente un grand potentiel pour être utilisée dans la réalisation de LPFG plus stables en utilisant différents type de fibres. Des données expérimentales et illustrations de microstructures sont présentées, incluant les déformations biconiques de l'index de modulation dûes aux contraintes de tension.

1.0 Introduction

Since their market introduction in 1995, the use of optical Fiber Bragg Gratings in commercial products has grown exponentially, largely in the fields of telecommunications and stress sensors. The demand for broadband is rapidly increasing. This demand for more bandwidth in telecommunication networks has rapidly expanded the search and development of new optical components and devices (especially in Wavelength Division Multiplexers). Optical fiber components are key elements in WDM systems (Figure 1).

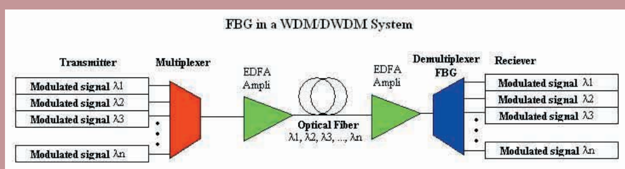


Figure 1. Using FBG in a WDM/DWDM system.

Today, the technology of Fiber Bragg gratings (FBG) and long period fiber gratings (LPFG) has been recognized as one of the most significant enabling technologies for fiber optic communications due to its use in several applications such as gain equalization for Erbium-Doped Fiber Amplifier (EDFA)[4,22], specialized narrowband lasers[19], wavelength division multiplexing (WDM) narrowband and broadband tunable filters[7,20], dispersion compensators for long-distance telecommunication networks[18] and even sensors [8,9,17,23]. The grating period Λ and the grating length (L) are both important factors in building FBG & LPFG.

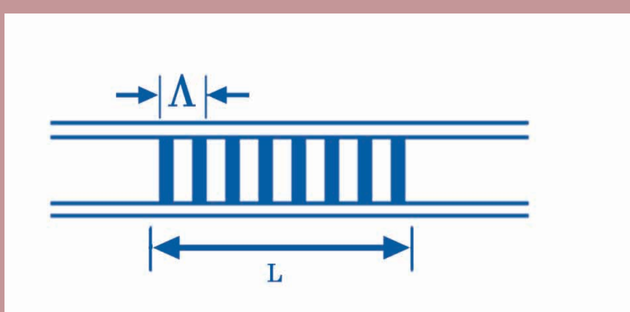


Figure 2: Length and period of FBG and LPFG.

1.1 Fabrication concept

The FBG is a periodic perturbation of the refractive index along the fiber length. Generally, this periodic modification is performed by exposure of the core to an intense optical interference pattern.

UV irradiation through phase masks generates fringe patterns on the fibers therefore producing a periodic index grating which couples the core mode to the dissipating cladding modes [16,18]. Although the UV-based fabrication method is a well-established technology, it has problems. It requires complex and time-consuming processes, including annealing and hydrogen loading for photosensitive fibers (Germanium doped) as well as the need for a large number of photo-masks with various periods.

The first difference between a FBG and a LPFG lies in the size of the grating period, which is respectively about 0.1µm and in the range of 200 µm to 700 µm. Another difference concerns the rejection of the optical data signal with Bragg wavelength. In an FBG, at selected wavelength, the optical signal is reflected (shown in red on Fig. 3) while the other signals are allowed to be transmitted.

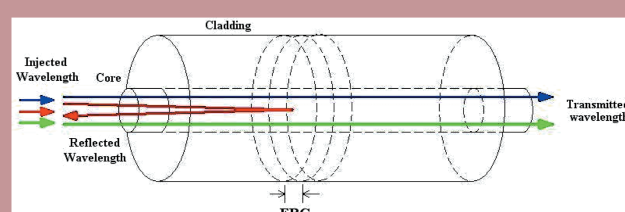


Figure 3: Reflected optical signal in FBG

In an LPFG, for the selected Bragg wavelength, the optical signal exchanges power with the gain mode and is lost (attenuated) while the other signals are allowed to be transmitted.

Another difficulty with UV-induced gratings lies in the photosensitivity of the fibers. This technique requires that fibers contain photosensitive sites, and thus it cannot be applied to those that have no photoreaction

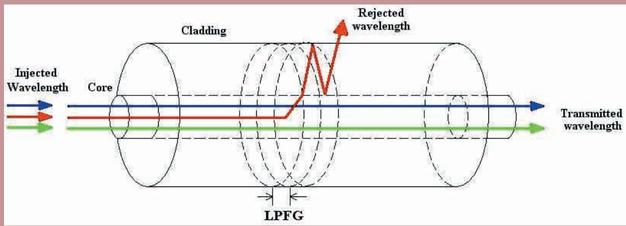


Figure 4. Attenuated optical signal in LPFG.

centers inside 3, 20. But ultimately the UV grating inscription requires expensive and complex laser equipment.

Recently, several photo-insensitive fabrication methods have been reported[1, 2, 3, 5, 6, 11, 12, 21] which overcome some of the technological problems mentioned above while providing comparable results. Some fabrication methods have been demonstrated to be more stable, flexible, and possess additional useful properties.

One of the assets of using the electric arc technique lies in the fact that it is so simple and flexible to use while offering a high thermal stability to the optical component. Studies[13,18] have demonstrated that the gratings implemented by the electric arc technique shows a wavelength shift caused by thermal variation of 0.07nm/100ºC compared to 5 – 15nm/100ºC for UV induced gratings. The temperature sensitivity is related to the refractive index change on the outer cladding of an optical fiber. By using the electric arc technique, temperature insensitive LPFG were produced in this study, thereby eliminating the deterring problem of unstable optical telecommunication components; more specifically building LPFG that is more robust to environmental stress and variations.

The present paper will primarily focus on the electric-arc-based fabrication technique. This technique provides a high thermal stability in the LPFG[7,8,9,18] while using simple and inexpensive fabrication procedure and equipment. To better understand the usefulness of FBG and the LPFG, the limitations of these fiber components and their associated technologies should be investigated. In particular, the instability problem due to environmental changes is worth being investigated. The electric-arc-based technique provides the flexibility to explore new non-conventional grating geometries, which have yet to be introduced. In particular, the technique of combining electric arcs and geometric deformation to produce LPFG will be discussed. For illustration purposes, one of the various microstructures including bi-conic deformation on the modulation index, due to tensile stress, will be presented. The prospects of the fibre gratings and the demands to overcome the present limitations will be presented at the end.

2.0 Limitations with UV radiation technique

In 1978, K. O. Hill et al [10] launched intense Argon-ion laser radiation into a Germanium-doped fiber and observed that after several minutes an increase in the reflected light intensity occurred which grew until almost all the light was reflected by the fiber. This achievement, subsequently called "Hill gratings," was an outgrowth of research on the non-linear properties of Germanium-doped silica fiber. This discovery later led to the UV inscribed fabrication process, which is performed by using the phase mask to create an interference pattern of UV beams in the core of an optical fiber thereby modifying its refractive index along its axis. In a single mode FBG, these interferences patterns or gratings couple the fundamental mode to a contra-propagating for a resonant wavelength thereby reflecting a specific wavelength when white light is injected into the particular fiber. On the other hand, in a single mode LPFG, the fundamental mode is not coupled with a contra-propagating mode. It's coupled with several forward-propagating cladding modes for a resonant wavelength. These lasts decays rapidly as they propagate along the fiber therefore they can be used as band rejection filters.

The UV fabrication process is still the most common and readily used fabrication method in the industry [14]. However, it's relatively complex and time-consuming as mentioned before. FBG and LPFG produced by this method are also plagued by adverse environmental instabilities. These instabilities are caused by strain, bending and thermal sensitivity, doping concentrations, photosensitive degradation, polarization dependence, photo-induced birefringence and etc… Due to these weaknesses, FBG and LPFG based optical components have reached certain limita-

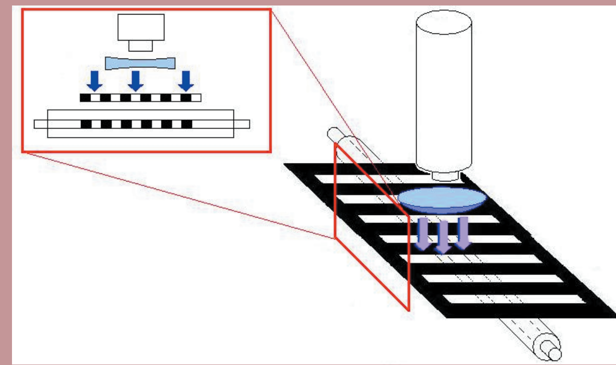


Figure 5. UV used for FBG writing through a phase mask

tion especially in high-speed telecommunication applications. There is a definite technological requirement to overcome such limitation in order to further develop and improve the utilization of the FBG and LPFG based components in high-speed, all optical network applications.

The instability due to sensitivity to temperature and stress is neither specific to fiber grating nor associated to the fabrication technique; the drawback is rather linked to the fiber material in which the gratings are recorded. In order to surmount and overcome this obstacle, new methods of fabricating fiber gratings have been reported. These fabrication processes offer many advantages and introduce the prospects of using different material composites to produce more stable fiber components.

The use of electric arc is powerful and rentable fabrication technique. This method provides a simple, flexible and low cost means of producing LPFG with good overall performance. Moreover, LPFG can be written on any type of optical fiber with this method while providing a high thermal and mechanical stable optical component. The electric arc technique will also provide the flexibility to explore new non-conventional formations. In the following section, we'll take a closer look at how this fabrication process works and the experimental results it produced.

3.0 Experimental Setup

There exist many diverse fiber grating fabrication methods. Each method has a different effect and analysis on the fiber grating knowledge that is essential to the total development of this evolving technology. The electric arc technique provides a very simple yet robust solution to some of the future LPFG development simply because it will allow researchers to explore new various geometric structures on different types and generations of optical fibers like the photonic crystal fibers. One of the greatest advantages of using the electric arc technique resides in the fact that it is so simple and flexible to use yet still providing a high thermal stability to the optical component it helps fabricate. Studies [13,18] have demonstrated that the electric arc technique only has a thermal variation of 0.07nm/100ºC as compared to 5 – 15nm/100ºC on UV induced gratings. The temperature sensitivity has been related to the refractive index change on the outer cladding of an optical fiber. Using the electric arc technique, temperature insensitive LPFG were produced in this study, thereby eliminating the deterring problem of unstable optical telecommunication components; more specifically building LPFG that is more resistant and robust to environmental stress and variations.

Writing LPFG using the electrical arc technique consists of placing an uncoated optical fiber between the electrodes (Fig. 6) of either a splicing machine or an arc generator to induce a refractive index change.

An electric arc, with an approximate diameter of 150um, is generated from the splicing machine creating a grating on the optical fiber. The fiber is then moved periodically to create a series of electrically induced gratings. White light is injected into one end of the optical fiber through a system of focalizing lenses while both end of the fiber are fixed to motorized translation stages that are co-controlled by a central computer. This will provide the option of either displacing the translation stages in unison or to explore the effects of applying micro-tensile stress on an optical fiber to create tapering. The other end of the optical fiber is connected to a spectral analyzer, where the spectral signal will be saved and analyzed. Once the splicing machine cover is closed an internal camera is used to visualize the micro-displacement of the optical fiber while the fabrication process is activated.

Not only are the translation stages connected to the central computer, but the spectral analyzer and the electric splicing machine are as well. The central computer system will oversee all the control and manipulation of the physical hardware of the entire experiment. The objective of having the experiment completely software driven is an attempt to completely isolate the experimental setup to prevent and/or minimize random human error, which can corrupt or affect the experimental data.

A spectral analyzer is used to analyze the component output optical power. This optical signal is characterized while the gratings are inscribed on the optical fiber.

The electric arcs serve to create periodic perturbations along the fiber by modifying the refractive index profile or the geometry of the fiber. These perturbations give rise to the LPFG coupling effect. In this case, the fundamental mode yields a part of its power to the various modes that are being propagated in the fiber (core and cladding modes). The coupling is carried out differently according to the wavelength, and the interaction between modes is characterized by an important attenuation of the output optical power for one wavelength.

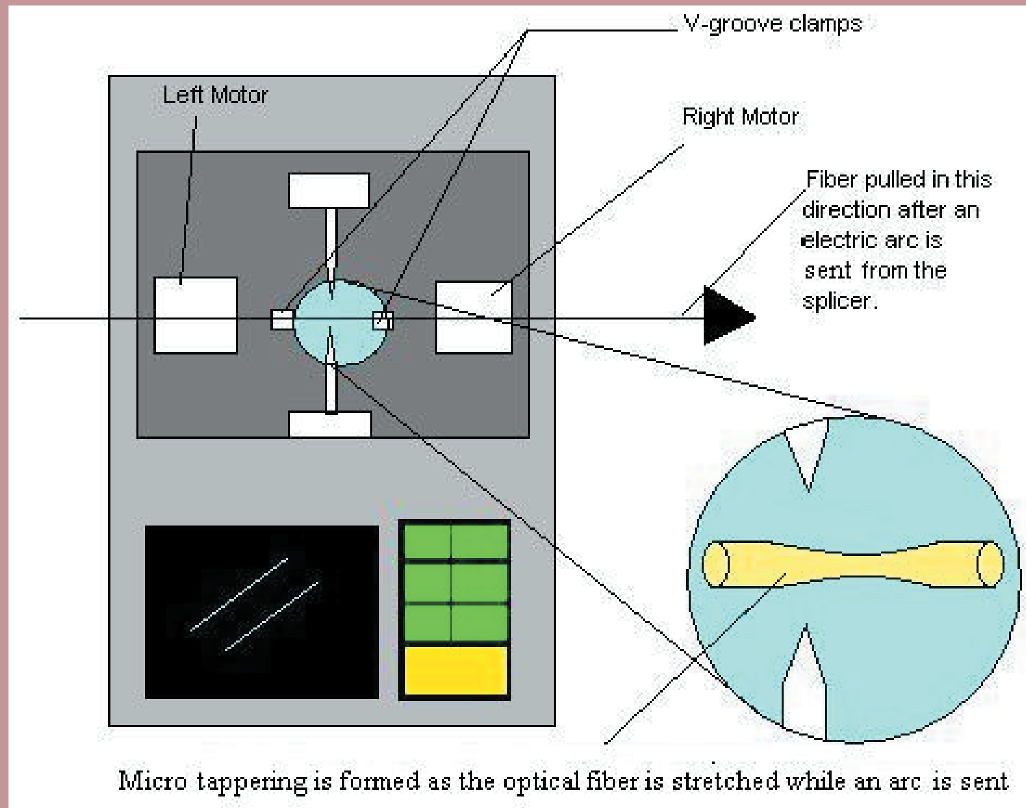


Figure 6. Refractive index changing using electric arc.

4.0 Experimental results

LPFG are fabricated with grating period that varies from 200-700nm while FBG have periods lower than 1um. Since the width of an electric arc is approximately 400um, it's logical that the technique is more suitable to LPFG. Given that the electric arc technique provides the ability to use many different types of optical fiber, an adaptable and accommodating setup is necessary to unsure that flexibility is not lost on encumbering experimental support hardware. In another word, the flexibility of the technique has made it an ideal tool in exploring and analyzing optical components and new geometric formation generated by fiber tapering. In figure Fig. 8 and for a 500µm LPFG period size, we have used a 1mA of the electrical-arc intensity without fiber elongation. After a several exposures to the electrical arc, the transmission spectrums show the output optical power attenuations for different durations of the arc.

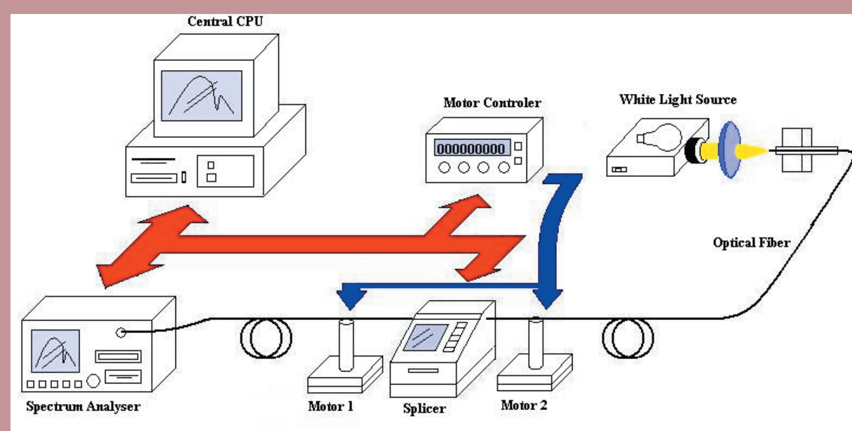


Figure 7. Experimental setup

We note that the electric arc discharge can be used for writing and implementing the Long Period Fiber Bragg Gratings. The fiber doesn't need to be a Germanium doped one. These techniques will also provide the flexibility to explore new non-conventional formations which have yet to be introduced. For the simulation we can use the coupled modes equations [2] to find out the fundamental mode output power at the output of the LPFG. The optical fiber can be considered as an ideal fiber with refractive index variations and core radius perturbations with considering a core modes and cladding modes propagation. After the fabrication process, the LPFG sensitivity to the temperature variations can be analyzed using the heating module mounted on the splicing machine.

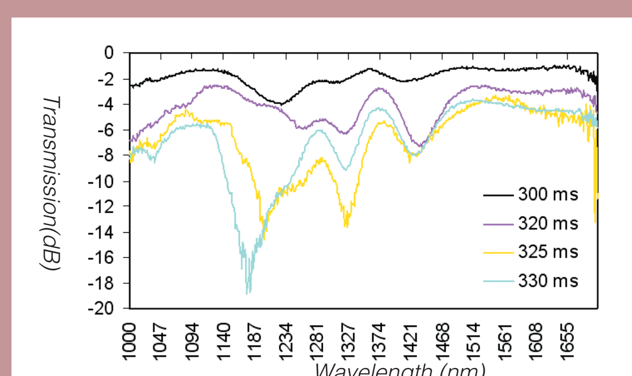


Figure 8. Transmission spectrums for 500µm LPFGs.

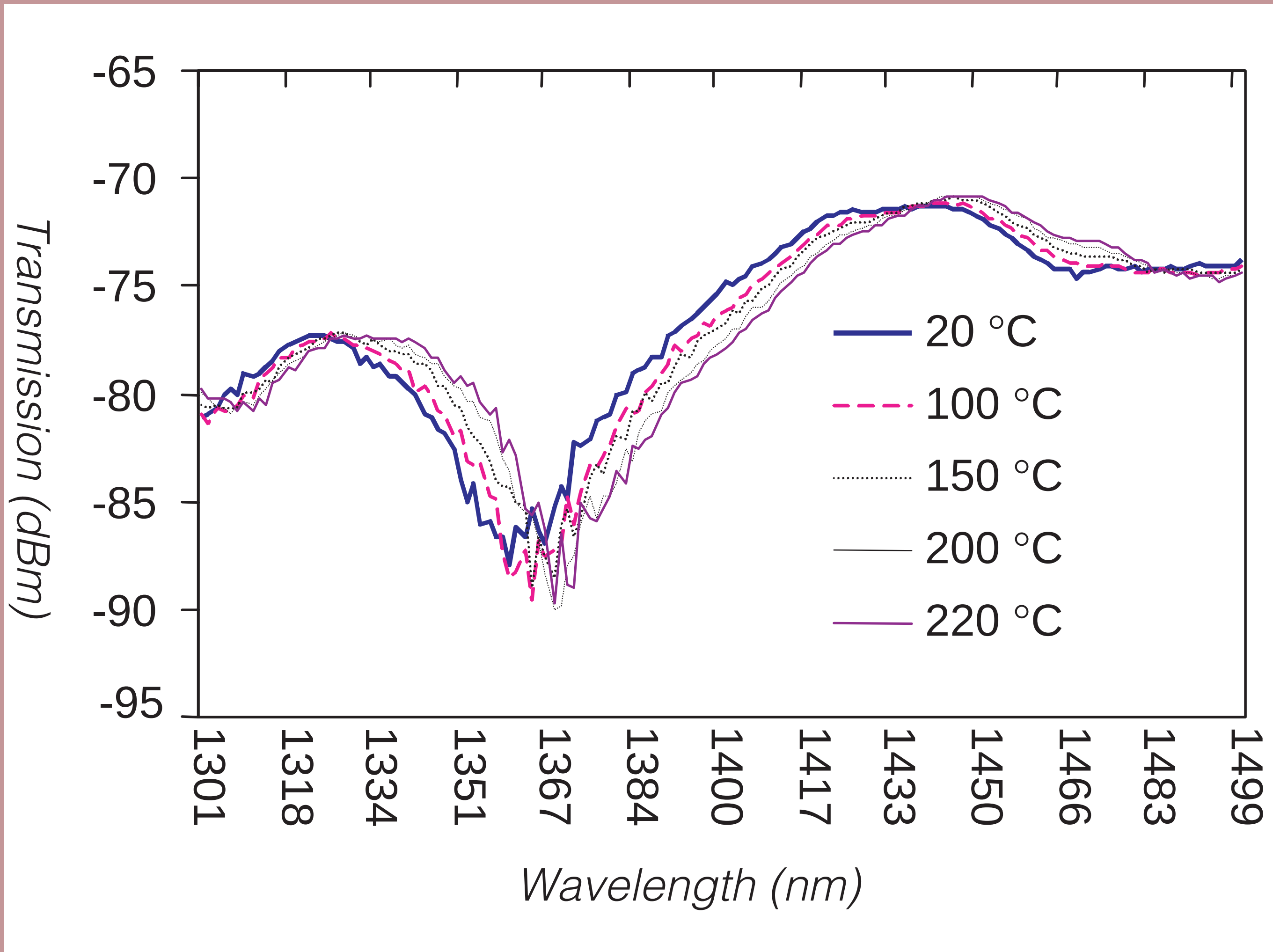


Figure 9. Figure spectrum senstivity to the temperature.

As shown in Fig. 9, electric arc based fabrication techniques provide a thermal stability of the LPFG components. On this figure an important rejection of the optical signal around the wavelength 1367 nm. The vertical axis represents the attenuation in dBm (relative to 1mw power). We note that an attenuation of 3 dB represents 50% of rejection. The LPFG was exposed to different temperatures between 0°C and 220 °C. We observe that the wavelength spectrum shift to greater wavelengths. The sensitivity can be calculated after determination of the wavelength shift as function as the variation of the temperature. For the case shown before, the average wavelength shift is 11 nm (± 1nm) between 1300 nm et 1450 nm for a temperature variation of 200°C. The sensitivity will be around 0.055 nm/ °C (± 0.005nm/ °C). The figure below shows that the sensitivity seems to be linear as function of the temperature variations.

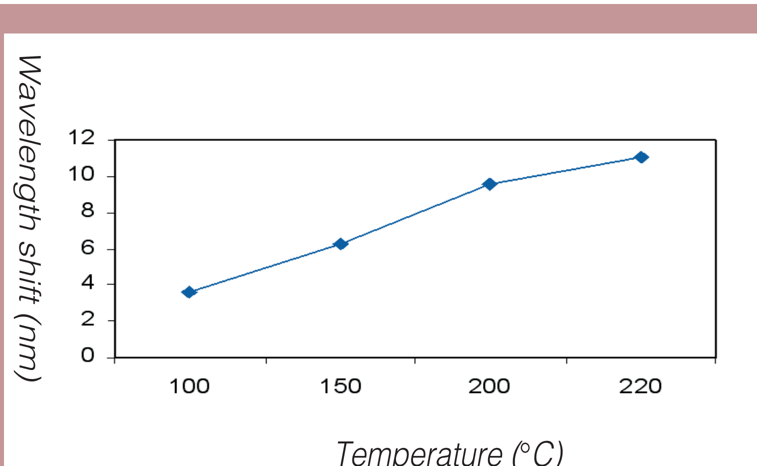


Figure 10. LPFG sensitivity to the temperature.

The electric arc technique provides a very simple yet robust solution to some of the future LPFG development simply because it will allow researchers to explore new various geometric structures on different types and generations of optical fibers like the photonic crystal fibers.

On the computer-controlled translation stage, the fiber can move with a precision under a micrometer. If the optical fiber is elongated under exposition, micro deformations can be produced on the fiber. The LPFG fabrication is accomplished by one or the both processes; by exposition to the arc discharge, and by elongating the fiber using the micro-displacement stage. These two methods create a permanent change of the refractive index of the fiber or/and modulate the effective index along the optical fiber. For micro-deformations we can use also a CO2 laser beam [2]. If the fiber core radius after deformation becomes smaller than the cut-off frequency radius, the core mode becomes a cladding one. At the output optical power is subjected to wavelength oscillations and rejections. Hence, in an LPFG device, optical power is exchanged between core and cladding modes. Periodic

expositions of the optical fiber to the electrical arc produce a permanent and periodic modification of refractive indexes.
The elongation distance is the most important parameter in the fabrication processes. As shown on the figure below we can produce an LPFG only with a few elongations if we use the right elongation distance. The transmission powers are measured for 200µm, 300µm and 400µm elongation sizes.

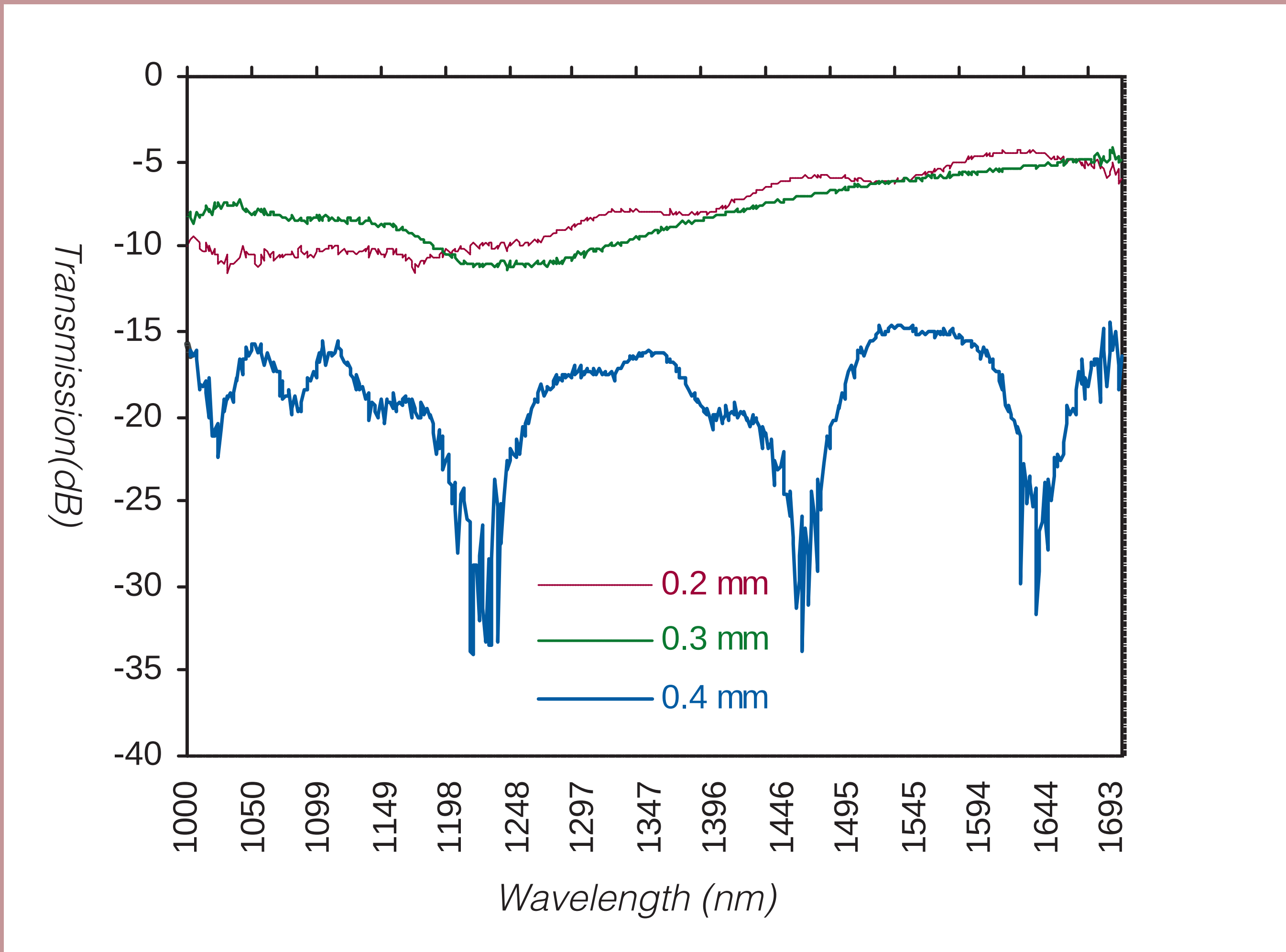


Figure 11. LPFG with different elongation sizes.

The exposition duration is about 350ms; the period size is 500µm.The effect of tension on grating formation was also studied in [19]; by increasing the tension and keeping the arc parameters constant, it is possible to get higher isolation loss with less discharges although insertion loss increases. So with these results, we can say that the axial tension during the LPFG fabrication is favorable to the writing process. Also, it's important to say that different tensions during the writing process produce different resonance wavelengths [19].

Experimental results have been obtained by combining the effects of electric arc and geometric deformation. The objective was to improve the quality and the efficiency of producing LPFG using electric arc by manipulating other favorable external parameters. In our experiment we generated a series of electrically tapered grating in effort to analyze the combined effects on a LPFG. The result shows greater wavelength isolation was obtain as a result of combining the two effects. Even though an initial insertion loss was observed, the final result of the LPFG demonstrated a pronounced wavelength isolation with less inscriptions.

In general, using the electric arc technique has produced comparable and useable wavelength isolation as compared to the conventional UV technique. Cutoff wavelengths with more than 25 db have been produced within the ranges of 1250 nm and 1600 nm. Depending on the type of fiber the gratings has been inscribed on; peak loss position obtained have varied. It demonstrates that the potential to create better optical component resides in the exploration and the research of new types and generation of optical fiber. Therefore by using the electric arc technique it will provide the necessary tool to possibly continue advancing this technology.

5.0 Prospect

The advantage of this technique resides in the simplicity, flexibility and adaptability to study new generations of optical fibers. By using the unique characteristics of these fibers, we can explore and extract properties that will contribute and aide the progression of the development of useful optical component. One of the fibers that we are presently working on includes photonic crystal fibers. The effects of applying an electric arc across a holey fiber will be examined along with the use of other external parameter to create a useable optical component.

Another advantage the electric arc technique provides is the ability to build a self-sustaining optical component-fabricating machine. Instead of simply buying an electric splicing machine, manufacturers can easily build a machine that not only splice optical fibers together but produces custom LPFG as well. This allows producing customized optical components suiting the user's needs.

6.0 Conclusion

With the increase of the number of its applications and its fabrication, we can easily note that the long period fiber gratings are a booming technology. In addition to reducing the costs and the increase in the fabrication rate, every new fabrication method provides new types of LPFGs with new characteristics. Thus, LPFGs that are fabricated with a change of the fiber's macroscopic structure (using CO^2 laser or an electric arc) have a high thermal stability. Moreover, these new characteristics propose new application fields like high temperature applications for electric arc induced LPFGs.

The high economic potential to construct a tool that will enable us to better understand the potentials and the possibilities of this enabling technology is definitely worth investigating. This technique is not only simple to use but will provide a suitable developments on new fibre material which may radically solve the instability problem.

7.0 Acknowledgement

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A Comparative Analysis of Process Maturity Level and Quality

by Louis A. Poulin, Chief Technology Officer
GRafP Technologies Inc.

Abstract

In a world where outsourcing is fast becoming one of the largest revenue-generating business, Information Technology (IT) organizations in developed countries have come to recognize that in order to survive and to grow, they need to demonstrate to their clients that they are among the best. If not, they run the chance of becoming the next outsourcing statistic. Likewise, IT organizations in developing countries that provide outsourcing services also need to demonstrate to their clients in North America and Europe that they are among the best in the world, in order to benefit from outsourcing opportunities. This paper describes a method used to measure expected quality of products and services developed by organizations involved in Information Technology. The approach described herein is based on a sample of 40 comprehensive appraisals conducted in South America, Europe and North America, and shows that an IT organization's processes should focus on improving and deploying practices that prevent potential problems to which it is exposed from occurring, and degenerating into crises. Process maturity is meaningless without having this objective in mind.

Sommaire

L'impartition est en voie de devenir un des marchés les plus importants en termes de génération de revenus. Les organisations oeuvrant en technologies de l'information dans les pays développés en sont venues à reconnaître que pour survivre et croître, elles doivent démontrer à leur clientèle qu'elles sont parmi les meilleures dans leur domaine. Sinon, elles courent la chance de faire partie du nombre croissant d'organisations ayant imparties leurs services et le développement de leurs produits à l'étranger. De même, celles dans les pays en voie de développement doivent démontrer à leurs clients en Europe et en Amérique de Nord qu'elles sont parmi les meilleures au monde, afin de pouvoir bénéficier des opportunités d'impartition qui leur sont offertes. Cet article décrit une méthode utilisée pour mesurer la qualité anticipée des produits et services développés par les organisations oeuvrant en technologies de l'information. L'approche repose sur un échantillon de 40 évaluations détaillées effectuées en Amérique du Sud, en Europe et en Amérique de Nord. Elle démontre entre autres, que les processus déployés par une organisation devraient mettre l'accent sur l'amélioration et le déploiement de pratiques à même de prévenir que les problèmes potentiels auxquels elle est exposée se matérialisent et dégénèrent en crises. Le concept de maturité du processus demeure vide de sens si cet objectif est perdu de vue.

1.0 Introduction

GRafP Technologies has been involved in conducting Capability Maturity Model [1] (CMM®)-based and CMM Integration (CMMI)-based appraisals since 1993. These included Software Process Assessments (SPAs), CMM-Based Appraisals for Internal Process Improvement [2] (CBA IPIs) and appraisals using the Standard CMMI Appraisal Method for Process Improvement (SCAMPI).

Data from a set of 40 comprehensive appraisals conducted over the 10 years, and spanning Europe, North America and South America, was compiled and subsequently used to better understand the factors at stake in organizations developing products and services relying on Information Technology. These appraisals covered levels 2 and 3 of the CMM. In particular, some anomalies were detected that warranted more in-depth analysis. Even though correlation was observed between process maturity level and quality of resulting products and services, it was not true for all cases. Good quality products and services sometimes originated from organizations characterized by a low maturity level, resulting from the relatively low number of IT best practices that had been implemented, whereas in other cases, organizations characterized by a higher maturity level generated disappointing results.

2.0 Overview of the analysis method

Each appraisal was performed in a separate organization. Some examined only one project, whereas others included several (at times, up to five).

Three essential parameters were defined to characterize the state of information technology projects for each appraised organization: Risk Mitigation Capacity (RMC), Risk Perception Level (RPL) and Likelihood of Experiencing Problems (LEP) [3].

RMC corresponds to the practices (also referred to as mitigation mechanisms) that are in place to prevent problems from occurring. In the context of software development and maintenance, and given the selected information technology framework, namely the CMM, and the scope defined for the appraisals (maturity levels 2 and 3), this is equivalent to the process maturity i.e. the capability of integrating human resources, methods, procedures and tools in order to develop an application that satisfies the needs for which it was undertaken, on budget and on schedule. In the approach described herein, RMC was estimated through surveys where respondents qualified the degree to which best practices were implemented, interviews during which survey responses were investigated in greater detail, and at times, through a formal appraisal (e.g. CBA IPI). Given the scope of the appraisals, an RMC of 70% means that the degree of implementation of key practices at level 2 and level 3 is equal to 70% (100% would mean that all key practices are fully implemented and that there are no significant deficiencies).

RPL essentially corresponds to the vulnerability of experiencing problems, as perceived by personnel. To some extent, RPL depends on personnel experience and know-how. It also depends on the process maturity in the sense that an organization exhibiting a mature process is less likely to have to rely on the ability of its personnel to anticipate problems than an organization exhibiting a less mature process, since the former is more likely to have integrated mechanisms required to generate an early warning of upcoming problems. RPL was estimated using the Taxonomy-Based Risk Identification [6] with the help of surveys and interviews, where respondents qualified their perception of the possibility that an undesirable situation would occur or that a desirable situation would not. For instance, an RPL of 20% means that personnel feel that on average, projects undertaken by the organization have 20% chances of experiencing serious problems.

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Qualification of both RMC and RPL was performed using the scale in Table 1. In addition, the value of each practice and the impact of each risk were qualified using the scale in Table 2.

RMC is then calculated as the sum of (Practice Qualification) • (Practice Value) divided by the sum of Practice Values. Likewise, RPL is calculated as the sum of (Risk Qualification) • (Risk Impact) divided by the sum of Risk Impacts.

Finally, LEP is the probability that risks will materialize. In the context of software development and maintenance, this is equivalent to the probability that serious problems will occur in terms of cost overruns, schedule slippages and products or services that do not satisfy the needs for which they were undertaken, to the point of jeopardizing the project or making it a failure. A LEP equal to 30% indicates that on average, projects undertaken by an organization have a 30% probability of experiencing serious schedule, budget or functionality problems.

Qualification	Conversion to percentage
Strongly agree	100%
Agree	80%
Somewhat agree	60%
Somewhat disagree	40%
Disagree	20%
Strongly disagree	0%
Unknown	50%

Table 1

The relationship between RMC, RPL and LEP is defined as follows. The likelihood of experiencing a problem "p", expressed as LEP(p), given the probability P that its occurrence is higher than the perception of risk "r", expressed as RPL(r), and the status "m" of mitigation mechanisms, expressed as RMC(m), in the appraised organization, is based on the exponential cumulative probability distribution function. This function is effectively the one most commonly used to determine the probability of failure for large, complex systems, in which the failure modes are so elaborate that a very large number of paths leading to deterioration involving different failure scenarios are operable simultaneously [4], [5]. LEP is calculated with the following expression:

$$LEP = \int_0^1 r \frac{d}{dr}\Big(1 - P(p > r \mid \mathrm{m})\Big) dr$$

Impact or Value	Conversion to percentage
Very high	100%
High	75%
Moderate	50%
Low	25%
None	0%

Table 2

The nomogram shown in Figure 1 on Page 17 was developed to evaluate LEP, after RMC and RPL had been evaluated as per their aforementioned definition.

A fourth parameter, Software Quality Index (SQI) was also defined to estimate the quality of delivered products and services. Since the relationship between RMC, RPL and LEP is based on an exponential probability distribution, it makes sense, in order to obtain a rating on a linear scale, to calculate the natural logarithm of the result compiled at the organizational level or at the process area level. SQI is therefore calculated with the following expression:

$$SQI = \log_e [1+(RMC/(RPL \bullet LEP))]$$

Adding 1 to the ratio in parentheses ensures that SQI has a minimum value of 0.

Quality, in these appraisals, was defined in a broader context than simply an absence of defects. It also covered aspects such as budget, schedule, functionality, and customer satisfaction. One can expect sustained quality products and services from organizations that are characterized by a high mitigation capacity and a low likelihood of problems. SQI is therefore expected to be high where RMC has a large value and LEP has a low value. The risk perception level does play a role, as a result of the factor RPL • LEP in the denominator of the expression for calculating SQI, but for a given mitigation capacity, a low risk perception level will result in a higher likelihood of experiencing problems, and a high risk perception level will result in a lower likelihood of experiencing problems. The lower the value of the RPL • LEP factor, the higher the value of SQI will be. Since RPL depends to some extent on RMC, a good match between the risk mitigation capacity and the risks facing the organization will increase the value for RPL, decrease the value for LEP and overall, decrease the value of the RPL • LEP factor; conversely, a poor match between the risk mitigation capacity and the risks facing the organization will decrease the value for RPL, increase the value for LEP and overall, increase the value of the RPL • LEP factor. A good match between the risk mitigation capacity and the risks facing an organization is established when practices qualified as having a high value decrease risks that have been qualified as having a high impact.

The ratio RMC/(RPL • LEP) theoretically ranges from 0 to infinity, and so does SQI. In practice, however, SQI was found to range from 1 to 5. Anything lower than 1 is dreadful and anything over 5 is terrific. The fact that this scale corresponds to the maturity levels associated with either CBA IPIs or SCAMPIs is purely coincidental. To reflect this range of values, the Software Quality Index numeric scale was translated into an alphabetic rating scale similar to college report grades, with the help of Table 1:

$0 < SQI \leq 1$	E	Failure
$1 < SQI \leq 2$	D	Poor
$2 < SQI \leq 3$	C	Satisfactory
$3 < SQI \leq 4$	B	Good
$4 < SQI \leq 5$	A	Excellent
$5 < SQI$	A+	Outstanding

Table 3 - Quantitative characteristics of SQI

3.0 Results

Results of the comparative analysis are shown in Table 2. The size of the appraised organizations ranged from 10 software professionals to 750, with an average of 113.5, a standard deviation of 237 and a median of 55. Organizations were followed for several years after an appraisal had been performed to assess their evolution and the overall quality of their products and services. This was done by reviewing business journals in which their overall performance (including financial) had been analyzed, and interviewing personnel involved in developing products and services in these organizations. Findings are summarized in the Notes column of Table 2.

CBA IPIs (formal appraisals covering maturity level 2 and 3) were also conducted in 7 out of the 40 organizations and were used to verify that SQI and maturity level were correlated, and that SQI could be used to measure the expected quality of delivered products and services.

Organizations 2 and 14 were almost a disaster. They survived only because another larger one acquired them at bargain prices; otherwise they would have declared bankruptcy. Their SQI were 1.1 and 1.14, respectively. Organization 23, with an SQI of 0.86, was a complete failure, and would have collapsed had it been operating in a market-driven environment. Government subsidies kept it afloat. The RMC of all three organizations (43.9%, 44.6%, and 37.6%, respectively) suggests low process maturity (level 1).

Organization	RPL	RMC	LEP	SQI	Rating	Formal Appraisal	Maturity Level	Notes
1	48.5%	52.9%	34.1%	1.43	D	No	-	Less than average quality
2	41.3%	43.9%	53.4%	1.10	D	No	-	Near-disaster - Organization almost declared bankruptcy
3	41.4%	58.8%	32.5%	1.68	D	No	-	Average quality
4	22.9%	62.4%	48.2%	1.90	D	No	-	Disaster - Organization declared bankruptcy
5	28.8%	65.7%	35.5%	2.00	C	No	-	Average quality
6	43.2%	59.8%	29.3%	1.74	D	No	-	Average quality
7	40.5%	59.7%	32.1%	1.72	D	No	-	Average quality
8	41.1%	60.9%	29.9%	1.78	D	No	-	Average quality
9	40.1%	62.6%	28.2%	1.88	D	No	-	Average quality
10	31.9%	55.4%	46.9%	1.55	D	No	-	Mediocre results - Survived with subsidies
11	41.2%	59.8%	31.3%	1.73	D	**Yes**	**1**	Less than average quality
12	32.2%	58.6%	42.1%	1.67	D	No	-	Disaster - Organization declared bankruptcy
13	36.1%	54.0%	44.6%	1.47	D	No	-	Near-disaster - Organization was bought out
14	38.0%	44.6%	55.4%	1.14	D	No	-	Near-disaster - Organization was bought out
15	64.5%	43.5%	30.0%	1.18	D	No	-	Average quality
16	44.0%	40.2%	56.1%	0.97	E	No	-	Unknown quality
17	28.5%	81.8%	10.7%	3.33	B	**Yes**	**3**	Good quality
18	36.2%	63.3%	31.1%	1.89	D	No	-	Average quality
19	39.0%	72.6%	15.0%	2.60	C	No	-	Good quality
20	47.1%	60.7%	24.2%	1.84	D	No	-	Better than average quality - Organization was bought out
21	21.0%	83.7%	14.4%	3.36	B	No	-	Good quality
22	35.3%	57.4%	40.6%	1.61	D	No	-	Less than average quality
23	50.1%	37.6%	54.7%	0.86	E	No	-	Mediocre results - Survived with subsidies
24	31.7%	64.3%	34.3%	1.93	D	No	-	Unknown quality
25	34.9%	68.0%	25.5%	2.16	C	No	-	Good quality
26	51.8%	51.1%	33.3%	1.38	D	No	-	Less than average quality
27	38.4%	61.8%	31.1%	1.82	D	No	-	Less than average quality
28	54.1%	60.7%	17.3%	2.01	C	No	-	Better than average quality
29	18.2%	76.7%	32.1%	2.65	C	**Yes**	**2**	Average quality
30	44.7%	59.7%	28.0%	1.75	D	No	-	Average quality
31	34.3%	60.8%	36.8%	1.76	D	No	-	Better than average quality following difficult recovery
32	17.4%	82.0%	22.9%	3.07	B	**Yes**	**2**	Good quality
33	25.6%	67.5%	36.7%	2.10	C	**Yes**	**2**	Less than average quality
34	35.5%	68.0%	24.8%	2.17	C	No	-	Better than average quality
35	37.3%	58.0%	37.8%	1.63	D	**Yes**	**1**	Less than average quality
36	20.2%	80.2%	22.3%	2.93	C	**Yes**	**2**	Good quality
37	32.2%	56.0%	45.9%	1.57	D	No	-	Mediocre results - Survived with subsidies
38	52.7%	63.4%	15.2%	2.19	C	No	-	Better than average quality
39	52.7%	49.5%	34.8%	1.31	D	No	-	Mediocre results - Survived with subsidies
40	32.3%	72.0%	22.0%	2.41	C	No	-	Good quality

Table 3 - Comparative Analysis Results

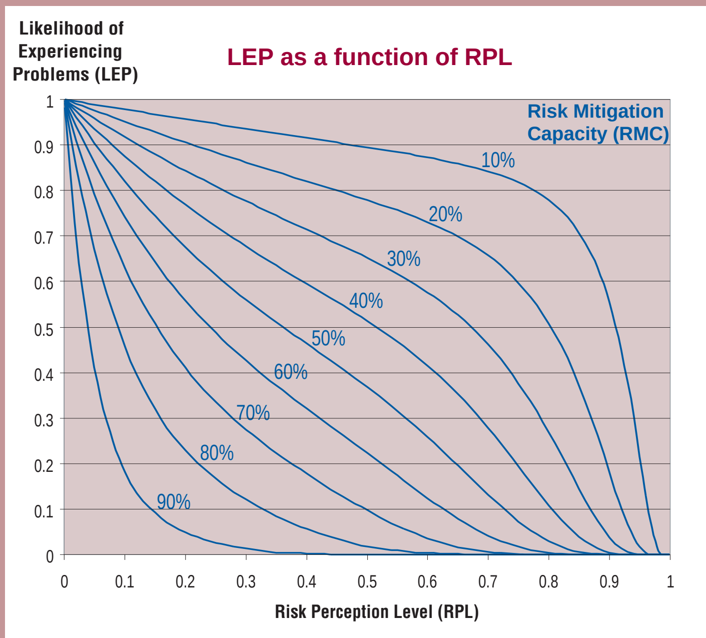

Figure 1 - Nomogram plotting LEP as a function of RPL for several values of RMC

Likewise, organizations 21 and 19, with an SQI of 3.36 and 2.6, respectively, achieved good performance. Had organization 21 been formally appraised, it would likely have been rated at maturity level 3, given its RMC of 83.7%, and as for organization 19, with an RMC of 72.6%, it would likely have achieved maturity level 2, probably with a few goals satisfied at maturity level 3.

Some inconsistencies were nevertheless detected. Organization 4 was characterized by an SQI of 1.9. One can presume that with an RMC equal to 62.4%, it would achieved maturity level 2, or at least satisfied a large number of goals for Process Areas at maturity level 2. Yet, it experienced a loss of 75 million $ and had to declare bankruptcy. Conversely, organization 5, with a similar SQI and an RMC only marginally higher at 65.7%, was performing satisfactorily. In these cases, the LEP parameter had special significance; organization 4 had a 48.2% likelihood of experiencing serious problems whereas for organization 5, this likelihood was 35.5%. This discrepancy was even more pronounced for organizations 28, 29, and 34. Organization 29 was formally appraised at maturity level 2 (RMC equal to 76.7%) and its SQI was equal to 2.65. However, it turned out that the quality of its products and services were below what could have been expected from the process with which they were developed. By comparison, organizations 28 and 34 had an SQI of 2.01 and 2.17, and an RMC of 60.7% and 68%, respectively, but the quality of their products and services was markedly higher. Comparing these three organizations on the basis of their likelihood of experiencing problems was more revealing. Organizations 28, 29 and 34 had an LEP of 17.3%, 32.1%, and 24.8%, respectively. In other words, even though organization 29 had the highest SQI of all three, its LEP suggested a relatively large number of problems to deal with, and a less than ideal match between the IT best practices that had been implemented (i.e. its process maturity) and the problems it was facing. Consequently, its chances of success were reduced as some of these problems had the potential of degenerating into crises, resulting in lower efficiency and productivity.

4.0 Conclusion

Maturity level or SQI complemented with LEP was found to provide a more accurate picture of an organization's capability to develop and maintain software applications than maturity level or SQI alone. LEP provided more insight into what makes an organization more or less capable than another, even when the degree to which they have implemented IT best practices is similar.

Collected data suggests that CMM practices (and CMMI practices, since they are similar) are not all equal, given the context in which an organization operates. Some practices have high risk-mitigation potential, and these should be improved and deployed on a priority basis, since efficiency and productivity are improved by minimizing the number and severity of problems an organization has to deal with in the course of pursuing its business objectives. Others have little value. Implementing them will increase the organization's process maturity level, but their contribution to improving an organization's capability will be minimal.

A final observation was made from the results compiled as part of the comparative analysis. The critical threshold associated with the likelihood of experiencing problems appears to be approximately 40%. A project or an organization cannot sustain such a likelihood of experiencing problems for any significant duration relative to the planned or current activities. In fact, a likelihood of problems equal to 50% would correspond to a project or an organization operating at random, and if such were the case, it would be wishful thinking to expect any successful outcome over a significant period of time. Out of the 40 appraisals that were conducted, 25% exceeded this 40% threshold and in all cases, with the exception of organization 16 where no follow-up could be performed, major difficulties were observed during the 12 to 18 months that followed. Projects were indeed canceled, with the resulting losses or missed opportunities that this entailed, some organizations declared bankruptcy, and others went through a very difficult period. In some cases, the high likelihood of problems was only a symptom of deeper problems, somewhat akin to looking in a dwelling living room and finding a mess because its occupants were trying to salvage what they could out of a house on fire.

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About the author

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Paths Beneath the Seas: Transatlantic Telephone Cable Systems

by Jeremiah F. Hayes
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Abstract

The year 2006 marks the fiftieth anniversary of the first transatlantic telephone cable, TAT-1, which inaugurated the modern era of global communications. Over the last fifty years since TAT-1 went into service, the capacity of telephone cables has grown explosively from the initial thirty-six voice-band channels to modern broadband optical fiber systems, which can carry 100 million voice circuits. As well as a beginning, TAT-1 was a continuation; submarine telegraph cables had been in operation for 90 years. The paper reviews the history of submarine cable starting with the telegraph era, continuing through the TAT-1 and the coaxial systems that succeeded it and culminating in the modern optical systems. The prominent role played by Canada in all of these developments is highlighted.

Sommaire

L'année 2006 souligne le 50e anniversaire du premier câble téléphonique transatlantique, TAT-1, qui a inauguré l'ère moderne des télécommunications globales. Depuis les 50 ans que TAT-1 a été mis en service, la capacité des câbles téléphoniques a crû de façon explosive depuis les 36 canaux initiaux à fréquence vocale jusqu'aux systèmes modernes de fibres optiques à large bande, lesquels peuvent transporter 100 million de circuits vocaux. De même qu'un commencement, TAT-1 a été une continuation : les câbles télégraphiques sous-marins étaient en opération depuis 90 ans. Cet article parcourt l'histoire du câble sous-marin depuis l'ère télégraphique, en passant par TAT-1 et les systèmes coaxiaux qui l'ont succédé et culminant vers les systèmes optiques modernes. Le rôle substantiel joué par le Canada dans tous ces développements est souligné.

1.0 Inception of True Global Telecommunications

It is nearly 50 years since the September 26, 1956 edition of the New York Times had the front page headline:

First Call Made by Phone to Europe
Line's Capacity is 3 Times as Great as Radiophone's

On the same day, similar stories appeared in newspapers throughout Canada. The subject was TAT-1, the first transatlantic telephone system, which had been inaugurated on the previous day. Simultaneously, a symposium on the Atlantic Cable was in progress at the Chateau Laurier in Ottawa. TAT-1 began the modern era of global communications. Before TAT-1, voice was carried on unreliable and expensive radio channels. Text messaging was carried on submarine telegraph cables (the technology of the previous 90 years) which was reliable, but slow and expensive.

2. Back to the Beginning

As well as being a beginning, TAT-1 is the continuation of a story that began on November 8, 1850 with a letter by the Catholic bishop of Newfoundland, J.T.M. Mullock in the St. John's Courier . His Grace outlined a scheme whereby messages dropped from ships passing the eastern coast could be relayed by telegraph across Newfoundland and the Cabot Strait to mainland North America, effecting a saving of days. Fredrick Glisborne, an English telegraph engineer took up the challenge and began the construction of the telegraph line across the rugged interior of Newfoundland. Unfortunately, he ran out of money a short way out from St. John's. Before shuffling off the historical scene, Glisborne's made one lasting contribution: enlisting the involvement of a retired paper manufacturer, Cyrus Field. Field immediately went beyond the relay scheme by advocating transatlantic telegraph transmission. His first concerns were with, what he called, the twin problems of "geography and lightning". On the latter, the challenge of long distance electrical transmission, he consulted Samuel Morse, receiving assurances of feasibility. On the geography, he was encouraged by Lt M. F. Maury, Head of the National Observatory in Washington. In 1853, the US Brig Dolphin had surveyed the ocean floor on the likely path across the Atlantic and found a 'telegraph ridge', whose depth and the surface were suitable for cable laying.

The 1857 and 1858 Expeditions

The first task was installing the cable across the Newfoundland (See Figure 1.) The route consisted of four hundred miles of wilderness with mountains, rivers and gorges – formidable obstacles. In 1856 a cable connecting Cape Ray to Cape Breton in Nova Scotia was laid.

The project then turned, in the summer of 1857, to the bridging of the Atlantic. The American naval ship Niagara started from Queenstown (now called Cobh) followed by the British ship Agamemnon, both fully loaded with cable. The plan was for Niagara to start laying from Valencia Harbour. Agamemnon would then finish the lay to Trinity Bay in Newfoundland after a mid-ocean splice. William Thompson, later Lord Kelvin was the electrician on board, monitoring electrical continuity with his mirror galvanometer. Unfortunately, after 200 miles the cable broke and was lost in 2000 fathoms.

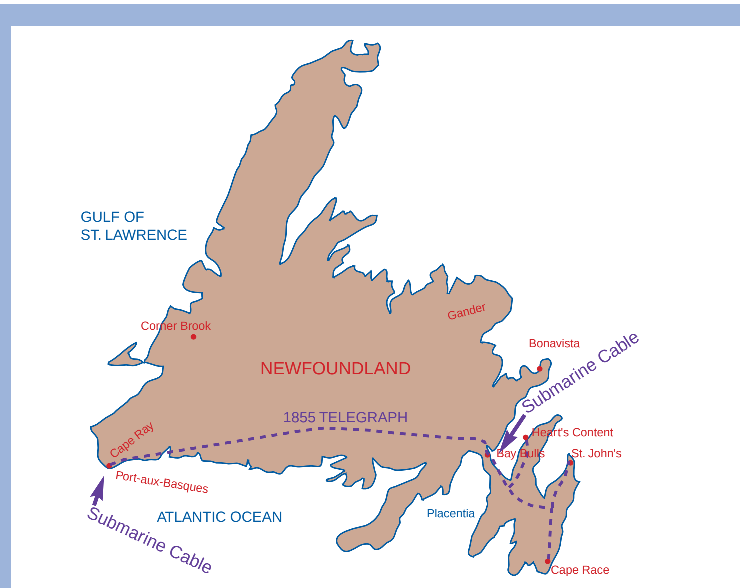


Figure 1: The Route of the 1855 Telegraph Across Newfoundland

The same cable was used in the 1858 attempt; it was, in retrospect, an error. The same two ships met in mid-ocean with Niagara laying. to the west and Agamemnon to the east. Based on the lessons learned in 1857, the cable laying machinery had been improved. There were still cable breaks; nevertheless, the lay finally succeeded.

The new telegraph connection to England was greeted with a widespread outpouring of joy in the New World. This spirit is exemplified in Figure 2 which shows a woodcut depicting huge bursts of fireworks over New York's City Hall[1]. The cable never worked very well and failed after a month of shaky operation.

1 This as well as other wonderful illustrations are reproduced in [2].

The 1865 and 1866 Expeditions

Alarmed by a succession of costly failures in cable laying operations, the British government convened a blue ribbon committee to examine the whole question and to make recommendation. There had been a few examples of success providing grounds for hope. The committee made a number of recommendations one of which was a heavier and bulkier cable; accordingly, the demands on the cable laying ship were correspondingly greater. By a stroke of good fortune, just the right vessel was available-the Great Eastern, which was five or six times the size of anything else afloat when completed in 1857.

Armed with experience and new equipment, the 1865 lay went well until there was a break 600 miles from Newfoundland. The position was carefully noted for future retrieval. Flaws were identified and rectified, and the expedition in 1866 succeeded. The cable was brought ashore at Heart's Content a deep, still inlet on Trinity Bay. There was a message from Vancouver to London on July 31, 1866. There was a double triumph as the Great Eastern grappled for and found the end of the 1865 cable. Thus, there were two fully operational cables! There has been continuous operation ever since.

Figure 2: Fireworks in N.Y. City, celebrating the Atlantic telegraph cable
Illustration reproduced with permission of Emphemera Society of America

Thereafter, submarine cable telegraph service developed continually. A noteworthy point was reached on November 1, 1902 when the "All-Red Route" was inaugurated. This was a globe encircling telegraph path linking only parts of the British Empire. On the west coast the route was across Vancouver island and entered the ocean at Bamfield connecting to Fanning Island over the longest link in the system, 4000 nautical miles.

A significant improvement in cable performance was obtained by applying the principle of inductive loading derived by Oliver Heaviside. In 1924, permalloy, a Bell Labs invention, was wrapped around telegraph cable increasing the bandwidth to 100 Hz, which represented increase in capacity to 400 of words per minute. Further improvement was provided by using paragutta as the insulating material; this is a derivative of guttapercha, the material used from the earliest days of submarine cable. (In later systems, this insulating material would be superseded by the British development, polyethylene.) The siphon detector, invented by Lord Kelvin, continued as the means of deciphering electrical signals by skilled operators.

3. TAT-1

Laying the Groundwork

Long wave radio service was established in 1927 and short wave in 1928[2]. While radio circuits provided a voice service, they are subject to the vagaries of sunspot and seasonal and daily variations ; consequently, submarine cable still had a role to play. The first undersea telephone was a link in a circuit between London and Paris in 1891. In 1921, deep-water telephone cables were laid between Key West and Havana.

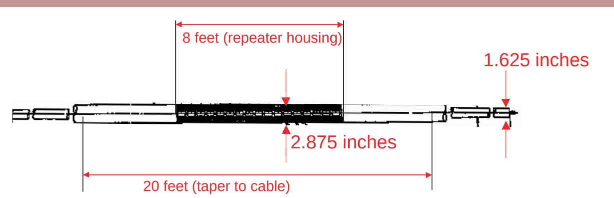
[2] Oliver Heaviside contributed to this aspect of transoceanic transmission as well; he suggested the existence of an atmospheric channel for radio waves, the Heaviside layer.

In 1919, a study of transoceanic submarine telephone cable was initiated by American Telephone and Telegraph Company(AT&T). The advances in materials, mentioned above, enhanced the feasibility of the project. In 1928 this work culminated in a proposal for a repeaterless cable bearing a single voice channel across the Atlantic. Two considerations killed the project: radio circuits were continuously improving and the cost estimate was $15,000,000, a substantial sum in the midst of the Great Depression.

By the early 1930's electronic technology had advanced to the point where a submarine cable system with repeaters became feasible for the transatlantic link. The design of repeaters presented two challenges: electrical and mechanical. The electrical challenge was reliability; repeaters were expected to lie on the ocean bottom for twenty years. The cost associated with the repair due to component failure was prohibitive. All of the electrical components were subject to rigid reliability requirements; however, most fragile were the vacuum tubes, which were the only means of amplification. Development of these super reliable tubes was initiated in 1932. They were life tested for a period of eighteen years. When installed they were significantly below the current state of the art, a mutual conductance of 1000 vs. 6000 micro mhos. They were manufactured under conditions that presaged those of modern semiconductor fabrication.

The repeater design features also contributed to reliability. In order to increase tube life, the signal levels into each stage of the amplifier were a level lower than that causing grid current to flow. In parallel to the three stages of the amplifier was a gas tube which would fire and bypass the stages in the event of a tube failure. In each repeater, was a crystal tuned to a frequency unique to the repeater, thus allowing a malfunctioning repeater to be identified.

The mechanical challenge was the laying of cable in the open sea to depths of up to two and a half statute miles. Standard coaxial cable had spiralled external armouring, which was in danger of kinking if the ship stopped to drop a repeater. The solution to the mechanical problem was a flexible repeater, which, with some modification, could be laid with equipment designed for telegraph systems. (Projected traffic did not justify the construction of a ship designed to lay rigid repeater cable in a continuous fashion.) The repeater used in TAT-1, shown in Figure 3, was designed to flex enough to be wound over the cable drum. The cable itself was coax. The stray capacitance and inductance engendered by the close proximity of components within the repeater restricted bandwidth with the result that amplification could only be in one direction and two cables would be necessary, resulting in a physical four-wire system. The flexible repeater technology in deep water was tested by the 1950 Havana-Key West cable, which used an earlier version of the TAT-1 repeater.



- Gain 60 dB(Top frequency)
- Three stages-pentodes
- Gas diode
- Identification crystals
- Associated passive elements

Figure 3: Flexible Repeater

The British Post Office (BPO) pioneered an alternative approach to submarine telephone cable, deploying rigid repeaters with a far larger diam-

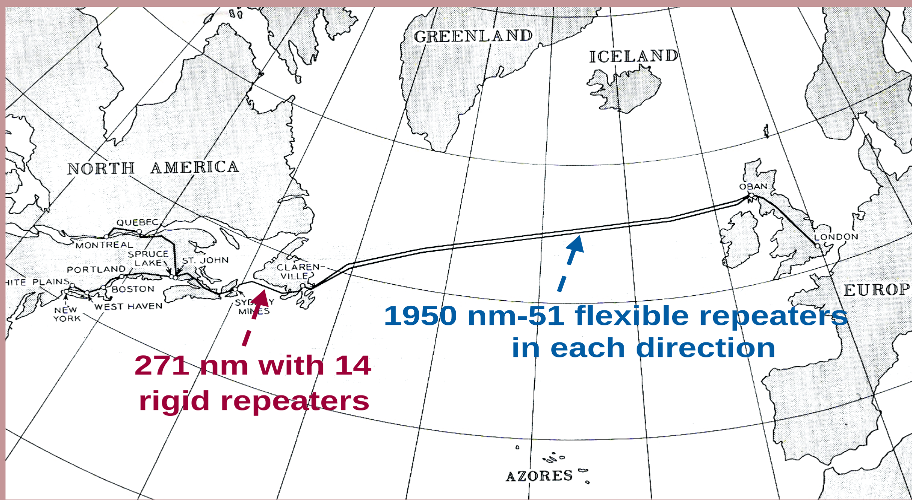


Figure 4: TAT-1 system

eter. This configuration together with more modern vacuum tubes allowed wider bandwidth. With wider bandwidth, the same repeater, with suitable filtering, could be used for both directions of transmission. Undersea telephone systems, using repeaters were not without precedent. In 1943,the British Post Office(BPO) installed a single repeater link between Anglesey and the Isle of Man. The same shallow-water repeater system connected UK and continental Europe in 1946. These steps were the culmination of work that had been going on since 1938.

Laying the Cable

TAT-1 was a joint enterprise between AT&T and its Canadian subsidiary, the Eastern Telephone and Telegraph Company, the BPO and the Canadian Overseas Telecommunications Corporation[3]. Its basic geography is shown in Figure 4. The flexible repeater cable was laid between Oban, Scotland and Clarenville, Newfoundland over the summers of 1955 and 1956 on a route well to the north of existing telegraph cables. Each link was coaxial cable approximately 1950 nautical miles long with 51 repeaters spaced at 37.5 nautical mile intervals. The maximum feasible number of repeaters was determined by the maximum terminal voltage which could be applied to power the systems without affecting the reliability of the high voltage components. The bandwidth of the system was, in turn dictated by the number of repeaters. In addition to the repeaters there were 8 undersea equalizers in the East-West link and 6 in the West-East link. The equalizers served to correct accumulated misalignment in the frequency band. Although the gross difference in cable loss across the transmission band of 144 kHz was 2100 dB, the correction of the equalizers and the repeater circuits led to a difference of less than 1 dB across the band.

As the New York Times headline states, TAT-1 immediately tripled the circuit capacity across the Atlantic. The band of the Atlantic link was between 20 and 164 kHz, allowing 36 voice channels (4 kHz), which were split with six between London and Montreal and twenty nine between London and New York. A single channel was dedicated to narrow band uses such as telegraph and order wire for maintenance.

The system also included an overland portion across the Burin Peninsula to Terrenceville, Newfoundland and an underwater link under the Cabot Strait to Sydney Mines, Nova Scotia. The Cabot Strait link was a single cable 271 nautical miles long with 14 repeaters spaced at 20 nautical miles intervals. The repeater were the rigid type pioneered by the British. This link carried 60 voice channels, 24 of which carried traffic between Newfoundland and Nova Scotia.

Improvements in Terminal Equipment

Transatlantic bandwidth was so costly that it made sense to increase to develop terminal equipment which would use it more efficiently. The BPO designed a channel bank which increased the number of voice channels in the standard 48 kHz band from 12 to 16 by fitting the voice signal into 3 kHz rather that the standard 4 kHz. A two-stage filtering process reduced the guard band between channels without a significant decrease in quality.

A second advance in terminal equipment was Time Assigned Speech Interpolation (TASI). This system was design to take advantage of the fact that, with listening and inter-syllabic pauses, the average speaker uses the voice channel only a quarter of the time, on average. With a voice-activated switch, available bandwidth could be allocated to an active speaker on demand. Using this technique, TASI allowed a doubling of the number of voice circuits, with an imperceptible impairment.

4. Coaxial Systems Following TAT-1

Systems with a flexible repeaters and unidirectional transmission are designated as SB. These systems were subsequently deployed between Clarenville and Penmarch, France (1959) Port Angeles, Washington and Ketchican, Alaska and Port Angeles and Hanauma, Hawaii. Indeed, all of the systems that followed TAT-1, coaxial and optical, were deployed in all of the worlds oceans; however, space limitations require us to concentrate our discussion on cables that crossed the North Atlantic as typical of long-haul submarine cable technology.

After TAT-1, transatlantic traffic grew at a rate of over 20 % year after year. To keep pace with this growth, systems after TAT-1 employed technology that was ever closer to the state of the art in land systems. In 1961 the BPO and the Canadian Overseas Telecommunications Corporation installed CANTAT 1, a system incorporating a lightweight, armourless cable between Hampden, Newfoundland and Oban, Scotland. The cable had strength member in the center rather than the periphery; consequently, in contrast to armoured cable, there was far less danger of kinking if the ship stopped during the lay. The new cable allowed the deployment, in the open sea, of a rigid repeater, with its inherently larger bandwidth . With the larger bandwidth and increased space for circuitry, the repeater, could, by suitable bypass circuitry, carry traffic in both directions on a single cable. The number of available channels increased from 48 to 160. After this last installation, all subsequent transatlantic systems were the single cable, rigid repeater type.

In 1963, TAT-3, a system incorporating SD technology, similar to that of CANTAT-1, was laid between Tuckerton, New Jersey and Widemouth Bay, England by the newly launched cable ship Long Lines. Repeaters were at 20 nautical miles intervals. As in the case of TAT-1, the number of repeaters was limited by the allowable maximum voltage. The bandwidth allowed 138 voice channels in each direction on the single cable. A vacuum tube developed for the SD system improved performance. Reliability was safeguarded by a parallel strings of tubes in the repeater, with one in reserve. A second SD system, TAT-4, was installed between Tuckerton, New Jersey and St Hilaire de Riez, France in 1965.

In addition to increases in the number of voice channels, increases in repeater gain-bandwidth product allowed longer systems.TAT-3 was the first transatlantic system that did not terminate in Canada. Part of the motivation for this change was increased reliability. From the beginning cables have been vulnerable to damage by fishing trawlers. There have been several such breaks on the Grand Banks, whose size increases the hazard. In order to reduce trawler damage, the way that cable lay on the ocean floor was studied in detail by means of submersible , remote controlled vehicles. This study led to the development of techniques for burying cable on the ocean floor.

In 1970, semiconductor technology, in the form of germanium transistors was introduced to submarine cable design with the SF system. The technology was used in TAT-5 which stretched between Tuckerton, New Jersey and St Hilaire de Riez, France. The Canadian cable ship, John Cabot buried the cable in the shallow water off the coasts while Long Lines laid the deeper portions. The lower power requirements of transistors allowed repeater spacing to be decreased to 10 nautical miles resulting in a sizable increase in the number of voice channels, from 138 to 845.

The next advance was the silicon technology, deployed by CANTAT-2 in 1974. This system provided 1840 voice channels between Beaver Harbour, Nova Scotia and Widemouth Bay, England. CANTAT-2 was a second joint effort of the BPO and the Canadian Overseas Telecommunications Corporation.

[3] Later to become Teleglobe Canada

What was to be the last coaxial system to be deployed across the North Atlantic, the SG system, was a joint development by AT&T, the BPO and the French Ministry for Posts and Telecommunications (FPTT). Two cables, each providing 4200 voice circuits, were laid: in 1976, TAT-6, between Green Hill, Rhode Island and St Hilaire de Riez, France and in 1983, TAT-7 between Tuckerton, New Jersey and Lands End, England. Repeater spacing was 5.1 nautical miles. In keeping with the pace of the introduction of technology, amplification in the repeaters was provided by silicon transistors. At a relatively late stage in the system development, it was discovered that the attenuation of cable lying on the ocean floor could change with time. In response, a shore-controlled equalized was developed.

5. Optical Systems

The continual exponential growth rate of well over 20% per year motivated the development of ever higher capacity systems, leading naturally to optical fibre with its vast capacity. Coincidentally, the time of introduction of optical fibre was the beginning of a whole new era in the organization of the telecommunications industry. In the coaxial cable era, systems were developed by public service oriented organizations, like British Telecom, AT&T, France Telecom, and KDD. In the optical era, the business was thrown open to competition. It is symptomatic that the submarine cable operations at AT&T moved, lock stock and personnel to Tyco Inc. In this new competitive era, the number of systems have proliferated; we focus here on typical systems with a Canadian connection.

The use of optical fibre in submarine cable introduced two new requirements in existing optical technology. The first was the familiar requirement for reliability. The vast increase in traffic over fibre limited the role of satellites as backup. The requirement was system lifetimes of twenty-five years with an average of three failures of components. Secondly, the laying and anticipated repair operations placed new demanded on the strength and flexibility of optical fibre.

The first transoceanic optical system, TAT-8[4], went into service in 1988. Transmission was at 1.3 µm over single-mode fibre. The technology mandated digital transmission; signals were generated by injection lasers and detected by newly developed high sensitivity photodiodes. The repeaters were regenerators, which converted from optical to electrical and back again. The system delivered 280 Mbps providing 4000 voice circuits over a pair of fibres.

The system connected Tuckerton, New Jersey, Widemouth Bay, England and Penmarch, France. The inherently smaller size of fibre, compared to coax, allowed two fibre pairs to be housed in the same cable assembly. Repeaters were spaced at 67 km. The repeaters had spare lasers that could be switched into service by shore-based commands. Shore command could also be used to monitor performance. The system also provided a branching unit (BU) at its eastern end, which connected legs from France and England to a single transatlantic cable. The BU enabled switching of branches and fibre pairs in the event of failure in one of the branches.

The innovations of TAT-8 were radical in the conservative milieu of submarine cable; however, TAT-8 amply demonstrated the viability of digital undersea lightwave technology. By 1993 more than 125,000 kilometres of TAT-8 systems were in service worldwide, which almost matched the total length of analog submarine coaxial installations, but installed in 5 rather than 30 years. As time went on, optical cable, with its vastly greater capacity, replaced satellites as the major carrier of intercontinental traffic.

TAT-9, representing a second generation of regenerated undersea lightwave systems, was developed by AT&T and Standard Telephone and Cable (STC) and installed in the summer of 1991. It is a regenerative system with repeater spacing as long as 100 km and three fibre pairs per cable, operating at 560 Mbps. One of the pairs was held in reserve on segments of the system. There are five land terminals: Pennant Point, Nova Scotia, Manahawkin, New Jersey, Conil, Spain, St. Hillaire, France, and Goonhilly, England. Three Undersea Branching Multiplexers (UBM), developed in Canada by MPB Communications, provided circuitry allowing for 140 and 45 Mbps exchanges among fibre pairs. In addition to traffic regeneration and multiplexing, in the UBMs there was DC circuitry to allow for different system powering arrangements, primarily for fault location and restoration after a power fault. The subsequent transatlantic systems, TAT-10 and TAT-11, were a similar design with regenerative repeaters and UBMs.

[4] The generic designation for this system was SL; however, usage changed with optical systems. There was never SM, SN, … Term like SL-280, indicating the bit rate and SL-2000, the millennium became current.

In 1994, the last transatlantic regenerative repeater system, CANTAT 3 went into service. It was developed by Standard Telephone and Cable. The landing points are Nova Scotia, Vestmannaeyjar, Iceland, Tjornuvik, Faroes, Redcar, England, Blaabjerg, Denmark and Sylt, Germany. This was another system employing branching at the eastern end of the cable. The total length of the system was 7500 km with 89 repeaters. The line rate was 2.5 Gbps.

Submarine cable system employing regenerative repeaters have two fundamental limitations:

- The data rate is inherently limited by the intermediate electrical stage in the repeater.
- The data rate of a system is fixed, once the repeater is in the water. Improving performance by upgrades to terminal equipment, such as the 3 kHz channel banks and TASI in TAT-1, is not possible.

The next generation of optical fibre systems employed erbium doped optical amplifiers in the undersea repeaters. These amplifiers amplify signals in the optical band centered at 1.55 µ; there is no optical/electrical conversion. Within the optical band covered by the amplifier, one or more information bearing wavelengths can be placed. This dense wavelength division multiplexing (DWDM) allows data streams to be added as technology advances.

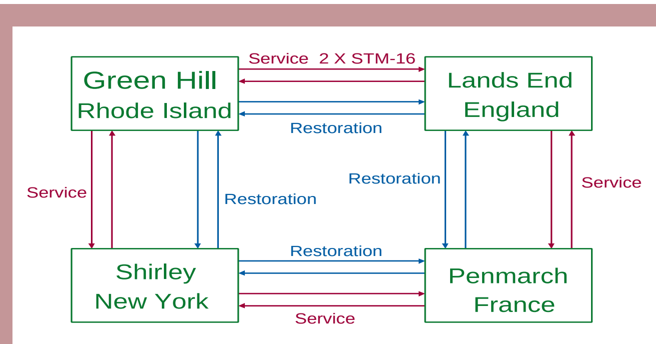


Figure 5: TAT-12/13

The first transatlantic system to employ optical amplifiers was TAT-12/13, which went into service in 1995. The system was a joint development by AT&T-Submarine Systems Inc (SSI), British Telecom, France Telecom and Toshiba. As indicated in Figure 5, the TAT-12/13 has a bidirectional ring topology connecting points in the USA, England and France. The links between Rhode Island and the UK and between France and New York are 5913 km and 6321 km, respectively. Both contain repeaters spaced at 45 km intervals. The segment between the UK and France is 370 km in length and contains four repeaters spaced 74 km apart. Finally, between New York and Rhode Island, high powered optical amplifiers in the terminals power the signal over a repeaterless link.

The cables between the terminals contained two fibre pairs, one in service and a spare. The bidirectional data rate on each of the pairs is 5 Gbps. During normal operation the spare carries lower priority traffic that can be interrupted without penalty. In the event of a cable break, service can be restored in full, immediately by rerouting traffic in the opposite direction around the ring over the spare pair. Subsequently, data was transmitted of two additional wavelengths (colours); thereby tripling capacity.

The latest generation system is represented by TAT-14, which was developed and installed in 2001 by KDD and SCS, a subsidiary of Pirelli. The system is in the form of a bidirectional ring topology. Going counter-clockwise around the ring the its terminals are: Manasquan, New Jersey, Blaabjerg, Denmark, Norden, Germany, Katwijk, Holland, St Valery en Caux, France, Bude-Haven, England and Tuckerton, New Jersey. The capacity of TAT-14 is 640 Gbps, carried on four fibre pairs, two pairs in regular service and two in reserve for restoration of service. Each pair carries sixteen wavelengths bearing a 10 Gbps digital traffic stream.

The latest generation system is the Tyco Global Network (TGN) which was laid in both the Atlantic and Pacific Ocean in 2000-2003. The submarine cable has eight fiber pairs each using DWDM. The total capacity of the system is 7.68Tbps. It can carry more than 100 Million voice circuits. Consider the growth from 36 circuits in fifty years!

The author is grateful to S. Barnes, R.L. Lynch and Y. Niiro for their generous advice on the details of the recent subcable systems.

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About the Author

Jeremiah F. Hayes received the BEE from Manhattan College, the MS in mathematics from New York University and the PhD in Electrical Engineering from the University of California, Berkeley. Dr. Hayes has taught at Purdue University and McGill University, and on 01/01/01 he retired as Distinguished Professor Emeritus from Concordia University in Montreal. As well as academic positions, he was also a member of technical staff at Bell Telephone Laboratories. He is a Life Fellow of the Institute of Electrical and Electronic Engineers. In 1998, he was the fourth recipient of the Canadian Award for Telecommunications research.

Book Review / ***Revue de livre***

Photonic Devices

Author: Jia-Ming Liu,
Cambridge University Press, 2005
ISBN-13 978-0-521-55195-3,
Pages: 1104

Reviewed by: *Habib Hamam*
University of Moncton

Mohsen Guizani
Western Michigan University

This book is composed of five parts: The first part presents a background for photonic devices; the other four parts are: "waveguides and couplers", "nonlinear photonics", "lasers" and "semiconductor optoelectronics".

The book covers the photonic devices subject in a relatively exhaustive way, devoting several chapters to some parts. Each chapter ends with a series of problems and advanced reading lists, which is a very useful for teaching and helpful in research as well. It is well written, well structured and coherently presented, and therefore easy to understand for interested readers. The figures and curves are illustrative and clearly marked.

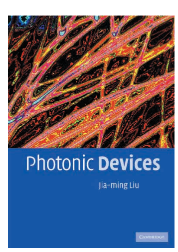
To facilitate the comprehension of equations, the author provided at the beginning of the book an exhaustive 16 pages list of symbols used throughout the book. The reader can refer to this list whenever he/she lost the meaning of one symbol in any equation. A list of abbreviations is also given at the beginning of the document to explain the used acronyms. Fourteen pages have been devoted to only listing the captions of the figures illustrated in the document; this indicates how numerous are the figures and therefore how illustrative is the book.

Specific subjects

In addition to the fourth part handling semiconductors, more than the third of the document has been devoted to non-linear optics and non-linear optical devices (part II). However, despite G. Agrawal's abundant works in this field, only one of his publications ("Semiconductor Lasers", co-authored by N. K. Dutta, Second edition published in 1993 by Kluwer Academic) is referred to in this book.

We believe that an important field such as fiber non-linear optics is worth a separate chapter, although it is not totally ignored in the present edition. The devices associated to this field such as components for dispersion management or for nonlinear management are very useful. While solitons are very important in fiber based applications, they are briefly mentioned in the present book on pages 119, 154, 441 and 468. Covering fiber non-linear optics in more details in the next edition, based on Agrawal's work, should further enrich this part.

Optical fiber components such as fiber gratings are partially covered in an elegant way in the present edition. However, devices such as chirped gratings, micro-structured fiber components, photonic crystal fiber components and tapered optical fiber and sensors merit attention given their wide usefulness.



As well, diffractive optical elements in both versions: fixed (multilevel glass plates … etc.) and reconfigurable (spatial light modulators) are almost totally absent from this publication. Such optical devices are very interesting in communications, instrumentation, metrology, measurements, displays, etc. The most popular diffractive optical element is the diffraction grating designed by Dammann in the 70s. A lot of documents are available online about this subject.

Recommendation

The readers should greatly benefit from this edition, but will benefit more if the next one includes at least a separate section on optical fiber components and applications. All in all, we congratulate the author and the publisher for such an excellent publication.

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