HUGO UPGRADE

THE THIRD LIFE OF THE GEMINI SUBSEA CABLE SYSTEM

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Abstract:

There are several common techniques for upgrading a submarine cable system, including upgrading line terminal equipment and recovering and repairing a repeatered system. This article discusses the first upgrade done by the insertion of innovative new repeaters into an unrepeatered system.

Submarine cable systems form the invisible backbone that carries almost all international data traffic. There has been exponential growth in capacity demand fueled not only by increasing number of users but also increasing methods of access and increasing numbers of services. Businesses also now store less data local and rely on cloud services and data centers adding to demand.

One way to extend the lifetime of existing submarine cable systems is by upgrading the line terminal equipment to higher transmission rates thereby increasing capacity and in the main lowering the cost per transported bit. Such terminal upgrades have become popular since the beginning of the 2000's. Additionally, the use of non-base system vendor equipment for upgrades on dark unused fiber pairs and as shared spectrum on working fibers is now an established upgrade practice.

The recovery and re-lay of out of service submarine cable systems is another way to extend their lifetime. The recovery of a repeatered cable system gives the opportunity to repair faulty repeaters or upgrade the older receive, re-time and retransmit (3R) repeaters (regenerator type) by replacing them with advanced optically amplified repeaters with better optical performance.

This article discusses the first upgrade done by the insertion of innovative new repeaters into an unrepeatered system. The wet plant upgrade of the HUGO cable system increased the capacity and system life of a cable system that was itself built using re-deployed sections from the de-commissioned Gemini system.

Previous Lives of Gemini Cable System

First Ages

Gemini was a transatlantic cable system connecting Porthcurno (UK) to Manasquan (USA), deployed by Cable & Wireless (now Vodafone) and put into service in 1998. The system used a slotted core cable with LS fibers, with a dispersion wavelength of about 1570 nm. The cable system used early second-generation amplified repeaters with a narrow optical spectrum, enabling an original design system capacity of 4 x 2.5 Gbit/s.

Repeatered Revival

The Gemini system was retired in 2006 due to commercial obsolescence, as newer cables had a lower cost per bit. The Gemini cable was broken up into several sections for re-use by Cable & Wireless. Three of these sections were recovered

Figure 1: Gemini South and North legs across the Atlantic Ocean

and re-laid by C&W and Xtera to build regional cable systems in the West Atlantic Ocean. The Gemini Bermuda cable system between Manasquan and Bermuda (1,572 km), the Caribbean Bermuda US (CBUS) cable system between Bermuda and Tortola in the British Virgin Islands (1,692 km), and East West Cable system connecting Jamaica, Dominican Republic and the British Virgin Islands (1,745 km). These redeployed cable systems made use of the original Gemini repeaters and were upgraded to transport up to 720 Gbit/s using the most up-to-date transmission equipment at the time of the redeployment.

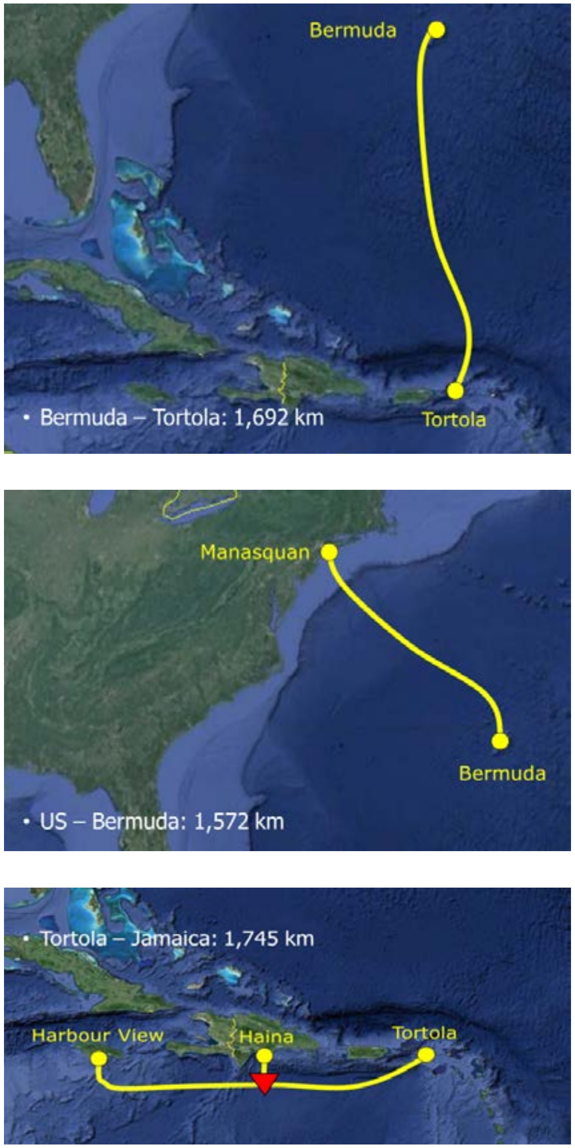


Figure 2: Three regional subsea cable systems built with pieces from decommissioned Gemini cable system.

Conversion to Unrepeatered – HUGO

The eastern portion of Gemini South was re-routed by C&W and France Telecom Marine (now Orange Marine) from Porthcurno in Cornwall to Guernsey (270 km) and from Guernsey to Lannion in France (170 km) in 2006. The repeaters were removed from both segments and returned to the original supplier Alcatel for recycling. The system was called the High capacity, Undersea Guernsey Optical-fiber (HUGO), although the acronym was partly chosen in honor of the author Victor Hugo who lived in Guernsey. Xtera supplied the submarine line terminal equipment to launch 10G optical wavelengths into both segments. Due to the high zero dispersion wavelength at about 1570 nm, optical wavelengths were allocated above 1590 nm (about 40 waves could be used between 1593 and 1618 nm). The driver for this wavelength allocation was:

- Getting away from the zero dispersion wavelength in order to avoid significant nonlinear Four-Wave Mixing (FWM) effect favored by low chromatic dispersion and high channel power (as required in long unrepeatered link);
- Operating in the positive chromatic dispersion regime for better transmis-

Figure 3: High capacity, Undersea Guernsey Optical-fiber (HUGO) subsea cable system.

sion performance and easier chromatic dispersion compensation.

The English Channel is one of the world's busiest seaways as well as being a fertile fishing ground. As a result, knocks from anchors and fishing nets caused higher than expected losses. Individual losses tended to be small but the large number of them and their distribution along the cable prevented economic repair. This limited the system from reaching its maximum upgrade design capacity with satisfactory performance. Furthermore, the increase in cable attenuation prevented upgrading to 100G waves.

A New Lease on Life: Back to Repeatered!

Two options were considered for increasing the capacity of the HUGO cable system. The first option was the insertion of two Remote Optically Pumped Amplifiers (ROPAs) into the cable. A ROPA is a very simple sub-system that is typically placed 60 to 150 km ahead of the receive end, depending on the system length and fiber attenuation. This sub-system is made on a few passive optical components that are placed inside an enclosure and jointed into the cable. As the ROPA is passive it requires no remote electrical power feeding from the cable end. The energy, necessary for creating optical amplification, is sent to the ROPA by optical pump waves launched into the line fiber from the terminal equipment. Although usually effective, in this case ROPAs would only have enabled a limited increase in capacity, due to the nature of the losses, thus not justifying the cost.

The second option was the insertion of optical repeaters, with the clear benefit to significantly boost the system capacity and optical margin, and enabling an upgrade to 100G waves. This option was possible due to the copper conductor in the original Gemini repeatered cable enabling electrical power feeding. Due to the short segment length only two repeaters were required in the longest segment between Porthcurno and Guernsey making it possible to use a low voltage Power Feed Equipment (PFE).

Figure 4: Simplified repeater assembly

The return on investment clearly favored the repeater option in terms of capacity, optical margin, ultimate upgrade capacity and system life.

Innovative Repeaters for Creative Undersea Repeater Upgrade

Since the introduction of fiber optics to submarine telecommunications in the 1980's there has only been one major revolutionary change in repeater technology, this being the switch from regenerative (3R) repeaters to optically-amplified repeaters. Other changes have been evolutionary increments of established designs. Such low speed of innovation seems surprising if compared with other advances in undersea communication technology and the tremendous growth in capacity across the globe. The change to optically amplified repeaters made the undersea plant agnostic (to some extent) to data speeds (2.5G, 10G, 100G, etc.). This allowed suppliers to develop ever more advanced transmission equipment to service capacity demands without addressing the limitations of repeaters.

With this in mind Xtera launched a new repeater in 2013. It had to be an evolutionary increment to existing industry designs in order to satisfy demanding reliability requirements, but also needed to offer a substantial capacity increase.

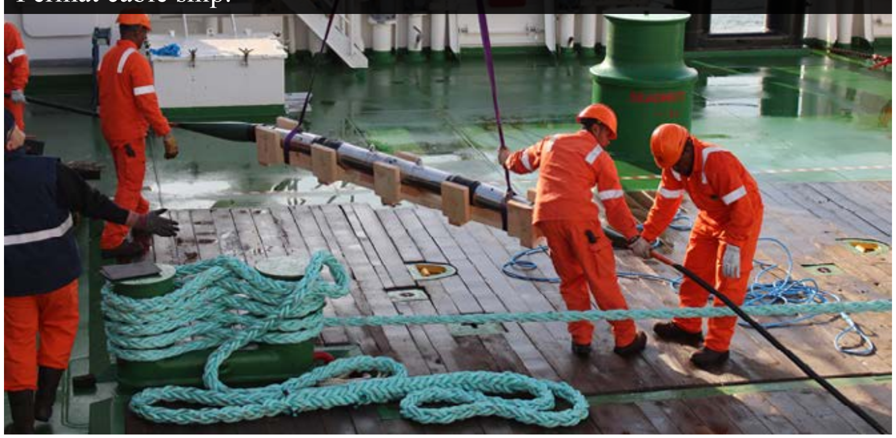
With the advantage of not being restricted by an existing design, Xtera have been able to find modern solutions to old problems. All previous designs of repeaters used Erbium Doped Fiber Amplifiers (EDFA). Due to the physics of amplification, the bandwidth is limited to about to around 35 nm. By combining this amplifier with a Raman amplifier (named after the Nobel Prize winning physicist C.V. Raman), a bandwidth of up to 60 nm can be achieved.

Beyond the improved optical performance, Xtera's repeater offers the industry's smallest form factor repeater product, enabling easy pass through cable ploughs and facilitating deployment operations.

Project Implementation

The challenges encountered during the system design phase of the new repeatered system are somewhat similar to those faced when unrepeatered line terminal equipment was selected in 2006. The small fiber core, relatively high loss, some ageing and a high zero dispersion wavelength above the conventional operation band of a traditional EDFA (the so called C band, typically ranging from 1530 to 1565 nm), were all challenging. In order to limit the amount of fiber nonlinearities, an unusual bandwidth window (above the C band on a wavelength scale) and a lower than usual output power was selected.

Figure 5: Loading HUGO repeaters on Orange Marine's Pierre de Fermat cable ship.



The challenging time schedule for the HUGO upgrade project was imposed by a combination of declining optical margin, customer demand for increased capacity, the limited weather window in the English Channel, vessel availability and customers request to minimize down-time. The contract was signed in December 2014, and the system was operational mid-June 2015.

Discussion

Once the repeaters had been installed and terminals upgraded the system performed far in excess of initial expectations. The optical margin is now greater than when the system was originally installed in 2006. The maximum upgrade capacity is in excess of 9 Tbit/s, which is 225 times that of the original Gemini system. The Gemini cable was first installed in 1998 and after this upgrade can now be expected to carrying traffic until at least 2040.

This type of upgrade has many advantages over a new turnkey build. Not least there is a significant cost advantage and it makes good sense to get the maximum possible life out of an existing investment. However, such an upgrade is not as simple as a turnkey project. There will be unexpected issues that may cause delays and extra costs, which require careful management in order to ensure success. Xtera is grateful to the submarine engineering team in Vodafone and their consortium partners Sure Telecom for helping make this project a success and adopting this new approach to growing capacity demands.

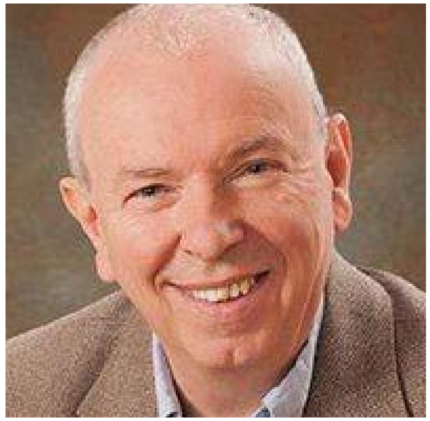
Organizations involved in the upgrade

Xtera Communications, Inc. (NASDAQ: XCOM) have been upgrading submarine systems since 2004 and with its new repeater offering has become the world's most innovative of turnkey submarine supplier.

Orange Marine, previously France Telecom Marine, have been a leading supplier of marine services to the telecom industry for decades. It has recently taken delivery of the one of the industry's most advanced cable ships the Pierre de Fermat.

Sure, originally The States Telephone department, was founded in 1892 and is the leading provider of telecom services in Guernsey and well as Jersey and the Isle of Man.

Vodafone, previously Cable & wireless, has been involved in submarine engineering since its beginning in the 1860's and is still a leading provider of engineering services.



Stuart Barnes joined Xtera in 2007 and serves as the Senior Vice President and General Manager, Xtera Submarine Business. Stuart has over 30 years of experience in the submarine telecommunications business. Prior to Xtera, Stuart was the founder and COO of Polariq, as well as founder and CTO of both Azea Networks and of ilotron. In addition, Dr. Barnes has held senior management positions at Atlas Venture, Alcatel Recherche, STC Submarine Systems and STC Cables Newport. Stuart holds over 20 patents, has published over 40 papers, and has been recently appointed to the Advisory Board of the Aston University Institute of Photonics.

Bertrand Clesca is Head of Global Marketing for Xtera and is based in Paris, France. Bertrand has over twenty five years of experience in the optical telecommunications industry, having held a number of research, engineering, marketing and sales positions in both small and large organizations. Bertrand Clesca holds an MSC in Physics and Optical Engineering from Institut d'Optique Graduate School, Orsay (France), an MSC in Telecommunications from Telecom ParisTech (fka Ecole Nationale Supérieure des Télécommunications), Paris (France), and an MBA from Sciences Po (aka Institut d'Etudes Politiques), Paris (France).

Tony Frisch started at BT's Research labs and then moved to Alcatel Australia, becoming involved in testing submarine systems. A move to Bell Labs gave him experience in terminal design and troubleshooting, after which he went back to Alcatel France, where he worked in Alcatel Submarine Networks' Technical Sales before moving to head Product Marketing. He is now SVP, Repeaters and Branching Unit for Xtera Communications.