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In This Issue:

Time Has Come For Taking Innovation Under Water: The How And Why Of A New Repeater

SEACOM – Upgrading the African Internet

'Onwards and Eastwards' E-marine MD & CEO Highlights The Challenges And Ambitions Of Hosting The Next SubOptic

Trends In African International Capacity Purchasing

Time Has Come For Taking Innovation Under Water

The How And Why Of A New Repeater

Stuart Barnes, Tony Frisch
& Joerg Schwartz

Since the introduction of fiber optics to submarine telecommunications in the 1980's there has only been one major evolutionary change in repeater technology, this being the switch from regenerative (3R) repeaters to optically-amplified repeaters, which made the undersea plant agnostic to the line rate and format. Such low speed of innovation seems surprising if compared with other advances in undersea communication technology. For example, let's have a look at how terminal equipment, and in particular the Time Division Multiplexing (TDM) line rate, has changed over the same period. The first repeatered cable system was UK-Belgium 5 laid in 1986, operated with a single plesiochronous channel (it was regenerative!) at 140Mbit/s; recently, 100Gbit/s per wavelength was deployed on submarine links of the GBI network by Xtera. With odd releases (such as 420Mbit/s) there were eight incremental changes to the line rate per system or subsequently wavelength in a period where repeater technology has only changed once! Submerged plant, however, needs to be very much more reliable than terminal equipment that explains the reluctance of suppliers to make changes without some pressure.

Lightweight repeater undergoing extensive terrestrial test to simulate deployment, handling and recovery

Other than the miniaturized 2-pair repeater developed by start-up company RedSky (subsequently acquired by Huawei Marine Networks) and some internal improvements, such as better spectral flattening, repeater technology has been little changed for well over a decade. With the introduction of coherent detection techniques coupled with breakthroughs in Forward Error Correction (FEC) – such as soft-decision coding – the TDM approach continues to be appealing. However, there is not much further to go with FEC; other digital technologies to allow transmit pulse shaping and mitigate the effects of non-linear impairments seem likely to be a route to increased capacity. There is no doubt that scientists and engineers will continue to rise to this challenge, but it is equally clear that this is not the only solution and that revisiting the somewhat neglected submerged amplifier might also yield some benefits.

About 3 years ago Xtera therefore embarked on a journey to develop a new repeater to satisfy the conflicting needs of the industry. On the one hand, it had to be evolutionary to meet the stringent reliability expectations of the industry, but on the other hand it also had to address the need for more bandwidth/capacity at lower cost per transmitted bit.

One key advantage that Xtera had from the beginning was its rich history in Raman amplifier design. Xtera started its company history in the late 1990's as a start-up that was specifically focused on Raman amplifier design, filing well over 100 patents on this topic alone. This has been a consistent theme running through all its product innovations, both in terrestrial and unrepeatered submarine systems where Raman amplification leads to higher line capacity and longer reach when compared to the conventional amplification approach. Coupled with that, the UK arm of Xtera has a rich vein of skills in long-haul submarine system design and had been able to learn from the experience of upgrading a number of different systems.

So what are the main differentiators that are accessible by using Raman amplification technology in a repeater? There are actually two answers to this question: the Raman effect can be used to create gain in the line fiber, thus attaining a noise figure that is inherently lower than that of a traditional Erbium-Doped Fiber Amplifier (EDFA); the Raman effect can also be utilized to create gain outside the fixed window provided by classical EDFA amplifiers. The former opens the gate to increasing the inter-repeater spans for some specific applications, while the latter can be used to widen the useable optical bandwidth in a system.

So far Raman amplification has had no place in a real submerged amplifier, although there have been numerous publications, some suggesting a hybrid mix of EDFA and distributed Raman. However, the pumps needed are less efficient than EDFA pumps and more power is required, which might explain why people have shied away from this approach so far. Through careful attention to the electronic design and using more modern approaches to drive circuitry Xtera has overcome this barrier and is now able to offer the first hybrid EDFA / distributed Raman amplifier for use underwater.

In doing this, Xtera has not forgotten the critical standards of performance and reliability demanded by the submarine communications industry with a design that uses six pumps per amplifier pair with redundancy to cover the possibility of a pump failing. Xtera has also selected pumps which have very good reliability pedigree and will also be using control / supervisory unit redundancy. Throughout the whole design and development process Xtera has always been mindful of the conservative approach that is demanded by submarine cable system operators. The first repeater release has a bandwidth of more than 50nm on transoceanic distances – nonetheless a significant increase over current EDFA designs – with an overall architecture that will be recognizable as essentially an evolution from the "industry standard".

Next, Xtera has developed a modular approach to amplifier design that allows the offering of at least three variants of the optical amplifier to target different market segments. Xtera has also learned from terrestrial amplifier module suppliers who long ago surpassed subsea cable system industry in terms of miniaturization. Allied to some proprietary tricks Xtera has developed a product that is easier to manufacture, offering the option to assemble the repeater in much less specialized, clean room environments, and that may also offer the ability to take some of the assembly and test closer to the deployment location.

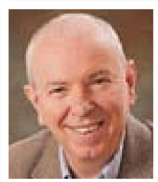
Finally, Titanium was chosen for the housing and external metal units. Titanium has become the material of first choice in the hydrospace sector, in particular oil and gas. It has the best specific strength of all the candidate materials and excellent corrosion characteristics in sea water. Together with a small form factor amplifier module, Xtera has evolved a much lighter, smaller form factor product that is suitable for both surface laying and plough burial. In general, the mechanical design was equally challenging from inside to outside. The first challenge was building a scalable internal unit that gave intimate contact with the inside polymeric liner (need for electrical insulation) in order to give optimal heat transfer to the outside of the repeater and supported by comprehensive thermal modeling. Xtera has carried out extensive work with Southampton University to understand some of the fundamental characteristics of Titanium, such as corrosion, thermal, and hydrogen permittivity. In addition Xtera had to design new bulkheads and seals and new interconnection solutions. These designs were extensively tested at a conceptual level prior to mechanical testing and formal qualification.

Armored cable being made ready for recent sea trial

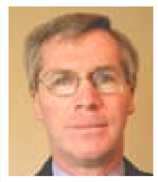
The journey has been long and arduous, as one would expect from a multi-disciplinary task such as this, with full knowledge that some of the concepts discussed above would require extensive concept and qualification testing, often with the assistance of cable or installation partners. In addition to designing a higher-bandwidth amplifier, Xtera had to select electrical and optical components to meet the stringent reliability requirements of the industry. From an electrical perspective Xtera was focused not only on the control and supervisory aspects, but also on broader system requirements such as surge resilience and the high voltage reliability of the extremity boxes that join the repeater to the cables.

Formal and extensive qualification is the subject in this industry that burns up a lot of time and cost. Based on in-house experience developing and introducing terminal equipment to the submarine systems market Xtera felt it necessary to ask a reputable Tier 1 operator to act as an independent qualification authority; this Tier 1 operator has audited the design, specification and qualification process, which includes the usual gamut of terrestrial testing and sea trials. The latter were facilitated by Xtera's already ongoing and expanding activities in the submarine turnkey market, through which Xtera has already executed a number of full system deployments, ranging from redeployments to completely new systems and including repeatered and unrepeatered installations of different sizes. Through this Xtera has not only vastly expanded its in-house expertise in planning and execution of submerged installation, but also developed partnerships with cable manufacturers, survey companies, or marine installation suppliers.

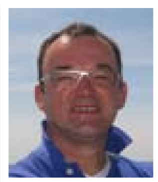
These partnerships, combined with in-house SLTE and abundant system engineering expertise, will enable Xtera to be a serious player in this market by having control of the following elements either through an internal resource or through partnership means: system design, transmission equipment design and manufacture, ocean cable, installation plant and finally repeater technology. Having established relationships with recognized leaders in cable and installation Xtera was happy to embark on an exciting journey that has led to today's product – which will continue by serving the needs of new customers that are looking for a new generation of submerged plant for maximizing the reach, capacity and value of their subsea assets.



Dr. Stuart Barnes joined Xtera in 2007 and serves as the CTO for submarine systems. 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.



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 for Xtera Communications.



Dr. Joerg Schwartz is responsible for Xtera's Turnkey Solutions product offering, delivering end-to-end submarine solutions to network operators based on the company's transmission, equipment, and project execution expertise. Prior to this, Joerg has directed the NXT system definition and developed Xtera's systems engineering team, providing network solution design, field and lab trials, sales support, and systems research. Other previous experiences include engineering and operational management roles for Ericsson, submarine terminal development for Alcatel, and founding an optical components company.