Transforming Subsea Optical Cables into a Giant Network of Environmental Sensors

G. Marra[1], D. M. Fairweather[2], V. Kamalov[3], P. Gaynor[1], M. Cantono[3], S. Mulholland[1], B. Baptie[4], J. C. Castellanos[3], G. Vagenas[1], J.-O. Gaudron[1], J. Kronjäger[1], I. R. Hill[1], M. Schioppo[1], I. Barbeito Edreira[1], K. A. Burrows[1], C. Clivati[5], D. Calonico[5], A. Curtis[2]

[1]National Physical Laboratory (NPL), Teddington, UK.
[2]School of GeoSciences, University of Edinburgh, Edinburgh, UK
[3]Google LLC, Mountain View, CA, USA. 4British Geological Survey, Edinburgh, UK
[5]Istituto Nazionale di Ricerca Metrologica (INRIM), Turin, Italy

giuseppe.marra@npl.co.uk

Abstract: We show that seafloor-cables, when combined with ultra-stable interferometry, can act as arrays of environmental sensors for earthquakes, ocean currents and other ocean signals, with potentially game-changing applications in Earth monitoring.

The extensive seafloor optical cable infrastructure has revolutionized global communication, enabling the exponential growth of digital services in our society. Now, this vast subsea infrastructure could bring another revolution in Earth monitoring if combined with ultra-stable interferometry. Indeed, despite substantial expansion of sensing capabilities the oceans are still largely unmonitored, limiting our understanding of the Earth's structure and dynamic behaviour. We have previously shown that optical fibre links used for optical frequency metrology can be used as earthquake detectors [1]. In this new work we demonstrate a novel technique that enables seafloor cables to be used as arrays of sensors, by isolating the environmentally-induced optical perturbations on each cable span. We achieve this by exploiting the architecture of modern optical repeaters which include a return path between the two fibres of the telecommunication fibre pair, enabling loop-back interferometric measurements over the optical path to each repeater (figure 1A). By performing the difference between loop-back signals we were able to isolate the environmental perturbations acting on the cable between the repeaters, effectively transforming the cable into an array of sensors.

We tested our technique on a 5,860 km-long intercontinental seafloor cable between the UK and Canada (figure 1B), demonstrating the detection of earthquakes, ocean currents and storms. By applying this technique to the existing seafloor infrastructure, a dense and extensive real-time sensor array network for ocean floor monitoring on a global scale could be achieved, without any changes to the subsea infrastructure. The cable-based environmental sensor network could enable game-changing applications in seismology, oceanography and climate change research and, potentially, early detection of tsunamis.

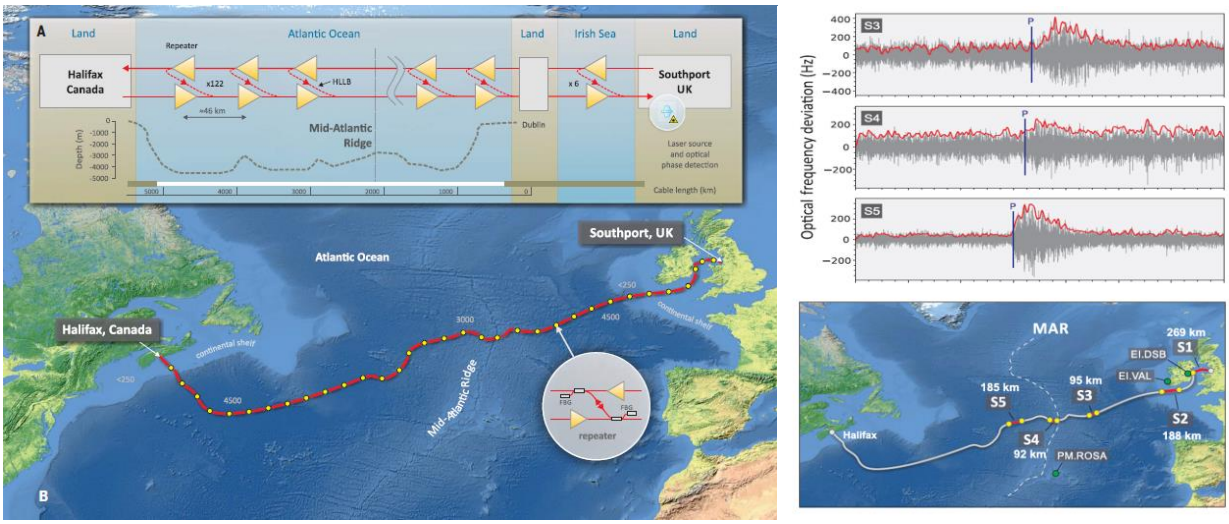

Fig 1. Left: A: loop-back topology of modern submarine cables. B: map of the 5,860 km-long seafloor optical cable between the UK and Canada. Right: magnitude 7.5 earthquake with epicentre in Peru (28 November 2021) detected by three sections of the seafloor cable (S3, S4 and S5 in bottom-right panel). Figures from [2].

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