Leveraging the Power of FPGAs for Frequency Metrology

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We demonstrate the implementation of a 300-channel high-resolution frequency counter with a Field Programmable Gate Array (FPGA)-based System on Chip (SoC) board. This solution was developed for the detection of earthquakes and ocean currents with seafloor cables[1]. It can easily be reconfigured and extended with additional functions to be used as a generic compact frequency metrology platform for complex laboratory and field measurements.

In 2022, we demonstrated an optical interferometry technique capable of detecting environmental perturbations on individual sections of subsea telecommunication links[1]. The UK-Canada seafloor cable we used is equipped with 128 optical repeaters to compensate for fibre losses. The interferometric interrogation of these repeaters in our tests results in a comb of radio frequency (RF) signals, one for each repeater. A section of the resulting RF spectrum is shown in Fig. 1. In order to measure the environmental perturbations impinging on repeater-to-repeater spans, the environmentally-induced frequency changes of each of these frequencies need to be determined.

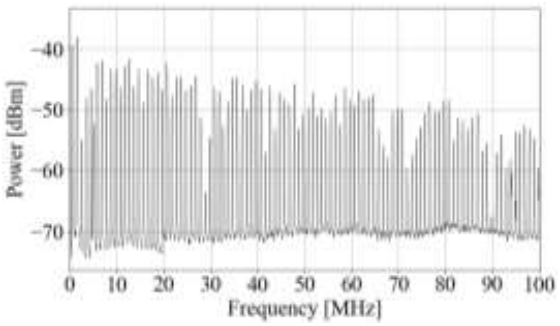

Fig. 1: Section of the RF frequency comb obtained by interferometric interrogation of the optical repeaters along the UK-Canada seafloor link[1].

Fig. 2: The Xilinx RFSoC development board in a custom-made enclosure

We have developed an FPGA solution capable of simultaneously measuring over 300 frequencies, each selected by a 6th-order infinite impulse response (IIR) filter in the FPGA. We have implemented the solution using a state-of-the-art Xilinx RFSoC (Fig. 2). In addition to the multi-channel frequency counting and filtering, the FPGA also generates the interferometry probe signal, consisting of a frequency chirp with a bandwidth of several hundred MHz centred at 7 GHz, directly synthesised using on-chip RF DACs.

The developed solution could easily be expanded to include other functionalities such as PID controllers, DDSs, PLLs, simple oscilloscopes or spectrum analysers. While the solution was initially developed for NPL's seafloor-based environmental detection tests, we anticipate that it can be expanded and configured as a solution for many frequency metrology tasks, especially those requiring complex measurement setups, such as optical clocks, frequency comb-based universal synthesisers and many more.

[1] G. Marra et al. Optical interferometry–based array of seafloor environmental sensors using a transoceanic submarine cable. Science 376, 874-879 (2022).