Low cost OFDR-based delay measuring system for the Square Kilometre Array Radio-Telescope

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This paper presents a low-cost delay measuring system based on Optical Frequency Domain Reflectometry (OFDR) to be integrated in the first prototype of the low frequency subsystem of the Square Kilometre Array radio telescope.

Keywords: Square Kilometre Array, OFDR system.

1. Introduction

The Square Kilometre Array (SKA) which plays a primary role among the future Radio Astronomic realizations, will consist of huge arrays, composed of hundreds of thousands of antennas [1]. In phase 1 of its low frequency bandwidth (50MHz-350MHz) subsystem, named SKA1-LOW, a first verification system has been recently developed in the Australian desert, where Wavelength Division Multiplexing (WDM) G652D-based Radio over Fiber (RoF) links, carrying the two orthogonal polarizations of the signal, have been installed connecting each antenna to the central processing room [2]. In this context, to monitor the. group delay introduced by the optical link will be of primary importance for the data processing. Even considering a cluster of RoF downlinks to be served by the same monitoring system, their final number is expected to be huge, and their cost should then be kept low. This paper presents a simple low-cost delay measuring system based on the Optical Frequency Domain Reflectometry (OFDR) easily integrable into the prototype of SKA1-LOW.

2. System proposed

The scheme of the OFDR-based delay measuring system proposed for SKA1-LOW is shown in Fig.1.

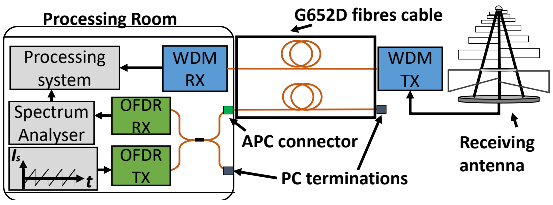

Fig. 1. Proposed integration of OFDR system in SKA1-LOW verification system.

This system exploits the variation of the source frequency $\Delta F(t)$, which takes place in Distributed Feedback (DFB) lasers under direct modulation [3], proportional to the current amplitude I_s through the factor K_f. To produce a simple linear sweep of $\Delta F(t)$, a sawtooth signal of frequency f_m is used, and, being the spectrum of the sawtooth signal composed of harmonics of f_m, to know the behaviour of $\Delta F(t)$, a frequency characterization of K_f must be performed (see Fig.2(a)). The corresponding modelled behaviour of $\Delta F(t)$ is shown in Fig. 2(b) with a current amplitude employed of 2mA. The OFDR TX, composed of a DFB laser and an isolator, is connected to a 50/50 coupler where the two output ports are connected to a known reference path and to 2Km of G652D, both PC terminated to enhance the end reflections. The two reflected signals are then combined in the OFDR RX composed of a PIN photodetector and an amplifier. The output power spectrum of the photocurrent originates a frequency peak f_{peak} related to the fibre delay τ as follows:

$$2\tau = \frac{f_{peak}}{\Delta F_{max} \cdot f_m} \qquad (1)$$

Fig.2 visualizes the measurement results referred to one of the applications performed.

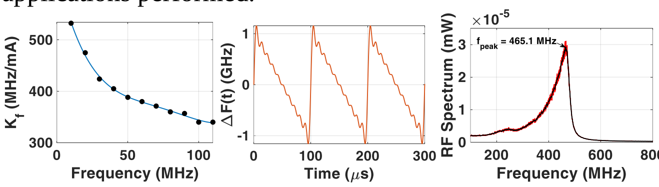

Fig. 2. Frequency characterization of K_f , (b) corresponding modelled $\Delta F(t)$ and (c) photocurrent power spectrum.

In this example $f_m = 10$ KHz, $\Delta F_{max} = 2.312$ GHz and $f_{peak} = 465.1$ MHz (see Fig. 2(c)), which leads to a value of $\tau = 10.058\ \mu s$. This value is in accordance with the estimated length (2Km) of the fibre employed. Initial validation tests, which will be extended and quantitatively illustrated at the Conference, indicate a high reliability of the measurement, and make the proposed system to be a good candidate for integration in the present prototype of SKA1-LOW.

References

1. Bolli, P., Pupillo, G., Virone, G. et al. *Radio Science*, **51**, 160-175 (2016)
2. Nanni, J., Giovannini, A., Hadi, M.U. et al, *Proc. Int. Top. Meeting on Microw. Photonics*, Ottawa, Canada, Oct., (2019)
3. Nanni, J., Barbiroli, M., Fuschini F. et al, *Applied Optics*, **55**, 7788-7795 (2016)