GPS – INDEPENDENT TIME TRANSFER TECHNIQUE ON A WIRELESS TELECOMMUNICATION LINK.

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Abstract: We present a newly conceived clock system based on time-to-digital converter (TDC) principle to generate, transfer and compare time coded sequences (TCS) with nanoseconds accuracy, using a wireless telecommunication link. Comparison provided mid-term stability comparable to good OCXO oscillators showing the feasibility of a low cost, GPS - independent technique, exhibiting highly performing stability.

Key words: Clocks, remote synchronization, distance measurements, time dissemination.

1. INTRODUCTION

Remote wireless time transfer for slave clock synchronization is an essential need in navigation, target localization and tracking, digital telecommunications, command of time controlled actuators such as wireless sensor networks [1].

Measurement of stability in clocks and oscillators are commonly expressed by the Allan variance or deviation [2]. Classical GPS-based (Global Positioning System) clocks using civilian "unauthorized" receivers mid-term Allan deviation [2] stability of about 3 10^{-11} at $\tau = 10^3$ seconds and sub-microsecond accuracies [3-6]. After the turning off of GPS (SA) in May 2001 [5-8] accuracies were dramatically improved (few to tens of ns) by a new generation of GPS timing receivers [6] using "one-way" time transfer technique [5-8], exhibiting typical mid-term Allan deviation of the order of 4 10^{-12} at $\tau = 10^3$ seconds.

Time transfer technique independent from GPS is desirable for the back-up of GNSS determinations in certain critical applications as well as for the new concept for remote geo-positioning, "Geolocal" currently being developed in Brazil [9-11].

2. THE NEW SYSTEM

An innovative clock reading concept derived from the time-to-digital-converter (TDC) principle [12,13] was developed [14]. It allows ns accuracy with clock reading based on counts at low frequencies. A block diagram is shown in Figure 1.

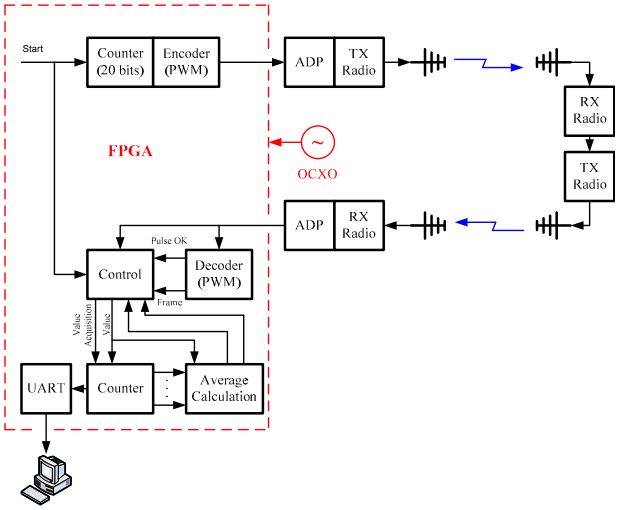

Fig. 1. Clock block diagram showing the OCXO standard oscillator, the frequency synthesizer made of voltage controlled oscillator (VCO) phase locked loop (PLL), followed by the delay cells, counters and registers [14].

An OCXO (oven controlled crystal oscillator) frequency signal is fed into an enhanced PLL (phase lock loop) that raises the frequency to be compared to a VCO (voltage controlled oscillator). Both blocks are built in a Stratix II FPGA (Field Programmable Gate Array) component [15]. The VCO output is split into N controlled outputs, each one submitted to software-driven logic element to produce the desired delay.

However delay cells need to be added to correct the different circuit lengths between each VCO output to its respective counter. Every corrected delayed element is fed into independent and identical counters. The registers freeze the counters results for every time coded sequence (TCS). A given time clock is then obtained just by mathematical operations on the registered values.

3. RESULTS

A telecommunication link has been set from Inatel laboratory, at the town of Santa Rita do Sapucaí, Minas Gerais State, Brazil, to the transponder located at a high mountain top ("Manuela" mountain), with geodetic coordinates and altitudes well known in advance. The line-of-sight distance to the transponder was 4.8 km. The transit time on antennas is obtained for the pair of antennas on the link. An example of the measured total delay is given in Figure 2.

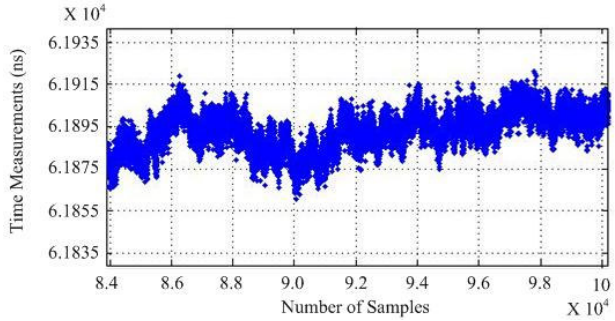

Fig. 2. Sample for the final clock reading obtained at the UART interface providing the total time delay that includes the propagation time in free space (ranging) and the delays produced by troposphere propagation and the electronic units. The readings are (in units of 10^{-5} s) accurate to one nanosecond.

We subtract the added delays (due to propagation in the troposphere, transmission cables, connectors, transmission and receiving equipments) from the free space propagation time on the well known path (i.e., of 32,032.45 ns). The Allan deviation for the whole set of measured data exhibits mid-term stability (at $\tau \leq 10^3$ seconds) approaching to good quality OCXO commercial oscillator (by a factor 3) [17], as well as to typical rubidium controlled crystal oscillator at $\tau \approx 10^4$ seconds (by a factor 3) [6]. Despite the technical distinction between the system presented here and the advanced GPS timing principles, the current single frequency L1 GPS mid-term stability are within the same order of magnitude (i.e. by a factor of about 6 at $\tau \approx 10^3$ seconds and a factor of about 3 at 10^4 seconds [6]). These results are particularly relevant considering they were obtained using standard transmitters, transponder and reception units, without any temperature control added.

The implementation of a fully operational Geolocal system brings the possibility to allow real-time independent determinations, to compare and provide support to other systems (i.e., GPS and similarly conceived systems GLONASS, GALILEO, COMPASS) [17][18].

4. ACKNOWLEDGMENTS

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