DEVELOPMENT OF THE TWSTFT CARRIER-PHASE TECHNIQUE AT LNE-SYRTE*

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ABSTRACT. The Two-Way Satellite Time and Frequency Transfer (TWSTFT) method (Achkar at al. 2006) permits to compare two remote atomic clocks by using a microwave link through a geostationary satellite. The best performance reachable today at OP is achieved on the Ku band link with a frequency stability of 8.10^{-16} at one day (Zhang et al. 2009). In order to improve stability of the two-way links in the short term, the TWSTFT carrier-phase is the most appropriate method. The work proposed here is limited to the development of the TWSTFT carrier-phase method. The main idea is to calculate the offset between the frequencies of the two clocks located each one in a different station. The Doppler's effect is taken into consideration regarding the spread of the signal between each station and the satellite and vice versa. Note that, one Doppler coefficient corresponds to each Station-Satellite link in both directions. The same hardware is used in the two methods. We establish the equation system of the TWSTFT carrier-phase technique composed by four nonlinear equations with four unknown values which are : the first Doppler coefficients, the satellite's local oscillator frequency and the frequency offset of the distant clocks. This system cannot be solved directly (Fonville et al. 2004). As a first approach, we use the Newton-Raphson method to transform the nonlinear system to a linear one. Then, the singular value decomposition technique is used to solve the resulting linear system.

1. INTRODUCTION

The national metrology institute LNE-SYRTE has developed on the site of the Observatoire de Paris a TWSTFT earth station using a microwave link through a geo-stationary telecommunication satellite. The station is equipped with a SATRE modem which applies the spread spectrum method over a generated pseudo random noise code sequence at 1 MChips/s, carrying the clock signal. The main goal is to improve the contribution of the French atomic clocks to the international atomic time TAI calculated by the BIPM and to have an accurate system to compare primary frequency standards which are developed through the national laboratories.

2. TWSTFT CARRIER-PHASE

The most equipment used in the standard method (Achkar at al. 2006) is required. The reference station is the station 1. Considering that the frequency of the clock 1 is f_{sys}, the frequency of clock 2 is then shifted from f_{sys} by a value df. As shown in Figure 1, F_{11} and F_{22} are the ranging frequencies, F_{12} is the frequency of the signal transmitted from to station 2 to the station 1 and F_{21} is the frequency of the signal transmitted from the station 1 to the station 2. The ranging and two-way signals are subject to the Doppler effect.

3. THE EQUATION SYSTEM

$$\begin{cases} F_{11} = f_{tx}(1+k_1)^2 - f_{slo}(1+k_1) \\ F_{22} = f_{tx}(1+k_2)^2 - f_{slo}(\frac{f_{sys}}{f_{sys}+df})(1+k_2) \\ F_{12} = f_{tx}(\frac{f_{sys}+df}{f_{sys}})(1+k_1)(1+k_2) - f_{slo}(1+k_1) \\ F_{21} = f_{tx}(\frac{f_{sys}}{f_{sys}+df})(1+k_1)(1+k_2) - f_{slo}(\frac{f_{sys}}{f_{sys}+df})(1+k_2) \end{cases}$$

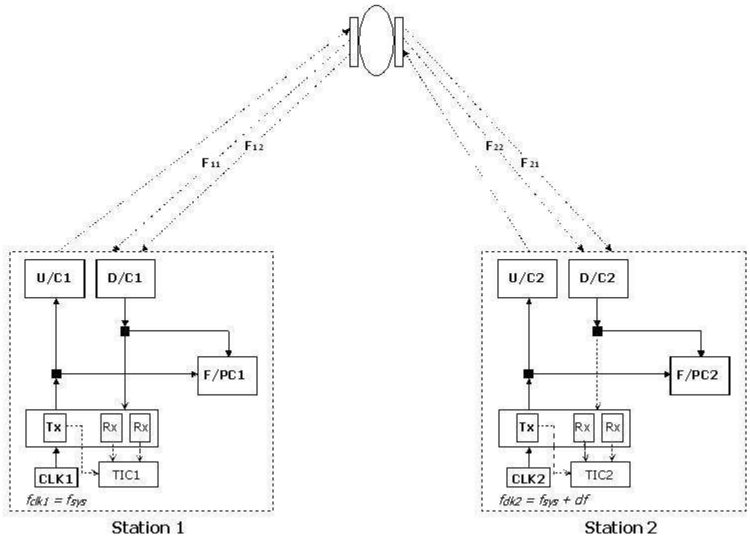

Figure 1: TWSTFT carrier-phase technique

4. SOLVING THE EQUATION SYSTEM

The Newton-Raphson method is the most appropriate method for solving non linear equation systems (Press et al. 1992). We start from an initial estimation vector for the system's unknowns. The Taylor development is applied to each system's function. Therefore, the non linear system is transformed to a linear system with a singular Jacobian matrix thus the system cannot be solved directly. The singular value decomposition is used to find the inverse of the matrix. The solution vector is then updated and we continue the iterations in order to reach the most suitable solution.

5. CONCLUSION

The TWSTFT carrier-phase allows to improve the short term stability of the TWSTFT method. In this paper, we have established the equation system of this technique. Then, we have applied the Newton Raphson method combined with the singular value decomposition to solve the obtained system. For the method's implementation, routines from numerical recipes in C language are used (Press et al. 1992).

6. REFERENCES

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