Carrier Smoothing of Code Pseudoranges

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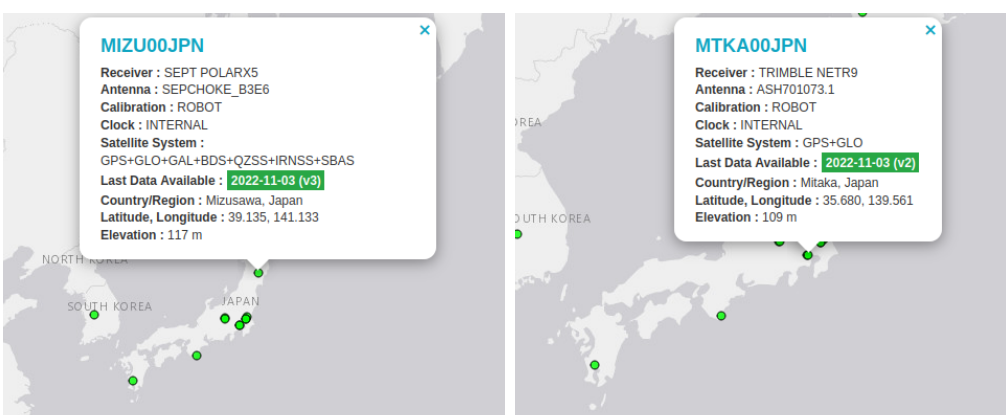
Carrier Smoothing of Code Pseudoranges

With precise carrier phase measurements , the code pseudorange measurements can be smoothed preciser. One of the famous and simple algorithm is Hatch , the Hatch algorithm is done with several methods which are given as follows :

1 Normal Hatch algorithm

for k-th epoch $\hat{R}(s;k)$ (as output of smoothed method) :
$\hat{R}(s;k) = \frac{1}{n}R(s;k) + \frac{n-1}{n}[\hat{R}(s;k-1) + (\Phi(s;k) - \Phi(s;k-1))]$
if $k < N \rightarrow n = k$ and when $k >= N \rightarrow n = N$
but what is N ?
In most of case N is the interval between two Cycle-Slip
in combination of $R - \Phi$, ionosphere term is double because of both of them have opposite sign in their equation,this manifests the bias which is caused divergency in code smoothing method(Normal Hatch algorithm), which can be rewritten as :
$\hat{R} = \Phi_1(k) + < R_1 - \Phi_1 >_{(k)} = r(k) + I_1(k) + 2(< I_1 >_{(k)} - I_1(k))$
the divergency is indicating necessity of new Divergence free algorithm.

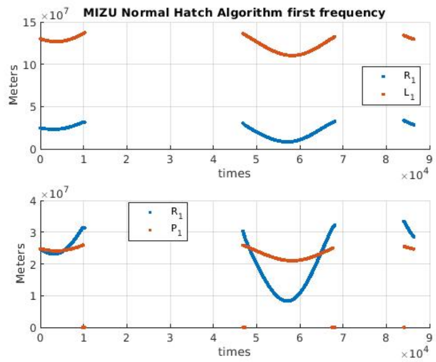
In this Study two Japanese GNSS station(Mizusawa and Mitaka) are selected in two different date(2015.03.18 and 2016.11.22) both.



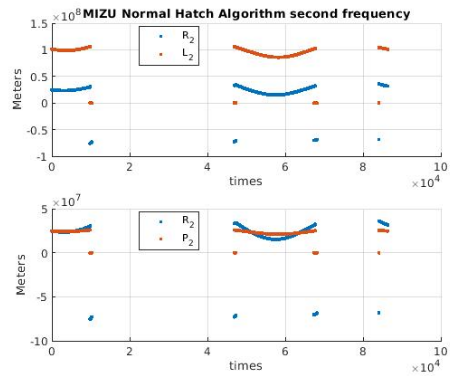
(a) MIZU. (b) MTKA.

Figure 1: Location of GNSS station in Japan.

Result of Normal Hatch methode :

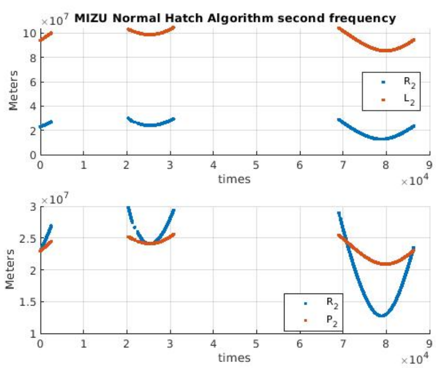


(a) $L_1 and R_1$ GPS SAT PRN = 28.

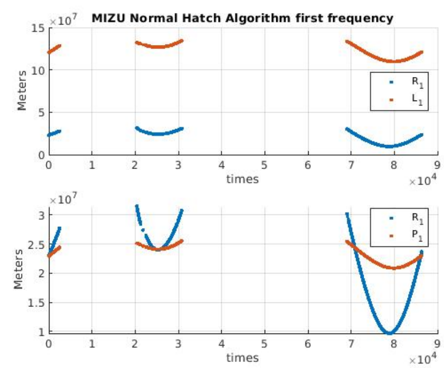


(b) $P_2 and R_2$ GPS SAT PRN = 28.

Figure 2: MIZU GNSS station 2015.03.18.

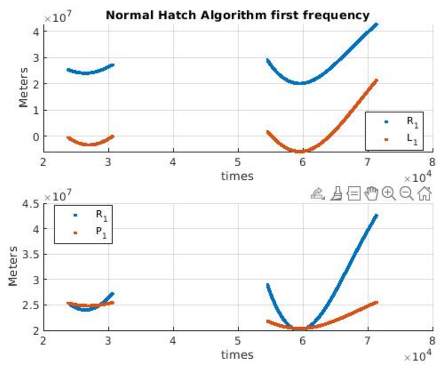


(a) $L_2 and R_2$ GPS SAT PRN = 28.

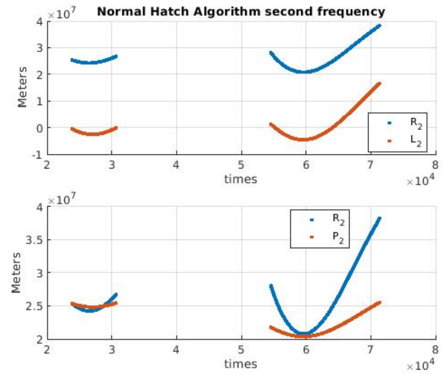


(b) $P_1 and R_1$ GPS SAT PRN = 28.

Figure 3: MIZU GNSS station 2016.11.22.

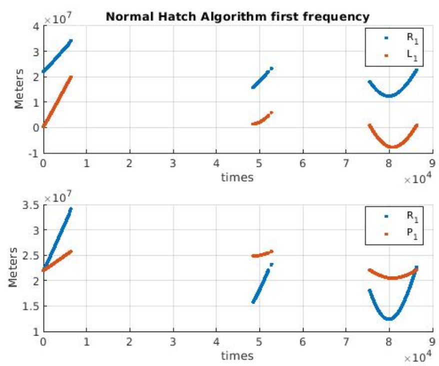


(a) $L_1 and R_1$ GPS SAT PRN = 28.

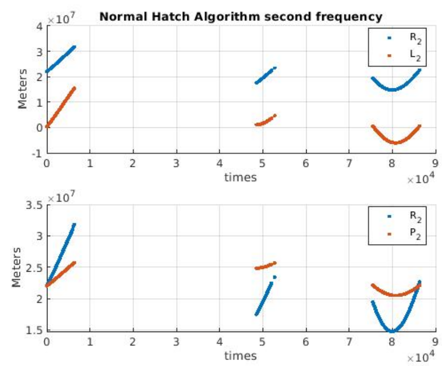


(b) $P_2 and R_2$ GPS SAT PRN = 28.

Figure 4: MTKA GNSS station 2015.03.18.



(a) $L_1 and R_1$ GPS SAT PRN = 28.



(b) $P_2 and R_2$ GPS SAT PRN = 28.

Figure 5: MTKA GNSS station 2016.11.22.

2 Divergence Effect Free Hatch algorithm

By defining new phase carrier measurment as $\Phi_{1_{DF}} = \Phi_1 2\tilde{\alpha_1}(\Phi_1 - \Phi_2)$, $\Phi_{1_{DF}}$ is free of ionosphere divergency so with this form $\hat{R_1}$ in hatch algorithm has the same ionospheric delay as the orginal unsmoothed one.

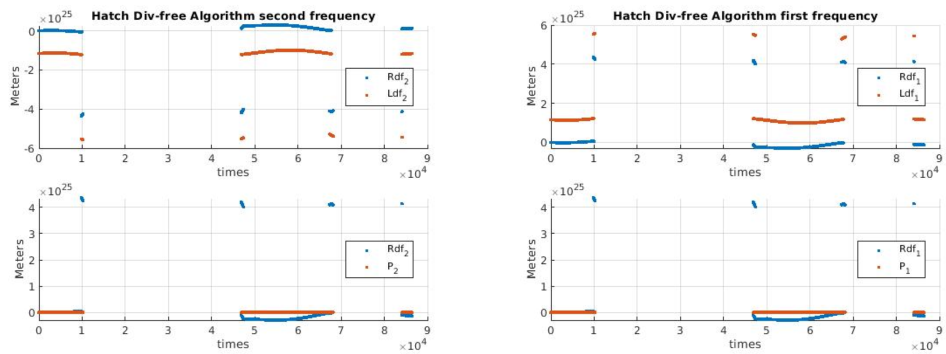
$R_1 - \Phi_{1_{DF}} = B_{12} + \epsilon_{12}$

making smoothed code in this new method still has some disadvantage is given as follows :

1- using two-frequency(Φ_1, Φ_2)

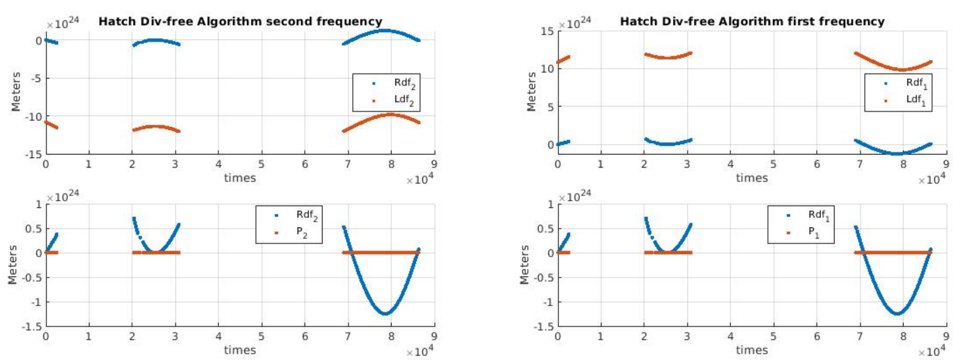
2- divergency is still being indecated in bad ionospheric interval.

Result of Divergence Effect Free Hatch methode :



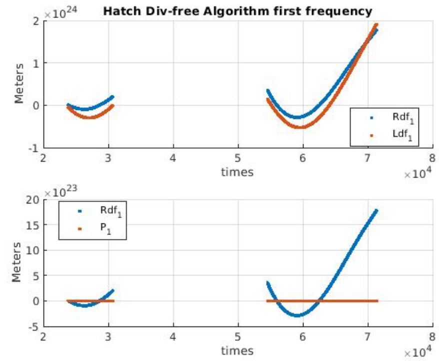
(a) $L_{df_1} and R_{df_1}$ GPS SAT PRN = 28. (b) $P_{df_2} and R_{df_2}$ GPS SAT PRN = 28.

Figure 6: MIZU GNSS station 2015.03.18.

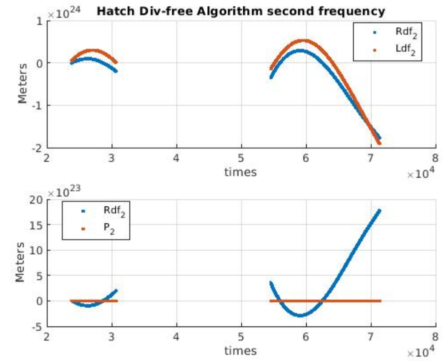


(a) $L_{df_1} and R_{df_1}$ GPS SAT PRN = 28. (b) $L_{df_2} and R_{df_2}$ GPS SAT PRN = 28.

Figure 7: MIZU GNSS station 2016.11.22.

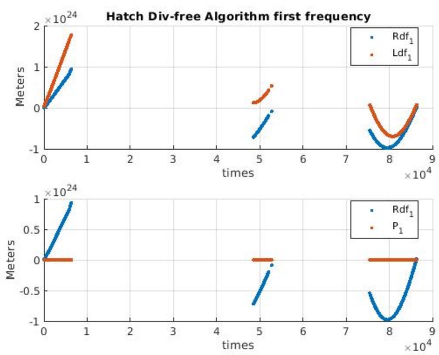


(a) $L_{df_1} and R_{df_1}$ GPS SAT PRN = 28.

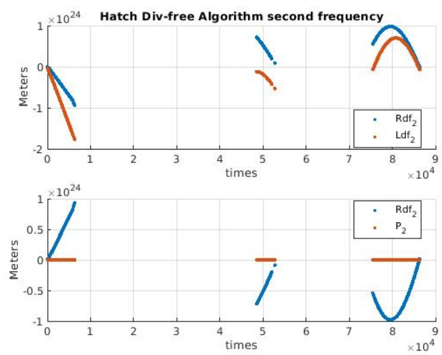


(b) $P_{df_2} and R_{df_2}$ GPS SAT PRN = 28.

Figure 8: MTKA GNSS station 2015.03.18.



(a) $L_{df_1} and R_{df_1}$ GPS SAT PRN = 28.

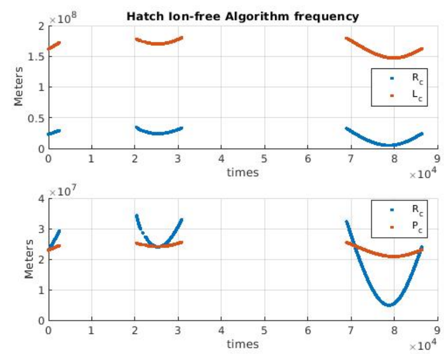


(b) $L_{df_2} and R_{df_2}$ GPS SAT PRN = 28.

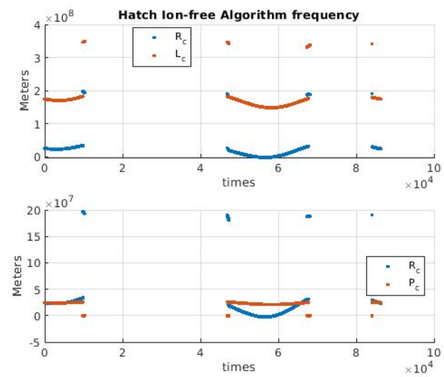
Figure 9: MTKA GNSS station 2016.11.22.

3 Ionosphere Free Hatch algorithm

By using both code and carrier daul-frequency measurements as ionosphere-free combinations (R_c, Φ_c) the resulte comes in this way :
$R_c - \Phi_c = B_c + \epsilon_c \rightarrow \hat{R}_c = r + v_c$ this method is free of ionospheric terms but it has some disbenefits like :
it makes the whole work suboptimal in case of cost , time and ... .
Result of onosphere Free Hatchmethode :

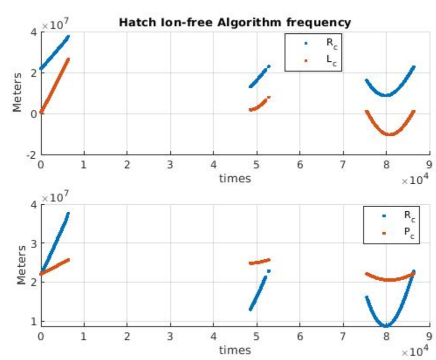


(a) $L_c and R_c$ GPS SAT PRN = 28.

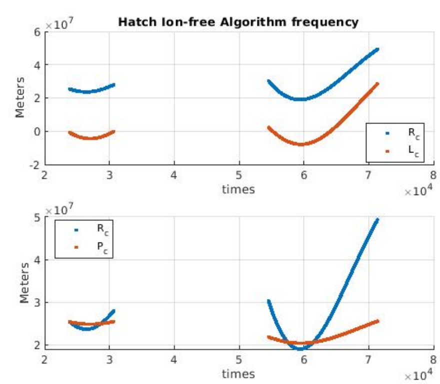


(b) $L_c and R_c$ GPS SAT PRN = 28.

Figure 10: MIZU GNSS station 2016.11.22(a) 2015.03.18(b).



(a) $L_c and R_c$ GPS SAT PRN = 28.



(b) $L_c and R_c$ GPS SAT PRN = 28.

Figure 11: MTKA GNSS station 2016.11.22(a) 2015.03.18(b).