World Applied Sciences Journal 21 (Special Issue of Applied Math): 127-129, 2013
ISSN 1818-4952;

DOI: 10.5829/idosi.wasj.2013.21.am.21134

Modification of Hydrostatics UNBab Mapping Function for Tropospheric Delay

Hamzah Sakidin

Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal Melaka

Abstract: Several established mapping function models are in the form of continued fractions that need many operations in calculation. That's why the mapping function models need to be modified to allow faster calculation. There are 7 mathematical operations for UNBab mapping function for getting the mapping function value. The ability to calculate mapping function value down to 2 degree of elevation angle is the unique character for UNBab mapping function to be modified. Regression method can be used to modified the mapping function model and also can produce the same result. The sum of errors calculation shows that the deviation of the modified models from the original models is not significant.

Key words: mapping function . tropospheric . zenith

INTRODUCTION

Marini [1], the founder of mapping function in term of continued fraction, states that the elevation angle ε dependence of any horizontally stratified atmosphere can be approximated by expanding in a continued fraction in term of 1/sin ε. The mapping function values is used for getting the total tropospheric delay due to its function as the coefficient of zenith hydrostatic delay and also zenith non hydrostatic delay as given in equation (1) below [2]:

$$TD = ZHD.m_h(\varepsilon) + ZWD.m_w(\varepsilon) \qquad (1)$$

where:

ZHD: Zenith hydrostatic delay (m)
ZWD: Zenith wet delay (m)
m_h (ε): Hydrostatic mapping function
m_{nh} (ε): Non-hydrostatic mapping function

PROCESS OF MODIFICATION OF UNBab MAPPING FUNCTION

Guo [3] from the University of New Brunswick has established the UNBab(E) mapping function model. This model has 7 operations in a form of continued fraction. The hydrostatic component of UNBab(E) is written as [3]:

$$UNBab_h(E) = \frac{1 + \dfrac{a_h}{1 + b_h}}{\sin E + \dfrac{a_h}{\sin E + b_h}} \qquad (2)$$

where, E: elevation angle.

The parameters a_h and b_h for the hydrostatic function are:

a_h = (1.53804-0.039491H+0.17020cos ϕ)/1000,
b_h = (50.0724-0.814759H+2.35232cos ϕ)/1000,

where H = 0.1km and ϕ is 45 degrees.

The mapping function for the original $UNBab_h$(E), named as P shown in Fig. 1.

The mapping function in a shape of hyperbola and equation (2) can be modified as

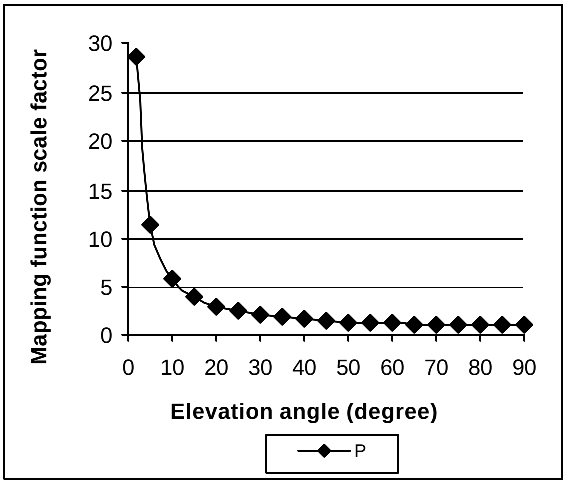

Fig. 1: Graph of mapping functions for P

Corresponding Author: Hamzah Sakidin, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal Melaka

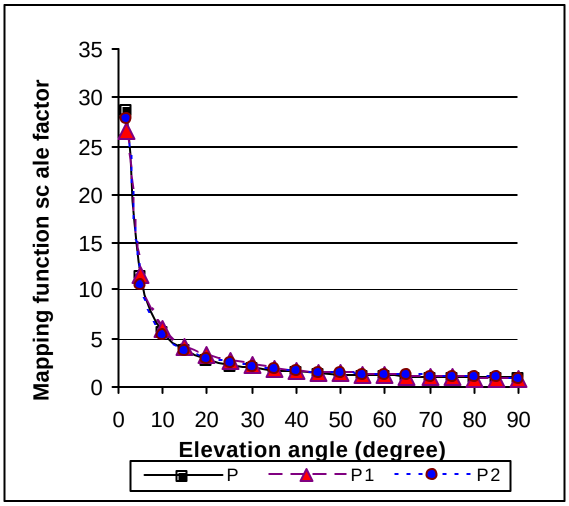

Fig. 2: Graphs of P, P1 and P2 for $UNBab_h(E)$ mapping function

$$P1(E) = AE^{B} \quad (3)$$

where
P1(E): Modified $UNBab_h(E)$
A,B: Constants
E: Elevation angle (degree).

In logarithm scale, equation (3) can be written as

$$\log_{10} P1 = B\log_{10} E + \log_{10} A \quad (4)$$

By linear regression method, equation (4) becomes

$$\log_{10} P1 = -0.8924\log_{10} E + 1.6604 \quad (5)$$

where, B = -0.8924 and $\log_{10}A$ = 1.6604 which gives A = 45.751.
Therefore, equation (5) becomes

$$P1(E) = 45.751E^{-0.8924} \quad (6)$$

By regression method, polynomial equation, log P2 can be generated from the original model (log P) in a form of quadratic equation as given below

$$\log_{10} P2 = 0.1575(\log_{10} E)^2 - 1.2761(\log_{10} E) + 1.8509 \quad (7)$$

The graphs of P, P1 and P2 can be shown in Fig. 2.

CALCULATION OF SUM OF ERROR FOR $UNBab_h(E)$

Sum of error (SOE) method can be used to show how the modified models deviate from the original model. Smaller deviation is better, which shows that the modified model is closer to the original model.

Table 1: Sum of error between $UNBab_h(E)$, P and modified models P1 & P2

E	P	P1	ABS (P-P1)
2	28.628	24.646	3.982
5	11.470	10.880	0.590
10	5.758	5.861	0.103
15	3.863	4.082	0.218
20	2.924	3.157	0.234
25	2.366	2.587	0.221
30	2.000	2.199	0.199
35	1.743	1.916	0.173
40	1.556	1.701	0.145
45	1.414	1.531	0.117
50	1.305	1.394	0.088
55	1.221	1.280	0.059
60	1.155	1.185	0.030
65	1.103	1.103	0.000
70	1.064	1.032	0.032
75	1.035	0.971	0.065
80	1.015	0.916	0.099
85	1.004	0.868	0.136
90	1.000	0.825	0.175
Total	71.625	68.135	4.87%

Table 2: Comparison for the computation time

Model	Computation time for original model (ms)	Computation time for modified model (ms)	Reduction of computation time (times)
$UNBab_h$	281	110	2.6

Table 1 shows that the percentage of the sum of error is only 4.87% which shows that the modified model is closer to the original model. Therefore, the difference of mapping function between the original model and the modified model is not significance. (less than 5% mapping function)

COMPUTATION TIME FOR $UNBab_h(E)$

The computation time for calculating (100,000 cycles) the original model and also the modified model for $UNBab_h(E)$ can be shown using CodeGear C++ Builder 2007 software [4].

Table 2 shows that the computation time between the original model and modified model shows that the modified $UNBab_h(E)$ model is 2.6 times faster than the original model.

From Table 3, the modified $UNBab_h(E)$ model can reduce the number of operations up to 71.4 percent compared to the original model.

Table 3: Reduction percentage of the number of model operations

Model	Number of operations (Original model)	Number of operations (Modified model)	Operation reduction	Percentage of reduction
$UNBab_h$	7	2	5	71.4

CONCLUSION

The modified $UNBab_h(E)$ mapping function model can be used to replace the original model due to its simpler model, smaller sum of error values and also the shorter computation time compared to the original model. This study has a commercial value by replacing the continued fraction algorithm into either hyperbolic or linear form for its mapping function algorithm.

ACKNOWLEDGMENT

I would like to thanks my employer, Universiti Teknikal Malaysia Melaka for giving me a grant for this project. I would also like to thanks all the Faculty of Electrical Engineering academic staff for supporting me in giving ideas and full support throughout this project.

REFERENCES

1. Marini, J.W., 1972. Correction of satellite tracking data for an arbitrary tropospheric profile. Radio Science, 7 (2): 223-231.
2. Schuler, T., 2001. On Ground-Based GPS Tropospheric Delay Estimation. Ph.D dissertation, University of Munchen.
3. Guo, J., 2003. A New Tropospheric Propagation Delay Mapping Function For Elevation Angles Down To 2° Proceeding of ION GPS/GNSS 2003. 16th International Technical Meeting of the Satellite Division of the Institute of Navigation, Portland, OR, pp: 386-396.
4. Hamzah, S., 2008. Modeling and modification of GPS Tropospheric Delay Mapping Function. Ph.D thesis, University Putra Malaysia.