GPS Geodesy - LAB 6

GPS data: Multipath and Quality Control

The objective of this lab is to quantify the level of noise in our GPS measurements from the pseudorange and phase data. We are looking for the main contributors to that noise, the multipath effects and the receiver noise.

The GPS pseudorange measurements can be modeled as:

$$\begin{aligned} P1 &= R + I1 + MP1 \\ P2 &= R + I2 + MP2 \end{aligned} \qquad (1)$$

with: P1 = L1 pseudorange (m)
P2 = L2 pseudorange (m)
R = satellite-receiver geometric range (m)
I1 = L1 ionospheric delay
I2 = L2 ionospheric delay
MP1 = P1 multipath plus receiver noise (m)
MP2 = P2 multipath plus receiver noise (m)

Similarly, the phase measurements can be modeled as:

$$\begin{aligned} L1 &= R - I1 + mp1 + B1 \\ L2 &= R - I2 + mp2 + B2 \end{aligned} \qquad (2)$$

with: L1 = L1 phase measurement (m)
L2 = L2 phase measurement (m)
B1 = L1 phase ambiguity (m)
B2 = L2 phase ambiguity (m)
mp1 = L1 phase multipath plus receiver noise (m)
mp2 = L2 phase multipath plus receiver noise (m)

Phase noise is much smaller than pseudorange noise, therefore $mp1 >> MP1 \sim 0$ and $mp2 >> MP2 \sim 0$.

Now let's combine (1) and (2) in order to find MP1:

$$\begin{aligned} & P1 - L1 = 2I1 + MP1 - B1 \\ & \Rightarrow MP1 - B1 = P1 - L1 - 2I1 \end{aligned} \qquad (3)$$

We need to solve for *I1*. Let's combine *L1* and *L2* from (2):

$$L1 - L2 = I2 - I1 + B1 - B2 \qquad (4)$$

Now we have to deal with *I1* and *I2*. We know that the ionospheric delay is proportional to the ionospheric electron content (*IEC*) and depends on the signal wavelength. It can be written as (see lecture notes):

$$
\begin{aligned}
I1 &= \frac{A}{f_1^2} IEC \\
I2 &= \frac{A}{f_2^2} IEC \qquad (5) \\
\Rightarrow \frac{I2}{I1} &= \left(\frac{f1}{f2}\right)^2 = \alpha
\end{aligned}
$$

Substituting (5) into (4) gives:

$$
\begin{aligned}
& L1 - L2 = I1(\alpha - 1) + B1 - B2 \\
& \Rightarrow 2I1 = \frac{2}{\alpha - 1}(L1 - L2) + \frac{2(B2 - B1)}{\alpha - 1}
\end{aligned} \qquad (6)
$$

Now we can substitute *I1* from (6) into (3) to get:

$$
MP1 - B1 = P1 - L1 - \frac{2}{\alpha - 1}(L1 - L2) - \frac{2}{\alpha - 1}(B2 - B1) \qquad (7)
$$

We can rearrange (7) by putting all the constant terms on the right hand side:

$$
\begin{aligned}
& MP1 - P1 + L1 + \frac{2}{\alpha - 1}(L1 - L2) = \frac{2}{\alpha - 1}(B2 - B1) + B1 \\
& \Rightarrow MP1 - P1 + \left(\frac{2}{\alpha - 1} + 1\right) L1 - \frac{2}{\alpha - 1} L2 = const.
\end{aligned} \qquad (8)
$$

Since *MP1* has a zero mean, we are only interested in the structure of *MP1* over time, not in the constant DC bias term (constant for each given orbit arc). We can therefore compute the constant by averaging *MP1* over a given orbit arc, and then subtract this average value from the *MP1* values at each epoch. Consequently, after removing that bias, the pseudorange multipath noise can be written as (same derivation for *MP2*):

$$
\begin{aligned}
MP1 &= P1 - \left(\frac{2}{\alpha - 1} + 1\right) \times L1 + \left(\frac{2}{\alpha - 1}\right) \times L2 \\
MP2 &= P2 - \left(\frac{2\alpha}{\alpha - 1}\right) \times L1 + \left(\frac{2\alpha}{\alpha - 1} - 1\right) \times L2
\end{aligned} \qquad (9)
$$

⇒ Isn't there an important additional noise term that is not modeled here and which, consequently, is present in MP1 and MP2 as derived above?

⇒ Write a Matlab function to compute and plot MP1 and MP2 from GPS data. You will be provided with a function to read the rinex data file.
  - Compute and plot MP1 and MP2 for PRN10 and PRN31.
  - Extra credit if your program plots MP1 and MP2 any PNR requested by the user.

Use the following values:

$f_1 = 1.57542 \times 10^9$ Hz;
$f_2 = 1.2276 \times 10^9$ Hz;
$c = 0.299792458 \times 10^9$ m/s;
$\lambda 1 = c/f1$;
$\lambda 2 = c/f2$;