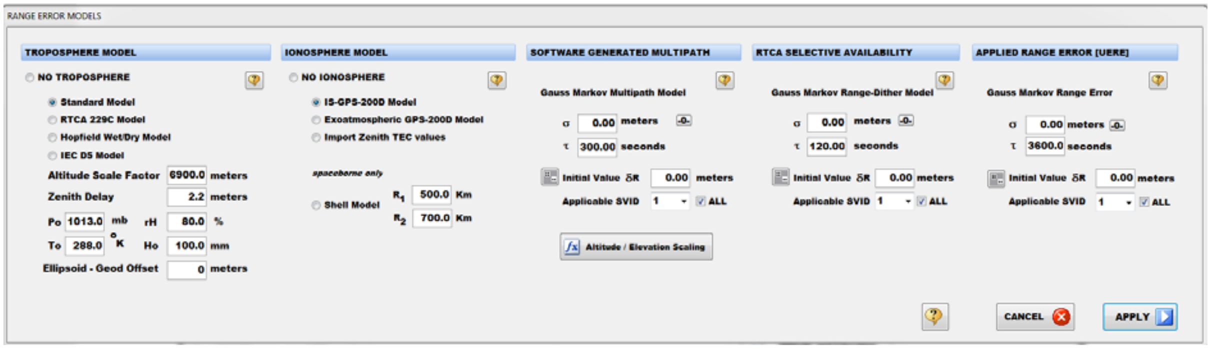
TAPESTRY RANGE MODELS

GPS Ranging Data traverses the Earth Atmosphere and Ionosphere encountering delay and dispersion. Other perturbing process result in an imperfect agreement between ephemerides data and the true GPS orbits. Ground based effects also contribute to signal perturbation.

This document provides a description of models applied to the Tapestry-broadcast Slant Range measurements captured by the **RUT**.

RANGE MODELS



TROPOSPHERE MODEL

Standard Model

There are several provided models. The default model (**standard model**) is popular and used widely in the industry. This model uses a modified Chow algorithm with a guard angle to prevent low angle divergence.

$$\tau = \frac{\textbf{Numerator}}{(\sin\theta_e + 0.000143/(\tan\theta_e + 0.0455)}$$

If (H < 1000) the **Numerator** becomes:

$$2.5119 - 0.3248H/1000.0 - 0.022395\,H^2$$

If (H < 9000) the **Numerator** becomes:

$$-0.1191 + 2.2838*\exp^{(0.1226*(1.0 - H))}$$

If (H > 9000) the **Numerator** becomes:

$$0.73736*\exp^{(0.1424*(9.0 - h))}$$

Descriptions of the other models are contained in these links:

..\..\..\..\Tapestry\Documentation\Manuals\TropomodelHopField.pdf

..\..\..\..\Tapestry\Documentation\Manuals\Tropomodel229C.pdf

IONOSPHERE MODEL

There are several provided models. The default model (**standard model**) is described in IS-GPS-200D . Other models have been provided to us for special applications. If you have an exo-atmosphere or high-altitude application you might want to consider this model,

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This model we developed and consists of concentric shells designed for use in LEO applications:

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Another approach would be to import a Total Vertical Electron Count (TEC) and Tapestry performs the slant range computations. For a description look here:

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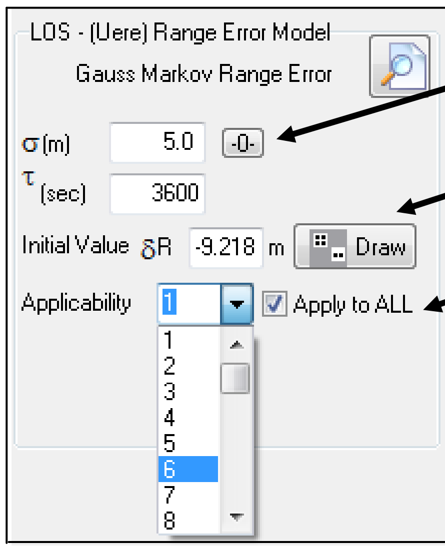
With any of these models, we compute the Ionosphere group and phase delay effects for the L_5 link by using the IS-GPS-200D L_1/L_2 scaling formula to construct the L_5 Ionosphere delay and associated phase advance.

LOS (UERE) RANGE ERROR MODEL

The Tapestry system simulates modeling errors for the control segment through the use of the User Equivalent Range Error (**UERE**). This model applies a random slowly varying bias to the output truth-range for each satellite – uncorrelated from satellite to satellite – yet perfectly correlated from RF to RF.

The model is implemented as a 2nd order Gauss Markov Process with either a user specified initial condition or a random draw based upon a user entered standard deviation.

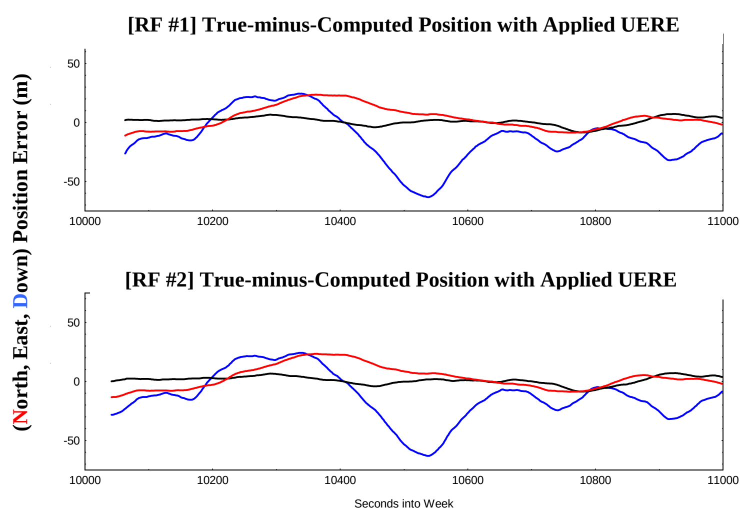


Use this to zeroize ALL of the standard deviations.

It is important to use the **DRAW** control to set the initial condition in place for the **UERE**. The initial value varies in time controlled by the time constant τ and standard deviation **σ**.

- **Apply to All: NOT CHECKED**. The values in the various controls apply only to the Satellite shown in the pulldown combo box.
- **Apply to All: CHECKED**. Depressing the **DRAW** button will select the initial condition for all 32 Satellites. Sigma and Tau will be the same for all Satellites.

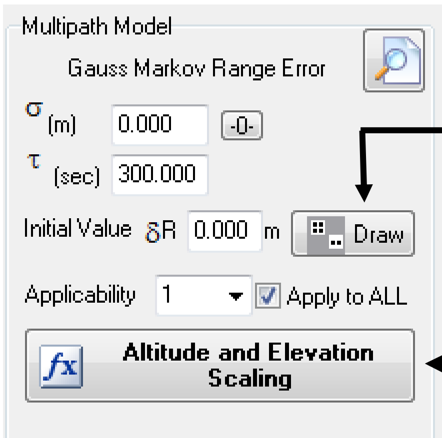
The Computed UERE error is applied directly to the computed range (and the derivative to the range-rate) and therefore <u>does</u> <u>not</u> <u>vary</u> <u>from</u> <u>RF</u> <u>to</u> <u>RF</u> yet <u>does</u> vary from satellite-to-satellite as specified by (σ,τ). The following plot illustrates both effects. This example is a two RF run for a stationary host vehicle. To exaggerate the error for illustrative purposes, a standard deviation of 10 meters and time constant of 100 seconds was specified (a more realistic set of values would be 2-5 meters with a 3600 second time constant). As can be seen from the plots, the derived position error from each RF output is statistically identical yet the overall position error for both vehicles is corrupted consistent with the values of the model and the PDOP.



SOFTWARE MULTIPATH MODEL

In Tapestry, Multipath can be generated either by using dedicated hardware channels or via a software model. This form describes the software modeling implemented as a 2nd order Gauss Markov model. The following data form controls this model.

The standard deviation and time constant can be entered independently for each RF output (vehicle)

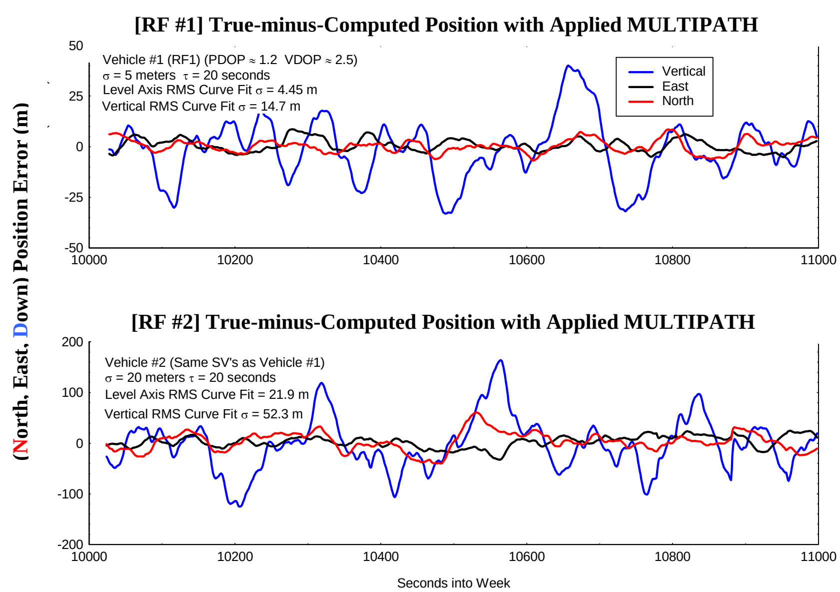


The **Draw** button executes a random selection of the initial condition based upon the entered σ.

For **Multipath**, the sigma associated with the random draw of the Gauss Markov model can be modified by altitude of the host vehicle or elevation angle of the satellite relative to the host vehicle. An ASCII file controls this aspect of the model. 20 values are available for elevation angle scaling – this divides 90^{O} into 18 bins 5^{O} each with two spare values. The user enters a multiplier. Nominally the multiplier should be 1.0 – to increase the multipath effect make the value larger, to decrease make it smaller. A value of zero will freeze the multipath at the current output of the 2nd order Markov process when the satellite enters the elevation bin.

The altitude-scaling format consists of 5 pairs of values. The first value is the altitude threshold in meters and the second value is the scaling value – 1.0 is nominal. These pairs are repeated four more times. The nominal scaling value = 1.0. As the vehicle transitions from one bin to the next, (threshold) the new scaling value will be used.

The following plots illustrate an example of a two RF simulation. In this example, for illustrative purpose, all satellites broadcast from RF#1 were programmed with a multipath error of σ = 5 meters and τ = 20 seconds. For RF#2 the satellites were programmed with σ = 20 meters and τ = 20 seconds. As can be seen, the applied errors are statistically uncorrelated between the two RF outputs.



The Multipath model parameters and scaling values are stored in ASCII files within the scenario folder. The format of these files is useful because some of the items within can only be hand edited.

Multipath Control File

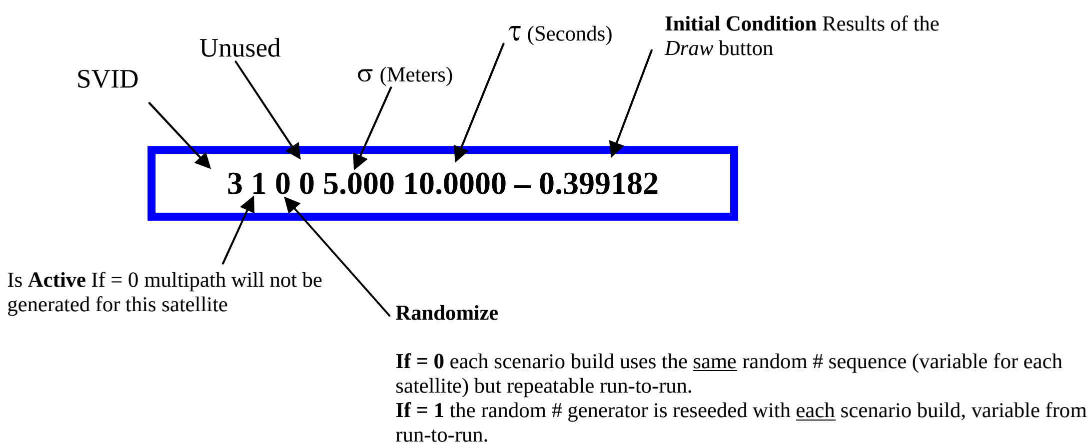
The model values and parameters associated with simulated multipath are entered into a control file residing in the simulation folder. The files are named SwMulti1.scn and SwMulti2.scn for RF1 and 2 respectively. An example of the one of the files is shown below.

Example of SwMulti1/2.scn

```
1
1 1 0 0 5.000000 10.000000 7.165136
2 1 0 0 5.000000 10.000000 1.972259
3 1 0 0 5.000000 10.000000 -0.399182
4 1 0 0 5.000000 10.000000 -1.878109
5 1 0 0 5.000000 10.000000 1.010468
                    …

29 1 0 0 5.000000 10.000000 4.508347
30 1 0 0 5.000000 10.000000 -2.880490
31 1 0 0 5.000000 10.000000 -1.983703
32 1 0 0 5.000000 10.000000 -0.793786
```

There is one record at the top – this is the global flag that controls how random draws are performed when you press the ***DRAW*** button in the dialog form discussed previously. Don't change it. The following 32 records correspond to one for each GPS satellite. In some cases you can only control certain aspects of the multipath model by editing this file. To access this file use the press the **Altitude and Elevation Scaling** control. This item brings up the multipath control files associated with each RF output. The fields associated with the records are as follows



Elevation and Altitude Scaling File

This file controls the scaling that can be applied to the multipath error as a function of altitude or elevation angle. This file is ASCII and can only be accessed using the control button within the multipath data form. There are two files, one for each RF output named **SwMpElev1.scn** and **SwMpElev2.scn** respectively. An example of one of these files is shown below:

Example of SwMpElev1/2.scn

```
1 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
2 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
3 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
...
31 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
32 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
0.000 1.000 0.000 1.000 0.000 1.000 0.000 1.000 0.000 1.000
```

This file has 32 records, one for each satellite with 20 entries on a line. One additional record follows the last satellite record. The Satellite records divide 90^{O} elevation angle into 18 bins with two unused bins at the end. Each bin has a 5^{O} width. The values corresponding to the scaling associated with the bin. For example, records like this:

```
3 2.500 2.000 1.500 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 0.000 0.000 0.000 0.000 1.000 1.000
```

This will cause the multipath model to operate as follows on Satellite 3:

- When the elevation angle is between $0\text{-}5^{O}$ multiply the entered σ by 2.5
- When the elevation angle is between 5^{O+}- 10^{O} multiply the entered σ by 2.0
- When the elevation angle is between 10^{O+}- 15^{O} multiply the entered σ by 1.5
- When the elevation angle is between 15^{O+}- 75^{O} multiply the entered σ by 1.0
- When the elevation angle is > 75^{O+} apply no multipath error.

The last record is the altitude scaling record. It provides 5 threshold bins and scaling values. Altitude scaling applies to all satellites. Note that altitude and elevation angle scaling effects are multiplicative. An example is:

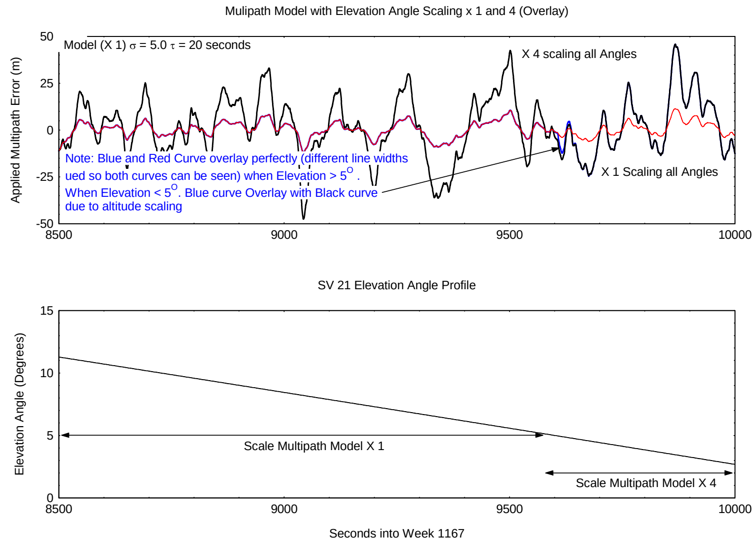
```
0.0 1.0 2000.0 1.5 4000.0 1.0 10000.0 2.0 20000.0 0.0
```

This will cause the multipath model to operate as follows for all Satellites

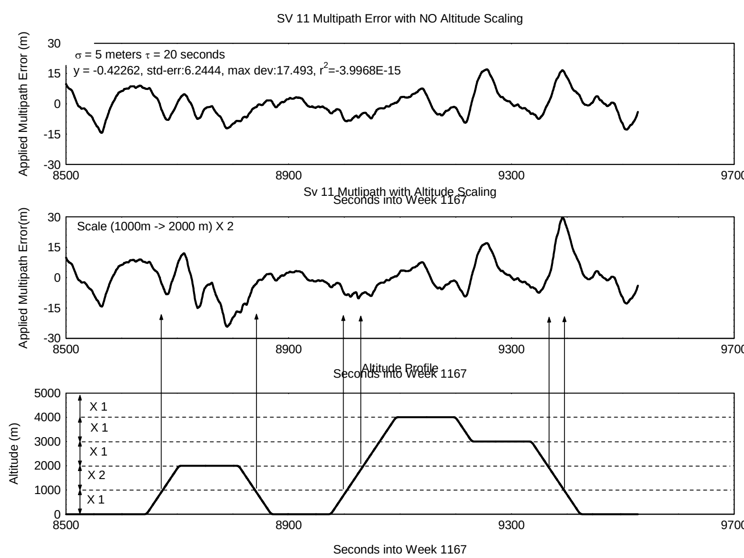
- When the altitude is between 0-2000 meters multiply the entered σ by 1.0
- When the altitude is between 2000+ - 4000 meters multiply the entered σ by 1.5
- When the altitude is between 4000+ - 10000 meters multiply the entered σ by 1.0
- When the altitude is between 10000+ - 20000 meters multiply the entered σ by 1.0
- When the altitude is > 20000+ meters apply no multipath

The following plots illustrate some of these features.

The first set illustrates elevation angle scaling. In this example Satellite 21 was scaled by a factor of 4 when the elevation was less than 5^{O}. The top plot overlays the range residual when the scaling is X 4 for all elevation angles (the **black** curve), X 1 for all elevation angles (the red curve) and X 4 only when the elevation angle is < 5^{O} (the blue curve). The blue curve is hard to see. This is because it perfectly lies behind the red curve for the region of elevation angle > 5^{O} and perfectly lies behind the black curve for elevation angle < 5^{O}. All that can be seen is the small region in which the residual transitions from the X 1 to the X 4 results.



The next plots illustrate the effects of altitude scaling for one of the generated satellites (*remember altitude scaling applies to all satellites*). The bottom plot presents the simulated altitude profile. Scaling will be applied during the 1000-2000 meter bin by a factor of 2 and all other altitude scaled by a factor of 1.



The top plot is the applied multipath error for satellite 11 when no differential scaling is applied. The second plot illustrates the results when differential scaling in the 1000-2000 meter bin is used. As can be seen, the error growth in this region is doubled but maintains the same general shape.