Report on TEC

Introduction:

The parameter of ionosphere that produces most of the effects on radio signals is total electron content (TEC). By modelling TEC parameter, the evaluation of the ionospheric error and the correction of these ionospheric errors for differential GPS can be done. The ionosphere causes GPS signal delays to be proportional to TEC along the path from the GPS satellite to a receiver. TEC is defined by the integral of electron density in a 1 m^2 column along the signal transmission path. TEC is a key parameter in the mitigation of ionospheric effects on radio system. The TEC measurements obtained from dual frequency GPS receivers are one of the most important methods of investigating the Earth's ionosphere. The TEC itself is hard to accurately determine from the slant TEC because this depends on the sunspot activity, seasonal, diurnal and spatial variations and the line of sight which includes knowledge of the elevation and azimuth of the satellite.

Model:

Given for the model:-

R=6371e3;
H=800e3;
f=430e6;
N=1e10;

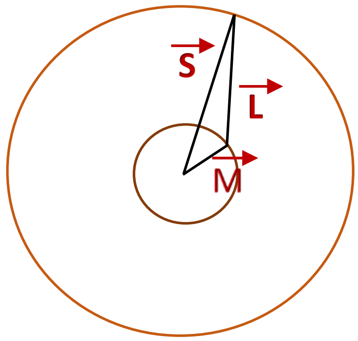
Elevation angle goes from 0-90° and azimuthal goes from 0-360°. We are dividing elevation in 20 equal parts and azimuthal in 80 equal parts, so there will be 21 different values of elevation angle and 81 different values of azimuthal angle. No. of elements along altitude is taken to be 1. Transformation matrix from ECEF to NED is defined as a zero matrix of 3*3. Assuming latitude and longitude is given for a particular place, respective angles can be calculated.

Defining co-ordinates of ground station in

*M=[R*cos(Lat_m*pi/180)*cos(Long_m*pi/180), R*cos(Lat_m*pi/180)*sin(Long_m*pi/180), R*sin(Lat_m*pi/180)];*

As we have 20 divisions in elevation angle and 80 divisions in azimuthal, so total no. of possible combination of both angles will be 21*81. Now defining rotational angle as a matrix of 21*81. Then we initialize modulus of angle of rotation and alpha. Alpha represents the value of magnitude of vector from ground station to satellite. Direction of vector from ground station to satellite is defined as $\hat{L}$ whose value can be given by

*$\hat{L}$=[sin(a(a1)*pi/180)*cos(b(b1)*pi/180), cos(a(a1)*pi/180), sin(a(a1)*pi/180*sin(b(b)*pi/180)]*



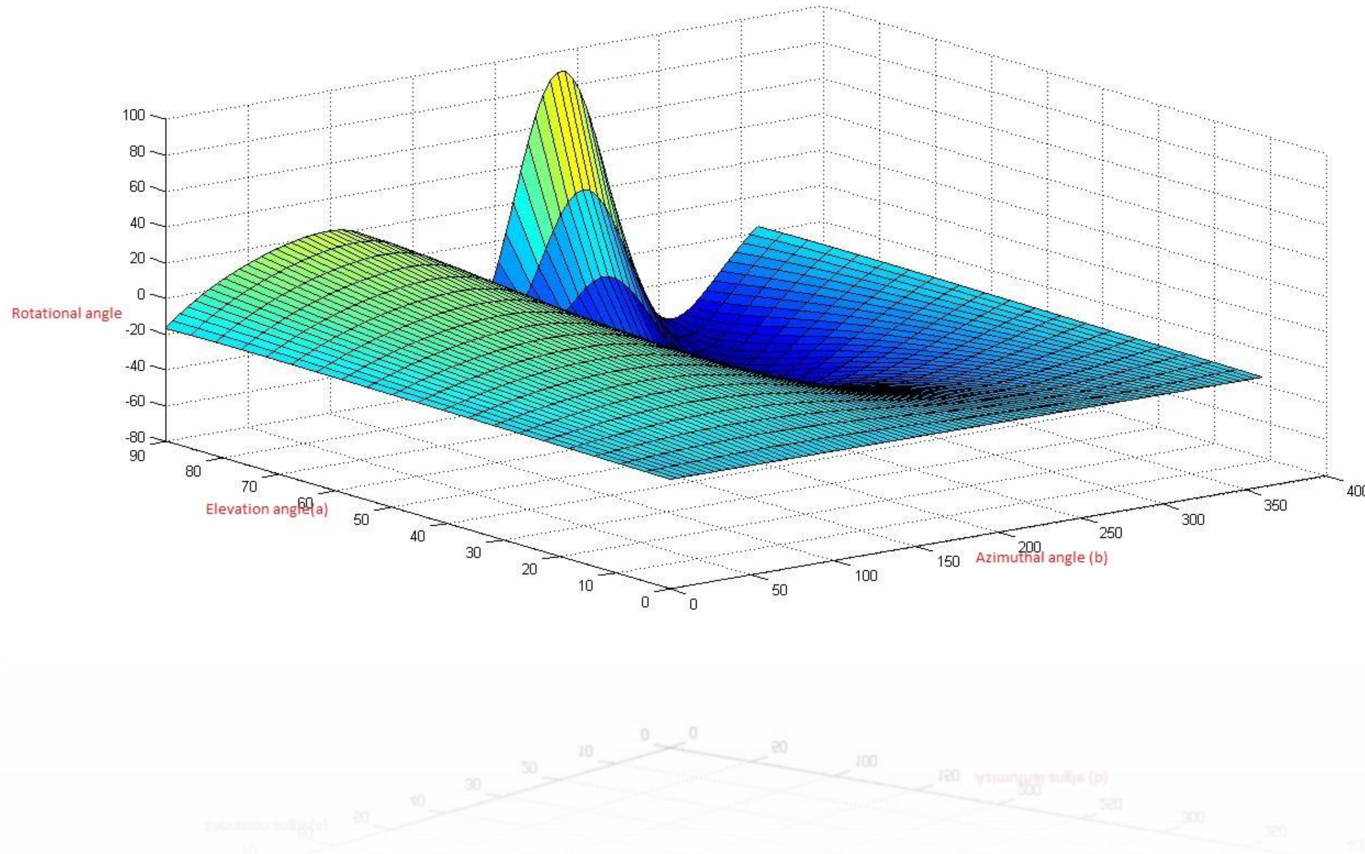
*c=[1 2*dot(M,L_unit) -2*R*H-H*H];*

Where c is just a temporary variable (a vector of size 3) that stores the coefficients of the polynomial and then this vector is passed into "roots" function that computes the roots of the polynomial (in this case a quadratic).

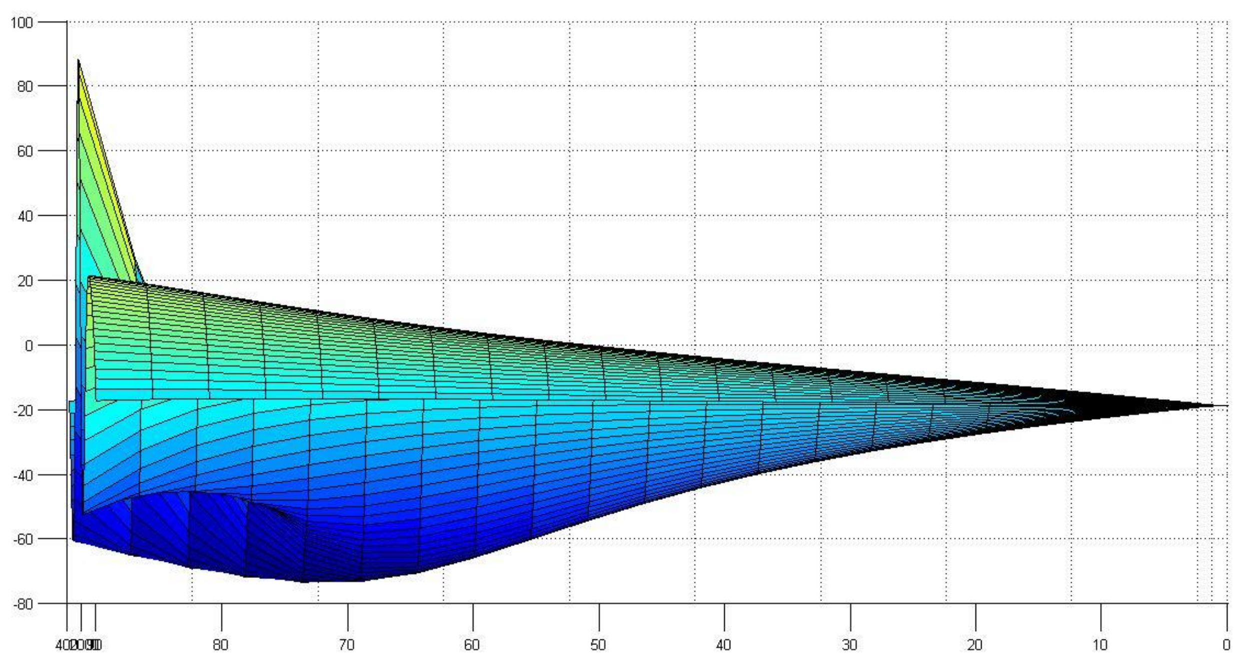
The coefficients of the polynomial come of the constraint that distance of satellite from the centre of earth should be equal to R+H.
Using roots of quadratic equation we will calculate value of alpha i.e. magnitude of $\vec{L}$. For calculating alpha we have to check which root is alpha. Condition for root to be equal to alpha is as below
If dot product of $\vec{M}$ and root one is greater than zero and dot product of $\vec{M}$ and root two is less than zero than the value of alpha is equal to root one of equation and if signs are opposite of above than value of alpha will be equal to root 2. This condition is obtained on the basis of fact that angle between $\vec{M}$ and $\vec{L}$ should be acute.

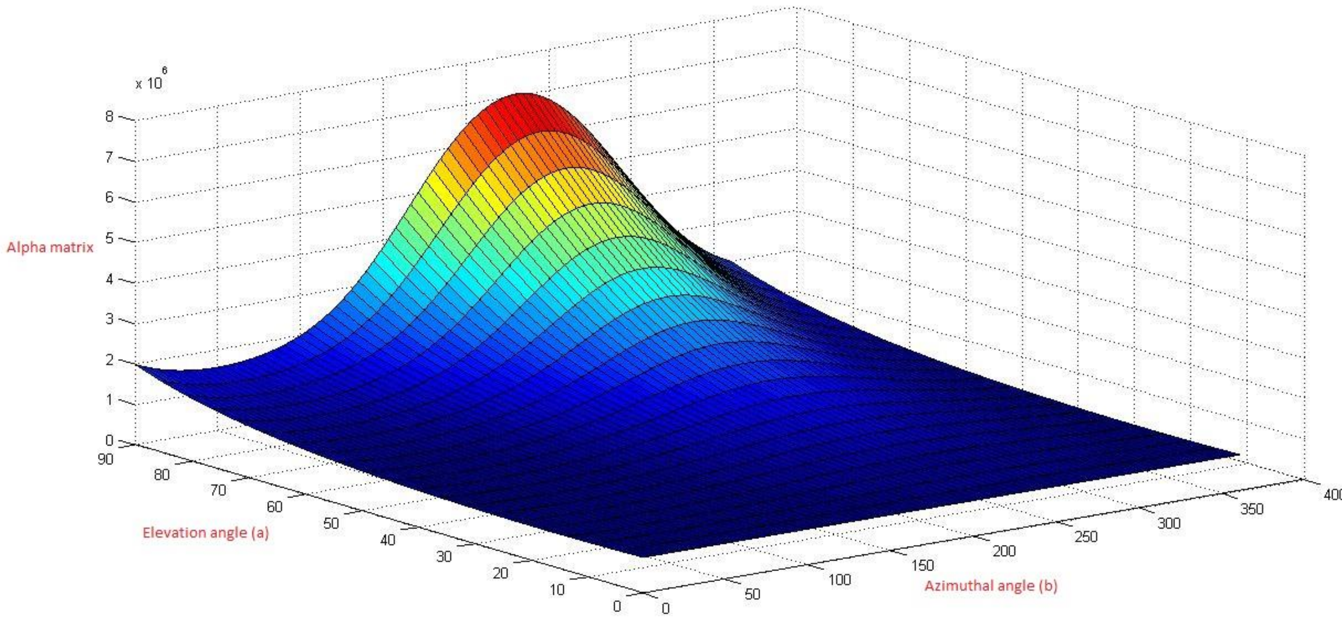
Position vector of satellite in ECEF frame is defined by $\vec{S}$ = $\vec{M}$+alpha*$\hat{L}$_unit
And distance of satellite from ground station is such that radius of orbit is R+H.

Now we calculate a point just below satellite on the earth, i.e. a point lying on earth and the line joining the satellite and centre of earth. Using $\vec{S}$ and radius of earth latitude and longitude of satellite can be measured and then vector in the direction of ECEF frame to NED frame can be calculated using latitude and longitude calculated above.
For different set of elevation and azimuthal angles temperature values can be calculated and can be plotted with respect to different axes where elevation Is from 0 to 90° .

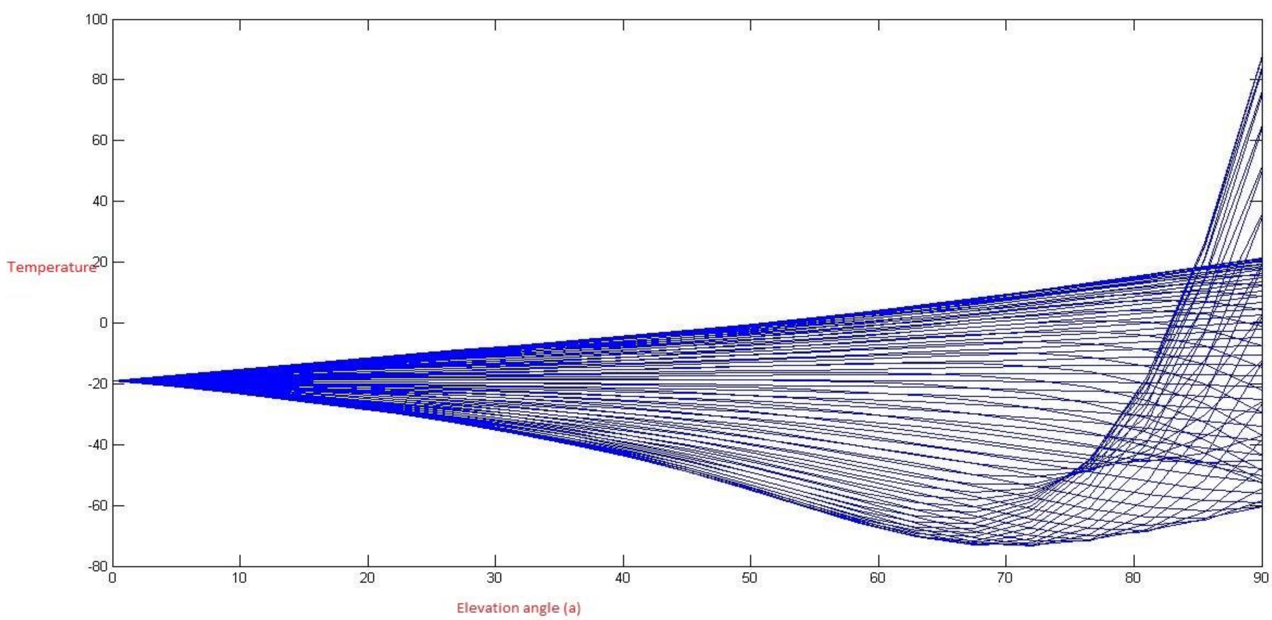


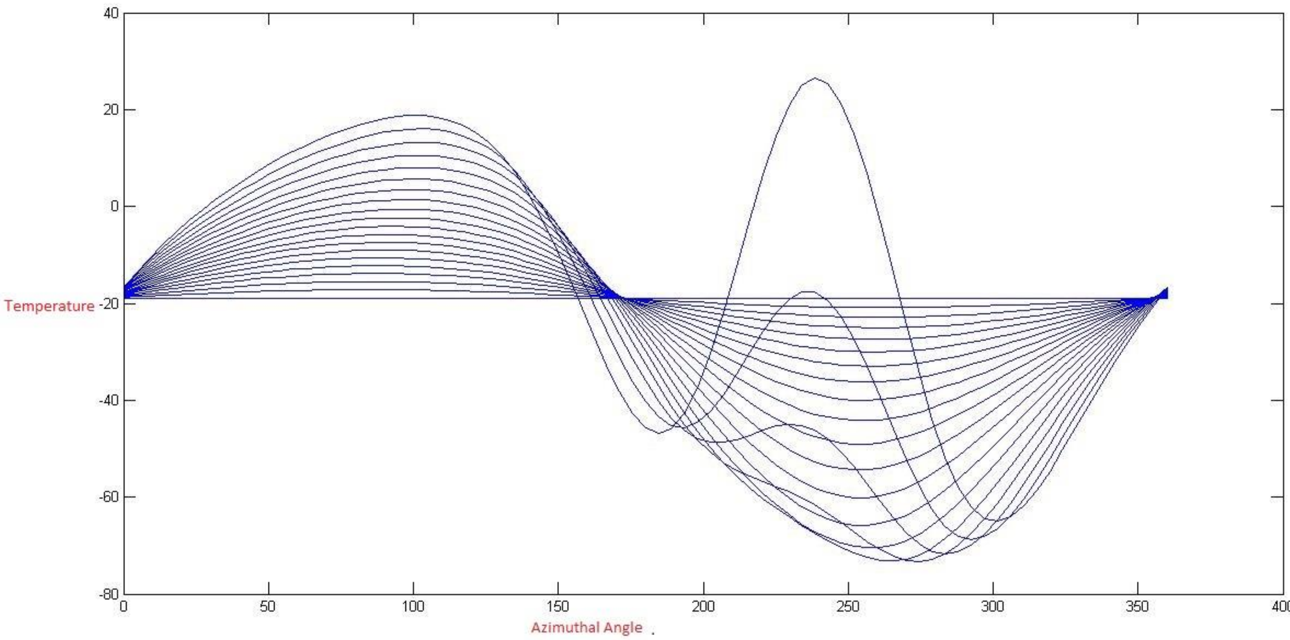
Front view of above graph





Above graph shows the variation of rotational angle with respect to elevation and azimuthal angle and graph which is below shows the variation of alpha matrix (which is used to calculate magnitude of $\vec{L}$.





Inference

From the front view of 3D graph of rotational angle vs elevation and azimuthal angle it can be easily seen that Elevation 0° is vertical and 90° is horizontal. In alpha matrix and elevation angle curve for constant azimuthal angle value of alpha continuously decreases as elevation angle increases. In temperature vs elevation angle graph range of temperature increases as elevation angle increases and in temperature vs azimuthal angle graph tempreture first increases then decreases and become zero when angle is ° .

Made by

Vikas garg