

**Universität Stuttgart**

**Satellite Geodesy**

**“Klobuchar ionospheric correction”**

Lab-2

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## **Aim**

To compute the Klobuchar range corrections for all the visible satellites and to make the time correction plots.

## **Introduction**

Signals, on their path between satellites and ground stations, propagate through atmospheric regions of different nature and variable state, and thus experience different kinds of influences. Perturbations may occur to the direction of propagation, to the velocity of propagation and to the signal strength. Information on the state of the upper atmosphere can be obtained when the received satellite signals are compared with signals that would be observed under atmospheric free conditions.

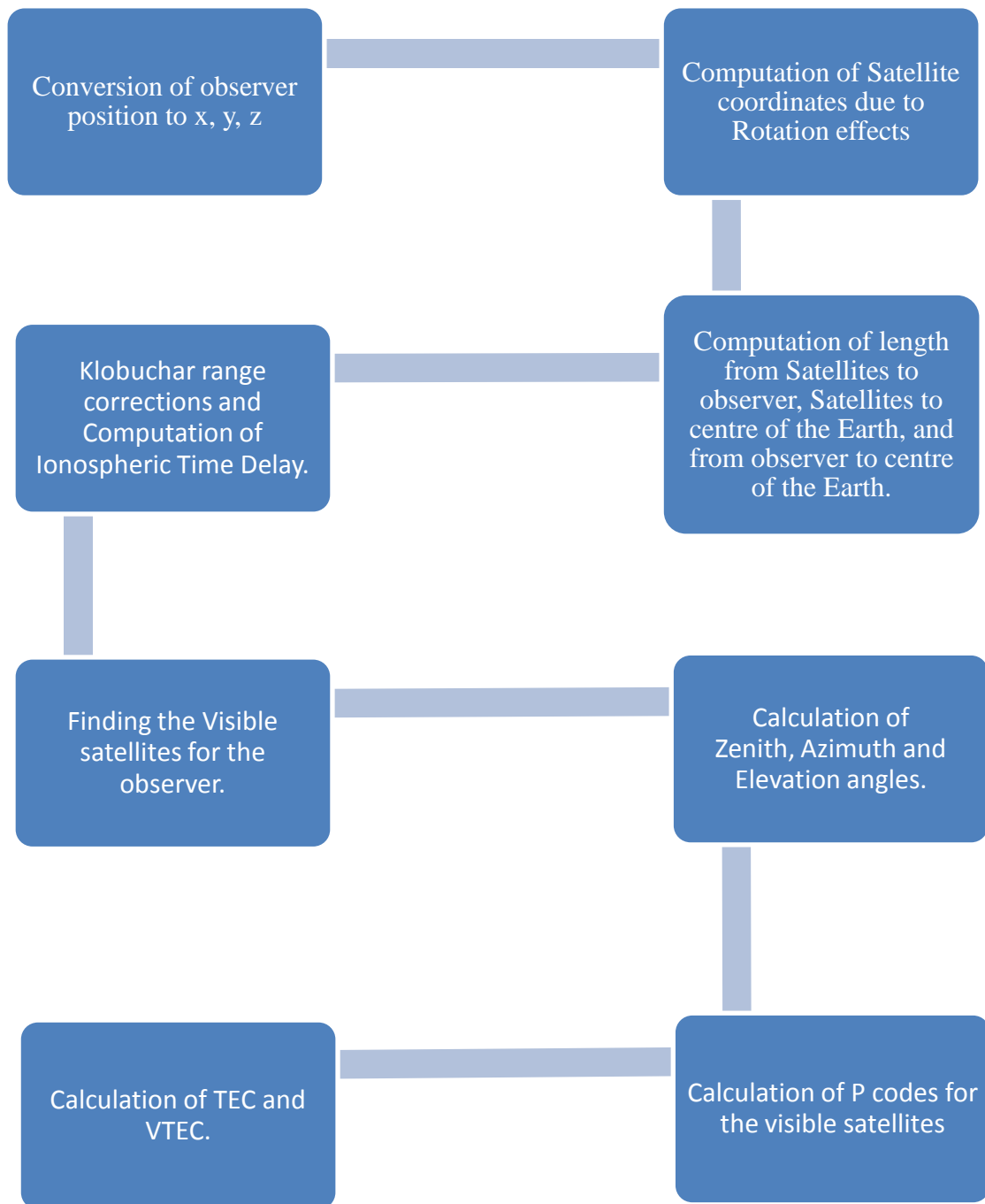
A diagram indicating the number of ions produced as a function of heights shows a maximum in ion production rate. Such a diagram is called the Chapman Profile. The exact shape of the curve and related numerical values are depending on several parameters, and they are highly variable functions. Here, we are going to find those values for all visible satellites which should be found from the given sets of satellite data's.

## **Objective**

The main objectives of this lab are:

- Find all visible satellites to the observer.
- To get a good understanding of sky-plot of all visible satellites.
- Klobuchar range-corrections.
- Time-correction for all satellites

## Methodology



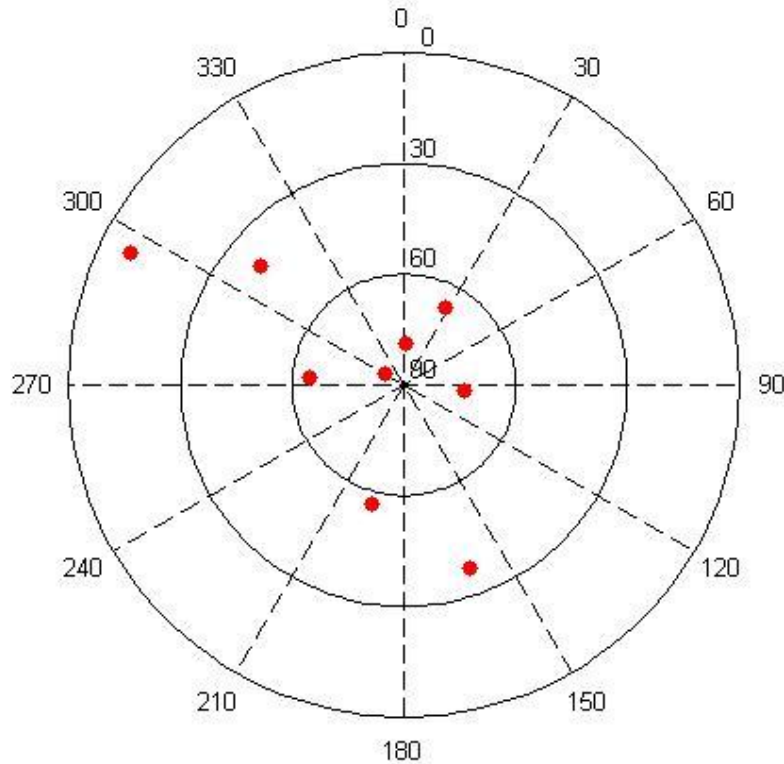
**Explanation:**

Fig. (1): Sky plot for the 9 visible satellites

**1. Computng satellite coordinates due to rotation effects**

The coordinates of the observer to receive the GPS Signal is given and these kinds of coordinates are global ellipsoidal and geographic coordinates  $L, B$  and  $H$ . Also, the coordinates of different satellites are given in different epoch and these kinds of coordinates are spatial Cartesian coordinates.

It can be calculated by:

```

for i = 1:9
Ri = [cos(omega*t(i)) sin(omega*t(i)) 0; ...
      sin(omega*t(i)) -cos(omega*t(i)) 0; ...
      0 0 1];
xyzM = [x(9*(i-1)+1) x(9*(i-1)+2) x(9*(i-1)+3) x(9*(i-1)+4); ...
        y(9*(i-1)+1) y(9*(i-1)+2) y(9*(i-1)+3) y(9*(i-1)+4); ...
        z(9*(i-1)+1) z(9*(i-1)+2) z(9*(i-1)+3) z(9*(i-1)+4)];
xyzi = Ri*xyzM;
xyzt = [xyzt;xyzi];
end
xyzt = xyzt(4:end,:);

Pos_Rcv=(X0*ones(9,4)),(Y0*ones(9,4)),(Z0*ones(9,4));
Pos_SV=(xyzt(1:3:27,:),xyzt(2:3:27,:),xyzt(3:3:27,:));

```

## 2. Calculate of the angles

%%% Length from satellites to the observer

```
S_RS = sqrt((xyz(1:3:27,:)-X0*ones(9,4)).^2 + (xyz(2:3:27,:)-Y0*ones(9,4)).^2 + (xyz(3:3:27,:)-Z0*ones(9,4)).^2);
```

%%% Length from satellites to the center of the earth

```
S_CS = sqrt((xyz(1:3:27,:)-zeros(9,4)).^2 + (xyz(2:3:27,:)-zeros(9,4)).^2 + (xyz(3:3:27,:)-zeros(9,4)).^2);
```

%%% Length from the observer to the center of the earth

```
S_OS = r*ones(9,4);
```

%% Calculate the angle

```
Angle_RS_RC = acos((S_RS.^2 + S_OS.^2 - S_CS.^2)./(2.*S_RS.*S_OS));
```

```
z = 180 - (Angle_RS_RC*180/pi);
```

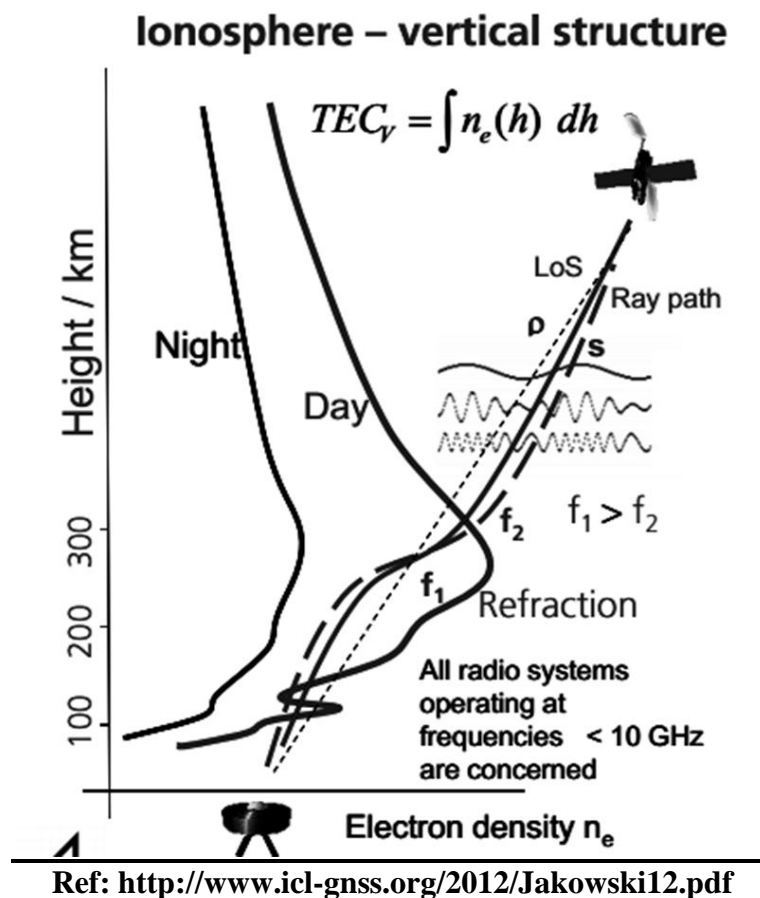
```
zI = asin((r./(r + 1.0e6)).*sin(z));
```

```
azi=z*180/pi;
```

```
el=90-(Angle_RS_RC*180/pi);
```

```
a=z;
```

## 3. Klobuchar range-corrections



GPS satellites broadcast the parameters of the Klobuchar ionospheric model for single frequency users. The Klobuchar model was designed to minimise user computational complexity

and user computer storage as far as to keep a minimum number of coefficients to transmit on satellite-user link.

It can be calculated by:

```

psi = (0.0137 / (el(9,4) + 0.11)) - 0.022;

phi_1 = phi + (psi * cos(a));

lambda_1 = lambda + ((psi * sin(a)) / cos(phi));

phi_m = phi_1 + (0.064 * cos(lambda_1 - 1.617));

yy=2014;
mm=9;
dd=1;
hh_1=8;
hh_2=10;

tGPS = G2JD(yy,mm,dd,hh_1,0,0) - G2JD(yy,mm,dd,hh_2,0,0);

t_IPP = (43200 * lambda_1) + tGPS;

alpha_1 = 2.6534D-08;
alpha_2 = 2.2772D-09;
alpha_3 = -3.5174D-07;
alpha_4 = 5.1246D-07;

beta_1 = 1.4918D+05;
beta_2 = 8.4820D+04;
beta_3 = -1.5726D+06;
beta_4 = 4.0023D+06;

s_1 = (alpha_1 * phi_m) + (alpha_2 * phi_m) + (alpha_3 * phi_m) + (alpha_4 * phi_m);

s_2 = (beta_1 * phi_m) + (beta_2 * phi_m) + (beta_3 * phi_m) + (beta_4 * phi_m);

A_1 = max(0,s_1);

P_1 = max(72000,s_2);

X_1 = (2 * 3.14 * (t_IPP - 50400)) / P_1(9,4);

F = 1.0 + (16 * ((0.53 - el).^3));

if X_1 <= +1.57
    dT_L1 = ((5 .* ((10).^(-9))) + (s_1 .* (1 - (((X_1).^2)/2) + (((X_1).^4)/24)))) .* F;
else
    if X_1 <= -1.57
        dT_L2 = ((5 .* ((10).^(-9))) + (s_1 .* (1 - (((X_1).^2)/2) + (((X_1).^4)/24)))) .* F;
    else
        dT_L3 = (5 * ((10).^(-9))) * F;
    end
end
end

```

#### 4. Vertical Total Electron Content (VTEC)

```
epoch =epoch(1:9:81);
```

```
f1 = 1575.42*1e+6; f2 = 1227.60*1e+6; T = 1/(40.3*(1/f1^2 - 1/f2^2));
```

```
%% TEC computation
```

```
TEC_S1 = T*S1;
TEC_S2 = T*S2;
TEC_S3 = T*S3;
TEC_S4 = T*S4;
TEC_S5 = T*S5;
TEC_S6 = T*S6;
TEC_S7 = T*S7;
TEC_S8 = T*S8;
TEC_S9 = T*S9;
```

```
%% VTEC computation
```

```
VTEC_S1 = TEC_S1.*cos(zI(1:81:9))
VTEC_S2 = TEC_S2.*cos(zI(2:81:9))
VTEC_S3 = TEC_S3.*cos(zI(3:81:9))
VTEC_S4 = TEC_S4.*cos(zI(4:81:9))
VTEC_S5 = TEC_S4.*cos(zI(5:81:9))
VTEC_S6 = TEC_S4.*cos(zI(6:81:9))
VTEC_S7 = TEC_S4.*cos(zI(7:81:9))
VTEC_S8 = TEC_S4.*cos(zI(8:81:9))
VTEC_S9 = TEC_S4.*cos(zI(9:81:9))
```

```
%% Plots
```

```
figure;
plot(epoch,S1,epoch,S2,epoch,S3,epoch,S4,epoch,S5,epoch,S6,epoch,S7,epoch,S8,epoch,S9);
xlabel('Epoch','FontSize',14);
ylabel('P1','FontSize',14);
title('P code','FontSize',16);
legend('Sat 1','Sat 2','Sat 3','Sat 4','Sat 5','Sat 6','Sat 7','Sat 8','Sat 9');
```

```
figure;
```

```
plot(epoch,TEC_S1,epoch,TEC_S2,epoch,TEC_S3,epoch,TEC_S4,epoch,TEC_S5,epoch,TEC_S6,epoch,TEC_S7,epoch,TEC_S8,epoch,TEC_S9);
xlabel('Epoch','FontSize',14);
ylabel('TEC','FontSize',14);
title('TEC','FontSize',16);
legend('Sat 1','Sat 2','Sat 3','Sat 4');
```

```
figure;
```

```
plot(epoch,VTEC_S1,epoch,VTEC_S2,epoch,VTEC_S3,epoch,VTEC_S4,epoch,VTEC_S5,epoch,VTEC_S6,epoch,VTEC_S7,epoch,VTEC_S8,epoch,VTEC_S9,epoch,VTEC_average);
xlabel('Epoch','FontSize',14);
ylabel('VTEC','FontSize',14);
title('VTEC','FontSize',16);
legend('Sat 1','Sat 2','Sat 3','Sat 4','VTEC','V-a');
```

```
for i=1:size(azi,1),
    svx(i)=el(i)*cos(a(i));
    svy(i)=el(i)*sin(a(i));           %Calculate polar co-ordinates
end
```

```
polarhg([30 60])           %Prerequisite script used to format axis
hold on
plot( svx,svy,'.r','markers',20); %Plot satellite location
hold off
```

```
%% Format output
for i=1:el,
```



```

text(svx(i)+7,svy(i),num2str(prn(i)), 'FontSize',10); %Add PRN labels to each point
end

```

```

axis('square')
grid on;
set(gcf, 'Color', 'w'); %Change background of figure from grey to white
ti = get(gca,'TightInset') ; %Remove extra spacing around figure
set(gca, 'LooseInset', [0,0,0,0.01]); %Depending on the figure, you may need to add extra spacing [left bottom width
height])
print( '-dtiff', ['skyPlot'], '-r600'); %Change "-r600" to the required DPI

```

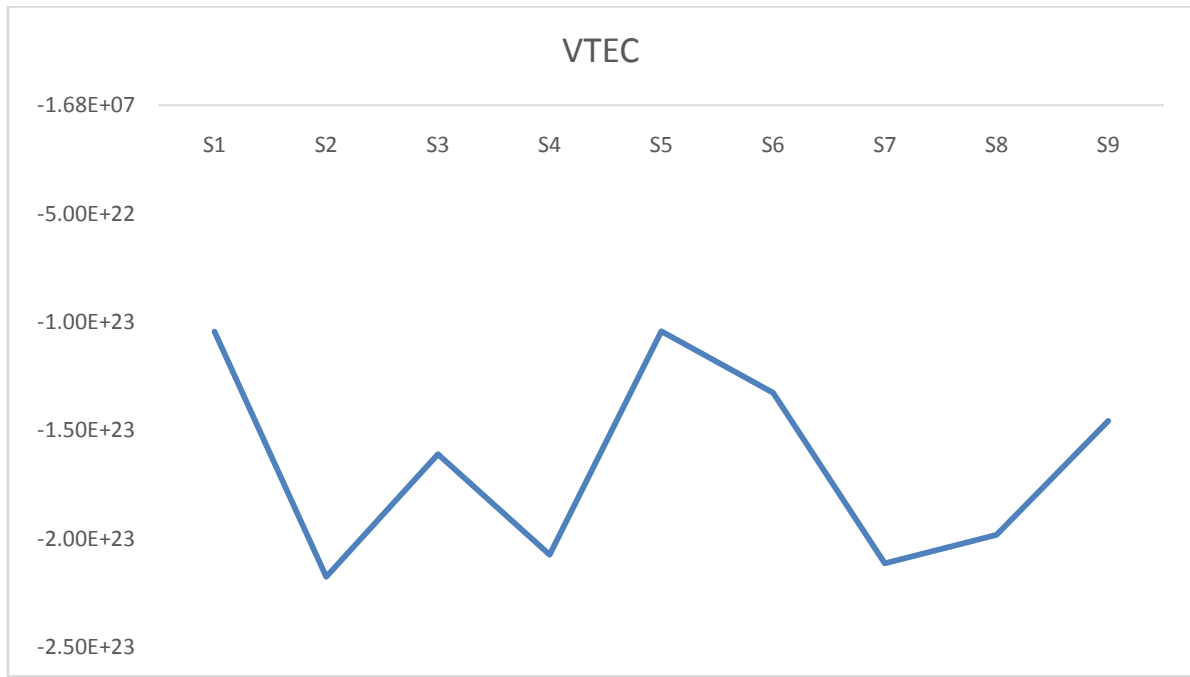


Fig. – (3): VTEC for the 9 visible satellites

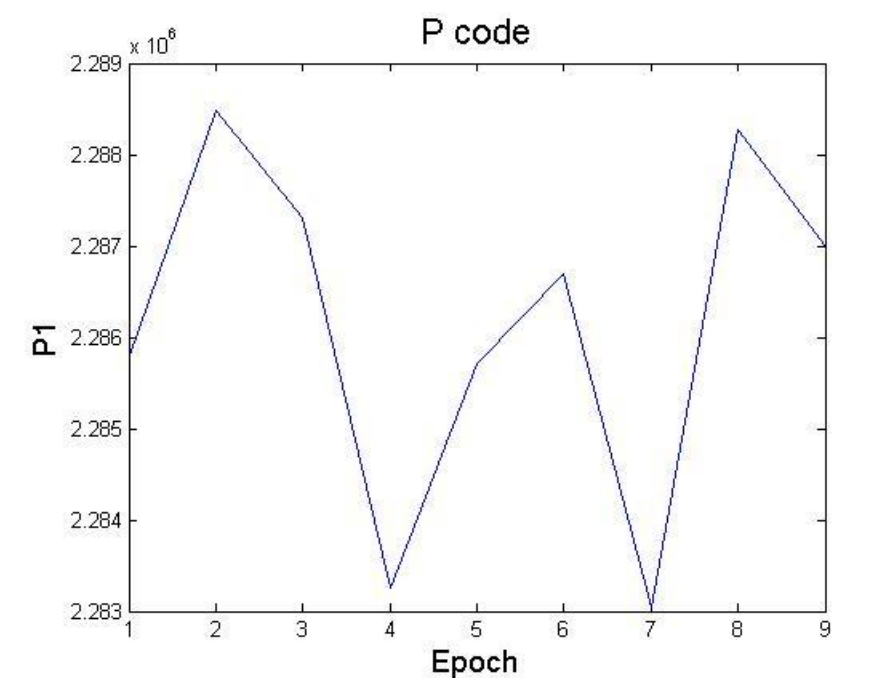


Fig. – (4): P codes for the 9 visible satellites

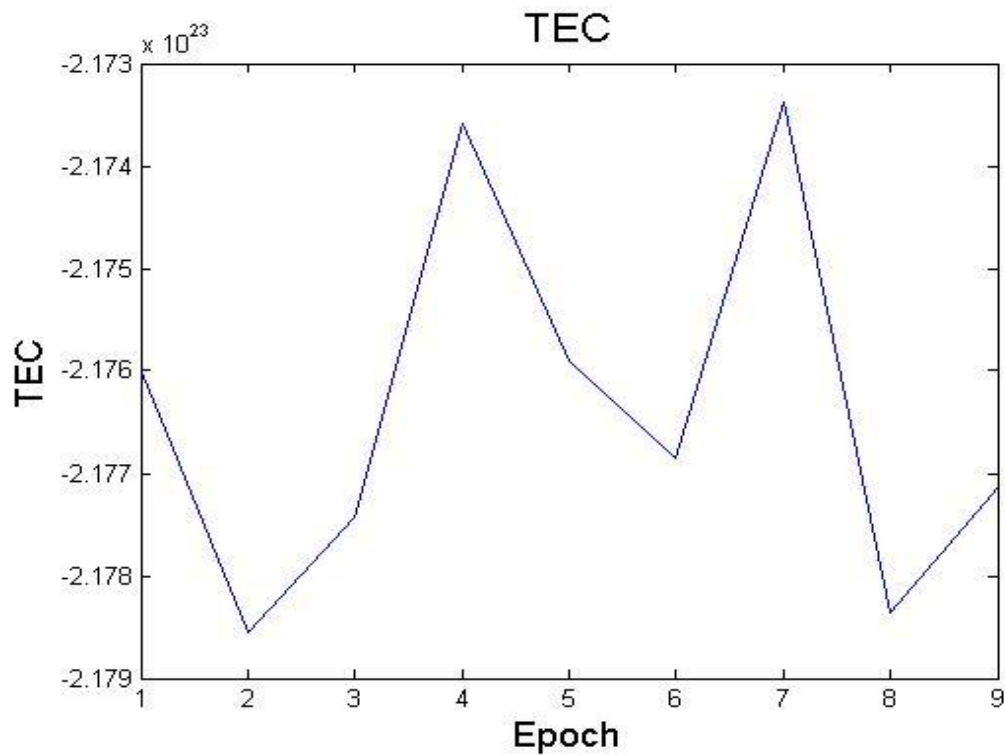


Fig. – (5): TEC for the 9 visible satellites

## **Conclusion**

There are 9 visible satellites for the observer. The impact of the state of the ionosphere on the propagation of waves is characterized by the Total Electron Content of these satellites in the varying epochs.

## **Reference**

1. Guenter Seeber- Satellite Geodesy – 2nd edition
2. wikipedia
3. [http://www.gmat.unsw.edu.au/snap/gps/gps\\_survey/chap5/532.htm](http://www.gmat.unsw.edu.au/snap/gps/gps_survey/chap5/532.htm)
4. [http://www.navipedia.net/index.php/Klobuchar\\_Ionospheric\\_Model](http://www.navipedia.net/index.php/Klobuchar_Ionospheric_Model)
5. <http://www.icl-gnss.org/2012/Jakowski12.pdf>