Globalstar Satellites System for Ranging and Positioning Analytical Study

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Abstract: *The aim of this paper is to find out and discuss the system which can be used for positioning and ranging. It also covers the basic knowledge of what exactly is global positioning system (GPS) and what do we mean by positioning and ranging any object on the earth surface.*

Methods for positioning using a satellite in a Low earth orbits (LEO) are discussed. As in GLOBALSTAR®, LEO satellite system similar to Iridium Satellite System. This paper discusses implementation on the satellite system for positioning and ranging of a user terminal on the earth. The simulation is carried out in MATLAB about the about the above mentioned satellite system.

Keywords: *Low earth orbits satellite, positioning, ranging*

1. INTRODUCTION TO GLOBALSTAR

GLOBALSTAR satellite system with forty eight (48) satellite system at altitude of 1400 km high is designed for the maximum coverage around the globe with from seventy (70) degrees latitude north and south. The GLOBALSTAR satellite user terminal uses wireless handheld device or fix sets with normal Subscriber Identity Module (SIM) cards. The user views satellite for 10-15 minutes. Soft hand off occurs between the satellite to better performance and excellent communication.

GLOBALSTAR is connected to the Public switched telephone network (PSTN) service through the gateway terminals are which are at different places on the earth (approximately 60) Gateways cover a radius of approximately 2000km.The ground gateway has ground operation control center (GOCC) which performs the planning and management with the satellite operation control center (SOCC). Satellite foot prints are divided into beans through beam forming antennas. The frequency plan is divided into:

- User to satellite is the reverse uplink in L band (1610-1623 MHz)
- Satellite to user in the forward downlink in S band(2483.5-2500 MHz)
- From gate way to satellite is forward uplink in C band (6875-7055 MHz)
- From satellite to gateway is the reverse downlink (6875-7055 MHz)

The GLOBALSTAR system is a blend of many advanced technologies combining such as Code division multiple access (CDMA) and Frequency-division multiple access (FDMA) technologies along with Multiple Beam Array (MBA). The entire frequency bandwidth of 16.5 MHz in L and S band is divided in units of 1.223 MHz. Each frequency channel is further code multiplexed by 128 Walsh channels.

THE use of the CDMA technique which helps in reducing the interference and spectrum efficiency combined with Frequency Division Multiplexing of different channels make this scheme an efficient access technique to provide point to point communication over a wide area on the earth [10].

The satellite uses a 16 beam active phased array antenna feeding 16 transponders in the forward and reverse links. A single beam transmit antenna with 8 FDMA channels in each of the right hand circular and left hand circular polarization provides the link from the satellite to the gateway. A single beam received through an antenna provides the communication from the Gateway to the Satellite with the channelization described earlier. The 16 channels are further amplified by 16 transponders in the forward direction and then passed to a 16 beam active transmit phased antenna to serve the user clusters [11].

GLOBALSTAR system uses four separate segments of the radio frequency spectrum: CDMA is employed, and data rates of up to 9600bps are supported on terminals.

GLOBALSTAR contains a forward link, which consists of an uplink from a gateway ground station and a downlink to a subscriber radio and a return link, which consists of an uplink from the user and a downlink to the Gateway. A typical forward link for a particular telephone conversation would have an effective isotropic radiated power (EIRP) from the Gateway of 41 dBw and the signal is received at the user with 3.9 dB with two circuits operating. For the return link, the user typically has an EIRP of - 9.2 dBw and the return link is 5.7 dB, assuming satellite diversity. This makes high-quality voice reception [1] [2].

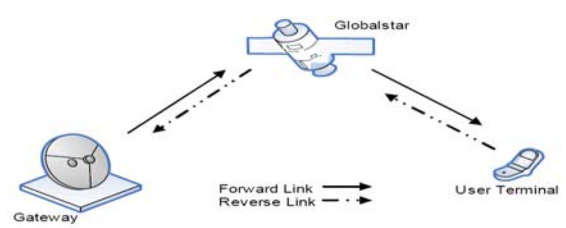


Figure 1: The GLOBALSTAR system model [1]

1.1 FACTORS INVOLVED IN POSITIONING AND RANGING

To find a position of a user terminal on a spherical earth involves finding the range between the satellite and the user and the area where the user is. To make use of the current satellite system which is used for voice and data transmission our goal involves the following:

- Range or the instantaneous distance between the satellite and the user
- The instantaneous elevation angle φ
- The Doppler shift δ
- The projection on to the surface of the earth that is angle θ
- The attitude of the satellite and the radius of the Earth

Range

Range is the distance between the satellite and the user terminal. It is the maximum distance between the earth station and the satellite .In figure 2, distance‘d’ is the range. This can be calculated by the time required from the signal to receive at the user terminal into the speed of light. This gives the exact range or how far is the satellite from the user.

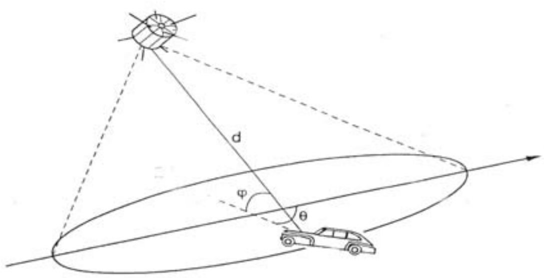


Figure 2: The Three Parameters Required for self positioning

The elevation angle

Elevation refers to the angle between the user straight line towards the satellite, and the local horizontal plane.

At low elevation angles around 10 deg the atmospheric blockage is longer and the signals are degraded by rain attenuation and rain thermal noise. The GLOBALSTAR system used here has its orbit at 52 deg inclination angle and for this research we will be using 10 to 20 degrees of elevation angle. The constellation was designed to provide coverage between 70 degrees N and 70 degrees S latitudes with a view of at least 2 or more satellites at an elevation greater than 10 degrees from any point in the service region [3].

Doppler Effect

It is referred to as the change in the frequency of a moving object when it comes near or goes away from the source. Doppler’s effect plays an important role in the method of finding the position. Doppler’s effect is negligible in the case of other navigation system working in the higher orbits. The speed of those satellites is almost the same with the speed of the earth where as in the satellites in the LEO orbit they moves more faster around in the orbit then the earth spin.

The projection angle

Angle θ is the projection angle between surface of the Earth which is then tracked by the satellite and a straight line segment passing through satellite and user. This is calculated by the Doppler shift δ and instantaneous elevation angle φ and the range d.

1.2 EXPLANATION OF POSITIONING METHOD

The user and the reference terminal track the carrier signal from the LEO satellites in S band. These carrier signals are then sampled and compared at the reference station to get the reference carrier phase information. There is a communication link between the reference station and the user terminal which is used to send this reference carrier phase information to the user terminal [4].

The user device is equipped with an antenna which is used to track signals directly from the LEO satellites which are in the S band. The signals from the reference station and the signal from the LEO satellites are fed in to the user terminal.

The reference receiver calculates the differential code phase delay measurement and transmits it to the user/ receiver over the communication link between them. The reference receiver then conveys its information of the carrier phase measurement and the measurement correction data over the communication link to the user terminal.

This transmission of the signal from the reference station to the user terminal is carried out every second during the process of navigation.

1.2.1 The data link between User and the reference terminal

LRU is implemented between the user terminal and the reference terminal .The purpose of this unit is to convey carrier phase measurement from the reference terminal to the user device .This LRU conveys the following information to the user from the satellites:

- Ephemeris data to the user obtained by direct data link between the satellites and the reference terminal
- Receiver clock offset which is used to for correction of the differential measurement. By sending this correction for the range a number of

times to the user the user can correct the phase performance on the satellites.

- The position of the reference station antenna by which user can know the rough location of the reference station
- The conditional characteristics such as health and signal for each satellite.

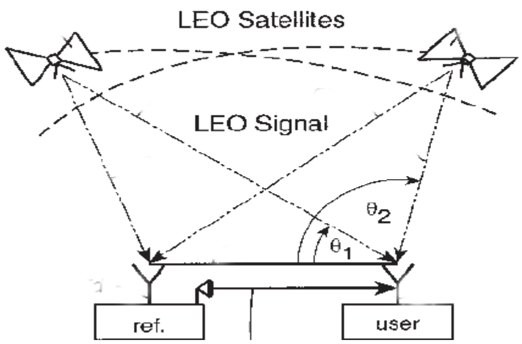


Figure 3: System using LEO satellites for navigation [6]

The user and the reference receiver as shown in the fig track S band carrier phase signals from the GLOBALSTAR satellite. Communication and telemetry data is exchanged between the gateway and the GLOBALSTAR satellite system through the C band. At the receiver GLOBALSTAR uses a rake filter that processes multiple received components of the transmitted signal. This rake filter has a property of adding received signal which are the multi-path reflected signal created by the satellite beams digitally.

To maximize capacity of the system, CDMA requires that the Eb/No received from all users is at a similar level at the Gateway. Users transmitting more power then the gateway create more interference, which reduces the system capacity. For this problem, GLOBALSTAR uses dynamic power control on the return traffic channel to reduce the user power output and on the forward traffic channel.

The navigational capability of the system mainly depends upon the user knowing the exact position the satellite. This knowledge as a function of time can be obtained via the satellite ephemeris data. This data consist of several parameter of each satellite as the orbit path and the change in that orbit over time. This data must be updated daily by the user.

As shown in the figure 3, the data transmitted from the SOCC to an ephemeris data provider. This data is transmitted to the reference station through a line modem or a regular land telephone. This information can also be obtained from the GLOBALSTAR data link and then transmitted to the user terminal. Whether the information is taken from the tracking source or from the SOCC this information plays an important role and must be updated and sent to the user terminal [5][6][7].

The position calculation involves the correction of the carrier phase measurement, which is based on the information received from the reference terminal and the satellite ephemeris data. RAIM (receiver autonomous the receiver to independently use the satellite ephemeris data for position solution may use integrity monitoring [5] [6] [7].

1.3 RESEARCH ANAYLSIS AND TECHNIQUE

To prove the system suitable for navigation GLOBALSTAR system data and orbit parameters were used in MATLAB to check the availability, performance and the feasibility of the research.

The analysis is divided in to the following section

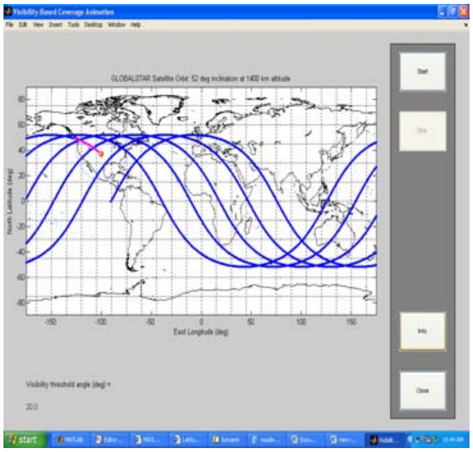
- Coverage area
- Number of satellites seen simultaneously by the user in that particular area
- Feasibility of that area
- Accuracy of the position

1.3.1 Coverage area

This application developed by Dr. PG. Bonanni and Dr. I. Ali of Motorola in MATLAB shows visibility-based coverage region animation.

This also displays and animates the visibility-based coverage region of a typical LEO satellite. Visibility from points on the Earth's surface is established if the satellite appears above a given elevation angle in the sky. Using the above mentioned application and putting the values of the GLOBALSTAR satellite system we achieved the coverage region of the satellites.

The result from the simulation shows that the GLOBALSTAR is designed in such a way that the user on the earth between 70 degrees north and 70 degrees south latitude is able to see at least one satellite. This makes it possible for the method of positioning using one satellite and the use of Doppler shift to be implemented. The result of the simulation is shown in Graph 1.



Graph 1**:** GUI based demo shows visibility-based coverage by P. G. Bonanni and I. Ali

1.3.2 The Number of satellites seen simultaneously

To perform the position and ranging we need three satellites for the x, y and z coordinates and one satellite for the clock errors. Now the number of satellite seen simultaneously by the user in the coverage area is figured out by looking at the table 1.

In Table 1 the area between the latitude 40 degrees to 50 degrees the user is able to see 3 satellites at a time.

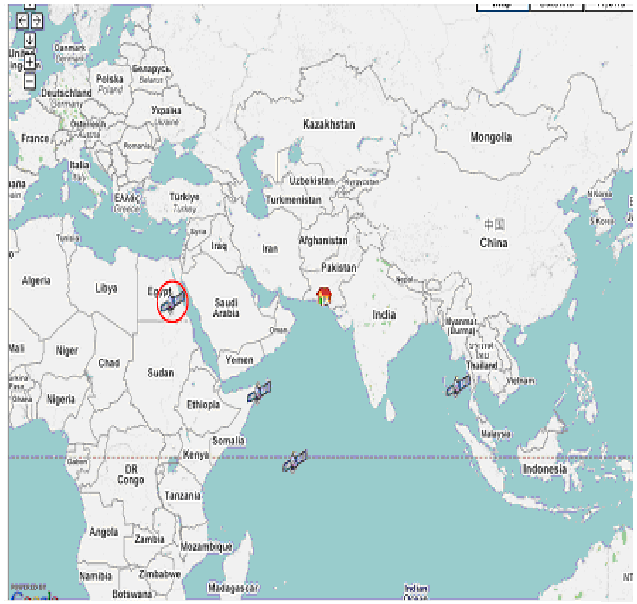
Latitude	Number of simultaneous satellites visible above 20° elevation			
	0	1	2	3
0°	3 %	77 %	20 %	0 %
10°	11	57	32	0
20°	4	60	36	0
30°	0	43	55	2
40°	0	10	70	20
50°	0	19	71	10
60°	0	70	30	0
70°	75	25	0	0

Table 1: Distribution of Number of Satellites Seen Simultaneously [8]

1.3.3 The area feasibility

Taking a location then performing the simulation with the GLOBALSTAR data carried out this analysis. The user location was set in Karachi in Pakistan. Satellites were tracked at various interval of time during the day.

The figure and data are the real time satellite tracking data. The satellite shown is the GLOBALSTAR satellite M061, M060, M043 satellite and M044.



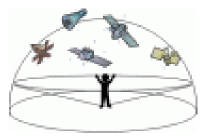


Figure 4: Real Time GLOBALSTAR satellites tracking

The user less then 10 degrees elevation saw the above satellites. The real time tracking data above user in this area can see three or more satellites simultaneously.

1.3.4 System Accuracy and Navigation.

Accuracy measurement of the system is an important in the navigation process. The accuracy can be measured by using the error least square minimization technique. This technique is commonly used in the GPS to calculate the clock errors. It will also consider a fixed location of the receiver which is not known to the system then the simulation will calculate the position and compare it with the assigned location. This will tell us the error in the position.

1.4 ANALYSIS

Considering our location in Karachi Pakistan having the latitude and longitude:

Latitude = 24.867° Longitude 67.05

By the using the formulas it was that X Y and Z earth fixed Cartesian coordinates of the user. By using the code in MATLAB we calculated the X Y and Z coordinates of the user.

Similarly when converting the latitude and longitude of the tracked GLOBALSTAR satellites X, Y and Z coordinates of all the four satellites. Using similar method it was found that the fixed position of the receiver. The calculated the range between them by applying distances formula giving the range from each of the four satellites seen.

In order to find out the error we used the least square minimization technique to see the accuracy of the position and errors

The results from least square minimization method shows the location coordinates and which when compared with original coordinates shows the error in the position. The results the error is quite significant.

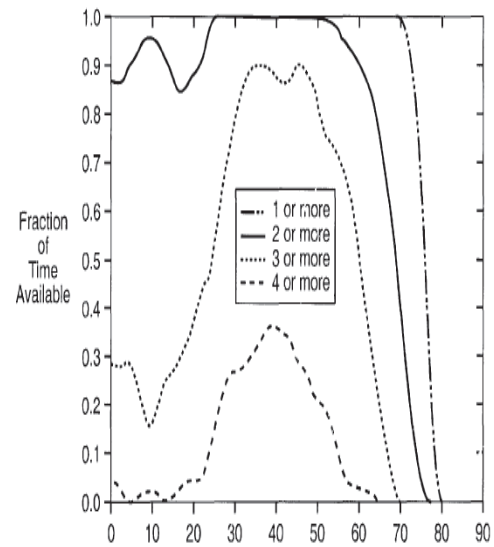
1.5 RESULT AND CONCLUSION

All the data obtained are the real time satellite data. The satellites were tracked and monitored during various interval of time during the day. The numbers of satellites seen were below 10 degrees elevation angle (Pakistan). *Signal from the LEO satellites are not meant for the navigation purposes and rather for used for other services like voice communication data transmission.* The research gone through is not to alter the current specification of the GLOBALSTAR satellite system but to find out the feasibility to use it for positioning and ranging. My thesis was implementing the research on the GLOBALSTAR and see if the system has the right specification to fit on the invention.

The invention and the method discussed states:

- Three or more LEO satellites should be available for ideal positioning and tracking.
- Carrier signal should be able to monitor for several minutes.
- Accurate satellite ephemeris should be known
- Sufficient SNR ratios should be there for accurate phase carrier estimation

The figures below describe availability of satellites at different latitudes in. It is worth noting that there are all the time 2 satellites obtainable and GLOBALSTAR itself is inclined at 52 degrees latitude covering the earth from 70 degrees north and 70 degrees south latitude. This explains that in areas between 40 degrees latitude and 60 degrees latitude the three or more satellites can be seen for a longer period of time.



Graph 2: The GLOBALSTAR Air Interface: Modulation and Access [8]

Secondly the GLOBALSTAR constellation has GPS sensors on board so that the satellite ephemeredes can be regulated to <20m rms.

GLOBALSTAR uses particularly high SNR ratio for high quality voice reception "As discussed typical forward link have an effective isotropic radiated power (EIRP) from the Gateway of 41 dBw and the signal is received at the user with 3.9 dB with two circuits operating .And return link, the user typically has an EIRP of - 9.2 dBw and 5.7 dB, assuming satellite diversity [9].
GLOBALSTAR also has the fowling features which suits the invention

- Significant Doppler shift due to the low orbit of the relay satellite,
- Ability to make time and frequency measurements at both ends, the UT and the GW,
- Availability of a two-way communication link to relay the measurements between the two ends, and synchronized time and frequency transmissions from several satellites serving the same GW

[8]

Concluding all the results above and viewing all the technical aspects of the GLOBALSTAR satellite system it is found that this satellite is ideal for the ranging and positioning

1.6 SIMULATION CONCLUSION

The overall coverage analysis and the simulation analysis shows that the GLOBALSTAR satellite is seen for a short period that is 10 to 15 minutes which makes it a little difficult and may affect the accuracy or some delays in finding in the user location. Design of the GLOBALSTAR is such that user in every part of the world will be able to get three or four satellite in view but for a short span of time. The more satellite seen by the user makes the calculation of accuracy and losses easier and accurate.

The values obtained from the simulation I have performed may not give the exact result or values. This is because of the random values generated by various online tools. The thesis was performed taking values from the tracked satellites of GLOBALSTAR system. The method discussed and simulation performs can be used on the exact values obtained from the system to find the range and errors in the positioning.

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