The Positioning Accuracy and Performance Simulation Analysis of BeiDou-3 in Cote d’Ivoire

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Abstract: BeiDou Navigation Satellite System will operate world widely in 2020. Therefore, it is very important to master the accuracy and positioning performance of BeiDou-3 in West Africa. The number of visible satellite, the navigation accuracy and Geometric Dilution of Precision (GDOP) of BeiDou-3 (3GEO-3IGSO-24MEO) are simulated using STK software in Cote d’Ivoire. Using data of five stations in Cote d’Ivoire, the simulation results are compared for BeiDou-3 and GPS. Thus, the results are allowed to possess a database about the positioning performance of BeiDou-3 not only for Cote d’Ivoire but also benefit for surrounding Regions of the Gulf of Guinea.

1. Introduction
The three steps strategy of BeiDou Navigation Satellite System (BDS) development opted by China is almost accomplished. The experimental system (BeiDou-1, 2000-2003) has provided Radio Determination Satellite Service, two ways of positioning, timing and short message service in China[1-3]. In addition, the second step has established a regional service system (BeiDou-2, 2004-2012) with more satellites orbiting around the earth and provided more applications in Asia-Pacific region[4-6].

After the two compatible steps hereinafter, the interoperable BeiDou-3, which combines the qualities of BeiDou-1 and BeiDou-2 including short message service, will be revealed to the world in 2020 and join GPS (USA) and GLONASS (RUSSIA) in the exclusive club of the GNSS in full operation. A great number of researchers have done considerable works about the satellite visibility and GDOP (Geometric Dilution of Precision) of BeiDou-3 in China and other Asia Pacific region[7-9], but little work is done about the positioning performance analysis of BeiDou-3 in Cote d’Ivoire.

In order to show positioning performance of BeiDou-3 from five specific locations in Cote d’Ivoire, the STK10.0 software is used to simulate BeiDou-3 in term of the number of access of MEO satellites, navigation accuracy, and geometric dilution of precision. The results are compared with those of GPS in these locations.

2. BeiDou-3 constellation and simulation parameters

2.1. BeiDou-3 constellation
BeiDou-3 is composed of three (3) GEO (Geostationary orbit), three (3) IGSO (Inclined Geosynchronous Orbit, 55 degrees) and twenty-four (24) MEO (Medium Earth Orbit). 3-Dimension and 2-Dimension scenes of this hybrid constellation are shown by STK software in Figure1 and Figure2.
2.2. Simulation parameters

The Positioning performance is observed by using the number of access of BeiDou-3 MEO satellites. STK software provides data, graphs of the above types of parameters in real time. The maximum, minimum, average and standard deviation values are calculated.

The minimum elevation angle is 15 degrees (angle between the horizontal plane and the line of sight as show in Figure 3, measured in the vertical plane and referring to the horizontal plane). The simulation time is set from 04 o’clock 02 May 2019 to 04 o’clock 03 May 2019.

3. Observation stations analysis

Cote d’Ivoire is a country of western sub-Saharan Africa. Located in the northern hemisphere close to the equator, it borders Liberia and Guinea in the west, Mali and Burkina-Faso in the north, Ghana in the east, and the Gulf of Guinea (Atlantic Ocean) in the south. Because of its geographic position and the geometric shape of this coastal country, the choice of Abidjan in the south, Yamoussoukro in the center, Korhogo in the north, Man in the west and Abengourou in the east can replace the distribution characteristics of the entire country. The distribution of Cote d’Ivoire is displayed in Figure 4.

3.1. BeiDou-3 simulation results

|                | Number of Access | GDOP | Navigation Accuracy (m) |
|----------------|------------------|------|-------------------------|
| Abidjan        | 6.9              | 2.91 | 14.53                   |
| Yamoussoukro   | 6.7              | 3.27 | 16.36                   |
| Korhogo        | 9.6              | 1.73 | 8.84                    |
| Abengourou     | 9.7              | 1.69 | 8.46                    |
| Man            | 9.6              | 1.73 | 8.66                    |
The main conclusions about BeiDou-3 are as follows:

- In general, 9 MEO satellites are observed at the same time, but 6 MEO satellites are observed at the same time for Abidjan and Yamoussoukro, it means that BeiDou-3 can calculate the users’ position accurately in Abidjan and Yamoussoukro.
- GDOP is around 2.27, it can meet the requirements of trilateral measurement
- The navigation accuracy value is between 8.5 and 16.5 meters.

3.2. Constellation and simulation results of GPS

3.2.1. GPS constellation

GPS Constellation consists of twenty-four (24) satellites are uniformly distributed on six (6) medium orbital plane inclined by 55 degrees with respect to the equator:

![Image](5D.jpg)

Figure 5. 3D GPS constellation

![Image](2D.jpg)

Figure 6. 2D GPS constellation

3.2.2. Simulation results of GPS

| Number of Access | GDOP | Navigation Accuracy |
|------------------|------|---------------------|
| Abidjan          | 9.7  | 1.62                | 8.12                |
| Yamoussoukro     | 9.7  | 1.62                | 8.09                |
| Korhogo          | 9.6  | 1.62                | 8.1                 |
| Abengourou       | 6.6  | 3.07                | 15.33               |
| Man              | 9.5  | 1.62                | 8.24                |

Using the mean values of the three analysis parameters, the conclusions are as follows:

- Taking Abengourou as an example, where there are 6 satellites in views, 9 GPS satellites are in views in the others cities. GPS can calculate position accurately.
- Except for this Abengourou, GDOP is stable around 1.62, thus geometrics distribution of GPS satellites are excellent in most areas.
- The navigation accuracy is less than 8.5 meters in most areas.

4. Comparison of BeiDou-3 and GPS

According to the above results for BeiDou-3 and GPS, the number of access, GDOP and the navigation accuracy are compared in the five stations of Cote d’Ivoire.

4.1. Comparison of the number of access

The number of access or the visible satellite of BeiDou-3 and GPS can be seen in the following statistics Table 3.
Table 3. Number of access BDS-3 VS GPS

|                     | BeiDou-3 | GPS |
|---------------------|----------|-----|
| Abidjan             | 6.9      | 9.7 |
| Yamoussoukro        | 6.7      | 9.7 |
| Korhogo             | 9.6      | 9.6 |
| Abengourou          | 9.7      | 6.6 |
| Man                 | 9.6      | 9.5 |

Table 3 shows that the number of GPS and BeiDou-3 satellites are both good enough for trilateration in the five cities, but GPS users can capture more satellites than BeiDou-3 in Abidjan and Yamoussoukro, while BeiDou-3 captures more in Abengourou.

4.2. Comparison of GDOP

The statistics of geometric dilution of precision of BeiDou-3 and those of GPS are shown in table 4.

|                     | BeiDou-3 | GPS |
|---------------------|----------|-----|
| Abidjan             | 2.91     | 1.62|
| Yamoussoukro        | 3.27     | 1.62|
| Korhogo             | 1.73     | 1.62|
| Abengourou          | 1.69     | 3.07|
| Man                 | 1.73     | 1.62|

Mean value of geometric dilution of precision of BeiDou-3 is around 2.27 while that of GPS is stable at 1.62. Both are excellent, but the GPS’ GDOP is less than BeiDou-3’ GDOP, excepted in Abengourou where BeiDou-3’ GDOP is a little over half of GPS.

4.3. Comparison of navigation accuracy

At least, the navigation accuracy are obtained in the locations and the Simulation results are summarized in Table 5.

|                     | BeiDou-3(m) | GPS(m) |
|---------------------|-------------|--------|
| Abidjan             | 14.53       | 8.12   |
| Yamoussoukro        | 16.36       | 8.09   |
| Korhogo             | 8.84        | 8.1    |
| Abengourou          | 8.46        | 15.33  |
| Man                 | 8.66        | 8.24   |

The navigation accuracy value of BeiDou-3 is more than 8.5 meters in general, the minimum value is obtained in Abengourou where the accuracy of BeiDou-3 is higher than GPS (Table5). Otherwise, the navigation accuracy value of GPS is less than 8.5 meters in the four other cities.

5. Conclusion

(1) Using STK software to simulate BeiDou-3 constellation from 4 o’clock 02 may to 4 o’clock 03 may 2019 in five representative locations (Abidjan, Yamoussoukro, Korhogo, Abengourou and Man) situated in south, center, north, east and west respectively in Cote d’Ivoire, the results are conclusive for BeiDou-3. The BeiDou-3 is accurate with less than 16.5 meters position errors, and this value can decrease to 8.5 meters in the east part of Cote d’Ivoire.
(2) Navigation accuracy of GPS at the same moment shows better accuracy in the different parts of Cote d’Ivoire with less than 8.5 meters position errors, but this performance of GPS is less than that of BeiDou-3 in the east part of Cote d’Ivoire. 

(3) BeiDou-3 can provide continuous and reliable navigation services in Cote d’Ivoire, indirectly in the surrounding region of the Golf of Guinea. In general, GPS positioning is better in the most important cities in Abidjan and Yamoussoukro. The output positioning performance of BeiDou-3 in the east part of Cote d’Ivoire is better than GPS. Simply, using some BeiDou-3 specific receivers and products of enhancement should improve the performance of BeiDou-3 in Cote d’Ivoire.

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