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A new Model of Free Global Positioning System using Triple DME

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Abstract - - *This paper introduces a new scheme of global positioning system (GPS) without using of satellites or GPS-Free positioning. It is based on using triple distance measurement equipment (DME) which can be implemented with a map includes; determined longitude and latitude on the user`s receiver. First, advantages, previous studies and activities which are related to this subject is described as well as the DME properties are presented. Then, a practical model of triple DME and implementation of mathematical model on the map for finding the positions are discussed. Finally, the results of simulations are shown as well as the future of GPS-Free project and its prospective is stated.*

***Key Words*:** **altitude, DME, GPS, hand off, longitude**

1. INTRODUCTION

1.1 Scheme

The idea of GPS free positioning [1] cause to an independency from GPS systems. Also, integration of wireless networks [2-5] is a way to realize the lack of GPS. In this scheme, triple DME is used in order to model the coverage area, communications and then, user positioning which is either equipped with an altimeter or not. In [6] and [7] performance specification of DME is investigated. A DME/DME model introduced in [8, 9] and also, minimum performance standards in different ways are shown in [10] through [11]. The method in [12] assess the capability of DME for future use and [13] shows DME/DME for alternate position, navigation, and timing (APNT). In order to find the position of user with regard to DME transceiver and local geographical conditions, DMEs are installed by using mathematical model. For this reason, a latitude and longitude comprehensive geographical map is provided on the receiver of the user according to accomplished measurements which can show the exact position of the user in terms of latitude and longitude. After height and distance measurement by DMEs, they can find and identify the position of the user, then, inform the receiver of the user. This model causes that find the position of the user become independent from satellite, then, whole tracking can be more secure. Also, it makes installation and maintenance of the equipment easier as well as the cost which is the main challenge is decreased.

1.2 DME

DME is used to measure slant range distance in which the users can estimate their distance by the pair pulses. These pulses are send and receive between the user and land based transponder. The distance is measured by multiplication of time (half of the total time minus 50 μs) and the rate (velocity of the pulses). DME interrogator set its frequency to VOR frequency. The user uses 1025 to 1150 MHz. and 1025 to 1150 MHz respectively for transmitting and receiving on a band (962 to 1213 MHz) which is divided into 126 channel with 1MHz [14, 15]
space.

2. Triple DME model

In practical design, the regional and geographical conditions must be exactly identified. Antenna of DMEs must be installed with a certain distance according to geographical conditions, therefore, the operation process of design must be adapted to the aforementioned conditions, then, the distance and height of the user is measured and a software in the transmitter calculates the mathematical calculations and the position of the users is specified and finally is shown in the comprehensive map. Final information is sent to the receiver screen and user can exactly find its own position. A specified code is allocated to each DME in order to inform the user from its real time position and related communicating DME. DMEs communicate with each other in a cellular topology and user must be covered by three DMEs permanently and continuously, therefore, it receives the transmitting powers and continue the operation. It is possible to use finite element method [16, 17] for electromagnetic propagation.

There are two cases in this sketch: user is equipped with an altimeter or not. In the first case, user can measure its own height. In the second one, the height should be identified with mathematical calculation. When a user receives signals from more than three DMEs, selects the three of them with the highest power level. If the level of DME power becomes lower than the predefined threshold in the border of the cell or outside of it while the user is roaming within the cell, a hand off occurs among DMEs. This hand off can be happened not only in the border of cell or outside, but also, in the central area of a cell with any reason which causes power loss when it is covered with more than three DMEs. In this sketch, the amount of threshold is RSS_{th}= 1000W (peak power). Also, process of the handoff is shown in Fig. 1.

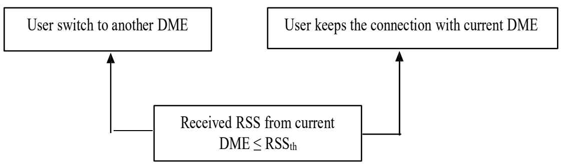


Fig -1: Hand off procedure

In Fig.2, practical model of triple DME with the coverage process in which the user is roaming within a common coverage area is shown. The distances between DMEs should be set in order to cover the entire area. There is no problem in draught lands, but, in wet lands, DMEs should be installed on platforms, towers, ships and other such places. In draught lands, the geographical conditions should be considered, also, suitable distance among DMEs should be measured. In this design, the distance between DMEs is not fixed, but, is less than 500 km (the radius of DME coverage is 200 nm or almost 250 km).

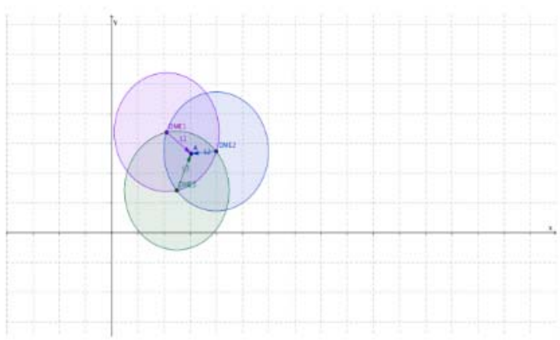


Fig -2: Coverage area of triple DME

3. Mathematical model

In order to simulate the mathematical model, the earth is divided into 90 to -90 degree latitude ($-90 \le \Delta_{lat} \le 90$) and 180 to -180 degree longitude ($-180 \le \Delta_{long} \le 180$) as the coordination axes and the interception of the equator and meridian is considered as coordination origin. The map of longitude and latitude of the earth is shown in Fig. 3.

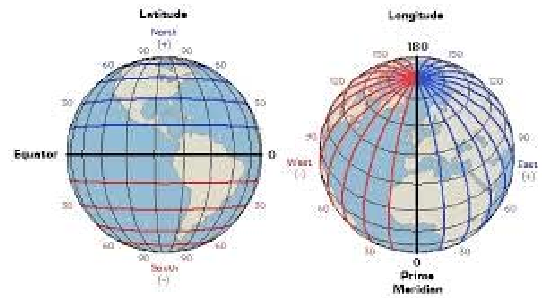


Fig -3: The map of longitude and latitude of earth

According to WGS84 standard, the time division in longitude and latitude is 60 minutes per degree. In this scheme, the following triangular mathematical model is used for finding user position as (1) through (3):

$$(x_4 - x_1)^2 + (y_4 - y_1)^2 + (z_4 + z_1)^2 = L12 \quad (1)$$
$$(x_4 - x_2)^2 + (y_4 - y_2)^2 + (z_4 + z_2)^2 = L_2^2 \quad (2)$$
$$(x_4 - x_3)^2 + (y_4 - y_3)^2 + (z_4 + z_3)^2 = L_3^2 \quad (3)$$

Where the (x_1, y_1, z_1), (x_2, y_2, z_2) and (x_3, y_3, z_3) are related to DME1, DME2 and DME3 coordination, respectively. (x_4, y_4, z_4) is user coordination. L_1, L_2 and L_3 are distances of the user from DME1, DME2 and DME3, respectively. x, y, z and L are respectively latitude, longitude and altitude from the sea surface and slant range. All the parameters are in kilometer unit. Also, the three slant ranges of user from DMEs are shown in Fig. 4.

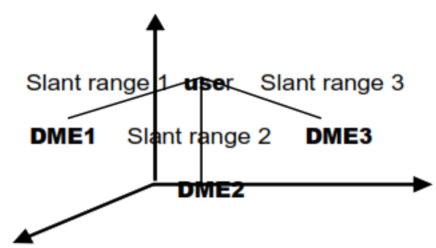


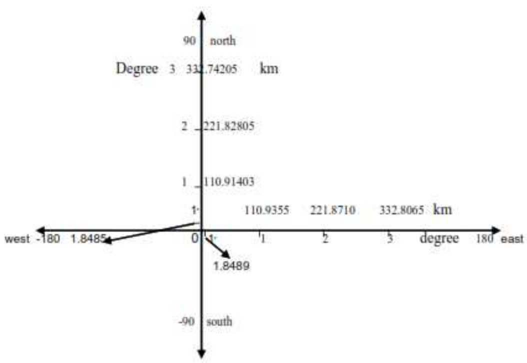
Fig -4: Slant ranges

DME1, DME2 and DME3 are fixed points and it causes to have fixed coordination. Also, L_1, L_2 and L_3 are measured by DMEs according to user movement and the variables are the coordination of the user (x_4, y_4, z_4) which can be gained from (1). z_4 is the altitude from the sea surface and the two important parameters x_4 and y_4 should be converted to a degree in order to specify the longitude and latitude of the user. The conversion of latitude and longitude which is defined in a kilometer unit is required in this phase. Latitude and longitude distances (km/degree) is defined as (4) and (5).

$$\Delta_{lat} = \frac{\pi a\left(1-e^2\right)}{180\left(1-e^2\sin^2\varphi\right)^{\frac{1}{2}}} \qquad (4)$$

$$\Delta_{long} = \frac{\pi a\cos\varphi}{180\left(1-e^2\sin\varphi\right)^{\frac{1}{2}}} \qquad (5)$$

where a and b are earth diameters which are respectively 6356.137km and 6356.7523142 km, e is eccentricity and is equal to $e^2 = \frac{a^2-b^2}{a^2}$, φ is latitude in degree. According to (4) and (5), the longitude is fixed and is 111.320 km per degree ($\varphi = 0$ on equator axis), but, latitude is variable and is measured for each degree (variable φ on meridian axis). The obtained accuracy level for longitude and latitude respectively are $\frac{110.9355}{60} = 1.8489$ (km) and $\frac{\Delta\varphi \text{ in Kilometer}}{60}$ km per 1 minute. Fig. 5. Shows the measured longitude and latitude on the coordination plan.



The amount of x_1, x_2, x_3, y_1, y_2, y_3 (in degree) can be converted to km and inserted in (1) through (3), then x4 and y4 are obtained in kilometer unit, then, they are converted to a degree from the process which were discussed in the current section and, finally, the user can identify its own position.

4. Mathematical model

The coordination of DMEs are as following:
DME1: 15° east and 10° north and 1.2000 km height
DME2: 16° east and 10° north and 2.5000 km height
DME3: 16° east and 11° north and 3.2000 km height

According to Fig. 5. and (1) through (3), respectively, the fixed points coordination of DME1, DME2 and DME3 are defined as: (x_1=1664.0325 km, y_1=1109.1376km, z_1=1.2000 km), (x_2=1774.9680 km, y_2=1109.1376 km, z_2=2.5000 km) and (x_3=1774.9680 km, y_3=1220.0506 km, z_3=3.2000 km). As mentioned before, L_1, L_2 and L_3 are measured by DMEs in kilometer according to user movement. Therefore, by using these coordination in (1) through (3), the results for 10 situations of the user are shown in Table 1.

5. Conclusion

As discussed in this paper, we used the advantages of this scheme to simulate a GPS network independent of satellite so called GPS-Free positioning to find the position of any object or user. In the simulation, distances finding by DMEs, then, the positioning of the user with the aim of mathematical model was investigated. This scheme can be extended in the future, also, there are some methods to modify or upgrade it such as guidance of the user to the predefined point, navigate the users which are roaming on the ground, DME error minimization, mobile DMEs which can be modeled especially on the ships, different cases of hand off among cells, improve the performance of power consuming in the transponder of user [18, 19], Health effects of radiation[20], classification and statistical test of errors, cyber attacks [21-23] and the error modification which obtain from previous schemes and is edited according to this scheme.

Table -1: The coordination of x_4, y_4 and z_4

L_1 (km)	L_2 (km)	L_3 (km)	X_4 (km)	X_4 (degree)	Y_4 (km)	Y_4 (degree)	Z_4 (km)
15.5915	100.4577	141.1836	1675.1260	15.06′ east	1120.2289	10.06′ north	3.0480
31.2227	91.4803	125.4966	1686.2196	15.12′ east	1131.3202	10.12′ north	3.0480
46.8911	84.4851	109.8096	1697.3131	15.18′ east	1142.4114	10.18′ north	3.0480
62.5689	79.9936	94.1225	1708.4067	15.24′ east	1153.5027	10.24′ north	3.0480
78.2505	78.4372	78.4355	1719.5002	15.30′ east	1164.5941	10.30′ north	3.0480
93.9339	79.9874	62.7484	1730.5938	15.36′ east	1175.6854	10.36′ north	3.0480
109.6183	84.4733	47.0615	1741.6873	15.42′ east	1186.7767	10.42′ north	3.0480
125.3033	91.4639	31.3746	1752.7808	15.48′ east	1197.8679	10.48′ north	3.0480
140.9888	100.4376	15.6879	1763.8744	15.54′ east	1208.9592	10.54′ north	3.0480
156.6748	110.9144	0.1520	1774.9680	16.00′ east	1220.0506	11.00′ north	3.0480

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