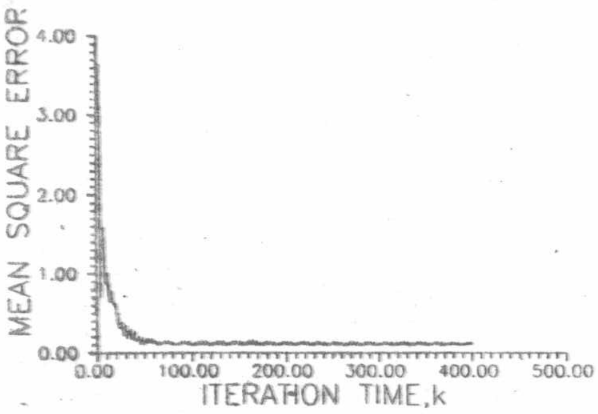

Figure 2 The learning curve of the zero-pole filter (μ = 0.02)

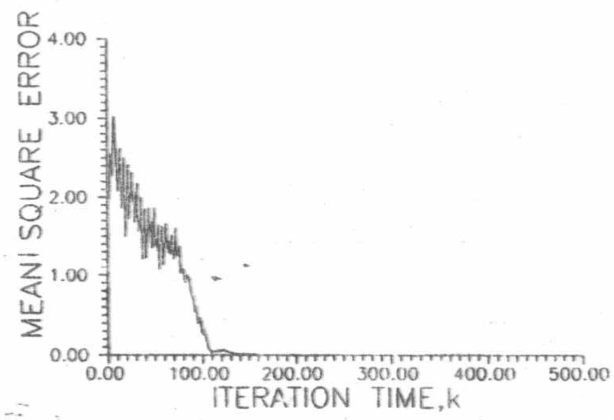

Figure 3 The learning curve of the all pole filter (μ = 0.02)

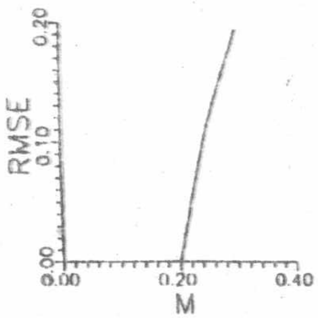

Figure 4 The RMSE of the zero-pole filter versus misadjustment, M

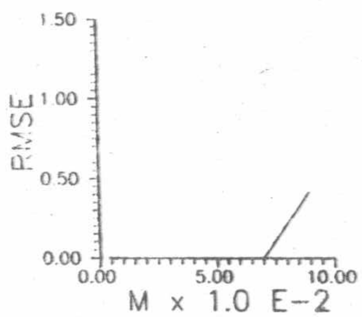

Figure 5 The RMSE of all pole filter versus misadjustment, M

MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

1-

2- **IMPLEMENTING THE NAVSTAR/GPS IN EGYPT**

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4- ABSTRACT

The Global Positioning System (NAVSTAR/GPS) should reach full 3 D capability in about 1992. Due to budget constraints, funds were cut back from a level which would provide a 24 satellite constellation to the present level which will maintain only 18 satellites plus three fully functioning on-orbit spares. As a consequence, there will be continuously some areas of temporarily reduced accuracy, requiring those who are using such data to periodically adjust their operations as consequence. One way of doing that is to calculate the changes in system measurements accuracy factors, mainly the geometric dilution of precision (GDOP) which is a measure of how satellite geometry degrades accuracy. This is very important for users relying only on four satellites GPS navigation such as our case. The used algorithm gives the user at Cairo city the changes of the GDOP with that of the satellites' geometry and consequently with time.

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1. INTRODUCTION

The original base line constellation for the Navstar/Global Positioning system consisted of 24 satellites. This would provide continuous world-wide three-dimensional navigation, and it would insure an accurate navigation solution 100 percent of the time at any location on the earth [1]. As a cost-saving measure, the constellation will have only 18 satellites plus three on-orbit spares. This results in a constellation which will cause Navstar users to experience occasional outages of the system. To minimize these outages, this means a constellation for which :

1) There are almost always at least four satellites in view,
2) These visible satellites possess good geometry from the point of view of precise navigation.

This leads to the concept of geometric dilution of precision (GDOP), a measure of how satellite geometry degrades accuracy. Some properties of this quantity are :

1) GDOP, in effect, the amplification factor of pseudo-range measurement errors into user errors due to the effect of satellite geometry.
2) GDOP is independent of the co-ordinate system employed.

Users must recognize this built-in shortcomings of the system and how to acquire the information necessary for adjusting these shortcomings. This is extremely important for users relying only on four satellite GPS navigation as in our case.

2. NAVSTAR/GPS CONSTELLATION

Studies have been performed of various alternative 18-satellite constellations with the goal being to minimize the impact of outages on the Navstar user. Until recently, it has been generally accepted that with 6 satellites in each of the 3 orbit planes, the best arrangement would be to have the satellites spaced uniformly 60 degrees apart. Studies by the Aerospace Corporation, El Segundo, California, [2] have shown that this is not true. A three-plane non-uniform arrangement has been found to provide far superior performance from the point of view of minimizing outages. Still another approach is to have 18 separate orbit planes one for each satellite. Also analysis were undertaken [3] to determine if placing the three active spares in an equatorial orbit at the same altitude as the other satellites would improve the situation. It was clear that for any given time the degraded area is smaller and that for any given location the duration of the degradation is less than previously calculated.

The primary objective of the GPS user set is to acquire and recover GPS satellite data, make pseudorange and deltarange measurements, and process these measurements in real time to provide the best estimate of the user position, velocity, and system time. Measurements from four satellites, after compensation for ionosphere, troposphere, antenna lever arm, satellite clock error, and user clock phase and frequency errors, provide the GPS set with sufficient information to solve for three components of user position, velocity, and clock error [4]. In this paper it will be described a navigation algorithm for solving the GPS navigation equations, estimate both the user position error, and user geometric dilution of precision (GDOP).

3. NAVIGATION ALGORITHMS

The objective of the user receiver is to take pseudorange measurements so that the receiver can perform continuous navigation fixes. In this section, it will be described in detail the navigation algorithms used. The performance criteria of the navigation algorithms are good accuracies, fast computation time, and easy implementation.

Let the coordinate system be the Earth-centered-Earth-Fixed (ECEF) coordinate. The user position will be denoted (X, Y, Z) and the i^{th} satellite position is denoted by (U_i, V_i, V_i) as shown in fig. (1). Let R_i be the pseudorange measurements from the i^{th} satellite to the user and T be the user's clock bias with respect to the GPS system time. Since the satellite positions can be precomputed from the ephemeris data, the user position and clock bias can be derived from the following non-linear non-homogeneous equations [5] :

$$
\begin{aligned}
R_1 &= \left((U_1-X)^2 + (V_1-Y)^2 + (W_1-Z)^2 \right)^{1/2} + T \\
R_2 &= \left((U_2-X)^2 + (V_2-Y)^2 + (W_2-Z)^2 \right)^{1/2} + T \\
R_3 &= \left((U_3-X)^2 + (V_3-Y)^2 + (W_3-Z)^2 \right)^{1/2} + T \\
R_4 &= \left((U_4-X)^2 + (V_4-Y)^2 + (W_4-Z)^2 \right)^{1/2} + T
\end{aligned}
\qquad (1)
$$

It is often desirable to transform the ECEF coordinate system into longitude-latitude-altitude coordinate system. The transformation may be accomplished by the following equations :

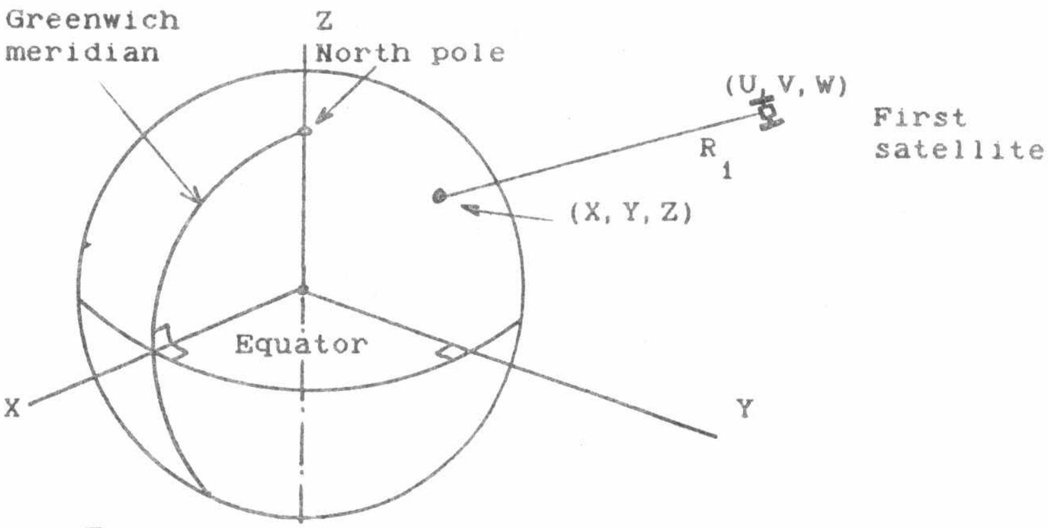

Fig. (1) ECEF coordinate system

$$f = \frac{1}{298.26} \quad (2)$$

$$e^2 = 1 - (1-f)^2 \quad (3)$$

$$a = 6378135 \text{ meter} \quad (4)$$

$$R_N = \frac{a}{(1-e^2\sin^2(lt))^{1/2}} \quad (5)$$

$$X = (R_N + h).\cos(lt).\cos(lg) \quad (6)$$

$$Y = (R_N + h).\cos(lt).\sin(lg) \quad (7)$$

$$Z = (R_N(1-e^2) + h).\sin(lt) \quad (8)$$

where

f	the flattening of the WGS-72 ellipsoid, (see fig. 2)
e	eccentricity of the WGS-72 ellipsoid,
a	semi-major axis of the WGS-72 ellipsoid,
R_N	radius of curvature in the prime vertical,
lt	latitude,
lg	longitude,
h	altitude.

Let us rewrite equation (1) as

III. SELECTION OF CONVENIENT SET OF POSITION LINES

Having obtained three different families of position-lines (hyperbolas , circles and ellipses) by simple manipulation, one becomes in a situation of either using any of these different families or combining them to obtain higher accuracy from the system .

Examining Fig. 7 , we see that :

1. Circular lines-of-position offer superior coverage of operational zones and can be used in stand-alone configuration. In this aspect , it is noteworthy that the modified system offers the one-way distance measurement without need of either very-high stable oscilators at receiving points or reference-time-keeping as in the GPS (satellites , OMEGA and modified LORAN-C).

2. Elliptical or combined ellipto-hyperbolic lines-of-position offers superior coverage compared to solely hyperbolic-type set at given zones mainly in the area of [ρ>= 1 and $\vartheta \le (-30, +30)^{\circ}$].

IV. CONCLUSIONS

The present work evaluates proposed solution issues to some long lasting problems inherent in the hyperbolic navigation systems (DECCA , LORAN-C and low-cost OMEGA). Through the proposed modifications, better position fixing utilizing such conventional systems becomes feasible. Several schemes of utilizing newly generated lines are possible . This ranges from their own use as stand-alone set to their combination with the conventionally generated hyperbolic ones . Hence a new survivability issue to DECCA , LORAN-C and low-cost OMEGA systems in plane position fixing in front of newly introduced GPS systems. Implantations as an "Add-on" product to currently existing systems along with necessary software for selecting best combination of lines of positions is the subject of a forthcoming paper.

Appendix

To determine service areas in the various investigated cases, we need to unify the used coordinate system . For this purpose , we describe the geometry of position lines and relevant position errors in terms of ρ and ϑ with the master station situated at the origin and 120-degree lines or normalized length unity as shown in Fig. 2. From this figure :

$$\cos(\phi_j) = (\rho - \cos \vartheta_j) / \sqrt{1 + \rho^2 - 2 \rho \cos \vartheta_j}$$

with $j = 1 , 2$ and $\vartheta_1 = 60 - \vartheta$; $\vartheta_2 = 60 + \vartheta$

From this relation , values of K_j are calculated as :

$K_{jh} = 0.5 / \sin(\phi_j/2) = 0.5 / \sqrt{[1-\cos(\phi_j)]/2}$ for hyperbolic lines
$K_{je} = 0.5 / \cos(\phi_j/2) = 0.5 / \sqrt{[1+\cos(\phi_j)]/2}$: elliptic lines.

Equations describing position error variances are evaluated using these relations.

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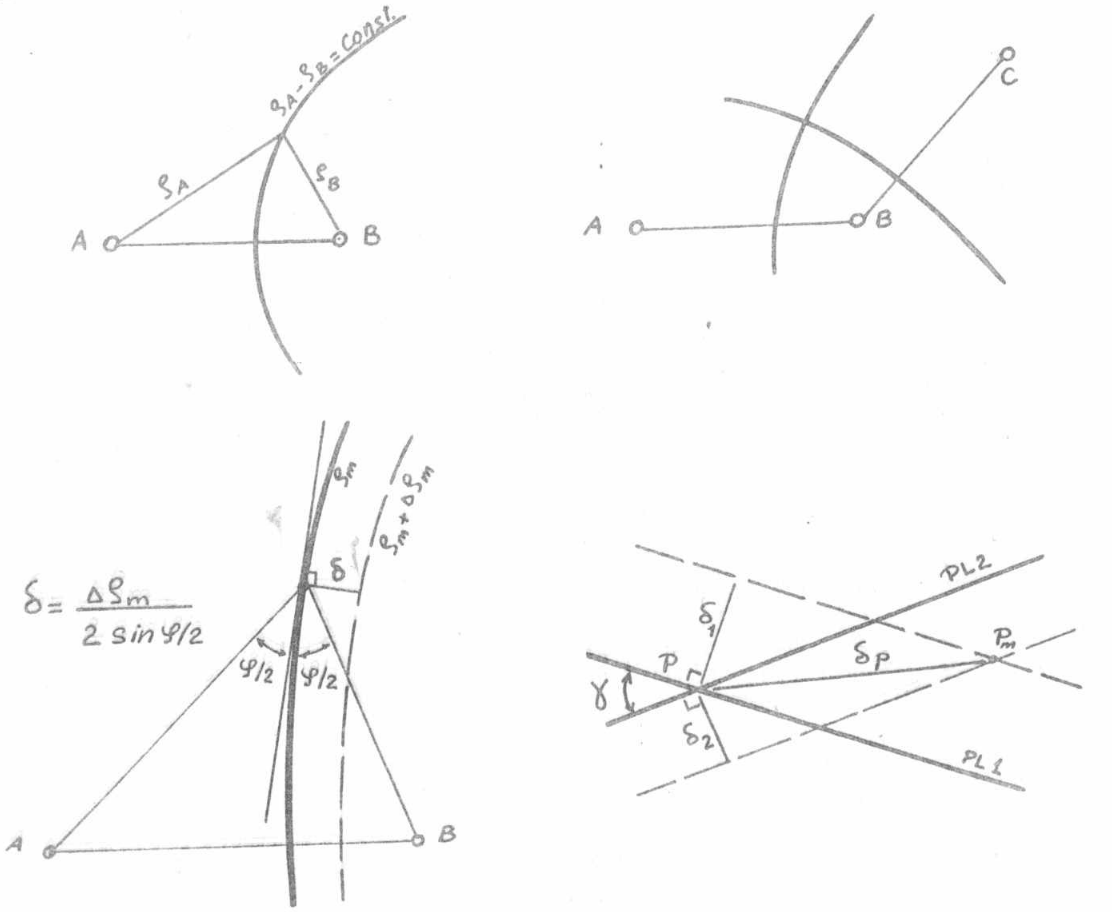

Fig.1. Definition of Hyperbolic System Position Errors

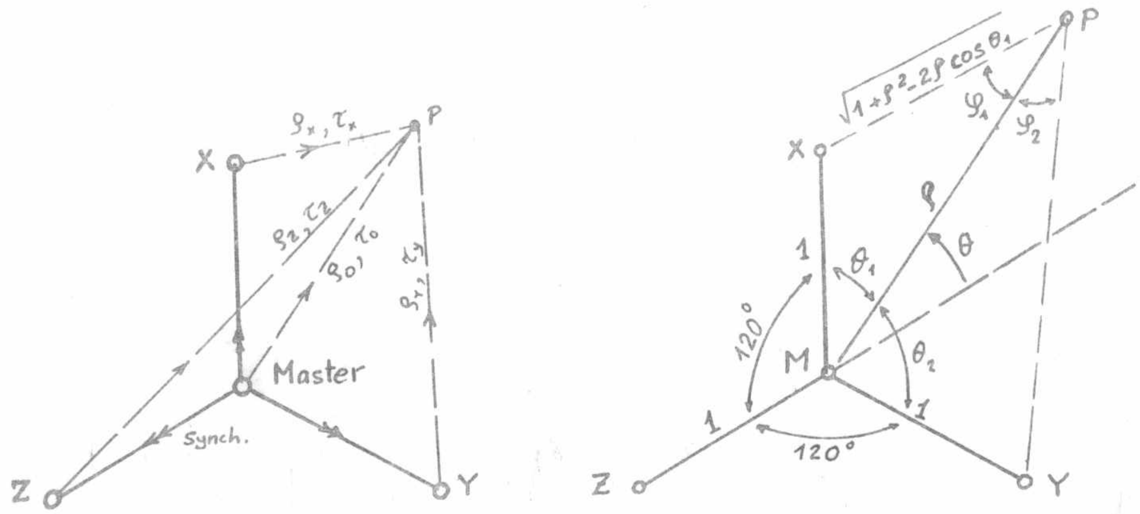

Fig.2. Principal Configuration and Coordinates of Hyperbolic System

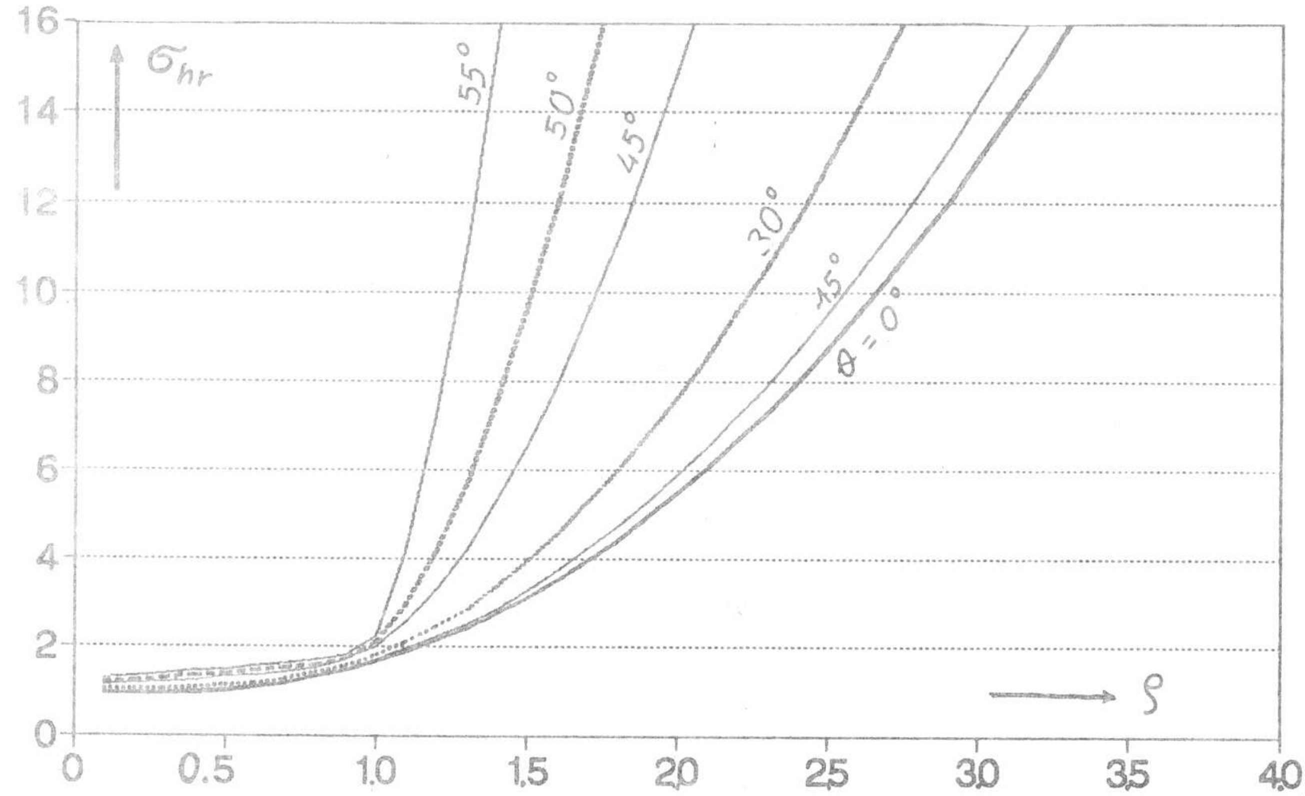

Fig. 3. Normalized (σ_{hr}) of Position Error for Hyperbolic LOPs

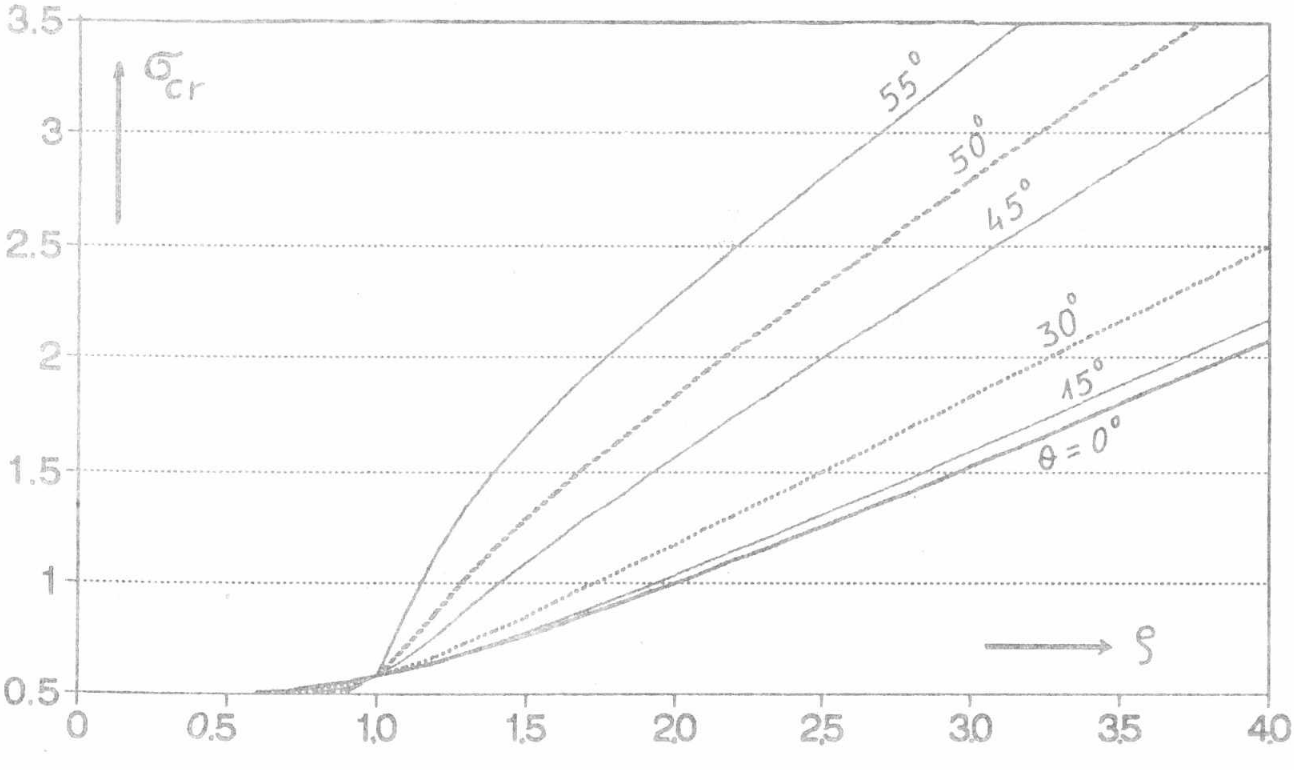

Fig. 4. Normalized (σ_{cr}) of Position Error for Circular LOPs

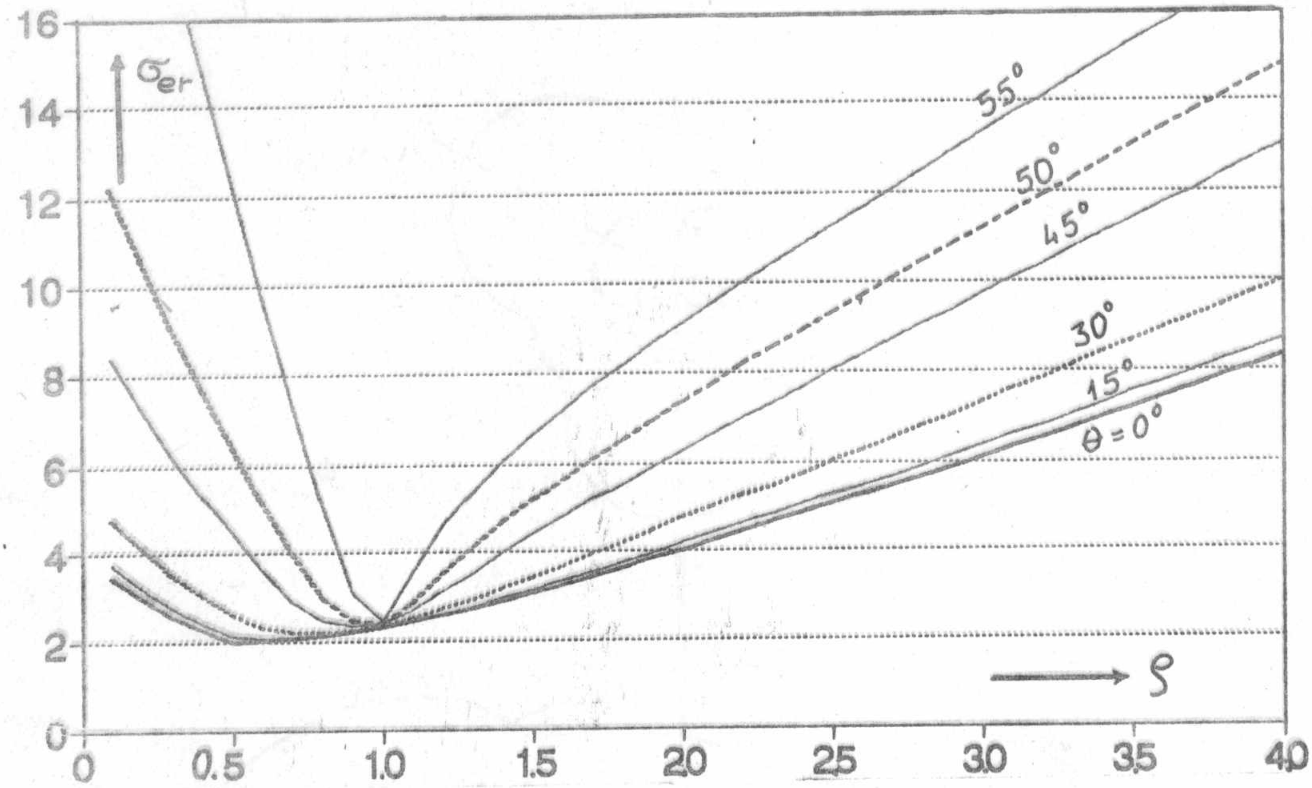

Fig. 5. Normalized (σ_{er}) of Position Error for Elliptical LOPs

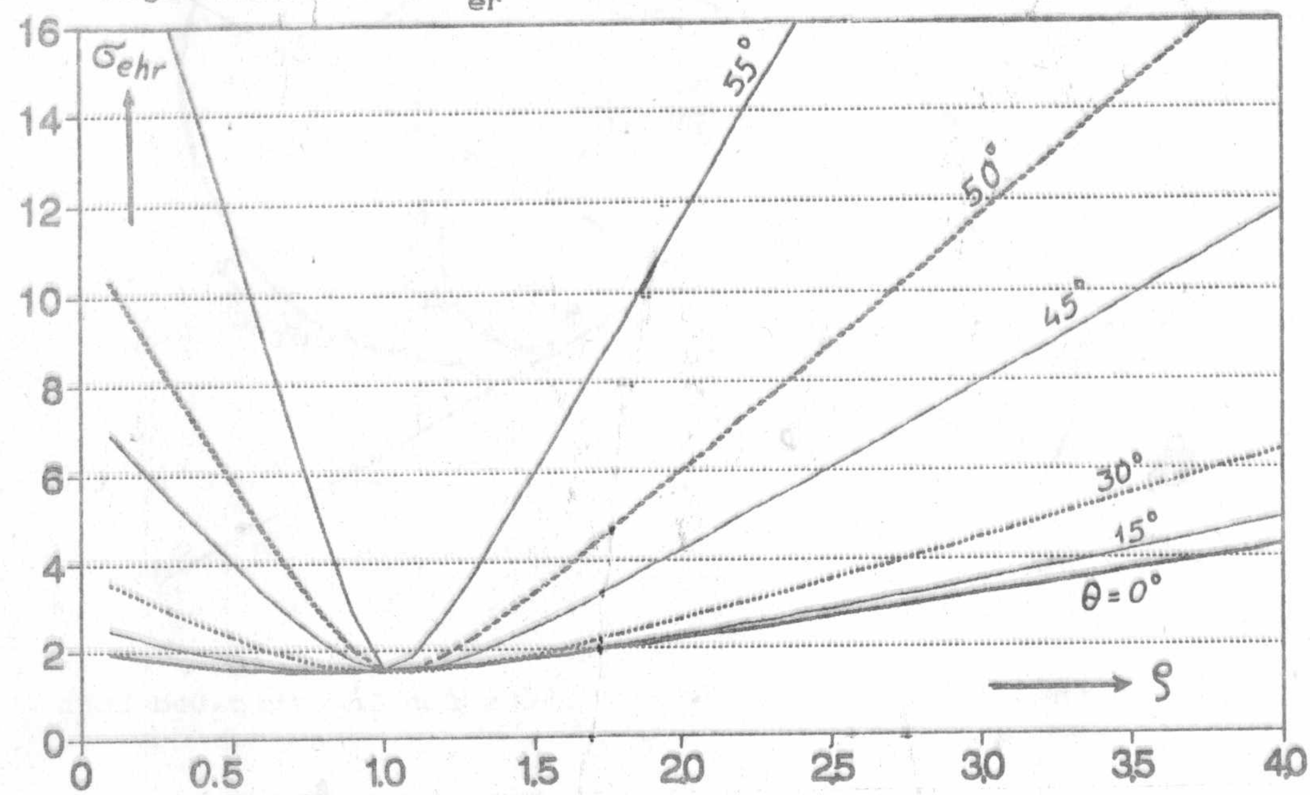

Fig. 6. Normalized (σ_{ehr}) of Position Error for Combined Ellipto-Hyperbolic LOPs

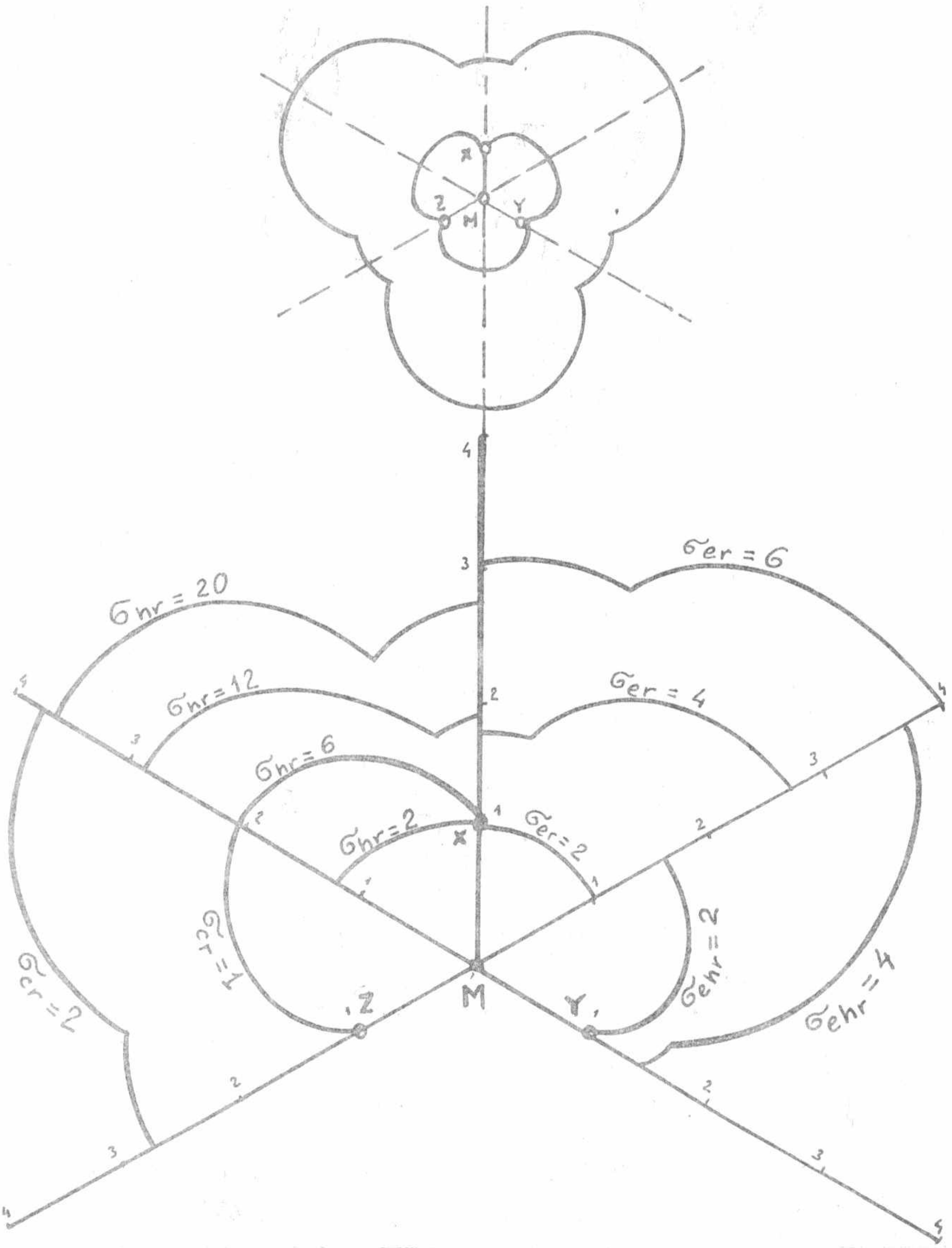

Fig.7.Obtained 60 °-Sectored Service Areas for Investigated LOPs