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Positioning and navigation with the geostationary satellite system

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POSITIONING AND NAVIGATION WITH THE GEOSTATIONARY SATELLITE SYSTEM

by

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The contents of this paper reflect my personal views and are not necessarily endorsed by the UNIVERSITY.

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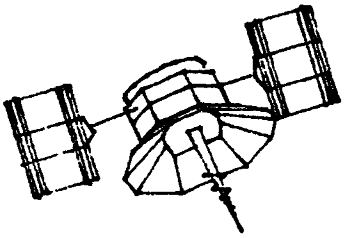
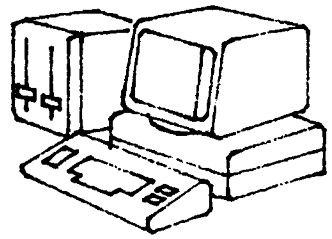
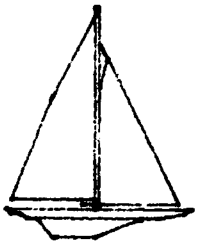
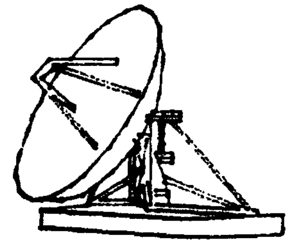




SATELLITE NAVIGATION





TO

MY WIFE, CECILE CLARISSE SAGNA

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ABSTRACT

This thesis makes some proposals for the idea of the possibility of a satellite of navigation system based on the geostationary orbit and the possibily of its integration with satellite communication system for civilian use.

At present time only the satellite communication systems based on the geostationary orbit and the advantages and desadvantages of this orbital system in the integration process are examined also. This integration process encounters many difficulties and problems relating to non -compatibility of systems, cost, military uses, political reasons and others.

When all the advantages and desadvantages of the above approach are taken to consideration, it is being suggested that only a satellite navigation system based on the geostationary orbit can provide the solution to the problems.

In outline, the thesis reviews the satellite communication system,gives a general examination and study of geostationary orbit and satellites and range measurements. Under the idea of integration, the actual problem, the requirements and proposals are discussed.

A study on the accury and limitations of a geostationary satellite navigation system have been undertaken and solutions have been suggested.

In more specific terms it has been recommended that:

1) A constellation of six (6) satellites for vavigation based on the geostationary orbit should be adequate for worldwide coverage limited to latitude upto 70 degrees North and 70 degrees South.

2) Three (3) Northern and three (3) Southern Molnya- type satellites should be necessary to complete the worldwide coverage above 70 degrees North and 70 degrees South and area not covered by the constellation of six (6) geostationary satellites navigation as above mentioned.

3) Accuracy position fixing with two (2) satellites may approach less than 100 metres.

4) The integrated system discussed in this thesis should be under the control and operation of INMARSAT.

PREFACE

The development and use of satellites as means of communication and navigation have been increasing over the past thirty years since the launch of the First Space Vehicle in 1957 by the USSR. Since that time many other countries have become involved in the space programme giving rise to many satellite systems on a worldwide basis. Among those involved are :

1) The USA with GPS - NAVSTAR and GEOSTAR;

2) The USSR with GLONASS;

3) FRG with GRANAS ;

4) The European space agency with Italy , U.K, FRANCE, etc... with NAVSAT.

Through the use of these satellite systems for both navigation and communications many problems associated with accuracy which have existed for centuries in these areas are being resolved and accuracy continues to be better as satellite technology becomes sophisticated. However , one problem which still exist is that of integration of satellite communication with satellite navigation. Despite efforts by the International Maritime Organisation (IMO) and many other countries to bring solution , the problem remains unresolved today.

In 1983, the IMO instructed its sub _ committee on Safety of Navigation to study "the development of a worldwide satellite positioning system for safety of navigation in all areas and for providing accurate position information for the Future Global Maritime Distress and Safety System (FGMDSS)".

Many years ago the link between communication and navigation and the advantages in stablishing a satellite system were recognized. Many countries , regions and

International Organisation have also acknowledged that a single wordwide system of navigation and communications is very actractive since it would ensure compatibility along with low cost.

Today , many proposals have been put forward in the area. But chief among them is the replacement of Omega, Loran c, and Transit by the American Global Positioning System (GPS), also known as NAVSTAR on one side and the USSR Glonas systetm on the other. Both systems possess very high accuracy and are practically similar. However, the problem of one over the other for wordwide application is very complex for many reasons:

i) both systems are in priority for military use,

ii) they are very expensive to put into place and maintain,

iii) the question of user fee. Will civil use be free of charge?

iv) the question of whether the international community would be prepared to accept a system - GPS or Glonas - which is under the control of a single country and its military.

In addition to the issue of GPS and Glonas being accepted as a wordwide system, a third system known as Geostar will enter into the competition. This system (Geostar) is based on the geostationary orbit. However, it has been fund that the Geostar concept is not optimally efficient as a radiodetermination system since it would require about 115 MHZ of bandwidth while a fully global radiodetermination service is anticipated to be provided by GPS would use a 2 MHZ of bandwidth . This GPS is like a broadcast system in that it can accomodate an infinite number of users unlike the proposed Geostar system of both receive and transmit, and hence is frequency - limited.

In the light of these numerous problems outlined above and encountrered by the international community in its attempts to establish a worldwide satellite and communication system, the paper examines the proposal of a geostationary satellite system for navigation and positions while at the same time fulfilling a major part of the requirement for satellite communication.

It is also the theory or assumption that having geostationary system for navigation and positioning would make integration with a communication satellite system more feasible.

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CHAPTER 1

GEOSTATIONARY ORBIT AND SATELLITES.

1 1. INTRODUCTION.

The discussion of the technical aspects of satellites communications and navigation should start with the satellite orbit. More than the essential properties of our orbit (the geostationary orbit) to be considered but also the criteria of selecting the orbit, the satellite positioning ; the maintenance of a stable orbit ; and the advantages and disadvantages of the geostationary orbit. Choosing our orbit we should be able to calculate also the satellite performance and its continuity of service. In this part we will discuss the following topics:

- orbital dynamics;
- orbital characteristics;
- behavior of the satellite in the orbit.
- etc...

1.2. ORBITAL DYNAMICS.

The behavior of a space satellite is described by the laws of celestial mechanics. The movement of the space satellite having been considered as a Kepler_ movements so the Kepler's laws have been applied to Earth's satellite. All satellites are attracted by the Earth with a force known as Earth attraction according Newton's law of Universal Gravitation which is expressed in the following terms: " The force of attraction between two bodies is directly proportional to the square of the distance between them".

$$Fa = G. M.ms/r2$$

Fa - Attractive force

G - Gravitation constant (9.81 m/s)

M - Earth's mass

ms - Satellite's mass.

Kepler's laws applied to the Earth satellite could be expressed as follows:

First law : The planes of an elliptical orbit are passing through the center of the Earth and one of the foci of the ellips lies at the Earth's center.

Second law: it defines the speed of a satellite around an elliptical orbit and is as follows: The radius vector of a satellite will sweep_out equal areas in equal times. It can be expressed in other way by:

$$ms.r.v = constant.$$

Third law: It states that the square period is proportional to the cube of the major_axis of the satellite's orbit.

For a circular orbit the period equals to :

$$T = 2\pi.r/vs \; [s]$$

r _ distance center Earth to the satellite

vs _ satellite velocity

$$vs = 2\pi.r/T \qquad (1.1)$$

But we know that the satellite velocity in the orbit is given as follows:

$$vs = \left[GM/r \right]^{1/2} \qquad (1.2)$$

By comparing formulas (1.1) and (1.2) we get

$$2\pi.r/T = \left[GM/r \right]^{1/2}$$

$$T^{2} = 4\pi.r^{3}/GM$$

$$T = 2\pi r^{3/2} / GM^{1/2} \qquad (1.3)$$

The equations (1.1); (1.2) and (1.3) give the 3 forms of the Kepler's third law.

1.3. Orbital characteristics.

1.3.1 Orbital shape

From a mathematical analysis it is shown that an artificial satellite projected into a gravitational fields in general describe a family of curves known as conic sections.

Amount these curves we have ellipse, circle, parabola and hyperbola. In satellite communications the orbits used are either elliptical or circular.

An ellipse is defined by two foci and an eccentricity. The apogee is the point in the orbit where the satellite is farthest from the Earth and where its speed is lowest. The piregee is the point of the orbit where the satellite is nearest from the Earth and where it is travelling with a maximum speed.

The eccentricity is expressed by this formulae:

$$e = ((a^2 - b^2)^{1/2} / a)$$

a - major semiaxis

b - minor semiaxis

From the formula we can see that:

- $e = 0$ results in a circle
- $0 < e < 1$ results in an ellipse
- $e = 1$ results in a parabola
- $1 < e$ results in an hyperbola

1.3.2 Types of orbit.

In general there are three types of orbit:
Low orbit satellite:
height: 100-100 miles
rotation period 1 1/2 hours, approximatly.
Medium altitude satellite
height: 6000-12000 miles.
rotation period 5-12 hours.

Geostationary orbit
height: 22282 miles
rotation period 24 hours
This orbit is above the Earth's equator.

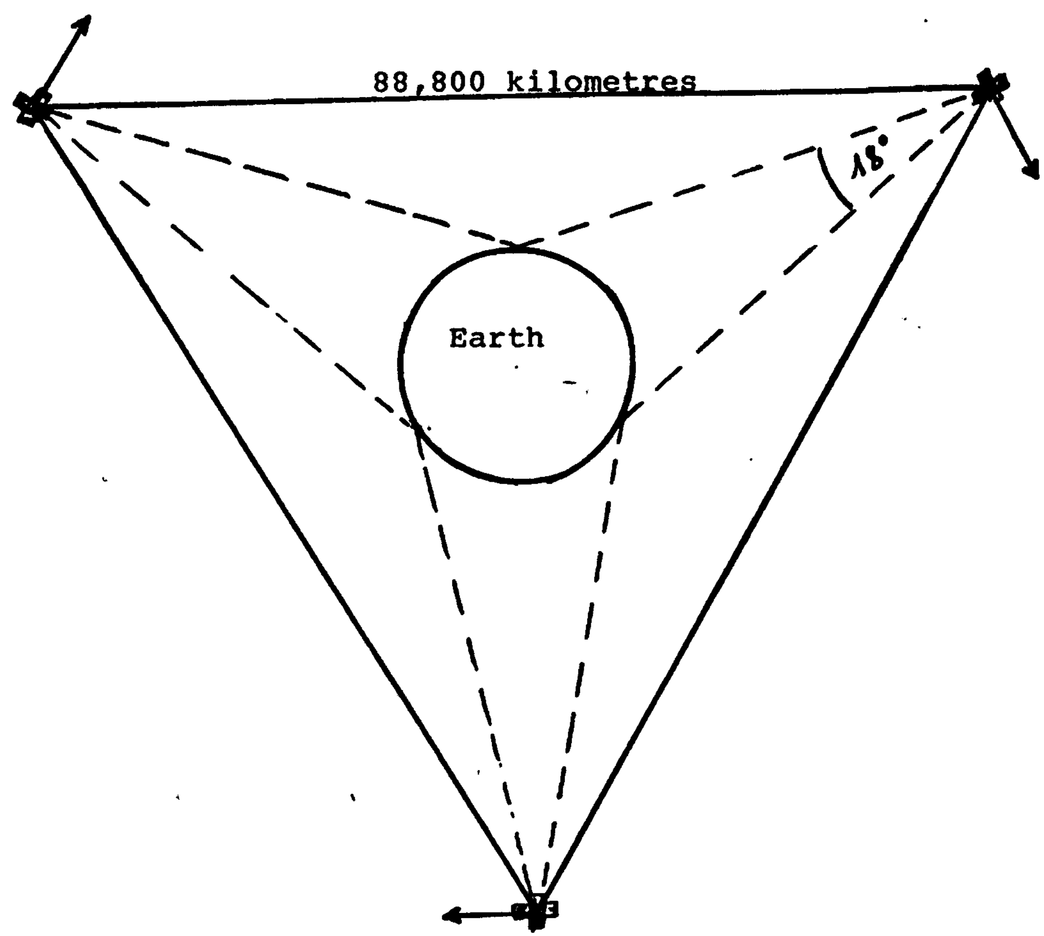
1.4 Geostationary orbit and satellite.

The geoatationary orbit is the favorit orbit for the communication. The term of "geostationary orbit" is sometimes employed in place of "geosynchronous orbit" but in practice the usage is not strictly correct.

A geosynchronous orbit can be elliptical or circular and inclined at various angles to the plane of the equator. The geostationary orbit is unique: it is circular and lies in the equatorial plane. Angle of inclination equals zero. The satellite in the geostationary orbit has the same direction as the Earth.

From the fig (1.1) it is shown that three geostationary satellites placed at the vertics of an equilateral triangle having a side equal to 88.800 kilometres can cover all the Earth except the regions closed to the poles.1(*)

1(*) INTRODUCING SATELLITE COMMUNICATION (page 71)



(Fig: 1.1) GEOSTATIONARY ORBIT

The portion of the Earth to be covered depends upon the height of the satellite, the larger is the portion of the Earth which is covered. The portion of the Earth covered by a satellite influences also on the permissible distance between Earth stations to garantee simultaneous line of sight, therefore the intercommunication capability. It appears that the geostationary orbit is the optimum in this respect. The geostationary satellite has an angle of view is about 17.3 degrees and it covers about 42.3% of the Earth's surface. The maximum permissible distance between Earth stations is about 11.000 miles.

1.4.1 Advantages and desavantages of the geostationay orbit. 2(*)

1.4.1(i) Advantages:

The geostationary orbit has several major advantages which are:

- Because the satellite remains stationary relative to Earth the cost of sophiscated tracking equipment is avoided, thereby minimising the cost and the complexity of the Earth stations;
- Locations within the satellite's area of coverage remain in line - of - sight constact. The breack in transmission, which occurs when a non- stationary satellite disappears over the horizon, is thereby avoided;
- Because of the large covered area, a large number of Earth stations can intercommunicate;
- A relatively low number of satellites can provide almost total global coverage;
- Because the satellite, apart from the difts, experience

no motion relative to the Eath station, there is almost no Doppler shift. A familiar example Doppler shift is the change in the apparent pitch of the round as a train approches an observer and then recedes. Satellite motion relative to the Earth would similarly cause a change in the apparent frequency of the radiation to and from satellite. Satellites in elliptical orbits have different Doppler shift with respect to different Earth stations, and this increases the complexity and costs of the earth stations.

1.4.1(ii) The disadvantages of the geostationary orbit are :

- latitude greater than 81.5 degrees North and South are not covered; and this is reduced to 77 degrees North and South,if antenna elevations less than 5 degrees are excluded. However there is little else but polar ice at these latitude.
- because of great distance, the received signal strength, which is inversely proportional to the square of the distance is very weak - about 1 picowatt.
- The signal propagation time also proportional to distance, and at 270 milliseconds (on average), this is sufficient for it to have a significant effect on transmission efficiency although the impact on the ultimate and user depends upon the nature of the information being transmetted on the application;
-Compared with lower altitude orbits, more powerful rocketry and on board fuel supplier are required to achieve geostationary orbits;

2(*) INTRODUCING SATELLITE COMMUNICATIONS (page 72)

-With increasing altitude the effects of Earth and lunar eclipse become increasingly pronounced;
- Because an antenna is not 100% efficient there is always some loss of radiated energy to space. This is referred to as the Free Space loss and is the largest source of transmission loss in satellite communication system. The Free Space loss increases with increasing distance.

1.4.2 Satellite spacing and orbital capacity.3(*)

Because it is finite in extent, a theoritical upper limit on the number of satellites than can be packed in the geostationary orbit can be taken into consideration. In practice there are a number of considerations which influence packing density and give sometimes problemes to satellite designers in overcoming orbital capacity limitations. The most important constraint is the operating frequency of the satellite. If the satellites are placed too close together, their transmissions will interfere with each other because they use the same frenquency. In the same geostationary orbit, the satellites operate with a frequency of 6/4 GHZ band and a spacing of an angular separation of 4-5 degres has been found satisfactory.But the problem today is to place satellites close with each other without interference of their transmissions.The question is complex and depends upon a number of factors which are:

- The transmission frequency and the power of the Earth stations;
- The bandwidth, frequency and power of the satellite's transponders;
- The diameter and performance of both the Earth station and the satellite antenna.

But because of the rapid expansion of satellites of communication, the problem of orbit capacity becomes very complex. Requirement of new application are introduced . All this brought a significant political situation into international forums. There is the problem of reducing satellite spacing and increasing satellite transmission capacity.

The first adopted way to solve the problem is to use other positions of frequency spectrum. Thus if a satellite transmitting in the 6/4 GHZ band is stationed next to one employing the 14/11 band ,the greatly reduced likelihood of mutual interference enables them to be packed more closely together.

The allocation of orbital slots and satellite frequency is subject to international agreement, the principal forum being the International Telecommunications Union (I.T.U),althougth INTELSAT also played an important role.

International Proposals for satellite spacing is adopted (see table 1.1)

The international proposals would create a total of more than 120 positions around the Earth's equatorial circumference. It would reduce also the distance between satellites from 22,000 km to less the 1,500 km and to require Earth_ station antennae to produce narrower microwave beam.

To satisfy the proposals, some satellites will be repositioned and Earth station to be modified.

The table ( ) in the appendix will helpe to convery the idea of the projected demand for orbital slots. In the table it is shown existing and proposed satellite positions for the section of the orbit extending from Longitude 19 degres West to Longitude 35 degres East.

3(*) INTERNATIONAL SATELLITE COMMUNICATION (page 73)

FREQUENCY	STAGE 1 SEPARATION	STAGE 1 SEPARATION
6/4 GHZ	4	2 (GRADUALLY)
14/11 GHZ	3	2 May 1982
30/20 GHZ	To be determined	1 ?

(Table 1.1) INTERNATIONAL PROPOSALS FOR SATELLITE SPACING.

1.4.3 ANGLE OF ELEVATION .

The angle of elevation of a satellite is the angle between the Earth and the line of the slight from the Earth station to the satellite (see fig 1.2) . The angle of elevation varies with the location of the Earth station or user depending upon its Latitude and Longitude.

In the geostationary orbit the satellite being fixed with an angle of coverage of 18 degres,an Earth station will depend upon the angle of elevation relative to the satellite.

(Fig. 1.3) shows the relationship between the angle or elevation and the percaentage of the part of Earth which is covered at that angle of elevation.

A simple mathematical formula can show that the angle of elevation is also related to the distance between the satellite and Earth station or user (see page 12)

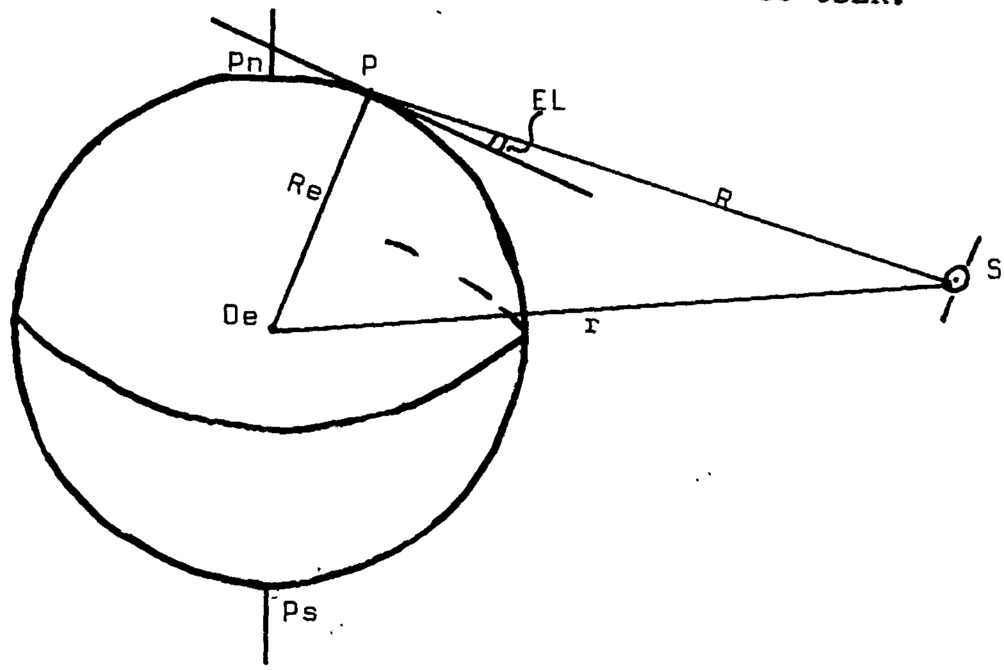
The smaller the angle of elevation the bigger the distance thus the further the signal has to travel and this has two consequencies:

-During its journey the signal has to pass through more of the Earth's atmosphere; and precipitation in the form of clouds,rain and fog can impair the signal quality (Absorption of electrical energy thus reduction of signal strength etc...) see chapter relating to range measurements

- Knowing that the signal transmission time or propagation delay is directly proportional to the distance travelled so bigger will be the distance,bigger will be the signal transmission time .

(Fig. 1.4) shows distances and propagation times for a geostationary satellite.

(FIG 1.2) DISTANCE FROM SATELLITE TO USER.



In triangle O P S using cosine formula we have:

$$r^2 = Re^2 + R^2 - 2.Re.R\cos(EL+90)$$

$$r^2 = Re^2 + R^2 + 2.Re.R\sin EL \qquad (1)$$

$$R^2+2\sin EL.Re.R + (Re^2+r^2) = 0 \qquad (2)$$

$$R^2+2Re.R\sin EL-(r^2-Re^2) = 0 \qquad (3)$$

$$R = \frac{-2Re\sin EL+(4Re^2\sin^2 EL+4(r^2-Re^2))^{1/2}}{2}$$

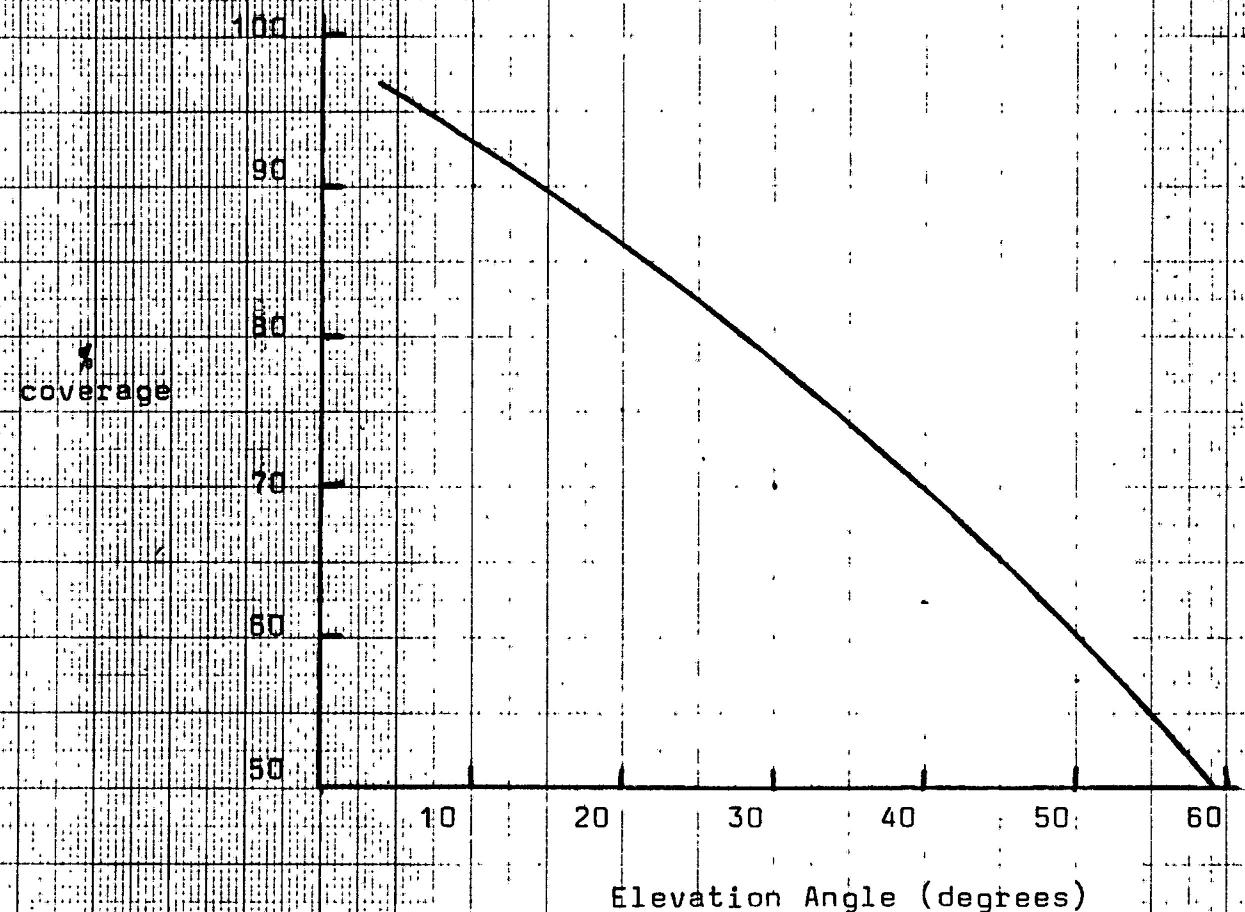
$$R = -Re\sin EL+(Re^2\sin^2 EL+r^2-Re^2)^{1/2} \qquad (4)$$

$$R = Re(-\sin EL+(\sin^2 EL+\frac{r^2}{Re^2}-1)^{1/2}) \qquad (5)$$

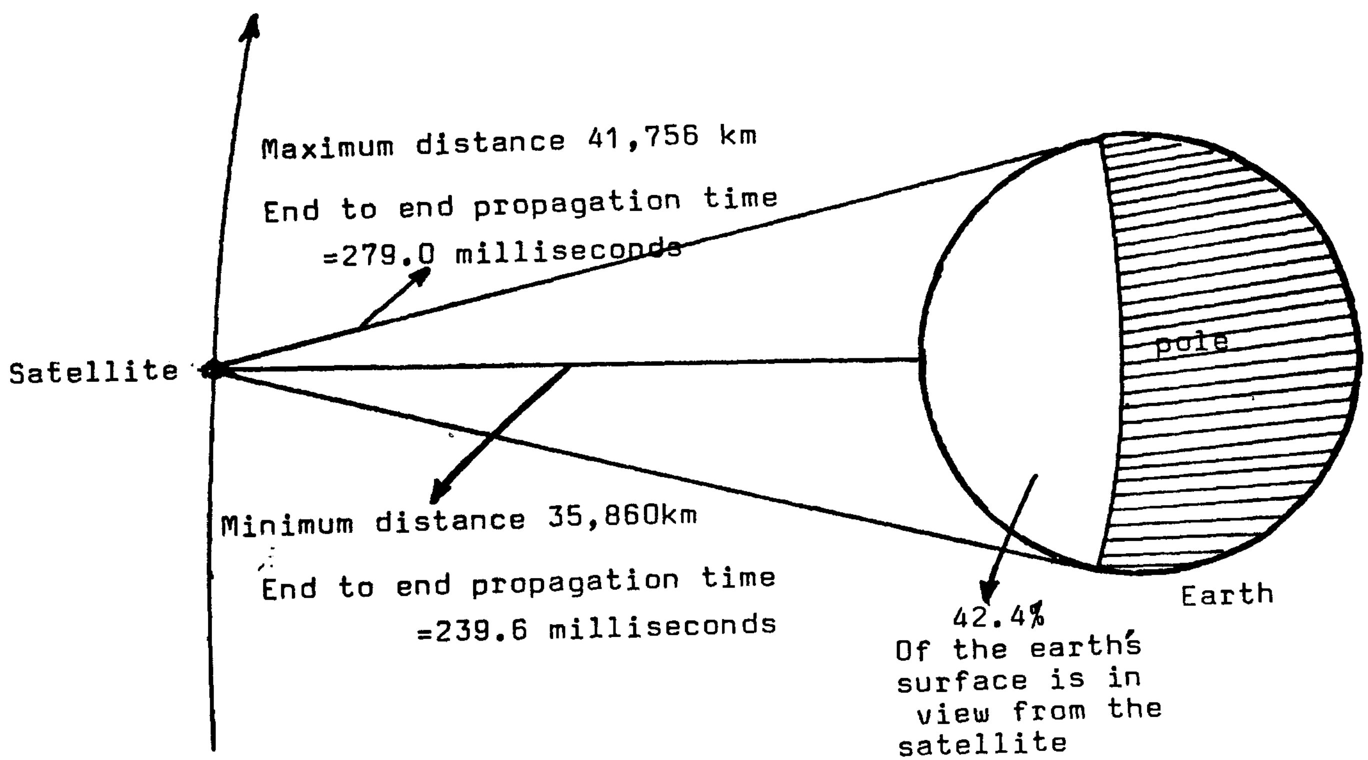
$$R = Re((r^2/Re^2-\cos^2 EL)^{1/2}-\sin EL) \qquad (6)$$

By solving (6) we find distance from the user P to satellite S, in function of Elevation and distance from the centre O to Satellite S
Elevation angle we find solving eq. (3)

$$\sin EL = \frac{r^2-Re^2-R^2}{2Re.R} \qquad (7)$$

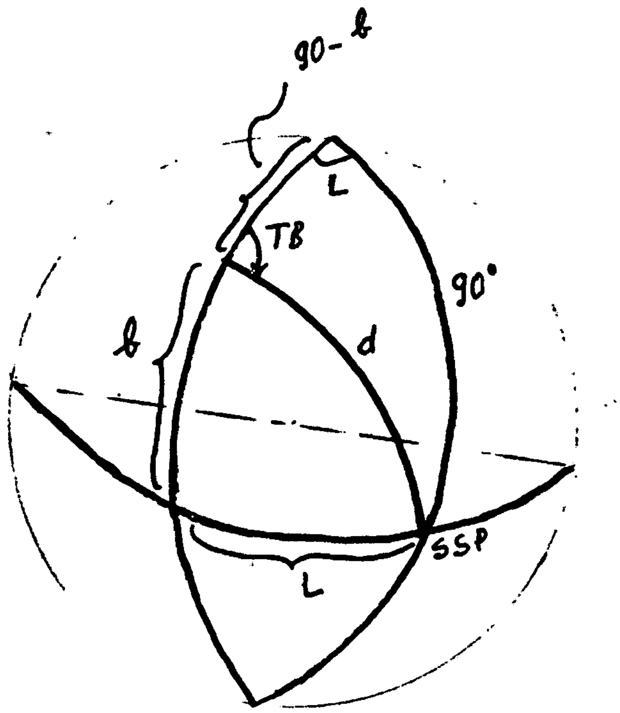


(Fig. 1.3) Percent Hemipheric Coverage and Elevation Angle



(Fig. 1.4) - DISTANCES AND PROPAGATIONTIMES FOR A GEOSTATIONARY SATELLITE

(Fig. 1.5) TRUE BEARING OF THE SATELLITE



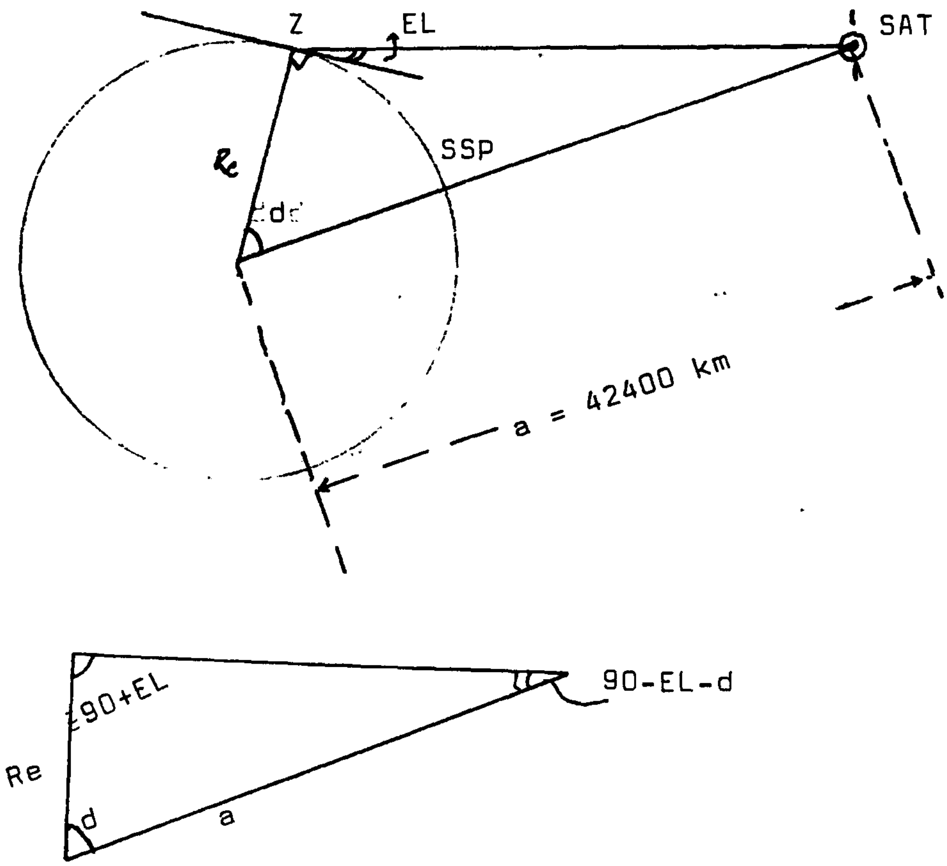
$$\cos d = \cos b . \cos L \qquad (1)$$

$$\cos 90 = \sin b . \cos d + \cos b . \sin d . \cos TB$$

$$\cos TB0 = - - \frac{\tan b}{\tan d} \qquad (2)$$

TB : true bearing.

(Fig. 1.6) ANGLE OF ELEVATION OF THE SATELLITE



From the triangle we can write:

$$\frac{\sin(90+EL)}{a} = \frac{\sin(90-EL-d)}{Re} \qquad (1)$$

$$\frac{\cos EL}{a} = \frac{\cos(EL+d)}{Re}$$

$$\frac{Re}{a}\cos EL = \cos EL\cos d - \sin EL\sin d \qquad (2)$$

$$\left(\frac{Re}{a} - \cos d\right)\cos EL = -\sin EL\sin d \qquad (3)$$

$$\tan EL = \frac{1}{\sin d}\left(\cos d - \frac{Re}{a}\right) \qquad (4)$$

LONG.\LATITUDE	BEARING																								
	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54
4	135	146	153	158	161	164	166	167	168	169	170	171	172	172	172	173	173	174	174	174	174	174	175	175	175	175
6	124	135	143	149	153	157	159	161	163	164	166	167	167	168	169	169	170	170	171	171	171	172	172	172	172	173
8	116	127	135	141	146	150	153	156	158	159	161	162	163	164	165	166	167	167	168	168	169	169	169	170	170	170
10	112	121	128	135	140	144	147	150	153	155	157	158	159	161	162	162	163	164	165	165	166	166	167	167	167	168
12	108	116	123	129	134	139	142	145	148	150	152	154	156	157	158	159	160	161	162	162	163	164	164	164	165	165
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22	100	105	109	113	117	121	124	127	130	133	135	137	139	141	143	144	145	147	148	149	150	151	151	152	153	153
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56	93	94	95	97	98	99	101	102	103	104	105	106	108	109	110	111	112	113	113	114	115	116	117	117	118	119
58	92	94	95	96	97	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	113	114	115	116	116	117
60	92	93	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	110	111	112	113	113	114	114	115
62	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	107	108	109	110	110	111	112	112	113	113
64	92	93	94	95	96	97	98	99	99	100	101	102	103	104	104	105	106	107	107	108	109	109	110	110	111	
66	92	93	94	94	95	96	97	98	99	99	100	101	102	103	103	104	105	105	106	107	107	108	108			
68	92	92	93	94	95	96	96	97	98	99	99	100	101	101	102	103	103	104	105	105	106					
70	91	92	93	94	94	95	96	96	97	98	98	99	100	100	101	102	102	103								
72	91	92	93	93	94	94	95	96	96	97	98	98	99	99												
74	91	92	92	93	93	94	95																			

(Tabl. 1.2)

LONG.\LATITUDE	BEARING											
	52	54	56	58	60	62	64	66	68	70	72	74
4	175	175	175	175	175	175	176	176	176	176	176	176
6	172	173	173	173	173	173	173	173	174	174	174	174
8	170	170	170	171	171	171	171	171	171	171	172	172
10	167	168	168	168	168	169	169	169	169	169	169	170
12	165	165	166	166	166	166	167	167	167	167	167	168
14	162	163	163	164	164	164	164	165	165	165	165	165
16	160	160	161	161	162	162	162	163	163	163	163	163
18	158	158	159	159	159	160	160	160	161	161	161	
20	155	156	156	157	157	158	158	158	159	159	159	
22	153	153	154	155	155	155	156	156	156	157	157	
24	151	151	152	152	153	153	154	154	154	155	155	
26	148	149	150	150	151	151	152	152	152	153	153	
28	146	147	147	148	148	149	149	150	150	150	151	
30	144	144	145	146	146	147	147	148	148	148	149	
32	142	142	143	144	144	145	145	146	146	146		
34	139	140	141	142	142	143	143	144	144	144		
36	137	138	139	139	140	141	141	142	142	142		
38	135	136	137	137	138	138	139	139	140	140		
40	133	134	135	135	136	136	137	137	138			
42	131	132	133	133	134	134	135	135	136			
44	129	130	131	131	132	132	133	133	134			
46	127	128	129	129	130	130	131	131				
48	125	126	127	127	128	128	129	129				
50	123	124	125	125	126	127	127					
52	122	122	123	124	124	125	125					
54	120	120	121	122	122	123						
56	118	119	119	120	120							
58	116	117	117	118	118							
60	114	115	116	116								
62	113	113										
64	111											

(Tabl. 1.2)

ELEVATION

LONG.\LATITUDE	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54
4	83	81	79	77	75	72	70	68	65	63	61	58	56	54	51	49	47	45	42	40	38	36	33	31	29	27
6	81	80	78	76	74	72	69	67	65	63	60	58	56	53	51	49	47	44	42	40	38	35	33	31	29	27
8	79	78	76	74	73	71	68	66	64	62	60	57	55	53	51	48	46	44	42	39	37	35	33	31	29	26
10	77	76	74	73	71	69	67	65	63	61	59	57	54	52	50	48	46	43	41	39	37	35	33	30	28	26
12	75	74	73	71	70	68	66	64	62	60	58	56	54	52	49	47	45	43	41	39	36	34	32	30	28	26
14	72	72	71	69	68	66	64	63	61	59	57	55	53	51	49	47	44	42	40	38	36	34	32	30	28	26
16	70	69	68	67	66	64	63	61	59	58	56	54	52	50	48	46	44	42	40	37	35	33	31	29	27	25
18	68	67	66	65	64	63	61	60	58	56	54	53	51	49	47	45	43	41	39	37	35	33	31	29	27	25
20	65	65	64	63	62	61	59	58	56	55	53	51	49	48	46	44	42	40	38	36	34	32	30	28	26	24
22	63	63	62	61	60	59	58	56	55	53	52	50	48	46	45	43	41	39	37	35	33	31	29	27	26	24
24	61	60	60	59	58	57	56	54	53	52	50	48	47	45	43	42	40	38	36	34	32	31	29	27	25	23
26	58	58	57	57	56	55	54	53	51	50	48	47	45	44	42	40	39	37	35	33	32	30	28	26	24	22
28	56	56	55	54	54	53	52	51	49	48	47	45	44	42	41	39	37	36	34	32	31	29	27	25	24	22
30	54	53	53	52	52	51	50	49	48	46	45	44	42	41	39	38	36	35	33	31	30	28	26	24	23	21
32	51	51	51	50	49	49	48	47	46	45	43	42	41	39	38	36	35	33	32	30	29	27	25	24	22	20
34	49	49	48	48	47	47	46	45	44	43	42	40	39	38	36	35	34	32	31	29	28	26	24	23	21	19
36	47	47	46	46	45	44	44	43	42	41	40	39	37	36	35	34	32	31	29	28	26	25	23	22	20	19
38	45	44	44	43	43	42	42	41	40	39	38	37	36	35	33	32	31	29	28	27	25	24	22	21	19	18
40	42	42	42	41	41	40	40	39	38	37	36	35	34	33	32	31	29	28	27	25	24	23	21	20	18	17
42	40	40	39	39	39	38	37	37	36	35	34	33	32	31	30	29	28	27	25	24	23	22	20	19	17	16
44	38	38	37	37	36	36	35	35	34	33	32	32	31	30	29	28	26	25	24	23	22	20	19	18	16	15
46	36	35	35	35	34	34	33	33	32	31	31	30	29	28	27	26	25	24	23	22	20	19	18	17	15	14
48	33	33	33	33	32	32	31	31	30	29	29	28	27	26	25	24	23	22	21	20	19	18	17	16	14	13
50	31	31	31	30	30	30	29	29	28	27	27	26	25	24	24	23	22	21	20	19	18	17	16	14	13	12
52	29	29	29	28	28	28	27	27	26	26	25	24	24	23	22	21	20	19	18	17	16	15	14	13	12	11
54	27	27	26	26	26	26	25	25	24	24	23	22	22	21	20	19	19	18	17	16	15	14	13	12	11	10
56	25	24	24	24	24	23	23	23	22	22	21	21	20	19	19	18	17	16	15	15	14	13	12	11	10	9
58	22	22	22	22	22	21	21	21	20	20	19	19	18	18	17	16	15	15	14	13	12	12	11	10	9	8
60	20	20	20	20	20	19	19	19	18	18	17	17	16	16	15	15	14	13	13	12	11	10	9	9	8	7
62	18	18	18	18	18	17	17	17	16	16	16	15	15	14	13	13	12	12	11	10	10	9	8	7	7	6
64	16	16	16	16	16	15	15	15	14	14	14	13	13	12	12	11	11	10	9	9	8	8	7	6	5	
66	14	14	14	14	13	13	13	13	12	12	12	11	11	11	10	10	9	9	8	7	7	6	6			
68	12	12	12	12	11	11	11	11	11	10	10	10	9	9	8	8	7	7	6	6	5					
70	10	10	10	10	9	9	9	9	9	8	8	8	7	7	7	6	6	5								
72	8	8	8	8	7	7	7	7	7	6	6	6	6	5												
74	6	6	6	6	5	5	5																			

(Tabl. 1.3)

LONG.\LATITUDE ELEVATION

	52	54	56	58	60	62	64	66	68	70	72	74
4	29	27	25	22	20	18	16	14	12	10	8	6
6	29	27	24	22	20	18	16	14	12	10	8	6
8	29	26	24	22	20	18	16	14	12	10	8	6
10	28	26	24	22	20	18	16	14	12	10	8	6
12	28	26	24	22	20	18	16	13	11	9	7	5
14	28	26	23	21	19	17	15	13	11	9	7	5
16	27	25	23	21	19	17	15	13	11	9	7	5
18	27	25	23	21	19	17	15	13	11	9	7	
20	26	24	22	20	18	16	14	12	11	9	7	
22	26	24	22	20	18	16	14	12	10	8	6	
24	25	23	21	19	17	16	14	12	10	8	6	
26	24	22	21	19	17	15	13	11	10	8	6	
28	24	22	20	18	16	15	13	11	9	7	6	
30	23	21	19	18	16	14	12	11	9	7	5	
32	22	20	19	17	15	13	12	10	8	7		
34	21	19	18	16	15	13	11	10	8	6		
36	20	19	17	15	14	12	11	9	7	6		
38	19	18	16	15	13	12	10	9	7	5		
40	18	17	15	14	13	11	9	8	6			
42	17	16	15	13	12	10	9	7	6			
44	16	15	14	12	11	10	8	7	5			
46	15	14	13	12	10	9	8	6				
48	14	13	12	11	9	8	7	6				
50	13	12	11	10	9	7	6					
52	12	11	10	9	8	7	5					
54	11	10	9	8	7	6						
56	10	9	8	7	6							
58	9	8	7	6	5							
60	8	7	6	5								
62	7	6										
64	5											

(Tabl. 1.3)

LONG. LATITUDE DISTANCE

	4	6	8	10	12	14	16	18	20	22	24	26	28
4	35827	35851	35885	35928	35981	36043	36115	36195	36284	36382	36488	36603	36725
6	35851	35875	35909	35952	36005	36067	36138	36218	36307	36404	36510	36624	36746
8	35885	35909	35943	35986	36038	36100	36170	36250	36338	36435	36540	36654	36775
10	35928	35952	35986	36028	36080	36141	36212	36291	36378	36474	36579	36692	36812
12	35981	36005	36038	36080	36132	36192	36262	36340	36427	36523	36626	36738	36857
14	36043	36067	36100	36141	36192	36252	36321	36399	36485	36579	36682	36792	36910
16	36115	36138	36170	36212	36262	36321	36389	36466	36551	36644	36745	36855	36971
18	36195	36218	36250	36291	36340	36399	36466	36541	36625	36717	36817	36925	37040
20	36284	36307	36338	36378	36427	36485	36551	36625	36708	36799	36897	37003	37117
22	36382	36404	36435	36474	36523	36579	36644	36717	36799	36888	36984	37089	37200
24	36488	36510	36540	36579	36626	36682	36745	36817	36897	36984	37080	37182	37292
26	36603	36624	36654	36692	36738	36792	36855	36925	37003	37089	37182	37282	37390
28	36725	36746	36775	36812	36857	36910	36971	37040	37117	37200	37292	37390	37495
30	36855	36875	36904	36940	36984	37036	37095	37163	37237	37319	37408	37504	37607
32	36992	37012	37040	37075	37118	37169	37227	37292	37365	37445	37531	37625	37725
34	37137	37156	37183	37217	37259	37308	37365	37428	37499	37577	37661	37752	37849
36	37288	37307	37333	37366	37407	37454	37509	37571	37640	37715	37797	37885	37980
38	37446	37464	37489	37522	37561	37607	37660	37720	37786	37859	37939	38024	38116
40	37610	37628	37652	37683	37721	37766	37817	37875	37939	38010	38086	38169	38258
42	37780	37797	37820	37850	37887	37930	37980	38035	38097	38165	38239	38319	38405
44	37956	37972	37994	38023	38059	38100	38148	38201	38261	38326	38398	38474	38557
46	38137	38152	38174	38201	38235	38275	38321	38372	38429	38492	38561	38634	38713
48	38322	38337	38358	38384	38417	38455	38498	38548	38603	38663	38728	38799	38874
50	38513	38527	38547	38572	38603	38639	38681	38728	38780	38838	38900	38968	39040
52	38708	38721	38740	38764	38793	38828	38867	38912	38962	39017	39076	39140	39209
54	38906	38919	38937	38960	38987	39020	39058	39100	39147	39199	39256	39317	39382
56	39109	39121	39137	39159	39185	39216	39252	39292	39336	39385	39439	39496	39558
58	39314	39325	39341	39362	39386	39415	39449	39487	39529	39575	39625	39679	39737
60	39523	39533	39548	39567	39590	39618	39649	39684	39724	39767	39814	39865	39919
62	39734	39744	39758	39776	39797	39823	39852	39885	39921	39962	40006	40053	40104
64	39948	39957	39970	39986	40006	40030	40057	40087	40121	40159	40199	40243	40291
66	40164	40172	40184	40199	40217	40239	40264	40292	40323	40358	40395	40436	40479
68	40381	40389	40400	40413	40430	40450	40473	40499	40527	40559	40593	40630	40670
70	40600	40607	40617	40629	40645	40663	40683	40707	40733	40761	40792	40826	40862
72	40820	40826	40835	40846	40860	40876	40895	40916	40939	40965	40993	41023	41055
74	41041	41047	41054	41064	41076	41091	41107						

	30	32	34	36	38	40	42	44	46	48	50	52	54
4	36855	36992	37137	37288	37446	37610	37780	37956	38137	38322	38513	38708	38906
6	36875	37012	37156	37307	37464	37628	37797	37972	38152	38337	38527	38721	38919
8	36904	37040	37183	37333	37489	37652	37820	37994	38174	38358	38547	38740	38937
10	36940	37075	37217	37366	37522	37683	37850	38023	38201	38384	38572	38764	38960
12	36984	37118	37259	37407	37561	37721	37887	38059	38235	38417	38603	38793	38987
14	37036	37169	37308	37454	37607	37766	37930	38100	38275	38455	38639	38828	39020
16	37095	37227	37365	37509	37660	37817	37980	38148	38321	38498	38681	38867	39058
18	37163	37292	37428	37571	37720	37875	38035	38201	38372	38548	38728	38912	39100
20	37237	37365	37499	37640	37786	37939	38097	38261	38429	38603	38780	38962	39147
22	37319	37445	37577	37715	37859	38010	38165	38326	38492	38663	38838	39017	39199
24	37408	37531	37661	37797	37939	38086	38239	38398	38561	38728	38900	39076	39256
26	37504	37625	37752	37885	38024	38169	38319	38474	38634	38799	38968	39140	39317
28	37607	37725	37849	37980	38116	38258	38405	38557	38713	38874	39040	39209	39382
30	37716	37831	37953	38080	38214	38352	38496	38644	38798	38955	39117	39282	39451
32	37831	37944	38063	38187	38317	38452	38592	38737	38887	39040	39198	39360	39525
34	37953	38063	38178	38299	38426	38557	38694	38835	38981	39130	39284	39442	39603
36	38080	38187	38299	38417	38540	38668	38800	38937	39079	39225	39374	39528	39684
38	38214	38317	38426	38540	38659	38783	38912	39045	39182	39324	39469	39618	39770
40	38352	38452	38557	38668	38783	38903	39027	39156	39290	39427	39567	39711	39859
42	38496	38592	38694	38800	38912	39027	39148	39272	39401	39533	39669	39809	39951
44	38644	38737	38835	38937	39045	39156	39272	39393	39516	39644	39775	39910	40047
46	38798	38887	38981	39079	39182	39290	39401	39516	39636	39758	39885	40014	40146
48	38955	39040	39130	39225	39324	39427	39533	39644	39758	39876	39997	40121	40248
50	39117	39198	39284	39374	39469	39567	39669	39775	39885	39997	40113	40232	40353
52	39282	39360	39442	39528	39618	39711	39809	39910	40014	40121	40232	40345	40461
54	39451	39525	39603	39684	39770	39859	39951	40047	40146	40248	40353	40461	40571
56	39624	39693	39767	39844	39925	40009	40097	40187	40281	40378	40477	40579	40684
58	39799	39865	39934	40007	40083	40162	40245	40330	40419	40510	40604	40700	40799
60	39977	40039	40104	40172	40243	40318	40395	40476	40559	40644	40733	40823	40916
62	40158	40215	40276	40340	40406	40476	40548	40623	40701	40781	40863	40948	41035
64	40341	40394	40450	40510	40571	40636	40703	40773	40845	40919	40996	41075	
66	40526	40575	40627	40681	40738	40798	40860	40924	40991	41060			
68	40712	40757	40805	40855	40907	40962	41018	41077					
70	40900	40941	40984	41030	41077								
72	41090												
74													

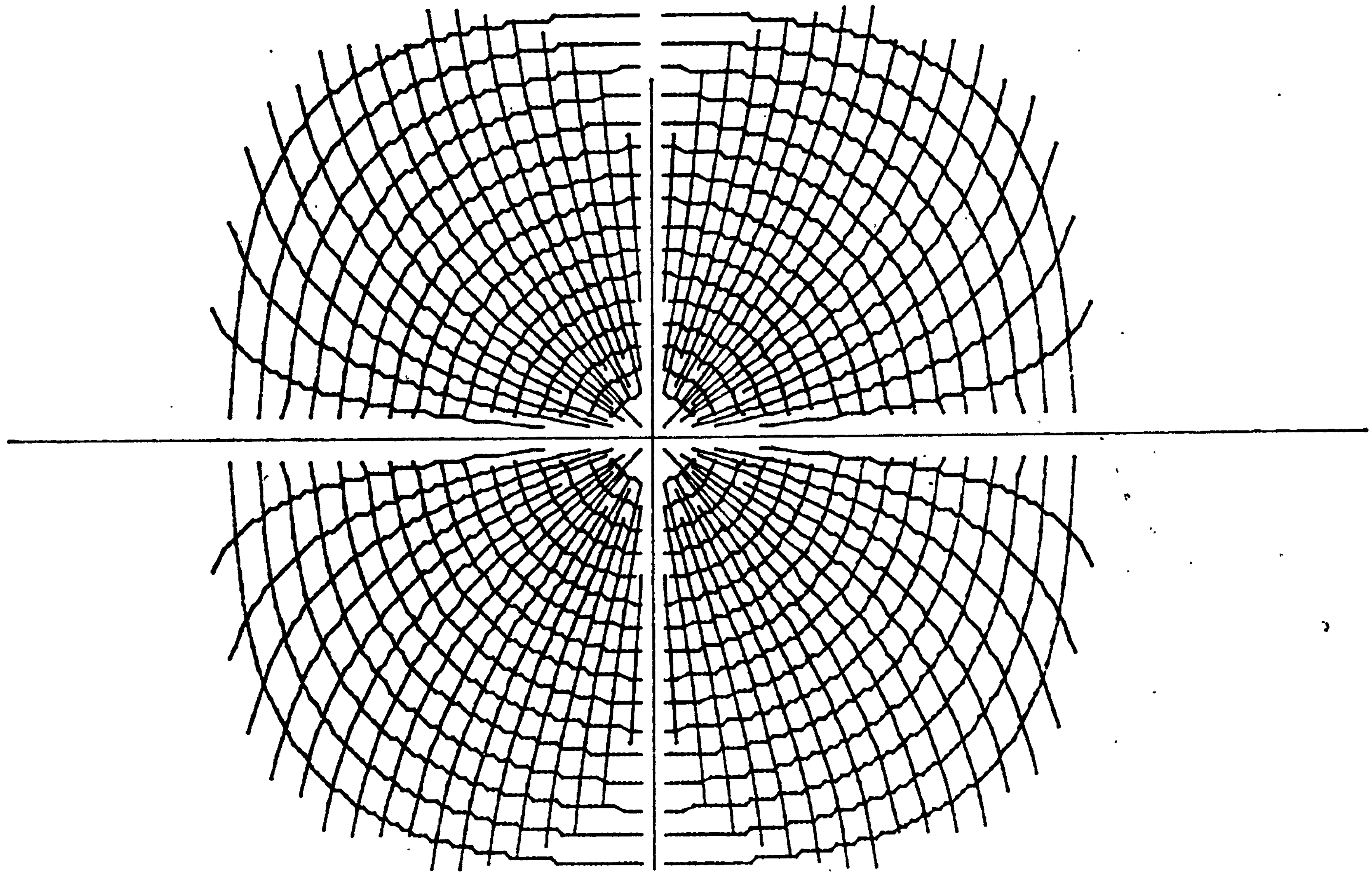
(Tabl. 1.4 9

LONG.\LATITUDE DISTANCE

	52	54	56	58	60	62	64	66	68	70	72	74
4	38708	38906	39109	39314	39523	39734	39948	40164	40381	40600	40820	41041
6	38721	38919	39121	39325	39533	39744	39957	40172	40389	40607	40826	41047
8	38740	38937	39137	39341	39548	39758	39970	40184	40400	40617	40835	41054
10	38764	38960	39159	39362	39567	39776	39986	40199	40413	40629	40846	41064
12	38793	38987	39185	39386	39590	39797	40006	40217	40430	40645	40860	41076
14	38828	39020	39216	39415	39618	39823	40030	40239	40450	40663	40876	41091
16	38867	39058	39252	39449	39649	39852	40057	40264	40473	40683	40895	41107
18	38912	39100	39292	39487	39684	39885	40087	40292	40499	40707	40916	
20	38962	39147	39336	39529	39724	39921	40121	40323	40527	40733	40939	
22	39017	39199	39385	39575	39767	39962	40159	40358	40559	40761	40965	
24	39076	39256	39439	39625	39814	40006	40199	40395	40593	40792	40993	
26	39140	39317	39496	39679	39865	40053	40243	40436	40630	40826	41023	
28	39209	39382	39558	39737	39919	40104	40291	40479	40670	40862	41055	
30	39282	39451	39624	39799	39977	40158	40341	40526	40712	40900	41090	
32	39360	39525	39693	39865	40039	40215	40394	40575	40757	40941		
34	39442	39603	39767	39934	40104	40276	40450	40627	40805	40984		
36	39528	39684	39844	40007	40172	40340	40510	40681	40855	41030		
38	39618	39770	39925	40083	40243	40406	40571	40738	40907	41077		
40	39711	39859	40009	40162	40318	40476	40636	40798	40962			
42	39809	39951	40097	40245	40395	40548	40703	40860	41018			
44	39910	40047	40187	40330	40476	40623	40773	40924	41077			
46	40014	40146	40281	40419	40559	40701	40845	40991				
48	40121	40248	40378	40510	40644	40781	40919	41060				
50	40232	40353	40477	40604	40733	40863	40996					
52	40345	40461	40579	40700	40823	40948	41075					
54	40461	40571	40684	40799	40916	41035						
56	40579	40684	40791	40900	41010							
58	40700	40799	40900	41002	41107							
60	40823	40916	41010	41107								
62	40948	41035										
64	41075											

(Tabl. 1.4)

Figure 1.7



In table 1.2 , figures represent the bearings of a geostationary satellite with different positions of the user. The results are obtained with eq.(2) in page 15 .

In table 1.3 , figures represent the angles of elevation of a geostationary satellite with different positions of the user. The results are obtained with eq.(4) in page 16 .

The figures in table 1.4, represent the distances between a geostationary satellite and an user with different positions. The results are obtained using eq.(6) in page 12 .

In figure (1.7), circles represente angles of Elevation and graphes represent bearings. Having two of that figure, it is possible to use them for calculating R95 with two geostationary satellites.

1.4.4 ECLIPSES.

Most satellites carry storage batteries which are charged continuously from solar cells and these provide standby power during an eclipse.A solution to this problem is that the satellite might be designed so that on a proportion of the transponders are operational for the duration of the eclipse.

Sometimes the satellite passes directly in front of the sun.It can occur serious form of solar interference.The only mean to solve this problem is sto have a duplicated satellite in the orbit.

CHAPTER II

GEOSTATIONARY COMMUNICATION SYSTEM

2.1 INTRODUCTION

It was during the night of 10 - 11th july 1962, when television pictures were first flashed across the Atlantic via Fi the Telstar satellite, that began the age of satellite of communication. Three year after the Telstar I, the first Intelsat satellite was launched. Ater less than twenty of existance Intelsat covered about two third of the international telecommunication traffic accross the oceans of the world. The relaying of speech and television programmes was the earliest application of satellite communications, and continues to be its major role today.

In 1982 began to operate an other worldwide satellite communication organization known under the name of International Maritime satellite (INMARSAT). INMARSAT is more or less oriented to the maritime field. Its major role was communication between ship to ship or ships to land.

Both Intelsat and INMARSAT use the geostationary orbit.

2.2 Intelsat.

The origins of the Intelsat Organisation are thus, in a sense, rooted in the worldwide rivaly between the Soviet Union and the United States in all its dimensions, but particularly in the contest that emerged in the 1950's and early 1960's to demonstrate a superior prowess in outer space.

Both nations were interested in the applications of the technology for scientific satellite programs releating to weather,communications, navigation, reconnaissance, education, environmental resources surveying and other applications. In United States through the Federal government and the private, effort and attention were focused on communications satellite development. The first satellite will be called SYNCOM which proved to be direct ancestor of the world's first commercial communication satellite. Intelsat I later known as Early Bird 1(*). The Intelsat, for many reasons, has known different generations characterized by Intelsat I to Intelsat VI.

2.2.1 Intelsat I or Early Bird.

In November 1963, was built a satellite eventually to be known as Early bird which was to become the world's first communication satellite. he successful launch and operation demonstrated that the geotationary orbit could be achieved with a lightweight satellite and that such a satellite could provide reliable microwave service between space and Earth.

2.2.2 Intelsat II

This satellite is twice as large as Early bird and will introduce a new generation. It was the largest communication satellite ever launched in a gestationary orbit. In design concept, the satellite follows the same principles developed for Early Bird.

1(*) SANTIAGO ASTRAIN - Global Overview of Satellite Communications.

1.3. Intelsat III

2.2.3 Intelsat III

The Intelsat III satellite serie represented a number of important operational, technical, and institutional first for Intelsat, and, in many ways, can perhaps be considered a major turning point in Intelsat's development.

- It was the first satellite wherein Intelsat engaged in a full - international request for proposal process.
- Intelsat III represented a major technological innovation. With Intelsat III, we started to have low - cost, high - quality transmission facility and new market has quickly developed.
- Intelsat III program introduced to Intelsat the many political, technical and operational problems in the operation of a global satellite system.
- Intelsat III serie marked the definitive commitment by Intelsat to the operation of a global three - region geostationary satellite system.

An important aspect of the Intelsat III programm was the abandonment of the idea that nongeostationary satellites could provide a more cost - effective service. The concept had been studied under several research contracts that examined whether a number of simple, low - orbit satellites could be launched simultaneously at a fairly low cost per satellite. The relatively low orbit of these satellites would have reqùired much lower transmission power from the satellite, which would have increased their relative technical performance vis - a - vis the geostationary satellite system, and have eliminated much of the "delay" problem.

On the opposite side of the problem were some big negatives. The rapid velocity of low or medium altitude satellites with respect to the earth, and the need for frequent poitovers as satellites appear and disappear, indicated that very sophisticated tracking and telemetry equipment and costly Earth terminals would be required to maintain operations. This aspect in particular would have inhibited the use of the global satellite system by smaller or developping countries.

An other factor, perhaps the most important, was that even with elaborate tracking networks picking up the various satellites as they came over the horizon , non geostationary satellites will still result in periods of brief outages.

With the decision to proceed with the Intelsat III all considerations of nongeostationary satellites operation and noncontineous operation was abandoned.

In the technical side of Intelsat III, we can notice many improvement.

- an enfanded bandwidth used at the same time for the up and downlink.
- an increase in radiated power as a result of the increased solar cells capability of the satellite.
- an mechanically despun antenna that allowed a high - gain antenna to always be funded towards the Earth.
- an increase in rotational speed of the motor.

etc...

2.2.4. Intelsats IV and IV - A

With these satellites, it was the recognition that satellites were now the dominant force in the communication revolution. Satellites had to be considered because of their reliability and cost efficiency. With the Itelsat IV generation many throughts were reffected; to extend lifetime of the satellites; to increase their physical size and mass; toa chieve higher capacities and to design and impliment highly sophisticated and complex communication devices.

Parallel the development of Intelsat IV was the planning for the Canadian geostationary Anik satellite system. The design of Intelsat IV brought numerous technical disputes; like wither the sustem world be gravity - gradient or spin - stabilized.

The idea of designing thus system came when COMSAT presented a proposal for the design of the multipurpose geosynchronous communication satellites with aeronautical and maritime communications capability.

That idea has been rejected by many European countries. By the end the system was designed but knew a lot of modifications.

The Intelsats IV and IV - A differed significantly from the Intelsat III. The power of Intelsat IV and IV - A is bigger than the power of Intelsat III. The antenna in lntelsat IV is larger than the antenna in Intelsat III.

2.2.5 Intelsat V and V - A

These satellites are the last in Intelsat system. They are different from the other satellites but presente some similarities with Intelsat IV.

Intelsat V and V-A are final studies and evolution from Intelsat I to Intelsat IV and IV - A.

2.2.6 Intelsat VI

The Intelsat VI series continues the process of the technical innovation represented by previous generations of Intelsat satellites. it is the largest and most sophiscated commercial satellite ever placed under control. The satellites are designed for ten years of operation in orbit. The satellite antenna configuration is dominated by two larges c - band reflector antennas. The Intelsat VI will introduce a number of new technologies to achieve a tripling of the communications capability relative to the previous generation satellites.

2.3 INTERNATIONAL MARITIME SATELLITE ORGANISATION (INMARSAT)

2.3.1 INTRODUCTION

Through history, it has been always impossible for seafarers to communicate with land or other ships once at sea. At close range, limited communication was available in the form of flags, lamps or flares, media that were neither reliable or adequate. At the end of the 19th century, the Marconi's invention of the wireless broke the age _ old isolation of seafarers, making ship _ to _ shore communication a reality, irespective of distance or weather. But the Titanic tragedy causing a loss of 1503 lives prompted new regulation demanding increased transmiting power.

In 1922 the first ship _ to _ shore voice communication took place between a station at Deal Beach in New Jersey, USA and the SS America, 650 km out at sea.

It was in 1927 that the word "Mayday" was adopted as the international distress call for maritime radio telephone, a word corrupted from the french term "m'aidez" meaning "help me".

All this progress, however, could not overcome the physical contraints of the frequencies in the medium, high and very high band (MF, HF and VHF). The natural peculiarities of propagation of the radio wave, the insufficient number of channels, the anomalies resulting from sunspot activity, the inability to transmit data and other limitations, make clear that, although the conventional means will continue to provide good service to the maritime community for many years, they cannot entirelly satisfy the rapidly advancing requirements of shipping. The solution came with the advent of satellites.

After the first commercial satellite "First Bird" put into operation in 1965 by Intelsat, the Inter _Governmental Maritime Consultative Organisation (IMCO), today known as IMO, in 1966 began studying the operational requirements for a maritime satellite organisation.

The IMCO Assembly of 1973 decided to convene an international conference on the establishment of an International Maritime Satellite Organisation (INMARSAT) and, in 1976 the INMARSAT agreement was adopted by this conference. By the end of 1979 , the first global system of commercial mobile satellite communications was in operation.

INMARSAT came into being an organisation in 16 July 1979, bringing with it a new international coperation in the sphere of maritime satellite communications. The INMARSAT system became operational on 1982 leasing the commercial capacity all three existing Marisat satellite as part of its initial space segment.

2.3.2 THE SYSTEM ITSELF.

INMARSAT's defined purpose is to provide the space segment for global maritime satellite communication, "thereby assisting in improving distress and safety of life at sea communications, efficiency and management of ship, maritime public correspondence service and radio determination (position fixing) capabilities. In doing so INMARSAT has to operate on a sound, commercial basis and its signatories.

The overall system comprises :

a - the coastal earth stations (CES) owned and operated by INMARSAT members. CESs link the space segment with the international and national telephone and telex networks;

b - The ship earth stations owned by shipowners;

c - The space segments,which includes the necessary ground control functions, provided by INMARSAT as international body;

d - One CES in each ocean region as a network coordination station;

e - An operation control center (OCC) in London, England to coordinate the operations of whole system.

Maritime setellite communications work in the L- band for the ship-satellite sector.

The uplink is characterized by the band of 19.0 MHZ bandwidth, the downlink by the band of 9 MHZ bandwidth.

The CESs communicate with the satellite in the C - band of 4 and 6 GHZ and frequency conversion takes place in the satellite.

The orbital positions of INMARSAT satellites are such that they provide all ocean coverage with a minimum of gap. The overall operation of the system is coordimated from the OCC. 2(*)

2.3.3 COMMUNICATION SERVICES

2.3.3.1 Satellite communications.

Maritime satellites communications are free from problems met in the conventional communications with automatic calling in the ship-to-shore direction,fully automatic interconnection ship-to-shore and shore-to-ship with the world wide telex network,low and medium-speed data transmission etc...

1(*)&2(*) Maritime Satellite Communications (journal of INMARSAT)

2.3.3.2 Future possibilities .

In addition to the services now provided, many others are under development or study. Future possibilities include:

a - automatic selection interrogations of ships;

b - enhanced meteorological and oceanographic data collection and reporting systems;

c - new SES concepts such as standard - c;

d - enhanced broadcasting services;

e - slow - scan TV;

f - standard data interface for other shipborne equipment (e.g navigation);

g - radio determination;

h - improved safety at sea communications. INMARSAT is contributing to the Future Global Maritime Distress and Safety System (FGDSSM) under development by the International Maritime Organisation (IMO);

i - new mobile terminal design will make satellite communication also available to aeronautical users.

Table 2.3.1 INMARSAT SPACECRAFT AVAILABILITY 3(*)

ocean region	spacecraft	location	launch date	status
Atlantic(AOR)	Marecs-B2	26.0 W	09 Nov 1984	Op *
	Intelsat V-MCS B	18.5 W	19 May 1983	Spare
	Marisat-F1	15.0 W	19 Feb 1976	Spare
Indian(IOR)	Intelsat V-MCS A	63.0 E	28 Sep 1982	Op *
	Intelsat V-MCS C	66.0 E	19 Oct 1983	Spare
	Marisat-F2	72.5 E	14 Oct 1976	Spare
Pacific(POR)	Intelsat V-MCS D	180.0 E	04 Mar 1984	Op *
	Marecs A	178.0 E	20 Dec 1981	Spare
	Marisat F3	176.5 E	09 Jun 1976	Spare

Op * :operational.

3(*) OCEAN VOICE (INMARSAT REVIEW)

2.3.4 The Space Segment

The INMARSAT space segment consists of the satellites themselves carrying communications repeaters or transponders and the tracking telelmetry and command facilities for the satellites. In orbit the communication signal processing is similar in all satellites of the INMARSAT system. Two repeaters are provided in each satellite, one for the shore-to-ship direction and one to the ship-to-shore direction.

The shore-to-ship repeater receives the 6 GHZ signal from the various coast earth stations, shifts their frequencies to about 1.5 GHZ and amplifies them to a level sufficiently high for reception by the small ship earth station antennae.

The ship-to-shore repeater receives the 1.6 GHZ signal from the ship earth station, shifts their frequencies to about 4 GHZ and amplifies them for transmission to the coast earth stations.

The space segment satellite uses geostationary orbit.

With one operational satellites over each major ocean almost total coverage can be provided.It must be noted that this coverage refers to a five degrees minimum elevation angle of the ship antenna towards the satellites.Between 5 and 0 degrees elevation angle the communication quality meets degradation. For ensuring continuity of service in case of failure of an operational satellite,in - orbit spares are provided.

2.4 CONCLUSION

Since 1976 , satellite communications for shipping has been a reality. Based on advanced space and electronic technology these communications provide the maritime community with the long-awaited possibility of significantly operational and safety of ships at sea. The International Maritime Satellite Organisation (INMARSAT), established through international cooperation, is responsible for providing and developing this revolutionary communications system.

CHAPTER III

R A N G E   M E A S U R E M N E N T S

3.1 INTRODUCTION

The space communications link is in general a portion of overall communications link, that is,the link from the end user to end user. In this chapter the space link is defined as the Earth station- to - user segment,including satellite.

The satellite link is a "carrier" system. The actual message is carried by a high-frequency signal. The form of the carrier can vary. It can be sinusoidal or square-shaped signal. It is transmitted as continuousor bursting RF wave. The eventual quality of a message signal can be analysed only after the discussion of the modulation, signaling, encoding and detection processes.

3.2 SPACE-LINK GEOMETRY 1(*)

The terrestrial coordinates of the receiving and transmitting Earth stations (control system and user in our case),together with the actual orbit location of the satellite in the geostationary arc, define the geometry of space-link.

The Earth station in the Earth's surface is determined by two parameters, Longitude and Latitude.The satellite in the geostationary orbit is determined by one parameter:the Longitude (the latitude equals zero).From that,the problem to solve is to find the distance between the satellite and the Earth station by giving an Earth station with coordinates Longitude and Latitude and a satellite at an orbital station with Longitude.(See result chapter 1)

3.2.1 SATELLITE UPLINK.

The satellite uplink where the transmitting Earth-station signal is received by the satellite receiving antenna at a distance Ru. The same power P_{TE} is transmitted by an isotropic reflector which will result in a flux density Φ_o at the satellite receiving antenna by the relationship:

$$\Phi_o = \frac{P_{TE}}{4\pi R_u^2} \qquad (3.1)$$

If the gain of the transmitting antenna is G_{TE}

$$\Phi_s = \frac{P_{TE} \cdot G_{TE}}{4\pi R_u^2}$$

-flux density of receiving antenna (3-2)

$P_{TE} \cdot G_{TE}$ is total effective isotropic radiated power (measured in decibels referred to 1 w (dB w).

Assume G_{RS} tahe satellite receiving antenna gain, A_R an effective aperture, Lu the total power in the transmitting path, the total power received by the satellite antenna will be:

$$P_{RS} = \frac{G_{TE} \cdot P_{TE}}{4\pi R_u^2} A_R \frac{1}{L_u} \qquad (3-3)$$

The effective area A of an antenna is defined as a function of the gain by the relation:

$$A = \frac{\lambda^2 G}{4\pi} \qquad (3-4)$$

λ -wavelength of the radiated wave.

From the definition $A_R = \frac{\lambda^2 G_{RS}^2}{4\pi}$ (3-5)

$$P_{RS} = \frac{G_{TE}\, P_{TE}\, \lambda^2 G_{RS}}{4\pi R_u^2 \; 4\pi} \cdot \frac{1}{L_u} \qquad (3\text{-}6)$$

$$\frac{P_{RS}}{P_{TS}} = G_{TE} \cdot G_{RS} \left(\frac{\lambda}{4\pi R_u} \right)^2 \cdot \frac{1}{L_u} \qquad (3\text{-}7)$$

$$\text{Free space loss} - \left(\frac{4\pi R}{\lambda} \right)^2 \qquad (3\text{-}8)$$

R- distance of transmitting in this case R = Ru.
In general there is no loss of power from the propagation through the free space. Because of the way that antenna gain G = $4\pi R/\lambda^2$ is defined, the factor $4\pi R_u/\lambda^2$ appears in equation (3-7).
However, the Radio Frequency is attenuated when it is transmitted through the atmosphere because of obsorption by the atmosphere, rain, fog etc...Because of Faraday rotation, it can also loose polarization. The signal attenuation is inclued in the facteur Lu and can be estimated from experimental data .
Equation (2-7) is fundamental relationship relating the power received by the satellite to the power transmitted by the Earth station.
If the effective noise temperature of the satellite receiver is Trs, then the noise power of the satellite receiver input will be $n_0 = kT_{RS}$, and if we replace P_{RS} by c, where c is the carrier power, we get:

$$\left(\frac{c}{n_0} \right)_u = P_{TE} \cdot G_{TE} \cdot \frac{G_{RS}}{T_{RS}} \left(\frac{1}{4\pi R} \right)^2 \cdot \frac{1}{L_u} \cdot \frac{1}{K}$$

where

$\left(\frac{c}{n_0} \right)_u$ - uplink carrier - to - noise density ratio

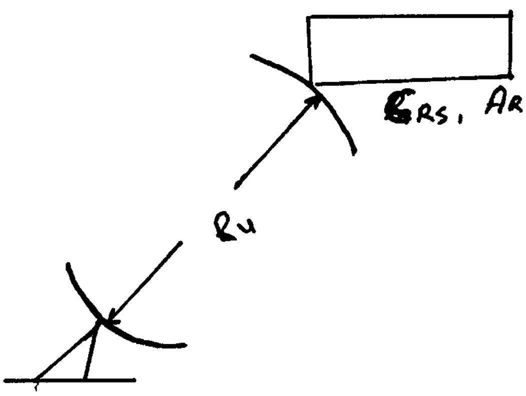
$P_{TE} G_{TE}$ – Earth station EIRP

$\frac{G_{RS}}{T_{RS}}$ – Satellite receiving sensitivity

$\left(\frac{4\pi R_u}{\lambda}\right)^2$ – Free space loss

Lu – uplink transmission medium losses

K – Boltzmann's constant



(Fig. 3.1) Earth station, GAIN _ G_{TE}

3.2.2 SATELLITE DOWNLINK

The reasoning applied for uplink can also be applied for downlink by remplacing the subscript E with S by δ
with E and U by D.

$$\left(\frac{C}{\eta_0}\right)_D = P_{TS}\, G_{TS} \cdot \frac{G_{RE}}{T_{RE}} \cdot \left(\frac{\lambda}{4\pi R_D}\right)^2 \cdot \frac{1}{L_D} \cdot \frac{1}{K}$$

where

$\left(\frac{C}{\eta_0}\right)_D$ – downlink carrier – to – noise density ratio

$P_{TS}.G_{TS}$ - satellite EIRP

$\frac{G_{RE}}{T_{RE}}$ - Earth station receiving density

$\left(\frac{4\pi R_D}{\lambda}\right)^2$ - downlink space loss

L_D - downlink transmission medium losses

K - Boltzmann's constant.

3.2.3 Total space link

The figure (3.2) represents the total space link configuration. Assume $n_s = KT_s$ the total noise power at the satellite input per unit bandwidth, if the transponder gain is G, we have , for the satellite noise at the satellite transmitter output,

$$\eta_{ST} = G.KT_s$$

Therefore the noise power at the Earth station receiver input , to the satellite generated noise, is

$$\eta_{SE} = G_D \eta_{ST}$$

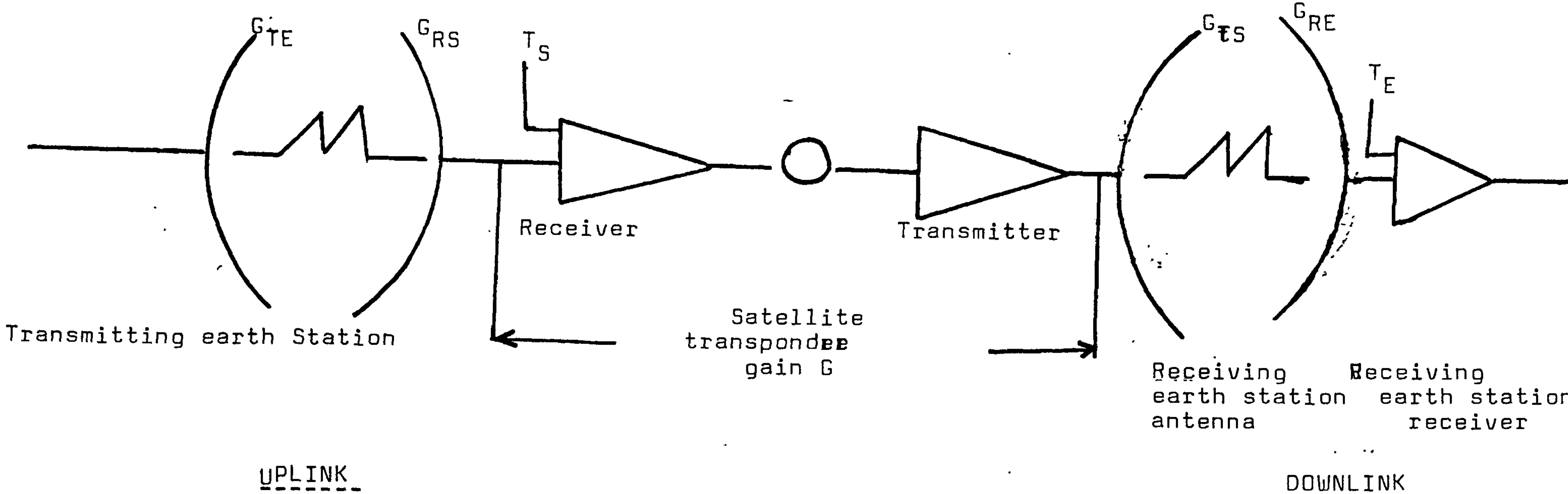
where

$$G_D = \frac{G_{TS}.G_{RE}\,\lambda^2}{(4\pi R_D)^2} \cdot \frac{1}{L_D}$$

Since KT is the additional noise power generated at the Earth station input, the total noise at the Earth station receiver input over a bandwidth Δf , that is, the total space - link noise, is

$$N_T = \eta_{SE}\,\Delta f + KT_E\,\Delta f$$

In regard to the carrier signal power, we have



(Fig. 3.2) Total space - link configuration.

$$C_{SR} = G_U P_{TE}$$

for the carrier power at the satellite receiver input, where

$$G_U = G_{TE}\, G_{RS} \left(\frac{\lambda}{2\pi R_U} \right)^2 \cdot \frac{1}{L_U}$$

from the equation (2-7) we can write that the carrier power at the satellite transmitter output is

$$C_{ST} = G_{SR}\, G$$

Consequently, the total carrier power at the Earth station receiver input is

$$C_{RT} = C_{ST}\, G_D$$

If we call $C_{RE} = C_T$ the total link carrier power at the end of the space link, and therefore

$$\frac{C_T}{N_T} = \frac{C_{ST}\, G_D}{\eta_{SE}\,\Delta f + K T_E\,\Delta f}$$

or by inversion,

$$\left(\frac{C}{N}\right)_T^{-1} = \left(\frac{C_T}{N_T}\right)^{-1} = \frac{\eta_{SE}\,\Delta f}{C_{ST}\, G_D} + \frac{K T_E\,\Delta f}{C_{ST}\, G_D}$$

$$= \frac{G_D\, G\, K T_S\,\Delta f}{G_{SR}\, G\, G_D} + \frac{K T_E\,\Delta f}{C_{RE}}$$

$$\frac{K T_S\,\Delta f}{C_{SR}} + \frac{K T_E\,\Delta f}{C_{RE}}$$

since

$$\frac{C_{SR}}{K T_S\,\Delta f} = \left(\frac{C}{N}\right)_U$$

which is the uplink carrier - to - noise ratio, and

$$\frac{C_{RE}}{K T_E\,\Delta f} = \left(\frac{C}{N}\right)_D$$

which is the downlink carrier - to - noise ratio,

$$\left(\frac{C}{N}\right)^{-1} = \left(\frac{C}{N}\right)_{U}^{-1} + \left(\frac{C}{N}\right)_{D}^{-1} \qquad (3-9)$$

3.2.4 GENERAL LINK EQUATION

Equation (3-9) gives the total carrier - to - noise ratio as a function of the carrier - to - noise ratios of the uplink and downlink. Assume that $\left(\frac{C}{N}\right)_{I}$ is the carrier - to - noise ratio due to intermodulation products introduced by the nonlinear transponder, the total carrier - to - noise ratio will be ,

$$\left(\frac{C}{N}\right)_{T}^{-1} = \left(\frac{C}{N}\right)_{U}^{-1} + \left(\frac{C}{N}\right)_{I}^{-1} + \left(\frac{C}{N}\right)_{D}^{-1}$$

In a similar fashion it can also be deduced that

$$\left(\frac{C}{N}\right)_{T}^{-1} = \sum_{1}^{n} \left(\frac{C}{N}\right)_{i}^{-1}$$

when there are n contributing causes. 1(*)

3.3 Disturbances

Sources of interference consist of a big number amount them the following.

3.3.1 Intermodulation products :

It is due to transponder nonlinearity and depolarization in orthogonally polarized transmission. We can analyse by a simple problem. Assume an output voltage e_o of a nonlinear amplifier in terms of the input voltage e_1 is given by the relationship:

1(*) MANUAL OF SATELLITE COMMUNICATION (from page 113 to page 121)

$$e_0 = K_1 e_1 + K_2 e_2^2 + K_3 e_3^3 \qquad (1)$$

We know that the input consist of two sinusoidals :

$$e_1 = A \cos w_1 t + B \cos w_2 t \qquad (2)$$

The intermodulation products and the suppression coefficient will be derived and we get

$$e_1^2 = A^2 \cos^2 w_1 t + B^2 \cos^2 w_2 t + 2 A.B \cos w_1 t \cos w_2 t \qquad (3)$$

Remembering trigonometrical formulae we can write

$$\cos^2 w_1 t = \frac{1}{2}(1 + \cos 2w_1 t)$$

$$\cos^2 w_2 t = \frac{1}{2}(1 + \cos 2w_2 t)$$

$$\cos w_1 t \cos w_2 t = \frac{1}{2} \cos(w_1 - w_2)t + \frac{1}{2}\cos(w_1 + w_2)t \qquad (4)$$

$$e^3 = A^3 \cos^3 w_1 t + B^3 \cos^3 w_2 t + 3A^2 B \cos^2 w_1 t \cos w_2 t$$

$$+ 3AB^2 \cos w_1 t \cos^2 w_2 t \qquad (5)$$

where

$$\cos^3 w_1 t = \frac{1}{4}(\cos 3w_1 t + 3 \cos w_1 t)$$

$$\cos^3 w_2 t = \frac{1}{4}(\cos 3w_2 t + 3 \cos w_2 t) \qquad (6)$$

If we introduce equations (3) and (5) into (1) and by using simplified equations (4) and (6) we get

$$e_0 = A_1 K_1 \left(1 + \frac{3K_3}{4K_1} A^3 + \frac{3K_3}{2K_1} B^2\right) \cos w_1 t + BK_1 \left(1 + \frac{3K_3}{4K_1} B^2 + \frac{3K_3}{2K_1} A^3\right) \cos w_2 t$$

$$+ \frac{3}{4} ABK_3 \left[A \cos (2w_1 - w_2)t + B \cos (2w_2 - w_1)t\right]$$

$$+ \frac{K_2}{2} \left[A^2 + B^2 + 2AB \cos (w_1 - w_2)t\right]$$

$$+ \frac{K_2}{2} \left[A^2 \cos 2w_1 t + B^2 \cos 2w_2 t + 2AB \cos (w_1 + w_2)t\right]$$

$$+ \frac{K_3}{4} \left[A^3 \cos 3w_1 t + B^3 \cos 3w_2 t + 3A^2 B \cos (2w_1 + w_2)t + 3AB^2 \cos (2w_2 + w_1)t\right]$$

If we assume $w_1 \cong w_2$

$$2w_1 - w_2 \cong w_1 \qquad 2w_2 - w_1 \cong w_2$$

$$w_1 - w_2 \cong 0$$

$$2w_1 + w_2 \cong 3w_1 \qquad 2w_2 + w_1 \cong 3w_2$$

$$e_0 = AK_1 \left(1 + \frac{3K_3}{4K_1} A^3 + \frac{3K_3 B^2}{2K_1}\right) \cos w_1 t$$

$$+ BK_1 \left(1 + \frac{3K_3}{4K_1} \qquad \frac{3K_3 A^2}{2K_1}\right) \cos w_2 t \qquad (7)$$

$$+ \frac{3}{4} ABK_3 \left[A \cos (2w_1 - w_2)t + B \cos (2w_2 - w_1)t\right]$$

In the first and second rows equation (7) gives the fundamentals supressed and in the third row it gives the third order intermodulation product.

3.3.2 Nonlinearities

Several of the devices and components involved in the implementation of the space link exhibit nonlinea characteristics resulting in the generation of intermodulation products within the band of transmission. The more severe nonlinearity is the one exhibited by the transponder power amplifier operated at saturation. In addition the various nonlinearities affect both the amplitude and phase of the modulated carrier. Because of the AM - PM convertion, amplitude effects will be translated in to phase effects and will interfer with angle - modulated signals.

3.3.3 Polarization interference.

For transmission with single polarization, a signal power loss will be experienced because of loss of polarization. In fact, if a rotation by an angle θ takes place, the electric -field component in the direction of the desired polarization will be decreased by a factor $\cos\theta$. The power of the signal will decrease by a factor of $\cos^2\theta$

2(*) MANUAL OF SATELLITE COMMUNICATIONS (page 83 to page 85)

In the case of a dual polarized transmission, an electric-field component will appear in the orthogonal direction. The magnitude of this component will vary as sinO and it will interfere with the main transmission in the other orthogonal mode. This electric - field component should be considered as noise power for purpose of computing the total carrier - to - noise ratio. A reduction of total carrier power will take place because of the cos effect. In the case of broadband transmission, a complete and detailed analysis requires consideration of total power spectrum.

3.3.4 Atmospheric effects.

The atmosphere consists of many elements. Some of them are rain, fog, ionized atmosphere and the troposphere.

3.3.4(i) The rain

In high frequencies, the most severe attenuation is due to the rain.

3.3.4(ii) The fog

For any signal transmission, the fog can create an attenuation.

3.3.4(iii) The ionized atmosphere.

The atmosphere of the earth is partly and not homogeneous ionized by the UV -radiation and X -rays wich mainly stem from sun radiation.

The degree of ionization is expressed in electron density (number of free electrons per m3)

The ionosphere influences radio wave - propagation greatly depending on Electron Density,`frequency and angle of incidence. With higher frequency effects are less but sometimes they are not negligeable with the high frequencies used in satellites application like UHF.

In range - rate the ionized atmosphere causes in increase of velocity with respect to the absolute velocity wich must be known to avoid errors in the processing of the received signals.

In range measurement satellite systems ionization causes a delay in the time of arrival (TOA) of the transmitted pulse.

3.3.5 The troposphere.

The part of the atmosphere exerts a slowing down effect on radio wave - propagation wich does not depend on the frequency in use. Error resulting from this source are only of significance in High Precision Positioning.

3.4 Range Errors

They are three main sources of errors introduced to range measurement in propagation link :

- Ionospheric delay
- Tropospheric delay
- Multipath

Errors due to presence of a finite transmission medium are generated by the ionosphere and the troposphere.

The finite transmission medium produces range bias errors. The signal moving through the medium cuts the ionosphere and the troposphere on diffent angles.

The parth of signals is modified as they travel through the earth atmosphere.

Mathematical models for estimate propagation link delay are established.

3.4.1 The ionosphere delay model.

The ionospheric delay can be calculated as $\Delta R_1 = c.\Delta t_I$
An expression for the ionospheric delay is given as :

$$\Delta R_I = K I_v \left[\operatorname{cosec}\left(EL^2 + 20.3^2\right)\right]^{1/2} \quad .$$

where

Iv - vertical electron content in electron /meter2

K - elevation angle in degrees

K - coefficient depends on L1, L2

L - frequency carrier in hertz.

$$K = \frac{b}{4L^2} \qquad b = 1.6\ 10^3 \qquad (3.1)$$

From the formulae 5.1 we can see how the value of ionospheric delay is varying in function of elevation angle and the total electron content (TEC) in square meter columes along slant range.

The electron density depends on

- diurnal variation (time of day)
- seasonal variation (time of year)
- geographical latitude (equator or pole)
- solar cycle variation (sun spot cycle)

At 90 degrees elevation the ionospheric delay can reach 10 n sec at night time and 50 n sec during day time. It can be larger in regions near the poles and near equator.
At 10 degrees elevation the ionospheric delay can be 3 times the values given, thus 30 n sec at night time and 150 n sec during day time.

3.4.2 Tropospheric delay model

The troposphere code phase delay can be calculated by different formulae.

The value of tronospheric delay depends on elevation angle of the satellite and state of the atmosphere defined by the refractivity index N. For precision receivers the model for tropospheric correction can be approximated to

$$\Delta R_I = c.N.cosecEL \qquad (3.2)$$

where

c - constant - environmental condition. It is equal to 7930 in some receivers.

N - average tropospheric refractivity index.

From the formula (3.2) we can say that errors increase rapidly for angles below 5 degrees.

3.4.3 Multipath errors.

The multipath errors results from more than one propation path that distorsts the antenna characteristic while range are made.

Characterization of multipath error is in practice impossible. The value of errors are dependant on nature of refractive surface and environmental properties surrounding the user antenna. In application to ships receivers, the multipath signal errors depends on the user altitudes, antenna alternations.

The value of multipath error may be expressed in function of atenna haight h and elevation angle of the satellite.

3.5 The user segment errors

Changes in pseudoranges in user receiver are effected by the following reasons :

- satellite movements in space,
- earth rotation effect
- user velocity.

All these effects will contribute errors to range measurements.

CHAPTER IV

INTEGRATION OF COMMUNICATION AND NAVIGATION SERVICES IN THE GEOSTATIONARY NAVIGATION SYSTEM.

4.1 INTRODUCTION.

Mobile satellite communications and Navigation are historicaly, interwined.

Many authors have published ideas aiming at the functional Intergration of communication and navigation subsystems with the advantage the name subsystems and components like transmitters, receivers, antennas can be used more efficiently.

The most important part of multifunction systems is the economy concepts.

In 1983 the Internationale Maritime Organisation instructed its sub- committee on Safety of Navigation to study the development of a world-wide satellite position system for safety navigtion in all areas and providing accurate position information for the Future Global Maritime Distress and safety System.(FGMDSS).1(*) This may require low-cost,reliable and accurate navigation capabilities.

4. 2 POSSIBILITIES OF A LINK.

The idea of a common system is not new.Twenty years ago, experts recognized the link between communcation and navigation and the advantages in establishing a satellite system that could provide both capabilities. In 1966, IMO instructed its subs-committees on radio-communication and safety of navigation to prepare operational requirements respectively for satellite communications and navigation.

1(*) Olof Lundberg - Mobile Satellite Communications and Navigation - The Journal of Navigation - vol.40 No.2

We can mention that in addition to the RDSS and radiodetermination there are still others being proposed or planned in other parts of the world. This proliferation of systems shows no sign of being resolved into a single internationally acceptable system in the near future. In 1986 IMO s Sub-Committee on Safety of Navigation noted that several members were of the opinion that IMO would recognize only one satellite system.

Others considered that IMO should recognize all those systems which were available and which satisfied the operational requirements. If only one satellite navigation system is to be recognized, it seemed to the group that either a new organization would need to be formed to provide, operation and fund the system, or an existing organization, such as INMARSAT would need to be involved.

INMARSAT is the only international organization serving the maritime community and the only one to have the international institutional competence to provide mobile satellite communication and radiodetermination.

4.6 A WAY FORWARD

The problem of the establishment of an international multifunction satellite of communication and navigation is very complex. GPS, Glonass cannot give a solution to that problem. The only solution to that problem is to establish an international satellite navigation system based in the geostationary orbit. So it would be easier to integrate that system and the communication satellite system. A satellite navigation system in the geostationary orbit will be based on the principle of the communication satellite system. A satellite navigation system in the geostationary orbit establish a panel of experts to study the operational requirements of a maritime mobile satellite system. On the other hand, the US Government noted, recent advances in space technology had indicated that satellite systems can play a major role in improving maritime operations in the area of reliable ship-to-shore communications and navigation. These same satellites can also serve as reference performing tone-code ranging experiments at L-band with its ATS5 satellites which showed that range measurements from geostationary satellites are a practical way to locate aircraft, and other vehicles between the latitude of 75 degrees north and south except that position fixes cannot be determined within about 5 degrees of the Equator.

The links between mobile communication and navigation were even more explicit when the USSR submitted a paper to the panel of experts in 1973 in which reference is made to the proposed satellite system "The International Maritime Satellite Communication and Radiodetermination System".

In March 1973, the US had presented a paper to the panel of experts in which it urged that "the provision of radiodetermination facilities by the first phase maritime satellite system should be given full consideration by the panel of experts".

In 1975 IMO convened an International Conference on the establishment of the maritime satellite system. It was noted that the design of the first phase should allow for the possible addition of radiodetermination facilities in the later phase of the system. We should mention that the relaying of radiodetermination signals will utilize the normal satellite channels and will have negligible impact on the space segment.

4.5 PROLIFERATION OF SYSTEMS

operate in frequency near those of GPS. Like GPS it is a broadcast system which could accommodate an infinite number of users. It is also life GPS in that it is a system developed primarily for the military, but which would also be a candidate for use by the international civil aviation and maritime communities. The plan to phase out other US operated systems in favour of GPS has generated a certain amount of controversy by relating to cost accuracy, international acceptance, coverage, etc.

First, GPS receivers are expensive, ranging from about $100,000. These costs, however, will undoubtedly drop markedly with volume production.

Second is the function of user fees. The US Department of Defence is expected to spend several billion dollars by the time GPS is fully operational. Initially, Congress wanted to recover some of those expenditures by levying fees on civil users of GPS. Subsequently, Congress changed its collective mind and now says civil use will be free of charge, although it retains the option of changing its mind again.

A third resource of controversy has been the accuracy of the GPS. Military users will use the precise positioning service (PPS) to achieve position fixing with accuracy. For national security reasons, civil accuracies have been restricted to about 100 m, using the standard positioning service (SPS).

A fourth source of controversy would be prepared to accept a system, whether GPS or Glonass, which is under the control of a single country, and its military at that.

In 1972 the IMO Maritime Safety Committee agreed to

4.3 INMARSAT PURPOSE

The purpose of the Organization is to make provision for the space segment necessary for improving maritime communication thereby assisting in improving distress and safety of life at sea, communication, efficiency and management of ships, maritime public correspondance services and radiodetermination facilities. So the nations of the world adopted a convention which gave INMARSAT the competence to provide both maritime satellite communication and radiodetermination capabilities.

4.4 ADEQUATE SYSTEM FOR INTEGRATION

In the INMARSAT Actual section 507, it was said that a study was to be undertaken of all government fundell radionavigation systems to determine the most effective manner of reducing the overlap of such system . Nowadays many systems have to be phased out. Among them Omega, Loran-C and transit. Their replacement should be the global positioning system (GPS), also known as NAVSTAR, which will eventually comprise a constellation of 24 satellites in circular orbits at 20,000 km altitude. The system would allow users to determine their precise location, spaced and time using passive receivers, each of which would have a built-in computer to perform the timing and triangulation. 2(*)

The USSR is developing a similar system, a 12 satellite constellation known as Glonass, to succeed its Tsikada (Yakuchenko) satellite system, which is comparable to the US transite.

--------2(*)Olof Lundberg - Mobile Satellite Communication - The Journal Navigation, Vol. 40, No. 2.

Glonass uses spread-spectrum techniques and would will be based on the principles of the communication satellite system. The both systems may have many common characteristics. Different ways for integration of both systems will be as follows:

4.6.1 Position Reporting

Both the navigation and communication systems require schemes of automatic position reporting and polling of the mobiles from authorities from the ground. A two-way system would derive position information from the satellite navigation system relay and the information to/from the mobile satellite communication to a central control station. The new mobile Earth station known as "Standard C" developed by INMARSAT will be able to solve this problem. The automatic position reporting and polling capabilities could find much wider application if vessel reporting systems which are administered by numerous national administrations around the world had a universal format and access arrangements to enable the data to be automatically transmitted, entered into the host computer and processed.

4.6.2 Ranging

Ranging measures the time it takes for a radio signal to travel between the vehicle, ship and a satellite. From the line taken the distance can be computed. Range measurements from the two or more satellites can be used to determine the position of the mobile. With two satellites, a two-dimensional fix can be derived as well.

4.6.3 Integrity channel

An "integrity channel" should be also very important for assisting an international navigation. An integrity channel would make it possible to indicate in short time period any system satellite malfunction so that the mobile does not obtain an erroneous position.

4.6.4 An International framework.

For a long time, the world has learned to live with systems which were developed by the US military. Today there is still concern in the international community absent accepting a system which is under the control of a single country and under the control of its military at that.

A system under international control is based on the following requirement.

1) The user wants a system (or choice of system) that is global, reliable available, and sufficiently accurate to meet his needs. Preferably, the system should be cheap, automated and easy to use. He wants a sense of continuity. The stability of an internationally supported system which connot simply be turned on or of at the volution of one country.

2) Governments want a system that is universal, non discriminatory, available to all. They want oversight and control over the system, rather done a system over which they have no control. They must recognize that they may have to pay for the degree of control they want.

3) The service providers want someone to pay for the system or services they offer. They could be funded by governments by civil agencies or the military by a slice of the port charges or by users themselves.

In the end someone pays, and it will be either the user or the taxpayer.

The international community might well give serious consideration to support of INMARSAT, and its various plans for providing radiodetermination and navigation services, and devising appropriate funding formulas.

CHAPTER V

GENERAL CHARACTERISTICS OF SATELLITE BASED ON THE GEOSTATIONANY ORBIT.

5 .1 INTRODUCTION.

A satellite based on the geostationary orbit will travel once around the earth in same time that the earth takes to complete one rotation. If the satellite travels in the same direction as the earth's direction of rotation its remains over the same poit on the equator and appears stationary to an observater on the ground. For a total coverage of the globe three satellites located at the vertces of an equilaterial triangle with sides of 88,000 km are sufficient .

Because of the large distances which are traversed, the signals received on earth and at the satellite are very weak indeed. In fact, for the signals to be usable they have to be amplified several hundred thousand million times at the satellite before transmission. In order to avoid interference between the weak incoming and the stronger outgoing signal, the frequency is changed before retransmission.For performing amplification and frequency conversion a transponder is placed on-board satellite.

To summarise,we can mention two essential components of a geostationary satellite:

- a satellite positioned in geostationary orbit able to receive,amplify and change the frequency of a radio frequency signal before retransmitting it;
- earth stations suitably equipped to transmit and receive signals to and from nominated satellites. The satellite system based on geostationary orbit consists of:

- ground segment
- space segment
- user segment

working together permit the fixing position and the provision of communication and other services.

5.2 Ground Segment

The ground segment of a satellite based on the geostationary orbit consists of the earth stations, the terrestrial distribution, and the network control facility.Earth stations on their more common configuration utilize an antenna system with a solid dish, a microwave feed, a pedestal and equipment for adjusting the dish orientation in azumuth and elevation.

The earth station will consist of benchmark transceivers. These transceivers will located in the coverage area. By using these transceivers we will reduce errors by minimizing propagation errors,compensating the imperfect knowledge of the earth's shape,and accounting satellite location uncertaintly.

The control center will consist of antenna systems. Each antenna can be dedicated to each satellite. All transmissions between users will be passed through the control center due to the network control facility. The network control facility permits low powered andd low cost transceivers to communicate each other.The control center's high speed computers will calculate user position and transmit it with any accompaning messages to the addressed users.

For a total coverage of the world,we need 2-3 control centers which will be able to access each satellite. A number of six satellites can be used.

5.3 User Segment

The user segment comprises users on land, sea and air. There are receivers capable of tracking at least satellilte signals.

The user set consists of:

- an antenna
- a receiver
- a data processor with software.
- a control display unit.

5.4 SPACE SEGMENT

The space segment will consist of 6 satellites at the height approximately equals to 36,000 km. The orbital period is about 24 hr so that satellites will appear to be stationary as viewedfrom the earth.

The satellite will carry transponders, broadcasting to the earth signals received from the ground stations.

The system concept will be designed so as to allow a likely satellite lifetime more than 10 years .

For the need atotal coverage , 3 northern and 3 southern Molnya-type can be added.

5.5 ACCURACY AND LIMITATIONS OF POSITIONING WITH TWO GEOSTATIONARY SATELLITES

The positioning accuracy requireménts vary upon the technical characteristics of the satellite and on the services being provided.

In satellite of navigation the accuracy depends upon:

- UERE:user equivalent range error;
- angle of elevation of the satellite;
- bearing of the satellite .

For obtaining R95,the following formula is used

$$R95 = \frac{2\ UERE\ (\sec^2 EL1 + \sec^2 EL2)^{1/2}}{\sin(B2 - B1)}$$

where

EL1 = elevation angle satellite 1

EL2 = elevation angle satellite 2

B1 = bearing satellite 1

B2 = bearing satellite 2

The UERE is chosen equal to 30m as in geostar system

Using two SVs for the purpose an accurate two-dimmensional position can be obtained,provided the geometry of the SVs is sufficient.

With different longitude differences (Δ Long) results obtained are represented by figure 1 to 12.

The figures are obtained by solving equation above All figures represent the areas where the satellites are seen with an angle of Elevation between 5 degrees and 70 degrees and with diffent positions of satellites. R95 in each area is equal or less than the required by IMO.

Fig.1 is obtained with Long = 10 degrees
Fig.2 ---------------- Δ Long = 20 -------
Fig.3 ---------------- Δ Long = 30 -------
Fig.4 ---------------- Δ Long = 40 -------
Fig.5 ---------------- Δ Long = 50 -------
Fig.6 ---------------- Δ Long = 60 -------
Fig.7 ---------------- Δ Long = 70 -------

Fig.8 ---------------- Δ Long = 80 --------

FIg.9 ---------------- Δ Long = 90 --------

Fig.10 --------------- Δ Long = 100 -------

Fig.11 --------------- Δ Long = 110 ------

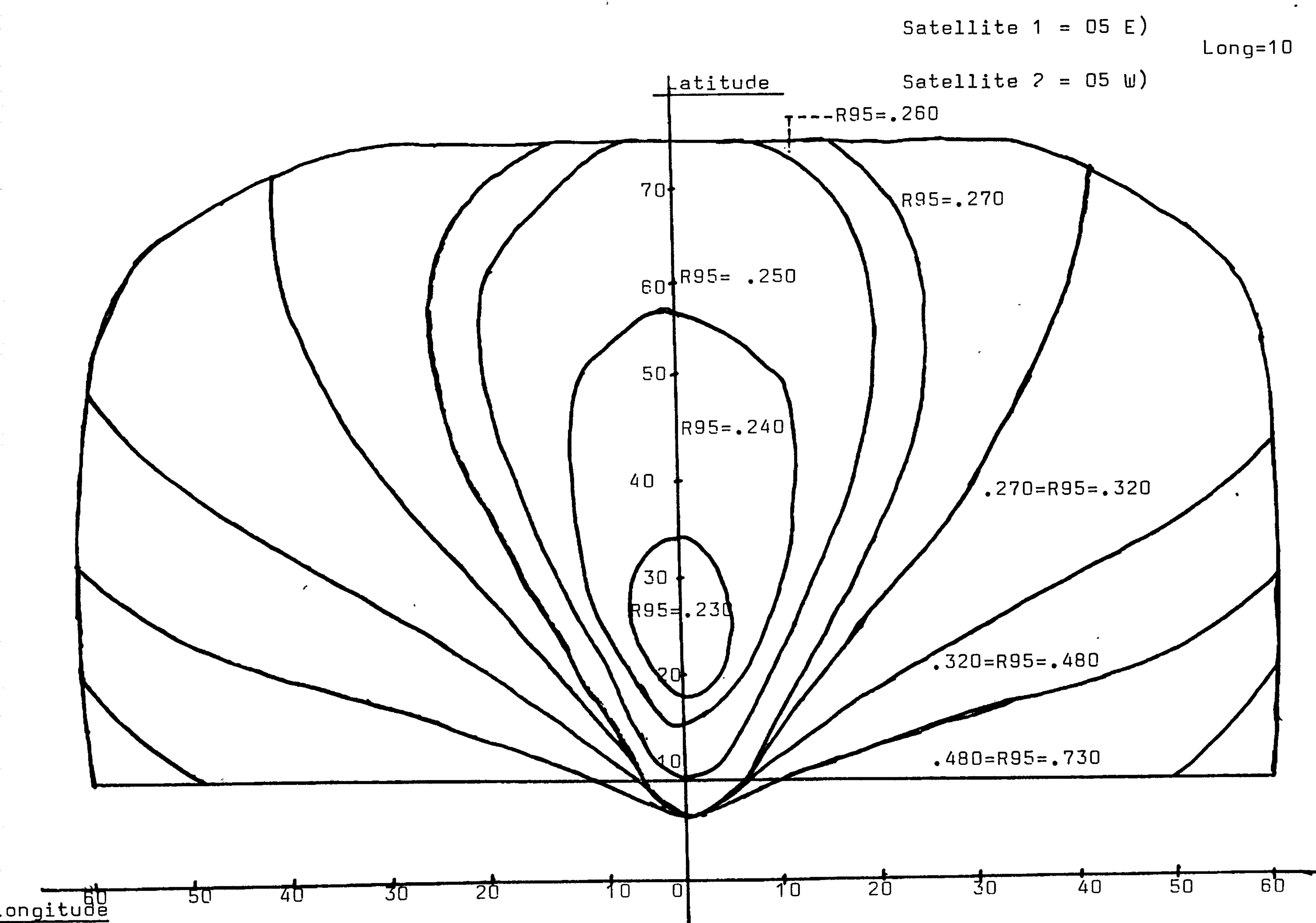
Fig.12 --------------- Δ Long = 120 ------

We can notice that the area decreases when increases Long but the values of R95 at the same time are decreasing.

After comparing all results obtained,it is shown that with a longitudinal difference (Δ Long) of 60 ,the accuracy obtained is high (R95 < 100m) and the area of coverage os also acceptable.(see fig 6). The satellites position is 30 degrees E and 30 degrees W.

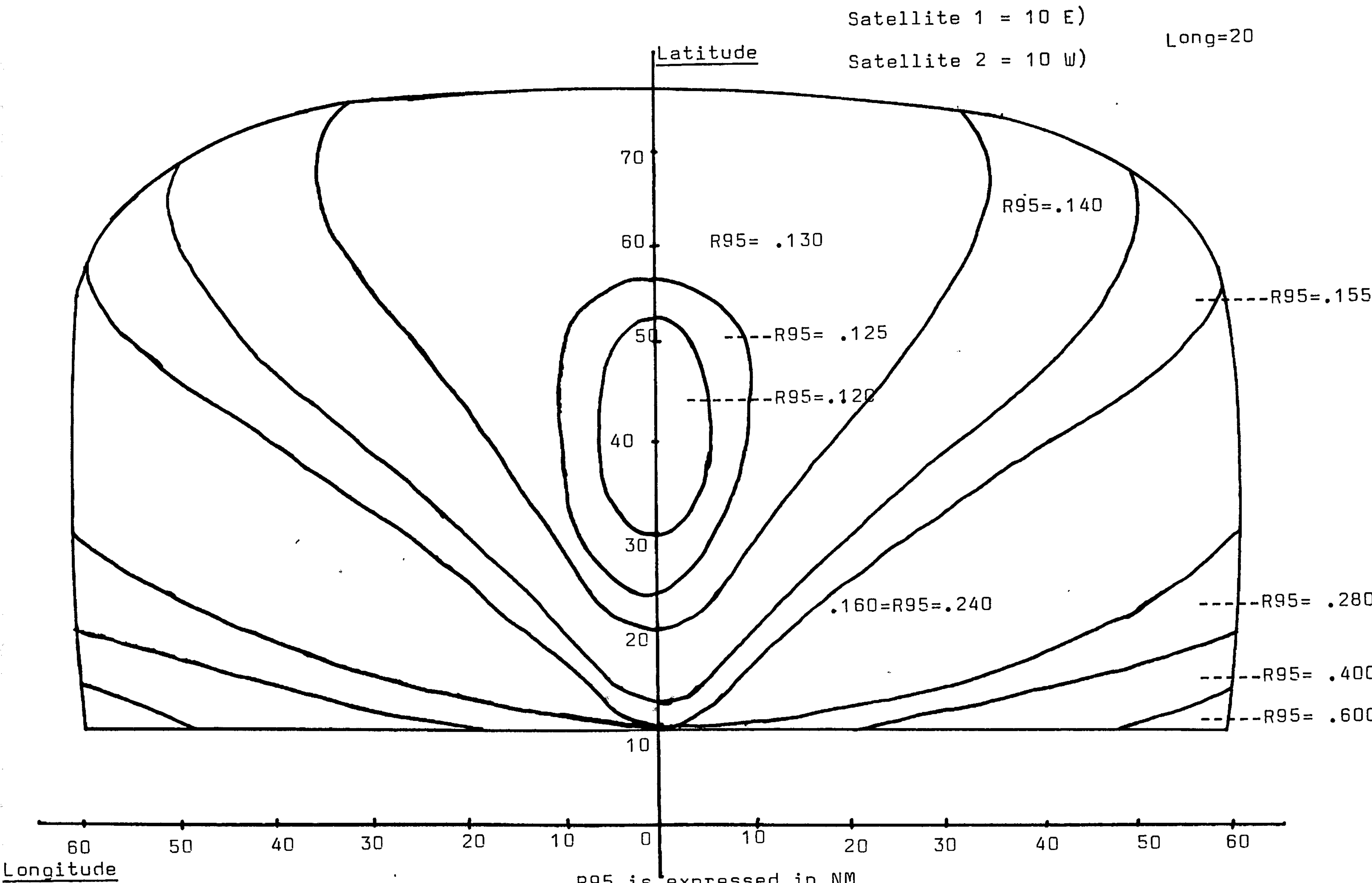
The conclusion from fig.6 is that in the equatorial region between latitudes 10 degrees N and 10 degrees S and latitudes higher than 70 degrees N and 70 degrees South, positioning is not possible.

For the uncovered areas it can be provided by expanding the system to a total of 6 geostationary satellites and 3 northern and 3 southern Molnya-type satellites.



R95 is expressed in NM

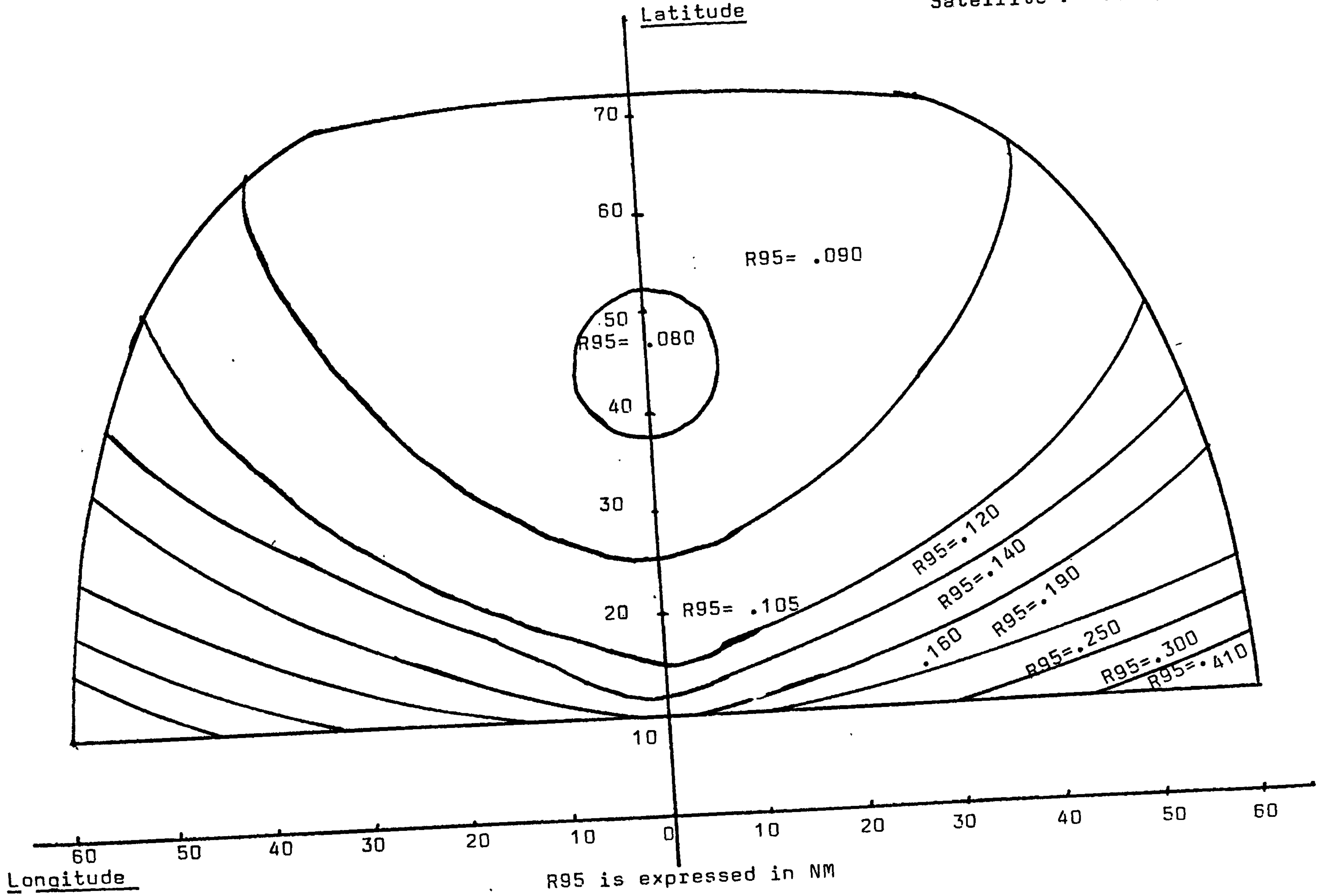
(Fig.1)



R95 is expressed in NM

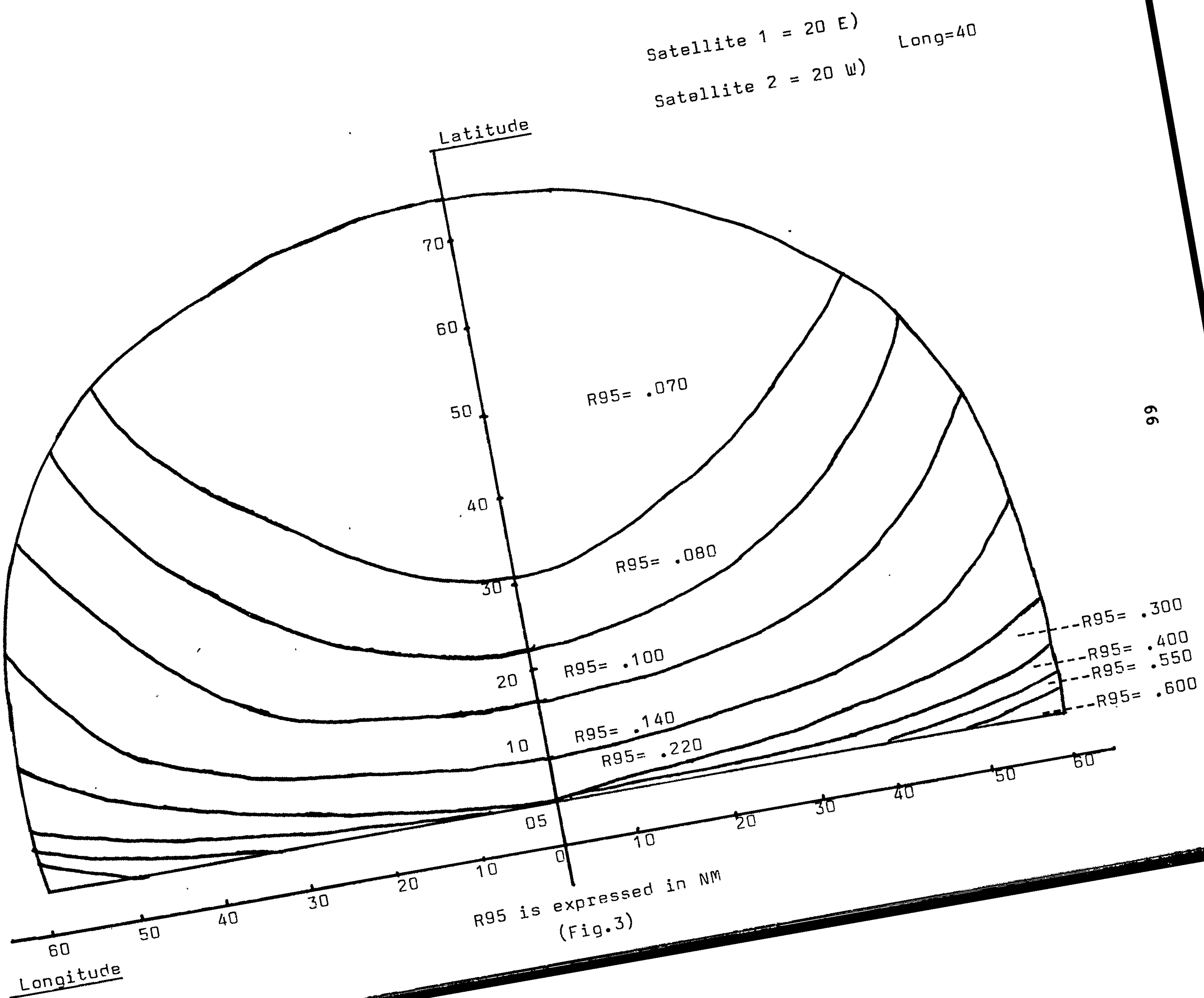
(Fig.2)

satellite 1 =15 E)
Satellite 2 =15 W)
Long=30



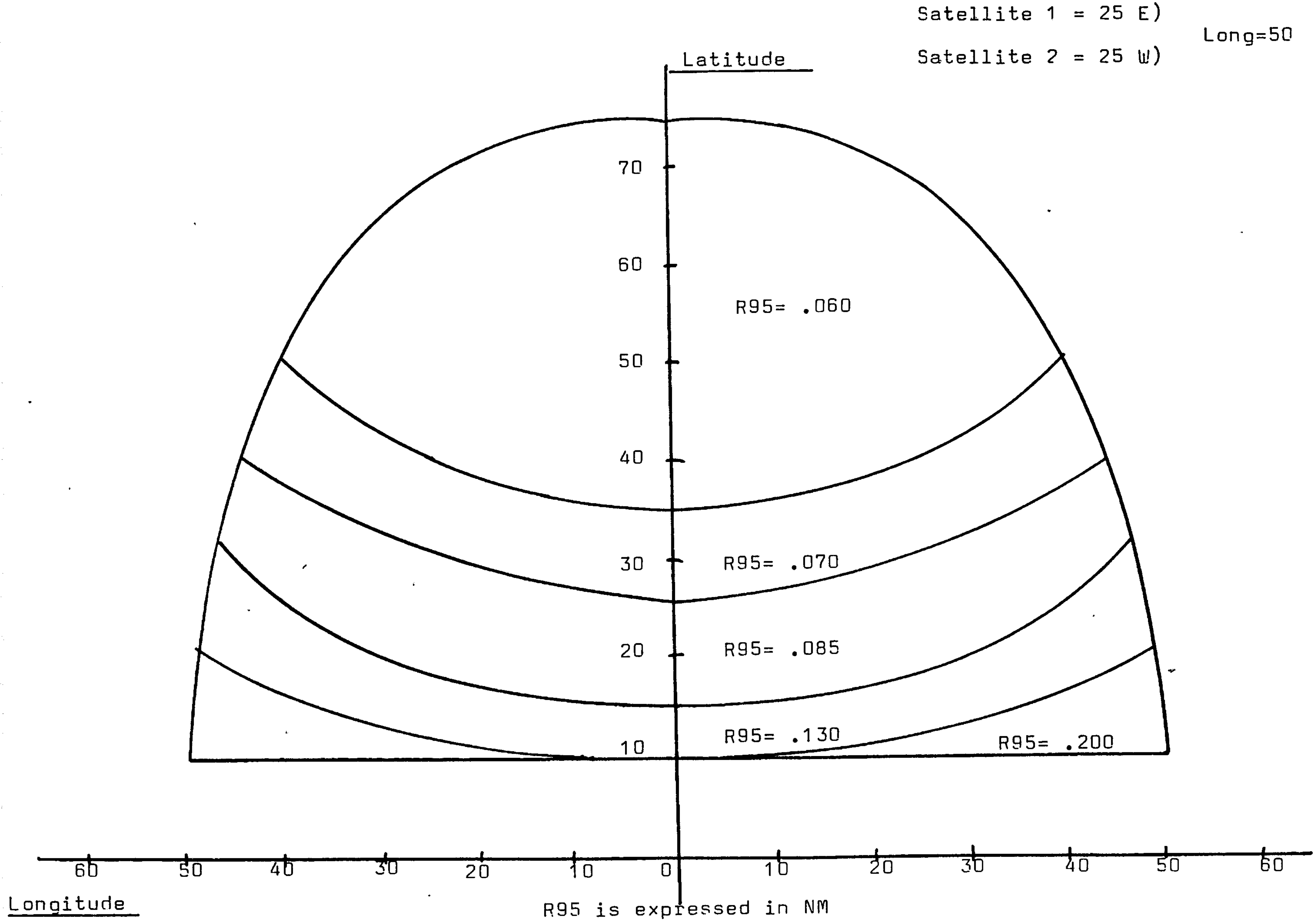
R95 is expressed in NM

(Fig.4)



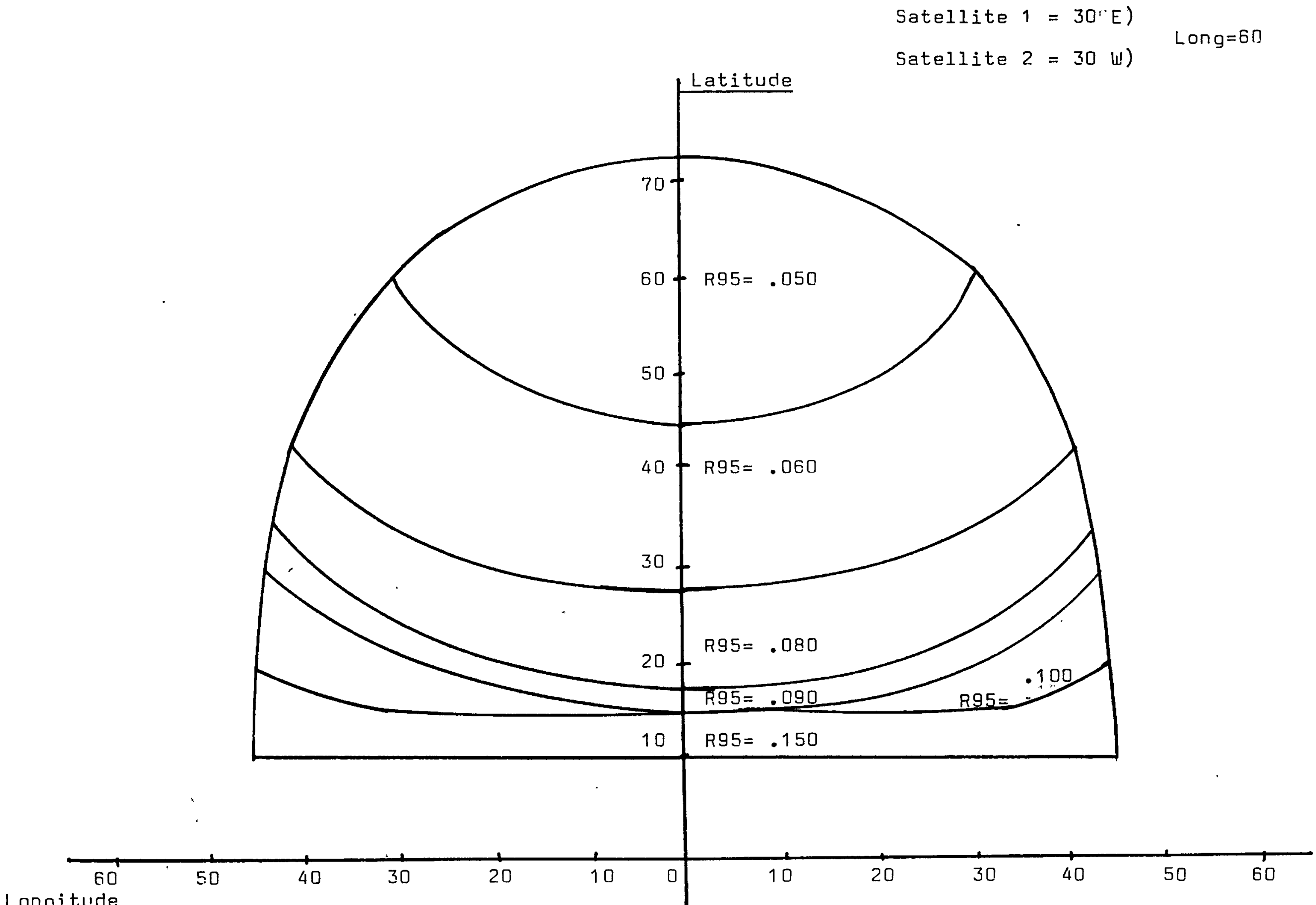
R95 is expressed in NM

(Fig.3)



R95 is expressed in NM

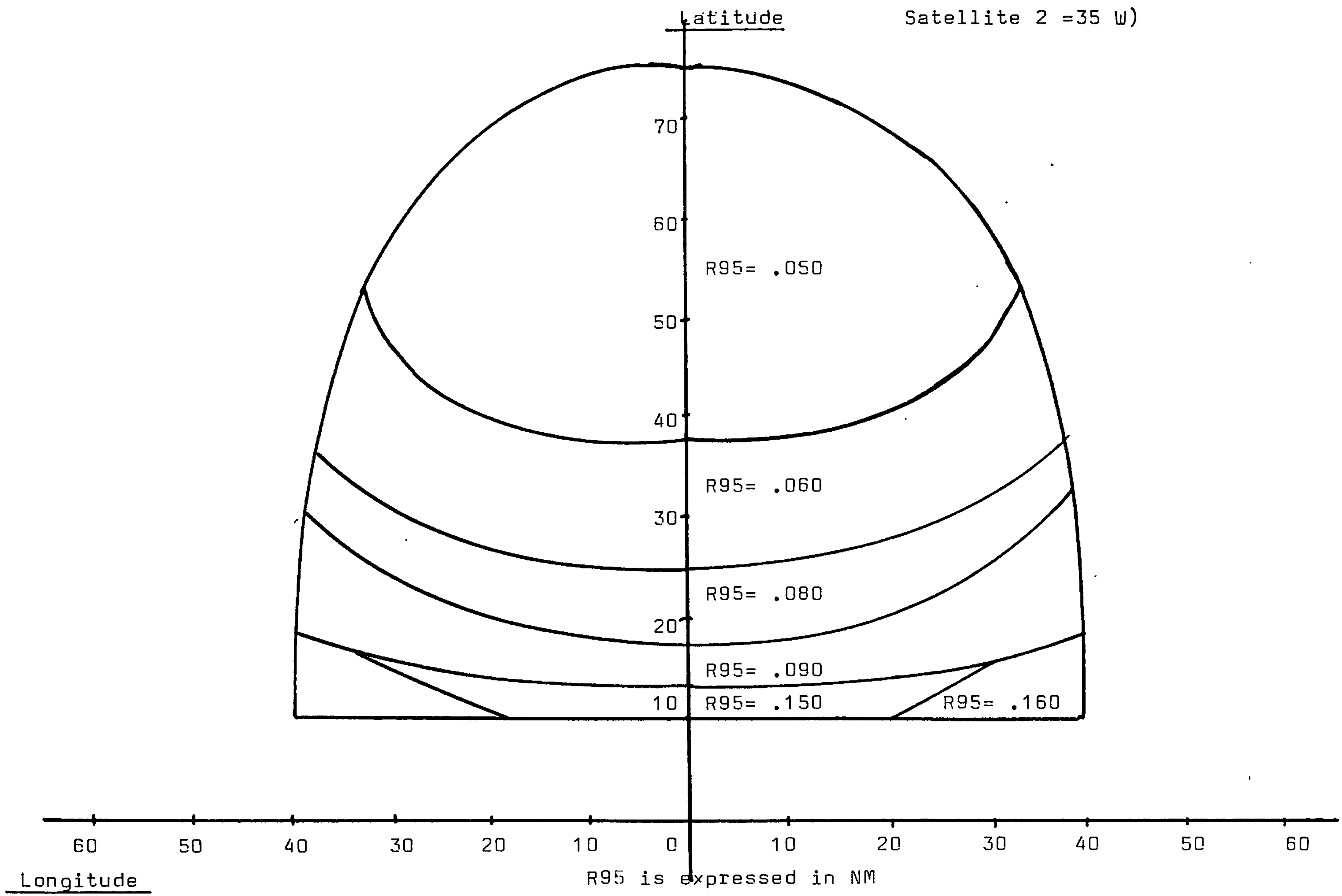
(Fig.5)



R95 is expressed in NM

(Fig.6)

Satellite 1 =35 E)
) Long=70
Satellite 2 =35 W)

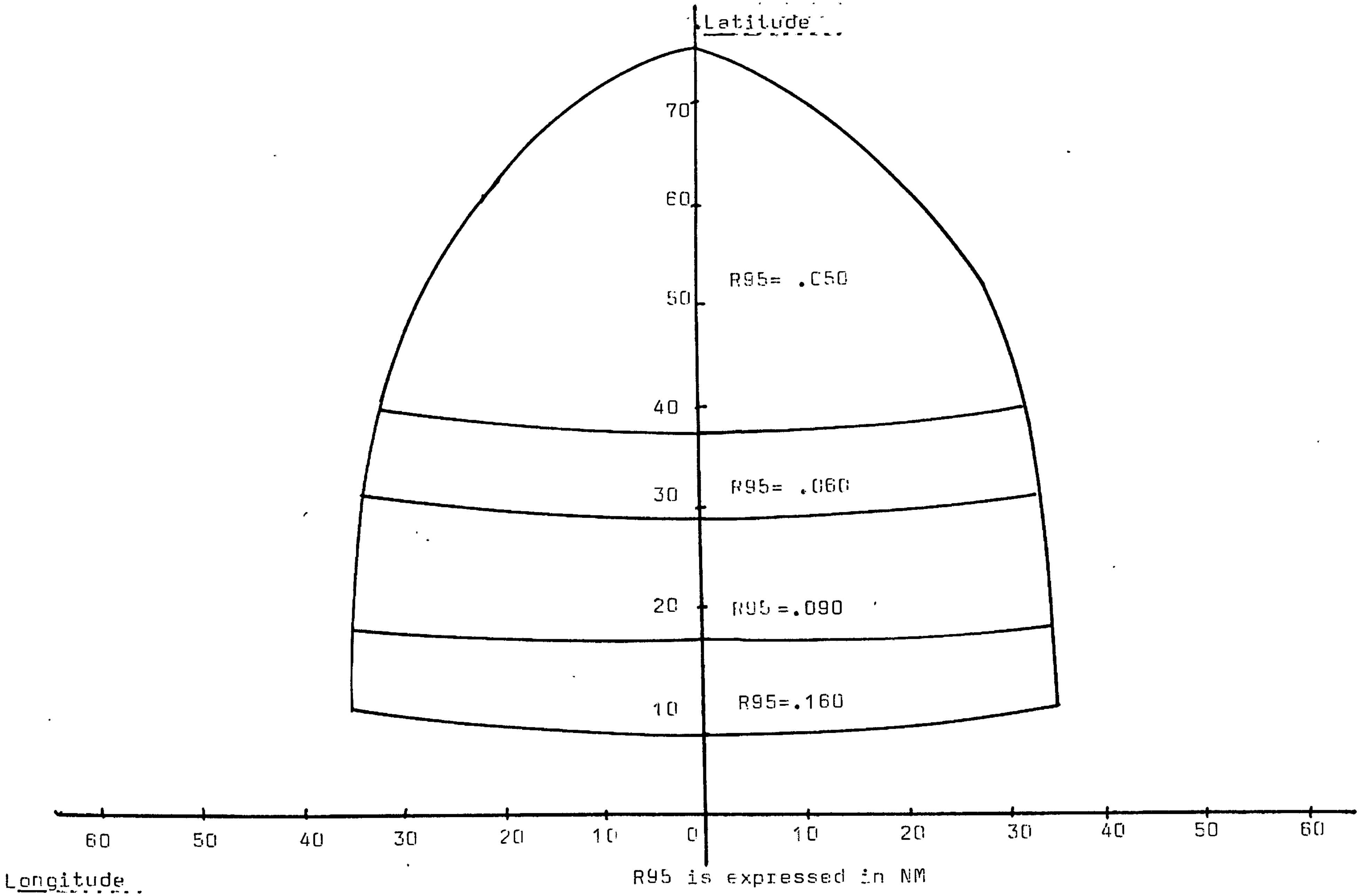


R95 is expressed in NM

(Fig.7)

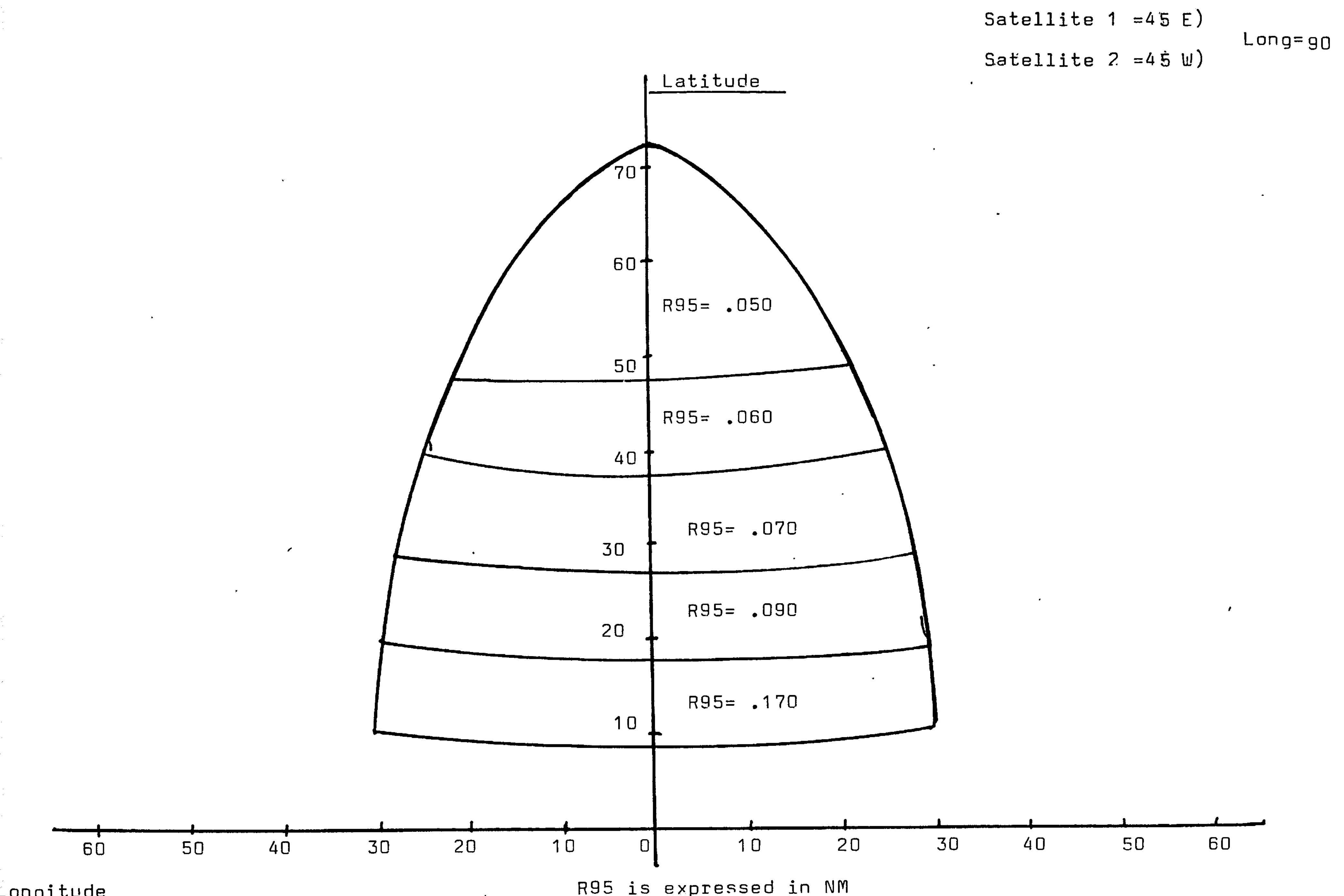
Satellite1 = 40 E)
Satellite2 = 40 W)

Long=80



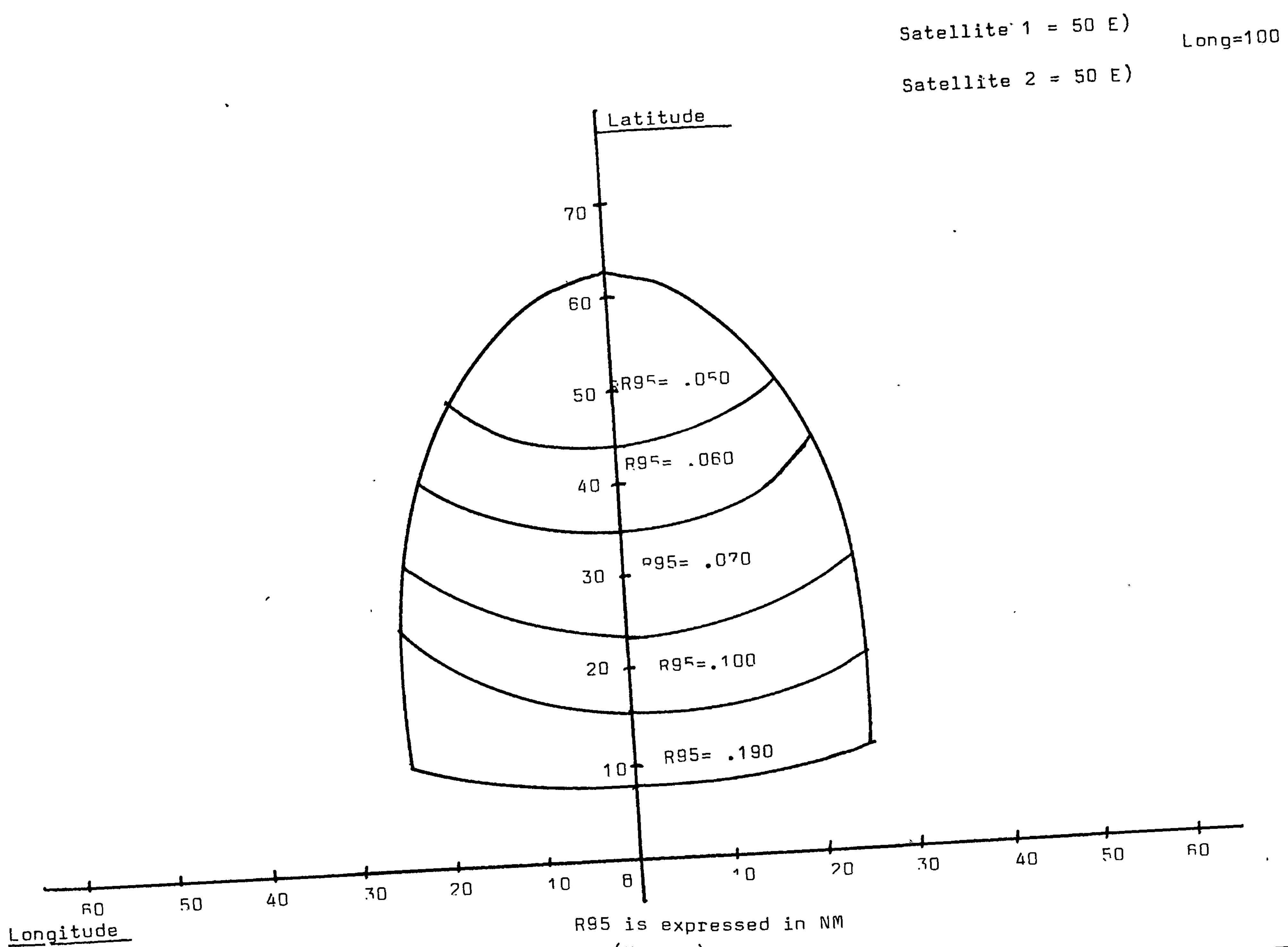
R95 is expressed in NM

(Fig.8)



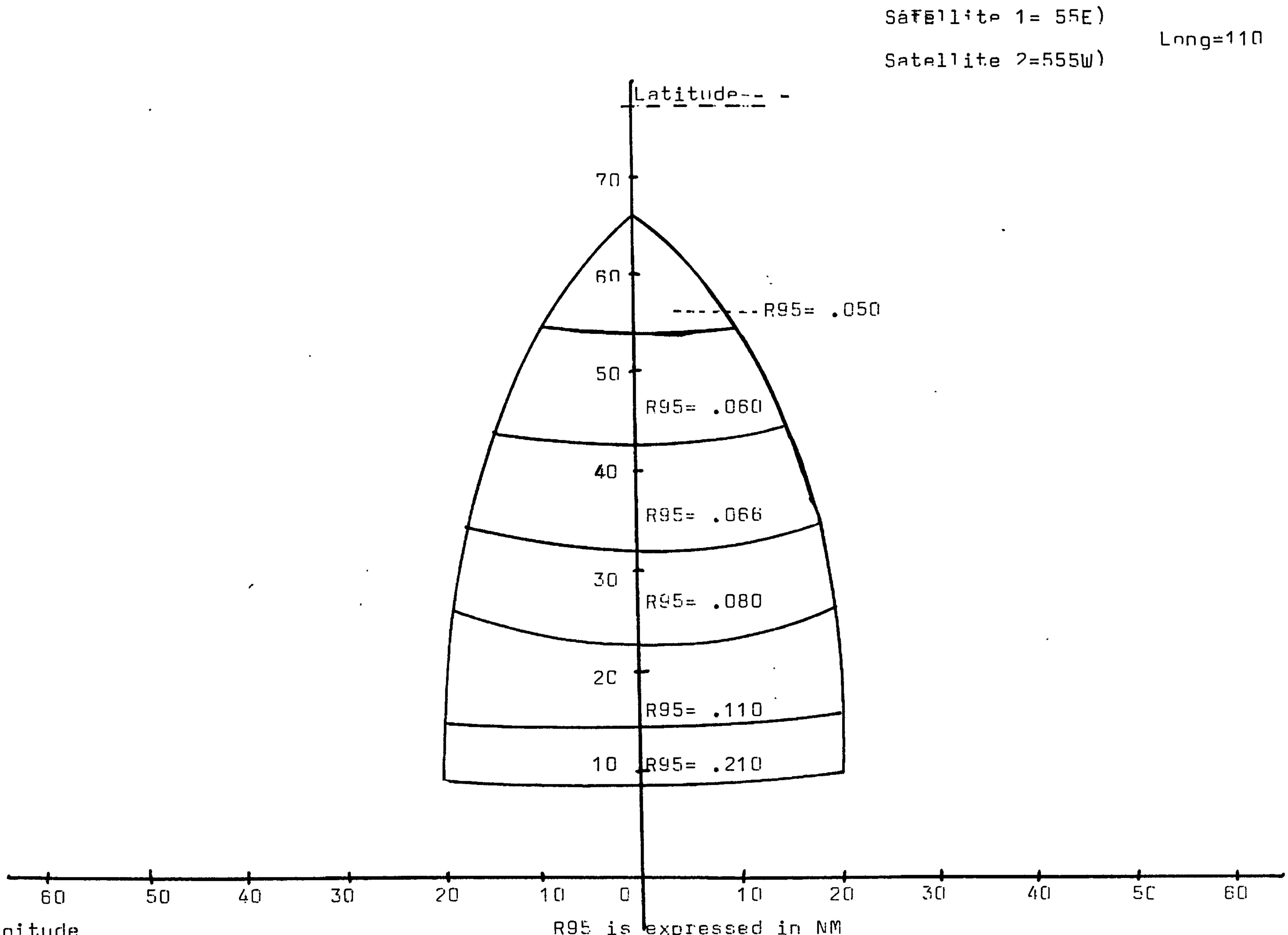
R95 is expressed in NM

(Fig.9)



R95 is expressed in NM

(Fig.10)

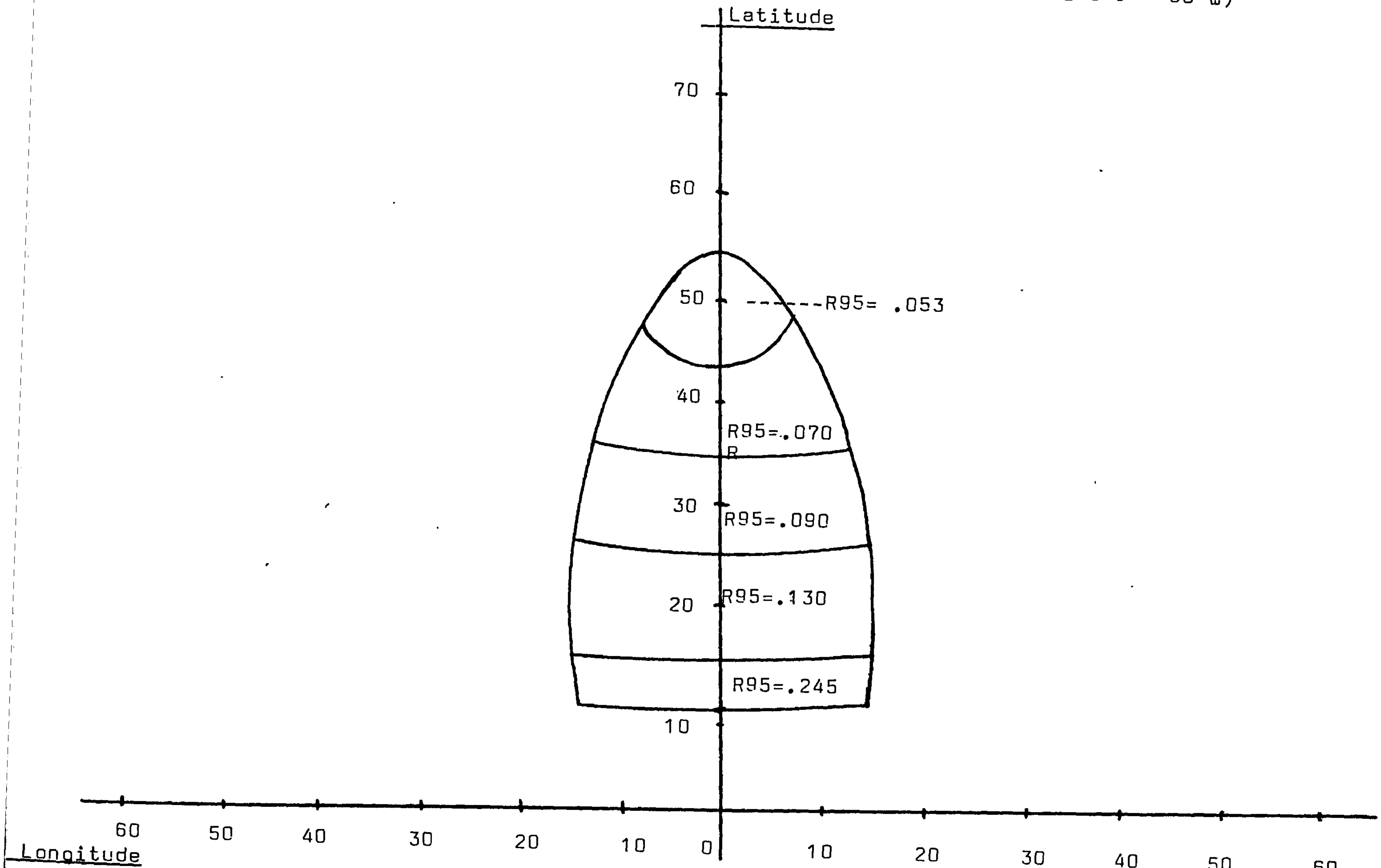


R95 is expressed in NM

(Fig.11)

Satellite 1 = 60 E)
Satellite 2 = 60 W)

Long=120



R95 is expressed in NM

(Fig.12)

For the uncovered areas it can be provided by expanding the system to a total of 12 geostationary satellites and 3 northern and 3 southern Molnya-type satellites.

CONCLUSION.

There is no doubt that a satellite _ based navigation system is the feasible solution able to satisfy the growing needs of the mobiles user population . There is also no doubt that mobile communication beyond the area of visibily of the geostationary orbit are required to that degree that such a mission cannot justify on economic grounds a dedicated satellite system. Since both functions (navigation and mobile communication) serve the same user population, it seems logical therefore that they should be combined.

It is not necessary to underline here once again that only an integrated satellite system of communication and navigation based on geostationary orbit can be accepted as a international system.

It is known that the large majority of land mobile users is situated withing the area of visibility of geostationary satellites. Hence, non _ geostationary satellites are not necessarily required.

The results obtained in this paper have shown that a geostationary satellite navigation system will encounter certain limitations in position _ fixing.

For local use, there is practically no problems because it gives a high accuracy. However for worldwide use the system possesses some limitations. In high latitude of more than 70 degrees, the system is practically unusuable.

To solve this problem of limitation of latitude it would suggered that six complementary satellites should be added: three covering the North pole and three others the South pole. For that the principles used in the Russian

MOLNYA satellite system might be an adequate solution.

In order to avoid any kind of problem which may act in preventing the establishment of a worldwide system it would appear that the best approach should be to have such et system controlled by an appropriate internationally accepted operational agency. At the present time only one such agency seems to have the credentials with the structure, credibility and the required charter and this is INMARSAT.

As the system will be also used for communications the navigation costs will be less than those for other systems discussed previously. The navigation receiver will be on integral part of INMARSAT Receiver. From a commercial point of view, the system is attractive because user fee can be collected.

BIBLIOGRAPHY

1 - Introducing Satellite Communications.
G. B. BLEAZARD.

2 - Electronic Aids to Navigation.
L. TETLEY and D. CALCUTT.

3 - Manual of Satellite Còmmunications.
EMMANUEL FTHENAKIS.

4 - The Intelsat Global Satellite System.(volume 93)
JOEL ALPER and JOSEPH N. PELTON.

5 - Communications Satellite Systems.
JAMES MARTIN.

6 - The journal of navigation vol.40 N.2

7 - Maritime Satellite Communications (INMARSAT).

8 - OCEAN VOICE (The journal of maritime satellite communications).

9 - SYLLABUS "SAtellite for navigation and position fixing" (WORLD MARITIME UNIVERSITY).
J.H. MULDERS and capt. M. JURDZINSKI

10 - Conference on Global Civil Navigation Systems 1984.
Royal Institute of Navigation.

11 - Conference on "Navigation into the 21 century"

Royal Institute of Navigation.

12 - The Future Navigation Syllabus of Maritime Training Institutions (WORLD MARITIME UNIVERSITY).
J.H. MULDERTS and capt. M. JURDZINSKI.

13 - Satellite Navigation. The scope for civil systems. (Interavia . eng . edit) GENEVA , December 1983.
By CAM'S BULLOCH.

14 - The PLAIN NAVIGATOR'S GUIDE to GPS (Navigation News. Volume 1. Ussue 4 , July 1986).

15 - GPS Differential (WORLD MARITIME UNIVERSITY . MALMO 1987).
By capt. M. JURDZINSKI.

16 - "Error Analysis of Position Fixing Systems and Methods".
By J.H. MULDERS.

17 - A Review of Navigational Techniques. (Radio and Navigation Department, Royal Aircraft Establihment. U.K)
By W.J. COUPERTHWAITE.

18 - The Geostar System.(paper submitted to Institute of Navigation, LONDON) 2 / 1 / 84.

19 - Interet d'un complement geostationnaire au system NAVSTAR (GPS).
Par M.L BERTHAULT et Y . LABASQUE.

20 - Technical Requirements for Enhanced Group Call Ship

Earth Station Receiver for Sea Trial Use.
INMARSAT. (Issue 1 . June 1986)

21 - INMARSAT STANDARD - C System defination Manual
Issue N.2.3. August 1986