Comparision of the Probability of Visibility of the Most Important Currently Projected Mobile Satellite Systems

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Abstract

During the next years a number of mobile satellite systems (MSS) for low earth orbits (LEO) and for medium earth orbits (MEO) will be available for global personal communications. The most important currently projected systems are Iridium, Globalstar, Odyssey, ICO (formerly Inmarsat-P), and Teledesic. These systems will provide mobile communication from any place on the earth to any person at another place on the earth. A main performance parameter of these systems is the visibility of satellites. Additionally for MSS without intersatellite links (ISLs) it is necessary, that a satellite always has one earthstation in view. In this paper the probability of visibility for different elevation angles will be presented for the named systems. The connection between the probability of visibility, the elevation constraint and the service radius is shown for the named systems without ISLs (Globalstar, Odyssey, ICO).

I.INTRODUCTION

Global personal communication systems (PCS) will consist of a personal communication handset that will provide communication services like voice, paging, data, messaging, fax, and geolocation via mobile base stations in an urban environment and via satellites where earth based communication systems are not available. Terrestrial and space based segments will be integrated globally in order that a person will be able to use a single handset to communicate from any place on the globe to any person at any other place on the globe and beyond.

A number of mobile satellite systems (MSS) for low earth orbits (LEO) and for medium earth orbits (MEO) have been proposed such as Iridium [1,3,8], Globalstar [4,8], Odyssey [5,8], ICO (formerly Inmarsat-P) [8], and Teledesic [10].

These systems will archive global coverage with acceptable elevation angles. The performance of these systems is primarily dependent on the probability of visibility and the elevation limit. The probability of visibility should be 100 % over a wide range of elevation limit where continious voice services are provided and should be 95 % where only data services are provided.

A critical parameter for the economies of MSS without intersatellite links (ISLs) is the number of earthstations that serve the system. The Iridium and Teledesic systems will have ISLs, the other MSS will not have ISLs. For systems with ISLs the messages are routed through direct connections between satellites in the same and in adjacent orbits whereas for systems without ISLs the messages of a user are transmitted to an earthstation and then into the terrestrial network or back to the satellite. Hence MSS without ISLs must see an earthstation. Therefore the earthstations must be distributed in a way, that at all times each satellite, used for communications, must have a connection to an earthstation. To calculate the distribution of earthstations the probability of visibility dependent on the elevation constraint and the service radius must be computed.

This paper is divided in two parts. In Section II-A we present the simulation results of the probability of visibility (POV) for different values of elevation angles for the named MSSs. In Section II-B we show the results of the POV for simultaneous visibility for the systems without ISLs (Globalstar, Odyssey, ICO). Both simulation methods have been implemented in the satellite simulation software system SatLab [6], which is used for this investigation

II.SIMULATION RESULTS

A. *Results for the probability of visibility for different values of the elevation angle*

In order to compute the probability of visibility of the named LEO and MEO satellite systems, a large number of users are distributed over the globe between latitudes ±60 deg for Iridium, Globalstar, Odyssey, ICO, and ±70 deg for Teledesic and are simulated for the named MSSs over repetitive time periods (with small time steps). Elevation angles from these user locations to the satellites are computed together with their statistics. The calculations are performed for multiple visible satellites (2,3,4).

(1) Results for Iridium

Motorola's Iridium [1,3,8] satellite constellation, based on the orbit design of [2] is to provide mobile satellite service for hand-held personal telephones. The used protocol is FDM/TDMA. Iridium will have 66 satellites in 6 orbital planes with a near circular polar constellation at an inclination of i=86 deg and an altitude of h=780 km. Figure 1 shows the POV as a function of elevation limit for one, two, three, and four satellites for latitudes of ±60 deg. The minumum elevation angle of Iridium for a POV of 100 % of one satellite is θ=8.2 deg. For a POV of 95 % the minimum elevation angle is θ=12 deg. The POV decreases for increasing elevation angles.

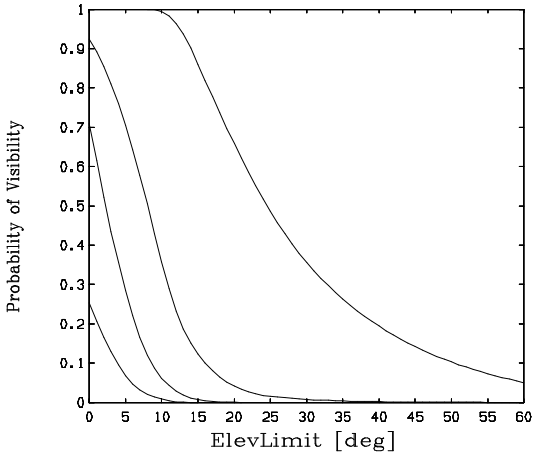

Fig. 1: Probability of visibility of Iridium for different elevation limits

(2) Results for Globalstar

The Globalstar satellite constellation [4,8] is a Walker-Delta configuration [7] of 48 satellites in 8 orbital planes at an altitude of h=1408 km which is optimized for operations in the areas of the main population centers between -70 degrees and + 70 degrees latitude. Globalstar will use the CDMA protocol. Figure 2 shows the POV over the elevation limit for one, two, three, and four satellites for latitudes of ±60 deg. The minimum elevation angle for a POV of 100 % of one satellite is θ=15 deg. This value is larger than the value of the Iridium MSS. The minimium elevation angle for a POV of 95 % is θ=21 deg. For two satellites the minimum elevation angle for a POV of 100 % is θ=5 deg.

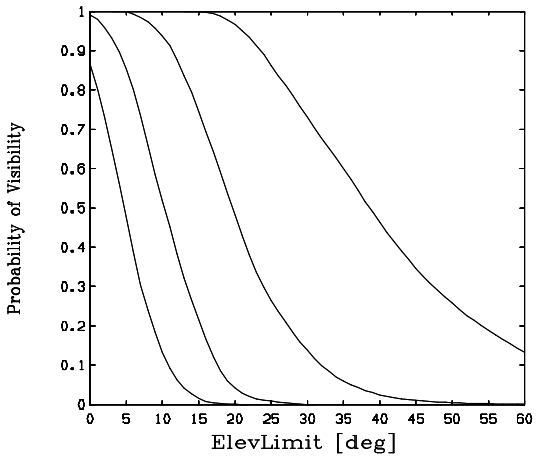

Fig. 2: Probability of visibility of Globalstar for different elevation limits

(3) Results for Odyssey

In contrast to Iridium and Globalstar Odyssey [5,8] is a MEO system. It will consist of 12 satellites in 3 orbital planes with an inclination of i=55 deg and an altitude of h=10354 km. Odyssey will also use the CDMA protocol.

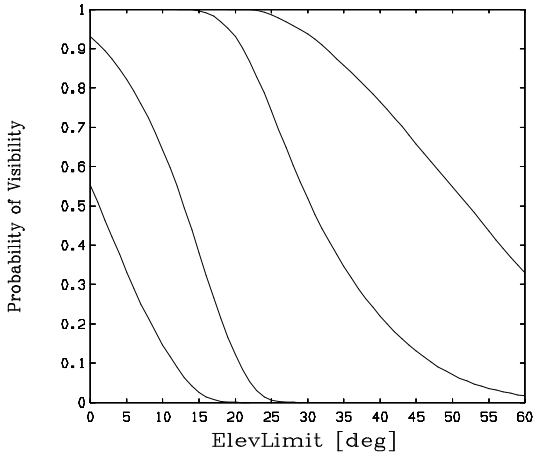

Fig. 3: Probability of visibility of Odyssey for different elevation limits

The elevation limit of the Odyssey MSS for a POV of 100 % of one satellite is θ=20 deg for latitudes of

±60 deg, Figure 3. This elevation limit is larger than the values for the Iridium and Globalstar MSSs. For a POV of 95 % the minimum elevation angle is θ= 28 deg. Figure 3 also shows, that for an elevation limit of θ=14 deg two satellites are visible with a POV of 100 %.

(4) Results for ICO (formerly Inmarsat-P)

The ICO satellite constellation [8] will have 10 satellites in 2 orbital planes. It will have an inclination of i =45 deg at an altitude of h=10354 km (MEO). ICO will use the TDMA protocol. In Figure 4 the POVs for different values of elevation limits are shown. The minimum elevation angle of ICO for a POV of 100 % is θ=12 deg and for a POV of 95 % it is θ=19 deg for latitudes of ±60 deg. In opposite to Odyssey the POV of 100 % is never reached for the case of two satellites.

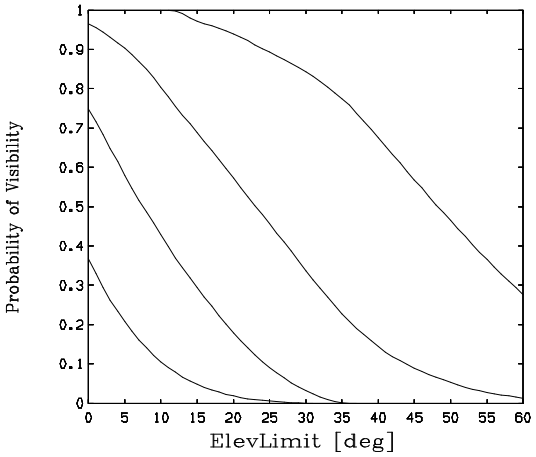

Fig. 4: Probability of visibility of ICO for different elevation limits

(5) Results for Teledesic

The Multimedia system Teledesic [9] will have 840 primary satellites in 21 orbital planes at inclinations of i=98.142-98.182 deg and altitudes of h=695-705 km. Because of the great number of satellites the POV is greater than that of the other MSSs. Figure 5 shows the POV as a function of the elevation limit for the latitude of ±70 deg. The elevation limit for a POV of 100 % is θ=38 deg for one satellite, for two satellites θ=29 deg., for three satellites θ=25 deg, and for four satellites θ=21 deg. For a POV of 95 % the minumum elevation angle is θ=47 deg for one satellite, for two satellites θ=33 deg, for three satellites θ=28 deg, and for four satellites θ=24 deg.

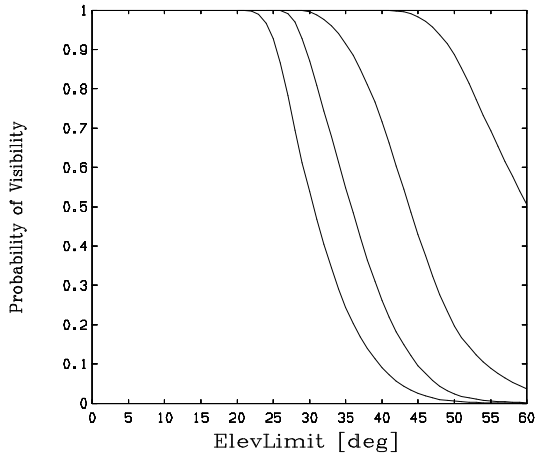

Fig. 5: Probability of visibility of Teledesic for different elevation limits

B. *Results for the probability of visibility dependent on the service radius and the elevation constraint*

The POV dependent on the service radius and the elevation constraint is an important function which must be calculated for systems without ISLs for establishing the needed earthstations. Each satellite, used for communications, must simultaneously have an earthstation in view.

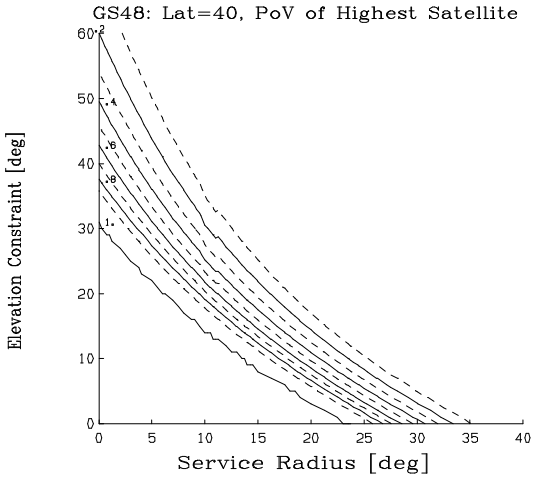

Fig. 6: Probability of visibility of Globalstar dependent on the service radius and the elevation constraint

For this purpose the POV of the highest satellite has been computed as a function of the elevation constraint and the service radius. This has been done for the systems Globalstar, Odyssey and ICO for a latitude of lat=40 deg. Figure 6 shows the POV of the Globalstar system. The minimum service radius for an elevation constraint of 10 deg is 13

deg. Figure 7 depicts the POV for the Odyssey system, for which the minimum service radius for an elevation constraint of 10 deg is 14 deg. Finally Figure 8 shows the POV for the ICO system, for which the minimum service radius for an elevation constraint of 10 deg is 22 deg.

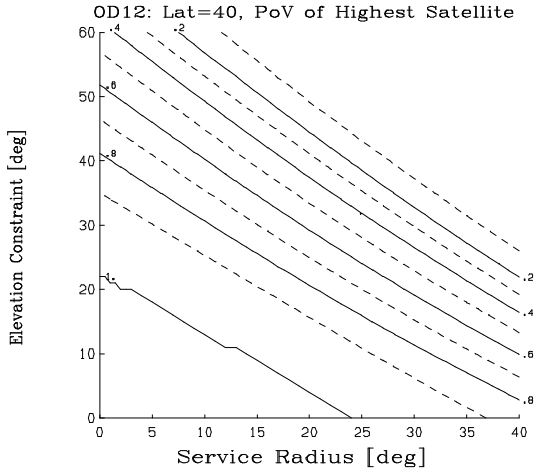

Fig. 7: Probability of visibility of Odyssey dependent on the service radius and the elevation constraint

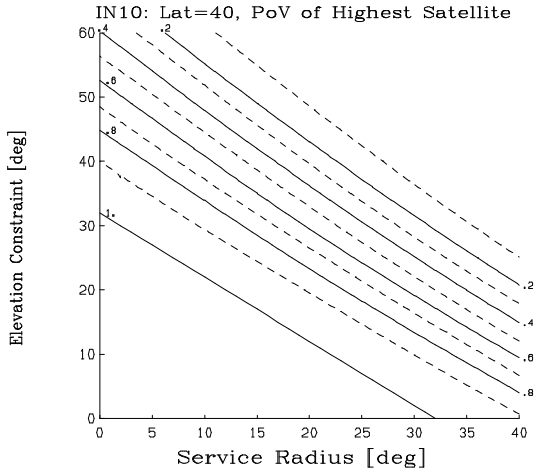

Fig. 8: Probability of visibility of ICO dependent on the service radius and the elevation constraint

III. CONCLUSION

This paper compares the probability of visibility of the mobile satellite systems Iridium, Globalstar, Odyssey, ICO (for latitudes of ±60 deg) and Teledesic (for latitudes of ±70 deg). The results may be summarized by the values for the minimum elevation angles for POVs of 100 %, needed for voice services and POVs of 95 %, needed for messaging services, Tab.1. The locations for these minima are at low latitudes and are larger at higher latitudes. For MSSs without ISLs these values are further reduced by the size of the service radius of earthstations. For an elevation constraint of 10 deg and a latitude of 40 deg the minimum service radii are 13 deg for the Globalstar MSS, 14 deg for the Odyssey MSS, and 22 deg for the ICO MSS.

	100 % POV	95 % POV
Iridium	8.2 deg	12 deg
Globalstar	15 deg	21 deg
Odyssey	20 deg	28 deg
ICO	12 deg	19 deg
Teledesic	38 deg	47 deg

Table 1: Comparision of minimum elevation angles

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