Comparision of the Probability of Visibility of New Planned Mobile Satellite Systems (M-Star, Celestri, SkyBridge)

Harald Keller, Horst Salzwedel

Faculty of Computer Science and Automation,
Technical University of Ilmenau, Ilmenau
P.O.Box 100565,
98684 Ilmenau / Germany

E-Mail: {keller, horst}@theoinf.tu-ilmenau.de

Abstract

In the years 1996 and 1997 some new mobile satellite systems for communication services with high data rates have been proposed. The most important systems are M-Star, Celestri, and SkyBridge. In this paper the probability of visibility is presented for these new planned mobile satellite systems for low earth orbits (LEO). The performance of a satellite system 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 in order to provide continual service. This papers presents the probability of visibility and the elevation limit for different latitudes and compares the three systems. Additionally, the three systems will be compared with the changed Teledesic systems, which constellation was reduced to 288 satellites in the year 1997.

I.INTRODUCTION

In the last years a number of mobile satellite systems for low earth orbits (LEO) and for medium earth orbits (MEO) have been proposed. The most important systems are Iridium [5], Globalstar [13], Odyssey [9], and ICO [3] (formerly Inmarsat-P). These systems will provide communication services like voice, data, fax, paging, messaging, and positioning with low data rates. The systems will start service in the years 1998/1999. Another planned system is Teledesic [10,11], which was planned with 840 satellites in the year 1994 and reduced to 288 satellites in the year 1997. Teledesic will establish multimedia over satellite. Since 1996 some new systems with new features are proposed as competitors to Teledesic. These systems are the M-Star [7] system and the Celestri [6] system of Motorola, and the SkyBridge [8] system of Alcatel Espace. These systems will provide communication service with high data rates, with up to 155 Mbps.

All the systems will offer mobile satellite service (MSS) and fixed satellite service (FSS). The systems M-Star, Celestri, and Teledesic will use intersatellite links (direct connections between satellites), whereas the SkyBridge system will use a great number of gateways on earth. The four systems are LEO systems. The systems will archive global coverage with acceptable elevation angles. The performance of these systems is primarily dependent on the probability of visibility (POV) and the elevation limit.

In this paper we compare the probability of visibility for different elevation limits. In order to compute the probability of visibility of the named systems we distribute a large number of users over the globe between latitudes ±60 deg. and simulate for the named MSSs over repetitive time periods (with appropriate time steps). Additionally, we show the elevation limit as a function of the latitude. The elevation limit is very important for coverage and it should be great in regions where the greatest number of users is expected. Both calculations are performed for one and for multiple visible satellites (2, 3, 4). The simulation methods have been implemented in the satellite simulation software system SatLab [2], which is used for this investigation.

II.SIMULATION RESULTS

(1) Results for M-Star

The M-Star system [7] of Motorola was first proposed in August 1996. The system contains 72 satellites in 12 planes of 6 satellites each. The constellation is an inclined circular orbit constellation [12] with an inclination angle of 47 deg at an altitude of 1350 km. The used protocol of M-Star is FDM/TDMA. The system is designed to provide businesses with broad bandwidth communications links around the world. It will provide wholesale low- and high-data-rate communications for large telecommunications companies, banks, businesses, and for the military.

Figure 1 shows the POV as a function of elevation limit for one, two, three, and four satellites for latitudes of ±60 deg. The minimum elevation angle of M-Star for a POV of 100 % of one satellite is $\theta = 21$ deg and for two satellites it is $\theta = 14$ deg. For a POV of 95 % the minimum elevation angle is $\theta = 28$ deg for one visible satellite The POV decreases for increasing elevation angles. The M-Star system has no global coverage.

MSS	M-Star	Celestri	SkyBridge	Teledesic
Number of satellites	72	63	2 x 32	288
Number of planes	12	7	2 x 8	12
Number of sat./plane	6	9	4	24
Altitude	1350 km (LEO)	1400 km (LEO)	1457 km (LEO)	1375 km (LEO)
Inclination	47°	48°	55°	84.72°
Eccentricity	0.0012	0.0013	0	0.00096
Protocol	FDM/TDMA	FDM/TDMA	?	FDMA/TDMA
System cost	$6.4 Bill.	$12.9 Bill.	$3.5 Bill.	$9.0 Bill.
Begin of service	2000	2002	2001/2002	2002

Table 1: Constellation parameters of the compared MSS

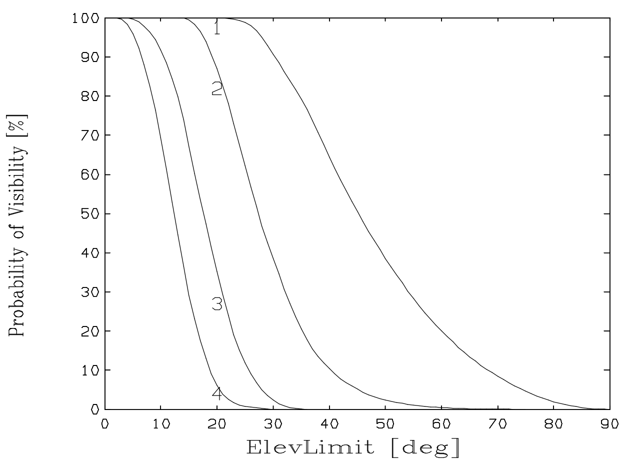

Fig. 1: Probability of visibility of M-Star for different elevation limits

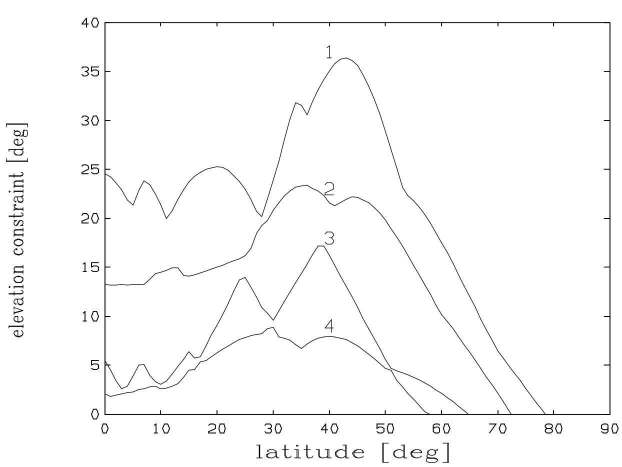

Fig. 2: Elevation constraint of M-Star for different latitudes

The system was planned to cover an area between latitudes of 65 deg north and 65 deg south [7]. The elevation constraint as a function of the latitude is shown in Figure 2. The system has its best coverage for latitudes between 30 deg and 55 deg. In this area the system also has its best minimal elevation angle of 36.38 deg for one visible satellite at a latitude of 42 deg. At the boundaries of this region the minimal elevation angle for one visible satellite is 23.90 deg for a latitude of 30 deg and 21.80 deg for a latitude of 55 deg. For two visible satellites the minimal elevation angle is up to 23.37 deg and it is 20.80 deg for a latitude of 30 deg and 15.23 deg for a latitude of 55 deg.

(2) Results for Celestri

The Celestri [6] system contains 63 satellites with 9 satellites in 7 inclined orbital planes. The satellites in each plane will rotate in orbits at an altitude of 1400 kilometers. The system has an inclination angle of 48 degrees with respect to the equator. The system is planned by Motorola and was first proposed in December 1996. It will provide multimedia applications (data, video, and voice).

Celestri services will include point-to-point, real-time symmetric connection services at speeds ranging from 64 kbps to 155 Mbps. The cost for the system will be about US$12.9 billion.

Figure 3 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 17 deg. For a POV of 95% the minimum elevation angle is θ=24 deg. The system provides no coverage of the whole earth, but between latitudes of 65 deg north and 65 deg south The system has its best coverage for latitudes between 30 deg and 55 deg. In this region the minimal elevation angle is up to 36.02 deg for one visible satellite and it is 28.84 deg for a latitude of 30 deg and 25.15 deg for a latitude of 55 deg. For two visible satellites the minimal elevation angle is up to 24.09 deg and it is 16.70 deg for a latitude of 30 deg and 13.72 deg for a latitude of 55 deg. (Figure 4).

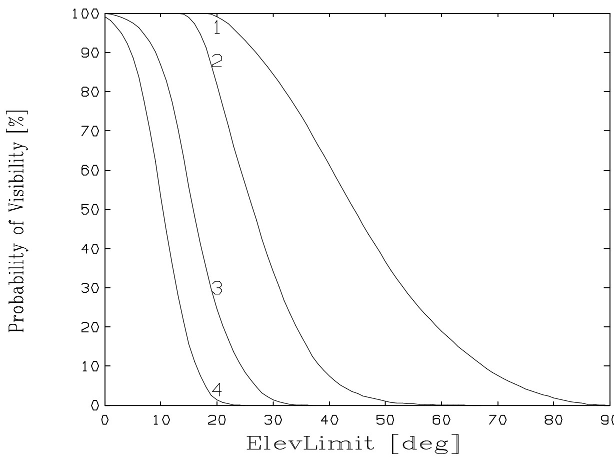

Fig. 3: Probability of visibility of Celestri for different elevation limits

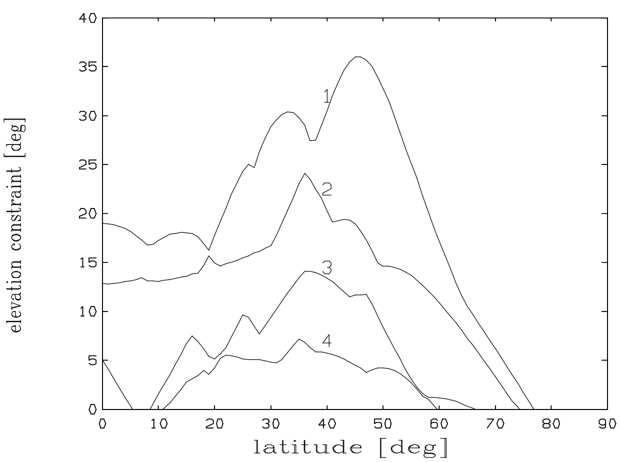

Fig. 4: Elevation constraint of Celestri for different latitudes

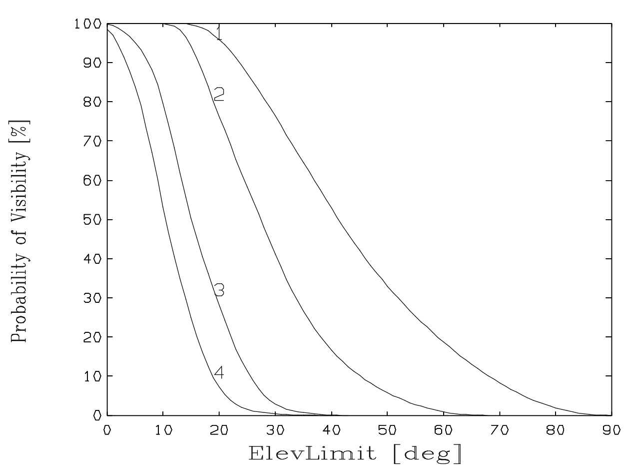

Fig. 5: Probability of visibility of SkyBridge for different elevation limits

(3) Results for SkyBridge

The SkyBridge [8] system (formerly Sativod) was first announced in February 1997. The system is planned by Alcatel Espace, a unit of Alcatel Alsthom. The system will have 64 satellites in a low earth orbit (LEO) constellation. It will provide high-speed, broadband, interactive services to business and residential users around the world. The estimated capital cost of the project is US$3.5 billion. The POV as function of elevation limit for one, two, three, and four satellites is shown in Figure 5. The minimum elevation angle of SkyBridge for a POV of 100% of one satellite is θ=13 deg. For a POV of 95% it increases to θ=21 deg. The SkyBridge system was planned for a coverage of a region between latitudes of 68 deg. north and 68 deg. south [8]. The best coverage of the system is between latitudes of 30 deg and 55 deg. In this region the system also has its best minimal elevation angle of 30.36 deg for one visible satellite. At the boundaries of this region the minimal elevation angle for one visible satellite decreases to 15.94 deg at a latitude of 30 deg and to 26.53 deg at a latitude of 55 deg. The minimal elevation angle for two visible satellites is up to 23.56 deg in this region and at the boundaries it is 14.68 deg at a latitude of 30 deg and 20.56 deg at a latitude of 55 deg. (Figure 6)

(4) Results for Teledesic

The Multimedia system Teledesic [10,11] will have 288 satellites in 12 orbital planes at an inclination angle of 84.72 deg. The Teledesic system was planned with 840 satellites in the year 1994 [10] and was reduced to 288 satellites in the year 1997 [11]. The Teledesic network is a high-capacity broadband network with two-way connections that provide up to 64 Mbps on the downlink and up to 2Mbps on the uplink.
Broadband terminals will offer 64 Mbps of two-way communication.
Figure 7 shows the POV as a function of the elevation limit for the latitude of ±60 deg. The elevation limit for a POV of 100 % is θ=42.0 deg for one satellite, for two satellites θ=28.8 deg, for three satellites θ=25.5 deg, and for four satellites θ=21.5 deg. For a POV of 95 % the minimum elevation angle is θ=48 deg for one satellite, for two satellites θ=34 deg, for three satellites θ=28 deg, and for four satellites θ=24 deg.
The Teledesic system is based on the polar circular orbit constellation [1] and provides global coverage of the whole earth. Because of the polar orbits the minimal elevation angle is increasing with higher latitudes. Teledesic has a minimal elevation angle for one visible satellite of at least 42.0 deg and of at least 28.8 deg for two visible satellites. (Figure 8)

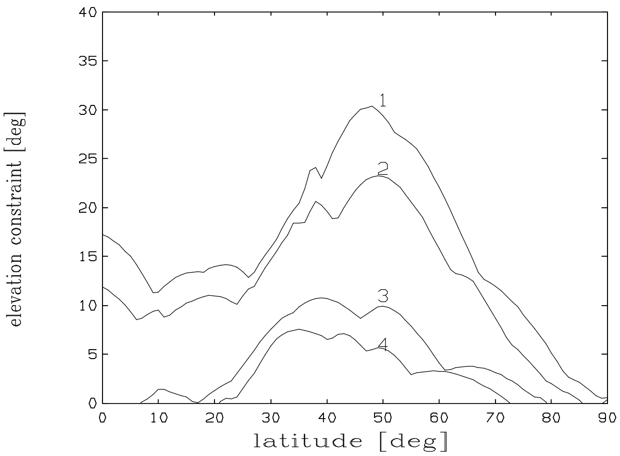

Fig. 6: Elevation constraint of SkyBridge for different latitudes

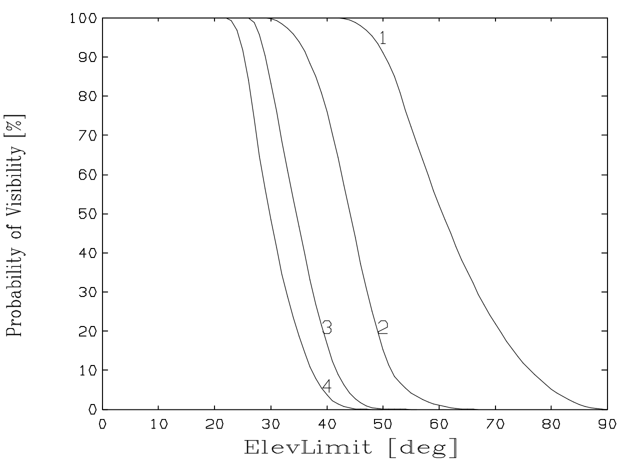

Fig. 7: Probability of visibility of Teledesic for different elevation limits

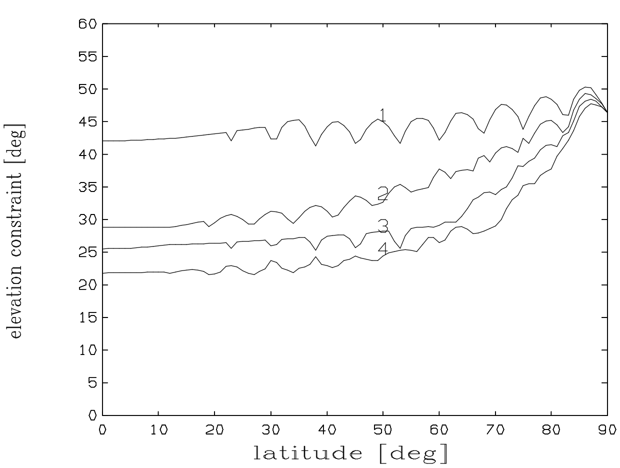

Fig. 8: Elevation constraint of Teledesic for different latitudes

III. COMPARISION/CONCLUSION

This paper compares the probability of visibility of the mobile satellite systems M-Star, Celestri, SkyBridge, and Teledesic (for latitudes of ±60 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.2.

	100% POV	95% POV
M-Star	21 deg	28 deg
Celestri	17 deg	24 deg
SkyBridge	13 deg	21 deg
Teledesic	43 deg	48 deg

Table 2: Comparision of minimum elevation angles of one visible satellite

In this table the Teledesic system has the best POV, but it also uses the greatest number of satellites. In Table 3 the minimum elevation limits of one visible satellite for a special region are listed. This region is between latitudes of 30 deg and 55 deg and is the location of the industrial countries, where the greatest number of users is expected. In this region Teledesic, again has the best coverage with an elevation limit of up to 45.32 deg for one visible satellite. In comparision between M-Star, Celestri, and SkyBridge the M-Star and the Celestri system have the best elevation limit in this region with up to 36 deg. At the lower latitude boundary the Celestri system has the best elevation limit with 28.84 deg at a latitude of 30 deg. SkyBridge has the best elevation limit of 26.53 deg at the upper boundary at the latitude of 55 deg, what is a result of the higher inclination angle of SkyBridge.

REFERENCES

[1] W.S.Adams and L.Rider, „Circular Polar Constellations Providing Continious Single or Multiple Coverage Above a Specified Latitude“, The Journal of the Astronautical Science, Vol. 35, No. 2, April-June 1987.

[2] Alta Group of Cadence Design System: „SatLab-Satellite Laboratory User’s Guide (for Use with BONeS DESIGNER).“, SAT8000-S4, Dec. 1994. [3] ICO Global Communications: Homepage of ICO http://www.ico.com

[3] ICO Global Communications: Homepage of ICO http://www.ico.com

[4] Keller, H.; Salzwedel, H.; Schorcht, G.; Zerbe, V.: Comparision of the Probability of Visibility of the Most Important Currently Projected Mobile Satellite Systems“, IEEE 47th Vehicular Technology Conference VTC’97, Phoenix, Arizona, May 4-7, 1997, pp. 238-241.

MSS	M-Star	Celestri	SkyBridge	Teledesic
elev. limit for one satellite in region 30°...55° up to	36.38°	36.02°	30.36°	45.32°
elev. limit for one satellite for lat.=30°	23.90°	28.84°	15.94°	42.30°
elev. limit for one satellite for lat.=55°	21.80°	25.15°	26.53°	44.95°
elev. limit for two satellites in region 30°...55° up to	23.37°	24.09°	23.26°	35.41°
elev. limit for two satellites for lat.=30°	20.80°	16.70°	14.68°	31.23°
elev. limit for two satellites for lat.=55°	15.23°	13.72°	20.56°	34.15°
elev. limit for three satellites in region 30°...55° up to	17.16°	14.10°	10.74°	28.56°
elev. limit for four satellites in region 30°...55° up to	8.84°	7.20°	7.54°	25.38°

Table 3: Elevation limits for the compared MSS

[5] R.J.Leopold, „The Iridium Communications System", Communications for Competitive Advantage Conference and Trade exhibition, Tuanz 1992, August 10-12, 1992.

[6] Motorola Global Communication Inc.: „Application For Authority to Construct, Launch and Operate the Celestri Multimedia LEO System", Filed before the FCC, June 1997.

[7] Motorola Global Communication Inc.: „Application For Authority to Construct, Launch and Operate the M-Star Satellite System", Filed before the FCC, September 4, 1996.

[8] Skybridge L.L.C.: „Application For Authority to Construct, Launch and Operate the SkyBridge System", Filed before the FCC, February 28, 1997.

[9] C.J.Spitzner, „Odyssey personal comm. satellite system", in Proc. 3rd Int. Mobile Sat. Conf., IMSC 1993, Pasadena, pp. 297-302, June 1993.

[10] Teledesic Corporation, „Amendment of Teledesic Corporation", File No. 22-DSS-P/LA-94, December 30, 1994.

[11] Teledesic L.L.C.:"Application For Authority to Construct, Launch and Operate the Teledesic Satellite System", Filed before the FCC, March 1997.

[12] J.G. Walker, „Circular orbit patterns providing continious whole earth coverage," Royal Aircraft Establishment, Tech. Rep. 70211 (UDC 629.195:521.6), Nov. 1970.

[13] R.A.Wiedeman and A.J.Viterbi, „The Globalstar mobile satellite system for worldwide personal communication.", in Proc. 3rd Int. Mobile Sat. Conf., IMSC 1993, Pasadena, pp. 291-296, June 1993.