

A Contribution to a Communication Quality Improvement by a Hand Check Survey

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Abstract: The use of different satellite systems in the world has known a large diffusion, not only in the services but in large scale communication networks as it is possible to communicate in any point of the globe. Lately, the communications in the satellite domain have reached a great importance thanks to the Low Earth Orbit (LEO) satellites. This study deals with the main survey of these networks by a demonstration of satellite constellations constitutions and the different interfering factors: the orbit numbers, the satellite numbers in each orbit, the altitude, hence modelling the Hand Check problems.

Key words: Hand check, cover, satellite systems, networks, modelling

INTRODUCTION

The satellite systems based on the Low Earth Orbit (LEO) satellites have a major advantage over the earth (land) networks as far as the globe cover is concerned.

They allow the users to have at their disposal telecommunication services extended over a very large zone and to be able to carry on a communication while moving in regions that are not covered by the land systems such as the GSM^[1].

However, these systems are characterized by a very high rate of Hand check temptations which can significantly deteriorate their performances.

The orbit altitude is considered as an essential element of the network. The constellations are defined with.

High Earth-Orbit (HEO): They are elliptic orbits at about 500 km altitude and an apogee at about 50000 km altitude and have a 63° inclination.

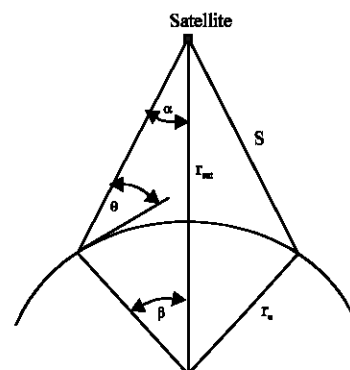
Geostationary Orbits (GEO): The geostationary orbits have a circular orbit of 42164 Km radius in a plane in the neighbourhood of the equator and their angular speed is equal to the earth rotation.

Medium Earth-Orbits (MEO): The Medium Earth-Orbit have an altitude of about 10000 Km and a 50°, the satellite revolution period is 6 h with a constellation of 10 to 15 satellites we can assure a global cover of the earth.

Low Earth-Orbits (LEO): They are orbits situated at an altitude comprised between a few hundreds kilometres and 2000 km from the earth surface with a signal propagation delay of the order of 10 to 20 ms^[2].

EARTH COVER NOTION

The cover is the land zone covered by the satellite also called print:



| | |
|-----------|-----------------------------------|
| α | Opening angle |
| β | Cover angle |
| θ | Elevation angle |
| H | Satellite altitude |
| r_e | Average value of the earth radius |
| r_{sat} | $H+r_e$ |

We can express the cover angle β and the Opening angle α according to the elevation angle θ and the satellite altitude H:

$$\beta = \arcsin (r_e \cos\theta / H+r_e) - \theta \quad (1)$$

$$\alpha = \arcsin (r_e \cos\theta / H+r_e) \quad (2)$$

The satellite cover zone is: $W=2re\beta$.

The satellite effective print is: $A=2\pi (re)^2(1- \cos\theta)$

We have plotted, on the Fig. 1, the variation of the angle β and α (cover, opening) versus the altitude H and we notice that the altitude H is proportional to the angle β and inversely proportional to α .

A calculation example with $\theta = 30^\circ$:

The Fig. 2 shows the satellite cover according to the satellite altitude H:

Theoretical case:

| | $\theta(^{\circ})$ | H (Km) | $\beta (^{\circ})$ | $\alpha (^{\circ})$ |
|-----|--------------------|--------|--------------------|---------------------|
| MEO | 30 | 10000 | 40 | 20 |
| LEO | 30 | 1000 | 11 | 49 |

Practical case:

| | $\theta(^{\circ})$ | H (Km) | $\beta (^{\circ})$ | $\alpha (^{\circ})$ |
|-----|--------------------|--------|--------------------|---------------------|
| MEO | 30 | 10000 | 40 | 20 |
| LEO | 30 | 1000 | 11 | 48 |

The satellite number necessary for a world cover: The satellite constellation setting in an orbit requires the knowledge of several parameters such as: the satellite number for each constellation.

For this purpose many studies have been carried out on the basis of communications systems modelling^[3,4].

Two methods can be approached:

A direct calculation: In order to cover the whole earth surface in telecommunication systems, the prints must overlap^[5].

For any constellation we consider the largest possible effective print of satellite as the largest hexagon inside the print.

The angle expression is given by:

$$\text{Tang } \Psi = (1/2 \sqrt{3} \times \beta) + (1/2\beta \cos\beta) = \sqrt{3}/\cos\beta$$

With $\sigma = 2\psi / 3 \pi$, the spherical excess of spherical triangles.

We will give the hexagon surface: $A_{hex}=6r_e^2 \sigma$.

So in order to cover the whole earth surface, we have got (n) satellites: $n=4 \pi r_e^2 / A_{hex} = \pi / 3\psi - \pi$.

$$n = \pi/3\psi - \pi \quad (3)$$

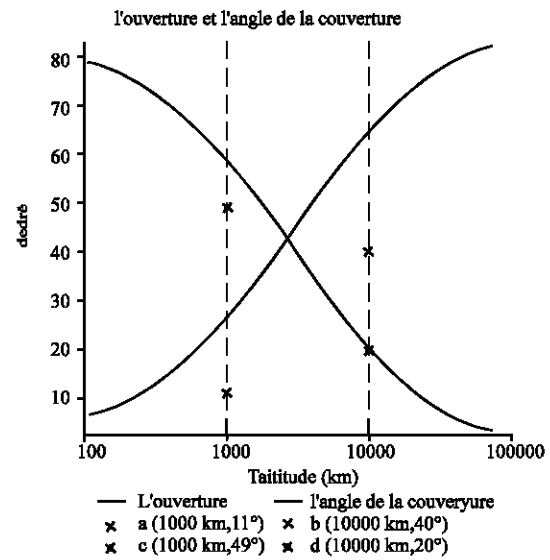


Fig. 1: The cover angle β and the Opening angle α according to the elevation angle θ and the satellite altitude H

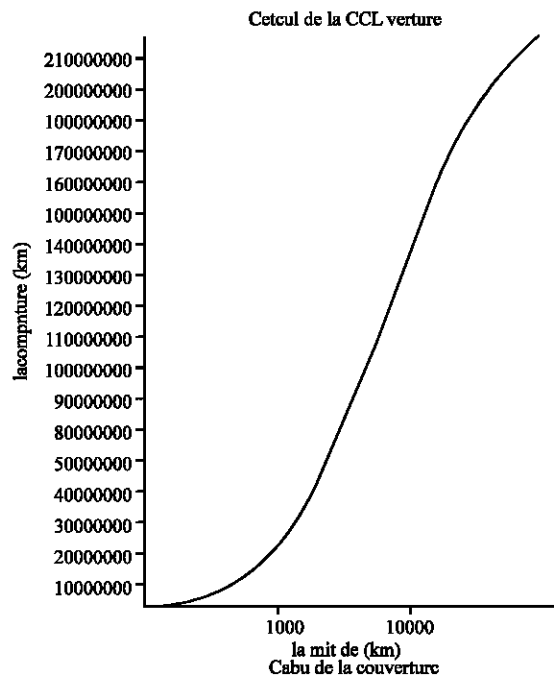


Fig. 2: The satellites cover according to the satellite altitude H

Let us plot on the Fig. 3 the required number of satellites to assure a global cover as a function of the altitude with different angles θ :

An indirect calculation: In this method, to calculate the satellites number that assures the largest earth print, there are two intervening elements:

- The necessary orbit number (m).
- The satellite number for each orbit (k).

$$\text{With: } n = m.k. \tag{4}$$

The necessary orbit number required for a world cover:
 In the study of mobile satellites the satellite orbit number must be determined with two conditions:

- The cover of a satellite under the equator.
- At least two satellites in each orbit.

We may then give the orbit number for a world cover:

$$m = 2 \pi / 3\beta \tag{5}$$

We show on Fig. 4 the necessary orbit number required for a world cover as a function of the altitude with different θ angle:

The satellite number for each orbit: In each orbit concerning the polar constellations we can give a more realistic estimation of a satellite number (k) in order to have a world cover:

$$K = 2\pi / \sqrt{3}\beta \tag{6}$$

The Fig. 5 shows the variations of the satellite number according to the altitude H (km) for different elevation angles for polar systems.

In order to improve the service quality of telecommunications systems, we must assume a satellite constellation. This enables us to strongly reduce the signal powers and the signal propagation times.

Hence for GEO systems, three satellites are sufficient enough to realize a global earth covers, but satellite LEO systems require dozens of satellites.

The hand check: Among the main problems met in the telecommunications is the communication switch from a satellite to another. This occurs when the first satellite can't cover the user as he enters in the next satellite zone^[6,7].

This technical operation consisting in a communication exchange from a satellite to another is called the Hand check.

Up to now, many surveys about the Hand check have been carried out to improve this technical operation. The purpose is to improve the technology in order to better manage the Hand check by eliminating the telecommunication interruption risks while crossing from a satellite zone to another.

The Hand check triggering probability in a source cell for any communication is given by:

$$P_{hi} = 1 - e^{-\lambda} \tag{7}$$

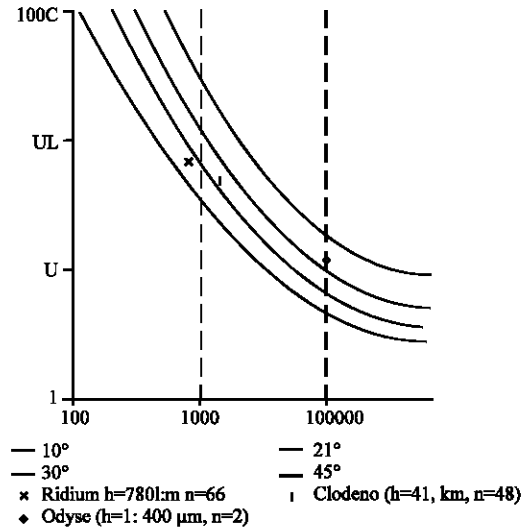


Fig. 3: The required number of satellites as a function of the altitude with different angles θ

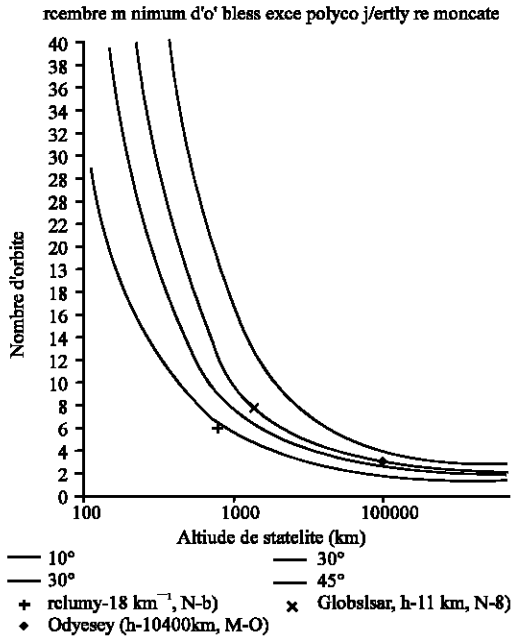


Fig. 4: The orbit number required for a world cover as a function of the altitude with different θ angle

The Hand check triggering probability in a transit cell for any communication is given by:

$$P_{h2} = e^{-\lambda} \tag{8}$$

Where λ is the movement factor:

$$\lambda = 2 R_{cell} / V_{orb} \cdot T_m \tag{9}$$

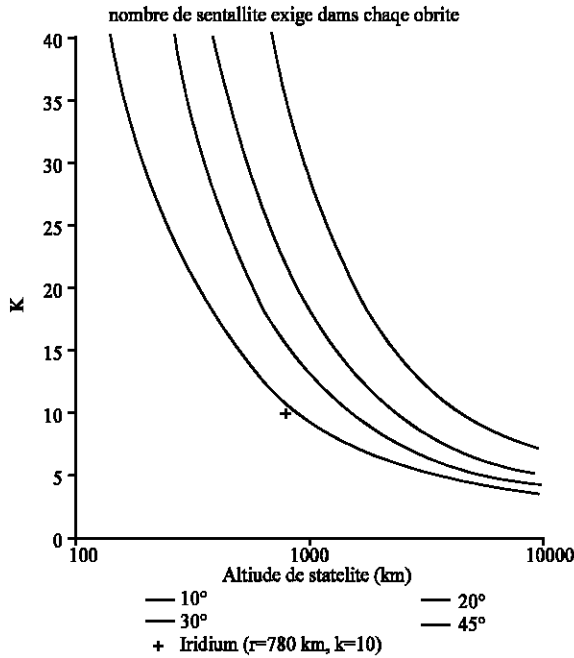


Fig. 5: The variations of the satellite number according to the altitude H (km) for different elevation angles for polar systems

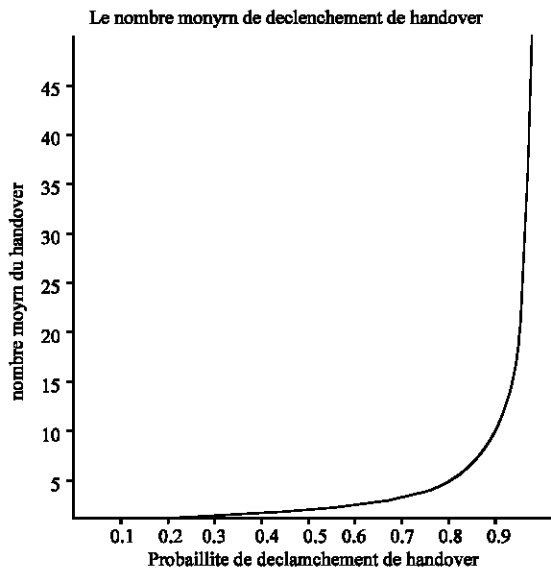


Fig. 6: Variations of the Hand check triggering average number as a function of the Hand check triggering probability

R_{cell} : hexagon half circle.

T_m : call duration.

V_{orb} : the satellite speed in an orbit.

$$V_{orb} = \sqrt{\mu + R + h} \quad (10)$$

μ : $3.986 \cdot 10^{14} \text{ m}^3\text{s}^{-2}$ gravitation factor.

The average number of Hand check triggering is:

$$K = P_{hi}/1 - P_{hi} \quad (11)$$

The variations of the Hand check triggering average number as a function of the Hand check triggering probability is shown on the Fig. 6.

CONCLUSION

In order not to lose the information i.e to make sure to maintain the communication uninterrupted between two satellite zones, the Hand check triggering average number must be comprised between two values: K superior and K inferior.

The results shown on the Fig. (1-6) were obtained by software elaborated in our research laboratory; however the perspectives of future work is to develop the software to better handle the Hand check triggering average number and reduce the telecommunication interruption risks and this to provide a better communication quality.

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