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Multibeam Coverage With A Parabolic Offset Antenna In Ka Band For Multimedia Service Broadcasting

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***Abstract*—This paper will be devoted to a study which consists in the design of a multibeam offset parabolic antenna embedded in the payload of a geostationary satellite in Ka-band; this antenna is responsible to ensure the communication between the satellite and multitude of receptor which are everywhere in a large area on earth and this for the broadcast of a multimedia service. First, we will start with a brief study of multibeam coverage and its characteristics, after we will study the parabolic antenna because it's this type of antenna which interests us in our application and also in order to choose the most appropriate model. In our case of study the parabolic antenna mounted in offset is the most appropriate. Finally, we will use specific software to simulate the antenna in order to arrive to determinate the different parameters of the antenna which can give us the best performances for ensure a coverage with high gain of all the area and ensure the reception of the service by all users.**

Keywords—telecommunication satellite, multibeam, offset parabolic antenna, payload, gain, beam width, aperture efficiency, Ka band.

I. Introduction

Since many years, telecommunication satellites play an important role in the development of telecommunications networks. Today, telecommunication services are essentially oriented to large bandwidth multimedia content transmission, in order to ensure the needs of users in terms of internet, high definition TV or video on demand. To provide such services, a rate of 2 to 20 Mbits/s is required between users [1]. For the satellite and its payload, this involves several constraints including the need for a high gain in order to obtain a sufficient effective isotropic radiated power (EIRP) to achieve high bandwidth coverage on large areas, ranging from simple country to continent.

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In order to achieve these characteristics, it is not possible to use antennas with a simple beam. Added to this, the same frequency band should be used on all the coverage, which will not favor capacity. This is why coverage with multiple directional beams is carried out, mostly with reuse of frequencies and polarizations to increase the capacity of different channels. In addition, these antennas with high gains allow the using of receiver antennas and terminal users small and not expensive.

For the satellite, the large gain can increase the G/T and EIRP, which limits the output repeaters power and therefore reduces the weight and cost of the payload. The antenna used for most of these applications is the reflector antenna, which allows having very high gains due to its focusing properties.

II. Problem Statement

The choice of an antenna is different depending on the type of system and the area to be covered, the emission levels are parameters which must be taken into account to select the type of antenna which is best suited to a particular system and this without omitting the cost and complexity of the antenna.

Indeed, an antenna broadcasting radiation pattern with wide opening can be achieved with a single radiating element. This solution is insufficient to perform more complex functions; such missions require the association of a set of radiating elements or acts of the principle of multibeam antennas.

Our work is in this context and we will try to make a contribution to the design of a Ka-band space communication payload, and that with the study and design of an embedded antenna system on the payload of a satellite ensuring the broadcasting of a service in the Ka band.

Practically, there are several types of antennas that are embedded on satellites, we noted among these types the parabolic reflector antennas which are usually the most used in the design of communication modules in payloads of most satellites in order to ensure effective coverage area and high gain, and it is this type of antenna that will be used in our study. For that, we will try to setup a multibeam parabolic antenna mounted on offset fed with a multi feed cluster "MFC" embedded on payload of a telecommunications satellite which is in geostationary orbit.

III. Multibeam Coverage

The radiation pattern of a satellite antenna is typically characterized by a main lobe, which concentrates most of the radiated power in a defined direction and low side lobes to minimize interference. The main lobe is conventionally called beam and its intersection with the earth is a spot. Since the gain of an antenna is inversely proportional to the beam aperture, it is necessary to use multibeam antennas to cover a large area with a homogeneous and high gain. The use of "N * N" spots to cover a given area divides by "N" the size of the latter. Therefore, the beams associated with each of these spots have an opening"N" time smaller. Thus, the gain of each of the spots and thus the coverage area will be increased by "20Log N". However, to increase the isolation between the spots, the frequency band is divided into channels. Thus, two adjacent spots operate in a different channel. Another advantage of these multibeam antennas is the rate. Indeed, with an "N * N" spots forming and using "M" sub-band, the rate is multiplied by "N / M" with respect to its counterpart in a single source [2].

An example of a cover made up of 48 spots operating in four frequency sub-band (A, B, C, D) is shown in "Fig. 1".

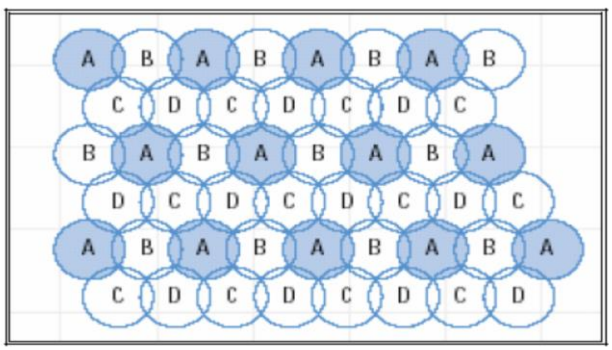

Figure 1. Multiple beams coverage.

However, the use of a multibeam system requires an antenna radiation pattern with low side-lobes and cross polarization minimum in order to limit interference between spots.

IV. Offset Parabolic Antenna

A parabolic antenna is an antenna that uses a parabolic reflector, a curved surface with the cross-sectional shape of a parabola, to direct the radio waves. The most common form is shaped like a dish and is popularly called a dish antenna or parabolic dish. The parabolic antennas projectors are equivalent to wave radiating apertures large compared to the wavelength. Their role is to transform a spherical wave emitted by the source placed at the focus of the reflector plane wave and vice versa. The dish is similar to a circular opening equivalent diameter D, the illumination law is equiphase with amplitude that depends on the radiation pattern of the primary source (feed). Radiation obtained forms a highly directional beam. High gain and low side lobes are also obtained with this type of antenna [3].

In practice, there are different types of parabolic antennas which are used on payload of satellite; we have:

- Simple reflector antenna;
- Double reflector antenna: For this type of reflector antenna we have Cassegrain and Gregorian antenna.

The choice of the type of parabolic antenna is depending on the cost of implementation and the level of performance required. In our case, after the study of several theses dealing with the subject of multibeam parabolic antennas for space applications [4] [5] [6], we conclude that the offset parabolic antenna "Fig. 2" is most commonly used in payload of satellites in Ka band.

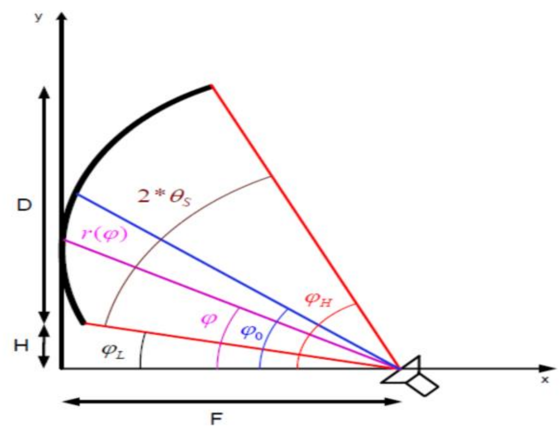

Figure 2. Representation of an offset parabolic reflector.

With: D: Diameter

- F: Focal length ($0.75 \leq F/D \leq 1.8$)
- H: Offset ($0.2 \leq H/D \leq 0.5$)

To generate a plurality of beams in the case of fixed multispot coverage of the Earth by an embedded antenna, all this is realized by using in the focal plane of the reflector as many sources as desired spots. Therefore, it is possible to obtain a multibeam radiation with a group of primary sources located in the focal plane of the reflector [7]. Each of these elements corresponds to a radiated beam whose direction depends on the position of the source considered in relation to the focal point as shown in "Fig. 3".

Pointing directions of the beams is multiple of a variable angle" θ_f", with a battery of" 2n +1" sources, the pointing angles of the beams are between- "n*θf" and "n *θf" whereas in the beam generated by the source focal point is at 0°.

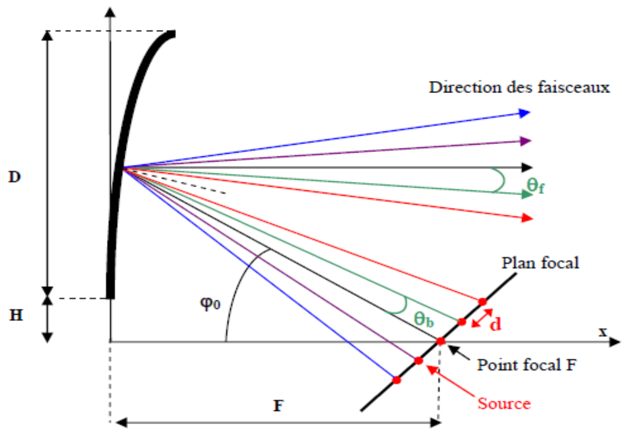

Figure 3. Multiple beams generated by the reflector.

V. Context Of Study

This work is inscribed in the context of a project entitled contribution to the design of a Ka-band payload for space communication; our work in this project is devoted to do the design and the study of embedded antenna system on the payload of a Ka band satellite. For this application the satellite payload will be responsible for receiving a signal transmitted by an earth station control and then broadcasting this signal (service) to multi-users over a large area "Fig. 4".

The antenna system on board will be comprised of a set of antennas and the part which we want to study is the communication module in it, it will consist of two separate antennas, the first is a parabolic reflector antenna mounted on offset to receive the signal from the earth station and the second and is this antenna which we will design in this study, this antenna is a parabolic reflector antenna mounted on offset against but here we will use a multibeam antenna to broadcast the signal (ensure the transmission of a service) to a set of users. In what follows we will make the design of a multibeam parabolic antenna mounted on offset fed by a set of horns in the Ka band to ensure full coverage of the area shown in "Fig.4".

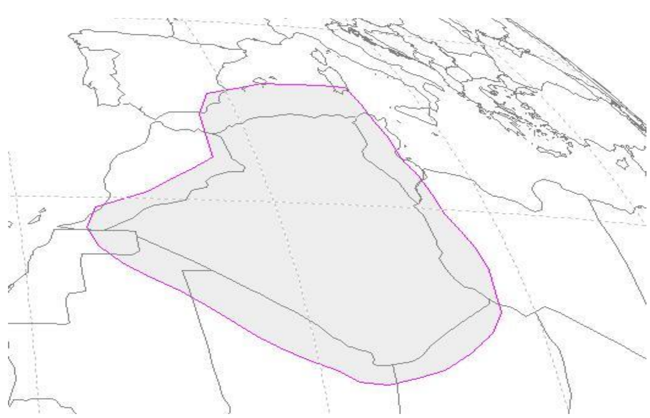

Figure 4. Geographical area to be covered.

VI. Working Methodology

To design the multibeam antenna embedded in the Ka band payload of communication satellite, the working methodology followed is given by the next steps:

1) Choice of working frequency.
2) Determinate the area to be cover by the antenna.
3) Determinate the type of antenna which is the best adapt to our case of study.
4) Selection of the different parameters of the antenna (N: number of spots, D: diameter, F: focal, H: the offset, polarization, type of feed).
5) Calculating the different parameters of the antenna.

VII. Simulation and Results

In this part, we will design and simulate a multibeam offset parabolic antenna that can be embedded in payload of a telecommunication satellite in the Ka band and intended to broadcast a received signal (service) to different users in a large area, after study of several thesis and according to what is practically done we will use a parabolic antenna mounted on offset fed by a multi feed cluster "MFC".

We will use these parameters for our study:

- Frequency (F=20 GHz, the downlink frequency of Ka band).
- Circular polarization (RHCP: Right Hand Circular Polarization).
- Circular horn as feed.

From there, we had done a multitude of calculations and simulations under SATSOFT [8] software to configure the parabolic antenna. First, we must define the number of spots which are needed to cover the entire geographical area; this number is equal to the number of feeds needed to be integrated in the network of illumination of the parabola.

Then we have the parabola size which consists in the determination of diameter, focal length to diameter ratio and the offset. After that, we must also find the optimal combination between the diameter of the feeds (circular horns) and the spacing between them in order to avoid an eventual overlap between the different spots and have a good crossover level.

So after that all simulations are done, we had the results which are reported in the following table:

TABLE I. DIFFERENT PARAMETERS OF THE ANTENNA

Parameters	Values
Frequency 'Fdown'/ wavelength 'λ'	20 GHz / 1.5 Cm
Number of spots	28
Antenna diameter 'D'	1.5 m
Focal length 'F'	2.2 m
F/D	1.47
Antenna offset 'H'	60 Cm
H/D	0.4
Feed diameter	2.27 Cm
Beam spacing	0.523 °
Feed spacing	2.27 cm
Crossover level	-2.23 dB
3 db Beamwidth	0.605°
Polarization	RHCP
Aperture Efficiency	53.23%
Gain	45.42 dB

From the above table, we can see that to cover the entire geographical area we have 28 spots "Fig.5", so we have 28 circular horns in the network to illuminate the parabolic reflector to provide global coverage of the area.

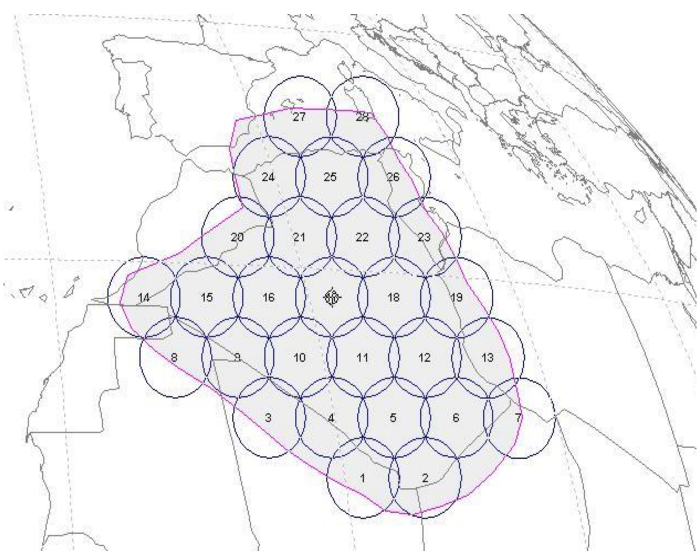

Figure 5. Number of spots needed to cover the area.

And for the other parameters of the antenna, we can note on the basis of table1 the following remarks:

- The parabolic antenna has a diameter of 1.5 m and a focal length of 2.2 m, so a ratio F/D = 1.47, so it is in the range "0.75 ≤ F/D≤ 1.8".
- The offset of the antenna is 0.6 m, so a ratio H/D = 0.4 which is also in the range "0.2≤ H / D ≤ 0.5", so the antenna will not be cumbersome for a geostationary satellite.
- The maximum gain of the antenna is 45.42 dB, this gain may vary from one spot to another "Fig.6", for example the gain for the spot No. 17 is 45.41dB and may decrease until to a value of 45.22 dB for the No. 14 spot, but the difference is not very substantial.
- The aperture efficiency is about 53%, which can be considered as a good performance given the number of horn feeds in the source of illumination.
- The 3dB beamwidth is low, which will generate an antenna with good directivity.
- Feed diameter is 2.27 cm as the feed spacing, which will avoid the problem of overlap between the beams.

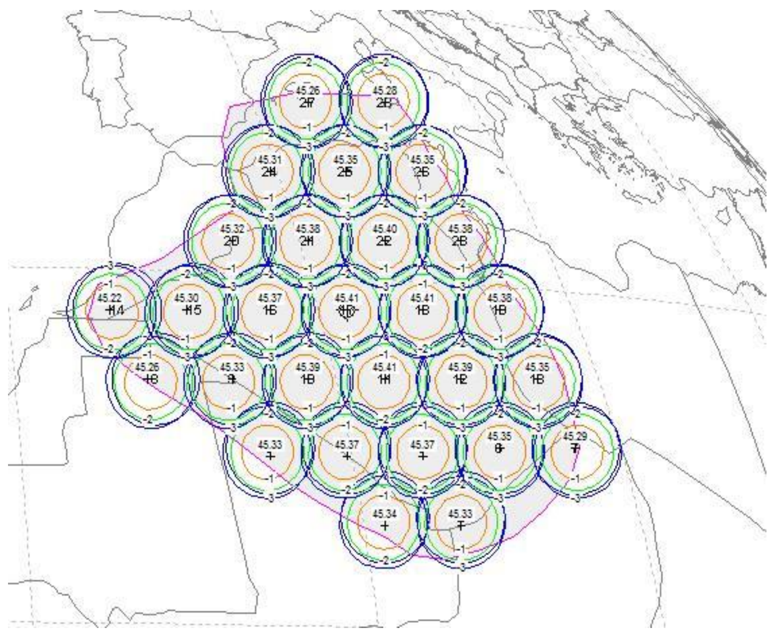

Figure 6. Multibeam coverage of the area.

In the previous figure, we have the global coverage of the desired area with a multibeam parabolic antenna mounted on offset and fed by a network of 28 circular horns, we have also in the figure the location of all the different spots and their gains.

In the following figure (obtained with the software Sabor), we plot the radiation pattern of the parabolic antenna which we had just designed but fed by just one circular horn. We noticed that the first side lobe is about -20 dB and the antenna has a narrow main lobe which explains what we have said above.

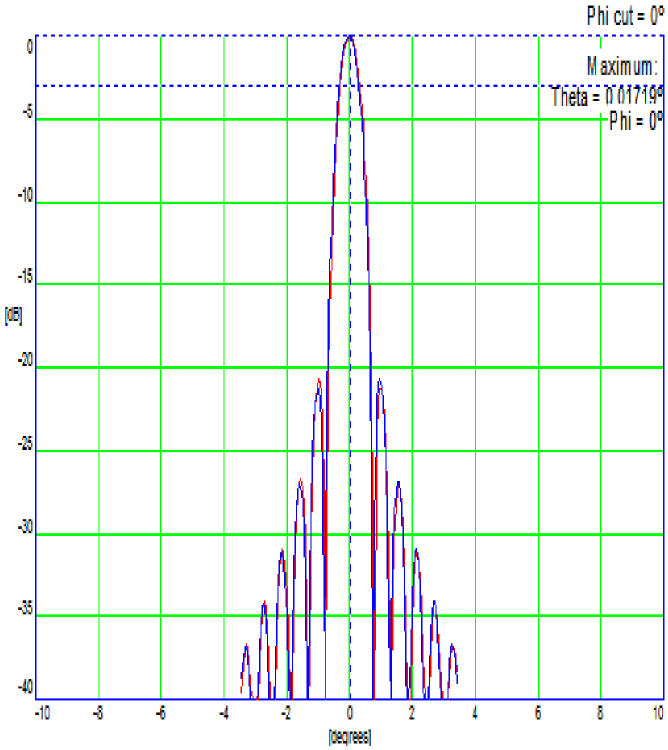

Figure 7. Radiation Pattern of the designed antenna fed by a single horn.

VIII. Conclusion

For our project, which consists in contributing to the design of a Ka-band payload communications satellite, we came to design the transmission antenna of the antenna subsystem for a communication module which will be embedded in the payload of a Ka-band satellite to ensure the transmission of a received service from an earth station to a group of users. For this antenna and after the study of different types of antennas that are used practically for this kind of applications is the parabolic reflector antenna mounted on offset is by far the most used and best suited.

So for the transmission antenna, we took a multibeam parabolic reflector antenna mounted on offset that provides a multibeam coverage of a large area with a set of spots and gain almost identical for all spots, this gain is of the order of 45.42 dB obtained with a network of 28 circular horns illuminating a parabolic reflector with 1.5 m in diameter and F / D = 1.47 with an offset of 0.6 m.

This type of antenna can be embedded in a communication satellite in Ka-band which is in geostationary orbit for the broadcasting of multimedia service over a wide geographical area and with good performances.

References

[1] Cyrille MENUDIER, "Caractérisation des performances d'antennes à réflecteurs paraboliques illuminées par une source focale BIE Application à l'optimisation d'une couverture multimédia multifaisceaux", Doctoral thesis, Faculté des sciences et techniques, Université de Limoges, October 2007.

[2] Règit CHANTALAT, " Optimisation d'un réflecteur spatial à couverture cellulaire par l'utilisation d'une antenne a bande interdite électromagnétique multisources", Doctoral thesis, Faculté des sciences et techniques, Université de Limoges, November 2003.

[3] Florin Doru HUTU, " Etude de la synchronisation d'oscillateurs : application aux antennes actives ", Doctoral thesis, Université de Poitiers, November 2007.

[4] Leila CHOUTI, " Contribution à l'étude d'antennes imprimées rectangulaires double bande et multi bandes tenant compte de l'effet de couplage ", Master thesis in electronic, Université MENTOURI-CONSTANTINE, February 2009.R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[5] Ahmad KANSO, "Etude, conception et réalisation d'antennes BIE bibande – Application au développement d'une structure focale pour des applications spatiales multimédia et multifaisceaux", Doctoral thesis, Faculté des sciences et techniques, Université de Limoges, December 2010.

[6] Majed KOUBEISSI, "Etude d'antenne multifaisceaux à base d'une nouvelle topologie de matrice de Butler. Conception du dispositif de commande associé ", Doctoral thesis, Faculté des sciences et techniques, Université de Limoges, December 2007.

[7] Sergio Luciano AVILA, " Optimisation multi objectif et analyse de sensibilité appliquées à la conception de dispositifs, Application : Synthèse d'antennes à réflecteur embarquées dans un satellite", Doctoral thesis, L'école Doctoral électronique, électrotechnique, automatique de Lyon., february 2006.

[8] http://www.satsoft.com/

[9] http://www.gr.ssr.upm.es/sabor.htm

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