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Interference Evaluations in Frequency Reuse by Using Offset-Parabolic-Reflector Antennas for a UHTS System

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Abstract: *In this work, it is analyzed features and parameters when to use an offset-fed parabolic reflector antenna for an Ultra High Throughput Satellite (UHTS) system for multiple spot-beams both for Q/V band and Ka-band. The Q/V band is only used for the feeder link while the Ka-band is used for the user link. There are some parameters that are essentials in satellite communications due to they take an important part of the frequency reuse configuration. For instance, cross-polarizations will be decisive for the system performance and feasibility. Therefore, it is necessary to evaluate theoretically various parameters that will be analyzed in this study for a satellite reflector antenna suitable for our system. For us, the most important aim is to adjust and reduce the interference levels and ensure availability for all satellite links for a UHTS system.*
Keywords*-Antennas, aperture antennas, satellite antennas, satellite communications, ultra-high throughput satellite, Ka-band, Q/V-band*

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I. INTRODUCTION

The High Throughput Satellite (HTS) systems have evolved in an exponential manner in the last decade. For instance, Spaceway 3 was launched in 2007, which has a capacity of up to 10 Gb/s, meanwhile, in 2017 the HTS satellite Echostar XIX, with a capacity of up to 200 Gb/s, was launched. Those HTS satellites are operating in Ka-band and multibeam with 100 beams per satellite at least. Thus, this indicates a significant market for satellite broadband in terms of households that will not be served by terrestrial means.

In order to have both reliability and a high performance of the satellite system, the satellite antennas accomplish an important role within in an HTS system. Such satellite antennas are important for more efficiency in both Earth to space (E-s) and space to Earth (s-E) communications but it must be reduced the interferences produced by the RF links. Therefore, the most suitable design of the reflectors will give us the guidelines so that our proposed system could be feasible. By 2020 the UHTS system will have reached the 1 Tb/s capacity. Techniques like frequency reuse, multiple spot beams, and circular polarization are needed in order to achieve such higher desired capacities.

In this work, it will be evaluatedtheoretically all features for increasing the parabolic reflector performance so as to obtain maximum advantage for frequency reuse configurations, multiple beams amount and circular polarization. Hence, the analyzed model will be fundamental to reach the communications system requirements for a UHTS system.

II. ANTENNA PARAMETERS

The geometry for the study is shown in Fig. 1, whose parameters will be indicated below later in this section. Moving the feed out of the aperture eliminates some of the problems with axisymmetrical reflectors. Blockage losses and diffraction-caused sidelobes and cross-polarization disappear.

Initially, there are some parameters that are obtained by geometry and illumination laws for parabolic reflectors. The θ_{3dB} beamwidth is the angle subtended by the half power points of the main lobe (Half Power Beamwidth). This parameter is used to characterize the width of the beam.

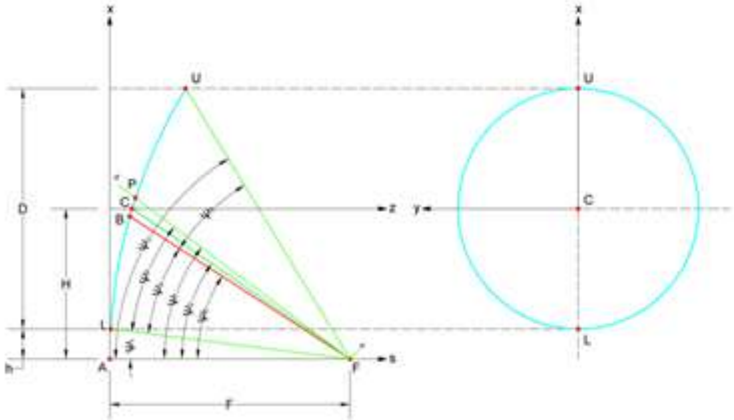

Fig. 1. The geometry for the offset-parabolic-reflector antenna, [1].

For reflector antennas, the coefficient depends on the illumination law. A typical value is 70º when the illumination law introduces some tapering at the edge of the reflector, which leads to the following expression for an aperture plane diameter D [2]:

(1) $$D = 70 \cdot \frac{\lambda}{\theta_{3dB}}$$

Where θ_{3dB}beamwidth will have a value of 0.2º in Q-band [3], while the θ_{3dB} beamwidth in Ka-band will have a value less than 0.5º [2]. The λ is the wavelength of the frequency band used in each link.
In this study, for an offset case (h>0), to provide a blockage-free region for structures in the focal region. The offset distance was considered [1]:

(2) $$h = \frac{D}{8}$$

Where h is the distance from the axis of symmetry to the lower reflector edge. This expression of h is popular in VSAT applications.
The distance from the symmetry to the center of the reflector is known as the offset of reflector center H [1]:

(3) $$H = \frac{D}{2} + h$$

In this assessment, one of the most important parameters is to keep the ratio of focal length F to diameter D constant, i.e., the value of the ratio is 1 [4]:

(4) $$\frac{F}{D} = 1$$

Our contribution to this study will be to modify D according to the beamwidth in both Ka and Q/V band.Hereinafter, we will determine the angles as shown in Fig. 1 which are indicated by Milligan [5]. The half of the angle subtended ψ_S by the reflector as viewed from the focal point which is expressed as:

(5) $$\psi_S = \tan^{-1}\left(\frac{8 \cdot F \cdot D}{16 \cdot F^2 + 4 \cdot H^2 - D^2}\right)$$

The angle which bisects the reflector subtended angle is identified as ψ_B and is defined by:

(6) $$\psi_B = \tan^{-1}\left(\frac{16 \cdot F \cdot H}{16 \cdot F^2 + D^2 - 4 \cdot H^2}\right)$$

The lower angle ψ_L can be graphically expressed as:

(7) $$\psi_L = \psi_B - \psi_S$$

The upper angle ψ_U is determined by the sum of subtended angle and lower angle. ψ_U is expressed as:

(8) $$\psi_U = 2 \cdot \psi_S + \psi_L$$

We direct the feed an angle ψ_f from the symmetry axis to the center of the projected diameter (point P). The angle is expressed as:

(9) $$\psi_f = 2 \cdot \tan^{-1}\left(\frac{H}{2 \cdot F}\right)$$

The angle from the lower edge of dish to feed pointing direction is defined by:

(10) $$\psi_P = \psi_f - \psi_L$$

For a parabolic reflector, the spherical spreading loss for both upper ψ_U and lower ψ_L edges is given by [1]:

(11) $$\mathrm{SPL}(\psi) = -20 \cdot \log\left[\cos^2 \frac{\psi}{2}\right]$$

Edge illuminations have a difference between them which is expressed in dB [1]:

(12) $$\Delta\mathrm{EI} = EI_U - EI_L$$

The negative of the edge illumination is the sum of the feed edge taper FT and the spherical spread loss SPL. It is expressed as [1]:

(13) $$\mathrm{FT}_L + \mathrm{SPL}_L = \mathrm{FT}_U + \mathrm{SPL}_U + \Delta\mathrm{EI}$$

Hence, substituting equation (11) into equation (13) obtains the design equation [1]:

(14) $$\Delta\mathrm{FT} = \mathrm{FT}_L + \mathrm{FT}_U = 40 \cdot \log\left\{\frac{\left[\cos\frac{\psi_L}{2}\right]}{\left[\cos\frac{\psi_U}{2}\right]}\right\} + \Delta\mathrm{EI}$$

Where $\Delta\mathrm{EI} = 0$ is used for the case of balanced aperture illumination. This is the method for obtaining an offset-parabolic-reflector antenna. In the next section, these equations will be applied to simulate the offset-parabolic-reflector antenna.

III. SIMULATION AND NUMERICAL RESULTS

The equations (1) – (4) are used for determining the feed angle ψ_f which is one of the most important parameters of the parabolic reflector as the well as the rest of parameters that will be calculated for defining the performance of parabolic reflector. In Table 1 are shown the parameters found by the previous equations.

The Q-band is used for the downlink (in the feeder link) with a frequency band of 40 GHz and a value of 0.20º for the beamwidth, while for the 20 GHz band is used for downlink in Ka-band. For the downlink in Ka-band, there are four beamwidths as shown in Table 1.

The ratio of focal length F to diameter D is kept constant, F/D = 1 [4], which is used in the antennas for an Eutelsat fleet. It is for this reason that the angle values are constants for all cases as shown in Table 1. The ratio F/D is ambitious but necessary for a UHTS system due to the fact that it is diminished the SPL losses.

Parameters	**Q Band**	**Ka Band**				**Unit**
Frequency	40.00	20.00	20.00	20.00	20.00	GHz
Beamwidth	0.20	0.48	0.40	0.32	0.26	deg
Diameter (*D*)	2.63	2.19	2.63	3.28	4.10	m
Offset (*h*)	0.33	0.27	0.33	0.41	0.51	m
Offset (*H*)	1.64	1.37	1.64	2.05	2.56	m
***F/D* ratio**	1.00	1.00	1.00	1.00	1.00	-
Focal (*F*)	2.63	2.19	2.63	3.28	4.10	m
ψ_B	32.93	32.93	32.93	32.93	32.93	deg
ψ_S	25.78	25.78	25.78	25.78	25.78	deg
ψ_L	7.15	7.15	7.15	7.15	7.15	deg
ψ_U	58.72	58.72	58.72	58.72	58.72	deg
ψ_f	34.71	34.71	34.71	34.71	34.71	deg
ψ_P	27.56	27.56	27.56	27.56	27.56	deg

Table 1. Offset-parabolic-reflector antenna parameters.

In Table 2 are shown the values of the edges illumination levels in both upper and lower. The feed was modeled using a symmetric Gaussian radiation pattern with a 10 dB beamwidth of 70º [1]. Thus, we will have two feed edge tapers, FT_L = 10.0 dB and FT_U = 10.0 dB.

Parameters	Q Band	Ka Band				Unit
Frequency	40.00	20.00	20.00	20.00	20.00	GHz
Beamwidth	0.20	0.48	0.40	0.32	0.26	deg
FT_U	10.00	10.00	10.00	10.00	10.00	dB
FT_L	10.00	10.00	10.00	10.00	10.00	dB
ΔFT	0.00	00.00	0.00	0.00	0.00	dB
SPL_U	2.39	2.39	2.39	2.39	2.39	dB
SPL_L	0.03	0.03	0.03	0.03	0.03	dB
EI_U	-12.39	-12.39	-12.39	-12.39	-12.39	dB
EI_L	-10.03	-10.03	-10.03	-10.03	-10.03	dB
ΔEI	-2.35	-2.35	-2.35	-2.35	-2.35	dB

Table 2. Edges illumination levels with a symmetric Gaussian radiation pattern.

The values of EI_U and EI_L are not recommendable, since a balanced aperture illumination, i.e. ΔEI = 0, is required so that the feed must be pointed with an angle desirable. Table 3 shows the parameters involved in balanced aperture illumination, ΔEI = 0, when the feed is pointed with an angle $\psi_{f.}$

Parameters	Q Band	Ka Band				Unit
Frequency	40.00	20.00	20.00	20.00	20.00	GHz
Beamwidth	0.20	0.48	0.40	0.32	0.26	deg
FT_U	10.00	10.00	10.00	10.00	10.00	dB
FT_L	12.35	12.35	12.35	12.35	12.35	dB
ΔFT	2.35	2.35	2.35	2.35	2.35	dB
SPL_U	2.39	2.39	2.39	2.39	2.39	dB
SPL_L	0.03	0.03	0.03	0.03	0.03	dB
EI_U	-12.39	-12.39	-12.39	-12.39	-12.39	dB
EI_L	-12.39	-12.39	-12.39	-12.39	-12.39	dB
ΔEI	0.00	0.00	0.00	0.00	0.00	dB

Table 3. Edges illumination levels with a Gaussian radiation pattern which is pointed with an angle ψ_f = 34.71º.

The feed angle is reduced until desirable cross-polarization performance is achieved. It turns out that this operating point produces a balanced aperture illumination. Therefore, for a feed's angle ψ_f = 34.71º the edge illumination levels in the aperture are equal in the plane of offset [1] as shown in Table 3.

To simulate the offset-parabolic-reflector antenna, we have used a computational tool known as GRASP® by TICRA® [6] which is useful for obtaining the radiation pattern that will determine the isolation level of cross-polarization, X_{pol}. In Fig. 2 is illustrated a radiation-pattern diagram for the offset-parabolic-reflector antenna in Q-band, i.e. for the downlink (s-E).

The offset-parabolic-reflector antenna is configured to operate in circular polarization, i.e. the antenna has dual-polarization both LHCP (Left Hand Circular Polarization) and RHCP (Right Hand Circular Polarization).

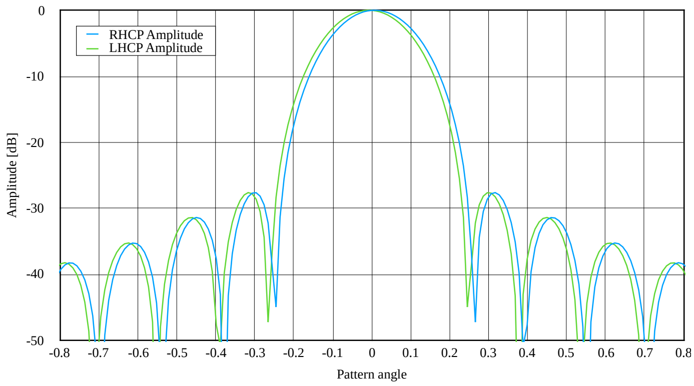

Fig. 2. Normalized pattern of the offset-parabolic-reflector antenna with circularly polarized feed.

Results obtained from various numerical simulations indicated that the pointing of the feed toughly influences cross polarization. In this case, the value obtained for cross polarization is X_{pol} = 27.78 dB, this value is within a suggested range of 20 – 40 dB. In Q band is recommended that the cross-polarization value is X_{pol} = 25 dB [3]. Thus, the X_{pol} value, that was obtained by simulation, is totally viable.

Consequently, the feeder link will be able to operate efficiently with dual-polarization configuration for the downlink (s-E). This link must have robustness for communicating with Earth Stations and to avoid interferences with each other.

In addition, simulations were run for the downlink in Ka-band (s-E), using GRASP, similar to simulations in Q band. The simulation results are shown in Table 4.

Frequency	**20.00**				GHz
Beamwidth	0.48	0.40	0.32	0.26	deg
X_{pol}	27.39	27.33	27.25	27.16	dB

Table 4. Cross-polarization X_{pol} values for the downlink (s-E) in Ka band.

As shown in Tab. 4, X_{pol} values are within the recommended range of 20 – 40 dB so that these values can be used with dual polarization for increasing the capacity on the downlink without impacting both RHCP and LHCP polarizations. All calculations in this paper are performed on an Intel Core i5 2.70 GHz machine with 16 GB RAM.

IV. MULTIPLE BEAM ANTENNA FOR SATELLITE COMMUNICATIONS

The multiple-aperture antenna design with a single element per beam typically uses three or four apertures. Adjacent beams are generated from different apertures, forming an interleaved spot-beam coverage on the ground [7]. The aim of this article is oriented to the apertures based on offset-parabolic reflectors. There are important advantages of the MBAs which are indicated as follows [8]:

- The effective spectral bandwidth is improved by several folds due to re-use of the frequency channels over numerous spot beams,
- The beam has a smaller size such that the antenna will have higher gain, resulting in enhanced effective isotropic radiated power (EIRP) for the downlink and improved gain-to-noise temperature (G/T) for the uplink,
- Gateway Earth Stations (GES) will have smaller antennas.

A multiple beam antenna generates adjacent beams from different apertures, creating an interleaved spot-beam coverage on the ground.

In references [7] and [8], author indicates that the closest spacing between beam centers reusing the same frequency θ_c is given by $1.732\theta_s$ for a three-reflector design (three-cell reuse scheme), while for a four-reflector design (four-cell reuse scheme) is given by $2.0\theta_s$, where θ_s is the center-to-center spacing between adjacent beams of the hexagonal-grid layout of the beams. In Fig. 3 is shown a three-cell reuse scheme over Mexico, while in Fig. 4 is illustrated a four-cell reuse scheme.

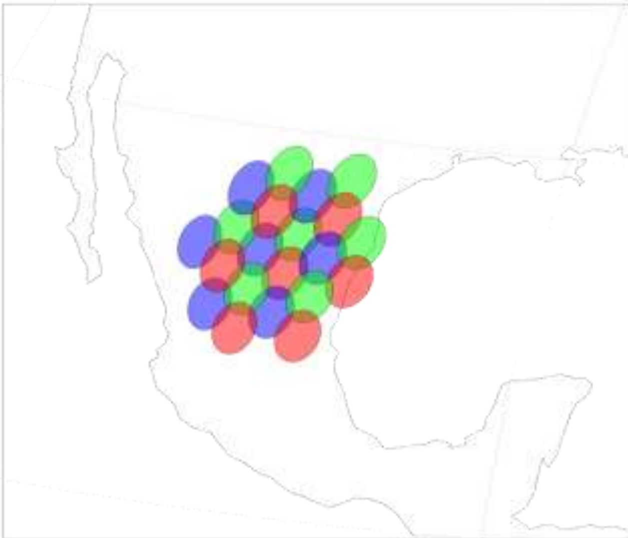

Fig. 3. Three-cell reuse scheme for a three-reflector design in Ka band for a beamwidth = 0.32º.

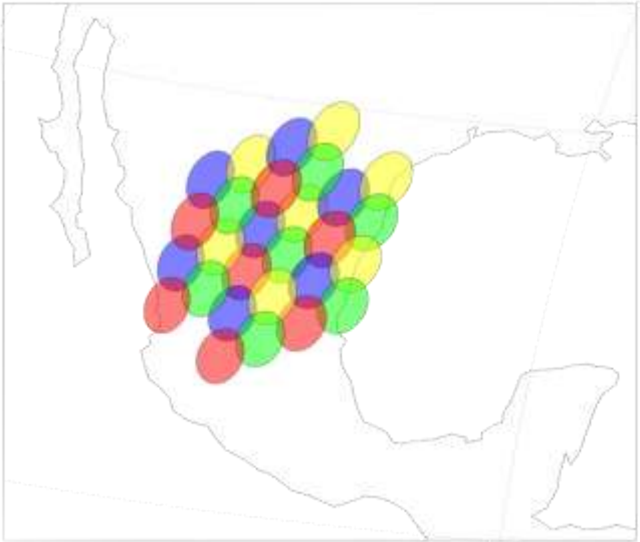

Fig. 4. Four-cell reuse scheme for a four-reflector design in Ka band for a beamwidth = 0.32º.

In the same references, it is explained that the larger beam spacing allows a proportionate increase in the feed horn size, which improves the antenna gain thorough reduced spillover loss, i.e., it optimally illuminates the reflector with increase beam end-of-coverage (EoC) gain and reduced sidelobe levels.

With these parameters, we could find the optimum beam diameter with uniform beams. However, in reference [8], the author determines the total number of the beams for circular coverage and non-circular shape where the area of the coverage region, in both cases, is in square degrees.

In this paper, we introduce an approximate concept based on the areas in square kilometers for both the hexagon beam layout and the coverage area, which will be applied to the Latin America region. We have divided the entire region into three parts: Mexico, Central America and the Caribbean, and South America. Applying this criterion, each region has a specific area, e.g., Mexico has a coverage area, $A_C = 1.972550 \times 10^6$ km^2, Central America, and the Caribbean, $A_C = 7.32755 \times 10^5$ km^2 and South America, $A_C = 1.80055 \times 10^7$ km^2.

Each spot beam has a beamwidth that comes from a multiple beam antenna mounted on geostationary satellite UHTS. In our study we have been studying four cases of beamwidth: $\theta_1 = 0.48º$, $\theta_2 = 0.40º$, $\theta_3 = 0.32º$ and $\theta_4 = 0.26º$, which are projected onto the Ground. These projected spot beams have an approximate radius of $r_1 \cong 150$ km, $r_2 \cong 125$ km, $r_3 \cong 100$ km and $r_4 \cong 80$ km respectively.

Therefore, we can calculate the area of hexagon A_H, which is inscribed in the projected circle (spot beam) of radius r, using geometry. Once this is done, it can determine the number of beams, N, that will be obtained as follows:

(15)
$$N = \frac{A_C}{A_H}$$

Table 5 is shown the number of beams for each region and entire Latin America. This methodology can be used for any region of the Earth.

Beamwidth/ cell radio projected	**θ_1= 0.48° 150 km**	**θ_2= 0.40° 125 km**	**θ_3= 0.32° 100 km**	**θ_4= 0.26° 80 km**
Number beams	**N**			
Mexico	34	49	76	119
Central America & the Caribbean	13	19	29	45
South America	309	444	694	1083
Total Beams N_T	**356**	**512**	**799**	**1247**

Table 5. The number of the beams for each Latin America region.

As shown in Table 5, it is possible that more than one UHTS is needed for covering Latin America due to the several numbers of the beams and the current limitations of the satellites.

V. Satellite Antenna Analysis

In this section, we will present a simplified analysis of the multiple-beam reflector-antenna model. The analysis is based on the Gaussian beam pattern. In addition, this analysis can be performed efficiently, using spreadsheets or scripts.

The model used in this work was developed by Kyrgiazos et al. [3]. In order to reduce the sidelobe levels, there is a need to taper the field distribution over the circular aperture. Hence, an alternative that uses a parabolic taper on a pedestal (offset) value at the edge is more adequate, and the antenna performance can be determined analytically for integer taper roll-off values.

In reference [3] is indicated that pedestal height is given by C. However, in this work the pedestal height is represented by offset as seen in equation (2).

For antenna-model analysis, we have referred to Appendix A in [3], which is more detailed by the author. However, we indicate the equations used in our script for determining the antenna pattern function and the relative gain G_r.

The antenna pattern function is given as:

(16)
$$f(\theta,n,h)=\frac{\left[h\cdot f(\theta,n=0)+\frac{1-h}{n+1}\cdot f(\theta,n)\right]}{h+\frac{1-h}{n+1}}$$

Where,

(17)
$$f(\theta,n)=2^{n+1}\cdot(n+1)!\cdot\frac{J_{n+1}(U)}{U^{n+1}}$$

(18)
$$U=\frac{2\pi}{\lambda}\cdot D\cdot\sin\theta$$

The offset value h is obtained by Equation (2). The field taper roll-off factor (n) ranging from 0 – 2, which depends on the pattern from the sum of the transforms [5]. J is the Bessel function of the n+1 kind. D is the antenna diameter and λ is the wavelength.

Finally, the relative gain is given by:

(19)
$$G_r(\theta)=20\cdot\log_{10}(|f(\theta,n,h)|)$$

Once the calculations are made by the previous equations, we can do the C/I antenna evaluation in the next section.

VI. CARRIER-TO-INTERFERENCE EVALUATION

The whole analysis, equations and C/I evaluation are according to Rao [7] but we will use them with the requirements for our study. In relation to Rao's work, the design equations provide a very good starting solution for the Multiple Beam Antenna (MBA) system.

For instance, in cellular networks the C/I must be in the range of 13 – 15 dB for digital systems [9]. However, in satellite systems this range can vary from 14.5 – 17.6 dB for the downlink in Ka band [10]. In Q band is required that C/I is above the 20 dB level and an average of 29 dB, which will indicate a good isolation between the gateways beams [3].

The calculations for the C/I evaluation will be only for the downlink in both Ka and Q band. After having calculated the antenna's diameter, relative gain, etc., it must be calculated the C/I. The following assumption are made regarding the downlink interference [3]:

- Identical transmitted signals in each beam.
- The forward uplink signals are the same at the center of each beam.
- There is only one carrier in each beam in the spectrum of interest.
- The terminal (GES) emitting the required signal is located at the beam center.

Thus, we will implement in our evaluation script the following expression [3]:

(20)
$$\frac{C}{I} = \frac{\frac{G(\alpha)}{PL_T}}{\sum_{i=1}^{n}\left(\frac{F_i(\beta)}{PL_i}\right)}$$

Where G(α) is the required beam antenna relative gain at the point of interest, PL_T is the path loss from the satellite to the terminal, PL_i represents the path loss from the satellite to the beam center of beam (i), and $F_i(\beta)$ is a function describing the nature interference.

In reference [3] Appendix B, the methodology for C/I evaluation is explained in detail and is the same methodology that we will use in this study. Therefore, it is important to mention that we have adopted this concepts and methodologies in our study. As illustrated in Fig. 5, it is observed the link interference geometry for the downlink. Fig. 6 is shown the beam geometry for C/I calculations used in reference [8].

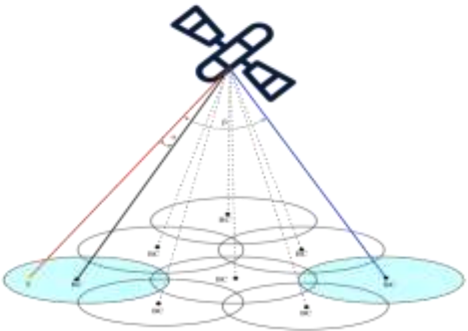

Fig. 5. Link interference geometry [3].

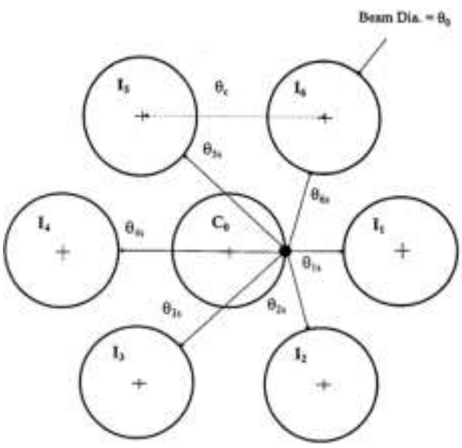

Fig. 6. The beam geometry for C/I evaluation [7].

VII. CARRIER-TO-INTERFERENCE EVALUATION RESULTS

7.1 Q-band

Q/V band is used only at the feeder link (Q-band for the downlink and V-band for the uplink respectively). One of the advantages of operating in the Q/V band is the capability of generating very narrow beams (θ = 0.20º). For the downlink is not necessary frequency reuse (FRF = 1) so that the whole spectrum can be used in each beam. The GES network, on the Ground Segment, is distributed across Latin America coverage area with the minimum distance between their beam centers being 500 km [3]. This consideration is to assure that the interference is minimized in order not to limit the entire system.

Table 6 shows the results obtained from evaluations, which were executed in our script developed for this study.

Parameters		**Unit**
Frequency Reuse Factor, FRF	1	
Polarization	2	
Geostationary orbital position	-74.1	deg
Frequency	40.00	GHz
Beamwidth	0.20	deg
Radio del Haz	62.50	km
Antenna diameter (D)	2.63	m
Edge of Taper	-12.39	dB
Taper roll-off	2	
Results in Q band		
C/I adjacent	30.00	dB
C/I co-polar*	36.09	dB
C/I cross-polar*	38.17	dB
C/I total	28.54	dB
X_{pol} isolation **	27.78	dB

Table 6. Results of the C/I evaluation for the downlink in Q band. (*)The values are obtained by the script made for this study. (**) The value is obtained by GRASP software.

The C/I total obtained is of 28.54 dB, which exceeds the minimum limit of 20 dB in Q-band. Therefore, the C/I obtained is an optimal reference for our study, having a good isolation among the gateways beams.

For this evaluation, we use 18 GES beams across Latin America coverage area, as illustrated in Fig. 7.

Fig. 7. The GES beams used for C/I calculations.

7.2 Ka-band

In our design, the Ka-band is used only for the user's link. In this case, we different configuration schemes for both frequency reuse and polarization, i.e., using a frequency reuse factor of 3 and 4 colors (as illustrated in both Fig. 3 and Fig. 4 respectively) with simple and double polarization. In reference [3], they have developed the nomenclature nFmP indicating the use of n colors and m polarizations.

For a better performance in our design, we recommend the 3-color scheme with simple or double polarization due to the fact that the evaluation results showed that is better option to cope the interferences caused by frequency reuse, their signals are stronger than the 4-color scheme.

The results obtained with the evaluation script are successful for our design and meet the requirements to operate in a UHTS system. For a 3-color scheme, the $C/I_{co\text{-}polar}$ evaluation values are more than 20 dB [3] and could be stronger to face interferences. However, in the 4-color schemes, the $C/I_{co\text{-}polar}$ evaluation values are less than 20 dB and this could be a big problem in the implementation. Nonetheless, the C/I_{total} is the referential value in our study, in both cases, the C/I_{total} value is in the range of 14.5 – 17.6 dB [10].

It is important to mention, as shown in Fig. 6, the co-polar isolation can be simplified by considering the closest six interferers, similar to cellular networks.

Finally, the level at the triple crossover point is according to Lutz et al. [11] and was calculated as indicated in references: [7], [8]. The triple-crossover-points values are shown in Table 7.

Table 7 contains results for the C/I evaluations for the schemes: 3F1P/3F2P and 4F1P/4F2P.

Parameters									**Unit**
GEO orbit position	-100.00								deg
Frequency	20.00								GHz
FRF	**3**				**4**				
Beamwidth	0.48	0.40	0.32	0.26	0.48	0.40	0.32	0.26	deg
Spot-beam radius	150.00	125.00	100.00	80.00	150.00	125.00	100.00	80.00	km
Ant. diameter (D)	2.19	2.63	3.28	4.10	2.19	2.63	3.28	4.10	m
Edge of Taper	-12.39	-12.39	-12.39	-12.39	-12.39	-12.39	-12.39	-12.39	dB
Taper roll off	0	0	0	0	0	0	0	0	
Results in Ka band									
Polarization	**Simple**								
C/I adjacent* **	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	dB
C/I co-polar*	21.03	21.20	21.29	21.36	18.95	18.95	18.95	18.94	dB
C/I total	17.47	17.55	17.59	17.62	16.43	16.43	16.43	16.43	dB
Polarization	**Double**								
C/I cross-polar*	23.99	24.07	24.19	24.32	23.14	23.09	23.03	22.96	dB
C/I total	16.60	16.68	16.73	16.77	15.59	15.58	15.57	15.56	dB
**Xpol isolation ** **	27.39	27.33	27.25	27.16	27.39	27.33	27.25	27.16	dB
Crossover level ****	-2.88	-2.97	-3.05	-3.10	-3.84	-3.96	-4.07	-4.13	dB

Table 7. Results of the C/I evaluation for the downlink in Ka band. (*)The values are obtained by the script made for this study. (**) The value is obtained by GRASP software. (***) The value is in reference [11]. (***) The value is calculated according to the reference [9].

VIII. CONCLUSIONS

In this paper, we determined theoretically that the beams that come from a UHTS for the downlink, both in Ka and Q bands, fulfilling the aim to achieve an efficient coverage and avoid interferences due to the frequency reuse and the several spot beams used of the system. The antenna model evaluated in this study is operating in theHTS fleet of Eutelsat. Thereby, the antenna could be used in a UHTS system but we think that a better design than the evaluated in this study, it could increase the performance of the entire system.

For covering the entire Latin America region, we consider that it will be necessary for a satellite fleet due to lots of beams required in our proposal. An important limitation of this work, it is the lack of comparisons with antenna real tests. However, our work is based on a theoretical assessment of a futuristic UHTS-system.

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REFERENCES

[1]. W. Stutzman, M. Terada, Design of Offset-Parabolic-Reflector Antennas for Low Cross-Pol and Low Side Lobes. IEEE Antennas and Propagation Magazine, 1993, vol. 35, no. 6, p. 46 – 49.

[2]. R. Swinford, B. Grau, High Throughput Satellites: Delivering future capacity needs. Arthur D. Little electronic publication, 2015, p. 1 – 20.

[3]. A. Kyrgiazos, B. Evans, P. Thompson, et al., A terabit/second satellite system for European broadband access: a feasibility study. International Journal of Satellite Communications and Networking,2014, vol. 32, no. 2, p. 63 – 92.

[4]. D. Serrano-Velarde, E. Lance, H. Fenech, et al., Novel Dimensioning Method for High-Throughput Satellites: Forward Link. IEEE Transactions on Aerospace and Electronic Systems, 2014, vol. 50, no. 3, p. 2146 – 2163.

[5]. T.A. Milligan,Modern Antenna Design(John Wiley & Sons Inc. and IEEE Press. 2nd ed., Hoboken, NJ (USA). 2005).

[6]. TICRA. GRASP: Analysis and design of reflector antennas software. [Online] Download Trial version at: http://www.ticra.com/software/grasp.

[7]. S.K. Rao, Design and Analysis of Multiple-Beam Reflector Antennas. IEEE Antennas and Propagation Magazine, 1999, vol. 41, no. 4, p. 53 – 59.

[8]. S.K. Rao, M. Tang, C.C. Hsu, Multiple Beam Antenna Technology for Satellite Communications Payloads. Aces Journal, 2006, vol. 21, no. 3, p. 353 – 364.

[9]. D. Tipper,Fundamentals of Cellular Networks. (slides). 22 pages. [Online] University of Pittsburgh, USA. Available at: http://www.pitt.edu/~dtipper/2720/2720_Slides4.pdf

[10]. ITU,Satellite system characteristics to be considered in frequency sharing analyses within the fixed-satellite service. (Recommendation ITU-R S.1328-4). 22 pages. [Online] Available at: https://www.itu.int/dms_pubrec/itu-r/rec/s/R-REC-S.1328-4-200209-I!!PDF-E.pdf

[11]. E. Lutz, M. Werner, A. Jahn,Satellite Systems for Personal and Broadband Communications (Springer, 2000. ISBN: 9783642597275).

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