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(54) **FEED SYSTEM FOR DOUBLE-REFLECTOR ANTENNAS**

(57) The present invention relates to a feeder system comprising at least one horn and a sub-reflector, for dual reflector antenna systems, with high-impedance surfaces for the reduction of surface currents and of the electric field generated that contributes to the increase in the secondary lobes and the cross-polar component.

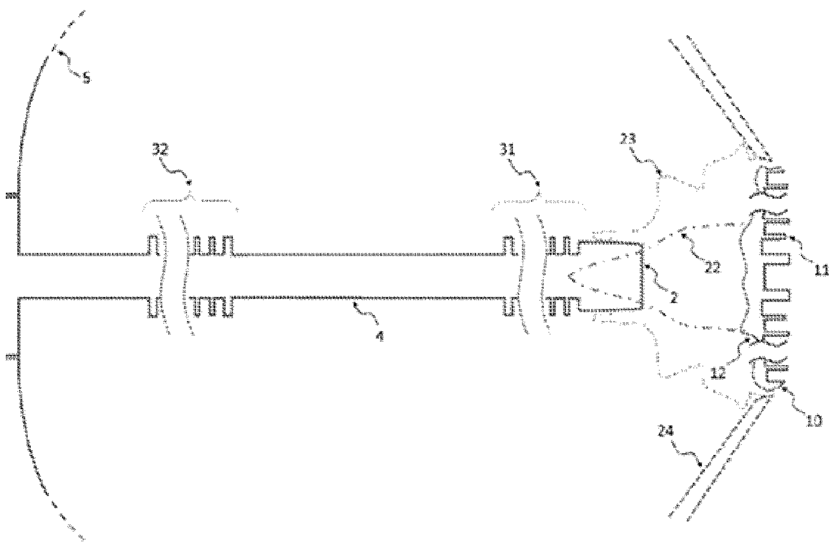

FIG. 1

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Description

TECHNICAL SECTOR

[0001] The present invention relates to the technical field of electronics, and more specifically to information and communication technologies using dual reflector antennas.

BACKGROUND OF THE INVENTION

[0002] Currently, antenna systems are constantly evolving, to enable them to be upgraded for satellite communications and to meet current and future requirements, with electrically small reflector antenna systems.

[0003] Over the past decade, communications systems such as mobile and satellite communications have moved into higher frequency bands, requiring compact high gain antennas in most cases. Antenna gain is affected by efficiency; when high efficiency is generally required, aperture antennas, such as reflectors, are considered. These are characterized by low losses due to their simple design and fewer antenna components. In this regard, the configuration of the reflector antenna is the simplest and most effective alternative for achieving high gain when the profile or size are not steering restrictions and an electronic beam direction is not required. In addition, mask specifications and compliance are a more stringent requirement of operators as the number of users and traffic requirements increase. This means that more users requiring higher data rates are linked to the satellite, and therefore more aggregated interference from the earth segment is affecting satellite systems. In this regard, adjacent satellite systems require a lower contribution from user interference, due to the side lobe level to ensure the aggregate quality indicators (CIR and CINR).

[0004] On the other hand, systems with self-supported sub-reflectors were created to prevent sub-reflector blocking. Systems fed by self-supported sub-reflectors have been used particularly to decrease the level of cross-polarization. The degrees of freedom provided by feeding with a self-supported sub-reflector are based on the design of the different components listed, such as waveguide, horn, supporting radome or struts, and sub-reflector.

[0005] In this respect, the state of the art presents evolved antenna systems with different configurations and sizes. Brief reference is made below to those most relevant, in both dual reflector antenna systems and self-supported or strut-supported sub-reflector feeder systems (dual reflector configuration, essentially a sub-reflector with an attached feed horn antenna) while analysing the contributing sources that increase the side lobe level and the principal antenna parameters that must be improved in small, compact reflector antenna systems, primarily the side lobe level (SLL) and the level of cross-polarization at the axis.

[0006] Dual reflector configuration is the most compact geometry for high-gain antenna systems. However, there are few Gregorian reflectors constructed in comparison with the Cassegrain antenna systems. In general, reflectors may be cylindrical, spherical, as well as displaced, symmetrical, or shaped for a custom radiation pattern. Although there are several types of principal and sub-reflector configurations, in these, the block produced by the sub-reflector, the struts, the feed support mechanism, the alignment, etc. is present. Geometries such as the displaced dual reflector prevent the block produced by the sub-reflector, although this increases the cross-polarization. These problems are often solved by the use of axially symmetrical geometries on both surfaces, reflector and sub-reflector.

[0007] Typically, the sub-reflector is several times smaller than the principal reflector; in the case of symmetrical AD (axially displaced) systems, measuring around 2λ - 4λ. On the other hand, AD systems may be compatible with dual-band feeders. There are several configurations for compact systems in terms of the configuration of the waveguide, horn (conical, corrugated, choke, open waveguide, etc.), sub-reflector and sub-reflector attachment mechanisms (radome-support, dielectric rod, or struts). The dielectric means to support the sub-reflector may also be used to equalize the impedances.

[0008] It has been demonstrated that using a single choke on the horn, the improvement in adaptation and lighting is fairly efficient. In this regard, the so-called "coffee can" design implements a single choke as the main improvement. This device is reproduced coaxially several times in the aperture of the Chaparral-type antenna to improve the purity of the linear polarization. Thus, the implementation of shocks reduces cross-polarization as well as the side lobe level.

[0009] As for the sub-reflector of the above systems, the state of the art contemplates, in one of the solutions, systems fed by a sub-reflector formed by chokes, called a 'hat'. Although this type of feed is initially proposed to reduce cross-polarization, it has been applied to increase the efficiency of the antenna by improving the illumination at the edge of the principal reflector, achieving a reduction in the side lobe and phase error compensation. As mentioned above, the dielectric lens has been implemented for several reasons, for the adjustment of the impedance, to adapt the field of the aperture to the surface of the sub-reflector and to support the sub-reflector.

[0010] On the other hand, other state-of-the-art solutions propose a sub-reflector supported by a dielectric lens at the aperture of the waveguide for feeding a parabolic antenna. The corrugations in the dielectric lens and the structure of the choke dish are optimized to improve the performance of the antenna. The feed structure is designed with an axis of symmetry and for low cross-polarization. The resulting structure provides a good gain and a correct cross-polarization level for Ka-band VSAT applications where the reception and transmission frequency bands are 20.2-21.2 GHz and 30-31 GHz, respectively. However, the secondary lobe level presented is still too high to meet the requirements and diagram masks imposed by most operators. Therefore, the compliance of the mask is limited to that corresponding on the power spectral density (PSD) that will be defined by the type of service (transmission rate).

[0011] The state of the art also comprises solutions that propose a reflector antenna, to improve return losses with respect to the systems developed previously, based on a circular waveguide antenna feed with a flat sub-reflector having a radial dielectric lens that together reflect the energy of the waveguide onto a rotationally symmetrical principal reflector. The dimensions of the antenna feed are also chosen so that its radiation pattern has a zero amplitude along the antenna feed axis. The latter further improves the return losses by minimizing the amount of energy from the main reflector that is directed back to the feed aperture. Alternatively, the same solution presents a feed radiation pattern with a narrowing of the asymmetric amplitude, to improve the side lobe ratio in a preferred plane.

[0012] For the same type of reflector systems with low focal distance ratio with regard to the diameter of the principal reflector, and the latter with the focal point very close to the aperture, the state of the art also comprises a solution with a dual reflector antenna and low secondary lobe, with a ratio between the focal length of the reflector and the diameter of the reflector established at less than 0.25. To feed the principal reflector, the system uses a waveguide coupled at the extremity thereof to a convex reflector, which provides illumination to the principal reflector. To do this, a dielectric block is used, coupled to an extremity, which as well as adapting the aperture of the waveguide, supports the convex sub-reflector. The diameter of the sub-reflector is sized to be 2.5 wavelengths or more than one desired operating frequency. The latter makes it a multi-band system and improves its efficiency.

[0013] Another of the possibilities found in the state of the art proposes a reduction in the density of the surface current near the edges of the parabolic reflector antenna to reduce the secondary lobe level of the reflector. To do this, the current density is reduced by placing conical resistive edge loads on the reflector to thereby gradually reduce the conductivity from the centre of the reflector to the edge.

[0014] Finally, a solution that improves the above techniques contemplates an antenna with a sub-reflector with reduction of side lobes. Said solution comprises a conical, convex, corrugated, anisotropic sub-reflector connected to a waveguide, and this is to be found at the focus of a deep main reflector with the focal point very close to the aperture. The sub-reflector has variable depth corrugations. The varying depths of the corrugations result in a variable reactance, or a taper of the sub-reflector reactance. This convex sub-reflector has a conical shape designed in such a way that it guides or directs the energy of the antenna feed to the main reflector, ensuring that the side lobes are very small. Further, the sub-reflector has a shape that can be formed to direct or guide the energy in the desired direction in an optimized manner. The deep geometry of the main reflector enables the small-sized sub-reflector to be placed within the edge of the main reflector, in such a way that the assembly can be covered with a flat radome.

[0015] However, all of the above solutions have drawbacks when efficiently reducing jointly the secondary lobes and cross-polar component level of the system, which continues to be a design challenge for the state of the art.

DESCRIPTION OF THE INVENTION

[0016] The present invention solves the aforementioned problems by reducing the secondary lobe level and the cross-polar component of an antenna. To this end, a first aspect of the invention relates to a feeder system for dual reflector antennas, comprising: a feed horn coupled to a waveguide; and a sub-reflector dish having a front side for reflecting radiation emitted by the feed horn, and a rear side, wherein the system is characterized in that it comprises at least one first high-impedance surface disposed on the rear side of the sub-reflector dish. Advantageously, the high-impedance surfaces implemented in the system of the present invention reduce the surface currents and those of the electric field generated, which are responsible for undesirable increases in the secondary lobes and the cross-polar component.

[0017] In one embodiment of the invention, the first high-impedance surface comprises at least one axial corrugation. In one embodiment of the invention, the first high-impedance surface comprises at least one choke of certain dimensions, tuned to a critical frequency. Advantageously, high-impedance corrugated surfaces are implemented on the rear side of the sub-reflector, unlike other state-of-the-art designs that use the corrugations to obtain a particular illumination. In the present invention, the axial corrugations, also known as chokes, are tuned to the critical frequencies at which it is desired to eliminate the contribution of the fields that may be generated on the surface of the sub-reflector. In this way, its contribution to the secondary lobes and to the cross-polar component is reduced.

[0018] The first high-impedance surface may be defined by its dimensions according to certain parameters: a first depth parameter, a second slot width parameter, and a third wall width parameter. In one specific embodiment of the invention, the values assigned to said parameters are equal to or greater than $\lambda/4$, $\lambda/8$ and $\lambda/80$, respectively.

[0019] According to a particular embodiment of the invention, the first high-impedance surface comprises at least five chokes, each of the chokes having dimensions different from or equal to the others.

[0020] The present invention contemplates a second high-impedance surface disposed at the waveguide. Specifically, one of the embodiments contemplates that the second high-impedance surface has at least one array of side chokes disposed transversely and exteriorly on the waveguide. Thus, advantageously, the currents coming from the aperture, as well as those displaced from other field sources, are reduced. This also contributes to the reduction in the secondary lobes of the overall diagram of the dual reflector antenna system.

[0021] Additionally, support means for the sub-reflector dish are contemplated. The support means may be selected from among a radome, a dielectric element or lens, and a number of rods.

[0022] The waveguide is contemplated to be interiorly disposed along a feed mast, engageable by one of its extremities to a main reflector dish of the dual reflector system and engageable by the opposite extremity thereof to the feed horn.

[0023] Optionally, a particular embodiment of the invention contemplates a main reflector dish, coupled at a first extremity of the feed mast, where the feed mast comprises two high-impedance surfaces with five chokes each; and wherein the sub-reflector dish is supported by a radome, such that the front side of the sub-reflector dish is disposed in a position facing the feed horn that reflects the radiation towards the main reflector dish, and where the front side of the sub-reflector dish has an elliptical geometry.

[0024] The feeder system of the present invention is not only applicable for new designs of dual reflector systems, but can advantageously be implemented in systems that are already designed, which it is desired to improve by reducing their cross-polar component level and their secondary lobe level.

[0025] In accordance with the foregoing, the advantages for dual reflector antenna systems are manifold. Among the advantages, for example, one may highlight the reduction in the secondary lobe level and in the cross-polar component which, in systems with a low focal length ratio with respect to the diameter of the main reflector (f/D) and of electrically small main reflectors of few lambdas (< 50λ), is a design challenge.

BRIEF DESCRIPTION OF THE FIGURES

[0026] To complement the description of the invention, and for the purpose of aiding a better understanding of the characteristics thereof, in accordance with a preferred exemplary embodiment thereof, a set of drawings is attached wherein, by way of illustration and not limitation, the following figures have been depicted:

- **Figure 1** portrays the overall embodiment of the low SLL and cross-polar component feeder system for dual reflector antennas.

- **Figure 2** portrays an embodiment option where the surface receiving the feeder fields and reflecting them towards the principal reflector is of a hyperbolic nature.

- **Figure 3** portrays another embodiment, where the surface receiving the feeder fields and reflecting them towards the principal reflector is of an elliptical nature, in this case causing the system to be of the displaced axis type with an elliptical sub-reflector.

- **Figures 4A, 4B and 4C** portray the rear side of the sub-reflectors, which influences the behaviour of the surface currents in the case of electrical surfaces and in the case when high-impedance surfaces with chokes are implemented. Where the greyscale represents the intensity of the surface currents, the lightest shade being that which corresponds to the highest current intensity.

- **Figures 5A and 5B** portray the mast of the feeder system and the influence on the behaviour of the surface currents for cases when one or two arrays of high-impedance surfaces with chokes are implemented.

- **Figures 6A, 6B, 6C and 6D** portray different propagation surfaces, which imply different behaviours of the electromagnetic plane waves TEM, TE and TM.

DETAILED DESCRIPTION OF THE INVENTION

[0027] The present invention discloses a solution for a dual reflector antenna feed with a reduced secondary lobe level and cross-polarization component. The description of the feeder system components and techniques employed is based on the embodiments depicted in the figures, discussed above, for illustrative purposes. However, the present invention can be implemented in any dual reflector system, primary and secondary, although its greatest contribution to optimization is presented in centred dual reflector systems.

[0028] The feeder system of the present invention achieves its advantageous effects by reducing the currents produced by the fundamental mode and the greater modes generated at the aperture or horn implemented. These currents are small on the horn mast and on the rear side of the sub-reflector. Such currents can be produced by the field delivered to the waveguide that feeds the horn, and therefore exist at the aperture, as well as by the fields diffracted from the remainder of the components or structure of the antenna system. This achieves the goal of reducing the level of unwanted secondary lobes and cross-polar component in the system.

[0029] The specific configuration of the system of the present invention, which produces the effect of reducing undesired currents, is based on the implementation of chokes with variable dimensions in keeping with each problem, on the metal surfaces considered to be critical. In this regard, one of the embodiments of the invention focuses on disposing corrugations on metallic planes with a canonical wave solution and where Kildal's correction can be applied. This analysis can also be used in the reduction of surface waves of electric fields since these are supported on magnetic surfaces.

[0030] **Figures 1, 2** and **3** portray a general diagram with the parts and components of the feeder system of the present invention, in accordance with different embodiments that disclose different options of support elements and geometries of the surface of the sub-reflector receiving the fields of the feeder. The operating bands of the system can be of any nature, both for narrow band systems, for broad band, and for multi-band systems, regardless of the type of polarization used. Thus, the feeder proposed has the following elements:

- a feeder mast **4,** wherein the mast in turn comprises the waveguide, which feeds a horn or aperture **2,** and a number of high-impedance surfaces **31** and **32.** The number of surfaces can vary, as can be seen in the different masts depicted in **Figures 5A and 5B,** where these surfaces are implemented as arrays of N (first array **51)** and L (second array **52)** chokes, which are defined on the basis of the system requirements to reduce the currents coming from the aperture, by the currents displaced and by the contribution by dispersion of the different components of the system;

- sub-reflector support elements, which depend on the type of sub-reflector implemented. For example, these support elements may be a radome **23** integrated into the exterior of the horn and holding the sub-reflector, a dielectric element or lens **22** adapted to the aperture or horn, and this supports the sub-reflector, or struts **24** (rods) that may be attached to the mast or from the main reflector 5, and hold the sub-reflector. All these options ensure the correct position of the sub-reflector according to the electromagnetic design of the system; and

- a sub-reflector **10** with a high-impedance surface at the rear surface **11,** and with any geometry or type of design for the side **12** receiving the fields from the feeder and reflecting them towards the main reflector.

[0031] The dual reflector systems included in the present invention may be classic or optimized. Among the classic type are, for example, the double Cassegrain, Gregorian and ADE (Axial Displaced Elliptical) systems, while among the non-classics, one can name the modified ADE systems in which the sub-reflector is not elliptical, but is replaced by another type of self-supporting sub-reflector such as those discussed in the state of the art, such as the "Hat-fed" type system, among others.

[0032] To understand the theoretical development that leads to the solution proposed by the present invention, it must first be assumed that the wave of the electric field is perpendicular to the corrugations, regardless of the direction of the source field being considered, also the field coming from the dispersion of the waves from various surfaces and from the structure of the antenna itself. To do this, the theoretical problem can be analysed from the results obtained on the surfaces, using a source that emits an electromagnetic field from one direction, as may be seen in **figures 4A, 4B and 4C.**

[0033] **Figures 6A-6D** present the different types of surfaces contemplated, which influences the behaviour of the electromagnetic waves, as will be seen below. Note that typically, the problems of 'overshoot' or exceeding the requirement masks, are more critical in the frequency bands defined for transmission, so the reduction in undesired currents can be concentrated for said frequencies. However, a narrow-band approach cannot be used, so the periodic use of resonant corrugations with a constant depth of lambda four must be rejected.

[0034] There are two types of electromagnetic plane waves, TEM, TE and TM, which may be present or may propagate along the surfaces of **Figures 6A-6D.** The waves of the TE fields define the electric field vector in the direction parallel to the XY plane, where this plane belongs to the surface under study with its orthogonal magnetic field vector, and both being orthogonal to the direction of propagation. On the other hand, the TM plane waves define the vector of the magnetic field parallel to the XY plane belonging to the surface under study, with its orthogonal electric field vector, and both being orthogonal to the direction of propagation. In both cases, the electrical and magnetic vectors comply with the right-hand rule describing the direction of propagation.

[0035] On the other hand, on the basis of the boundary conditions, it is defined that the electric field on an electrically conductive surface is zero ($|\vec{E}| = 0$) and that the magnetic field is different from zero ($|\vec{H}| \neq 0$). At the same time, on a magnetic surface, such as the corrugations or chokes proposed by the present invention, it is required that the magnetic field be zero ($|\vec{H}| = 0$) and the electric field be different from zero ($|\vec{E}| \neq 0$).

[0036] According to the above, surface **61** of **FIG. 6A** is a constant electrical surface in which the electric field of the surface is zero for its components on the XY plane.

[0037] For surfaces **62** and **63** of **figures 6B and 6C,** it is achieved that both the electric and magnetic fields parallel to the XY plane are zero, so the surface plane waves TE and TM are zero. This assumption applies to resonant structures whose dimensions can be defined as depth "d", slot or choke width "W" and wall width "w", as $\lambda/4$, $\lambda/8$ and $\lambda/80$ or greater, respectively. Furthermore, it is also assumed that the fields propagate in the direction of the z-axis, so the surface **63** will provide, for various field sources, a frequency dispersion property under the conditions of the previously established limits, due to the fact that the dimension "W" of the slot aperture changes in different sections parallel to the direction of the X-axis. Finally, if different sources are located at the same distance on a circular section concentric to the arc of the corrugation on the surface **63,** and their fields propagate towards the centre of these concentric circles, then a unique resonant behaviour is obtained on the surface.

[0038] On the surface **64** of **Figure 6D,** which belongs to a scenario with several sources located at different distances from its centre and surrounding the same in almost all directions of impact, the sources provide fields under evaluation, so they have to deal with the characteristics of the dispersive surface. Thus, the surface **64** has different depths, slots and wall widths to cover the entire frequency band. This means that a plane corrugated surface with chokes of a depth exactly equal to a quarter lambda mitigates the oblique plane wave whose vectors are perpendicular to the corrugations, which may be independent of the direction of the field. In this sense, these surfaces are known as polarization-independent surfaces.

[0039] Further, assuming that the chokes on the surface can be replaced by the boundary conditions of the corrugated surface, a single mode approach may be used to understand the problem. Further mathematical expansion analysis of the external fields over the square corrugated surface can also be performed, using the complete array of modes, and also for the cylindrical corrugation. Taking into account the decay factor α on the basis of the propagation factor, the Maxwell's equation for the coupled field related to the conditions of the boundaries can be solved with $\nabla X\vec{H}$ for $H_{and}(z = 0)$, and this leads to the relationship between the electric and magnetic fields which, by replacing them in the wave equation, both the electric and magnetic fields, gives the dispersion ratio $k^2 - k_x^2 + a^2 = 0$ that the decay factor provides.

[0040] It is important to mention that in real systems, a main petal-type reflector does not have the ideal symmetry and therefore the phase contribution of the pairs of current elements is not the same at each evaluation point. Further, the displaced currents produced by the field of the direct feed horn and that affect the surface of the sub-reflector also exist on the rear metal side of the sub-reflector.

[0041] To facilitate the understanding of the solution proposed in the present invention, a preferred embodiment thereof, based on the same figures explained above, is described below. Thus, the preferred embodiment of the low SLL and cross-polar component feeder system for dual reflector antennas consists of: a feeder mast **4** with two high-impedance surfaces **31** and **31** with five chokes each, where the mast contains the waveguide that feeds a horn **2** disposed at its extremity to feed a sub-reflector; a horn or aperture **2** of one or two frontal chokes; a radome **23** as a support element for the sub-reflector; and a sub-reflector **10** with a high-impedance surface at the rear surface **11** consisting of five chokes of varied dimensions, and with any geometry for the side **12** that receives the fields from the feeder and reflects them towards the elliptical, or elliptically-shaped type principal reflector.

[0042] The present invention should not be considered limited to the embodiment described herein. Other configurations may be made by persons skilled in the art in view of the present description. Accordingly, the scope of the invention is defined by the following claims.

Claims

1. A feeder system for dual reflector antennas, comprising:

   - a feed horn (2) coupled to a waveguide; and
   - a sub-reflector dish (10) having a frontal side (12) for reflecting radiation emitted by the feed horn, and a rear side (11),

   wherein the system is **characterized in that** it contains:

   - at least one first high-impedance surface disposed on the rear side of the sub-reflector dish.

2. A system as claimed in claim 1, wherein the first high-impedance surface comprises at least one axial corrugation.

3. A system as claimed in claim 1, wherein the first high-impedance surface comprises at least one choke of certain dimensions tuned to a critical frequency.

4. A system as claimed in any of the preceding claims, wherein the first high-impedance surface is defined by a first depth parameter, a second slot width parameter and a third wall width parameter.

5. A system as claimed in claim 4, wherein the first parameter, the second parameter and the third parameter have respectively a value of $\lambda/4$, $\lambda/8$ and $\lambda/80$ or greater.

6. A system as claimed in any of the preceding claims, wherein the first high-impedance surface comprises at least five chokes, wherein each of the chokes has dimensions different from or equal to the others.

7. A system as claimed in any of the preceding claims, further comprising at least one second high-impedance surface (31, 32) disposed at the waveguide.

8. A system as claimed in claim 7, wherein the second high-impedance surface comprises at least one array of side chokes (51) disposed exteriorly on the waveguide.

9. A system as claimed in any of the preceding claims, that further comprises support means for the sub-reflector dish.

10. A system as claimed in claim 9, wherein the support means are selected from among a radome (23), a dielectric element or lens (22) and a number of rods (24);

11. A system as claimed in any of the preceding claims, and further comprising a feed mast, where the waveguide is disposed interiorly along said feed mast.

12. A system as claimed in claim 11, and further comprising a main reflector dish (5), coupled at a first extremity of the feed mast, where the feed mast comprises two high-impedance surfaces (51, 52) with five chokes each; and
where the sub-reflector dish is supported by a radome, in such a way that the frontal side of the sub-reflector dish is disposed in a position facing the feed horn that reflects the radiation towards the main reflector dish, and where the frontal side of the sub-reflector dish has an elliptical geometry.

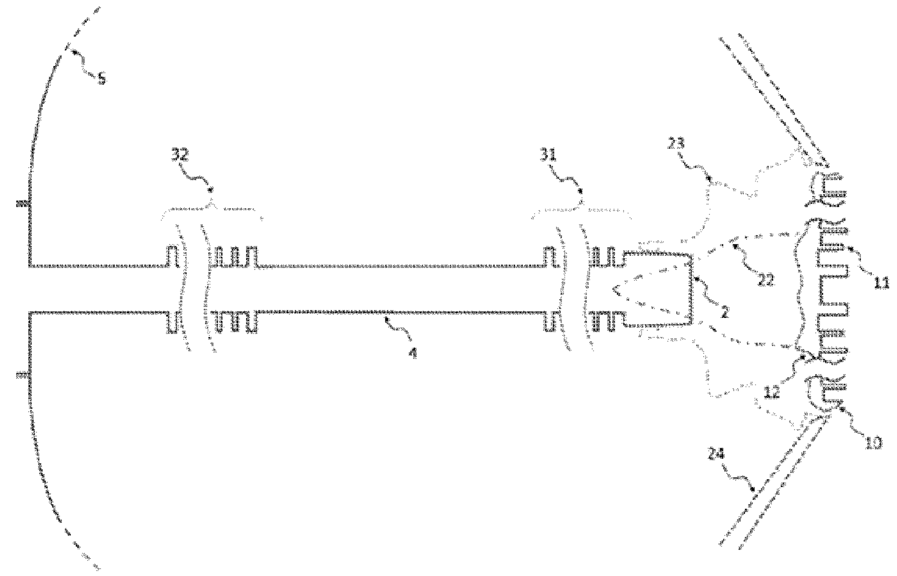

FIG. 1

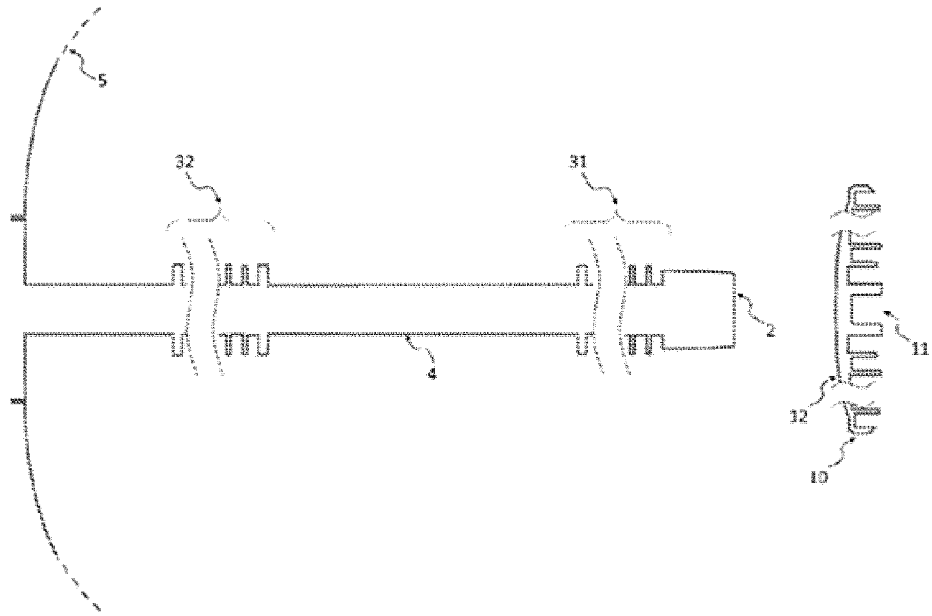

FIG. 2

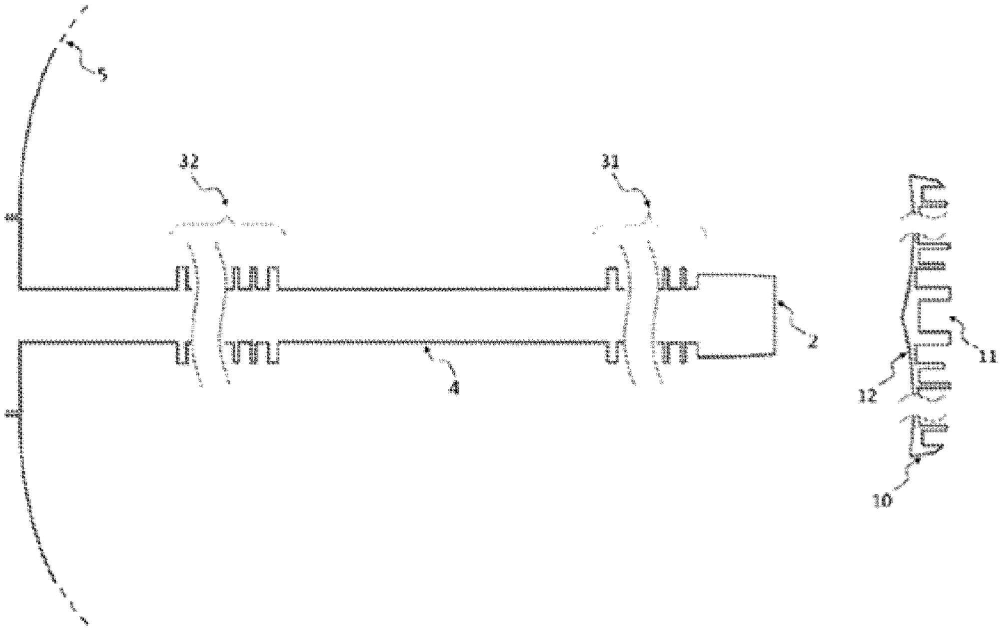

FIG. 3

FIG. 4A FIG. 4B FIG. 4C

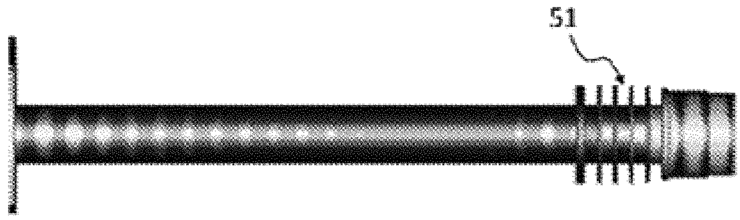

FIG. 5A

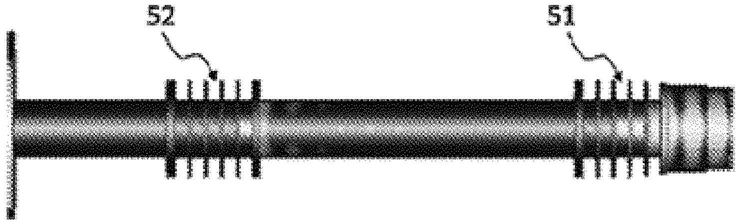

FIG. 5B

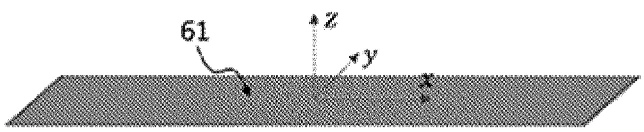

FIG.6A

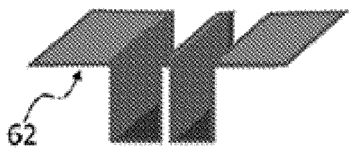

FIG. 6B

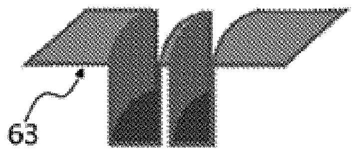

FIG. 6C

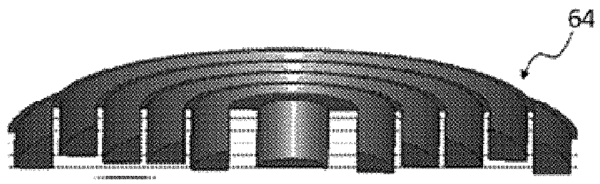

FIG. 6D

INTERNATIONAL SEARCH REPORT

International application No.
PCT/ES2019/070867

A. CLASSIFICATION OF SUBJECT MATTER

H01Q13/02 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, INVENES, WPI, NPL, XPESP, XPAIP, XPI3E, INSPEC.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ZANG SANDRO R et al.. Analysis of Omnidirectional Dual-Reflector Antenna and Feeding Horn Using Method of Moments. IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, 20140301 IEEE SERVICE CENTER, PISCATAWAY, NJ, US. 01/03/2014, Vol. 62, Nº 3, Pages 1534 - 1538, ISSN 0018-926X, <DOI: 10.1109/TAP.2013.2296775>	1-12
A	BAUERLE R J et al.. A center fed multi-band antenna for simultaneous satellite communication at C and Ku bands. MILITARY COMMUNICATIONS CONFERENCE, 2010 - MILCOM 2010, 20101031 IEEE, Piscataway, NJ, USA. 31/10/2010, Pages 1564 - 1571 ISBN 978-1-4244-8178-1; ISBN 1-4244-8178-3	1-12

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance.
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Date of the actual completion of the international search	Date of mailing of the international search report
07/04/2020	**(08/04/2020)**
Name and mailing address of the ISA/ OFICINA ESPAÑOLA DE PATENTES Y MARCAS Paseo de la Castellana, 75 - 28071 Madrid (España) Facsimile No.: 91 349 53 04	Authorized officer J. Botella Maldonado Telephone No. 91 3495382

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