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सत्यमेव जयते

क्रमांक : 044145611
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पेटेंट प्रमाणपत्र
PATENT CERTIFICATE
(Rule 74 of The Patents Rules)

पेटेंट सं. / Patent No.	:	409231
आवेदन सं. / Application No.	:	3767/CHE/2012
फाइल करने की तारीख / Date of Filing	:	11/09/2012
पेटेंटी / Patentee	:	INDIAN SPACE RESEARCH ORGANISATION
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प्रमाणित किया जाता है कि पेटेंटी को, उपरोक्त आवेदन में यथाप्रकटित DUAL POLARISED, S&X BAND MONOPULSE FEED FOR TRACKING LEO SATELLITES नामक आविष्कार के लिए, पेटेंट अधिनियम, 1970 के उपबंधों के अनुसार आज तारीख सितम्बर 2012 के ग्यारहवें दिन से बीस वर्ष की अवधि के लिए पेटेंट अनुदत्त किया गया है।

It is hereby certified that a patent has been granted to the patentee for an invention entitled DUAL POLARISED, S&X BAND MONOPULSE FEED FOR TRACKING LEO SATELLITES as disclosed in the above mentioned application for the term of 20 years from the 11th day of September 2012 in accordance with the provisions of the Patents Act,1970.

पेटेंट कार्यालय
THE PATENT OFFICE
GOVT.OF INDIA
भारत सरकार

अनुदान की तारीख :
Date of Grant : 18/10/2022

पेटेंट नियंत्रक
Controller of Patent

टिप्पणी - इस पेटेंट के नवीकरण के लिए फीस, यदि इसे बनाए रखा जाना है, सितम्बर 2014 के ग्यारहवें दिन को और उसके पश्चात प्रत्येक वर्ष मे उसी दिन देय होगी।

Note. - The fees for renewal of this patent, if it is to be maintained will fall / has fallen due on 11th day of September 2014 and on the same day in every year thereafter.

FORM 2

THE PATENTS ACT, 1970
(39 of 1970)
THE PATENTS RULES, 2003

COMPLETE SPECIFICATION

(See section 10; rule 13)

TITLE OF THE INVENTION

"DUAL POLARISED, S AND X BAND MONOPULSE FEED FOR TRACKING LEO SATELLITES"

APPLICANT

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The following specification particularly describes the invention and the manner in which it is to be performed

Dual Polarized, S and X Band Monopulse Feed for Tracking LEO Satellites

FIELD OF THE INVENTION

This invention generally relates to satellite communication, more specifically to ground station antenna system to track and receive data from remote sensing satellites.

BACKGROUND OF THE INVENTION

Remote sensing satellites are mainly LEO satellites which orbit very fast regarding to ground station making tracking of these satellites is very critical in order to collect imagery data from the satellite without any loss. By using orbital Keplarian parameters, the trajectory of the LEO satellite can be estimated and be used in a Program Tracking System (PTS). As PTS tracking is not highly accurate, different methods of tracking have been adopted since the early days of radar and satellite tracking. Lobe switching and conical scanning are the methods, which generally uses the amplitude of the target echoes for radar tracking. A crude way of determining the angular position of a target and note the pointing direction that gives maximum amplitude. This method is called lobe switching. In the case of conical scanning, beam is moved electronically or mechanically in circular way. When the beam axis is closest to the target direction, the echo or received signal will be modulated approximately at the greatest scanning frequency. However, these two above mentioned methods have inherent limitations because of the error originating from the amplitude fluctuations of the target echoes. Also, as at least four echo pulses or four antenna positions are required in order to get angle information which restricts their use in high data rate applications. Low SNR and mechanical vibration also limits these techniques in satellite and radar tracking. A more sophisticated way of tracking is monopulse. This method usually use plurality of antennas for simultaneously getting angular information in both azimuth and elevation direction. A monopulse tracking technique is very accurate, free from mechanical vibration, gives high SNR and has been adopted in most of the ground stations for tracking LEO satellites. But when the beam width of the reflector is very narrow, particularly at higher frequencies, designing an accurate tracking system is a challenging task for the designers and criticality of the design is mainly imposed upon feed in order to obtain optimum radiation pattern for both Sum and difference in orthogonal plane. Four horns or five horns antennas are conventionally used in the tracking feed. The main difficulty in multi element tracking system is inter-element placement of the radiating elements in the array. In this present Cassegrain antenna configuration, the sub reflector subtends an angle of ±14.5deg at the aperture. This requires a high directive antenna to illuminate the sub-reflector with a suitable taper -15 to -20dB. To generate a beam that will meet the above requirement a feed aperture of 2.7λ is required. In a 2×2 array for the feed inter element spacing becomes 1.35λ. Arrays with inter element spacing of more than 1λ exhibit array factor single main lobe and multiple grating lobes. To have maximum gain, grating lobes should be suppressed. These grating lobes also contribute to spillover and overall efficiency reduces. One way of suppressing these lobes is to incorporate a radiating element which is sharp with less aperture cross section. The Dielectric radiating element having its lager dimension in the longitudinal direction rather than a plane transverse to the direction of maximum radiation, gives designer the flexibility to optimize the array radiation pattern in order to obtain an optimal Sum and Difference radiation pattern. Also, at higher frequency, use of dielectric element instead of metallic antennas, reduces mechanical complexity.

The main difficulty in designing of monopulse is that in order to realize its inherent superior capability it needs more equipment and more painstaking design and adjustment of components. Conventional monopulse requires three channels, one for Sum or reference and two for Azimuth and Elevation difference. This increases corresponding RF and IF electronics equipment resulting in more complex and expensive system. Here a smart way of reducing radio frequency and intermediate frequency electronics has been adopted. The two difference signals are multiplexed into a single channel using device called a monoscan converter. The multiplexed error signals then added with the Sum signal using directional coupler thus resulting in a single channel receiver. The output of the directional coupler results in a signal, the envelope is error signal and Sum signal acts as reference. This signal is demodulated, Azimuth (AZ) and Elevation (EL) signals are extracted to drive the servo system.

Prior patent document US7315283B2 discloses a dual band circularly polarized antenna comprised of chamfered corner and ground plane. The dual band circularly polarized antenna, as disclosed in US7315283B2, consists of simple radiating elements used for transmission and reception of circularly polarized signals in two different frequency bands simultaneously and applied in the antenna modules of RFID system, antenna modules of base station of mobile communication system or in antenna modules of satellite communication system. These kinds of antennas are not suitable for high gain Cassegrain antenna. In contrast, the present invention relates to an efficient dual band, dual polarized feed for Cassegrain reflector.

Prior patent publication DE60131581T2 describes a low profile commercially usable antenna mounted on a flat circular plate that rotates to scan the azimuth direction. DE60131581T2 is related to equatorial constellation satellite tracking, not for LEO satellite. This invention is related to phased array antenna with a limited scanning capability, not full hemisphere.

Prior patent publication US4356459A demonstrates design of a septum polarizer where trapped mode resonators and tuning screws are used. The septum polarizer proposed in present invention is completely different from the one described in US4356459A. In contrast to the invention of US4356459A, in the present invention resonators and tuning screws are not used in the design of septum polarizer.

With a view therefore to overcome the difficulties associated with conventional feed systems for tracking LEO satellites the inventors felt the need to develop a novel dual polarized S and X band monopulse feed system for tracking LEO satellites. The dual polarized feed, as proposed by the invention, is capable of tracking in four modes, such as X-RHCP, X-LHCP, S-RHCP and S-LHCP. This provides the user great amount of flexibility as it has the capability of operating in either of these modes which one is receiving more signal strength or according to user's choice. Instead of using conventional four horns or five horns as feed elements, here dielectric rod radiating elements with high aperture efficiency, rotationally symmetric beams with low side lobe levels, have been used. Dielectric rods are lightweight, low cost and easily machinable and have good sealing and corrosion properties. Dielectric rod gives designer a great deal of flexibility it has its larger dimension in the longitudinal direction rather than a plane traverse to the direction of maximum radiation. The X-band radiating elements are dual polarized and capable of receiving data in both right hand circular polarization (RHCP) and left hand circular polarization (LHCP). This allows frequency reuse and diversity application.

In the present invention a septum polarizer is used to separate LHCP and RHCP component and produce linear polarized signal for the comparator output. Septum polarizer exhibits good return loss and isolation between two ports, which receive orthogonal polarized components. This feed consists of a waveguide monopulse comparator, which exhibits low insertion loss, minimum amplitude and phase imbalance and high isolation between sum and difference port. Wave guide magic tee is used as basic building block of the comparator network. S-band elements are composed of 20 turn tapered helix wound on a nylon former. Total eight helices are used, four for RHCP and four for LHCP, and capable of tracking in both orthogonal polarized modes. Microstrip rat race hybrids are used as the S band comparator network. This design gives good electrical characteristics in miniaturized form. Thus, with the present invention it was possible to reduce the RF and IF electronics. The two difference signals are multiplexed into a single channel then added with the Sum signal or reference signal resulting in a single channel receiver.

Dielectric antennas are suitable at higher frequencies as at these frequencies resistive losses introduce a significant problem in metallic antennas, which may be compounded by increasing manufacturing costs. Availability of high performance low-loss dielectric materials thus makes dielectric antenna viable candidates for microwave and millimeter wave applications. This type of antenna has further advantage of exhibiting high aperture efficiency compared to horn antennas resulting in a compact feed system. They are usually lightweight, low cost and easily machinable and have good sealing and corrosion properties. The solid dielectric cylinder with conical taper at the end is excited with a circular wave guide.

SUMMARY OF THE INVENTION

Accordingly, the present invention provided a novel dual polarized S and X band monopulse feed system to track and receive data for tracking LEO satellites comprising:

- an X band feed system comprising of four X band radiating elements, four septum polarizers, an X band RHCP monopulse comparator and an X band LHCP monopulse comparator,
- an S band feed system comprising of eight S band radiating elements, two monopulse comparators, namely a S band RHCP monopulse comparator and S band LHCP monopulse comparator,
- two monoscan convertors, namely a RHCP Monoscan convertor and a LHCP Monoscan convertor,
- four low noise amplifiers, first low noise amplifier, second low noise amplifier, third low noise amplifier and the fourth low noise amplifier, wherein said first low noise amplifier and second low noise amplifier being configured as RHCP chain,

said first low noise amplifier is for amplifying RHCP sum signal and said second low noise amplifier is for amplifying RHCP error signal, wherein said third low noise amplifier and fourth low noise amplifier being configured as LHCP chain, said third low noise amplifier is for amplifying LHCP error signal and said fourth LNA is for amplifying LHCP sum signal,

wherein said X band radiating element comprises of an array of four conical radiating elements , each of said conical radiating element is in the form of a dielectric rod antenna with conical taper, said dielectric rod being configured to be excited by a circular waveguide,

and wherein each of said X band radiating element is connected to a corresponding septum polarizer, and said septum polarizer configured to be fed with the output of its corresponding X band radiating element and is configured to receive both RHCP and LHCP signals simultaneously and thereupon separate X band RHCP and X band LHCP components with good isolation and provide linear polarized output to said RHCP monopulse comparator,

and wherein each of said X band RHCP monopulse comparator and X band LHCP monopulse comparator comprises E-plane and H-plane magic tee assemblies to generate corresponding LHCP and RHCP sum signals, elevation difference signals , Azimuth difference signals in X band from the signal fed from respective LHCP and RHCP ports of said septum polarizer, and wherein said S band radiating element comprises of an array of eight helical elements, four RHCP S band helical elements are configured to receive RHCP signals and four LHCP S band helical elements are configured to receive LHCP signals in S band,

and wherein each of said S band RHCP monopulse comparator and said LHCP monopulse comparator is in the form of a microstrip circuit having four rat-race hybrid couplers, and wherein said S band RHCP and LHCP monopulse comparators are configured to generate RHCP and LHCP sum signals in S band, RHCP and LHCP elevation difference signals in S band, and RHCP and LHCP Azimuth difference signals in S band from the signal fed from said four S band RHCP radiating elements,

and wherein each of said RHCP monoscan convertor and said LHCP monoscan convertor comprise of PIN diode switches and four magic tees, said RHCP monoscan converter is configured to multiplex said RHCP elevation difference signal and said RHCP Azimuth difference signal received from said X band RHCP monopulse comparator, and said S band RHCP monopulse comparator into a single channel and said LHCP monoscan converter is configured to multiplex said LHCP elevation difference signal and said LHCP Azimuth difference signal received from said X band LHCP monopulse comparator and from said S band LHCP monopulse comparator into a single channel,

and wherein said first low noise amplifier is configured amplify the S and X band RHCP sum signals received from said S and X band RHCP monopulse comparator, and wherein said second low noise amplifier is configured to amplify the RHCP error signals received from said S and X band RHCP monopulse comparator and wherein said third low noise is configured to amplify said LHCP error signals received from said S and X band LHCP monopulse comparator and wherein said fourth low noise amplifier is configured to amplify the LHCP sum signal error signals received from said S and X band LHCP monopulse comparator.

In the invented feed system said S and X band feed is configured to allow simultaneous RHCP and LHCP signal reception in both S and X band.

Preferably, the invented system is provided with two test loop couplers, a first test loop coupler and a second test loop coupler, first test loop coupler connected to said X band RHCP monopulse comparators and the second test loop coupler connected to X band LHCP monopulse comparators respectively. The said first loop coupler is fed with said RHCP sum signals generated from said X band RHCP monopulse comparator, and wherein said second loop coupler is fed with said LHCP sum signals generated from said X band LHCP monopulse comparator .

According to one embodiment of the invented feed system for tracking LEO satellites, the S and X band feed is configured to allow simultaneous RHCP and LHCP signal reception in S and X band with enhancing data reception capability upto 640 Mbps data rate.

According to one embodiment of the invented feed system for tracking LEO satellites, the X band radiating element is made of dielectric rod antenna with conical taper and having circular cross section.

According to a preferred embodiment of the invented feed system, the S band radiating element is as tapered helix formed by helically winding 20 turns on a nylon former.

According to yet another embodiment of the invented feed system, said X band radiating elements are connected to said septum polarizer by means of a circular to square flange.

According to a further embodiment of invented feed system is capable of tracking any one of said X-RHCP, X-LHCP, S-RHCP and S-LHCP modes. Then the difference signals are multiplexed into a single channel using said monoscan converter then added with the sum signal using a directional coupler resulting in a single channel receiver.

According to a further embodiment of invented feed system, the X band monopulse comparators may be a combination of three magic tees configured to produce said RHCP sum, difference output signals and LHCP sum, difference output signals.

According to a further embodiment of invented feed system, the X band monopulse comparators may be a combination of four magic tees configured to produce said RHCP sum, difference output signals and LHCP sum, difference output signals.

According to a preferred embodiment of the invention, said S band monopulse comparators consists of microstrip circuit consisting of four rat-race hybrid couplers.

According to another preferred embodiment of the invented system, said magic tee is a four port network configured to generate said sum and said difference signals incident on its co-linear arm, in H-plane and E-arm respectively.

According to another preferred embodiment of the invented system, the magic tee comprises a metallic platform and thin septum polarizer in a WR 90 waveguide and is fabricated by spark erosion EDM method. The amplitude and phase imbalance of the magic tees are 0.2 dB and 20 dB respectively.

According to a further embodiment of the invention, the insertion loss of the total comparator assembly is 0.3 dB and the feed system is integrated with a reflector of 7.5mm diameter in cassegrain configuration. Preferably, the feed system is integrated with a reflector with dual shaped reflector of 7.5mm diameter in cassegrain configuration.

According to another preferred embodiment of the invented system, the monoscan converter is a microwave three port device and is configured to convert Azimuth and elevation input difference signals to form a time division multiplex of Azimuth and elevation difference signals with biphase modulation.

The present invention also provides a novel method for generating dual polarized S and X band monopulse feed to track and receive data from satellites, which transmits high data rate signals using frequency re-use techniques.

The invented method comprising the steps of:

- receiving X band signals in an assembly of four X band radiating elements, each of said X band radiating element being made of a tapered dielectric rods,
- receiving S-band signals in an assembly of S band radiating elements, said S band radiating elements being made of eight circularly polarized helical

antennas, where four of said circularly polarized helical antennas are designated for reception of RHCP signals and the other four of said circularly polarized helical antennas are designated for reception of LHCP signals,

- separating the signals output from each of said X band radiating elements into RHCP and LHCP components by means of septum polarizers, each of said X band radiating elements being provided with a corresponding septum polarizer,

- receiving said RHCP and LHCP signals generated from said X band radiating elements by means of a RHCP monopulse comparator and a LHCP monopulse comparator respectively,

- receiving said RHCP and LHCP signals generated from said S band radiating elements by means of a RHCP monopulse comparator and a LHCP monopulse comparator respectively,

- receiving said RHCP signals from said X and S band radiating elements in a RHCP monopulse comparator and thereupon generating sum, azimuth and elevation signals by means of said RHCP monopulse comparator ,

- receiving said LHCP signals from said X and S band radiating elements in a LHCP monopulse comparator and thereupon generating sum, azimuth and elevation signals by means of said LHCP monopulse comparator,

- receiving said azimuth and elevation signals generated from said RHCP in a RHCP monoscan convertor and thereupon multiplexing said azimuth and elevation signals to generate single channeled RHCP error signal,

- receiving said azimuth and elevation signals generated from said LHCP in a LHCP monoscan convertor and thereupon multiplexing said azimuth and elevation signals to generate single channeled LHCP error signal,
- receiving said multiplexed error signal generated from said RHCP and LHCP monoscan converters and the sum signals from the RHCP and the LHCP monopulse comparator in respective low noise amplifiers and thereupon amplifying the signals to output amplified RHCP sum signal, amplified RHCP error signals, amplified LHCP sum signals, amplified LHCP error signals,
- receiving said amplified RHCP sum signal, said amplified RHCP error signals, said amplified LHCP sum, said amplified LHCP error signals from said respective low noise amplifiers and thereupon multiplexing said amplified RHCP sum, said amplified RHCP error signals, said amplified LHCP sum signal, and said amplified LHCP error signals into amplitude modulated signals by means of a directional coupler.

In a preferred embodiment of the invented method, the S and X band feed is configured for receiving RHCP and LHCP signals in both S and X band.

In another preferred embodiment of the invented method, the X band radiating elements are being made of dielectric rod antenna having circular cross section with a conical taper. The Dielectric antennas of circular cross section exhibit radiation patterns with enhanced aperture efficiency, rotationally symmetric beams and extremely low side lobe level.

In yet another embodiment of the invented method, the S band radiating element is being made of tapered helix formed by helically winding 20 turns on nylon former.

According to still another embodiment of the invented method, the X band radiating elements are being connected to said septum polarizer by means of a circular to square flange.

According to yet another embodiment of the invented method, the dual polarized S and X band feed is capable of tracking in one of said X-RHCP, X-LHCP, S-RHCP and S-LHCP modes based on auto diversity.

According to yet another embodiment of the invented method, the difference signals are being multiplexed into a single channel using said monoscan converter then being coupled with the sum signal using a directional coupler.

According to a further embodiment of the invented method, the X band monopulse comparators are combinations of three magic tees being configured for producing said RHCP sum, difference output signals and LHCP sum, difference output signals.

According to a further embodiment of the invented method, the X band monopulse comparators are combinations of four magic tees being configured for producing said RHCP sum, difference output signals and LHCP sum, difference output signals.

According to one embodiment of the invented method, S band monopulse comparators are realized in a microstrip circuit comprising of four rat-race hybrid couplers.

According to another embodiment of the invented method, the magic tee is a four port network being configured to generate said sum and said difference signals incident on its co-linear arm, in H-plane and E-arm respectively.

According to a further embodiment of the invented method, the magic tee comprising of a metallic platform and thin septum polarizer in a WR 90 waveguide.

According to an embodiment of the invented method, the magic tee is being fabricated by spark erosion EDM method and the amplitude and phase imbalance of the magic tees are 0.2 dB and 20 dB respectively.

According to one embodiment of the invented method, the insertion loss of the total comparator assembly is 0.3 dB.

According to yet another embodiment of the invented method, said feed system is integrated with a reflector of 7.5mm diameter in dual shaped reflector Cassegrain configuration.

According to yet another embodiment of the invented method, where the monopulse converters is a microwave three port device and is configured to convert Azimuth and elevation input difference signals to form a time division multiplex of Azimuth and elevation difference signals with biphase modulation.

According to a specific application of the invented system, the payload data from satellites is transmitted through dual circularly polarized X-Band signals. The two data streams, each Quadrature phase-shift keying (QPSK modulated) at 320 Mbps data rate and a total of 640 Mbps are transmitted to ground station. The bandwidth available for data reception in X-Band is being 375 MHz, the two streams with a total data rate of 640 Mbps are transmitted to ground through RHC and LHC polarized signals at X-Band carrier frequency of 8212.5 MHz using the frequency re-use technique. The ground station consists of a high efficient 7.5 m diameter antenna system with dual shaped reflectors in Cassegrain configuration. A new dual polarized feed has been designed, fabricated and integrated with antenna system. The station provides G/T of 32 dB/deg K. The new dual polarized feed has been designed, fabricated and evaluated for primary radiation patterns and for secondary antenna patterns

BRIEF DESCRIPTION OF THE DRAWINGS

For better understanding an embodiment of the invention will now be described with reference to the accompanying drawings. It will, however, be appreciated that the embodiment exemplified in the drawings are merely illustrative and not limitative to the scope of the invention, because it is quite possible, indeed often desirable, to introduce a number of variations in the embodiment that have been shown in the drawings. In the accompanying drawings:

Figure 1 is the block diagram of the Dual polarized S and X band monopulse feed assembly, according to a particular embodiment of the invention.

Figure 2 shows the internal arrangement of magic tees in a RHCP and LHCP monopulse comparator, according to a particular embodiment of the invention.

Figure 3 shows both S and X band radiating elements, according to a particular embodiment of the invention.

Figure 4 illustrates the X band radiating element, according to a particular embodiment of the invention.

Figure 5 illustrates the S-band radiating element, according to a particular embodiment of the invention.

Figure 6(a) and 6 (b) schematically show the septum polarizer, according to a particular embodiment of the invention.

Figure 7 is the X band radiating element along with the septum polarizer, according to a particular embodiment of the invention.

Figure 8 schematically shows the monopulse comparator for X band, according to a particular embodiment of the invention.

Figure 9 is the line diagram of the monopulse comparator for X band, according to a particular embodiment of the invention.

Figure 10 (a) is line diagram of the monopulse comparator with the magic tees for X band according to a particular embodiment of the invention.

Figure 10 (b) schematically shows a magic tee used in the monopulse comparator of figure 10 (a)

Figure 10 (c) is block diagram of the monopulse comparator for X band according to a particular embodiment of the invention

Figure 11 shows the integrated X band feed assembly according to a particular embodiment of the invention.

Figure 12 is the illustration of the RHCP monopulse comparator in S band according to a particular embodiment of the invention.

Figure 13 is the illustration of the LHCP monopulse comparator in S band according to a particular embodiment of the invention.

Figure 14 schematically shows the working of the monoscan converter according to a particular embodiment of the invention.

Figure 15 is the Graphical representation of sum, error and isolation pattern for RHCP at 8.25 GHz according to a particular embodiment of the invention.

Figure 16 is the Graphical representation of sum, error and isolation pattern for RHCP at 2.25 GHz according to a particular embodiment of the invention.

Figure 17 is the Graphical representation of sum, error and isolation pattern for LHCP at 8.25 GHz according to a particular embodiment of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to figure 1, 6, 12 and 13 of the accompanying drawings, the invented dual polarized S and X band monopulse feed system (100) comprises of:

- S band radiating elements (102),
- X band radiating elements (104),
- four septum polarizers (106), each having an LHCP port and RHCP port (shown in figure 6) ,
- two monopulse X band comparators namely X band RHCP monopulse comparator (108-1) and X band LHCP monopulse comparator (108-2),
- two monopulse S band comparators namely S band RHCP monopulse comparator (110-1) (as shown in figure 12) and S band LHCP monopulse comparator (110-2) (as shown in figure 13),
- two monoscan convertors, namely a RHCP Monoscan convertor (114-1) and a LHCP Monoscan convertor (114-2),
- four Low Noise Amplifiers (LNAs), first LNA (116-1), second LNA (116-2), third LNA (116-3) and the fourth LNA (116-4).

The first LNA (116-1) being connected to RHCP monopulse comparators (108-1, 110-1) and is configured to amplify the RHCP sum signals in X and S band. The second LNA (116-2) being connected to the RHCP monopulse comparators (108-1, 110-1) and is configured to amplify the RHCP error signals in X and S band. The third LNA (116-3) being connected to the LHCP monopulse comparators (108-2, 110-2) and is configured to amplify the LHCP error signals in X and S band. The fourth LNA (116-4) being connected to the LHCP monopulse comparators (108-2, 110-2) and is configured to amplify the LHCP sum signals in X and S bands.

The X band feed system comprises of four X band radiating elements (104) (shown in figure 4) four septum polarizers (106) (shown in figure 6) and two monopulse comparators namely X band RHCP monopulse comparator (108-1) and X band LHCP monopulse comparator (108-2). Each of the X band radiating elements (104) is followed by circular to square flange (not shown) which interfaces the septum polarizer (106) to the radiating element (104). Septum polarizer (106) separates RHCP and an LHCP component, in X band, and provides input to the waveguide comparator as shown in block diagram. In S-band separate radiating elements (102), are used for RHCP and LHCP, so polarizer is not used in this case. An integrated X band feed assembly has been shown in figure 11.

The S-band feed system comprises of eight S-band radiating elements (102) (shown in figure 3 and 5) two monopulse comparators namely S band RHCP monopulse comparator (110-1) and S band LHCP monopulse comparator (110-2).

Referring to figure 4, each X band radiating element (104) is made of a dielectric rod antenna having circular cross section with conical taper. The dielectric rod is excited by a circular waveguide which exhibits very good pattern characteristics such as circular pattern symmetry, low side lobes and low cross polar levels. This is achieved by the excitation of HE_{11} mode in the dielectric rod. The tapering at the wave guide end provides proper impedance matching and launching of hybrid mode in the dielectric rod. This feed is designed for dual polarization signal reception. A circular to square wave guide flange is used to connect the radiating element with septum polarizer. This feed exhibits good axial ratio (<1.5dB), return loss (-20dB).

Figure 5 shows an S-band radiating element (102). A 20 turn tapered helix wound on a nylon former operating in the axial mode is used as the radiating element which comprises of an array of eight helical radiating elements (102), four of the radiating elements for RHCP and four of them for LHCP. Four RHCP S band helical elements (102) are configured to receive RHCP signals and four LHCP S band helical elements (102) are configured to receive LHCP signals in S band. Impedance near the connector (SMA probe) is matched by soldering a matching strip to the helix wire. As the performance of the ground station should be maintained at both the S and X bands, the feed array configuration needs to be optimized. Therefore the need to maintain 1.3λ spacing between the radiating element in the 2 X 2 array configuration calls for use of high gain, narrow beam (half power beam width of ±16 °) to reduce the side lobe levels and grating lobes. S band reception is intended for the reception of telemetry signals or S band low bit rate data signals transmitted by the satellite both in RHCP and LHCP. Eight helical elements used for this purpose, four for RHCP and other four for LHCP.

Figure 6 (a) shows a septum polarizer (106). Each septum polarizer (106) is connected to the X band radiating element (104) through circular to square flange as shown in figure 7. Since the X band radiating element (104) is capable of receiving dual polarized signal (RHCP and LHCP) simultaneously, it is necessary to separate LHCP and RHCP components as they should be processed separately providing frequency reuse technique / polarization diversity application. Septum polarizer (106) separates these two orthogonal polarized components and provides linear polarized output to the monopulse comparators (108-1 and 108-2). This septum polarizer (106) is designed to obtain minimum insertion loss so the G/T requirement is met as this loss results in G/T degradation. The septum polarizer (106) is used to bifurcate the incoming signals and hence the amplitude balance is ensured.

The working of the septum polarizer (106) has been schematically shown in figure 6(b). Septum polarizer (106) is configured to separate Right hand circular polarized (RHCP) and Left hand circular polarized (LHCP) signals in a feed. The septum polarizer (106) helps in realizing dual circular polarized feed for X band in the invented system (100). As seen in figure 6 (b) the septum polarizer has three ports: two rectangular ports which are dedicated to the waves of one circular polarization (RHCP and LHCP) and the common circularly polarized waves, i.e., representing orthogonal TE_{10}, TE_{01} semi signals with the corresponding 90 degrees phase relation. The bifurcation region contains an unsymmetrical septum. The septum (106) may have a continuous or stepped shape over its length. The complete polarizer function (power splitting/combination and +/- 90-degree differential phase shift) is imposed on the septum region. The shape is optimized for best performance. A TE_{10} mode signal in the square waveguide is split into two TE_{10} mode signals in the bifurcated rectangular section having same direction. A TE_{01} mode signal in the square waveguide is split into two TE_{10} mode signals in the bifurcated rectangular section having opposite direction. Hence, as the orthogonal TE_{10}, T_{E01} modes in the common square waveguide represent, depending on their orientation, LHCP or RHCP modes, respectively, the mode signals in the left or right rectangular waveguide ports, respectively are extinguished.

In the present invention the septum polarizer (106) was designed at X-band (8.0 – 8.5 GHz) with a septum of four steps. For accommodating the waveguide flanges between two rectangular ports, an optimised mitered bend at one of the ports has been used and are physically isolated. The full structure is fabricated by milling technique. The measured return loss was better than 22 dB and axial ratios between 0.2 to 0.6dB over the required range of operation.

The RHCP monopulse comparator (108-1) and the LHCP monopulse comparator (108-2) in the X band is in the form of the comparator (108) illustrated in figure 8. Figure 9 schematically illustrates an integrally formed RHCP and LHCP monopulse comparator in X band. The monopulse tracking system (100) requires azimuth, elevation difference signals and a sum signal from equal amplitude and phase signals obtained through four X band radiating elements (104) and the same is accomplished by using a monopulse comparator (108). The essential features for a monopulse comparator (108) are (i) low insertion loss (ii) minimum amplitude and phase imbalance (iii) high isolation between sum and difference ports. Waveguide magic tee (109) shown in figure 10 (hybrid T junction) is used as a basic building block in the comparator network of the monopulse comparator (108). Three or four magic tees (109) may be used to construct the comparator (108). The magic-tee (109) is a four port network which can generate sum and difference of the signals incident on its co linear arm, in H-plane and E-plane arm respectively. The working of the invented feed system (100) under X band has been schematically shown in figure 2. This dual polarized feed system (100) is capable of functioning to track any of the X-RHCP, X-LHCP, S-RHCP or S-LHCP modes. Initially acquisition starts in S-band (LHCP/RHCP) and switches to X band when X band signal is ON. But it has the capability of operating either of these modes according to user's choice. The difference signals AZ and EL are needed to be multiplexed into single channel in order to reduce corresponding electronics for down conversion and produce required IF. Monoscan converter (114) is responsible for multiplexing these two difference signal into a single channel.

The monopulse tracking system (100) requires azimuth and elevation difference signals and a sum signal from four equal amplitude and phase signals. Monopulse Comparators (MPC) (108-1, 108-2, 110-1,110-2) are used for deriving Azimuth & Elevation difference signals in S band. It should have low insertion loss, minimum amplitude and phase imbalance, and high isolation between the output ports.

In the invented system (100) Magic tees (109) are the basic building block in the monopulse comparator assembly (108-1, 108-2) for X band as shown in figure 10 (b) . Magic tees (109) with E and H plane waveguide bends are used to form the comparator. Four magic tees (109) are used to realize wave guide MPC in X band. Figure 10(b) shows the block diagram of magic tee (109). Magic tee (109) is a four port network in which a signal incident on any one of the ports gets divided between two output ports and the remaining port being isolated. Physically it can be considered as a combination of E-plane and H-plane power dividers and has the advantage of being completely matched at all ports. Each magic tee (109) in the comparator generates sum and difference signals for the two equal amplitude and phase inputs. Four magic tees (109) are combined to generate the total sum, azimuth and elevation error signals. The essential features of the magic tee (109) are good impedance matching at all ports, low insertion loss, minimum amplitude and phase imbalance, high isolation between sum and difference port. E-plane and H-plane bends are used to interconnect the magic tees (109) to construct the comparator. Compact bends are essential to reduce the size but impedance matching is required in the bending region. The optimized bends are fabricated using EDM (Electro Discharge Machining) method with 20 micron accuracy.

Referring to figure 10 of the accompanying drawings, each magic tee (109) is a combination of E and H plane tees and comprises of four arms, namely a first arm (111-1), a second arm (111-2), a third arm (111-3) and a fourth arm (111-4). The third arm (111-3) forms an H-plane tee with the first arm (111-1) and the second arm (111-2). The fourth arm (111-4) forms an E-plane tee with the first arm (111-1) and the second arm (111- 2). The combinations of magic tees (109) produces sum and difference output as seen in figure 10(c). such that

$$SUM=A+B+C+D$$

$$AZ= (A+C)-(B+D)$$

$$EL= (A+B)-(C+D)$$

The optimized magic tee (109) consists of a metallic platform and thin septum in a waveguide. The platform is used to cancel out the junction reactance and hence good return loss is obtained at all ports. The optimized magic tee (109) is accurately fabricated using spark erosion EDM method.

On conducting a typical experiment on the invented system (100) it was observed that the measured return loss at sum and difference ports of the comparator (108) was better than 20 dB over the required bandwidth. It was also observed that the amplitude and phase imbalance were 0.2 dB and 20 dB respectively. Insertion loss of the total comparator assembly (108) is 0.3 dB. The isolation between sum and difference ports was better than 30 dB and the same order of isolation observed between the two difference ports was observed. The low insertion loss of the comparator (108) gives good G/T for the Earth station for data reception. As the amplitude and phase balance between the input signals is low, optimum sum and difference patterns are obtained.

Figures 12 and 13 of the accompanying drawings shows a RHCP monopulse comparator (110-1) and LHCP monopulse comparator (110-2) monopulse comparator for the S band. The monopulse comparator at S-Band is realized in a microstrip circuit. It consists of four rat-race hybrid couplers. The rat-race hybrid is the basic building block in the comparator network and it is simulated in LINMIC software for electrical characteristics. The total network is optimized for better return loss, amplitude and phase response and isolation characteristics. The circuit is configured to operate in 2.0-2.3 GHz frequency band and performances better at 2.2 to 2.3 GHz band. The optimized circuit is etched on TFG (1/16 inch thickness and 2.55 dielectric constant). The measured insertion loss is about 0.2 dB and the return loss of the sum and difference ports is better than -30dB.The amplitude and phase imbalance of the comparator are 0.1dB and ±20 respectively over the required band of 2-2.3 GHz. Isolation between sum and difference port is better than 30dB and isolation between difference ports is better than 30dB.

The monopulse tracking system requires azimuth and elevation difference signals and a sum signal from four equal amplitude and phase signals. Monopulse Comparator (MPC) (110-1,110-2) for S band is used for deriving Azimuth & Elevation difference signals. It should have low insertion loss, minimum amplitude and phase imbalance, and high isolation between the output ports. Microstrip rat-race hybrids have been used as the basic building block in the monopulse comparator assembly in S band for RHCP, as shown in figure 12. Four such rat-race hybrids are used to form the comparator. Figure 12 shows the block diagram for RHCP monopulse comparator (110-1) in S band. The azimuth and elevation difference signals are connected to servo system and the diagonal error port is not used and it is terminated with 50 ohms load. Microstrip configuration is selected due to its size and weight. Rat-race hybrid is a four-port network in which a signal incident on any one of the ports gets divided between two output ports with the remaining port being isolated. Rat race hybrid consists of a ring 1.5 wavelengths in circumference having four arms separated by 60° angular rotations. This has a common input arm, there are two output arms spaced one-quarter wavelength away and a fourth terminated arm spaced a quarter wavelength away from one of the output arm and three quarters of a wavelength from the other output arm. Mitered bends and micro-strip straight lines are used to connect these hybrids to form the comparator the MPC (110-1) has been fabricated on a 1.6 mm thick Teflon Fibre Glass (TFG) microwave substrate using PCB etching method. The complete network is plated with solder to provide the environmental protection.

The monopulse comparator assembly in S band for LHCP (110-2) is comprised of three rat race hybrids as seen in figure 13.

The Monoscan Converter (114-1 and 114-2), as shown in figure 1, is a waveguide module, which uses PIN diode switches and four magic tees. The said monoscan convertor (114-1 and 114-2) is divided into a RHCP monoscan convertor (114-1) and a LHCP monoscan convertor (114-2) for receiving the RHCP and LHCP signals respectively. The said monoscan convertors multiplexes the RHCP Azimuth and elevation signals and LHCP Azimuth and elevation signals received from said monopulse comparators into a single channel. The waveguide phase shifters are designed to have a 0° or 180° phase shift. The azimuth and elevation signals are applied to the sum and difference arms of a magic tee. The two output arms pass through two identical waveguide sections containing identical diode switches. The two waveguide sections then connect to two input arms of the second magic tee. The sum output is the monoscan output port and the difference output is loaded. The monoscan conditions can be generated, depending upon the setting of the two diode switches. A total of four lines controls the monoscan diode switches. The scan code signals required by MSC (114) are square wave signal waveforms.

Referring to figure 14 each of the monoscan converters (114-1,114-2) is a microwave three port device. It converts Azimuth and elevation input difference signals to form a time division multiplex of Azimuth and Elevation difference signals with biphase modulation. Difference signals are entered into two input ports. Both these inputs are fed to a SPDT switch which selects one of the two inputs. This input select switch will accept TTL level commands at rates of 1 KHz. The output is then feds to a 0 deg/180 deg phase transmission lines via another PSDT switch. The second switch operated at 500 Hz. All switches were realized using PIN diodes and Microstrip transmissions line are made on Rogers's dielectric substrate

The sum signals generated from the said RHCP (108-1) and LHCP (108-2) monopulse comparators in X band may optionally be fed to the loop couplers (112-1 and 112-2), as shown in figure 1. According to as preferred embodiment each of the loop couplers (112-1, 112-2) are in the form of a 30 dB test coupler and is provided at the input of sum LNA (116), for injecting test signal into the front- end of the system and enable testing of receive chains in local loop mode.

As seen in figure 1, four Low Noise Amplifiers (116-1, 116-2, 116-3, and 116-4). The first LNA (116-1) is configured to receive RHCP sum signals from RHCP monopulse comparator and to amplify them. The Second LNA (116-2) is configured to receive RHCP error signal from the RHCP monopulse comparator and to amplify them. The third LNA is configured to receive LHCP error signal from LHCP monopulse comparator and ro amplify the LHCP error signal. The fourth LNA is configured to receive LHCP sum signal from the LHCP monopulse comparator and to amplify the received signal. The LNA has 50 dB gain and 45°K noise temperature. It has WR 112 waveguide adaptor to interface with the Monopulse Comparator (108-1 and 108-1'). The LNA's (116-1 and 116-4) receives the sum signals from test loop coupler (112-1 and 112-2) and amplify the same. The LNA's (116-2 and 116-3) receives the error signal from the Monoscan Convertor (114-1 and 114-2) and amplifies the same.

A typical specification of the invented feed system is provided in the below table:

TABLE 1

Frequency range	8.0 – 8.5 GHz at X-Band 2.2 – 2.3 GHz at S-Band
Feed Type	Cassegrain, Single channel Monopulse
Edge Taper on Sub-Dish	-30.0 dB for ± 14.5°
Null Depth	25 dB & better
Side lobe	14 dB
Polarization	RHCP & LHCP
Cross polar Isolation	20 dB
Axial Ratio	1.5 dB max
Return Loss	–15 dB and better
Insertion Loss	< 0.35 dB at X-Band
Electrical Interface	WR 112 at X band SMA at S-Band

The foregoing description is a particular embodiment of the present invention. It should be appreciated that the embodiment that has been described for purpose of illustration only, and that numerous alterations and modifications may be practiced by those skilled in the art without departing from the spirit and scope of the invention as claimed or the equivalent thereof.