**SATELLITE AND OPTICAL COMMUNICATION**

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**Abstract:**

Introduction :

Satellite crosslinks generally require narrower bandwidths for increased power concentration. We can increase the power concentration by increasing the cross link frequency with the same size antenna. But the source technology and the modulation hardware required at these higher frequency bands are still in the development stage. Use of optical frequencies will help to overcome this problem with the availability of feasible light sources and the existence of efficient optical modulation communications links with optical beams are presently being given serious considerations in intersatellite links. And establishing an optical cross link requires first the initial acquisition and cracking of the veacon by the transmitting satellite followed by a pointing of the LASER beam after which data can be modulated and transmitted.

Communication links between space crafts is an important element of space infrastructure, particularly where such links allow a major reduction in the number of earth stations needed to service the system. An example of an inter orbit link for relaying data from LEO space craft to ground is shown in the figure below

I. The antenna can be much smaller. A typical microwave dish is around 1 to 2m across and requires deployment in the orbit, An optical antenna (le a telescope) occupies much less space craft real estate having a diameter in the range of 5 to 30 cm and is therefore easier to accommodate and deploy.

II. Optical beam widths are much less than for microwaves, leading to very high antenna gains on both transmit and receive. This enables low transmitter (ie laser) powers to be used leading to a low mass, low power terminal. It also makes the optical beam hard to introsept on fan leading to convert features for military applications, consequently there is a major effort under way in Europe, USA and Japan to design and flight quality optical terminals

SOUT:

The European Space Agency (ESA) has programmes underway to place Satellites carrying optical terminals in GEO orbit within the next decade. The first is the ARTEMIS technology demonstration satellite which carries both microwave and SILEX (Semiconductor Laser Intro satellite Link Experiment) optical interorbit communications terminal. SILEX employs direct detection and GaAIAs diode laser technology; the optical antenna is a 25cm diameter reflecting telescope. The SILEX GEO terminal is capable of receiving data modulated on to an incoming laser beam at a bit rate of 50 Mbps and is equipped with a high power beacon for initial link acquisition together with a low divergence (and unmodulated) beam which is tracked by the communicating partner. ARTEMIS will be followed by the operational European data relay system (EDRS) which is planned to have data relay Satellites (DRS). These will also carry SILEX optical data relay terminals.

Once these elements of Europe’s space Infrastructure are in place, these will be a need for optical communications terminals on LEO satellites which are capable of transmitting data to the GEO terminals. A wide range of LEO space craft is expected to fly within the next decade including earth observation and science, manned and military reconnaissance system.

The LEO terminal is referred to as a user terminal since it enables real time transfer of LEO instrument data back to the ground to a user access to the DRS s LEO instruments generate data over a range of bit rates extending of Mbps depending upon the function of the instrument. A significant proportion have data rates falling in the region around and below 2 Mbps. and the data would normally be transmitted via an S-brand microwave IOL

ESA initiated a development programme in 1992 for LEO optical IOL terminal targeted at the segment of the user community. This is known as SMALL OPTICAL USER TERMINALS (SOUT) with features of low mass, small size and compatibility with SILEX. The programme is in two phases. Phase I was to produce a terminal flight configuration and perform detailed subsystem design and modelling. Phase 2 which started in september 1993 is to build an elegant bread board of the complete terminal.

The link from LEO to ground via the GEO terminal is known as the return interorbit link (RIOL). The SOUT RIOL data rate is specified as any data rate upto 2 Mbps with bit error ratio (BER) of better than 106. The forward interorbit link (FIOL) from ground to LEO was a nominal data rate of (34 K although some missions may not require data transmissions in this directions. Hence the link is highly asymmetric with respect to data rate.

The LEO technical is mounted on the anti earth face of the LEO satellite and must have a clear line of sight to the GEO terminal over a large part of the LEO orbit. This implies that there must be adequate height above the platform to prevent obstruction of the line of sight by the platform solar arrays, antenna and other appertages. On the other hand the terminal must be able to be accommodated inside the launcher fairing. Since these constraints vary greatly with different LEO platforms the SOUl configurations has been designed to be adaptable to a wide range of platforms.

The in-orbit life time required for a LEO mission in typically 5 years and adequate reliability has to be built into each sub-systems by provision of redundancy improved in recent years. and GaAIAs devices are available with a projected mean time to failure of 1000 hours at 100 MW output power.

The terminal design which has been produced to meet these requirements includes a number of naval features principally, a periscopic coarse pointing mechanism (CPA) small refractive telescope, fibre coupled lasers and receivers, fibre based point ahead mechanism (PAA), anti vibration mount (soft mount) and combined acquisition and tracking sensor (ATDU). This combination has enabled a unique terminal design to be produced which is small and lightweight These features are described in the next sections.

LINK DESIGN:

*Wave length and polarization:*

The transmit and receive wavelengths are determined by the need for interoperability with future GEO terminals such as SILEX which are based on GaAIAs laser diodes. Circular polarisation is used over the link so that the received power does not depend upon the orientation of the satellite. The transmit and receive beams inside the terminal are arranged to have orthogonal linear polarisation and are separated in wave length. This enables the same telescope and pointing system to be used for both transmit and receive beams since the optical deplexing scheme can then be used.

*Link budgets for an asymmetric link:*

The requirement to transmit a much higher data rate on the return link than on the forward link implies that the minimum configuration is one with a large telescope diameter at GEO ie maximise the light collection capabilities and a smaller diameter telescope at Leo. A smaller telescope at LEO has the disadvantages of reduced light collection hut the advantage of reduced pointing loss due to wider beam width.

The smaller telescope on LEO facilitates the design of a small user terminal. For SILEX the telescope diameter in 25 cm but it is highly desirable k a telescope with less than 10 cm aperture in the user terminal. The design process begins with the link budgets to ensure that adequate link margins is available at end of life too the chosen telescope diameters and laser powers.

*Pointing, Acquisition and Tracking:*

The narrow optical beam width gives rise to a need to perform the following critical pointing factions.

*Pointing*:

The LEO terminal must be able to point in the direction of the GEO terminal around a large part of the LEO orbit. Pointing error do occur some time and it is determined by the accuracy with which the transmitting satellite can illuminate the receiving satellites. This is turn depends on

1. Accuracy to which one satellite knows the location of the other

2. Accuracy to which it knows its own attitude and

3. Accuracy to which it can aim its beam knowing the required direction.

*Acquisition:*

The transmitted beam cannot be pointed at the communicating pointer in the open loop made with sufficient accuracy because of uncertainties in the attitude of the space craft, pointing uncertainties in the terminal and inadequate knowledge of the location of the other satellite. Consequently before communication can commence, a high power beam laser located on GEO end has to scan over the region of uncertainty until it illuminates the GEO terminal and is detected. This enables the user terminal to lock on to the beacon and transmit its communication beam back along the same path. Once the GEO terminal receives the LEO communication beam it switches from the beacon to the forward link communication beam. The LEO and GEO terminals then track on the received communication beams, thereby foaming. a communication link between the LEO and GEO space craft.

*Tracking:*

After successful acquisition, the LEO and GEO terminals are operating in tracking mode In this mode the on-board disturbances which introduce pointing fitter into the communication beam are alternated by means f a fine pointing control loop (FPL) to enable acceptable communications to be obtained. These disturbances are due to thruster firings, solar arrays drive mechanisms, instrument harmonics and other effects.

*Point ahead:*

This is needed because of the relative orbital motion between the satellites which calls for the transmitted beam to be aimed at a point in space where the receiving terminal will be at the time of arrival of the beam. The point ahead angle is calculated using the equation

Point ahead angle 2Vt /c where

Vt = transverse Velocity component of the satellite.

The point ahead angle is independent of the satellite cross link distance.

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C = speed of light

GENERAL OPTICAL TERMINAL :

The block diagram for a generic direct detection optical terminal is shown.

In this system a nested pair of mechanism which perform the course pointing and fine pointing functions is used. The former is the coarse pointing assembly (CPA) and has a large angular range but a small band width while the latter, the fine pointing assembly (EPA) has a small angular range and large band width. These form elements of control loops in conjuction with acquisition and tracking sensors which detect the line of sight of the incoming optical beam. A separate point ahead mechanism associated with the transmitter sub system carries out the dual functions of point ahead and internal optical allignment.

*Communications performance:*

A property of free space links is the occurrence of burst errors. A burst error results when the instantaneous bit error rate (BER) drops below a defined value. This is caused by beam mispointing which reduces the optical power collected by the receiving terminal. For SOUT

the probability of a burst error occurring must be less than 10-6.

OVERVIEW OF THE SOUT TERMINAL

The SOUT terminal consists of two main parts: a terminal head unit and a remote electronics module (REM). The REM contains the digital processing electronics for the pointing acquisition and tracking (PAT) and terminal control functions together with the communications electronics. This unit is hard mounted to the space craft and has dimensions 200 by 200 by 150mm. The REM will have the advantage of advanced packaging ASIC and technologies to obtain a compact low mass design.

*Small optical user terminal configuration:*

In the figure the SOUT configuration head unit is shown. The REM is not shown and the supporting structure and terminal control hardware have been removed for clarity. The terminal head performs the critical functions of generating and pointing the transmit laser beam and acquiring and tracking the received beacon and tracking beams.

There is fixed head unit with a periscopic course pointing assembly (CPA) on top of the telescope. The telescope with the CPA is referred to as the optical antenna. The head unit is soft mounted to the satellite by a set of three anti vibration mounts arranged in a triangular geometry. This fillers out high frequency microvibrations, originating from the space craft. Inclusion of the soft mount has a major impact on the terminal fine pointing loop design and structural configuration as described below. All of the optical components and mechanisms needed for transmit and receive functions except for the telescope and CPA are mounted on the double sided optical bench. The head unit also includes an electronics package (CPEM) which contains electronics required to be in close proximity to the sensors and pointing mechanisms.

Key elements of the head unit are the integrated transmitter comprising diode laser and point ahead assembly (PAA) optical antenna comprising telescope and coarse pointing assembly, fine pointing loop comprising acquisition and tracking sensor

(ATDU) and fine pointing assembly (FPA) and optical bench.

OPTICAL ANTENNA

The optical antenna comprises the telescope and coarse pointing assembly. The telescope is a refractive keplerian design which does not have the secondary mirror obscurration loss associated with reflective systems. The CPA uses stepping motors together with a conventional spur gear and planetary gear. The total height of the optical antenna is a major contributor to the height of the CPA above the platform which affects LEO and GEO link obscurration by solar arrays, antennas and other space craft appendages.

INTEGRATED TRANSNHTTER

This consists of a prime/redundant pair of laser modules, a redundancy switch, and a point ahead assembly (PAp). The lasers are connected to the PM by a single mode polarisation. This allows grater layout flexibility on the optical bench and simplifies redundancy switching. Each laser module contains a laser diode, collimating lenses, cylindrical le and focusing lense for coupling light into the fiber. Coupling effiency into the fiber is expected to exceed 70%.

The point ahead angular is ±200 prad for both polar orbiting and equatorial LEO orbits. The PAA is used in calibration mode to coalign the transmit and receive paths. The PAA is a piezoelectricaily actuated device which translates the optical fibre from the selected laser source in the focal plane of a collimating lens so as to introduce the required angular offet to the transmit beam direction. Orthogonal piezos provide for two dimensional pointing of the beam Capacitive, sensors measure the relative position of the fibre and lens enabling pointing bias and noise levels of less than 2 micoral and less than 0.4 microrad respectively to be realised. The redundancy switching is implemented by a paraffin actuator which translates the required fibre into the focal point or the PAA collimating lens.

FINE POINTING LOOP

The fine pointing loop (FPL) is required to attenuate external pointing disturbances so that the residual mispoint angle is a small fraction of the optical beam width. The closed loop tracking subsystem consists of a tracking sensor which determines the direction of the incoming communications beam with an angular resolution around 5% of the optical beam width and a fine pointing mirror assembly (FPA) which compensates beam mispointing effects. The SOUT FPL is used to compensate for frequencies upto 80 HZ.

A three point antivibration mount (soft mount) acts as a low pass filter to form an isolating interface between the satellite microvibration environment and the SOUT thereby reducing the bandwidth requirements of the FPL. This also removes any concerns about uncertainities in the vibration spectrum of the user space craft. The EPA is implemented by a pair of orthogonal mirrors. The EPA for the SOUT is based on a dual axis tilting mirror mechanism. This employs a single mirror and a permanently excited DC motor.

OPTICAL BENCH

The diplexer, quarter wave plate and other lens system required too acquisition and tracking are all placed in the optical bench. The diplexer has a dietetric multilayer coating which provides efficient transmission of one type polarised light at the transmit wavelength (848 nm) and rejects another type poiarised light at the receive wavelength (800 nm). A quarter wave plate (QWP) converts the transmit light to circular polarisation state prior to the telescope. The PAA, lasers, and redundancy switching mechanisms are on one side while the diplexer, receive paths and calibration path are on the other side of the optical bench.

STRUCTURAL CONFIGURATION

The SOUT has a novel structural and thermal design which satisfies the unique demands imposed by the various sub-systems. The main structural elements are a truss frame assembly which supports the optical antenna orthogonal to the optical bench, a triangular plate which forms the lower truss support and carries the soft mounts, optical bench and electronic units. Key design drivers for the structure are the optical bench pointing stability, soft mount constrains and base-bending moments associated with the telescope CPA. There has to be a high degree of Coaligtnment between the transmit and receive beam paths on the optical bench in order that the transmit beam can be pointed towards the GEO terminal with an acceptably small pointing loss.

The height of the terminal above the space craft depends upon the mounting interface; options include mounting through a hole in the side wail of the space craft (Suitable for large platforms), external mounting on a support frame, mounting on a deployment mechanism. The head unit occupies an area of about 40 by 40cm depending upon the platform interface.

*Mass and Power:*

The base-line SOUT has a total mass (including REM) of around 25 Kg and a dynamic mass of 3.7kg due to the motion of the CPA. The maximum power dissipation is around 65 W

APPLICATIONS OF SATELLITE COMMUNICATION:

Artificial earth satellites have been used for more than 40 years and satellite communications form a unique part of daily routine life which serving billions of people and granting access to a vast range of voice, data and video telecommunication applications.

Why we need satellite communication? Satellite communication able to provide:

1.Long distance education. Article on Tele-Education

2.Entertainment - Broadcasting via satellite offers a variety of programming to the avid viewer including local and foreign programs.

do serve civilian in rural area where terrestrial communication network does not exist by providing telephony service.

3.In military sector, providing robust and sophisticated secure communications network

to provide communication when the terrestrial systems fail due to disaster such as earthquake, volcanic eruption floods, drought, cyclones, landslides and epidemics.

4.Tele-medicine.

APPLICATIONS OF OPTICAL COMMUNICATIONS:

1.INTERCONNECTS:

Interconnections are one of the largest and most widely used areas for fiber optic cables and assemblies.

2.NETWORKING:

Networking is a wide ranging and loosely defined area in the industry.

3.MILITARY:

Timbercon fiber optic products are used in a variety of military applications requiring rigorous testing and harsh environment certification to ensure reliability..

4.SPACE:

Over the last several years, fiber optics have become increasingly popular in space environments.

CONCLUSION:

Optical intersatellite communication promises to become an important element in future

space infrastructure and considarable development effort is currently underway in Europe and

else where.