CEC 352 – SATELLITE COMMUNICATION

Prepared

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UNITII/SPACESEGMENTANDSATELLITELINKDESIGN

Spacecraft Technology- Structure, Primarypower, Attitude and Orbit control, Thermal control and Propulsion, Communication Payload and supporting subsystems, Telemetry, Tracking and command. Satellite Uplink and Downlink Analysis and Design, Link Power Budget, C/Ncalculation, G/T ratio-Performance Impairments-System noise, Inter-modulation Noise, Noise Temperature, Propagation Factors, Rain and Ice effects, Polarization.

SpacecraftTechnology- Structure

A satellite communications system can be broadly divided into two segments—a ground segment and a space segment.

The space segment will obviously include the satellites, but it also includes the ground facilitiesneededtokeepthesatellitesoperational,thesebeingreferredtoastheT*racking*,*Telemetry, and Command* (TT&C) facilities. In many networks it is a common practice to employa ground station solely for the purpose of TT&C.

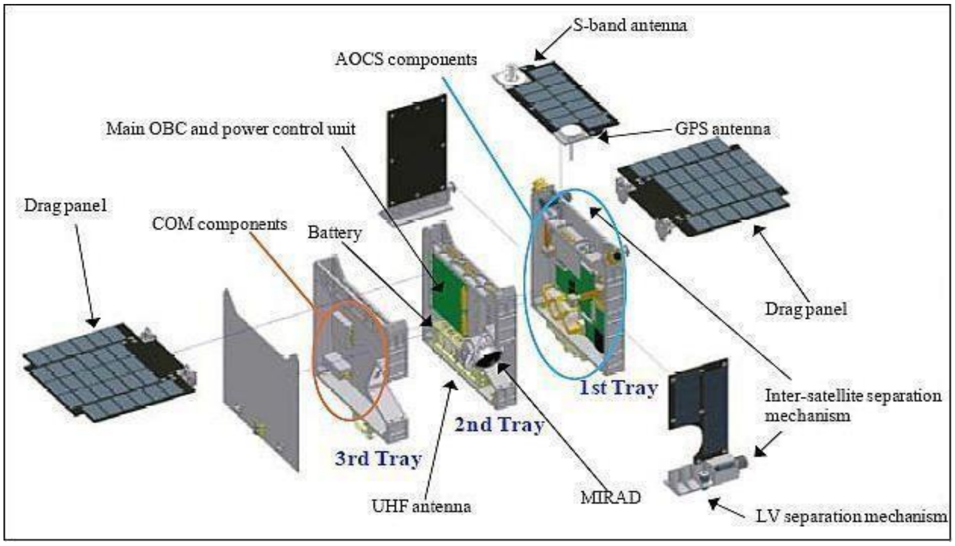


Fig2.1 SatelliteStructure

Theequipmentcarriedaboardthesatellitealsocanbeclassifiedaccordingtofunction.The *payload*referstotheequipmentusedtoprovidetheserviceforwhichthesatellitehasbeenlaunched.

In a communications satellite, the equipment which provides the connecting link between thesatellite'stransmitandreceiveantennasisreferredtoastheT*ransponder*.Thetransponderforms oneofthe main sectionsofthepayload, theother being theantenna subsystems. Inthis chapterthe main characteristics of certain bus systems and payloads are described.

ThePowerSupply

The primaryelectricalpower for operating the electronic equipment is obtained fromsolar cells. Individual cells can generate only small amounts of power and therefore, arrays of cells in series-parallelconnectionarerequired.Figure2.1showsthesolarcellpanelsfortheHS376satellite manufactured byHughes Space and Communications Company.

Ingeostationaryorbitthetelescopedpanelisfullyextendedsothatbothareexposedto sunlight.Atthebeginningoflife, thepanelsproduce 940Wdcpower, whichmaydropto760Watthe end of 10 years. During eclipse, power is provided by two nickel-cadmium (Ni-Cd) long-life batteries, whichwilldeliver 830 W.At the end oflife, batteryrecharge time is less than16h.

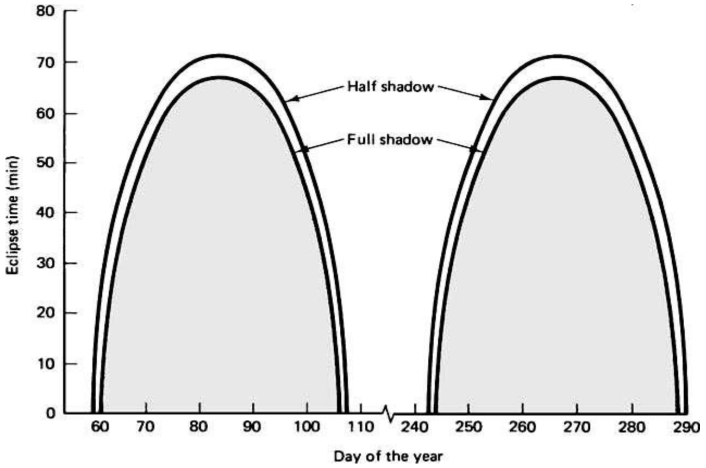


Fig2.2 SatelliteEclipsetimeasafunctionofthecurrentdayoftheyear

Incylindricaland solar-sailsatellites,the cross-overpoint is estimatedtobeabout2kW,wherethe solar-sailtype is more economicalthanthe cylindricaltype.

AttitudeControl&OrbitControl

The *attitude* of a satellite refers to its orientation in space. Much of the equipment carried aboard a satellite is meant for the purpose of controlling its attitude. Attitude control is necessary, toensurethatdirectionalantennaspoint intheproperdirections.Inthecaseofearthenvironmental satellites, the earth-sensing instruments mustcover the required regions of the earth, which also requires attitude control. A number of forces, referred to as *disturbance torques*, can alter the attitude,someexamplesbeingthegravitationalfieldsoftheearthandthemoon,solarradiation, and meteorite impacts.

Attitudecontrolmust not beconfusedwithstationkeeping, whichisused for maintaininga satellite in its correct orbital position, although the two are closely related. To exercise attitude control, there must be available some measure of a satellite’s orientation in space and of any tendencyforthisto shift. Inone method, infraredsensors,referredto as*horizondetectors*,areused to detect the rimofthe earthagainst the background ofspace.

Withtheuseoffoursuchsensors,oneforeachquadrant,thecenteroftheearthcanbereadily established as a reference point. The attitude-controlprocess takes place aboard the satellite, but it isalsopossibleforcontrolsignalstobetransmittedfromearth,basedonattitude dataobtainedfrom the satellite. Whenever a shift in attitude is desired, an *attitude maneuver* is executed. The control signals needed to achieve this maneuver may be transmitted from an earth station.

Controlling torques may be generated in a number of ways. *Passive attitude control* refers totheuseofmechanismswhichstabilizethesatellitewithoutputtingadrainonthesatellite'senergy supplies; at most, infrequent use is made of these supplies, for example, when thruster jets are impulsed to provide corrective torque. Examples of passive attitude control are *spin stabilization* and *gravity gradient stabilization*.

The other formofattitude controlis *active control.* Withactive attitude control, there is no overall stabilizing torque present to resist the disturbance torques. Instead, corrective torques are applied inresponsetodisturbancetorques.Methodsusedto generateactivecontroltorquesinclude momentum wheels, electromagnetic coils, and mass expulsion devices, such as gas jets and ion thrusters.

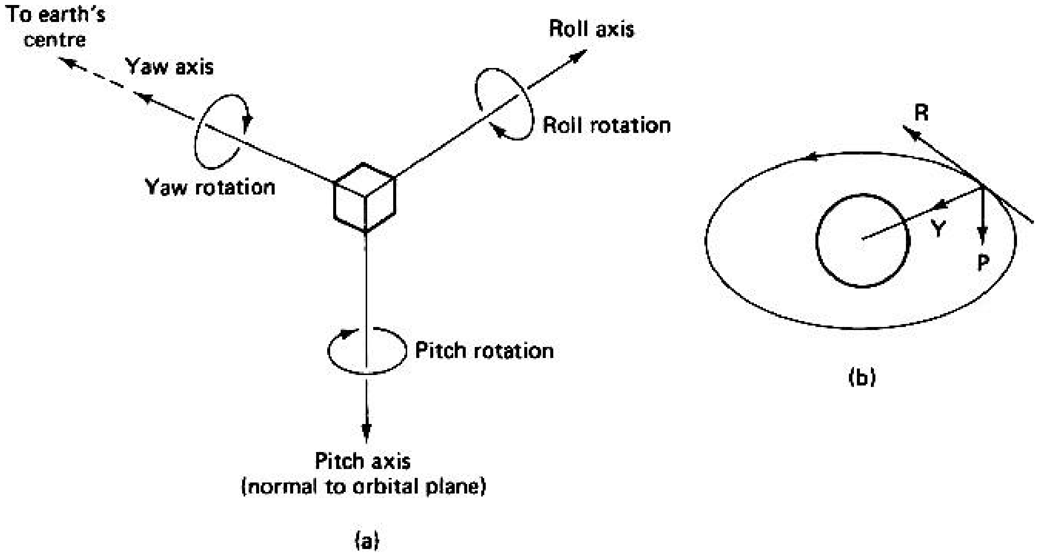


Fig2.3 Roll,Pitch, andYawAxes(*b*)RPYaxesforGeostationaryOrbit

The three axes which define a satellite's attitude are its *roll, pitch*, and *yaw* (RPY) axes. These areshownrelativetotheearthinFigure2.3.Allthreeaxespassthroughthecenterofgravity of the satellite. For an equatorial orbit, movement of the satellite about the roll axis moves the antennafootprintnorthandsouth;movementaboutthepitchaxismovesthefootprinteastandwest; and movement about the yaw axis rotates the antenna footprint.

SpinningSatelliteStabilization

Spinstabilizationmaybeachievedwithcylindricalsatellites. Thesatellite is constructedso that it is mechanically balanced about one particular axis and is then set spinning around this axis. For geostationary satellites, the spin axis is adjusted to be parallel to the N-S axis of the earth, as illustrated inFigure2.4. Spinrate istypically intherangeof50 to 100rev/minute. Spin is initiated during the launch phase by means of small gas jets.

In the absence of disturbance torques, the spinning satellite would maintain its correct attitude relative to the earth. Disturbance torques are generated ina number ofways, bothexternal and internal to the satellite.

Solar radiation, gravitational gradients, and meteorite impacts are all examples of external forces which can give rise to disturbance torques. Motor-bearing friction and the movement of satellite elements such as the antennas also can give rise to disturbance torques.

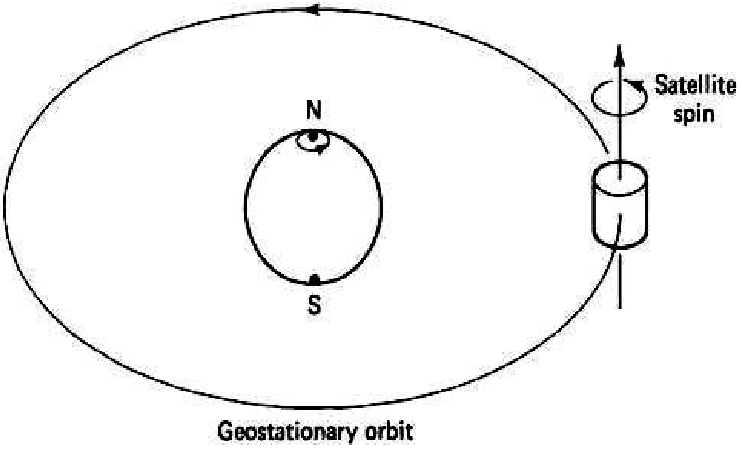


Fig2.4 Spinstabilizationinthegeostationaryorbit

Theoveralleffectisthatthespinratewilldecrease,andthedirectionoftheangularspinaxis willchange. Impulse-type thrusters, or jets, can be used to increase the spin rate again and to shift the axis back to its correct N-S orientation.

Nutation,whichisaformofwobbling,canoccurasaresultofthedisturbancetorquesand/or frommisalignment orunbalanceofthecontroljets. This nutationmust bedampedout by meansof energy absorbers known as *nutation dampers*. The antenna feeds can be connected directly to the transponders without the need for radiofrequency rotary joints, while the complete platform is despun. Of course, control signals and power must be transferred to the despun section and a mechanicalbearing must beprovided. Thecompleteassemblyfor this isknownasthe *bearingand power transfer assembly* (BAPTA). Figure 2.5 shows a photograph of the internal structureofthe HS 376.

Certaindual-spinspacecraftobtainspinstabilizationfromaspinningfly- wheelratherthanby spinning the satellite itself. These flywheels are termed *momentum wheels*, and their average momentum is referred to as *momentumbias*.

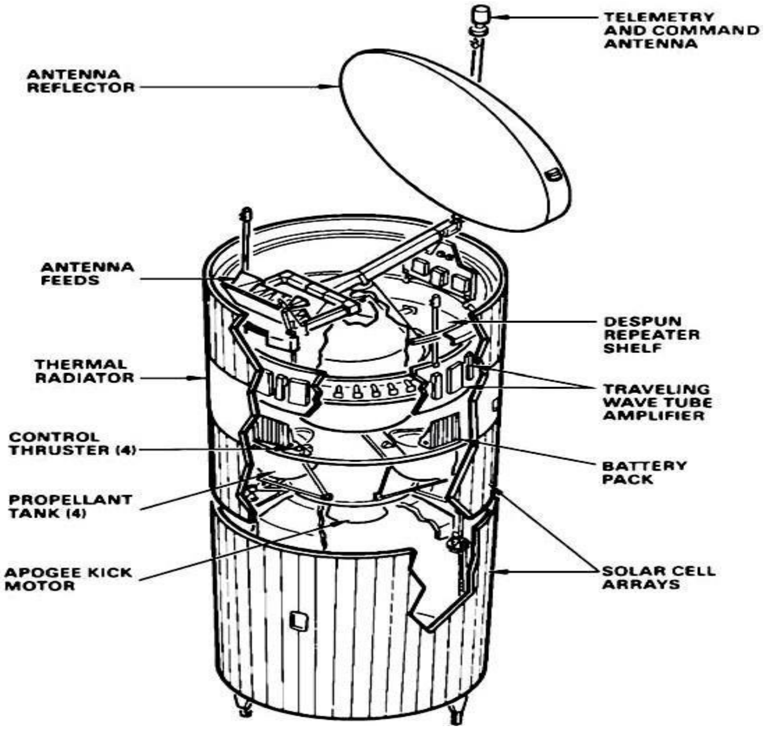


Fig2.5HS376Spacecraft

Momentumwheelstabilization

In the previous section the gyroscopic effect of a spinning satellite is shown to provide stabilityforthesatelliteattitude. Stabilityalso canbeachieved byutilizingthegyroscopiceffectof aspinningflywheel,andthisapproachisusedinsatelliteswithcube-likebodiesandtheINTELSAT V type satellites. These are known as *body-stabilized* satellites. The complete unit, termed a momentum wheel, consists of a flywheel, the bearing assembly, the casing, andanelectric drive motor with associated electronic control circuitry. The flywheel is attached to the rotor, which consists of a permanent magnet providing the magnetic field for motor action. The stator of the motor is attached to the body of the satellite. Thus the motor provides the coupling between the flywheel and the satellite structure. Speed and torque control of the motor is exercisedthroughthe currents fed to the stator.

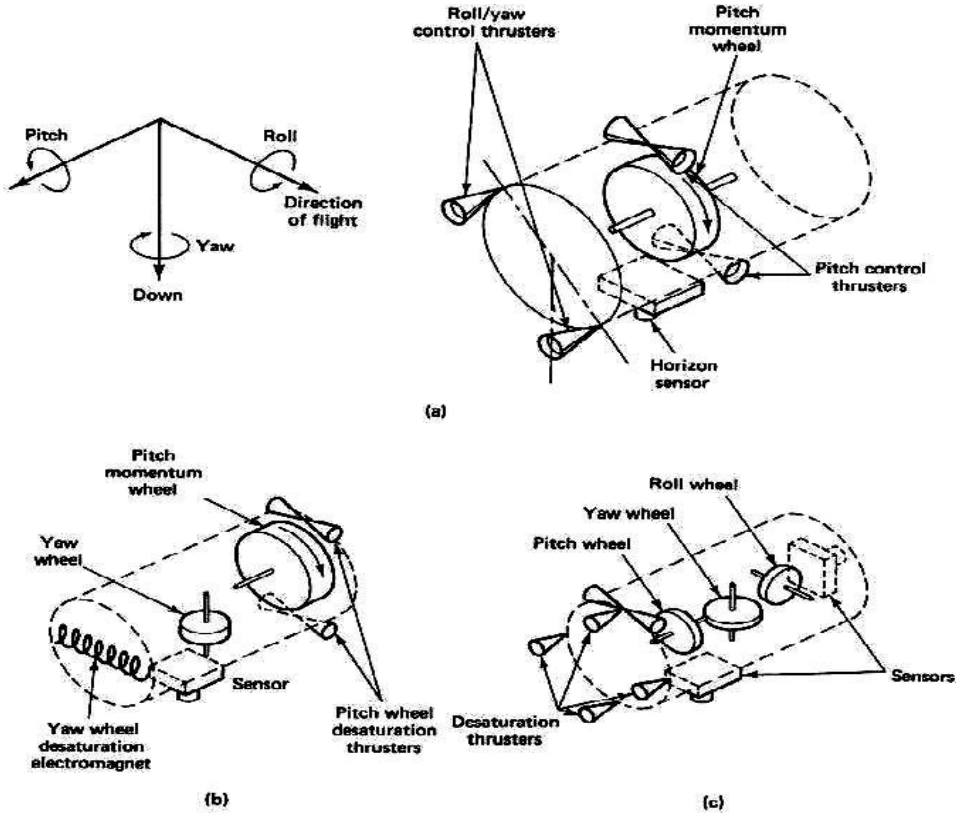


Fig 2.6 Alternativemomentumwheelstabilizationsystems:(*a*)one-wheel, (*b*)two- wheel, (*c*)three-wheel

When a momentum wheel is operated with zero momentumbias, it is generallyreferred to as a *reaction wheel*. Reaction wheels are used in three- axis stabilized systems. Here each axis is stabilized bya reactionwheel, asshown inFigure 2.6.Reactionwheelscanalso be combined with a momentum wheel to provide the control needed.

Random and cyclic disturbance torques tends to produce zero momentum on average. However,therewillalwaysbesomedisturbancetorquesthatcausesacumulative increaseinwheel momentum, and eventually at some point the wheel *saturates*. In effect, it reaches its maximum allowableangular velocityandcanno longer takeinanymore momentum. Massexpulsiondevices arethenusedto unloadthewheel,remove momentumfromit.Theoperationof the mass expulsion devices consumes part of the satellite's fuelsupply.

ThermalControlandPropulsion

Satellites are subject to large thermal gradients, receiving the sun's radiation on one side while the other side faces into space. In addition, thermal radiation from the earth and the earth's *albedo*, which is the fraction of the radiation falling on earth which is reflected, can be significant for low-altitude earth-orbiting satellites, although it is negligible for geostationarysatellites.

Equipment inthesatellitealsogeneratesheatwhichhastoberemoved.Themostimportant consideration is that the satellite’s equipment should operate as nearly as possible in a stable temperature environment. Thermal blankets and shields may be used to provide insulation. Radiation mirrors are often used to remove heat fromthe communications payload.

The mirrored thermal radiator for the Hughes HS 376 satellite can be seen in Figure 2.5. These mirrored drums surround the communications equipment shelves in each case and provide goodradiation paths for the generated heat to escape into the surroundingspace.

Oneadvantageofspinningsatellitescomparedwithbody-stabilizedisthatthespinningbody provides an averaging ofthe temperature extremes experienced fromsolar flux and the cold background ofdeepspace.Inordertomaintainconstanttemperatureconditions,heatersmaybeswitched on to make up for the heat reduction which occurs when transponders are switched off. The INTELSAT VI satellite heaters are used to maintain propulsion thrusters and line temperatures.

CommunicationPayloadandSupportingSubsystems

Thephysicalprincipleofestablishingcommunicationconnections betweenremotecommunication devicesdatesbacktothelate1800swhenscientistswerebeginningtounderstandelectromagnetism and discovered that electromagnetic radiation generated by one device can be detected byanother located at some distance away.

Bycontrollingcertainaspectsoftheradiation,usefulinformationcanbeembeddedintheEMwaves and transmitted from one device to another. The second major module isthe communication payload, which is made up oftransponders. A transponder is capable of -

- Receivinguplinkedradiosignals fromearthsatellitetransmissionstations (antennas).
- Amplifyingreceivedradiosignals.
- Sorting the input signals and directing the output signals through input/output signal multiplexers to the proper downlink antennas for retransmission to earth satellite receiving stations(antennas).

Telemetry,TrackingandCommandSubsystem(TTC)

The TT&C subsystem performs several routine functions aboard the spacecraft. The telemetry function could be interpreted as *measurement at a distance*. It refers to the overall operationofgeneratinganelectricalsignalproportionaltothequantitybeingmeasuredandencoding andtransmitting thisto adistant station, whichforthesatellite is oneoftheearthstations.

Datatransmittedastelemetrysignalsincludeattitudeinformationsuchasthatobtainedfrom sunandearthsensors;environmentalinformationsuchasthemagneticfieldintensityand direction, thefrequencyofmeteoriteimpactetcandspacecraftinformationsuchastemperatures,powersupply voltages, and stored-fuel pressure.

The telemetrysubsystemtransmits informationaboutthe satellitetothe earthstation, while the command subsystem receives command signals from the earth station, often in response to telemetered information. The command subsystemdemodulates and decodesthe command signals androutesthesetotheappropriateequipment neededtoexecutethenecessaryaction. Thusattitude changes may be made, communication transponders switched in and out of circuits, antennas redirected, and station-keeping maneuvers carried out on command. It is important to prevent unauthorized commands from being received and decoded, and the command signals are often encrypted.

Encrypt isderived fromaGreekword*kryptein*, meaning*tohide*, andrepresentstheprocess of concealing the command signals in a secure code. This differs from the normal process of encoding which converts characters in the command signal into a code suitable for transmission. Tracking of the satellite is accomplished by having the satellite transmit beacon signals which are received at the TT&C earth stations. Tracking is obviously important during the transfer and drift orbitalphases of the satellite launch. Once it is on station, the position of a geo-stationary satellite will tend to be shifted as a result of the various disturbing forces. Therefore, it is necessary to be able to track the satellite's movement and send correction signals as required.

Transponders

A transponder is the series of interconnected units which forms a single communications channelbetweenthereceiveandtransmitantennasinacommunicationssatellite.Someoftheunits utilized by a transponder in a given channel may be common to a number of transponders. Thus, althoughreference maybe madeto aspecifictransponder,this must bethoughtofasanequipment *channel* rather than a single itemofequipment.

Before describing in detail the various units of a transponder, the overall frequency arrangementofatypicalC-bandcommunicationssatellitewillbeexaminedbriefly.Thebandwidth allocated for C-band service is 500 MHz, and this is divided into sub-bands, one transponder.

Atypicaltransponderbandwidthis36MHz,andallowingfora4-MHzguard-bandbetweentransponders, 12 suchtransponderscan be accommodated in the 500-MHz bandwidth.

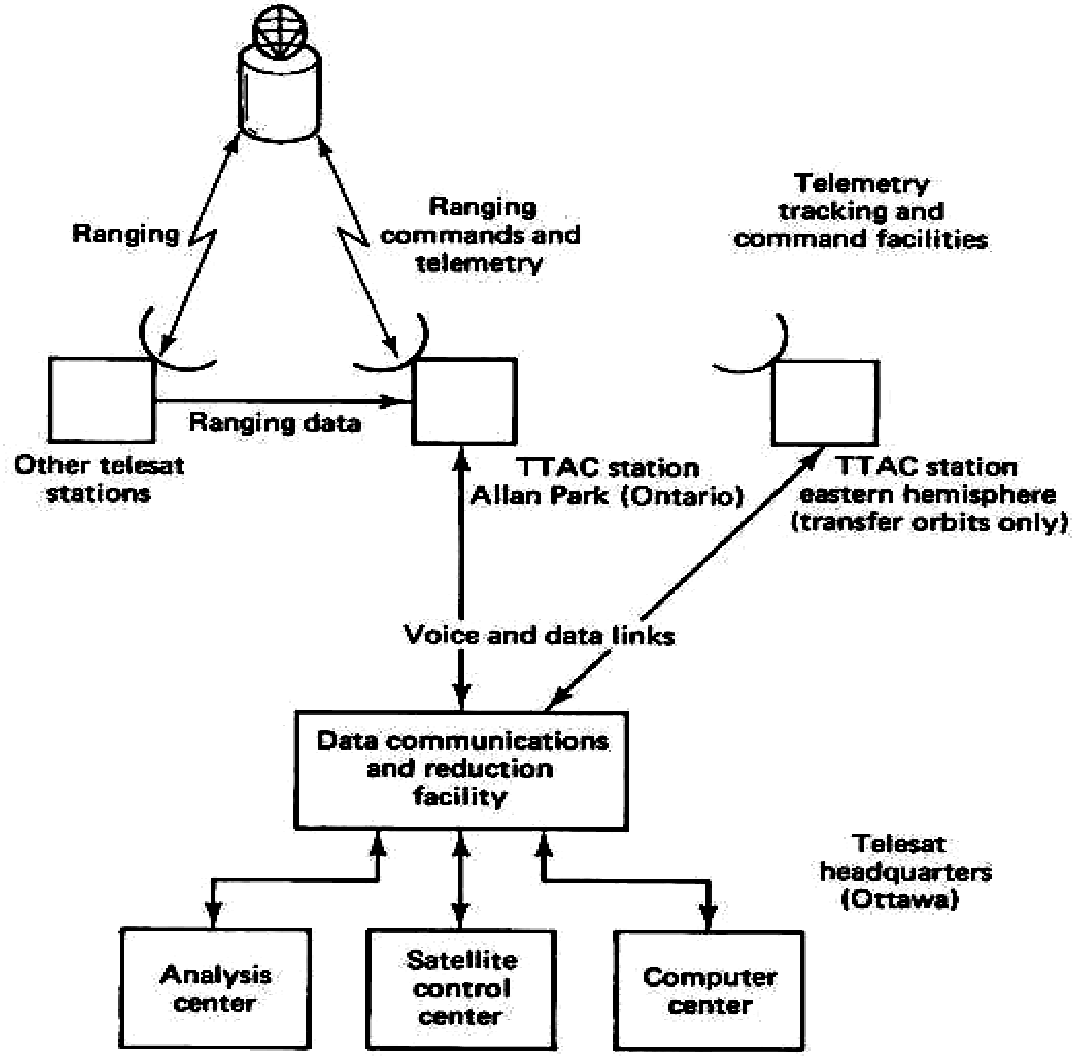
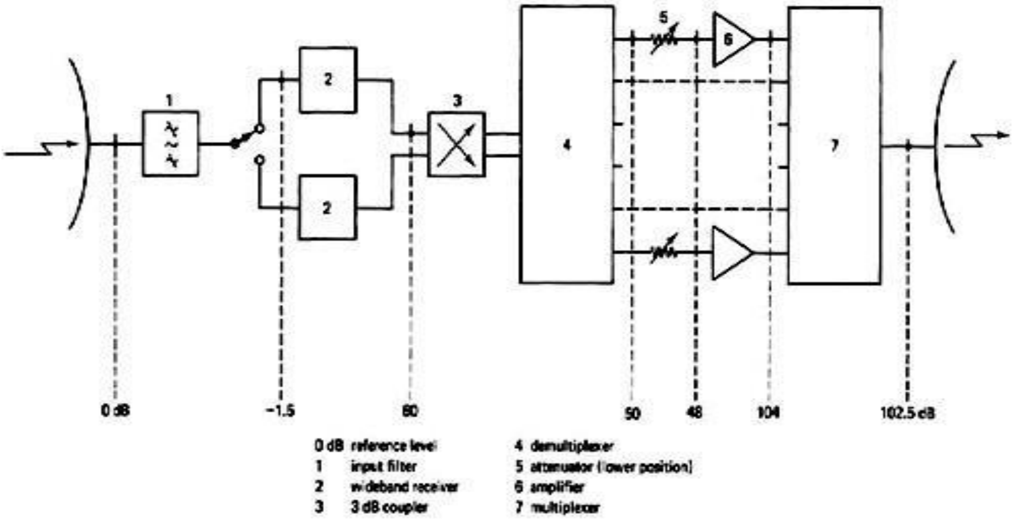


Fig2.7 SatelliteControlSystem

By making use of *polarization isolation*, this number can be doubled. Polarization isolation refers that carriers, which may be onthe same frequency but withopposite senses ofpolarization, canbe isolated fromone another byreceiving antennas matched tothe incoming polarization. With linear polarization, vertically and horizontally polarized carriers can be separated in this way, and with circular polarization, left-hand circular and right-hand circular polarizations can be separated. Because the carriers with opposite senses of polarization mayoverlap in frequency, this technique isreferred to as*frequencyreuse*. Figure2.8 showspart ofthe frequencyand polarizationplan for a C-band communications satellite.



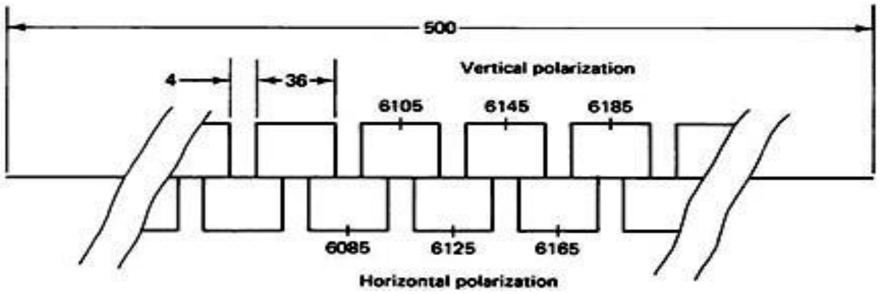


Fig2.8 Section of an Uplink Frequency and Polarization Plan

Frequency reuse also may be achieved with spot-beam antennas, and these may be combined with polarization reuse to provide an effective bandwidth of 2000 MHz from the actual bandwidth of 500 MHz. For one of the polarization groups, Figure 2.8 shows the channeling scheme for the 12 transponders in more detail. The incoming, or uplink, frequency range is 5.925 to 6.425 GHz. The frequency conversion shifts the carriers to the downlink frequency band, which is also 500 MHz wide, extending from 3.7 to 4.2 GHz. At this point the signals are channelized into frequency bands which represent the individual transponder bandwidths.

The wideband receiver

The wideband receiver is shown in more detail in Fig.2.10. A duplicate receiver is provided so that if one fails, the other is automatically switched in. The combination is referred to as a *redundant receiver*, meaning that although two are provided, only one is in use at a given time.

The first stage in the receiver is a *low-noise amplifier* (LNA). This amplifier adds little noise to the carrier being amplified, and at the same time it provides sufficient amplification for the carrier to override the higher noise level present in the following mixer stage.

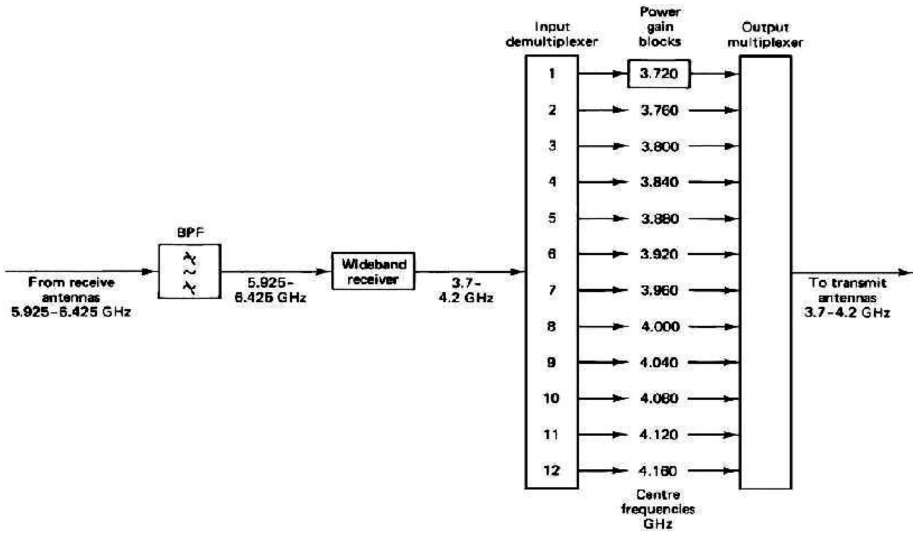


Fig2.9 SatelliteTransponderChannels

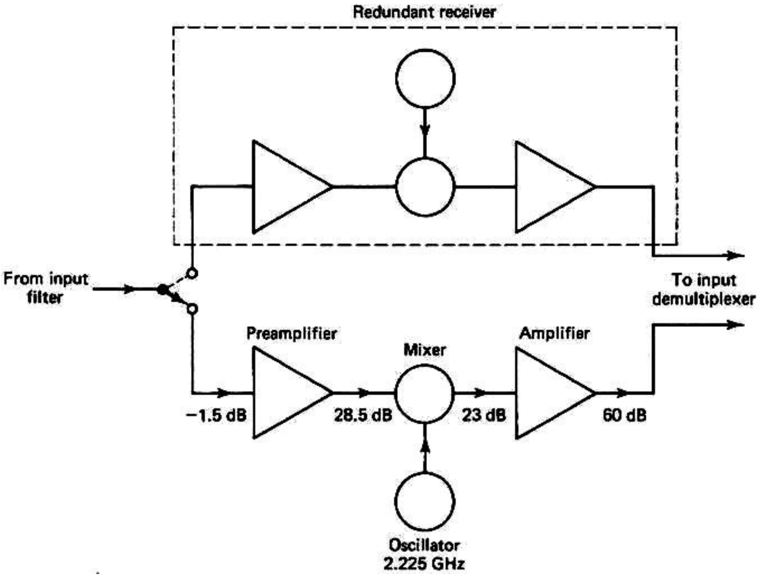


Fig2.10 SatelliteWidebandReceiver

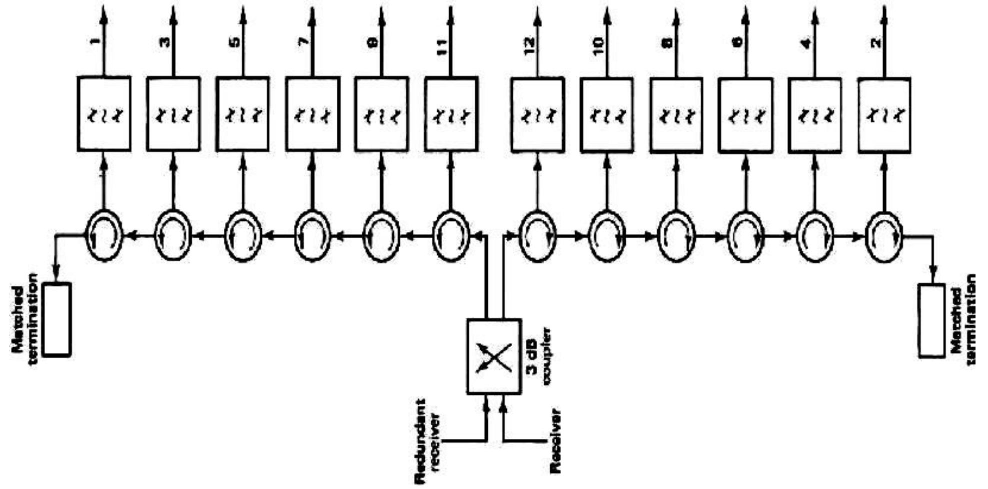
It is more convenient to refer all noise levelstothe LNA input,where thetotal receiver noise may be expressed in terms of an equivalent noise temperature. In a well-designed receiver, the equivalent noise temperature referred to the LNA input is basically that of the LNA alone. The overallnoise temperature must take into accountthe noise added fromthe antenna. The equivalent noise temperature ofa satellite receiver may be on the order ofa few hundred kelvins.

TheLNAfeedsintoamixerstage,whichalsorequiresa*localoscillator*(LO)signalforthe frequency-conversion process. With advances in *field-effect transistor* (FET) technology, FET amplifiers, whichofferequalorbetterperformance, arenowavailable forbothbands. Diode mixer stages are used. The amplifier following the mixer mayutilize *bipolar junction transistors* (BJTs) at 4GHz and FETs at 12 GHz, or FETs may in fact be used in bothbands.

Theinputde-multiplexer

Theinputde-multiplexerseparatesthebroadbandinput,coveringthefrequencyrange3.7to 4.2 GHz, into the transponder frequency channels. This provides greater frequency separation betweenadjacentchannelsinagroup,whichreducesadjacentchannelinterference.Theoutputfrom the receiver is fed to a power splitter, which in turn feeds the two separate chains of circulators.

Fig2.11 SatelliteInput Multiplexer



The fullbroadband signalistransmitted along eachchain, and the channelizing isachieved bymeansofchannelfiltersconnectedtoeachcirculator.Eachfilterhasabandwidthof36MHz and istunedtotheappropriatecenterfrequency,asshowninFig. 2.11.Althoughthereareconsiderable lossesinthedemultiplexer,theseareeasilymadeupintheoverallgainforthetransponderchannels.

Thepoweramplifier

Thefixedattenuationisneededtobalanceoutvariationsintheinputattenuationsothat each transponderchannelhasthesamenominalattenuation,thenecessaryadjustmentsbeingmadeduring assembly.Thevariableattenuationisneededtosetthelevelasrequiredfordifferenttypesofservice. Because this variable attenuator adjustment is an operational requirement, it must be under the control of the ground TT&C station.

Traveling-wave tube amplifiers (TWTAs) are widely used in transponders to provide the finaloutput powerrequiredto thetransmit antenna. Figure 2.12shows the schematic ofa *traveling wavetube*(TWT)anditspowersupplies.IntheTWT,anelectron-beamgunassemblyconsistingof a heater, a cathode, and focusing electrodes is used to form an electron beam. A magnetic fieldis required to confine the beamto travelalong the inside ofa wire helix.

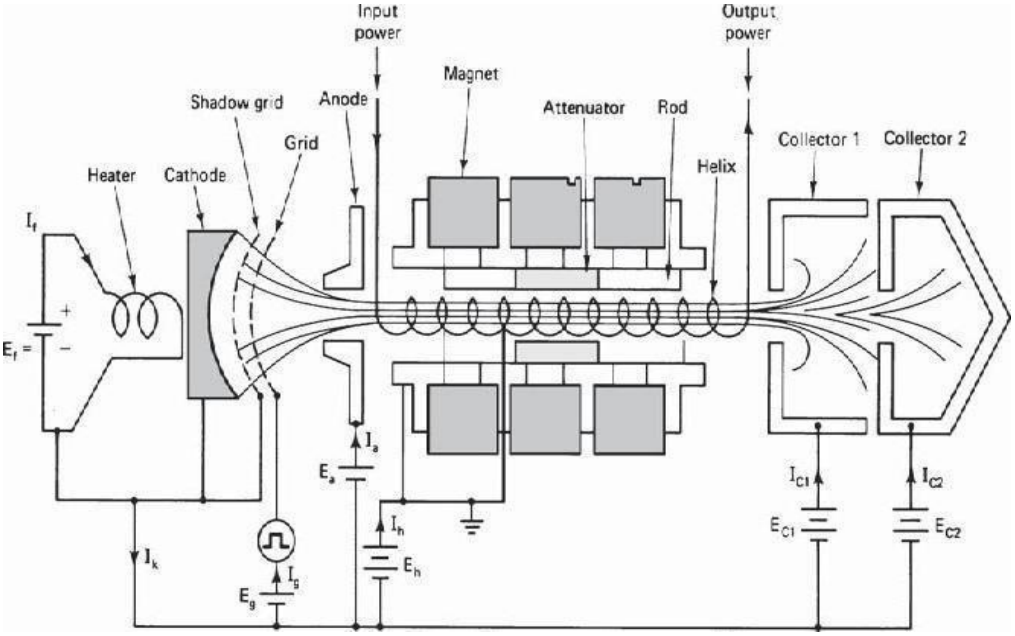


Fig2.12 SatelliteTWTA

The magnetic field can be provided by means of a solenoid and dc power supply. The comparatively large size and high-power consumption of solenoids make them unsuitable for use aboard satellites and lower-powerTWTs are usedwhich employpermanent-magnet focusing. The wave will travel around the helical path at close to the speed of light, but it is the axial component of wave velocity which interacts with the electron beam.

This component is less thanthe velocityof light approximatelyinthe ratio ofhelix pitchto circumference.Becauseofthiseffectivereductioninphasevelocity,thehelixisreferredtoasa*slow wavestructure*. TheadvantageoftheTWToverothertypesoftubeamplifiers isthat it can provide amplification over a very wide bandwidth. Input levels to the TWT must be carefully controlled, howevertominimizetheeffectsofcertainformsofdistortion.Theresultsfromthenonlineartransfer characteristic of the TWT are illustrated in Figure 2.13.

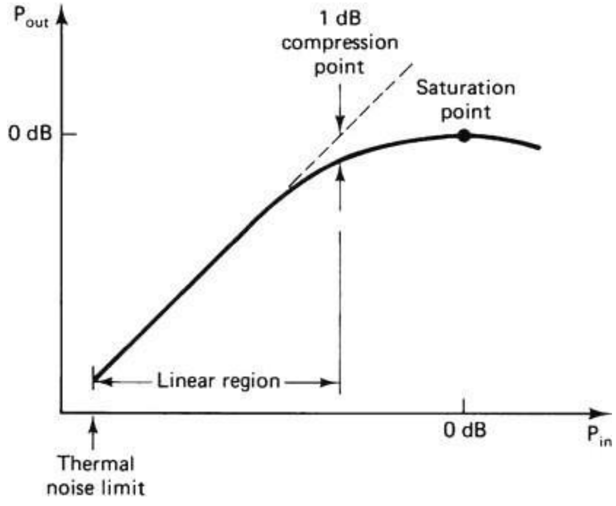


Fig2.13 PowerTransferCharacteristicsofaTWT

At low-input powers, theoutput-input power relationship is linear. At higher power inputs, the output power saturates, the point of maximum power output being known as the *saturation point*. Thesaturationpointisaveryconvenientreferencepointandinputandoutputquantitiesareusually referredtoit.ThelinearregionoftheTWTisdefinedastheregionboundbythethermal noiselimit atthelowendand bywhat istermedthe *1-dB compressionpoint* attheupper end. This isthepoint where the actualtransfer curve drops.

SatelliteUplinkandDownlinkAnalysisandDesign

Introduction

The link-power budget calculations basically relate two quantities, the transmit power and the receive power, and show in detail how the difference between these two powers is accounted for. Link-budget calculations are usually made using decibel or decilog quantities. Where no ambiguityarisesregardingtheunits,theabbreviationdBisused.Forexample,Boltzmann'sconstant is givenas 228.6dB, although, strictlyspeaking, this should be givenas 228.6 decilogs relative to 1 J/K.

EquivalentIsotropicRadiatedPower

A key parameter in link-budget calculations is the *equivalent isotropic radiated power*, conventionally denoted EIRP. The maximum power flux density at some distance '*r'* for transmitting antenna of gain '*G*i'

$$Pr= \frac{GP}{4\pi^2}$$

AnisotropicradiatorwithaninputpowerequaltoGP*S*wouldproducethesamefluxdensity. Hence, this product is referred to as the EIRP, or EIRP is often expressed in decibels relative to 1 W, or dBW. Let*PS* be in watts; then [EIRP] = [*PS*] x [*G*] dB , where [*PS*] is alsoin dBWand [*G*] is in dB.

TransmissionLosses

The [EIRP] may be thought of as the power input to one end of the transmission link, and theproblemistofindthepowerreceivedattheotherend.Losseswilloccuralongtheway,someof which are constant. Other losses can only be estimated fromstatisticaldata, and some ofthese are dependent on weather conditions, especially on rainfall.

The first step in the calculations is to determine the losses for *clear- weather* or *clear-sky conditions*.Thesecalculationstakeintoaccountthelosses,includingthosecalculatedonastatistical basis which does not vary with time. Losses which are weather-related, and other losses which fluctuate with time, are then allowed for by introducing appropriate *fade margins* into the transmission equation.

Free-spacetransmission:

As a first step in the loss calculations, the power loss resulting from the spreading of the signal in space must be determined.

Feederlosses:

Losses will occur in the connection between the receive antenna and the receiver proper. Suchlosseswilloccur intheconnectingwaveguides, filters,andcouplers.Thesewillbedenotedby RFL, or [RFL] dB, for *receiver feeder losses*.

Antennamisalignmentlosses:

Whenasatellitelinkisestablished,theidealsituationistohavetheearthstationand satellite antennasalignedformaximumgain,asshowninFigure2.14.Therearetwopossible sourcesofoff- axis loss, one at the satellite and one at the earth station. The off-axis loss at the satellite is taken into account by designing the link for operation on the actual satellite antenna contour; this is described in more detail in later sections. The off-axis loss at the earth station is referred to as the *antennapointingloss*.Antennapointinglossesareusuallyonlyafewtenthsofadecibel.Inaddition topointing losses, lossesmayresult attheantenna frommisalignment ofthe polarizationdirection. The polarization misalignment losses are usually small, and it will be assumed that the antenna misalignment losses, denoted by [AML], include both pointing and polarization losses resulting from antenna misalignment.

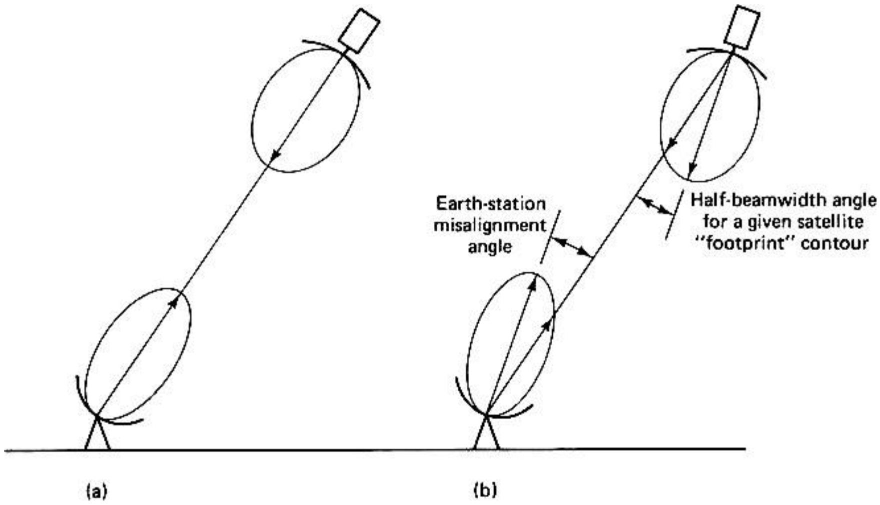


Fig2.14(*a*)Satelliteandearth-stationantennasalignedformaximumgain;(*b*)earthstationsituatedona given satellite "footprint," and earth-station antenna misaligned.

TheLink-PowerBudgetEquation

The losses for the link have been identified, the power at the receiver, which is the power output of the link, may be calculated simplyas [EIRP] [LOSSES] [G_R], where the last quantity is the receiver antenna gain. The major source of loss in any ground-satellite link is the free-space spreading loss [FSL], the basic link-power budget equation taking into account this loss only. However,theother lossesalso must be takeninto account,andthesearesimplyadded to [FSL].

Thelossesforclear-skyconditionsare

[LOSSES]= [FSL]+[RFL]+[AML]+[AA] -[PL]equationforthereceivedpoweristhen $[P_R]$ = [EIRP] X $[G_R]$ -[LOSSES]

Where

[PR]-thereceived power,dBW

[EIRP]-equivalentisotropicradiatedpower, dBW[FSL]free-spacespreadingloss,dB [RFL] -receiver feeder loss,dB

[AML]-antennamisalignmentloss,dB

[AA]-atmosphericabsorptionloss,dB[PL]polarizationmismatchloss, dB

AmplifierNoiseTemperature

Consider first the noise representation ofthe antenna and the *lownoise amplifier* (LNA) showninFig.2.15.TheavailablepowergainoftheamplifierisdenotedasG,andthenoisepower output, as P_{no}.

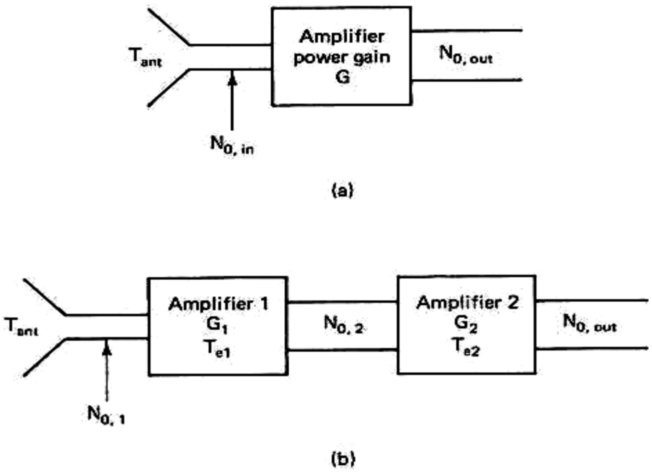


Fig2.15LNAAmplifierGain

For themoment, thenoisepowerper unitbandwidth,whichissimply noiseenergy injoules as shown bythe following Equation. The input noise energy coming fromthe antenna is

$$N_{0,\text{ant}} = kT_{\text{ant}}$$

TheUplink

Theuplinkof asatellitecircuitistheoneinwhichtheearthstationistransmittingthe signaland he satellite is receiving it^{t}specificallythat the uplink is being considered.

$$\frac{C}{N} = [EIRP] - [LOSSES] + [k]$$

Intheaboveequation,thevaluestobeusedaretheearthstationEIRP,thesatellitereceiver feeder losses,andsatellitereceiver *G*/*T*.The free-space lossandother losseswhichare frequency- dependent are calculated for the uplink frequency.

Inputback-off

Since the number of carriers are present simultaneously in a TWTA, the operating point must be backed offto alinear portionofthetransfer characteristicto reducetheeffectsofinter modulation distortion.Suchmultiplecarrieroperationoccurswith*frequency-divisionmultipleaccess*(FDMA). Thepointtobemadehereisthat *backoff*(BO)mustbeallowedforinthelink-budgetcalculations. Suppose that the saturation flux density for single-carrier operation is known. Input BO will be specified for multiple-carrier operation, referred to the single- carrier saturation level. Theearth-stationEIRPwillhavetobereducedbythespecifiedBO,resulting inanuplinkvalueof

$$[\mathrm{EIRP}]_U = [\mathrm{EIRP}_S]_U + [\mathrm{BO}]_i$$

TheearthstationHPA

The earth station HPA has to supply the radiated power plus the transmit feeder losses, denotedherebyTFL,or[TFL]dB.Theseincludewaveguide,filter,andcouplerlossesbetweenthe HPAoutputandthetransmitantenna.Theearthstationmayhavetotransmitmultiplecarriersandits output also will require back off, denoted by$[\mathrm{BO}]_{\mathrm{HPA}}$. The earth station HPA must be rated for a saturation power output given by

$$[P_{\mathrm{HPA,sat}}] = [P_{\mathrm{HPA}}] + [\mathrm{BO}]_{\mathrm{HPA}}$$

Downlink

Thedownlinkofasatellitecircuitistheoneinwhichthesatelliteistransmittingthesignaland theearthstationisreceivingit.Equationcanbeappliedtothedownlink,but subscript*D*willbeused to denote specificallythat the downlink is being considered.

$$\frac{C}{N} = [EIRP] - [LOSSES] + [k]$$

Intheaboveequation,thevaluesto beusedarethesatelliteEIRP,theearth-stationreceiver feeder losses, and the earth-stationreceiver *G*/*T*. The free space and other losses are calculated for the downlink frequency. The resulting carrier-to-noise density ratio appears at the detector of the earth station receiver.

Outputback-off

WhereinputBOisemployedasdescribedinacorrespondingoutputBOmust beallowedfor in the satellite EIRP. As the curve of Figure 2.16 shows that output BO is not linearly related to inputBO.Aruleofthumb, frequentlyused,istotaketheoutputBOasthepointonthecurvewhich is5dBbelowtheextrapolatedlinearportion.Sincethelinearportiongivesa1:1change indecibels, therelationshipbetweeninputandoutputBOis$[\mathrm{BO}]_0[\mathrm{BO}]_i$5dB.Forexample,withaninput BO of $[\mathrm{BO}]_i$ 11 dB, the corresponding output BO is $[\mathrm{BO}]_0$

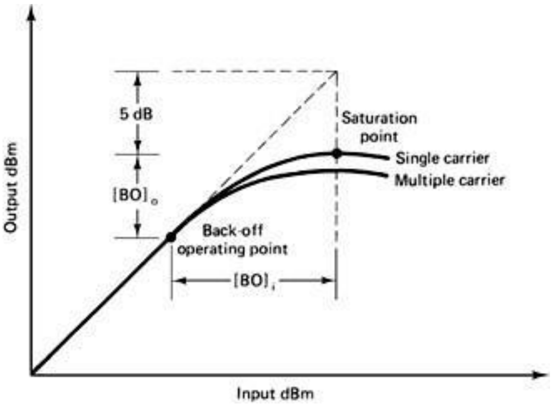
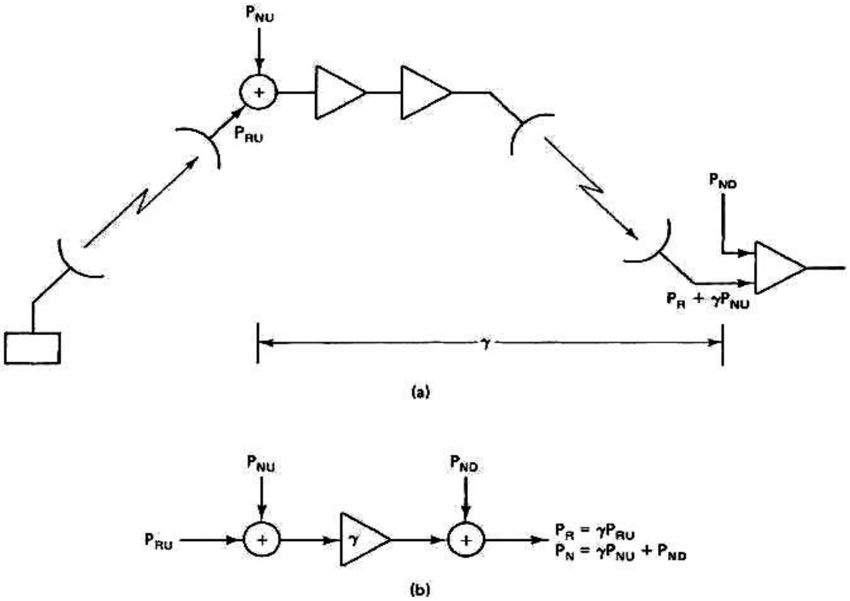


Fig2.16 Input and output back-off relationship for the satellite traveling-wave-tube amplifier

Effects of Rain

In the C band and, more especially, the Ku band, rainfall is the most significant cause of signal fading. Rainfall results in attenuation of radio waves by scattering and by absorption of energy from the wave. Rain attenuation increases with increasing frequency and is worse in the Ku band compared with the C band. This produces a depolarization of the wave; in effect, the wave becomes elliptically polarized. This is true for both linear and circular polarizations, and the effect seems to be much worse for circular polarization. The C/N_0 ratio for the downlink alone, not counting the P_{NU} contribution, is P_R/P_{ND}, and the combined C/N_0 ratio at the ground receiver is

Fig2.17(*a*) Combined uplink and downlink (*b*) power flow diagram



The reason for this reciprocal of the sum of the reciprocals method is that a single signal power is being transferred through the system, while the various noise powers, which are present are additive. Similar reasoning applies to the carrier-to-noise ratio, C/N.

Inter-modulationandInterference

Inter-modulation interference is the undesired combining of several signals in a nonlinear device, producing new, unwanted frequencies which can cause interference in adjacent receivers located at repeater sites. Not all interference is a result of inter-modulation distortion. It can come from co-channel interference, atmospheric conditions as well as man-made noise generated by medical, welding and heating equipment.

Most inter-modulation occurs in a transmitter's nonlinear power amplifier (PA). The next most common mixing point is in the front end of a receiver. Usually, it occurs in the unprotected first mixer ofolder modelradios or in some cases anoverdriven RF front-end amp.

Inter-modulation can also be produced in rusty or corroded tower joints, guy wires, turnbuckles and anchor rods or any nearby metallic object, which can act as a nonlinear "mixer/rectifier" device.

PropagationCharacteristicsandFrequencyConsiderations

Introduction

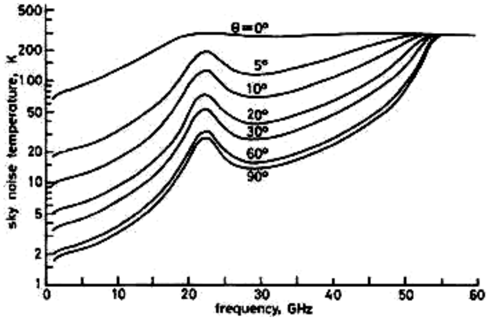
Anumberoffactorsresulting fromchangesintheatmospherehavetobetakenintoaccount when designing a satellite communications system in order to avoid impairment of the wanted signal. Generally, a margin in the required carrier-to-noise ratio is incorporated to accommodate such effects.

RadioNoise

Radio noise emitted by matter is used as a source of informationinradio-astronomyand inremote sensing. Noise ofa thermalorigin has a continuous spectrum, but severalother radiation mechanisms cause the emission to have a spectral-line structure. Atoms and molecules are distinguished by their different spectral lines. For other services such as satellite communications noise is a limiting factor for the receiving system. Generally, it is inappropriate to use receiving systemswithnoisetemperatureswhicharemuchlessthanthosespecifiedbytheminimumexternal noise. From about 30 MHz to about 1 GHz cosmic noise predominates over atmospheric noise except during localthunderstorms,but willgenerallybeexceeded byman-made noise inpopulated areas.

In the bands of strong gaseous absorption, the noise temperature reaches maximum values ofsome290K.Attimes,precipitationwillalsoincreasethenoisetemperatureatfrequenciesabove 5 GHz. Figure 2.18 gives an indication of sky noise at various elevation angles and frequencies.

Fig2.18 Sky-NoiseTemperaturefor Clear Air



SystemReliabilityandDesignLifetime

Systemreliability

Satellites are designed to operate dependably throughout their operational life, usually a number of years. This is achieved through stringent quality control and testing of parts and subsystemsbeforetheyareusedintheconstructionofthesatellite.Redundancyofkeycomponents is often built in so that ifa particular part or subassembly fails,another can perform its functions. Inaddition,hardwareandsoftwareonthesatelliteareoftendesignedsothatground controllerscan reconfigure the satellite to work around a part that has failed.

2.12.2.Designlifetime

The Milstar constellationhasdemonstratedexceptionalreliabilityand capability, providing vital protected communications to the warfighter," said Kevin Bilger, vice president and general manager, Global Communications Systems, Lockheed Martin Space Systems in Sunnyvale. "Milstar's robust system offers our nation worldwide connectivity with flexible, dependable and highly secure satellite communications."

The five-satellite Milstar constellation has surpassed 63 years of combined successful operations,andprovidesaprotected,globalcommunicationnetworkforthejointforcesofthe U.S.military.Inaddition,itcantransmitvoice,data,andimagery,andoffersvideoteleconferencing capabilities. The system is the principal survivable, endurable communications structure that the President, the SecretaryofDefense and the Commander, U.S. Strategic Command use to maintain positive command and controlof the nation's strategic forces.

Inadditionto this 10-year milestone for Flight-5, eachofthe first two Milstar satellites has been on orbit for over 16 years – far exceeding their 10-year design life. The next-generation LockheedMartin-built AdvancedEHFsatellites, joiningtheMilstarconstellation, provide five times faster data rates and twice as many connections, permitting transmission of strategic and tactical military communications, such as real-time video, battlefield maps and targeting data. Advanced EHF satellites are designed to be fully interoperable and backward compatible with Milstar.

Headquartered in Bethesda, Md., Lockheed Martin is a global security company that employs about 123,000 people worldwide and is principally engaged in the research, design, development, manufacture, integration and sustainment ofadvanced technologysystems, products and services. The Corporation's net sales for 2011 were $46.5 billion.

APPLICATIONSOFSATELLITES:

Satellites that are launched in to the orbit by using the rockets are called man-made satellites or artificial satellites. Artificial satellites revolve around the earth because ofthe gravitational force of attraction between the earth and satellites. Unlike the natural satellites (moon), artificial satellites are used in various applications. The various applications ofartificial satellites include:

1. Weatherforecasting
2. Navigation
3. Astronomy
4. Satellitephone
5. Satellitetelevision

6. Militarysatellite
7. Satelliteinternet
8. Satelliteradio.

1. Weatherforecasting

Weatherforecastingisthepredictionofthefutureofweather.Thesatellitesthatareusedtopredict the future of weather are called weather satellites. Weather satellitescontinuously monitor the climate and weather conditions of earth. They use sensors called radiometers for measuring the heat energy released from the earth surface. Weather satellites also predict the most dangerous storms such as hurricanes.

2. Navigation

Generally, navigation refers to determining the geographical location of an object. The satellites that are used to determine the geographic location of aircrafts, ships, cars, trains, or any other object are called navigation satellites. GPS (Global Positioning System) is an example of navigationsystem. It allows the user to determine their exact locationat anywhere inthe world.

3. Astronomy

Astronomy is the study of celestial objects such as stars, planets, galaxies, natural satellites, comets, etc.Thesatellitesthat areusedtostudyorobservethedistant stars,galaxies, planets, etc. arecalledastronomicalsatellites.Theyaremainlyusedtofindthenewstars,planets,andgalaxies. Hubble space telescope is an example of astronomical satellite. It captures the high- resolution images of the distant stars, galaxies, planets etc.

4. Satellitephone

Satellitephoneisatypeofmobilephonethat usessatellitesinsteadofcelltowersfortransmitting the signalor informationover long distances.Mobile phones that use celltowers will workonly withinthecoverageareaofacelltower.Ifwego beyondthecoverageareaofa celltowerorifwe reach the remote areas, it becomes difficult to make a voice call or send text messages with the mobilephones.Unlikethemobilemobiles,satellitephoneshaveglobalcoverage.Satellitesphones uses geostationarysatellites and low earthorbit (LEO) satellites for transmitting the information. Whenapersonmakesacallfromthesatellitephone,thesignalis sent tothesatellite.Thesatellite willreceivesthat signal, processes it, andredirectsthesignal backtotheearthviaagateway. The gateway then send the signal or call to the destination by using the regular cellular and landline networks.TheusageofsatellitephonesisillegalinsomecountrieslikeCuba,NorthKorea,Burma, India, and Russia.

5. Satellitetelevision

SatellitetelevisionorsatelliteTVisawirelesssystemthatusescommunicationsatellitestodeliver the television programs or television signals to the users or viewers.

TV or television mostly uses geostationary satellites because they look stationary fromthe earth. Hence,thesignaliseasilytransmitted.Whenthetelevisionsignalissendtothesatellite,it receives the signal, amplifies it, and retransmit it back to the earth.The first satellite television signalwas send fromEuropeto North America by using the Telstar satellite.

6. Militarysatellite

Militarysatellite is anartificialsatellite used bythe armyfor various purposes suchas spying on enemy countries, military communication, and navigation.

Military satellites obtain the secretinformation from the enemy countries. These satellites also detect the missiles launched bythe other countries in the space.

Militarysatellitesareusedbyarmed forcestocommunicatewitheachother.Thesesatellitesalso used to determine the exact location of an object.

7. Satelliteinternet

Satellite internet is a wireless system that uses satellites to deliver the internet signals to users. High-speed internet is the main advantage of satellite internet. Satellite internet does not use cable systems, but instead it uses satellites to transmit the information or signal.

8. Satelliteradio

Satellite radio is a wireless transmission service that uses orbiting satellites to deliver the informationor radio signals to the consumers. It is primarilyused in thecars.Whentheground stationtransmit signaltothesatellitethatisrevolving around the earth, the satellite receives the signal, amplifies it, and redirects the signal back to the earth (radio receivers in the cars).