SATELLITE COMMUNICATIONS SYSTEMS

Systems, Techniques and Technology

Fifth Edition

Gérard Maral

Ecole Nationale Supérieure des Télécommunications, Site de Toulouse, France

Michel Bousquet

Ecole Nationale Supérieure de l'Aéronautique et de l'Espace (SUPAERO), Toulouse, France

Revisions to fifth edition by **Zhili Sun**
University of Surrey, UK

with contributions from Isabelle Buret, Thales Alenia Space

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ACRONYMS

AAL	ATM Adaptation Layer
A/D	Analog-to-Digital conversion
ABCS	Advanced Business Communications via Satellite
ABM	Apogee Boost Motor
ACD	Average Call Distance
ACI	Adjacent Channel Interference
ACK	ACKnowledgement
ACTS	Advanced Communications Technology Satellite
ADC	Analog to Digital Converter
ADM	Adaptive Delta Modulation
ADPCM	Adaptive Pulse Code Modulation
ADSL	Asymmetric Digital Subscriber Line
AES	Audio Engineering Society
AGCH	Access Granted CHannel
AKM	Apogee Kick Motor
ALC	Automatic Level Control
ALG	Application Level Gateway
AM	Amplitude Modulation
AMAP	Adaptive Mobile Access Protocol
AMP	AMPlifier
AMPS	Advanced Mobile Phone Service
AMSC	American Mobile Satellite Corp.
AMSS	Aeronautical Mobile Satellite Service
ANSI	American National Standards Institute
AOCS	Attitude and Orbit Control System
AOM	Administration, Operation and Maintenance
AOR	Atlantic Ocean Region
APC	Adaptive Predictive Coding
APD	Avalanche Photodetector
API	Application Programming Interface
AR	Axial Ratio
ARQ	Automatic Repeat Request
ARQ-GB(N)	Automatic repeat ReQuest-Go Back N
ARQ-SR	Automatic repeat ReQuest-Selective Repeat
ARCS	Astra Return Channel System
ARQ-SW	Automatic repeat ReQuest-Stop and Wait
ARTES	Advanced Research in TElecommunications Systems (ESA programme)
ASCII	American Standard Code for Information Interchange
ASIC	Application Specific Integrated Circuit
ASN	Acknowledgement Sequence Number
ASN	Abstract Syntax Notation
ASTE	Advanced Systems and Telecommunications Equipment (ESA programme)
ASTP	Advanced Systems and Technology Programme (ESA programme)
ASYNC	ASYNChronous data transfer
ATA	Auto-Tracking Antenna
ATC	Adaptive Transform Coding
ATM	Asynchronous Transfer Mode
BAPTA	Bearing and Power Transfer Assembly
BCH	Broadcast Channel
BCR	Battery Charge Regulator
BDR	Battery Discharge Regulator
BECN	Backward explicit congestion notification
BEP	Bit Error Probability
BER	Bit Error Rate
BFN	Beam Forming Network
BFSK	Binary Frequency Shift Keying
BGMP	Border Gateway Multicast Protocol
BGP	Border Gateway Protocol
BHCA	Busy Hour Call Attempts
BHCR	Busy Hour Call Rate
BISDN	Broadband ISDN
BIS	Broadband Interactive System
BITE	Built-In Test Equipment
BOL	Beginning of Life
BPF	Band Pass Filter
BPSK	Binary Phase Shift Keying
BS	Base Station

BSC	Binary Synchronous Communications (bisync)
BSN	Block Sequence Number
BSS	Broadcasting Satellite Service
BT	Base Transceiver
BTS	Base Transceiver Station
BW	BandWidth
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CAMP	Channel AMPlifier
CATV	CAbleTeleVision
CBDS	Connectionless broadband data service
CBO	Continuous Bit Oriented
CBR	Constant Bit Rate
CCI	CoChannel Interference
CCIR	Comité Consultatif International des Radiocommunications (International Radio Consultative Committee)
CCITT	Comité Consultatif International du Télégraphe et du Téléphone (The International Telegraph and Telephone Consultative Committee)
CCSDS	Consultative Committee for Space Data Systems
CCU	Cluster Control Unit
CDMA	Code Division Multiple Access
CEC	Commission of the European Communities
CELP	Code Excited Linear Prediction
CENELEC	Comité Européen pour la Normalisation en ELECtrotechnique (European Committee for Electro-technical Standardisation)
CEPT	Conférence Européenne des Postes et Télécommunications (European Conference of Post and Telecommunications)
CFDMA	Combined Free/Demand Assignment Multiple Access
CFM	Companded Frequency Modulation
CFRA	Combined Fixed/Reservation Assignment
CIR	Committed Information Rate
CIRF	Co-channel Interference Reduction Factor
CIS	Commonwealth of Independent States
CLDLS	ConnectionLess Data Link Service
CLEC	Competitive Local Exchange Carrier
CLNP	ConnectionLess Network Protocol
CLTU	Command Link Transmission Unit
CMOS	Complementary Metal Oxide Semiconductor
CNES	Centre National d'Etudes Spatiales (French Space Agency)
CODLS	Connection Oriented Data Link Service
COMETS	Communications and Broadcasting Engineering Test Satellite
CONUS	CONtinental US
CoS	Class of Service
COST	European COoperation in the field of Scientific and Technical research
COTS	Commercial Off The Shelf
CPS	Chemical Propulsion System
CRC	Communications Research Centre (Canada)
CS	Cell Selection
CSMA	Carrier Sense Multiple Access
CT	Cordless Telephone
CTR	Common Technical Regulation
CTU	Central Terminal Unit
D-AMPS	Digital Advanced Mobile Phone System
D-M-PSK	Differential M-ary Phase Shift Keying
D/C	Down-Converter
DA	Demand Assignment
DAB	Digital Audio Broadcasting
DAC	Digital to Analog Converter
DAMA	Demand Assignment Multiple Access
DARPA	Defense Advanced Research Project
DASS	Demand Assignment Signalling and Switching
dB	deciBel
dBm	Unit for expression of power level in dB with reference to 1 mW
dBm	Unit for expression of power level in dB with reference to 1 mW
dBmO	Unit for expression of power level in dBm at a point of zero relative level (a point of a telephone channel where the 800 Hz test signal has a power of 1 mW)
DBF	Digital Beam Forming
DBFN	Digital Beam Forming Network
DBS	Direct Broadcasting Satellite
DC	Direct Current
DCCH	Dedicated Control Channel
DCE	Data Circuit Terminating Equipment
DCFL	Direct Coupled Fet Logic
DCME	Digital Circuit Multiplication Equipment
DCS	Digital Cellular System (GSM At 1800 MHz)
DCT	Discrete Cosine Transform
DCU	Distribution Control Unit
DDCMP	Digital Data Communications Message Protocol (a DEC Protocol)
DE	Differentially Encoded

DE-M-PSK	Differentially Encoded M-ary Phase Shift Keying
DECT	Digital European Cordless Telephone
DEMOD	DEMODulator
DEMUX	DEMUltipleXer
DES	Data Encryption Standard
DM	Delta Modulation
DNS	Domain Name Service (host name resolution protocol)
DOD	Depth of Discharge
DOF	Degree of Freedom
DQDB	Distributed Queue Dual Bus
DSCP	Differentiated Service Code Point
DSI	Digital Speech Interpolation
DSL	Digital Subscriber Loop
DSP	Digital Signal Processing
DTE	Data Terminating Equipment
DTH	Direct To Home
DTTL	Data Transition Tracking Loop
DUT	Device Under Test
DVB	Digital Video Broadcasting
DWDM	Dense Wave Division Multiplexing
EA	Early Assignment
EBU	European Broadcasting Union
EC	European Community
ECL	Emitter Coupled Logic
EFS	Error Free Seconds
EIA	Electronic Industries Association
EIR	Equipment Identity Register
EIRP	Effective Isotropic Radiated Power (W)
ELSR	Edge Label Switch Router
EMC	ElectroMagnetic Compatiblity
EMF	ElectroMagnetic Field
EMI	ElectroMagnetic Interference
EMS	European Mobile Satellite
ENR	Excess Noise Ratio
EOL	End of Life
EPC	Electric Power Conditioner
EPIRB	Emergency Position Indicating Radio Beam
ERC	European Radiocommunications Committee
ERL	Echo Return Loss
ERO	European Radiocommunications Office (of the ERC)
ES	Earth Station
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
ETR	ETSI Technical Report
ETS	European Telecommunications Standard, created within ETSI
ETSI	European Telecommunications Standards Institute
EUTELSAT	European Telecommunications Satellite Organisation
FAC	Final Assembly Code
FCC	Federal Communications Commission
FCS	Frame Check Sequence
FDDI	Fibre Distributed Data Interface
FDM	Frequency Division Multiplex
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FES	Fixed Earth Station
FET	Field Effect Transistor
FETA	Field Effect Transistor Amplifier
FFT	Fast Fourier Transform
FGM	Fixed Gain Mode
FIFO	First In First Out
FM	Frequency Modulation
FMA	Fixed-Mount Antenna
FMS	Fleet Management Service
FMT	Fade Mitigation Technique
FODA	FIFO Ordered Demand Assignment
FPGA	Field Programmable Gate Array
FPLMTS	Future Public Land Mobile Telecommunications System
FS	Fixed Service
FR	Frame Relay
FSK	Frequency Shift Keying
FSS	Fixed Satellite Service
FTP	File Transfer Protocol
GA	ETSI General Assembly
GaAs	Gallium Arsenide
GBN	Go Back N
GC	Global Coverage
GCE	Ground Communication Equipment
GCS	Ground Control Station
GDE	Group Delay Equalizer
GEO	Geostationary Earth Orbit
GMDSS	Global Maritime Distress and Safety System
GOS	Grade Of Service
GPRS	General Packet Radio Service
GPS	Global Positioning System
GRE	Generic Routing Encapsulation
GSM	Global System for Mobile communications
GSO	Geostationary Satellite Orbit
GTO	Geostationary Transfer Orbit
HDB3	High Density Binary 3 code
HDLC	High Level Data Link Control
HDTV	High Definition TeleVision
HEMT	High Electron Mobility Transistor
HEO	Highly Elliptical Orbit
HIO	Highly Inclined Orbit

HIPERLAN	HIgh PErformance Radio Local Area Network
HLR	Home Location Register
HPA	High Power Amplifier
HPB	Half Power Beamwidth
HPT	Hand Held Personal Telephone
HTML	Hyper Text Markup Language
HTTP	Hyper Text Transfer Protocol
IAT	Interarrival Time
IAU	International Astronomical Unit
IBA	Independent Broadcasting Authority
IBO	Input Back-off
IBS	International Business Service
ICMP	Internet Control Message Protocol
ICI	Interface Control Information
ICO	Intermediate Circular Orbit
IGMP	Internet Group Management Protocol
IDC	Intermediate rate Digital Carrier
IDR	Intermediate Data Rate
IDU	Interface Data Unit, also. InDoor Unit
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
I-ETS	Interim ETS
IF	Intermediate Frequency
IFRB	International Frequency Registration Board
IGMP	Internet Group Management Protocol
ILS	International Launch Services
IM	InterModulation
IMP	Interface Message Processor
IMP	InterModulation Product
IMSI	International Mobile Subscriber Identity
IMUX	Input Multiplexer
IN	Intelligent Network
INIRIC	International Non-Ionising RadIation Committee
INMARSAT	International Maritime Satellite Organisation
INTELSAT	International Telecommunications Satellite Consortium
IOR	Indian Ocean Region
IOT	In Orbit Test
IP	Internet Protocol (a network layer datagram protocol)
IPA	Intermediate Power Amplifier
IPE	Initial Pointing Error
IPsec	IP security policy
IRCD	Internet Relay Chat Program Server (a teleconferencing application)
IRD	Internet Resources Database
IRD	Integrated Receiver Decoder
ISDN	Integrated Services Digital Network
ISC	International Switching Center
ISL	Intersatellite Link
ISO	International Organisation for Standardisation
ISS	Inter-Satellite Service
ISU	Iridium Subscriber Unit
ITU	International Telecommunication Union
IUS	Inertial Upper Stage
IVOD	Interactive Video On Demand
IWU	InternetWorking Unit
JDBC	Java Database Connectivity
JPEG	Joint Photographic Expert Group
LA	Location Area
LAN	Local Area Network
LAPB	Link Access Protocol Balanced
LDP	Label Distribution Protocol
LEO	Low Earth Orbit
LFSR	Linear Feedback Shift Register
LHCP	Left Hand Circular Polarization
LLC	Logical Link Control
LLM	Lband Land Mobile
LMDS	Local Multipoint Distribution System
LMSS	Land Mobile Satellite Service
LNA	Low Noise Amplifier
LNB	Low Noise Block
LO	Local Oscillator
LOS	Line of Sight
LPC	Linear Predictive Coding
LPF	Low Pass Filter
LR	Location Register
LRE	Low Rate Encoding
LSP	Label Switched Path
LSR	Label Switching Router
LU	Location Updating
M-PSK	M-ary Phase Shift Keying
MAC	Medium Access Control
MAC	Multiplexed Analog Components (also Monitoring, Alarm and Control)
MACSAT	Multiple Access Satellite
MAMA	Multiple ALOHA Multiple Access
MAN	Metropolitan Area Network
MCPC	Multiple Channels Per Carrier
MEB	Megabit Erlang Bit rate
MEO	Medium altitude Earth Orbit
MES	Mobile Earth Station
MESFET	Metal Semiconductor Field Effect Transistor
MF	Multifrequency
MHT	Mean Holding Time
MIC	Microwave Integrated Circuit
MIDI	Musical Instrument Digital Interface
MIFR	Master International Frequency Register
MMDS	Multipoint Multichannel Distribution System

MMIC	Monolithic Microwave Integrated Circuit
MOD	MODulator
MODEM	Modulator/Demodulator
MOS	Mean Opinion Score
MOS	Metal-Oxide Semiconductor
MoU	Memorandum of Understanding
MPEG	Motion Picture Expert Group
MPLS	Multi-Protocol Label Switching
MPSK	M-ary Phase Shift Keying
MS	Mobile Station
MSC	Mobile Switching Center
MSK	Minimum Shift Keying
MSS	Mobile Satellite Service
MTBF	Mean Time Between Failure
MTP	Message Transfer Part
MTU	Maximum Transferable Unit
MUX	MUltipleXer
MX	MiXer
NACK	No ACKnowledgment
NASA	National Aeronautics And Space Administration (USA)
NASDA	National Aeronautics And Space Development Agency (Japan)
NAT	Network Address Translation
NGSO	Non-Geostationary Satellite Orbit
NH	Northern Hemisphere
NIS	Network Information System
NMT	Nordic Mobile Telephone
NNTP	Network News Transfer Protocol
NOAA	National Oceanic and Atmospheric Administration
NORM	Nack-Oriented Reliable Multicast
NSO	National Standardisation Organisation
NRZ	Non-Return to Zero
NTP	Network Time Protocol
NVOD	Near Video On Demand
OACSU	Off-Air Call Set-Up
OBC	On-Board Computer
OBO	Output Back-Off
OBP	On-Board Processing
ODU	Outdoor Unit
OICETS	Optical Inter-orbit Communications Engineering Test Satellite
OMUX	Output MUltipleXer
ONP	Open Network Provision
OSI	Open System Interconnection
OSPF	Open Shortest Path First
PABX	Private Automatic Branch eXchange
PACS	Personal Access Communications System
PAD	Packet Assembler/Disassembler
PAM	Payload Assist Module
PB	Primary Body (orbits)
PBX	Private (automatic) Branch eXchange
PC	Personal Computer
PCCH	Physical Control CHannel
PCH	Paging CHannel
PCM	Pulse Code Modulation
PCN	Personal Communications Network (often refers to DCS 1800)
PCS	Personal Communications System
PDCH	Physical Data CHannel
PDF	Probability Density Function
PDH	Plesiochronous Digital Hierarchy
PDU	Protocol Data Unit
PFD	Power Flux Density
PHEMT	Pseudomorphic High Electron Mobility Transistor
PHB	Per Hop Behaviour
PHP	Personal Handy Phone
PHS	Personal Handyphone System
PICH	PIlot Channel
PILC	Performance Implication of Link Characteristics
PIMP	Passive InterModulation Product
PKM	Perigee Kick Motor
PLL	Phase Locked Loop
PLMN	Public Land Mobile Network
PM	Phase Modulation
PMR	Private Mobile Radio
PN	Personal Number
PODA	Priority Oriented Demand Assignment
POL	POLarisation
POR	Pacific Ocean Region
PP	Portable Part
PPP	Point to Point Protocol
PRMA	Packet Reservation Multiple Access
PSD	Power Spectral Density
PSK	Phase Shift Keying
PSPDN	Packet Switched Public Data Network
PSTN	Public Switched Telephone Network
PTA	Programme Tracking Antenna
PTN	Public Telecommunications Network
PTO	Public Telecommunications Operator
PVA	Perigee Velocity Augmentation
PVC	Permanent Virtual Circuit
QoS	Quality of Service
QPSK	Quaternary Phase Shift Keying
RAAN	Right Ascension of the Ascending Node
RACE	Research and development in Advanced Communications
RACH	Random Access Channel
RADIUS	Remote Authentication Dial In User Service
RAM	Random Access Memory

RAN	Radio Area Network
RARC	Regional Administrative Radio Conference
RAS	Radio Astronomy Service
RCVO	Receive Only
RCVR	ReCeiVeR
RDS	Radio Data System
RDSS	Radio Determination Satellite Service
RE	Radio Exchange
Rec	Recommendation
Rep	Report
RES	Radio Equipment Systems, ETSI Technical Committee
RF	Radio Frequency
RFHMA	Random Frequency Hopping Multiple Access
RFI	Radio Frequency Interference
RGS	Route Guidance Service
RHCP	Right-Hand Circular Polarization
RIP	Routing Information Protocol
RL	Return Loss
RLAN	Radio Local Area Network
RLL	Radio in the Local Loop
RLOGIN	Remote login application
RMA	Random Multiple Access
RMTP	Realisable Multicast Transport Protocol
RNCC	Regional Network Control Center
RNR	Receiver Not Ready
RORA	Region Oriented Resource Allocation
RR	Radio Regulation
RS	Reed Solomon (coding)
RSVP	Resource reSerVation Protocol
RTCP	Real Time transport Control Protocol
RTP	Real Time transport Protocol
RTU	Remote Terminal Unit
RX	Receiver
S-ALOHA	Slotted ALOHA protocol
SAMA	Spread ALOHA Multiple Access
SAP	Service Access Point
SAW	Surface Acoustic Wave
SB	Secondary Body (orbits)
SBC	Sub-Band Coding
SC	Suppressed Carrier
S/C	SpaceCraft
SCADA	Supervisory Control and Data Acquisition
SCCP	Signalling Connection Control Part
SCH	Synchronization CHannel
SCP	Service Control Point
SCPC	Single Channel Per Carrier
SDH	Synchronous Digital Hierarchy
SDLC	Synchronous Data Link Control
SDU	Service Data Unit
SEP	Symbol Error Probability
SEU	Single Event Upset
SFH	Slow Frequency Hopping
SH	Southern Hemisphere
SHF	Super High Frequency (3 GHz to 30 GHz)
SIM	Subscriber Identity Module
S-ISUP	Satellite ISDN User Part
SIT	Satellite Interactive Terminal
SKW	Satellite-Keeping Window
SL	SatelLite
SLA	Service Level Agreement
SLIC	Subscriber Line Interface Card
SMATV	Satellite based Master Antenna for TV distribution
SME	Small and Medium Enterprise
SMS	Satellite Multi-Services
SMTP	Simple Mail Transfer Protocol
SNA	Systems Network Architecture (IBM)
SNDCP	SubNet Dependent Convergence Protocol
SNEK	Satellite NEtworK node computer
SNG	Satellite News Gathering
SNMP	Simple Network Management Protocol
SNR	Signal-to-Noise Ratio
SOC	State of Charge
SOHO	Small Office Home Office
SORA	Satellite Oriented Resource Allocation
SORF	Start of Receive Frame
SOTF	Start of Transmit Frame
SPADE	Single-channel-per-carrier PCM multiple Access Demand assignment Equipment
S-PCN	Satellite Personal Communications Network
S/PDIF	Sony/Philips Digital Interface Format
SPDT	Single-Pole Double-Throw (switch)
SPMT	Single-Pole Multiple-Throw (switch)
SPT	Stationary Plasma Thruster
SPU	Satellite Position Uncertainty
SR	Selective Repeat
SS	Satellite Switch
SSB	Single Side-Band
SSMA	Spread Spectrum Multiple Access
SSO	Sun-Synchronous Orbit
SSOG	Satellite Systems Operations Guide (INTELSAT)
SSP	Signalling Switching Point
SSPA	Solid State Power Amplifier
SS-TDMA	Satellite Switched TDMA
STC	ETSI Sub-Technical Committee
STM	Synchronous Transport Module
STS	Space Transportation System
SU	Subscriber Unit
SVC	Switched Virtual Circuit
SW	Switch

SW	Stop and Wait
SWR	Standing Wave Ratio
SYNC	SYNChronisation
TA	ETSI Technical Assembly
TACS	Total Access Communication System
TBC	To Be Confirmed
TBD	To Be Defined
TBR	Technical Basis Regulation
T/R	Transmit/Receive
TC	Telecommand
TCH	Traffic CHannel
TCP	Transmission Control Protocol
TDM	Time Division Multiplex
TDMA	Time Division Multiple Access
TDRS	Tracking and Data Relay Satellite
TELNET	remote terminal application
TEM	Transverse ElectroMagnetic
TETRA	Trans European Trunk Radio
TFTS	Terrestrial Flight Telephone System
TIA	Telecommunications Industry Association
TIE	Terrestrial Interface Equipment
TM	Telemetry
TM/TC	Telemetry/Telecommand
TP4	Transport Protocol Class 4
TPR	Transponder
TRAC	Technical Recommendations Application Committee
TTC	Telemetry, Tracking and Command
TTCM	Telemetry, Tracking, Command and Monitoring
TTL	Transistor Transistor Logic
TTL	Time To Live
TTY	TelegraphY
TV	TeleVision
TWT	Travelling WaveTube
TWTA	Travelling WaveTube Amplifier
Tx	Transmitter
U/C	Up-Converter
UDLR	UniDirectional Link Routing
UDP	User Datagram Protocol
UHF	Ultra High Frequency (300 MHz to 3 GHz)
UMTS	Universal Mobile Telecommunications System
UPS	Uninterruptible Power Supply
UPT	Universal Personal Telecommunications
USAT	Ultra Small Aperture Terminal
USB	Universal Serial Bus
UW	Unique Word
VBR	Variable Bit Rate
VC	Virtual Channel (or Container)
VCI	Virtual Channel Identifier
VDSL	Very high-speed Digital Subscriber Line
VHDL	VHSIC Hardware Description Language
VHSIC	Very High Speed Integrated Circuit
VHF	Very High Frequency (30 MHz to 300 MHz)
VLR	Visitor Location Register
VLSI	Very Large Scale Integration
VOW	Voice Order Wire
VPA	Variable Power Attenuator
VPC	Virtual Path Connection
VPD	Variable Phase Divider
VPS	Variable Phase Shifter
VPI	Virtual Path Identifier
VPN	Virtual Private Network
VSAT	Very Small Aperture Terminal
VSELP	Vector Sum Excitation Linear Prediction
VSWR	Voltage Standing Wave Ratio
WAN	Wide Area Network
WAP	Wireless Application Protocol
WARC	World Administrative Radio Conference
Web	Worldwide Web
XPD	Cross Polarization Discrimination
XPI	Cross Polarisation Isolation
Xponder	Transponder

NOTATION

a	orbit semi-major axis
A	azimuth angle (also attenuation, area, availability, traffic density and carrier amplitude)
A_{eff}	effective aperture area of an antenna
A_{AG}	attenuation by atmospheric gases
A_{RAIN}	attenuation due to precipitation and clouds
A_{P}	attenuation of radiowave by rain for percentage p of an average year
B	bandwidth
b	voice channel bandwidth (3100 Hz from 300 to 3400 Hz)
B_{n}	noise measurement bandwidth at baseband (receiver output)
B_{N}	equivalent noise bandwidth of receiver
Bu	burstiness
c	velocity of light $= 3 \times 10^8$ m/s
C	carrier power
C/N_0	carrier power-to-noise power spectral density ratio (W/Hz)
$(C/N_0)_{\text{U}}$	uplink carrier power-to-noise power spectral density ratio
$(C/N_0)_{\text{D}}$	downlink carrier power-to-noise power spectral density ratio
$(C/N_0)_{\text{IM}}$	carrier power-to-intermodulation noise power spectral density ratio
$(C/N_0)_{\text{I}}$	carrier power-to-interference noise power spectral density ratio
$(C/N_0)_{\text{I,U}}$	uplink carrier power-to-interference noise power spectral density ratio
$(C/N_0)_{\text{I,D}}$	downlink carrier power-to-interference noise power spectral density ratio
$(C/N_0)_{\text{T}}$	carrier power-to-noise power spectral density ratio for total link
D	diameter of a reflector antenna (also used as a subscript for 'downlink')
e	orbit eccentricity
E	elevation angle (also energy and electric field strength)
E_{b}	energy per information bit
E_{c}	energy per channel bit
f	frequency (Hz)
F_{c}	nominal carrier frequency
f_{d}	antenna focal length
f_{m}	frequency of a modulating sine wave
f_{max}	maximum frequency of the modulating baseband signal spectrum
f_{D}	downlink frequency
f_{U}	uplink frequency
F	noise figure
ΔF_{max}	peak frequency deviation of a frequency modulated carrier
f_{S}	sampling frequency
g	peak factor
G	power gain (also gravitational constant)
G_{sat}	gain at saturation
G_{R}	receiving antenna gain in direction of transmitter
G_{T}	transmitting antenna gain in direction of receiver
G_{Rmax}	maximum receiving antenna gain
G_{Tmax}	maximum transmitting antenna gain
G_{SR}	satellite repeater gain
G_{SRsat}	saturation gain of satellite repeater
G/T	gain to system noise temperature ratio of a receiving equipment
G_{CA}	channel amplifier
G_{FE}	front end gain from satellite receiver input to satellite channel amplifier input
G_{ss}	small signal power gain
i	inclination of the orbital plane
k	Boltzmann's constant $= 1.379 \times 10^{-23}$ W/KHz
k_{FM}	FM modulation frequency deviation constant (MHz/V)
k_{PM}	PM phase deviation constant (rad/V)

K_P	AM/PM conversion coefficient
K_T	AM/PM transfer coefficient
l	earth station latitude
L	earth station-to-satellite relative longitude also loss in link budget calculations, and loading factor of FDM/FM multiplex also message length (bits)
L_e	effective path length of radiowave through rain (km)
L_{FRX}	receiver feeder loss
L_{FTX}	transmitter feeder loss
L_{FS}	free space loss
L_{POINT}	depointing loss
L_{POL}	antenna polarisation mismatch loss
L_R	receiving antenna depointing loss
L_T	transmitting antenna depointing loss
m	satellite mass
mc	power reduction associated with multicarrier operation
M	mass of the earth (kg) (also number of possible states of a digital signal)
N_0	noise power spectral density (W/Hz)
$(N_0)_U$	uplink noise power spectral density (W/Hz)
$(N_0)_D$	downlink noise power spectral density (W/Hz)
$(N_0)_T$	total link noise power spectral density (W/Hz)
$(N_0)_I$	interference power spectral density (W/Hz)
N	noise power (W) (also number of stations in a network)
p	pre-emphasis/companding improvement factor (also rainfall annual percentage)
p_w	rainfall worst month time percentage
P	power (also number of bursts in a TDMA frame)
P_b	information bit error rate
P_c	channel bit error rate
P_{HPA}	rated power of high power amplifier (W)
P_T	power fed to the antenna (W)
P_{Tx}	transmitter power (W)
P_R	received power (W)
P_{Rx}	power at receiver input (W)
P_{is}	input power in a single carrier operation mode
$P_{o\,1}$	output power in a single carrier operation mode
$(P_{i\,1})_{sat}$	input power in a single carrier operation mode at saturation
$(P_{o\,1})_{sat}$	saturation output power in a single carrier operation mode
$P_{i\,n}$	input power in a multiple carrier operation mode (n carriers)
$P_{o\,n}$	output power in a multiple carrier operation mode (n carriers)
$P_{IMX\,n}$	power of intermodulation product of order X at output of a non-linear device in a multicarrier operation mode (n carriers)
Q	quality factor
r	distance between centre of mass (orbits)
R	slant range from earth station to satellite (km) (also symbol or bit rate)
R_b	information bit rate (s^{-1})
R_c	channel bit rate (s^{-1})
R_{call}	mean number of calls per unit time
R_E	earth radius = 6378 km
R_o	geostationary satellite altitude = 35 786 km
R_p	rainfall rate (mm/h) exceeded for time percentage p of a year
R_s	symbol (or signalling) rate (s^{-1})
S	user signal power (W)
S/N	signal-to-noise power ratio at user's end
T	period of revolution (orbits) (s) (also noise temperature (K))
T_A	antenna noise temperature (K)
T_{AMB}	ambient temperature (K)
T_b	information bit duration (s)
T_B	burst duration (s)
T_c	channel bit duration (s)
T_e	effective input noise temperature of a four port element system (K)
T_E	mean sidereal day = 86164.15
T_{eATT}	effective input noise temperature of an attenuator (K)
T_{eRx}	effective input noise temperature of a receiver
T_F	frame duration (s) (also feeder temperature)
T_m	effective medium temperature (K)
T_0	reference temperature (290 K)
T_{eRX}	effective input noise temperature of a receiver (K)
T_S	symbol duration (s)
T_{SKY}	clear key contribution to antenna noise temperature (K)
T_{GROUND}	ground contribution to antenna noise temperature (K)
U	subscript for 'uplink'
v	true anomaly (orbits)
V_s	satellite velocity (m/s)

$V_{\mathrm{Lp/p}}$	peak-to-peak luminance voltage (V)
$V_{\mathrm{Tp/p}}$	peak-to-peak total video signal voltage (including synchronisation pulses)
V_{Nms}	root-mean-square noise voltage (V)
w	psophometric weighting factor
X	intermodulation product order (IMX)
α	angle from boresight of antenna
γ	vernal point
Γ	spectral efficiency (bit/s Hz)
δ	declination angle (also delay)
η	antenna aperture efficiency
λ	wavelength ($= c/f$) also longitude, also message generation rate (s^{-1})
φ	latitude
τ	propagation time
$\theta_{3\mathrm{dB}}$	half power beamwidth of an antenna
	wavelength $= c/f$
θ_{R}	receiving antenna pointing error
θ_{T}	transmit antenna pointing error
μ	$= GM$ ($G =$ gravitational constant, $M =$ mass of earth; $G = 6.67 \times 10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}}$, $M = 5.974 \times 10^{24}$ kg; $\mu = GM = 3.986 \times 10^{14}\ \mathrm{m^3\,s^{-2}}$
ρ	code rate
σ	Stefan–Boltzmann constant $= 5.67 \times 10^{-8}\ \mathrm{Wm^{-2}\,K^{-4}}$
ϕ	satellite–earth station angle from the earth's centre
Φ	power flux density ($\mathrm{w/m^2}$)
Φ_{max}	max maximum power flux density at transmit antenna boresight
Φ_{nom}	nom nominal power flux density at receive end required to build up a given power assuming maximum receive gain (no depointing)
Φ_{sat}	power flux density required to operate receive amplifier at saturation
ψ	polarisation angle
ω	argument of perigee
Ω	right ascension of the ascending node
Ω_{E}	angular velocity of rotation of the earth = 15.0469 deg/hr = 4.17×10^{-3}deg/s$=7.292 \times 10^{-5}$rad/s