

SATELLITE COMMUNICATIONS SYSTEMS

Systems, Techniques and Technology

Fifth Edition

Gérard Maral

*Ecole Nationale Supérieure des Télécommunications,
Site de Toulouse, France*

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*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*



A John Wiley and Sons, Ltd, Publication

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John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

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Library of Congress Cataloging-in-Publication Data

Maral, Gérard.

[Systèmes de télécommunications par satellites. English]

Satellite communications systems / Gérard Maral, Michel Bousquet. — 5th ed.

p. cm.

Includes bibliographical references and index.

ISBN 978-0-470-71458-4 (cloth)

1. Artificial satellites in telecommunication. I. Bousquet, Michel. II. Title.

TK5104.M3513 2009

621.382'5—dc22

2009023579

A catalogue record for this book is available from the British Library.

ISBN 978-0-470-71458-4 (H/B)

Typeset in 9/11 pt Palatino by Thomson Digital, Noida, India.

Printed in Singapore by Markono Print Media Pte Ltd.

This book is printed on acid-free paper responsibly manufactured from sustainable forestry, in which at least two trees are planted for each one used for paper production.

Original translation into English by J.C.C. Nelson.

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ACKNOWLEDGEMENT

Reproduction of figures extracted from the 1990 Edition of CCIR Volumes (XVIIth Plenary Assembly, Düsseldorf, 1990), the *Handbook on Satellite Communications* (ITU Geneva, 1988) and the ITU-R Recommendations is made with the authorisation of the International Telecommunication Union (ITU) as copyright holder.

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ACRONYMS

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

BSC	Binary Synchronous Communications (bisync)	CNES	Centre National d'Etudes Spatiales (French Space Agency)
BSN	Block Sequence Number	CODLS	Connection Oriented Data Link Service
BSS	Broadcasting Satellite Service	COMETS	Communications and Broadcasting Engineering Test Satellite
BT	Base Transceiver	CONUS	CONTinental US
BTS	Base Transceiver Station	CoS	Class of Service
BW	BandWidth	COST	European COoperation in the field of Scientific and Technical research
CAD	Computer Aided Design	COTS	Commercial Off The Shelf
CAM	Computer Aided Manufacturing	CPS	Chemical Propulsion System
CAMP	Channel AMPlifier	CRC	Communications Research Centre (Canada)
CATV	CABleTeLeVision	CS	Cell Selection
CBDS	Connectionless broadband data service	CSMA	Carrier Sense Multiple Access
CBO	Continuous Bit Oriented	CT	Cordless Telephone
CBR	Constant Bit Rate	CTR	Common Technical Regulation
CCI	CoChannel Interference	CTU	Central Terminal Unit
CCIR	Comité Consultatif International des Radiocommunications (International Radio Consultative Committee)	D-AMPS	Digital Advanced Mobile Phone System
CCITT	Comité Consultatif International du Télégraphe et du Téléphone (The International Telegraph and Telephone Consultative Committee)	D-M-PSK	Differential M-ary Phase Shift Keying
CCSDS	Consultative Committee for Space Data Systems	D/C	Down-Converter
CCU	Cluster Control Unit	DA	Demand Assignment
CDMA	Code Division Multiple Access	DAB	Digital Audio Broadcasting
CEC	Commission of the European Communities	DAC	Digital to Analog Converter
CELP	Code Excited Linear Prediction	DAMA	Demand Assignment Multiple Access
CENELEC	Comité Européen pour la Normalisation en ELECtrotechnique (European Committee for Electro-technical Standardisation)	DARPA	Defense Advanced Research Project
CEPT	Conférence Européenne des Postes et Télécommunications (European Conference of Post and Telecommunications)	DASS	Demand Assignment Signalling and Switching
CFDMA	Combined Free/Demand Assignment Multiple Access	dB	deciBel
CFM	Companded Frequency Modulation	dBm	Unit for expression of power level in dB with reference to 1 mW
CFRA	Combined Fixed/Reservation Assignment	dBm	Unit for expression of power level in dB with reference to 1 mW
CIR	Committed Information Rate	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)
CIRF	Co-channel Interference Reduction Factor	DBF	Digital Beam Forming
CIS	Commonwealth of Independent States	DBFN	Digital Beam Forming Network
CLDLS	ConnectionLess Data Link Service	DBS	Direct Broadcasting Satellite
CLEC	Competitive Local Exchange Carrier	DC	Direct Current
CLNP	ConnectionLess Network Protocol	DCCH	Dedicated Control Channel
CLTU	Command Link Transmission Unit	DCE	Data Circuit Terminating Equipment
CMOS	Complementary Metal Oxide Semiconductor	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	EUTELSAT	European Telecommunications Satellite Organisation
DECT	Digital European Cordless Telephone	FAC	Final Assembly Code
DEMOD	DEMODulator	FCC	Federal Communications Commission
DEMUX	DEMULTiplexer	FCS	Frame Check Sequence
DES	Data Encryption Standard	FDDI	Fibre Distributed Data Interface
DM	Delta Modulation	FDM	Frequency Division Multiplex
DNS	Domain Name Service (host name resolution protocol)	FDMA	Frequency Division Multiple Access
DOD	Depth of Discharge	FEC	Forward Error Correction
DOF	Degree of Freedom	FES	Fixed Earth Station
DQDB	Distributed Queue Dual Bus	FET	Field Effect Transistor
DSCP	Differentiated Service Code Point	FETA	Field Effect Transistor Amplifier
DSI	Digital Speech Interpolation	FFT	Fast Fourier Transform
DSL	Digital Subscriber Loop	FGM	Fixed Gain Mode
DSP	Digital Signal Processing	FIFO	First In First Out
DTE	Data Terminating Equipment	FM	Frequency Modulation
DTH	Direct To Home	FMA	Fixed-Mount Antenna
DTTL	Data Transition Tracking Loop	FMS	Fleet Management Service
DUT	Device Under Test	FMT	Fade Mitigation Technique
DVB	Digital Video Broadcasting	FODA	FIFO Ordered Demand Assignment
DWDM	Dense Wave Division Multiplexing	FPGA	Field Programmable Gate Array
		FPLMTS	Future Public Land Mobile Telecommunications System
EA	Early Assignment	FS	Fixed Service
EBU	European Broadcasting Union	FR	Frame Relay
EC	European Community	FSK	Frequency Shift Keying
ECL	Emitter Coupled Logic	FSS	Fixed Satellite Service
EFS	Error Free Seconds	FTP	File Transfer Protocol
EIA	Electronic Industries Association		
EIR	Equipment Identity Register	GA	ETSI General Assembly
EIRP	Effective Isotropic Radiated Power (W)	GaAs	Gallium Arsenide
ELSR	Edge Label Switch Router	GBN	Go Back N
EMC	ElectroMagnetic Compatiblity	GC	Global Coverage
EMF	ElectroMagnetic Field	GCE	Ground Communication Equipment
EMI	ElectroMagnetic Interference	GCS	Ground Control Station
EMS	European Mobile Satellite	GDE	Group Delay Equalizer
ENR	Excess Noise Ratio	GEO	Geostationary Earth Orbit
EOL	End of Life	GMDSS	Global Maritime Distress and Safety System
EPC	Electric Power Conditioner	GOS	Grade Of Service
EPIRB	Emergency Position Indicating Radio Beam	GPRS	General Packet Radio Service
ERC	European Radiocommunications Committee	GPS	Global Positioning System
ERL	Echo Return Loss	GRE	Generic Routing Encapsulation
ERO	European Radiocommunications Office (of the ERC)	GSM	Global System for Mobile communications
ES	Earth Station	GSO	Geostationary Satellite Orbit
ESA	European Space Agency	GTO	Geostationary Transfer Orbit
ESTEC	European Space Research and Technology Centre	HDB3	High Density Binary 3 code
ETR	ETSI Technical Report	HDLCL	High Level Data Link Control
ETS	European Telecommunications Standard, created within ETSI	HDTV	High Definition TeleVision
ETSI	European Telecommunications Standards Institute	HEMT	High Electron Mobility Transistor
		HEO	Highly Elliptical Orbit
		HIO	Highly Inclined Orbit

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

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

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

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

NOTATION

a	orbit semi-major axis	E	elevation angle (also energy and electric field strength)
A	azimuth angle (also attenuation, area, availability, traffic density and carrier amplitude)	E_b	energy per information bit
A_{eff}	effective aperture area of an antenna	E_c	energy per channel bit
A_{AG}	attenuation by atmospheric gases	f	frequency (Hz)
A_{RAIN}	attenuation due to precipitation and clouds	F_c	nominal carrier frequency
A_P	attenuation of radiowave by rain for percentage p of an average year	f_d	antenna focal length
		f_m	frequency of a modulating sine wave
		f_{max}	maximum frequency of the modulating baseband signal spectrum
B	bandwidth	f_D	downlink frequency
b	voice channel bandwidth (3100 Hz from 300 to 3400 Hz)	f_U	uplink frequency
B_n	noise measurement bandwidth at baseband (receiver output)	F	noise figure
B_N	equivalent noise bandwidth of receiver	ΔF_{max}	peak frequency deviation of a frequency modulated carrier
Bu	burstiness	f_s	sampling frequency
c	velocity of light = 3×10^8 m/s	g	peak factor
C	carrier power	G	power gain (also gravitational constant)
C/N_0	carrier power-to-noise power spectral density ratio (W/Hz)	G_{sat}	gain at saturation
$(C/N_0)_U$	uplink carrier power-to-noise power spectral density ratio	G_R	receiving antenna gain in direction of transmitter
$(C/N_0)_D$	downlink carrier power-to-noise power spectral density ratio	G_T	transmitting antenna gain in direction of receiver
$(C/N_0)_{\text{IM}}$	carrier power-to-intermodulation noise power spectral density ratio	G_{Rmax}	maximum receiving antenna gain
$(C/N_0)_I$	carrier power-to-interference noise power spectral density ratio	G_{Tmax}	maximum transmitting antenna gain
$(C/N_0)_{I,U}$	uplink carrier power-to-interference noise power spectral density ratio	G_{SR}	satellite repeater gain
$(C/N_0)_{I,D}$	downlink carrier power-to-interference noise power spectral density ratio	G_{SRsat}	saturation gain of satellite repeater
$(C/N_0)_T$	carrier power-to-noise power spectral density ratio for total link	G/T	gain to system noise temperature ratio of a receiving equipment
D	diameter of a reflector antenna (also used as a subscript for 'downlink')	G_{CA}	channel amplifier
e	orbit eccentricity	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 = 1.379×10^{-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	$P_{i\ n}$	input power in a multiple carrier operation mode (n carriers)
K_T	AM/PM transfer coefficient	$P_{o\ n}$	output power in a multiple carrier operation mode (n carriers)
l	earth station latitude	$P_{IMX\ n}$	power of intermodulation product of order X at output of a non-linear device in a multicarrier operation mode (n carriers)
L	earth station-to-satellite relative longitude also loss in link budget calculations, and loading factor of FDM/FM multiplex also message length (bits)	Q	quality factor
L_e	effective path length of radiowave through rain (km)	r	distance between centre of mass (orbits)
L_{FRX}	receiver feeder loss	R	slant range from earth station to satellite (km) (also symbol for bit rate)
L_{FTX}	transmitter feeder loss	R_b	information bit rate (s^{-1})
L_{FS}	free space loss	R_c	channel bit rate (s^{-1})
L_{POINT}	depointing loss	R_{call}	mean number of calls per unit time
L_{POL}	antenna polarisation mismatch loss	R_E	earth radius = 6378 km
L_R	receiving antenna depointing loss	R_o	geostationary satellite altitude = 35 786 km
L_T	transmitting antenna depointing loss	R_p	rainfall rate (mm/h) exceeded for time percentage p of a year
m	satellite mass	R_s	symbol (or signalling) rate (s^{-1})
mc	power reduction associated with multicarrier operation	S	user signal power (W)
M	mass of the earth (kg) (also number of possible states of a digital signal)	S/N	signal-to-noise power ratio at user's end
N_0	noise power spectral density (W/Hz)	T	period of revolution (orbits) (s) (also noise temperature (K))
$(N_0)_U$	uplink noise power spectral density (W/Hz)	T_A	antenna noise temperature (K)
$(N_0)_D$	downlink noise power spectral density (W/Hz)	T_{AMB}	ambient temperature (K)
$(N_0)_T$	total link noise power spectral density (W/Hz)	T_b	information bit duration (s)
$(N_0)_I$	interference power spectral density (W/Hz)	T_B	burst duration (s)
N	noise power (W) (also number of stations in a network)	T_c	channel bit duration (s)
p	pre-emphasis/companing improvement factor (also rainfall annual percentage)	T_e	effective input noise temperature of a four port element system (K)
p_w	rainfall worst month time percentage	T_E	mean sidereal day = 86164.15
P	power (also number of bursts in a TDMA frame)	T_{eATT}	effective input noise temperature of an attenuator (K)
P_b	information bit error rate	T_{eRX}	effective input noise temperature of a receiver
P_c	channel bit error rate	T_F	frame duration (s) (also feeder temperature)
P_{HPA}	rated power of high power amplifier (W)	T_m	effective medium temperature (K)
P_T	power fed to the antenna (W)	T_0	reference temperature (290 K)
P_{Tx}	transmitter power (W)	T_{eRX}	effective input noise temperature of a receiver (K)
P_R	received power (W)	T_S	symbol duration (s)
P_{RX}	power at receiver input (W)	T_{SKY}	clear key contribution to antenna noise temperature (K)
P_{is}	input power in a single carrier operation mode	T_{GROUND}	ground contribution to antenna noise temperature (K)
$P_{o\ 1}$	output power in a single carrier operation mode	U	subscript for 'uplink'
$(P_{i\ 1})_{sat}$	input power in a single carrier operation mode at saturation	v	true anomaly (orbits)
$(P_{o\ 1})_{sat}$	saturation output power in a single carrier operation mode	V_s	satellite velocity (m/s)

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

