RECOMMENDATION ITU-R S.1328-3

Satellite system characteristics to be considered in frequency sharing analyses between geostationary-satellite orbit (GSO) and non-GSO satellite systems in the fixed-satellite service (FSS) including feeder links for the mobile-satellite service (MSS)*

(Questions ITU-R 205/4, ITU-R 206/4 and ITU-R 231/4)

(1997-1999-2000-2001)

The ITU Radiocommunication Assembly,

considering

a) that the World Radiocommunication Conference (Geneva, 1995) (WRC-95), in Resolutions 116 (WRC-95) and 117 (WRC-95), allocated frequencies to the FSS for use by feeder links of non-GSO MSS systems;

b) that WRC-95, in Resolution 118 (WRC-95), provided for parts of the 30/20 GHz bands in the FSS to be used by the non-GSO FSS without the restrictions of Radio Regulations (RR) No. S22.2;

c) that WRC-95, in Resolution 120 (WRC-95), provided for parts of the 30/20 GHz band in the FSS to be shared with feeder links of the non-GSO MSS;

d) that WRC-95, in Resolution 121 (WRC-95), advocated the development of interference criteria and methodology for sharing between feeder links of the non-GSO MSS and networks of the GSO FSS;

e) that the World Radiocommunication Conference (Geneva, 1997) in Resolution 130 (WRC-97), advocated the development of interference criteria and methodology for sharing between non-GSO FSS and networks of the GSO FSS,

recommends

1 that, in the planning and development of new FSS networks, both GSO and non-GSO, and feeder links for MSS systems affecting the FSS allocations, the technical characteristics of existing and planned satellite systems in Annexes 1 to 11 be taken into consideration;

2 that, in studies pertaining to the development of sharing criteria between satellite systems, the technical characteristics of existing and planned systems in Annexes 1 to 11 be used in interference analyses;

3 that administrations planning modifications to these systems or proposing future satellite system networks in FSS bands are urged to submit their technical characteristics to the ITU-R to update this data source.

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* NOTE 1 – References to Ku bands refer to the 10-15 GHz bands.

References to Ka bands refer to the 17-30 GHz bands.

References to V bands refer to the 40-50 GHz bands.

ANNEX 1

TABLE 1

Technical characteristics of several LEO and GSO satellite networks

Parameters	Non-GSO MSS							
	LEO A	LEO B	LEO C	LEO D	LEO E		LEO F	LEO G
1 *Orbital parameters*								
Shape of orbit	Circular	Circular	Circular	Circular	Elliptical	Circular	Circular	Circular
Height (km)	780	10 355	2 000	1 414	7 846 × 520	80-90	10 355	1 500
Inclination angle (degrees)	86	50	55	52	116.6	0	45	74
Coherence (track repeat (h))	–	–	–	47.5	3	4.8	–	–
Number of satellites per plane	11	4	5	6	5	7	5	12
Number of orbital planes	6	3	8	8	2	1	2	4
Satellite separation within plane (degrees)	32.7	90	45	60	72	51	–	30
Satellite phasing between planes (degrees)	31.6 (22)	30	–	7.5	36	–	0	90
2 *Targeted frequency range and polarization*								
Uplink frequency (GHz)	29.1-29.3	29.1-29.5	5.091-5.250	5.091-5.250	15.45-15.65		5.100-5.250	14
Uplink polarization	RHCP	LHCP	RHCP/LHCP	LHCP/RHCP	–		–	LHCP
Downlink frequency (GHz)	19.4-19.6	19.3-19.7	6.875-7.075	6.875-7.055	6.875-7.075		6.925-7.075	11
Downlink polarization	LHCP	RHCP	RHCP/LHCP	LHCP/RHCP	–		–	RHCP
3 *Spectrum required in each direction* (MHz)	200	400	200	159/180	200		100	50
4 *Carrier transmission parameters*								
Modulation type	FDMA/QPSK Rate ½, coded Rate 6.25 Mbit/s	CDMA	CDMA/FDMA	CDMA/FDMA	QPSK	QPSK	TDMA/QPSK	CDMA/FDMA
Number of service link beams		–	32	16	61	37	16,3	–
Number of feeder-link segments/polarization		–	1	8	31	31	–	–
Segment bandwidth (MHz)		–	12	16.5	12	12	–	–
Receiver bandwidth (kHz)	3 000	2 500	200	1 230	3 000/7 000	3 000/7 000	25	5 800
Transmission bandwidth (kHz)	4 370	2 500	2 500	1 230	3 000/7 000	3 000/7 000	25	5 800
Overall (C/N_0) per user (dB/Hz) or (C/N) (dB)	–	–	44.7-46.6	44	–	–	48	42 (E_b/N_0)

TABLE 1 (*continued*)

Parameters	Non-GSO MSS							
	LEO A	LEO B	LEO C	LEO D	LEO E		LEO F	LEO G
4 *Carrier transmission parameters (continued)*								
Uplink e.i.r.p./carrier (dBW)	ARC 34.0 to 43.5	54.25	40.2	54	50	50	47.5	49
Downlink e.i.r.p./carrier (dBW)	ARC 4.5 to 15.0	5.31	–8.5	–5	–	–	0	–6 (nadir)
Type of satellite transponder	Regenerative	Transparent	Transparent	Transparent	Transparent	Transparent	–	–
5 *Satellite antenna parameters*								
Tx maximum gain (dBi)	26.9, 2 dB axial ratio	35.7	3	2	11	15	13	5 (nadir)
Rx maximum gain (dBi)	30.1, 2 dB axial ratio	38.5	3	2	11	15	10	5 (nadir)
Main lobes	RR Appendix S8	–	–3 dB	ISO flux ± 2 dB	–	–	RR Appendix S30B	–
Side lobes	RR Appendix S8	–	–3 dB	–14 dB	–16 dB	–16 dB	–	–
Back lobes	–	–	–10 dB	–35 dB	–38 dB	–38 dB	–	–
Steerable antenna or not	(Programmed pointing) Steerable (4/SAT)	Steerable	No	No	No	No	No	No
6 *Earth station antenna parameters*								
Peak Tx gain (dBi)	56.3 (beamwidth 0.24°)	64.8	47.7	47.5	55.3		47.8	41
Peak Rx gain (dBi)	53.2 (beamwidth 0.36°)	60.8	50.2	50.0	48.2		50.7	42
Radiation pattern	RR Appendix S8	Rec. ITU-R S.465	Rec. ITU-R S.580	Rec. ITU-R S.465	–		Rec. ITU-R S.580	$32.3 - 25 \log \varphi$
Minimum operating elevation angle (degrees)	5 Acquisition 8.3 Service (auto tracking)	10	10	10	5		5	10
7 *Number of earth stations and distribution*	25 WW 7 USA	8-12	50-100	100-200	20-40		6-30	3 or more
8 *Earth station switching strategy*	Nom. 10° minimum, make before break	≥ minimum elevation angle	Highest elevation angle	Select highest elevation angle	Highest and 2nd highest elevation angle		≥ minimum elevation angle	

TABLE 1 (*continued*)

Parameters	Non-GSO FSS				LEO N user and feeder-links	
	LEO N		MEO V		User links	Feeder-links
1 *Orbital parameters*						
Shape of orbit	Circular		Circular		Circular	
Height (km)	700		10 360		700	
Inclination angle (degrees)	82		82.5		82	
Coherence (track repeat (h))	46		24		46	
Number of satellites per plane	13		6		13	
Number of orbital planes	7		4		7	
Satellite separation within plane (degrees)	27.7		60		27.7	
Satellite phasing between planes (degrees)	25.7		45		25.7	
2 *Targeted frequency range and polarization*						
Uplink frequency (GHz)	12.75-13.25		29.5-29.9		1.98-2.01 2.675-2.69	19.3-19.6
Uplink polarization	Circular		Circular		Circular	Circular
Downlink frequency (GHz)	10.7-10.95		19.8-20.2		2.17-2.20	15.43-15.63
Downlink polarization	Circular		Circular		Circular	Circular
3 *Spectrum required in each direction* (MHz)	200		400		45(1)/30(2)	300(1)/200(2)
4 *Carrier transmission parameters*						
Modulation type	FDM/TDMA/QPSK		FDM/CDMA/TDMA; FDM/TDMA/QPSK		CDMA/QPSK	TDMA/QPSK
Number of service link beams	37		625		37	–
Number of feeder-link segments/polarization	–		–		–	1
Segment bandwidth (MHz)	–		–		–	–
Receiver bandwidth (kHz)	Up 50 000(3); 4 160(4)	Down 50 000(3); 4 920(4)	Up 40 000(3); 50 000(4)	Down 50 000(3); 40 000(4)	1 250(1), 15 000(2)	20 000(1); 20 000(2)
Transmission bandwidth (kHz)	50 000(3); 4 160(4)	50 000(3); 4 920(4)	40 000(3); 50 000(4)	50 000(3); 40 000(4)	1 250(1), 15 000(2)	20 000(1); 20 000(2)
Overall (C/N_0) per user (dB/Hz) or (C/N) (dB)	6.5 dB (E_b/N_0)		6 dB (E_b/N_0)		6.5 dB (E_b/N_0)	6.5 dB (E_b/N_0)
Uplink e.i.r.p./carrier (dBW)	53.7(3); 40.7(4)		57-67 (ARC)(3); 45.8-55.8 (ARC)(4)		1.5	67.2
Downlink e.i.r.p./carrier (dBW)	90º:10.5; 65º:12.3; 45º:16.2; 20º:20(3) 90º:11.9; 65º:13.7; 45º:17.6; 20º:21.4(4)		43.6(3), 50.4(4)		31.7	15.8
Type of satellite transponder	On-board processing		Transparent		Processing	Processing

TABLE 1 (*continued*)

Parameters	Non-GSO FSS		LEO N user and feeder-links	
	LEO N	MEO V	User links	Feeder-links
5 *Satellite antenna parameters*				
Tx maximum gain (dBi)	16.4	43.9	16.4	5.2
Rx maximum gain (dBi)	16.4	43.9	16.4	5.2
Main lobes	–	–	–	–
Side lobes	–	–	–	–
Back lobes	–	–	–	–
Steerable antenna or not	Yes	Yes	No	No
6 *Earth station antenna parameters*				
Peak Tx gain (dBi)	45[3]; 32[4]	55.6[3]; 43.2[4]	3	48.4
Peak Rx gain (dBi)	43.5[3]; 32[4]	52.1[3]; 39.7[4]	3	48.4
Radiation pattern	Rec. ITU-R S.580[3] Rec. ITU-R S.465[4]	Rec. ITU-R S.580[3] Rec. ITU-R S.580[4]	Not yet defined	Rec. ITU-R S.465
Minimum operating elevation angle (degrees)	10	40	10	10
7 *Number of earth stations and distribution*	–	–	Up to 4 million	Up to several dozens
8 *Earth station switching strategy*	By programme	By programme	≥ minimum operating elevation angle	Maximum duration of communication session

TABLE 1 (*continued*)

Parameters	Non-GSO/MSS	GSO FSS					GSO MSS
	LEO	GSO 1	GSO 2	GSO 3	GSO 13	GSO 20	
1 *Orbital parameters*							
Shape of orbit	Circular				Circular	Circular	Circular
Height (km)	1 000	36 000	36 000	36 000	36 000	36 000	36 000
Inclination angle (degrees)	83	–	–	–	0	–	–
Coherence (track repeat (h))	–	–	–	–	–	–	–
Number of satellites per plane	1	–	–	–	17	–	–
Number of orbital planes	7	–	–	–	1 (GSO)	–	–
Satellite separation within plane (degrees)	–	–	–	–	At least 2 for co-channel sharing	–	–
Satellite phasing between planes (degrees)	51.4	–	–	–	Not applicable	–	–
2 *Targeted frequency range and polarization*							
Uplink frequency (GHz)	7	6	6	14	30	30	30
Uplink polarization	RHCP	Circular	Circular	V and H	Circular with reuse	LHCP/RHCP	LHCP/RHCP
Downlink frequency (GHz)	5	4	4	12	20	20	20
Downlink polarization	LHCP	Circular	Circular	V and H	Circular with reuse	LHCP/RHCP	RHCP
3 *Spectrum required in each direction* (MHz)	50 up 66 down	500	500	500	1 000-2 500	1 000	500
4 *Carrier transmission parameters*							
Modulation type	CDMA/FDMA	FM/TV	64 kbit/s	FM/TV	FDMA up/FDMA down	FDMA/QPSK	FDMA/QPSK
Number of service link beams	–	–	–	–	48	8	4
Number of feeder-link segments/polarization	–	–	–	–	Not applicable	–	–
Segment bandwidth (MHz)	–	–	–	–	Not applicable	–	–

TABLE 1 (*continued*)

Parameters	Non-GSO/MSS	GSO FSS					GSO MSS
	LEO	GSO 1	GSO 2	GSO 3	GSO 13	GSO 20	
4 *Carrier transmission parameters (continued)*							
Receiver bandwidth (kHz)	2 050	30 000	51.2	27 000	500 uplink/ 120 000 downlink	241 up	1 800
Transmission bandwidth (kHz)	2 050	30 000	51.2	27 000	340 uplink/ 81 000 downlink	1 800 down	1 800
5 *Satellite antenna parameters*							
Tx maximum gain (dBi)	3				46.5/35.0	48.9	40.9
Rx maximum gain (dBi)	3				46.5/35.0	48.9	40.9
Main lobes	–				ex-CCIR Report 558	RR Appendix S30B	RR Appendix S30B
Side lobes	–				ex-CCIR Report 558	–	–
Back lobes	–				ex-CCIR Report 558	–	–
Steerable antenna or not	No				No, fixed pointed array	Yes	Yes
6 *Earth station antenna parameters*							
Peak Tx gain (dBi)	43.1	57.8	51.6	62.3	44.5/53.3	34.0-43.5	37.5-43.5
Peak Rx gain (dBi)	48.5	54.0	47.7	60.2	44.5/53.3	30.5-40.0	34.0-40.0
Radiation pattern	29 – 25 log φ	–	–	–	29 – 25 log φ	32 – 25 log φ	32 – 25 log φ
Minimum operating elevation angle (degrees)	10	–	–	–	5	10	10
7 *Number of earth stations and distribution*	4 or more				Unlimited, through urban and suburban areas and certain rural areas		
8 *Earth station switching strategy*					Not needed/used	Not applicable	Not applicable

TABLE 1 (*continued*)

Parameters	Non-GSO FSS			FSS	
	MEO J	MEO K	LEO SAT-1	GSO 30	QUASI-GSO 31
1 *Orbital parameters*					
Shape of orbit	Circular	Circular	Circular	Circular	Elliptical
Height (km)	13 900	13 900	700	36 000	1 000-43 000
Inclination angle (degrees)	75	75	98.2	–	63
Coherence (track repeat (h))	8	8	Not applicable	–	12
Number of satellites per plane	1	1	40	1	1
Number of orbital planes	9	9	21	12	8
Satellite separation within plane (degrees)	Not applicable	Not applicable	9	–	–
Satellite phasing between planes (degrees)	73.5	73.5	Random	–	Varies
2 *Targeted frequency range and polarization*					
Uplink frequency (GHz)	29.5-30	27.6-28.6	28.6-29.1	30	30
Uplink polarization	LHCP/RHCP	LHCP/RHCP	LHCP/RHCP	RHCP/LHCP	RHCP/LHCP
Downlink frequency (GHz)	19.7-20.2	17.8-18.8	18.8-19.3	19	19
Downlink polarization	LHCP/RHCP	LHCP/RHCP	LHCP/RHCP	RHCP/LHCP	RHCP/LHCP
3 *Spectrum required in each direction* (MHz)	500	1 000	500	1 000-3 200	1 000-3 200
4 *Carrier transmission parameters*					
Modulation type	QPSK FDMA/TDMA up TDM down	TCM TDM	Shaped QPSK FDMA up/ TDMA down	Phase	Phase
Number of service link beams	256	256	< 49 per satellite	–	–
Number of feeder-link segments/polarization	–	–	–	–	–
Segment bandwidth (MHz)	–	–	–	–	–

TABLE 1 (*end*)

Parameters	Non-GSO FSS			FSS	
	MEO J	MEO K	LEO SAT-1	GSO 30	QUASI-GSO 31
4 *Carrier transmission parameters (continued)*					
Receiver bandwidth (kHz)	250 000	125 000	0.275-35.2 (MHz)	3 200 000	3 200 000
Transmission bandwidth (kHz)	125 000	125 000	500 (MHz)	3 200 000	3 200 000
5 *Satellite antenna parameters*					
Tx maximum gain (dBi)	–	–	29.8 (90°), 30.9, 32.0 (40°)	55	55
Rx maximum gain (dBi)	–	–	29.8 (90°), 30.9, 32.0 (40°)	55	55
Main lobes	–	–	–	ex-CCIR Report 558	ex-CCIR Report 558
Side lobes	–	–	–	ex-CCIR Report 558	ex-CCIR Report 558
Back lobes	–	–	–	ex-CCIR Report 558	ex-CCIR Report 558
Steerable antenna or not	No	No	64 steerable beams	Yes	Yes
6 *Earth station antenna parameters*					
Peak Tx gain (dBi)	45	62.1	36	70	70
Peak Rx gain (dBi)	41.5	58.6	33	70	70
Radiation pattern	29 – 25 log φ	29 – 25 log φ	RR Appendix S8, Annex III	RR Appendix S8	RR Appendix S8
Minimum operating elevation angle (degrees)	–	10	40	5	5
7 *Number of earth stations and distribution*	± 90° of coverage latitude bounds Unlimited within coverage	± 90° of coverage latitude bounds	Up to 20 million, worldwide	Global	Global
8 *Earth station switching strategy*	Best elevation	–	Track nearest satellite		

ARC: automatic range compensation

LHCP: left-hand circular polarization

RHCP: right-hand circular polarization

(1) Uplink.

(2) Downlink.

(3) Feeder link/gateway.

(4) Service link/user station.

ANNEX 2

TABLE 2

Technical characteristics of feeder links of GSO MSS satellite networks

Parameters	GSO-C	GSO-D	GSO-E	GSO-F	GSO-G	GSO-H
2 *Frequency range* (GHz)						
Uplink	12.75-13.25	12.75-13.25	6	28.75-28.6/29.5-30.0	27.5-29.5	27.5-29.5
Downlink	10.7-10.95	11.2-11.45	4	18.55-18.80/19.7-20.2	18.4-19.7	18.4-19.7
3 *Spectrum requirements in each direction* (MHz)	200	150	50	250/500 up 250/500 down	1 300	1 300
4 *Carrier transmission parameters*						
Carrier type	600HG1ECF, 2K40G1EDF, 5K25G1EDF, 12K0G1EDF, 56K0G1EDF	2K40G1EDF, 4K80G1EDF, 32K0M7EDT, 144KG1EDF, 1M25G1EDC	QPSK/TDMA	FDM/TDMA/QPSK up TDM/QPSK down	QPSK	QPSK
Receiver bandwidth (kHz)	0.75-70	3-90	30	125 000	76.8	76.8
Allocated bandwidth (kHz)	5-100	5-1 250	33	125 000	84.5	84.5
Overall (C/N_0) (dB(Hz))	32-58	41-57	48	19.4 up/14.1 down per user	66.6	66.6
Uplink e.i.r.p./carrier (dBW)	34-47	36-52.0	53.2	53.2	67.5	61.5
Downlink e.i.r.p./carrier (dBW)	–8 to 5	–2 to 14	3.8	61.8	40.6	34.6
5 *Satellite antenna parameters*						
Peak Tx gain (dBi)	30 at all frequencies	30 at all frequencies	20	49.0	–	–
3 dB bandwidth (degrees)	–	–	17.8	–	–	–
Peak Rx gain (dBi)	–	–	20	49.0	–	–
3 dB bandwidth (degrees)	–	–	17.8	–	–	–
Sidelobe gain or pattern			RR Appendix S30B standard	RR Appendix S30B	Rec. ITU-R S.672	Rec. ITU-R S.672
Roll-off pattern			RR Appendix S30B standard	–	Square law	Square law
Steerable antenna or not	None	None	No	Fixed points		
6 *Earth station antenna parameters*						
Maximum Tx gain (dBi)	61.3 at 13 GHz	61.3 at 13 GHz	50.2	57.2	49.2	55.2
Maximum Rx gain (dBi)	60.0 at 11 GHz	60.0 at 11 GHz	45.5	53.5	45.7	51.7
Radiation pattern	Rec. ITU-R S.580	Rec. ITU-R S.580	Rec. ITU-R S.580	Rec. ITU-R S.465	Rec. ITU-R S.580	Rec. ITU-R S.580
Minimum elevation angle (degrees)	25	25	5	10	10	10
7 *Number of earth stations and distribution*	Diversity pair	Diversity pair	Up to 30	Unlimited	–	–

TABLE 3

Technical characteristics of GSO satellite networks using FSS frequency bands

1a *Frequency band* (GHz)	6/4 (Conv.)				6/4 (Allot.)	14/12 (Conv.)		14/12 (Allot.)	30/20		
1b *System*	GSO 1	GSO 2	GSO 5	GSO 6	GSO 9	GSO 3	GSO 7	GSO 10	GSO 11	GSO 12	GSO 13
Number of co-located satellites	1				1	1		1	1	1	2
Number of beams/satellite and polarization	2 and RHCP + 2 and LHCP					V and H		V and H	7V and 7H	1 circular polarization	24 and RHCP + 24 and LHCP
2 *Spectrum required in each direction* (MHz)	500				300	500		500	800	1 000	1 000-2 500
3a *Uplink carrier*	FM/TV		64 kbit/s IDR			FM/TV	64 kbit/s		147 Mbit/s	65 Mbit/s	384 kbit/s
Beam identification	Global	Hemi	Global	Hemi		Spot	Spot		Spot	Spot	Spot (global)
Occupied bandwidth	30 MHz	30 MHz	51.2 kHz	51.2 kHz		27 MHz	51.2 kHz		110 MHz	110 MHz	500 kHz
Minimum required C/N or E_b/N_0 (dB)											8
3b *Downlink carrier*	Same as uplink				Same as uplink	Same as uplink		Same as uplink	Same as uplink		Data musk
Occupied bandwidth (MHz)	Same as uplink				Same as uplink	Same as uplink		Same as uplink	Same as uplink		120
Minimum required C/N or E_b/N_0[(1)] (dB)	17.7		9.7			17.7	9.7				5
4 *Uplink parameters*											
Transmitter power to antenna (dBW)									20		–11.5 to –3.5 (power control)
Transmitting antenna size (m)									5	11.5	0.66
Transmitting antenna gain (dBi)	57.8	57.8	51.6	51.6	52.5	62.3	55.5	50.7	61.9	69.0	44.3
e.i.r.p. (dBW)	85.4	87.8	48.3	46.1	6.6[(2)]	86.3	40.9	14.6[(2)]	81.9	91.0	32.8-40.8 (power control)
Peak system G/T (dB(K^{-1}))									21.8		18.9
Receiving antenna beamwidth (degrees)											0.9
Receiving antenna side-lobe pattern											
Steerable or not											No

TABLE 3 (*end*)

5 *Downlink parameters*											
Transmitter power to antenna (dBW)									6		12.5
Peak transmitting antenna gain (dBi)									49.5	33.0	46.5
Peak e.i.r.p. (dBW)	30.5	35.0	0.5	0.9	–35.6(2)	50.0	7.7	–21(2)	55.5	39.0	59
Transmitting antenna beamwidth (degrees)									0.44		1.4
Receiving antenna size (m)									5		0.66
Peak receiving antenna gain (dBi)	54.0	54.0	47.7	47.7	49.1	60.2	53.5	49.4	58.4	33.0	41.0
6 *Earth segment*											
Number of earth stations											600 000
Distribution of earth stations											Home and business location

IDR: intermediate data rate

(1) For GSO 1-GSO 12, this is the *C*/*N* for the overall link (uplink and downlink).

(2) The e.i.r.p. is given in dB(W/Hz). The total e.i.r.p. is given in Annex 1 of Appendix S30B as the indicated e.i.r.p. density averaged over the necessary bandwidth.

ANNEX 3

TABLE 4

Technical characteristics of planned 30/20 GHz GSO FSS networks

Satellite system	A	A'	B	J	K	L	M	N	S	T	U
General parameters											
Nominal frequency (GHz)	20/30	20/30	20/30	20/30	20/30	20/30	20/30	20/30	20/30	20/30	20/30
Number of transponders per satellite	64	64	48	48	40						48
Transponder bandwidth (MHz)	120	250	120	120	120	120	120	24	120	54	36
Transponder high power amplifier (W)	30	30	20	30	60			95		40-60	60-90
Satellite e.i.r.p. (dBW)(1)	61	61	59	61	61	60	60.2	54	58	61	51-55
Polarization(2)	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Linear	Linear
Downlink parameters											
Modulation/access	TDM	CDMA	TDM	TDM	TDM	TDM	TDM	TDM	TDM	PSK/ MCPC	PSK/ MCPC
Central frequency (GHz)	19.5	19.5	19.5	19.5	19.7	19.5	19.95	19.5	20.0	19.92	18.95
Data rate (Mbit/s)	92	95.04	92	155	92	155	130	40	90	51.84	38.88
Digital service(3)	Narrow-band data	Narrow-band data	Narrow-band data	Narrow-band data	Narrow-band data	Narrow-band data	Narrow-band data	Narrow-band data	Narrow-band data	SC/TV	SC/TV
e.i.r.p. spectral density (dB(W/Hz))	–23.6	–26.6	–21.3	–25.9	–20.8	–20.8	–20.9	–22.0	–22.6	–16.3	–18.0
Uplink parameters											
Central frequency (GHz)	29.5	29.5	29.5	29.5	29.5	29.5	29.75	29.5	30.0	29.72	28.75
Modulation/access	CDMA	CDMA	FDM	FDM	FDM	FDM	FDM	FDM	FDM	TV/MCPC	TV/MCPC
Nominal rate (kbit/s)	384	384	384	384	384	384	128	384	384	51 840	38 880
Minimum earth station antenna diameter (m)	0.66	0.66	0.66	0.66	0.70	0.70	0.65	0.75	0.70	4.6/0.6	4.6/0.6
Up/down earth station antenna discrimination at 2° (dB)	22.5/19	22.5/19	22.5/19	22.5/19	23/19.5	23/19.5	22.5/19	23.5/20	23/19.5	40/18	40/18
Maximum power spectral density (dB(W/Hz))	–61.7	–70	–60.5	–58.9	–57.9	–57.9	–65.9	–63.7	–58.9	–61.1	–61.9

TABLE 4 (*end*)

Satellite system	V	W	X	Y	Z
General parameters					
Nominal frequency (GHz)	20/30	20/30	20/30	20/30	20/30
Number of transponders per satellite					360(4)
Transponder bandwidth (MHz)	125				25-120
Transponder high power amplifier (W)	40				
Satellite e.i.r.p. (dBW)(1)	60-62	22.6	62.8		70(5)
Polarization(2)	Circular				Linear
Downlink parameters					
Modulation/access	TDM	TDM	FDM		TDM/FDM/CDMA
Central frequency (GHz)	20	20	20.2	17.7-20.2	(6)
Data rate (Mbit/s)	92.16	0.064	1.544/0.384		To be determined
Digital service(3)	Narrow-band data	Narrow-band data	Narrow-band data/video		
e.i.r.p. spectral density (dB(W/Hz))	–19.1	–25.5	–23.1/–16.0	–63/–38	–4.1
Uplink parameters					
Central frequency (GHz)	30	30	30	27.5-30.0	(6)
Modulation/access	FDM	FDM	FDM		TDM/FDM/CDMA
Nominal rate (kbit/s)	384	64	1 544/384		
Minimum earth station antenna diameter (m)	0.70	0.60	1.0/0.3		0.3-12.0
Up/down earth station antenna discrimination at 2° (dB)	23/19.5	21.5/18	26/12		Rec. ITU-R S.580
Maximum power spectral density (dB(W/Hz))	–58.8	–45.1	–65.9/–56.8	–40	–44.0

MCPC: multi-channel per carrier
SC: single carrier
(1) Estimated peak e.i.r.p. values of spot beams, with edge of coverage of spot beams from 3 to 5 dB below peak.
(2) Left- and right-hand circular polarization used for uplinks and downlinks.
(3) Narrow-band digital data rates may include mixtures of 64, 128, 384 and 1 544 kbit/s.
(4) Co-location of six or more satellites providing a total of 360 transponders with 25 MHz bandwidth. Where larger bandwidths are used the number of transponders will vary.
(5) In compliance with No. 2578 of the Radio Regulations (edition of 1994).
(6) Uplink frequency (GHz): 18.1-18.2/27.5-28.0/28.0-31.0.
Downlink frequency (GHz): 21.9-22.0(7), 21.4-21.9(7)/18.2-21.2.
(7) Downlink operation in accordance with RR Resolution 525 (WARC-92).

TABLE 5

Technical characteristics of planned 30/20 GHz GSO FSS networks
Satellite system P

Type of satellite/service	GSO FSS			
Type of transponder	Transparent		Regenerative	
Type of carrier	Ka-1	Ka-2	Ka-3	Ka-4
Uplink and/or downlink	Up and down	Up and down	Up	Down
Frequencies (GHz) Earth-to-space/space-to-Earth	30/20	30/20	30/20	30/20
Uplink e.i.r.p. (dBW) Minimum Maximum	73.0 77.0	66.1 70.1	37.7 41.7	– –
Earth station peak Tx gain (dBi)	63.7	63.7	45.1	–
Uplink free-space path length (dB) Minimum Maximum	213.1 214.2	213.1 214.2	213.1 214.2	213.1 214.2
Downlink e.i.r.p. (dBW) Maximum Minimum	62.0 58.0	57.0 53.0	– –	62.5 58.5
Satellite peak Tx/Rx gain (dBi)	53.2	53.2	47.7	46.2
Earth station peak Rx gain (dBi)	60.1	60.1	–	41.6
Earth station Tx/Rx diameter (m)	6.0/6.0	6.0/6.0	0.66/–	–/0.66
Satellite Tx/Rx 3 dB beamwidth (degrees)	0.3/0.3	0.3/0.3	–/0.6	0.6/–
Occupied bandwidth (MHz)	186.6	186.6	0.333	115
Downlink free-space path length (dB) Minimum Maximum	209.5 210.6	209.5 210.6	209.5 210.6	209.5 210.6
Earth station elevation angle to satellite (degrees) Minimum Maximum	10 90	10 90	10 90	10 90
Intersatellite links (Yes or No)	Yes	Yes	Yes	Yes
On-board processing (Yes or No)	No	No	Yes	Yes
Message type (voice, data, video, paging, messaging, etc.)	All	All	All	All
Reference information data rate (Mbit/s)(1)	155.52	155.52	0.384	120
Modulation	QPSK	QPSK	QPSK	QPSK
FEC (type)	1/2 convolutional	1/2 convolutional	3/4 convolutional and Reed-Solomon	2/3 convolutional and Reed-Solomon
Spectral shaping factor	1.2	1.2	1.2	1.2
Network performance (design values): BER and performance mask 4% of year 1% of year 0.6% of year 0.5% of year 0.04% of year	 1×10^{-9} Not applicable 1×10^{-8} Not applicable 1×10^{-6}	 1×10^{-9} Not applicable 1×10^{-8} Not applicable 1×10^{-6}	 Not applicable 1×10^{-10} Not applicable 1×10^{-8} Not applicable	 Not applicable 1×10^{-10} Not applicable 1×10^{-8} Not applicable
BER threshold Required C/N (dB) Required margin (dB)	1×10^{-6} 6.9 18	1×10^{-6} 6.9 12	1×10^{-8} 5.8 2.5	1×10^{-8} 4.8 2.5

(1) The above information data rates may vary according to traffic/user requirements, and should be taken as reference for general analysis.

TABLE 6

Technical characteristics of a planned 30/20 GHz GSO/FSS networks using on-board processing
Satellite system Q

	Residential terminals	Business VSAT	Gateway
1 *Frequency range and polarization*			
Uplink frequency (GHz)	29.5-30.0	28.35-30.0	28.35-29.5
Uplink polarization	LHCP/RHCP	LHCP/RHCP	LHCP/RHCP
Downlink frequency (GHz)	19.7-20.2	18.55-20.2	18.55-19.7
Downlink polarization	LHCP/RHCP	LHCP/RHCP	LHCP/RHCP
Spectrum in each direction (MHz)	Up to 500	Up to 1 500	Up to 1 000
Transponder bandwidth (MHz)	110-120	110-120	110-120
2 *Uplink transmission parameters*			
Access technique	MF-TDMA	MF-TDMA	TDMA
Modulation type	O-QPSK/PFMO	O-QPSK/PFMO	O-QPSK/PFMO
User bit rate (Mbit/s)	0.512-2.048	2.048	65.536
Nominal carrier bandwidth (MHz)	0.8-3.0	3.0	110.0-115.0
Transmit earth station size (m)	0.45-0.75	1.2-1.8	3.0
Transmit earth station gain (dBi)	41.0-45.5	49.5-53.0	57.5
Uplink e.i.r.p. per carrier (dBW)	44.0-48.5	49.5-53.0	72.5-79.5
Typical clear sky C/N_0 (dB/Hz)	70.5-74.5	82.0	103.0
3 *Satellite antenna parameters*			
Beamwidth	0.55 diameter	0.55 diameter	0.55 diameter
Beam shape	Circular	Circular	Circular
Maximum Rx/Tx gain (dBi)	49.0	49.0	49.0
Radiation pattern	Rec. ITU-R S.672	Rec. ITU-R S.672	Rec. ITU-R S.672
Peak satellite G/T (dB(K^{-1}))	20.0	20.0	20.0
Peak satellite e.i.r.p. (dBW)	65.0	65.0	65.0
Type of transponder	On-board processing	On-board processing	On-board processing
4 *Downlink transmission parameters*			
Modulation type	TDM/QPSK	TDM/QPSK	TDM/QPSK
User bit rate (Mbit/s)	65.536	65.536	65.536
Nominal carrier bandwidth (MHz)	109.5	109.5	109.5
Receive earth station size (m)	0.45-0.75	1.2-1.8	3.0
Receive earth station gain (dBi)	37.5-42.0	46.0-49.5	54.0
Receive earth station G/T (dB(K^{-1}))	14.5-19.0	23.0-26.5	31.5
Typical clear sky C/N_0 (dB/Hz)	95.0	99.0	102.0
5 *Earth station parameters*			
Expected number of earth stations	Millions	Thousands	Less than 50
Minimum elevation angle (degrees)	10	10	20
Antenna pattern	$32 - 25 \log \varphi$	$32 - 25 \log \varphi$	$29 - 25 \log \varphi$
6 *Fade compensation strategy*	UPC, adaptive FEC, rate reduction	UPC, adaptive FEC, rate reduction	UPC, adaptive FEC, site diversity

PFMO: pulse frequency modulation (offset)

UPC: upward power control

APPENDIX 1

TO ANNEX 3

TABLE 7

Typical one-way link availability objectives (BER of 1×10^{-9})

Connection between			One-way availability (%)
Residential terminal	and	residential terminal	99.5
Residential terminal	and	business VSAT	99.6
Residential terminal	and	gateway	99.7
Business terminal	and	business terminal	99.7
Business terminal	and	gateway	99.8
Gateway	and	gateway	99.8-99.9

ANNEX 4

TABLE 8

Technical characteristics of some current 30/20 GHz GSO FSS networks Satellite system R

Satellite system	R-1	R-2	R-3	R-4	R-5	R-6
General parameters						
Nominal frequency (GHz)	20/30					
Number of transponders per satellite(1)	10					
Transponder bandwidth (MHz)	100					
Transponder high power amplifier (W)	29					
Satellite e.i.r.p. (dBW)(2)	55					
Polarization	Circular					
Downlink parameters						
Modulation/access	TDM	FDM	FDM	FDM	FDM	FM
Central frequency (GHz)(3)						
Data rate (Mbit/s)	20.4	0.032	0.032	1.544	7.2	Not applicable
Digital service	Voice, data and fax	Voice, data and fax	Voice, data and fax	Voice, data and fax	Digital video	TV-FM
e.i.r.p. spectral density (dB(W/Hz))	–9.1	–3.1	–5.3	–14.6	–17.0	–3.9(4)
Uplink parameters						
Central frequency (GHz)(3)						
Modulation/access	TDMA	FDMA	FDMA	FDMA	FDMA	FM
Nominal rate (Mbit/s)	20.4	0.032	0.032	1.544	7.2	Not applicable
Minimum earth station antenna diameter (m)	7.6	1.4	3.6	3.6	1.4	3.0
Up/down earth station antenna discrimination at 2° (dB)	Rec. ITU-R S.465					
Maximum power spectral density (dB(W/Hz))	–31.1	–23.3	–25.3	–27.6	–28.2	–14.0(4)

(1) Include 3 transponders connected to spot beams.

(2) Peak e.i.r.p. of national beam.

(3) Not specified.

(4) Modulated by 1 MHz peak-to-peak energy dispersal signal.

ANNEX 5

TABLE 9

Technical characteristics of a planned 10.95-11.2, 11.45-11.7/13.75-14.5 GHz non-GSO FSS network: FSAT-MULTI 1-B

1 *Orbital parameters*					
Shape of orbit	Circular				
Height (km)	1 457				
Inclination angle (degrees)	55				
Coherence (track repeat (h))	665				
Number of satellites per plane	4				
Number of orbital planes	16				
Satellite separation (degrees) within plane	90				
Satellite phasing between planes	Not applicable				
2 *Targeted frequency range and polarization*					
Uplink frequency (GHz)	13-14				
Uplink polarization	Circular				
Downlink frequency (GHz)	11-12				
Downlink polarization	Circular				
3 *Spectrum required in each direction* (MHz)	1 000 within the above frequency range				
4 *Carrier transmission parameters*					
Modulation type	SSMA				
Number of service link beams	< 45				
Number of feeder-link segments/polarization	–				
Segment bandwidth (MHz)	–				
Receiver bandwidth (kHz)	Forward: 41 000; return: 5 200				
Transmission bandwidth (kHz)	Forward: 41 000; return: 5 200				
Overall (C/N_0) per user (dB/Hz) or (C/N) (dB)	4 dB (E_b/N_0)				
Uplink e.i.r.p./carrier (dBW)	63.8[1]	68[1] (13.75-14 GHz)		35.5[2]	
Downlink e.i.r.p./carrier (dBW)	90°: 17.5[2] 4.8[1]	75°: 19.7[2] 7.1[1]	50°: 21.2[2] 8.6[1]	32°: 23.1[2] 10.2[1]	
Type of satellite transponder	Transparent				
5 *Satellite antenna parameters*					
Tx maximum gain (dBi)	90°: 17.2	75°: 19.8	50°: 21.7[2]	32°: 23	
Rx maximum gain (dBi)	90°: 16.9	75°: 19.5	50°: 21.4	32°: 22.7	
Main lobes	–				
Side lobes	–				
Back lobes	–				
Steerable antenna or not	Yes				
6 *Earth station antenna parameters*					
Peak Tx gain (dBi)	51.6[1]	54.1[1] (13.75-14 GHz)		33[2]	
Peak Rx gain (dBi)	50.5[1]	53[1] (13.75-14 GHz)		31.8[2]	
Radiation pattern	Rec. ITU-R S.580			–	
Minimum operating elevation angle (degrees)	5			10	
7 *Number of earth stations and distribution*	Up to 20 millions				
8 *Earth station switching strategy*	Track best elevation satellite within the operating range				

(1) Feeder link/gateway.

(2) Service link/user station.

TABLE 10

Technical characteristics of a planned 30/20 GHz non-GSO satellite network: FSAT-MULTI 1-A

a) Orbital parameters

The satellites are distributed between two types of planes, as shown in the following Table:

Number of planes	161
Number of satellites per plane	1
Right ascension node (degrees)	$0 + 1\,315\ i$ for $i = 0\text{-}160$
Altitude (km)	1 675
Eccentricity	0
Inclination (degrees)	87 1133

b) Communication parameters

2 *Frequency range* (GHz)			
Uplink frequency	27.5-30.0		
Downlink frequency	17.3-20.2		
4 *Carrier transmission parameters*			
Modulation type	QPSK + Viterbi and Reed-Solomon coding		
Information rate (Mbit/s)	0.384	2.048	33.0
Transmission bandwidth (MHz)	0.500	2.66	42.9
Required E_b/N_0 (dB)	6.0	6.0	6.0
Uplink e.i.r.p./carrier (dBW) Minimum Maximum (depends on the antenna diameter and on the elevation angle (rain fades compensation))	32.4	29.5 53.4	
Downlink e.i.r.p./carrier (dBW) depends on the elevation angle (3 dB edge of the beam value)	–	–	41 at 20°, 36 at 30°, 31.2 at 50°, 29.2 at 70°, 28.9 at 90°
Type of satellite transponder	On-board processing		
5 *Satellite antenna parameters*			
Tx maximum gain (dBi) (beam edge)	31.7 at 20°, 28.6 at 30°, 24.5 at 50°, 22.7 at 70°, 22.4 at 90°		
Rx maximum gain (dBi) (beam edge)	31.7 at 20°, 28.6 at 30°, 24.5 at 50°, 22.7 at 70°, 22.4 at 90°		
Main/side/back lobes			
6 *Earth station antenna parameters*			
Radiation pattern	Rec. ITU-R S.580 (side lobes), RR Appendix S30B (main beam)		
Minimum operating elevation angle (degrees) (depends on the latitude)	20 at the Equator		

ANNEX 6

TABLE 11

Additional parameters for the feeder links of the non-GSO MSS and FSS systems of LEO-G

	FL MSS	FL FSS	FSS
1 *Orbital parameters*			
Shape of orbit		Circular	
Height (km)		1 500	
Inclination angle (degrees)		74	
Satellites per plane		12	
Number of orbital planes		4	
Satellite separation within plane (degrees)		30	
Satellite phasing between planes (degrees)		90	
2 *Targeted frequency range and polarization*			
Uplink frequency (GHz)	19.3-19.6	28.6-29.1	28.6-29.1
Uplink polarization	LHCP	LHCP	LHCP
Downlink frequency (GHz)	15.45-15.65	18.8-19.3	18.8-19.3
Downlink polarization	RHCP	RHCP	RHCP
3 *Spectrum required in each direction* (MHz)	200	300	200
4 *Carrier transmission parameters*			
Receiver bandwidth (kHz)	48 000	64 000	32 000
Transmission bandwidth (kHz)	48 000	64 000	32 000
Overall C/N_0 per user (dB/Hz)	46	46	46
Uplink e.i.r.p./carrier (dBW) Maximum Minimum	 67 29.6	 63.9 28.2	 60.9 28.2
Downlink e.i.r.p./carrier (dBW) Maximum Minimum	 24.9 –3.8	 29.1 2.0	 29.7 5.6
5 *Satellite antenna parameters*			
Tx maximum gain (dBi)	22	30	30
Rx maximum gain (dBi)	22	30	30
Main, side and back lobes			
Steerable antenna or not	Yes	Yes	Yes
6 *Earth station antenna parameters*			
Peak Tx gain (dBi)	49	49	45
Peak Rx gain (dBi)	49	49	45
Radiation pattern			
Minimum operating elevation angle (degrees)	10	10	10
7 *Number of earth stations and distribution*	6 or more	6 or more	Multiple
8 *Earth station switching strategy*	≥ minimum elevation angle		

ANNEX 7

TABLE 12

Technical characteristics of two current 30/20 GHz GSO FSS networks: Ka-J1 and Ka-J2

Satellite system	Ka-J1	Ka-J2
General parameters		
Nominal frequency (GHz)	20/30	20/30
Number of transponders per satellite	5	6
Transponder bandwidth (MHz)	100	200
Input power of satellite transmit antenna (dBW)	11	11
Satellite e.i.r.p. (dBW)	52	58
Polarization	Circular	Circular
Digital service (voice, data, video, paging, etc.)	All	All
Downlink parameters		
Modulation/access	QPSK/TDMA	QPSK/TDM
Central frequency (GHz)[1]		
Occupied bandwidth (MHz)	35	140
Earth station antenna diameter (m): Minimum Maximum	 3.0 11.5	 1.8 4.2
e.i.r.p. spectral density (dB(W/Hz))	–23.4	–23.5
Uplink parameters		
Modulation/access	QPSK/TDMA	QPSK/TDM
Central frequency (GHz)		
Occupied bandwidth (MHz)	35	140
Earth station antenna diameter (m): Minimum Maximum	 3.0 11.5	 1.2 4.2
Maximum power spectral density (dB(W/Hz))	4.6	–1.9

(1) Not specified.

TABLE 13

Technical characteristics of a planned 30/20 GHz GSO FSS network: GSO-EKX

1 *Orbital parameters*	
Shape of orbit	Circular
Height (km)	35 786
Inclination angle (degrees)	0 inclination to equatorial plane
Number of satellites per plane	8-2 each in 4 orbit slots
Requested orbital locations	99° E, 117° W, 69° W, 26.2° W
Satellite separation (degrees) within plane	> 2
2 *Frequency range and polarization*	
3 *Spectrum required* (GHz)	1.0 for United States of America domestic network 1.5 for international network
4 *Carrier transmission parameters*	
Uplink Earth-to-space centre frequencies (United States of America) (GHz)	28.475, 29.375, 29.625 and 29.875
Downlink space-to-Earth centre frequencies (United States of America) (GHz)	17.925, 18.175, 18.425, 18.675, 19.825 and 20.075
Uplink Earth-to-space centre frequencies (Europe and S-E Asia) (GHz)	27.975, 28.225, 28.475, 29.375, 29.625 and 29.875
Downlink space-to-Earth centre frequencies (Europe and S-E Asia) (GHz)	17.925, 18.175, 18.425, 18.675, 19.825 and 20.075
Number of service link beams	32 dual polarization, receive and transmit
Modulation type	QPSK
User access	FDMA/TDMA
Receiver bandwidth (MHz)	250
Number of FDMA carriers per beam	8, 4 × 2 polarizations
Number of TDMA users	Up to 100 T1 users
Overall C/N_0 per user (dB/Hz)	89.5
Uplink e.i.r.p./carrier in clear (dBW)	62.2
Uplink e.i.r.p./carrier in rain (dBW)	67.2
Downlink e.i.r.p./carrier (dBW)	56.4
5 *Satellite antenna parameters*	
Tx maximum gain (dBi)	48.4
Rx maximum gain (dBi)	48.4
Tx side lobes (dB)	–15 relative to peak
Rx side lobes (dB)	–20 relative to peak
6 *Earth station antenna parameters*	
Tx maximum gain (dBi)	58.2 (typical value)
Rx maximum gain (dBi)	54.8 (typical value)
Tx side lobes (dB)	–15 relative to peak
Rx side lobes (dB)	–20 relative to peak
7 *Number of earth stations and distribution*	Number of sites is unlimited. Distribution of earth stations shall be in North and South America, Europe, Africa, South-East Asia and Australia, plus sites for transpacific and transatlantic
8 *Earth station switching strategy*	Interference avoidance while operating at the highest possible elevation angle

TABLE 14

Technical characteristics of a planned 30/20 GHz non-GSO FSS network: NGSO-KX

1 *Orbital parameters*	
Shape of orbit	Circular
Height (km)	10 352
Inclination angle (degrees)	55
Repeatable track	Approximately every 6 h
Number of satellites per plane	5
Number of orbital planes	4
Satellite separation (degrees) within plane	72
2 *Frequency range and polarization*	
Uplink frequency (GHz)	28.6-29.1
Uplink polarization	LHCP/RHCP
Downlink frequency (GHz)	18.8-19.3
Downlink polarization	LHCP/RHCP
3 *Spectrum required in each direction* (MHz)	500
4 *Carrier transmission parameters*	
Modulation type	O-QPSK
Number of service link beams	20
Receiver bandwidth (MHz)	3-200
Transmission bandwidth (kHz)	3-200
Overall *C*/*N*	Depends on antenna size: uplink at 30° elevation: over 6 dB for users downlink at 30° elevation: over 6 dB
Uplink e.i.r.p./carrier (dBW)	37-45
Downlink e.i.r.p./carrier (dBW)	55-60
Type of satellite transponder	On-board processing
5 *Satellite antenna parameters*	
Minimum antenna gain (dBi)	39
Beamwidth	1° at the 3 dB point
Steerable antenna or not	Yes
6 *Earth station antenna parameters*	
Peak Tx gain (dBi)	39.7-53.8 (for 36 cm to 2 m)
Peak Rx gain (dBi)	35.9-50.1 (for 36 cm to 2 m)
Radiation pattern	Rec. ITU-R S.465
Minimum operating elevation angle (degrees)	30
7 *Number of earth stations and distribution*	Global/unlimited
8 *Earth station switching strategy*	Interference avoidance/highest elevation angle

TABLE 15

Technical characteristics of a planned 30/20 GHz system: LEOSAT-2

1 *Orbital parameters*					
Satellites	63				
Shape of orbit	Circular				
Planes	7				
Altitude	1 400 km (870 miles)				
Inclination (degrees)	48				
Plane phasing (degrees)	+28.57				
Orbit period	6 825 s (1.9 h)				
Usable capacity (Gbit/s)	80				
Service region at 16° elevation angle	60° N and S latitude extends to 70° by mitigating affect of elevation angle (view or antenna)				
Peak d.c. power (kW)	13.6				
Average d.c. power (kW)	4.6				
Mission life (years)	8 (10 expendable)				
Stabilization and position sensing	3-axis stabilized; GPS				
Dimensions (length width height, stored)	3 × 2 × 5 m (120 × 80 × 200 in)				
Wet mass	3 100 kg (6 834 lb)				
Dry mass	2 500 kg (5 512 lb)				
Propellant	600 kg (1 323 lb)				
2 *Frequency range and polarization*					
Number of beams per satellite - uplink	432				
Frequency – uplink (GHz)	28.6-29.1 and 29.5-30.0				
Number of beams per satellite – downlink	260				
Frequency – downlink (GHz)	18.8-19.3 and 19.7-20.2				
Number of optical inter-satellite links per satellite	6				
Optical intersatellite link data rate (Gbit/s)	4.5				
3 *Spectrum required in each direction* (MHz)	1 000				
4 *Carrier transmission parameters*					
Modulation type	QPSK, 8-PSK				
Information rate (Mbit/s)	2.048	10.0	16.384	51.84	155.52
Transmission bandwidth(MHz)	4.10	20.0	32.8	104	311
Required E_b/N_0 (dB)	6.2	6.2	8.9	8.0	14.3
Uplink e.i.r.p./carrier (dBW):					
Nominal	35.3	39.8	–	48.5	50.8
Maximum (rain faded)	39.0	52.0	–	60.7	60.4
Downlink e.i.r.p./carrier (dBW):					
Nominal	–	–	41.3	32.6	35.9
Maximum (rain faded)	–	–	44.8	40.6	42.9
Type of satellite transponder	On-board processing				
Satellite switch rate (Gbit/s)	17.5				
Aggregate data rate (Gbit/s)	8.9				
5 *Satellite antenna parameters*					
Tx maximum gain (dBi)	32.8[(1)], 37.4[(2)]				
Rx maximum gain (dBi)	35.3[(1)], 40.9[(2)]				
6 *Earth station antenna parameters*					
Radiation pattern					
Minimum operating elevation angle (degrees)	16				

(1) For data rates of 2.048, 10.0, 16.384 and 51.84 Mbit/s.
(2) For data rate of 155.52 Mbit/s.

TABLE 16

Technical characteristics of the MEOSAT-X system in the 20/30 GHz and 40/50 GHz bands

Band	20/30 GHz	40/50 GHz
1 *Orbital parameters*		
Shape of orbit	Circular	
Height (km)	10 352	
Inclination angle (degrees)	50	
Coherence (track repeat (h))	6	
Number of satellites per plane	8	
Number of orbital planes	4	
Satellite separation within plane (degrees)	30 and 60 (within each plane satellites will fly in pairs with 30° between members of a pair and 60° between pairs)	
Satellite phasing between planes (degrees)	67.5	
2 *Frequency range and polarization*		
Uplink frequency (GHz)	28.35-29.1 and 29.5-30.0	47.2-50.2
Uplink polarization	LHCP/RHCP	
Downlink frequency (GHz)	18.05-18.3, 18.8-19.3 and 19.7-20.2	37.5-42.5 (3 GHz of spectrum in this band)
Downlink polarization	LHCP/RHCP	
3 *Spectrum required in each direction* (MHz)	1 250	3 000
4 *Carrier transmission parameters*		
Modulation type	O-QPSK	
Number of service link beams	360 MBA (multi-beam antenna) beams for the downlink and 360 MBA (multi-beam antenna) beams for the uplink, 2 separate links for gateway applications	4 beams supporting 16 channels
Number of feeder-link segments/polarization		Not available
Receiver bandwidth (MHz)	Uplink: 1.5, 3.5, 17, 120 (depends on data rate); downlink: 120	500
Transmission bandwidth	Uplink: 100 kHz – 125 MHz downlink: 125 MHz	Uplink: 500 MHz; downlink: 100 kHz, 500 MHz
Overall C/N_0 per user (dB/Hz) or C/N (dB)	Uplink at 20° elevation: 20 dB for users 34 dB for gateways; downlink at 20° elevation: 10-19 dB (depends on antenna size); gateway uplink: 34 dB Gateway downlink: 26.9 dB	Uplink at 20° elevation: 32.7 dB Downlink at 20° elevation: 27.3 dB

TABLE 16 (*end*)

Band	20/30 GHz	40/50 GHz
4 *Carrier transmission parameters (continued)*		
Uplink e.i.r.p./carrier (dBW)	51-66 (for 65 cm to 180 cm user antennas); 81.23 (for gateways)	88 (4.8 m antenna)
Downlink e.i.r.p./carrier (dBW)	53 (users); 54 (gateways)	60 (4.8 m antenna)
Type of satellite transponder	On-board processing	
5 *Satellite antenna parameters*		
Tx maximum gain (dBi)	37.5 (MBA), 38.32 (steerable beam)	45.19 (steerable beam)
Rx maximum gain (dBi)	37.48 (MBA), 42.21 (steerable beam)	47.86 (steerable beam)
Main lobes	2° beamwidth at the 3 dB point for the MBA	
Side lobes (dB)	14-17 first side lobe for the MBA; 20 for the steerable beam	20, first side lobe
Back lobes (dB)	25 for the MBA and the steerable beam	25
Steerable antenna or not	No for MBA; yes for steerable beam	Yes
6 *Earth station antenna parameters*		
Peak Tx gain (dBi)	44-53 (for 65 cm to 180 cm)	66.08 (for 4.8 m)
Peak Rx gain (dBi)	40-50 (for 65 cm to 180 cm)	45.19 (for 4.8 m)
Radiation pattern	Rec. ITU-R S.580 (29 – 25 log (angle))	
Minimum operating elevation angle (degrees)	20	
7 *Number of earth stations and distribution*	Unlimited/global	
8 *Earth station switching strategy*	Interference avoidance/highest elevation angle	

ANNEX 8

TABLE 17

Technical characteristics of a planned GSO FSS network above 30 GHz: GSO-VX

1 *Orbital parameters*	
Shape of orbit	Circular
Height (km)	35 786 (geosynchronous)
Inclination angle (degrees)	0 (referenced to Equator)
Coherence (track repeat (h))	Not applicable
Number of satellites per plane	14
Number of orbital planes	1 (GSO)
Satellite separation (degrees) within plane	At least 2
Satellite phasing between planes (degrees)	Not applicable
Satellite locations (number per location)	99° W(2), 101° W(2), 103° W(2) 63° W(1), 53° W(1), 8.5° E(2), 48° E(1)
2 *Frequency range and polarization*	
Uplink frequency (GHz)	
V-band	47.2-50.2
Ku-band	12.75-13.25
Uplink polarization	
V-band	LHCP/RHCP
Ku-band	LHCP/RHCP
Downlink frequency (GHz)	
V-band	39.5-42.5
Ku-band	10.70-10.95, 11.2-11.45
Downlink polarization	
V-band	LHCP/RHCP
Ku-band	LHCP/RHCP
3 *Spectrum required in each direction* (MHz)	
V-band	3 000
Ku-band	500
4 *Carrier transmission parameters*	
Modulation type	
V-band (uplink and downlink)	Differential QPSK, TDMA/FDMA
Ku-band (uplink and downlink)	Differential QPSK, TDMA/FDMA
Number of service link beams	
V-band	40
Ku-band	16
FDM channels per beam	
V-band	10
Ku-band	1
Bandwidth per FDM channel (MHz)	
V-band	300
Ku-band	250
TDM channels per FDM channel	
V-band	100
Ku-band	100
TDMA burst rate (Mbit/s)	
V-band	155.52 to 200
Ku-band	155.52 to 200

TABLE 17 (*end*)

4 *Carrier transmission parameters (continued)*	
Receiver bandwidth (MHz)	
V-band	300
Ku-band	250
Transmitter bandwidth (MHz)	
V-band	300
Ku-band	250
Overall C/N_0 per user (dB/Hz)	
V-band	Uplink (clear air): 96.8 Uplink (rain): 93.9 Downlink (clear air): 95.4 Downlink (rain): 91.7
Ku-band	Uplink (clear air): 96.3 Uplink (rain): 93.7 Downlink (clear air): 97.2 Downlink (rain): 94.2
Uplink e.i.r.p./carrier (dBW)	
V-band	73.8
Ku-band	68.5
Downlink e.i.r.p./carrier (dBW)	
V-band	56.0
Ku-band	47.0
Type of satellite transponder	Processor controlled SS-TDMA switch
5 *Satellite antenna parameters*	
Transmit antenna maximum gain (dBi)	
V-band	49.0
Ku-band	33.5
Receive antenna maximum gain (dBi)	
V-band	49.0
Ku-band	48.8
Transmit side-lobe level (dB below peak)	
V-band	18
Ku-band	18
Back lobes (dB below peak)	25
Steerable antenna or not	No, V-band and Ku-band antennas are satellite body mounted
6 *Earth station antenna parameters*	
Peak transmit gain (dBi)	
V-band	59.5 for 2.5 m
Ku-band	48.8 for 2.5 m
Peak receive gain (dBi)	
V-band	58.0 for 2.5 m
Ku-band	47.3 for 2.5 m
Radiation pattern	Rec. ITU-R S.580 (29 – 25 log (angle))
Minimum operating elevation angle (degrees)	20
7 *Number of earth stations and distribution*	Global/unlimited
8 *Earth station switching strategy*	Interference avoidance/highest elevation angle

SS: satellite switched

TABLE 18

Technical characteristics of a planned GSO FSS network above 30 GHz: GEO-SV(1)

System	GEO-SV
1 *Orbital parameters*	
Shape of orbit	Circular
Height (km)	35 786
Inclination angle (degrees)	0
Coherence (track repeat (h))	–
Number of satellites per plane	6
Number of orbital planes	1 (GSO)
Satellite separation (degrees) within plane	At least 2
Satellite phasing between planes (degrees)	–
2 *Frequency range and polarization*	
Uplink frequency (GHz)	47.2-50.2
Uplink polarization	LHCP/RHCP
Downlink frequency (GHz)	39.5-42.5
Downlink polarization	LHCP/RHCP
3 *Spectrum required in each direction* (MHz)	3 000
4 *Carrier transmission parameters*	
Modulation type	D-QPSK
Number of service link beams	40, 0.15° uplink and downlink beams
User data rate per TDMA carrier (Mbit/s)	155 (1 to 2.5 m ground terminals) 26.4 (45 cm ground terminals)
Coding rate	0.609
Effective overall rate (coding and data overhead)	0.517
Carrier occupied bandwidth (MHz)	199.85 (1 to 2.5 m terminals) 34.04 (45 cm terminals)
Required $E_b/(N_0 + I_0)$ without loss (dB)	5.0
Modem implementation loss (dB)	1.5
Receiver/transmitter bandwidth (MHz)	257 (1 to 2.5 m ground terminals) 43.7 (45 cm terminals)
Uplink e.i.r.p. per carrier (dBW)	75.5(2)
Downlink e.i.r.p. per carrier (dBW)	62.0
Type of satellite transponder	SS-TDMA
5 *Satellite antenna parameters*	
Receiver sensitivity, *G/T* (dB(K^{-1}))	26.4
Tx maximum gain (dBi)	58.0
Rx maximum gain (dBi)	58.0
Antenna downlink beamwidth	0.15° at the 3 dB point
Steerable antenna or not	Not
Radiation pattern	
6 *Earth station antenna parameters*	
Apertures	Tx: 2.5 m only Rx: 2.5 m; 1 m; 45 cm
Peak Tx gain (dBi)	59.5
Peak Rx gain (dBi)	50.8 (1 m) 43.8 (45 cm)
Receiver sensitivity *G/T* (dB(K^{-1}))	23.8 (1 m) 16.8 (45 cm)
Radiation pattern	Rec. ITU-R S.580 (29 – 25 log (angle))
Minimum operating elevation angle (degrees)	15
7 *Number of earth stations and distribution*	Global/unlimited
8 *Earth station switching strategy*	

(1) The GEO-SV system is a hybrid system that also includes a Ku-band payload.

(2) Uplink power control.

TABLE 19

Technical characteristics of a planned GSO FSS network above 30 GHz: GEO-LV

1 *Orbital parameters*	
Shape of orbit	Circular
Height (km)	35 786
Inclination angle (degrees)	0
Number of satellites per plane	
Number of orbital planes	1 (GSO)
Satellite separation within plane (degrees)	At least 2
2 *Frequency range and polarization*	
Uplink frequency (GHz)	45.5-46.7
Uplink polarization	LHCP/RHCP
Downlink frequency (GHz)	37.5-38.6
Downlink polarization	LHCP/RHCP
3 *Spectrum required in each direction* (GHz)	1.1
4 *Carrier transmission parameters*	
Modulation type	QPSK
Number of service link beams	
Receiver bandwidth (MHz)	Depends on data rate: Uplink: minimum of 3 Downlink: minimum of 3
Transmission bandwidth (MHz)	Depends on data rate: Uplink: minimum of 3 Downlink: minimum of 3
Overall C/N_0 per user (dB/Hz)	Minimum of 59
Uplink e.i.r.p./carrier (dBW)	Depends on antenna size and data rate. Over 41
Downlink e.i.r.p./carrier (dBW)	Depends on antenna size and data rate. Over 55
Type of satellite transponder	On-board processing
5 *Satellite antenna parameters*	
Satellite minimum antenna gain (dBi)	52
Main lobes	0.15° beamwidth at the 3 dB point
Steerable antenna or not	Yes
6 *Earth station antenna parameters*	
Minimum Tx gain (dBW)	33
Minimum Rx gain (dBW)	31
Radiation pattern	RR Appendix S8, Annex III
Minimum operating elevation angle (degrees)	30
7 *Number of earth stations and distribution*	Global/unlimited

TABLE 20

Technical characteristics of a planned GSO FSS network above 30 GHz: MEO-LV

1 *Orbital parameters*	
Shape of orbit	Circular
Height (km)	10 352
Inclination angle (degrees)	55
Coherence (track repeat (h))	6
Number of satellites per plane	5
Number of orbital planes	4
Satellite separation (degrees) within plane	72
2 *Frequency range and polarization*	
Uplink frequency (GHz)	45.5-46.7
Uplink polarization	LHCP/RHCP
Downlink frequency (GHz)	37.5-38.6
Downlink polarization	LHCP/RHCP
3 *Spectrum required in each direction* (GHz)	1.1
4 *Carrier transmission parameters*	
Modulation type	QPSK
Receiver bandwidth (MHz)	Depends on data rate: Uplink: minimum of 3 Downlink: minimum of 3
Transmission bandwidth (MHz)	Depends on data rate: Uplink: minimum of 3 Downlink: minimum of 3
Overall C/N_0 per user (dB/Hz)	Minimum of 57
Uplink e.i.r.p./carrier (dBW)	Depends on antenna size and data rate. Over 41
Downlink e.i.r.p./carrier (dBW)	Depends on antenna size and data rate. Over 55
Type of satellite transponder	On-board processing
5 *Satellite antenna parameters*	
Satellite minimum antenna gain (dBi)	41
Main lobes	6° beamwidth at the 3 dB point
Steerable antenna or not	Yes
6 *Earth station antenna parameters*	
Minimum Tx gain (dBW)	33
Minimum Rx gain (dBW)	31
Radiation pattern	RR Appendix S8, Annex III
Minimum operating elevation angle (degrees)	30
7 *Number of earth stations and distribution*	Global/unlimited
8 *Earth station switching strategy*	Interference avoidance/highest elevation angle

TABLE 21

Technical characteristics of several LEO and GSO satellite networks above 38 GHz

Parameters	Non-GSO above 38 GHz FSS			GSO above 38 GHz FSS
	LEO V1		LEO V2	OSG V1
1 *Orbital parameters*				
Shape of orbit	Circular		Circular	Circular
Apogee/perigee (km)	1 350/1 350		10 355/10 355	35 878
Inclination angle (degrees)	47		50	
Number of satellites per plane	6		5	
Number of orbital planes	12		3	
Satellite separation within plane	60° + 25° plane inclination		72°	
Satellite phasing per plane, RAAN (degrees)	θ + 30		120	
2 *Targeted frequency range and polarization*				
Uplink frequency (GHz)	47.2-50.2		47.2-50.2	47.2-50.2
Uplink polarization/axial ratio (dB)	RHCP/__ dB		RHCP/LHCP	RHCP/LHCP
Downlink frequency (GHz)	37.5-40,5		37.5-42.5	37.5-42.5
Downlink polarization/axial ratio (dB)	LHCP/__ dB		RHCP/LHCP	RHCP/LHCP
3 *Carrier transmission parameters*				
Modulation type	QPSK		O-QPSK	O-QPSK
Coding rate	0.449		≈ 0.5	0.5
Number of service link beams	16		48	24
Target BER	1×10^{-6}	1×10^{-9}	1×10^{-7} to 1×10^{-10}	1×10^{-7} to 1×10^{-10}
Burst information data rate (Mbit/s)	10.24	51.84	OC3 to 10 × OC3	OC3 to 10 × OC3
Bandwidth per channel (MHz)	18	90	300 to 3 000	300 to 3 000
Required $E_b/(N_0 + I_0)$ without loss (dB)	2.2	2.7	6.0	6.0
Modem implementation loss (dB)	1.5	1.5 (+0.55/hop)	2.0	2.0
Receiver bandwidth (MHz)				
Transmission bandwidth (MHz)				
Uplink e.i.r.p./carrier (dBW)	44.9 to 50.5 ARC	60.2 to 65.8 ARC	69.7 to 78.9	73.7 to 80.0
Downlink e.i.r.p./carrier (dBW)	28.3 to 33.9 ARC	46.9 to 52.5 ARC	49.5 to 58.8	57.5 to 66.4
Type of satellite transponder	Transparent		Processed payload	Regenerative
4 *Satellite antenna parameters*				
Effective aperture (m)	0.45 Tx/0.36 Rx		0.65 Tx/0.52 Rx	1.36 Tx/1.1 Rx
Tx maximum gain (dBi)	40.6		45.5	53
Rx maximum gain (dBi)	40.6		45.2	53
Receiver sensitivity G/T (dB(K^{-1}))	10.5		16.9	24.4
Radiation pattern	RR Appendix S8		Ex-CCIR Report 558	Ex-CCIR Report 558
Steerable antenna or not	Yes		Yes	Yes
5 *Earth station antenna parameters*				
Effective aperture (m)	0.66	1.5	2.2	2.2
Peak Tx gain (dBi)	49.3	56.4	59.7	59.7
Peak Rx gain (dBi)	47.3	54.4	57.8	57.8
Receiver sensitivity, G/T (dB(K^{-1}))	19.3	26.4	32.4	32.4
Radiation pattern	Rec. ITU-R S.465[1]	Rec. ITU-R S.465	Rec. ITU-R S.465	Rec. ITU-R S.465
Minimum operating elevation angle (degrees)	22		30	30
6 *Number of earth stations and distribution*	43 000 active worldwide	1 500 active worldwide	Unknown (< 50 000)	Unknown (< 30 000)
7 *Earth station switching strategy*	Make before break		Make before break	Make before break

OC3: optical carrier system operating at the 3rd hierarchical level

RAAN: right ascension of the ascending node

(1) Recommendation ITU-R S.465 radiation pattern is consistent with the proposed frequency of operation when extrapolated to the proposed frequency band.

TABLE 22

Technical characteristics of the GEOSAT-X system in the 40/50 GHz bands

1 *Orbital parameters*	
Shape of orbit	Circular
Height (km)	35 786
Inclination angle (degrees)	–
Coherence (track repeat (h))	–
Number of satellites per plane	9
Number of orbital planes	1 (GSO)
Satellite separation within plane (degrees)	At least 2
Satellite phasing between planes (degrees)	–
2 *Frequency range and polarization*	
Uplink frequency (GHz)	47.2-50.2
Uplink polarization	LHCP/RHCP
Downlink frequency (GHz)	39.5-42.5 (3 GHz of spectrum in this band)
Downlink polarization	LHCP/RHCP
3 *Spectrum required in each direction* (MHz)	3 000
4 *Carrier transmission parameters*	
Modulation type	QPSK
Number of service link beams	48
Number of feeder-link segments/polarization	8 beams for gateway communication 2 downlink beams for HCDR service
Receiver bandwidth	*User service beams:* Uplink: 500 kHz, 3 MHz, 11 MHz, depending on data rate Downlink: 125 MHz *Gateway beams:* Uplink and downlink: 125 MHz *HCDR beams:* Downlink: 1 GHz
Transmission bandwidth	*User service beams:* Uplink: 500 kHz, 3 MHz, 11 MHz, depending on data rate Downlink: 125 MHz *Gateway beams:* Uplink and downlink: 125 MHz *HCDR beams:* Downlink: 1 GHz
Overall C/N_0 per user(dB/Hz) or C/N (dB)	*User service beams* C/N_0: Uplink (clear air): 75.6, 76.9, 84.3, 93.2; (rain): 67.8, 67.8, 75.5, 81.6, depending on data rate Downlink (clear air): 89.8, 92.1, 94.8, 103.5; (rain): 82.8, 82.8, 86.2, 90.3, depending on terminal size *Gateway beams* C/N_0: Uplink (clear air): 111.8; (rain): 92.3 Downlink (clear air): 110.5; (rain): 93.0 *HCDR beams* C/N_0: Downlink (clear air): 115.8; (rain): 101.6
Uplink e.i.r.p./carrier (dBW)	User service beams (edge of coverage): 49.9, 53.0, 60.4, 69.2, depending on terminal size Gateway beams: 83.9

TABLE 22 (*end*)

4 *Carrier transmission parameters (continued)*	
Downlink e.i.r.p./carrier (dBW)	User service beams (edge of coverage): 61.2 Gateway beams: 62.7 HCDR beams: 62.2
Type of satellite transponder	On-board processing
5 *Satellite antenna parameters*	
Tx maximum gain (dBi)	56.5 for user and gateway links 53.7 for high data rate up to OC-48
Rx maximum gain (dBi)	53.8
Main lobes	
Side lobes (dB)	Tx: 14 below peak Rx: 25 below peak
Back lobes (dB)	25 below peak
Steerable antenna or not	Yes, phase array antenna for user and gateway beams
6 *Earth station antenna parameters*	
Peak Tx gain (dBi)	44.8-59.3 for user earth stations from 45 cm to 240 cm 64.8 for gateway earth stations
Peak Rx gain (dBi)	43.3-57.8 for user earth stations from 45 cm to 240 cm 63.3 for gateway earth stations 69.3 for HCDR earth stations
Radiation pattern	Rec. ITU-R S.580 (29 – 25 log (angle))
Minimum operating elevation angle (degrees)	20
7 *Number of earth stations and distribution*	Global/unlimited
8 *Earth station switching strategy*	Interference avoidance/highest elevation angle

HCDR: high capacity data rate

ANNEX 9

TABLE 23

Technical characteristics of non-GSO FSS systems: System USAKU-L1

1 *Orbital parameters*			
Shape of orbit	Circular		
Height (km)	1 457		
Inclination angle (degrees)	55		
Coherence (track repeat (h))	665		
Number of satellites per plane	4		
Orbital planes	16		
Satellite separation (degrees) within plane	90		
2 *Targeted frequency range and polarization*			
Uplink frequency (GHz)	12/17		
Uplink polarization	Circular		
Downlink frequency (GHz)	10/12		
Downlink polarization	Circular		
3 *Spectrum required in each direction* (MHz)	1 050 within the above frequency range		
4 *Carrier transmission parameters*			
Modulation type	QPSK/BPSK		
Number of service link beams	< 45		
Number of uplink transponders/polarization	4		
Transponder bandwidth (MHz)	250 or 300		
Earth station noise bandwidth (MHz)	Forward: 22.6, return: 2.93		
Overall E_b/N_0 (dB)	3.5		
Earth station useful e.i.r.p. (dBW)	64.6(1) to 68(2)	30.3 to 43.4(3)	
Satellite useful e.i.r.p./carrier (dBW) Forward Return	 16.4 to 18.5 (residential), 11 to 17.6 (provincial, international) –3.5 to –1.7 (residential), –7.2 to –2.4 (provincial, international)		
Type of satellite transponder	Transparent bent pipe		
5 *Satellite antenna parameters*			
Tx maximum gain (dBi)	15 at Nadir –22.8 at EOC		
Rx maximum gain (dBi)	18.2 at Nadir –25.7 at EOC		
Steerable antenna or not	Yes		
6 *Earth station antenna parameters*	Provincial	International(3)	Residential(3)
Peak Tx gain (dBi)	49.4(1)/53.8(2)	37	29.5-32.2
Peak Rx gain (dBi)	48.1(1)/52.5(2)	35.7	28.1-30.8
Radiation pattern	Rec. ITU-R S.580	RR Appendix S8	RR Appendix S8
Minimum specified elevation angle (degrees)	5	5	10
7 *Number of earth stations and distribution*	Up to 20 million worldwide		
8 *Earth station switching strategy*	Track best elevation satellite within the operating range outside the non-operating zone		

EOC: edge of coverage

(1) Gateway.

(2) Gateway in 13.75-14 GHz.

(3) User terminal.

TABLE 24

Technical characteristics of a quasi-GSO FSS network: USAKU-H1

1 *Orbital parameters*	
Shape of orbit	Elliptical
Apogee/perigee (km)	41 449/4 100
Inclination (degrees)	63.4
Coherence (track repeat (h))	14 (approximately)
Number of satellites per plane	4
Number of orbital planes	3
Satellite phasing between planes (degrees)	120
Argument of perigee (degrees)	270
Minimum satellite separation from geosynchronous plane (degrees)	40
Maximum latitude/longitude operating range (degrees)	19/3
Nominal operational longitude	100° W/30° W/120° E/170° E
2 *Frequency range*	
Uplink frequency (GHz)	17.3-17.8
Uplink polarization	LHCP/RHCP
Downlink frequency (GHz)	10.7 to 12.7
Downlink polarization	RHCP/LHCP
3 *Spectrum required in each direction* (MHz)	500
4 *Carrier transmission parameters*	
Modulation	QPSK
Access	FDMA/TDM
Number of service link beams	10
Segment (transponder) bandwidth (MHz)	24
Receive bandwidth (MHz)	24
Transmission bandwidth (MHz)	24
Overall C/N_0 (dB/Hz)	86
Uplink e.i.r.p./carrier (dBW)	77
Downlink e.i.r.p./carrier (dBW)	58
5 *Satellite communication parameters*	
Type of satellite transponder	Transparent
Transmit maximum gain (dBi)	38
Receive maximum gain (dBi)	24
Steerable antenna or not	Yes (phased array)
6 *Earth station characteristics*	
Feeder link transmit gain (dBi)	55
Feeder link e.i.r.p. per 24 MHz (dBW)	77
Receive antenna gain (minimum) (dBi)	30
Antenna pattern	$29 - 25 \log (\theta)$

TABLE 25

Technical characteristics of a quasi-GSO FSS network: Tanya

1 *Orbital parameters*	
Shape of orbit	Elliptical
Apogee/perigee (km)	41 449/4 100
Argument of perigee (degrees)	270
Inclination (degrees)	63.4
Coherence (track repeat (h))	12 (approximately)
Number of satellites per plane	1
Number of orbital planes	4
Satellite phasing between planes (degrees)	90
Minimum satellite separation from geostationary orbit plane (degrees)	53.3
Operational stationary latitude/longitude locations	58.3° N/90° E 58.3° N/90° W
Maximum latitude/longitude operating range (degrees)	10/2
Minimum elevation angle from earth stations (degrees)	25
Short-term/long-term pfd at Earth's surface (dB(W/(m^2 · MHz)))	Identical
2 *Frequency range*	
Uplink frequency (GHz)	13.75-14.5/17.3-17.8
Uplink polarization	LHCP/RHCP
Downlink frequency (GHz)	10.7-12.7
Downlink polarization	RHCP/LHCP
3 *Spectrum required in each direction* (MHz)	1 250
4 *Carrier transmission parameters*	
Modulation	QPSK
Access	FDMA/TDM
Number of service link beams	10
Segment (transponder) bandwidth (MHz)	24
Receive bandwidth (MHz)	24
Transmission bandwidth (MHz)	24
Overall C/N_0 (dB/Hz)	86
Uplink e.i.r.p./carrier (dBW)	77
Downlink e.i.r.p./carrier (dBW)	58
5 *Satellite communication parameters*	
Type of satellite transponder	Transparent
Transmit maximum gain (dBi)	38
Receive maximum gain (dBi)	24
Steerable antenna or not	Yes (phased array)
6 *Earth station characteristics*	
Feeder link transmit gain (dBi)	55
Feeder link e.i.r.p. per 24 MHz (dBW)	77
Receive antenna gain (minimum) (dBi)	30
Antenna pattern	29 – 25 log (θ)

ANNEX 10

TABLE 26

Technical characteristics of two GSO satellite telemetry and command sub-systems

	Emergency		On-station	
	GSO-A	GSO-B	GSO-A	GSO-B
Telemetry				
Frequency (GHz)	11.7		11.7	
Modulation	PM		PM	
Satellite e.i.r.p. (dBW)	7.2	10.1	12.4	16
Earth station G/T (dB(K^{-1}))	37	35	37	35
C/N_0 (dB/Hz)	66.5	67.4	71.7	73.5
Losses (dB)	7	5	7	5
Telemetry bit rate (dB/Hz)	27.1	33.1	27.1	33.1
E_b/N_0 (dB)	32.4	29.3	37.6	35.2
Required E_b/N_0 (dB/Hz)	9.6	12	9.6	12
Command				
Frequency (GHz)	14.5	17.3	14.5	17.3
Modulation	FM		FM	
Earth station e.i.r.p. (dBW)	88	89	59	65
Satellite antenna gain (dBi)	0	0	43	29
Receiver input power (dBW)	–125.9	–126.3	–122.9	–125
Receiver threshold (dBW)	–141.5	–143	–141.5	–143
System noise temperature (dB(K^{-1}))	28	27.4	29.6	28.9
C/N_0 (dB/Hz)	74.7	74.9	76.1	74.7
Required C/N_0 (dB/Hz)	58.5	57	58.5	57

PM: phase modulation

ANNEX 11

TABLE 27

Technical characteristics of a planned V-band system: GSOV-B1

2 *Frequency range and polarization*						
Uplink frequency (GHz)			47.2-50.2			
Uplink polarization			Linear			
Downlink frequency (GHz)			37.5-40.5			
Downlink polarization			Linear			
3 *Spectrum required in each direction* (MHz)			3 000			
4 *Carrier transmission parameters*						
Modulation type			QPSK/SS-TDMA			
Number of service link beams			24 × 0.3° beams			
User data rate per TDMA carrier			88 Mbit/s 128 kbit/s			
Occupied bandwidth			105.6 MHz 167 kHz			
Coding			R 1/2			
5 *Satellite antenna parameters*						
Antenna beam gain (dBi)			51.5			
Satellite *G/T* (dB(K^{-1}))			23.4			
Satellite noise temperature (K)			650			
Beam size (degrees)			0.3			
Number of beams			24			
6 *Earth station antenna parameters*						
Antenna gain			See item 7 below			
Minimum elevation angle (degrees)			20			
7 *Power characteristic*			194KG7W		123MG7W	
Uplink/downlink	Earth station diameter (m)	Earth station gain (dBi)	Maximum power density (dB(W/Hz))	Minimum power density (dB(W/Hz))	Maximum power density (dB(W/Hz))	Minimum power density (dB(W/Hz))
Uplink clear sky	0.45	45.2	–47.3	–65.8	–48.7	–51.7
	0.9	51.2	–53.3	–71.8	–54.7	–57.7
	1.2	53.7	–55.8	–74.3	–57.2	–60.2
	6	67.7	–69.8	–88.3	–71.2	–74.2
Uplink degraded	0.45	45.2	–37.3	–65.8	–38.7	–51.7
	0.9	51.2	–43.3	–71.8	–44.7	–57.7
	1.2	53.7	–55.8	–74.3	–47.2	–60.2
	6	67.7	–59.8	–88.3	–61.2	–74.2
Downlink	0.45	43.7	–60.3	–69.3	(1)	(1)
	0.9	49.7	(2)	(2)	–66.2	–73.3
	1.2	52.2	67.3	–75.5	–66.2	–74.9
	6	66.2	–75.8	–78.8	–66.2	–77.5

(1) Not provided.

(2) Out of range.

TABLE 28

Technical characteristics of a planned V-band system: GSO V-B2

Technical characteristics of CANSAT GSO FSS satellite networks in the 50/40 GHz bands

GSO FSS network name – "CANSAT–_ _"	2A	2B	3A	3B	3C	3D	3E
Orbital position (° W)	70.5	82.0	91.0	111.1	114.9	118.7	107.3
1 *Orbital parameters*							
Shape of orbit	Circular						
Height (km)	35 786 (geosynchronous)						
Inclination angle (degrees)	≤ 0.1						
Number of orbital planes	1 (GSO)						
Separation within plane	–						
2 *Frequency range and polarization*							
Uplink frequency (GHz)	47.2-50.2						
Uplink polarization	–						
Downlink frequency (GHz)	37.5-40.5						
Downlink polarization	–						
3 *Spectrum required in each direction* (MHz)	3 000						
4 *Carrier transmission parameters*							
Modulation type	QPSK or 8-PSK						
Number of service link beams	Up to 80						
Number of FDM channels/beam	Up to 5						
Bandwidth/FDM channel (MHz)	150						
User rate/TDM channel (Mbit/s)	0.144 to 155.52		1.544 to 155.52				
Receiver bandwidth (MHz)	0.150 to 150 (depending upon data rate)		1.50 to 150 (depending upon data rate)				
Transmission bandwidth (MHz)	0.150 to 150 (depending upon data rate)		1.50 to 150 (depending upon data rate)				
Overall *C/N* per user (dB)	Minimum of 5.0 (depends on coding)						
Uplink e.i.r.p./carrier (dBW)	49.6 (144 kbit/s) 60.0 (1.544 Mbit/s) 76.2 (44.736 Mbit/s) 84.7 (155.52 Mbit/s)		60.0 (1.544 Mbit/s) 76.2 (44.736 Mbit/s) 84.7 (155.52 Mbit/s)				
Downlink e.i.r.p./carrier (dBW)	70.1 (144 kbit/s) 63.8 (1.544 Mbit/s) 47.1 (44.736 Mbit/s) 37.1 (155.52 Mbit/s)		63.8 (1.544 Mbit/s) 47.1 (44.736 Mbit/s) 37.1 (155.52 Mbit/s)				
Type of transponder	–						
5 *Satellite antenna parameters*							
Transmit gain (maximum) (dBi)	53.1						
Receive gain (maximum) (dBi)	53.1						
Main lobes	–						
Side lobes	–						
Steerable antenna or not	Yes						
6 *Earth station antenna parameters*							
Transmit gain (maximum) (dBi)	45.5 (46 cm) to 65.4 (4.5 m)		52.3 (1.0 m) to 65.4 (4.5 m)				
Receive gain (maximum) (dBi)	43.8 (46 cm) to 63.6 (4.5 m)		50.5 (1.0 m) to 63.6 (4.5 m)				
Radiation pattern	29 – 25 log (θ)						
Minimum operating elevation angle (degrees)	Generally ≥ 20		Minimum elevation determined by climatic zone, and desired availability				
7 *Number of earth stations and distribution*	Unlimited/visible Earth		Unlimited/anywhere on visible Earth				
8 *Earth station switching strategy*	–						

ANNEX 12

TABLE 29

Pan African 6/4 GHz and 14/11 GHz bands GSO satellite network

1a	*Frequency band* (GHz)	6/4	14/11-12
1b	*System*		
	Number of co-located satellites	1	
	Number of beams/satellite and polarization	1 (to be defined)	1-10 (Linear)
2	*Spectrum requirements in each direction* (MHz)	To be provided later	
3a	*Uplink carrier*		
	Beam identification	Unknown	
	Occupied bandwidth (Hz)	To be provided later	50-5 000 kHz
	Minimum required C/N or E_b/N_0	Provided in downlink category for total link	
3b	*Downlink carrier*		
	Occupied bandwidth (MHz)	Same as uplink	
	Minimum required C/N or E_b/N_0 (dB)	To be provided later	1.7-4.6
4	*Uplink parameters*		
	Transmitter power to antenna (dBW)		
	Transmitting antenna size (m)	To be provided later	0.6-5
	Transmitting antenna gain (dBi)		
	e.i.r.p. (dBW)	To be provided later	35-55
	Peak system G/T (dB(K^{-1}))	To be provided later	
	Receiving antenna beamwidth (degrees)	To be provided later	
	Receiving antenna side-lobe pattern	To be provided later	
	Steerable or not	No/Shaped beam	No/Multi-spots
5	*Downlink parameters*		
	Transmitter power to antenna (dBW)	To be provided later	
	Peak transmitting antenna gain (dBi)	To be provided later	32-38
	Peak e.i.r.p. (dBW)	To be provided later	21-29 (per carrier)
	Transmitting antenna beamwidth (degrees)	To be provided later	
	Receiving antenna size (m)	To be provided later	0.6-5
	Peak receiving antenna gain (dBi)	To be provided later	
6	*Earth segment*		
	Number of earth stations	To be provided later	
	Distribution of earth stations	Global within the coverage	

ANNEX 13

1 Parameters of USAKUM1

USAKUM1 includes two services, the integrated digital service (IDS) and the backhaul data service (BDS). Only the IDS links are given here to avoid confusion. The BDS service has steerable service beams and is considered to be covered by the IDS service conditions.

1.1 Orbit parameters

Parameter	Value	Variation
Number of satellites	20	N/A
Number of planes	4	N/A
Number of satellites per plane	5	N/A
Orbit type (select one)	Circular	N/A
Repeating ground track	Yes	N/A
Orbit inclination (degrees)	57	
Orbit period (min)	718.2	
Apogee altitude (km)	20 182	
Perigee altitude (km)	20 182	
Argument of perigee (degrees)	0	
Eccentricity	0	
Satellite angular separation within a plane (degrees)	72	
Satellite phasing between first satellites of adjacent planes (degrees)	36	
Angular separation between planes (degrees)	90	

1.2 Link parameters

1.2.1 Uplink to non-GSO

1.2.1.1 Satellite antenna configuration

Parameter	Value	Reference
Beam orientation method (pick one)	Feeder link: steerable Service link: sat fixed	§ 1.2.1.2 § 1.2.1.4
Maximum possible number of beams per satellite	Feeder link: 2 Service link: 37	–
Frequency and polarization reuse pattern (attach diagram or describe in sufficient detail). Submit multiple entries if necessary	Three-cell reuse pattern (see Fig. 2)	–

1.2.1.2 Steerable beams (feeder link)

Parameter	Value	Reference
Gain pattern		§ 1.2.1.3

1.2.1.3 Gain pattern (feeder link)

Parameter	Value	Reference
Method to determine shape (select one)	Equation	§ 1.2.1.3.1
Polarization (select one)	LHCP RHCP	–
Frequency (GHz)	12.75-13.25 13.75-14.50 17.3-17.8 (Regions 1 and 3)	–
Maximum number of carriers per beam	132 (61 per polarization)	–

1.2.1.3.1 Gain patterns using an equation (feeder link)

Parameter	Value
Reference pattern (text e.g. ITU-R Recommendation or set of equations) Also describe the reference coordinate system (text, e.g. satellite fixed, earth fixed)	$32 - 25 \log(\theta)$ Sidelobe pattern
Parameters as required by reference pattern	–

1.2.1.4 Satellite fixed beams (service link)

Parameter	Value	Reference
Boresight azimuth (degrees)	–	Table 30
Boresight elevation (degrees)	–	Table 30
Rotation angle around beam boresight (if gain pattern is non-symmetric) (degrees)	N/A	–
Gain pattern (text to reference list below)	–	§ 1.2.1.5

1.2.1.5 Gain patterns (service link)

Parameter	Value	Reference
Method to determine shape (select one)	One dimensional table	Table 31
Polarization (select one)	LHCP RHCP	–
Frequency (GHz)	14.0-14.5	–
Maximum number of carriers per beam	96 (48 carriers per polarization)	–

TABLE 30

Boresight azimuth and elevation

Beam Number	Azimuth (degrees)	Elevation (degrees)
0	0.00	0.00
10	4.75	0.00
11	2.38	4.11
12	–2.38	4.11
13	–4.75	0.00
14	–2.38	–4.11
15	2.38	–4.11
20	9.00	0.00
21	7.14	4.13
22	4.50	7.79
23	0.00	8.25
24	–4.50	7.79
25	–7.14	4.13
26	–9.00	0.00
27	–7.14	–4.13
28	–4.50	–7.79
29	0.00	–8.25
210	4.50	–7.79
211	7.14	–4.13
30	12.00	0.00
31	11.06	3.97
32	8.97	7.59
33	6.00	10.39
34	2.09	11.56
35	–2.09	11.56
36	–6.00	10.39
37	–8.97	7.59
38	–11.06	3.97
39	–12.00	0.00
310	–11.06	–3.97
311	–8.97	–7.59
312	–6.00	–10.39
313	–2.09	–11.56
314	2.09	–11.56
315	6.00	–10.39
316	8.97	–7.59
317	11.06	–3.97

TABLE 31

One dimensional gain pattern (service link)

Angle (degrees)	Gain (dB)
0	32.2
0.25	32.2
0.5	32.0
0.75	31.7
1	31.4
1.25	30.8
1.5	30.2
1.75	29.5
2	28.5
2.25	27.5
2.5	26.2
2.75	24.8
3	23.0
3.25	21.0
3.5	18.4
3.75	15.3
4	10.9
4.25	3.5
4.5	–15.2
4.75	3.6
5	8.0
5.25	10.2
5.5	11.2
5.75	11.5
6	11.3
6.25	10.6
6.5	9.4
6.75	7.6
7	5.0
7.25	1.2
7.5	–5.7
7.75	–22.7
8	–4.5
8.25	0.3
8.5	2.7
8.75	4.1
9	4.7
9.25	4.7
9.5	4.3
9.75	3.4
10	1.9
10.25	–0.4
10.5	–3.9
10.75	–10.2
11	–36.6
11.25	–10.0
11.5	–4.8
11.75	–2.0
12	–0.4

1.2.2 Downlink from non-GSO

1.2.2.1 Satellite antenna configuration

Parameter	Value	Reference
Beam orientation method (pick one)	Feeder link: steerable Service link: sat fixed	§ 1.2.2.2 § 1.2.2.4
Maximum possible number of beams per satellite	Feeder link: 2 Service link: 37	–
Frequency and polarization reuse pattern (attach diagram or describe in sufficient detail). Submit multiple entries if necessary	Three-cell reuse (see Fig. 2)	–

1.2.2.2 Steerable beams (feeder link)

Parameter	Value	Reference
Gain pattern	–	§ 1.2.2.3

1.2.2.3 Gain patterns (feeder link)

Parameter	Value	Reference
Method to determine shape (select one)	One dimensional table	Table 30
Polarization (select one)	LHCP RHCP	–
Frequency (GHz)	10.7-11.7	–
Maximum number of carriers per beam	98 (49 per polarization)	–

1.2.2.3.1 Gain patterns using an equation (feeder link)

Parameter	Value
Reference pattern (text e.g. ITU-R Recommendation or set of equations) Also describe the reference coordinate system (text, e.g. satellite fixed, earth fixed)	$32 - 25 \log(\theta)$ Sidelobe pattern
Parameters as required by reference pattern	–

1.2.2.4 Satellite fixed beams (service link)

Parameter	Value	Reference
Boresight azimuth (degrees)	–	Table 30
Boresight elevation (degrees)	–	Table 30
Rotation angle around beam boresight (if gain pattern is non-symmetric) (degrees)	N/A	–
Gain pattern (text to reference list below)	–	§ 1.2.2.5

1.2.2.5 Gain patterns (service link)

For each of the gain patterns used the following is required:

Parameter	Value	Reference
Method to determine shape (select one)	One dimensional table	Table 31
Polarization (select one)	LHCP RHCP	–
Frequency (GHz)	11.7-12.7	–
Maximum number of carriers per beam	6 (3 carriers per polarization)	–

1.3 Beam and satellite selection strategies

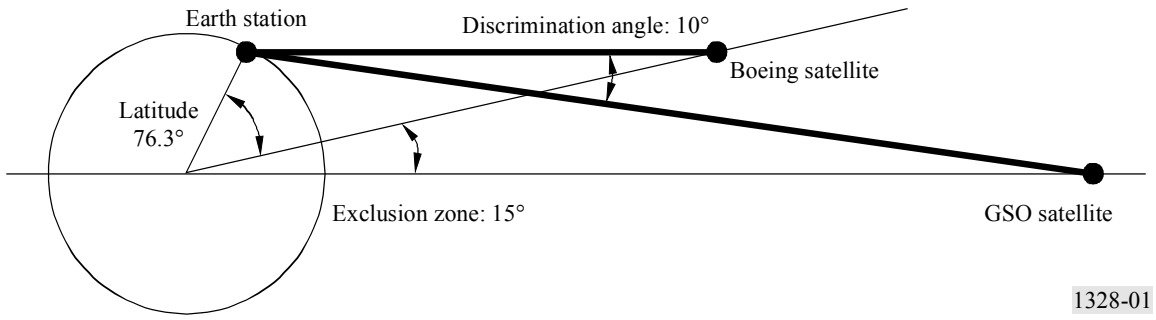
Parameter	Value
GSO arc avoidance angle and whether the angle is from a point or an area (degrees)	±10 (see Note 1)
Minimum elevation angle to the user station and whether the angle is from a point or an area (degrees)	30 (under all conditions)
Maximum number of simultaneous co-frequency beams per satellite while in the non-operating and operating zones	Operating zone: Service links: 13 Feeder links: 2 Non-operating zone: All beams off
Maximum number of simultaneous copolarization beams per satellite while in the non-operating and operating zones	Operating zone: Service links: 37 Feeder links: 2 Non-operating zone: All beams off

NOTE 1 – The USAKU1 system employs an interference mitigation technique that eliminates main-beam to main-beam interference. The USAKUM1 satellites are at a medium Earth orbit (MEO) altitude of 20 182 km

and neither the satellites nor associated earth stations will transmit when the spacecraft are within 15° latitude of the Equator. When the USAKUM 1 satellites enter the exclusion zone, traffic is switched to a USAKUM1 satellite that is not within the exclusion zone. This interference geometry is shown in Fig. 1 (see Note 2).

FIGURE 1

GSO interference geometry



NOTE 2 – This diagram shows the interference geometry when both the earth station and USAKUM1 satellite are at northern latitudes. Because the USAKUM1 satellite constellation is symmetric, the interference geometry will be symmetric in the southern latitudes. In the following discussion, reference is made only to the northern latitudes recognizing this symmetry.

Figure 1 serves two purposes in this interference analysis. When addressing non-GSO space-to-Earth interference, the earth station in this Figure refers to an earth station operating in a GSO network. When addressing non-GSO Earth-to-space interference into GSO networks, the same earth station refers to an earth station operating as a part of the USAKUM1 non-GSO FSS system.

In both cases, the earth station has a minimum discrimination angle of at least 10° between GSO satellites and all USAKUM1 non-GSO satellites – illustrating the fact that main beam-to-main beam events never occur with the USAKUM1 system. The earth station's location, 76.3º is at the worst-case location for a GSO earth station.

The worst-case geometry occurs when an earth station, a GSO satellite and a non-GSO satellite all operate at the same longitude. This is the basic conservative geometric configuration used in this Annex. With the USAKUM1 non-GSO satellite at the edge of the exclusion zone (15º latitude), and the GSO earth station at 76.5º latitude operating with a minimum elevation angle of 5º, the discrimination angle between the GSO satellite and the USAKUM1 non-GSO satellite is 10º.

In all other realistic scenarios, an earth station communicating with a GSO satellite will have a larger discrimination angle between the GSO arc and any operating USAKUM1 satellite. There is no point on Earth where a GSO earth station antenna would have a transmitting USAKUM1 satellite in its main beam and no point on Earth where a USAKUM1 earth station antenna would have a GSO satellite in its main beam. In other words, because of the use of a MEO constellation and a 15º latitude equatorial exclusion zone, main beam-to-main beam and sidelobe-to-main beam interference scenarios do not occur with respect to space-to-Earth transmissions from the USAKUM1 system into GSO earth stations. At the same time, the main beam-to-main beam and main beam-to-sidelobe interference scenarios do not occur with respect to Earth-to-space transmissions from USAKUM1 earth stations into GSO satellites.

1.4 RF link parameters

1.4.1 Transparent payload – IDS feeder and service links (return)

Performance objectives	Value
Required $C/(N + I)$ (dB) % of the year $C/(N + I)$ should be exceeded	–19.8
Maximum operating pfd on the ground (dB(W/(m^2 · 4 kHz)))	–149
Wave form description	
Access type (TDMA, FDMA, CDMA…)	CDMA
If CDMA, then provide the maximum number of co-frequency carriers	98
Modulation type (e.g. FM, QPSK, BPSK)	QPSK
Noise bandwidth per carrier (MHz)	20
Occupied bandwidth per carrier (MHz)	20
Assigned bandwidth per carrier (MHz)	20
Transmit earth station characteristics (service link)	
Rain model (ITU/Crane)	ITU
Peak antenna gain (dB)	34.6
Antenna beamwidth (degrees)	3
Antenna pointing loss (dB)	0.2
Antenna pattern	29 – 25 log(θ)
On-axis earth station transmit e.i.r.p./carrier (dBW)	45
Inter-modulation earth station ratio (dB)	To be defined
Power control range (> 0, 0 dB in none) (dB)	20
Power control accuracy (applicable only if uplink power control used) (dB)	To be defined
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	To be defined
Receive earth station characteristics (feeder link)	
Earth station receive noise temperature (K)	198.7
Peak antenna gain (dBi)	52.2
Antenna beamwidth (degrees)	0.4
Antenna pointing loss (dB)	0.2
Antenna pattern	29 – 25 log(θ)
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	To be defined
Tracking strategy (fixed or tracking)	Tracking
If fixed, indicate either omnidirectional or supply azimuth and elevation pointing angles	–
Space station receive characteristics	
Transponder bandwidth (MHz)	20
Receive frequency (GHz)	14.0-14.5
Receive polarization (H: horizontal, V: vertical, C: circular)	C
Satellite receive temperature (K)	453.6
Receive cross-polarization isolation ratio (100 if not applicable) (dB)	To be defined
Receive frequency reuse isolation ratio (dB)	20

	Value
Space station transmit characteristics	
Transponder bandwidth (MHz)	20
Transmit polarization (H, V, C)	C
Maximum satellite e.i.r.p. (dBW)	38.9
Transmit cross-polarization isolation ratio (100 if not applicable) (dB)	To be defined
Transmit frequency reuse isolation ratio (100 if not applicable) (dB)	To be defined
Transponder inter-modulation ratio (100 if not applicable) (dB)	To be defined

1.5 Re-modulating payloads – IDS feeder and service links (forward)

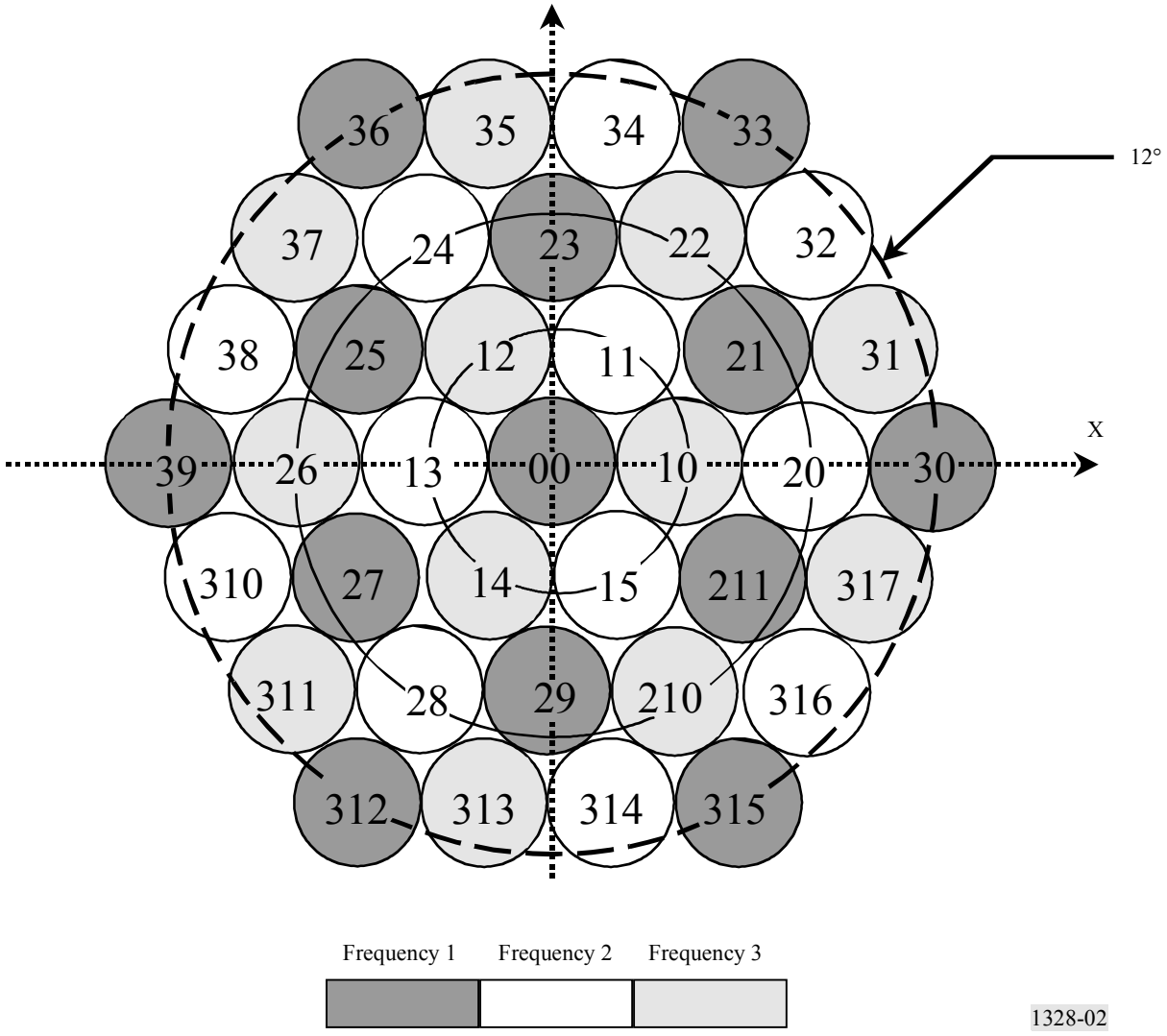
Uplink performance objectives	Value
Required $C/(N + I)$ (dB) % of the year $C/(N + I)$ should be exceeded	7.0
Uplink wave form description	
Variable coding rate	No
Access type (TDMA, FDMA, CDMA...)	FDM
If CDMA, then provide the maximum number of co-frequency carriers	–
Modulation type (e.g. FM, QPSK, BPSK)	QPSK
Noise bandwidth per carrier (MHz)	5.2
Occupied bandwidth per carrier (MHz)	6.24
Assigned bandwidth per carrier (MHz)	7.15
Repeater receive bandwidth (MHz)	–
Downlink performance objectives	
Required $C/(N + I)$ (dB) % of the year $C/(N + I)$ should be exceeded	–10.8
Maximum operating pfd on the ground (dB(W/(m^2 · 4 kHz)))	–149
Downlink wave form description	
Variable coding rate	No
Access type (TDMA, FDMA, CDMA...)	CDM
Modulation type (e.g. FM, QPSK, BPSK)	QPSK
Noise bandwidth per carrier (MHz)	124.8
Occupied bandwidth per carrier (MHz)	166
Assigned bandwidth per carrier (MHz)	166
Repeater transmit bandwidth (MHz)	–
Transmit earth station characteristics (feeder link)	
Rain model (ITU/Crane)	ITU
Peak antenna gain (dB)	53.5
Antenna beamwidth (degrees)	0.4
Antenna pointing loss (dB)	0.2
Antenna pattern	29 – 25 log(θ)
On-axis earth station transmit e.i.r.p./carrier (dBW)	48.6

	Value
Transmit earth station characteristics (feeder link) (continued)	
Inter-modulation earth station ratio (100 if not applicable) (dB)	To be defined
Power control range (> 0, 0 dB in none) (dB)	20
Power control accuracy (applicable only if uplink power control used) (dB)	To be defined
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	To be defined
Receive earth station characteristics (service link)	
Earth station receive noise temperature (K)	232
Peak antenna gain (dBi)	36.1
Antenna beamwidth (degrees)	2.6
Antenna pointing loss (dB)	0.3
Antenna pattern	$29 - 25 \log(\theta)$
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	To be defined
Tracking strategy (fixed or tracking)	Tracking
If fixed, indicate either omnidirectional or supply azimuth and elevation pointing angles	–
Space station receive characteristics	
Receive frequency (GHz)	12.75-13.25 13.75-14.5 17.3-17.8 (Regions 1 and 3)
Receive polarization (H, V, C)	C
Satellite receive temperature (K)	450
Receive cross-polarization isolation ratio (100 if not applicable) (dB)	To be defined
Receive frequency reuse isolation ratio (100 if not applicable) (dB)	To be defined
Space station transmit characteristics	
Transmit polarization (H, V, C)	C
Maximum satellite e.i.r.p. (dBW)	50.2
Transmit cross-polarization isolation ratio (100 if not applicable) (dB)	To be defined
Transmit frequency reuse isolation ratio (100 if not applicable) (dB)	To be defined
Transponder inter-modulation ratio (dB)	To be defined

1.6 Distribution of non-GSO earth stations

Parameter	Value
Coverage latitude bounds (degrees)	±90
Maximum number of co-frequency earth stations in the service zone of one satellite	3 552
Maximum number of typical co-frequency earth stations in a beam	96
Predicted density of earth stations per unit area in geographical territories (urban, suburban, low-populated areas) (m^{-2})	

FIGURE 2
Frequency and polarization reuse pattern



The USAKUM1 system has been designed so that it should not cause synch-loss events in GSO FSS or BSS systems.

2 Parameters of USAKUL1

This section provides the characteristics for USAKUL1 system to be used to simulate the system in the 80 satellite configuration. The parameters provided should also be used to update the characteristics for USAKUL1 in this Recommendation.

2.1 Orbit parameters

Parameter	Value	Variation
Number of satellites	80	N/A
Number of planes	20	N/A
Number of satellites per plane	4	N/A
Orbit type (select one)	Circular	N/A
Repeating ground track	Yes	N/A
Orbit inclination (degrees)	53	
Orbit period (min)	115	
Apogee altitude (km)	1 469.3	
Perigee altitude (km)	1 469.3	
Argument of perigee (degrees)	90	
Eccentricity	0	
Satellite angular separation within a plane (degrees)	90	
Satellite phasing between first satellites of adjacent planes (degrees)	67.5	
Angular separation between planes (degrees)	18	

2.2 Link parameters

2.2.1 Uplink to non-GSO satellite

2.2.1.1 Satellite antenna configuration

Parameter	Value	Reference
Beam orientation method	Steerable beams	§ 2.2.1.2
Maximum possible number of beams per satellite	24	–
Frequency and polarization reuse pattern (attach diagram or describe in sufficient detail). Submit multiple entries if necessary	No	–

2.2.1.2 Steerable beams

Parameter	Value	Reference
Max gain pattern		§ 2.2.1.3
Cell size and shape (km)	Circular cell of 350 km radius	–
Cell locations (latitude and longitude) (degrees)	Worldwide (latitude from –68 to 68 for the gateway location)	–

2.2.1.3 Gain patterns

Parameter	Value	Reference
Method to determine shape	Equation	§ 2.2.1.3.1
Polarization	LHCP RHCP	–
Frequency (GHz)	12.75-13.25 in Regions 1 and 3 13.75-14.5 in Region 2 17.3-17.8 in Regions 1 and 3 17.8-18.1 in Regions 1 and 3	–

2.2.1.3.1 Gain patterns using an equation

Parameter	Value	Reference
Reference pattern (text e.g. ITU-R Recommendation or set of equations) Also describe the reference coordinate system (text, e.g. satellite fixed, earth fixed)	See antenna gains hereafter	§ 2.2.1.3.2
Parameters as required by reference pattern	–	–

2.2.1.3.2 Satellite antenna gain

The gain of the USAKUL1 antennas can be modelled by an analytical function described below. This analytical function makes symmetrical the sidelobe peaks around the boresight of the antenna which worsens this aspect of interference into GSOs:

$$\frac{G(u)}{G_{max}} = \frac{2\,J_1(u)}{u} \times \prod_{i=1}^{3} \frac{\left[1 - \dfrac{u^2}{180^2 \times 1.1692^2 \times [0.95277^2 + (i - 1/2)^2]}\right]}{\left[1 - \left(\dfrac{u}{180\,\mu_i}\right)\right]} \times \frac{4\pi\,d_1^2}{4\pi\,d_2^2}$$

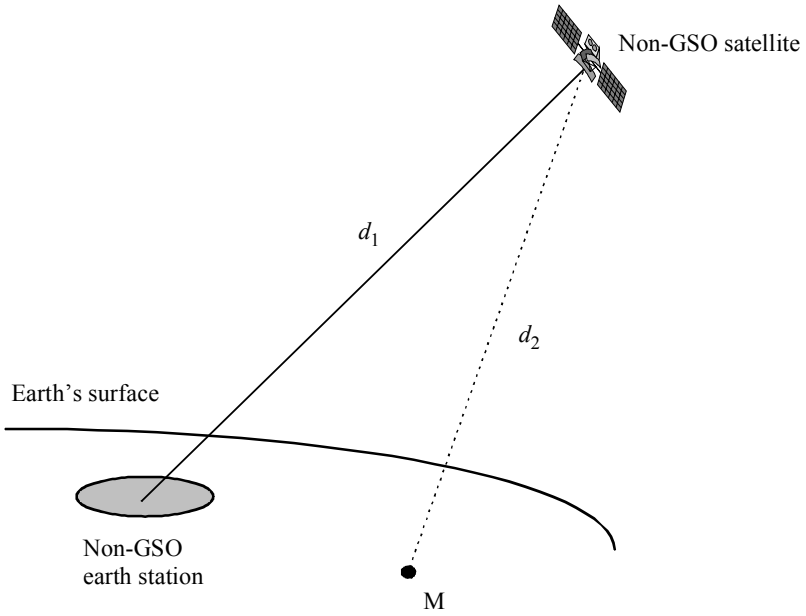
with:

μ_1, μ_2, μ_3: three primary roots of the J_1 Bessel function

d_1: distance between the non-GSO satellite and the non-GSO earth station

d_2: distance between the non-GSO satellite and the point where the gain is calculated.

FIGURE 3



Calculation of *u*

u is a function of both the antenna characteristics and the angle between the sub-satellite point and the illuminated beam as seen from the non-GSO satellite.

Let:

(θ, φ): coordinates of the centre of the illuminated beam

L_r and L_t: radial and transverse sizes of the effective radiating area of the satellite transmit antenna,

then:

$$u = \frac{\pi}{\lambda}\sqrt{(L_r \sin\theta\cos\varphi)^2 + (L_t \sin\theta\sin\varphi)^2}$$

The parameters L_r and L_t are defined with regard to the pointing angle of the illuminated spot as follows:

θ	[0°;40°]	[40°;47°]	[47°;49°]	[49°;52.5°]	[52.5°;54°]
$\frac{L_r}{\lambda}$	$\frac{0.74}{\sin a}$	$\frac{0.64}{\sin a}$	$\frac{0.51}{\sin a}$	$\frac{0.32}{\sin a}$	12.57
$\frac{L_t}{\lambda}$	$\frac{0.74}{\sin b}$	$\frac{0.64}{\sin b}$	$\frac{0.64}{\sin b}$	$\frac{0.65}{\sin b}$	4.84

where:

a: half radial axis distance of the illuminated beam

b: half transverse axis distance of the illuminated beam.

2.2.2 Downlink from non-GSO satellite

2.2.2.1 Gain patterns

Parameter	Value	Reference
Method to determine shape		–
Polarization	LHCP RHCP	–
Frequency (GHz)	10.7-12.7 in Region 2 10.7-12.75 in Regions 1 and 3	–

The other downlink parameters are the same as the uplink parameters.

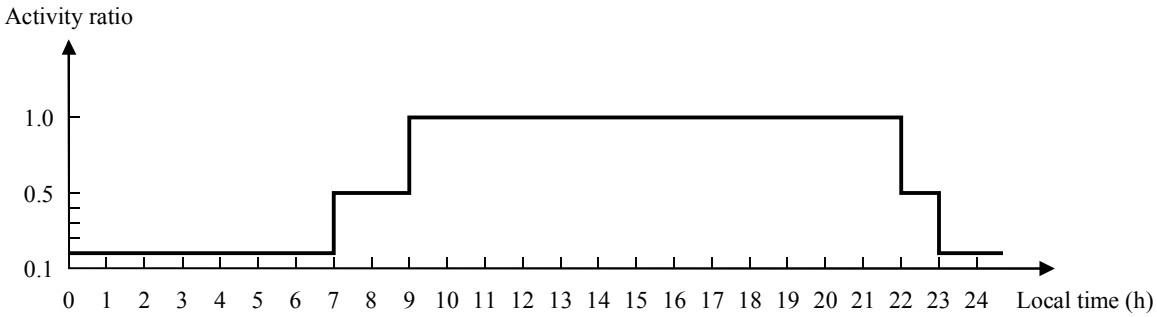
2.2.2.2 Beam and satellite selection strategies

The GSO arc protection consists in switching off the beams when any earth point within a cell sees an angular separation between the GSO arc and a USAKUL1 satellite of less than 10°.

The reference satellite selection strategy is a best elevation strategy.

A traffic model is applied to each beam with regard to its local time. The traffic model is shown in Fig. 4.

FIGURE 4



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Parameter	Value
GSO arc avoidance angle and whether the angle is from a point or an area (degrees)	±10° from any point in the beam area
Minimum elevation angle to the user station and whether the angle is from a point or an area (degrees)	10° from a user terminal
Maximum number of simultaneous co-frequency beams per satellite while in the non-operating and operating zones	24
Maximum number of simultaneous co-polarization beams per satellite while in the non-operating and operating zones	12

2.3 RF link parameters

2.3.1 Forward link

2.3.1.1 Transparent payload

Performance objectives	Value
Required $E_b/(N + I)$ (dB) % of the year $E_b/(N + I)$ should be exceeded	3.5
Maximum operating pfd on the ground (dB(W/(m^2 · 4 kHz)))	–155
Wave form description	
Access type (TDMA, FDMA, CDMA…)	FDM/TDM/CDMA
If CDMA, then provide the maximum number of co-frequency carriers (codes/carrier)	80
Modulation type (e.g. FM, QPSK, BPSK)	QPSK
Noise bandwidth per carrier (MHz)	22.6
Occupied bandwidth per carrier (MHz)	22.6
Assigned bandwidth per carrier (MHz)	22.6
Transmit earth station characteristics	
Rain model (ITU/Crane)	ITU
Peak antenna gain at 13 GHz (dBi)	53.1 (resp[(1)] 48.8)
Antenna beamwidth (degrees)	0.36 (resp 0.65)
Antenna pointing loss (dB)	–1.1 (resp –0.34)
Antenna pattern	29 – 25 log(θ)
Maximum on-axis earth station transmit e.i.r.p./carrier (dBW)	59.3 (resp 54.2)
Inter-modulation earth stations radio (dB)	–
Power control range (> 0, 0 dB in none) (dB)	6
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	20
Receive earth station characteristics	
Earth station receive noise temperature (K)	180 (resp 140)
Peak antenna gain at 12 GHz (dBi)	31.2 (resp 37.0)
Antenna beamwidth (degrees)	4.9 (resp 2.5)
Antenna pointing loss (dB)	–0.2 (resp –0.2)
Antenna pattern	36 – 25 log(θ) (resp 32 – 25 log(θ))
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	20
Tracking strategy (fixed or tracking)	Tracking
Space station receive characteristics	
Transponder bandwidth (MHz)	250
Receive frequency (GHz)	13
Receive polarization (H, V, C)	RHCP/LHCP
Satellite receive temperature (K)	455
Receive cross-polarization isolation ratio (100 if not applicable) (dB)	17
Receive frequency reuse isolation ratio (dB)	–

	Value
Space station transmit characteristics	
Transponder bandwidth (MHz)	250
Transmit frequency (GHz)	12
Transmit polarization (H, V, C)	RHCP/LHCP
Maximum satellite e.i.r.p. (dBW)	27.5
Transmit cross-polarization isolation ratio (100 if not applicable) (dB)	20
Transmit frequency reuse isolation ratio (100 if not applicable) (dB)	–
Transponder inter-modulation ratio (100 if not applicable) (dB)	–

(1) The term "resp" refers to the characteristics of a second earth station of this system.

2.3.1.2 Re-modulating payloads

Not applicable to USAKUL1.

2.3.2 Return link

2.3.2.1 Transparent payload

Performance objectives	Value
Required $E_b/(N + I)$ (dB) % of the year $E_b/(N + I)$ should be exceeded	3.5
Maximum operating pfd on the ground (dB(W/(m^2 · 4 kHz)))	–155
Wave form description	
Access type (TDMA, FDMA, CDMA…)	FDM/TDM/CDMA
If CDMA, then provide the maximum number of co-frequency carriers	40
Modulation type (e.g. FM, QPSK, BPSK)	QPSK
Noise bandwidth per carrier (MHz)	2.93
Occupied bandwidth per carrier (MHz)	2.93
Assigned bandwidth per carrier (MHz)	2.93
Transmit earth station characteristics	
Rain model (ITU/Crane)	ITU
Peak antenna gain (dB)	32.7 (resp(1) 38.4)
Antenna beamwidth (degrees)	4.1 (resp 2.1)
Antenna pointing loss (dB)	–0.2 (resp –0.3)
Antenna pattern	36 – 25 log(θ) (resp 32 – 25 log(θ))
Maximum on-axis earth station transmit e.i.r.p./carrier (dBW)	36 (resp 46.4)
Inter-modulation earth station ratio (dB)	–
Power control range (> 0, 0 dB in none) (dB)	2 (resp 5)
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	20

	Value
Receive earth station characteristics	
Earth station receive noise temperature (K)	190
Peak antenna gain (dBi)	51.9 (resp 47.5)
Antenna beamwidth (degrees)	0.4 (resp 0.75)
Antenna pointing loss (dB)	–0.8 (resp –0.16)
Antenna pattern	29 – 25 log(θ)
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	20
Tracking strategy (fixed or tracking)	Tracking
Space station receive characteristics	
Transponder bandwidth (MHz)	300
Receive frequency (GHz)	14.15
Receive polarization (H, V, C)	RHCP/LHCP
Satellite receive temperature (K)	455
Receive cross-polarization isolation ratio (100 if not applicable) (dB)	20
Receive frequency reuse isolation ratio (dB)	–
Space station transmit characteristics	
Transponder bandwidth (MHz)	300
Transmit frequency (GHz)	11.25
Transmit polarization (H, V, C)	RHCP/LHCP
Maximum satellite e.i.r.p./carrier (dBW)	28.7
Transmit cross-polarization isolation ratio (100 if not applicable) (dB)	17
Transmit frequency reuse isolation ratio (100 if not applicable) (dB)	–
Transponder inter-modulation ratio (100 if not applicable) (dB)	–

(1) The term "resp" refers to the characteristics of a second earth station of this system.

2.3.2.2 Re-modulating payloads

Not applicable to USAKUL1.

3 Parameters of the USAKU-H2 system

The proposed USAKU-H2 system consists of fifteen (15) non-geostationary satellites in sub-geosynchronous inclined elliptical orbits. It is proposed to provide FSS to all of the world's populated land masses through a combination of user and gateway links in the C-band and Ku-bands, as well as through ISL in the optical frequencies.

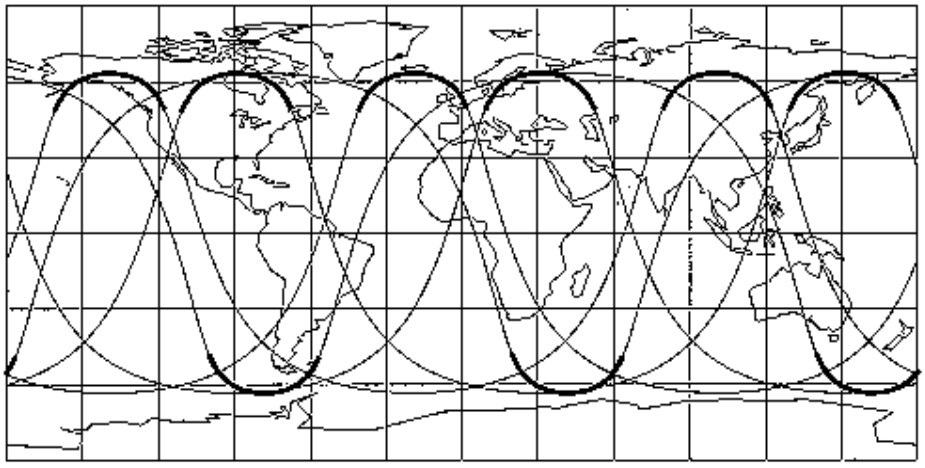
3.1 Orbit parameters

The proposed USAKU-H2 system is comprised of three five-satellite sub-constellations - two for Northern Hemisphere operation (and identified herein as Aurora I^{TM} and Aurora II^{TM} and one for Southern Hemisphere operation (identified herein as Australis^{TM}). The active arcs of the USAKU-H2 satellites in each sub-constellation occur only when the satellites are at latitudes above 45°, when they are at high elevations over much of their primary service areas in the Northern and Southern Hemispheres, respectively. The USAKU-H2 system thus achieves an optimized combination of very high elevation angles, low signal propagation delays compared to geostationary satellites, and limited satellite handoffs. It also provides non-uniform distribution of capacity to the Northern and Southern Hemispheres in proportion with demand. Figure 5 shows the

Northern and Southern Hemispheres in proportion with demand. Figure 5 shows the sub-satellite ground tracks of the USAKU-H2 system, with the active service arcs indicated by the bold line.

FIGURE 5

Sub-satellite ground tracks of the USAKU-H2 system



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The proposed USAKU-H2 system operates in a manner that is effectively transparent to co-frequency geostationary FSS and geostationary BSS networks. USAKU-H2 satellites are separated from the geostationary arc by at least 40° at all times within the system's service areas.

Parameter	Value	Variation
Number of satellites	15	N/A
Number of planes	15	N/A
Number of satellites per plane	1	N/A
Orbit type (select one)	Elliptical	N/A
Repeating ground track	Yes	N/A
Orbit inclination (degrees)	63.435	
Orbit period (min)	480	
Apogee altitude (km)	27 288.3	
Perigee altitude (km)	517.4	
Argument of perigee (degrees)	See Table below	
Eccentricity	0.66	
Satellite angular separation within a plane (degrees)	N/A	
Satellite phasing between first satellites of adjacent planes (degrees)	See Table below	
Angular separation between planes (degrees)	See Table below	

Additional orbit information for the USAKU-H2 system is provided in following Table. All orbits have a semi-major axis of 20 281 km. These orbital elements are defined for an epoch date of 0 h UTC, 1 January 2005.

Additional orbit parameters

Plane	Right ascension of the ascending node (RAAN) of plane	Angular separation between planes (degrees)	Mean anomaly of satellite in plane (degrees)	Satellite phasing relative to previous plane	Argument of perigee (degrees)
1	39.3	57.8	36.2	36.2	270
2	52.5	13.2	0	323.8	90
3	53.5	1	144	144	270
4	111.3	57.8	180.2	36.2	270
5	124.5	13.2	144	323.8	90
6	125.5	1	288	144	270
7	183.3	57.8	324.2	36.2	270
8	196.5	13.2	288	323.8	90
9	197.5	1	72	144	270
10	255.3	57.8	108.2	36.2	270
11	268.5	13.2	72	323.8	90
12	269.5	1	216	144	270
13	327.3	57.8	252.2	36.2	270
14	340.5	13.2	216	323.8	90
15	341.5	1	0	144	270

3.2 Link parameters

3.2.1 Uplink to non-GSO

3.2.1.1 Satellite antenna configuration

Parameter	Value	Reference
Beam orientation method	Steerable	§ 3.2.1.2
Maximum possible number of beams per satellite: User beams Gateway beams	 > 28 4	–
Frequency and polarization reuse pattern (attach diagram or describe in sufficient detail). Submit multiple entries if necessary	Full frequency reuse by orthogonal polarizations Beams are reconfigurable	–

3.2.1.2 Steerable beams

Parameter	Value	Reference
Gain pattern	See Doc. PDNR S.[4A/422]	§ 3.2.1.3

3.2.1.3 Gain patterns

Parameter	Value	Reference
Method to determine shape	Equation	§ 3.2.1.3.1
Polarization	Both LHCP and RHCP	–
Frequencies (GHz): User beams Gateway beams	 14.000-14.500 12.750-13.250 13.800-14.000 17.300-17.800 (Regions 1 and 3) 5.925-6.725	–
Maximum number of carriers per beam	Variable – multi-carrier	–

3.2.1.3.1 Gain patterns using an equation

Parameter	Value
Reference pattern (text e.g. ITU-R Recommendation or set of equations)	See Doc. PDNR S.[4A/422]
Parameters as required by reference pattern	$L_N = -15$ dB; $L_F = -25$ dB Peak gain is dynamically variable to compensate for changing altitude during active service arc

3.2.2 Downlink from non-GSO

3.2.2.1 Satellite antenna configuration

Parameter	Value	Reference
Beam orientation method	Steerable	§ 3.2.2.2
Maximum possible number of beams per satellite: User beams Gateway beams	 > 28 4	–
Frequency and polarization reuse pattern (attach diagram or describe in sufficient detail). Submit multiple entries if necessary	Full frequency reuse by orthogonal polarizations Beams are reconfigurable	–

3.2.2.2 Steerable beams

Parameter	Value	Reference
Gain pattern	See Doc. PDNR S.[4A/422]	§ 3.2.2.3

3.2.2.3 Gain patterns

Parameter	Value	Reference
Method to determine shape	Equation	§ 3.2.2.4
Polarization	Both LHCP and RHCP	–
Frequencies (GHz): User beams Gateway beams	 11.200-12.700 10.700-11.200 3.700-4.200	–
Maximum number of carriers per beam	Variable – multi-carrier	–

3.2.2.4 Gain patterns using an equation

Parameter	Value
Reference pattern (text e.g. ITU-R Recommendation or set of equations)	See Doc. PDNR S.[4A/422]
Parameters as required by reference pattern	$L_N = -15$ dB; $L_F = -25$ dB Peak gain is dynamically variable to compensate for changing altitude during active service arc

3.3 Beam and satellite selection strategies

GSO protection main principles: GSO networks are protected by complete arc avoidance. Whenever the non-GSO space station is within 40° of the line-of-sight of the GSO link (measured at the GSO Rx earth station in the case of the downlink, and at the non-GSO Tx earth station in the case of the uplink) all communication transmissions to and from that non-GSO space station will cease.

Mitigation technique strategy (non-operating zone strategy): No satellite diversity switching is required to implement the above arc avoidance scheme. non-GSO satellites are only active during the portions of their orbit near to apogee, and the orbits are highly inclined.

Reference tracking strategies: Earth stations generally track the non-GSO satellite with the highest elevation angle.

Parameter	Value
GSO arc avoidance angle and whether the angle is from a point or an area (degrees)	40 (area)
Minimum elevation angle to the user station and whether the angle is from a point or an area (degrees)	40 (area)
Maximum number of simultaneous co-frequency beams per satellite while in the non-operating and operating zones	None (non-operating zone) 7 user beams (operating zone) 4 gateway beams (operating zone)
Maximum number of simultaneous co-polarization beams per satellite while in the non-operating and operating zones	None (non-operating zone) 14 user beams (operating zone) 4 gateway beams (operating zone)

3.4 RF link parameters

3.4.1 Transparent payload

Performance objectives	Value
Required $C/(N + I)$ (dB) % of the year $C/(N + I)$ should be exceeded	3.0 (Availability depends on rain zone)
Maximum operating pfd on the ground (dB(W/(m^2 · 4 kHz))): User beams in the 11.200-12.700 GHz band Gateway beams in the 10.700-11.200 GHz band Gateway beams in the 3.700-4.200 GHz band	 –151 –160 –165
Wave form description	
Access type (TDMA, FDMA, CDMA…)	FDMA
If CDMA, then provide the maximum number of co-frequency carriers	N/A
Modulation type (e.g. FM, QPSK, BPSK)	QPSK
Noise bandwidth per carrier (kHz)	Variable – multi-carrier
Occupied bandwidth per carrier (MHz)	Variable – multi-carrier
Assigned bandwidth per carrier (MHz)	Variable – multi-carrier
Transmit earth station characteristics	
Rain model (ITU/Crane)	ITU
Peak antenna gain (dBi): User terminal in the 14.000-14.500 GHz band Gateway terminal in the 12.750-13.250 and 13.800-14.000 GHz bands Gateway terminal in the 17.300-17.800 GHz band Gateway terminal in the 5.925-6.725 GHz band	 34.3 55.1 57.0 48.2
Antenna beamwidth (degrees): User terminal in the 14.000-14.500 GHz band Gateway terminal in the 12.750-13.250 and 13.800-14.000 GHz bands Gateway terminal in the 17.300-17.800 GHz band Gateway terminal in the 5.925-6.725 GHz band	 3.3 0.30 0.24 0.66
Antenna pointing loss (dB)	0.2
Antenna pattern	36 – 25 log(θ)

	Value
Transmit earth station characteristics (continued)	
On-axis earth station transmit e.i.r.p. density (dB(W/Hz)): User terminal in the 14.000-14.500 GHz band Gateway terminal in the 12.750-13.250 and 13.800-14.000 GHz bands Gateway terminal in the 17.300-17.800 GHz band Gateway terminal in the 5.925-6.725 GHz band	 −21.7 −10.9 −9.0 −12.8
Inter-modulation earth station ratio (dB)	22
Power control range (above maximum levels given above) (dB): User terminal in the 14.000-14.500 GHz band Gateway terminal in the 12.750-13.250 and 13.800-14.000 GHz bands Gateway terminal in the 17.300-17.800 GHz band Gateway terminal in the 5.925-6.725 GHz band	 5.5 13.5 14.5 5.7
Power control accuracy (applicable only if uplink power control used) (dB)	To be defined
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	25
Receive earth station characteristics	
Earth station receive noise temperature (K): User terminal in the 11.200-12.700 GHz band Gateway terminal in the 10.700-11.200 GHz band Gateway terminal in the 3.700-4.200 GHz band	 110 110 80
Peak antenna gain (dBi): User terminal in the 11.200-12.700 GHz band Gateway terminal in the 10.700-11.200 GHz band Gateway terminal in the 3.700-4.200 GHz band	 32.8 53.7 44.1
Antenna beamwidth (degrees): User terminal in the 11.200-12.700 GHz band Gateway terminal in the 10.700-11.200 GHz band Gateway terminal in the 3.700-4.200 GHz band	 3.9 0.35 1.06
Antenna pointing loss (dB)	0.2
Antenna pattern	$36 - 25 \log(\theta)$
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	25
Tracking strategy (fixed or tracking)	Tracking
If fixed, indicate either omnidirectional or supply azimuth and elevation pointing angles	N/A
Space station receive characteristics	
Transponder bandwidth (MHz)	To be defined
Receive frequency (GHz): User beams Gateway beams	 14.000-14.500 12.750-13.250 13.800-14.000 17.300-17.800 (Regions 1 and 3) 5.925-6.725
Receive polarization (H, V, C)	C
Satellite receive temperature (K)	600
Receive cross-polarization isolation ratio (100 if not applicable) (dB)	28
Receive frequency reuse isolation ratio (dB)	18
Space station transmit characteristics	
Transponder bandwidth (MHz)	To be defined
Transmit polarization (H, V, C)	C

	Value
Space station transmit characteristics (continued)	
Maximum satellite e.i.r.p. spectral densities (dB(W/Hz)): User beams in the 11.200-12.700 GHz band Gateway beams in the 10.700-11.200 GHz band Gateway beams in the 3.700-4.200 GHz band	 –25.0 –37.3 –42.3
Transmit cross-polarization isolation ratio (100 if not applicable) (dB)	28
Transmit frequency reuse isolation ratio (100 if not applicable) (dB)	18
Transponder inter-modulation ratio (100 if not applicable) (dB)	22

3.5 Distribution of non-GSO earth stations

Parameter	Value
Coverage latitude bounds	90° S to 90° N
Maximum number of co-frequency earth stations in the service zone of one satellite	21
Maximum number of typical co-frequency earth stations in a beam	3
Predicted density of earth stations per unit area in geographical territories (urban, suburban, low-populated areas) (m^{-2})	To be defined

4 Parameters of the USAKUL2 system

4.1 Orbit parameters

Parameter	Value	Variation
Number of satellites	70	N/A
Number of planes	10	N/A
Number of satellites per plane	7	N/A
Orbit type (select one)	Circular	N/A
Repeating ground track	Yes	N/A
Orbit inclination (degrees)	54.5	
Orbit period (min)	115	
Apogee altitude (km)	1 490	
Perigee altitude (km)	1 490	
Argument of perigee (degrees)	0	
Eccentricity	0	
Satellite angular separation within a plane (degrees)	51.42	
Satellite phasing between first satellites of adjacent planes (degrees)	30.857	
Angular separation between planes (degrees)	36	

4.2 Link parameters

4.2.1 Uplink to non-GSO

4.2.1.1 Satellite antenna configuration

Parameter	Value	Reference
Beam orientation method	Satellite fixed	–
Maximum possible number of beams per satellite	210	Fig. 6
Frequency and polarization reuse pattern (attach diagram or describe in sufficient detail). Submit multiple entries if necessary	7 colour frequency reuse	–

4.2.1.2 Satellite fixed beams (service link)

Parameter	Value	Reference
Boresight azimuth (degrees)	See reference	Fig. 6
Boresight elevation (degrees)	See reference	Fig. 6
Rotation angle around beam boresight (if gain pattern is non-symmetric) (degrees)	N/A	–
Gain pattern (text to reference list below)	–	Fig. 7

FIGURE 6

USAKUL2 spot beam coverage (Tx and Rx)

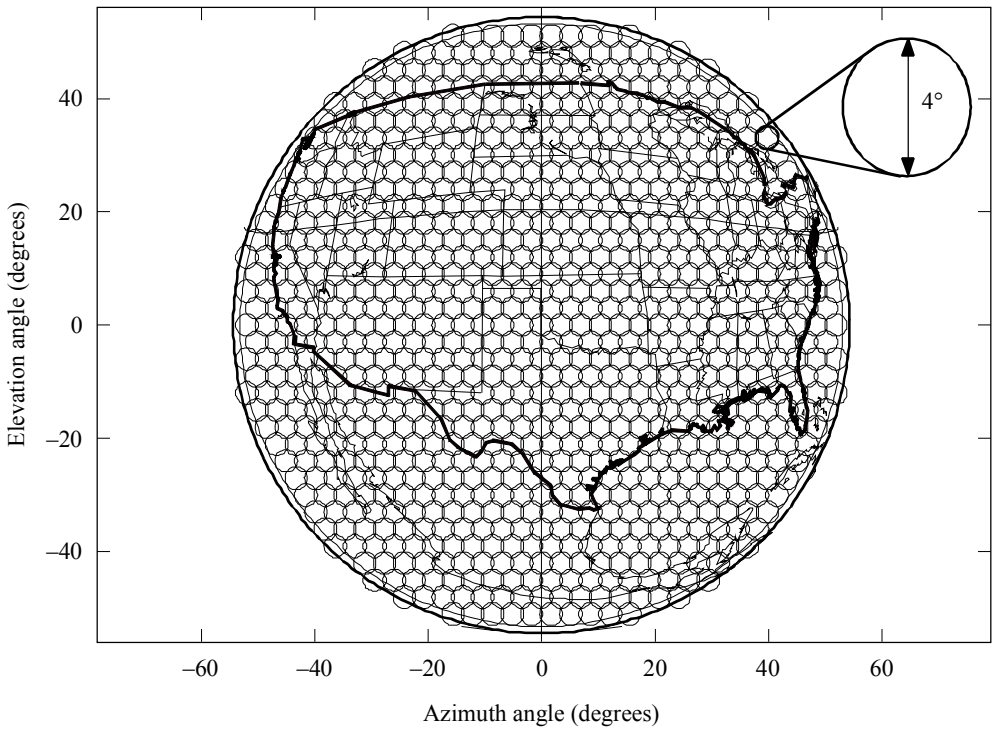
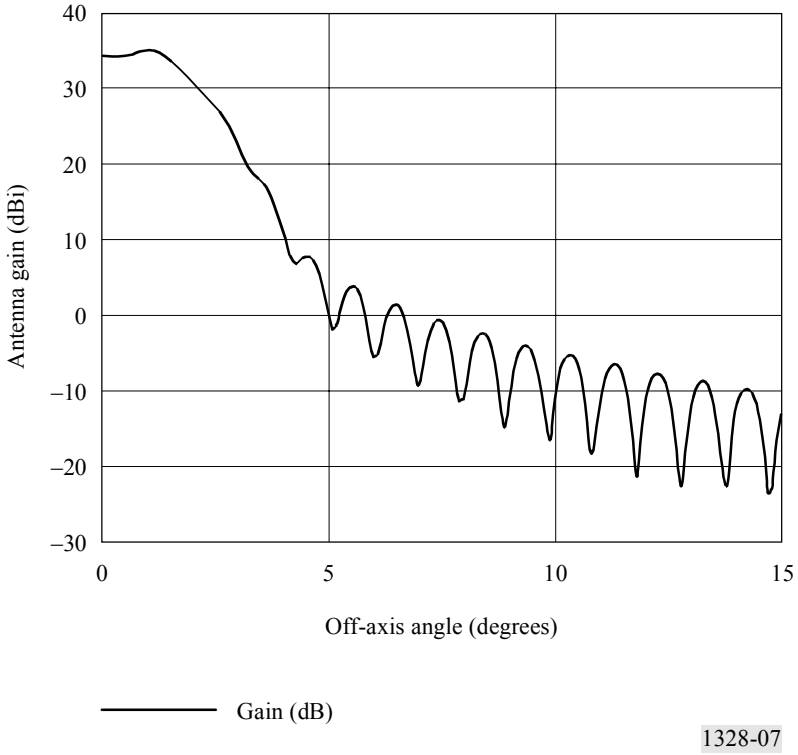


FIGURE 7

USAKUL2 spot beam antenna gain pattern (Tx and Rx)



4.2.1.3 Gain patterns (service link)

Parameter	Value	Reference
Method to determine shape (select one)	See reference	Fig. 7
Polarization (select one)	LHCP or RHCP	–
Frequency (GHz)	1 GHz spectrum within 12.75-13.25, 13.75-14.5 and 17.3-17.8 (Regions 1 and 3 only)	–
Maximum number of carriers per beam	To be defined	–

4.2.2 Downlink from non-GSO

4.2.2.1 Satellite antenna configuration

Parameter	Value	Reference
Beam orientation method	Satellite fixed	–
Maximum possible number of beams per satellite	210	Fig. 6
Frequency and polarization reuse pattern (attach diagram or describe in sufficient detail). Submit multiple entries if necessary	7 colour frequency reuse	–

4.2.2.2 Satellite fixed beams (service link)

Parameter	Value	Reference
Boresight azimuth (degrees)	N/A	Fig. 6
Boresight elevation (degrees)	N/A	Fig. 6
Rotation angle around beam boresight (if gain pattern is non-symmetric) (degrees)	N/A	–
Gain pattern (text to reference list below)	–	Fig. 7

4.2.2.3 Gain patterns (service link)

Parameter	Value	Reference
Method to determine shape (select one)	See reference	Fig. 7
Polarization (select one)	LHCP or RHCP	–
Frequency (GHz)	1 GHz spectrum within 10.7-12.7 (Region 2) and 10.7-12.75 (Regions 1 and 3)	–
Maximum number of carriers per beam	To be defined	–

4.3 Beam and satellite selection strategies

Parameter	Value
GSO arc avoidance angle and whether the angle is from a point or an area (degrees)	±10 (Any point in the beam)
Minimum elevation angle to the user station and whether the angle is from a point or an area (degrees)	9
Maximum number of simultaneous co-frequency beams per satellite while in the non-operating and operating zones	30 (867 beams position) (15 co-frequency and co-polarization)
Maximum number of simultaneous co-polarization beams per satellite while in the non-operating and operating zones	105

4.4 RF link parameters

4.4.1 Return links

4.4.1.1 Transparent payload

Performance objectives	Value
Required $C/(N + I)$ (dB) % of the year $C/(N + I)$ should be exceeded	7
Maximum operating pfd on the ground (dB(W/(m^2 · 4 kHz)))	–160
Reference bandwidth (Hz)	4 000
Wave form description	
Access type (TDMA, FDMA, CDMA…)	FDMA/TDMA
If CDMA, then provide the maximum number of co-frequency carriers	–
Modulation type (e.g. FM, QPSK, BPSK)	Offset QPSK
Noise bandwidth per carrier (MHz)	67
Occupied bandwidth per carrier (MHz)	67
Assigned bandwidth per carrier (MHz)	67
Transmit earth station characteristics (service links)	
Rain model (ITU/Crane)	ITU
Peak antenna gain (dB)	40.5 (at 90 cm)
Antenna beamwidth (degrees)	1.7
Antenna pointing loss (dB)	To be defined
Antenna pattern	RR Appendix S8, Annex III
On-axis earth station transmit e.i.r.p./carrier (dBW)	46.7
Inter-modulation earth station ratio (dB)	N/A
Power control range (> 0, 0 dB in none) (dB)	To be defined
Power control accuracy (applicable only if uplink power control used) (dB)	To be defined
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	To be defined
Receive earth station characteristics (feeder links)	
Earth station receive noise temperature (K)	155
Peak antenna gain (dBi)	55.6 (at 6 m)
Antenna beamwidth (degrees)	0.26
Antenna pointing loss (dB)	0.5
Antenna pattern	RR Appendix S8, Annex III
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	To be defined
Tracking strategy (fixed or tracking)	Tracking
If fixed, indicate either omnidirectional or supply azimuth and elevation pointing angles	N/A
Space station receive characteristics (service links)	
Carrier bandwidth (MHz)	67
Receive frequency (GHz)	To be defined
Receive polarization (H, V, C)	C
Satellite receive temperature (K)	460

	Value
Space station receive characteristics (service links) (continued)	
Receive cross-polarization isolation ratio (100 if not applicable) (dB)	To be defined
Receive frequency reuse isolation ratio (dB)	To be defined
Space station transmit characteristics (feeder links)	
Transponder bandwidth (MHz)	67
Transmit polarization (H, V, C)	C
Maximum satellite e.i.r.p. (dBW)	25.2
Transmit cross-polarization isolation ratio (100 if not applicable) (dB)	To be defined
Transmit frequency reuse isolation ratio (100 if not applicable) (dB)	To be defined
Transponder inter-modulation ratio (100 if not applicable) (dB)	To be defined

4.4.2 Forward links

4.4.2.1 Transparent payload

Performance objectives	Value
Required $C/(N + I)$ (dB) % of the year $C/(N + I)$ should be exceeded	7
Maximum operating pfd on the ground (dB(W/(m^2 · 4 kHz)))	–155
Reference bandwidth (Hz)	4 000
Wave form description	
Access type (TDMA, FDMA, CDMA…)	FDMA/TDMA
If CDMA, then provide the maximum number of co-frequency carriers	–
Modulation type (e.g. FM, QPSK, BPSK)	Offset QPSK
Noise bandwidth per carrier (MHz)	67
Occupied bandwidth per carrier (MHz)	67
Assigned bandwidth per carrier (MHz)	67
Transmit earth station characteristics (feeder links)	
Rain model (ITU/Crane)	ITU
Peak antenna gain (dB)	57 (at 6 m)
Antenna beamwidth (degrees)	0.26
Antenna pointing loss (dB)	To be defined
Antenna pattern	RR Appendix S8, Annex III
On-axis earth station transmit e.i.r.p./carrier (dBW)	55.3
Inter-modulation earth station ratio (dB)	N/A
Power control range (> 0, 0 dB in none) (dB)	To be defined
Power control accuracy (applicable only if uplink power control used) (dB)	To be defined
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	To be defined

	Value
Receive earth station characteristics (service links)	
Earth station receive noise temperature (K)	155
Peak antenna gain (dBi)	39.1 (at 90 cm)
Antenna beamwidth (degrees)	1.7
Antenna pointing loss (dB)	0.5
Antenna pattern	RR Appendix S8, Annex III
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	To be defined
Tracking strategy (fixed or tracking)	Tracking
If fixed, indicate either omnidirectional or supply azimuth and elevation pointing angles	N/A
Space station receive characteristics (feeder links)	
Carrier bandwidth (MHz)	67
Receive frequency (GHz)	13.7
Receive polarization (H, V, C)	C
Satellite receive temperature (K)	–
Receive cross-polarization isolation ratio (100 if not applicable) (dB)	To be defined
Receive frequency reuse isolation ratio (dB)	To be defined
Space station transmit characteristics (service links)	
Transponder bandwidth (MHz)	67
Transmit polarization (H, V, C)	C
Maximum satellite e.i.r.p. (dBW)	31.1
Transmit cross-polarization isolation ratio (100 if not applicable) (dB)	To be defined
Transmit frequency reuse isolation ratio (100 if not applicable) (dB)	To be defined
Transponder inter-modulation ratio (100 if not applicable) (dB)	To be defined

4.5 Distribution of non-GSO earth stations

Parameter	Value
Coverage latitude bounds (degrees)	±70
Maximum number of co-frequency earth stations in the service zone of one satellite	30
Maximum number of typical co-frequency earth stations in a beam	2
Predicted density of earth stations per unit area in geographical territories (urban, suburban, low-populated areas) (m^{-2})	To be defined

5 Parameters of the USAKUM3 system

Parameters provided are subjected to change by hardware specification.

5.1 Orbit parameters

Parameter	Value	Variation
Number of satellites	22	N/A
Number of planes	3(1)	N/A
Number of satellites per plane	8 (pln 1), 7 (pln 2 and 3)	N/A
Orbit type (select one)	Circular	N/A
Repeating ground track	Yes	N/A
Orbit inclination (degrees)	0 (pln 1), 45 (pln 2 and 3)	
Orbit period (min)	518.45	
Apogee altitude (km)	15 000	
Perigee altitude (km)	15 000	
Argument of perigee (degrees)	0	
Eccentricity	0	
Satellite angular separation within a plane (degrees)	45 (pln 1), 51.42 (pln 2 and 3)	
Satellite phasing between first satellites of adjacent planes (degrees)	0	
Angular separation between planes (degrees)	22.5 (pln 1 and 2), 180 (pln 2 and 3)	

(1) One non-inclined plane (pln 1) and two inclined planes (pln 2 and pln 3).

5.2 Link parameters

5.2.1 Uplink to non-GSO

5.2.1.1 Satellite antenna configuration

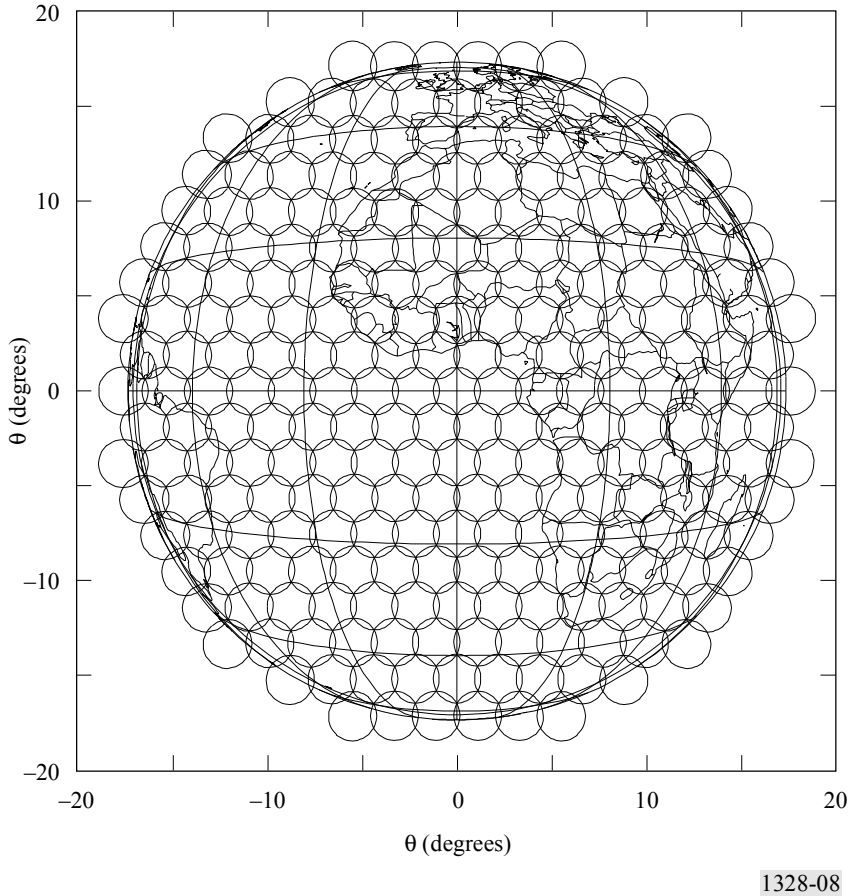
Parameter	Value	Reference
Beam orientation method	Satellite fixed	–
Maximum possible number of beams per satellite	50	Fig. 6
Frequency and polarization reuse pattern (attach diagram or describe in sufficient detail). Submit multiple entries if necessary	4 colour frequency reuse	–

5.2.1.2 Satellite fixed beams (service link)

Parameter	Value	Reference
Boresight azimuth (degrees)	See reference	Fig. 8
Boresight elevation (degrees)	See reference	Fig. 8
Rotation angle around beam boresight (if gain pattern is non-symmetric) (degrees)	N/A	–
Gain pattern (text to reference list below)	–	Fig. 9

FIGURE 8

USAKUM3 spot beam coverage (Tx and Rx)

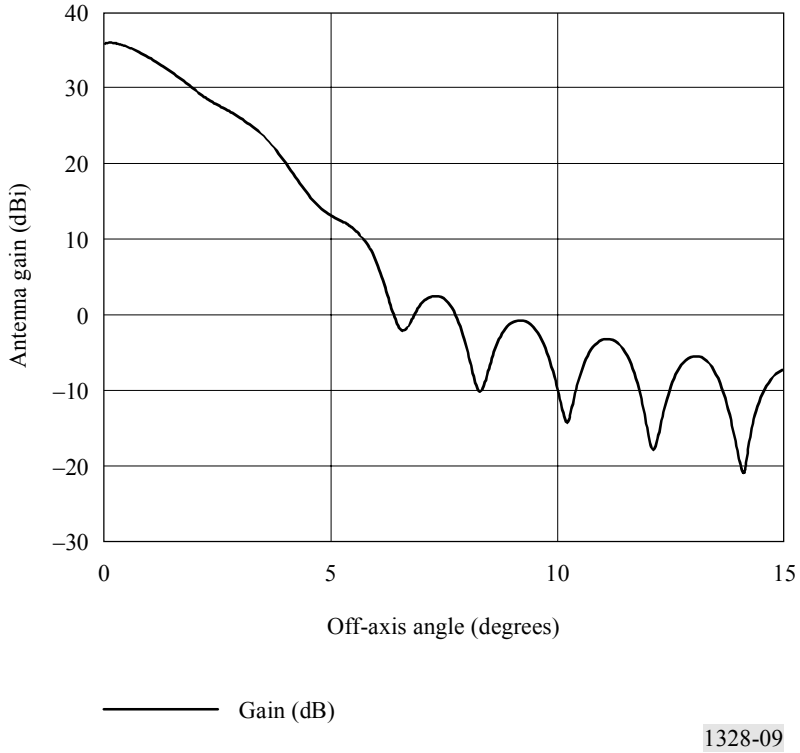


5.2.1.3 Gain patterns (service link)

Parameter	Value	Reference
Method to determine shape (select one)	See reference	Fig. 9
Polarization (select one)	LHCP or RHCP	–
Frequency (GHz)	1 GHz spectrum within 12.75-13.25, 13.75-14.5, and 17.3-17.8 (Regions 1 and 3 only)	–
Maximum number of carriers per beam	To be defined	–

FIGURE 9

USAKUM3 spot beam antenna gain pattern (Tx and Rx)



5.2.2 Downlink from non-GSO

5.2.2.1 Satellite antenna configuration

Parameter	Value	Reference
Beam orientation method	Satellite fixed	–
Maximum possible number of beams per satellite	50	Fig. 8
Frequency and polarization reuse pattern (attach diagram or describe in sufficient detail). Submit multiple entries if necessary	4 colour frequency reuse	–

5.2.2.2 Satellite fixed beams (service link)

Parameter	Value	Reference
Boresight azimuth (degrees)	N/A	Fig. 8
Boresight elevation (degrees)	N/A	Fig. 8
Rotation angle around beam boresight (if gain pattern is non-symmetric) (degrees)	N/A	–
Gain pattern (text to reference list below)	–	Fig. 9

5.2.2.3 Gain patterns (service link)

Parameter	Value	Reference
Method to determine shape (select one)	See reference	Fig. 9
Polarization (select one)	LHCP or RHCP	–
Frequency (GHz)	1 GHz spectrum within 10.7-12.7 (Region 2) and 10.7-12.75 (Regions 1 and 3)	–
Maximum number of carriers per beam	To be defined	–

5.3 Beam and satellite selection strategies

Parameter	Value
GSO arc avoidance angle and whether the angle is from a point or an area (degrees)	±10 (pln 2 and 3)[1] (any point in the beam)
Minimum elevation angle to the user station and whether the angle is from a point or an area (degrees)	10
Maximum number of simultaneous co-frequency beams per satellite while in the non-operating and operating zones	13 (253 beams position)
Maximum number of simultaneous co-polarization beams per satellite while in the non-operating and operating zones	25

(1) GSO arc avoidance angle for pln1 is undefined and depends on the final requirement of interference mitigation (epfd masks).

5.4 RF link parameters

5.4.1 Transparent payload

Performance objectives	Value
Required $C/(N + I)$ (dB) % of the year $C/(N + I)$ should be exceeded	7
Maximum operating pfd on the ground (dB(W/(m^2 · 4 kHz)))	–158.1
Reference bandwidth (Hz)	4 000
Wave form description	
Access type (TDMA, FDMA, CDMA…)	FDMA/TDMA
If CDMA, then provide the maximum number of co-frequency carriers	–
Modulation type (e.g. FM, QPSK, BPSK)	Offset QPSK
Noise bandwidth per carrier (MHz)	100
Occupied bandwidth per carrier (MHz)	100
Assigned bandwidth per carrier (MHz)	100
Transmit earth station characteristics	
Rain model (ITU/Crane)	ITU
Peak antenna gain (dB)	44.9 (at 1.5 m)
Antenna beamwidth (degrees)	1.0
Antenna pointing loss (dB)	0.5
Antenna pattern	RR Appendix S8, Annex III
On-axis earth station transmit e.i.r.p./carrier (dBW)	59.5
Inter-modulation earth station ratio (dB)	N/A
Power control range (> 0, 0 dB in none) (dB)	To be defined
Power control accuracy (applicable only if uplink power control used) (dB)	To be defined
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	To be defined
Receive earth station characteristics	
Earth station receive noise temperature (K)	155
Peak antenna gain (dBi)	43.5 (at 1.5 m)
Antenna beamwidth (degrees)	1.0
Antenna pointing loss (dB)	0.5
Antenna pattern	RR Appendix S8, Annex III
Polarization isolation (ratio of wanted to unwanted polarization) (dB)	To be defined
Tracking strategy (fixed or tracking)	Tracking
If fixed, indicate either omnidirectional or supply azimuth and elevation pointing angles	N/A
Space station receive characteristics	
Carrier bandwidth (MHz)	100
Receive frequency (GHz)	To be defined
Receive polarization (H, V, C)	C
Satellite receive temperature (K)	460
Receive cross-polarization isolation ratio (100 if not applicable) (dB)	To be defined
Receive frequency reuse isolation ratio (dB)	To be defined

	Value
Space station transmit characteristics	
Transponder bandwidth (MHz)	100
Transmit polarization (H, V, C)	C
Maximum satellite e.i.r.p. (dBW)	43.9
Transmit cross-polarization isolation ratio (100 if not applicable) (dB)	To be defined
Transmit frequency reuse isolation ratio (100 if not applicable) (dB)	To be defined
Transponder inter-modulation ratio (100 if not applicable) (dB)	To be defined

5.5 Distribution of non-GSO earth stations

Parameter	Value
Coverage latitude bounds (degrees)	±90
Maximum number of co-frequency earth stations in the service zone of one satellite	13
Maximum number of typical co-frequency earth stations in a beam	2
Predicted density of earth stations per unit area in geographical territories (urban, suburban, low-populated areas) (m^{-2})	To be defined

ANNEX 14

TABLE 32

Technical characteristics of the N-SAT-HEO1 non-GSO satellite network

Parameters	Non-GSO/FSS		
	N-SAT-HEO1		
1 *Orbital parameters*			
Shape of orbit	Elliptical		
Height (km)	44 641 × 26 932		
Inclination angle (degrees)	42.5		
Coherence (track repeat in h)	23 h 56 min		
Number of satellites per plane	1		
Number of orbital planes	3-5		
Satellite separation within plane (degrees)	–		
Satellite phasing between planes (degrees)	Variable		
2 *Targeted frequency range and polarization*			
Uplink frequency (GHz)	5.15-5.25	13.75-14.5	17.7-18.1
Uplink polarization	Circular	Circular	Circular
Downlink frequency (GHz)	6.7-7.075	12.25-12.75	15.43-15.63
Downlink polarization	Circular	Circular	Circular
3 *Spectrum required in each direction (MHz)*	100(1)/375(2)	750(1)/500(2)	400(1)/200(2)

TABLE 32 *(end)*

Parameters	Non-GSO/FSS		
	N-SAT-HEO1		
4 *Carrier transmission parameters*			
Modulation type	CDM, TDM, CDM/FDM (QPSK)		
Number of service link beams	1	1	1
Number of feeder-link segments/polarization	–	–	–
Segment bandwidth (MHz)	–	–	–
Receiver bandwidth (kHz)	2 500, 6 000	2 500, 6 000, N/A, N/A	2 500, 6 000, N/A, N/A
Transmission bandwidth (kHz)	15 000, 700	15 000, 700, 17 800, 6 000	15 000, 700, 17 800, 6 000
Overall (C/N_0) per user (dB/Hz) or (C/N) (dB)	8, 8	8, 8 6, 6	8, 8 6, 6
Uplink e.i.r.p./carrier (dBW)	62.4, 34.9	72.4, 44.9, 72.8, 75.8	74.4, 46.9, 74.8, 77.3
Downlink e.i.r.p./carrier (dBW)	48.5, 52.2	42.5, 46.3, N/A, N/A	48.5, 52.2, N/A, N/A
Type of satellite transponder	Transparent	Transparent	Transparent
5 *Satellite antenna parameters*			
Tx maximum gain (dBi)	41.9	44.9	41.9
Rx maximum gain (dBi)	39.0	45.5	44.5
Main lobes	–	–	–
Side lobes	–	–	–
Back lobes	–	–	–
Steerable antenna or not	Steerable	Steerable	Steerable
6 Earth station antenna parameters			
Peak Tx gain (dBi)	50.3	60.3	62.4
Peak Rx gain (dBi)	52.7	58.6	60.5
Radiation pattern	Rec. ITU-R S.580	Rec. ITU-R S.580	Rec. ITU-R S.580
Minimum operating elevation angle (degrees)	70	70	70
7 *Number of earth stations and distribution*	Up to 100	Up to 100	Up to 100
8 *Earth station switching strategy*	Minimum operating elevation angle		

(1) Uplink

(2) Downlink