HMS Utfordringer i Nordområdene
Satellitt-Kommunikasjon
Arbeidsseminar 1 – Mars 2014

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TOPICS

- Communications Options
- Satellite Technology
  - Spectrum
  - Coverage
  - Performance
  - Sample Systems
- Specific Challenges for Arctic region
  - Theory
  - Measurement Results

STATUS TODAY

Communication at high latitudes

	System	Characteristics	Polar (>80°N)	Sub-Polar (70°N - 80°N)	Other (<70°N)
Terrestrial systems	HF, MF	Safety related messages and voice communications	OK, but unsuitable for digital communications	OK, but unsuitable for digital communications	OK, but unsuitable for digital communications
	VHF, digital VHF, GSM, 3G	Line-of-sight, voice and low data rate communications	No base stations, ship-to-ship OK	Few base stations, ship-to-ship OK	VHF is OK close to the coast, GSM/3G limited coastal coverage
Satellite systems	GEO satellites, including Inmarsat.	Medium capacity. Low to medium latency.	Not available	Potential problems with quality and availability	OK (except in fjords and similar special areas)
	LEO satellites; Iridium OpenPort	Currently max. 128 kbps. High and variable latency.	Potential problems with quality	Potential problems with quality	OK, except for areas around equator
	HEO satellites	Properties comparable to GEO. Currently unavailable.	Expected to provide good coverage, capacity and quality in the Polar and Sub-Polar areas. Spare capacity can be used in other sea areas. Not yet implemented.		

Source: HMS Utfordringer i nordområdene - litteraturgjennomgang

Satellite Technology - Spectrum

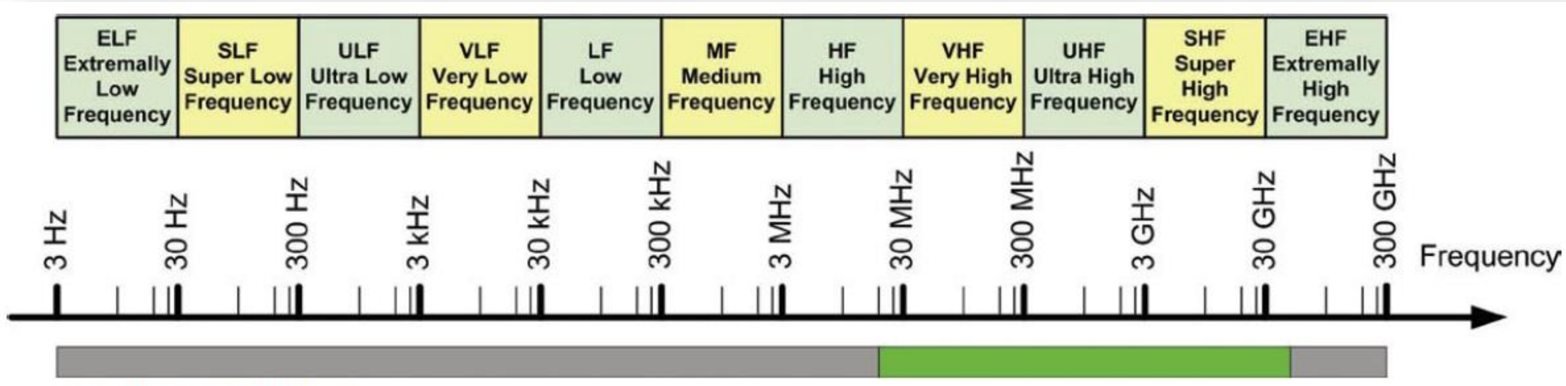


Figure 1. Frequency spectrum.

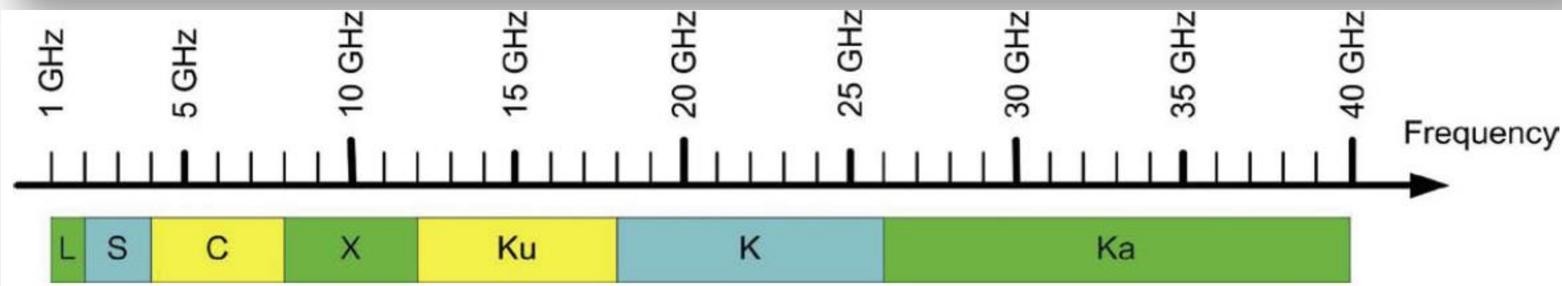
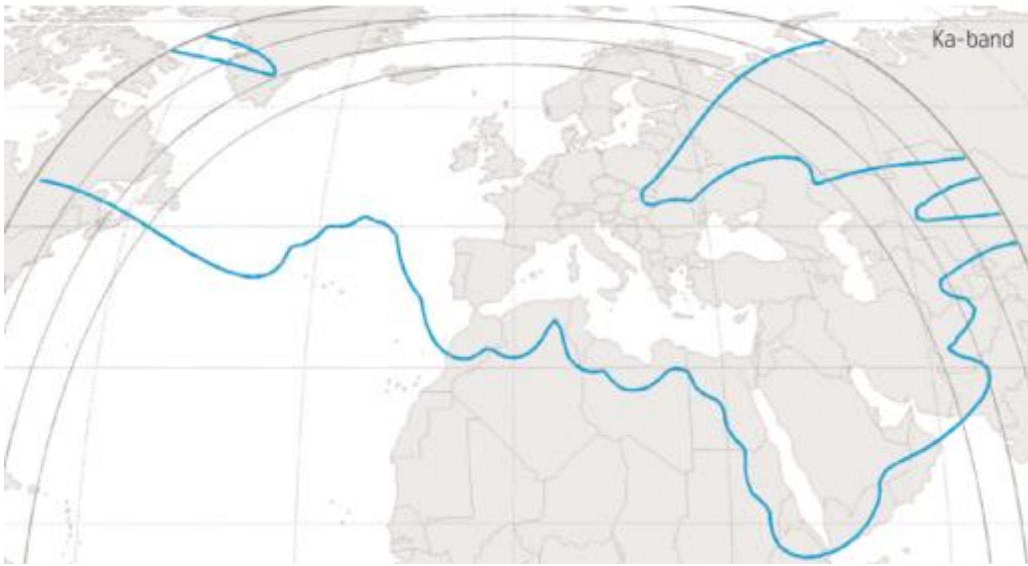
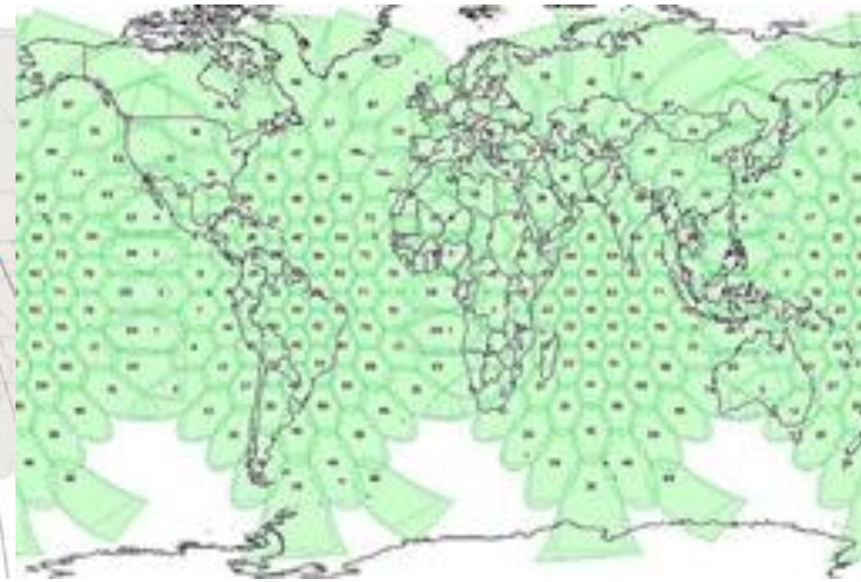


Figure 2. Satellite bands.

- L-band used by Inmarsat and other MSS operators (low bit-rates, very high availability)
- C-band used for TV (DTH) and VSAT Data services (medium bit-rates, high availability)
- Ku-band used for TV(DTH) and VSAT Data services (high bit-rates, medium/high availability
- Ka-band used primarily for consumer and professional broadband connectivity and in the US also for TV(DTH). (high bit-rates, medium availability but can provide high availability provided proper system dimensioning)

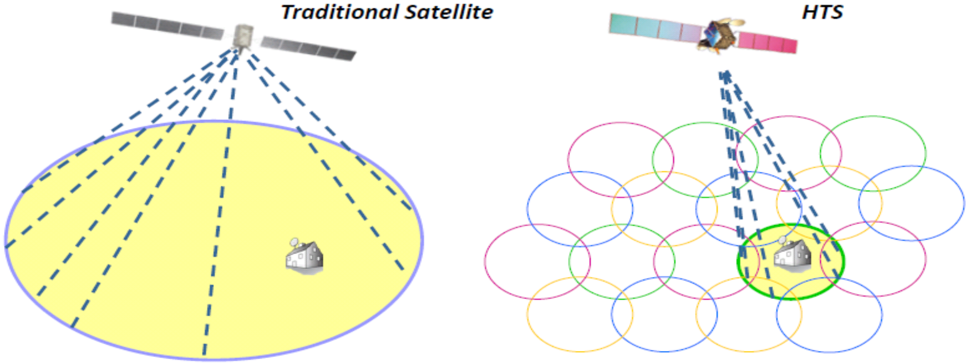
Satellite Technology - Coverage
(Regional vs. Global)





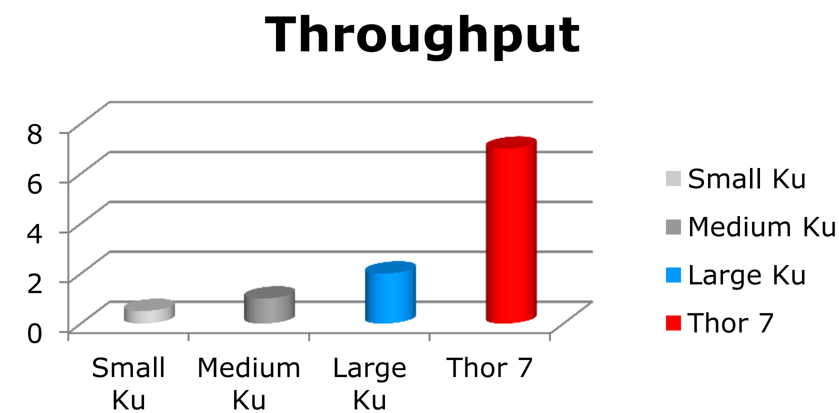
- Regional system such as Thor 7 covers only a relatively small part of the world with ~30 spot beam – throughput around 6-9 Gbps
- A global systems such as Inmarsat GX covers most of the world with 3 satellites each having 89 spot beams – throughput around 6-10 Gbps per satellite
- A gross simplification: the larger the coverage area, the lower the performance

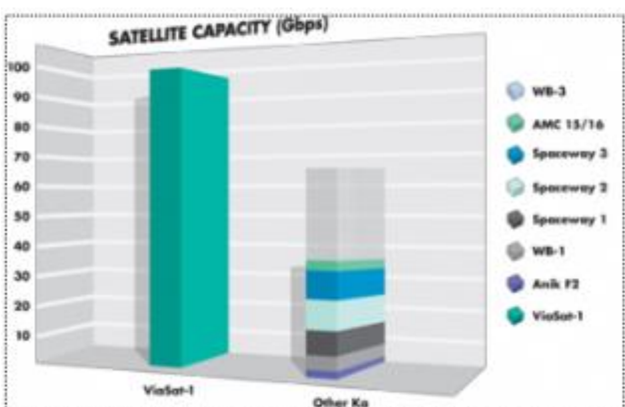
Satellite Technology - Performance (HTS Satellites)



- Next generation satellites often called HTS – High Throughput Satellites

- Frequency reuse drive throughput up
- Smaller spot beams have higher gain/performance than wide spot beams

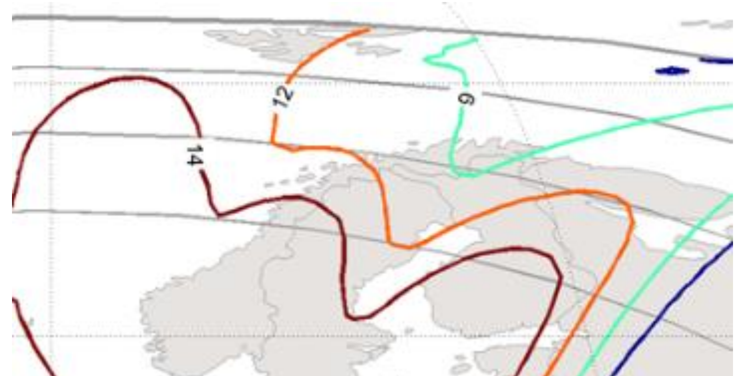


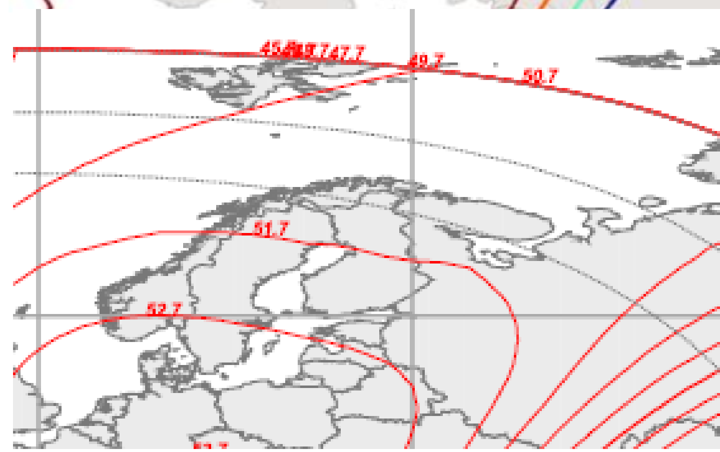


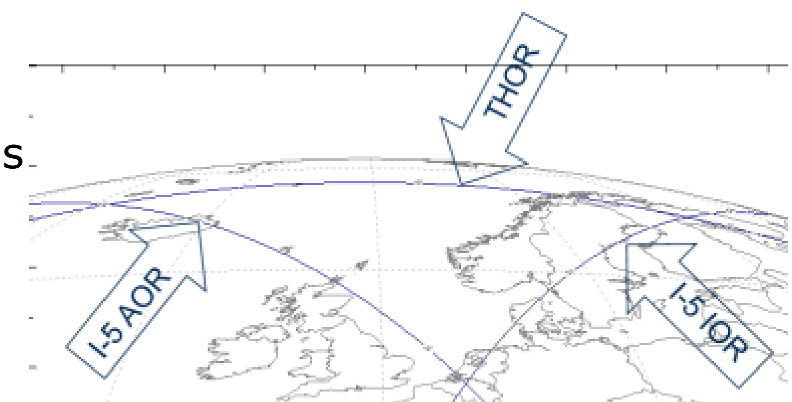
- Highest performing satellites existing today reach 100+ Gbps

Some Current and Planned Systems

- Thor 7 – operational Q1-2015 (GEO) @ 1W
  - Ka-band spot beams
  - Can support 10’s of Mbps download and 6+ Mbps upload speeds for 1meter antenna
  - Service guaranteed to elevation of 6-7 deg
- Thor 10-02 (GEO) @ 1 West
  - Ku-band wide spot beam
  - Can support 10’s of Mbps download and 2+ Mbps upload for1 meter antenna, more for larger antennas
  - Service guaranteed to elevation of 5 deg
- Inmarsat GX (GEO) (3 satellites)
  - Ka-band spot beams
  - Use westerly and easterly satellite positions and cannot therefore provide service in Norwegian Sea and Barents Sea regions (see 10 deg elevation contours)

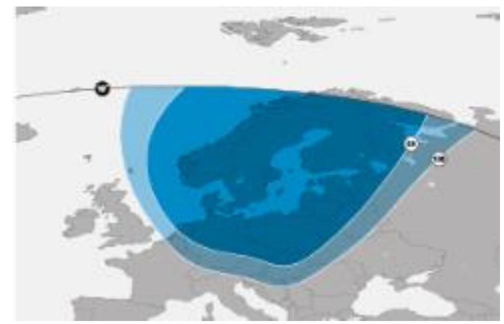






Some Current and Planned Systems

- Intelsat IS 907 @ 18 West
  - Ku-band wide spot beam
  - Used extensively for maritime VSAT
  - North-Western Europe coverage
- Astra 4A
  - Ku-band wide spot beam
  - Used extensively for maritime VSAT
  - Northern European coverage
- Iridium / Iridium NEXT (LEO)
  - L-band spot beams
  - Mostly used for voice comms, supports low data rates. NEXT expexted to provide a few hundred kbps (similar to Inmarsat BGAN)
  - Worldwide coverage



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Specific Challenges for the Arctic

- First GEO system via commercial satellites for Arctic region was installed by Telenor at Isfjord Radio around 40 years ago – in 1974 – and provided telephony services to mainland Norway
- Later in 1979 a much larger antenna was installed and from then on Svalbard also received TV broadcasts in addition to the telephony service.
- Over the years, Telenor have conducted multiple measurement campaigns
- Key issues relate to rain attenuation, elevation and scintillation fading

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The Relation Between Availability and Attenuation (dB)
(for 30 GHz uplink signal from a location near Oslo)

Satmaster Pro Mk8.1q - [Table - Availability v Rain Attenuation 30 GHz (ITU-R)]

File Edit View Map Graph Table Calculate Options Window Help

AV(av.yr.)	AV(w.m.)	ATTN	XPD	DT(av.yr.)	DT(w.m.)
99.999	99.993	53.51	7.00	0.088	0.051
99.998	99.987	45.83	8.39	0.175	0.093
99.997	99.982	41.25	9.33	0.263	0.133
99.996	99.977	38.03	10.04	0.351	0.171
99.995	99.972	35.57	10.62	0.438	0.207
99.994	99.967	33.60	11.12	0.526	0.243
99.993	99.962	31.96	11.55	0.614	0.278
99.992	99.957	30.57	11.93	0.701	0.312
99.991	99.953	29.36	12.28	0.789	0.346
99.990	99.948	28.30	12.22	0.877	0.379
99.980	99.905	21.82	14.41	1.753	0.693
99.970	99.865	18.46	15.80	2.630	0.985
99.960	99.827	16.29	16.82	3.506	1.266
99.950	99.790	14.73	17.63	4.383	1.537
99.940	99.753	13.53	18.32	5.260	1.801
99.930	99.718	12.58	18.90	6.136	2.059
99.920	99.683	11.79	19.42	7.013	2.313
99.910	99.649	11.12	19.88	7.889	2.563
99.900	99.615	10.55	20.29	8.766	2.809
99.800	99.297	7.32	23.01	17.532	5.134
99.700	99.000	5.82	24.75	26.298	7.305
99.600	98.716	4.92	26.02	35.064	9.382
99.500	98.440	4.30	27.01	43.830	11.393
99.400	98.172	3.84	27.84	52.596	13.351
99.300	97.910	3.49	28.55	61.362	15.267
99.200	97.653	3.20	29.16	70.128	17.148
99.100	97.399	2.97	29.71	78.894	18.998

Order - Avail av.yr. %, Avail w.m. %, Rain Atten., XPD, Down hr.av.yr., Down hr.w.m.

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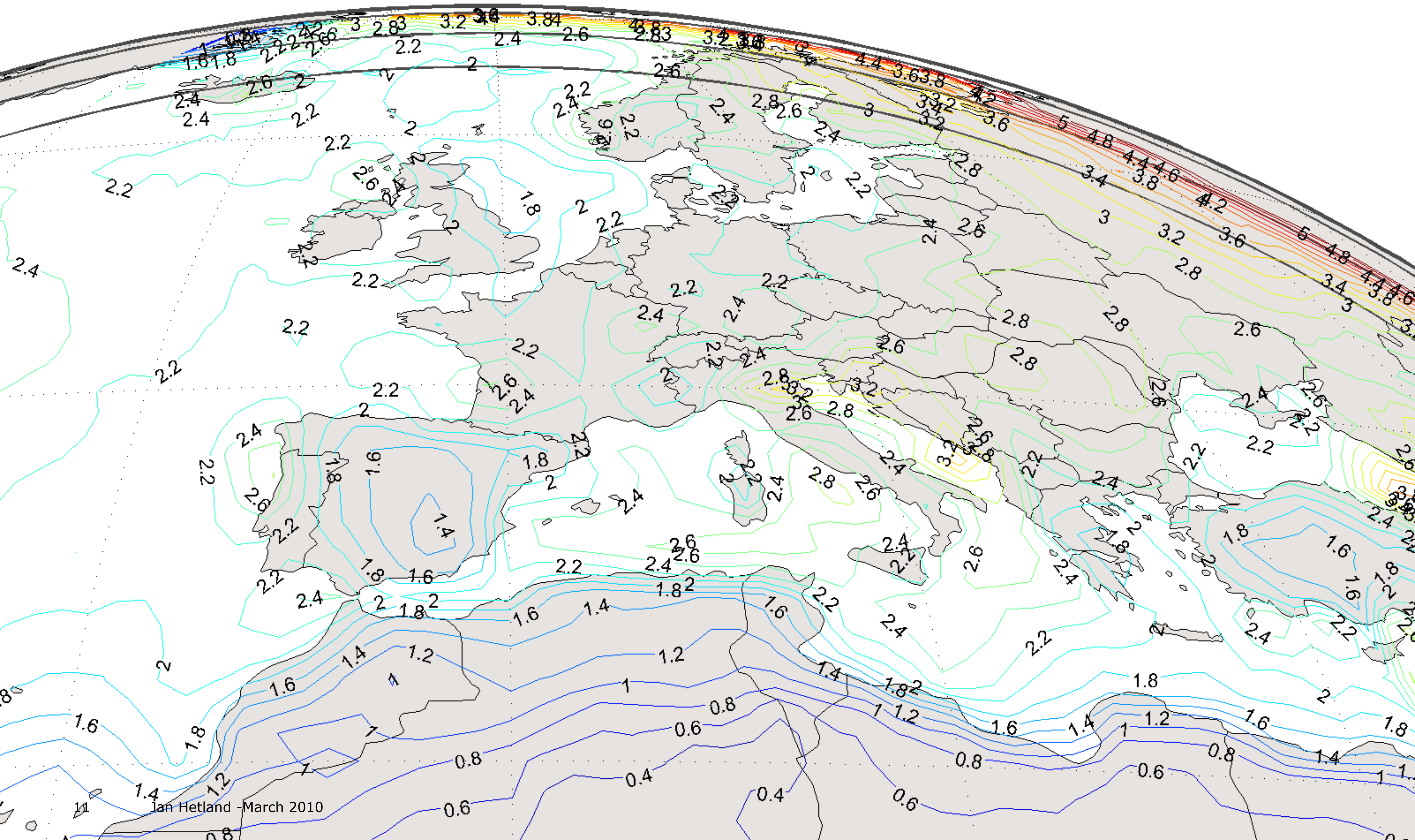
Difference in attenuation between Ka-band and Ku-band downlink signals (20 GHz vs. 12 GHz) @ 99.7% availability



Tropospheric Scintillation

- Scintillation is caused by discontinuities in atmosphere’s refractive index and causes rapid fluctuations in signal level around a mean value
- Scintillation increases with decreasing (lower) elevation angle
- Generally considered to be significant as elevation drops below around 5 degrees
- Scintillation increases with increasing frequency
- Tends to be worse in the warmer periods of the year
- ITU-R models for scintillation are somewhat difficult to use, particularly as there is a discontinuity in the models depending on whether you are above or below 5 degrees of elevation

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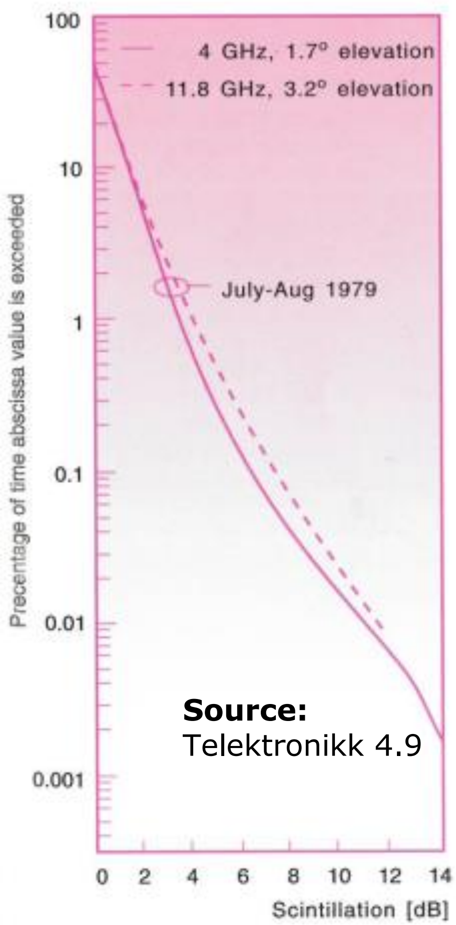
Measurement Highlights

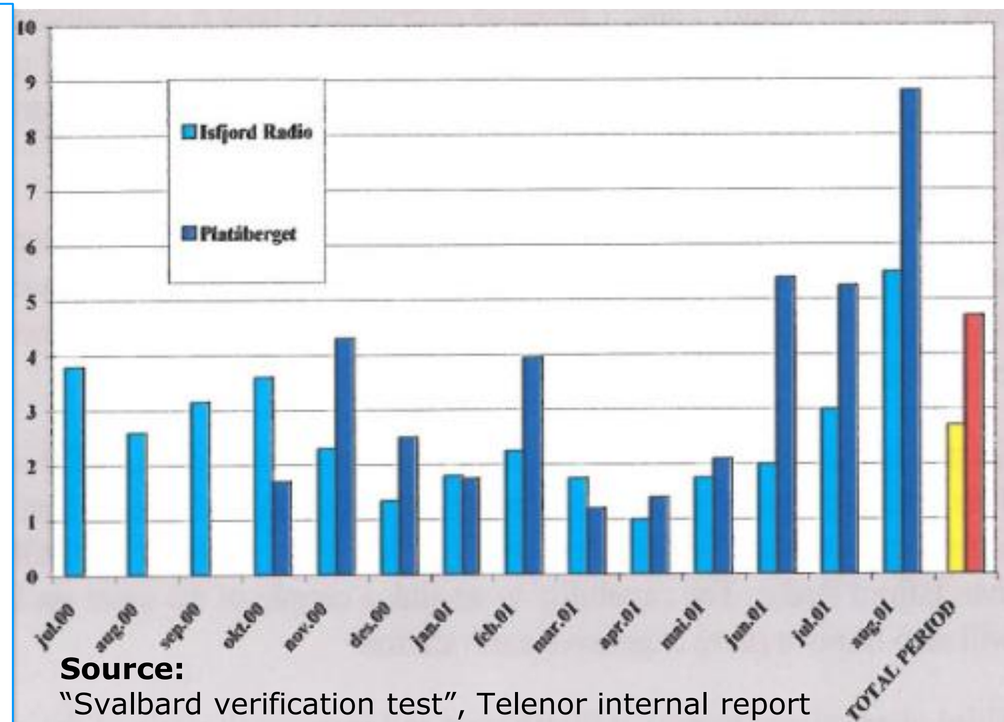
1979: Scintillation effect on C/Ku-band
C- and Ku-band signals received at Isfjord simultaneously with different elevation angle



Source:
Telektronikk 4.9

2000/2001: Elevation effect on Ku-band
Ku-band signal beacon measured simultaneously at Isfjord and Platåberget showing the effect of elevation angle

Fade depth exceeded 0.05% of time



Source:
"Svalbard verification test", Telenor internal report

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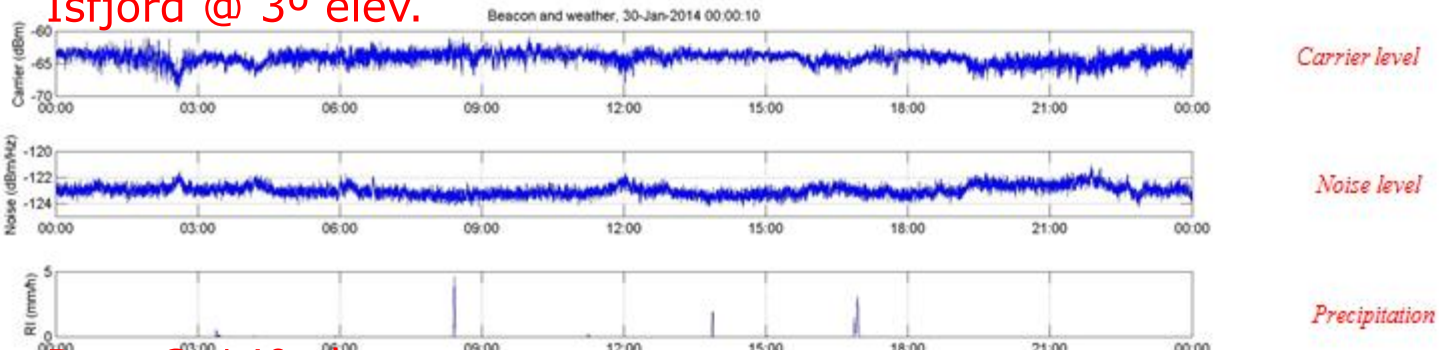
Current Ka-band Measurement Campaign

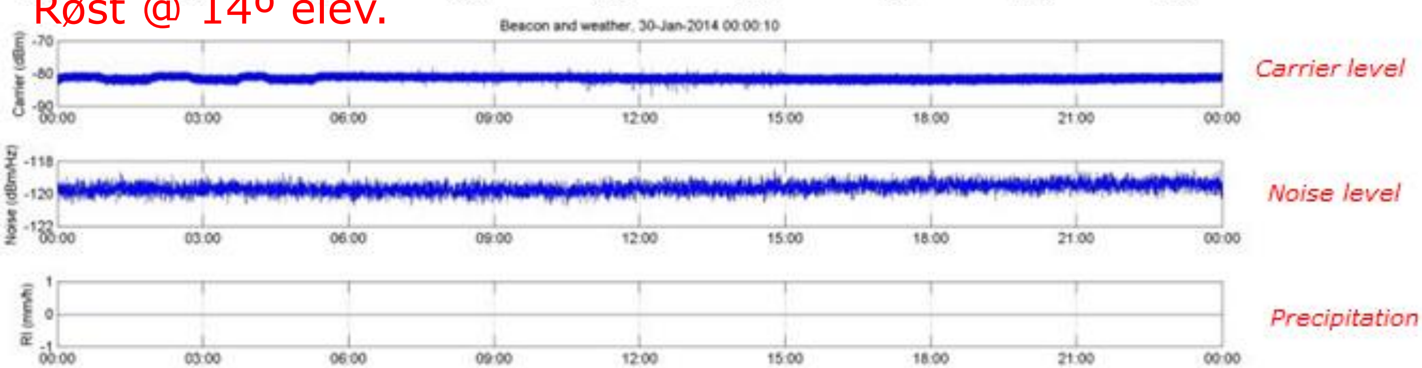
Telenor currently chairing an ESA sponsored study of Ka-band propagation effects in Northern regions:

- Isfjord (el. 3º)
- Vadsø (el. 10º)
- Røst (el. 14º)
- Eggemoen (el. 22º)
- Nittedal (el. 22º)

Isfjord @ 3º elev.



Røst @ 14º elev.



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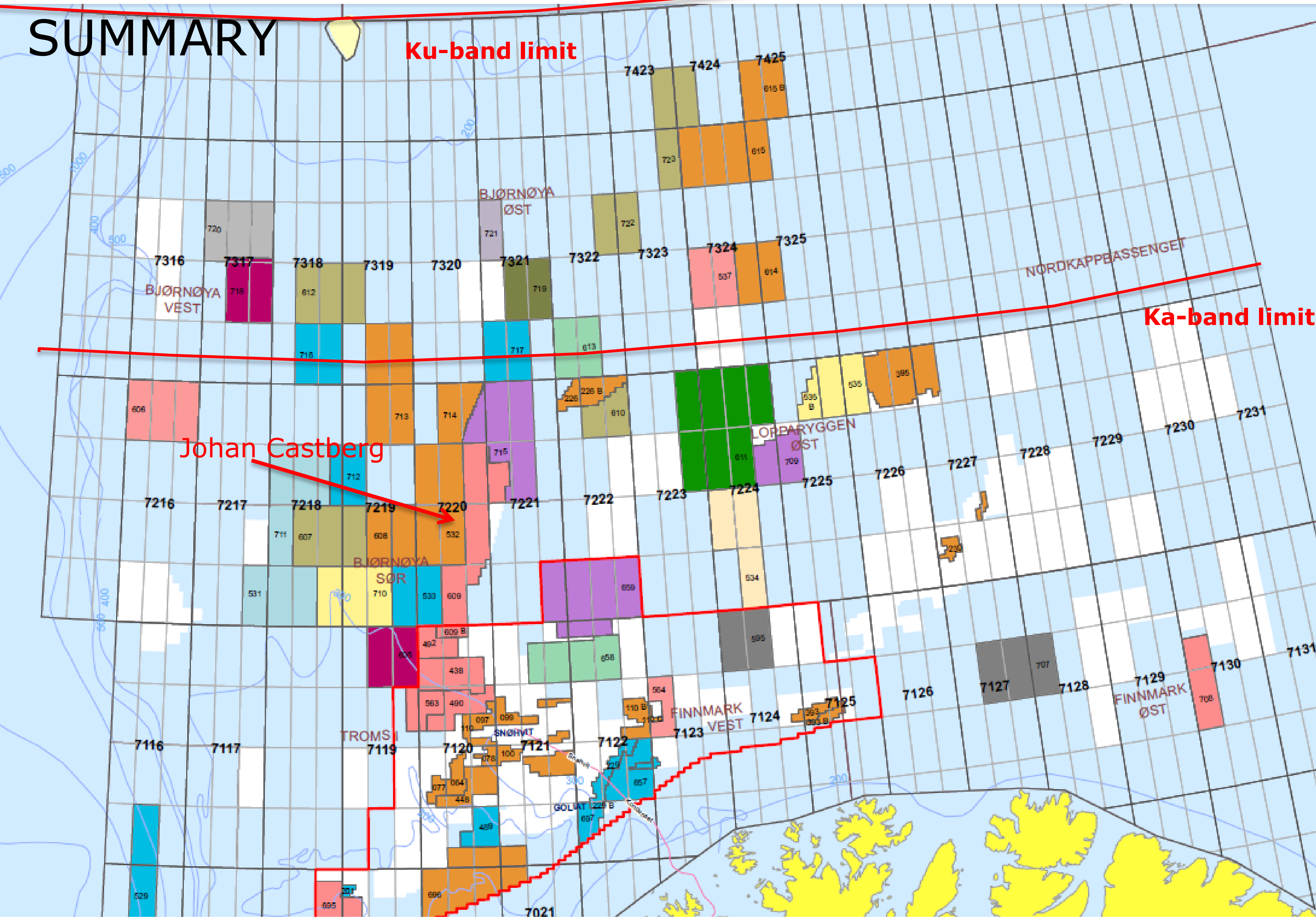
SUMMARY

- Satellite communication signals in the Arctic region mainly affected by following 2 parameters
  - Rain attenuation
  - Tropospheric Scintillation and Multipath fading
- Both of these get worse with lower elevation angle

- Many GEO operators use following limits for guaranteed service
  - C-band: 5 degrees (requires large antennas, capacity expensive)
  - Ku-band: 5-10 degrees (medium antennas, capacity costs lower)
  - Ka-band: 10+ degrees (medium/small antennas, lowest cost capacity)
- Telenor's experience suggest the following is possible, given careful system design:
  - C-band: 3 degrees
  - Ku-band: 5 degrees (but known to work semi-reliably at 3degrees)
  - Ka-band: 6-7 degrees (but needs further validation)

SUMMARY



Ku-band limit
Ka-band limit
Johan Castberg
BJØRNØYA VEST
BJØRNØYA ØST
BJØRNØYA SØR
NORDKAPPBASSENGET
LOPPARYGGEN ØST
TROMS I
FINNMARK VEST
FINNMARK ØST
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