

TECHNICAL APPENDIX

Tyvak Nano-Satellite Systems Inc. 60-Day Special Temporary Authorization (STA)

- I. 400 MHz Yagi Radiation Hazard Report
- II. Nkom Email Authorization

****Proprietary & Confidential****

I. Radiation Hazard Study

400 MHz Earth Station

This study analyzes the non-ionizing radiation levels for a 400 MHz Yagi tracking earth station. This report is developed in accordance with the prediction methods contained in OET Bulletin No. 65, Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields, Edition 97-01.

Bulletin No. 65 specifies that there are two separate tiers of exposure limits that are depending on the area of exposure and/or the status of the individuals who are subject to the exposure -- the General Population/Uncontrolled Environment and the Controlled Environment, where the general population cannot access.

The maximum level of non-ionizing radiation to which individuals may be exposed is limited to a power density level of 1.33 milliwatts per square centimeter (1.33 mW/cm^2) averaged over any 6 minute period in a controlled environment, and the maximum level of non-ionizing radiation to which the general public is exposed is limited to a power density level of 0.27 milliwatt per square centimeter (0.27 mW/cm^2) averaged over any 30 minute period in a uncontrolled environment.

In the normal range of transmit powers for satellite antennas, the power densities at or around the antenna surface are expected to exceed safe levels. The purpose of this study is to determine the power flux density levels for the earth station under study as compared with the MPE limits. This comparison is done in each of the following regions:

1. Far-field region
2. Near-field region
3. Transition region
4. The region between the antenna edge and the ground

Input Parameters

The following input parameters were used in the calculations:

<u>Parameters:</u>	<u>Value</u>	<u>Unit</u>	<u>Symbol</u>
<i>Antenna Diameter</i>	3.57	m	<i>D</i>
<i>Antenna Transmit Gain</i>	16.2	dBi	<i>G</i>
<i>Transmit Frequency</i>	400	MHz	<i>f</i>
<i>Power Input to the Antenna</i>	44.7	W	<i>P</i>

Calculated Parameters:

The following values were calculated using the above input parameters and the

corresponding formulas:

<u>Parameter</u>	<u>Value</u>	<u>Unit</u>	<u>Symbol</u>	<u>Formula</u>
<i>Antenna Surface Area</i>	1.964	m ²	<i>A</i>	$G\lambda^2/(4\pi)/\lambda$
<i>Antenna Efficiency</i>	0.95		η	$G\lambda^2/(\pi^2 D^2)$
<i>Gain Factor</i>	41.7		<i>g</i>	$10^{G/10}$
<i>Wavelength</i>	0.75	m	λ	$300/f$

Behavior of EM Fields as a Function of Distance

The behavior of the characteristics of EM fields varies depending on the distance from the radiating antenna. These characteristics are analyzed in three primary regions: the near-field region, the far-field region and the transition region. Of interest also is the region between the antenna and ground.

For yagi antennas with circular cross sections, such as the antenna under study, the near-field, far-field and transition region distances are calculated as follows:

<u>Parameter</u>	<u>Value</u>	<u>Unit</u>	<u>Formula</u>
<i>Near-Field Distance</i>	4.25	m	$R_{nf} = D^2/(4\lambda)$
<i>Distance to Far-Field</i>	10.2	m	$R_{ff} = 0.60D^2/(\lambda)$
<i>Distance of Transition Region</i>	4.25	m	$R_t = R_{nf}$

The distance in the transition region is between the near and far fields. Thus, $R_{nf} \leq R_t \leq R_{ff}$. However, the power density in the transition region will not exceed the power density in the near-field. Therefore, for purposes of the present analysis, the distance of the transition region can equate the distance to the near-field.

Power Flux Density Calculations

The power flux density is considered to be at a maximum through the entire length of the near-field. This region is contained within a cylindrical volume with a diameter, *D*, equal to the diameter of the antenna. In the transition region and the far-field, the power density decreases inversely with the square of the distance. The following equations are used to calculate power density in these regions.

<u>Parameter</u>	<u>Value</u>	<u>Unit</u>	<u>Symbol</u>	<u>Formula</u>
<i>Power Density in the Near-Field</i>	8.65	mW/cm ²	S_{nf}	$16.0 \eta P/(\pi D^2)$
<i>Power Density in the Far-Field</i>	0.14	mW/cm ²	S_{ff}	$GP/(4\pi R_{ff}^2)$
<i>Power Density in the Transition Region</i>	8.65	mW/cm ²	S_t	$S_{nf} R_{nf}/(R_t)$

The power density between the antenna and ground, is calculated as follows:

<u>Parameter</u>	<u>Value</u>	<u>Unit</u>	<u>Symbol</u>	<u>Formula</u>
<i>Power Density b/w Reflector and Ground</i>	2.28	mW/cm ²	S_g	P/A

The below table summarizes the calculated power flux density values for each region. In a controlled environment, the only regions that exceed FCC limitations are shown below.

These regions are only accessible by trained technicians who, as a matter of procedure, turn off transmit power before performing any work in these areas.

<u>Power Density</u>	<u>Value</u>	<u>Unit</u>	<u>Controlled Environment</u>
<i>Far Field Calculation</i>	0.14	mW/cm ²	Satisfies FCC MPE
<i>Near Field Calculation</i>	8.65	mW/cm ²	Exceeds Limits
<i>Transition Region</i>	8.65	mW/cm ²	Exceeds Limits
<i>Region b/w Antenna & Ground</i>	2.28	mW/cm ²	Exceeds Limits

In conclusion, the results show that the antenna, in a controlled environment, may exist in the regions noted above and applicant will take the proper mitigation procedures to ensure it meets the guidelines specified in 47 C.F.R. § 1.1310.

The antenna will be installed at DS12 Access Road, Prudhoe Bay, Alaska 99734. Access to the antenna requires a 45 ft man-lift, which should safely restrict any public access. It should be noted that all spaces at least 7.5m away from the antenna satisfy the FCC MPE limits for the general population. The earth station will be marked with the standard radiation hazard warnings, as well as the area in the vicinity of the earth station to inform the general population, who might be working or otherwise present in or near the path of the main beam.

The applicant will ensure that the main beam of the antenna will be pointed at least one diameter away from any building, or other obstacles in those areas that exceed the MPE limits. Since one diameter removed from the center of the main beam the levels are down at least 20 dB, or by a factor of 100, public safety will be ensured.

Finally, the earth station's operational personnel will not have access to areas that exceed the MPE limits while the earth station is in operation. The transmitter will be turned off during periods of maintenance so that the MPE standard of 1.33 mW/cm² will be complied with for those regions in close proximity to the antenna, which could be occupied by operating personnel.

II. Nkom Email Authorization

From: "Målen Frode" <frode.maaen@nkom.no>
Sent: Fri, 21 Apr 2017 07:56:17 +0000
To: "BRMAIL, ITU" <BRMail@itu.int>

Subject: Submission of Advance Publication Information for Satellite Network Tyvak-0082
Attachments: Tyvak-0082-API.zip

Dear Sirs,

With reference to Radio Regulations Article 9, no. 9.1, we are pleased to forward information on a Norwegian satellite network: Tyvak-0082 for Advanced Publication of Information in the BR IFIC. The network are not subject to coordination, cf. Article 9, Sub-Section IA.

The Tyvak-0082 network is a n-GSO systems with 4 satellites in one orbital plane with 97,6° inclination. The validity is 20 years.

The technical data for the network has been prepared in accordance with Radio Regulations Appendix 4, Annex 2. Enclosed please find the filing in the zipped format, prepared in the SpaceCap program.

The operating agency for the networks is Orbital Networks A/S, Norway. In the API, clause A3a is given as 9999. Notification Form of the List of Recognized Operating Agencies (ROAs) for Orbital Networks AS will be sent in a separate e-mail.

We kindly ask BR to initiate the relevant procedures under Article 9 of the Radio Regulations with regard to this network.

If further clarification is necessary, we are pleased to be at your disposal.

This E-mail has been confirmed by fax transmission to BR today.

Best regards,
Frode Målen
Senior Engineer
Section for Frequency Planning
Norwegian Communications Authority
Switchboard: + 47 22 82 46 00
Direct: + 47 22 82 46 04
Mobile: + 47 93 45 58 64
www.nkom.no



Tyvak Proprietary

E_TSUM Requested by: RICKYP					Date: 19.04.2017 10:20:01 AM			DB: TYVAK-0082-API.MDB			Plan Id.:		Notice type: NONGEO		
A	A1a Sat. Network		TYVAK-0082		A1f1 Notifying adm.		NOR	A1f3 Inter. sat. org.		BR1 Date of receipt		22.02.2017	BR20 BR IFIC no.		
BR6a/BR6b Id. no.			6	BR3a Provision reference			9.1/IA		BR2 Adm. serial no.					UHFRX	R

A1f2 Submitted on behalf

A4b1 No. of orbital planes

1

A4b2 Ref. body

T

A4b3a No. of space stations simult. trans. on Northern Hemisphere

A4b3b No. of space stations simult. trans. on Southern Hemisphere

Orbital plane id. no.	A4b4a Inclination angle	A4b4b No. of satellites in this plane	A4b4c Period	A4b4d Apogee	A4b4e Perigee	A4b4f Min. altitude
1	97.6	4	0-01:37	600e0	600e0	600

B1a/BR17 Beam designation	UHFRX	B1b Steerable	B2 Emi-Rcp	R	B3a1 Max. co-polar gain	2
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B2bis.a Transmit only when visible from notified service area

B2bis.b Min. Elev. Angle

B3c1 Co-polar antenna pattern

Co-polar ref. pattern	Coef. A	Coef. B	Co-polar rad. diag.
ND-SPACE			

List of orbital planes

1

B4a3a1 Angle alpha

B4a3a2 Angle beta

BR92 Attach. for missing angle alpha/beta

BR7a/BR7b Group id.

12

BR1 Date of receipt

22.02.2017

C2c RR No. 4.4

BR14 Special Section

C4a Class of station

EW

C3a Assigned freq. band

C5a Noise temperature

303

C4b Nature of service

CR

C6a Po

larization type

CL

C6b Polarization angle

C11a2 Service area

NOR

C11a3 Service area diagram

A2b Period of valid.

20

A3a Op. agency

999

A3b Adm. resp.

A

BR16 Value of type C8b

BR60 Regulatory deadline(s) 11.44/11.44.1

C1 Frequency Range			
C1a Lower limit		C1b Upper limit	
401	MHz	401.3	MHz

C7a Design. of emission	C8a1/C8b1 Max. peak pwr	C8a2/C8b2 Max. pwr dens.	C8c1 Min. peak pwr	C8c2 Attch.	C8c3 Min. pwr dens.	C8c4 Attch.	C8e1 C/N ratio	C8e2 Attch.	C8f2 E.i.r.p. on the beam axis
1 16K5G1D	22.6	-19.6	13		-29.2		84		

C7b Carrier frequency of the emissions (16K5G1D)													
404.04	MHz	401.08	MHz	401.12	MHz	401.16	MHz	401.2	MHz	401.24	MHz		
C10b1 Assoc. earth station id.		C10b2 Type	C10c1 Geographical coord.		C10c2 Ctry	C10d1/C10d2 Cls. / Nat.		C10d3 Max. iso. gain	C10d4 Brmwidth				
ORBEX1		S	018E29 14	69N03 19	NOR	1	TW	CR	16.2	25			

	C10d5a Co-polar antenna pattern						
C10b1 Assoc. earth station id.	Co-polar ref. pattern	Coef. A	Coef. B	Coef. C	Coef. D	Phi1	Co-polar rad. diag.
ORBEX1	REC-580-6						

13C Remarks	
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B1a/BR17 Beam designation

SBANDTX

B1b Steerable

B2 Emi-Rcp

E

B3a1 Max. co-polar gain

5

Tyvak Proprietary

E_TSUM Requested by: RICKYP		Date: 19.04.2017 10:20:01 AM		DB: TYVAK-0082-API.MDB		Plan Id.:		Notice type: NONGEO	
A	A1a Sat. Network	TYVAK-0082	A1f1 Notifying adm.	NOR	A1f3 Inter. sat. org.		BR1 Date of receipt	22.02.2017	BR20 BR IFIC no.
BR6a/BR6b Id. no.		6	BR3a Provision reference		9.1/IA		BR2 Adm. serial no.		SBANDTX E

B2bis.a Transmit only when visible from notified service area ☐ Y B2bis.b Min. Elev. Angle 10

B3c1 Co-polar antenna pattern					
Co-polar ref. pattern	Coef. A	Coef. B			Co-polar rad. diag.
ND-SPACE					

B4a3a1 Angle alpha B4a3a2 Angle beta

BR92 Attach. for missing angle alpha/beta

BR7a/BR7b Group id.	10	BR1 Date of receipt	22.02.2017	C2c RR No. 4.4	
BR14 Special Section					
C4a Class of station	ET	EW	C3a Assigned freq. band		
C4b Nature of service	CR	CR	C6a Polarization type	CL	C6b Polarization angle
C8d1 Max. tot. peak pwr.			C8d2 Contiguous bandwidth		
C11a2 Service area	XVE	C11a3 Service area diagram			

A2b Period of valid. 20 A3a Op. agency 999 A3b Adm. resp. A BR16 Value of type C8b

BR60 Regulatory deadline(s) 11.44/11.44.1

C1 Frequency Range	
C1a Lower limit	C1b Upper limit
2200 MHz	2202 MHz

C7a	C8a1/C8b1	C8a2/C8b2	C8c1	C8c2	C8c3	C8c4	C8e1	C8e2	C8f1
Design. of emission	Max. peak pwr	Max. pwr dens.	Min. peak pwr	Attch.	Min. pwr dens.	Attch.	C/N ratio	Attch.	E.i.r.p. on the beam axis
1 1M50G1D	3	-58	-3		-64		80		3

C7b Carrier frequency of the emissions (1M50G1D)											
2201	MHz										

C10b1	C10b2	C10c1	C10c2	C10d1/C10d2	C10d3	C10d4	C10d6		
Assoc. earth station id.	Type	Geographical coord.	Ctry	Cls. / Nat.	Max. iso. Bmwth gain	Bmwth	Noise temp.		
ORBOPEX	T			1 TT 2 TW	CR	40	1.6	150	

		C10d5a Co-polar antenna pattern					
C10b1 Assoc. earth station id.	Co-polar ref. pattern	Coef. A	Coef. B	Coef. C	Coef. D	Phi1	Co-polar rad. diag.
ORBOPEX	REC-580-6						

13C Remarks

B1a/BR17 Beam designation UHFTX B1b Steerable B2 Emi-Rcp E B3a1 Max. co-polar gain 2

B2bis.a Transmit only when visible from notified service area ☐ Y B2bis.b Min. Elev. Angle 10

B3c1 Co-polar antenna pattern					
Co-polar ref. pattern	Coef. A	Coef. B			Co-polar rad. diag.
ND-SPACE					

B4a3a1 Angle alpha B4a3a2 Angle beta

BR92 Attach. for missing angle alpha/beta

Tyvak Proprietary

E_TSUM Requested by: RICKYP		Date: 19.04.2017 10:20:01 AM		DB: TYVAK-0082-API.MDB		Plan Id.:		Notice type: NONGEO	
A	A1a Sat. Network	TYVAK-0082	A1f1 Notifying adm.	NOR	A1f3 Inter. sat. org.		BR1 Date of receipt	22.02.2017	BR20 BR IFIC no.
BR6a/BR6b Id. no.		6	BR3a Provision reference		9.1/IA		BR2 Adm. serial no.		UHFTX E

BR7a/BR7b Group id.	9	BR1 Date of receipt	22.02.2017	C2c RR No. 4.4	
BR14 Special Section					
C4a Class of station	ET	C3a Assigned freq. band			
C4b Nature of service	CR	C6a Polarization type	CL	C6b Polarization angle	
C8d1 Max. tot. peak pwr.		C8d2 Contiguous bandwidth			
C11a2 Service area	NOR				

C11a3 Service area diagram

A2b Period of valid. 20 A3a Op. agency 999 A3b Adm. resp. A BR16 Value of type C8b

BR60 Regulatory deadline(s) 11.44/11.44.1

C1 Frequency Range			
C1a Lower limit		C1b Upper limit	
401	MHz	401.3	MHz

C7a Design. of emission	C8a1/C8b1 Max. peak pwr	C8a2/C8b2 Max. pwr dens.	C8c1 Min. peak pwr	C8c2 Attch.	C8c3 Min. pwr dens.	C8c4 Attch.	C8e1 C/N ratio	C8e2 Attch.	C8f1 E.i.r.p. on the beam axis
1 16K5G1D	3	-39.2	0.5		-41.7		57		3

C7b Carrier frequency of the emissions (16K5G1D)									
401.04	MHz	401.08	MHz	402.12	MHz	401.16	MHz	401.2	MHz

C10b1 Assoc. earth station id.	C10b2 Type	C10c1 Geographical coord.	C10c2 Ctry	C10d1/C10d2 Cls. / Nat.	C10d3 Max. iso. gain	C10d4 Bmwdth	C10d6 Noise temp.		
ORBOP	S	018E29 14 69N03 19	NOR	1 TT CR	30	5	150		

C10d5a Co-polar antenna pattern						
C10b1 Assoc. earth station id.	Co-polar ref. pattern	Coef. A	Coef. B	Coef. C	Coef. D	Phi1
ORBOP	REC-580-6					

13C Remarks

B1a/BR17 Beam designation XBANDTX B1b Steerable B2 Emi-Rcp E B3a1 Max. co-polar gain 8

B2bis.a Transmit only when visible from notified service area Y B2bis.b Min. Elev. Angle 10

B3c1 Co-polar antenna pattern					
Co-polar ref. pattern	Coef. A	Coef. B			Co-polar rad. diag.
ND-SPACE					

B4a3a1 Angle alpha B4a3a2 Angle beta

BR92 Attach. for missing angle alpha/beta

BR7a/BR7b Group id.	11	BR1 Date of receipt	22.02.2017	C2c RR No. 4.4	
BR14 Special Section					
C4a Class of station	EW	C3a Assigned freq. band			
C4b Nature of service	CR	C6a Polarization type	CL	C6b Polarization angle	
C8d1 Max. tot. peak pwr.		C8d2 Contiguous bandwidth			
C11a2 Service area	XVE				

A2b Period of valid.

20

A3a Op. agency

999

A3b Adm. resp.

A

BR16 Value of type C8b

C11a3 Service area diagram



Tyvak Proprietary

E_TSUM Requested by: RICKYP		Date: 19.04.2017 10:20:01 AM		DB: TYVAK-0082-API.MDB		Plan Id.:		Notice type: NONGEO	
A	A1a Sat. Network	TYVAK-0082	A1f1 Notifying adm.	NOR	A1f3 Inter. sat. org.		BR1 Date of receipt	22.02.2017	BR20 BR IFIC no.
BR6a/BR6b Id. no.		6	BR3a Provision reference		9.1/IA	BR2 Adm. serial no.			XBANDTX E

BR60 Regulatory deadline(s) 11.44/11.44.1

C1 Frequency Range			
C1a Lower limit		C1b Upper limit	
8045	MHz	8059	MHz

C7a Design. of emission		C8a1/C8b1 Max. peak pwr	C8a2/C8b2 Max. pwr dens.	C8c1 Min. peak pwr	C8c2 Attch.	C8c3 Min. pwr dens.	C8c4 Attch.	C8e1 C/N ratio	C8e2 Attch.	C8f1 E.i.r.p. on the beam axis
1 1M72G1D		-3	-65.4	-3.5		-65.9		90		3

C7b Carrier frequency of the emissions (1M72G1D)											
8046	MHz	8050	MHz	8054	MHz	8058	MHz				

C10b1 Assoc. earth station id.	C10b2 Type	C10c1 Geographical coord.	C10c2 Ctry	C10d1/C10d2 Cls. / Nat.	C10d3 Max. iso. Bmwidth	C10d4 Noise temp.	C10d6 gain		
ORBEX2	T			1 TW CR	50	0.5	150		

C10d5a Co-polar antenna pattern						
C10b1 Assoc. earth station id.	Co-polar ref. pattern	Coef. A	Coef. B	Coef. C	Coef. D	Phi1
ORBEX2	REC-580-6					

13C Remarks

C9 Modulation characteristics	C7a Designation of emission 16K5G1D
C9a1 Type of modulation	PSK
C9a2a Lowest frequency	
C9a2b Highest frequency	
C9a2c Frequency deviation	
C9a3a Freq. deviation of the pre-emphasized signal	
C9a3b Pre-emphasis characteristics	
C9a3c Type of multiplexing	
C9a4a Bit rate	
C9a4b Number of phases	
C9a5a Modulating signal attached (see attch. no.)	
C9a5b Amplitude modulation	
C9a6a Peak-to-peak freq. dev.	
C9a6b Sweep frequency	
C9a6c Energy dispersal waveform	
C9a7 Type of energy dispersal	
C9a8 Other types of modulation (see attch. no.)	
C9a9 TV standard	
BR7a Group id.	9, 12

Tyvak Proprietary

E_TSUM Requested by: RICKYP			Date: 19.04.2017 10:20:01 AM			DB: TYVAK-0082-API.MDB			Plan Id.:			Notice type: NONGEO		
A	A1a Sat. Network	TYVAK-0082	A1f1 Notifying adm.	NOR	A1f3 Inter. sat. org.		BR1 Date of receipt	22.02.2017	BR20 BR IFIC no.					
BR6a/BR6b Id. no.		6	BR3a Provision reference			9.1/IA	BR2 Adm. serial no.					XBANDTX	E	

C9 Modulation characteristics	C7a Designation of emission 1M50G1D
C9a1 Type of modulation	PSK
C9a2a Lowest frequency	
C9a2b Highest frequency	
C9a2c Frequency deviation	
C9a3a Freq. deviation of the pre-emphasized signal	
C9a3b Pre-emphasis characteristics	
C9a3c Type of multiplexing	
C9a4a Bit rate	
C9a4b Number of phases	
C9a5a Modulating signal attached (see attch. no.)	
C9a5b Amplitude modulation	
C9a6a Peak-to-peak freq. dev.	
C9a6b Sweep frequency	
C9a6c Energy dispersal waveform	
C9a7 Type of energy dispersal	
C9a8 Other types of modulation (see attch. no.)	
C9a9 TV standard	
BR7a Group id.	10

C9 Modulation characteristics	C7a Designation of emission 1M72G1D
C9a1 Type of modulation	PSK
C9a2a Lowest frequency	
C9a2b Highest frequency	
C9a2c Frequency deviation	
C9a3a Freq. deviation of the pre-emphasized signal	
C9a3b Pre-emphasis characteristics	
C9a3c Type of multiplexing	
C9a4a Bit rate	
C9a4b Number of phases	
C9a5a Modulating signal attached (see attch. no.)	
C9a5b Amplitude modulation	
C9a6a Peak-to-peak freq. dev.	
C9a6b Sweep frequency	
C9a6c Energy dispersal waveform	
C9a7 Type of energy dispersal	
C9a8 Other types of modulation (see attch. no.)	
C9a9 TV standard	
BR7a Group id.	11

BR22 Administration remarks

BR23 Radiocommunication Bureau comments