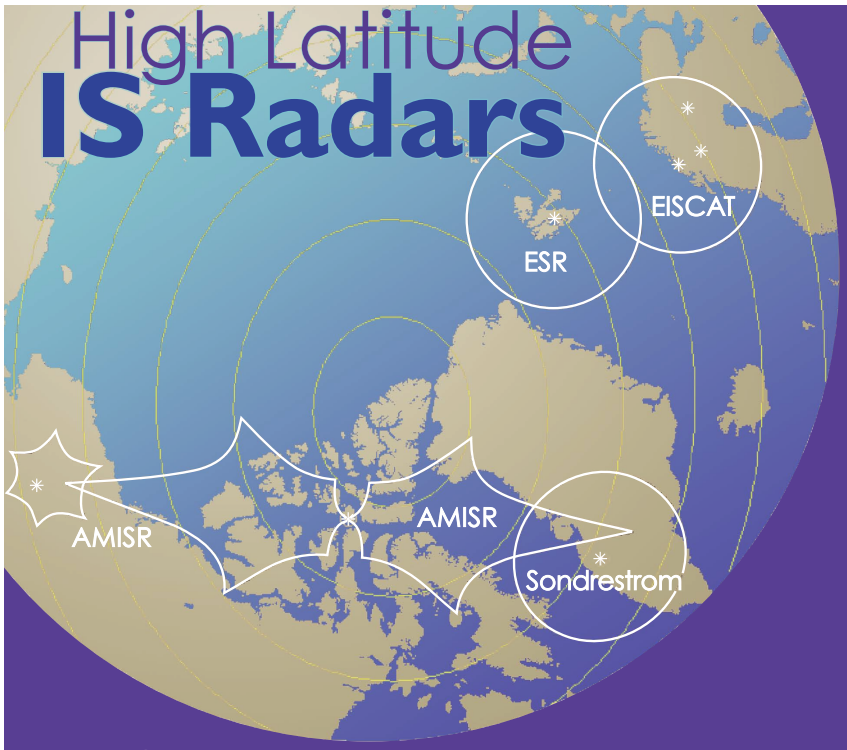
High Latitude IS Radars

EISCAT2003



Useful Constants

$c_0 = 2.99792458 \times 10^8$ ms^{-1} — $m_e = 9.10938188 \times 10^{-31}$ kg

$\mu_0 = 4\pi \times 10^{-7}$ NA^{-2} — $e = 1.602176462 \times 10^{-19}$ C

$\varepsilon_0 = 1/\mu_0 c_0^2$ — $r_e = 2.817940285 \times 10^{-15}$ m

$\varepsilon_0 = 8.854187817 \times 10^{-12}$ Fm^{-1} — $u = 1.66053873 \times 10^{-27}$ kg

$k_b = 1.3806503 \times 10^{-23}$ JK^{-1} — $G = 6.673 \times 10^{-11}$ m^{3}kg^{-1}s^{-2}

Plasma frequency, $\omega_p = \left(\frac{n_e e^2}{\varepsilon_0 m_e}\right)^{1/2} = 2\pi\sqrt{80.6\, n_e}$

Debye length, $\lambda_D = \left(\frac{\varepsilon_0 k_b T_e}{n_e e^2}\right)^{1/2} = 69\sqrt{\frac{T_e}{n_e}}$

Electron thermal speed, $v_{the} = \left(\frac{2 k_b T_e}{m_e}\right)^{1/2} = 5506\sqrt{T_e}$

Ion thermal speed, $v_{thi} = \left(\frac{2 k_b T_i}{m_i}\right)^{1/2} = 129.1\sqrt{\frac{T_i}{W}}$

Ion- acoustic speed, $c_s = \left(\frac{k_b (T_e + T_i)}{m_i}\right)^{1/2} = 91.2\sqrt{\frac{T_e + T_i}{W}}$

Electron gyro frequency, $\Omega_e = \frac{eB}{m_e} = 1.759 \times 10^{11}\, B$

Ion gyro frequency, $\Omega_i = \frac{eB}{m_i} = 9.649 \times 10^7 \frac{B}{W}$

Electron gyroradius, $r_{Le} = \frac{v_{the}}{\Omega_e} = 3.13 \times 10^{-8} \frac{\sqrt{T_e}}{B}$

Ion gyroradius, $r_{Li} = \frac{v_{thi}}{\Omega_i} = r_{Le}\sqrt{\frac{1827\, W}{T_e / T_i}}$

W: molecular weight; $m_i = W \bullet u$

ESR

Geographic coord.	78° 09'11" N 16° 01'44" E
Geomag. dip angle	82° 06'
Invariant latitude	75° 10'48" N
Local time	UT + 1 (UT + 2 summer)
Magnetic time	UT + 2:45
Elevation	445 m
Coverage	360° az., above 30° elev.*

*No transmission below this elevation.

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	Tromsø	Kiruna	Sodankylä
Geographic coord.	69° 35'11" N 19° 13'38" E	67° 51'38" N 20° 26'07" E	67° 21'49" N 26° 37'37" E
Geomag. dip angle	77° 30'	76° 48'	76° 43'
Invariant latitude	66°12' N	64° 27' N	63° 34'N
Local time	UT+1 (UT + 2 summer)	UT + 1 (UT + 2 summer)	UT + 2 (UT + 3 summer)
Magnetic time	UT + 2:30	–	–
Elevation	86 m	418 m	197 m
Coverage	UHF: 360° az., above 20°–22° elev.* VHF: ±15° az., 30°–90° elev. (north only)	Fully steerable	Fully steerable

*Dependent on azimuth No transmission below this elevation.

AMISR

	Poker Flat*	Resolute Bay*
Geographic coord.	65° 7'12" N 147° 25'48" W	74° 43'46" N, 94° 54'16" W
Geomag. dip angle	77° 32'	88° 47'
Invariant latitude	66° 7' N	83° 37' N
Local time	UT – 9 (Alaska)	UT – 6 (central)
Magnetic time	UT – 11:20	UT – 7:45
Elevation	–	–
Coverage	±25°	±25°

*Initial locations. Poker Flat (one face) operational Spring 2005. Resolute Bay (two faces) operational Winter 2006. One face = 128 panels.

Sondrestrom

Geographic coord.	66° 59'12" N 309° 03'02" E
Geomag. dip angle	80° 24'
Invariant latitude	74° 11'24" N
Local time	UT – 3 (UT – 2 summer)
Magnetic time	UT – 1:58
Elevation	177 m
Coverage	360° az., above 25°–30° elev.*

*Dependent on azimuth. No transmission below this elevation.

The Incoherent Scatter RADAR Equation:

$$\text{Signal, } P_r = \frac{C c_0 G \lambda^2}{2 (4\pi)^2} \frac{P_t \tau_p}{r^2} \frac{\sigma_e n_e (r)}{(1 + k^2 \lambda_D^2)(1 + k^2 \lambda_D^2 + T_r)}$$

$$\text{Noise, } P_n = k_b T_{sys} \cdot BW \;:\; BW - \text{bandwidth}$$

$$\sigma_e = 4\pi r_e^2 \simeq 9.98 \times 10^{-29}\ \text{m}^2 \quad \text{Radar cross section of a free electron}$$

C = Constant containing antenna shape and illumination (~0.4)

ESR

Center transmit frequency, f	500 MHz
Wavenumber, k	10.48 m^{-1} ($2k = 20.96\ m^{-1}$)
Wavelength, λ	0.5996 m ($\lambda/2 = 0.2998$ m)
Peak power, P_t	1 MW
Max duty cycle	25%
Pulse length, τ_p	<1 – 2000 μs
Antenna size (dia.)	32 m / 42 m
Antenna gain, G	42.5 dBi / 45 dBi
Antenna beamwidth*	0.6°
System temperature, T_{sys}	55 – 65 K
Antenna type	Parabolic dish
Feed system	Cassegrain
Polarization	Circular

ESR

Tromsø

Kiruna

Sodankylä

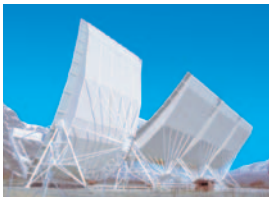
EISCAT

	Tromsø UHF	Kiruna UHF	Sodankylä UHF
Center transmit frequency, f	928.4 MHz	–	–
Wavenumber, k	19.46 m^{-1} ($2k = 38.92\ m^{-1}$)	220 km**, $2k \sin\theta = 36\ m^{-1}$	220 km**, $2k \sin\theta = 33\ m^{-1}$
Wavelength, λ	0.3229 m ($\lambda/2 = 0.1615$ m)	220 km**, $\lambda/2 = 0.17$ m	220 km**, $\lambda/2 = 0.19$m
Peak power, P_t	2 MW	–	–
Max duty cycle	12.5%	–	–
Pulse length, τ_p	1-2000 μs	–	–
Antenna size (dia.)	32 m	32 m	32 m
Antenna gain, G	48 dBi	48 dBi	48 dBi
Antenna beamwidth*	0.5°	0.5°	0.5°
System temperature, T_{sys}	70 – 80 K	30 – 35 K	30 – 35 K
Antenna type	Parabolic dish	Parabolic dish	Parabolic dish
Feed system	Cassegrain	Cassegrain	Cassegrain
Polarization	Circular	Any	Any

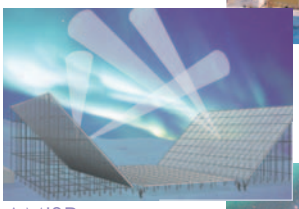
Sondrestrom

EISCAT VHF

Center transmit frequency, f	224 MHz
Wavenumber, k	4.695 m^{-1} ($2k = 9.389\ m^{-1}$)
Wavelength, λ	1.3384 m ($\lambda/2 = 0.6692$ m)
Peak power, P_t	2 x 1.5 MW
Max duty cycle	12.5%
Pulse length, τ_p	1 – 2000 μs
Antenna size	120 x 40 m (4 x (30 m x 40 m))
Antenna gain, G	46 dBi
Antenna beamwidth*	Whole antenna: 0.6° EW x 1.7° NS; Half antenna: 1.2° EW x 1.7° NS
System temperature, T_{sys}	250 – 350 K
Antenna type	Offset parabolic cylinder
Feed system	Line feed
Polarization	Circular



Tromsø VHF



AMISR

Sondrestrom

AMISR

Center transmit frequency, f	449 MHz
Wavenumber, k	9.4 m^{-1} ($2k = 18.82\ m^{-1}$)
Wavelength, λ	0.6677 m ($\lambda/2 = 0.3338$ m)
Peak power, P_t	2 MW
Max duty cycle	10%
Pulse length, τ_p	1 – 2000 μs
Antenna size	128 x (1.5 x 3.5 m)
Antenna gain, G	43 dBi
Antenna beamwidth*	1°
System temperature, T_{sys}	120 K
Antenna type	Crossed dipole phased array
Feed system	Distributed amplifiers
Polarization	Circular

Sondrestrom

Center transmit frequency, f	1290 MHz
Wavenumber, k	27.04 m^{-1} ($2k = 54.07\ m^{-1}$)
Wavelength, λ	0.2323 m ($\lambda/2$=0.1162 m)
Peak power, P_t	3.5 MW
Max duty cycle	3%
Pulse length, τ_p	2 – 500 μs
Antenna size (dia.)	32 m
Antenna gain, G	49 dBi
Antenna beamwidth*	0.5°
System temperature, T_{sys}	85 K
Antenna type	Parabolic dish
Feed system	Cassegrain
Polarization	Circular

* Full width, half power ** Tromsø field line

Useful Constants on front page from Physics Today, Vol 85, No 8, Aug 2003.

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