Observations of Mesosphere Summer Echoes at different sites at 69°N and 78°N using calibrated radar experiments

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10th International Workshop on Technical and Scientific Aspects of MST Radar
Piura, Peru, May 13-20, 2003

LEIBNIZ-INSTITUT FÜR ATMOSPHÄREN PHYSIK IAP

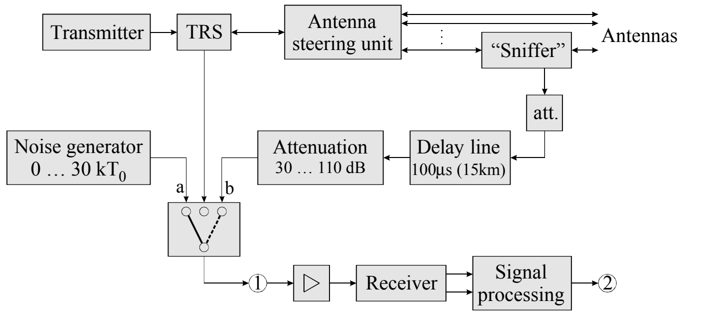
Introduction

Polar Mesosphere Summer Echoes (PMSE) have been observed with VHF radars around 50 MHz at various high-latitude locations for more than 20 years. The occurrence and seasonal variation of PMSEs, their dependence on solar and geomagnetic activity, their relation with mesospheric dynamics and possible causes of this phenomenon are widely studied.

A still open question is the inter-comparison of the various radar experiments as well as the latitudinal dependence of the strength of PMSE as most of the observations are based on relative signal-to-noise ratios and not on absolutely calibrated echo power. In addition, absolute measurements allow also the estimation of further physical parameters (e.g. energy dissipation rate). A few radars were absolutely calibrated using comparable methods such as signals from a noise source and from a delay line. These are the ALOMAR SOUSY radar operated at Andenes/Norway (69°N) from 1994 to 1997, the SOUSY Svalbard radar in operation at Longyearbyen/Svalbard (79°N) since 1999, and the ALWIN radar at Andenes/Norway since 1998.

The advantages and disadvantages of the calibration techniques are discussed. PMSE/MSE observations from two locations at 69°N and 79°N are converted to radar reflectivity. The sensitivity of the different radar experiments as well as strong PMSE events are compared on an absolute level.

Absolute calibration methods



a) Noise generator

A signal from a noise source calibrated in ***kTo*** is fed into the receiving part of the radar system. Since the environment temperature ***T*** and the receiver bandwith Δf are known, the input noise power can be derived by

$$P_{inp-a}\,[W] = \Delta f\, k\, T = c\, T$$

The output of the signal processing unit is usually given as power P_{out-a} in digitiser units or *tpu* and linear depending on P_{inp-a}.

b) Delay line

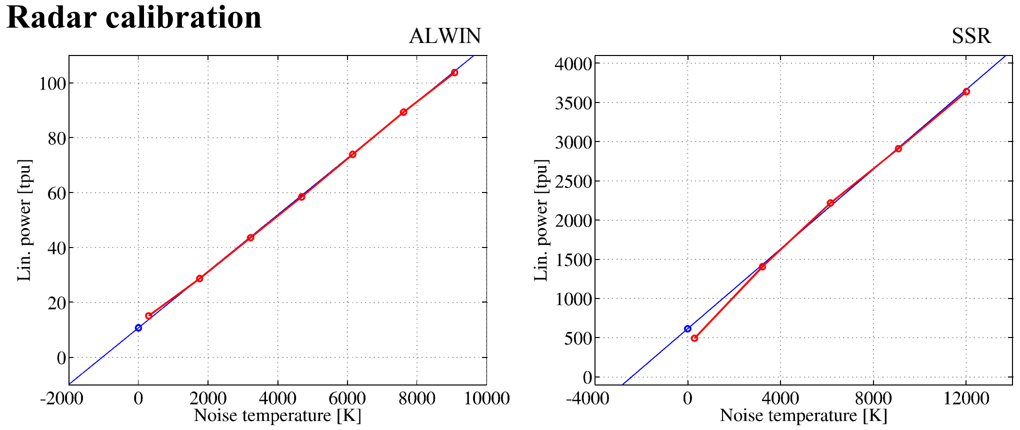
A fraction of the transmitted signal with the known powe r P_{inp-b} is sent through a "delay line" what simulates an echo return. The delayed and attenuated signal is fed into the receive path and results in an output signal P_{out-b} in *tpu* what is proportional to P_{inp-b}.

The ratio P_{inp-b} / P_{out-b} from procedure b) gives a factor E_b for converting *tpu* output power of a coherent received signal into real power. Procedure a) results in a calibration factor E_a for incoherent signals what is in relation to E_b by

$$E_a = (2\,M\,N\,L)\,E_b$$

where *N* is the code length, *M* is the number of coherent integrations and *L* is equal 2 in case of phase flipping.

Radar calibration



The pictures show output power P_{out-a} vs. noise temperature (red curve) after calibration measurements at ALWIN radar (left) and Svalbard SOUSY radar (right). A straight (blue) line $P_{out-a}[tpu] = a + b\,T$ was fit into the curves with the parameters $b = \Delta P_{out-a} / \Delta T$ and $a = P_{out-a}(T=0)$ (blue dots). Since the input noise power is $P_{inp-a}\,[W] = \Delta f\, k\, T = c\, T$ the calibration factor for incoherent signals can be determined by:

$$E_a = \frac{P_{inp-a}[W]}{\left(P_{out-a}[tpu] - a\right)} = \frac{c}{b}$$

from what the calibration factor for coherent signals E_b can be derived. These factors as well as radar and experiment parameters for both radars are shown in the right table.

Basic parameters \ Radar		SSR	ALWIN	
Frequency		53.5 MHz	53.5 MHz	
Peak power		60 kW	36 kW	
System efficiency		0.63	0.66	
Antenna	Number of Yagis	356	144	
	Half-power-width	4°	6°	
	Gain	33 dBi	28.8 dBi	
Parameter \ Experiment		**DBS**	**SA**	**DBS**
Pulse repetition frequency		1.0 kHz	1.5 kHz	
Number of coherent integrations		82	64	
Number of data points		64	256	128
Height range [km]		72.0 - 120.0	73.2 - 96.6	
Pulse width		300m / 2µs	300m / 2µs	
Pulse shape		0.2 µs rise	„normal“	
Code		20 bit complementary	16 bit complementary	
Postdetection filter bandwidth [kHz]		250	500	
Beam off-zenith		5°	0°	7°
Beam azimuth		V, NW, SE, NE, SW	V	V, NW, SE, NE, SW
Calibration factor	E_a	$1.35 \cdot 10^{-17}$	$6.74 \cdot 10^{-16}$	
	E_b	$\mathbf{8.04 \cdot 10^{-21}}$	$\mathbf{6.58 \cdot 10^{-19}}$	

Basic radar parameters and experiment configurations

Results

The calibration procedure allows to convert the received power P_r from tape units (tpu) to physical units (W). If daily variation of the noise power P_n is known, the signal or echo power $P_s = P_r - P_n$ can be expressed in terms of radar reflectivity (Inhester, et.al, 1990):

$$\eta_{radar}\,[m^{-1}] = \frac{8 r^2 k_{radar}^2}{G \Delta r} \cdot \frac{P_s}{\alpha P_t}$$

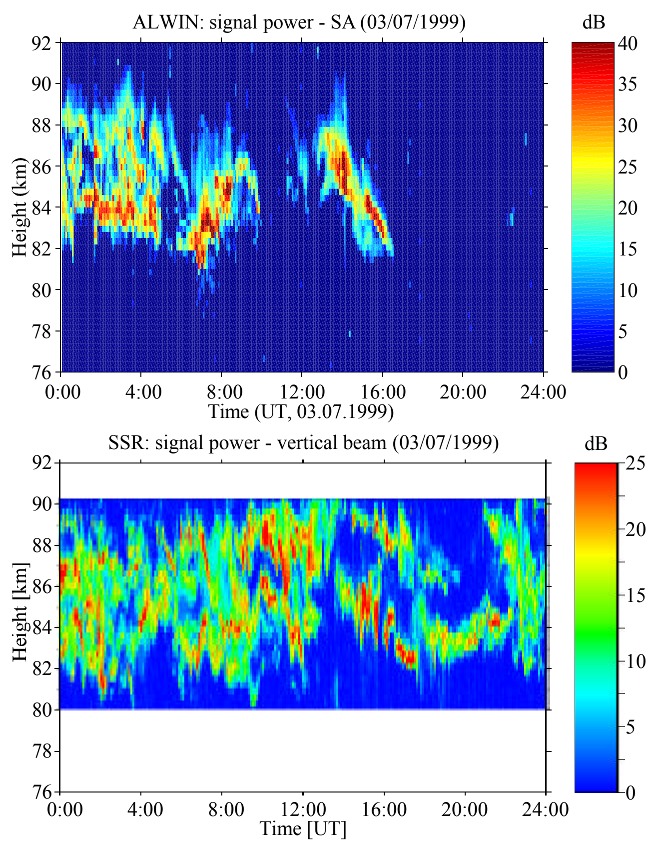
where k_{radar} is the radar wave number, ***G*** is the antenna gain, α is a value for all losses in the transmission and receiving path of the radar system and P_t the peak power.

With the 1999 PMSE experiment configuration parameters from both radars a minimum detectable radar reflectivity η_{min} could be determined using E_b based on the connection between E_a and E_b.

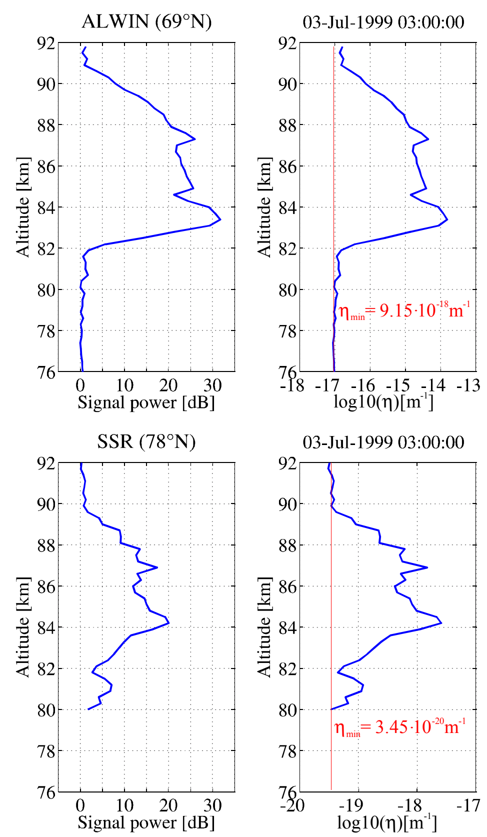
	ALWIN	SSR
$\eta_{min}[m^{-1}]$	$\mathbf{9.15 \cdot 10^{-18}}$	$\mathbf{3.45 \cdot 10^{-20}}$

Since the connection between the correlation factors E_a and E_b is based on ideal assumptions, the real minimum detectable radar reflectivity η_{min} may be a larger value. Calibration measurement using a *delay line* after procedure b) will be performed soon to verify the results.

The OSWIN radar at Kühlungsborn (54°N) provides continuous observations of Mesosphere Summer Echoes (MSE) at mid-latitudes since 1998. We will add results from this radar to this comparison to get a latitudinal dependence of the strength of PMSE based on radar reflectivity.



A typical PMSE observed on July 7, 1999 at 78°N and 69°N presented as contour plot of signal power P_s.



Profiles of signal power P_s (left) and converted radar reflectivity η (right) using factor E_b. The minimum detectable radar reflectivty η_{min} was derived from these example profiles.