From Pulse to Product,

Highlights of the digital-if upgrade of the Dutch national radar network

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1. Introduction

In 2007 KNMI has successfully finished the upgrade of the Dutch radar network. The main results of this upgrade are the extension of the usable life of our radar systems with another 10 years, and the enhancement of the radar processing with capabilities found in modern radar equipment.

In the European tender carried out during this project SELEX SI (formerly known as Gematronik) was awarded a contract to perform the upgrade. During the realization phase of this project the radar sensors were updated with digital receivers and completely new data processing equipment. This modern equipment was integrated in the existing METEOR 360AC radar sensors.

The radar product processing, in our central computer facilities, was replaced too. The Rainbow based Radar Product Processor is offering off the shelf data processing, but is extended with KNMI maintained input and output filters, in order to create flexibility in the conversion to and from formats used by KNMI.

Figure 1 A nice view at the De Bilt radar site

2. Radar Layout and Characteristics

KNMI operates two identical C-band Doppler weather radars type Meteor 360 AC from SELEX, located at KNMI in De Bilt (52.103N, 5.179E) and at a military naval base in Den Helder (52.96N, 4.79E) respectively. The radars use 4.2 m diameter parabolic antennas offering a 1 degree beam.

Some characteristics of the radar production chain, as shown in figure 2, are explained below.

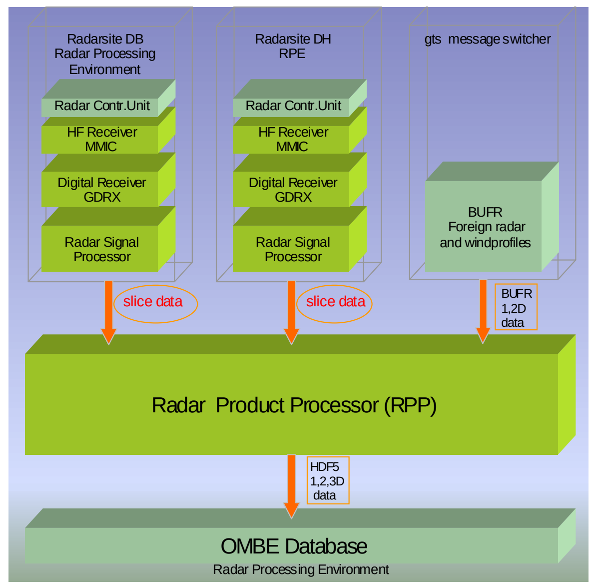

Figure 2 The radar production chain

2.1 Transmitter

The transmitter, mostly untouched during the upgrade project, is of a classical layout. So KNMI uses magnetron based C-band transmitters offering a peak power of the transmitted pulses between 250 and 300 kW. The long-pulse mode, with a pulse duration of 2 microseconds, is used with Pulse Repetition Frequencies (PRFs) below 500 Hz. The short pulse mode (0.8 microseconds) is used for PRFs up to 1200 Hz.

To enhance reliability the thyratron powered switch unit, used to “fire” the magnetron’s pulse forming network, has been replaced by a solid-state switch unit. From a performance point of view the advantage of a solid state switch is that the characteristics do not alter while the unit is aging, offering a transmitter that is firing with a more accurate timing and with less pulse to pulse jitter.

2.2 Receiver

The returned echo signal is captured by an analog frontend that allows for a 110 dB dynamical range, and a 2 dBf noise figure. This frontend uses two separate receivers that have a gain offset of 20 dB. The most sensitive receiver is used until intermediate levels are received, the less sensitive receiver handles the higher reflectivity's. By clever combining of the signals the 110 dB dynamical range is reached. The receiver is down mixing the received signals to an Intermediate Frequency (IF) of 60 MHz. The analog IF signals are digitized in the GDRX digital receiver directly, using 80 MHz ADCs. The GDRX receiver takes in the attenuated HF pulse generated by the magnetron too. This TX-sample is used to generate In-phase and Quadrature-phase (I & Q) signals, and to monitor the transmitted power.

For quality control purposes the analog receiver has a built in signal generator and noise source used for auto checking the receiver at regular intervals.

2.3 Signal Processor

The radial velocity and spectral width are extracted from the received in-phase and quadrature phase components using pulse-pair processing. Prior to the pulse-pair processing data are averaged to 0.5 km and 1 degree in range and azimuth, respectively.

The unambiguous velocity is extended using the dual-PRF technique (Sirmans 1976, Holleman and Beekhuis 2003). In dual-PRF mode, the primary velocity is obtained by combining data from the actual ray with that from the previous ray. Subsequently the velocity data from the actual ray are unfolded using the primary velocity estimate. In our case PRF switching is done near the middle of a ray, such that low and high PRF processing is based upon the same amount of pulses. By doing so artifacts induced by PRF switching are avoided. This dual-PRF unfolding is completely handled by the Signal Processor. Moreover the signal processor is capable of processing all moments (uZ, Z, V, W) simultaneously.

From the Signal Processor data are sent to the central Product Processor on a per PPI basis thus minimizing lag times due to transmission.

2.4 Control Processor

The radar control processor runs on standard industrial hardware, and is responsible for controlling all the radar hardware. Of course the antenna is the most "active" element to be controlled. The Control processor interfaces legacy "synchro" position sensors, as well as modern serial SPI position encoders. KNMI kept the original antenna drive system in operation, but considers an optional drive upgrade, offering brushless motors and a more accurately controlled antenna.

2.5 Product Processor

The Linux based Radar Product Processor is using Rainbow5 application software for the product generation and configuration control of the radars. To enhance reliability two machines run simultaneously in a HOT- COLD configuration, with an automated failover. All single radar products are generated on this platform. In addition it performs compositing of local and European radar data. The Product Processor is extended with user maintainable input and output converters. As a result it is able to process BUFR data delivered by the GTS, as well as the sensor data coming in from the radar sensors. Output of the system is fed into the central KNMI database.

3. Scan schedule

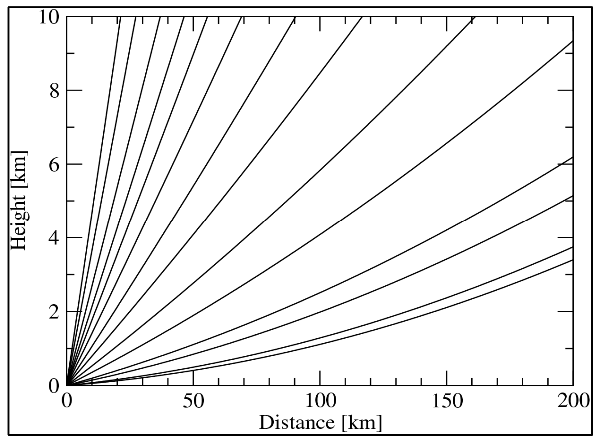

Figure 3 The Volume Coverage Pattern

The operational scanning of the KNMI weather radars generates a 14-elevation volume every 5 minutes. Figure 3 displays the Volume Coverage Pattern of the KNMI weather radars. For all elevations in this volume scan, the parameters can be chosen independently. Table 1. lists the main parameters of the volume scan.

Table 1 Parameters of the KNMI volume scanning

no	Elevation	deg/sec	PRF	Range	binsize
1	0.3	18	250	320	1.0
2	0.4	18	600/450	240	1.0
3	0.8	18	600/450	240	1.0
4	1.1	18	600/450	240	1.0
5	2	18	600/450	240	1.0
6	3	24	800/600	170	0.5
7	4.5	24	800/600	170	0.5
8	6	30	1000/750	145	0.5
9	8	30	1000/750	145	0.5
10	10	36	1200/900	120	0.5
11	12	36	1200/900	120	0.5
12	15	36	1200/900	120	0.5
13	20	36	1200/900	120	0.5
14	25	36	1200/900	120	0.5

4. Corrections applied on Volume Data

4.1 Clutter Processing

The KNMI ground clutter processing scheme, based upon statistical filtering has been redesigned to be applied on polar volume data. Nowadays this filter is applied on the lowest (non-Doppler) elevation only. As all other elevations are run in Doppler mode, DFT-filtering with spectral reconstruction is applied on these elevations. By doing so all products derived from the volumes share the same clutter correction.

4.2 Occultation correction

Even in a country as flat as the Netherlands the radar beam can be obstructed, be it mostly by man made objects. The applied occultation correction reconstructs blocked sectors on a per elevation basis by performing a linear weighted averaging of data found at the edges of the blockage.

5. Quality Monitoring, Looking at the sun

The sun emitting in its spectrum weak radar signals offers the possibility to check the radar sensors against an external source. By offline processing of received volume sets KNMI is monitoring the sun passages during sunrise and sunset. The output of this tool offers a day to day record of the sun power compared to the DRAO standard. It shows that our installations follow DROA observations within 0.2 dB, thus offering a valuable monitoring tool for the sustained sensitivity of our receivers. In a similar way deviations in the pointing of the antenna as small as 0.05 degree are easily detected.

6. Data Model

The KNMI internal standard for operational radar products and volume data is based on HDF5. KNMI uses a proprietary (although freely available) data model.

As a result of harmonization with other KNMI remote sensing sources, such as lightning and satellite, data of these sources is available in the same data model . Using this data model KNMI can offer access to the archived volume data in a widely used scientific format, facilitating research.

One of the advantages of the hierarchical structure of HDF5 is the way metadata can be stored along with the data. As an example: KNMI stores the measured transmitted power in its volume files as metadata to the moment data for a every elevation as shown in figure 4.

7. Product generation

The following products are produced operationally from the weather radar scans:

7.1 Reflectivity Composites

Reflectivity composites at low altitude (1500 meter above msl) for Netherlands and Western Europe. These main radar products are showing the temporal and spatial evolution of precipitation patterns.

7.2 Accumulated Precipitation

Precipitation is accumulated over 3 hour and 24 hour periods. The accumulations are based on the reflectivity composite and are adjusted with rain gauge observations.

7.3 Echotop Height Composites

The echotop height composites show the observed maximum height of the radar echoes. They are of special interest for aviation purposes.

7.4 Hail Warning Product

Large hail is detected using the height difference between the 45 dBZ echotops and the freezing level from Numerical Weather Prediction model (Holleman 2001).

7.5 Wind Profiles

Weather radar wind profiles are extracted from the Doppler scans. A study focused on the optimization and verification of these wind profiles has been performed at KNMI (Holleman 2005). These profiles are considered to add valuable time series information to the bi-daily radiosonde sounding. They are distributed to the CWINDE data hub for international use.

7.6 Wind Shear (new in 2008)

As we are now able to process data on a sub-kilometer grid the reliable extraction of wind shear is greatly enhanced. This product is under evaluation now. This product might add up to extra safety in aviation.

7.7 Wind Field (new in 2008)

The distance between both KNMI radars is relatively small (approx. 90 Km). So the region that both radars have qualitative data available is substantial. As Schiphol airport is covered by both radars a wind field based upon simultaneous Doppler measurement of both radars is under evaluation.

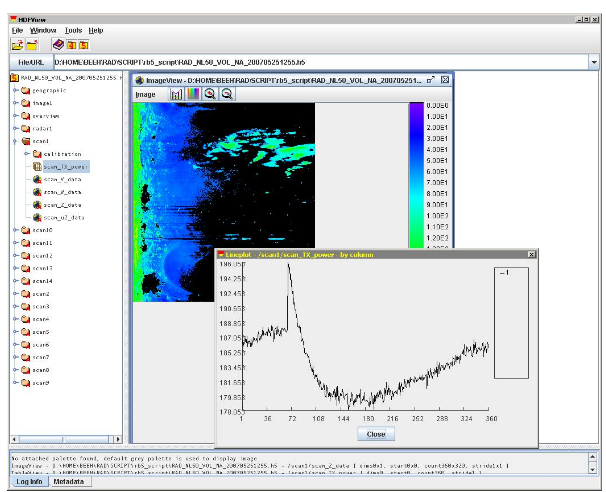

Figure 4 Transmitted power as metadata to moment data