IRCTR DRIZZLE RADAR

- IDRA -

DATASET DESCRIPTION DOCUMENT FOR THE CDS DATASETS

<cesar_idra_reflectivity_la1_t00_v1.0>

TU Delft Delft University of Technology

IRCTR

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	T. Otto	2010-12-08	appendix with NetCDF header dump added

General Overview

This dataset description document provides information for the CDS datasets
cesar_idra_reflectivity_la1_t00_v1.0.

IDRA is the TU Delft IRCTR drizzle radar that is located on top of the Cabauw tower, 213 m agl., since October 2007, Figure 1. IDRA is a polarimetric X-band (9.475 GHz, horizontal/vertical polarisations) FMCW radar developed at Delft University of Technology. Its antennas rotate at 1 rpm at a fixed low elevation angle providing plan position indicators (PPI) with a slant observation range of 15 km at a range resolution of 30 m. The radar transmits linear sawtooth frequency modulated sweeps alternately at horizontal and vertical polarisation. The backscattered signal is received simultaneously in an horizontally and a vertically polarised channel.

Figure 1: IDRA on top of the Cabauw tower. IDRA uses two antennas, one for transmit and one for receive.

The central frequency of 9.475 GHz, sensitive receivers with a large dynamic range, and the possibility to adjust the power of the transmitted signal, permit IDRA to monitor the horizontal spatial distribution of precipitation (from fog and drizzle to heavy convective rain).

This dataset contains a series of PPI's, i.e. full 360° - scans in azimuth, of the measured co-polarised reflectivities (dBZ) at horizontal polarisation as derived by the radar control computer. Out of five PPI's measured by IDRA, one is stored in this dataset. That corresponds to one minute of data each five minutes. The reflectivities are not corrected for propagation effects, i.e. attenuation. However, a spectral polarimetric filtering based on the polarimetric weather radar observables, such as differential reflectivity Z_{dr} and the linear depolarisation ratio *LDR,* is employed in order to reduce spurious echoes from interferences within the radar system itself, and from clutter.

IDRA data, including the polarimetric data streams, can also be found at the 3TU.Datacenter:

http://data.3tu.nl/repository/collection:cabauw

http://dx.doi.org/doi:10.4121/uuid:5f3bcaa2-a456-4a66-a67b-1eec928cae6d

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The Netherlands

Deployment Locations and History

IDRA is a stationary radar system, installed on top of the Cabauw tower. The following list gives an overview when IDRA was installed at the Cabauw tower, and in which periods IDRA was operational (green marker).

August 2007	Installation of IDRA on top of the Cabauw tower.
18-10-2007	First measurement, antenna stationary.
05-12-2007	First measurement with rotating antennas.
14-12-2007	Installation of the IDRA control computer.
26-06-2008	The real-time processing reaches an operational status.
28-11-2008	IDRA's electronics were removed from the tower to improve the receivers.
05-03-2009	IDRA's electronics were re-installed on the tower.
27-04-2009	IDRA is fully operational again.
09-12-2009	*Signal processing changed*, see Section "Signal Processing" for details.
26-12-2009	Mechanical problems with the antenna gear-box.
01-01-2010	Antenna gear-box problem solved. IDRA is back to normal operation.

Near-Real-Time Data Plots

Near-real-time data plots of IDRA measurements can be found online at:

http://ftp.tudelft.nl/TUDelft/irctr-rse/idra/

IDRA's near-real-time plots are updated once per minute.

Data Description and Examples

Figure 2 shows an example PPI of a reflectivity measurement of IDRA. The figure shows a squall line passing Cabauw in the evening of the 25th of May 2009. The radar is located in the middle of the plot. The ordinate and the abscissa of this PPI show the range (km) from the radar. The colours represent the co-polarised equivalent reflectivity factor at horizontal polarisation Z_{hh} (dBZ). The reflectivity in linear units ($mm^6 \cdot m^{-3}$) is proportional to the backscattered and received power. Using empirically derived Z-R relations, the rain rate might be directly inferred from the reflectivity.

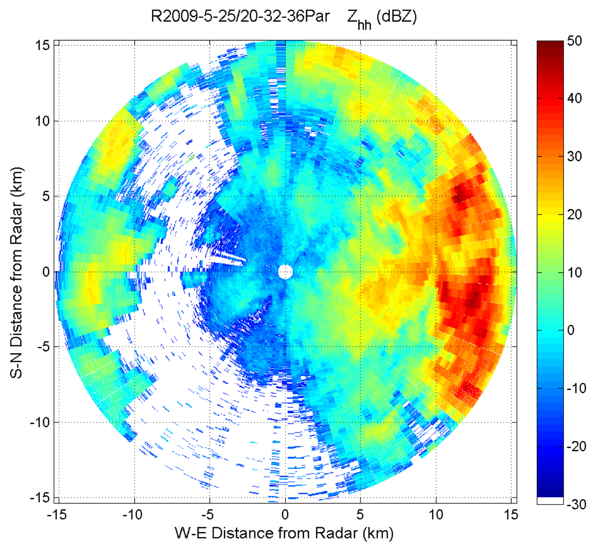


Figure 2: Example of a reflectivity measurement of IDRA.

The dataset contains one full PPI (one minute of data) each five minutes. The data are in polar coordinates to allow further processing on a profile-to-profile basis, e.g. attenuation correction. In irregular intervals, data might be missing. The missing data usually indicates that IDRA was not running in the standard mode but in a different mode. For a query whether missing data is available in a different data acquisition mode, please contact the PI.

Data File Contents

Table 1 summarises the dimensions, global attributes, and variables contained in the dataset. Additional information about the dimensions and variables can also be found directly in the dataset within the corresponding *units* and *comment* attributes.

Table 1: Data file contents.

Dimensions	Description
scalar	dimension used for variables with one value
time	time dimension
range	range dimension
Attributes	**Description**
global attributes	as specified by [2]
Primary variable	**Description**
equivalent_reflectivity_factor	the primary variable, the co-polarised equivalent reflectivity factor at horizontal polarisation Z_{hh} (dBZ)
Secondary variables	**Description**
iso_dataset	contains a copy of the dataset metadata, for more information refer to [2]
product	contains a copy of the product metadata, for more information refer to [2]
station_details	contains metadata describing station details, for more information refer to [2]
azimuth	the azimuth angle of each profile
range_resolution	the resolution along slant range
radiation_wavelength	IDRA's wavelength
frequency_excursion	frequency excursion of the transmitted linear up-chirp
sweep_time	sweep time of the transmitted linear up-chirp
tx_power	transmitted power
sample_size	number of samples that are averaged for the calculation of one profile
beam_width	antenna half-power beamwidth of the transmit and receive antenna
elevation	elevation angle of the antennas

Primary Variable and Expected Uncertainty

The primary variable of this dataset is the co-polarised equivalent reflectivity factor at horizontal polarisation *equivalent_reflectivity_factor* in the logarithmic unit *dBZ*, i.e. normalised with respect to 1 $mm^6 \cdot m^{-3}$. To illustrate this, one spherical raindrop with a diameter of 1 mm per cubic metre would produce a reflectivity of 0 dBZ.

The expected measurement uncertainty of the reflectivity is ±1 dB over the receiver dynamic range. In this context, the uncertainty displays the probable maximum deviation of the measured value from the true value within a 95% confidence interval. It must be stressed that further aspects may deteriorate the quality of the reflectivity measurements. Those are outlined in the chapter "Data Quality".

Quicklook

The CESAR database requirements demand that single files of the dataset contain the measurements for one whole day. These must be represented by one quicklook file.

Figure 3 shows an example for the quicklook. Each PPI was analysed on the whole using a histogram based technique, and categorised into the five classes. The quicklook shows the result of this classification in dependence of the time of the day. To retrieve stable classification results, also the linear depolarisation ratio *LDR* is employed in the classification process since it is a good indicator for precipitation.

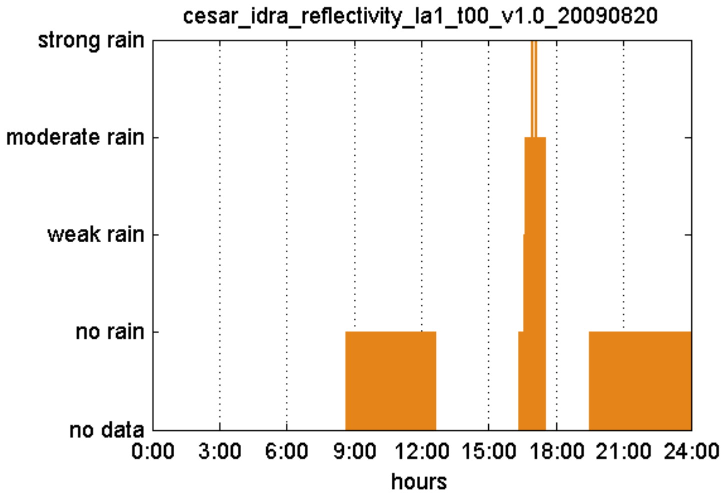


Figure 3: Example of a quicklook.

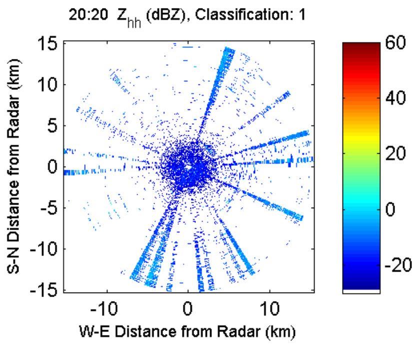
Table 2 gives an overview of the classes, and the conditions that are employed. Since each PPI is analysed on the whole, the resulting classification does not give an indication of the spatial distribution of the precipitation.

Table 2: Classes for the quicklook. A reflectivity of Z_{hh} = 20 dBZ corresponds approximately to an instantaneous rain rate of 1 mm/h, and Z_{hh} = 45 dBZ corresponds approximately to 25 mm/h.

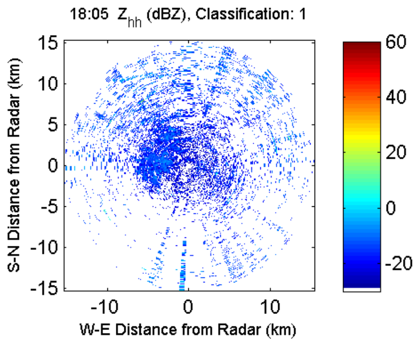
Class	Conditions
no data	No data available.
no rain	None of the other four classes matches.
weak rain	$Z_{hh} \geq 20$ dBZ or LDR < -20 dB in more than 3% of the PPI, and the condition for moderate and strong rain do not match
moderate rain	$Z_{hh} \geq 20$ dBZ or LDR < -20 dB in more than 3% of the PPI, and 20 dBZ < $Z_{hh} \leq 45$ dBZ in more than 5% of the PPI.
strong rain	$Z_{hh} \geq 20$ dBZ or LDR < -20 dB in more than 3% of the PPI, and $Z_{hh} > 45$ dBZ in more than 1% of the PPI.

The classification does not provide optimal results in all cases. Especially measurements of very light rain, drizzle or fog may be classified as *no rain* due to the difficulty to distinguish it on a histogram basis from clutter.

The following figures give for each class examples of corresponding PPI's.

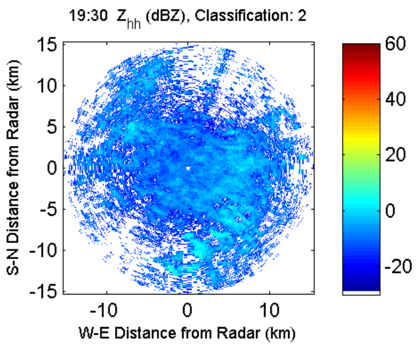


(a) 2009-05-26

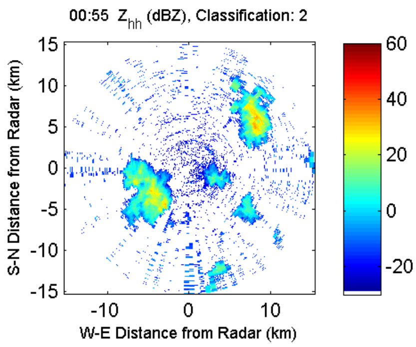


(b) 2009-05-27

Figure 4: PPI's classified as *no rain*.

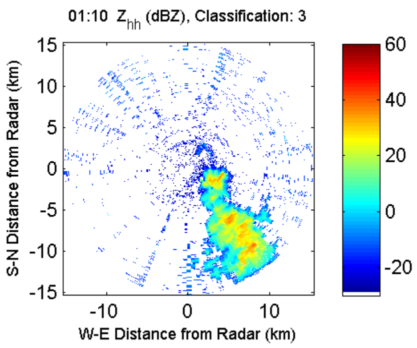


(a) 2009-05-27

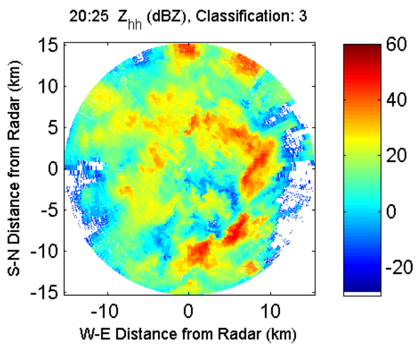


(b) 2009-05-28

Figure 5: PPI's classified as *weak rain*.



(a) 2009-05-28



(b) 2009-05-25

Figure 6: PPI's classified as *moderate rain*.

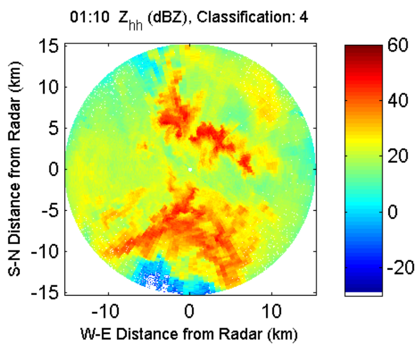


Figure 7: PPI from 2008-08-01 classified as *strong rain*.

Signal Processing

The real-time signal processing of IDRA is performed in the Doppler domain, and includes several filters to remove spurious interferences and clutter echoes.

For datasets with the version number until the 8th of December 2009, the signal processing comprehends the following steps:

- application of an Hamming window on the received complex voltages, and transformation into the range-Doppler domain by the application of a two-dimensional fast Fourier transform (FFT),
- determination of the power spectra for the co-polarised channels, i.e. linear horizontal and linear vertical polarisation, and for the cross-polarised channel,
- spectral filtering comprising a noise clipping, the application of a notch filter in the Doppler domain to suppress interferences and clutter echoes, and polarimetric filtering in the Doppler domain based on the linear depolarisation ratio, the differential reflectivity, and the differential propagation phase,
- calculation of the co-polarised equivalent reflectivity factor at horizontal polarisation.

Further details on the signal processing for can be found in Section 4.2.7 of [i].

For datasets after the 8th of December 2009, changes have been made to the spectral filtering. The noise clipping level has been reduced from 10 dB to 3 dB. The width of the Doppler notch filter has been reduced. Instead of suppressing Doppler velocities within -0.23 ms^{-1} and +0.23 ms^{-1}, only Doppler velocities between -0.08 ms^{-1} and 0.08 ms^{-1} are suppressed. The polarimetric filtering is based only on the spectral linear depolarisation ratio, i.e. Doppler bins with $LDR \geq -7$ dB are suppressed. A speckle filter in the Doppler domain has been introduced. If after all the spectral filtering, there are less than 2% of valid Doppler bins per range bin, the range bin is discarded. Further details on the updated signal processing are available as internal documentation at TU Delft IRCTR.

Data Quality

The raw data streams of IDRA are processed in real-time by the radar control computer. Data quality flags are not provided by this data processing. Thus, users of this dataset must be aware of the following issues that might deteriorate the measurements.

Clutter echoes

The signal processing employs a filtering of the polarimetric observables in the Doppler spectrum domain in order to suppress clutter echoes and interferences. However, some clutter and interference signatures are similar to meteorological signatures, and are thus preserved in the processed data. Figure 4 (a) shows an example with some interferences that are perceivable as radial structures along single profiles. The echoes close to the radar in a range of less than 5 km are probably due to insects.

Clutter filter

To suppress clutter echoes and interferences within the radar system, a notch filter in the Doppler domain is employed. Signals with Doppler velocities between -0.23 ms^{-1} and +0.23 ms^{-1} are suppressed for datasets until the 8th of December 2009.

For datasets after the 8th of December 2009, the notch filter width has been reduced, suppressed are only Doppler velocities between -0.08 ms^{-1} and 0.08 ms^{-1}.

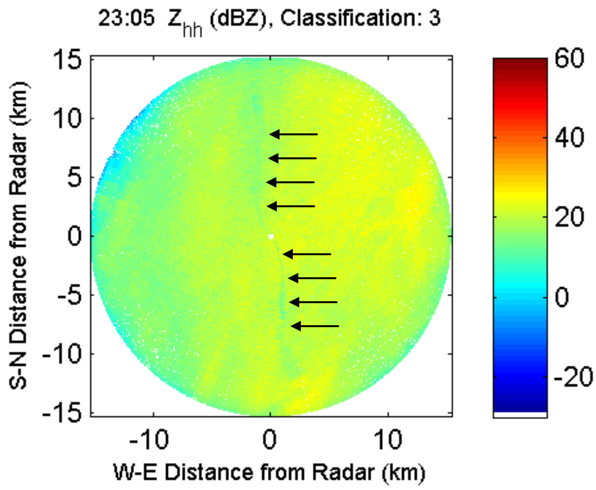
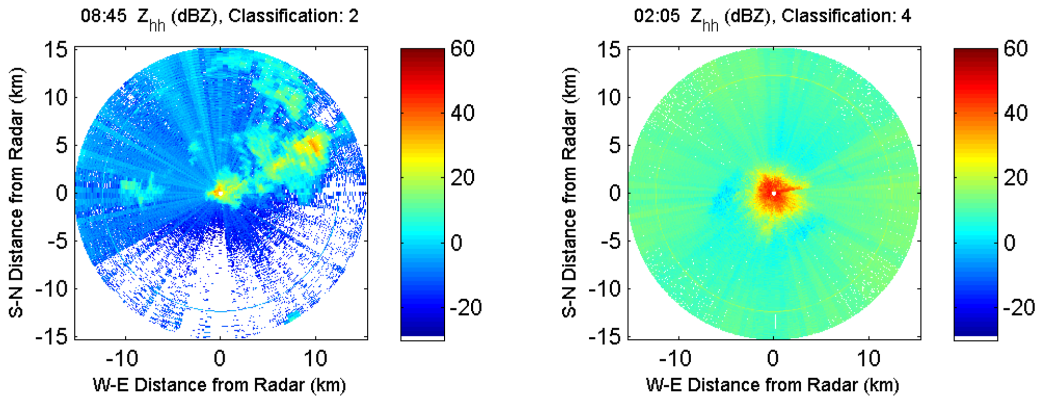


Figure 8: The effect of the clutter filter, 2008-08-03.

This also affects the estimated reflectivity in case when the radial velocity of the parts of the meteorological echo lays within suppressed band of Doppler velocities. The resulting reduction of the reflectivity of the meteorological echo is perceivable in the PPI, see for an example Figure 8.

Receiver Saturation

When the received echo exceeds the dynamic range of the radar receiver, saturation occurs. IDRA is equipped with an attenuator to reduce the transmitted power in these cases. This attenuator is however still not working in real-time. Thus, the data might include receiver saturation effects that due to the nature of a FMCW radar results in a smearing effect in range.



(a) 2009-06-04 (b) 2009-05-26

Figure 9: The effect of receiver saturation on reflectivity measurements.

Figure 9 as well as Figure 7 show examples of receiver saturation. Figure 9 (a) shows a case of weak receiver saturation that did not affect all azimuth angles. Instead, Figure 9 (b) shows a case of very strong receiver saturation with the result of a loss of information about the spatial distribution of the precipitation.

Attenuation

It must be stressed again that the reflectivity of this dataset is not corrected for attenuation. Since the radar operates at X-band, the attenuation may be quite significant. In strong precipitation events, the attenuation over the range of 15 km may be as large as 6 dB or more. Figure 10 show an example calculation for expected attenuations in dependence of the rain rate and the range. This figure is the result of electromagnetic scattering computations and should only be used as an indicator of possible attenuation levels.

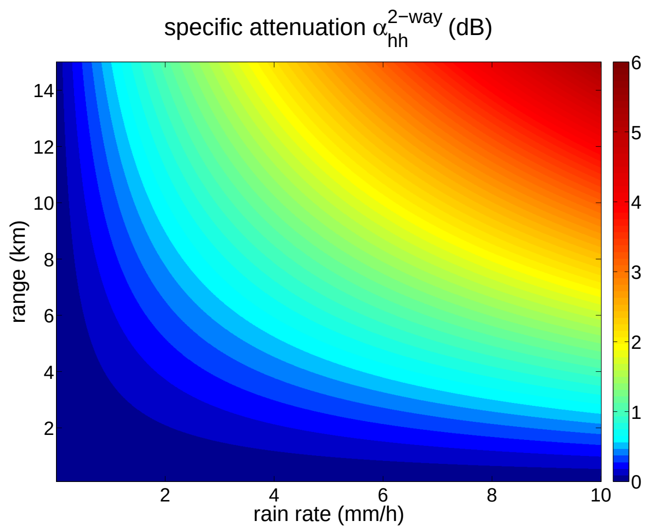


Figure 10: Two-way specific attenuation (dB) at horizontal polarisation assuming a propagation path with a homogeneous rain rate indicated along the abscissa. This figure is a result of an electromagnetic scattering computation for rain assuming the spheroidal raindrop shape model of Pruppacher and Beard, and the exponential raindrop-size distribution of Marshall and Palmer.

Multitrip echoes

In monostatic weather radar observations range aliasing can occur. In that case, the received signal stems from the transmission of an earlier sweep, and is thus designated to a wrong range closer to the radar. These multitrip echoes usually manifest in the PPI as radial reflectivity patterns with a low intensity as shown in Figure 11.

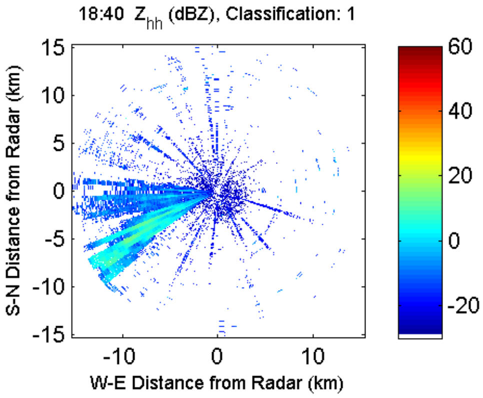


Figure 11: Multitrip echo, 2009-05-25.

PPI's that do not contain an homogeneous precipitation pattern should thus be discarded. Additionally one may also verify the presence of the multitrip echoes by evaluating the data of other instruments, e.g. using the operational weather radar data available online, e.g. at http://www.buienradar.nl/historie.aspx.

Synchronisation loss

For reasons that are still under investigation, a synchronisation loss occurs from time to time. This affects the computed weather radar observables. Figure 12 shows an example of such a corrupted reflectivity measurement. As for the multitrip echoes, the PPI does not show an homogeneous precipitation pattern. Such measurements if included in a dataset should be discarded as well.

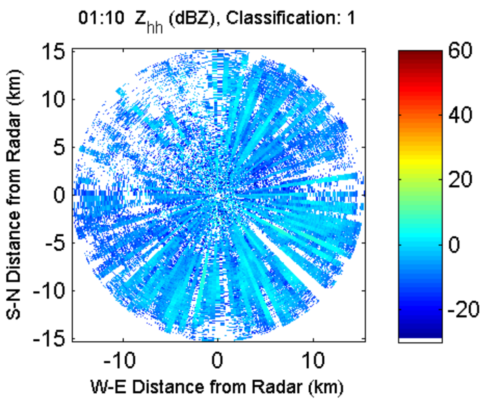


Figure 12: Corrupted IDRA reflectivity measurement due to the loss of synchronisation, 2009-06-04.

Instrument Details

Detailed Description

Figure 13 shows the block diagram of IDRA. The upper part of the figure shows the transmitter path. The lower part shows the co- and the cross-polarised receiver channels.

The synchronisation of the system is provided by a GPS timing board. This GPS timing board is also used to provide an accurate time stamp for the processed data.

For a detailed description of IDRA the reader is referred to [i].

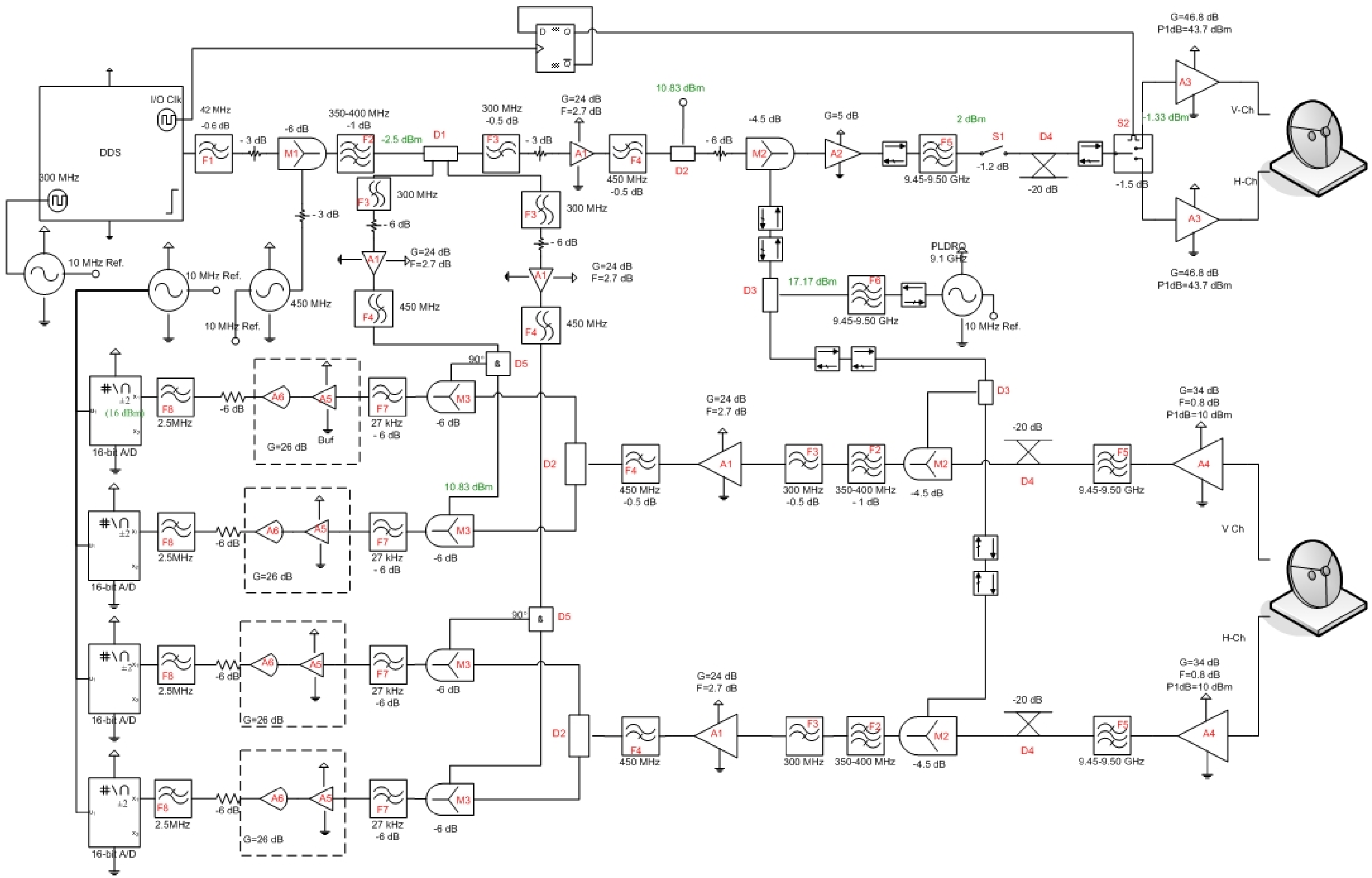


Figure 13: IDRA block diagram showing the transmitter and receiver channels.

Specifications

Table 3: Specifications of IDRA. For the measurements of this dataset, a frequency excursion of 5 MHz and a sweep time of 409.6 μs is employed.

Parameter	Value
latitude	51°58'11.92" North
longitude	04°55'37.16" East
height above sea-level	213 m agl.
transmitter	solid-state amplifiers, modulation achieved by a direct digital synthesiser
polarisation on transmit	linear horizontal, linear vertical, polarimetric (alternately linear horizontal and linear vertical)
frequency modulation on transmit	sawtooth
receiver	heterodyne, quadrature receiver, two channels, receiving the co- and the cross-polarised component (linear horizontal and linear vertical polarisation)
maximum range	15 km in standard mode operation
cross-polarisation isolation	< -30 dB
minimum detectable reflectivity	-15 dBZ at 15 km
dynamic range of the receiver	69 dB

Parameter	Symbol	Value
central frequency	f_c	9.475 GHz
frequency excursion, the corresponding range resolution is $c/(2 \cdot \Delta f)$	Δf	**5**, 10, 25, 50 (MHz)
sweep time	ΔT	102.4, 204.8, **409.6**, 819.2, 1683.4, 3276.8 (μs)
transmitted power	P_t	0, 1, 2, 5, 10, 20 (W)
antenna gain, transmit	G_t	38.65 dB
antenna gain, receive	G_r	38.65 dB
gain of the receiver chain	G_{rec}	53 dB
antenna half-power beamwidth, transmit	θ_t	1.8° (0.031 rad)
antenna half-power beamwidth, receive	θ_r	1.8° (0.031 rad)

Theory of Operation

IDRA employs the frequency-modulated continuous wave radar principle, i.e. the radar is transmitting and receiving at the same time. The frequency of transmitted signal is sawtooth modulated. The backscattered and received echo is shifted in frequency with respect to the transmitted signal. This frequency shift, called the beat frequency, is directly related to the range of the echo.

The beat frequency is evaluated by mixing the transmitted signal with the received signal. Subsequently, a Fourier analysis is performed to separate the contributions from different range bins. The radar equation for distributed targets is then applied to calculate the reflectivity of each range bin.

For a detailed overview of the theory of operation, the reader is referred to [i].

Calibration

After IDRA has been built, extensive measurements have been carried out in order to characterise the system, and to derive the radar system constant necessary for accurate reflectivity measurements. For details about the calibration, the reader is again referred to [i]. In order to sustain the calibration of the system, a noise measurement is performed every day which is used to monitor variations of the receiver gain of IDRA. However, recent analyses of IDRA data revealed a possible calibration offset for reflectivity measurements. Therefore, a novel operational calibration procedure has been devised which is based on the differential phase measurement, [4] and [5]. The data files in the CESAR database *are not calibrated with this procedure*. IDRA data files that contain the necessary data streams to allow the application of this procedure can be found at the 3TU.Datacenter:

http://data.3tu.nl/repository/collection:cabauw

http://dx.doi.org/doi:10.4121/uuid:5f3bcaa2-a456-4a66-a67b-1eec928cae6d

In irregular intervals, passive measurements of the sun position is carried out in order to ensure that 0° azimuth corresponds to the Geographic North Pole.

Operation and Maintenance

More information about the operation and the maintenance of IDRA are available as internal documentation at TU Delft IRCTR.

Glossary and Acronyms

CDS	CESAR database system
CESAR	Cabauw experimental site for atmospheric research
DDS	dataset description document
DDS	direct digital synthesizer
FFT	fast Fourier transform
FMCW	frequency-modulated continuous-wave
GPS	global positioning system
IDRA	IRCTR drizzle radar
IRCTR	International Research Centre for Telecommunications and Radar of the Delft University of Technology
LDR	linear depolarisation ratio
MDD	metadata description document
PI	principle investigator
PPI	plan position indicator
X-band	electromagnetic frequency band from 8 GHz to 12 GHz

Citable References

[i] J. Figueras i Ventura: “Design of a High Resolution X-band Doppler Polarimetric Weather Radar”, *PhD Thesis*, TU Delft, 2009.
Available online at the institutional repository of TU Delft:
http://repository.tudelft.nl/view/ir/uuid%3Ad90b9ad6-237b-435d-9dc5-5660d9e7fbdd/

[ii] J. Figueras i Ventura and H. W. J. Russchenberg: “Towards a better understanding of the impact of anthropogenic aerosols in the hydrological cycle: IDRA, IRCTR drizzle radar”, *Phys. Chem. Earth, Parts A/B/C*, vol. **34**, pp. 88 – 92.

References

[1] R. J. Doviak and D. S. Zrnić: “Doppler Radar and Weather Observations: Second Edition”, *Dover Publications*, 2006.

[2] H. Klein Baltink: “Cesar Database System – Metadata Description Document”, v0.7, KNMI, October 2007.

[3] H. Klein Baltink: “Cesar Database System – Interface Control Document”, v1.4, KNMI, August 2009.

[4] T. Otto and H. W. J. Russchenberg: “Estimation of the raindrop-size distribution at X-band using specific differential phase and differential backscatter phase”, *Proc. 6th European Conf. on Radar in Meteorology and Hydrology: Adv. in Radar Technology*, Sibiu, Romania, ISBN 978-973-0-09057-4, 171 – 176, 2010. http://www.erad2010.org/pdf/oral/thursday/xband/07_ERAD2010_0109.pdf

[5] T. Otto and H. W. J. Russchenberg: “Estimation of specific differential phase and differential backscatter phase from polarimetric weather radar measurements”, *IEEE Geosci. Remote Sens. Lett.*, submitted, 2010.

Appendix A: Header dump of the IDRA reflectivity dataset

```
dimensions:
   scalar   = 1;
   time     = 17017;
   range    = 512;
 variables:
   char iso_dataset(scalar=1);
     :title    = "IDRA Reflectivity";
     :abstract = "This dataset contains X-band (central frequency of 9.475 GHz)
                 weather radar measurements from the TU Delft IRCTR drizzle ra-
                 dar IDRA. It includes plan-position indicators (PPI) of the
                 co-polarised equivalent reflectivity factor at horizontal po-
                 larisation. IDRA is mounted at the top of the Cabauw tower at
                 213 m agl., and is scanning horizontally at a fixed low eleva-
                 tion angle, covering a slant range of 15 km with a range reso-
                 lution of 30 m. IDRA thus provides the horizontally spatial
                 distribution of precipitation over the CESAR observatory. The
                 dataset contains one whole PPI out of five measured by IDRA,
                 i.e. a measurement that is produced by one full antenna rota-
                 tion along the azimuth. Since the antenna of IDRA rotates at a
                 speed of one round per minute, this corresponds to one minute
                 of data every five minutes.";
     :status              = "onGoing";
     :hierarchyLevel      = "dataset";
     :url                 = "http://www.cesar-database.nl";
     :protocol            = "website";
     :uid_dataset         = "23C68026-D244-4562-B11A-8D3C4FACDB11";
     :topic               = "climatologyMeteorologyAtmosphere";
     :keyword             = "Radar, Reflectivity, Precipitation";
     :westbound_longitude = "4.707";
     :eastbound_longitude = "5.145";
     :southbound_latitude = "51.835";
     :northbound_latitude = "52.105";
     :temporal_extent     = "2008-06-26,onGoing";
     :date                = "2009-10-19";
     :dateType            = "publication";
     :statement           = "Calibrated reflectivity measurements, but not cor-
                             rected for propagation effects, i.e. attenuation.";
     :code                = "28992";
     :codeSpace           = "EPSG";
     :accessConstraints   = "CESAR data policy";
     :useLimitation       = "none";
     :organisationName_dataset = "Delft University of Technology (DUT)";
     :email_dataset       = "t.otto@tudelft.nl";
     :role_dataset        = "Principle Investigator";
     :metadata_id         = "B1268886-304E-469E-AF42-02846219CCC4";
     :organisationName_metadata = "Delft University of Technology (DUT)";
```

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  :role_metadata                 = "Principle Investigator";
  :email_metadata                = "t.otto@tudelft.nl";
  :url_metadata                  = "http://atmos.irctr.tudelft.nl/";
  :datestamp                     = "2009-10-06";
  :metadataDateType              = "creation";
  :language                      = "eng";
  :metadataStandardName          = "ISO-19115";
  :metadataStandardNameVersion   = "Nederlands profiel op ISO 19115 voor
                                    geografie, v1.2";
char product(scalar=1);
  :date_start_of_data       = "2008-06-27T14:10:00Z";
  :date_end_of_data         = "2008-06-28T00:00:59Z";
  :ref_doc                  = "cesar_idra_reflectivity_la1_t00_v1.0.pdf";
  :ref_doc_version          = "1.0";
  :format_version           = "netCDF,3.6.2";
  :originator               = "Otto T., DUT";
  :revision_date            = "2009-10-06";
char station_details(scalar=1);
  :name                     = "CESAR observatory";
  :latitude                 = "51.97";
  :longitude                = "4.926";
  :elevation                = "-0.7";
  :WMO_id                   = "06348";
  :address                  = "Zijdeweg 1";
  :postal_code              = "3411 MH";
  :city                     = "Lopik";
  :administration_area      = "Utrecht";
  :country                  = "the Netherlands";
double time(time=17017);
  :standard_name            = "time";
  :units                    = "hours since 2008-06-27 00:00:00 0:00";
  :axis                     = "T";
int range(range=512);
  :long_name                = "range";
  :scan_type                = "non-fixed";
  :units                    = "m";
  :comment                  = "Slant range (meter) to the leading edge of the
                               range bins. The radial extension of the range
                               bins is provided by the variable
                               <range_resolution>.";
float equivalent_reflectivity_factor(time=17017, range=512);
  :long_name                = "co-polarised equivalent reflectivity factor at
                               horizontal polarisation";
  :units                    = "dBZ";
```

```
  :comment                   = "Co-polarised equivalent reflectivity factor at
                               horizontal polarisation in logarithmic units
                               (dBZ, normalised to 1 mm6 m-3).";
  :_FillValue                = -999.0; // double
float azimuth(time=17017);
  :long_name                 = "azimuth";
  :units                     = "rad";
  :comment                   = "The azimuth (radian) is measured clockwise from
                               the Geographic North Pole.";
int range_resolution(scalar=1);
  :long_name                 = "range resolution";
  :units                     = "m";
  :comment                   = "Radial extension (meter) of one range bin.";
float radiation_wavelength(scalar=1);
  :long_name                 = "central radiation wavelength";
  :units                     = "m";
  :comment                   = "Central radiation wavelength (meter).";
int frequency_excursion(scalar=1);
  :long_name                 = "frequency excursion";
  :units                     = "s-1";
  :comment                   = "Frequency excursion of the transmitted linear
                               up-chirp.";
float sweep_time(scalar=1);
  :long_name                 = "sweep time";
  :units                     = "us";
  :comment                   = "Sweep time (microseconds) of the transmitted
                               linear up-chirp.";
int tx_power(scalar=1);
  :long_name                 = "transmitted power";
  :units                     = "W";
int sample_size(scalar=1);
  :long_name                 = "sample size";
  :comment                   = "Number of sweeps that are averaged for the cal-
                               culation of one profile.";
float beam_width(scalar=1);
  :long_name                 = "antenna beam-width";
  :units                     = "rad";
  :comment                   = "Half-power beam-width of the transmit and re-
                               ceive antennas (radian). The beam-width deter-
                               mines the resolution in azimuth and elevation.";
float elevation_angle(scalar=1);
  :long_name                 = "elevation";
  :units                     = "rad";
  :comment                   = "The elevation (radian) is measured from the ho-
                               rizon (0 rad) upwards.";
```

```
 :title            = "IDRA Reflectivity";
 :institution      = "Delft University of Technology (DUT)";
 :history          = "Calibrated reflectivity measurements, but not corrected for
                     propagation effects, i.e. attenuation.";
 :references       = "cesar_idra_reflectivity_la1_t00_v1.0.pdf @
                     http://www.cesar-database.nl";
 :Conventions      = "CF-1.4";
 :location         = "CESAR observatory, the Netherlands";
 :source           = "Ground-based polarimetric weather radar.";
 :example          = "http://bambi.et.tudelft.nl/~idra/";
}
```