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A 35 GHz Mobile Doppler Radar and a Microwave Disdrometer Network for Meteorological Research

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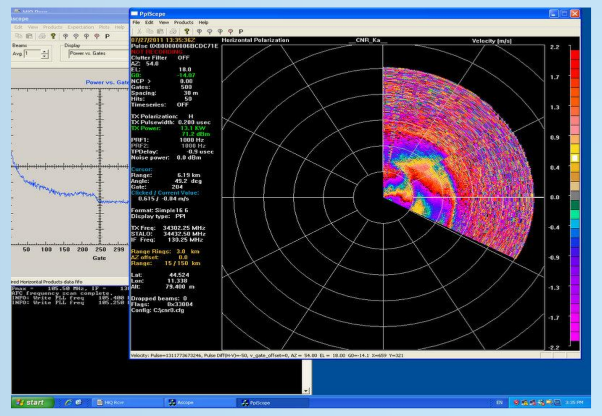
MILLIMETER-WAVE DOPPLER RADAR

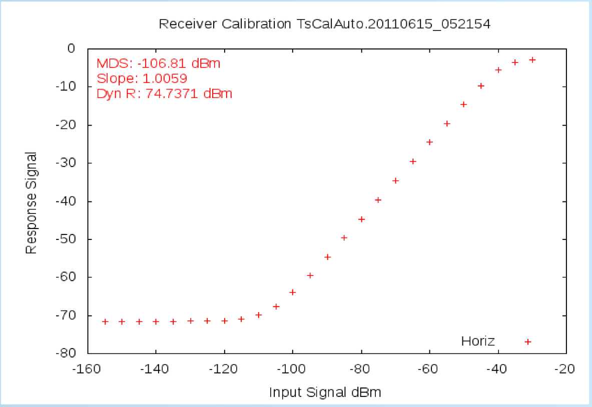
A mobile pulse Doppler radar system with dual polarization receive capability assembled at ISAC-CNR is described. To increase system sensitivity, separate antennas are used for the transmitter and receiver. All the transmitter waveguides are pressurized at 40 psi to prevent electrical arcs and breakdown in the waveguide parts and components.
The Magnetron Transmitter pulse width is 250 ns with a duty cycle of 0.0005.The transmitter can be fully controlled via a RS-232 bus and the dual-polarization receiver operating at 132.5 MHz is fully digital making the radar remotely controllable. The receiver has an overall Noise Figure of about 4.5 dB and the STALO is a phase-locked/Multiplier type. The radar is now undergoing the final testing and tune-up and it is expected to be fully operational within the next couple of months.

The antennas are 120 cm in diameter, Cassegrain fed parabolic reflectors. The feed system uses scalar conical horns and a hyperbolic sub-reflector. In the scalar horn, the direct radiation from the E-plane edge is reduced by introducing corrugations in the horn walls to increase the surface reactance and reduce the edge excitation in the E-plane. The resulting horn radiation pattern has very low side-lobes (about 30 dB down from the peak of the main lobe) and its main lobes are about the same in the E and H planes. The use of a scalar horn instead of a conventional diffraction-limited horn with a parabolic reflector allows polarization-diversity capability and it also yields higher aperture efficiencies, lower side-lobes and improved overall system noise temperatures. The overall antenna gain is about 50 dB and the 3 dB beam-width about 0,5 degrees.
The transmitter polarization is fixed linear and the receiver antenna has an orthomode transducer (OMT) that can be manually set to receive either both circular or linear polarizations. The radar, including all the transmitter functions and monitoring, is fully controlled via a RS-232 bus and therefore can be fully controlled remotely. The two antennas are mounted on a very rigid frame and they are collimated using a fixed target in the far-field. The antenna servo motors are controlled by the antenna control unit (ACU) sub-system which allows scanning speeds up to 30°/sec with pointing accuracies better than one tenth of a degree.
The stable local oscillator (STALO) in the dual channel receiver is a phase-locked Gunn diode oscillator and the Magnetron transmitter is tuned to yield an IF Reference of 132.5 MHz. This frequency and the two outputs of the receiver mixer-preamp go to the input of a digital receiver and its output goes to the Radar Signal Processor (DAQ). To increase the maximum unambiguous range and Doppler velocity measurement the radar can operate in the double-pulse mode which keeps the Magnetron duty cycle constant while changing the unambiguous range and Doppler velocity. The computer controlling the radar functions is also the data acquisition computer and has the NCAR TITAN software loaded in the system.

TECHNICAL DESCRIPTION

The radar is bistatic and so uses two separate antennas for the transmitter and the receiver. The use of two separate antennas improves the radar receiver sensitivity by about 3-4 dB since this is the insertion loss of commercially available transmit-receive (T-R) switches. There is an additional problem with the maximum peak power handling of this T-R switches which is typically limited to 100 kW. The tube used in our transmitter is a LITTON L-4524 coaxial magnetron which has a peak power output of 160 kW with a pulse width of 250 ns. The transmitter unit is fully protected and a microprocessor checks all the parameters sequentially to make sure they are in the specified ranges and shuts the transmitter down if they are out of range. To increase the transmitter tube life, the transmitter Duty Cycle was limited to a value of 0.0005. In summary the use of two separate antennas has improved the radar sensitivity by about 5 to 6 dB.





CALIBRATION PROCEDURE

A configuration file in the computer controlling the radar allows the operator to set up and optimize scan parameters before a scanning sequence is initiated or while the radar is scanning and data are being recorded. The use of the TITAN program allows, in addition to the meteorological parameters output, the optimization of clutter mitigation by computation of a clutter map from 30 to 40 volume scans of clear air regions where no weather is present. The program will compute the median reflectivity for these clear air scans and store the data as a clutter map. The TITAN program will also help mitigating Anomalous Propagation (AP) effects by looking at the gradients of vertical reflectivity between consecutive tilts of the radar beam.

MAIN RADAR SPECIFICATIONS

- Frequency of operation: 35 GHz
- Peak transmitted power: 160 kW
- Average transmitted power: 80 W
- Pulse width: 250 ns
- Antenna diameter: 1.20 m
- Antenna gain: 50 dB
- 3-dB beamwidth: 0.5 degrees
- Noise power: -106 dBm
- Minimum detectable reflectivity at 10 km: -29 dBZ

CONTACTS

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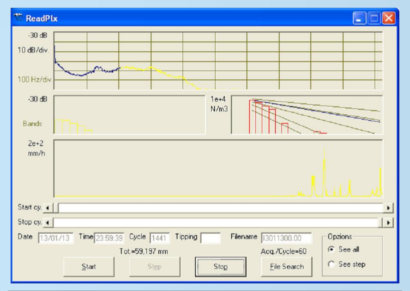
CONCLUSIONS

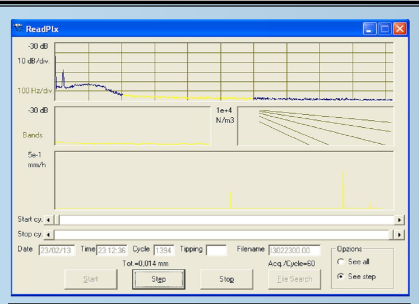
A mobile Ka band radar with advanced specifications is described. In addition to the advances in cloud microphysical characteristics determination, that we expect from this category of radars when operated alone, when in combination with microwave disdrometers we expect it will complement what C band radar already did with a similar network. Moreover satellite estimation methods for rain fall intensity can be improved.
The combination of Ka band radar and microwave disdrometers, individual or in network, is a promising addition also to the supersites which are established for ground truth of spaceborne W band radars.

MICROWAVE DISDROMETER NETWORK

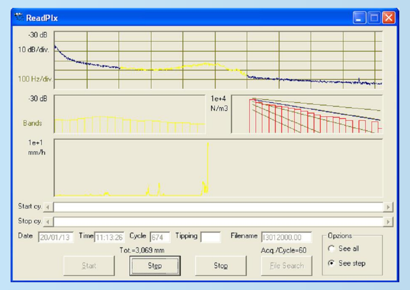
PLUDIX, an X-band microwave disdrometer, has obtained interesting results both as a stand alone instrument and in combination with meteorological radars. As a single measuring instrument placed in three locations at different elevations (including Tibetan plateau at 3300 m MSL) it has shown that collisional break-up position in the power spectrum increases towards higher frequencies with increasing altitude, while a mini-network of three under close coverage of a C-band radar (Project Aeroclouds) has shown the capability to fill the gap between the lowest useful elevation and the ground. This role is expected to be enhanced when the Ka mobile radar here described will be used in combination with a network of six PLUDIX in a middle size basin. This combination will also be in perspective an optimal arrangement in a ground truth testing supersite for space-borne active sensors.



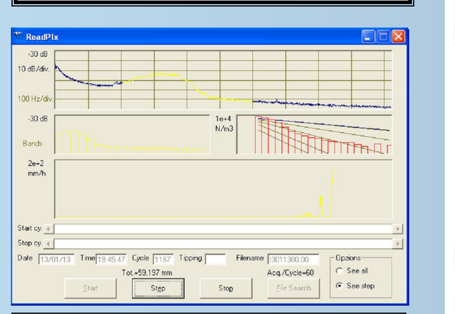
13/01/2013 – 12.33
Mixed rain and snow



23/02/2013 – 23.12
Snow

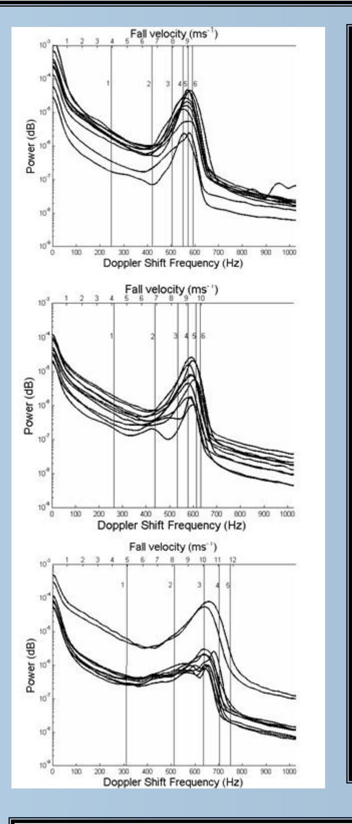


20/01/2013 – 11.13
Intense rain fall



13/01/2013 – 19.45 Intense rain with small/medium drops only

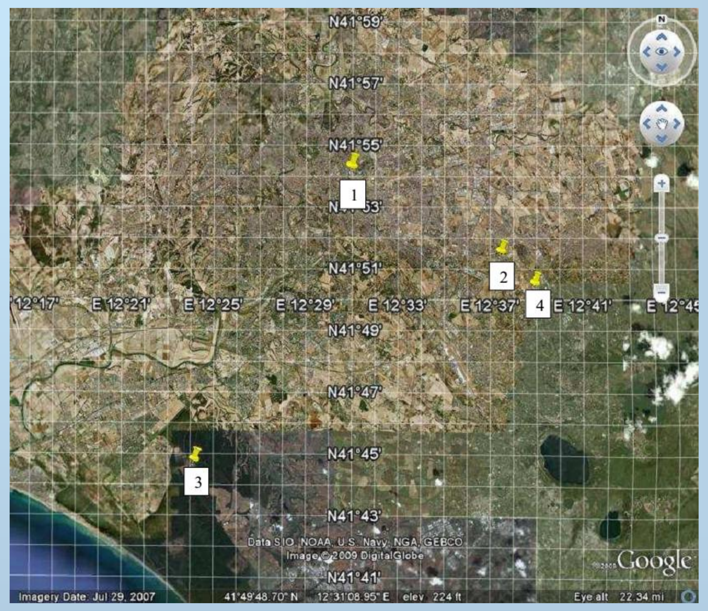
Pludix power spectra for different rain events

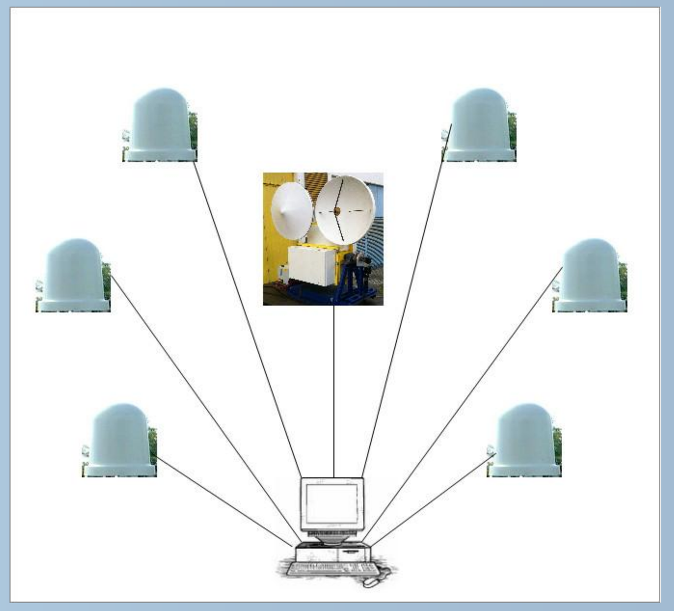


Pludix has evidenced for the first time that the breakup of rain drops is taking place at increasing Doppler frequencies with increasing elevation of the microwave disdrometer stations. In this figure Pludix power spectra for 10 selected breakup minutes in the (a) Ferrara (15 m MSL), (b) Wasserkuppe (959 m MSL), and (c) Lin Zi (3300 m MSL). Frequencies in Hz are 569, 587 and 652 respectively. See underlying Table for data.

Site	altitude (m a.s.l.)	f (Hz)	σ_f (Hz)	v (m/s)	σ_v (m/s)	D (mm)	σ_D (mm)
Ferrara	15	569	9	8.98	0.14	4.55	0.35
Wasserkuppe	950	587	10	9.25	0.16	4.02	0.32
LinZhi	3300	652	24	10.28	0.38	3.16	0.3

Porcù, F., L.P. D'Adderio, F.Prodi and C.Caracciolo,2013 Effects of altitude on maximum raindrop S size and fall velocity as limited by collisional breakup. J.Atmos.Sc, vol 70, 1129-1134





In the Project Aeroclouds for the first time a mini-network of three Pludix has been deployed under coverage of the C band Tor Vergata radar. For medium high rainfall intensities the gap between the the lowest useful radar elevation and the surface has been decreased.

A network of Pludix microwave disdrometers under the mobile Ka Band radar described in this poster will be deployed. In this case the expected improvements concern the light precipitation investigation (drizzle, very light rains…) for the less strong attenuation of the Ka band beam. In this case the combination of Ka band radar data with surface microwave disdrometer network will allow us to fill the gap from the lowest useful elevation of the radar and the surface data from the disdrometers. This configuration may lead to a cloud physics natural laboratory to verify evaporative cooling variation of DSD from the lowest elevation to the ground, evaporation of precipitation and hydrodynamics of precipitation particles. The role of horizontal winds in determining precipitation locations at the ground and collisional effects of the rain drops can also be investigated.