P5B.3 QUANTITATIVE RAIN MEASUREMENTS WITH A MOBILE, X-BAND, POLARIMETRIC DOPPLER RADAR

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1. INTRODUCTION

Since 1993, the University of Massachusetts Microwave Remote Sensing Laboratory and University of Oklahoma School of Meteorology have collaborated to study severe storms and tornadoes with a mobile 95 GHz Doppler radar (Bluestein and Pazmany, 2000). To complement the high resolution, but limited range (~10 km) W-band observations, a truck-mounted 9.4 GHz (3 cm wavelength) polarimetric radar was developed for measuring storm-scale reflectivity, Doppler velocity, and rain rate. A low cost, yet highly reliable, 25 kW commercial marine radar was modified to transmit equal power at vertical and horizontal polarizations and was equipped with a dual-channel coherent-on-receive, low noise-figure (1 dB LNA) receiver. This paper documents the radar system and presents examples of long range (up to 120 km) reflectivity images of storms, Doppler velocity images of mesocyclones and *Kdp*-based rain rate maps.

2. INSTRUMENT DESCRIPTION

The UMass XPol radar, shown in Figure 1, is a truck mounted pulsed Doppler radar with a 1.8 m dual polarized antenna, mounted on an elevation over azimuth pedestal. The radar transceiver, dual-polarized antenna and pedestal are mounted on the truck platform, while the data acquisition, positioner controller and display systems are located in the rear of the crew-cab cabin.

XPol was developed based on the 25 kW MK-2 “high-sea” marine radar transceiver, manufactured by Raytheon. The original transceiver was modified to transmit equal power vertically (V) and horizontally (H) polarized pulses (Seliga and Bringi, 1976; Zrnic, 1996), and equipped with a second receiver to allow the measurement of differential reflectivity and differential phase shift, used for rain-rate estimation, without an expensive high power T/R switch. The conventional coherent-on-receive technique was implemented for pulse-pair Doppler velocity measurements.

The transceiver is composed of a magnetron, an isolator, a waveguide splitter and separate circulators at the V and H T/R nodes. The equal power V and H components of the transmit pulse are fed simultaneously to the V and H ports of the antenna. Separate receivers are used to measure the V and H components of the backscattered signal. The first element in each receiver, after the T/R circulator, is a dual-stage gas/solid-state limiter, followed by a low-noise amplifier and a single side-band mixer. Next, a switch selects either a logarithmic detector or a second down-converter stage for direct offset IF sampling. Table 1 lists the significant system parameters.

Table 1. Characteristics of the UMass XPol radar

Transmitter	
Center frequency	9.41 GHz
Peak power output	25 kW
Pulse width	1 ms
Polarization	Equal power V&H
PRF	Staggered, 1.6 KHz – 2 KHz
Maximum unambiguous velocity	±60 m/s
Maximum unambiguous range	75 km
Antenna and Pedestal	
Type (size)	Dual–Polarized parabolic reflector (1.8 m)
3-dB beamwidth	1.25°
Gain	41 dB
Scan rate (max.)	24 deg/sec in Az and El
Receiver	
Dynamic range	70 dB
Noise figure	4 dB
Bandwidth	1 MHz
First IF	62.5 MHz
Second IF	2.5 MHz
Min. detectable signal in surveillance mode	-5 dBZ @ 10 km

The radar operator can choose to record the averaged reflectivity data in long range low data rate surveillance mode (to 120 km), or raw offset-IF time series data to compute co-pol reflectivity at H and V polarization (*Zh* and *Zv*), differential reflectivity (*Zdr*), specific differential phase (*Kdp*) and Doppler velocity mean and standard deviation.

3. COLLECTED DATA

During the 2001, 2002 and 2003 spring tornado season, XPol collected an extensive set of reflectivity, polarimetric and Doppler radar data from severe storms throughout the U.S. Central Plains. A sample set of storm images are shown in Figures 2 and 3. Figure 2 illustrates the benefit of *Kdp* based rain rate retrieval. Conventional reflectivity (Figure 2a) and differential reflectivity (Figure 2c) images are distorted by attenuation and differential attenuation respectively, shifting the apparent storm core closer to the radar.

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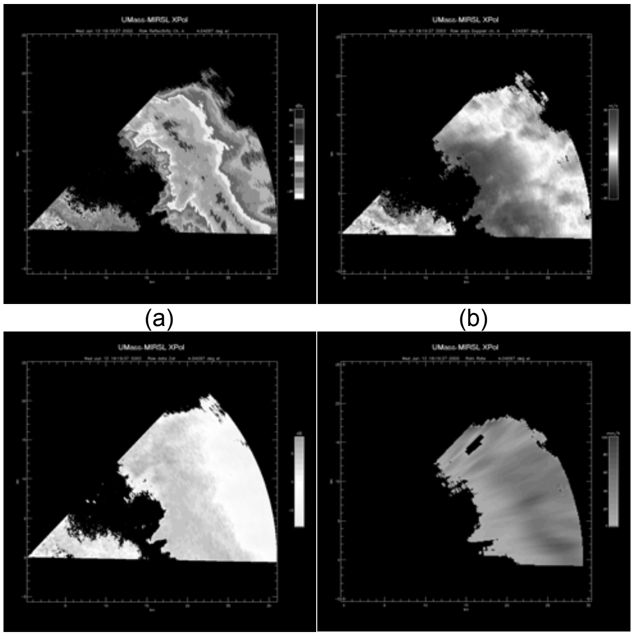
Since the *Kdp* based rain-rate image (Figure 2d) is unaffected by attenuation, it correctly locates the storm core behind the strongest observed reflectivity regions. However, the accurate estimation of *Kdp* requires spatial smoothing, so the retrieved rain rate maps lack fine scale detail.

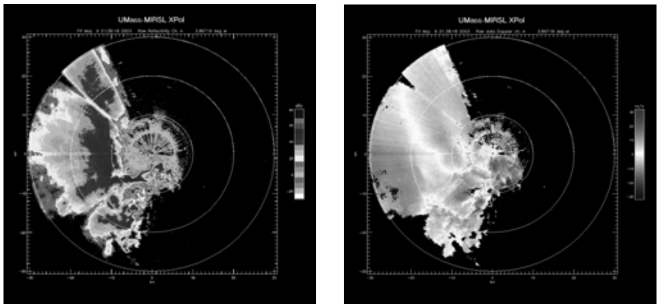
Figure 1. The UMass XPol radar



(a) (b)

(c) (d)

Figure 2. XPol 30 km range, 4º elevation angle, sector scan data set collected on June 12, 2002 near Matador, TX at 18:19:37 CDT. (a) H-pol reflectivity (-30 to +80 dBZ scale), (b) Doppler velocity (±30 m/s scale), (c) differential reflectivity (±8 dB scale) and (d) *Kdp* based rain rate (0-100 mm/hr scale). The negative *Zdr* values, in the far side of the storm, are caused by differential attenuation. Attenuation shifts the apparent reflectivity core of the storm (a) in front of the heaviest rain rate regions retrieved with *Kdp* data (d), which is unaffected by attenuation or differential attenuation.



(a) (b)

Figure 3. XPol 30 km range, 4º elevation angle, PPI scan data set from a mesocyclone collected on May 9, 2003, near Binger, OK at 20:38:18 CDT. (a) H-polarized reflectivity and (b) Doppler velocity (±30 m/s scale).

4. CONCLUSIONS

The combination of fine sensitivity (0 dBZ single pulse unity SNR @ 10 km range with 1 micro sec TX pulses), polarimetric and Doppler measurement capability and very low component cost (<$20K for RF section) makes this weather radar design cost effective for network applications and for small educational and research institutions.

5. ACKNOWLEDGEMENTS

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