An Experimental Evaluation of Phase Coding to Mitigate the Cross-Coupling Biases in PPAR

Igor R. Ivić(1)

(1) Cooperative Institute for Mesoscale Meteorological Studies, The University of Oklahoma and NOAA/OAR National Severe Storms Laboratory, Norman, Oklahoma

1. ABSTRACT

The Spectrum Efficient National Surveillance Radar (SENSR) program is exploring the feasibility of combining the functions of multiple national aircraft and weather surveillance radar networks into a single network of polarimetric phased array radar (PPAR) systems. One of the main challenges on this path is the use of PPAR for weather observations. In planar PPAR, this is due to the fact that the array copolar and cross-polar patterns vary with beam steering resulting in significant cross coupling between the horizontal (H) and vertical (V) channels. One proposed cross coupling mitigation technique is a 180° pulse-to-pulse phase change of signals injected in either the H or V ports of the transmission elements. Herein, this technique is evaluated using a ten-panel dual-polarization phased-array mobile demonstration system (referred to as the Ten Panel Demonstrator or TPD). This system has been developed by the MIT Lincoln Laboratory and is operated by the National Severe Storms Laboratory (NSSL).

2. THEORY

Received signal in the simultaneous transmit and simultaneous receive (STSR) mode from the *m*-th transmission can be represented as:

$$V_c(m) = V_c^{\mathrm{CO}}(m) + V_c^{\mathrm{X}}(m) + V_c^{\mathrm{XPC}}(m) \qquad (1)$$

c – horizontal (H) or vertical (V) channel

$V_c^{\mathrm{CO}}(m)$ - copolar signal

$V_c^{\mathrm{X}}(m)$ - cross-polar signal not affected by phase codes

$V_c^{\mathrm{XPC}}(m)$ - cross-polar signal affected by phase codes

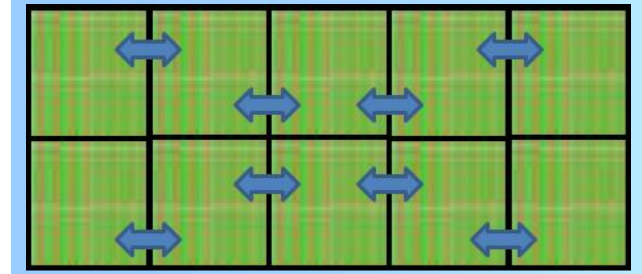
The estimated received power from *M* pulses is

$$\frac{1}{M}\sum_{m=0}^{M-1}\left|V_c(m)\right|^2 = \frac{1}{M}\sum_{m=0}^{M-1}\left|V_c^{\mathrm{CO}}(m)+V_c^{\mathrm{X}}(m)\right|^2 + \frac{2}{M}\sum_{m=0}^{M-1}\mathrm{Re}\left\{\left[V_c^{\mathrm{CO}}(m)+V_c^{\mathrm{X}}(m)\right]^* V_c^{\mathrm{XPC}}(m)\right\} + \frac{1}{M}\sum_{m=0}^{M-1}\left|V_c^{\mathrm{XPC}}(m)\right|^2 \qquad (2)$$

In (2), the expected value of the second sum is zero. In spectral domain, the third sum is shifted by the unambiguous velocity with respect to the first sum. If sufficiently separated, it may be removed via filtering. If this component is not removed, it may cause the bias in spectrum width estimates.

ACKNOWLEDGEMENT
Funding for part of this research was provided by NOAA/Office of Oceanic and Atmospheric Research under NOAA-University of Oklahoma Cooperative Agreement #NA11OAR4320072 , U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

3. THE TEN PANEL DEMONSTRATOR



Parameter	10-Panel	Units
Wavelength	11	cm
Peak Tx Po at Antenna	3.5	kW
EIRP @ 8% duty	87	dBm
Sensitivity at 40km	11	dBz
Pulse Width	80	μs
Rx Bandwidth	1	MHz
T*BW	80	
Receiver NF	4.7	dB
Receive Noise Floor	-109	dBm
Antenna Gain, Tx	33	dB
Antenna Gain, Rx (est)	31	dB
Azimuth Beamwidths		
Tx	2.5	°
Rx	3.0	°
Effective 1-way	2.7	°
Elevation Beamwidths		
Tx	6.3	°
Rx	7.4	°
Effective 1-way	6.7	°
Array Elements, Total	640	
Array Elements (X, Y)	40, 16	
Array Size (w, h)	2.0, 0.8	m

Overlapped subarray architecture. On transmit, each of the panels is treated as an independent channel, meaning 10 transmit channels are needed. On receive, the some panel signals are combined through an analog beamformer, creating an overlapped two-panel structure, and 16 receive channels (8 for H, 8 for V).

Photo courtesy of Kurt Hondl of NSSL

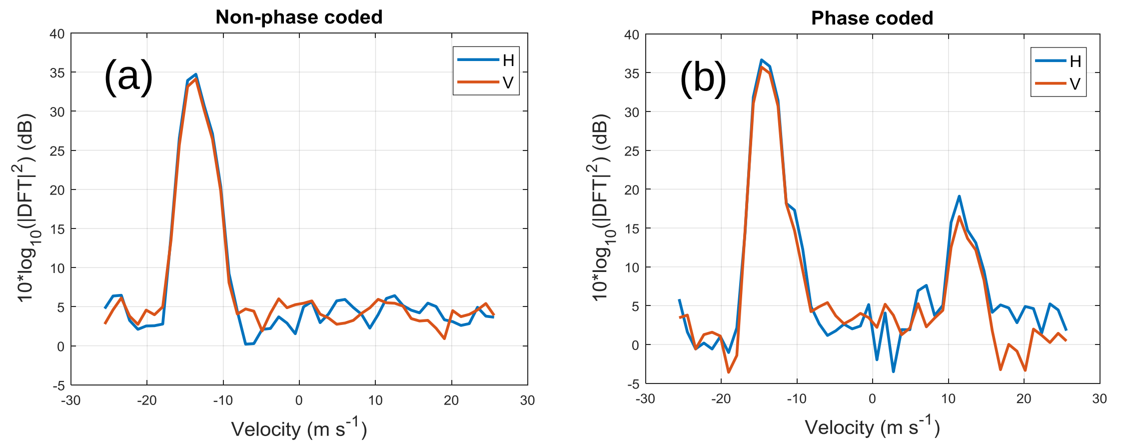


Fig. 1. Experimental data Doppler spectra for (a) non-phase, and (b) phase coded. signals.

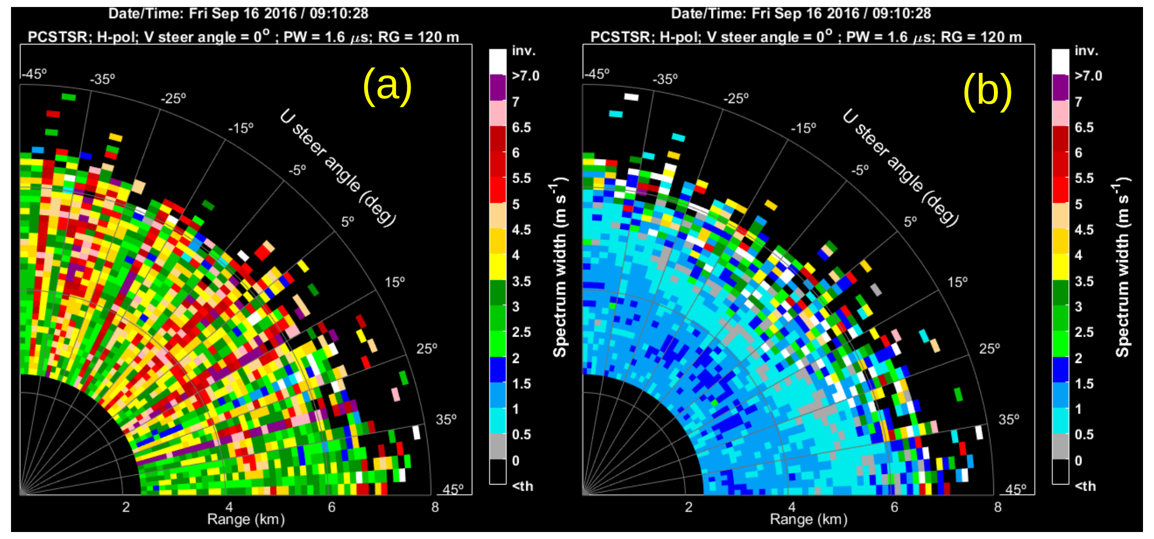


Fig. 2. Spectrum width fields produced from (a) non-phase, and (b) phase coded signals.

3. BEAM STEERING 7° OFF PRINCIPAL PLANE AT VERTICAL INCIDENCE (BIRDBATH)

STSR with subarray amplitude/phase alignment (SAP)

Phase coded STSR (PCSTSR) with subarray amplitude/phase alignment (SAP)

PCSTSR with subarray amplitude/phase alignment (SAP) and spectral filtering (FX)

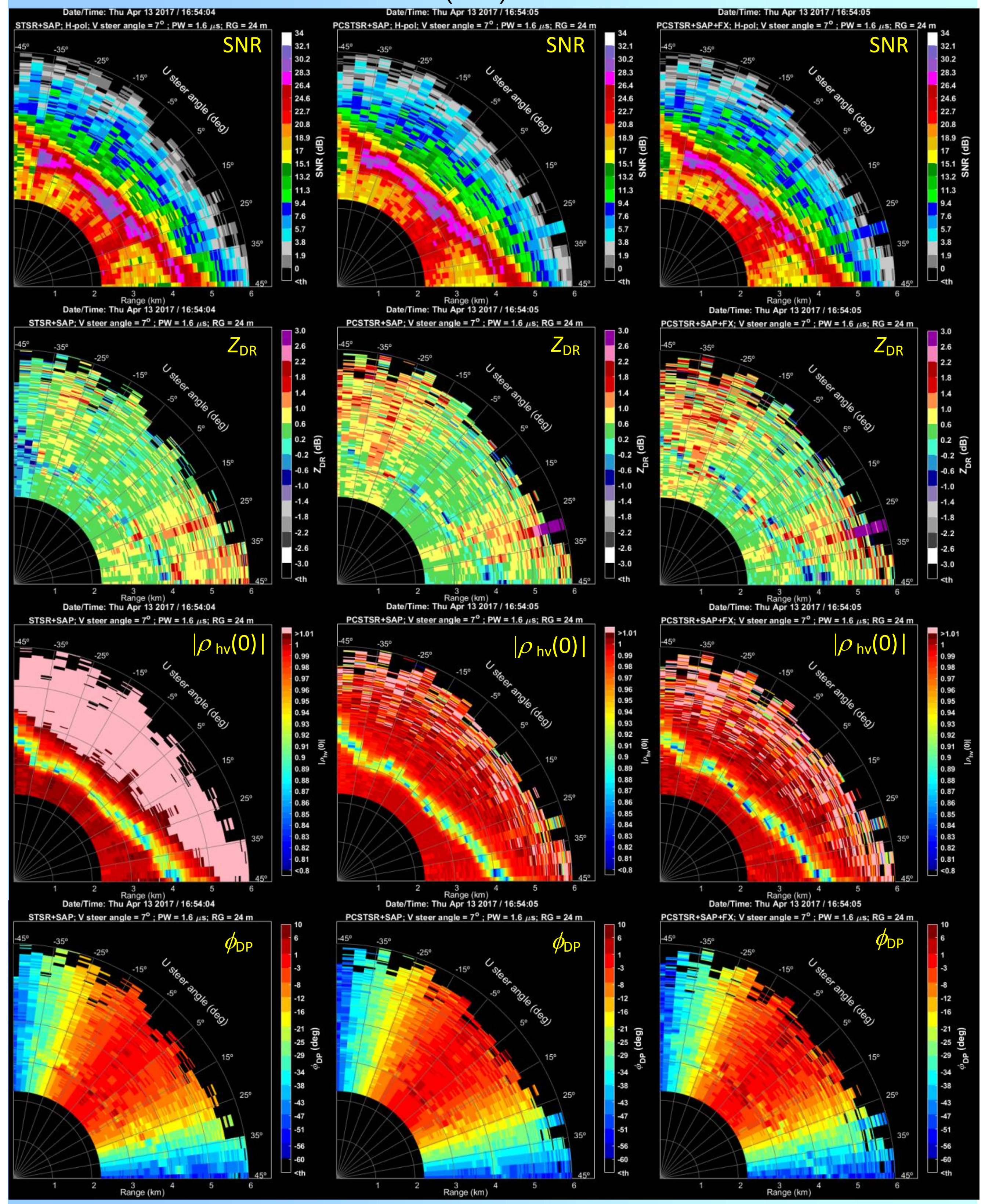


Fig. 3. Horizontal channel SNR, differential reflectivity, copolar correlation coefficient, differential phase.

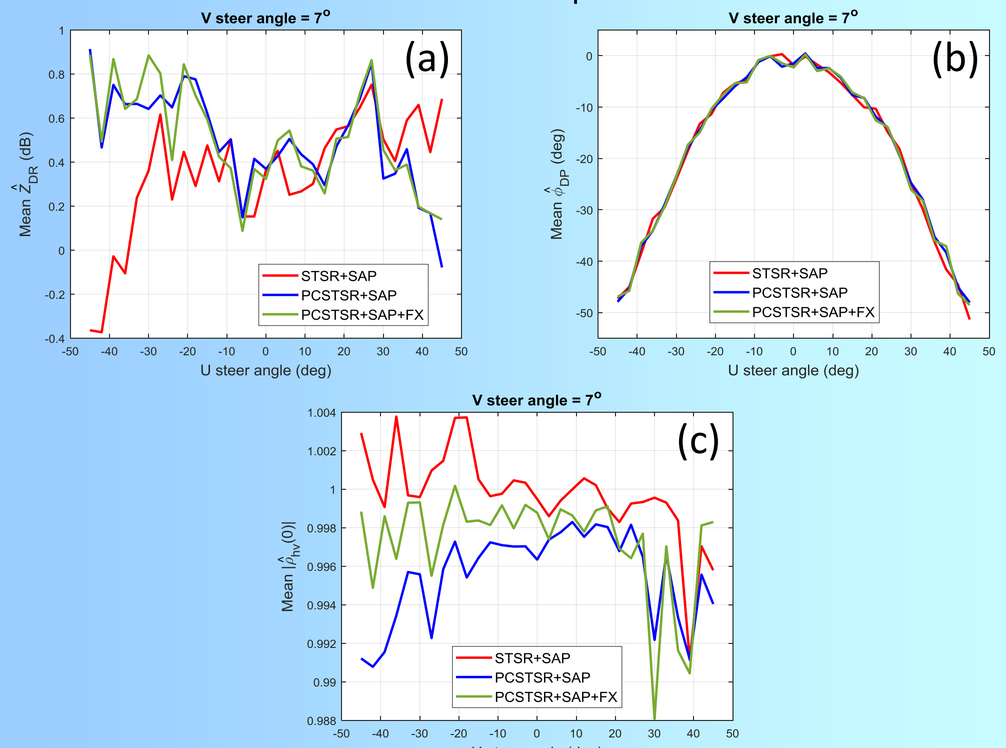


Fig. 4. Spatial mean (a) differential reflectivity, (c) differential phase, (c) copolar correlation coefficient.

4. BEAM STEERING 15° OFF PRINCIPAL PLANE AT VERTICAL INCIDENCE (BIRDBATH)

STSR with subarray amplitude/phase alignment (SAP)

Phase coded STSR (PCSTSR) with subarray amplitude/phase alignment (SAP)

PCSTSR with subarray amplitude/phase alignment (SAP) and spectral filtering (FX)

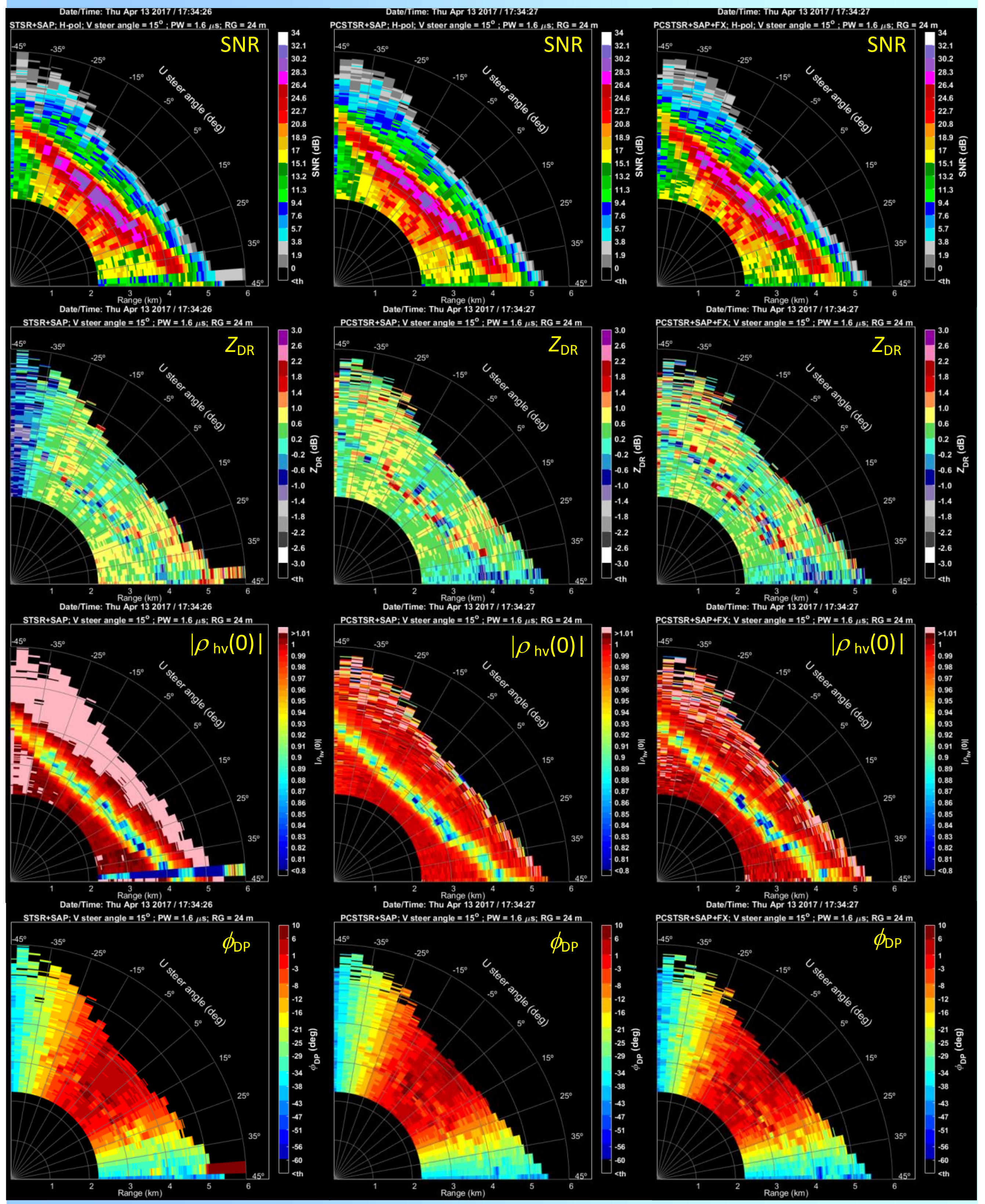


Fig. 5. Horizontal channel SNR, differential reflectivity, copolar correlation coefficient, differential phase.

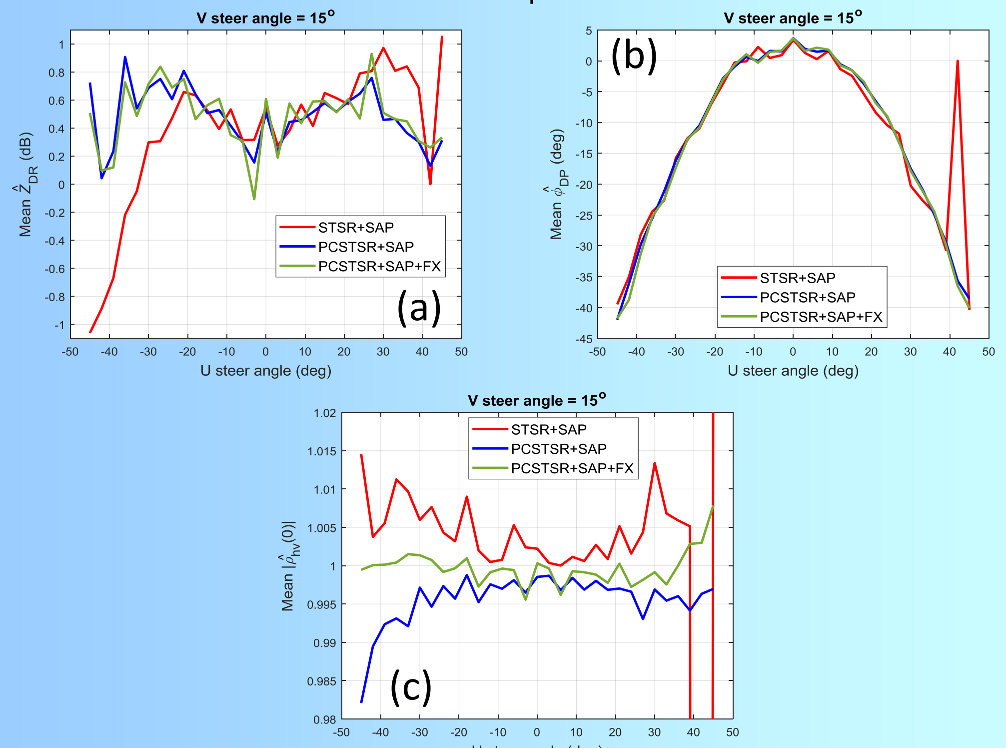


Fig. 6. Spatial mean (a) differential reflectivity, (c) differential phase, (c) copolar correlation coefficient.

38th International Conference on Radar Meteorology, 28 August - 1 September 2017, Chicago, IL