P10.14 AN OPERATIONAL MOBILE XPOL FOR HYDROMETEOROLOGICAL APPLICATIONS IN BRAZIL

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1. INTRODUCTION

This manuscript describes the mobile X-band dual polarization Doppler weather radar (MXPOL) of the Laboratory of Hydrometeorology (***LabHidro***) of the University of São Paulo, São Paulo, Brazil. It is a multi-functional system with several innovative technologies for multi-use applications from basic training courses to advanced operational monitoring of severe weather, the first Brazilian weather radar of its kind to be used on an operational basis to provide real time high spatial resolution polarimetric data. The MXPOL is part of the Hydrometeorological Forecast System (Pereira Filho et al., 2005) for the Metropolitan Area of São Paulo (MASP) which is located within the Alto Tietê Basin where the population, agriculture, industry, commerce, transport and government are often highly impacted by floods, electrical discharges, high wind gusts and hail during the rainy season and, heavy pollution, in the cold and dry season. The State of São Paulo Government has recently established a program termed Integrate Hydrometeorological System for the State of São Paulo (SIHESP) through the State of São Paulo Research Support Foundation (FAPESP) to mitigate the effects of extreme weather and climate conditions. The first phase of the SIHESP program has implemented a surface network of automatic weather stations statewide, upgraded to two radars in the center and western São Paulo State, high performance computational facilities for weather and regional climate prediction and the MXPOL. This new radar system was developed and assembled in Brazil with imported parts of hardware and software.

2. SYSTEM DESCRIPTION

Fig. 2 shows the block diagram of MXPOL. The antenna control and signal processing are done by SIGMET RCP8 and RVP8 processors, respectively. The LINUX based SIGMET software termed IRIS Radar controls RVP8 processor and the antenna control RCP8. It also displays real time PPI and generates the volume scan. The measured variables are correct (Z) and raw (T) reflectivity, radial velocity (V_r), spectral width (W), I/Q, differential reflectivity

Figure 1: Photo of the mobile X-band dual polarization Doppler weather radar (MXPOL) of the Laboratory of Hydrometeorology (***LabHidro***) of the Institute of Astronomy, Geophysics and Atmospheric Sciences (IAG) of University of São Paulo, São Paulo (USP), Brazil. It is seen the feed-horn, waveguides, reflector, pedestal, power generator, cabin, cell phone communication and air conditioning mounted on a Diesel truck.

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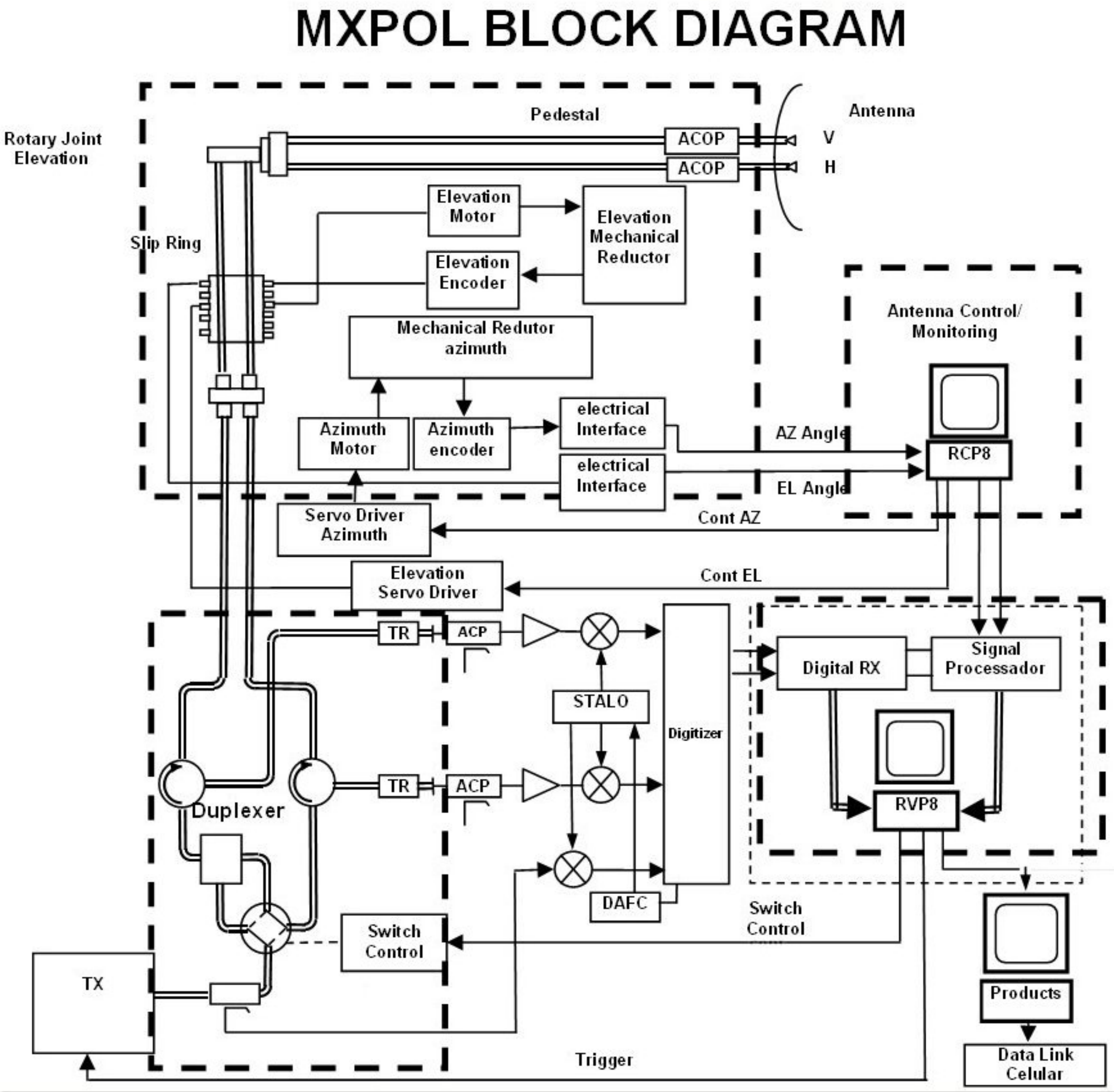

Figure 2: Block diagram of the MXPOL weather radar.

(Zdr), differential reflectivity (Z_{dr}), differential propagate on phase (ϕ_{dp}), specific differential phase (K_{dp}), correlation coefficient of signal magnitudes co-pol H and co-pol V (ρ_{oHV}), correlation coefficient of signal magnitudes co-pol H and cross-pol V (ρ_{oH}) and correlation coefficient between signal phases co-pol H and cross-pol V ($\rho\phi_{HV}$).

The software termed IRIS Analysis that generates products from volume scans was installed on a third processor for better system performance. The main products are PPI, RHI, CAPPI, ECHO TOPS, rainfall accumulation, maximum reflectivity profiles, cross-sections, specified horizontal and vertical products, storm motion forecast, storm tracking and forecasting, warn and centroid plotting, vertically integrated liquid, estimated wind speed and direction.

Table 1 shows the parameters of the antenna reflector, pedestal, transmitter and receptor of MXPOL. Each parameter has been tested recently and showed as specified or better performance. Other features of MXPOL include a six cylinder 180 HP WV Diesel truck,18 KVA Diesel generator with one week fuel autonomy, pneumatic suspension, automatic leveling with auxiliary supports for steep terrain, GPS, cell phone and wideband Internet communication systems, SIGMET antenna positioning system, microwave power generator and meter, and SIGMET automatic calibration software. The radar system was design and developed by ATMOS SYSTEMS LTDA, a Brazilian weather radar enterprise. Most parts were purchased in the USA (magnetron, waveguides, duplexer, switches, and receivers), Germany (elevation and azimuth motors and encoders and slip rings), Finland (reflector and supports) and Brazil (Diesel truck, power generator, air conditioner, cabin and racks). The pedestal was projected by ATMOS SYSTEM LTDA with an innovative maintenance free gear oil lubrication system.

MXPOL SYSTEM DESCRIPTION
REFLECTOR
Parabolic
Diameter 2.44 m
Antenna Gain 44 dB
HPBW @ 3dB < 1.0^o
PEDESTAL
Azimuth scan o to 360^o
Elevation scan 0 to 90^o
Maximum scan 36º s^{-1}
Pointing imprecision < 0.1^o
TRANSMITTER
Magnetron
Frequency 9.3 to 9.5 GHz
Peak power 80 KW
Pulse modulation
PRF 500Hz to 5000Hz
Pulse width 0.2 μs to 2μs
Linear polarization (H,V) simultaneous
Solid state modulator
Duty cycle 0.001
RECEPTION
Two digital channels (H,V)
Radar Noise Figure < 2.5 dB
Dynamic range (H,V) > 80 dB
ADC 14 bits
Local oscillator DAFC
MDS (H,V) -113 dBm @ 2μs

Table 1: Main parameters of the MXPOL

3. ANTENNA PERFORMANCE

The antenna and reflector were tested to check for the antenna gain and the bean width. A microwave power generator at 9.4 GHz @ 14 dBm was connected to feed-horn antenna that pointed towards the radar reflector at the minimum far-field distance. The signal was measured by the RVP8 processor at the digitizer. The antenna scan was controlled by the RCP8 processor that moves the antenna and reads its position. The power generator antenna was aligned to the radar antenna and performed scan in azimuth and elevation for both H and V polarizations. The antenna diagrams of the horizontal and vertical polarizations are shown in Figs. 3 and 4, respectively. The horizontal polarization azimuth scan yielded HPBW=0.95^o @ -3dB and the first sidelobe @ -26 dB and, the elevation scan, HPBW=0.97^o @ -3dB and the first sidelobe @ -28 dB. On the other hand, the vertical polarization azimuth scan yielded HPBW=0.90^o @ -3dB and the first sidelobe @ -22 dB and, the elevation scan, HPBW= 0.98^o @ -3dB and the first sidelobe @ -30dB. These results corroborate the manufacturer's specifications.

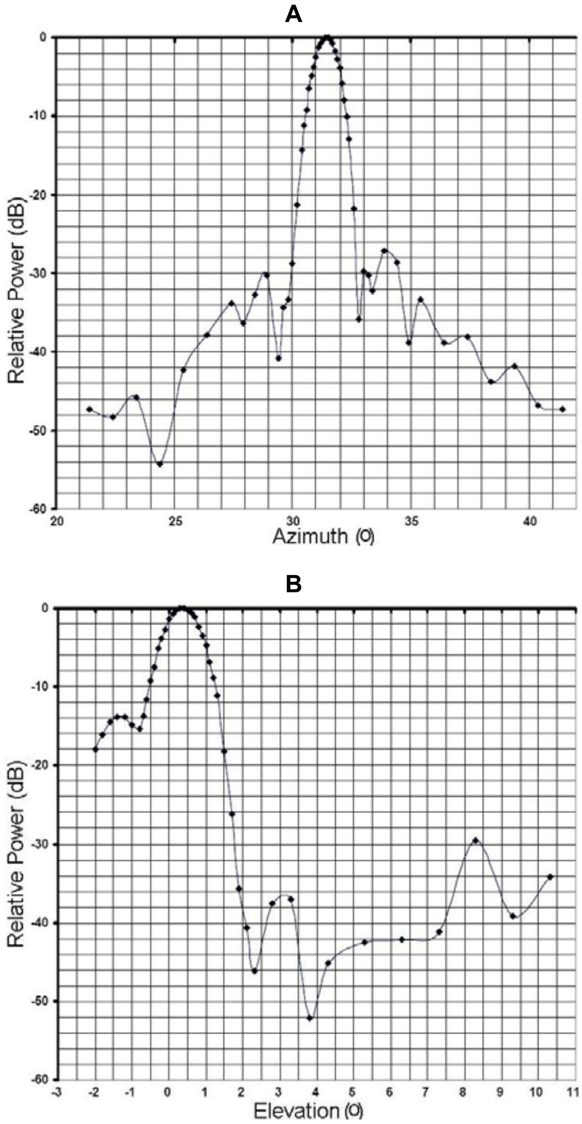

Figure 3: Antenna diagram of the MXPOL for transmission and reception of horizontal polarization only for azimuth (A) and elevation (B) scans.

4. GROUND ECHOES IN THE MASP

The MXPOL was placed at the West side of the MASP in Barueri City (Fig. 5A) to monitor an eastward moving squall line associated to a cold front on 26 April 2007 (Pereira Filho et al., 2007). Initially, a clear air scan was performed at three low elevations without filtering the data so to monitor boundary layer features and ground returns. Figs 5 B to H show a sequence of PPIs at 0.6^o elevation of reflectivity (Z_h), radial velocity (V_r), spectral width (W), differential reflectivity (Z_{dr}), differential propagation phase (ϕ_{dp}), specific differential phase (K_{dp}) and correlation coefficient VH (ρ_{oHV}) at 1528 UTC. Surface winds were from NNW at 3 m s^{-1} and gusting up to 7 m s^{-1} right before a squall line passed over São Paulo City.

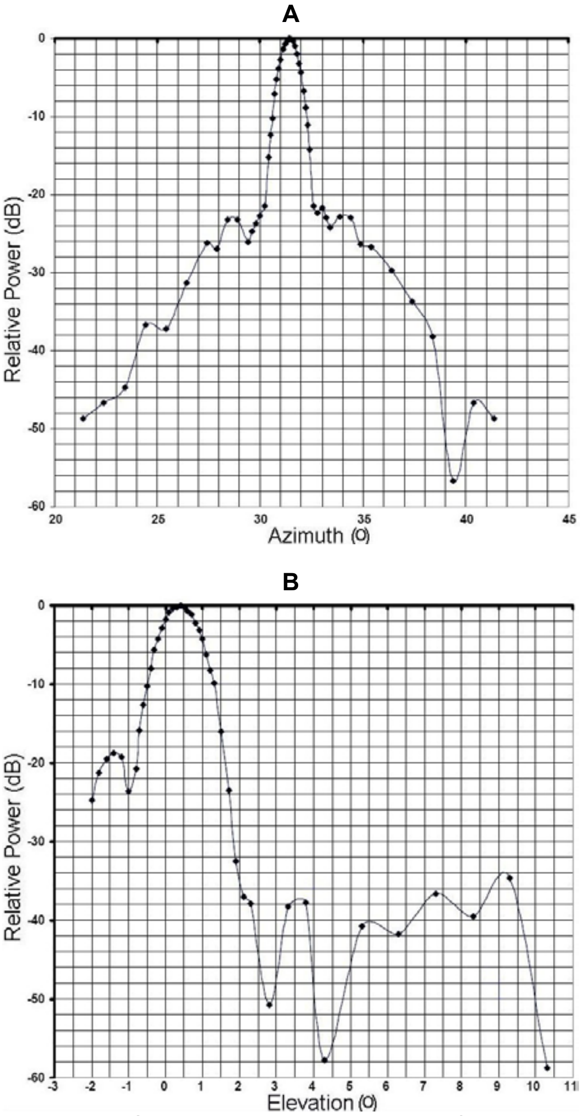

Figure 4: Similar to Fig. 3, except for vertical polarization only.

The 0.6^o elevation PPI of the reflectivity field is completely contaminated by ground echoes in the MASP. The stronger returns up to 80 dBZ were associated to hills, mountains, buildings, towers and many other urban structures. An animation of a time sequence of these PPIs (not shown) indicated that some weak echo returns were associated to a shallow layer of clouds. No mid to deep clouds had yet developed early in the afternoon. It is striking the similarity in shape between the satellite image of the MASP and the reflectivity field as well as of other of variables (V_r, W, Zdr and ρ_{oHV}). The low echo reflectivity sector between 180^o and 300^o azimuths were in the radar blocking zone towards the cabin of the truck. The PPI of radial velocities (Fig. 5C) shows zero isodops co-located with the area of the reflectivity field at the same time. On the other hand, the spectral width is between 0.2 m s^{-1} and 1.4 m s^{-1} at the center and borders of the MASP, respectively. Since surface winds were strong and gusting, turbulence and mixing in the boundary layer resulted in a significant spectral width with zero radial velocity.

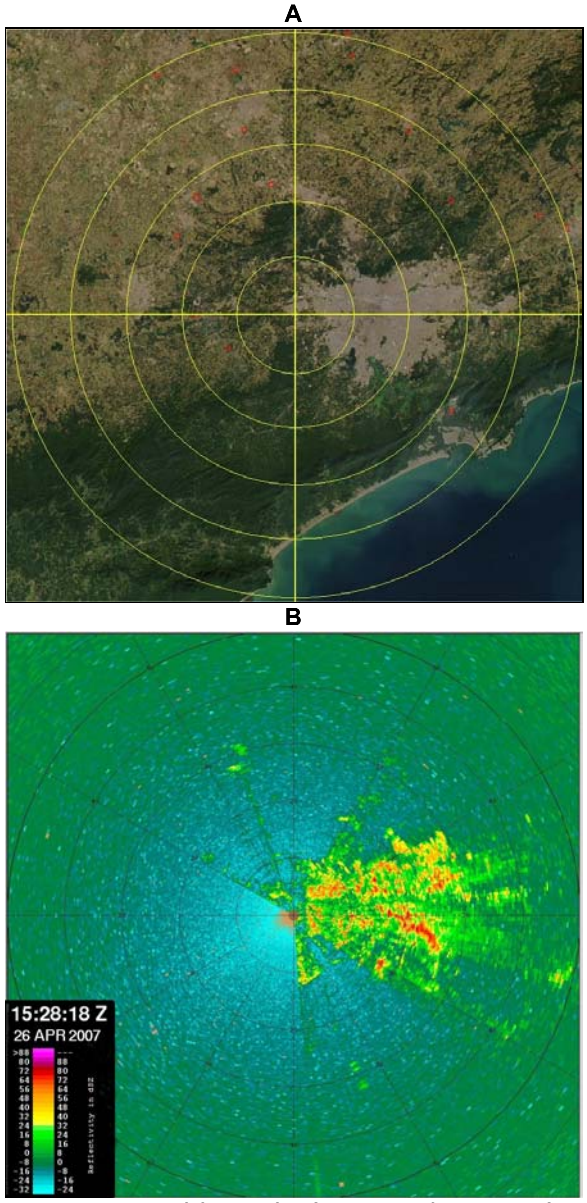

Figure 5: (A) ACQUA/MODIS image of Eastern São Paulo State on 20 July 2003. The cross indicates the MXPOL site (23^{o}32.2'S; 46^{o}52.8'W) in Barueri City, São Paulo, Brazil, on 26 April 2007. The large brown area east of the MXPOL site is the MASP. Concentric circumferences spaced every 20 km. Image source: **http://visibleearth.nasa.gov/**. PPI at 0.6^o elevation of reflectivity - Z_h (B), radial velocity – V_r (C), spectral width – W (D), differential reflectivity – Z_{dr} (E), differential propagation phase – ϕ_{dp} (F), specific differential phase – K_{dp} (G) and correlation coefficient VH - ρ_{oHV} (H) obtained with MXPOL at 1528 UTC on 26 April 2007. Ranges, directions and color scales are indicated in each PPI.

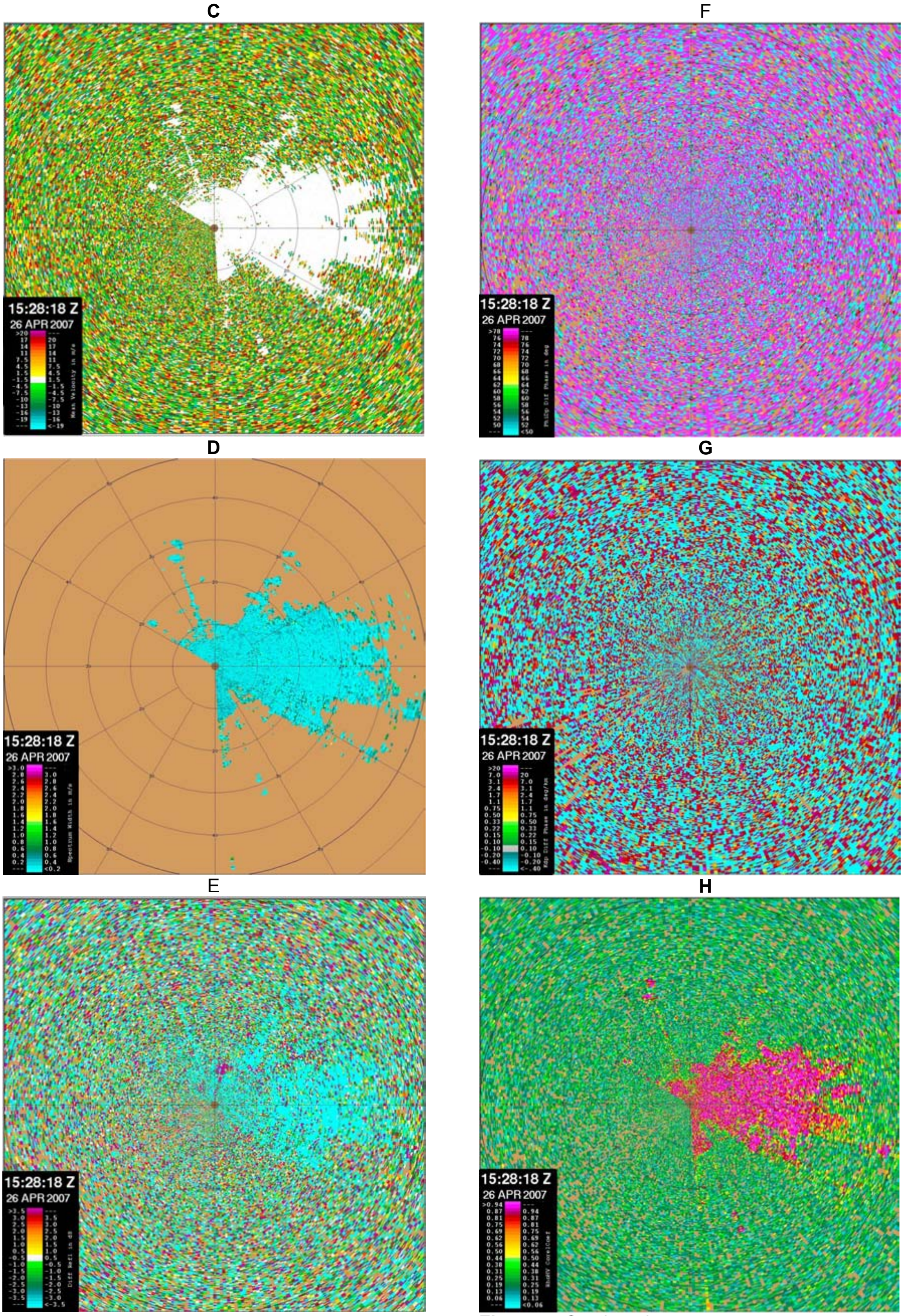

Figure 5: Continued.

The PPI of (Fig. 5E) are in general negative in the order of –3.0 dB throughout the MASP since São Paulo City alone has more than 33.000 buildings and have a greater cross-section vertically, the negative Z_{dr} is coherent with these scattering structures. One might notice that the azimuth sector between 0^o and 30^o at 20 km range is positive and above +3.5 dB. This feature is associated with the Jaraguá Peak, the highest point within the MASP. It is wider than tall, so the horizontal reflectivity power return is greater than the vertical one. The MASP is not apparent in the isotropic and chaotic fields of ϕ_{dp} and K_{dp} (Figs. 5G and H) since the specific phases of the H and V channels are equal at a given azimuth and range. Fig. 5H shows ρ_{oHV} higher correlation coefficients within the MASP and, lower, at the borders. Backscatter characteristics of the horizontally and vertically polarized echoes are not that much different within the MASP, thus ρ_{oHV} is higher. These low elevation polarimetric measurements yielded valuable information to separate weather echoes from ground echoes under almost clear air conditions over the MASP.

5. CONCLUSION

The MXPOL was designed and built for heavy duty use. The system was tested on various weather and landscape conditions (e.g., thunderstorms overhead, dirty roads and steep terrain). The power generator fuel autonomy allows it use on remote areas. Furthermore, its communication system based on cell phone technology, though limited can be quite useful to transfer products to remote distances.

The MXPOL also represents a significant technical and scientific advancement for radar meteorology in Brazil. It is the first of its kind to provide near real time polarimetric data and products for operational use to monitor and to nowcast severe weather in the MASP. The dual polarization allows for better rainfall estimation. Given its greater sensitivity and dynamic range, the MXPOL can detect the early development of convection. There is still room for improving since, for instance, the attenuation correction procedure of the MXPOL is still based on a simple logarithmic adjustment with distance. The mobility of the MXPOL makes it an important tool for experiments where infra-structure might not be available.

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