Examining Polarimetric Characteristics of Electronic Interference in Weather Radar Data

Thong N. Phan[1, 2], Valliappa Lakshmanan[3, 4], and John Krause[3, 4]

[1]National Weather Center Research Experience for Undergraduates Program
University of Oklahoma,
Norman OK

[2]East Central University Department of Physics
Ada, OK

[3]Cooperative Institute for Mesoscale Meteorological Studies
University of Oklahoma,
Norman, OK

[4]National Oceanic and Atmospheric Administration
National Severe Storms Laboratory
Norman, OK

ABSTRACT

Meteorologists have been able to examine the atmosphere using weather radars to look at what kinds of precipitation have been occurring for many decades. With the recent upgrade to dual-polarization radars (dual-pol) for the WSR-88D (Weather Surveillance Radar 1998 Doppler), meteorologists can now examine the atmosphere with dual-polarization products. These products are: Velocity (V), Reflectivity (Z), Differential Phase on Propagation (PhiDP), Correlation Coefficient (RhoHV), Differential Reflectivity (Zdr), and Spectrum Width (SPW). Though the products are very useful in determining what type of precipitation are in the atmosphere, how large the precipitation event is, and how severe it can be, it picks up many non-meteorological echoes. Electronic interference is a type of non-meteorological echo that has high reflectivity values and is mistakenly forecasted as precipitation by automated systems. This study looks at the reflectivity, differential reflectivity, and correlation coefficient of electronic interference and precipitation to find objective criteria to distinguish a difference between them. The findings are meant to aid in the current quality control algorithm to be more efficient for operational use.

1. INTRODUCTION

The National Weather Service network of weather radars has recently been upgraded to have dual-polarization capability. Weather surveillance radars pick up non-meteorological echoes such as birds, insects, and ground clutter (Lakshmanan et al. 2013b) and these cause problems for automated applications.

This study mainly examines electronic interference, which is another non-meteorological echo. According to Cordill et al. (2013) electronic interference becomes more and more of a problem as the advancement of technology increases. Infrastructure like cell phone towers and other communications towers (i.e. broadcasting and telecommunication towers) are built to keep up with the demand. As more technology and innovations develop, they give rise to additional communications towers. These towers emit radio waves in our atmosphere. This is especially problematic for meteorologists because these radio waves emit the same frequencies that weather radars do. Weather radars pick up these emissions unless the communications towers are modified to try to prevent it.

An example of electronic interference is when radio waves interact with an external source that also emits radio waves. Algorithms have been developed by researchers to identify meteorological and non-meteorological echoes (Lakshmanan et al. 2007), however electronic interference still comes up in the quality-

Corresponding author address: Thong Phan, East Central University, 1730 East Carl Albert Parkway, McAlester OK 74501 thonpha@email.ecok.edu

controlled product because of its high reflectivity values. This study uses statistical methods to examine the polarimetric characteristics of electronic interference and compares it to precipitation so as to potentially incorporate its findings into the Lakshmanan et al. (2013b) quality control technique.

2. DATA AND METHODS

a. Data Extraction

The data for this study were taken from specific cases, each case having electronic interference, or storms, or both. The cases are listed in Table 1.

Radar	Location	Date/Time (UTC)	Description
KBYX	Key West, FL	201231030 17:00	EI
KHGX	Houston-Galveston, TX	20131202 15:00	EI and Storms
KGRK	Fort Hood, TX	20131202 15:00	EI
KEWX	Austin-San Antonio, TX	20131202 15:00	EI
KSRX	Fort Smith, AR	20131202 15:00	EI
KINX	Tulsa, OK	20131202 16:00	EI
KICT	Wichita, KS	20131202 16:00	EI
KHGX	Houston-Galveston, TX	20131210 12:00	EI
KDDC	Dodge City, KS	20131210 15:00	EI
KBMX	Birmingham, AL	20131211 08:00	EI
KLNX	North Platte, NE	20131213 13:00	EI
KICT	Wichita, KS	20131216 10:00	EI
KEVX	Eglin AFK, FL	20140520 05:00	EI
KMOB	Mobile, AL	20140520 11:00	EI
KDOX	Dover AFB, DE	20140522 20:00	EI and Storms
KPDT	Pendleton, OR	20140527 16:00	EI
KMTX	Salt Lake City, UT	20140531 17:00	EI and Storms
KMHX	Morehead City, NC	20140617 23:00	EI and Storms

Table 1: List of cases used for this study. Electronic Interference is abbreviated (EI) the time in UTC is when the volume scan was started.

There are six products available for the quality control algorithm used for the WSR-88D polarimetric radar. Those products are: Velocity (V), Reflectivity (Z), Differential Phase on Propagation (PhiDP), Correlation Coefficient (RhoHV), Differential Reflectivity (Zdr), and Spectrum Width (SPW). This study examines the reflectivity (Z), differential reflectivity (Zdr), and correlation coefficient (RhoHV) values of the data. Data were examined using the WDSS-II (Warning Decisions Support System – Integrated Information) display. Polygons were drawn around electronic interference and precipitation to extract all data within the polygons in WDSS-II. This is demonstrated in Figure 1. A WDSS-II tool called w2polygondata was used to extract the data within the polygons.

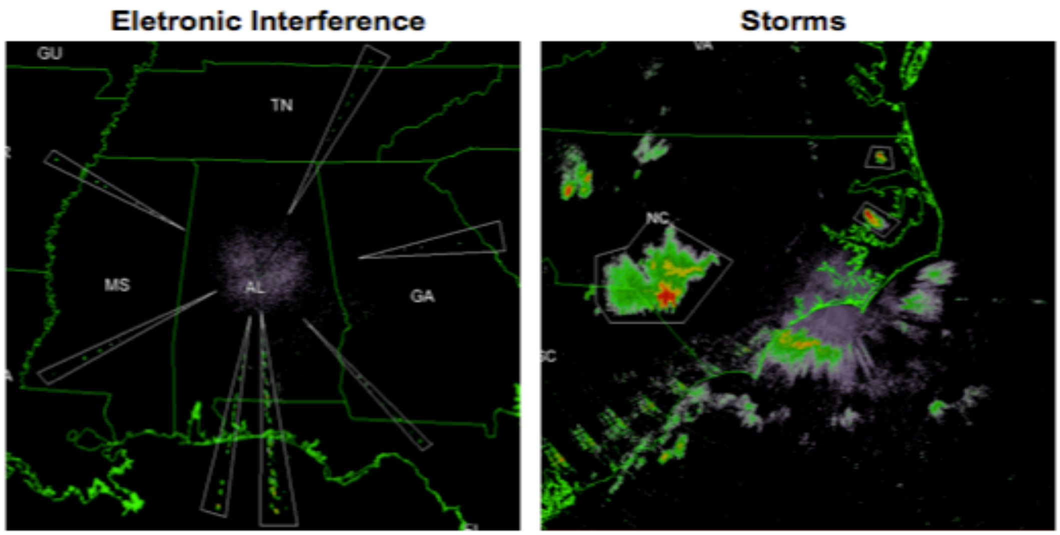

Figure 1: The picture on the left has polygons drawn around what is believed to be electronic interference, and the picture to the right has polygons drawn around what is believed to be precipitation.

All eighteen cases had data extracted into two different data sets, one the electronic interference data set, and the other a precipitation data set. All cases had some type of electronic interference, but not all cases had storms to go along with interference. For the cases that didn't have storms, polygons were drawn at an arbitrary area where no data was interpreted and were used as placeholders.

b. Methods

In order to better visualize the electronic interference and precipitation data sets, the reflectivity, differential reflectivity, and correlation coefficient values of each of the data sets were used to create 2-dimensional histograms. Figure 2 shows the histograms obtained from the study.

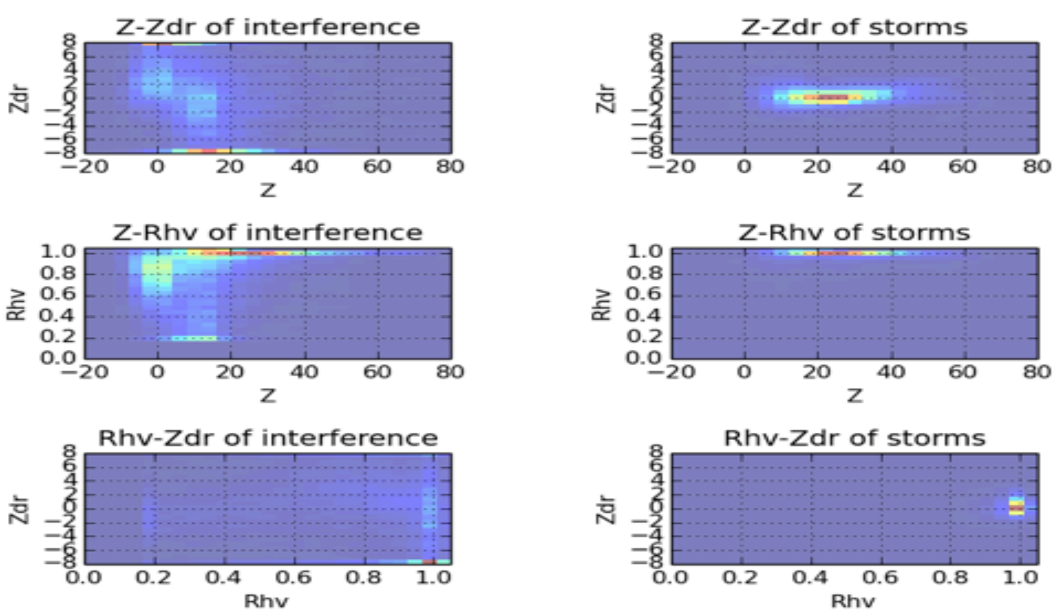

Figure 2: Two-dimensional histograms of the polarimetric variables between the electronic interference data set and precipitation data set. The histogram uses an RGB (Red-Green-Blue) color pallet, with red being the most intense, green being in the middle, and blue being the least intense. These intensities show where polarimetric characteristics occur the most for each data set.

From closely examining the 2-dimensional histograms, conditions were made to discriminate between EI (electronic interference) and meteorological echoes. Electronic interference is detected if either of these conditions are met:

- Reflectivity (Z) > 20 dBZ and Correlation Coefficient (RhoHV) > 1
- Differential Reflectivity (Zdr) < -2 dB or Differential Reflectivity (Zdr) > 6 dB

According to NOAA, (National Oceanic and Atmospheric Administration) reflectivity measures the intensity returned to the radar receiver after hitting precipitation. Reflectivity is measured in decibels (dBZ) and ranges from -30 to 80 dBZ. Light precipitation usually occurs around 20 dBZ, but electronic interference ranges in that area as well. To counteract the similar characteristics of reflectivity, another condition was made for the algorithm in order to identify EI correctly. The added condition was when the RhoHV value was greater than one. The RhoHV is a measure of how similar the horizontal and vertical pulses are within a pulse volume. RhoHV values are unit-less and can range from 0.2 to 1.05. Precipitation usually occurs around 0.80 to 1. A RhoHV value of more than 1 is too noisy and untrustworthy, so making the condition of having RhoHV greater than one for EI makes sense. Including any RhoHV values less than 0.80 to be EI was ruled out because many types of echoes are within that range and only EI echoes were wanted. Typical echoes of RhoHV values below 0.80 can include partial beam filling, biological scatter, or buildings. The physical justification to characterize EI when Z is greater than 20 dBZ and RhoHV greater than 1 is that reflectivity values of 20 dBZ indicates high signal strength and there is no noise and RhoHV values greater than 1 indicates over correction due to noise. This contradiction indicates the radars are evaluating things that aren't there.

Differential reflectivity (Zdr) measures the log of the ratio of the horizontal and vertical power returns. Zdr will range from -8 dB to 8 dB. Typical Zdr values of precipitation can range from -2 dB to 6 dB (NOAA). From looking at the 2-dimensional histograms, Zdr values occur well below -2 dB and above 6 dB. Making the conditions to where the Zdr values have to be less than -2 dB or greater than 6 dB for EI avoids precipitation.

3. RESULTS

The contingency table uses the conditions applied in the algorithm to characterize the number of hits, misses, false alarms, and corrected nulls for each of the data points collected in both data sets. A better visualization of the contingency table is found in Table 2.

An electronic interference data point meeting the conditions characterizes "Hits". An electronic interference data point not meeting the conditions characterizes "Misses". A precipitation data point meeting the conditions characterizes "False alarms". A precipitation data point not meeting the conditions characterizes "Correct(nulls)".

Electronic Interference	Does it meet conditions?	
	Yes	No
Yes	Hits (A)	Misses (B)
No	False alarms (C)	Correct (nulls) (D)

Table 2: Contingency table representing the four variables the algorithm assigns the values. This is modeled after the European Virtual Organisation for Meteorological Training contingency table.

From here the prediction of detection (POD), false alarm ratio (FAR), critical success index (CSI), and Heidke Skill Score (HSS) can all be calculated using the values from the contingency table (Wilks 2011). To calculate the four items mentioned, it is easier to assign letter variables to the Hits, Misses, False Alarms, and Correct(nulls). Table 2 above shows the letter variables assigned for each (Hits = (A)).

The equations for the POD, FAR, CSI, and HSS are:

- POD = $\frac{A}{(A+B)}$
- FAR = $\frac{C}{(A+C)}$
- CSI = $\frac{A}{(A+B+C)}$
- HSS = $\frac{2(AD-BC)}{[(A+B)(B+D)+(A+C)(C+D)]}$

The probability of detection (POD) shows how well the algorithm does to characterize all of the electronic interference within the electronic interference data set. The false alarm ratio (FAR) shows how well the algorithm does to characterize echoes of what it believes to be electronic interference in the precipitation data set. The critical success index (CSI) has a range from 0 to 1, with a value of 1 indicating a perfect forecast. The CSI is frequently used, with good reason. Unlike the POD and the FAR, it takes into account both false alarms and missed events, and is therefore a more balanced score. Finally, the Heidke Skill Score (HSS; Heidke

1926) is a measure of skill that is normalized by the total range of possible improvement over the standard. The range of the HSS is -∞ to 1. Negative values indicate that the chance forecast is better, 0 means no skill, and a perfect forecast obtains a HSS of 1. Contingency results and the list of calculations from the data sets can be seen in Table 3:

Electronic Interference	Does it meet conditions? Z >20 dBZ and RhoHV > 1 Zdr < -2 dB and Zdr > 6 dB		Marginal Total
	Yes	No	
Yes	Hits (A) 42,875	Misses (B) 41,987	A+B 84,862
No	False Alarms (C) 9,535	Correct(nulls) (D) 80,914	C+D 90,449
Marginal Total	A+C 52,410	B+D 122,901	A+B+C+D 175,311

Table 3: Contingency results from data sets

- POD = 0.5052
- FAR = 0.1819
- CSI = 0.4542
- HSS = 0.4046

4. CONCLUSION

A total of 175,311 data points were evaluated from the electronic interference and precipitation data sets. A POD of 0.5052 reveals that about half of EI could be quality controlled out of the data. Having a FAR of 0.1819 reveals that EI was over-characterized, resulting in a small bias, in other words, for every five data points the algorithm assesses correctly as EI, one data point from the precipitation data set is incorrectly characterized as EI. A CSI of 0.4542 reveals how successful the algorithm characterizes Hits overall, however it is a biased score in that it takes account of the false alarms and misses. The HSS of 0.4046 is a positive skill score, indicating that this algorithm for detecting EI is better at characterizing EI than the current algorithm. An ideal HSS would be 0.80 or greater, so there is still much more room for improvement.

Examining and comparing more polarimetric variables could help characterize EI more, which could in turn increase the HSS. Comparing Z versus Zdr values helped find a condition that could be incorporated into the contingency algorithm, as did comparing the RhoHV versus Zdr values. However, comparing Z versus RhoHV values did not lead to finding an additional condition to incorporate into the contingency algorithm because the values for EI and precipitation are too similar. Future work could include-the specific differential phase (KDP) values and could compare it with the other polarimetric variables. Adding another polarimetric variable and plotting it with the Z, Zdr, and RhoHV values to visualize the data could help find more conditions for EI. If further reasonable conditions could be made to characterize EI and improved the HSS, then the findings could be eventually incorporated into the Lakshmanan et al. (2013b) quality control technique.

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