Analysis And Application Of X-Band Dual-Polarization variables Of Ground Clutter

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Abstract Statistical characteristics of dual-polarization variables of ground clutter and weather echoes are presented，by analyzing radar low-elevation echo data of Chengdu summer clear and precipitation in 2010. The results show that the majority of ground clutter correlation coefficient are less than 0.85, while most of the weather echo correlation coefficient greater than 0.90. Differential reflectivity of ground clutter are randomly polarized characteristics, the intensity distribution covers -20 ~ 20dB, the mean concentration is at 0 dB, while the weather echo are concentrated at -3 ~ 6dB. The K_{DP} of ground clutter covers the entire π interval, and the K_{DP} of weather echo are concentrated from -6 to +6 deg / Km. Test data show that the K_{DP} distinguish the difference between clutter and weather echoes obviously. The important parameters of identifying ground clutter are K_{DP}, Z_{DR} and ρ_{hv}. Base on occurrence possibility of polarized parameters about clutter and weather echoes, fuzzy logic is utilized to identify ground clutter.

Key words Dual polarization, weather radar, clutter recognition

1. INTRODUCTION

Ground clutter echoes can't be neglected since it's able to contaminate meteorological radar products. The understandings of ground clutter characteristics can be used for detection and suppression of ground clutter. The clutter map is a usual way to provide the position and spectrum parameters of ground clutter while the radar is scanning at specific elevation angle. Kessinger et al (2003) proposed a fuzzy logic algorithm with three spectrum moments to classify echoes. Berenguer et al (2006)distinguished precipitation from ground clutter or sea clutter with speed, echo top, reflectivity intensity gradients, texture and so on. Zrnic et al(2006) analyzed the zero-order autocorrelation coefficient characteristic of ground clutter. The dual-polarization variables of ground clutter are far different from weather echoes, which can be used to identify the clutter. The clutter and weather echoes under different wavelength have tiny difference of detailed characteristic. The paper mainly analyzes the X-band characteristic of clutter and weather echoes.

2. X-band Dual-polarization radar specification

The XD radar located in Chengdu University of information technology is dual-polarimetric doppler weather radar. The XD radar adopts SHV mode (Simultaneous Horizontally and Vertically transmit/receive). The XD radar has only one transmitter. The power generated by klystron is split into H and V transmission by power splitter. The radar has dual-channel receiver which simultaneously receive H and V polarization echoes. The main technical specification of the radar are shown in Table 1.

Table 1 the system specification of XD weather radar

	specification
Frequency	9.42 GHz
Antenna	Rotational parabolic
Antenna diameter	2.4 m
Polarization mode	SHV
Scanning	PPI/RHI/VOL
Transmitted Peak power	75 Kw
Pulse width	0.883 us
Noise figure	≤4 dB
Improvement factor	45 dB
Dynamic range	≥90 dB

Signal Processing	PPP，FFT
Base products	Z /V /W ZDR /$\vert\rho_{hv}\vert$ /Φ_{DP}/ K_{DP}

3. Statistical distribution

The majority ground clutter observed by XD radar occur in elevation between the 0.5^o ~ 2.4^o, therefore the statistical dual-polarized characteristics of clutter and weather is concentrated on low elevation. The radar is well-calibrated before experiments. The experiments are divided to two main modes of clear and precipitation. The experiments collect and restore the raw I/Q data which are used to computed dual-polarized parameters without valid data range restriction. That helps us to understand the clutter better.

The experiments last the whole year of 2010. The probability density distribution of dual-polarization variables of clutters and weather echoes are displayed in figure 1.

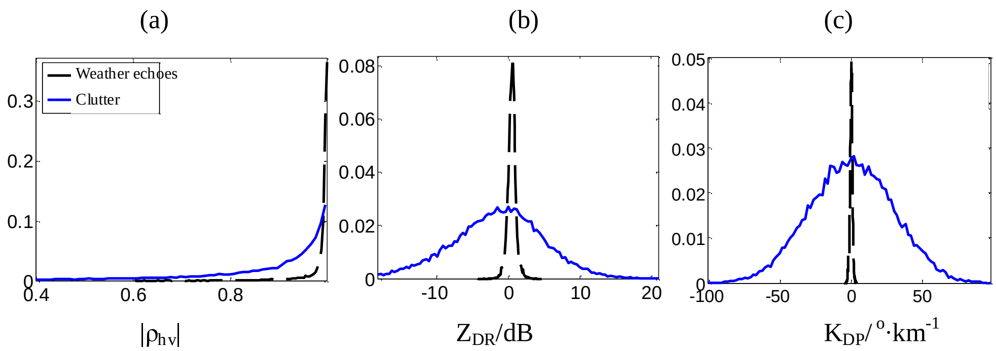

Fig.1 Normalized frequency distribution of polarized variables about clutter and weather echoes（a）correlation coefficient,（b）differential reflectivity,（c）specific differential phase

Compared with the differential phase, K_{DP} is naturally unbiased. As can be seen from Figure 1, the majority of ground clutter correlation coefficient are less than 0.85, while the majority of precipitation echo correlation coefficient are more than 0.90. Ground clutter has wide polarization differential reflectivity, intensity distribution coverage between -20 ~ 20 dB , and the mean value is concentrated at 0 dB, while the majority of precipitation echoes distribute between -3 ~ 6 dB. The K_{DP} of ground clutter cover the entire 180 deg/km, while the majority of the weather K_{DP} concentrates from -6 to 6 deg/km. Thus, the polarization characteristics of ground clutter and precipitation are obvious distinction. Furthermore, the occurrence probability of weather and clutter under specific data value range are observed (Table 2). As can be seen from Table 2, The occurrence probability of weather echoes are more than 99.5% according to the specific data range, while the occurrence probability of ground clutter are much lower. The result will be opposite if the polarization variables are at the outside of the specific data range. The K_{DP} is a better parameter to distinguish clutter and weather echoes.

Table 2 the occurrence possibility of ground clutter and precipitation echo under specific range

Data range	Precipitation (%)	Ground Clutter(%)
-3 dB≤Z_{DR}≤6 dB	99.5	43.2
$\vert K_{DP}\vert \le 6\ ^o.km^{-1}$	99.5	13.5
$\vert\rho_{hv}\vert \ge 0.80$	97.8	75.7

3. ground clutter identification

Fuzzy logic method can be used to identify the echo type . The identification with fuzzy logic method has four step including fuzzification, rule inference, aggregation, and defuzzification. The four parameters of Z_H, Z_{DR}, KDP, and | ρhv | are inputs.

The basic form of membership function(MSF) select asymmetric trapezoidal T-function, which determines the shape with the four parameters: left starting X1, the left end of the interval point value X2, the right starting point interval value X3, the right end of the interval point value X4.

$$T(x, X_1, X_2, X_3, X_4) = \begin{cases} 0 & x < X_1 \\ \dfrac{(x - X_1)}{(X_2 - X_1)} & X_1 \le x < X_2 \\ 1 & X_2 \le x < X_3 \\ \dfrac{(X_4 - x)}{(X_4 - X_3)} & X_3 \le x < X_4 \\ 0 & x \ge X_4 \end{cases}$$

Statistical polarization characteristics of weather echoes and clutter are used to construct their own MSF. Table 3 gives T-function parameters value of the weather echoes and ground clutter MSF.

The output range of Membership function is [0,1], the magnitude of the numerical results reflects the possibilities of ground clutter or weather echoes. Identification process have two kinds of identification type inference rules of clutter and precipitation, the four probe parameters were substituted into corresponding type of membership functions and calculated. The results are multiplied by a weighting factor of polarization variables, and then summed.

Table 3 Membership function values of polarimetric variables for weather echo and ground clutter

		Weather echoes	Ground clutter
$T(Z_H)$	X1/dBz	10	30
	X2/dBz	15	40
	X3/dBz	45	55
	X4/dBz	70	70
$T(Z_{DR})$	X1/dB	-3	-20
	X2/dB	-2	-5
	X3/dB	5	5
	X4/dB	,6	20
$T(K_{DP})$	X1/(deg.km^{-1})	-6	-100
	X2/(deg.km^{-1})	-4	-30
	X3/(deg.km^{-1})	4	30
	X4/(deg.km^{-1})	6	80
T	X1	0.7	0.2
	X2	0.85	0.9
	X3	1	1
	X4	1	1

For clutter type, the weighting factor value of K_{DP}, Z_H, Z_{DR} and $|\rho_{hv}|$ are correspondingly 0.5,0.2,0.15 and 0.15. For precipitation type, the weighting factor value of K_{DP}, Z_H, Z_{DR} and $|\rho_{hv}|$ are all 0.25. Next “aggregation" process is inferred from two separate rules, selecting the maximum value as the sole final result. Finally it’s converted to the specific recognition results.

Fig 2 shows an application of identification.

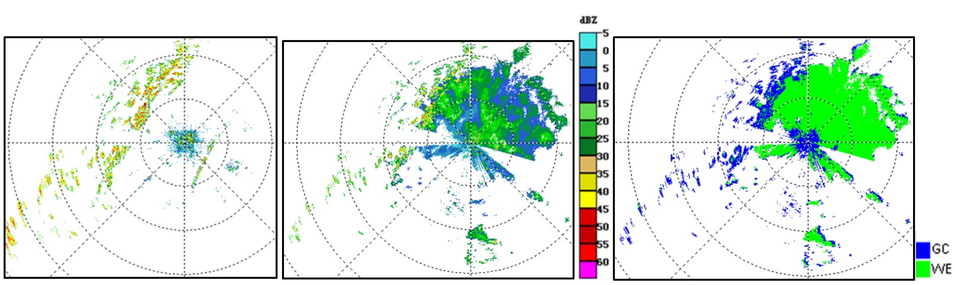

Fig.3 The PPIs of 0.5deg elevation are observed under clear and precipitation condition

(a)Z_H of ground clutter without precipitation (b) Z_H of precipitation (c) Fuzzy logic identification result,GC represents ground clutter, WE represents weather echoes.

4. CONCLUSION

Polarimetric variables are not pre-restricted with specific threshold range, which are more useful for the recognition of of ground clutter characteristics. The majority of recognized ground clutters are similar to observation under clear-sky, however there are still a small part of precipitation echoes mistakenly identified as ground clutter. False recognition rate is subject to the rules of the fuzzy logic inference and aggregation, such as: unrealistic parameter value of T-function and unfair distribution of weighting factors. Since the polarization characteristics of clutter and precipitation have small overlapping, it can't theoretically distinguish all clutter only by the polarization variables. Therefore it's need to consider a compromise weight distribution and threshold adjustment.

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