ISBN: 978-981-18-5852-9
WCSE 2022 Spring Event: 2022 9th International Conference on Industrial Engineering and Applications
doi: 10.18178/wcse.2022.04.175

# Narrowband RCS Feature Selection and Evaluation in Applications

Yu Cheng [1], Xi Li [1] and Lijun Liu [1]

[1] Jiuquan Satellite Launch Center

**Abstract.** Narrowband RCS is abundant in target characteristic information, and selection and evaluation of characteristic directly affect target identification. Sliding window is used for feature extraction in engineering applications. Window size and sliding step are the two basic parameters of sliding window method. Fisher criterion is adopted to estimate the effect of the parameters in narrowband RCS feature separability. Experimental results show that both the number of separable features and the feature separability increase,as the window size and sliding step increase. With different sliding window parameters, RCS spectrum mean which reflects the average distribution of spectrum exhibits good separability for the classification of aircraft and first stage.

**Keywords:** feature selection, sliding window parameters, Fisher criterion, feature evaluation

## 1. Introduction

Narrowband RCS (radar cross section) is important for early warning. The reflection intensity of incident wave is expressed in RCS, which is closely relevant to the target size, structure, material, attitude, and radar observation angle. RCS bears plenty of target characteristic information. Compared with wideband information, narrowband RCS is easier to obtain. Both target scattering properties and motion characteristic are contained in RCS[1-5]. Using narrowband RCS, fast and coarse target classification can be achieved. Statistical characteristics of narrowband RCS are commonly extracted for target recognition, such as the mean, max, min, median and so on.

Statistical characteristics of RCS and Mellin transform are adopted in [3,6]. Using fuzzy decision to identify fighter, missile and helicopter, and the average probability of recognition achieves 84.6%. RCS standard deviation and power spectrum entropy are used for coarse classification of ballistic missiles[7]. Support vector machine (SVM) classifier is designed to classify space objects, based on the selected central moments features by using Fisher criterion [8-9]. A binary tree SVM classifier is employed to classify true targets and baits based on RCS[4,10].

In applications, sliding window is often used in the computation of narrowband RCS statistical characteristics[11-13]. The two basic parameters (i.e., window size and sliding step) of sliding window method, directly affect RCS statistical results and feature separability. For a specific application, aircraft and first stage are chosen as the two main radar targets to be recognized. Then the influence of window size and sliding step in the separability of RCS statistical characteristics is analyzed in this paper.

Section 2 illustrates the narrowband RCS statistical characteristics and Fisher criterion. Section 3 analyzes the experimental results. We conclude in Section 4.

## 2. Evaluation of Narrowband RCS Statistical Characteristics

The process of feature template based target identification is shown in Fig 1.

Firstly, analyze the measuring data in the view of physical mechanism, grasp target characteristics, and find the feature which can be used in target identification.

Secondly, quantify feature separability, employ an optimal characteristics extraction method, and obtain stable and distinguishable feature.

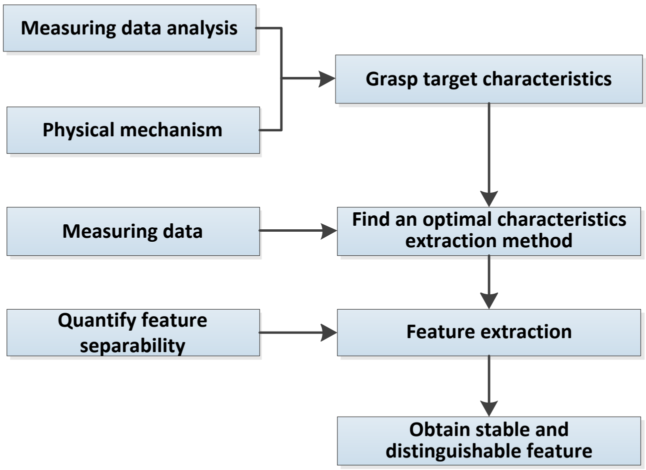



Fig. 1: feature extraction process.

In this paper, 12 narrowband RCS statistical characteristics (i.e., mean, standard deviation, max, min, range, median, average deviation, coefficient of variation, skewness, kurtosis, spectrum mean, autocorrelation mean) are selected.

Mean is the average RCS. Standard deviation presents the degree of dispersion. Max is the upper limit and min is the lower limit. Range denotes the dynamic range. Median shows the medium distribution. Average deviation and coefficient of variation both reflects the degree of dispersion. Skewness represents the departure from symmetry. Kurtosis represents the flatness degree of probability density distribution. Spectrum mean and autocorrelation mean are micro-motion modulation related characteristics. Spectrum mean denotes the average spectrum distribution of RCS sequence, and autocorrelation mean denotes the average distribution of RCS autocorrelation function.

In this paper, Fisher criterion is employed to evaluate the stability and separability of narrowband RCS statistical characteristics. In Fisher criterion, closer distance within class and wider distance between class are preferred to obtain stable and distinguishable feature.

Suppose C classes $w_i(i=1,2,\cdots,C)$ for the targets, each class of targets contains $K$ samples. The Fisher computation for the $n^{th}$ feature is defined in (1).

$$FDR(n)=\sum_{i=1}^{c}\sum_{j\neq i}^{c}\frac{\left(\mu_i(n)-\mu_j(n)\right)^2}{\sigma_i^2(n)+\sigma_j^2(n)} \tag{1}$$

$\mu_i(n)$ and $\sigma_i^2(n)$ are the mean and variance of the $n^{th}$ feature in the $i^{th}$ class respectively. $f_{ik}(n)$ represents the $k^{th}$ sample of the $n^{th}$ feature in the $i^{th}$ class.

$$\mu_i(n)=\frac{1}{K}\sum_{k=1}^{K}f_{ik}(n) \qquad \sigma_i^2(n)=\frac{1}{K}\sum_{k=1}^{K}\left(f_{ik}(n)-\mu_i(n)\right)^2 \tag{1}$$

## 3. Experimental Setup and Results

In this paper, the aircraft and the first stage are tracked, obtaining the measuring data of trajectory and RCS. Sliding window is employed for the computation of RCS statistical characteristics. Window size and sliding step are the two basic parameters of sliding window method, directly affecting the results of RCS statistical characteristics computation and feature separability. Window size is related with radar data sampling rate. We choose 4 different pair of parameters (window size, sliding step), i.e., (40s, 8s), (20s, 4s), (10s, 2s), (5s, 1s).

First of all, separability of RCS statistical characteristics is analyzed using the 4 different pair of parameters. The results of feature evaluation are shown in Fig 2.

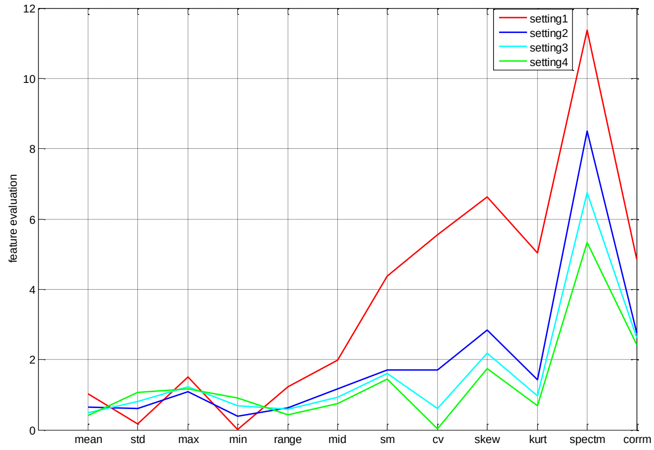



Fig. 2: narrowband RCS feature evaluation with different sliding window parameters.

Settings 1- 4 are (40s, 8s), (20s, 4s), (10s, 2s), (5s, 1s).

With the increasement of window size and sliding step, the number of features which can be separated increases, and the feature separability enhances at a certain extent. Compared with attitude-controlled targets (such as aircraft), the first stage is not attitude-controlled and exhibits obvious rolling characteristic. Usually, the rolling period of the first stage is not considered in the computation of RCS statistical characteristics, so the periodical feature of stages can hardly manifest with common window size and sliding step. In Fig2, we can see that the feature separability between aircraft and the first stage enlarges when the window size is bigger than the rolling period. Hence, with bigger window size, the feature information contained in RCS is more abundant and the RCS statistical characteristics separability is more obvious. For example, the separability of the mean spectrum which is highly related with periodical feature could improve at a certain extent.

Secondly, with large window size, the influence of sliding steps to feature separability is analyzed. The window size is 40s, and 3 sliding steps are 20s, 8s and 1s. If the sliding step is 40s, the number of data segments is less than 5, resulting in little statistical significance. The results of feature evaluation using different sliding steps are shown in Fig 3.

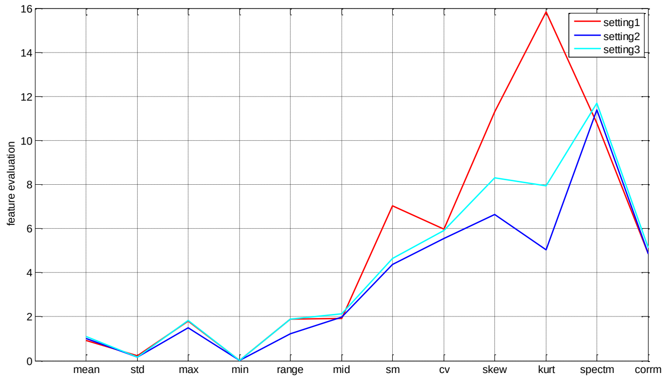



Fig. 3: narrowband RCS feature evaluation with different sliding steps (large window size).

Settings 1 – 3 are (40s,20s), (40s,8s), (40s,1s).

With the window size of 40s, feature separability is affected by the size of sliding step. The sliding step increases, then the number of features which can be separated increases. In the sight of mathematics, large window size and sliding step lead to the sharp reduction of data segments, thus resulting in the enhancement of separability. However, in the sight of physical mechanism, with large window size and sliding step, separability of features (e.g., skewness and kurtosis) would not improve. Therefore, feature separability enhances with the increasement of sliding step in the situation of large window size, which is induced by the decrease of data segments.

Therefore, it is necessary to select proper window size based on the data length and frequency. In the experiment, 10s is the optimal window size for feature selection and evaluation.

Lastly, with the window size of 10s, the influence of sliding steps to feature separability is illustrated. Hence, there are 4different pair of parameters (window size, sliding step), i.e., (10s, 10s), (10s, 5s), (10s, 2s), (10s, 1s). The results of feature evaluation using different sliding steps are shown in Fig 4.

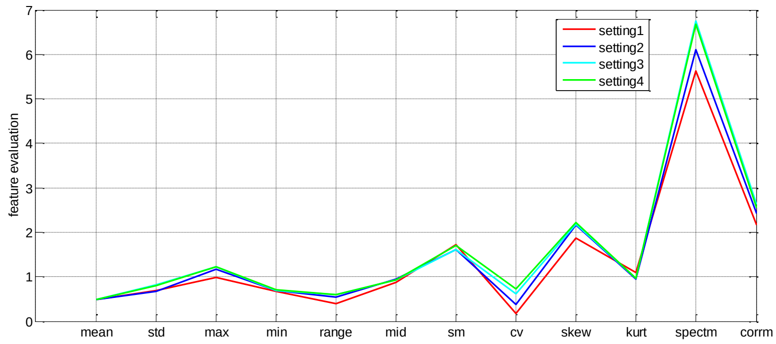


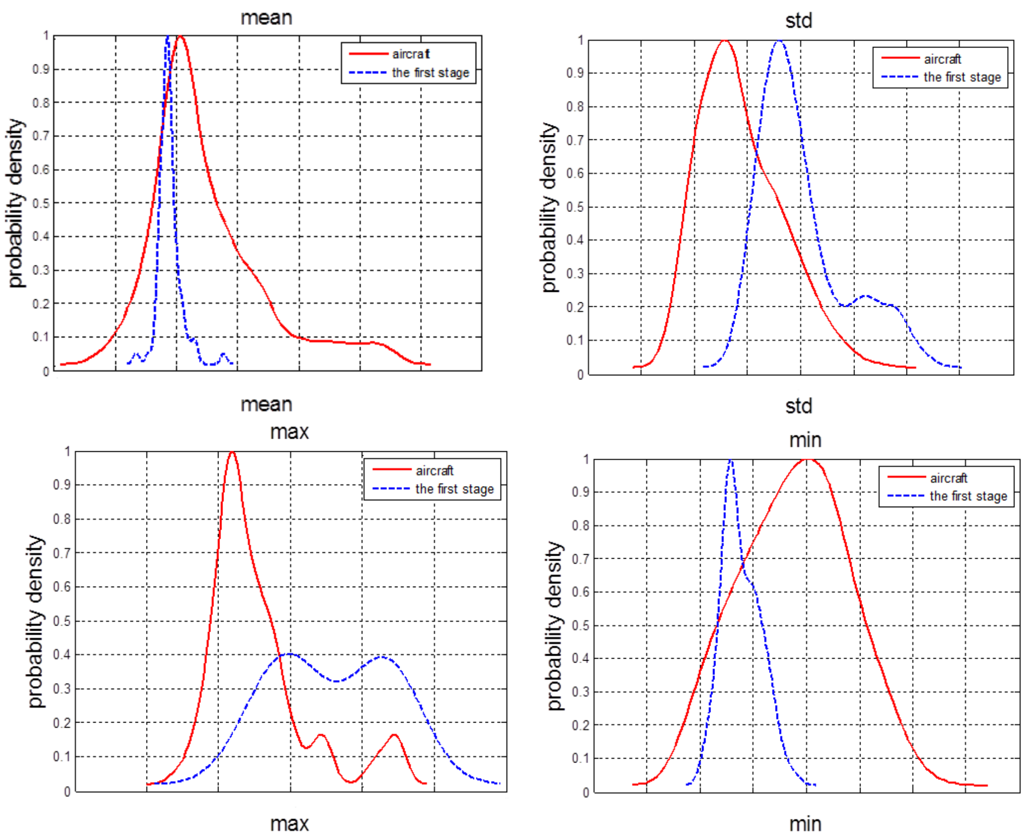

Fig. 4: narrowband RCS feature evaluation with different sliding steps (window size of 10s).

Settings 1 – 4 are (10s,10s), (10s,5s), (10s,2s), (10s,1s).

With the window size of 10s, sliding step can hardly affect feature separability.

Furthermore, we select the optimal window size and sliding step (i.e., (10s, 2s)), and then compute the probability density distribution of narrowband RCS for the aircraft and the first stage. The results are shown in Fig 5.

It is shown that spectrum mean exhibits good separability. Spectrum mean could be used for target identification between the aircraft and the first stage.



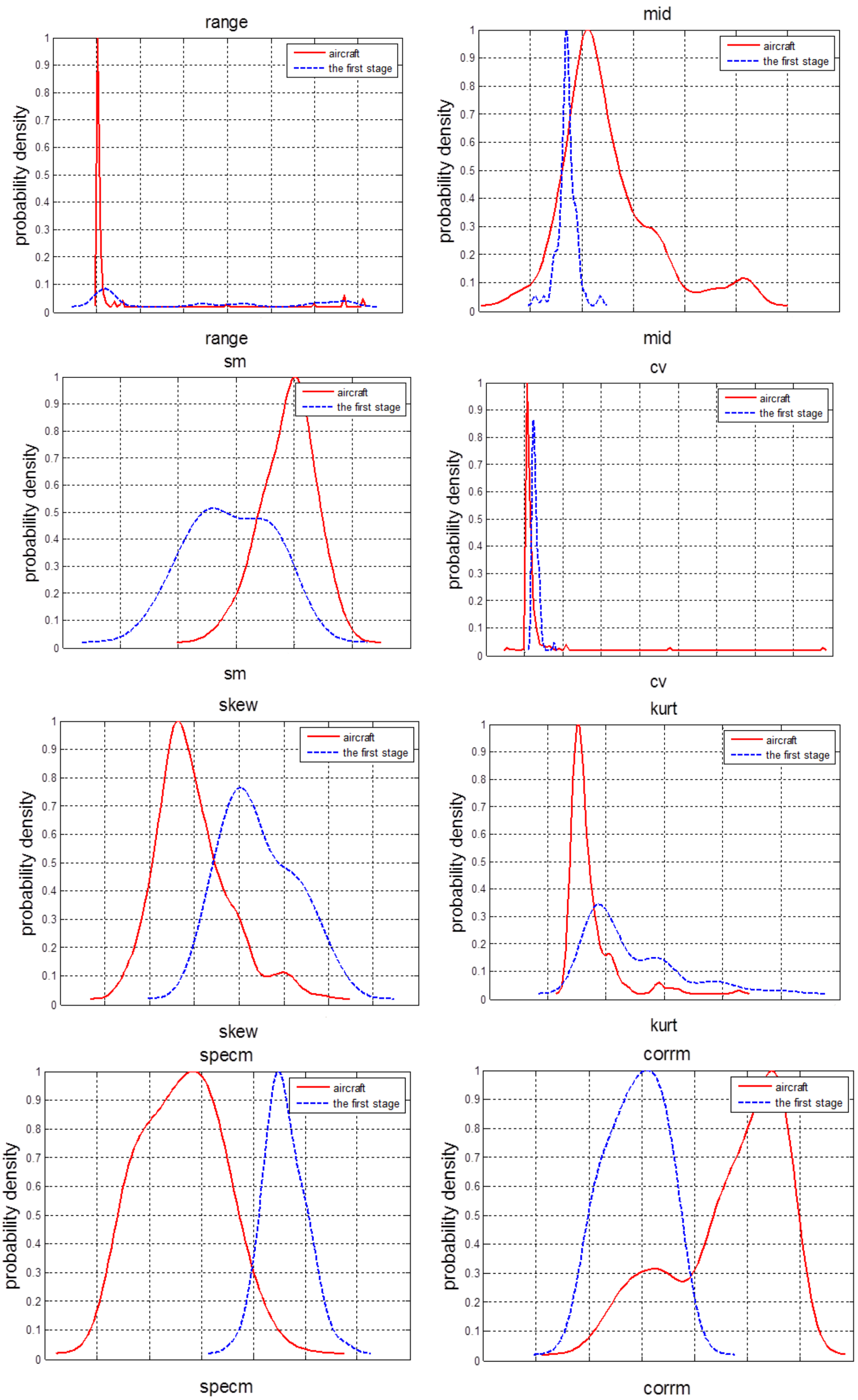



Fig. 5: probability density distribution of narrowband RCS for the aircraft and the first stage.

## 4. Conclusions

With the increase of window size and sliding step, the number of separable features increases, and the feature separability enhances at a certain extent. Compared with small window size, sliding step has greater impact on the separability of RCS statistical characteristics with large window size. However, the selection of window size should fully consider the real-time property and statistical significance.

Extraction of separable feature plays an important role in target recognition and determines the performance of target identification. For the targets chosen in this paper, spectrum mean is a separable feature for target identification. However, if certain situation changes, such as radar pulse repetition frequency, dwell time and so on, separable features would be quite different. Besides, considering the cluster target superposition, attitude adjustment, Signal-to-Noise Ration and other factors in applications, the measured RCS is unstable, thus inducing weak separability of RCS statistical characteristics. Therefore, we need to further expand the dimension and number of features, such as wideband feature and projective feature. A painstaking analysis of weak separable features in the sight of physical mechanism is planned to improve feature separability and stability.

## 5. References


[1] Wei, X. Z. , et al. "Estimation of Precession Period Based on Nonparametric Statistics." Acta Electronica Sinica (2010).

[2] Huang, S. Q. , et al. "SAR Image Point Target Change Detection Based on RCS Curves." Journal of Astronautics (2010).

[3] Feng, D. J. , J. Liu , and M. Dan . "RCS periodicity of ballistic target in midcourse and its estimation algorithms." Journal of Astronautics (2008).

[4] Wei, W. , and H Cai. "Narrowband Radar Ballistic Missile Target Recognition Technology Based on SVM." Electronic Science and Technology (2016).

[5] Jin, Jia Wei , H. L. Ruan , and B. Sun . "Micro-Doppler Period Estimation of Ballistic Targets Based on Circular Average Magnitude Difference Coefficients." 2020 International Conference on Information Science, Parallel and Distributed Systems (ISPDS) 2020.

[6] Lee, Kun Chou , C. W. Huang , and M. C. Fang . "RADAR TARGET RECOGNITION BY PROJECTED FEATURES OF FREQUENCY-DIVERSITY RCS." ,81,(2008) 81(2008):121-133.

[7] Xing-Xing, L. I. , H. Y. Yao , and W. F. Sun . "Rough Classification of Ballistic Midcourse Targets Based on RCS Characteristics." Journal of Air Force Early Warning Academy (2013).

[8] Tsui, K. L. , et al. Data Mining Methods and Applications. Springer London, 2006.

[9] Sheng, and Jing. "Target identity recognition method based on RCS distribution and spatial location - ScienceDirect." Procedia Computer Science 147(2019):632-637.

[10] Wang, C. , and S. Zhang . "Target Recognition of Ballistic RCS Data Based on Binary Tree SVM." Modern Radar (2015).

[11] Vaerenbergh, S. V. , V. Javier , and S. Ignacio . "Nonlinear System Identification using a New Sliding-Window Kernel RLS Algorithm." Journal of Communications 2.3(2007).

[12] Hargrave, C. , et al. "Radar target identification: Estimating the start of the late time resonant response." International Conference on Radar IEEE, 2013.

[13] Tian, Guishen , et al. "Electric Tower Target Identification Based on High-resolution SAR Image and Deep Learning." Journal of Physics: Conference Series 1453(2020).