# A Method of ISAR Sequences Quality Assessment for Aerospace Target

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**Abstract**— In this paper, the traditional ISAR image quality evaluation standard and its limitation is analyzed. An ISAR quality evaluation method of aerospace targets is presented, combining with ISAR imaging mechanism and the structural characteristics of aerospace targets, referencing the standard of optical image quality evaluation. Beyond some current commonly used indications, a new indication based on the power spectrum is adopted in this method. The simulation data and real data show the validity of the algorithm.

## 1. INTRODUCTION

Inverse synthetic aperture radar (ISAR) can generate 2D image for a non-cooperative moving target [1], and be used for military and civilian purpose. In practice, the effect of ISAR imaging is affected by many factors; some quality problem is existed in the ISAR image, such as blur, deformation, tailing, ghost copy etc. [2]. So it is necessary to evaluate the image quality by some corresponding parameters. In addition, the research on that how to choose the high quality image from the mass result, has important significance to realize image interpretation and obtain the target information. The techniques for SAR image quality assessment have been developed in recent years, and already formed a commercial product, but the research on ISAR image is still poor.

In the traditional method, image entropy and contrast is adopted to evaluate ISAR image quality, however, this method is only suitable for comparing the image quality from the same measurement data in different processing algorithm. It still has no viable standard on that how to evaluate the ISAR images in different measurement periods.

This paper analyzes the traditional ISAR image quality evaluation standard and its limitation in Section 2. ISAR imaging mechanism and the structural characteristics of aerospace targets is analyzed in Section 3. Referencing the standard of optical image quality evaluation, an ISAR quality evaluation method of aerospace targets is presented in Section 4. Beyond some current commonly used indications, a new indication based on the power spectrum is adopted in this method. Experimental results and performance analysis are reported in Section 5, followed by conclusion in Section 6.

## 2. TRADITIONAL STANDARD OF ISAR IMAGE QUALITY ASSESSMENT

Objective image quality measures have been developed to quantitatively estimate the perceived image quality. There are three types of objective image quality measures: full-reference (FR), reduced-reference (RR), and no-reference (NR), which have full, partial, and no access to a reference (distortion-free) image, respectively [3]. ISAR image quality assessment belongs to NR.

Currently, image entropy and contrast is adopted as two indications, when evaluating the ISAR images.Image entropy is used to characterize the image clarity. It is defined by:

$$Entropy = -\sum_{m=1}^{M}\sum_{n=1}^{N}\frac{|I(m,n)|^2}{S}\ln\frac{|I(m,n)|^2}{S} \tag{1}$$

When $S=\sum\limits_{m=1}^{M}\sum\limits_{n=1}^{N}|I(m,n)^2|$, $M$ denotes the number of HRRPs and $N$ is the number of range bins in HRRP. Figure 1 shows ISAR images with different entropy.

ISAR image contrast is defined by the ratio between the standard deviation and mean value of image intensity, which can be expressed as

$$C=\frac{\sqrt{E\left(\left(I^2(m,n)-E\left(I^2(m,n)\right)\right)^2\right)}}{E\left(I^2(m,n)\right)} \tag{2}$$

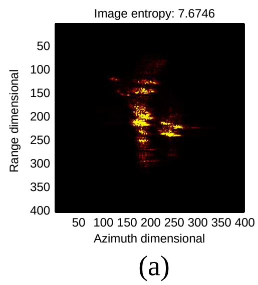



Figure 1: ISAR images with different entrop.

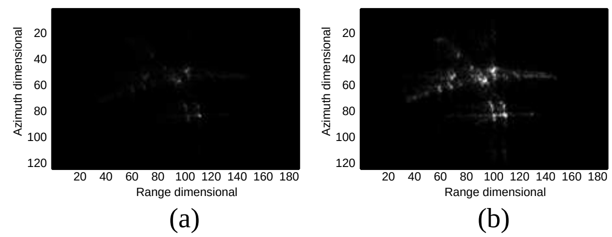



Figure 2: ISAR images with different contrast. (a) Original image. (b) Enhanced image.

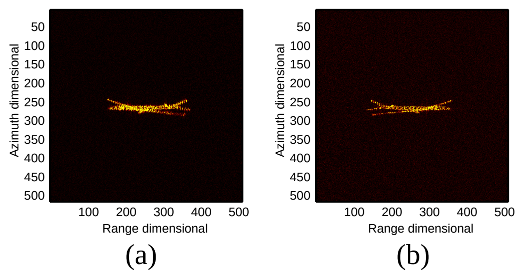



Figure 3: ISAR imaging results of Simulate data.

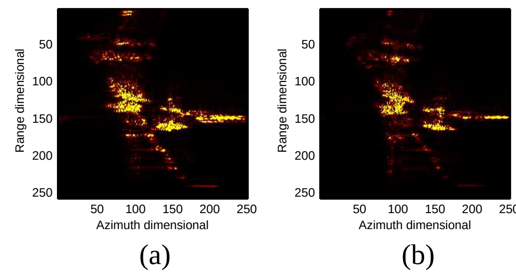



Figure 4: ISAR images with defocus blur.

Table 1: Entropy and contrast of ISAR images shown in Figure 3.

| | **Entropy** | **Contrast** | | **Entropy** | **Contrast** |
|---|---|---|---|---|---|
| Figure 3(a) | 8.1045 | 11.5667 | Figure 3(b) | 8.9662 | 11.1414 |

Image contrast has an important effect on image segmentation, target region extraction and target classification. Many factors may cause low image contrast. Sidelobe and coherent speckle increases the energy of background, disrupts the original outline structure of target, and thus reduces the contrast of target and background. Some ISAR images' dynamic range is small, resulting in the low contrast. The higher the ISAR image contrast, the clearer the image, more conducive to the extraction and classification of target. Figure 2 shows a group of ISAR images. The original image is shown in Figure 2(a). Figure 2(b) shows the enhancement result. It is obvious that the enhanced image highlights the target brightness, suppresses background noise, and improves image quality.

Entropy and contrast, can reflect the quality of ISAR, but need to point out that it is effective for comparing the ISAR images generated by the same measuring data under different processing algorithms; in other cases, it is not always reliable. Figure 3 shows two different ISAR imaging results. The contrast and entropy of them is shown in Table 1. From the entropy and contrast, the quality of Figure 3(a) is better; this is obviously inconsistent with the actual visual effects. It still has no viable standard on that how to evaluate the ISAR images in different measurement periods.

## 3. AEROSPACE COMPLEX TARGET ISAR IMAGE CHARACTERISTICS ANALYSIS

In the ISAR imaging process, there are many factors lead to blurred images, such as sidelobe enhancement, noise, ghost, defocusing etc.. Among them, the defocusing is one of the important factors that cause ISAR images blur.

For aerospace object, the motion parameters and the state is usually unknown. The existence of complex motion during the flight, such as maneuver, transfer etc., make the error in translational motion compensation, nonlinear correction, and cross-range scaling, is difficult to avoid. And the scattering centers of aerospace target is more intensive; even a high-resolution, it is difficult to avoid migration through resolution cells (MTRC). All these will lead to ISAR images focusing not well and generate blur image. As shown in Figure 4. Blur will lead to a decline in ability of target recognition of ISAR image, therefore need quantitative evaluation of blur degree.

The blur parameters assessment method based on the blur image spectrum diagram, which is presented in [4], has been widely researched and applied. The method which adopts the image edge along the direction of motion as a motion blur measure is indicated in [4–6]. Experiments show that the motion blur evaluation algorithms cannot be directly used in defocus blur degree evaluation of ISAR image, this is because the low signal-to-noise ratio (SNR) of ISAR image. ISAR has the similar imaging mechanism with SAR. According to the characteristic of SAR images, literature [7] proposed a new method using truncated spectrum of SAR images and average edge width of salient image areas after med-value filtering with big windows to evaluate the defocusing blur of SAR images. Because the quality, it is difficult to extract the edge of ISAR images, so the method of literature [7] is not applicable to ISAR images.

High frequency part of ISAR image can represent the image detail. For the image which exist defocusing blur, the high frequency part damage is serious, and the high frequency power spectrum will be lower, so we can consider using high frequency component of the power spectrum of image as a measurement of its blur degree.

## 4. ISAR IMAGE QUALITY ASSESSMENT

### 4.1. Image Power spectrum

In order to carry on the spectrum analysis, image can be transform to the frequency domain. The two-dimensional spectrum of ISAR image is written as $F(u, v)$, then the power spectrum $P(u, v)$ can be obtained by

$$P(u, v) = \frac{|F(u, v)|^2}{M \times N} \tag{3}$$

where $(u,\ v)$ is the frequency coordinate in two-dimensional space; and $M \times N$ is the size of image.

### 4.2. ISAR Image Quality Assessment Based on Wavelet Power Spectrum

Usually, when the image is blurred, the high frequency components will be lost, and the high frequency power spectrum of image will change with the change of the high frequency components, so we can use the change of the high frequency power spectrum to describe blurred image quality.

High frequency component often presents the edge of the image and the image contour, therefore we do the processing for image through the wavelet decomposition. First using the ISAR image wavelet transform to extract the approximate image $cA$, and three high frequency sub images $cHcV$, $cD$ that correspond to horizontal, vertical and diagonal, respectively. Because ISAR image defocus will lead to the change of the high frequency components,so we take the ratio between high frequency components and low frequency components, as the evaluation indexes. The higher the ratio is, the worse the image. Here the power spectrum of $cI$, $cH$, $cV$, $cD$, are written as $cI\_PS$, $cH\_PS$, $cV\_PS$, $cD\_PS$, respectively, which can be obtained according to (3). The evaluation indexes $InPs$ is defined as

$$InPs = \frac{3 * mean2(cI\_PS)}{mean2(cH\_PS) + mean2(cV\_PS) + mean2(cD\_PS)} \tag{4}$$

In the application process, it is found that the effect of proposed method is not very good, when the image in the sequence has a large change. This is because, with the changes of the pose, the shape and size of the object appeared in the image is also different. If the background region is too large, the mean of power spectrum will be reduced, which will affect the evaluation results. To exclude this effect, the method this paper adopts, is to intercept the target region; and only do the analysis for the power spectrum of target region.

## 5. EXPERIMENT RESULT AND ANALYSIS

In this section, we present two numerical examples to demonstrate the performance of the proposed approach.All the algorithms in this section run on Matlab 2010a. The operating system is

Table 2: Parameters of radar system.

| Parameter | Setting value | Parameter | Setting value |
|---|---|---|---|
| Carrier frequency | 10 GHz | Bandwidth | 1 GHz |
| Original azimuth | 45° | Original pitch | 45° |
| Echo number | 512 | Sampling number | 512 |

Microsoft Windows XP Professional SP3 and processor is Pentium Dual-Core 2.7 GHz ¤ 2 CPU. The computer memory is 2 GB of system RAM.

### 5.1. Simulation ISAR Sequences

In the simulated experiment, the parameters of the radar system are listed in Table 2. The model we choose in this paper is Boeing 737-800. Figure 5 shows the simulation ISAR sequences of the Boeing 737-800. The phase disturbance, which appends in the simulated experiment,satisfies $(b) > (d) > (c) > (a)$.

Figure 6 shows the target region which is extracted in this paper. Without loss of generality, here we present the assessment result using the proposed method and traditional evaluation index. The assessment result is shown in Table 3.

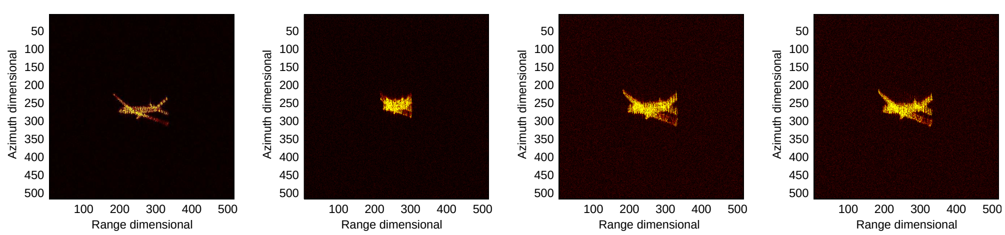
Table 3 indicates that the assessment result of proposed method satisfies $(b) < (d) < (c) < (a)$; this is consistent with the actual situation.

### 5.2. Real ISAR Sequences

In the experiment, the real data provided by Science and Technology on Automatic Target Recognition Laboratory (ATR) of China was used. The data were collected by ATR's experimental ground-based imaging radar. The target was a flying airplane of Boeing 737-800. The carrier frequency was $f_c = 10\,\text{GHz}$, and the bandwidth was $B = 1\,\text{GHz}$. Figure 7 shows the real ISAR

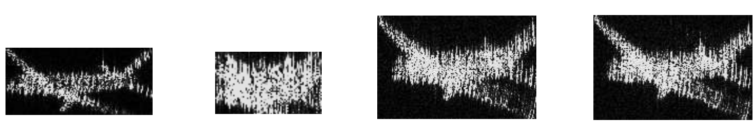
Table 3: The assessment result of simulation ISAR result.

| | (a) | (b) | (c) | (d) |
|---|---|---|---|---|
| Image entropy | 7.891 | 8.547 | 9.311 | 9.310 |
| Image contrast | 2.957 | 1.356 | 1.796 | 1.879 |
| Mean gradient | 0.0248 | 0.0253 | 0.0371 | 0.0365 |
| InPS (original image) | 6.654 | 11.484 | 9.574 | 9.840 |
| Proposed method InPS (target region) | 6.664 | 11.941 | 10.225 | 10.831 |



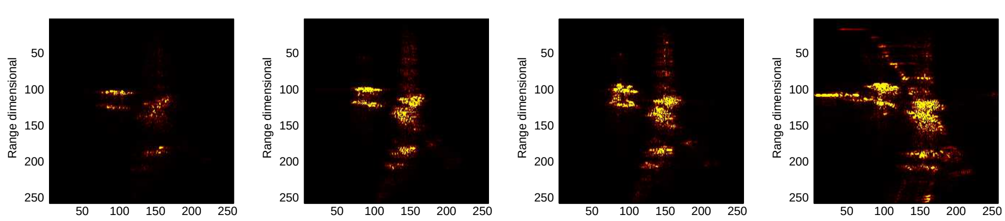

(a) (b) (c) (d)

Figure 5: Simulation ISAR sequence.



(a) (b) (c) (d)

Figure 6: The target region.




(a) (b) (c) (d)

Figure 7: Real ISAR sequence.

Table 4: The assessment result of real ISAR result.

| | (a) | (b) | (c) | (d) |
|---|---|---|---|---|
| Image entropy | 5.988 | 7.043 | 7.252 | 7.814 |
| Image contrast | 8.607 | 5.194 | 5.227 | 5.348 |
| Mean gradient | 0.0361 | 0.0683 | 0.0740 | 0.0948 |
| InPS(original image) | 7.335 | 8.945 | 9.755 | 11.930 |
| Proposed method InPS (target region) | 7.977 | 8.914 | 9.744 | 11.983 |

sequences of the Boeing 737-800. The result of quality assessment is shown in Table 4.

Table 4 indicates that the assessment result of proposed method satisfies $(d) < (c) < (b) < (a)$; this is consistent with the subjective assessment result.

## 6. CONCLUSION

This paper analyzes the traditional ISAR image quality evaluation standard and its limitation. An ISAR quality evaluation method of aerospace targets is presented. Beyond some current commonly used indications, a new indication based on the power spectrum is adopted in this method. The simulation data and real data show the validity of the algorithm.

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