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‘ADVANCED SIGNAL PROCESSING TECHNIQUES FOR INVERSE SYNTHETIC APERTURE RADAR (ISAR) IMAGING’

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I. GENERAL OVERVIEW OF FUNDAMENTAL PRINCIPLES OF ISAR IMAGING

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Introduction to ISAR imaging techniques

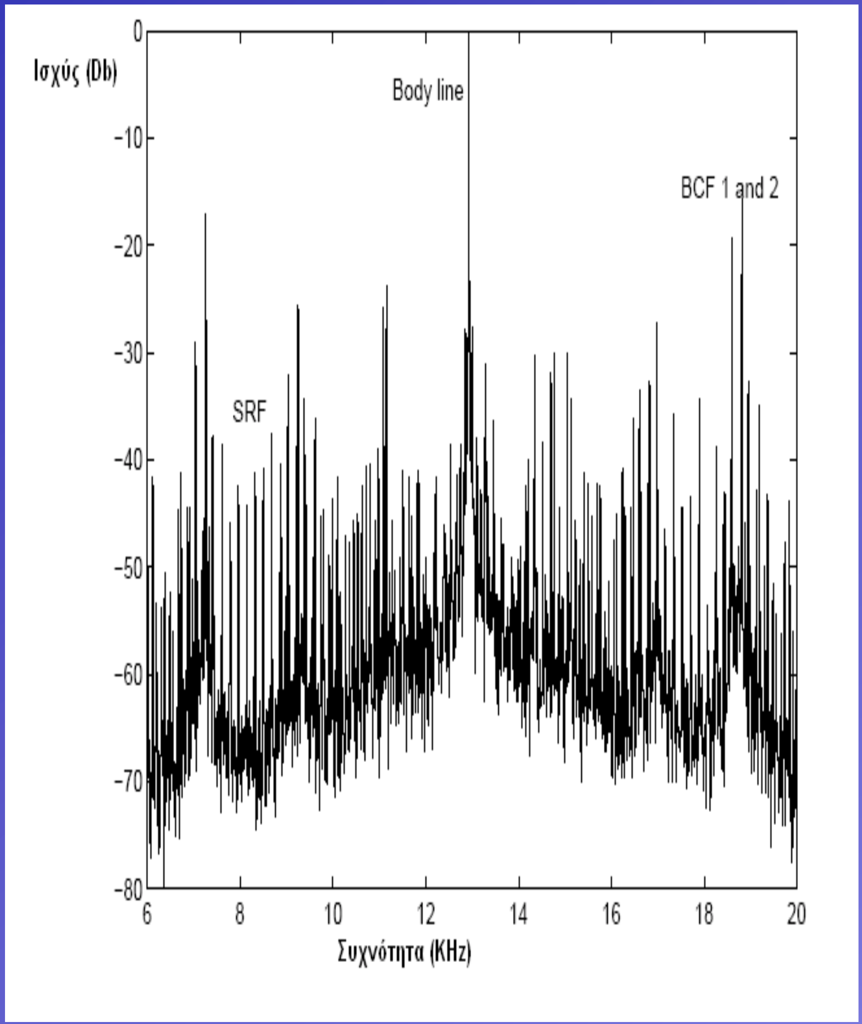
Non-Cooperative Radar Target Recognition Techniques (NCTR) :

(i) Jet Engine Modulation (JEM)

(ii) High – Resolution Radar Range Profiles (1D HRR)

(iii) Inverse Synthetic Aperture Radar (2D ISAR)

(i) Jet engine Modulation (JEM) [older technique]



- Body line :
  reflections from the whole aircraft
- Blade - Chopping Frequency - BCF :
  frequency corresponding to a full rotation of the first rotor stage
- Shaft – Rotation Frequency - SRF :
  frequency corresponding to a full rotation of a blade

Jet engine Modulation (JEM)

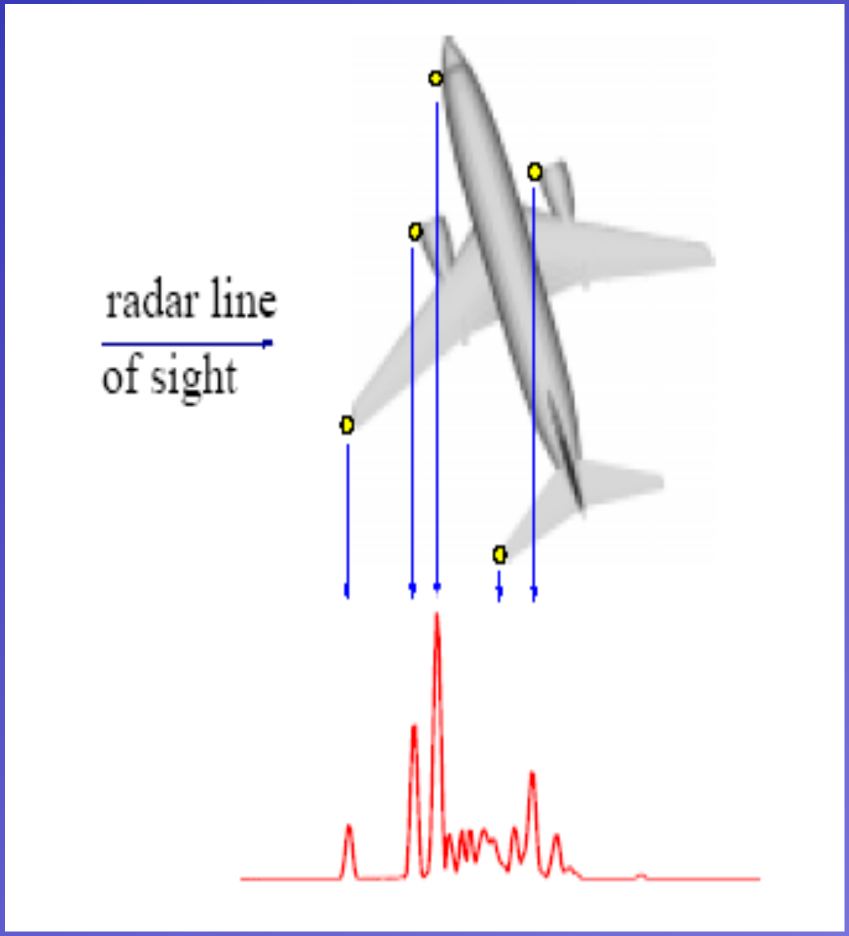
Advantages :

- ✓ Small and simple data base
- ✓ Short time-on-target
- ✓ Each aircraft has a unique engine type

Drawbacks :

- ✓ Dependence on the aspect angle
- ✓ Large signal-to-noise ratio
- ✓ Low reliability of classification results

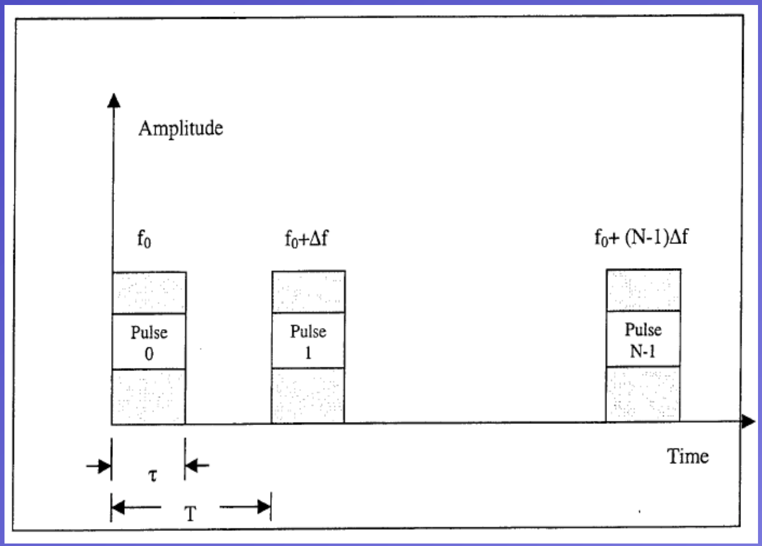
(ii) High Resolution Radar Range Profiles (HRR)

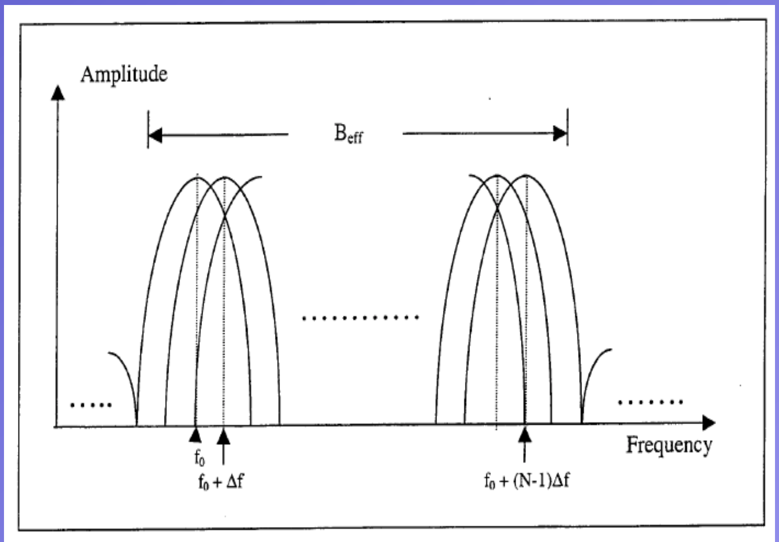


- Responses of the aircraft scatterers are projected on the radar line of sight
- Some partial information on the *geometry* of the target might be extracted

Transmitted Radar waveforms, in practice

1. *'Chirp' (Linear Frequency Modulation, LFM) pulses,* as used, from example, from the well - known TIRA radar, in Bonn, Germany.
2. *Stepped Frequency Waveform (SFW),* where the carrier frequency changes linearly from pulse to pulse, as shown below (in most cases, in this presentation, we will concern about SFW).





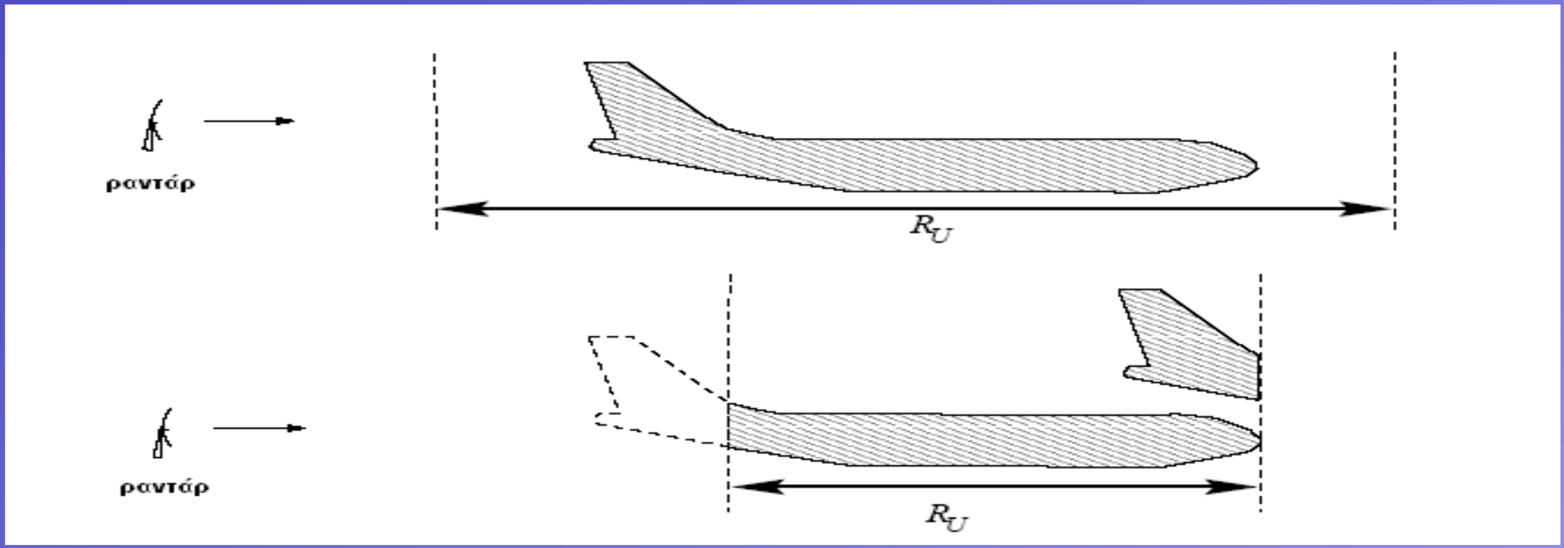
Selection of several radar parameters

- The radar range resolution equals to :

$$\Delta R_N = \frac{c}{2B}$$

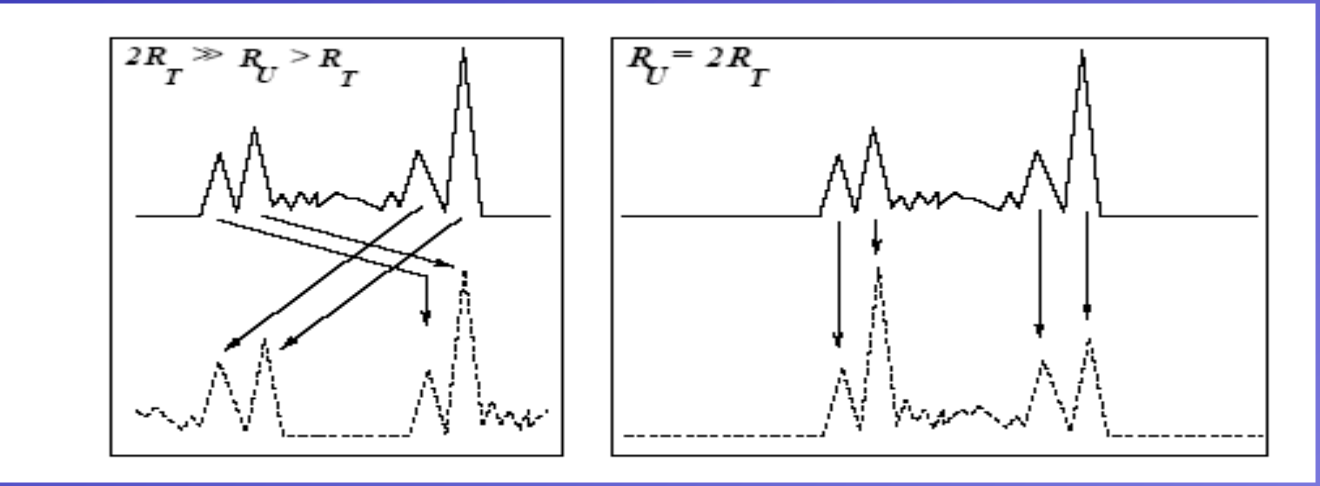
- The unambiguous range interval equals with :

$$R_u = \frac{c}{2\Delta f}$$



Radar waveform parameters

❖ **In order to avoid circular correlation effects :**



it is required :

✓ unambiguous range interval : $R_U = 2R_T$

High Resolution Radar Range Profiles (HRR)

Advantages :

- ✓ Classification is possible at any aspect angle
- ✓ Short time-on-target

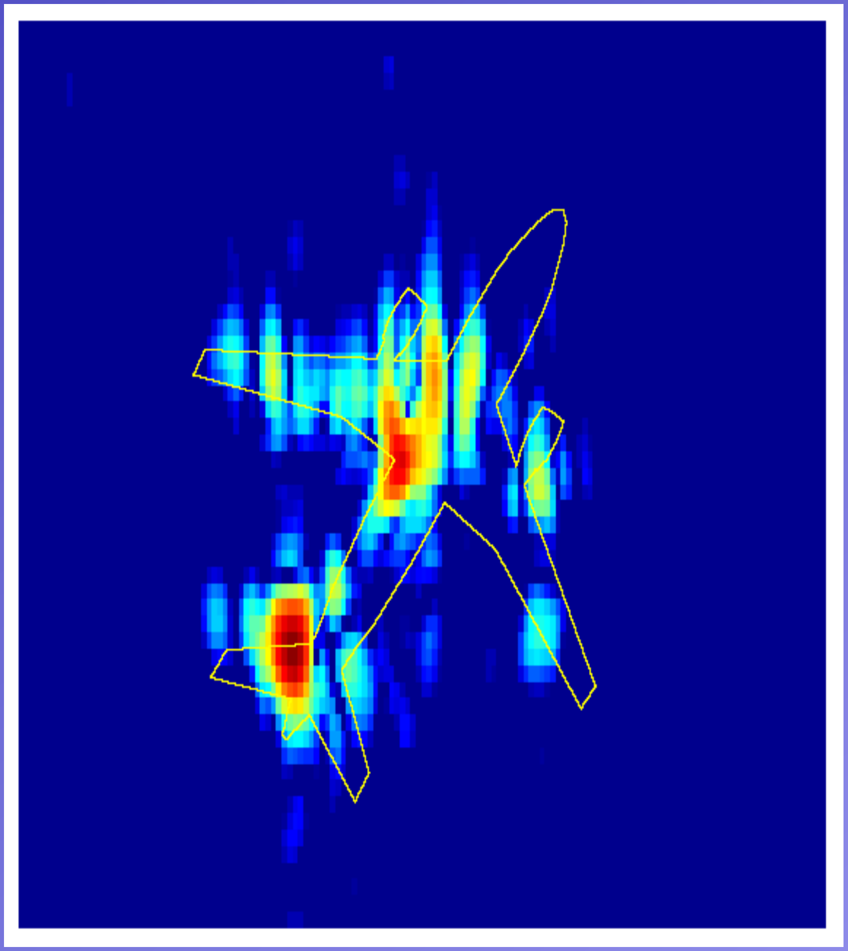
Drawbacks :

- ✓ Strong dependence of the shape of the aircraft on the aspect angle

(iii) Inverse Synthetic Aperture Radar (ISAR)

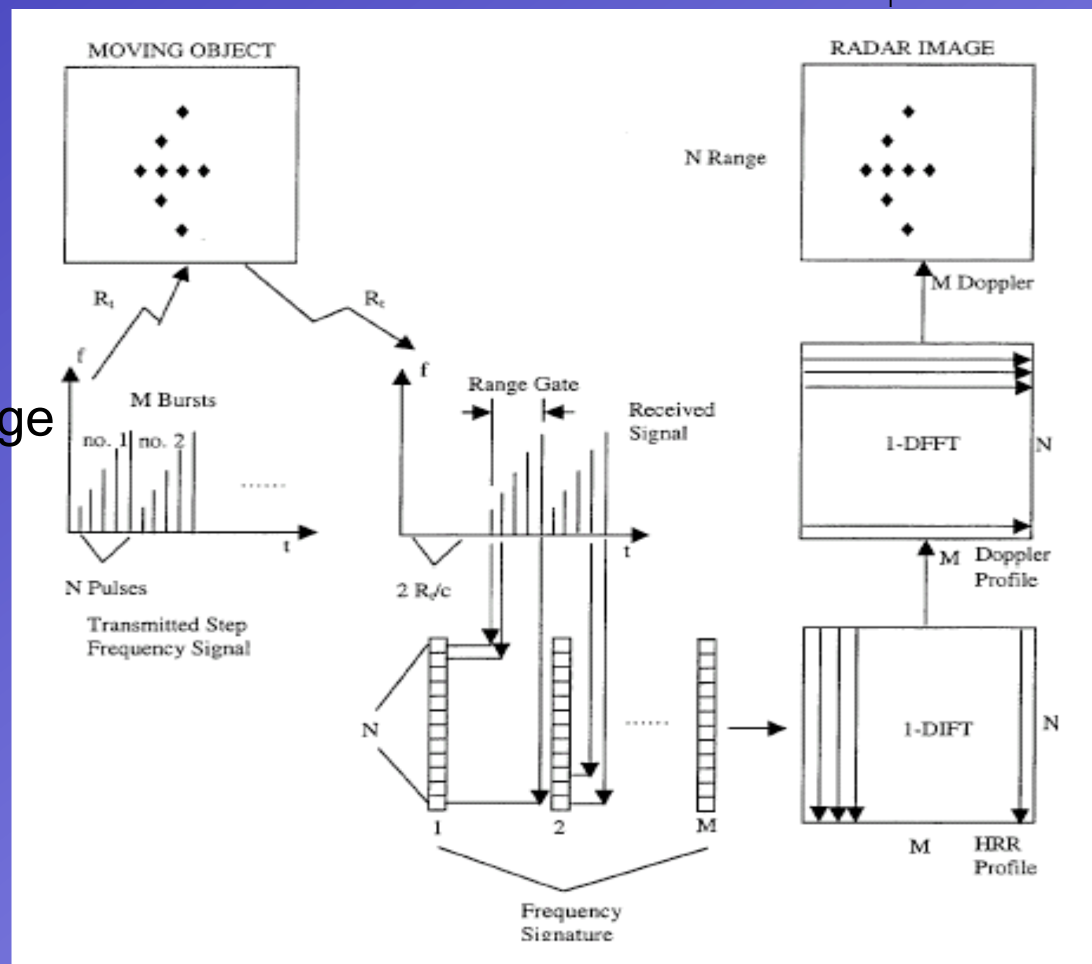
- Use of information in both down-range direction (received echoes from target scatterers in time domain) and cross-range direction (Doppler information)

- Two-dimensional (2D) images of the aircraft



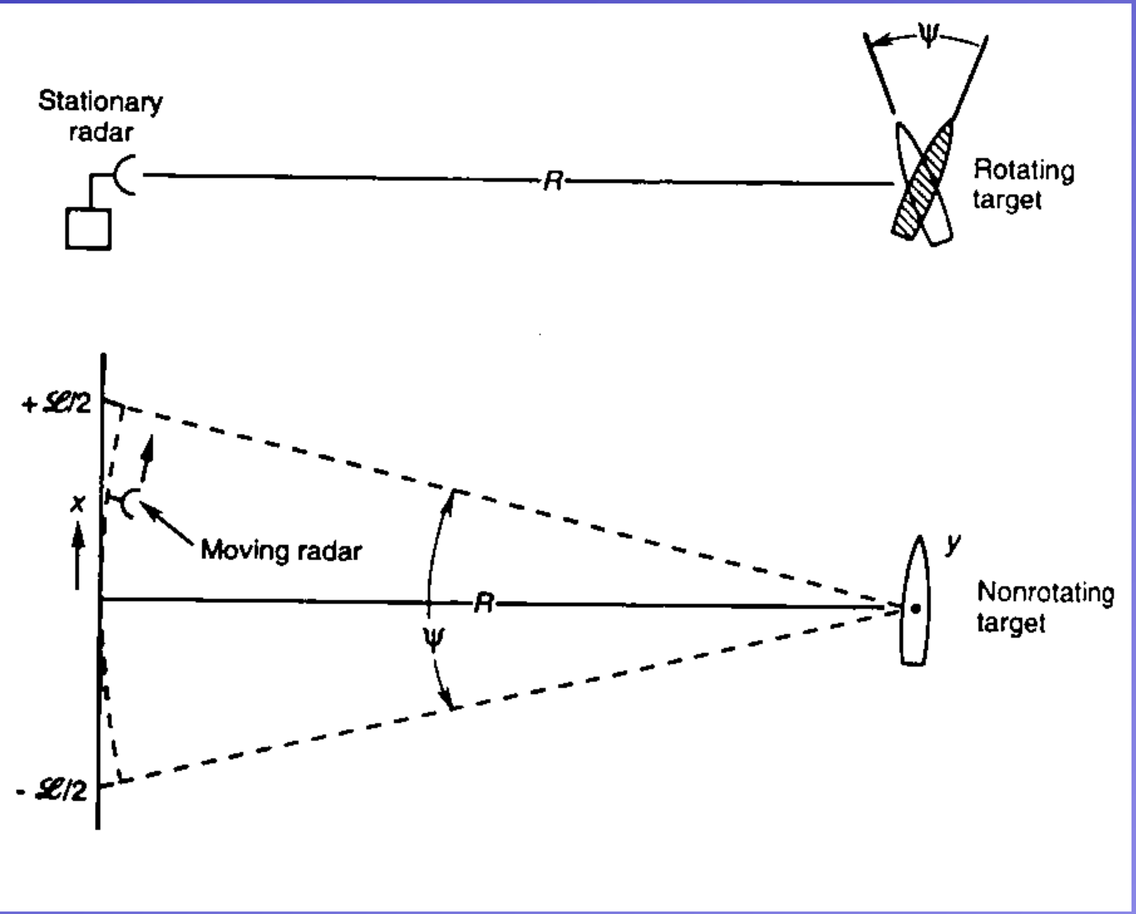
Traditional Method to generate a 2D ISAR image from real (raw, complex) Radar Data

For the SF transmitted waveform shown here, take one 1D-IFFT in the range direction and one 1D-FFT in the cross range direction (sequentially)



ISAR imaging

- ISAR imaging = spotlight SAR imaging



ISAR imaging

1. **Cross – range resolution**

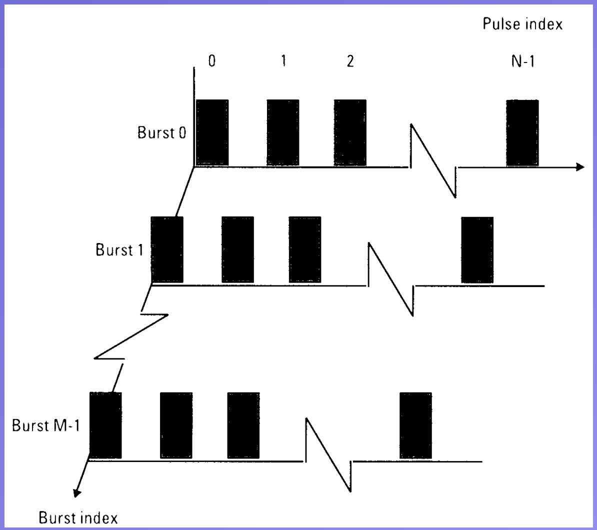
   Integration azimuth angle (ψ)

2. **Range Resolution**

   Total bandwidth of the emitted waveform

$$\Delta r_c = \frac{c}{2\omega T f_o} = \frac{\lambda}{2\omega T} = \frac{\lambda}{2\psi}$$

$$\Delta r_s = \frac{c}{2N\Delta f}$$



Inverse Synthetic Aperture Radar (ISAR)

Advantages :

- ✓ More detailed information on the target geometry is extracted
- ✓ 2D-ISAR images are suited for human interpretation

Drawbacks :

- ✓ Target motion should have a rotational component perpendicular to the line of sight
- ✓ Large time-on-target
- ✓ Complex and expensive motion compensation
- ✓ Large data set of signatures

Comparison of techniques for NCTR

	Advantages	Disadvantages
JEM	Short time on target Simple target data base Fast classification Mature technology	Aspect angle restrictions Not suitable for large distances
HRR	Relatively short time on target Applicable on all aspect angles	Large data set of signatures
2D-ISAR	Detailed object information	Depends on target motion Complex motion compensation Long time on target Large data set of signatures

Standard Motion Compensation Techniques for ISAR imaging

Step 1 : Align the range profiles, as obtained in the 'slow time' (i.e. from burst to burst) / a procedure usually called 'Radar Tracking'

Step 2 : Choose, with some criterion, a 'prominent scatterer', and assign to its phase the value zero (0) for all range profiles, by appropriate phase corrections ['Doppler Tracking' / this takes care of the time – varying Doppler shifts of the scatterers from burst to burst, i.e. in the 'slow time'.

[Ref. : V. Chen, 'Time-Frequency Transforms for Radar Imaging and Signal Analysis', Section 5.2, p.p. 102 - 104].