Кафедра електроніки, робототехніки і технологій моніторингу та інтернету речей
Факультет аеронавігації, електроніки та телекомунікацій (ФАЕТ)

ЕРМІТ

Електронні системи

Electronic Systems

Lecture #14

Яновський, Фелікс Йосипович
професор, доктор технічних наук,
лауреат Державної премії України, IEEE Fellow

Орієнтовний тематичний план лекцій

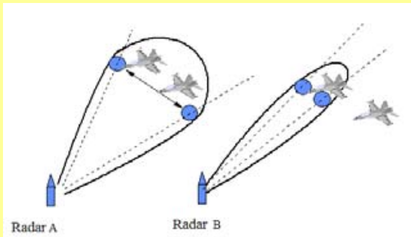
Основи теорії систем, сигнали і первинні перетворювачі електронних систем

1.	Вступ. Визначення і термінологія, класифікація	2	
2.	Характеристики електронних систем	2	
3.	Теорія систем, аналіз електронних систем	2	
4.	Первинні перетворювачі електронних систем	4	
5.	Сигнали електронних систем	2	
6.	Компоненти і обробка сигналів в ЕС	1	**7 семестр**
7.	Експлуатаційні характеристики електронних систем	2	
8.	Технічні характеристики електронних систем	2	
9.	Технічна реалізація системи	1	
10.	**Електронні системи локації**	**18**	
11.	Електронні системи зв'язку	8	**8 семестр**
12.	Електронні системи авіоніки	19	
	Всього годин	**63**	

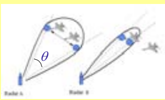
Електронні системи локації

1.	Основні терміни, принцип дії, класифікація та застосування.	2
2.	Відбиваючі властивості об'єктів.	2
3.	Виявлення сигналів.	4
4.	Дальність дії локаційної системи.	2
5.	**Роздільна здатність локаційної системи.**	**2**
6.	Вимірювання дальності та швидкості об'єктів.	2
7.	Вимірювання кутових координат.	2
8.	Методи підвищення роздільної здатності і точності вимірювань.	2
		18

Beam width vs Accuracy & Bearing Resolution



Bearing Resolution



BEARING RESOLUTION - (1) The ability of the radar equipment to separate two reflecting objects at identical ranges, but at different bearings (azimuths) from the antenna.

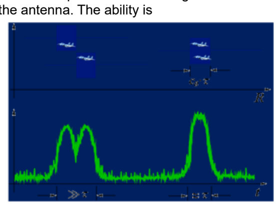
BEARING RESOLUTION - (2) The ability to distinguish between two targets solely by the measurement of their bearings (azimuths from the radar); usually expressed in terms of the minimum angle by which two targets of equal strength at the same range and elevation angles must be spaced to be separately indistinguishable.

$$\Delta\theta \approx \theta$$

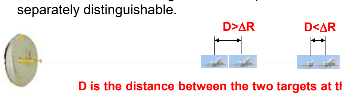
PULSED RADAR. Range Resolution ΔR

RESOLUTION - A measurement of the smallest detail which can be distinguished by a sensor system under specific conditions.

RANGE RESOLUTION - (1) The ability of the radar equipment to separate two reflecting objects on a similar bearing, but at different ranges from the antenna. The ability is determined primarily by the pulse length in use.



RANGE RESOLUTION - (2) The ability to distinguish between two targets solely by the measurement of their ranges (distances from the radar); usually expressed in terms of the minimum distance by which two targets of equal strength at the same azimuth and elevation angles must be spaced to be separately distinguishable.



D is the distance between the two targets at the same angle data

Range Resolution ΔR

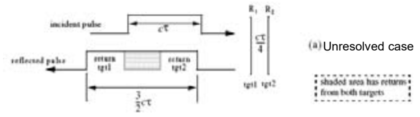
Consider two targets located at ranges R_1 and R_2, corresponding to time delays t_1 and t_2, respectively. Denote the difference between those two ranges as ΔR

$$\Delta R = R_2 - R_1 = c\frac{(t_2 - t_1)}{2} = c\frac{\delta t}{2}$$

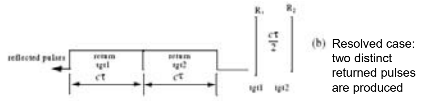
Question: What is the minimum δt such that **target 1** at R_1 and **target 2** at R_2 will appear completely resolved in range (different range bins)?

In other words, what is the minimum ΔR ?

a) Assume that the two targets are separated by $c\tau/4$; τ is the pulse width.



b) Assume that the two targets are separated by $c\tau/2$



Range Resolution ΔR

Radar designers seek to minimize ΔR in order to enhance the radar performance.

In order to achieve fine RR one must minimize the pulse width τ. However, this will reduce the average transmitted power P_{av} and increase the operating bandwidth **B**.

$$P_{av} = P_t d_t = P_t \tau / T = P_t \tau f_r \qquad \Delta R = \frac{c\tau}{2} = \frac{c}{2B}$$

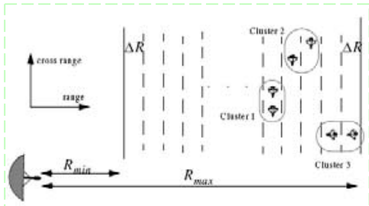
Achieving fine RR while maintaining adequate average transmitted power can be accomplished by using pulse compression techniques.

Range and Cross Range Resolution

Range resolution, denoted as ΔR, is a radar metric that describes its ability to detect targets in close proximity to each other as distinct objects.

$$M = \frac{R_{max} - R_{min}}{\Delta R}$$

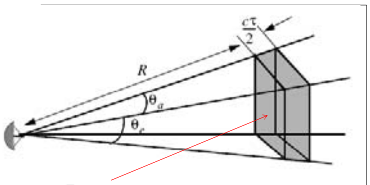
Targets separated by at least ΔR will be completely resolved in range:



Targets within the same range bin can be resolved in cross range (azimuth) utilizing signal processing techniques.

Resolution Volume

$V_W = \Delta R \cdot R\theta_a \cdot R\theta_e$.



$$V_W \approx \frac{\pi}{8}\theta_a\theta_e R^2 c\tau$$

Pulse Radar Parameters

- Pulse width (PW)
- Pulse Shape
- Pulse Repetition Frequency (PRF)
- Pulse Repetition Time (PRT)
- Peak Power
- Average Power
- Duty Cycle

Carrier Frequency

- The base frequency of the radar
- Determines the radar antenna size
- Affects
  - range, maximum and ambiguous
  - beam width
  - minimum target size
  - vulnerability to ECM and atmospheric conditions.

ECM = electronic countermeasures

Approach to Target Velocity Measuring

- We talked about range measuring and bearing.
- Now let us discuss surveillance of moving objects.
- Doppler effect.

Doppler Frequency

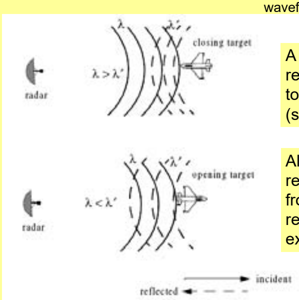
DOPPLER EFFECT - The effective change of frequency of a received signal due to the relative velocity of a transmitter with respect to a receiver.

DOPPLER SHIFT - The magnitude of the change in the observed frequency of a wave due to the DOPPLER EFFECT. The unit is the Hertz [Hz].

- Radars use Doppler frequency to extract target radial velocity (range rate).

Doppler Frequency

The Doppler phenomenon describes the shift in the center frequency of an incident waveform due to the target motion.



A closing target will cause the reflected equiphase wavefronts to get closer to each other (smaller wavelength).

Alternatively, an opening or receding target (moving away from the radar) will cause the reflected equiphase wavefronts to expand (larger wavelength).

Doppler Frequency. TIME APPROACH

New PRF f_r'

$$f_r' = \frac{c+v}{c-v} f_r$$

New carrier frequency f_0'

$$f_0' = \frac{c+v}{c-v} f_0$$

The Doppler frequency f_d is defined as the difference $f_0' - f_0$.

$$f_d = f_0' - f_0 = \frac{c+v}{c-v} f_0 - f_0 = \frac{2v}{c-v} f_0$$

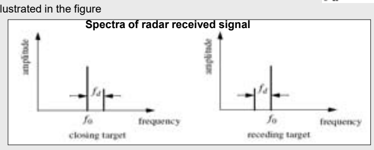
but since $v \ll c$ and $c = \lambda f_0$ ⟹

$$f_d \approx \frac{2v}{c} f_0 = \frac{2v}{\lambda}$$

The Doppler shift is proportional to the radial target velocity, and thus, one can extract f_d from range rate and vice versa

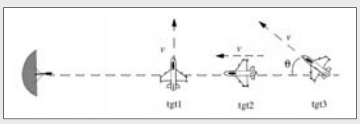
It can be shown that for a receding target the Doppler shift is $f_d = -2v/\lambda$

This is illustrated in the figure

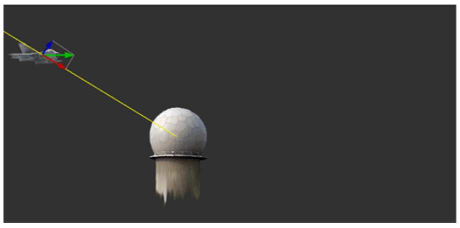


In all previous cases the target radial velocity with respect to the radar was equal to ***v***, but this is not always the case. In fact, the value of Doppler frequency depends on the target velocity component in the direction of the radar

Three cases:



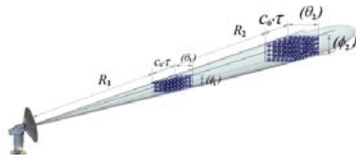
Target 1 generates zero Doppler. Target 2 generates maximum Doppler. Target 3 is in-between.



Velocity Resolution - Розділення по швидкості

$$\Delta F_D = (F_{D1} - F_{D2})_{\min}$$

$$F_D = \frac{2V_r}{\lambda}$$



Якщо два об'єкти рухаються в одному роздільному об'ємі з різними швидкостями, то їх можна розділити за швидкостями, хоча вони сприймаються як єдиний об'єкт за дальністю і кутовими координатами

Потенціальна і реальна роздільна здатність

- РГР