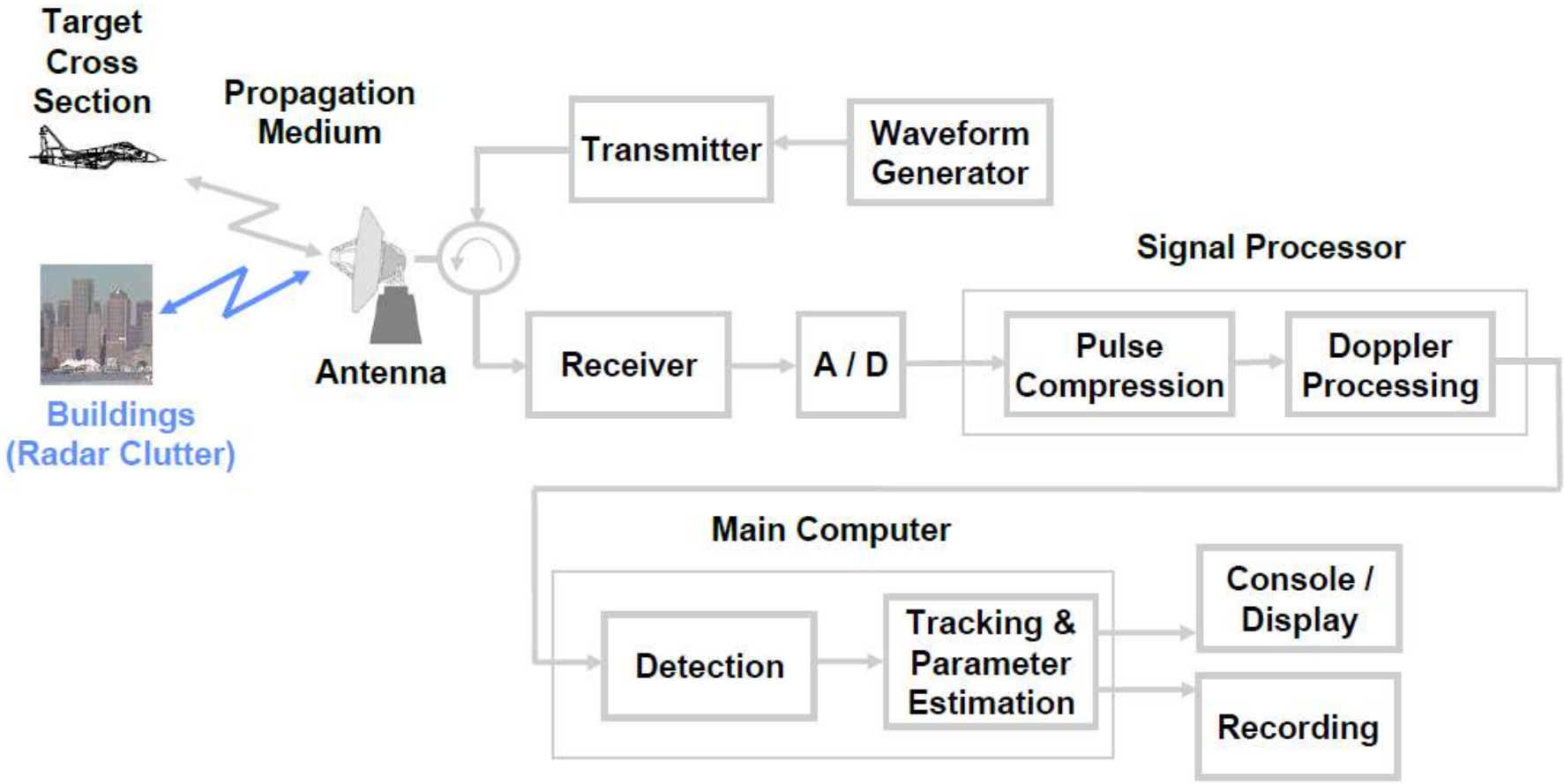
AJOU UNIVERSITY
1973

Radar Systems

Lecture 7. Radar Clutter and Chaff

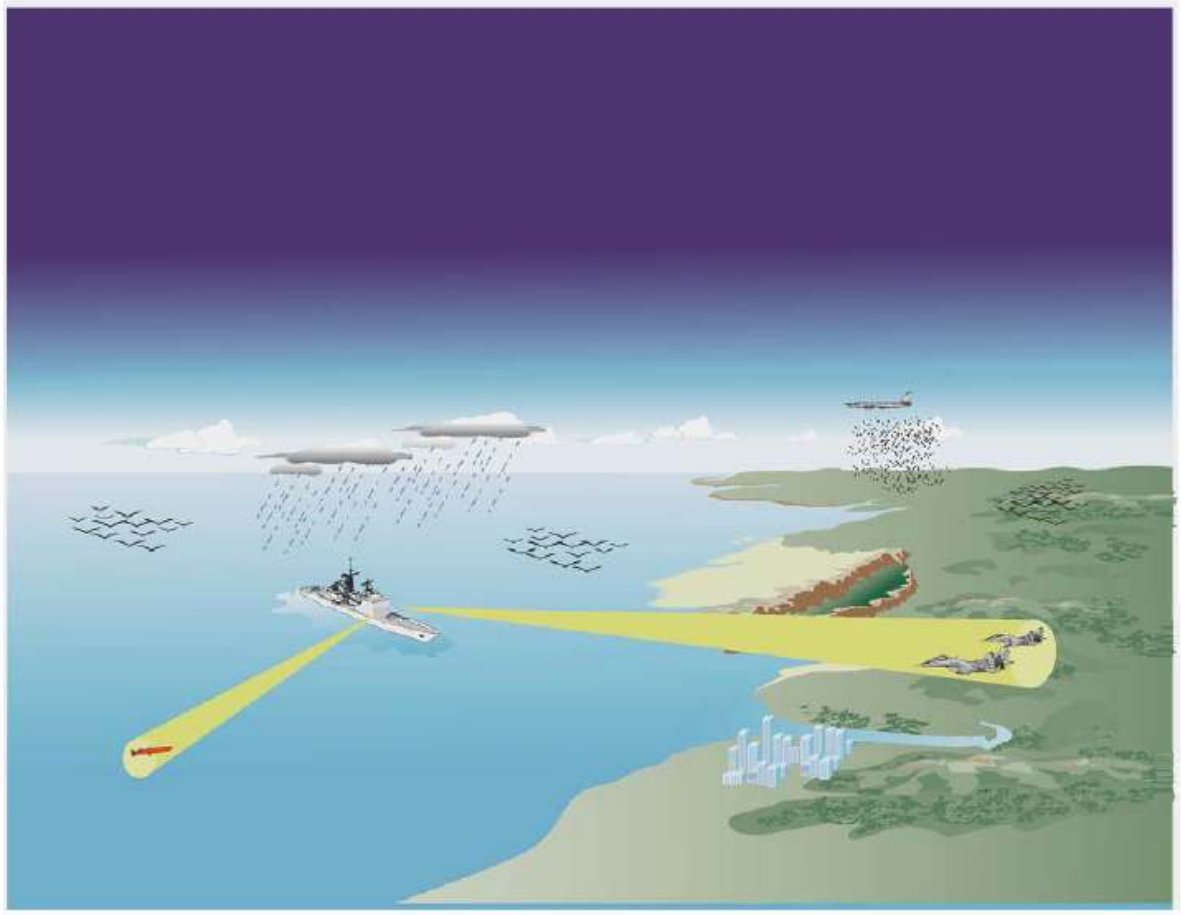
구 자 열

Radar Clutter



Why Understand Radar Clutter?

Naval Air Defense Scenario



Radar echo is composed of:

- Backscatter from target of interest
- Receiver noise
- Atmospheric noise
- Interference
  - From other radars
  - Jammers
- Backscatter from unwanted objects
  - Ground
  - Sea
  - Rain
  - Chaff
  - Birds
  - Ground traffic

차 례

- **Ground Clutter** ⟸
- **Sea Clutter**
- **Rain**
- **Chaff**
- **Birds and Insects**

Attributes of Ground Clutter

- Mean value of backscatter from ground clutter
  - Very large size relative to aircraft
  - Varies statistically
    - Frequency, spatial resolution, geometry, terrain type
- Doppler characteristics of ground clutter return
  - Innate Doppler spread small (few knots)
    - Mechanical scanning antennas add spread to clutter
  - Relative motion of radar platform affects Doppler of ground clutter
    - Ship
    - Aircraft

Photographs of Ground Based Radar's PPI (Different Levels of Attenuation)

Mountainous Region of Lakehead, Ontario, Canada
PPI Set for 30 nmi.

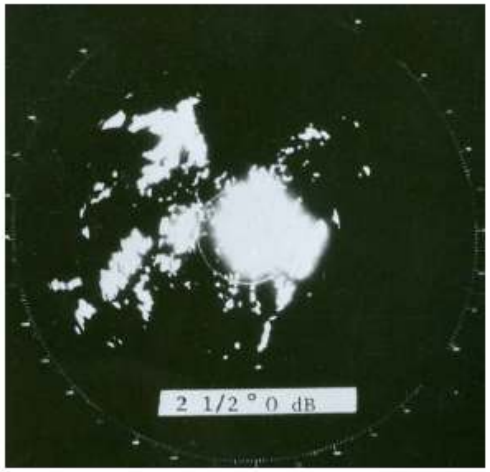
0 dB

60 dB

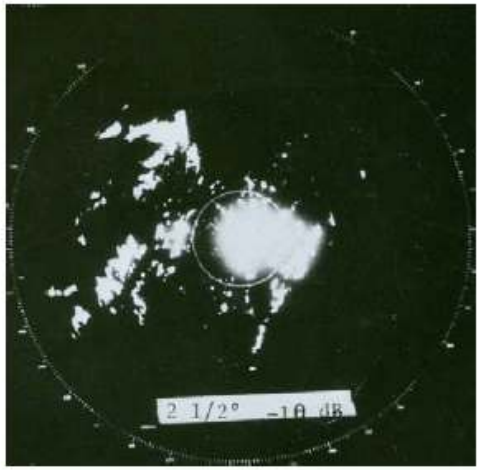
Courtesy of IEEE. Used with permission.
Source: Shrader, W. "Radar Technology Applied to Air Traffic Control," IEEE Transactions on Communications, Vol COM-21, No. 5, May 1973. © IEEE.

Photographs of Ground Based Radar's PPI (Different Levels of Attenuation)

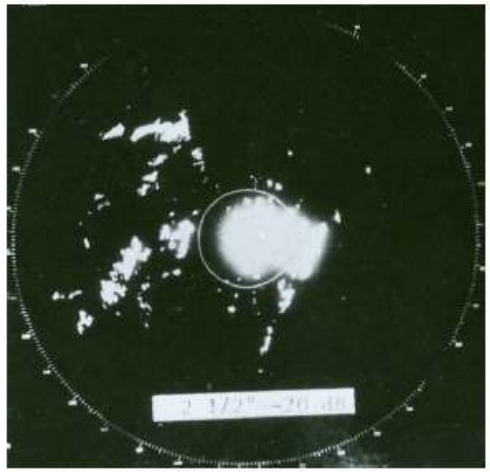
0 dB



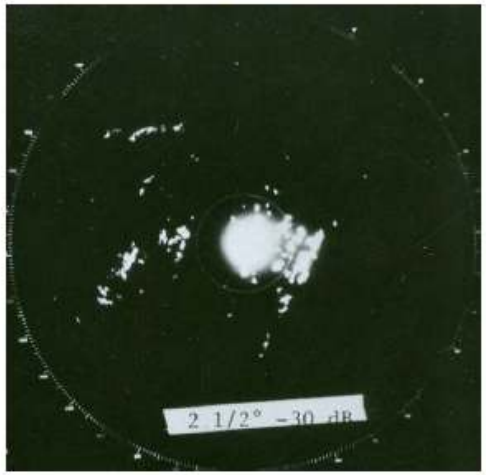
10 dB



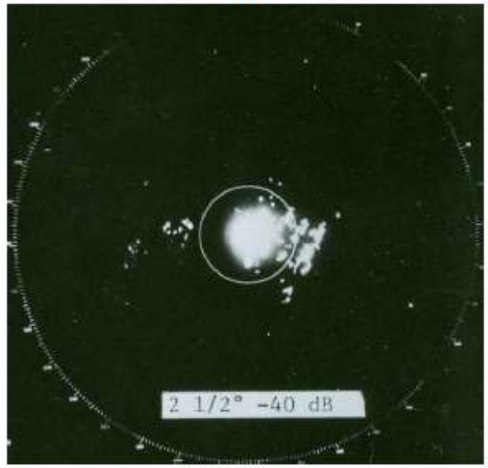
20 dB



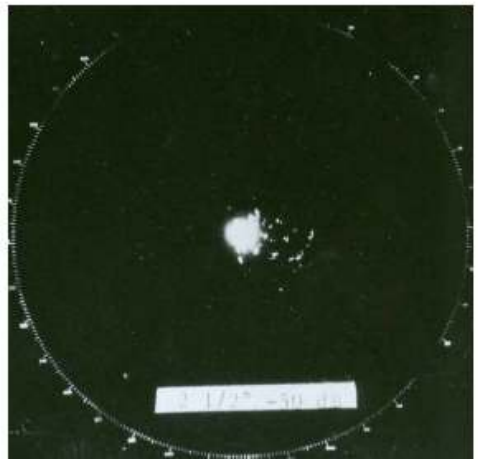
30 dB



40 dB

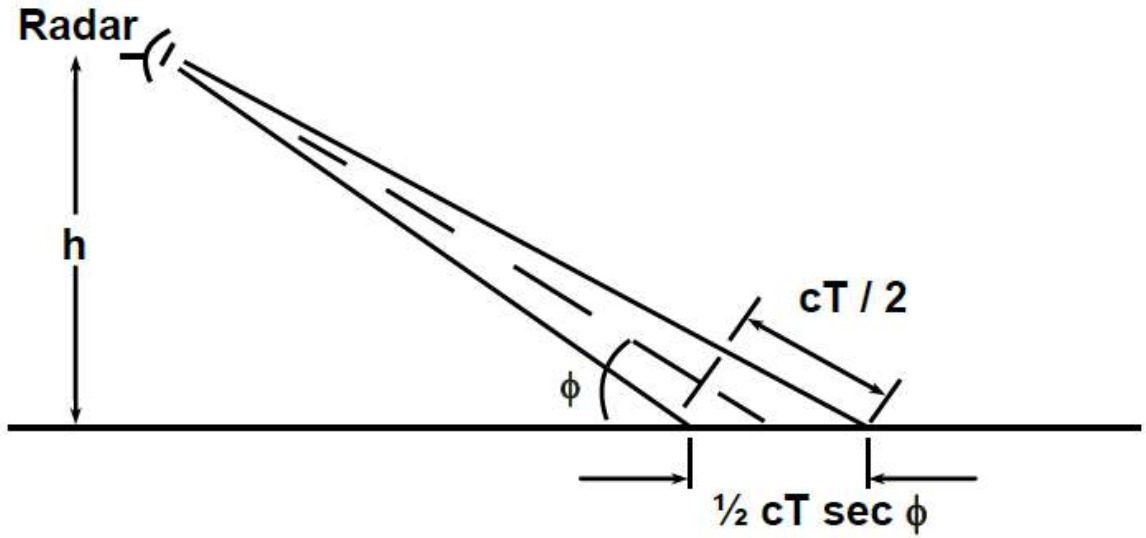


50 dB

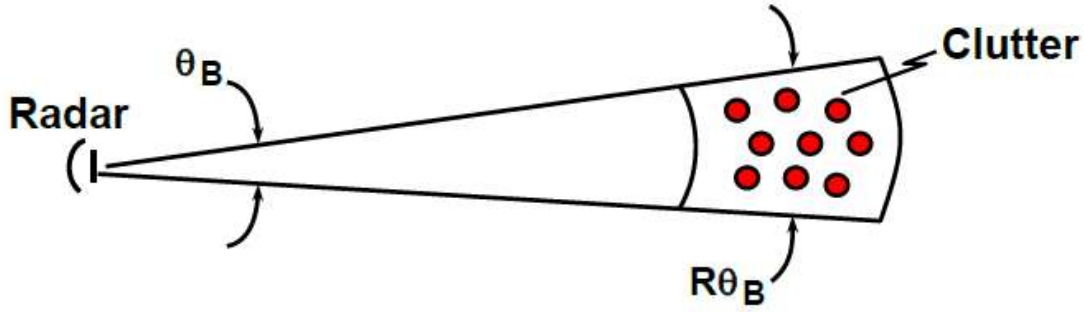


Geometry of Radar Clutter

Elevation View



Plan View



$$\sigma_0 = \frac{\sigma}{A} \qquad A = R\theta_B\,[\tfrac{1}{2}\,cT \sec\phi]$$

Calculation of Ground Clutter

- Typical Value of σ_o = -20 dB = $\frac{0.01\ m^2}{m^2}$
- $\sigma_{Clutter} = \sigma_o A = \sigma_o \frac{c\,T}{2} R\,\theta_B$
  - For ASR-9 (Airport Surveillance Radar)

$\frac{c\,T}{2}$ = 100m R = 60 km θ_B = 1.5° = 0.026 radians

- $\sigma_{Clutter} = \frac{0.01\ m^2}{m^2}$ x 100 m x 60,000 m x 0.026 radians = 1500 m^2

For σ_{Target} = 1 m^2 ⇒ $\frac{\sigma_{Target}}{\sigma_{Clutter}} = \frac{1}{1500}$ ⇒ $\frac{\sigma_{Target}}{\sigma_{Clutter}}$ = 20

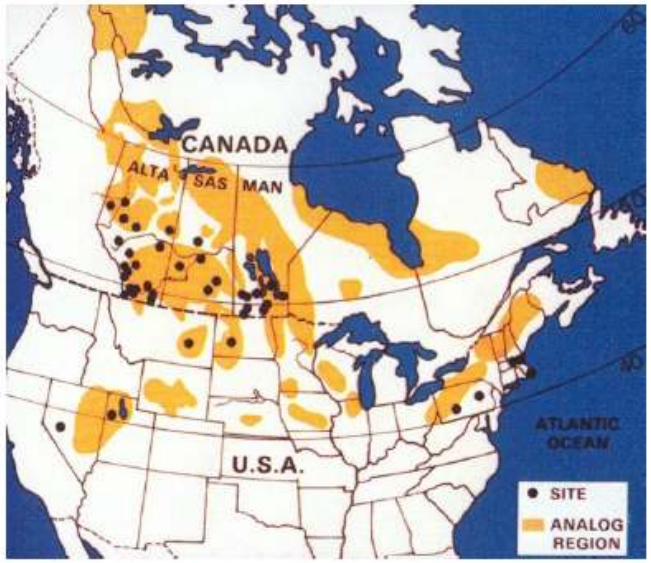
Small single-engine aircraft

∴ Must suppress clutter by a factor of 1500 x 20 = 30,000 = 45 dB

For good detection

Joint U.S./Canada Measurement Program

- Phase One radar
  - VHF, UHF, L-, S-, X-bands
- Measurements conducted 1982 – 1984
- Archival data at Lincoln Laboratory



- 42 sites
- Data shared with Canada and the United Kingdom

Clutter Physics

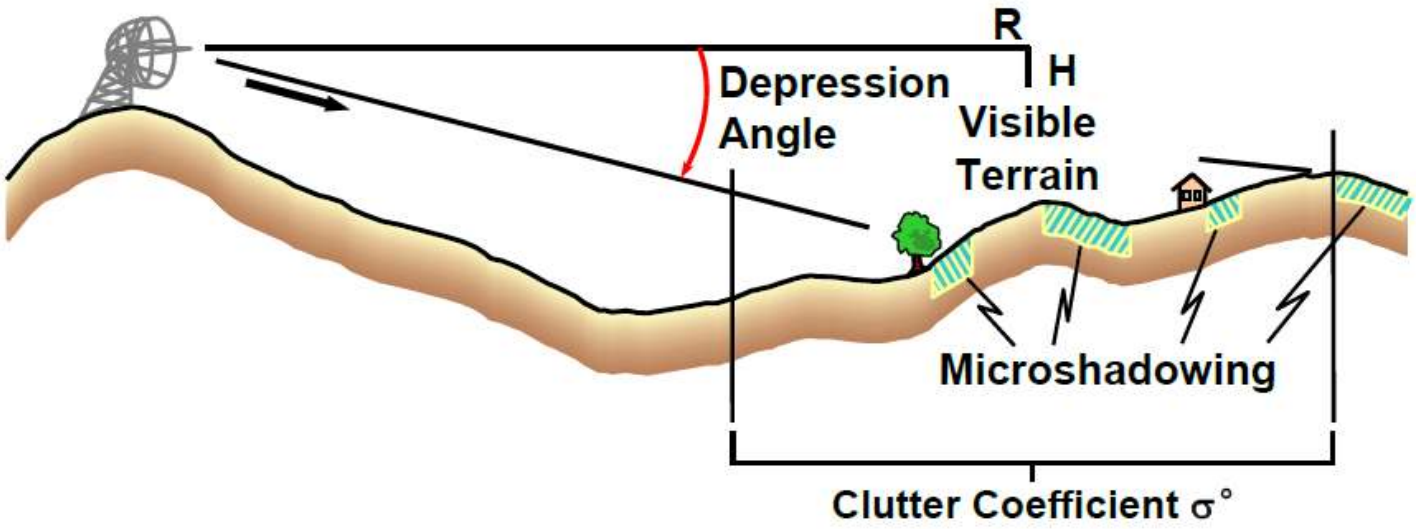


Image from Billingsley, J. B. *Ground Clutter Measurements for Surface Sited Radars*. Tech Report 786, Rev. 1. Lexington, MA: Lincoln Laboratory, February 1, 1993. Courtesy of Lincoln Laboratory

Clutter Physics

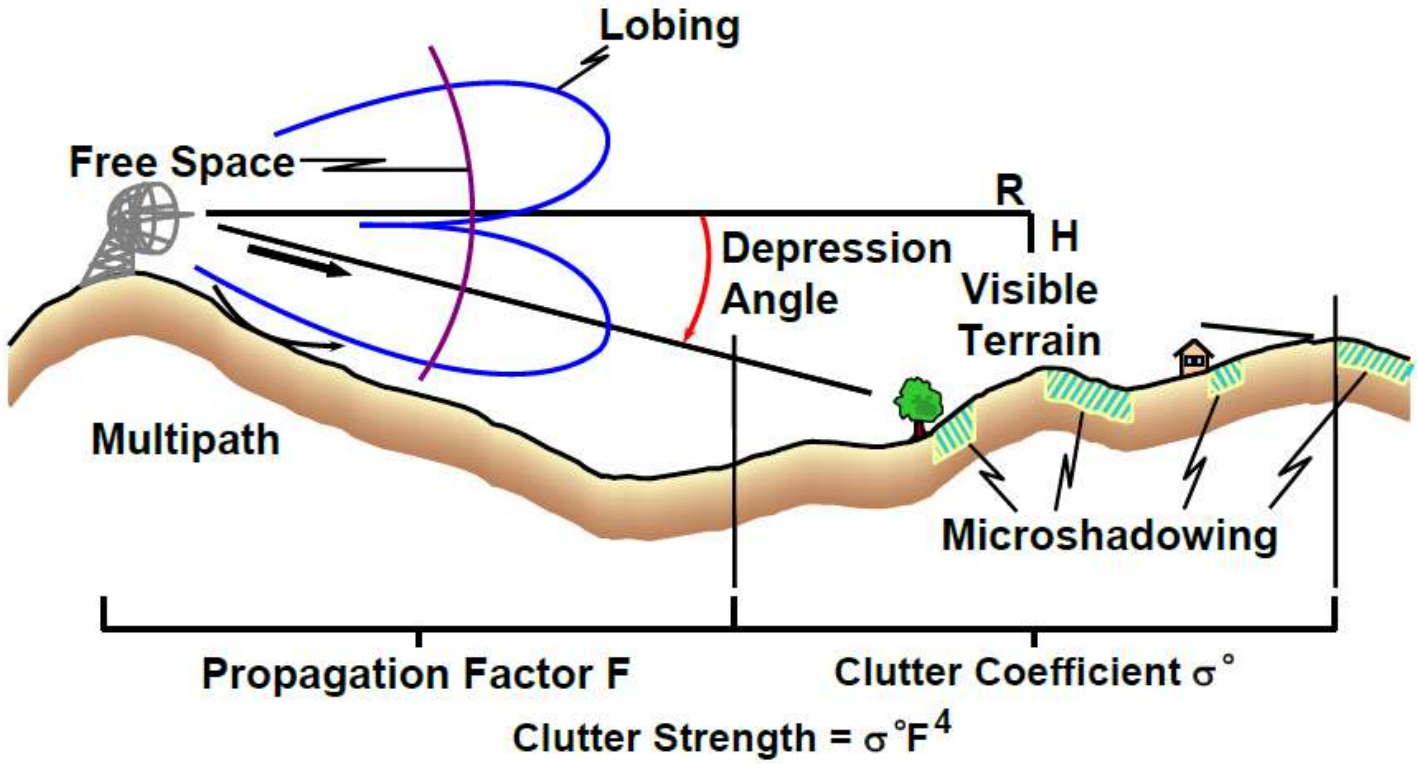


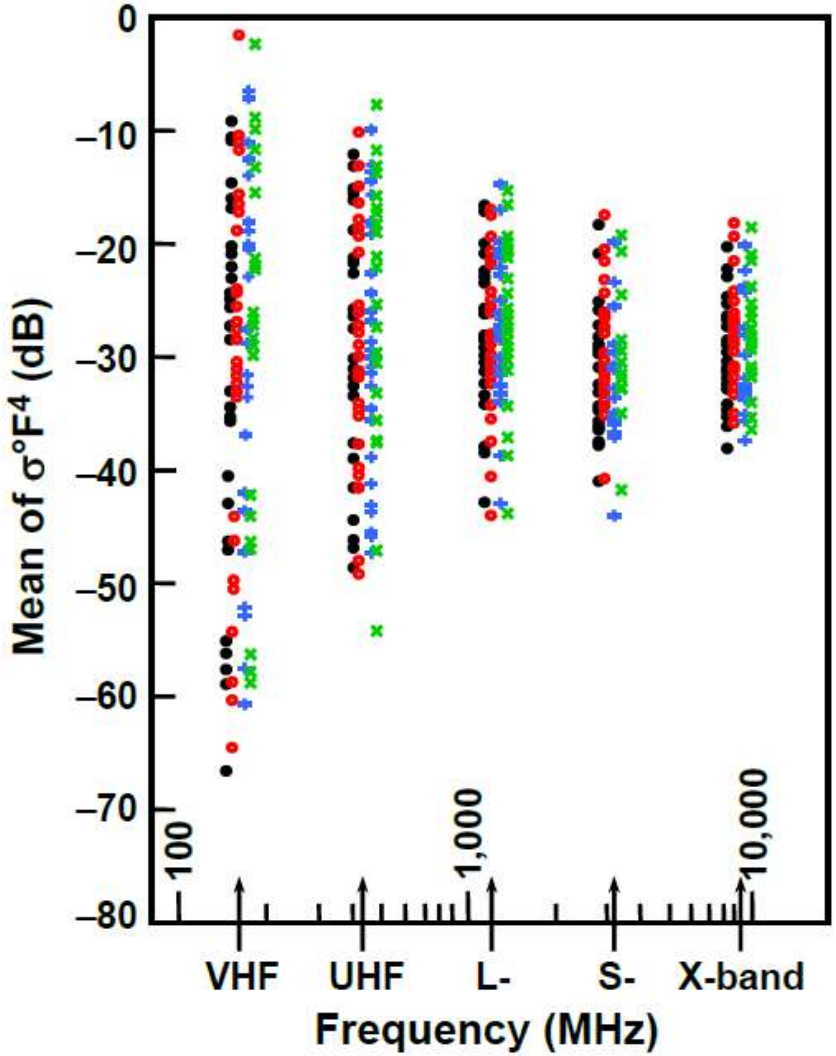
Image from Billingsley, J. B. *Ground Clutter Measurements for Surface Sited Radars.* Tech Report 786, Rev. 1. Lexington, MA: Lincoln Laboratory, February 1, 1993. Courtesy of Lincoln Laboratory

1) **Radar Parameters**
   - **Frequency, f**
   - **Spatial resolution, A**

2) **Geometry**
   - **Depression angle (Range R, Height H)**

3) **Terrain Type**
   - **Landform**
   - **Land cover**

Mean Ground Clutter Strength vs. Frequency



General Rural (36 Sites)

Key	
Range Resolution (m)	Polarization
150	H
150	V
15/36	H
15/36	V

차 례

- Ground Clutter
- Sea Clutter 
- Rain
- Chaff
- Birds and Insects

Attributes of Sea Clutter

- **Mean cross section of sea clutter depends on many variables**
  - **Wind and weather**
    - **Sea State**
  - **Radar frequency**
  - **Radar Polarization**
  - **Range resolution**
  - **Cross range resolution**
  - **Grazing angle**
  - **Too many variables**

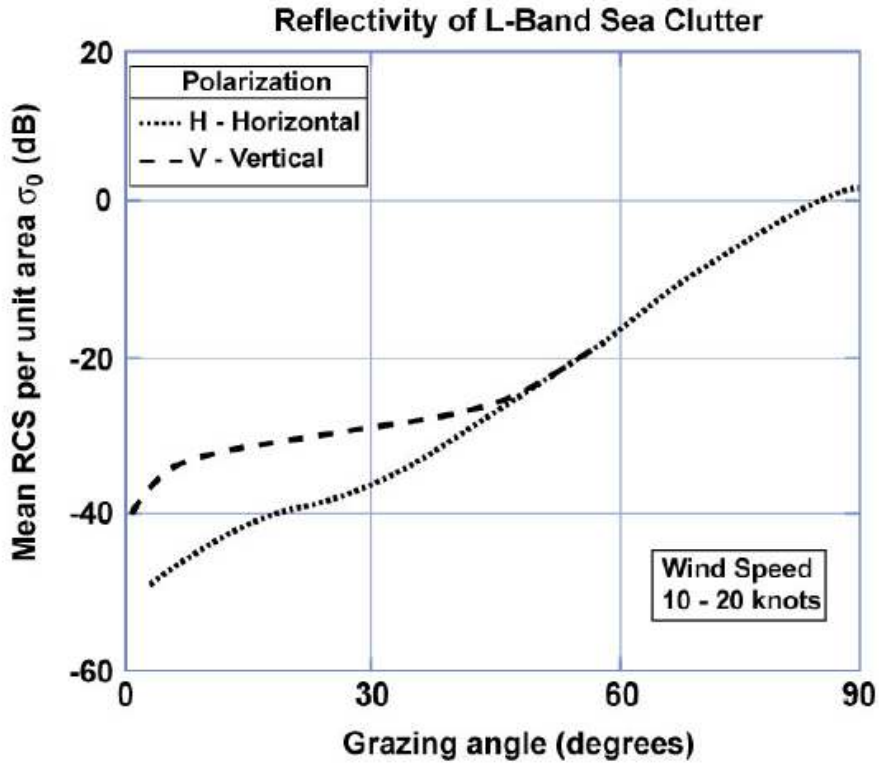


Figure by MIT OCW.

Mean sea backscatter is about 100 times less than ground backscatter

World Meteorological Organization
Sea State

Sea State	Wave Height (m)	Wind Velocity (knots)	Descriptive Term
0 to 1	0 to 0.1	0 to 6	Calm, Rippled
2	0.1 to 0.5	7 to 10	Smooth, Wavelets
3	0.6 to 1.2	11 to 16	Slight to Moderate
4	1.2 to 2.4	17 to 21	Moderate to Rough
5	2.4 to 4	22 to 27	Very Rough
6	4 to 6	28 to 47	High

Sea Spikes

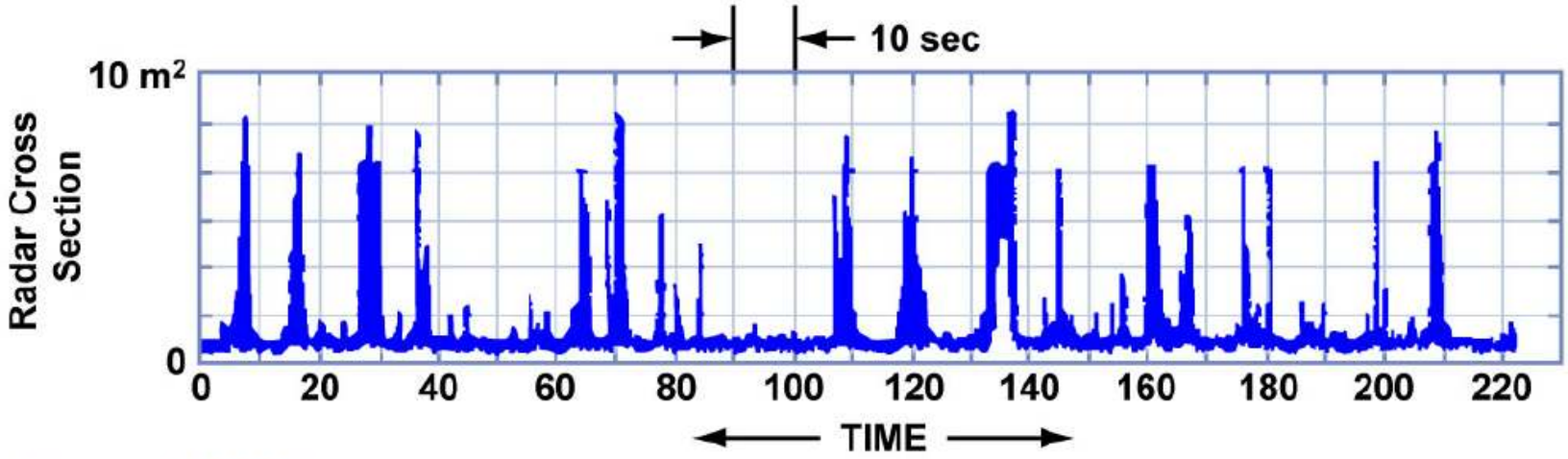


Figure by MIT OCW.

•Grazing angle 1.5 deg.
•Horizontal polarization

- At low grazing angles, sharp sea clutter peaks, known as "sea spikes", begin to appear
- These sea spikes can cause excessive false detections

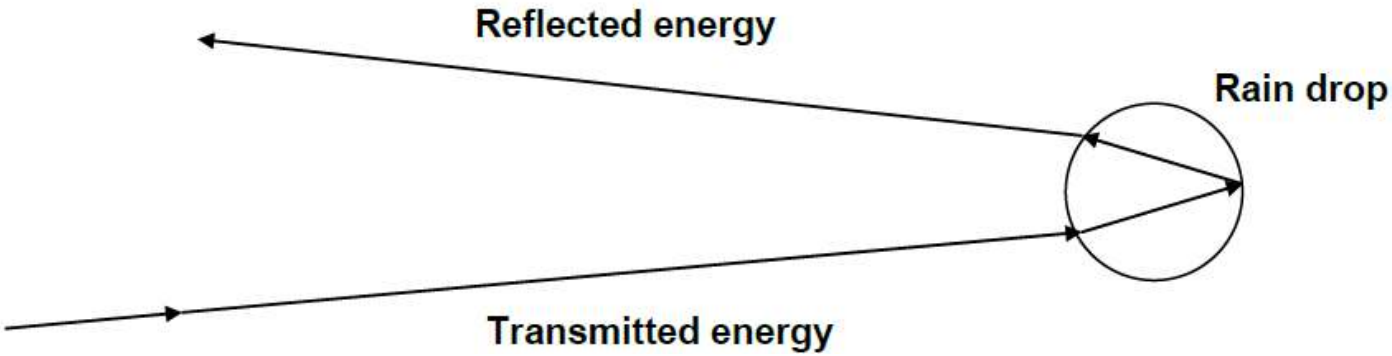
From Lewis and Olin, NRL

차 례

- Ground Clutter
- Sea Clutter
- Rain 
- Chaff
- Birds and Insects

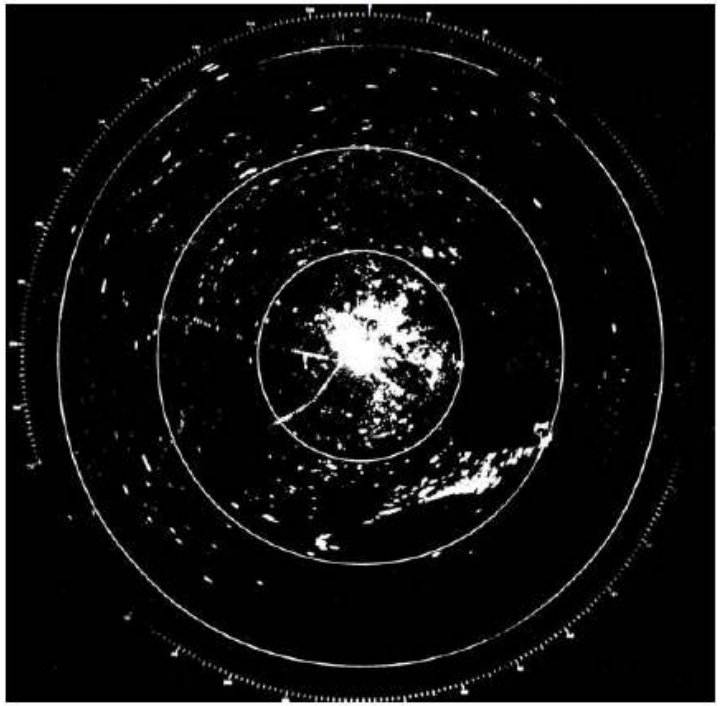
Attributes of Rain Clutter

- Rain both attenuates and reflects radar signals
- Problems caused by rain lessen dramatically with longer wavelengths (lower frequencies)
  - Much less of a issue at L-Band than X-Band
- Rain is diffuse clutter (wide geographic extent)
  - Travels horizontally with the wind
  - Has mean Doppler velocity and spread



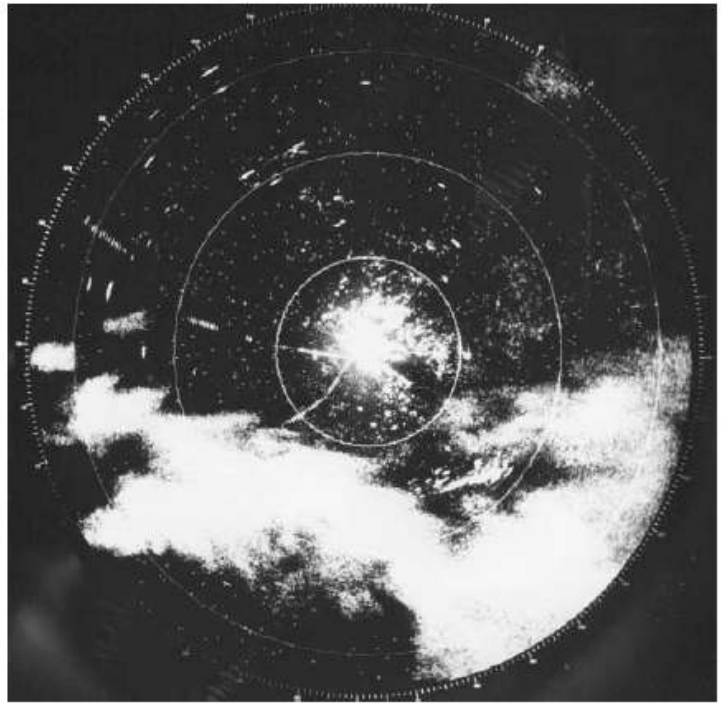
PPI Display Radar Normal Video

Clear Day (No Rain)



Airport Surveillance Radar
S Band
Detection Range - 60 nmi on
a 1 m^2 target

Day of Heavy Rain



10 nmi Range Rings on PPI
Display
August 1975, FAA Test
Center
Atlantic City, New Jersey

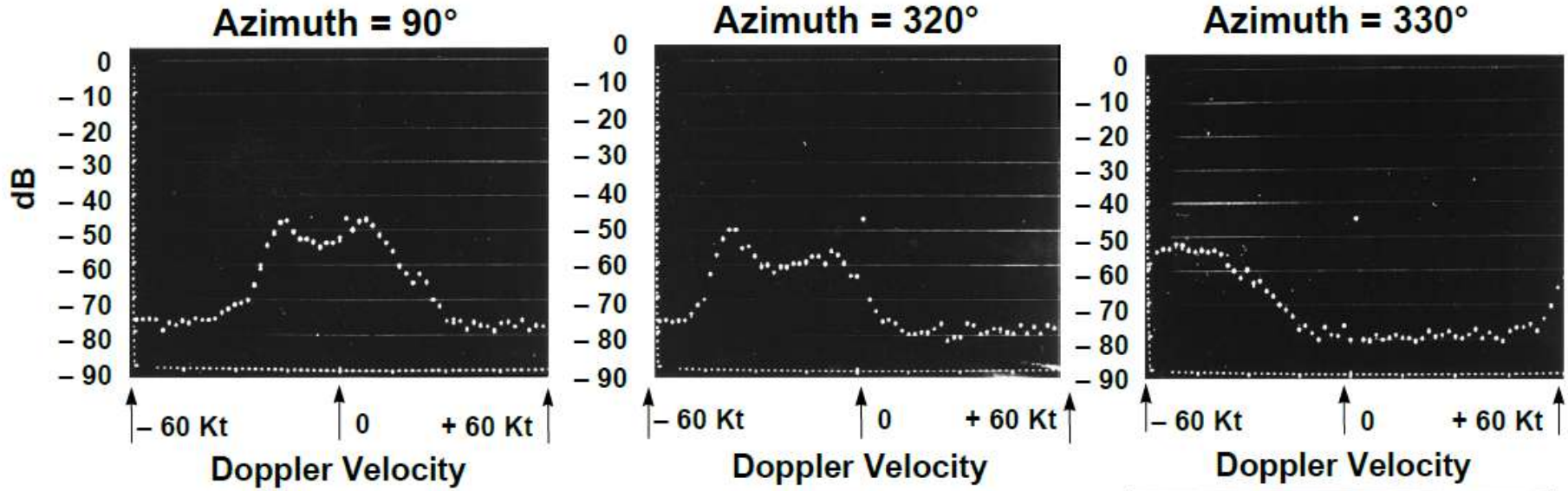
Reflectivity of Uniform Rain
(σ in dBm2/m3)

Rain Type	Frequency			
	S 3.0 GHz	C 5.6	X 9.3	Ka 35
Drizzle, 0.25 mm/hr	–102	–91	–81	–58
Light Rain, 1 mm/hr	–92	–81.5	–72	–49
Moderate, 4 mm/hr	–83	–72	–62	–41
Heavy Rain, 16 mm/hr	–73	–62	–53	–33

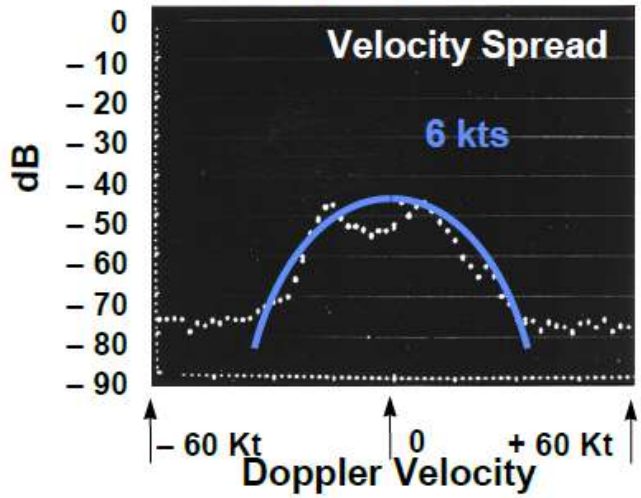
Figure by MIT OCW.

- Rain reflectivity increases as f^4 (or $1 / \lambda^4$)
  - Rain clutter is an issue at S-Band and a significant one at X-Band or higher frequencies

Measured S-Band Doppler Spectra of Rain



- Rain is not Gaussian
- Mean velocity varies as storm moves by radar
- In these examples the rainfall rate was approximately 20 mm/hr
- Winds 30 kts on ground, 50 kts at 6000 ft



차 례

- Ground Clutter
- Sea Clutter
- Rain
- Chaff ⟸
- Birds and Insects

Attributes of Chaff

- Large number of dipoles (metallic or metallic coated)
  - High reflectivity per pound
  - Optimum length 1/2 of radar wavelength
  - Moves with the wind
- Uses of chaff
  - Masking

    Large cloud can shield aircraft or missiles in or near the cloud
  - Deception

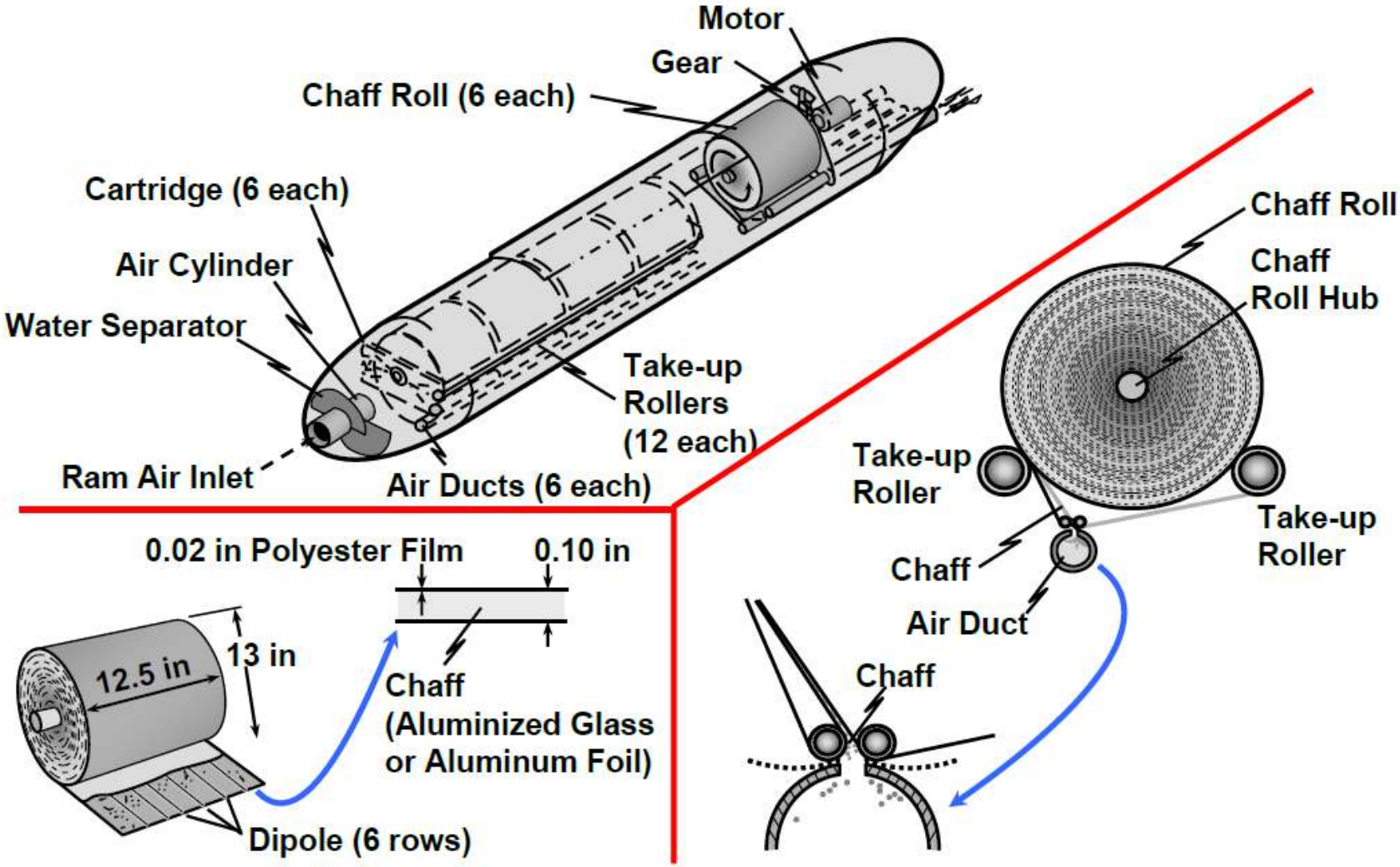
    Chaff "puff" can emulate a missile / aircraft and cause false detections

    Packets of chaff can divert radar tracker from target

Chaff Reflectivity and Density

- **Resonant Metallic Dipoles**
  - $\sigma = .18\ \lambda^2$ (in m^2) Average Cross Section per Dipole
  - Bandwidth 10-15% of center frequency
  - Fall rates 0.5 to 3 m/s
- **Aluminum foil dipoles (.001 in. x .01 in. x $\lambda/2$ long)**
  - $\sigma = 3000\ W / f$ (in m^2)
  - W = weight in lb, f = frequency in GHz
  - At S-Band, 400 lb yields = 265,000 m^2 or 54.3 dBsm

AN/ALE-38 Chaff-Dispensing System



차 례

- Ground Clutter
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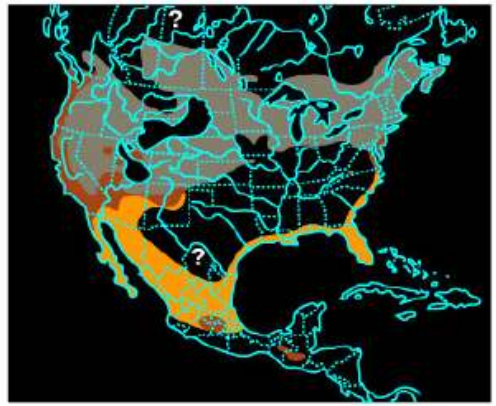
Bird Breeding Areas and Migration Routes

Gadwall

Northern Flicker

Virginia Rail

Photos courtesy of vsmithuk, sbmontana, and khosla.



Breeding Year-round Wintering

Figure by MIT OCW.

During the breeding season along the Gulf Coast, sea and wading bird colonies exist that have up to 60,000 birds. 10,000 birds are common. These birds are large; weighing up to 1 kg and having wingspreads from 0.75 to several meters.

Bird Breeding Areas and Migration Routes

Spotted Towhee

Black Tern

Northern Harrier

Photos courtesy amkhosla, Changhua Coast Conservation Action, and amkhosla.

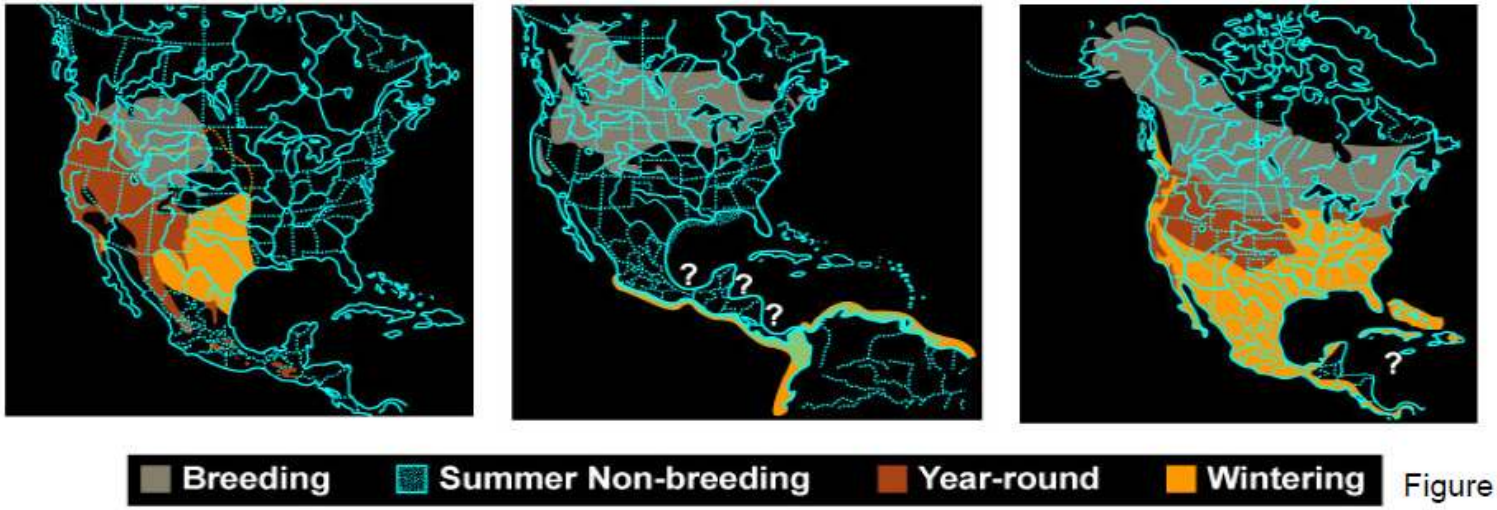
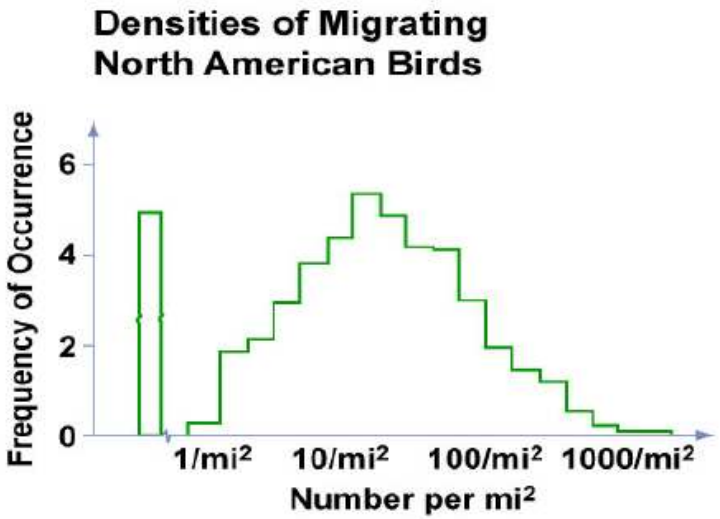
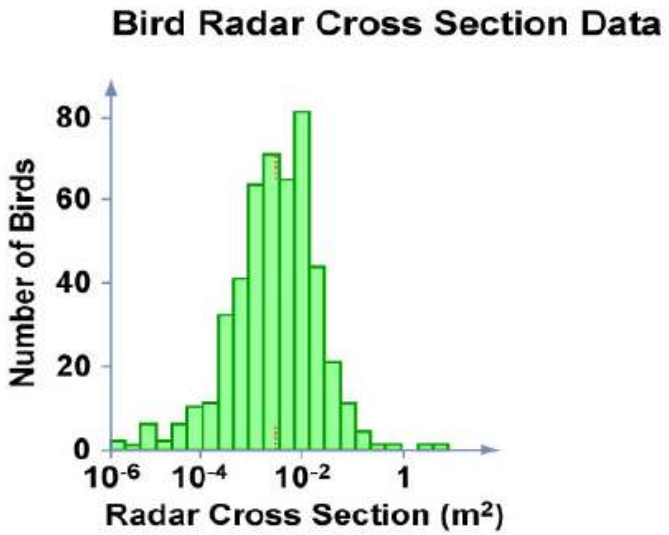


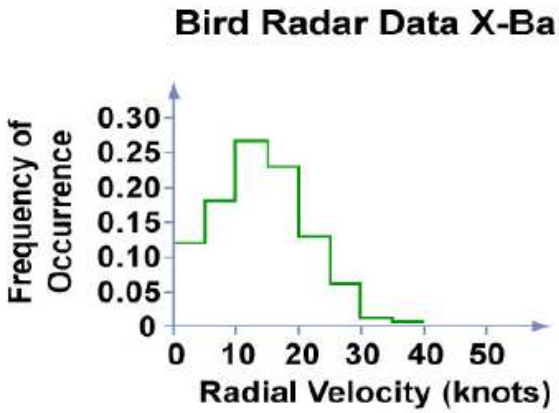
Figure by MIT OCW.

Within the lower Mississippi Valley, 63 blackbird roosts have been identified with over 1 million birds each. Many smaller roosts also exits. These birds disperse 30 miles for daily feeding.

Radar Properties of Birds



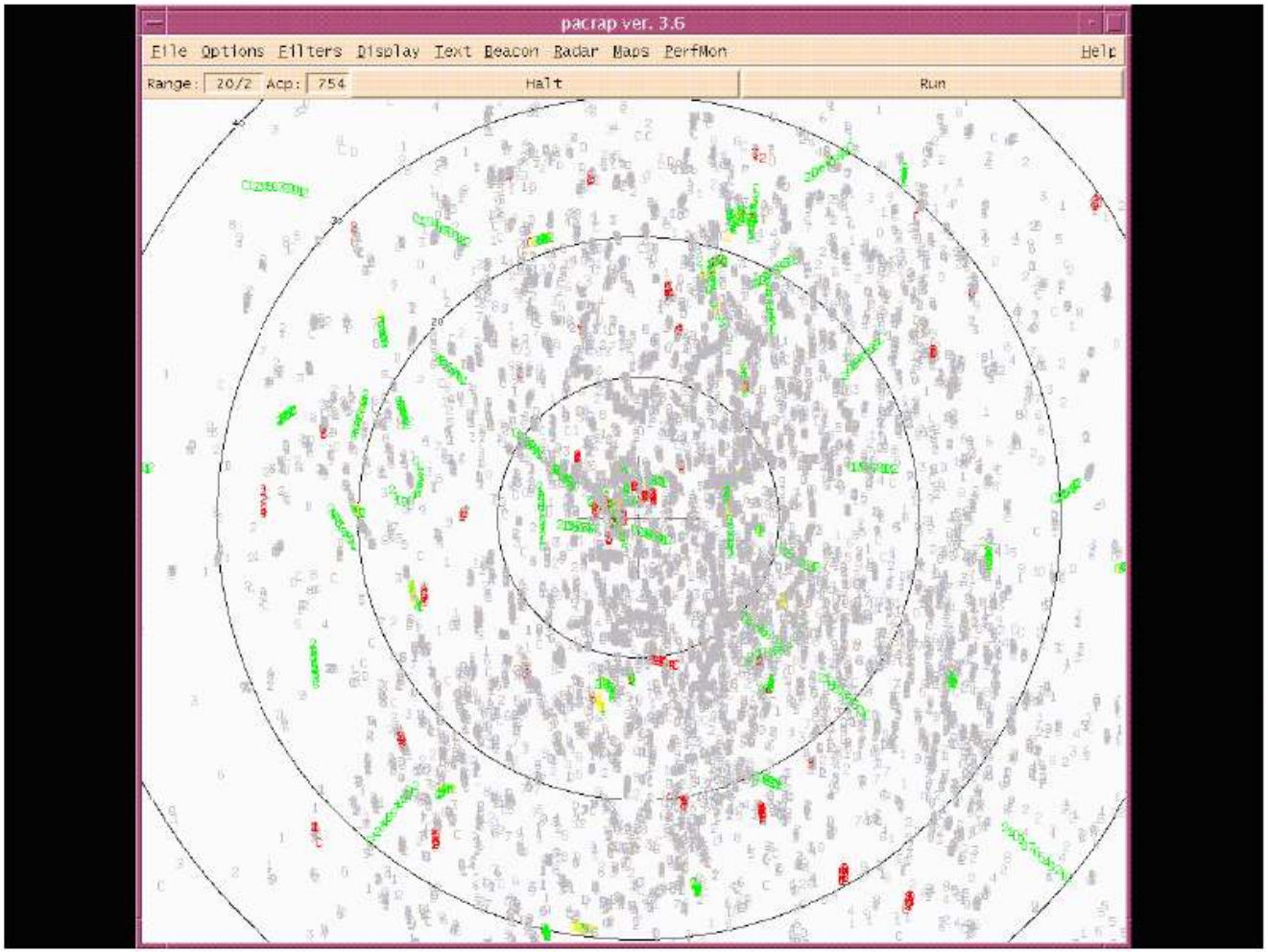




- Even though the radar echo of birds is relatively small, bird densities are so great that birds can often overload a radar with false targets
- Since birds move at relatively low velocities, their speed, if measured, can be used to preferentially threshold out the low velocity birds.

Figure by MIT OCW.

Bird Example from Dallas-Fort Worth

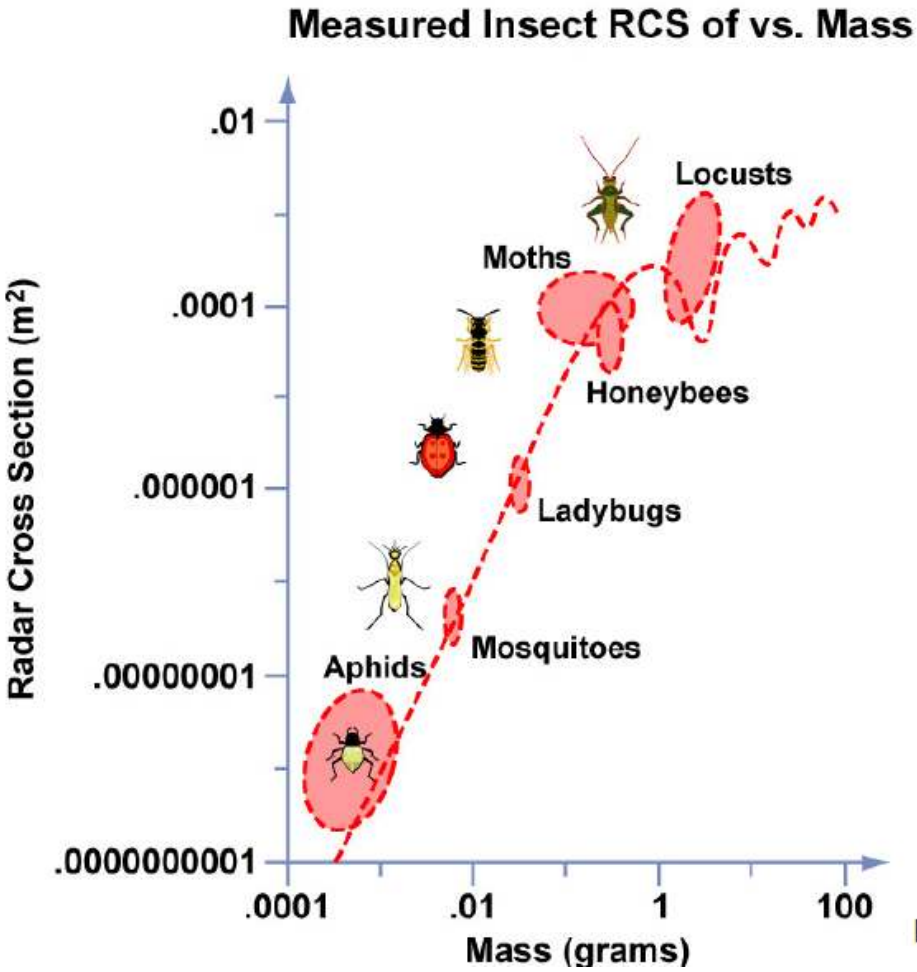


Radar&Beacon
Beacon-Only
Radar Uncorrelated
Radar Correlated

Attributes of Birds

- Birds are actually moving point targets
  - Velocity usually less than 60 knots
- Mean radar cross section is small, but a fraction of bird returns fluctuate up to a high level (aircraft like)
  - Cross section is resonant at S-Band and L-Band
- Lots of birds per square mile
  - 10 to 1000 bird / square mile
- Birds cause a false target problem in many radars
  - Significant issue for when detecting targets with low cross sections

Insects



- Insects can clutter the display and prevent detection of desired targets
- Density of insects can be many orders of magnitude greater than that of birds
- Insect flight path generally follows that of the wind
- Cross section can be represented as a spherical drop of water of the same mass
- Insect echoes broad side are 10 to 1,000 times than when viewed end on

Figure by MIT OCW.

Q & A