UNIVERSIDAD DE PUERTO RICO

RF Active Sensors

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IUCAF

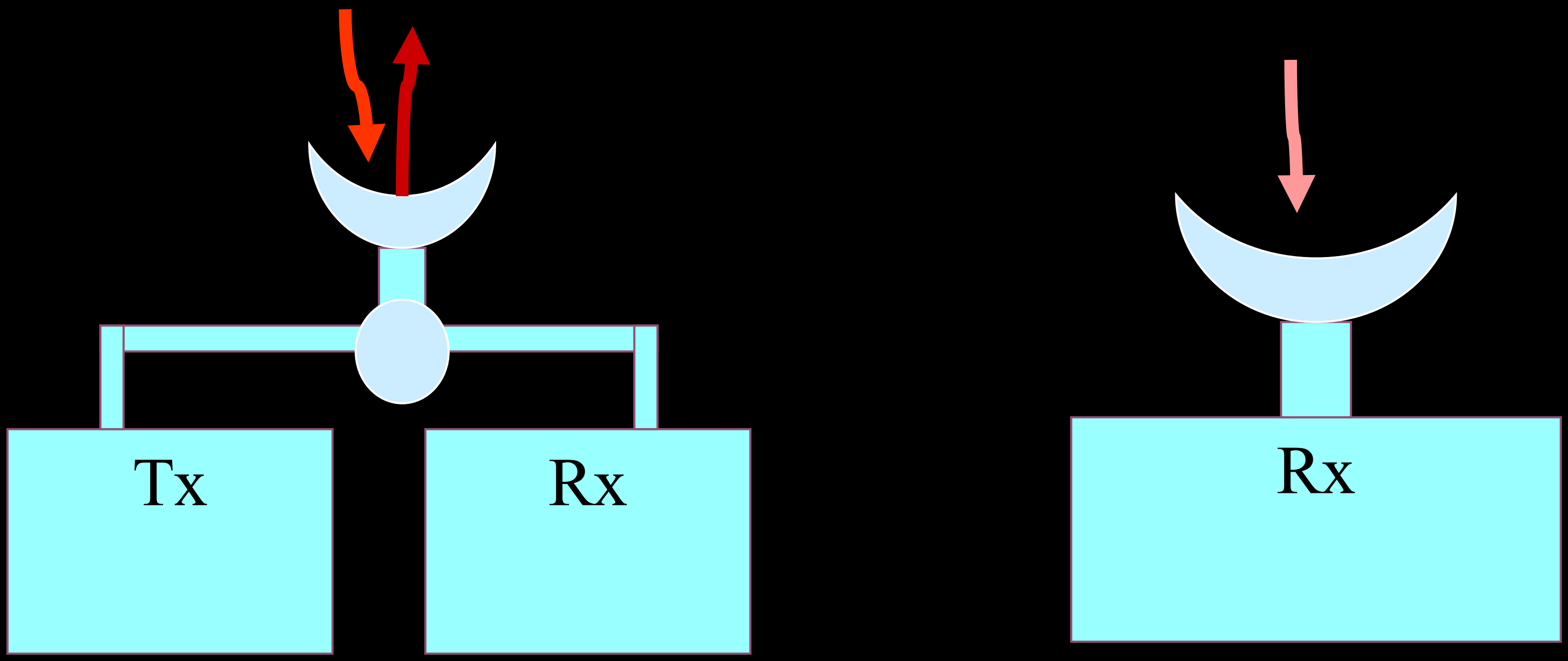
Stellenbosch, South Africa


UNITED STATES OF AMERICA
MEXICO
Gulf of Mexico
ATLANTIC
OCE
PACIFIC OCEAN
Caribbean Sea
Greater Antilles
CUBA
HAVANA
THE BAHAMAS
NASSAU
JAMAICA
KINGSTON
HAITI
PORT-AU-PRINCE
DOMINICAN REPUBLIC
SANTO DOMINGO
Puerto Rico (U.S.A.)
San Juan
Turks and Caicos Islands (U.K.)
Cayman Islands (U.K.)
BELIZE
BELMOPAN
GUATEMALA
GUATEMALA CITY
HONDURAS
TEGUCIGALPA
EL SALVADOR
SAN SALVADOR
NICARAGUA
MANAGUA
COSTA RICA
SAN JOSÉ
PANAMÁ
COLOMBIA
VENEZUELA
CARACAS
MEXICO CITY
Bahía de Campeche
Golfo de Tehuantepec
Golfo de Honduras
Straits of Florida
Shreveport
Jackson
Montgomery
Columbus
Augusta
Savannah
Austin
San Antonio
Houston
Lafayette
Baton Rouge
Gulfport
Mobile
New Orleans
Tallahassee
Jacksonville
Orlando
Tampa
St. Petersburg
Miami
Chihuahua
Torreón
Saltillo
Monterrey
Reynosa
Matamoros
Laredo
Corpus Christi
Durango
Aguascalientes
San Luis Potosí
León
Guadalajara
Querétaro
Morelia
Puebla
Veracruz
Acapulco
Mérida
Cancún
Tuxtla Gutiérrez
Flores
Belize City
La Ceiba
San Pedro Sula
Quetzaltenango
Escuintla
León
Matagalpa
Bluefields
Alajuela
Limón
Colón
David
Santiago
Barranquilla
Santa Marta
Soledad
Cartagena
Maracaibo
Barquisimeto
Valencia
Maracay
Cúcuta
Bucaramanga
Medellín
Santa Clara
Camagüey
Holguín
Santiago de Cuba
Pinar del Río
Montego Bay
Cap-Haïtien
Santiago
Aruba (NL)
Curaçao (NL)
Bonaire (NL)
Virgin Islands (U.S.A.)

Objectives

- Describe the difference between passive and active sensors
- Describe the basic components of active sensors
- Learn examples of RF/Microwave sensors

Microwave Sensors



Radar

(active sensor)

Radiometer

(passive sensor)

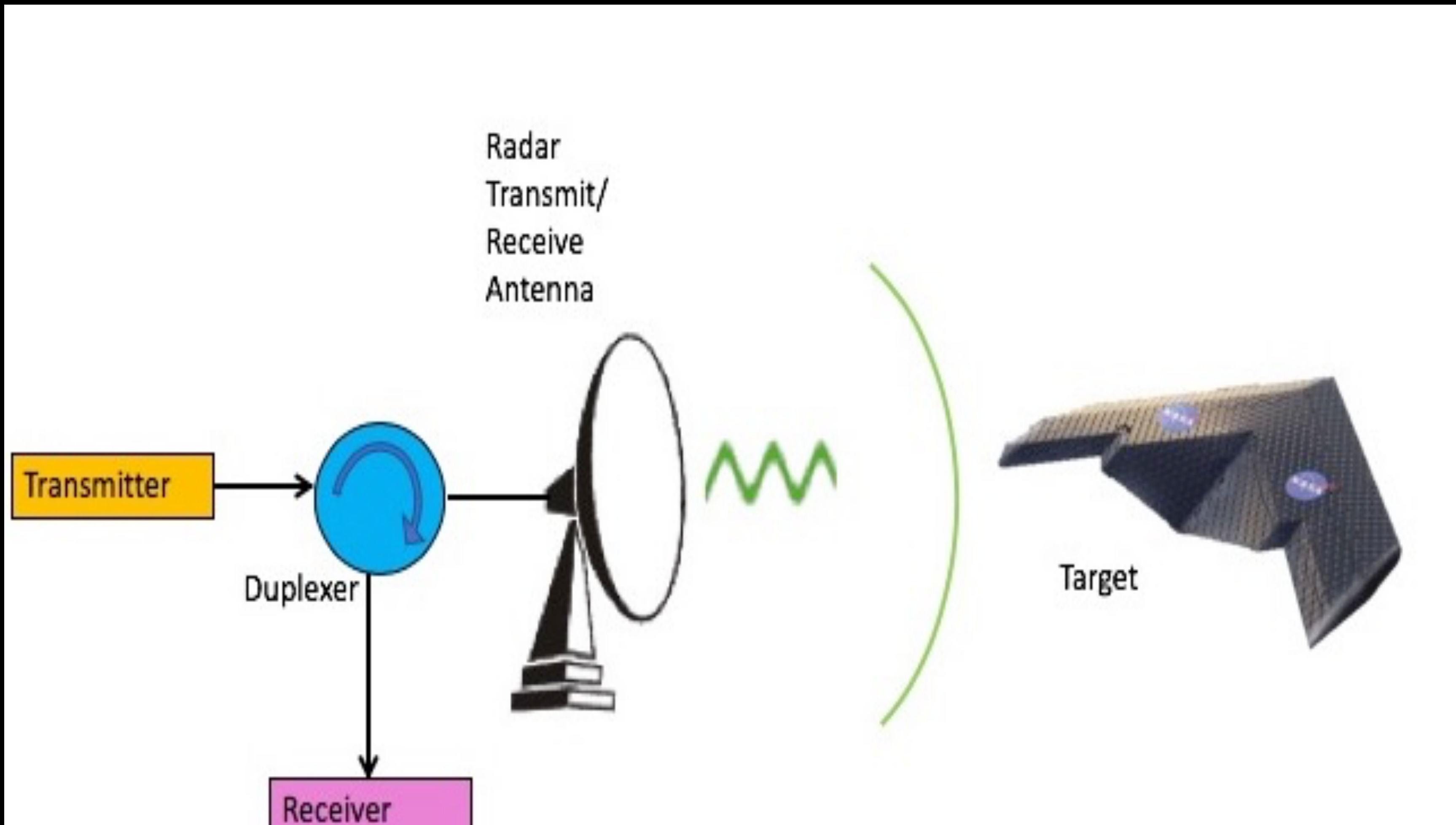
Examples

- Passive – radiometers to measure weather and climate variables, soil moisture and sea salinity, astronomy radiometers that study galaxies far away in space.
- Active – radars, altimeters, scatterometers, used for measuring weather and climate variables, cars, airplanes, astronomical studies of planets, ionosphere, and many other applications

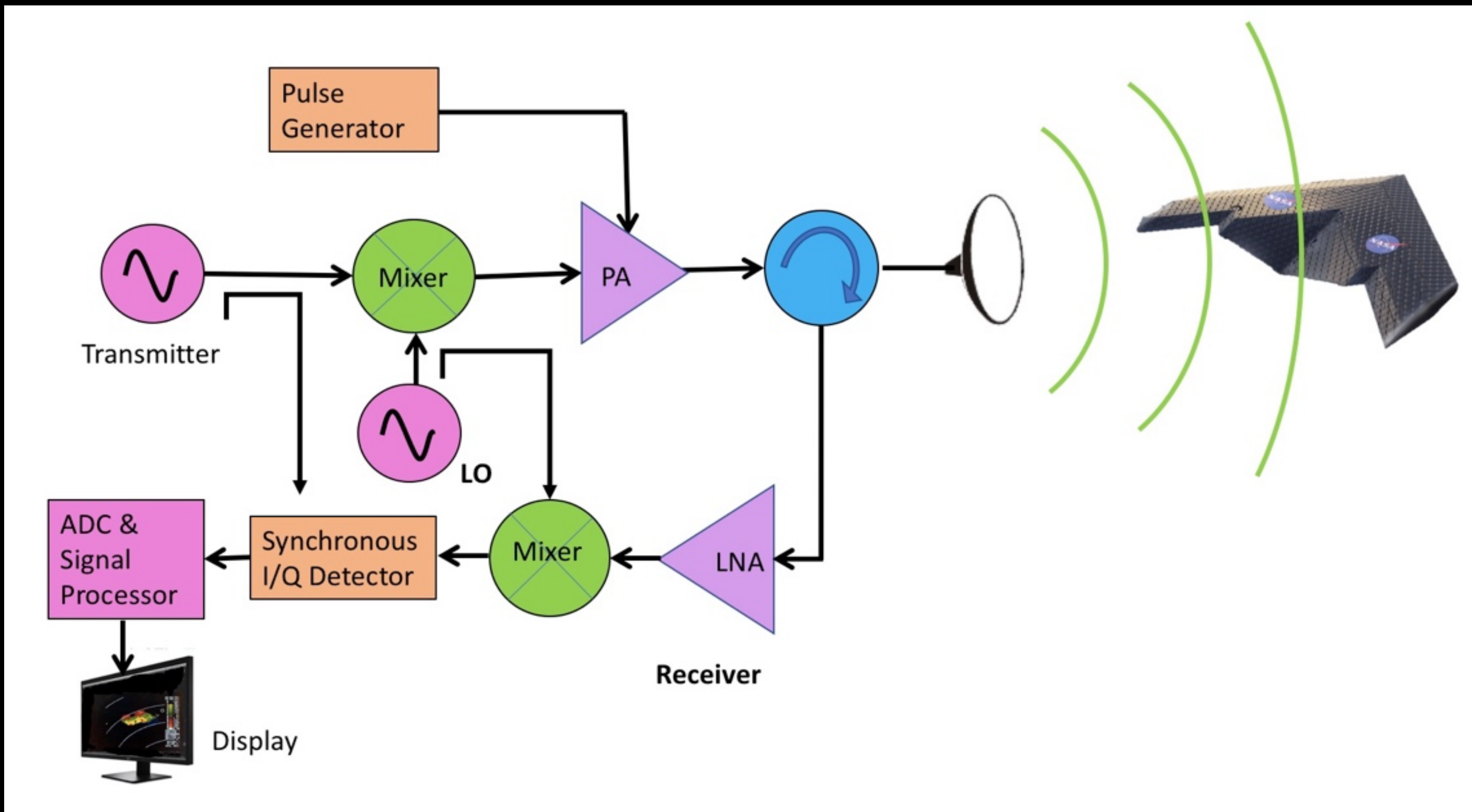
Radar original Definition

RADAR = RAdio Detection And Ranging

Basic Radar Diagram



Basic Radar



IF RF

Waveguides

APPENDIX I STANDARD RECTANGULAR WAVEGUIDE DATA

Band*	Recommended Frequency Range (GHz)	TE_{10} Cutoff Frequency (GHz)	EIA Designation WR-XX	Inside Dimensions [Inches (cm)]	Outside Dimensions [Inches (cm)]
L	1.12–1.70	0.908	WR-650	6.500 × 3.250 (16.51 × 8.255)	6.660 × 3.410 (16.916 × 8.661)
R	1.70–2.60	1.372	WR-430	4.300 × 2.150 (10.922 × 5.461)	4.460 × 2.310 (11.328 × 5.867)
S	2.60–3.95	2.078	WR-284	2.840 × 1.340 (7.214 × 3.404)	3.000 × 1.500 (7.620 × 3.810)
H (G)	3.95–5.85	3.152	WR-187	1.872 × 0.872 (4.755 × 2.215)	2.000 × 1.000 (5.080 × 2.540)
C (J)	5.85–8.20	4.301	WR-137	1.372 × 0.622 (3.485 × 1.580)	1.500 × 0.750 (3.810 × 1.905)
W (H)	7.05–10.0	5.259	WR-112	1.122 × 0.497 (2.850 × 1.262)	1.250 × 0.625 (3.175 × 1.587)
X	8.20–12.4	6.557	WR-90	0.900 × 0.400 (2.286 × 1.016)	1.000 × 0.500 (2.540 × 1.270)
Ku (P)	12.4–18.0	9.486	WR-62	0.622 × 0.311 (1.580 × 0.790)	0.702 × 0.391 (1.783 × 0.993)
K	18.0–26.5	14.047	WR-42	0.420 × 0.170 (1.07 × 0.43)	0.500 × 0.250 (1.27 × 0.635)
Ka (R)	26.5–40.0	21.081	WR-28	0.280 × 0.140 (0.711 × 0.356)	0.360 × 0.220 (0.914 × 0.559)
Q	33.0–50.5	26.342	WR-22	0.224 × 0.112 (0.57 × 0.28)	0.304 × 0.192 (0.772 × 0.488)
U	40.0–60.0	31.357	WR-19	0.188 × 0.094 (0.48 × 0.24)	0.268 × 0.174 (0.681 × 0.442)
V	50.0–75.0	39.863	WR-15	0.148 × 0.074 (0.38 × 0.19)	0.228 × 0.154 (0.579 × 0.391)
E	60.0–90.0	48.350	WR-12	0.122 × 0.061 (0.31 × 0.015)	0.202 × 0.141 (0.513 × 0.356)
W	75.0–110.0	59.010	WR-10	0.100 × 0.050 (0.254 × 0.127)	0.180 × 0.130 (0.458 × 0.330)
F	90.0–140.0	73.840	WR-8	0.080 × 0.040 (0.203 × 0.102)	0.160 × 0.120 (0.406 × 0.305)
D	110.0–170.0	90.854	WR-6	0.065 × 0.0325 (0.170 × 0.083)	0.145 × 0.1125 (0.368 × 0.2858)
G	140.0–220.0	115.750	WR-5	0.051 × 0.0255 (0.130 × 0.0648)	0.131 × 0.1055 (0.333 × .2680)

* Letters in parentheses denote alternative designations.

[redacted]

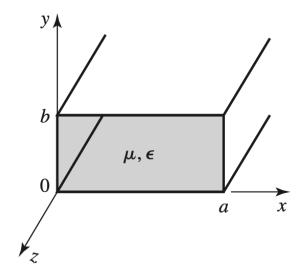


FIGURE 3.7 Geometry of a rectangular waveguide.

Pozar

Some Microwave Gossip

There is confusion and controversy about the microwave frequency band definitions used in North America. Legend has it that the designators were originally contrived during World War II to confuse the enemy. Engineers in Fort Monmouth New Jersey came up with the letter codes, which were classified as Secret at the time. Naturally, a logical progression of A, B, C wouldn't do for that purpose, so they chose L, C, X and K, and a whole bunch of lower-case letter sub-band designators that have been all but forgotten, with the exception of the Ku and Ka bands. After the war, Uncle Sam didn't declassify the system for everyone's use, different companies such as Sperry, Motorola, Narda, Hewlett Packard and Raytheon made educated guesses on the secret frequency bands, with inconsistent results and little attempt to organize an industry-wide standard.

In 1959 the world came to an agreement on the designator letters, at the International Telecommunications Union meeting in Geneva. The 1959 approved designators (Article 2, Section 11 of the Radio Regulations) are available in the ITT Reference Data for Radio Engineers. Now this data is obsolete, perhaps because they never considered that anyone would be interested in frequencies above 40 GHz. Kind of like when the phone company standardized on seven digit phone numbers, thinking that one area code for each U. S. state would provide enough phone numbers to last forever. Thanks to this short sightedness, the misery of changing area codes has become routine. But I digress...

In 1984, the IEEE microwave nerds agreed on the standard letter-band designations shown in the table below, the first two columns of which you should commit to memory if you want to be taken seriously. The first IEEE standard was published in 1976, then updated in 1984 and now exists as IEEE Standard 521-2002. The next update is estimated for 2019.

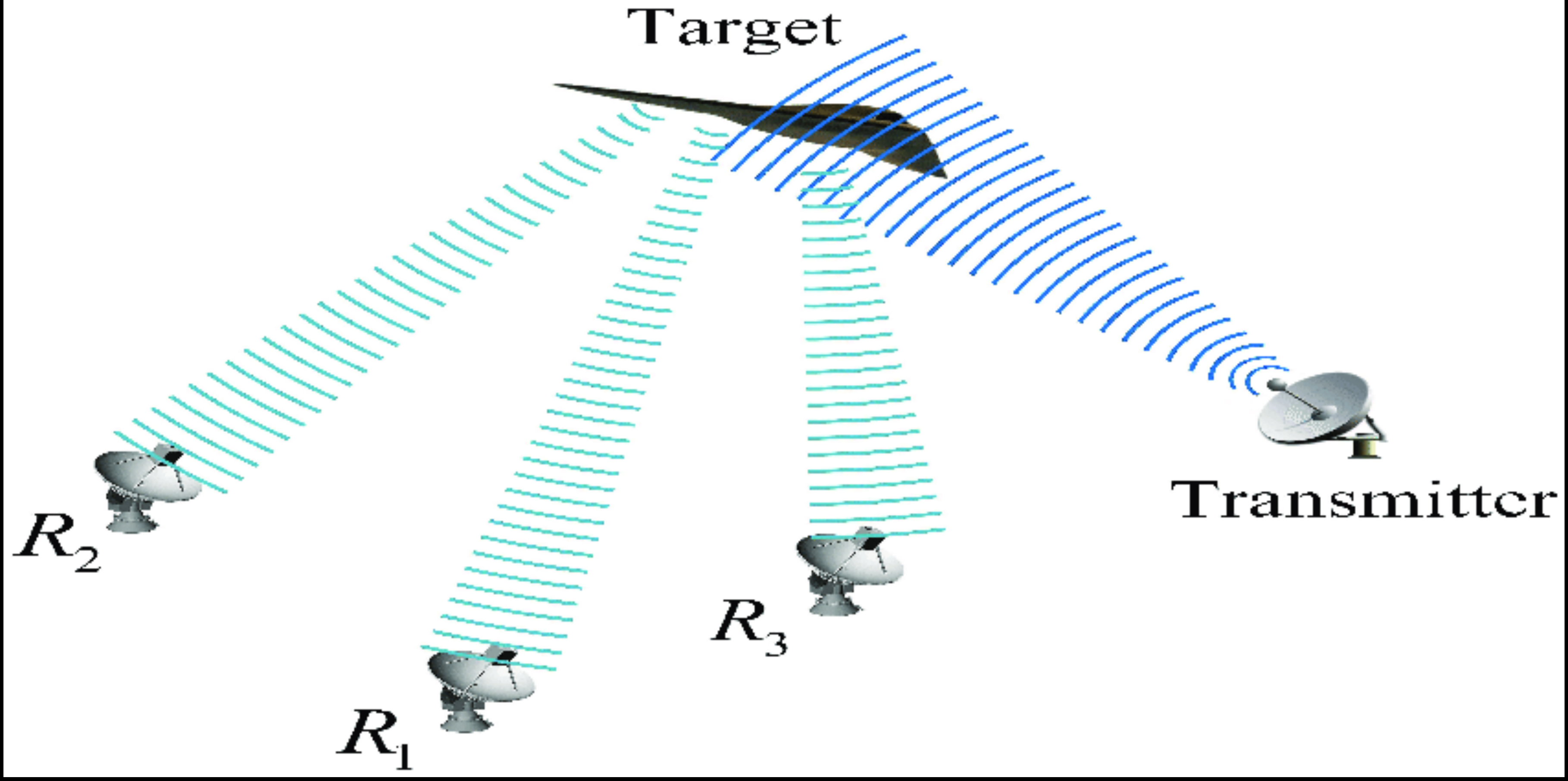
More ….

New material!

The material below just came to our attention, it also speaks to the origin of the microwave frequency letter bands, and it seems to make a good deal of sense.

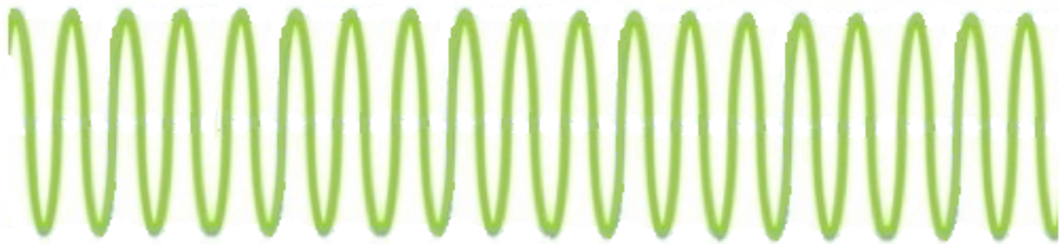
Band	Frequency Range	Origin of Name
I	up to 200 MHz	Unknown
G	200 to 250 MHz	Unknown
P	250 to 500 MHz	P for "previous", as the British used the band for the earliest radars, but later switched to higher frequencies.
L	0.5 to 1.5 GHz	L for "long" wave.
S	2 to 4 GHz	S for "short" wave. Don't confuse this with the short wave radio band, which is much lower in frequency
C	4 to 8 GHz	C for "compromise" between S and X band.
X	8 to 12 GHz	Used in WW II for fire control, X for cross (as in crosshair)
Ku	12 to 18 GHz	Ku for "kurz-under".
K	18 to 26 GHz	German "kurz" means short, yet another reference to short wavelength.
Ka	26 to 4-0	Ka for "kurz-above".
V	40 to 75 GHz	V for "very" high frequency band (not to be confused with VHF)
W	75 to 110 GHz	W follows V in the alphabet

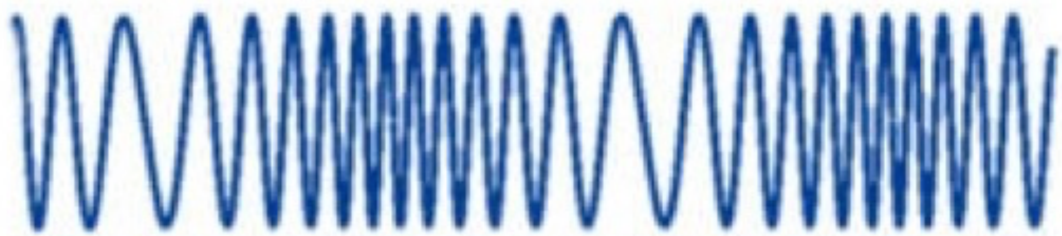
Passive radar is NOT a passive sensor
…it’s a Bistatic sensor

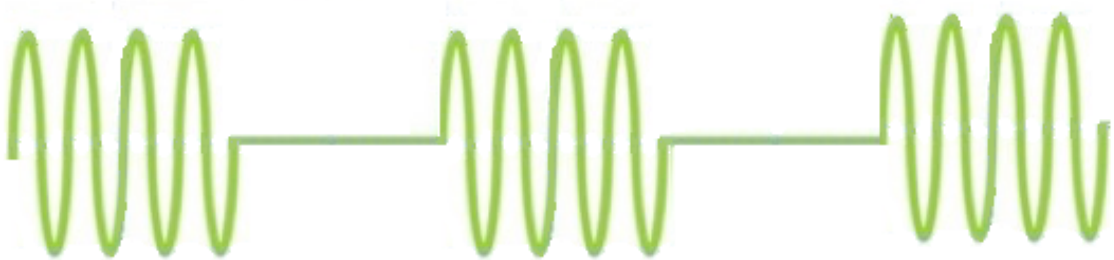


Types of Doppler Radar

- Continuous Wave (CW)
  - Simple
  - No range information
- Frequency Modulated CW, (FMCW)
  - Fine range resolution
  - Artefacts from target motion
- Pulse Doppler
  - Range and Doppler
  - No artefacts (except when pulse compression used)





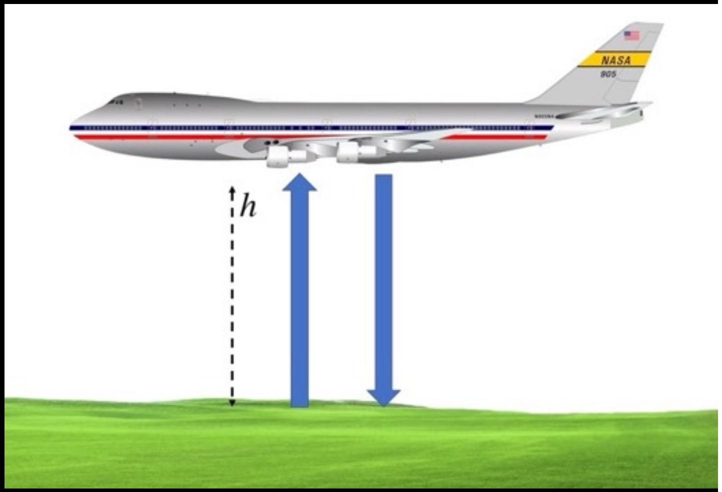


Altimeters

- h=ct/2
- Wet path delay correction

Used to MEASURE: ocean sea surface height, oceans circulation, and the amount of heat in the ocean

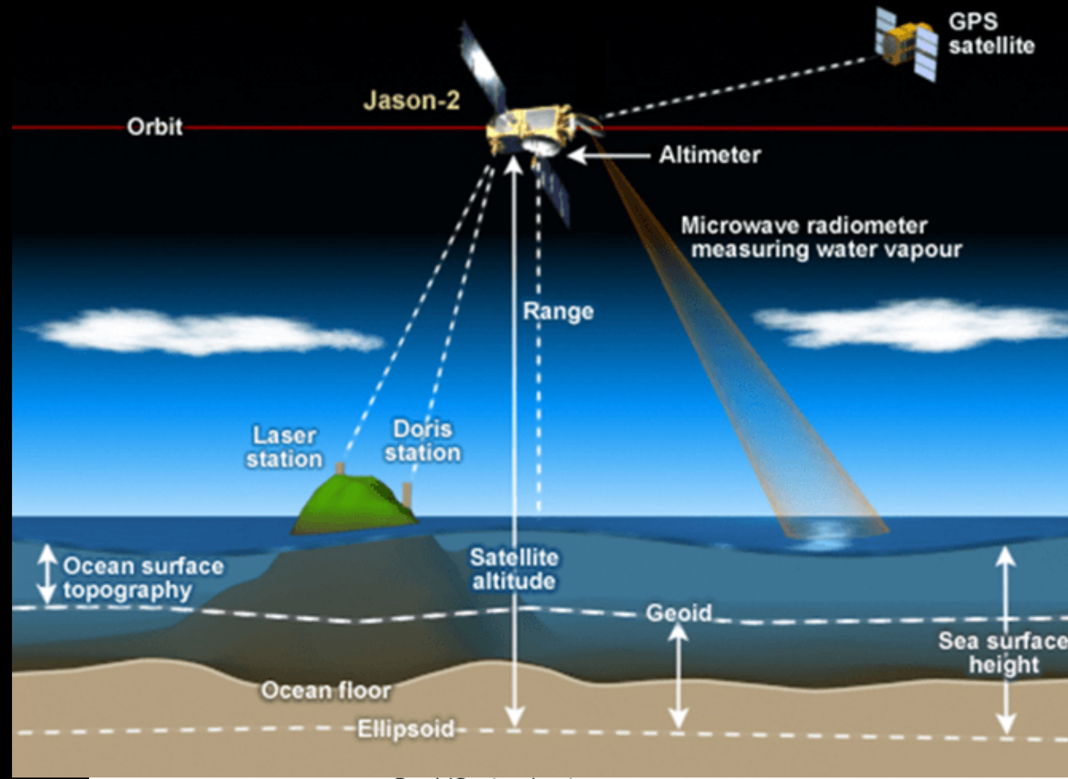
For these APPLICATIONS: monitor the El Niño event, and for weather, climate, navigation, fisheries management, and offshore operations

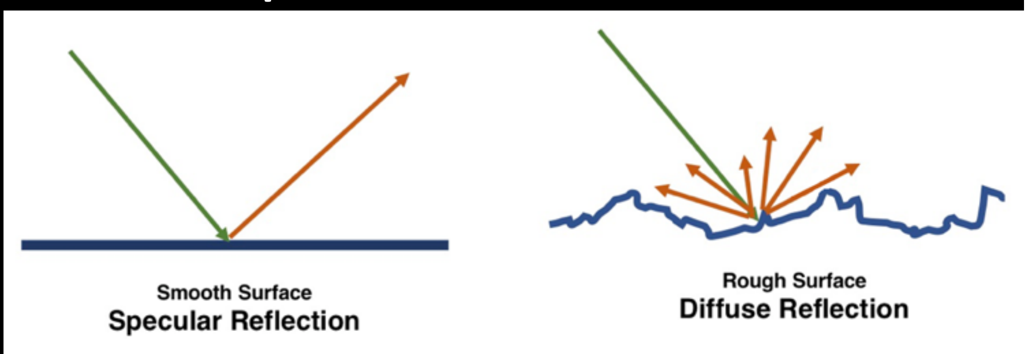


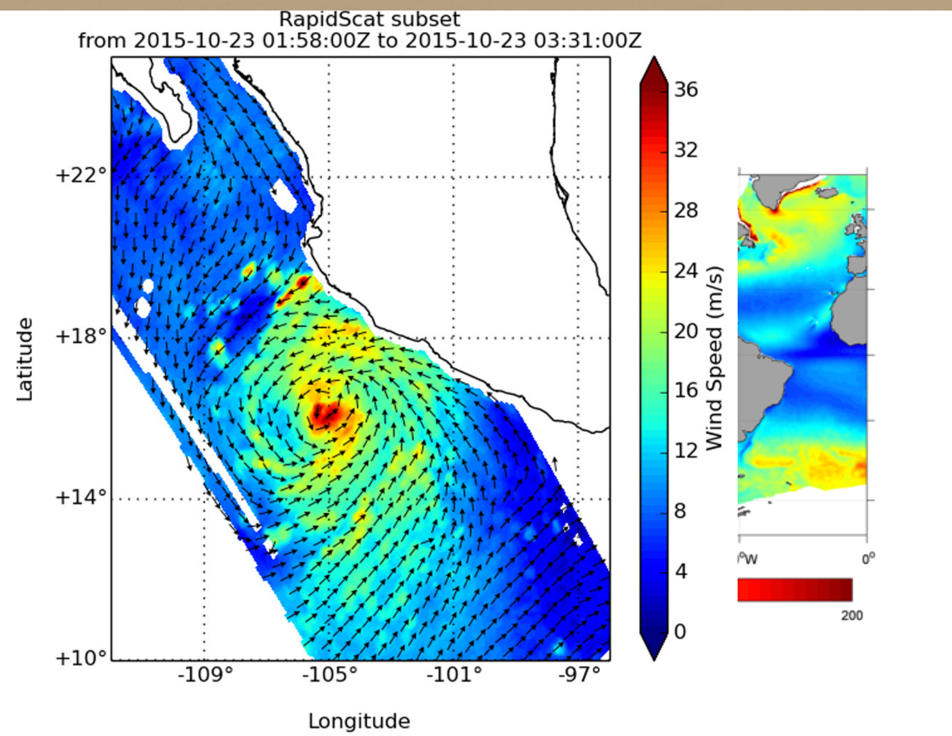
Scatterometers

- Radars that measure the intensity and shape of the returned pulse

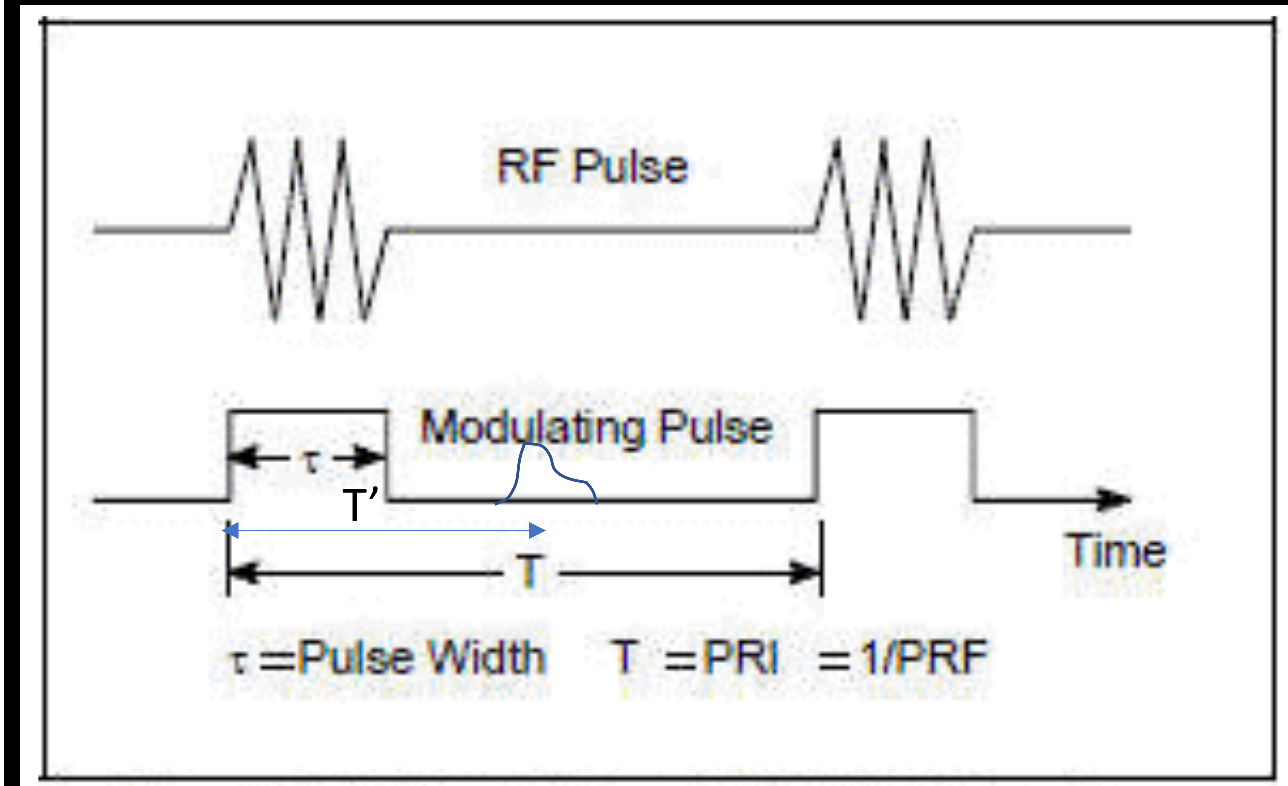
- The intensity scattered back the ocean is a measure of the average wind speed.







Pulse Radar



Range Resolution

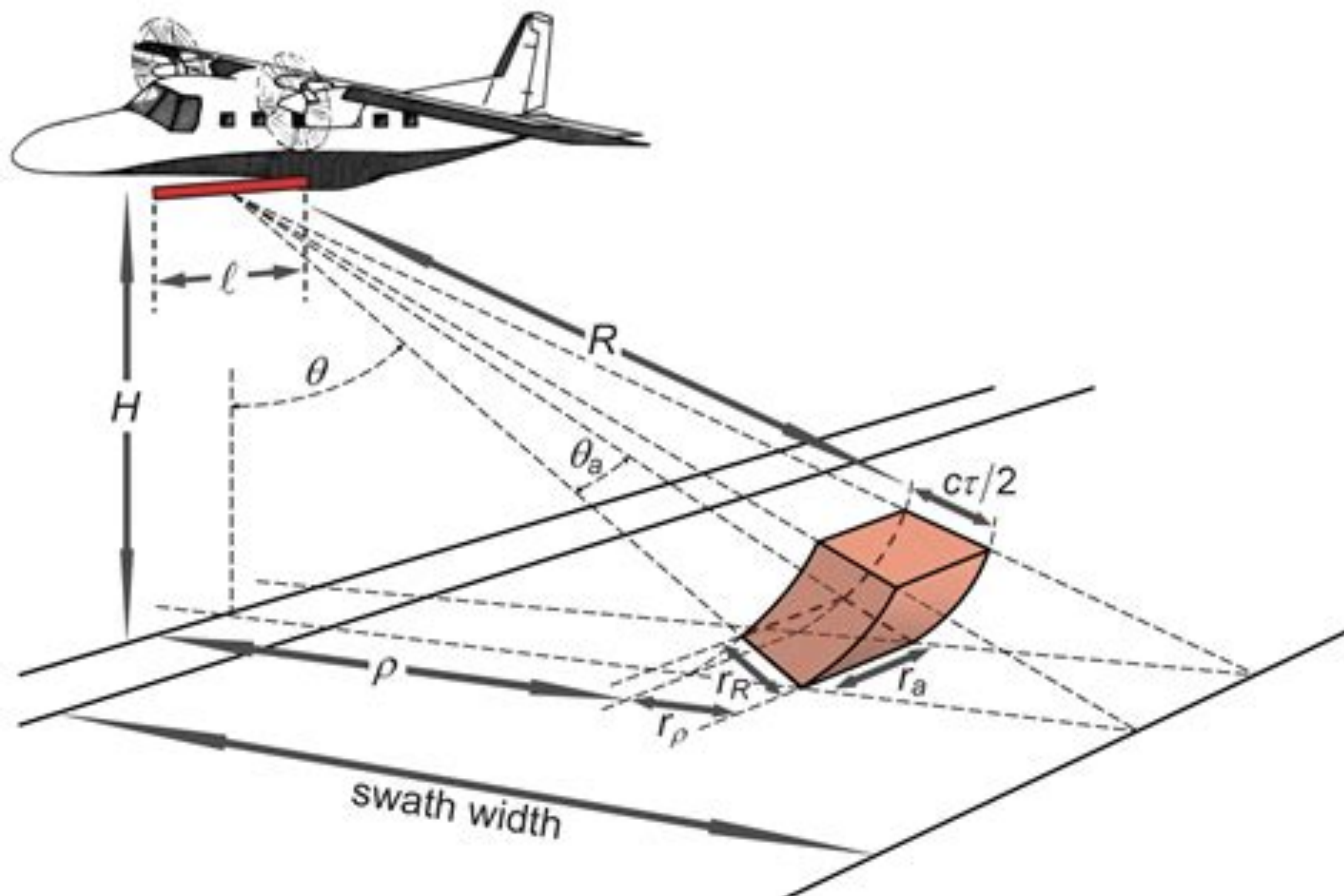
$$\Delta R = \frac{c\tau}{2}$$

$$BW = \frac{1}{\tau} = bandwidth$$

$$\Delta R = \frac{c}{2\,BW}$$

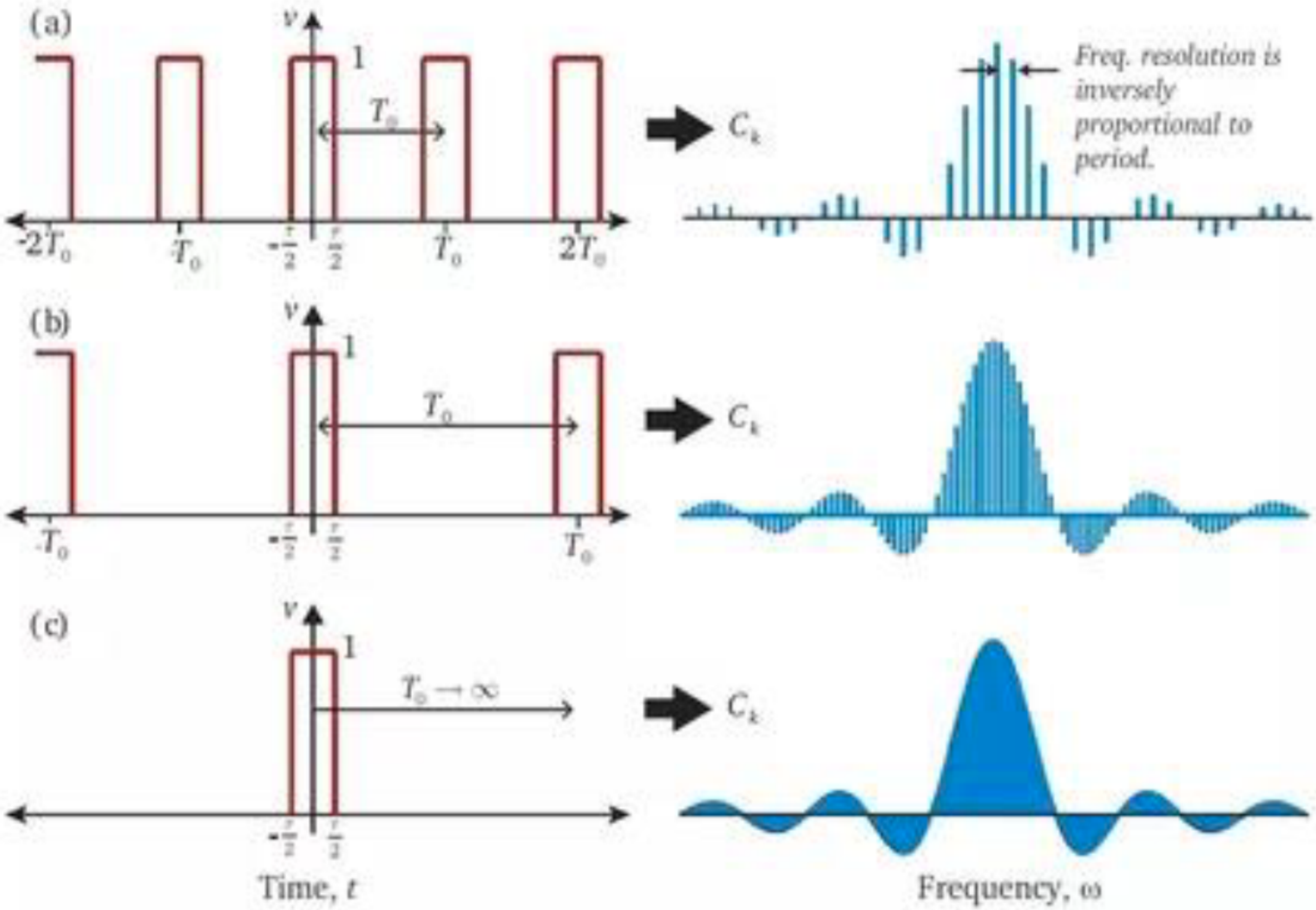
Range
2R=(cT')
R=(cT')/2

Unambigous Range
Rmax=(cT)/2=(c)(PRI)/2= c/(2PRF)



ℓ
H
θ
R
θ_a
cτ/2
ρ
r_R
r_a
r_ρ
swath width

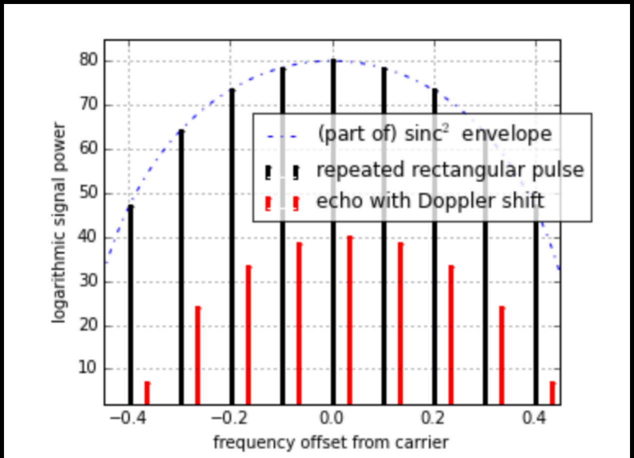
Periodic Pulse Train Morphing Into a Single Pulse



Velocity ambiguity

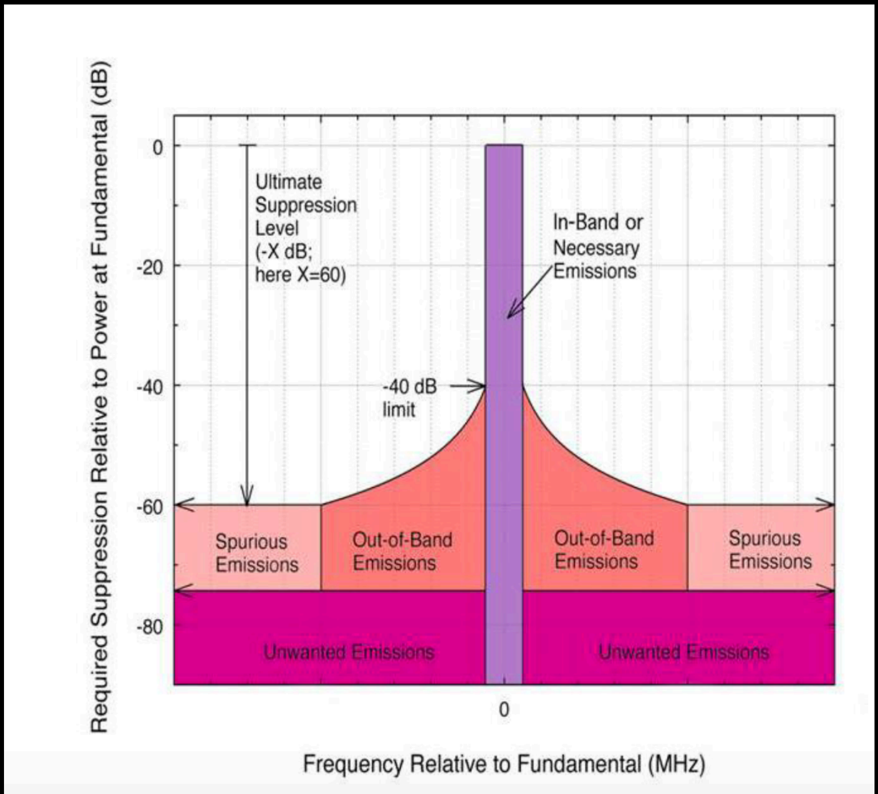
- For a Doppler radar the shift in frequency is related to the radial component of the target speed
- Delta f = Doppler Frequency = 2 (v_{radial}/ λ)

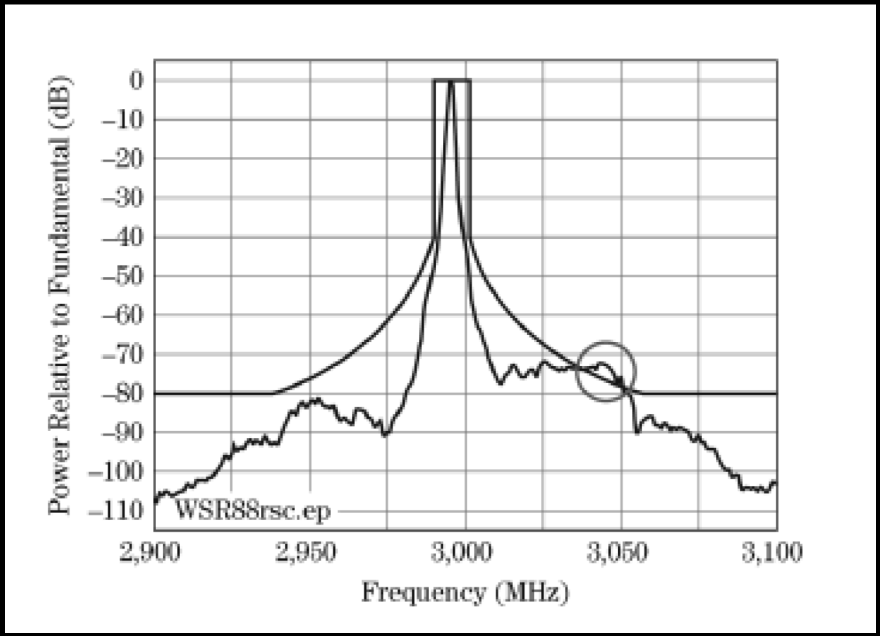
- The maximum unambiguous target velocity is given by:



- $V_{max} = \pm \frac{c\ PRF}{4f}$

ITU Guidelines Emissions Masks





“Manual of Regulations and Procedures for Federal Radio Frequency Management”,

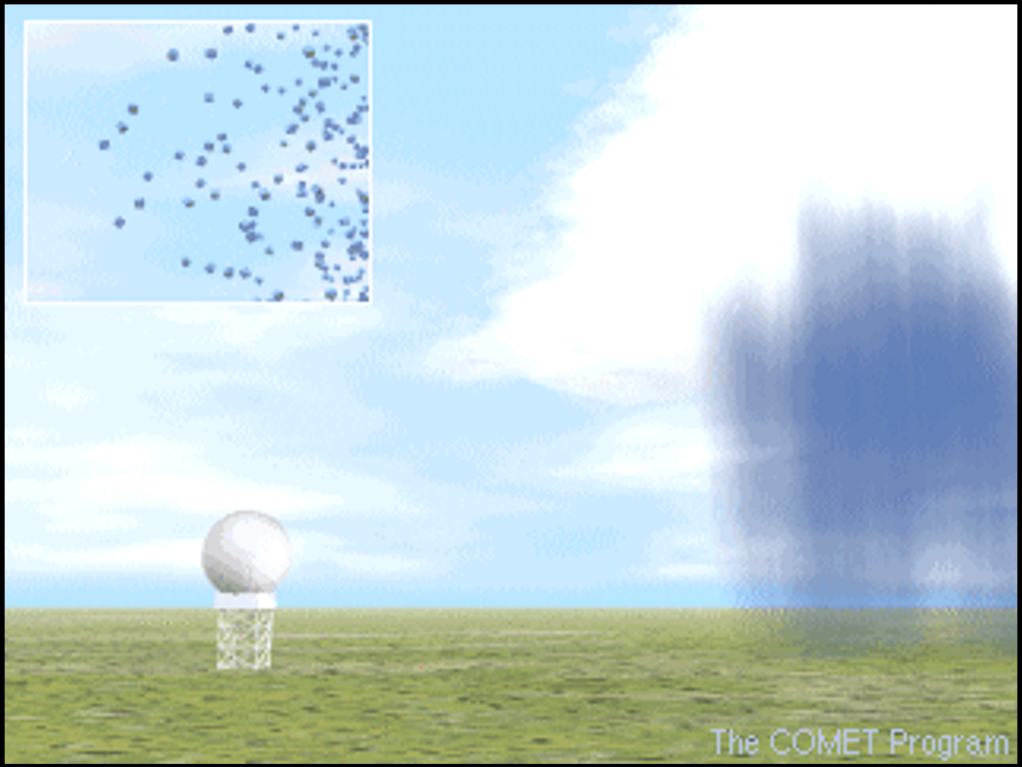
Chapter 5.5, Radio Spectrum Engineering Criteria (RSEC)

Griffiths

Pulse Radar

- The shorter the pulse, better range resolution
- Longer the pulse, more energy, better sensitivity.
- Use Pulse Compression
- The lower PRF increases R_{max}
- Higher PRF increases v_{max}
- Use Staggering PRF, scan schemes

Weather Applications: radar



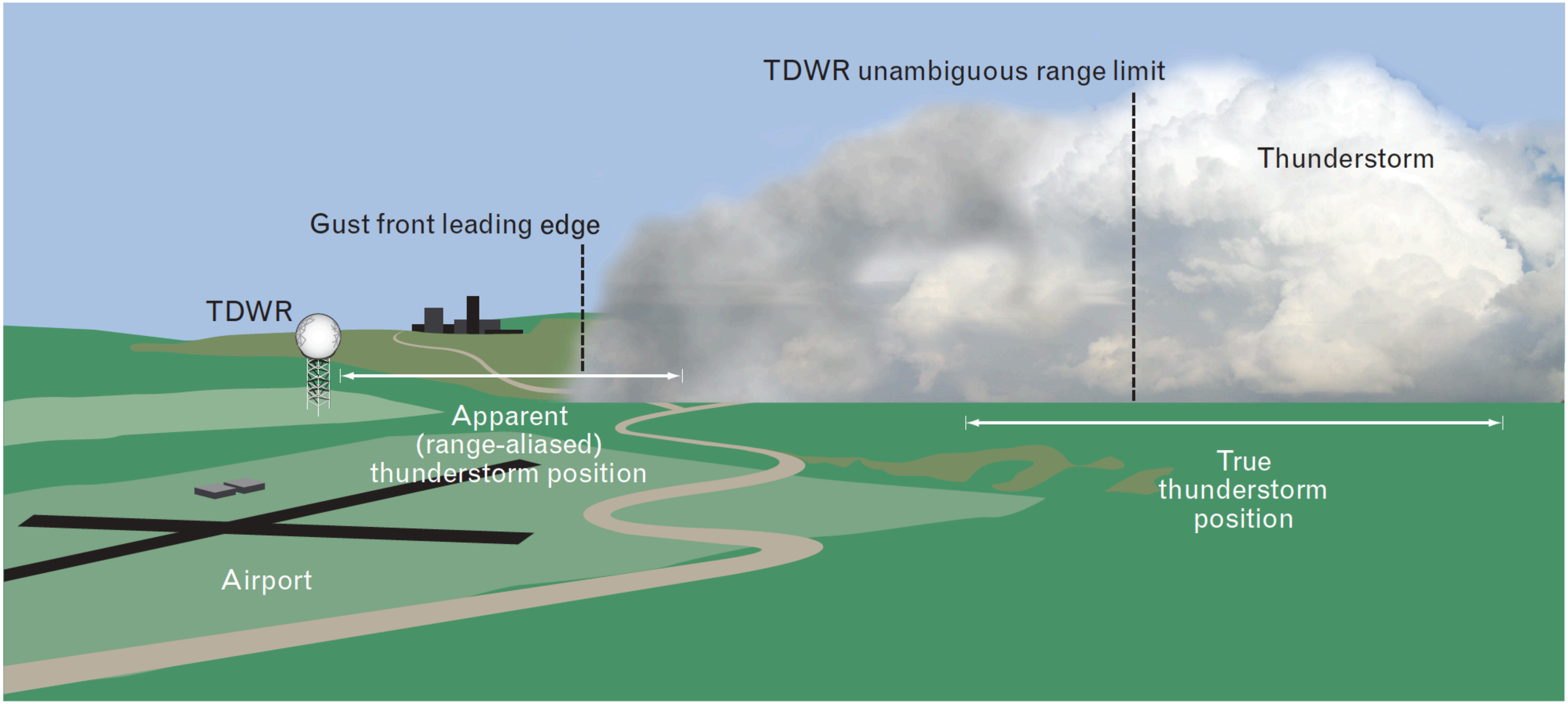
$$Z = \frac{1024\ln(2)}{c\pi^3}\left(\frac{\lambda^2}{P_t\tau G^2\Theta\Phi}\right)\left(\frac{\overline{P}_r r^2}{|K|^2}\right)$$

constants | Radar characteristics | Target characteristics

Radar for Meteorology

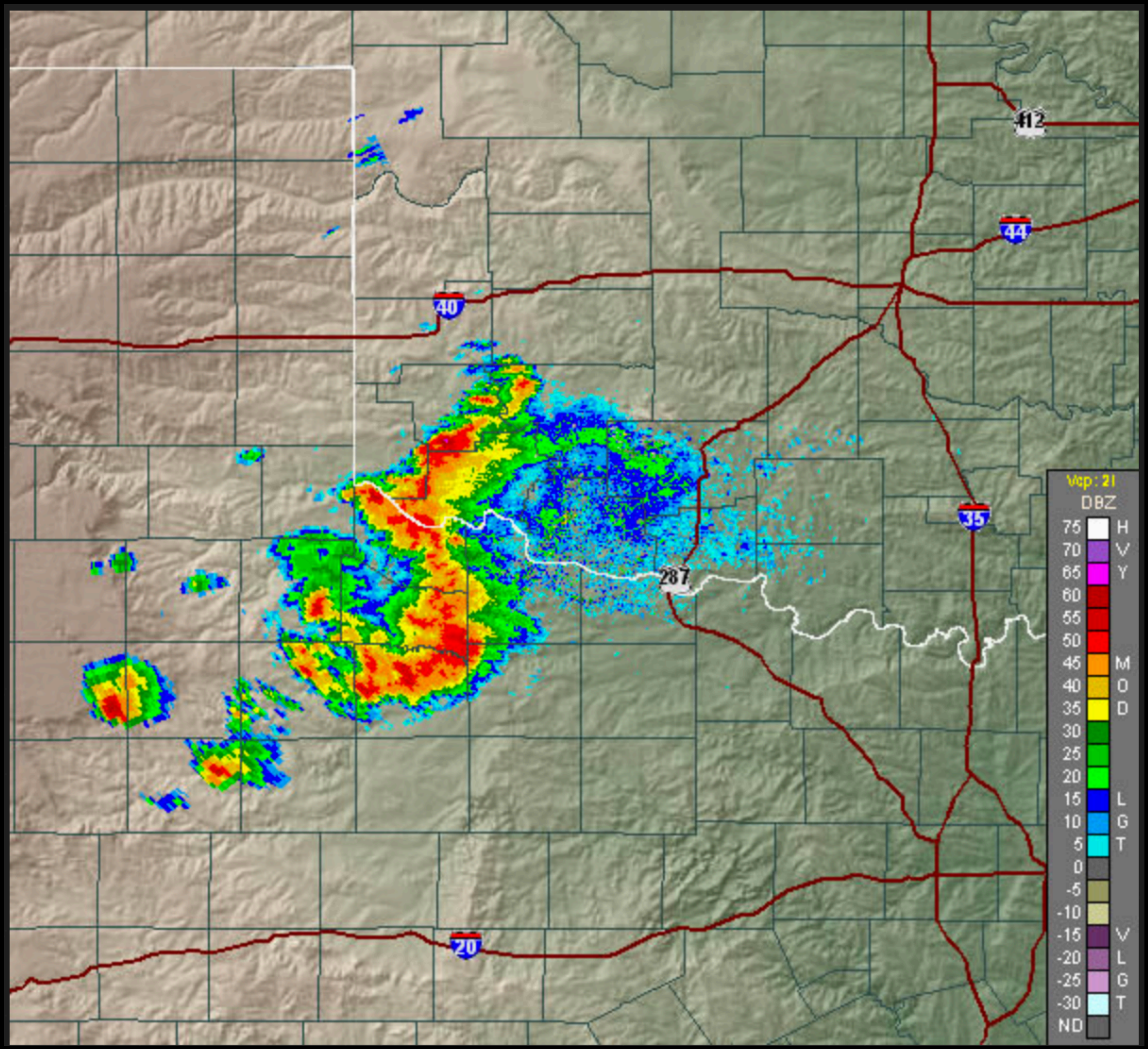
- Pulsed Doppler
- Polarimetric
- S-band - low attenuation, long range – NEXRAD
- C-band mid range – TDWR
- X band – short range – CASA/ DCAS

TDWR C-Band



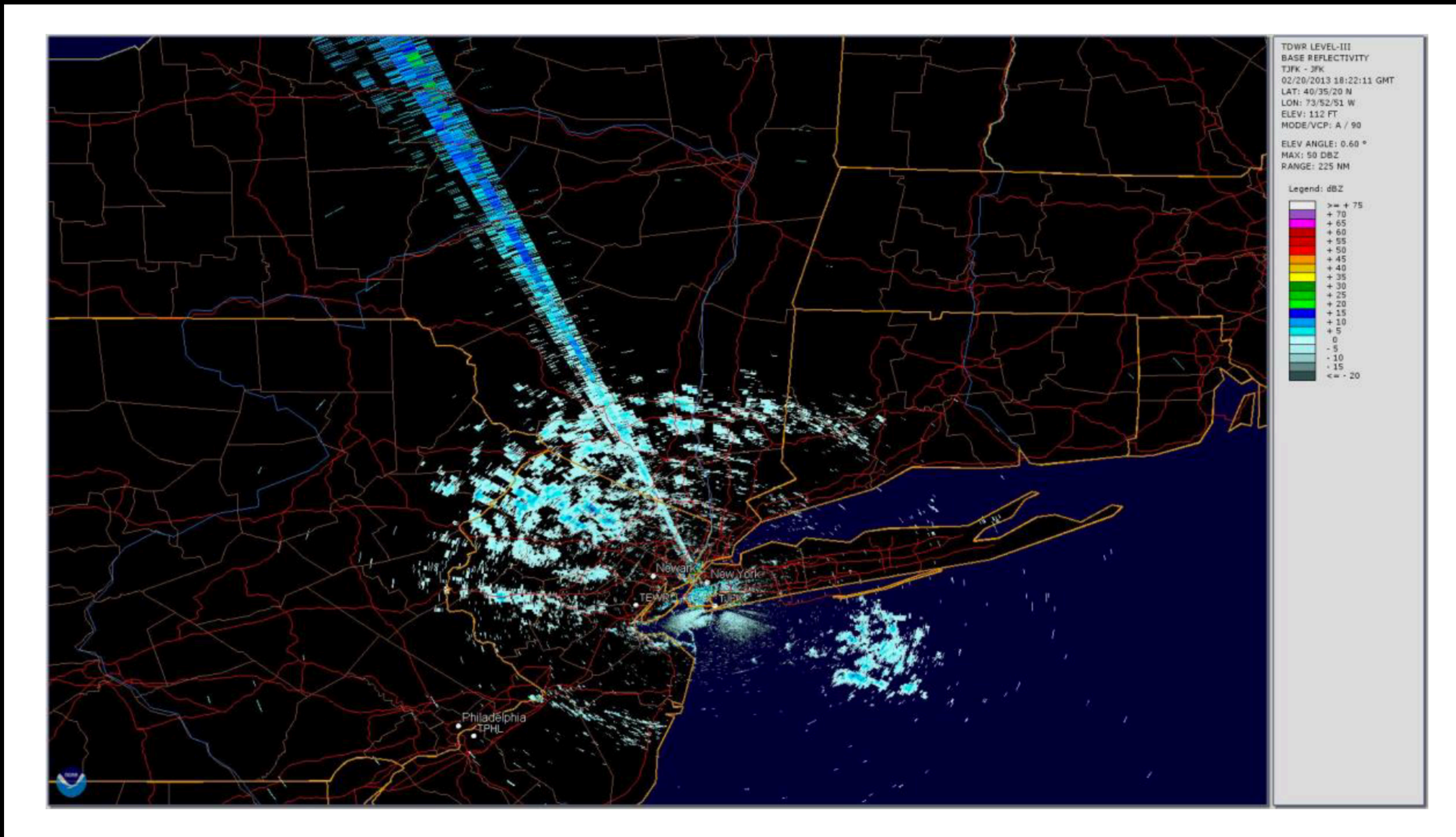
Weber

Typical Reflectivity Plot



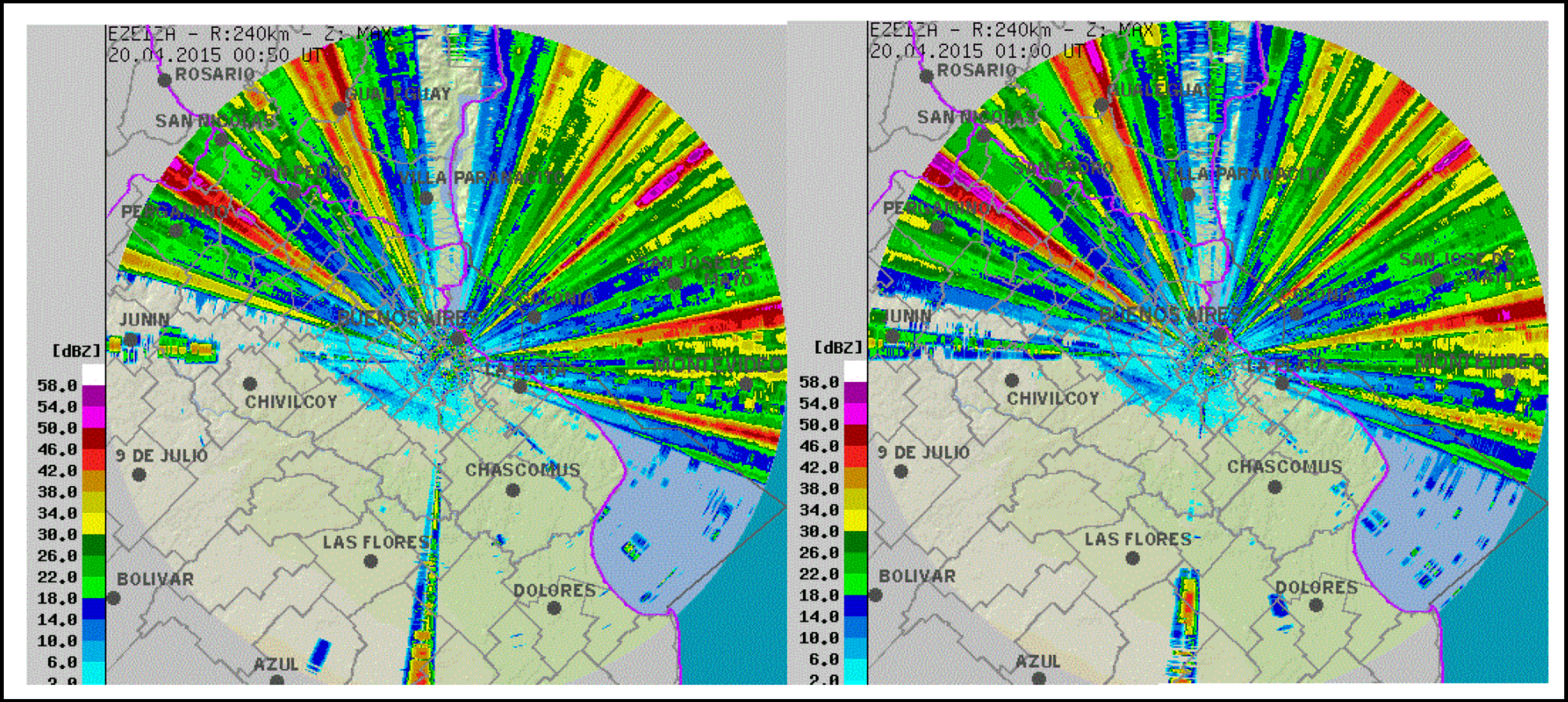
NWS

TDWR UNII Interference



AMS

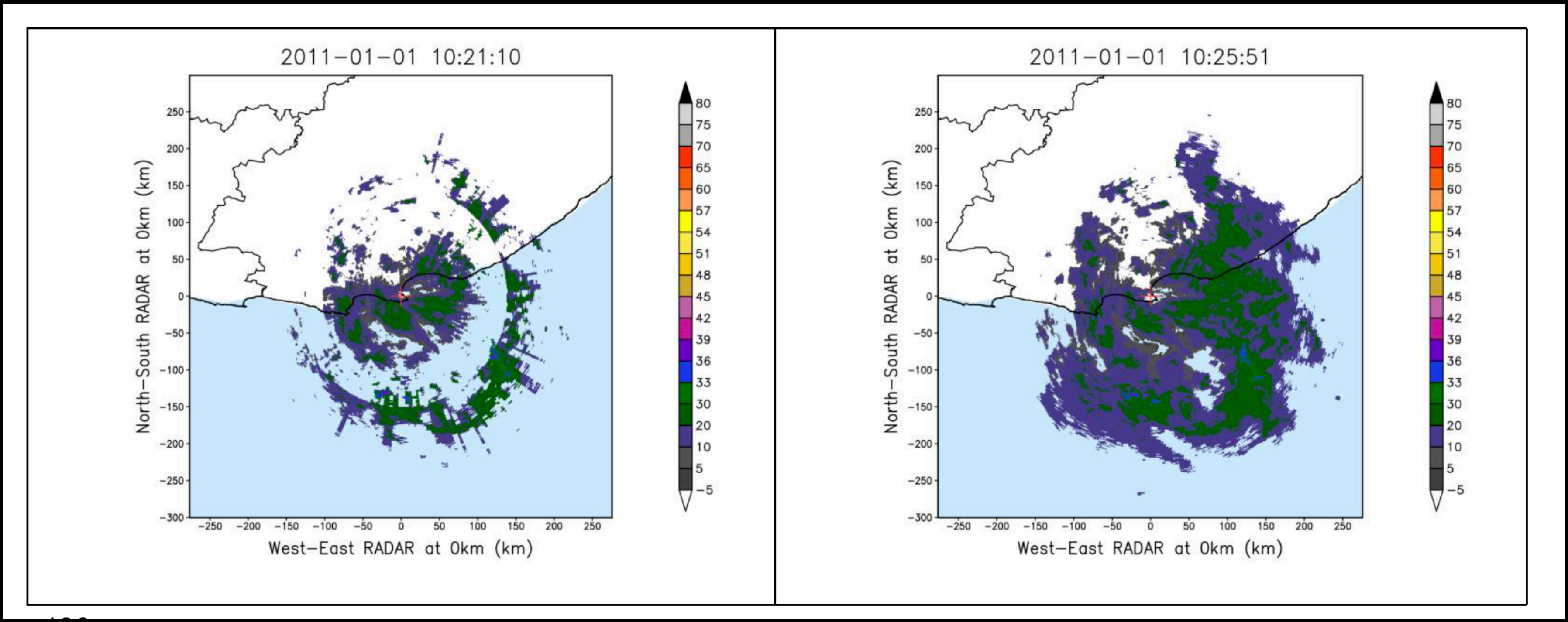
TDWR UNII Interference



Ezeia radar in Argentina

AMS

TDWR



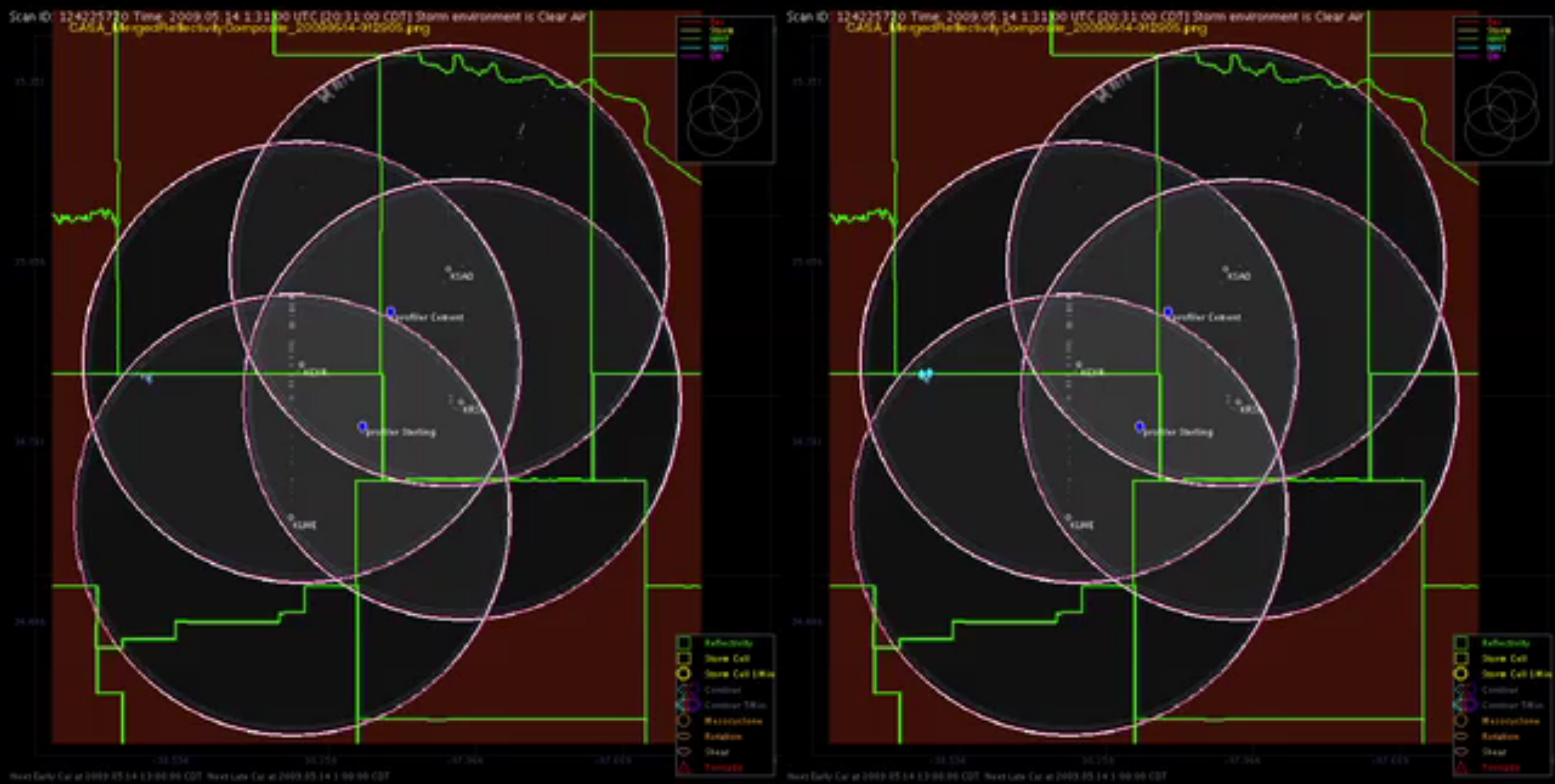
Port Elizabeth radar in South Africa

AMS

Summary

- Radar enables the control and management of air traffic, monitor and track severe weather, defense and homeland security, networks of driverless automobiles.
- Radar requires access to spectrum, great potential for approaches aimed at using the spectrum in an efficient and dynamically-controlled manner (NSF SWIFT)
- Advances in technology will be needed to contend with the growing congestion.

Installation of CASA Scan Technology in collaboration with UMass



MC&C Animation IP1 OK – M. Zink

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- http://www.millitech.com/pdfs/Radiometer.pdf
- NASA website
- ITU (International Telecommunication Union