ARM Southern Great Plains Radar Network

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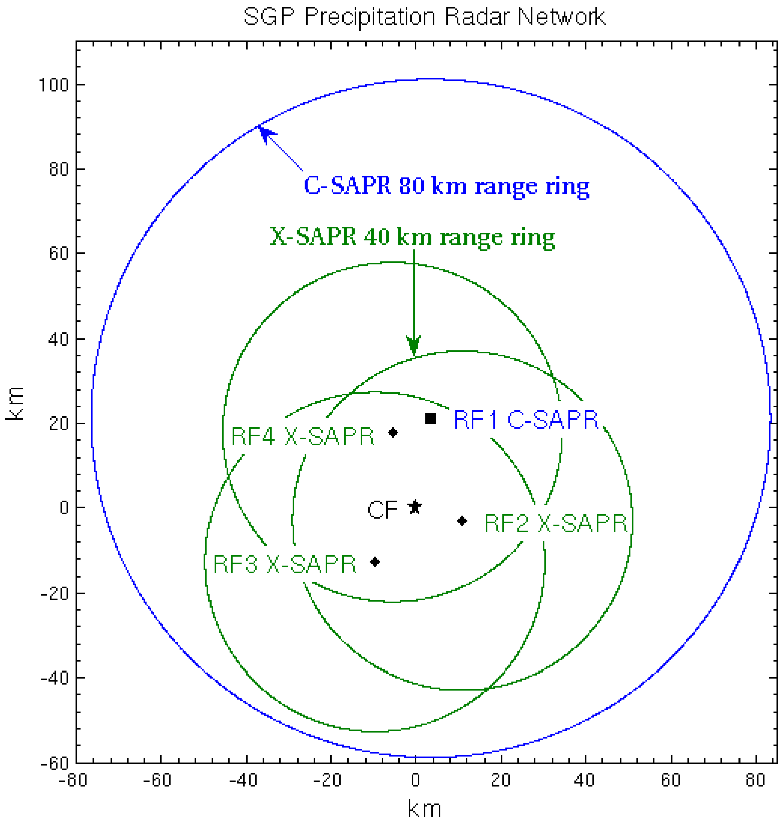
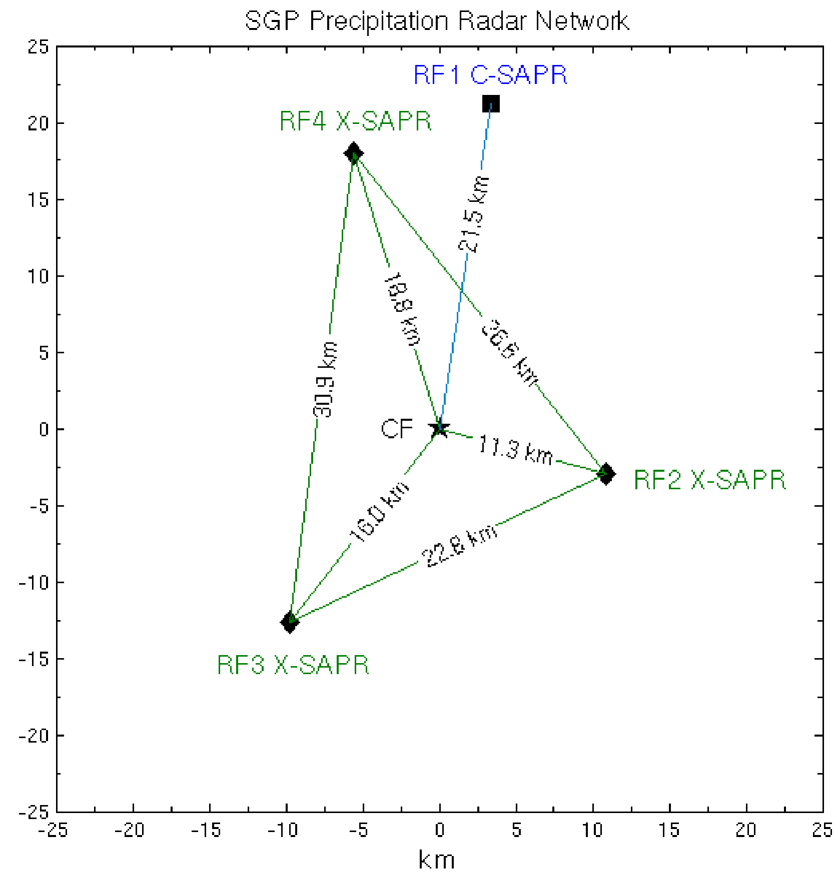
Outline

- SGP radar network
- Precipitation radar
- Polarization diversity
- Operational considerations

SGP Radar Network Geometry

- SGP radar network consists of
  - Three X-band ARM scanning precipitation radar (X-SAPR) (Sep 2010)
  - One C-band ARM scanning precipitation radar (C-SAPR) (Dec 2010)
  - One Ka/W-band ARM scanning cloud radar (Ka/W-SACR) at Central Facility (CF)
  - One Ka-band vertically pointing cloud radar (MMCR) at Central Facility (CF)





C-Band Scanning ARM Precipitation Radar (C-SAPR)

- Advanced Radar Corporation
- TITAN Processing Environment

Transmitter	
Type	Magnetron
Center frequency	5625 ± 25 MHz
Peak power output	250 kW
Average power output	250 W
Pulse width	200 ns - 2 μs
Polarization	Dual polarization, Simultaneous H and V
Max. Duty Cycle	0.1%
PRF	200 Hz - 5kHz
Antenna and Pedestal	
Type (diameter)	Parabolic reflector (4.27 m)
3-dB Beam width	0.98°
Gain	45.0 dB
ICPR	32 dB
Two-way Radome loss	1 dB
Scan rate	up to 36°/s
Acceleration	up to 30°/s^2
Receiver	
Type	Dual-channel HiQ digital
Dynamic range	> 80 dB
Noise figure	2.8 dB
Sampling rate	40 MHz
Decimation factor	Adjustable
Video Bandwidth	Adjustable

Core Products

Spectral Moments

- Reflectivity
- Mean Velocity
- Spectrum Width

Polarimetric Variables

- ZDR
- Differential Phase
- Co-polar corr coeff

Attenuation Correction

- Corr Reflectivity
- Corr ZDR
- KDP

Meta Data

X-Band Scanning ARM Precipitation Radar (X-SAPR)

- Radtec Engineering Inc
- RVP900 and IRIS Processing Environment

Transmitter	
Type	Magnetron
Center frequency	9500 ± 30 MHz
Peak power output	200 kW
Average power output	200 W
Pulse width	200 ns - 4.5 μs
Polarization	Dual polarization, Simultaneous H and V
Max. Duty Cycle	0.1%
PRF	200 Hz - 5kHz
Antenna and Pedestal	
Type (diameter)	2.4 m offset feed
3-dB Beam width	0.9°
Gain	45.0 dB
Two-way Radome loss	0.6 dB
Azimuth scan rate	up to 24°/s
Elevation scan rate	up to 15°/s
Receiver	
Type	Vaisala Sigmet RVP900
Dynamic range	< 105 dB
Noise figure	3.0 dB
Sampling rate	80 MHz
Decimation factor	Adjustable
Video Bandwidth	Adjustable

Core Products

Spectral Moments

- Reflectivity
- Mean Velocity
- Spectrum Width

Polarimetric Variables

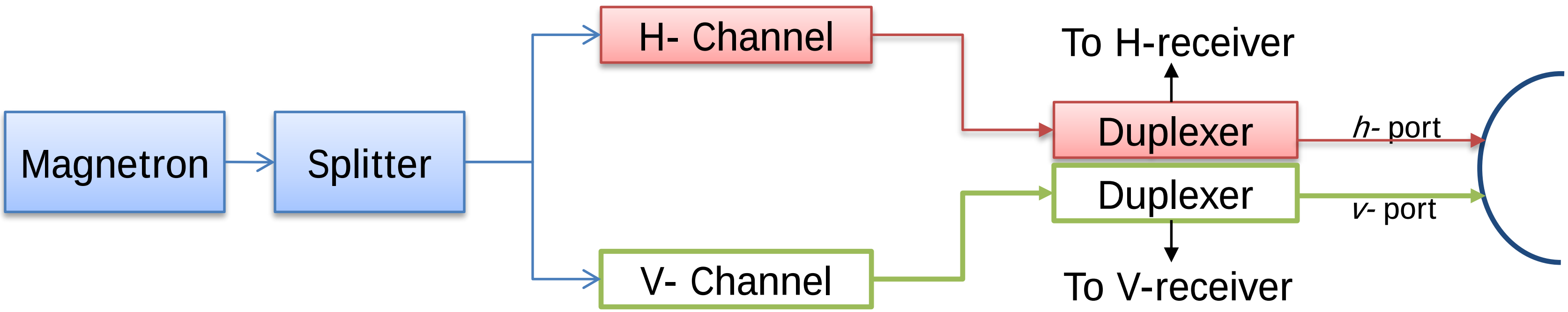
- ZDR
- Differential Phase
- Co-polar corr coeff

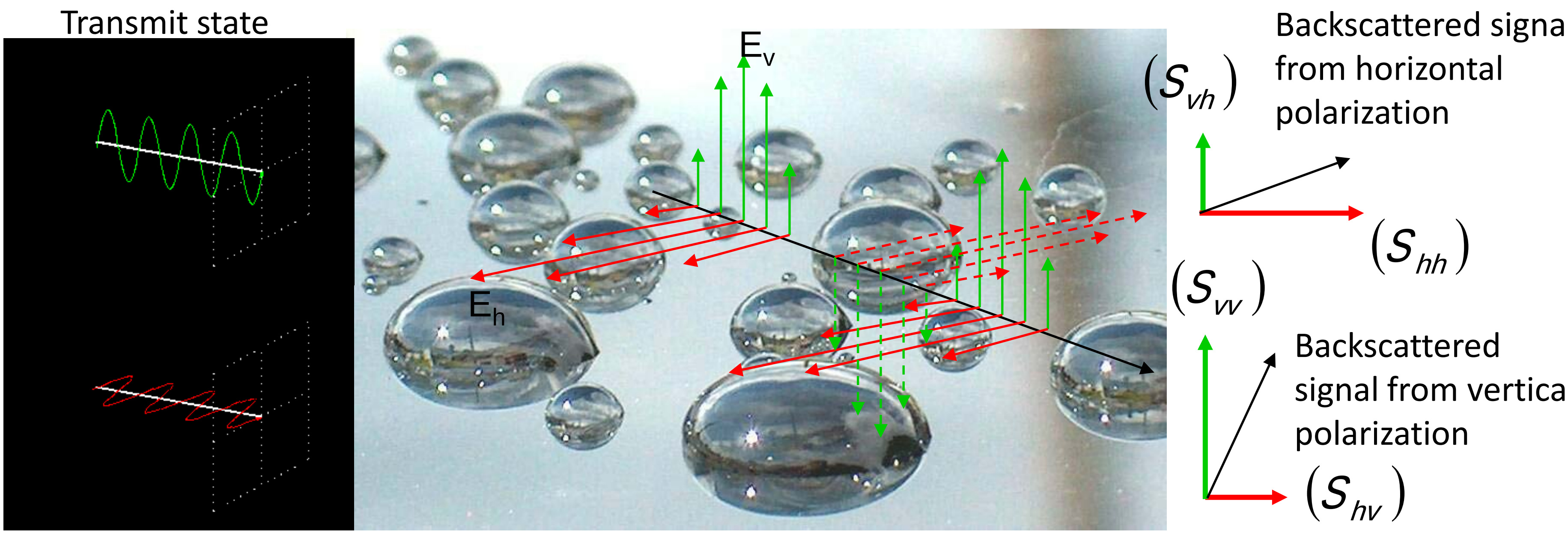
Attenuation Correction

- Corr Reflectivity
- Corr ZDR
- KDP

Meta Data

Dual Polarization Operations: Simultaneous Transmit and Receive (STAR) mode





$$\Sigma_{BSA} = \left\langle \begin{bmatrix} |S_{hh}|^2 & \sqrt{2}S_{hh}S_{hv}^* & S_{hh}S_{vv}^* \\ \sqrt{2}S_{hv}S_{hh}^* & 2|S_{hv}|^2 & \sqrt{2}S_{hv}S_{vv}^* \\ S_{vv}S_{hh}^* & \sqrt{2}S_{vv}S_{hv}^* & |S_{vv}|^2 \end{bmatrix} \right\rangle$$

Estimates of Polarimetric Variables

❖ Differential reflectivity between polarization channels provides a measure of mean particle shape

$$\hat{Z}_{dr} = 10\log_{10}\left(\frac{\hat{P}_h}{\hat{P}_v}\right)$$

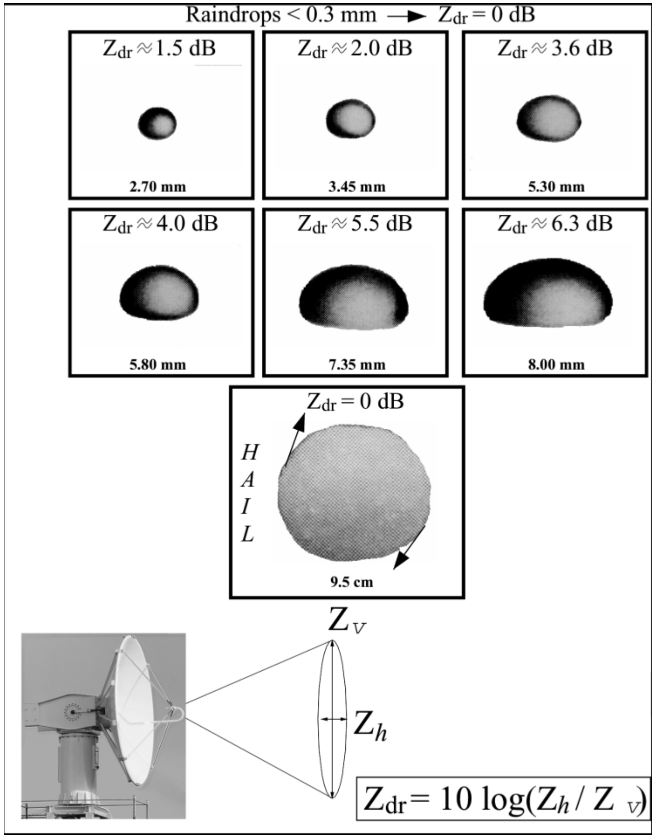
❖The differential propagation phase shift is the phase difference between vertical polarization and horizontal polarization as the wave propagates through rain

$$\hat{\psi}_{dp} = \arctan\left\{\sum_{k=0}^{N-1} v_v[k]v_h^*[k]\right\}$$

❖The correlation between the received signal in the horizontal polarization and vertical polarization is gives an indication of similarity in the nature of back scattering from the hydrometeors

$$|\hat{\rho}_{hv}(0)| = \frac{\left|\sum_{k=0}^{N-1} v_v[k]v_h^*[k]\right|}{\sqrt{\sum_{k=0}^{N-1}|v_h[k]|^2 \sum_{k=0}^{N-1}|v_v[k]|^2}}$$

❖ Linear depolarization estimates are not available



From Bringi and Chandrasekar (2001)

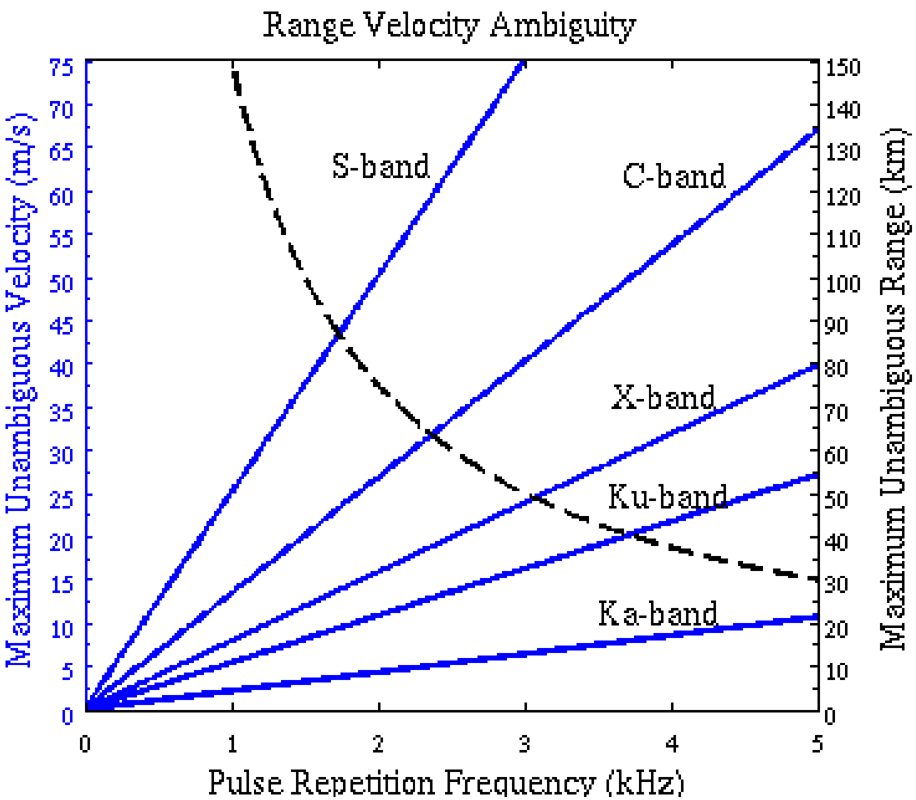
Consideration for operations

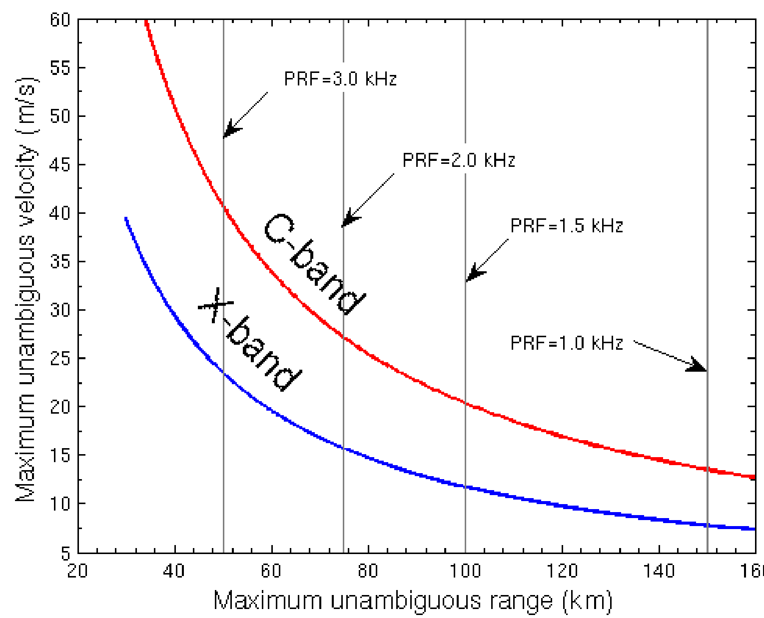
- Range velocity ambiguity
- Sensitivity
- Ground clutter suppression
- Calibration and verification
- Attenuation correction

Range-velocity ambiguity

- Maximum unambiguous range-velocity space is constrained by radar wavelength

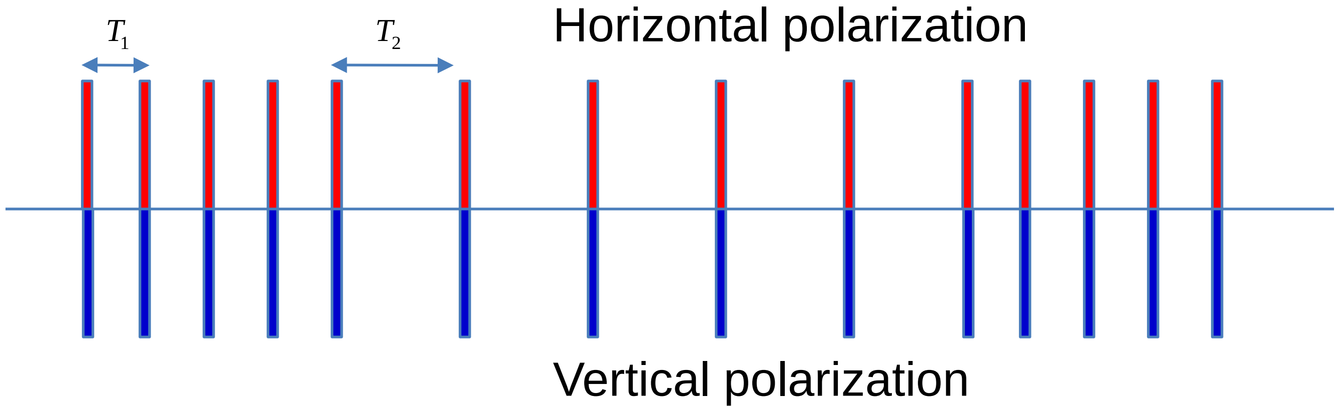
$$r_{\max} v_{\max} = \frac{c\lambda}{8}$$





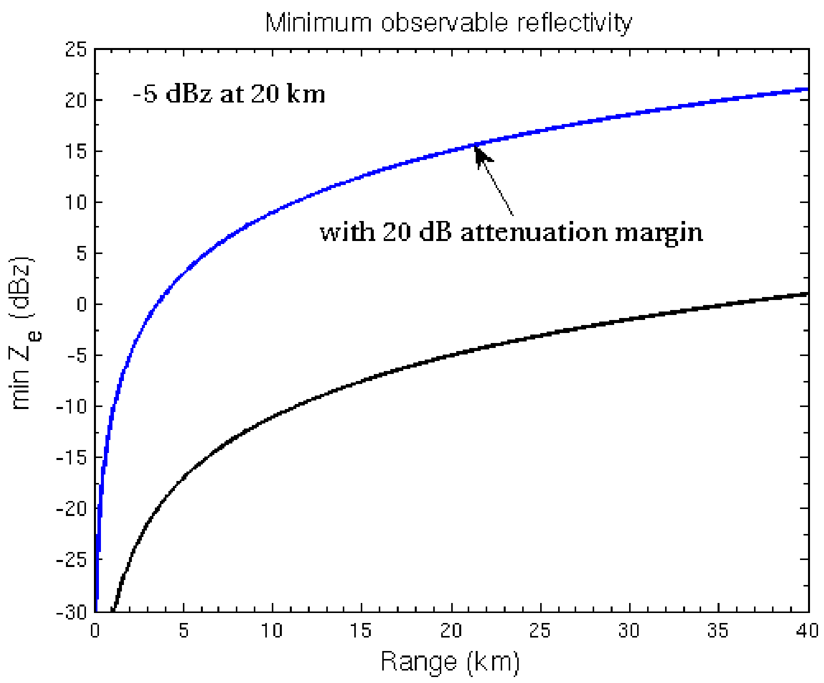
Range-velocity ambiguity

- At higher frequencies a uniform PRF waveform generally does not meet requirements
- Dual-PRF waveform is suitable for operations



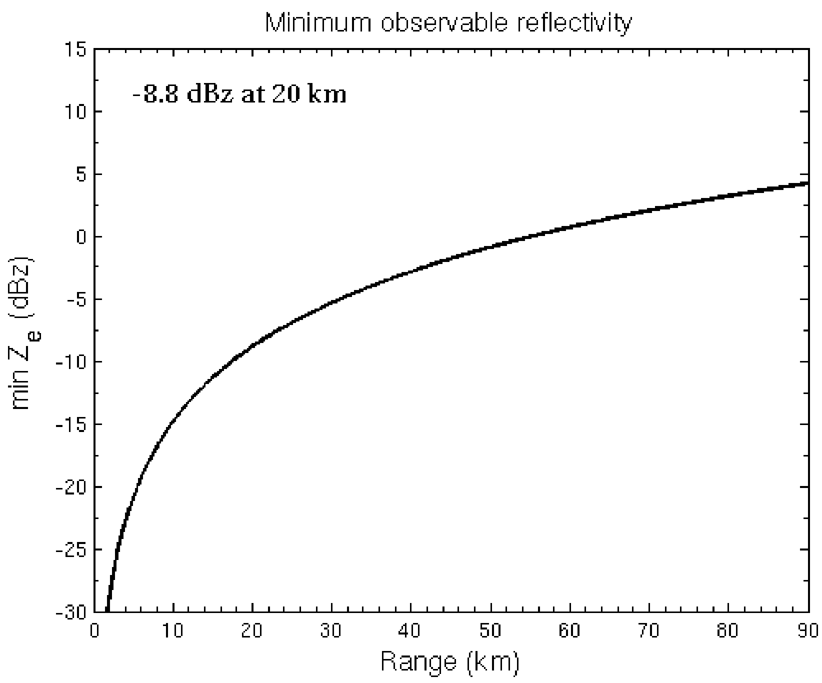
- Pulse width reduced for stable operation
- Sensitivity is reduced due to lowering of pulse width

Sensitivity of X-SAPR



❖ Range resolution: 60 m

Sensitivity of C-SAPR



❖ Range resolution: 90 m

Ground clutter suppression

- X-SAPR : Day 1 solution as provided by vendor
  - Chebyshev filter
  - GMAP: spectral domain filtering from Vaisala Sigmet RVP900 processor
  - Clutter filter on/off can be selected based on elevation angle
- C-SAPR : Day 1 solution as provided by vendor
  - Notch filter
  - Spectral domain clutter suppression
  - Clutter filter on/on selection: Clutter Mitigation Decision (CMD) from a fuzzy logic algorithm

Calibration and verification

- Calibration
  - Receiver calibration (dual channel)
  - Solar calibration
  - ZH calibration
  - ZDR Calibration
    - Using vertically pointing mode
    - Using precipitation like light rain and ice crystal observations
    - Self consistency approach
    - Spectral approach
- Verification
  - Cross-comparison between radars
  - Verification with disdrometers

Attenuation Correction

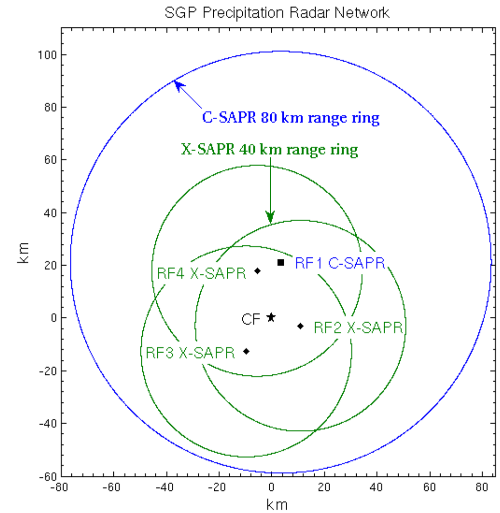
- X-SAPR
  - Vaisala's KDP estimation algorithm
  - Vaisala's version of attenuation correction algorithm
  - Mostly for rain and not mixed phase precipitation
- C-SAPR
  - ARC's KDP estimation algorithm
  - ARC's version of attenuation correction algorithm
  - Mostly for rain and not mixed phase precipitation
- Attenuation Correction only applicable with no signal extinction
- Mixed phase precipitation is an active research topic

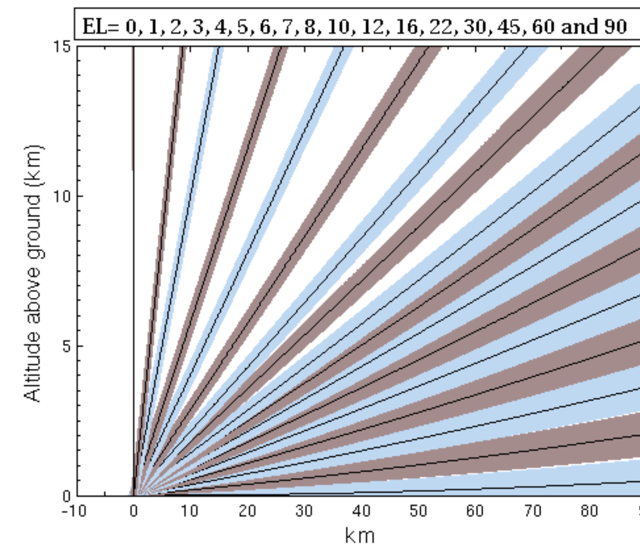
Need MC3E Specific requirements

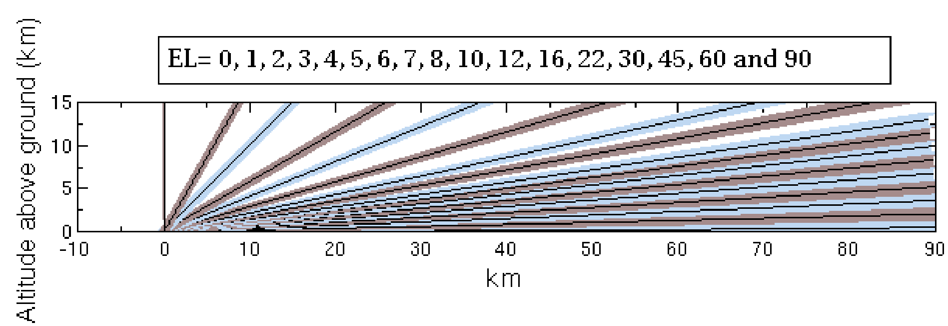
- The radar operating parameters are governed by operational requirements
- The volume coverage needs:
  - Spatial
  - Temporal
- For example, dual-Doppler synthesis
  - Coverage for storm top: Multiple RHIs
  - Coverage closer to the surface: Lower level PPIs
  - High Nyquist velocities
  - Operable for a fairly wide spectral width
  - Volume coverage from multiple radars are obtained in the same time interval
  - sampling volume is not too large
- And more …

Example : Volume scan for X-SAPR

- 17 tilts with PPI sweeps of 360 degree (including zenith)
- 24 cuts with RHI sweeps of 90 degree (15 deg interval in azimuth)
- One of the 24 RHI is over Central Facility
- ``Bird bath'' (Zenith sweep) for ZDR calibration
- Scan speed 22.5 deg/s
- ~7 min (PPI+RHI) volume update
- Dual-PRF waveform
- Unambiguous range: 60 km
- Unambiguous velocity: 39 m/s
- Range resolution: 60 m
- Azimuth resolution: 0.9 deg







Example : Volume scan for C-SAPR

- 17 tilts with PPI sweeps of 360 degree (including zenith)
- 24 cuts with RHI sweeps of 90 degree (15 deg interval in azimuth)
- One of the 24 RHI is over Central Facility
- ``Bird bath'' (Zenith sweep) for ZDR calibration
- Scan speed 16 deg/s
- ~9 min (PPI+RHI) volume update
- Dual-PRF waveform
- Unambiguous range: 90 km
- Unambiguous velocity: 43 m/s
- Range resolution: 90 m
- Azimuth resolution: 1.0 deg