Advances in the Testing and Evaluation of Airborne Radar through Realtime Simulation of Synthetic Clutter

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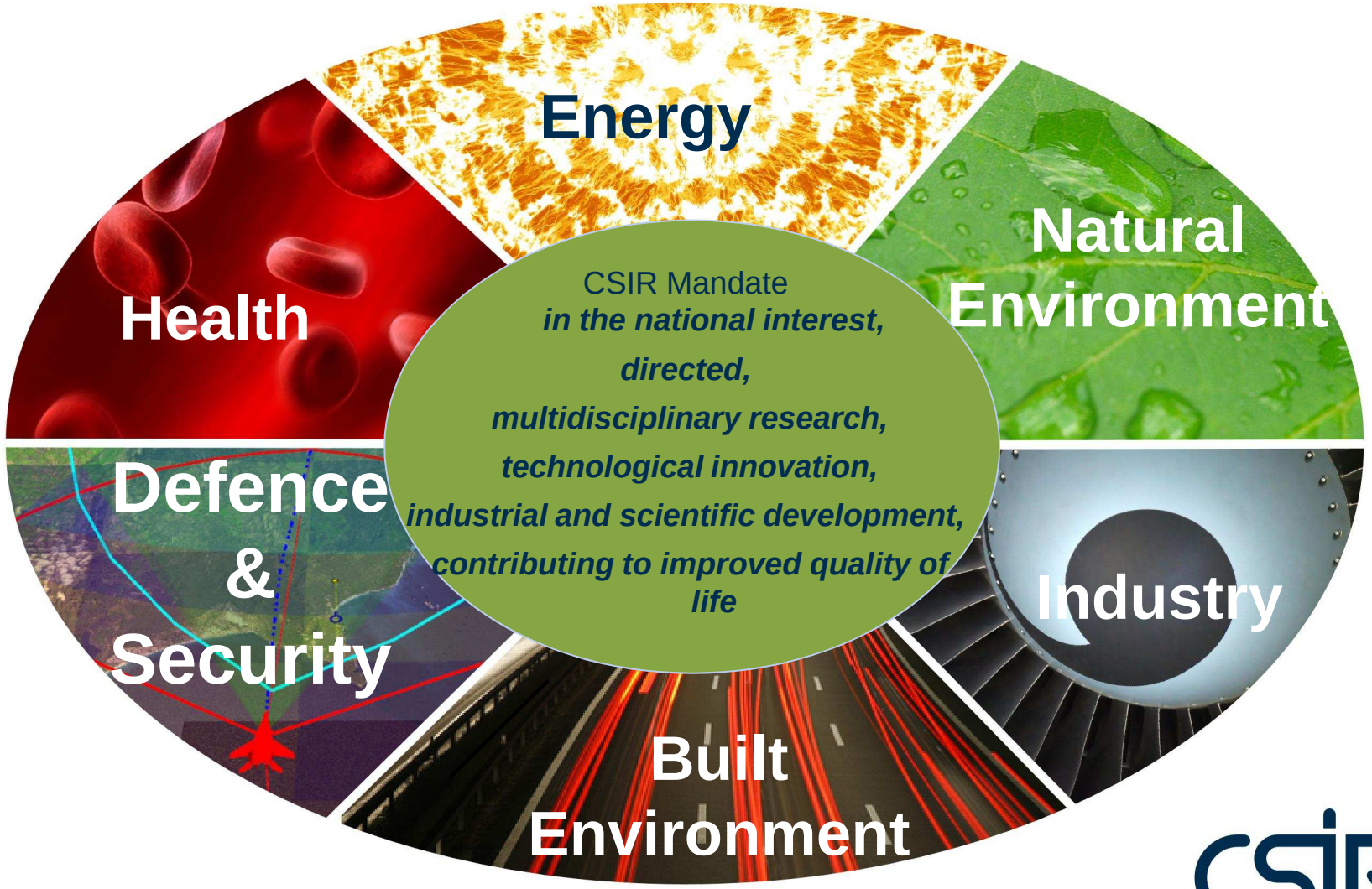
Synopsys of presentation objectives

- Short overview of the CSIR and its history in Radar
- Current state of clutter simulation technology on the CSIR 4th generation DRFM platform and its place in the radar environment simulation domain
- Technological advancements and challenges in the simulation of clutter for an airborne radar platform is discussed

Where we are from: South Africa

CSIR Research Impact Areas



CSIR DPSS Strategic Position with DOD

Fundamental research

-understanding fundamental principles

Strategic basic & applied research

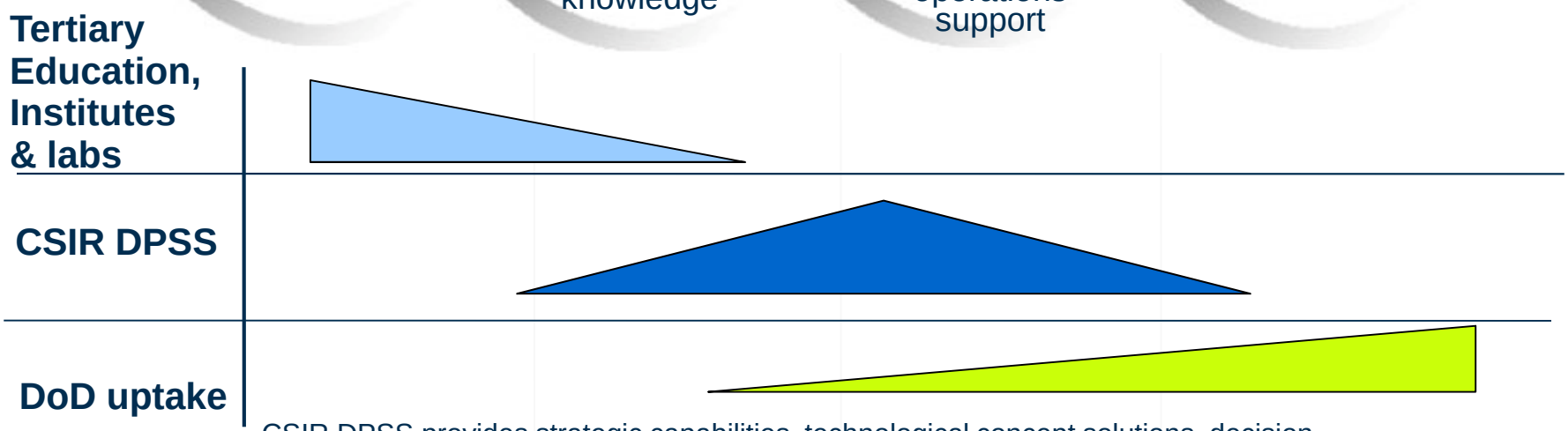
- generation of new knowledge and application of existing knowledge

Technology & Decision Support

- development of new concept solutions, decision & operations support

Technology uptake & implementation

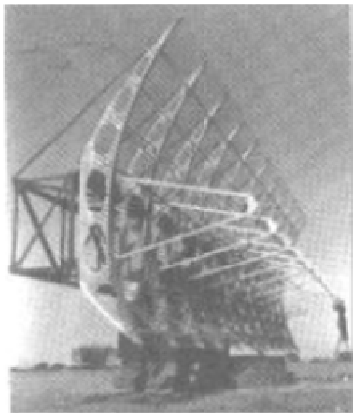
- Impact on DoD success



CSIR DPSS provides strategic capabilities, technological concept solutions, decision support, development of concepts of operation and the congruent with the DoD's operational needs as expected at some future date

Industry supplies the kit, often dictated by the specifications derived from CSIR DPSS work

Radar History Highlights

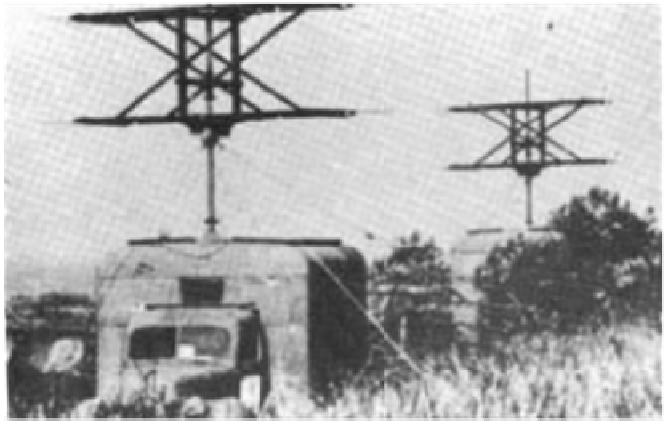


1939 1959 1968 1981 1988 1995 2001 2005

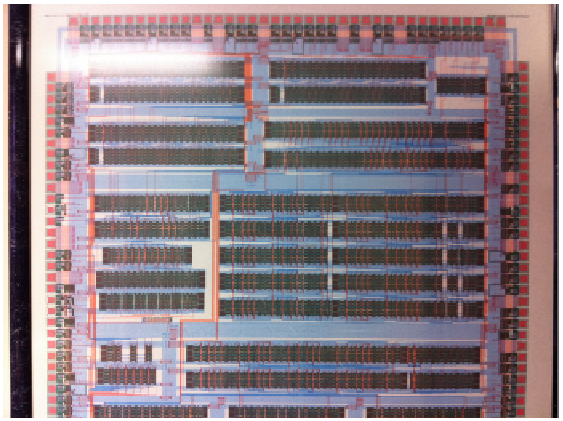
Radar Technology Development Projects

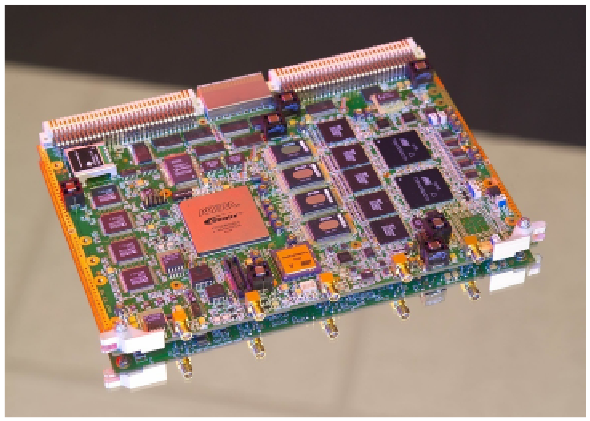
JB1 JB51 Cactus Nimbus Fynkyk Meccano ORT MECORT

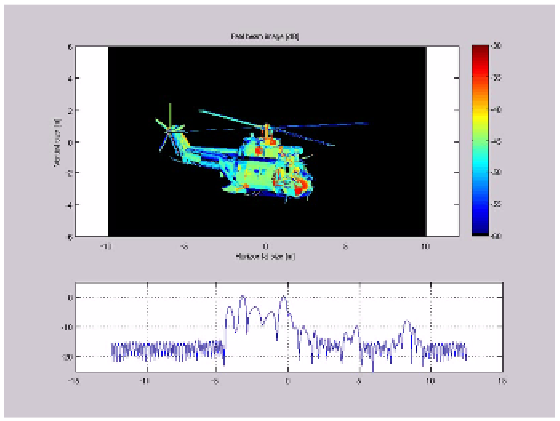
Angola border war 1966-1989



Digital Radio Frequency Memory History





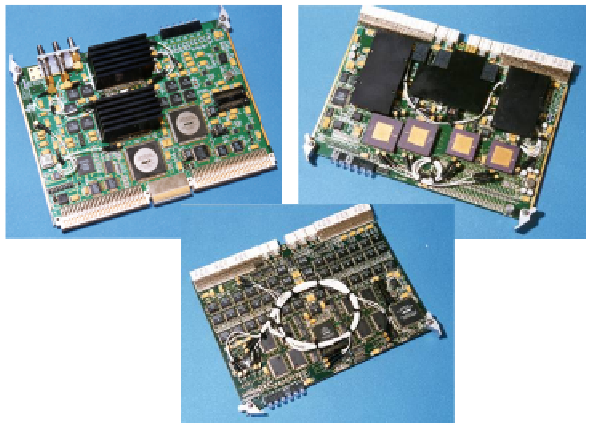


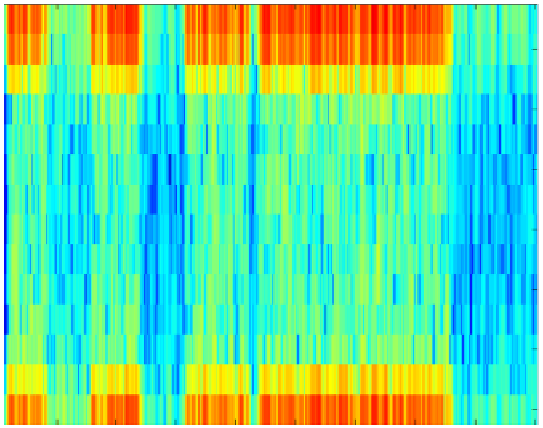
199x 1999 2004 2007 2009 2010 2012

DRFM Technology Development Projects

1st Gen 2nd Gen 3rd Gen 4th Gen Complex targets Clutter 5th Gen

IBW: 400 MHz 500 MHz 800 MHz 2 GHz



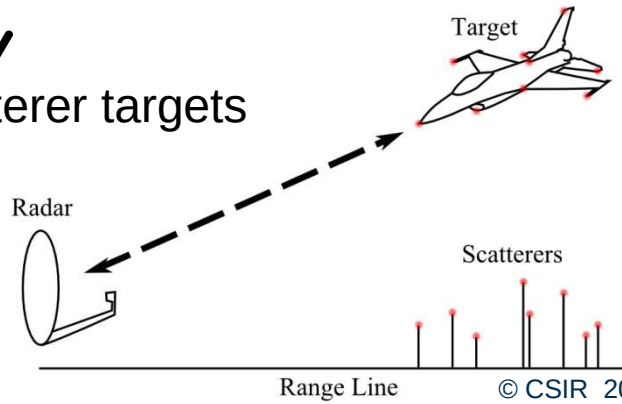


Radar Environment Simulation

Where does clutter simulation fit?

Radar Environment Simulation

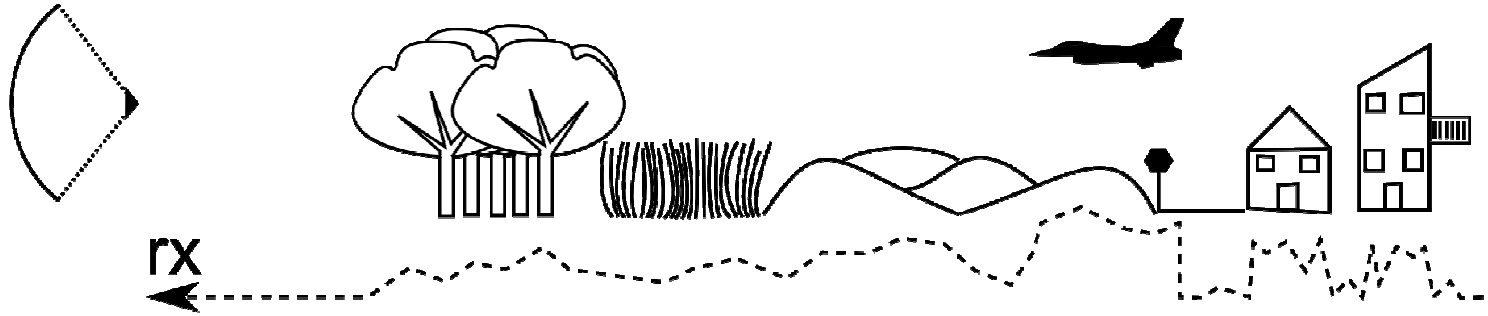
- **Target Simulation**
  - Point targets
    - Multi scatterer targets
- **Electronic Attack**
  - Jamming
- **Target Environment**
  - **Clutter**



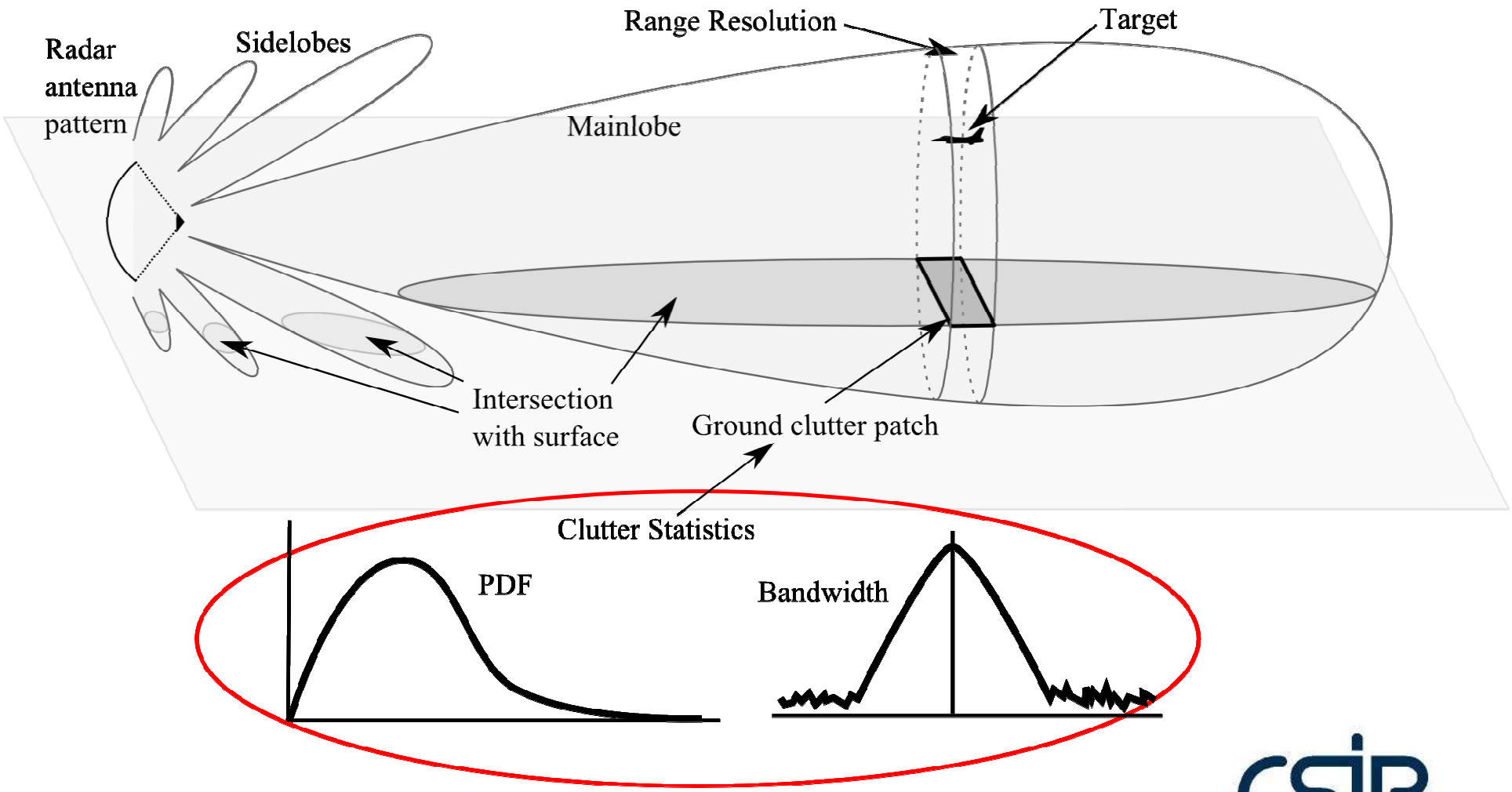
Radar Clutter context

Ideal case:

Reality:



Radar Clutter context



Radar Clutter context

The Problem:

- Clutter returns interfere with the object of interest (target)
- The performance in clutter is a critical aspect of the radar
- Real world testing of a radar against all types of clutter for all possible types of scenarios is costly and difficult to re-create
- Software simulation cannot take all the finer details of the complete design and implemented system into account
- Severely limited with software simulation if you are required to verify a radar purchased from a 3rd party

Radar Clutter context

The Solution:

- Hardware in the loop simulation on DRFM based hardware
- Statistical modelling of clutter, NOT recorded data
- Playback of recorded data is radar and configuration dependent

Radar Clutter context

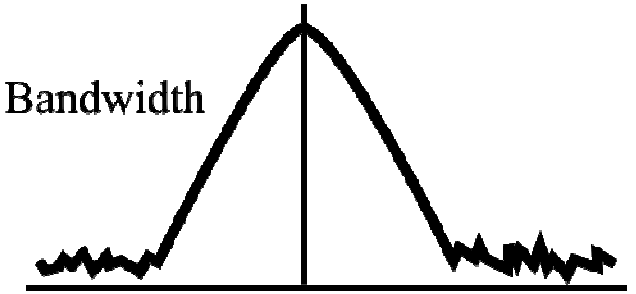
Advantages of this approach:

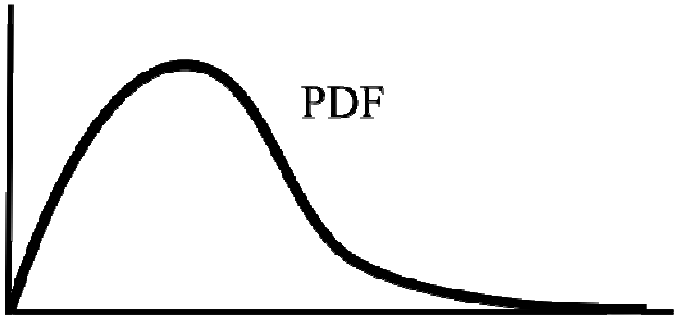
- Cost effective
- Test many different scenarios relatively quickly
- Repeatability of experiment with the same parameters
- DRFM approach to Hardware in the loop simulation is **radar independent**

Clutter from literature

Considerations for high fidelity clutter generation

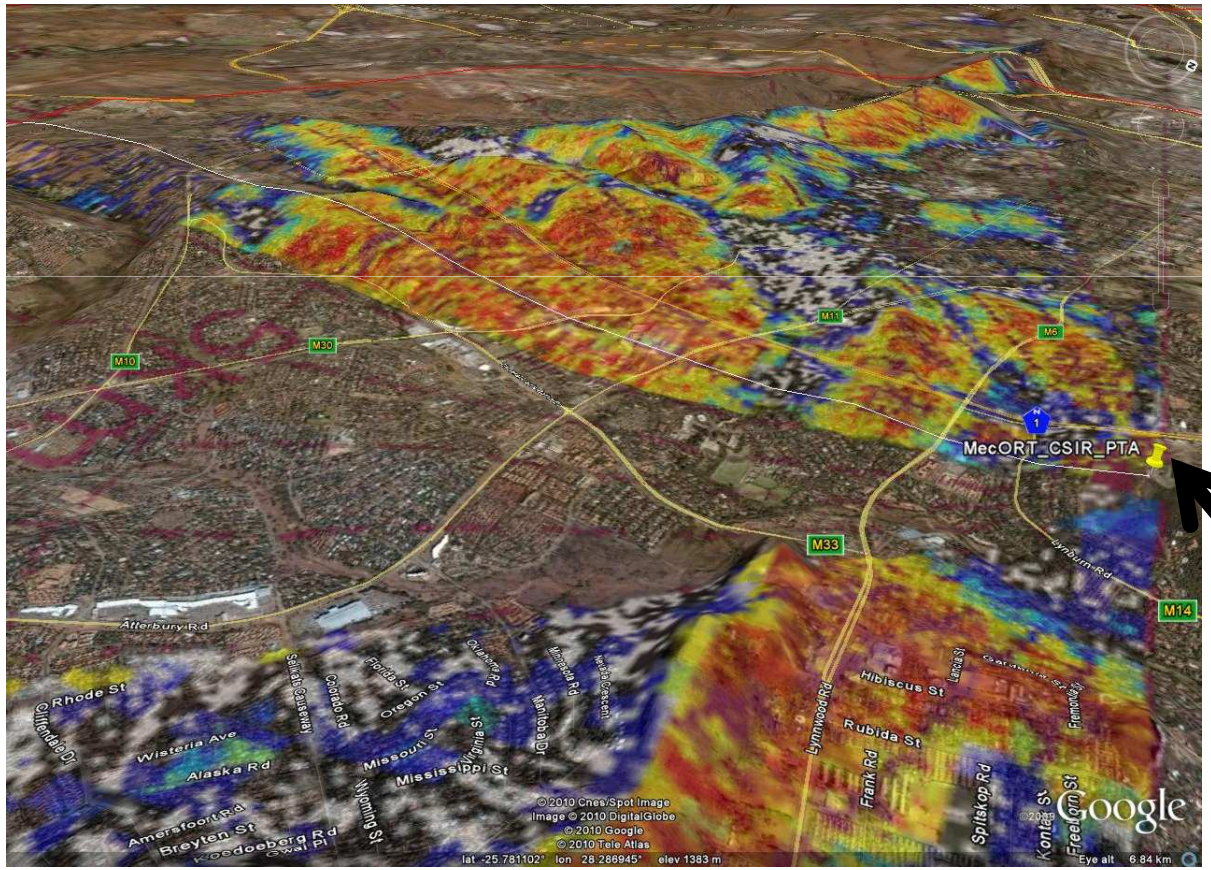
- Clutter Radar Cross Section (RCS)
- Number of discrete scatterers
- Spatial extent of clutter
- Velocity extent of clutter (Doppler spectrum)
- Wavelength dependence
- Amplitude distribution
- Spatial correlation
- Polarization properties





Synthetic Clutter Simulation

CSIR approach:



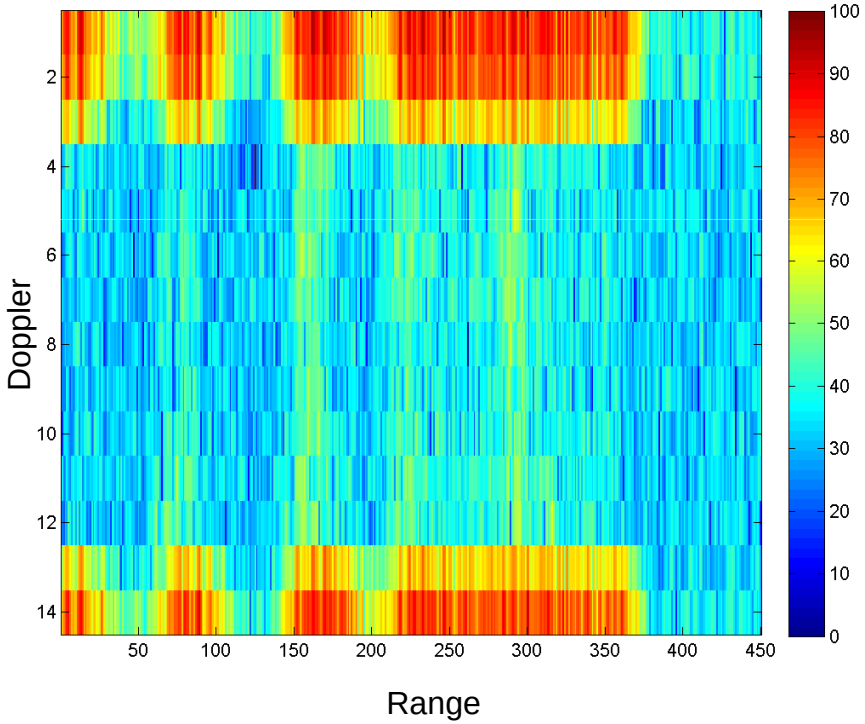
Record accurate data as part of the development cycle for a Synthetic clutter simulator

Figure on left:
Data captured with the measurement radar of the CSIR

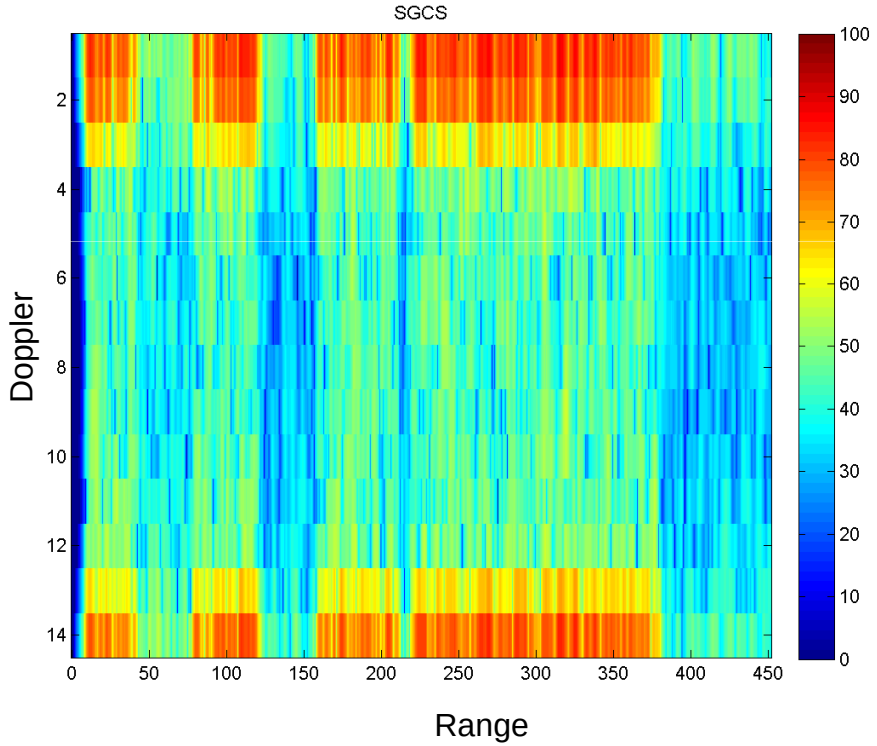
Synthetic Clutter Simulation

Synthetic Ground Clutter: Range Doppler map comparison

Measured clutter with CSIR radar



Synthetic Ground Clutter



Synthetic Clutter Simulation

What has been achieved thus far:

- **Correlated** ground clutter (Rayleigh, Weibull, Log-Normal)
- Stationary platform
- Gaussian approximation to clutter bandwidth
- **2 million**+ **independent** clutter **scatterers** in a range line
- **500 MHz** instantaneous bandwidth
- Input pulse lengths from 50 ns up to 300 us
- PRF from 0.8 kHz to 300 kHz

- Synthetic Clutter Simulation System covers large number of radar systems

Synthetic Clutter Simulation

Current research:

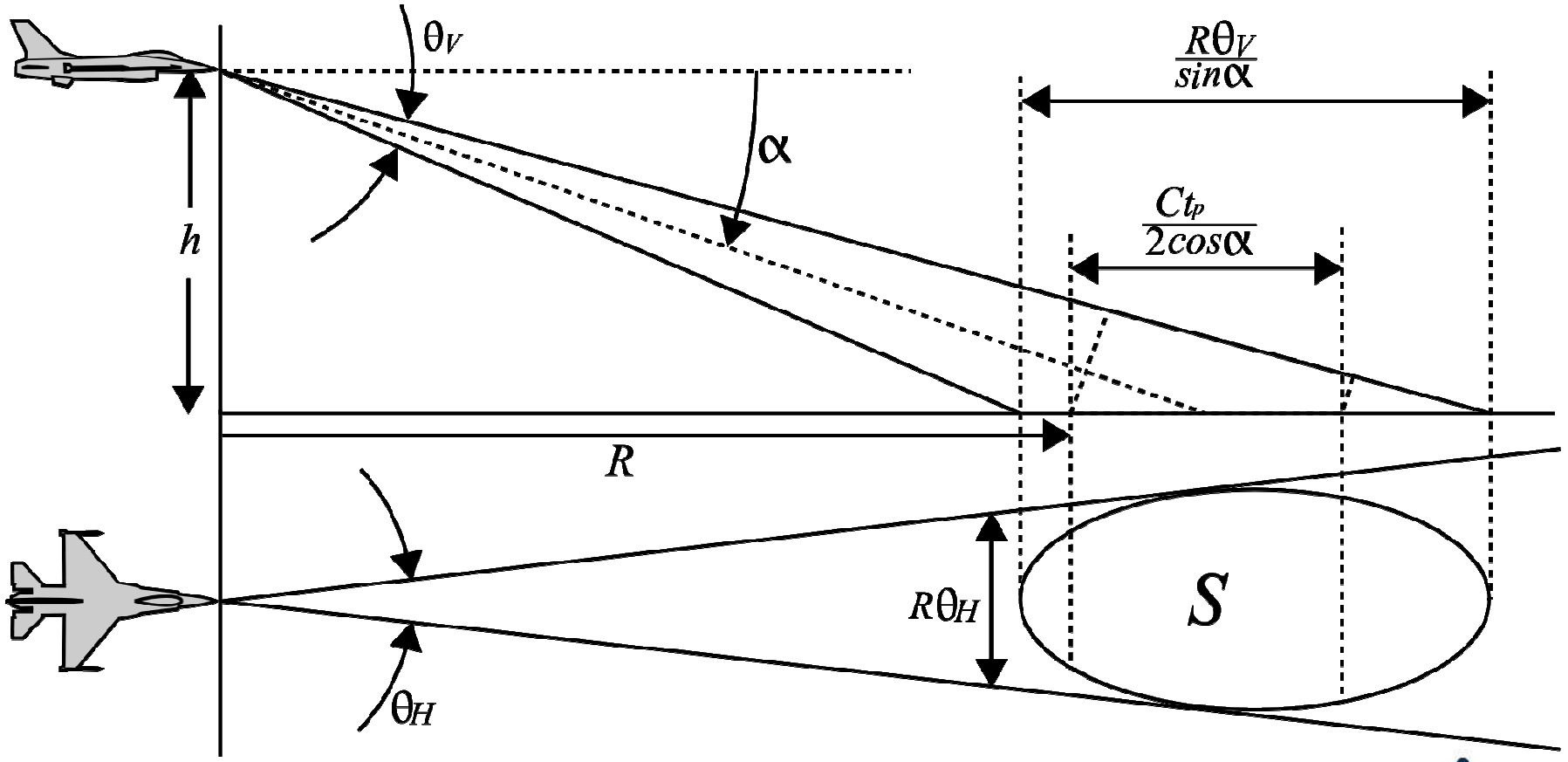
- Clutter for a moving airborne platform

The Challenge:

- For stationary radar platforms the mainlobe is sufficient
- For moving airborne radar platforms the mainlobe is not the only contributing factor to the radar range Doppler map
- Antenna sidelobes of the radar becomes a large contributing factor

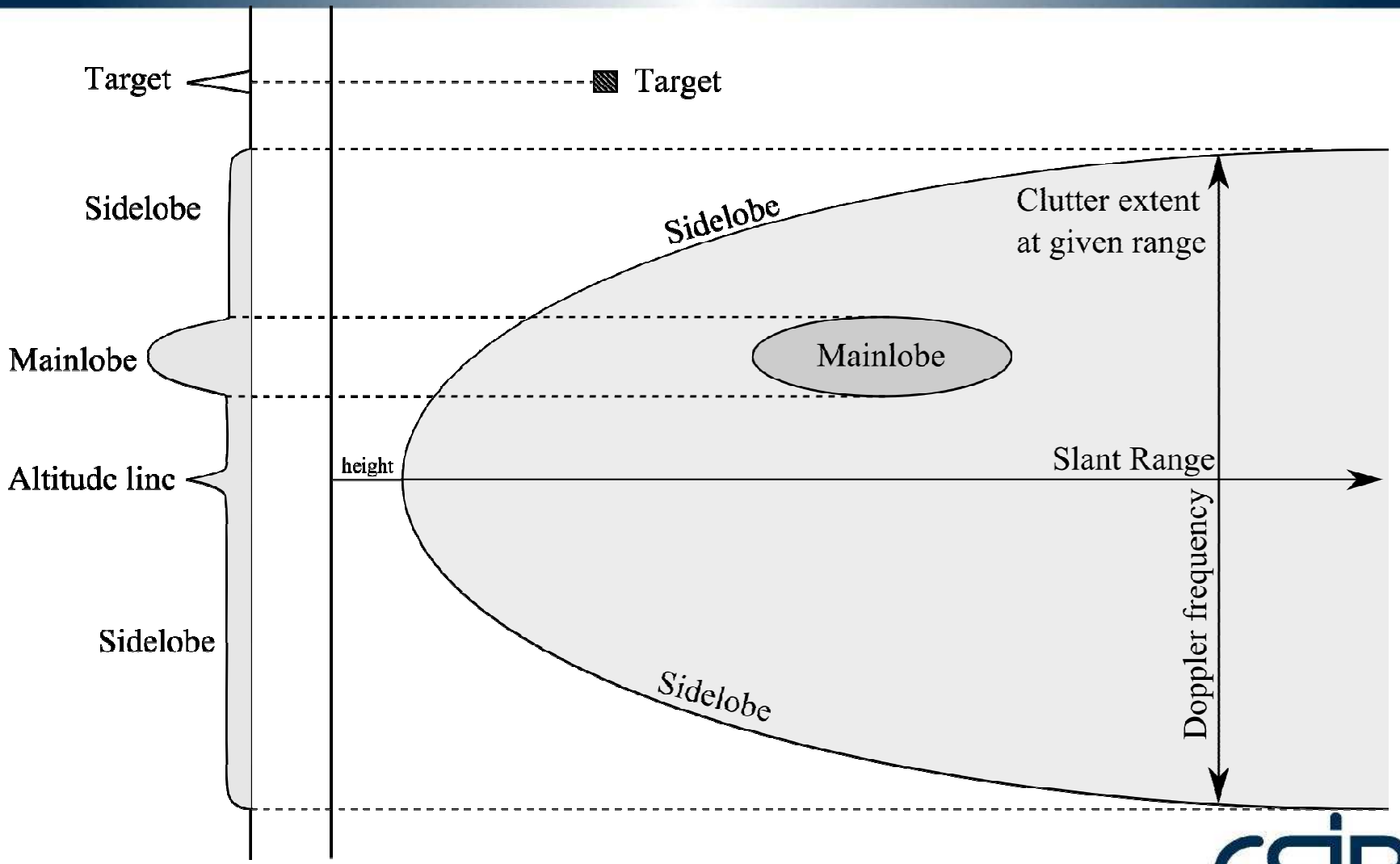
Synthetic Clutter Simulation

Mainlobe only scenario



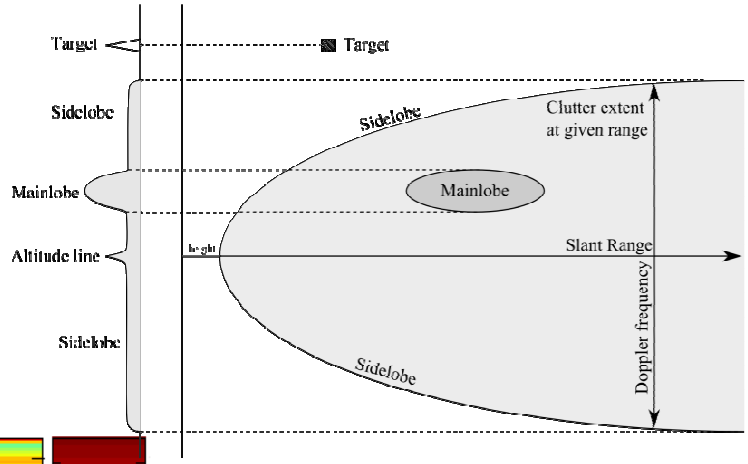
From: N. Levanon, Radar Principles

Synthetic Clutter Simulation

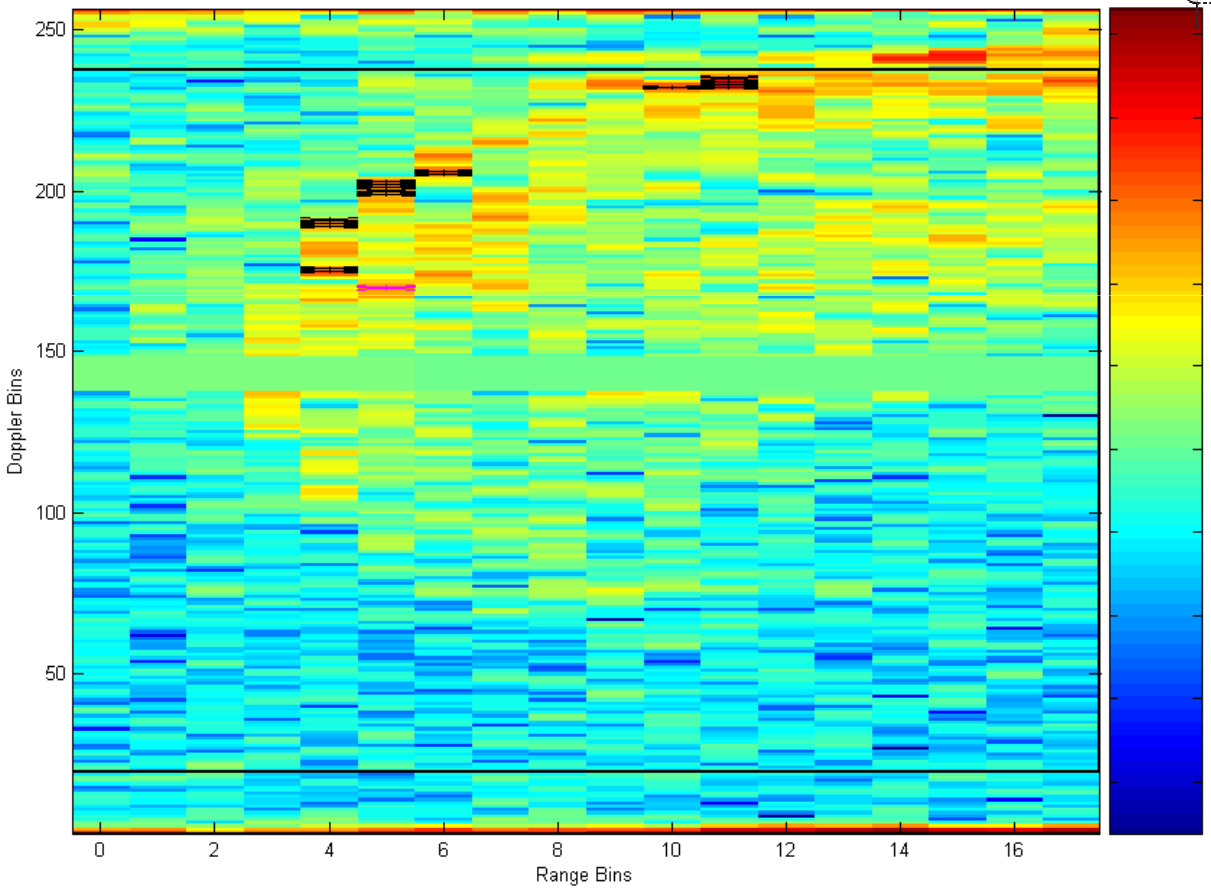


From: G. Morris and L. Harkness, Airborne Pulsed Doppler Radar

Synthetic Clutter Simulation



Recorded Data Airborne Range Doppler map



Data from:

DENEL DYNAMICS

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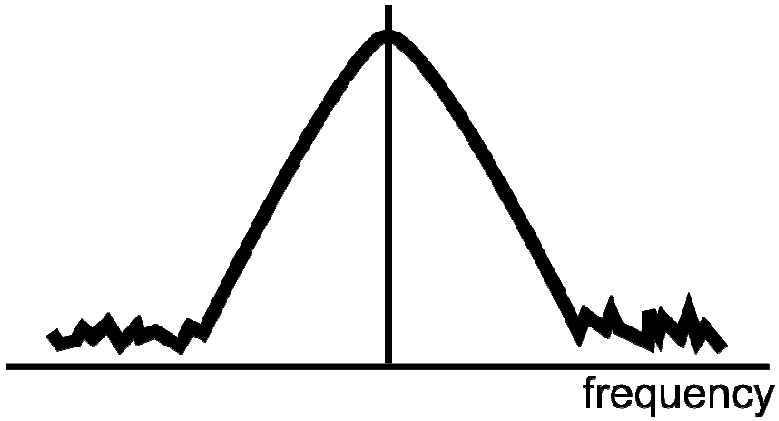
Synthetic Clutter Simulation

Building the airborne radar Range Doppler map:

- It is relatively easy to adapt the mainbeam of the stationary ground based platform to the moving airborne platform case
- Apply a Doppler offset that corresponds to the look direction and range of the intersection with the surface
- Airborne platform (because of its movement) spends less time looking at the same patch of ground, thus less correlation between pulses, which results in a wider bandwidth

Synthetic Clutter Simulation

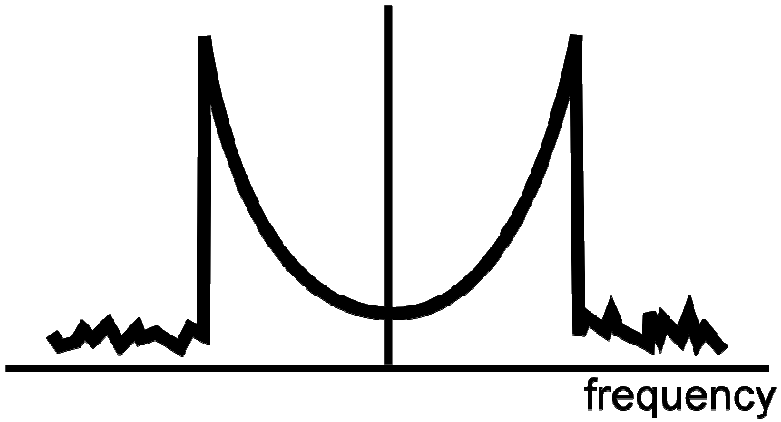
Spectrum of mainbeam



- Gaussian Doppler power spectrum

- Simple to implement

Spectrum of sidelobes



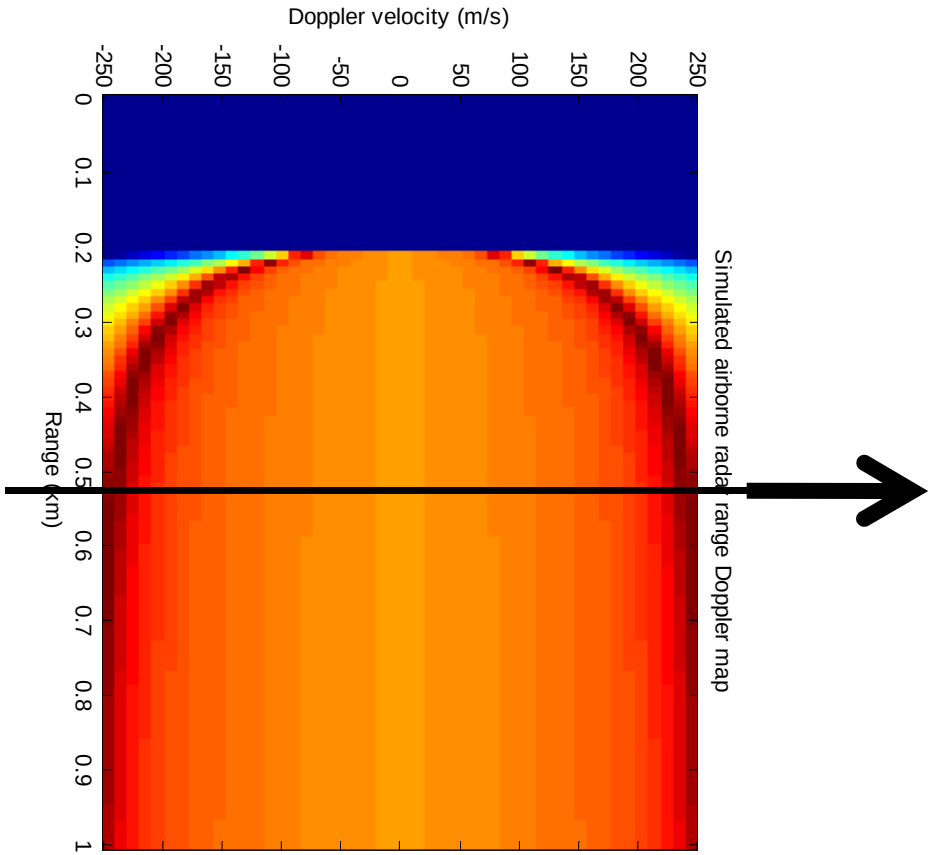
- Jakes Doppler power spectrum

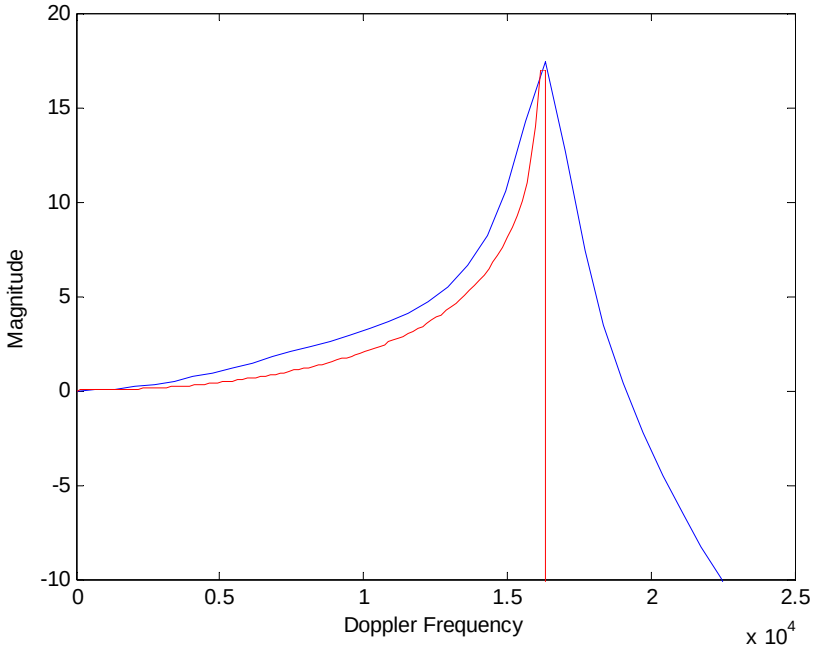
- Computationally expensive to implement

Synthetic Clutter Simulation

Sidelobe simulation

Simulated range Doppler map with the DRFM sidelobe clutter algorithm





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Synthetic Clutter Simulation

Technological tradeoffs:

- Bandwidth spectral shaping quality
- Fidelity of clutter (number / update frequency, of clutter samples)
- Complexity of statistical distribution shape
  - Rayleigh (least complex)
  - Weibull (medium complexity)
  - Log-Normal (medium complexity)
  - K-Distribution (most complex)

- More DRFMs in same system means more resources available

Synthetic Clutter Simulation

Challenges:

- Difficult to split a single scenario over multiple DRFMs
- "High" latency and "low" transfer rate between seperate DRFM systems (relative to on chip)
- This bottleneck makes it difficult to sync clutter scatterers

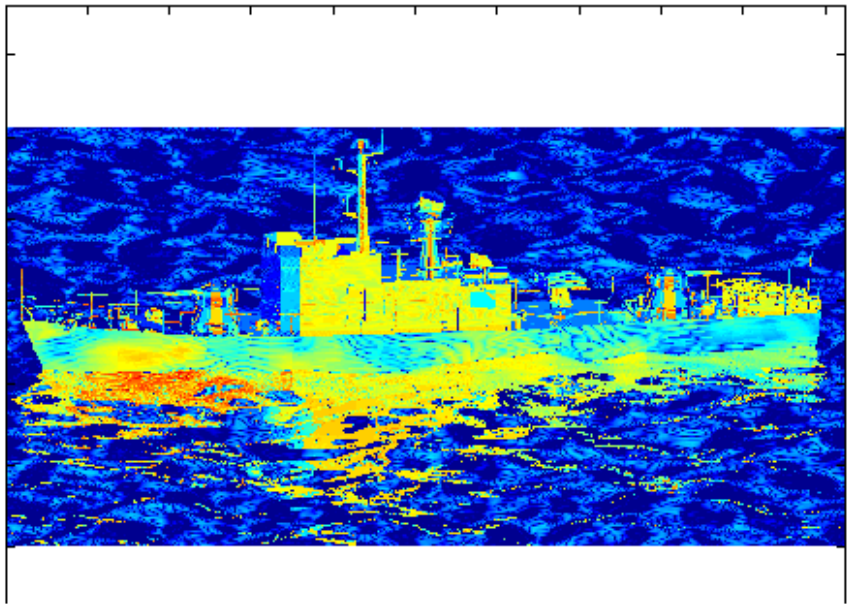
Synthetic Clutter Simulation

Possible Solution:

- Mainlobe / Sidelobe is an ideal split for the use of multiple DRFMs
- Statistics of mainlobe is different and uncorrelated to that of the sidelobe
- Thus one can get away with minimum sync of scatterers

Future of Synthetic clutter

- **Trend in capability:** Integrated systems combining all aspects of simulation
- Electro Magnetic (EM) modelling and advanced scenario control that feeds into the hardware in the loop radar environment simulation (RES)
- EM modelling drives complex scatterers for targets
- Advanced scenario control updates the RES



The End

Special thanks:

Airborne radar data provided by:

For further questions or comments please visit us at booth 1307 at the exhibition

Or contact me at - jjstrydom@csir.co.za