Radar Conference 2014 – Lille, France (part of the cycle of 5 …)

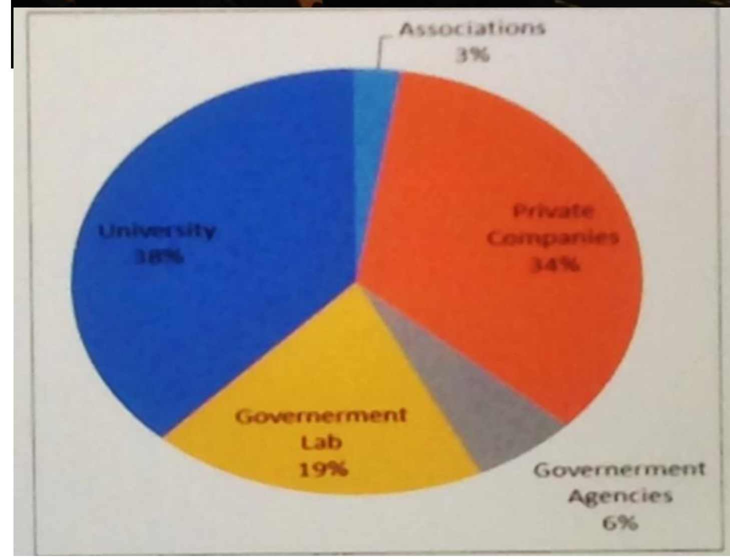
Attended by / inputs from (in no particular order)

W Nel, J Steyn, J de Witt, J Strydom, F Maasdorp

Some insights and 'trends'

Summary of conference

- > 450 attendees
- 381 submission, 247 selected papers
- Review Panel: 165 members
- 3 parallel tracks
- **New addition: Industry demonstration sessions**
- Several Invited / Special sessions
  - Metamaterials
  - Stealth target detection
  - Cognitive Radar & Resource management
  - ISAR Imaging and ATR
  - T/R Modules
  - ITP SIMCLAIRS



The main aim of SIMCLAIRS is to deliver **new technology solutions in the field of UAV RF payloads** with the combination of SAR/MTI, FOPEN, ESM and possibly comms.

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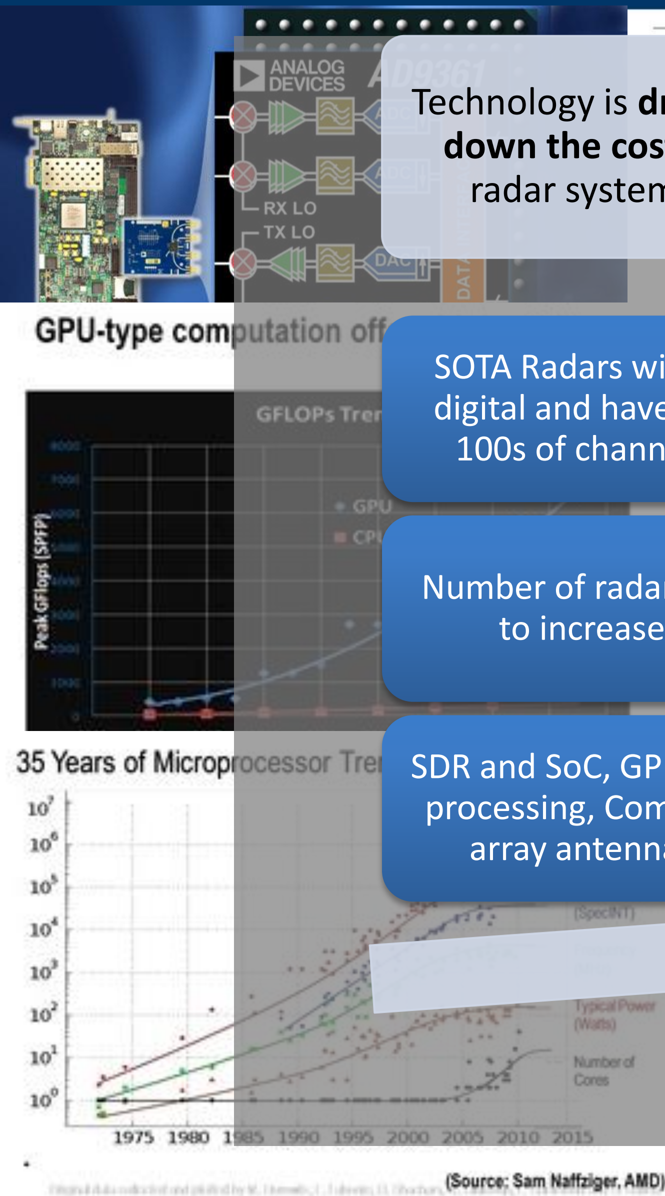
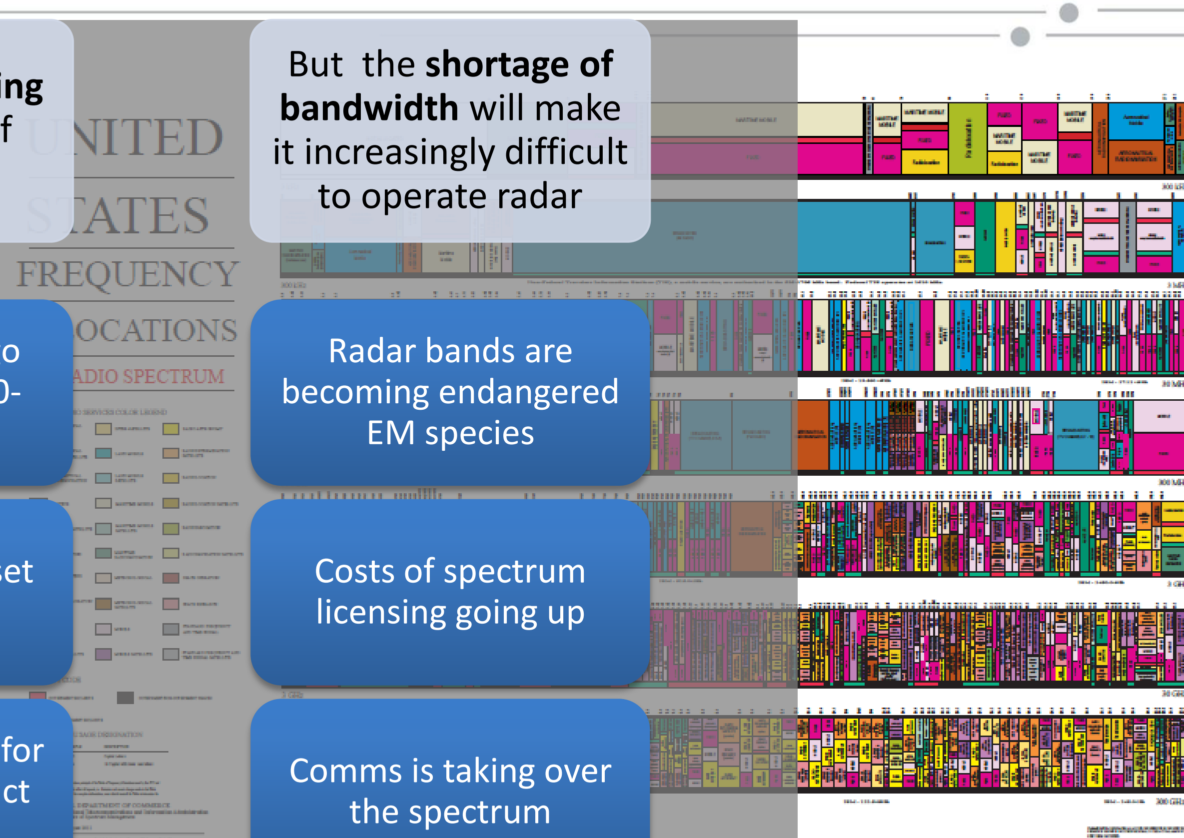
Diving right in: Underlying themes …





Technology is **driving down the cost** of radar systems

But the **shortage of bandwidth** will make it increasingly difficult to operate radar

SOTA Radars will go digital and have 10-100s of channels

Radar bands are becoming endangered EM species

Number of radars set to increase

Costs of spectrum licensing going up

SDR and SoC, GPUs for processing, Compact array antennas

Comms is taking over the spectrum

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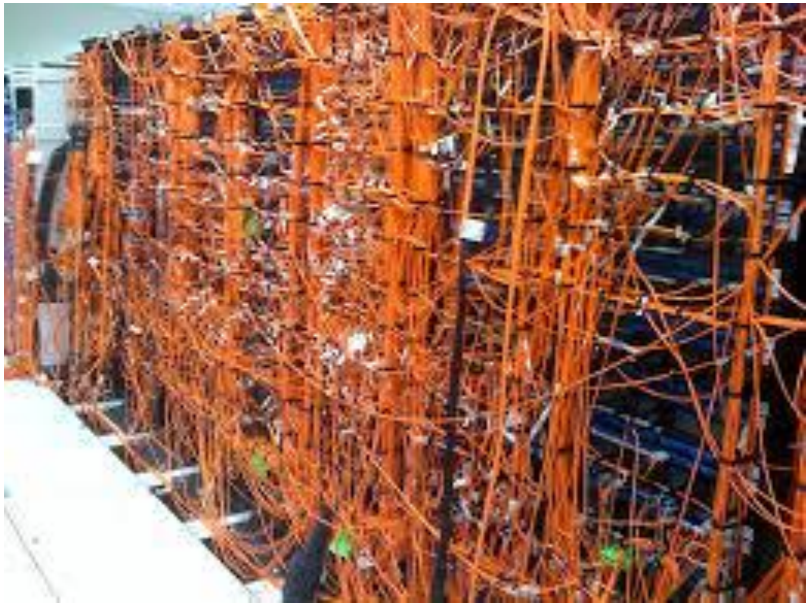
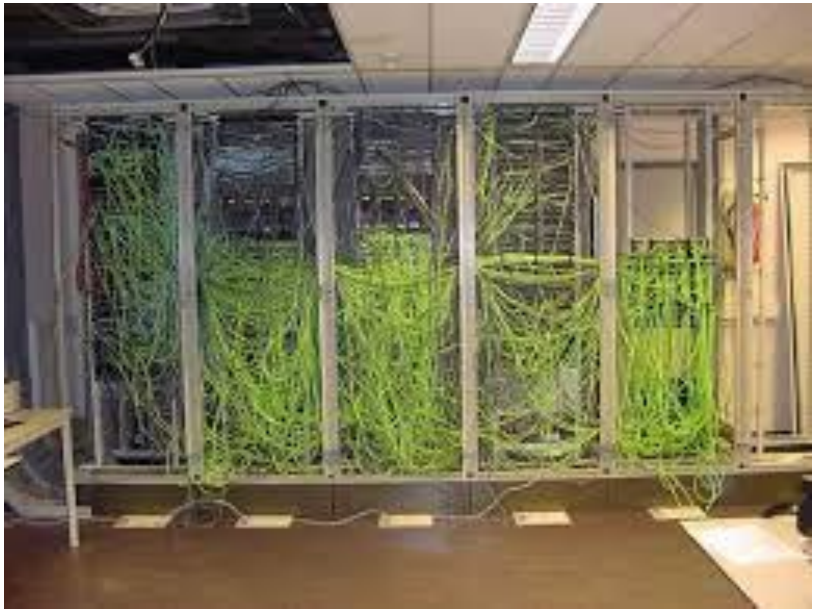
Digital radar with many channels might become quite a challenge





Careful not to end up with radar's that look like this!

Spectrum congestion & interference

- **Radar Implications: will have to share the spectrum**
  - No Control / access: PCL / Commensal
  - Some control / access: Multi-purpose coding, White-space systems
  - Shared Aperture: Joint designs – seems unlikely unless radar application brings significant benefit?
- Cognitive Radar and Waveform Diversity has become topics of regular interest at radar conferences
  - Aimed at handling some of these issues
- What could this mean for EW?
  - Less effort to jam because radars are already operating on the edge?
  - More effort to jam because radars will be made increasingly robust against interference?

Radar is a complex topic – but we are making progress!!

Early attempts at cognitive radar?

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European focus on UAV radar technology

- ONERA (France) developing CURACAO system
  - Very high-resolution X band SAR imagery with real-time processing capacity
  - Real-time coherent change detection
  - Detection of moving targets, integration of GMTI/STAP techniques, and SAR/GMTI combined modes
  - 25 kg

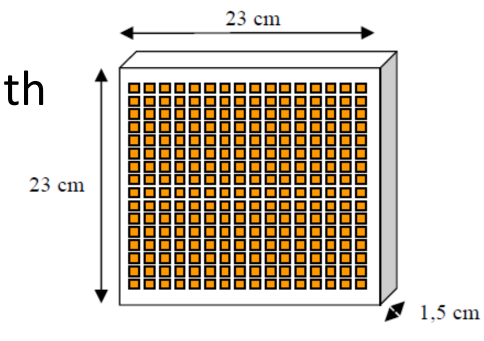
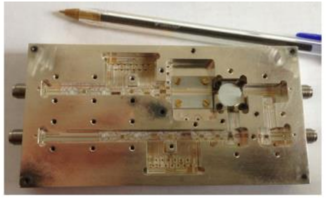


Figure 3. AESA Antenna



(a)

(b)

- ITP SIMCLAIRS program
  - Program by European Defence Agency, involving France, Sweden and UK (4 companies)
  - **S**tudies for **I**ntegrated **M**ulti-function **C**ompact **L**ightweight **A**irborne **R**adars and **S**ystems
  - Large budgets
  - Short time frame (4 years)
  - Develop technology building blocks up to TRL 4
  - Indicates Europe is serious about airborne radar for small platforms (UAVs)

SELEX GALILEO | SAAB
THALES
THALES UK
THALES
THALES SYSTEMES AEROPORTES

Steady advancement of technology ….

- Metamaterials moving from ‘science’ to ‘application’
  - absorbent material, **overcoming antenna size and scanning limits**, wave reflection direction vs aerodynamics, tiled arrays.
  - ‘practical’ cloaking on a small scale
    - Reducing signature
    - Or modifying it to look like something else
    - How do you engage a missile you can’t detect and track

IV. Measurement results

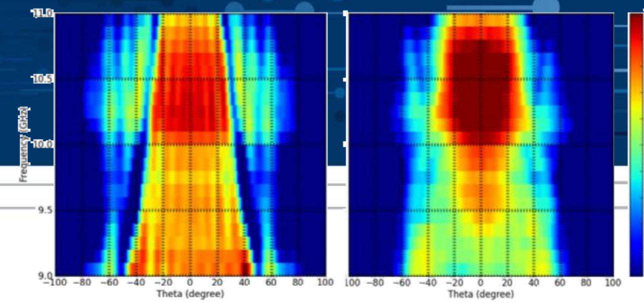
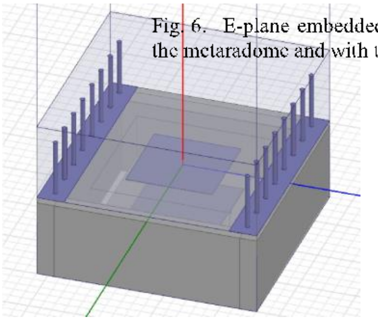
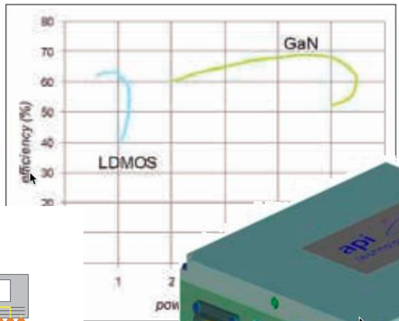
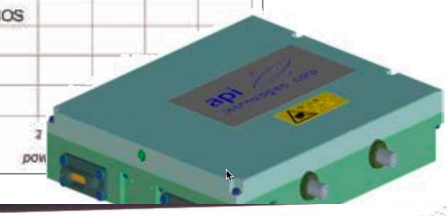


Fig. 6. E-plane embedded radiation patterns of the central element (without the metaradome and with the metaradome).







- GaN steadily advancing
  - Power amps
  - T/R modules
  - Configurable filters
  - Tile antennas
  - And more …

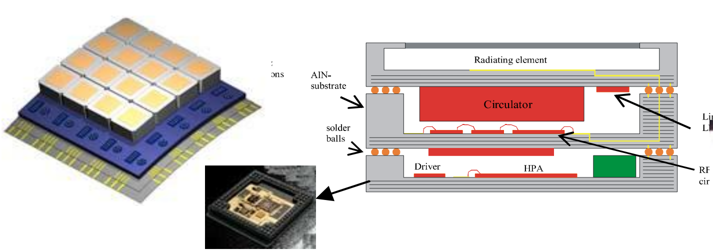
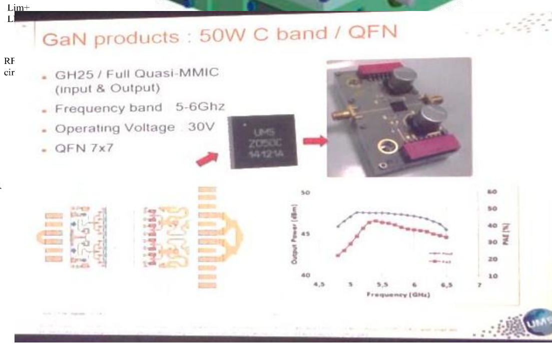
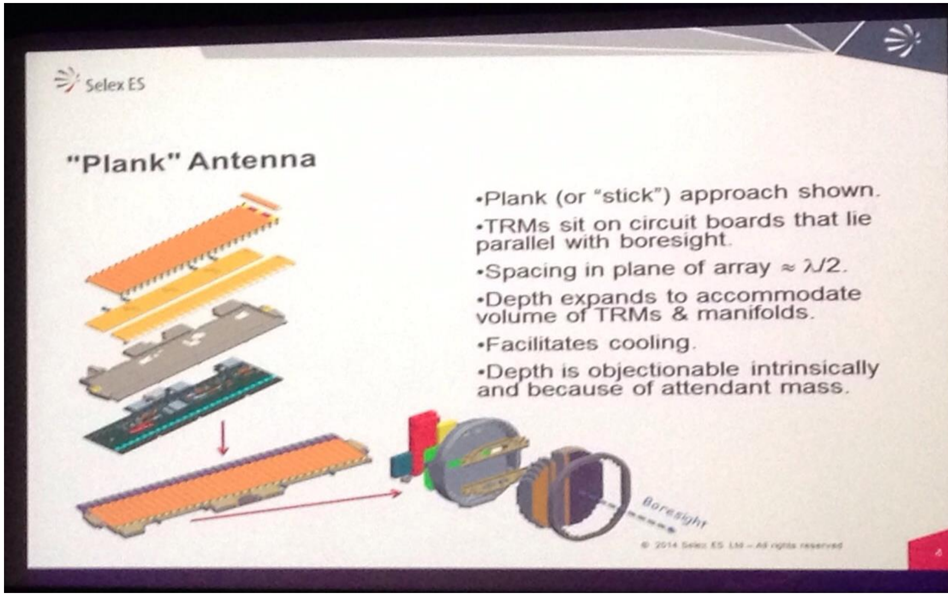
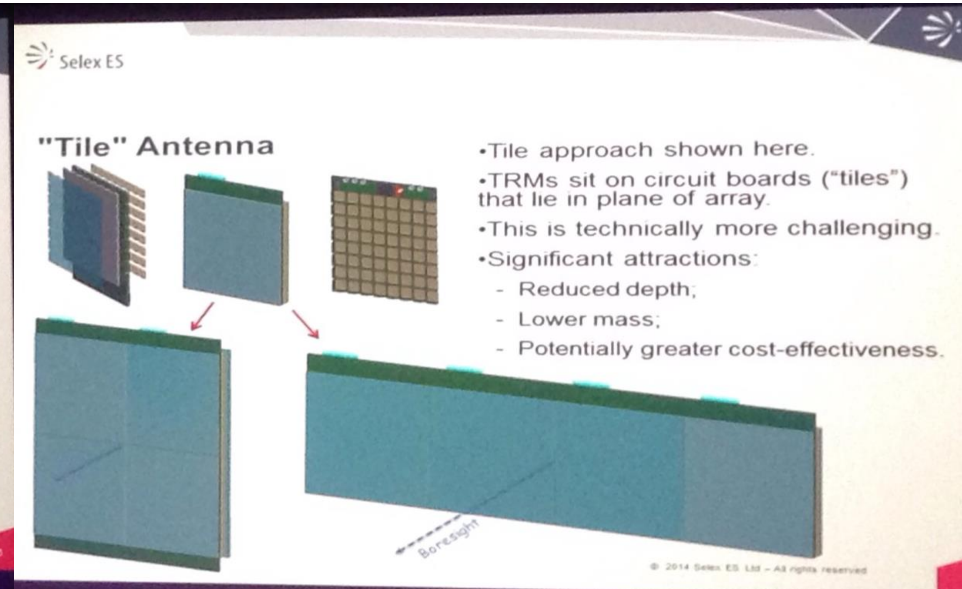


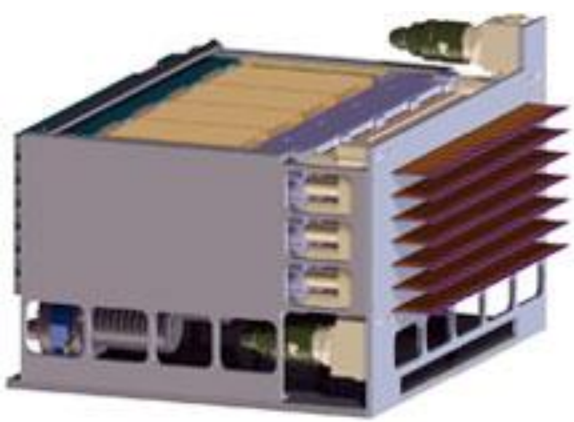
Figure 3: Conformal-antenna architecture (left) & Tile Module cross section



Antenna Technology Advancements
From 'planks' to 'tiles'







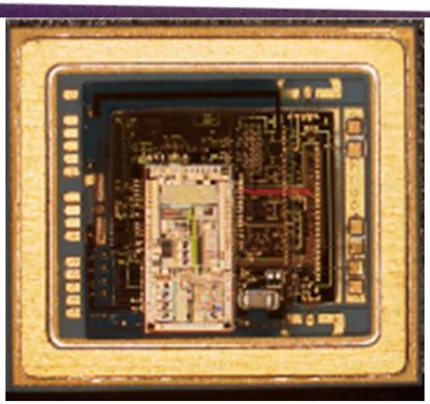


Fig. 1 Compact TR Module

Fig. 2 Tile Antenna

Advancing signal processing …

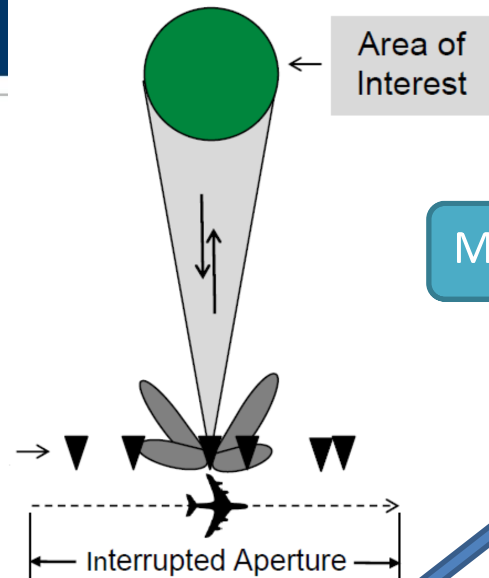
- **Compressed/Compressive sensing has come of age**
  - Advanced processing session are almost all about using sparsity in some way
    - Sparse arrays, sparse samples in frequency / time
  - Several examples of useful outputs
    - Non-linear sampling without unwanted grating lobes
    - Ability to handle periodic interference / jamming more gracefully
- Very fascinating tutorial on advances in the application of ***information geometry*** to radar
  - Field that RSA is likely not very strong in?
  - But shows significant potential for achieving more optimal results in many applications
    - STAP / GMTI
    - Phase denoising in SAR/ISAR
    - Robust CFAR
    - Polarimetric processing
  - Effectively shows how to more optimally solve 'covariance' based problems

Interrupted SAR – A CS Example Image Formation*

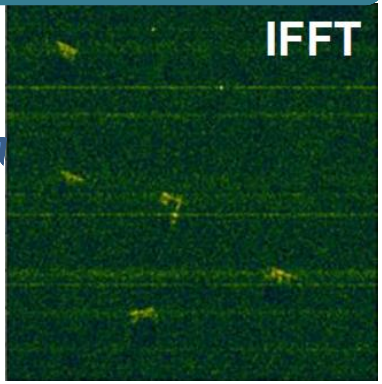
Single interrupts

Periodic interrupts

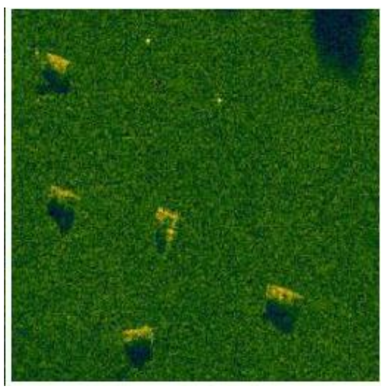
Random interrupts



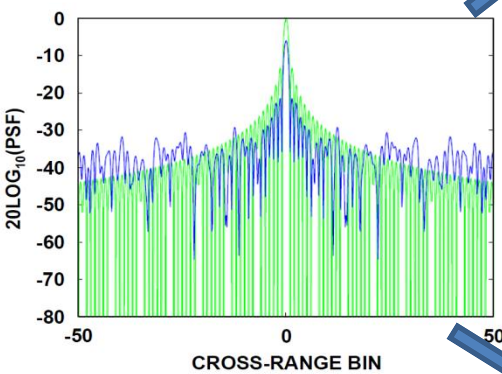
Matched Filter Processing



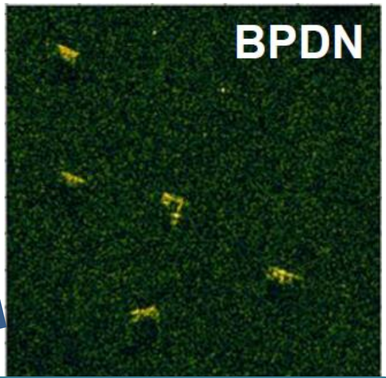
Uninterrupted Phase History



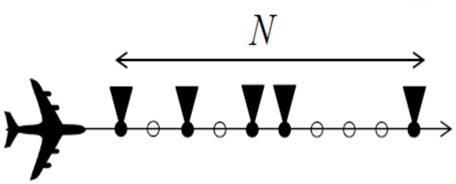
Random Interrupt



PSF



$$\underline{y} = RF\underline{x} + \underline{n}$$



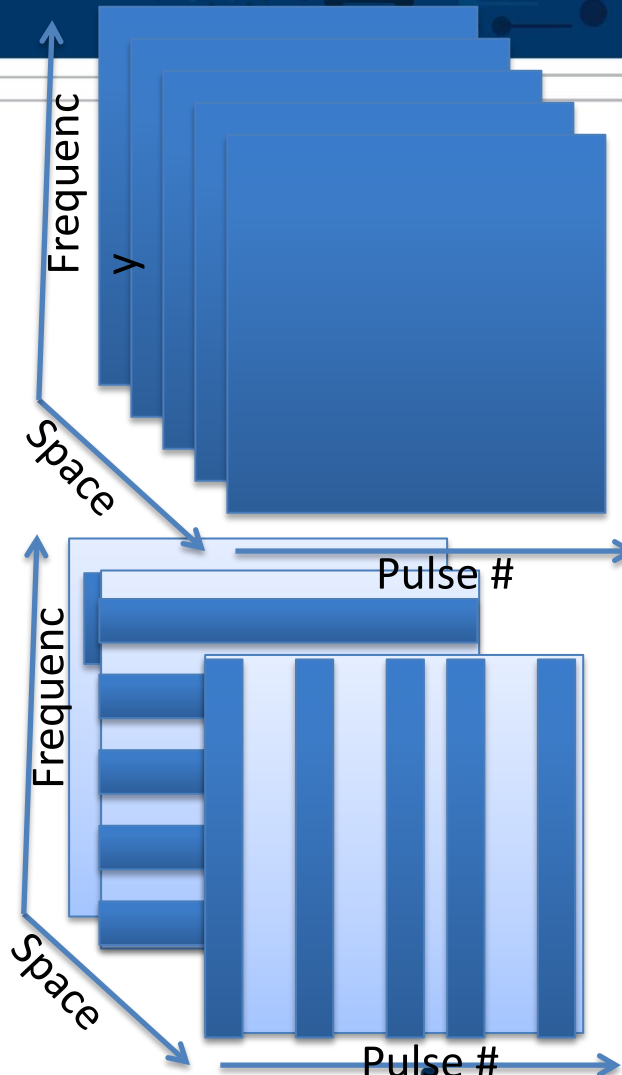
$$\left\| \underline{y} - RF\underline{x} \right\|_2 \le \sigma_{BPDN}$$

Basis Pursuit DeNoising (BPDN)

* Les Novak (Tutorial 3)

Further implications of interrupted SAR principles

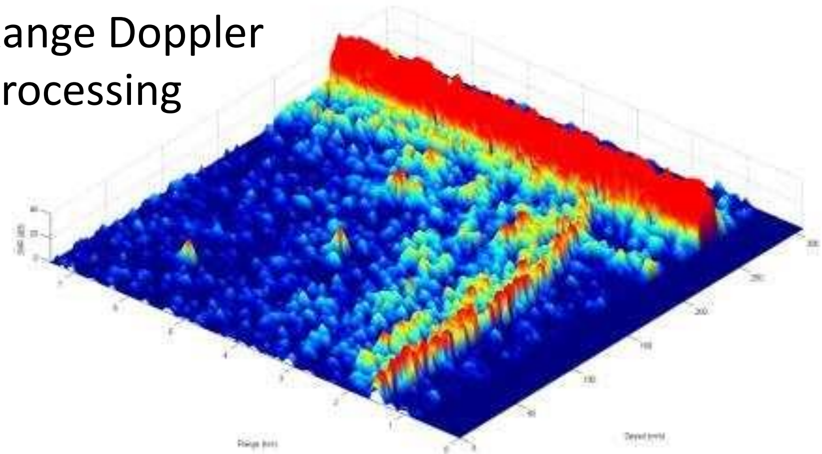
- Techniques underlying interrupted SAR essentially interpolates incomplete data sets
- These principles can and have been extended to time, frequency and spatial domains:
- Time domain:
  – **Interrupted SAR imagery** could result from need to share antenna aperture with EW or Communication systems at certain times, or due to jamming/external interference.
- Frequency domain:
  – Low frequency radar operation – e.g. **Foliage penetration applications**, are required to work in a very congested frequency band, resulting in some frequencies being unavailable
- Spatial domain:
  – **Phased array antennas** with high number of elements are extremely expensive. Thinning the array (removing certain elements) are possible, since these techniques will compensate for data missing in spatial domain.



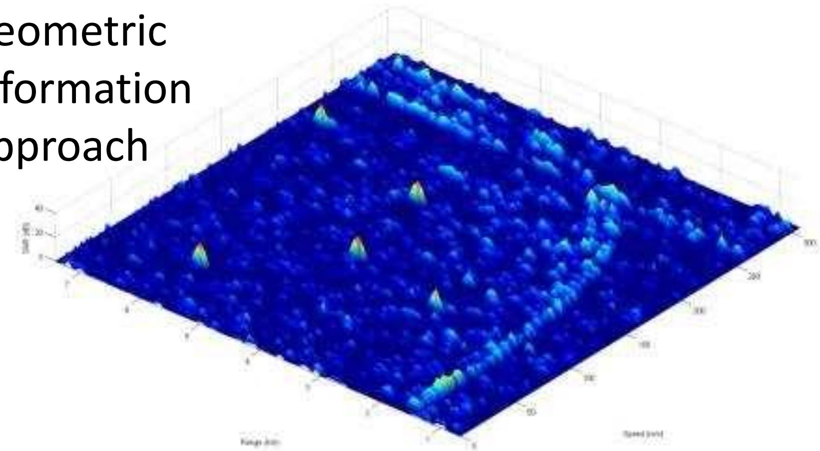
Information Geometric signal processing
To peak your interest …

- **Application to air-to-air radar mode: high heterogeneous sidelobes clutter + continuous mainlobe clutter**

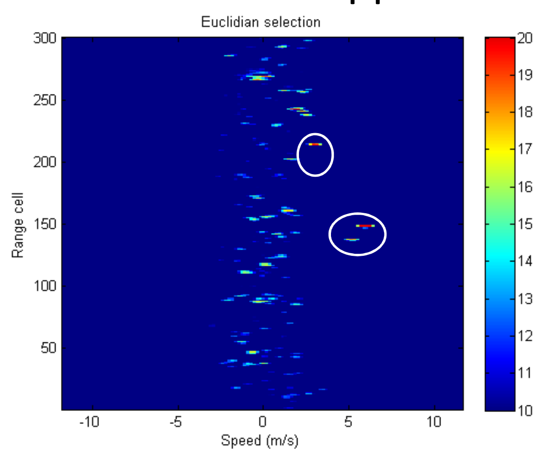
Range Doppler Processing



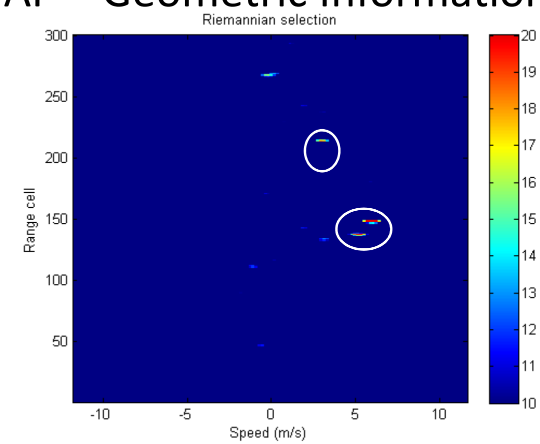
Geometric Information Approach



STAP – Euclidean approach



STAP – Geometric Information approach



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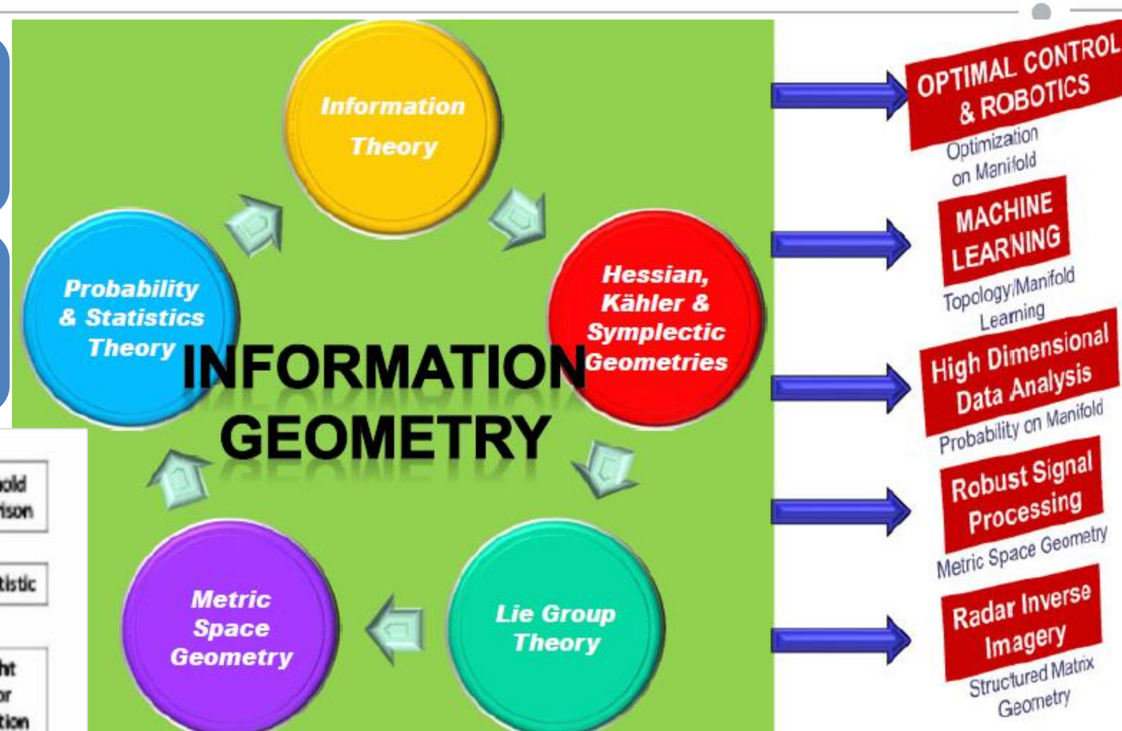
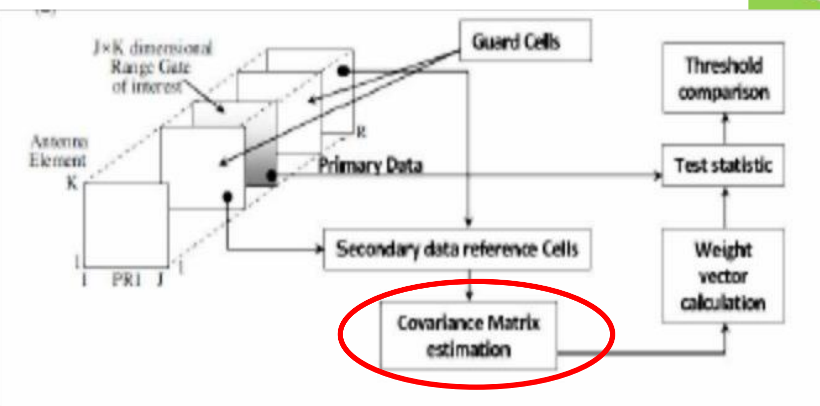
Geometry of Structured Matrices & Information Geometry*

Radar Signal Processing systems – typically use linear Algebra

Geometric tools – “intrinsic” properties to solve complex problems (from Physics)





Radar processing based on covariance matrix:

- Polarimetric Radar Processing (Polarimetry Covariance Matrix)
- STAP Processing (Space-Time Covariance Matrix)
- Doppler Processing (Time Covariance Matrix)

* Frédéric Barbaresco – THALES AIR SYSTEMS (Tutorial 1)

ISAR/SAR developments

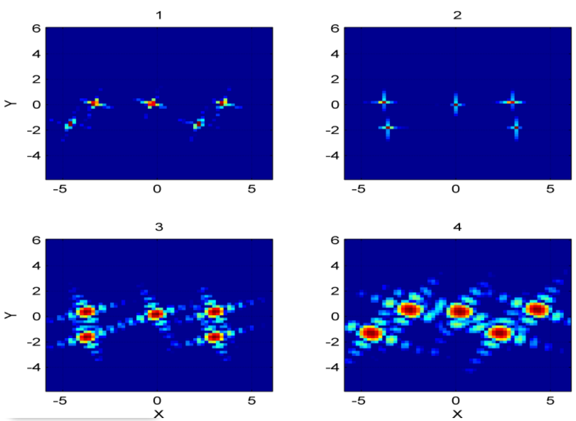
Multistatic ISAR*

Advantages

- Coherent Image Fusion (increase resolution/decrease integration time)
- Improved target estimation
- More information to estimate total rotation rate (cross-range scaling)

Challenges

- Geometrical restrictions with image fusion (have to resolve scatterers in three dimensions)
- Synchronization (time and frequency)
- Spatial Calibration (less precise than 10cm)

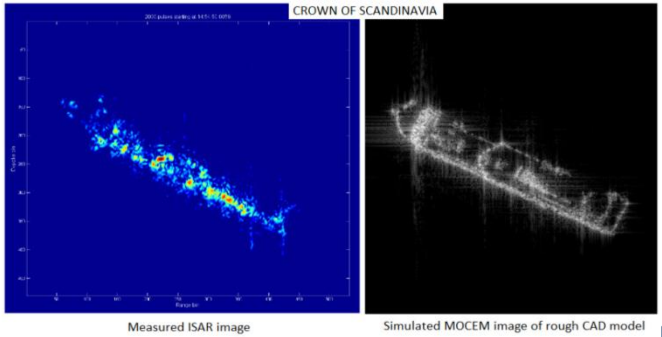


Simulated ISAR images from different receivers

* Stefan Brisken (THO.1.13.)

SAR simulations using MOCEM V4*

- SAR simulator
- Extended to simulate radar raw data
- Offers in real-time: phenomena such as delocalization, defocusing and deformation
- Reproduce PicoSAR acquisition using recorded motion data



Measured ISAR image
Simulated MOCEM image of rough CAD model

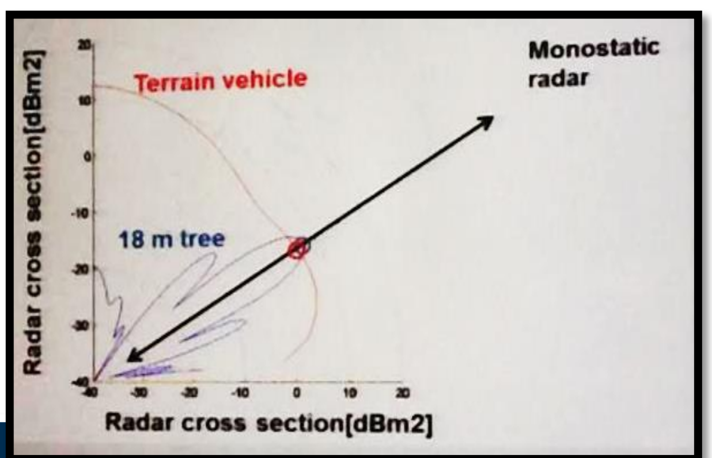
* Atle O Knapskog (THO.1.11.)

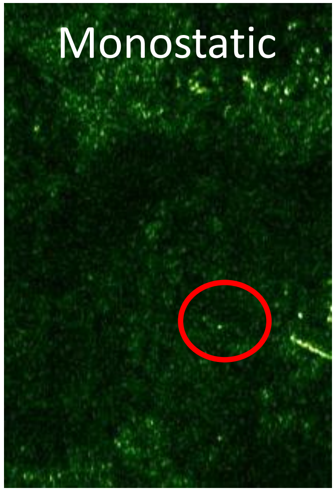
Bistatic and Multistatic radar resurgence ‘Cyclic hot topic’

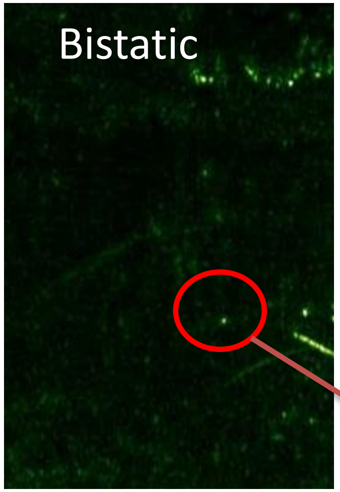
- Attention seems to be driven largely due to
  - Passive coherent location / Commensal radar
  - Usage of spaceborne illuminators – SAR / Reflectometry, etc
- Bistatic systems promise some advantages
  - Lower fluctuation with aspect angle – less fluctuation loss
  - Ability to detect stealth targets – low frequency bistatic
  - Improvement in handle ambiguity (time and space)
  - Multi-statics gives diverse looks on the target
- **Bistatic clutter remains a challenge**
  - Sea clutter focus by UCL/UCT and others
  - Land-clutter data sets remain very limites
- Interesting paper from FOI on bistatics in FOPEN
  - **Bistatic FOPEN shows promise of reducing falls alarms when detecting man-made objects under trees**

Bistatic SAR benefits target detection underneath foliage

- FOI (Sweden) illustrated advantage of bistatic low-frequency (25-83 MHz) SAR for target detection beneath foliage
- Scattering beamwidth of man-man objects (e.g. vehicles) are broader than tree-trunks, therefor bistatic operation supresses return from tree-trunks but does not significantly affect returns from man-man objects
- Even small bistatic angles (15^o-20^o) result in significant clutter rejection
- Could consider implementing these principles using a dual UAV configuration







Note the rejection of clutter in bistatic case

MIMO Radar

- **In concept**: Floodlight scene with multiple transmissions on array antenna that are orthogonal per element
- Form beam on receive for both the Tx and Rx array
  - Allowing fully digital beam-steering on Tx and Rx
- Many systems have now been designed that make use of Coherent MIMO
  - SAR / ISAR Imaging
  - Low Frequency OTHR Radar
- Doppler tolerant codes pose a issue at higher frequencies
  - But can be overcome with added signal processing complexity
- Antenna element mutual coupling is also a practical problem that has to be solved
- Some advocating MIMO promised gain in SNR compared to AESA approaches
  - Many debates about this at the conference happened in sessions and offline
  - Most experts now seem to agree that for a traditional search radar it does not increase SNR, and in tracking radar, the MIMO approach is less ideal
  - But it dos yield a system with higher update rates
  - Performance quite dependent on actual application
  - Not a 'silver bullet' – but one that should be considered in designs
- AFRL: Greatest potential believed to be in area of EW
  - Post jamming correction and null steering
  - More difficult to engage with EW systems due to waveform diversity
  - Bistatic MIMO quite difficult to handle from a jammer perspective

MIMO Bistatic video clip if time allows

Hyperlink

Conflicting views: MIMO is everything vs AESA is everything

- Presentation by Dr. W. Wiesbeck (MIMO is everything)
  - Karlsruhe Institute of Technology (KIT), Germany
  - titled "Radar 2020, The future of Radar Systems"
  - Radar evolution lagging communication growth
    - Last 20 years
  - Increased demand for radar applications
    - For example, vehicle market
  - Foresee the integration of communications with radars
    - Building block already exist for this
    - COFDM currently an example
    - Communication application
      - Extract the data
    - Radar application
      - Extract the; Delay, Doppler shift and Angle information

- MIMO vs Antenna Arrays
  - Eli Brookner presentation
  - MIMO has its uses, but in many cases will not outperform AESA

Passive Coherent Location (PCL)

- 2 Dedicated session to PCL
  - Passive Radar Systems
  - Passive Radar Signal Processing

- European nations actively researching this technology
  - Primarily for air-surveillance
  - Other publication exist
    - Application to maritime targets

- Technology maturing
  - Tendency to publish more on tracking accuracy achieved
  - Preferred illuminator DVB-T
    - Good low flying target detection capability
    - Reports on tracking accuracy of
      - Horisontal < 40m, Vertical < 103m
    - Hybrid Detection with FM
      - Early warning

PCL (2)

- Trials conducted by Thales
  - Multistatic, 1 Tx, 4 Rx exploiting DVB-T
  - Assessment as a primary radar
  - Funded by UK Technology Strategy board
  - Significant Tracking accuracy assessment
    - < 150m in many cases
  - PoD and PFA still to be calculated

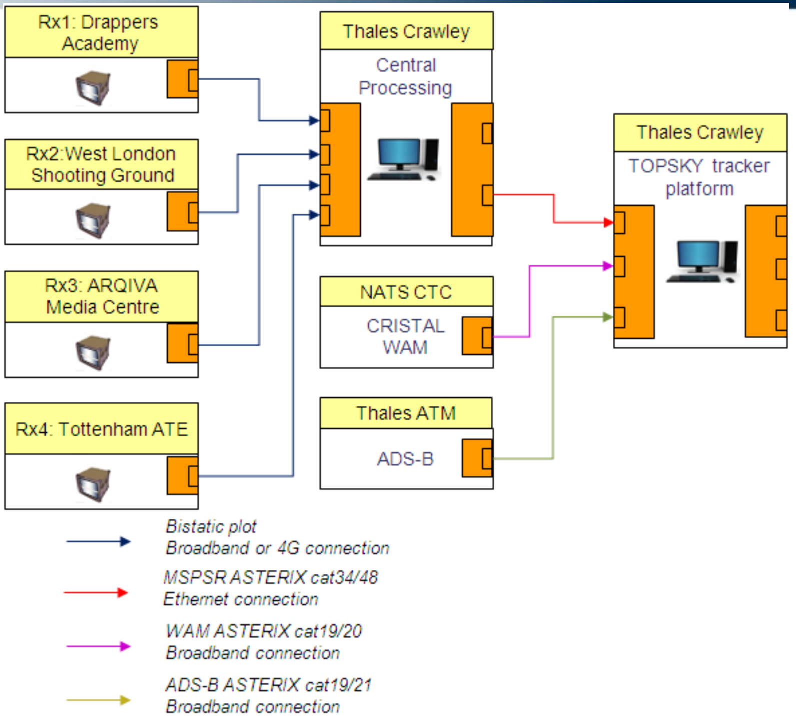


Fig. 1. MSPSR deployment for the London trial and available data

TABLE VI. MSPSR DISPLACEMENT FROM RUNWAY CENTRE-LINE

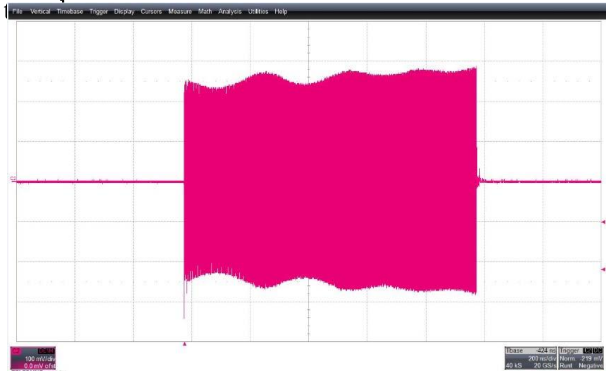
Number of tracks	Number of points	Mean lateral offset (m)	Std Dev (m)
36	1783	18.76	51.5

Technology advancement: Fully Digital radar

Dream of of fully digital radar (no analog up/down conversion) still remains a dream at higher bands

Btu progress is gradually being made …

A microwave DAC, EV12DS400, has been developed which can transform signals generated in baseband to L, S, C and lower X bands.
The device has been measured to give SFDR values of between 65dBc and 50dBc depending on mode used, at output frequencies up to 7GHz.
The output analog bandwidth of the device is estimated at 8GHz.
Chirps generated have been analyzed and the switching speed performance necessary for waveform agile systems has been



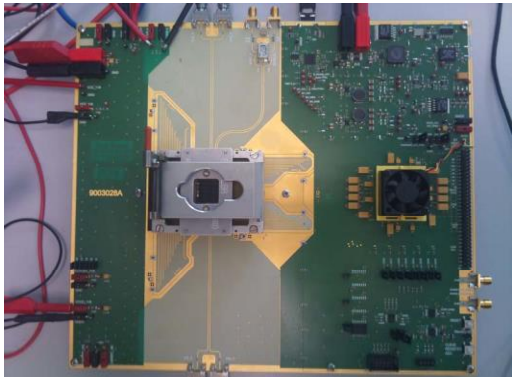


Fig. 8. 12-bit 4.5GSps ADC Evaluation Board

Other interesting papers:
300 GHz imaging radar for weapons detection

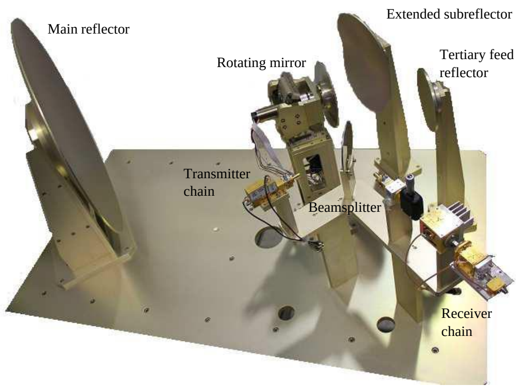
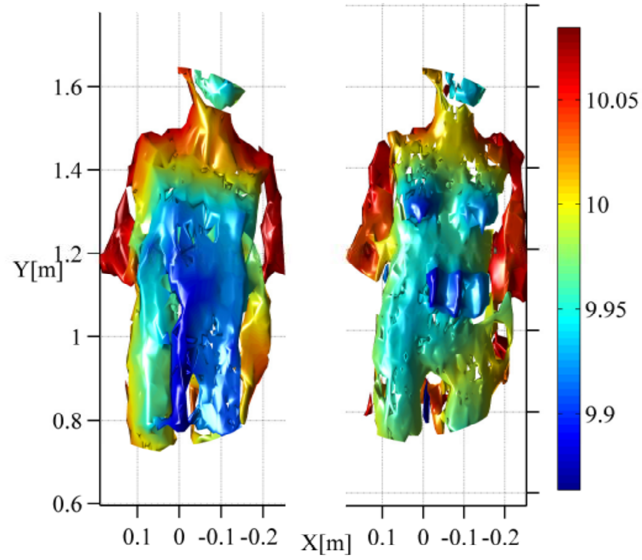


Fig. 2. Photograph of the scanning antenna subsystem integrated with the Tx-Rx chains.

(a)



(b)

Fig. 16. (a) Target scenario, where a simulated explosive is hidden under a mannequin's T-shirt. (b)-left: surface reconstruction of the external-layer image. (b)-right: surface reconstruction of the internal-layer image.

Radar Test & Evaluation (HWIL)

- Not a big topic at conferences, possibly due to the fact that it is so close to commercial / covered by control field
- Tutorials sessions and papers on the topic are more marketing than research (room for formalised approach)
- Radar test and evaluation systems are becoming more expensive than radars themselves
  – Radars are becoming cheap (software defined radar & radar on a chip)
  – HWIL systems have strict low latency requirements
  – HWIL have to be more capable than radar

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South Africa is becoming increasingly visible at these conference

- >7 papers this year from RSA
- Involved in the organisation, at least via Radar Systems Panel (Prof Inggs) and Technical Review (many of us)
- Opportunities in 1st world R&D space starting to become a real option
  - CSIR recently landed joint R&D work packages with ArmaSuisse
  - USA AFRL interested in collaborating on several topics including MIMO EW
- Has come through a history of taking part and presenting at these conferences since 2004/5

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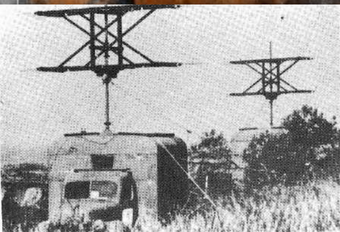
Taking a next step in the RSA Radar journey…



Come celebrate 75 years of radar in South Africa at a next milestone:
The first international IEEE radar conference in South Africa

cradle of humankind
world heritage site

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2015 IEEE Radar Conference

"Out of Africa – always something new"

Sandton Convention Centre, Johannesburg

27 – 30 October 2015

www.radarconf15.org or www.saradar2015.org