Operational Considerations for Passive Bistatic Radar

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Some Background

- Conventional radar is termed **monostatic**, i.e. receiver and transmitter are colocated
- **Bistatic radar:** transmitter and receiver are separated by some distance
- **PBR**: transmitter signal is external to system
- **Original British radar** experiment ('Daventry Experiment') in 1935 by Sir Robert Watson-Watt was PBR
- Sometimes called **Passive Coherent Location** (PCL)

History of PBR

- **Watson-Watt's** experiments in 1935 demonstrated concept
- First successful use of PBR system by Germany in WWII – ***Klein Heidelberg*** – which exploited British Chain Home radar transmitter
- Bistatic radar made way for conventional monostatic radar: enabled by development of **T/R switch**
- Resurgence in 1980s: emergence of **commodity computing**
- **LMC "Silent Sentry"** release 1998: 1st commercial product
- **Thales Homeland Alerter** 100 (2005-2007)
- Noticeable **resurgence in PBR** recently

Passive Radar: A $10 Billion opportunity


click to enlarge

Passive radar is different from traditional forms of radar in that it dies not emit any electromagnetic radiation. Instead, it relies on reflections from other electromagnetic signals in the atmosphere in order to provide a radar picture. Passive radar provides a number of distinct advantages that will allow it to corner a significant portion of defense, homeland security, and civilian radar markets. In addition to cost-efficiency, passive radar is also covert, an effective counter to stealth technologies, and environmentally friendly.

The market for passive radar is still in its infancy, and few companies have developed effective, marketable systems. However, as the technology becomes more sophisticated and affordable, more and more competitors can be expected to enter the market, particularly in defense and homeland security.

Related Research on ASDReports.com:
The Military and Civil Aviation Passive Radar Market: 2013 - 2023

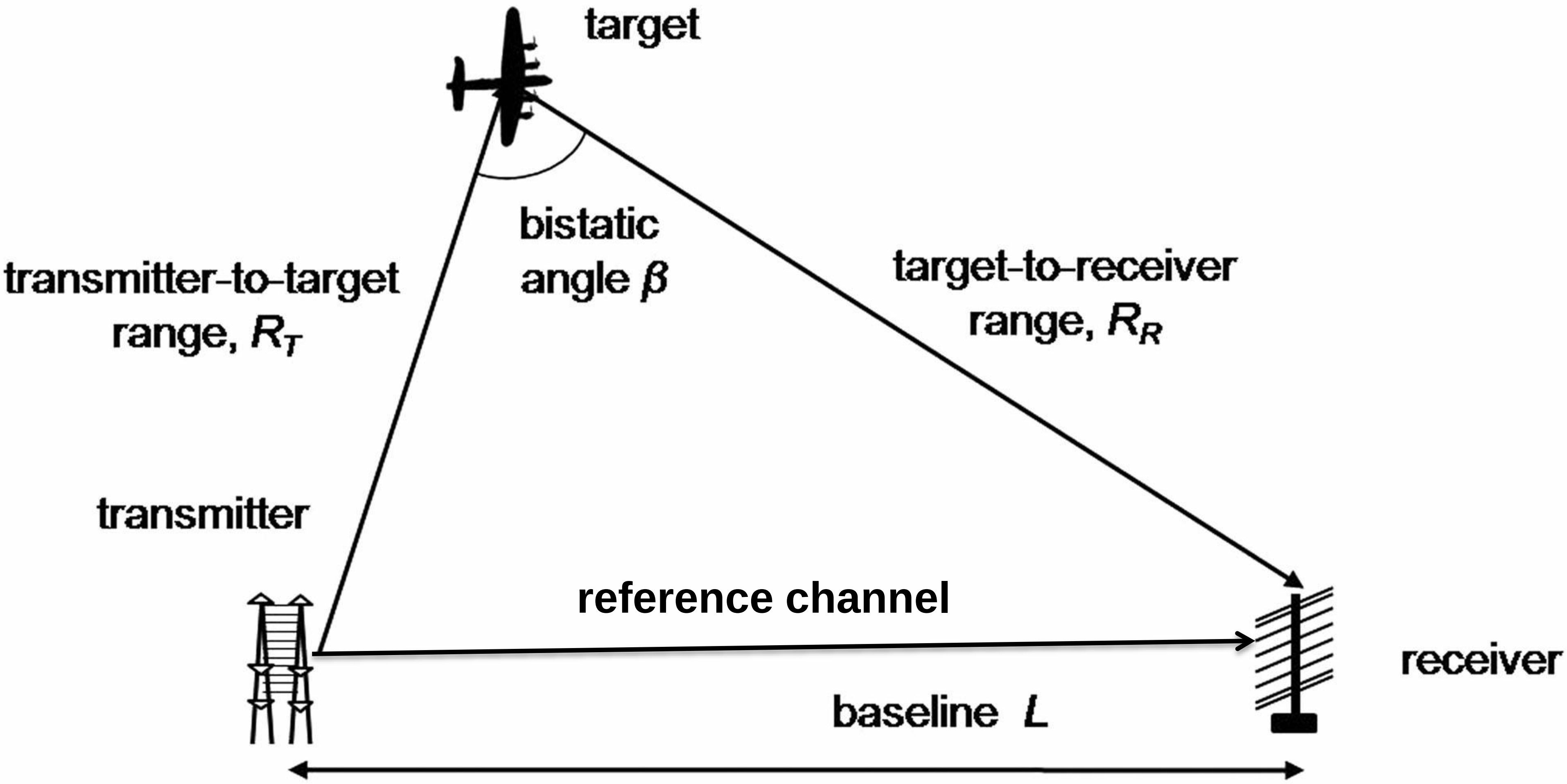
By the end of 2023, SNS Research expects passive radar technology investments to account of more than $10 billion in revenue, following a CAGR of nearly 36% between 2013 and 2023.

The "Military & Civil Aviation Passive Radar Market: 2013 – 2023" report focuses on the two markets where passive radar technology has the greatest potential: civilian aviation and military radar applications.

The report presents vendor strategies, overall depictions of potential growth in both sectors, as well as detailed qualitative and quantitative analysis of global and regional drivers and limitations on market potential from 2013 till 2023.

The report comes with an associated excel datasheet covering quantitative data from all revenue projection forecasts presented within the report.

PBR System Concept



Illuminators of Opportunity

- PBR systems will use other transmissions that just happen to be there, i.e. *illuminators of opportunity*, and the technique is sometimes known as
  - PBR,
  - hitchhiking,
  - parasitic radar or
  - passive coherent location (PCL)
- Such transmissions may be other radars, or communications, broadcast or navigation signals
  - In these days of spectral congestion there are more and more such transmissions.
- Important characteristics of illuminators of opportunity are :
  - power density at target
  - coverage (spatial and temporal) and geometry
  - waveform (frequency, bandwidth, CW carrier)

Signal Characteristics of Some Transmitters of Opportunity

Transmission	Frequency	Modulation, bandwidth	P_tG_t (typical)
HF broadcast	10 – 30 MHz[1]	DSB AM, 9 kHz DRM, 10 kHz	50 MW
VHF FM (analogue)	~ 100 MHz	FM, 50 kHz	250 kW
UHF TV (analogue)	~ 550 MHz	vestigial-sideband AM (vision); FM (sound), 5.5 MHz	1 MW
Digital Audio Broadcast	~ 220 MHz	digital, COFDM 220 kHz	10 kW
Digital TV	~750 MHz	digital, 6 MHz	8 kW
Cell-phone Networks (GSM)	900 MHz, 1.8 GHz	GMSK, FDM/TDMA/FDD 200 kHz	100 W [2]
Cell-phone Networks(3G)	~2 GHz	CDMA 3.84 MHz	100 W

Air Surveillance Applications

- Detection of non-emitting and LPI targets
- Long range border/coastal surveillance
- Near-range high precision slow and low target tracking
- Temporary, quick set-up event protection
- Complement to ATM
- Gap filler

Maritime and Ground Surveillance Applications

- Harbour awareness and protection
  - Ship detection and tracking
  - Air surveillance
- Possible ship self protection
- Border surveillance

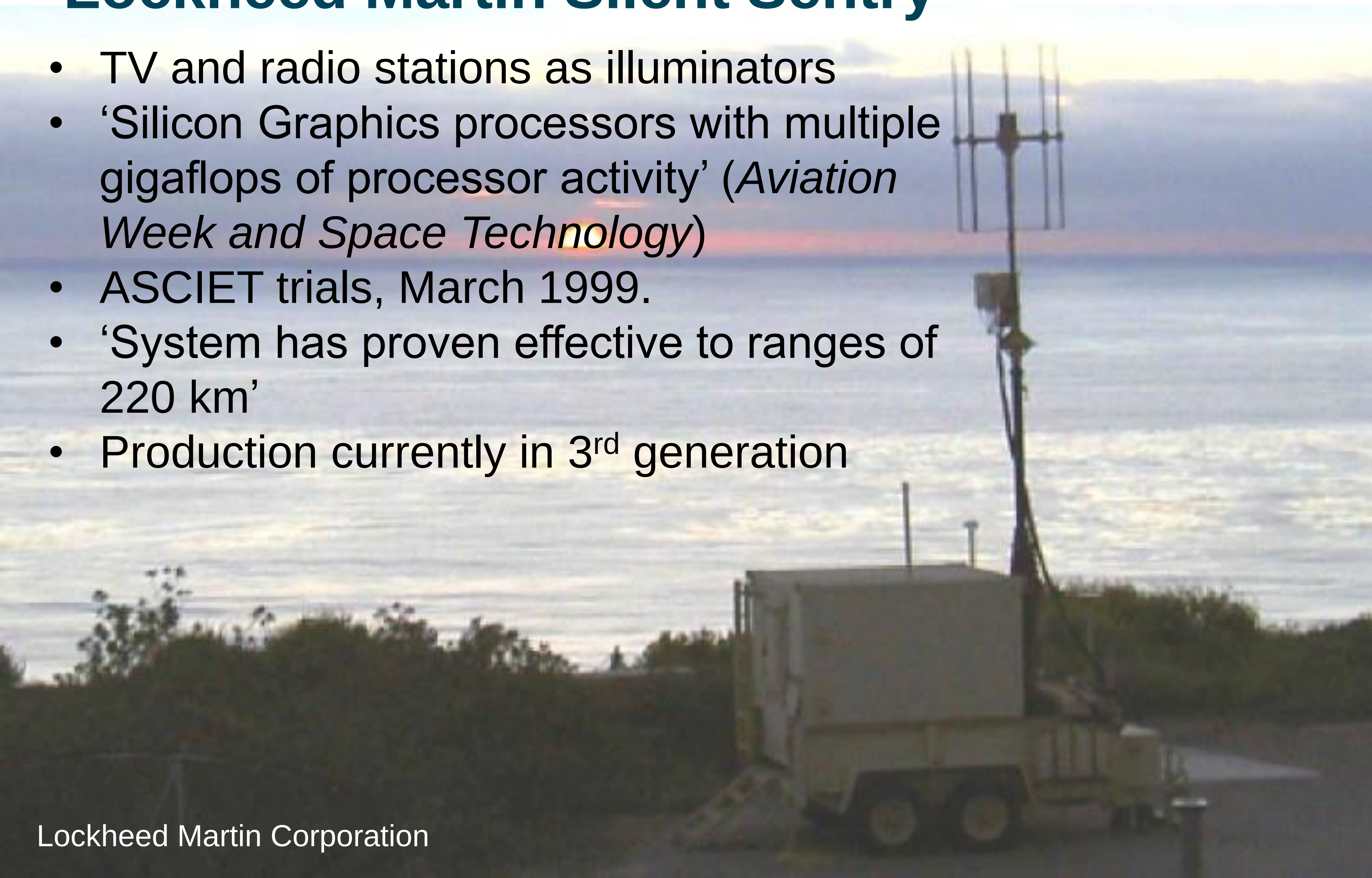
Advocates of PBR Cite Following Potential Operational Advantages

- Lower acquisition and O&M **costs** due to lack of transmitter and moving parts
- Physically **small**; easily deployed in places where conventional radars cannot be; operation in difficult terrain
- Remote, **standalone** operation possible
- Allows parts of **spectrum** (VHF, UHF, ...) not usually available for radar
- Minimised effects from **weather** conditions
- Capabilities against **stealthy** targets: low RF and multistatic geometries
- Detection of **low altitude** targets (by diffraction)
- **Rapid updates**, typically once a second
- **Covert operation**, including no need for frequency allocations
- **Resistant to ESM** detection; difficulty of jamming
- **Resilience** to ARM's
- 'Green radar'; **no EM pollution**

Opponents of PBR Cite Following Potential Operational Disadvantages

- Technical **immaturity**
- Reliance on **third-party illuminators**; suboptimal waveforms
- **Lower power** densities at the target
- May experience significant **RFI**
- **2D** operation
- May experience **high false alarm** rate
- **Complexity** of deployment. Geometries are a critical performance factor
- Signal content may be **inconsistent**
- Typically small receive aperture for low cost, convenience, and covertness: **degraded SNR** and spatial resolution
- **Fading** due to multipath
- **Ghosts** possible in multi-target environment
- **Noise floor** raised by dense emitter environment
- **Computationally intensive**

Lockheed Martin Silent Sentry



- TV and radio stations as illuminators
- ‘Silicon Graphics processors with multiple gigaflops of processor activity’ (*Aviation Week and Space Technology*)
- ASCIET trials, March 1999.
- ‘System has proven effective to ranges of 220 km’
- Production currently in 3rd generation

Lockheed Martin Corporation

Silent Sentry Product Specifications

Performance

Surveillance Volume
- Azimuth: Up to 360°
- Elevation: 60°
- Continuous Search

Range
- 50 to 100 NM within FOV

Targets
- 100+ simultaneously
- Aircraft and missiles

Accuracy
- 100-200 m horizontal position
- 1000 m vertical position
- <2 m/s horizontal velocity

Data Output
- SS track format, TADIL-J, or OTH Gold

Survivability

Operating Environment
- Room temperature
- Shelter protected
- 1.5 kw 120V power

Reliability
- Standard digital component based
- No moving parts

Precipitation
- All weather antenna
- Shelter protected equipment

Detectability
- Covert when operating with indigenous illumination

Transportability

Transport Speed
- Level highway: speed limit
- Cross country: 10-15mph

Transport Vehicle
- Shelterized HMMWV or SUV
- Enclosed truck/SUV

Grades and Road Conditions
- VME Rack
- Ideal for Road Transport
- Withstands moderate off-road conditions

Emplacement
- Less than 1 day
- 1-2 person setup

Lockheed Martin Corporation

Homeland Alerter 100 (Thales, France)

- In production
- Introduced at Paris Airshow in 2007
- Range : 100km
- Azimuth : 360°
- Elevation : 90°
- Transmitters of opportunity : FM radio, possible extension to DAB, AVB, DVB-T

Thales

Transportable Passive Radar by Airbus Defence and Space (Formerly Cassidian)

EADS

- Technology Demonstrator unveiled in 2012
- Transmitters of opportunity : FM, DAB, DVB
- Range : test results reported at 250 km bistatic
- Small ground based targets (cyclist) detected at short range

Other PBR Systems

- CELLDAR – CELL PHONE RADAR (BAE Systems – Roke, UK)
- AULOS Passive Covert Location Radar (Selex Sist. Int., Italy)
- Hellenic Multi-target Passive System – HEMPAS or CCIAS (“Thessaloniki Team”, Greece): multistatic PCL – ESM system
- Silent Guard – FM Radio (ERA, Czech Republic)

Conclusion

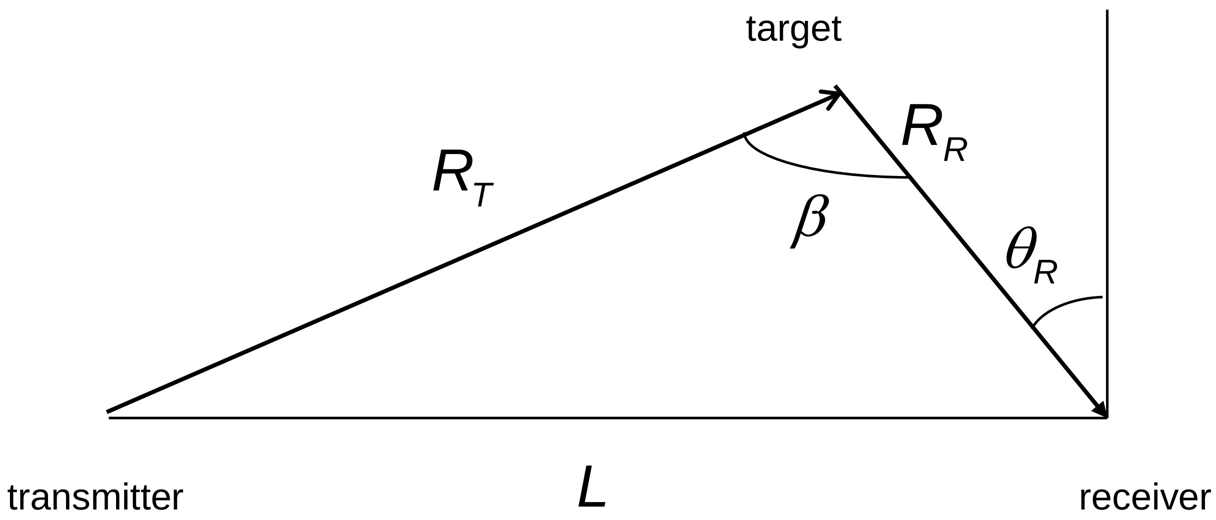
- Background and history of PBR
- PBR waveforms
- Operational applications of PBR
- Potential operational advantages and disadvantages
- Some production and prototype systems

Backup

Principle

- In conventional radar, time of transmission is exactly known, allowing target range to be easily calculated
- PBR does not have this info directly: uses reference receiver to monitor each transmitter being exploited; dynamically sample transmitted waveform.
- PBR typically employs following processing:
  - Reception of direct signal from transmitter(s) and from surveillance region on dedicated low-noise, linear, digital receivers
  - Digital beamforming to determine DOA of signals and spatial rejection of strong in-band interference.
  - Adaptive filtering to cancel any unwanted direct signal returns in the surveillance channel(s).
  - Transmitter-specific signal conditioning
  - Cross-correlation of reference channel with surveillance channel to determine object bistatic range and Doppler.
  - Detection using CFAR.
  - Association and tracking of object returns in range/Doppler space, known as “line tracking.”
  - Association and fusion of line tracks from each transmitter to form final estimate of targets location, heading and speed.

PBR Geometry

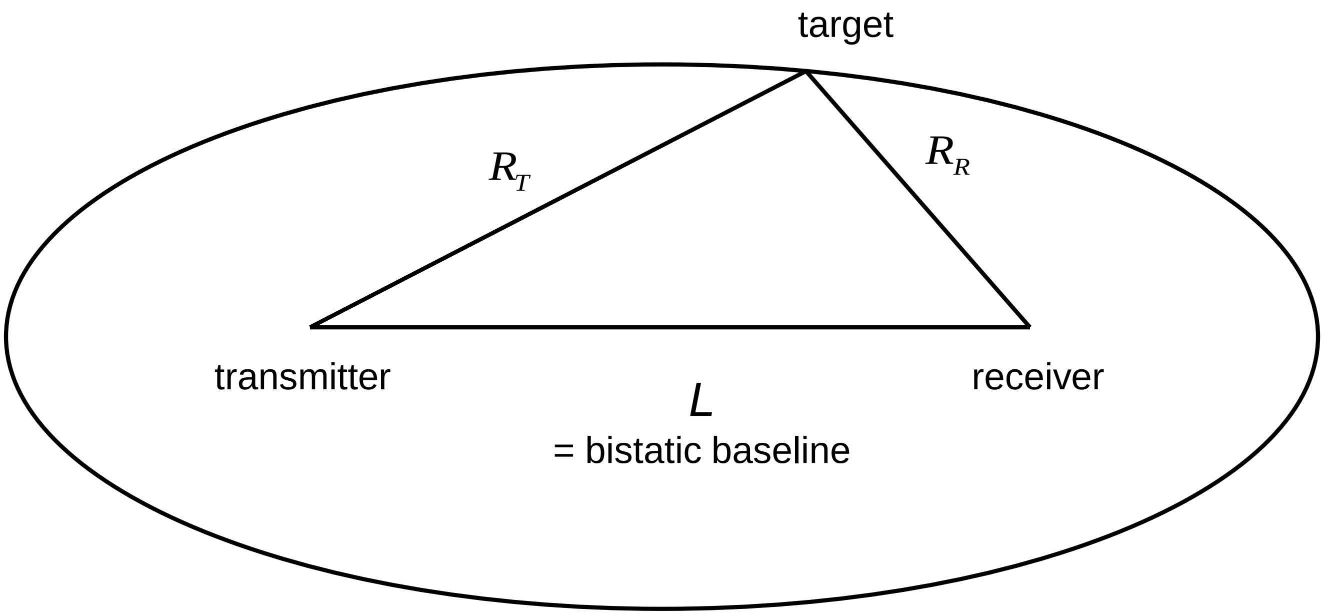


$$R_R = \frac{(R_T + R_R)^2 - L^2}{2(R_T + R_R + L\sin\theta_R)}$$

Jackson, M.C., 'The geometry of bistatic radar systems'; *IEE Proc*., Vol.133, Pt.F, No.7, pp604-612, December 1986.

PBR Geometry

Contours of constant bistatic range are ellipses, with transmitter and receiver as foci

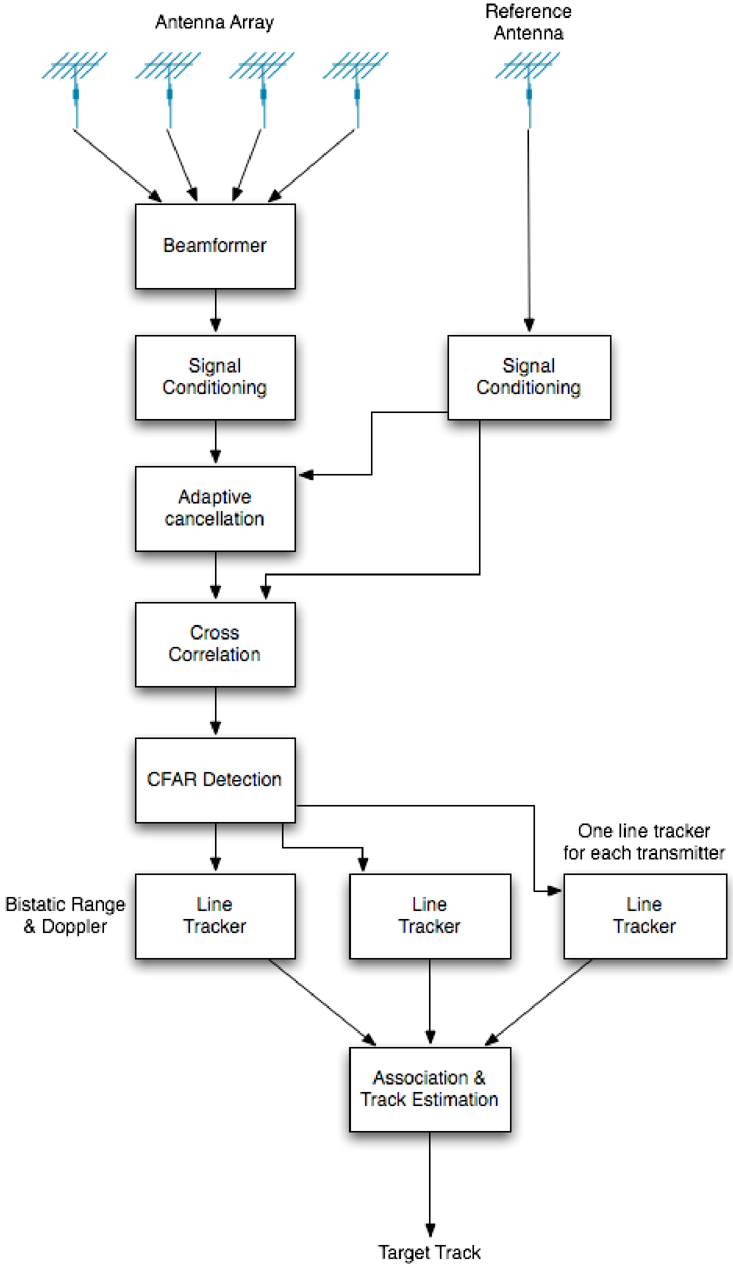


$$R_T + R_R = \text{const}$$

Targets lying on the transmitter-receiver baseline have zero bistatic range.

Typical Illuminators (30 MHz – 3 GHz)

- PBR systems have been developed that exploit following sources of illumination:
  - Analog TV
  - FM radio (88-108 MHz)
  - Cellular phone base stations
  - Digital Audio Broadcasting (DAB 174-240 MHz)
  - Digital Video Broadcasting Terrestrial (DVB-T including 30-300 MHz and 300 MHz – 3 GHz sub-bands)
  - Terrestrial high definition TV (North America)
  - GPS satellites
- Satellite signals have generally been found to be inadequate for passive radar use: either because powers are too low, or because orbits of satellites are such that illumination is too infrequent.
  - Possible exception to this is the exploitation of satellite-based radar and satellite radio systems



Generic PBR Signal Processing Scheme

Wikipedia

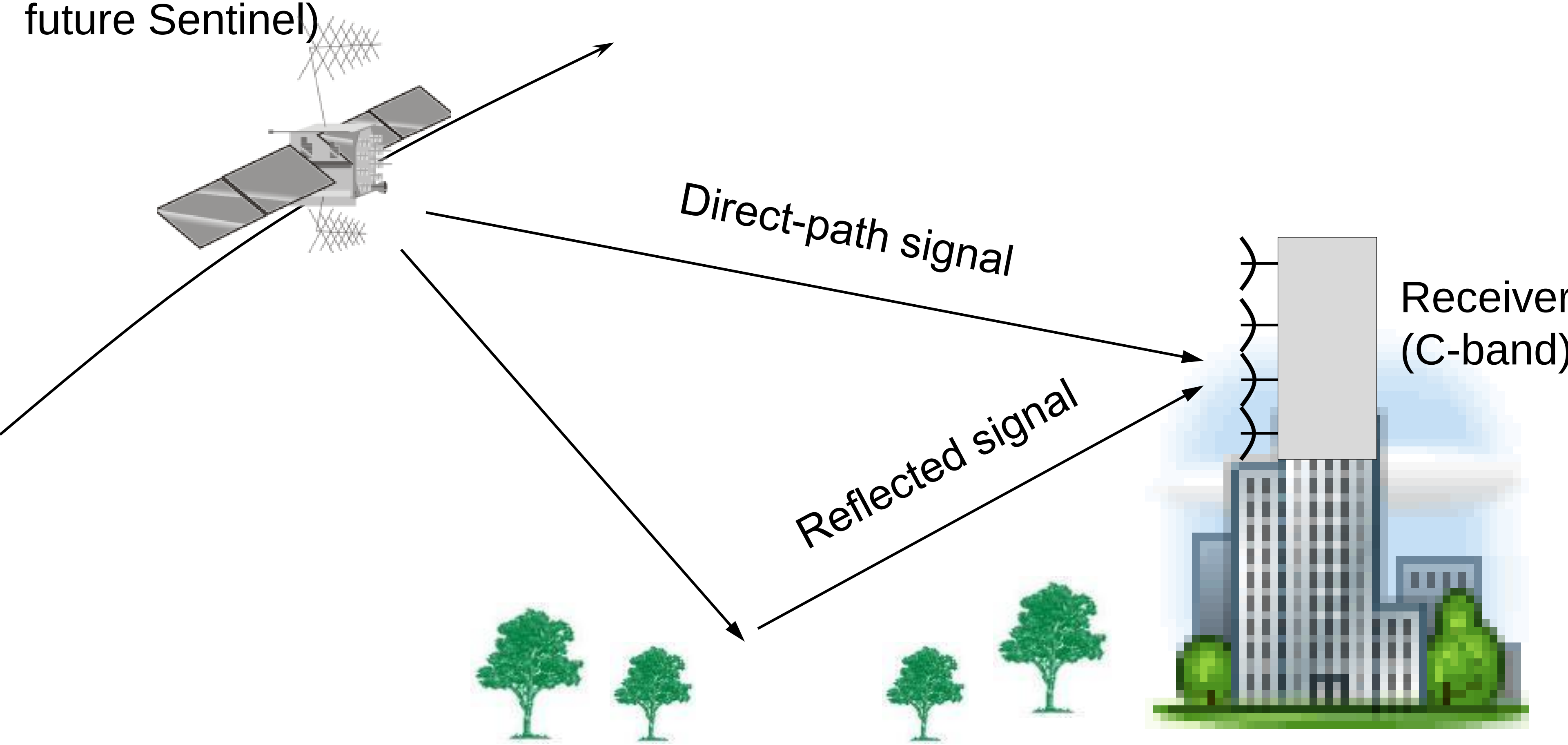
What Was NATO SET-164 ?

- Primary achievement of SET-164: analysis of bistatic VHF clutter obtained from FM radio based PBR data.
- RCS values and statistical distributions have been derived
- These can be used in system specifications and operational analysis studies.
- SET-164 has also undertaken a feasibility study of a number of important applications for PBR:
  - Harbour protection for Maritime Situational Awareness (MSA).
  - Bistatic SAR (BSAR) using satellites to increase military benefit when using satellite-borne illuminators.
  - Civil ATM and military air surveillance using PBR

Passive SAR System

Transmitter
(RADARSAT1/2,
future Sentinel)

Goal: produce images/interferograms



Capt Virginie Kubica, Belgium RMA