KELVIN HUGHES

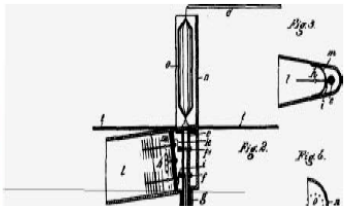
**Solid State Navigation and Situation Awareness Radar**

# Radar

**100 Years RADAR History :**
**UK Patent N° 13,17O**
**A.D. 1904 - Christian Hulsmeyer (GE)**

COMPLETE SPECIFICATION.

*" Hertzian-Wave Projecting and Receiving Apparatus Adapted to Indicate or Give Warning of the Presence of a Metallic Body, such as a Ship or a Train, in the Line of Projection of such Waves"*



-The receiver (top) and transmitter (middle) are mounted to a compass box "c" to allow the action of gravity to maintain a vertical orientation when the ship rolls and pitches (Figure 2)

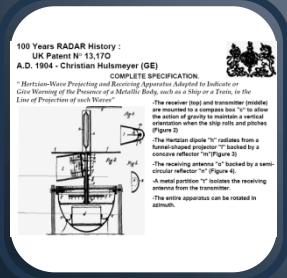
-The Hertzian dipole "h" radiates from a funnel-shaped projector "l" backed by a concave reflector "m"(Figure 3)

-The receiving antenna "o" backed by a semi-circular reflector "n" (Figure 4).

-A metal partition "t" isolates the receiving antenna from the transmitter.

-The entire apparatus can be rotated in azimuth.

**1904**



**1948- present**


**2008**

**1900** **1950** **2000**

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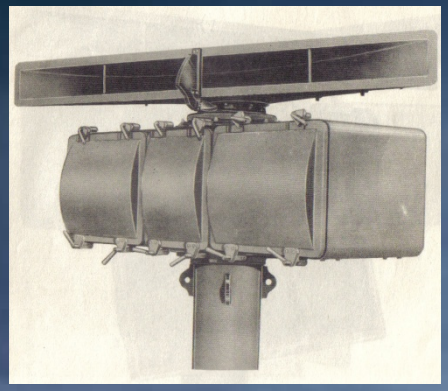
RADAR REINVENTED

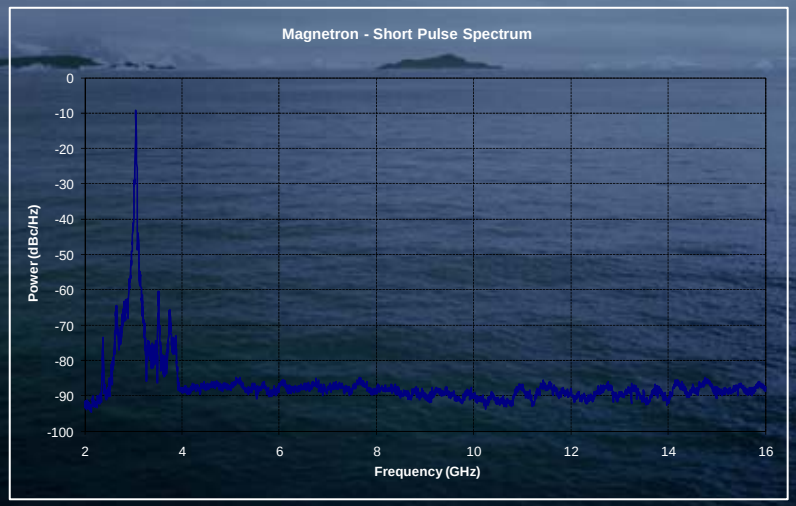
# Origins of Commercial Marine Radar



Kelvin Hughes New Marine Radar 1948

- Type 1
  - First UK Type Approved Marine Radar
    - 11th August 1948
  - Specification
    - Upmast Transmitter/Receiver
    - Antenna Rotation: 30RPM
    - Peak Power:- 30kW
    - RF Frequency:- 9.434GHz - 9.524GHz
    - PRF:- 1kHz
    - Pulse Width: 0.2$\mu$s
    - Azimuth Beamwidth:- 1.5˚
    - Elevation Beamwidth:- 27˚

# Sensor Improvements




Advances in Sensor Technology

- Low Noise Front Ends
- FET Modulators
- Improved Magnetron Life

Current Sensors at Peak of Performance

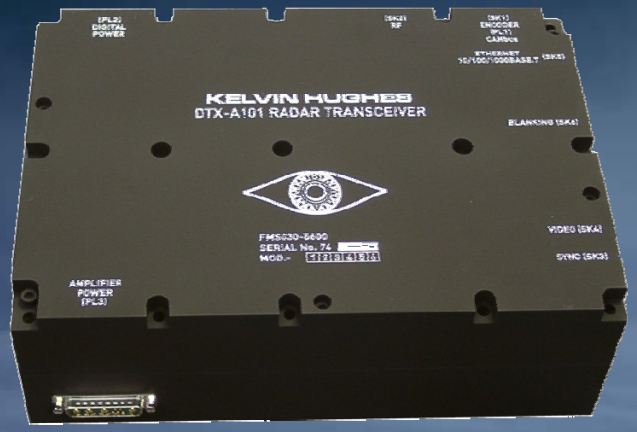
However.....

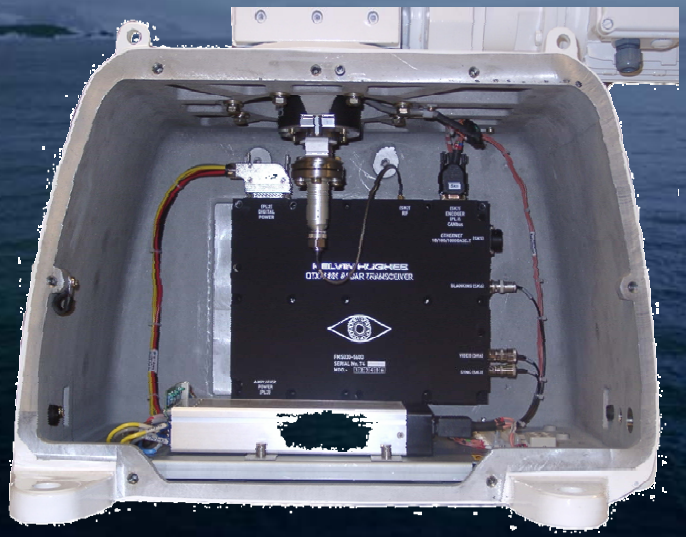
- Little improvement in performance in clutter
- Customers & Regulators demand detection of smaller targets
- Customers want more reliable systems
- Pressure from ITU to restrict radar bandwidth and out of band emissions

# SharpEye Introduction

- First ‘New Technology’ Marine Navigation Radar for 60 years
- Conforms to requirements of IMO & IEC
- ‘Family’ of Products
  - Built-in Flexibility through design and part selection
  - Considered future enhancements during concept/design phase
  - 100% PV Funded Development
- Performance/Cost Trade-Off
  - Minimum performance IEC 62388 (new radar standard - July 2008)
    - More performance expected but not at expense of production cost/quality
    - Achieve performance through innovation
  - Economies of scale
    - Re-use of components/sub-assemblies throughout product range
- Reliability and Maintainability high on our priorities

# SharpEye



## World's 1st Solid State Marine Navigation Radar

**Features include:**

- **Solid state transmitter**
- **Coherent transmitter and receiver**
- **Pulse compression**
- **Digital signal processing**
- **Interference suppression**
- **Low voltage operation**

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RADAR REINVENTED

# What sets Sharpeye apart

- Incorporates advantages in semi-conductor based radars but at a cost that competes with conventional magnetron systems
- Sharpeye incorporates low power RF architecture.
- Sharpeye outputs a clever frame of transmission pulses in a specified sequence
- Utilises Doppler processing techniques

# New Technologies - Solid State Transmitter


- Solid State Transmitter
  - Uses transistors instead of a magnetron
  - >200W peak power @ 13% duty
  - Coherent
    - RF transmissions have consistent phase & timing relationship
  - Controlled RF Spectrum
    - ITU Compliance
  - Selection of 12 RF frequencies
    - Extremely stable oscillators
      - No tuning necessary
  - Digital Waveform Generation
    - Direct Digital Synthesis

# Traditional Magnetron Radar

30,000W

Narrow pulse


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# Revolutionary Performance

**200W**

**Long Pulse**

?

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RADAR REINVENTED

**Since…**

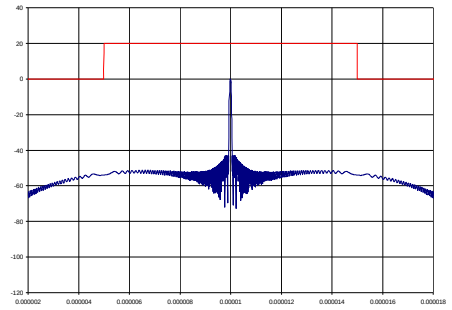
**Energy = power X time**

**…by significantly increasing the length of the pulse, the total energy leaving the aerial is more than equivalent to the energy leaving a 30kw system despite the peak pulse being reduced by more than 99%.**

# Revolutionary Performance

170W

Coherent Signal

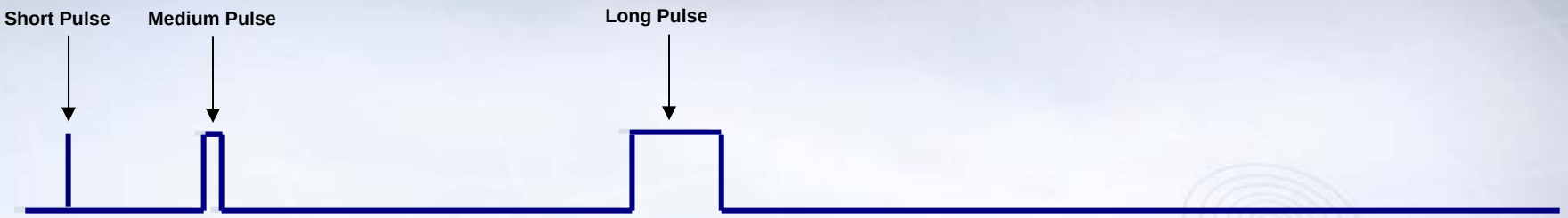


# SharpEye

**170W**

**Long Pulse with Pulse Compression**

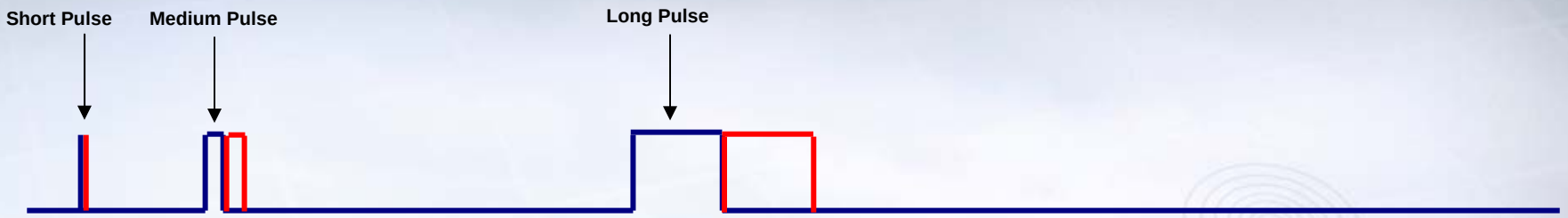
# Solid State Transmitter - Transmission Frame




## 3 Pulse Transmission Frame

- Short Pulse enables 30m Minimum Range
- Medium and Long Pulses provide Detection Performance
- Range Cell Size recovered via Pulse Compression
- Provides protection from multiple time around echoes
- Composite Video Formed from Received Data from frame
- Multiple Frames on Target per Beamwidth
- Block of Frames Doppler Processed to extract Velocity Information

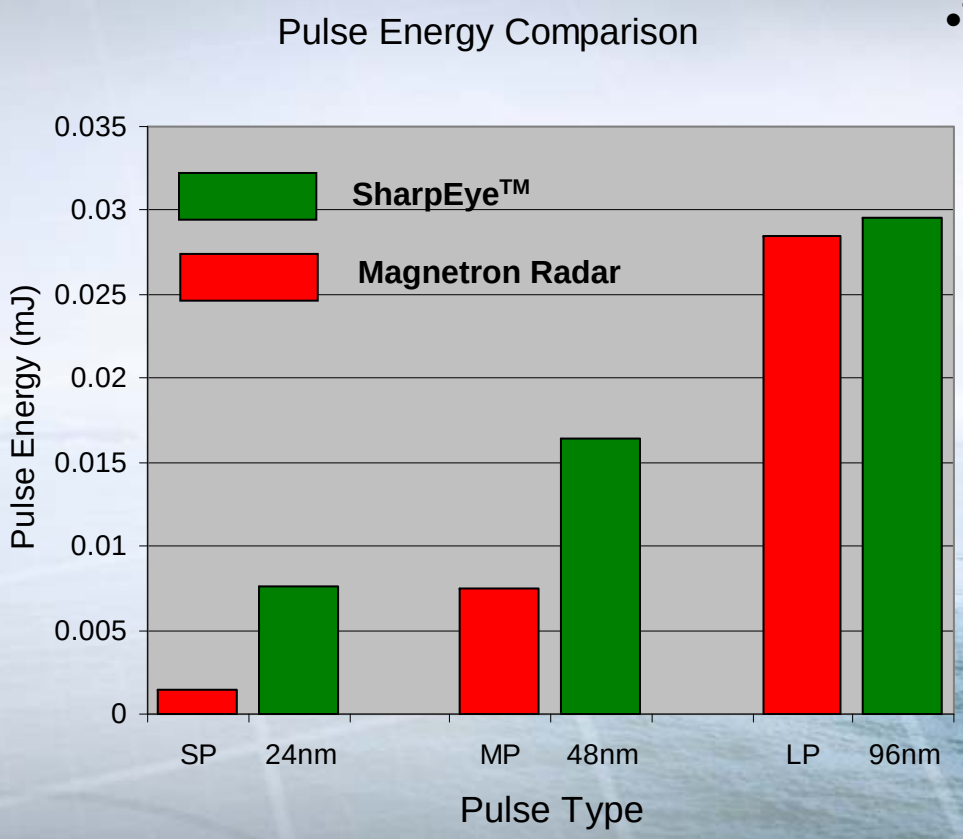
# Frequency Diversity - Transmission Frame




## Diversity Transmission Frame

- Additional Pulses inserted into frame
- Second receiver channel and signal processor added
- 30m Minimum Range maintained
- Channels processed independently & combined
- Improved detection & clutter performance
- Small improvement in multipath

# SharpEye™ - Solid State Transmitter




- Transmissions
  - Pulse Energy
    - Energy in pulse limits detection range, **NOT** peak power
  - Minimum range
    - For monostatic radar pulse duration defines minimum range
      - IEC 60936 states 50m (333ns)
  - Complex pattern of 3 pulses/frame
    - Provides energy for detection and meets minimum range constraint
    - Allows detection of targets close to clutter
  - Three Transmission Frame Types
    - 24nm Instrumented range
    - 48nm Instrumented range
    - 96nm Instrumented range

# Digital Signal Processor - Range Measurement


**Pulse Compression** converts long pulses into narrow range cells

- Range Cell Size maintained over entire instrumented range
- Short range performance in clutter and long range detection performance

Pulse Frame characteristics determined by Range Mode/Rotation Rate

- Appropriate pulse length automatically selected
- Reduced operator loading

Instrumented Range is independent of Range Display Setting

- Enables Tracking of target out to Instrumented range (e.g 24nm) regardless of display setting

Linear receiver

- Pulses are not stretched as in a logarithmic amplifier

# Digital Signal Processor
# Velocity Measurement

SharpEye™ determines Target Velocity via **Doppler Processing**

Conventional Radar

Targets must have an amplitude larger than the clutter to be detected

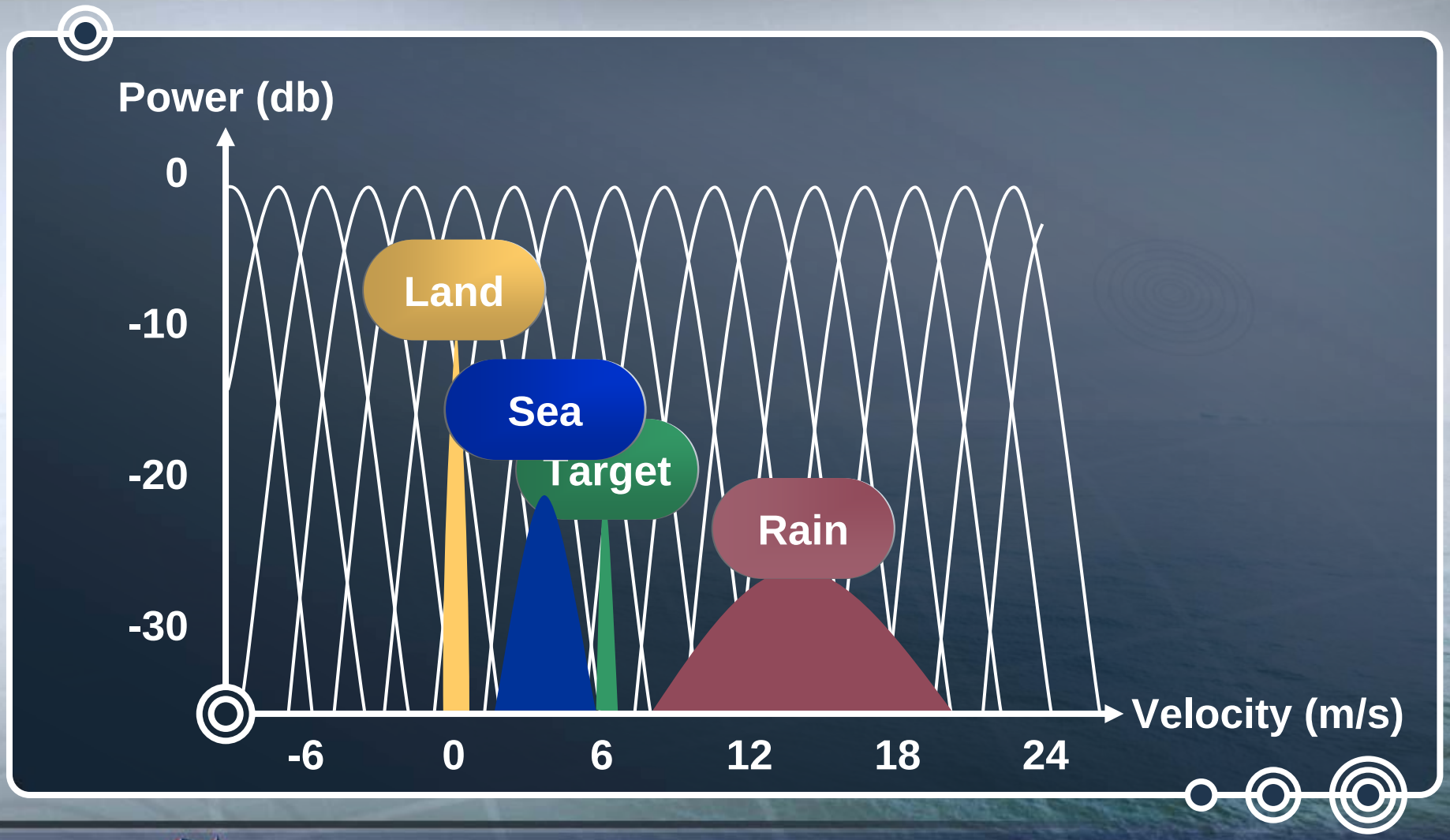
- Clutter controlled by raising threshold - small targets disappear

Sharpeye Monostatic Pulse Radar

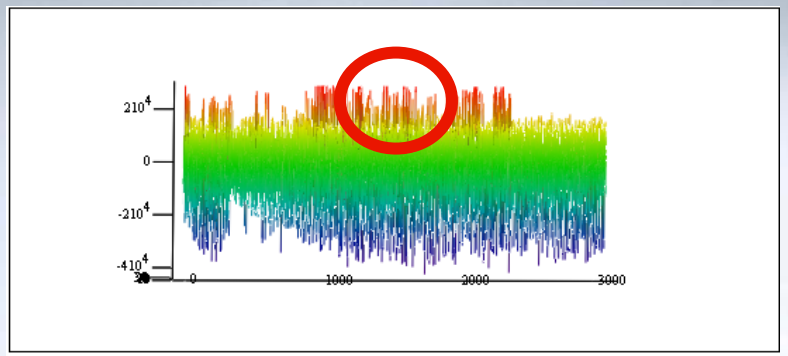
Targets and clutter are separated by measuring the radial velocity of target

- Frequency shifts in the returned signal helps to distinguish between target and clutter
- FFT or MTD Doppler Processing mechanisms available
  - MTD enables variation in filter characteristics across velocity space
- Flexibility of implementation provides potential for future growth
  - Adaptive MTD

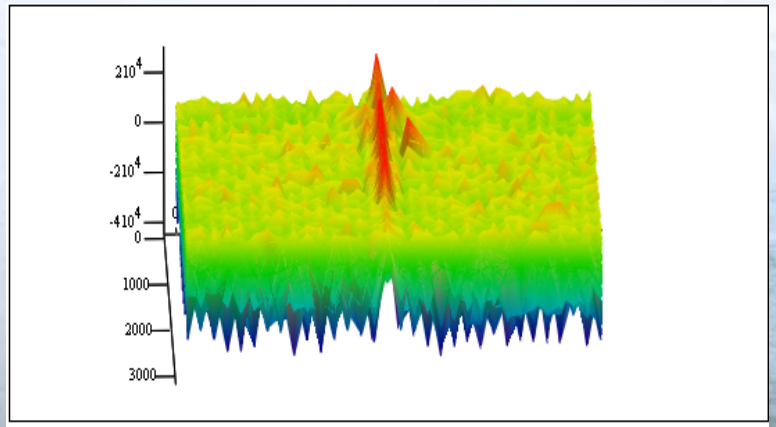
# Performance: In Clutter



# SharpEye™ Pulse Doppler




Imap




Imap

## Doppler Map

- Echoes from 1 burst (32 pulses)
  - Data obtained from Hainault area in September 2005
    - X axis (Horizontal)
      - » Radial Velocity
    - Y axis (Out of Page)
      - » Range
    - Z axis (Vertical)
      - » Signal Amplitude
- Central Ridge
  - Ground Clutter (zero velocity)
- Right Half Plane (+ve velocity)
  - Two Targets

# Solid State Transceiver - Physical Implementation

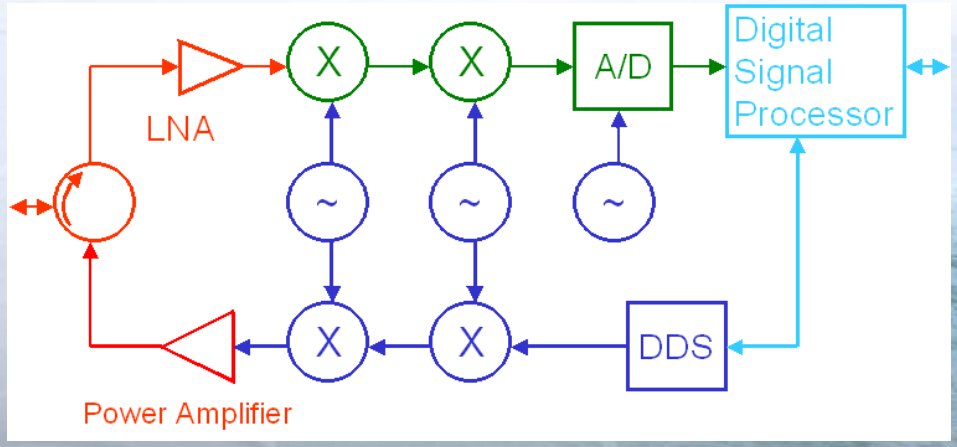
RF Front End

Receiver

Signal Generator

Digital Signal Processor

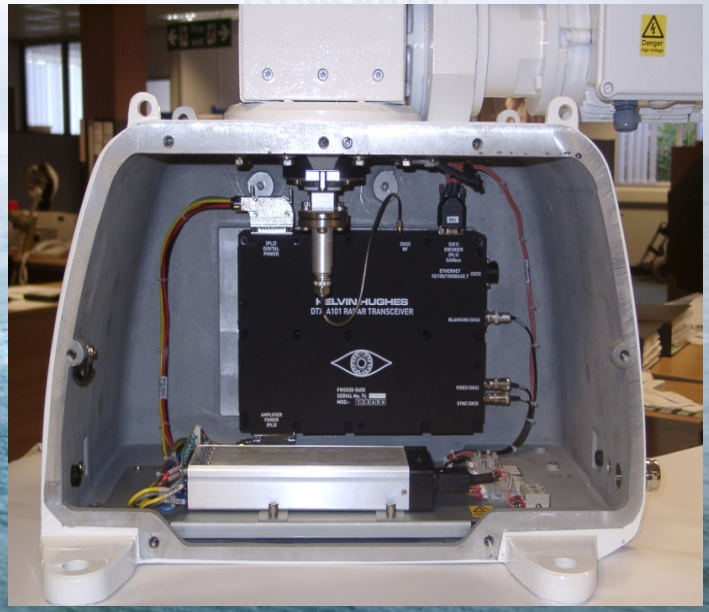
# Solid State Transceiver - Physical Implementation


- Internally 4 Layers
  - RF Front End
    - Power Amplifier
    - Circulator
    - Low Noise Amplifier
  - Signal Generator
    - Coherent Oscillators
    - DDS Waveform Generator
    - Up Converter
  - Receiver
    - Down Converter
    - Analogue to Digital Converter
  - Digital Signal Processor
    - Pulse Compression
    - Doppler Processing
    - CFAR & Detection
    - Video Output & Control

# Product Description

- Solid State Radar for Naval & Coastal Applications
  - S Band (2.9-3.1 GHz) and X Band (9.0-9.7 GHz)
  - Upmast Systems
    - Unstabilised Antenna
    - Electronics Housing
    - Transceiver
  - Conduction cooled
  - Functionally equivalent
    - Frequency Dependent variations
  - Multi-Mode
  - Digital Signal Processor
    - Doppler Processing enables Velocity Measurement
  - High Reliability
  - Flexible Design for Future Growth

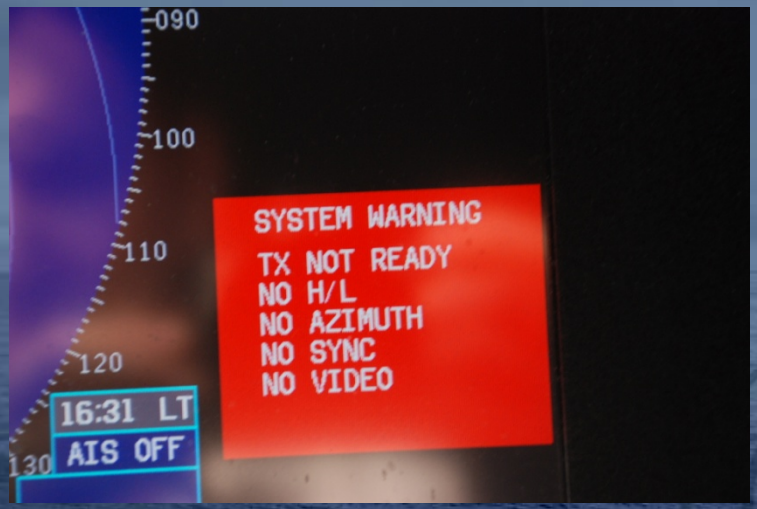


# Examples of SharpEye BITE

TX POWER
Will show up when the transmitter is running at half power.

TX NOT READY
Tx has 2 stage start up. VSWR is checked before Tx goes to full power.

NO SYNC
Will show up when the Tx stops or when the Trigger circuits go faulty




NO AZIMUTH
Will show up when scanner stopped or when azimuth pulse circuits are faulty

VSWR
Will show up when the transmitter output detects a poor VSWR

NO H/L. Will show up if antenna not turning or if the Heading Line circuits are faulty.

NO VIDEO
Will show up when the transmitter is not running or when there is a fault in the receiver circuits

# Standard System Modes and Sub-functions

- Surface Picture Modes
  - Primary System Modes
  - Defined by Instrumented Range (24nm & 48nm)
  - Operator Selection via Display
- Rotation Rate
  - Supports 12rpm, 24rpm, 46rpm Nominal Rates
  - Custom Waveform Design for Rotation Rate/Range Mode
- Sub-functions
  - Reduced Power
    - 7dB Reduction in Peak Power
  - Reverse Sweep
    - Reversed Pulse Modulation in Transmit

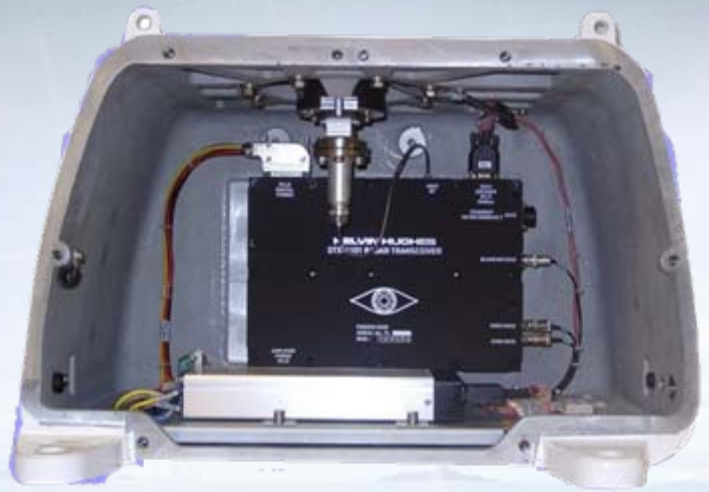
# System Modes - Incremental Capability Growth

- Flexible Design enables Incremental Capability Growth
  - Helicopter Tracking Mode
    - Higher Maximum Unambiguous Velocities (Up to 300 Knots)
    - Reduced Instrumented Range (10 nm)
  - Short Range Mode
    - Low Power Mode
    - Modified Transmission Waveform
    - Reduced Instrumented Range (3-4 nm)
    - Designed for Close In/Harbour Operation
  - Frequency Diversity
    - Provision made for Auxiliary RF Channel in Receiver
    - Custom Transmission Waveform and Signal Processing

# Reliability, Maintainability, Availability

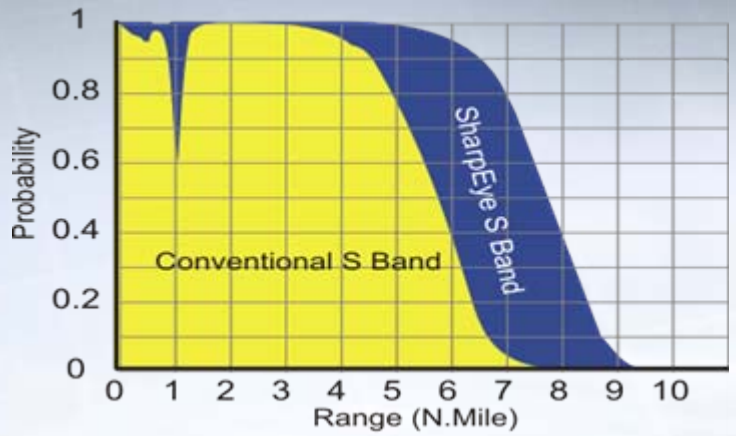
- Reliability
  - Transceiver >50,000 hours
    - >5 years continuous use (24/7)
- Maintainability
  - Continuous Monitoring
    - Peak Power, VSWR and Receiver Sensitivity
    - Automatically alarms when outside specified limits
    - Graceful degradation
  - Repair Philosophy
    - Replacement of Major Unit
    - Mean Time To Repair < 1 hour
- Availability
  - Transceiver
    - 99.995%

# SharpEye™ S Band (NATO F Band) Radar

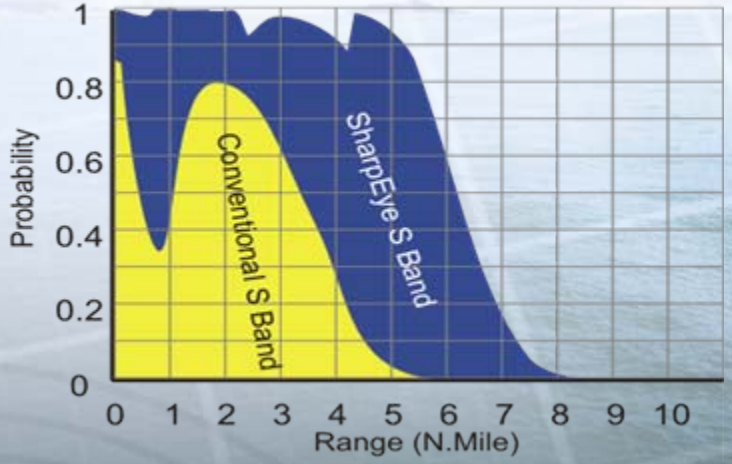


- Solid State
  - Transistor Power Amplifier Replaces Magnetron
    - » High Reliability & No ‘Lifed’ Items
    - » Low Voltages 36v max.
  - Low Peak Power 170W min, 200W typically
    - » Pulse Compression Recovers Range Resolution
    - » Triggers RACONs
- Optional Pulse Doppler variant
  - Coherent
  - Separates targets from clutter
- IMO compliant to current and ‘new’ (2008) standards

# SharpEye™ S Band (NATO F Band) Radar




**10m² target sea state 5 and heavy clutter conditions**




**0.5m² target sea state 5 and heavy clutter conditions**

## Cost vs Performance Comparison

### Performance

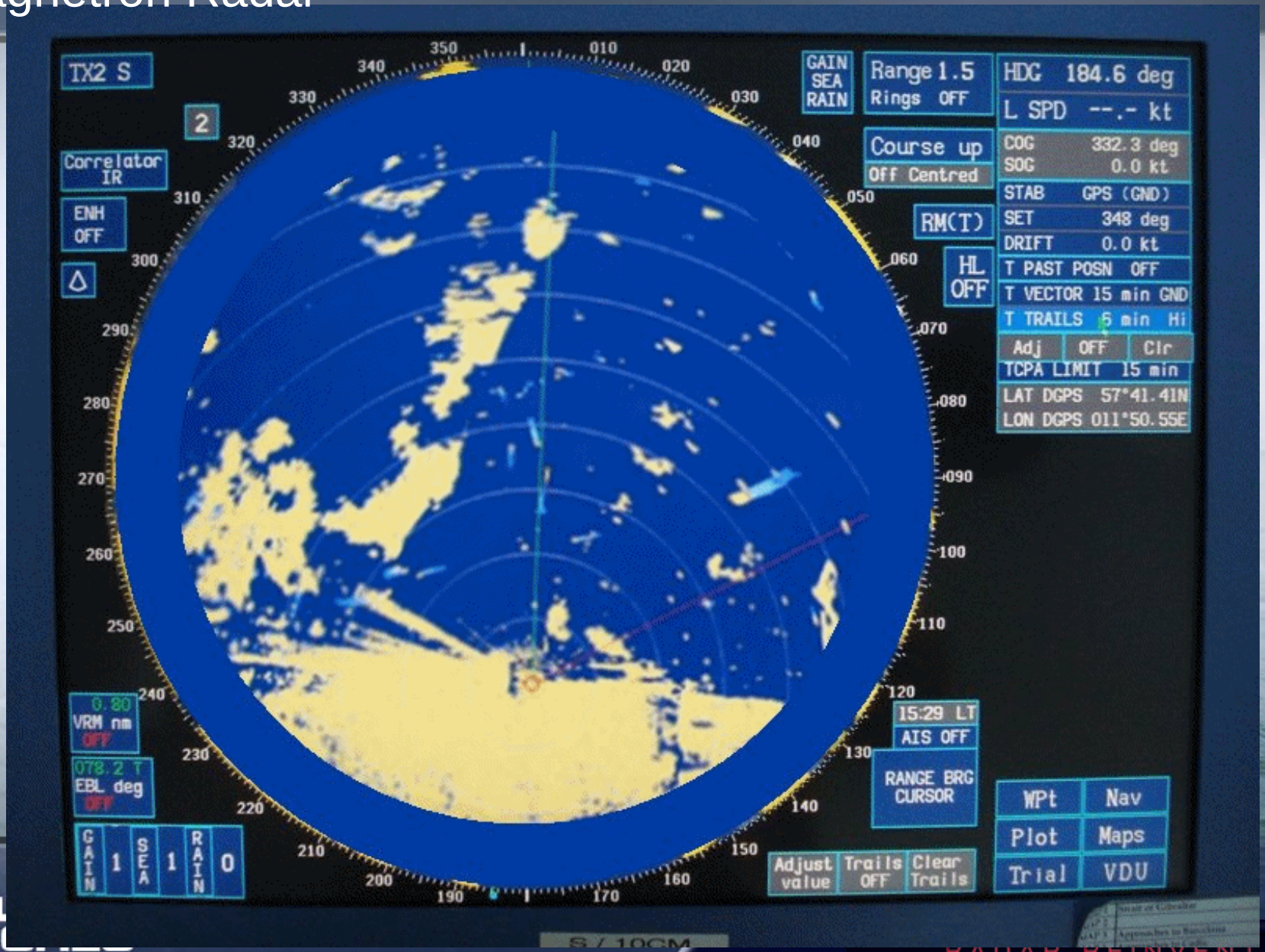
- Exceeds magnetron radars in almost all conditions

### Cost

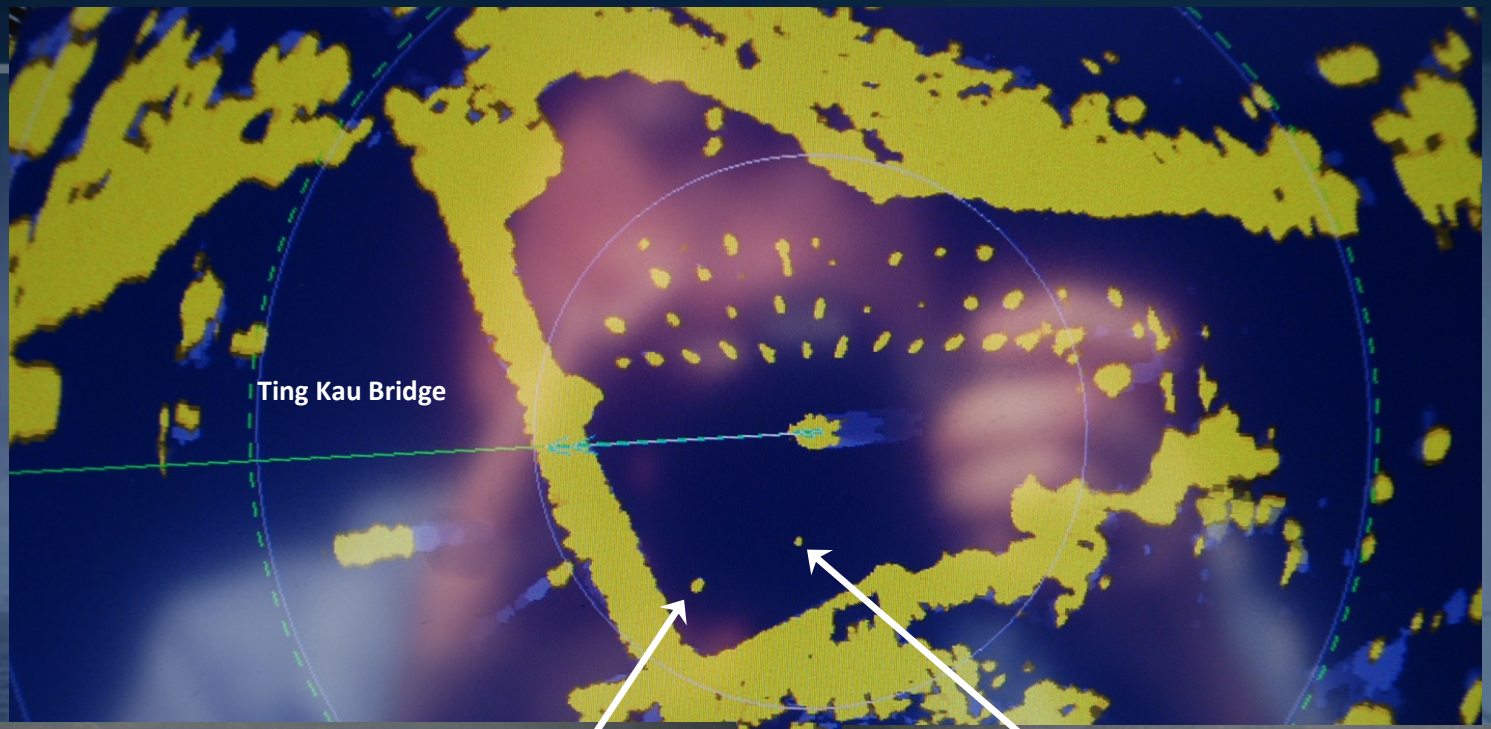
- Acquisition
- Comparable with a magnetron system
- Through-life
- Less than a magnetron system

# S Band SharpEye™ in Gothenburg

# Comparison: S Band SharpEye™ with 25kW X Band Magnetron Radar



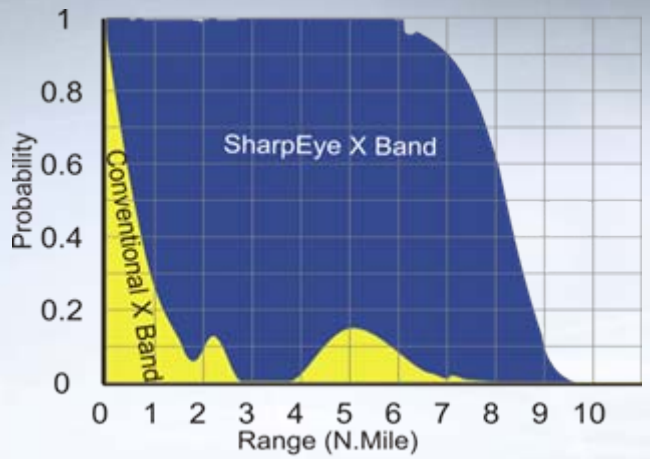
# S Band SharpEye™ in Gothenburg


Ting Kau Bridge

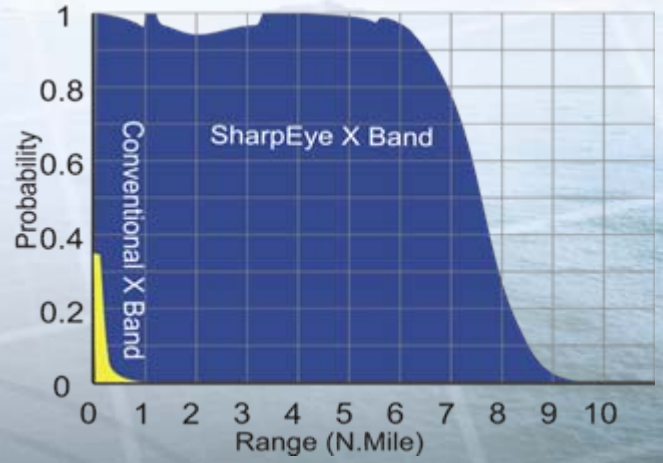
# SharpEye™ X Band (NATO I Band) Radar


- Solid State
  - Transistor Power Amplifier
    - High Reliability & No ‘Lifed’ Items
    - Low Voltages 15v max.
  - Peak power 170W min, 200W typ
    - Pulse Compression Recovers Range Resolution
    - Triggers RACONs & SARTs
  - Operational frequency
    - 9.0 GHz - 9.5 GHz
    - IMO compliant over band 9.2 GHz - 9.5GHz
- Pulse Doppler
    - Coherent
    - Measures the radial velocity of targets
    - Separates targets from clutter

# SharpEye™ X Band (NATO I Band) Radar




**10m² target sea state 5 and heavy clutter conditions**




**0.5m² target sea state 5 and heavy clutter conditions**

- Cost vs Performance Comparison
- Performance
  - Exceptional in its class
  - Exceeds magnetron radars in almost all conditions
- Cost
  - Acquisition
    - Comparable with a magnetron system
  - Through-life
    - Less than a magnetron system

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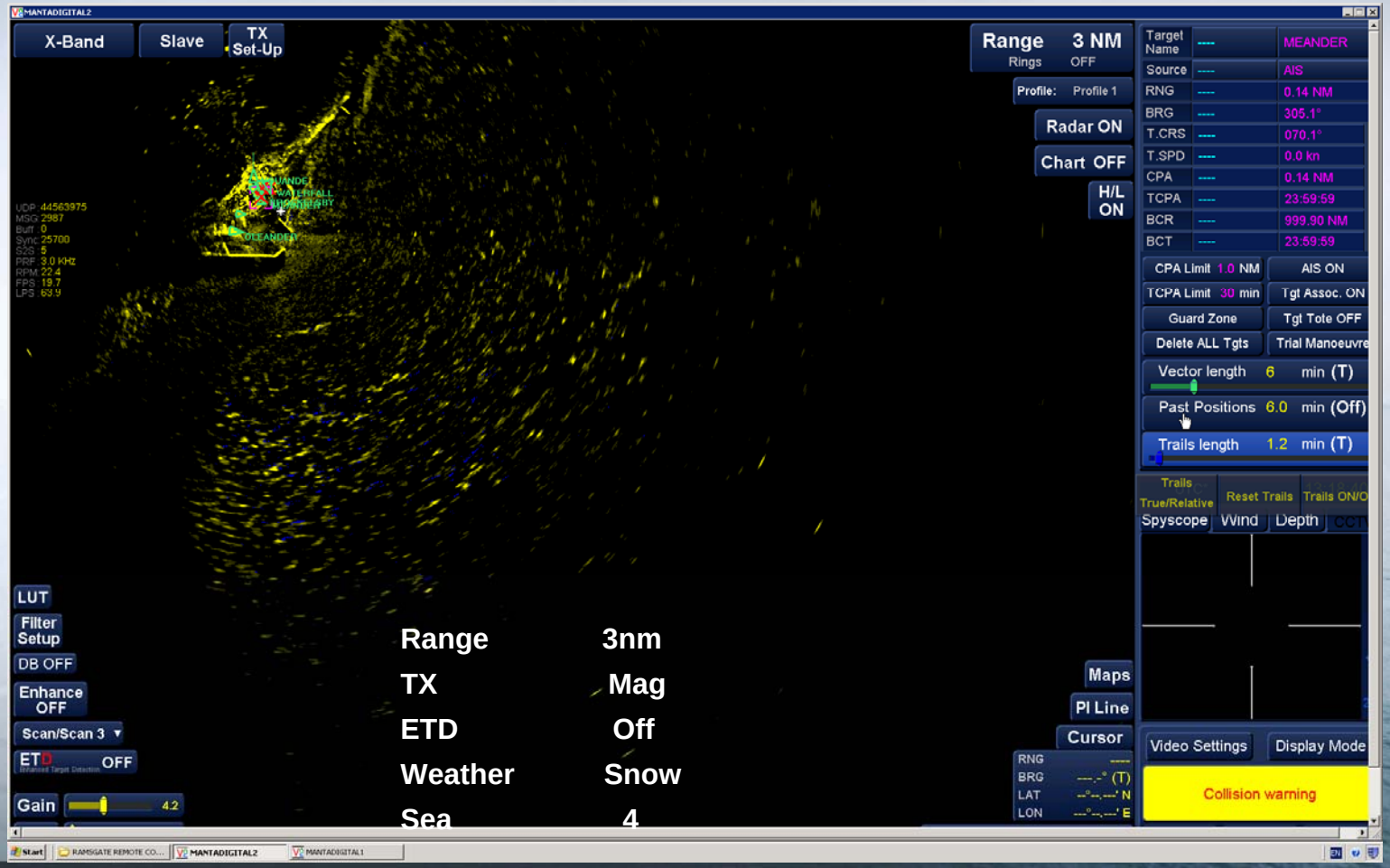
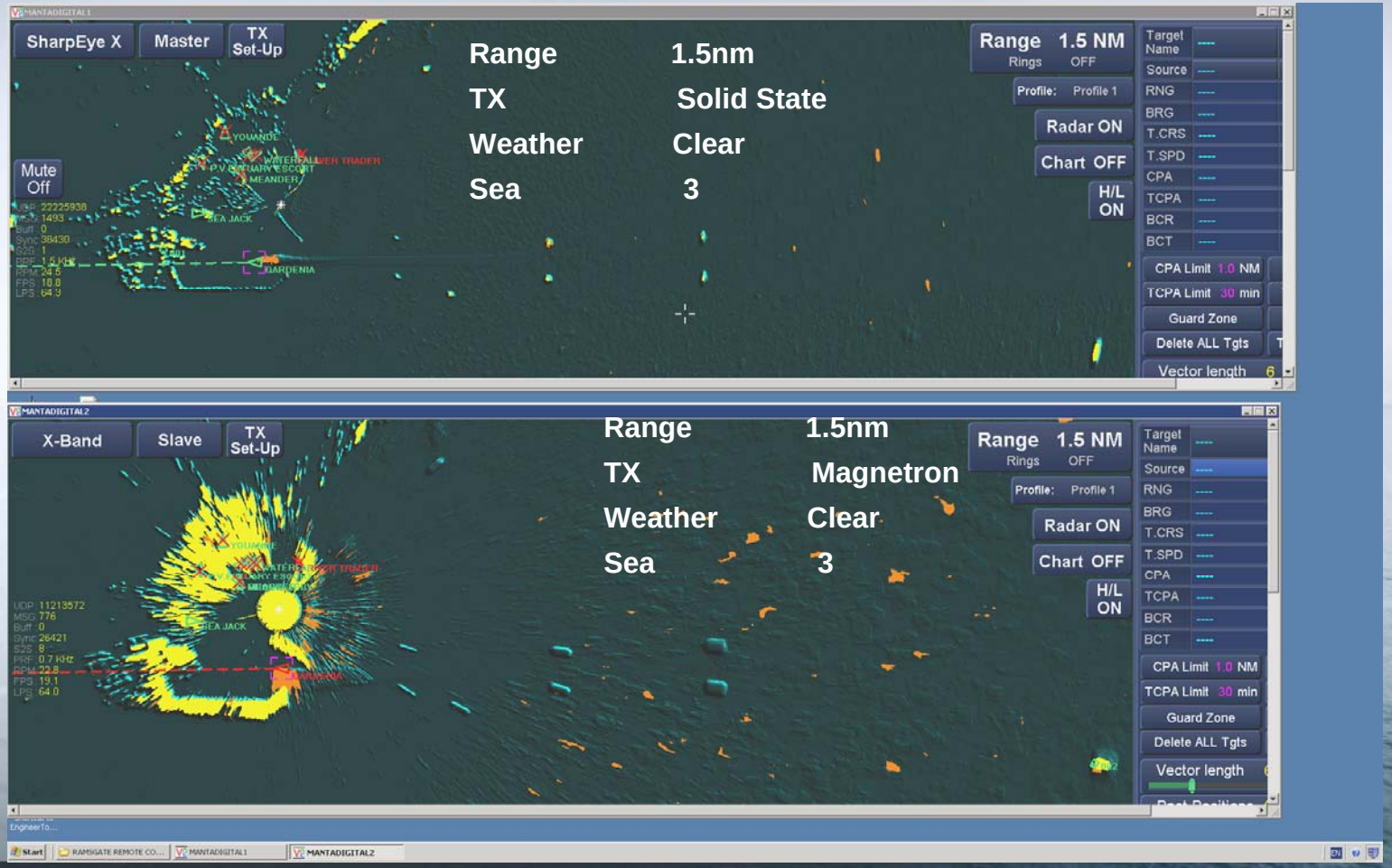
RADAR REINVENTED

# Conventional X Band



# Sharpeye X Band

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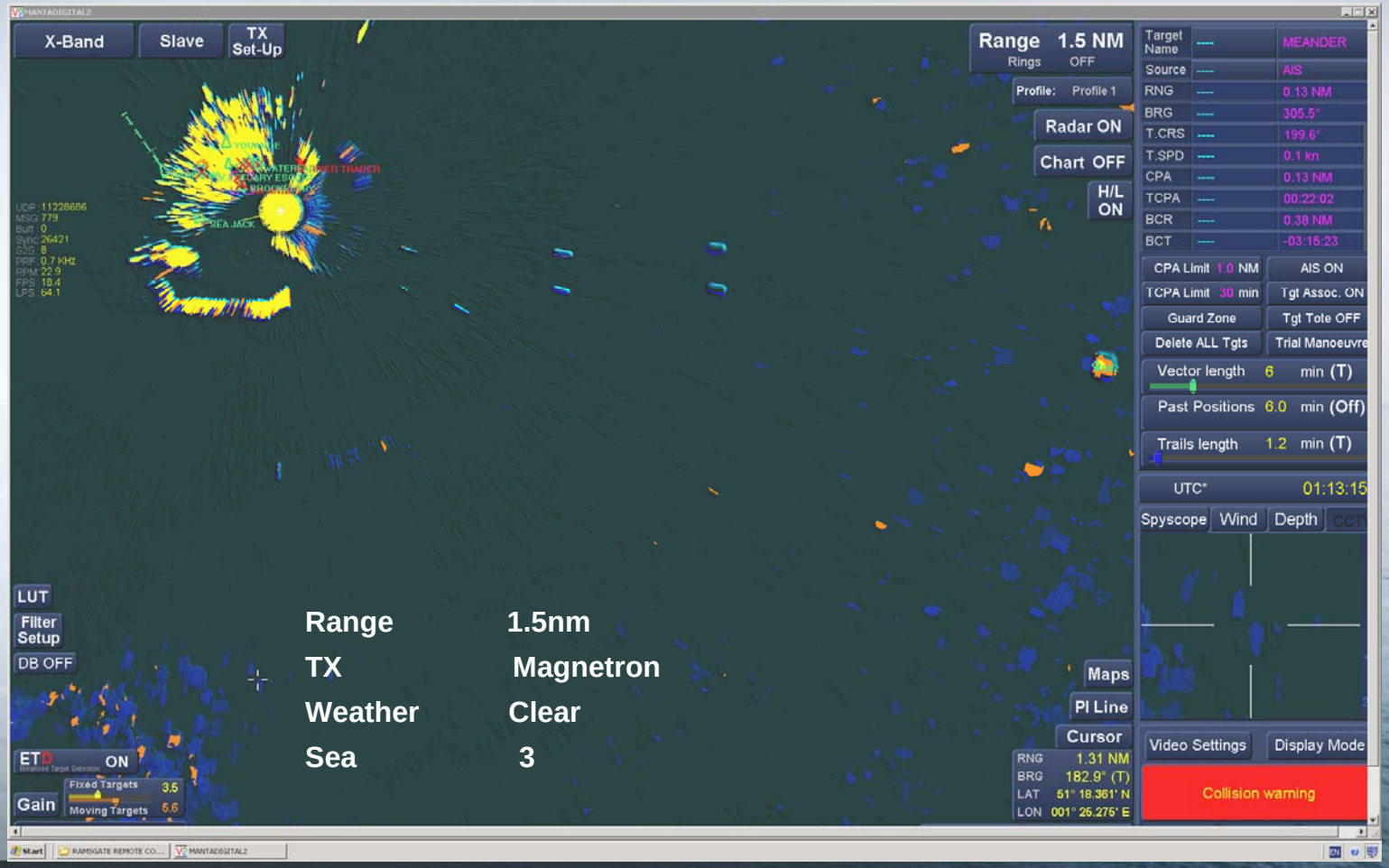
RADAR REINVENTED

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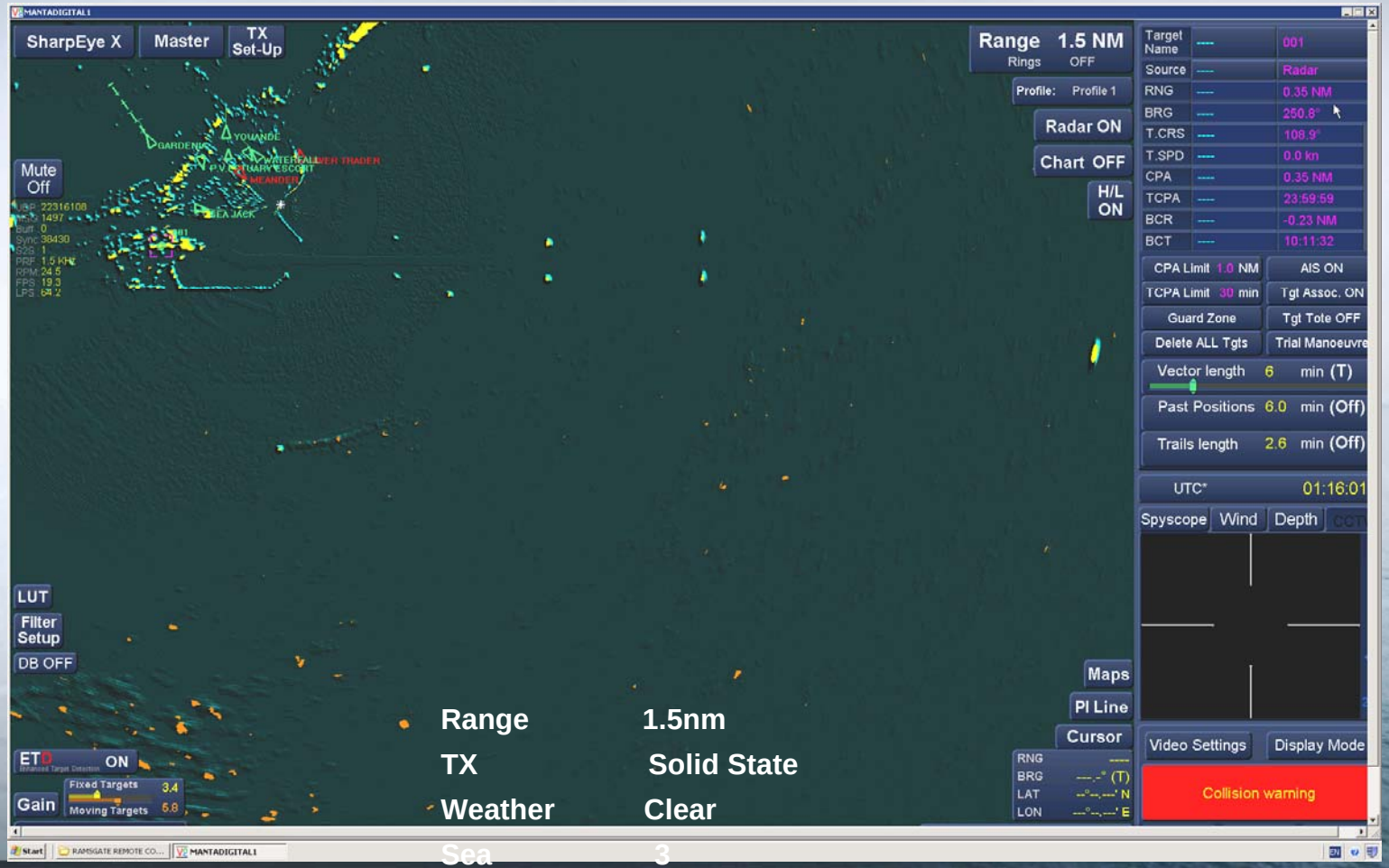
RADAR REINVENTED


SharpEye X
Master
TX Set-Up
Range 1.5 NM
Rings OFF
Profile: Profile 1
Radar ON
Chart OFF
H/L ON
Mute Off
Target Name ---- 001
Source ---- Radar
RNG ---- 0.35 NM
BRG ---- 250.8°
T.CRS ---- 108.9°
T.SPD ---- 0.0 kn
CPA ---- 0.35 NM
TCPA ---- 23:59:59
BCR ---- -0.23 NM
BCT ---- 10:11:32
CPA Limit 1.0 NM
AIS ON
TCPA Limit 30 min
Tgt Assoc. ON
Guard Zone
Tgt Tote OFF
Delete ALL Tgts
Trial Manoeuvre
Vector length 6 min (T)
Past Positions 6.0 min (Off)
Trails length 2.6 min (Off)
UTC* 01:16:01
Spyscope
Wind
Depth
LUT
Filter Setup
DB OFF
Maps
PI Line
Cursor
ET ON
Fixed Targets 3.4
Moving Targets 6.8
Gain
Video Settings
Display Mode
Collision warning
RNG ----
BRG ---.-° (T)
LAT --°--.---' N
LON ---°--.---' E
Range 1.5nm
TX Solid State
Weather Clear
Sea 3

# SharpEye™ - Coastal Surveillance & VTS

- Coastal
  - S Band
    - High reliability
    - Excellent performance in weather
    - Frequency diversity
  - X Band
    - High reliability
    - Good performance in weather
    - Frequency diversity
    - High angular resolution
  - Dual Band
    - S & X in a single turning unit
      - Detection of small boats
- Vessel Traffic Management
    - S or X band
    - Ports and harbours

# Sharpeye System Summary

- Solid state technical sensor that meets latest requirements for situational awareness, navigation safety, small target detection and helicopter tracking in high clutter
- Technology “borrowed” from military systems but delivered in a commercial cost effective system
- Designed to meet /exceed IMO performance standards
- Uses latest signal and graphic processing technology
- Software upgradable – future enhancements planned
- Low maintenance
- Low through life costs