NPS-EC-14-003

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

COMMERCIALLY AVAILABLE LOW PROBABILITY OF INTERCEPT RADARS AND NON-COOPERATIVE ELINT RECEIVER CAPABILITIES

by

Kathleen Heinbach, Rita Painter, Phillip E. Pace

September 2014

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From-To)*
30-09-2014	Technical Report	

4. TITLE AND SUBTITLE
Commercially Available Low Probability of Intercept Radars and Non-Cooperative ELINT Receiver Capabilities

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Kathleen Heinbach, Rita Painter, Professor Phillip Pace

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)
Naval Postgraduate School
Center for Joint Services Electronic Warfare
833 Dyer Road, SP-543
Monterey, CA 93943

8. PERFORMING ORGANIZATION REPORT NUMBER
NPS-EC-14-003

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
HQ USSOCOM/J24-S
7701 Tampa Point Blvd
MacDill AFB, FL 33621-5323

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report is divided into two sections. Section One profiles a range of Low Probability of Intercept radars organized by function that are currently marketed to be commercially available. Included are naval navigation and surveillance radar systems, ground surveillance radar systems, radar motion detector sensor chips, and modular radar systems developed for use in training and research applications. The profile for each radar system includes a picture, description of the radar system's major features and applications, and a table of unclassified technical parameters. Most of the systems included are low power systems that operate using frequency modulated continuous wave waveforms, although several also include frequency shift keying capabilities.
Section Two of this report presents modern ES/ELINT systems and their sensitivities. It is organized based on the platforms these systems are deployed on, including airborne, submarine/surface ship and ground mobile systems. The profile for each system includes a picture, description of the system's major features and applications and a table of technical available parameters.

15. SUBJECT TERMS
Low Probability of Intercept (LPI) Radar, ES/ELINT Systems, Receivers, Electronic Warfare

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Phillip E. Pace
Unclassified	Unclassified	Unclassified	Unlimited	138	**19b. TELEPHONE NUMBER** ***(include area code)*** (831) 656-3286

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

THIS PAGE INTENTIONALLY LEFT BLANK

NAVAL POSTGRADUATE SCHOOL
Monterey, California 93943-5000

Ronald A. Route
President

Douglas A. Hensler
Provost

The report entitled "*Commercially Available Low Probability of Intercept Radars and Non-Cooperative ELINT Receiver Capabilities*" was prepared for U.S. Special Operations Command and funded by U.S. Special Operations Command/J24-S.

Further distribution of all or part of this report is authorized.

This report was prepared by:

Kathleen Heinbach
Midshipman
ECE Department
United States Naval Academy
Annapolis MD 21402

Rita Painter
CJSEW Support
ECE Department
NPS
Monterey CA 93943

Phillip E. Pace, PhD.
Director, CJSEW
ECE Department
NPS
Monterey CA 93943

Reviewed by:

Ralph C. Robertson, Ph.D.
Chairman, ECE Department
Naval Postgraduate School

Released by:

Jeffrey D. Paduan, Ph.D.
Dean of Research
Naval Postgraduate School

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I. SECTION ONE – LPI RADARS……..1

A. MARITIME NAVIGATION AND SURVEILLANCE RADARS….....1

1. ALPER Naval LPI Radar……1
2. Elektronika CRM-203 Maritime Surface Surveillance Radar……... 2
3. Indera CX-3AH Coastal LPI Radar…….…….. 3
4. Indera MS-2AM Low-Power S-Band Naval Radar…….……...…… 4
5. Indera MX-2AH…….……..5
6. GEM Elettronica LPI-2000 Naval Radar…….……6
7. Detection Monitoring Technologies Dorado Marine Security Radar……..7
8. Thales Scout Mk3……8
9. Thales Variant 2D Surveillance Radar…… ...9
10. Simrad Broadband 4G Radar……10
11. SAAB Sea Giraffe AMB Radar……..…….. 11
12. Elektronika RM-100 Mobile Radar……...……12
13. Kelvin Hughes SharpEye…… .13
14. AIRES…….....15
15. SAAB PILOT……17
16. SCOUT Radar…….……...18
17. SMART-L Radar……...19

B. GROUND SURVEILLANCE RADAR……..….. 20

18. DRS MSTAR V6……...20
19. DRS Squire Ground Surveillance Radar System……...21
20. Pro Patria Electronics PGSR-3i Beagle……22
21. Pro Patria Electronics PSR-2i Doberman……..23
22. Blighter Revolution 360…….....24
23. Blighter B400 Series Radar……...25
24. Blighter B303 Radar……..26
25. Blighter B202 Mk 2 Radar…….....27
26. FLIR Ranger R2…….....28
27. FLIR Ranger R3D……..29
28. FLIR Ranger 5D……30
29. IAI ELTA ELM-2105……....31
30. IAI ELTA EL/M-2127……...32

C. LPI MOTION DETECTORS……..33

31. InnoSent IVS-148…… 33
32. InnoSent IVS-465…… 34
33. InnoSent IVS-179 ……... 35
34. InnoSent IVS-167…… 36
35. InnoSent IVS-948 ……... 37

36. InnoSent IVS-162 ……... 38

D. RESEARCH AND EDUCATIONAL RADARS……. 39

37. SkyRadar ToGo…… 39
38. SkyRadar FMCW and SAR…….. 40

II. SECTION TWO: NON-COOPERATIVE INTERCEPT RECEIVERS…...41

E. NON-COOPERATIVE INTERCEPT RECEIVER OVERVIEW…..……41

F. AIRBORNE INTERCEPT RECEIVERS……....42

39. DM/A-104 Radar Warning Receiver……..….. 42
40. AN/ALR-95(V) Electronic Support/Radar Warning Receiver System….43
41. ALR-2002 Radar Warning Receiver ……44
42. AN/ALR-66(V)4 Electronic Support/Radar Warning Receiver ……..….44
43. AN/ALR-67(V)3 Digital Radar Warning Receiver……..45
44. AN/APR-39D(V)2 Radar Warning Receiver……... 46
45. BOW-21 Radar Warning Receiver…….…...47
46. Chinese BM/KZ 8608 ELINT System…….…..47
47. Chinese KM/KJ-8602 Radar Warning Receiver…….…..48
48. EL/L-8382 ES/ELINT Series…….49
49. ELINT-FD ELINT System……50
50. AN/ALR-56A/C Radar Warning Receiver……51
51. ELT/750 Receiver……..53
52. ES-5080 Digital Receiver-based ELINT system……...54
53. Itata Airborne ELINT System……...….55
54. French Phalanger ELINT System……..57
55. Kestrel……58
56. LR-100 Receiver……60
57. SAGE Advanced Digital ESM……...62
58. Sea Petrel RQH-5(V) ESM/ELINT System……...…63
59. SEER…….……64
60. Sky Guardian 200 Radar Warning Receiver…….65
61. TOP-SCAN ES/ELINT System……66
62. UltraEAGLE ALR-510…….…67

G. SURFACE/SUBMARINE INTERCEPT RECEIVERS……..……..69

63. Thales Sealon…….……69
64. SAAB Electronics UME-100 and UME-200…….……72
65. ITT/RSS ES-3601…….….74
66. DR 200/3000/4000 RESM Suites……..75
67. AN/BLQ-10 Submarine Electronic Warfare Support System……...…76
68. Chilean Naval ELINT and ES Systems…….78
69. ES-3701 RESM Suite……...…….79
70. MRBR-800/ MRSR-800 RESM/ELINT Suites……80

71. SEAL……..81
72. NS-9003A –V2/NS-9005A-V2 EW Suite……82
73. NELTIS/SLQ-750 Integrated ES/ECM Suite……83
74. Timnex II ESM/ELINT Suite……84
75. Vigile Electronic Support Systems……85

H. GROUND INTERCEPT RECEIVERS…….…..86

76. Chinese DZ9001 and ZJ93011 ELINT Systems……86
77. CS-3360 ESM System……...88
78. Chinese ERR-107A Portable Radar Reconnaissance Receiver……89
79. ES-3000 ES/ELINT System……..89
80. INCE/Meerkat-S ES/ELINT System…….……90
81. Meerkat-SA ESM/ELINT System……...……..91
82. MUR-20 ELINT System……93
83. PRD-13(V)3 Tactical SIGINT System……..94
84. UltraEagle ULR-501 ESM/ELINT System……...95
85. UltraEagle URL-543 Man Portable……...96
86. VEGA (Orion) 85V6-A ELINT System……97
87. Turkish Land-Based Transportable ESM/ELINT System……98

I. SUMMARY OF RECEIVER SENSITIVITIES……...……99

III. REFERENCES……...……... 105

LIST OF FIGURES

Figure 1: ALPER EN (from [21]) 1
Figure 2: CRM-203 Installation (from[3]) 2
Figure 3: Indera CX-3AH Transmitting and Receiving Antennas (from [6]) 3
Figure 4: Display Console of Indera MS-2AM Radar (from [7]) 4
Figure 5: Transmitting and Receiving Antenna of Indera MX-2AH Radar (from [8]) 5
Figure 6: Transmitting/Receiving Antenna (from [9]) 6
Figure 7: Dorado Lite Radar with DCPM (DMIT Camera and Power Module) (from [10]) 7
Figure 8: Thales Scout Mk3 Antenna (from [11]) 8
Figure 9: Thales Variant Radar Antenna (from [13]) 9
Figure 10: Simrad Broadband 4G Radar Radome (from [14]) 10
Figure 11: Sea GIRAFFE AMB's 3-D phased –array antenna assembly (from [15]) 11
Figure 12: RM-100 Mobile Radar (from [17]) 12
Figure 13: SharpEye vs. Conventional Radar Probability of Detection (from [18]) 13
Figure 14: SharpEye vs. Conventional Radar Probability of Detection (from [18]) 13
Figure 15: SharpEye in Heavy Rain vs. Conventional Radar in Heavy Rain (from [19]) 14
Figure 16: Kelvin Hughes SharpEye Radar Transceiver (from [19]) 14
Figure 17: AIRES NAV Surface Surveillance and Navigation Radar (Indra) (from [23]) 15
Figure 18: AIRES CS Surveillance Radar (Indra) (from [23]) 16
Figure 19: Transceiver unit from which fits in a submarine mast (from [23]) 17
Figure 20: SCOUT Radar (from [25]) 18
Figure 21: SMART- L RADAR (from [27] 19
Figure 22: DRS MSTAR V6 radar antenna (from [30]) 20
Figure 23: Squire Radar Antenna (from [31]) 21
Figure 24: Pro Patria Beagle Transmitting and Receiving Antenna (from [33]) 22
Figure 25: Pro Patria Electronics PSR-2i Doberman Antenna (from [35]) 23
Figure 26: Blighter Revolution 360 Radar on Vehicle Mast (from [37]) 24
Figure 27: Blighter B402 shown with W2OS Antennas (from [38]) 25
Figure 28: Blighter B303 Radar (180° azimuth scan angle) (from [39]) 26
Figure 29: Blighter B202 Mk 2 Radar (from [40]) 27
Figure 30: FLIR Ranger R2 Radome (from [41]) 28
Figure 31: FLIR Ranger R3D Radome (from [42]) 29
Figure 32: FLIR Ranger 5D Receiving and Transmitting Antenna (from [43]) 30
Figure 33: ELM-2105 Mounted on a Surveillance Vehicle (from [44]) 31
Figure 34: 1. EL/M 2127 Ground Deployment with camera 32
Figure 35: IVS-148 K-Band VCO Transceiver (from [46]) 33
Figure 36: IVS-465 K-Band VCO Transceiver (from [47]) 34
Figure 37: IVS-179 K-Band VCO Transceiver (from [48]) 35
Figure 38: IVS-167 K-Band VCO Transceiver (from [49]) 36
Figure 39: IVS-948 K-Band VCO Transceiver (from [50]) 37
Figure 40: InnoSent IVS-162 K-Band VCO Transceiver (from [51]) 38

Figure 41: SkyRadar ToGo Antenna, Receiver, and Laptop Computer (from [52]) 39
Figure 42: SkyRadar 5.0 Base Unit with Digital Signal Processing Unit and Transceiver (from [53]) 40
Figure 43: DM/A-104 Radar Warning Receiver (from [54]) 42
Figure 44: AN/ALR-95(V) ES/RWR System (from [55]) 43
Figure 45: AN/ALR-66 ES components (from [57]) 44
Figure 46: AN/ALR-67(V)3 Components (from [59]) 45
Figure 47: AN/APR-39(V)2 Radar Warning Receiver (from [61]) 46
Figure 48: BM/KZ-8602 RWR (from [65]) 48
Figure 49: ELINT-FD Narrow-band ELINT System Schematic (from [67]) 50
Figure 50: Schematic of F-15 Eagle with AN/ARL-56C components (from [68]) 51
Figure 51: ELT/750 Receiver/processor unit (from [69]) 53
Figure 52: ES-5080 (from [70]) 54
Figure 53: Itata ELINT System (from [71]) 55
Figure 54: Phalanger ES/ELINT System Antenna head (from [72]) 57
Figure 55: Kestrel System Components (from [73]) 58
Figure 56: LR-100 Receiver (from [74]) 60
Figure 57: S-100 flying trials with new SAGE ESM/ELINT Payload (from[76]) 62
Figure 58: Sea Petrel RQH-5(V) (from [78]) 63
Figure 59: SEER RWR System Components (from [79]) 64
Figure 60: Sky Guardian 2000 RWR (from [81]) 65
Figure 61: TOP-SCAN sensor module (from [82]) 66
Figure 62: UltraEAGLE ALR-510 (from [83]) 67
Figure 63: Thales Sealion Antenna (from [86]) 70
Figure 64: Thales Sealion Console (from [86]) 71
Figure 65: UME-100 System (Radar Warning Receiver Antenna, ESM Antenna, and Electronic Warfare Controller) (from [87]) 72
Figure 66: UME-200 System (Radar Warning Receiver Antenna, ELINT Antenna, and Electronic Warfare Processor) (from [87]) 72
Figure 67: UME-100 System installed onboard South African Navy Type 209 submarine (from [87]) 73
Figure 68: ES-3601 AS-360 Acquisition and DF Antenna Assembly, SP-360 Receiver/Processor, and CP-360 Operator Workstation (from [89]) 74
Figure 69: DR 4000U IMF ESM System Console (from [93]) 75
Figure 70: AN/BLQ-10 (from [94]) 77
Figure 71: ES-3701 (from [97]) 79
Figure 72: Typical Components for the MRBR-800 RESM Suite (from [98]) 80
Figure 73: SEAL on mast of Abu Dhabi-class FHS of the UAE Navy (from [99]) 81
Figure 74: Typical Configuration for the NS-9003A-V2/NS-9005A-V2 ES/ECM Suite (from [100]) 82
Figure 75: TIMNEX II System Components (from [102]) 84
Figure 76: Vigile APZ Receiver Array (from [103] 85
Figure 77: DZ901 ELINT Station (from [104]) 86
Figure 78: Man-Portable ZJ9301-1 (from [104]) 87
Figure 79: Condor CS-3360 ESM System (from [106]) 88
Figure 80: ES-3000 ELINT/ESM System (from [108]) 89

Figure 81: INCE/Meerkat-S Sensor Station Configuration (from [109]) 90
Figure 82: Meerkat-SA Components (from[110]) 92
Figure 83: MUR-20 (from [111]) 93
Figure 84: PRD-13(V)3 Tactical SIGINT System (from [112]) 94
Figure 85: UltraEAGLE URL-501 (from [113]) 95
Figure 86: UltraEagle URL-543 Man-Portable (from [114]) 96
Figure 87: ORION 85V6-A ELINT Station (from [115]) 97

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

Table 1: Technical Parameters for the ALPEN EN [2] 2
Table 2: Technical Parameters of CRM-203 [3] 3
Table 3: Technical Parameters of Indera CX-3AH [6] 3
Table 4: Technical Parameters of Indera MS-2AM Radar [7] 4
Table 5: Technical Parameters of Indera MX-2AH [8] 5
Table 6: Technical Parameters of GEM Elettronica LPI-2000 [9] 6
Table 7: Technical Parameters of Dorado Lite, Dorado 18, Dorado 24, and Dorado 24B [10] 7
Table 8: Technical Parameters of Thales Scout Mk3 [11, 12] 8
Table 9: Technical Parameters of Variant Radar [13] 9
Table 10: Technical Parameters of Simrad Broadband 4G Radar [14] 10
Table 11: Technical Parameters of Sea GIRAFFE Radar [16] 11
Table 12: Technical Parameters of Elektronika RM-100 [17] 12
Table 13: Technical Parameters of Kelvin Hughes SharpEye Radar [20] 15
Table 14: Technical Characteristics of the PILOT [24] 18
Table 15: Technical Parameters of the SCOUT [25. 26] 19
Table 16: Technical Parameters of the SMART-L Radar [26, 29] 19
Table 17: Technical Parameters of DRS MSTAR V6 [30] 20
Table 18: Technical Parameters of Squire [31, 32] 21
Table 19: Technical Parameters of Pro Patria PGSR-3i Beagle [34] 22
Table 20: Technical Parameters of Pro Patria Electronics PSR-2i Doberman [36] 23
Table 21: Technical Parameters of Blighter Revolution 360 [37] 24
Table 22: Technical Parameters of Blighter B400 Series Radar [38] 25
Table 23: Technical Parameters of Blighter B303 Series Radar [39] 26
Table 24: Technical Parameters of Blighter B202 Mk 2 Radar [40] 27
Table 25: Technical Parameters of FLIR Ranger R2 [41] 28
Table 26: Technical Parameters of FLIR Ranger R3D [42] 29
Table 27: Technical Parameters of FLIR Ranger R5D [43] 30
Table 28: Technical Parameters of ELM-2105 [44] 31
Table 29: Technical Parameters of ELM-2127 [45] 32
Table 30: Technical Parameters of IVS-148 [46] 33
Table 31: Technical Parameters of IVS-465 [47] 34
Table 32: Technical Parameters of IVS-148 [48] 35
Table 33: Technical Parameters of IVS-167 [49] 36
Table 34: Technical Parameters of IVS-948 [50] 37
Table 35: Technical Parameters of IVS-162 [51] 38
Table 36: Technical Parameters of SkyRadar ToGo [52] 39
Table 37: Technical Parameters of SkyRadar 5.0 FMCW [53] 40
Table 38: Technical Parameters of the DM/A-104 RWR [54] 43
Table 39: Technical Parameters for ARL-2002 RWR [56] 44
Table 40: Technical Parameters of the AN/ARL-66(V)3 [58]) 45
Table 41: Technical Parameters for AN/ALR-67(V)3 [59] 46

Table 42: Technical Parameters for AN/APR-39D(V)2 [61] 46
Table 43: Technical Parameters for BOW-21 RWR [62 63] 47
Table 44: Technical Parameters for the BM/KZ-8608 ELINT System [64] 47
Table 45: Technical Parameters for the BM/KJ-8602 RWR [58] 49
Table 46: Technical Parameters for the EL/L-8382 System [66] 49
Table 47: Technical Parameters for the ELINT-FD System [67] 50
Table 48: Technical Parameters of AN/ALR-56C RWR [28] 52
Table 49: Technical Parameters for the ELT/750 [69] 53
Table 50: Technical Parameters for the ES-5080 [70] 54
Table 51: Technical Parameters of the Itata ELINT System [71] 56
Table 52: Technical Parameters of the Phalanger [72] 57
Table 53: Technical Parameters for the Kestrel [73] 59
Table 54: LR-100 Receiver [75] 60
Table 55: Technical Parameters for SAGE [77] 62
Table 56: Technical Parameters for the Sea Petrel RQH-5(V) [78] 64
Table 57: Technical Parameters of the SEER RWR [80] 65
Table 58: Technical Parameters of the Sky Guardian 2000 [81] 66
Table 59: Technical Parameters of the TOP-SCAN System [82] 67
Table 60: Technical Parameters of the ARL-510 [84] 68
Table 61: Technical Parameters of Thales Sealion [86] 71
Table 62: Technical Parameters of SAAB UME-100 and UME-200 [87, 88] 73
Table 63: Technical Parameters of ITT/RSS ES-3601 [89] 75
Table 64: Technical Parameters of DR 3000 Suites [92] 76
Table 65: Technical Parameters of the DR 4000U [92] 76
Table 66: Technical Parameters for DMA-302S [96] 78
Table 67: Technical Parameters for the ES-3701 [97] 79
Table 68: Technical Parameters for the MRBR-/MBSR-800 [98] 80
Table 69: Technical Parameters of the ES Subsystem [100] 83
Table 70: Technical Parameters for the ESM receiver [101] 84
Table 71: Technical Parameters for the Timnex II [102] 84
Table 72: Technical Parameters (typical configuration) for Vigile 400 [103] 86
Table 73: Technical Parameters of DZ9001 ELINT System [105] 87
Table 74: Technical Parameters for CS-3360 [106] 88
Table 75: Technical Parameters for the ERR-107A [107] 89
Table 76: Technical Parameters for the ES-3000 System [108] 90
Table 77: Technical Parameters for the INCE Meerkat-S [109] 91
Table 78: Technical Parameters for the Meerkat-SA [110] 92
Table 79: Technical Parameters for MUR-20 [111] 93
Table 80: Technical Parameters for the PRD-13(V)3 [112] 95
Table 81: Technical Parameters of the ULR-501 [113] 96
Table 82: Technical Parameters for the URL-543 [114] 96
Table 83: ORION 85V6 ELINT Station [115] 98
Table 84: Summary of Deployed Intercept Receiver Sensitivities 99

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

In today's defense and security applications, the vulnerability of emitter to electronic warfare support and precision electronic and conventional attack make low probability of intercept (LPI) radars a tactical necessity. LPI radar is defined as radar that uses a special emitted waveform intended to prevent a non-cooperative intercept receiver from intercepting and detecting its emission [1]. The radar tries to hide its radio frequency (RF) emission or active signature from detection by applying various techniques such as low signal power and /or specially constructed wave forms. LPI radar characteristics include low power, wide bandwidth, ultra-low side lobes, and frequency variability. LPI radar attributes are commonly achieved through the use of periodically modulated continuous waveforms with very high duty cycle. Continuous wave (CW) radars output much lower peak power than conventional pulse radars because their average-to-peak power ratio is one. Using continuous waveforms, most modern LPI radars can equal the detection capabilities of conventional pulse radars with only a few watts of output power. The most common CW pulse compression modulation technique used in commercially available radars today is frequency modulated continuous waveform (FMCW). Frequency modulation allows for range resolution of CW signals and makes the detection of these signals by a narrow band receiver more difficult. Frequency shift keying, another CW modulation technique, is much less commonly available in commercial radar systems.

As LPI radar systems continue to improve, so do the non-cooperative ES/ELINT systems designed for their detection. The ability for LPI radars to stay undetected

depends heavily on an intercept receiver's characteristics. Modern electronic warfare systems include intercept receivers that are increasingly capable of detecting radars, while electronic attack systems are increasingly capable of attacking these radars. The need for LPI radar systems has therefore dramatically increased. With recent increases in the sensitivity of available ES/ELINT systems, the threshold for what constitutes a successful LPI radar system is constantly being elevated.

This report is divided into two sections. Section One profiles a range of LPI radars organized by function that are currently marketed to the commercial maritime industry or to countries who lack home-grown radar or electronics industries. Included are naval navigation and surveillance radar systems, ground surveillance radar systems, radar motion detector sensor chips, and modular radar systems developed for use in training and research applications. The profile for each radar system includes a picture, description of the radar system's major features and applications, and a table of available unclassified technical parameters. Most of the systems included are low power systems that operate using frequency modulated continuous wave waveforms, although several also include frequency shift keying capabilities.

Section Two of this report presents modern ES/ELINT systems and their sensitivities. It is organized based on the platforms these systems are deployed on; including airborne, submarine/surface ship and ground mobile systems. The profile for each system includes a picture, description of the system's major features and applications and a table of technical available unclassified parameters.

THIS PAGE INTENTIONALLY LEFT BLANK

I. SECTION ONE – LPI RADARS

Section One of this report presents profiles of commercially available LPI radars, organized by their functions. Most of the systems profiled are marketed for use in maritime navigation and security or ground surveillance. The remaining systems included in this section are radar motion detection chips and training/research radar systems.

A. MARITIME NAVIGATION AND SURVEILLANCE RADARS

1. ALPER Naval LPI Radar

Figure 1: ALPER EN (from [21])

The ALPER (Aselsan Low Power ECCM Radar) is a Turkish LPI navigation radar system for detecting surface targets in all weather conditions. The manufacturer is Aselsan, a Turkish Armed Forces Foundation company. The radar has an operating frequency of X-band and uses FMCW waveform. General specifications include LPI, frequency hopping, low antenna sidelobe levels, and sector blanking. Known technical parameters are noted in Table 1 [2].

Table 1: Technical Parameters for the ALPEN EN [2]

Frequency:	X-band
Waveform:	FMCW
Range Accuracy:	<5m in distance at 12 NM scale
Selectable Range Scales:	12, 24, and 36 NM
Maximum Range:	36 NM
Scanning Rate:	>20 rpm
Output Power:	1W, 0.1 W, 0.01 W, 0.001W (selectable)

2. Elektronika CRM-203 Maritime Surface Surveillance Radar

Figure 2: CRM-203 Installation (from[3])

The Polish Elektronika CRM-203 radar is a low power, solid-state radar system designed for maritime navigation and surveillance [3]. The manufacturer is Przemyslowy Instytut Telekomunikacji (PIT), a Bumar Group company [5]. As shown in Table 1, the CRM-203 transmits a low power (1mW-2W), FMCW waveform that gives it strong LPI capabilities. It features small targets detection capabilities in heavy sea clutter conditions and high range resolution [4]. It automatically detects and tracks up to 100 surface contacts and can be integrated with National Maritime Safety System and other command and control systems [3]. The CRM-203 comes equipped with ARPA anti-collision functions and built-in interfaces for AIS receivers, satellite compass, GPS, gyro, and other sensors [5].

Table 2: Technical Parameters of CRM-203 [3]

Beamwidth H/V:	0.70/22°
Scan Rate:	12 to 30 rpm (settable in 1 rpm increments)
Side lobes:	-28 dB [4]
Output Power:	1mW to 2w
Frequency:	9.3-9.5 GHz
Bandwidth:	4 MHz
Waveform:	DDS based linear FMCW
Scale Range:	12 / 24 / 48 NM
Range Cell Size:	5.6 / 11 / 22 m
Range Measurement Accuracy:	1% of selected range or 50m (whichever is greater)
Angle Resolution:	0.1°
Bearing Accuracy:	0.7°

3. Indera CX-3AH Coastal LPI Radar

Figure 3: Indera CX-3AH Transmitting and Receiving Antennas (from [6])

The Indonesian Indera CX-3AH is a coastal radar system with solid-state FMCW and frequency agility, designed to automatically detect and track up to 200 maritime surface contacts in sea traffic monitoring systems [6]. It is manufactured and marketed by Radar & Communications Systems, Jakarta, Indonesia [6]. As shown in Table 2, it operates at a max output power of 5W. It comes equipped with Maritime Tracking Aid software with ARPA functionality, Automatic Identification System Receiver, electronic chart overlay (ECDIS), and real-time weather data, which allows the CX-3AH to serve as the principal sensor in a traffic monitoring system such as VTS and VTMIS [6].

Table 3: Technical Parameters of Indera CX-3AH [6]

Beamwidth H/V:	1.6/20°
Scan Rate:	20 rpm

Side lobes:	-20 dB
Output Power:	5 W max
Frequency:	9.38, 9.40, 9.42 GHz
Bandwidth:	60 MHz
Waveform:	FMCW
Range Resolution:	.9 meter max, 72 meter min
Doppler speed:	30kts max

4. Indera MS-2AM Low-Power S-Band Naval Radar

Figure 4: Display Console of Indera MS-2AM Radar (from [7])

The Radar & Communications Systems Company in Jakarta, Indonesia, also manufactures and markets the Indera MS-2AM radar, which is a 2D naval surveillance system with a solid-state FMCW waveform and frequency agility [7]. It is primarily designed to operate as a navigation radar system and can operate in both a surveillance mode and a Low-Probability-of-Intercept mode. It comes equipped with Maritime Tracking Aid software with ARPA, AIS, electronic navigational chart overlay, and compass, so that it can act as a stand-alone navigation system. As shown in Table 3, the MS-2AM operates in the S-Band with output power ranging from 1mW-2W in Low Probability of Intercept mode to 50W maximum in surveillance mode.

Table 4: Technical Parameters of Indera MS-2AM Radar [7]

Beamwidth H/V	2.2/26°
Scan Rate	20 rpm
Side lobes	-20 dB
Output Power	Surveillance mode: 50 W max LPI mode: 1 mW-2W

Frequency	S-Band
Bandwidth	60 MHz
Waveform	FMCW
Range Resolution	5.4 meter max

5. **Indera MX-2AH**

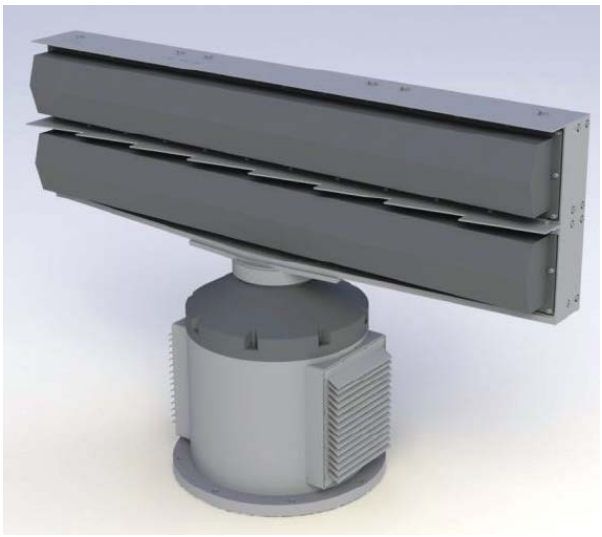

Figure 5: Transmitting and Receiving Antenna of Indera MX-2AH Radar (from [8])

The Indonesian Indera MX-2AH is a low power, solid-state FMCW naval navigation radar system with frequency agility [8]. It features Doppler FFT processing, Maritime Tracking Aid software with ARPA, AIS, electronic navigational chart overlay, GPS, and compass, so that it can be used as a standalone navigation system. As show in Table 4, the Indera MX-2AH is capable of automatically or manually detecting and tracking up to 200 targets.

Table 5: Technical Parameters of Indera MX-2AH [8]

Beamwidth H/V	1.6/20°
Scan Rate	20 rpm
Side lobes	-20 dB
Output Power	Surveillance mode: 5 W max LPI mode: 1 mW-2W
Frequency	9.38, 9.40, 9.42 GHz
Bandwidth	60 MHz
Waveform	FMCW
Range Resolution	.9 m max, 72 meter min
Tracking/Acquisition	Automatic or manual of up to 200 targets

6. GEM Elettronica LPI-2000 Naval Radar

Figure 6: Transmitting/Receiving Antenna (from [9])

The Italian, GEM Electtronica manufactured, LPI-2000 is a kit that can be integrated with conventional naval radar to provide a low probability of intercept mode of operation without lowering detection capabilities [9]. It features fully coherent solid state technology, low and medium range high resolution, ESM compatibility, output power selection capability (9.5 W average, 95 W peak power), sector blanking, and a rugged console. As shown in Table 5, the LPI-2000 utilizes a nonlinear chirp FMCW waveform. The LPI-2000 processors implement digital pulse compression and frequency sampling.

Table 6: Technical Parameters of GEM Elettronica LPI-2000 [9]

Frequency	9.3-9.5 GHz
Output Power	95W peak power, 9.5 W average
Beam Widths	Azimuth: < 1.3° (3 dB), < 2.3° (10 dB) Elevation: < 25° (3 dB), <54° (10 dB)
Scan Rate	22 ± 2 rpm
Side lobe levels	< -26 dB within ±10° < -30 dB elsewhere
Bandwidth	20 MHz
Output Waveform	Non Linear Chirp FM

7. DTS Dorado Marine Security Radar

Figure 7: Dorado Lite Radar with DCPM (DMIT Camera and Power Module) (from [10])

The Dorado Lite, Dorado LP18, Dorado LP24, and Dorado LP24B are short to long range solid-state FMCW radar systems that are designed for maritime navigation and surveillance (range increases on the list) [10]. They are manufactured by Detection Monitoring Technologies (DTS) LLC, which is headquartered in Sterling, Virginia, but has offices world-wide. The peak output power for these systems increases from 0.2 W for the Dorado Lite, to 1 W for Models 18 and 24, and finally to 2W for the Model 24B (Table 6). The up to 50 RPM scan rate for these systems allows for very quick updates over a wide area. The radomes for these systems include a mounting hole for additional equipment, such as cameras. The Dorado radar systems feature embedded GPS, separate antennas for transmitting and receiving, and Windows XP Pro internal operating system. This family of radar systems is designed specifically for the detection of small objects in wide open areas [10].

Table 7: Technical Parameters of Dorado Lite, Dorado 18, Dorado 24, and Dorado 24B [10]

Transmitted Frequency	X-band, 9.41 GHz
Peak Radiated Power	0.2 W (Dorado Lite) 1 W (Models 18 and 24) 2 W (Model 24B)
Average Power	0.2 W (Dorado Lite) 0.2 W (Model 18 and 24) 0.4 W (Model 24B)
Antenna Beamwidth (azimuth x elevation)	5° x 25° (Dorado Lite, Model 18) 4° x 25° (Model 24) 3° x 25° (Model 24B)
Scan Rate	24 RPM 50 RPM
Bandwidth	70 MHz
Waveform	FMCW
Range Resolution	2m

8. **Thales Scout Mk3**

Figure 8: Thales Scout Mk3 Antenna (from [11])

The Scout Mk3, manufactured by Thales Nederland B.V., is a low power LPI radar system specifically designed to automatically detect very small targets in heavy clutter [11]. As seen in Table 7, it operates on frequencies from 8 to 20 GHz, with output power that varies from 10 mW to 3 W [11,12]. The system consists of an antenna/FMCW transceiver assembly and a processor unit. The antenna is a dual array that features isolation between its transmit and receive elements in order to maximize range performance. It can be used as a standalone unit or integrated with pulsed navigation radar. The Scout radar is integrated in the NS 100 and Variant radar systems. It is particularly suited for detection of asymmetric threats and is safe for personnel due to the low transmitter power.

Table 8: Technical Parameters of Thales Scout Mk3 [11, 12]

Frequency	I/J Band (8-20 GHz[10], 17 frequencies, operator selectable)
Transmit Power	10 mW – 3 W
Beamwidth H/V	1.2° / 20°
Waveform	FMCW
Range Accuracy (at 6 NM)	1m
Minimum Range	< 15m
Rotation Speed	10, 20, 40 RPM
Clutter Suppression	> 60 dB

9. **Thales Variant 2D Surveillance Radar**

Figure 9: Thales Variant Radar Antenna (from [13])

The Thales Variant is a lightweight, short to medium range 2D naval surveillance radar system, which consists of a dual-band pulse-Doppler radar, FMCW radar, and an IFF antenna with monopulse capability [13]. As shown in Table 8, the Variant radar can automatically track up to 200 surface or air contacts. It can be installed on ships ranging from small naval vessels to large support vessels and features Surface gun Fire Control Support. It can also be used for helicopter support and guidance.

Table 9: Technical Parameters of Variant Radar [13]

Frequency	I Band
Transmit Power	5 W
Horizontal Beamwidth	1.8°
Waveform	FMCW
Rotation Speed	14, 28 RPM
Instrumented Ranges	Air Targets: 120 km Surface Targets: 70 km
Roll Range	25°
Pitch Range	10°
Elevation Coverage	up to 35°
Number of Tracks	Air: 200, Surface: 200

10. **Simrad Broadband 4G Radar**

Figure 10: Simrad Broadband 4G Radar Radome (from [14])

The U.S. Simrad Marine Electronics manufactured Broadband 4G radar system is a short to long range naval navigation radar designed for recreational vessels. It features beam sharpening with target separation control, side lobe suppression, dual range from 200' to 36 nm, InstantOn, and target separation control [14]. The Simrad Broadband 4G radar system operates with 165 mW peak output power in the X Band frequency range from 9.3-9.4 GHz, as seen in Table 9.

Table 10: Technical Parameters of Simrad Broadband 4G Radar [14]

Frequency	X Band (9.3-9.4 GHz)
Transmit Power	165 mW peak power
Waveform	FMCW
Rotation Speed	24, 36, 48 rpm
Bandwidth	75 MHz max
Side Lobe Level	> -18 dB (within ± 10°) > -24 dB (outside ± 10°)
Beamwidth H/V	5.2° / 25°
Radar Ranges	200ft/50m to 36 nm/66km with 18 range settings, dual range mode.

11. **SAAB Sea Giraffe AMB Radar**

Figure 11: Sea GIRAFFE AMB's 3-D phased –array antenna assembly (from [15])

Sweden's SAAB Sea GIRAFFE radar system is a multirole surveillance radar system that includes functionalities for air surveillance and tracking, surface surveillance and tracking, target classification, navigation, target indication for onboard weapon systems, gunfire support, and localization [15]. As shown in Table 10, the Sea GIRAFFE operates at 3 W output power and over 5.4-5.9 GHz [16]. It features instantaneous and simultaneous 0-70° coverage on all antenna revolutions, a wide detection range for high-speed targets and small RCS targets on the surface, a high degree of automation, 360° mortar/rocket alert and weapon location, and Data Distribution Service interface for easier CMS integration [15].

Table 11: Technical Parameters of Sea GIRAFFE Radar [16]

Frequency	5.4-5.9 GHz
Transmit Power	9 W
Waveform	FMCW
Antenna Rotation Rate	30 and 60 rpm
Beamwidth	2.1°
Range	180 km instrumented
Track Capacity	Up to 500

12. **Elektronika RM-100 Mobile Radar**

Figure 12: RM-100 Mobile Radar (from [17])

The Polish Elektronika RM-100 Mobile Radar is quiet maritime radar with an AIS receiver, a data-fusion system, and a data-transmission system [17]. It detects and automatically tracks maritime surface targets and determines their coordinates. Its recommended applications include littoral waters monitoring and economic zone protection. As shown in Table 11, the RM-100 uses FMCW technology and operates with output power from 1 mW to 2 W. The detection performance is comparable to that of conventional navigational pulse radar radiating up to 25 kW peak power. The system includes a Mobile Radar post which features a land navigation system and a communication system enabling operating within automated Naval Command and Control System. The antenna array is mounted atop a 20-meter mast.

Table 12: Technical Parameters of Elektronika RM-100 [17]

Frequency	8- 12.5 GHz
Transmit Power	1 mW – 2 W
Waveform	Linear FMCW
Receiver Bandwidth	4 MHz
Antenna Beamwidth H/V	1.3° / 22°
Antenna Rotation	12-30 rpm
Accuracy	1% (range) 1° azimuth
Deployment Time	<30 minutes

13. **Kelvin Hughes SharpEye™ Solid State Radar Systems**

SharpEye™ is the United Kingdom's Kelvin Hughes maritime digital radar technology system that is available in both X and S band frequencies. The graphs below compare the performance of the SharpEye™ with the performance of conventional magnetron radar [18].

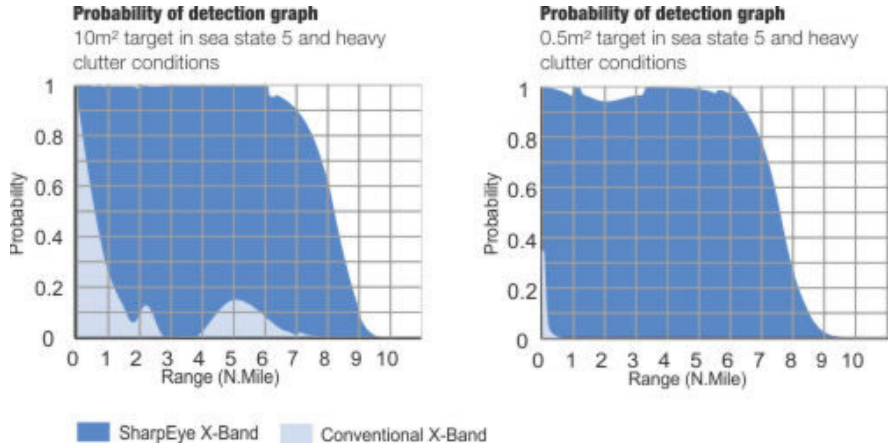

Figure 13: SharpEye vs. Conventional Radar Probability of Detection (from [18])

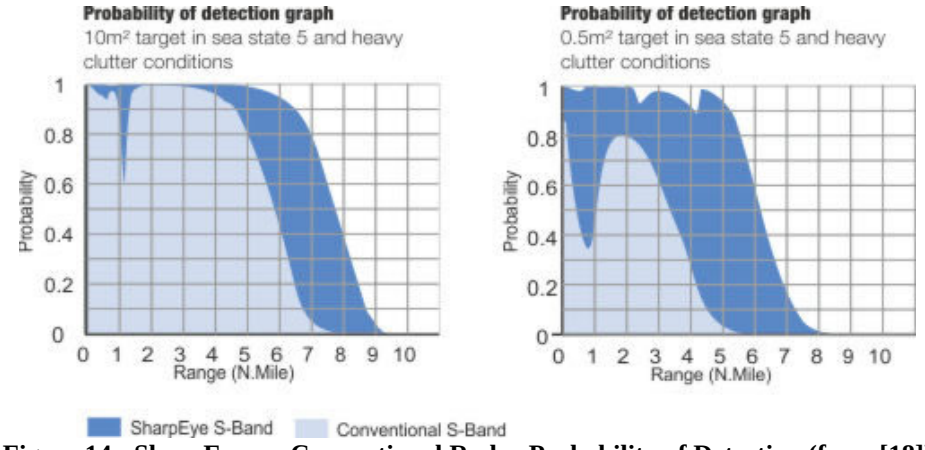

Figure 14: SharpEye vs. Conventional Radar Probability of Detection (from [18])

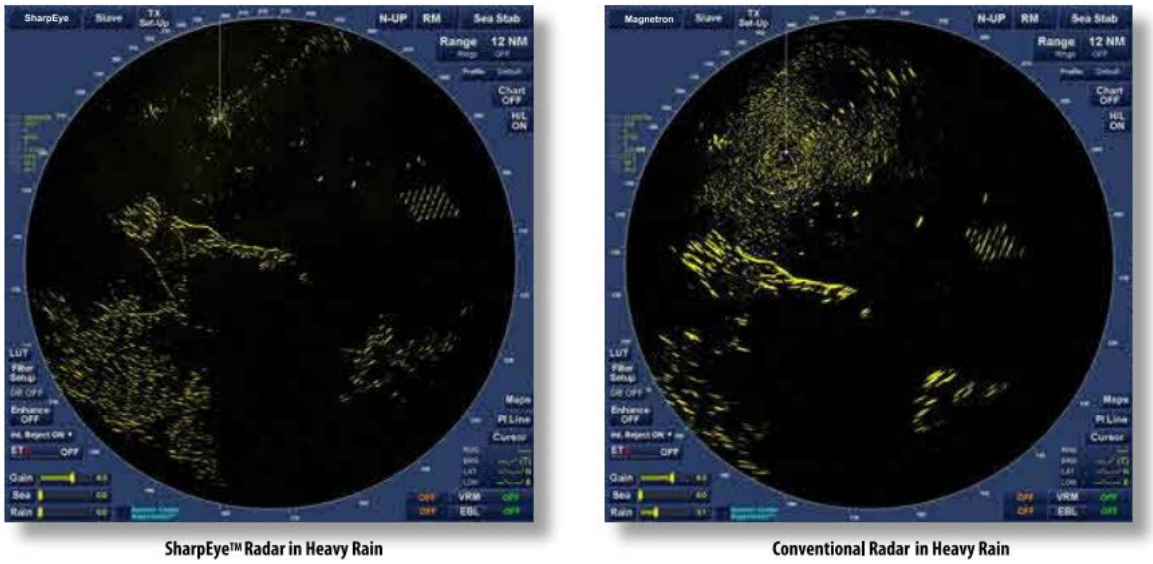

Figure 15: SharpEye in Heavy Rain vs. Conventional Radar in Heavy Rain (from [19])

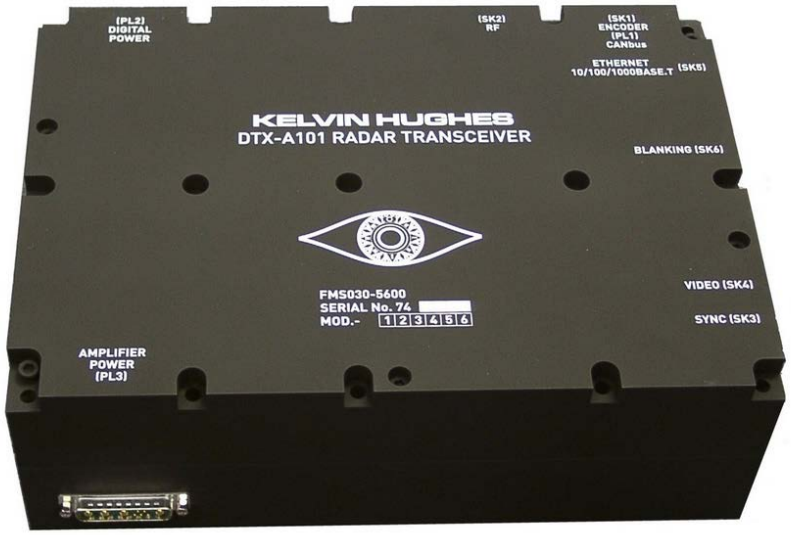

Figure 16: Kelvin Hughes SharpEye Radar Transceiver (from [19])

The Kelvin Hughes SharpEye Radar System provides superior radar performance, low cost of ownership, and high reliability through its solid state electronics [20]. As seen in Figure 12, the SharpEye radar has a significantly higher probability of detection for targets in sea state 5 and heavy clutter conditions than conventional radar systems [18]. This system also features short, medium, and long pulse transmission, Doppler processing, small target detection, clutter removal without picture degradation, frequency diversity, pulse compression, ultra-high reliability, covert, low peak power, customizable waveforms, and frequency selection [20]. As shown in Table 12, the SharpEye utilizes a nonlinear chirp FM waveform.

Table 13: Technical Parameters of Kelvin Hughes SharpEye Radar [20]

	I-Band (X-Band)	E/F-Band (S-Band
Frequency	9.2-9.5 GHz	2.9-3.1 GHz
Frequency Diversity	Yes	No
Waveform	Non-linear Chirp FM	Non-Linear Chirp FM
Frequency Channels	Non FD: 14 / FD: 7	8
Peak Power	Up to 300W	Up to 200W
Average RF Power	39W	20W
Clutter Discrimination	Up to 16 filters	Up to 32 filters
Minimum Range	<40m	<40m
Beamwidth H/V	<.95° / -26°	<2.0° / -26°

14. **ARIES**

Figure 17: AIRES NAV Surface Surveillance and Navigation Radar (Indra) (from [23])

The ARIES family of LPI radars is suitable for the detection and acquisition of low Radar Cross Section surface targets in a cluttered sea environment. The systems use Frequency Modulated, Continuous Waveform (FMCW) techniques to enable it to obtain long detection ranges with minimal peak transmission powers [22]. The equipment is designed to be modular and flexible, allowing for a variety of shipborne and land-based installations and applications in support of naval, commercial, maritime and airborne control operations and is centered around a physically integrated antenna array and FMCW transceiver on a pedestal mounting [22].

Span's Indra Company has stated only the system modulation type but it is probable that this radar functions within the 9.2 to 9.5 GHz region of NATO I-band, as this part of the radio frequency (RF) spectrum is generally acknowledged the best compromise for navigational radars. No other data is given, although information states that 'the FMCW principle offers a high-range resolution of the order of a few centimeters', suggesting broadband RF agility, perhaps in the order of 200 MHz or more. By inference and related to other FMCW systems, the RF agility may be as wide as 600 MHz but such an agility bandwidth may not be permissible under ITU regulations for commercial marine applications [22].

The system is of modular architecture implemented on commercial, off-the-shelf (COTS) digital signal processing (DSP) boards, with integrated built-in test equipment (BITE) to enhance reliability and facilitate maintainability. A dedicated communication board permits interfaces with multiple displays and other navigational subsystems such as GPS, gyrocompasses, and speed logs. Processing includes advanced image identification algorithms to enable small target tracking, and the complete system is managed through a series of user-friendly pop-up menus and graphical interface controls. One unusual feature for an FMCW navigation system is the optional addition of a pulsed transceiver, which is difficult to understand but may be because of a lack of direct switching between ARIES and other pulsed systems to a selected display, as is a feature in some competitive solutions [23].

Figure 18: AIRES CS Surveillance Radar (Indra) (from [23])

The ARIES CS, as seen in Figure 16, uses the standard FMCW transceiver with a pair of high-gain, dual-curvature antennas for greater sensitivity and is designed for coastal surveillance to detect and track all vessels that enter a country's territorial waters [22].

15. **SAAB PILOT**

The Pilot, manufactured by Saab, is an X-band (8 to 12.5 GHz) LPI navigation and threat detection radar. It uses the FMCW transmission technique and is suitable for coast guard vessels, fast attack craft, fast patrol boats, frigates, and submarines and coastal/land surveillance applications. It can function both in stand-alone and add-on configurations. In the add- on configuration, the Pilot radar uses the X-band antenna of the platform's existing radar, which can be any available pulsed navigation radar system. The Pilot radar has a low average power output, the 2.4 m range cell resolution, a resistance to electronic support system detection and/or anti-radiation missile attack, and the use of a "fully" solid-state [24].

The stand-alone PILOT configuration consists of a Transceiver Unit (TRU) and a Signal Processor Unit (SPU). To create a complete radar system for a navigation application, the units should be integrated with a standard antenna and turntable as well as a display or MFC, (which should include ARPA functionality). The standard video and control interfaces of the PILOT allow flexible integration with virtually all X(I) band antennas and displays/MFCs on the market [24].

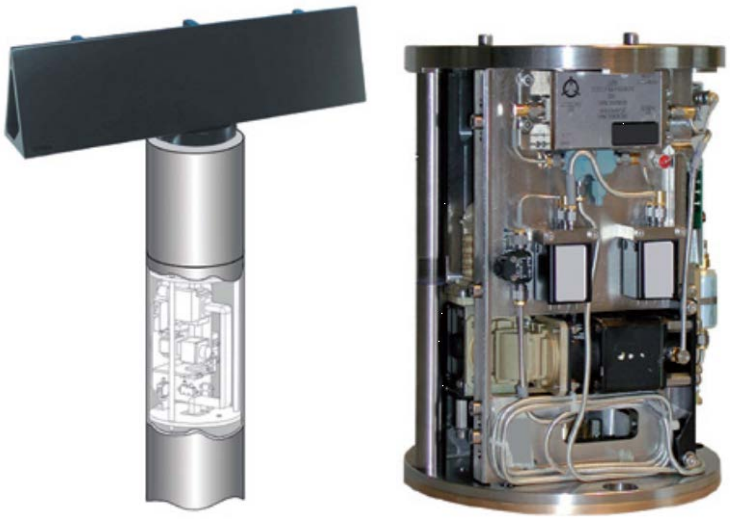

Figure 19: Transceiver unit from which fits in a submarine mast (from [23])

An advanced transceiver design has made it possible to combine the FMCW transmission with a conventional single X(I)-band antenna. This enables easier integration with surface ships and is essential on submarines. Even a close visual inspection will not reveal the existence of PILOT onboard [24].

Table 14: Technical Characteristics of the PILOT [24]

Frequency	X-Band (I-Band)
	9.1-9.5 GHz
Frequency agility band	400 MHz
Waveform	FMCW
Frequency Channels	Non FD: 14 / FD: 7
Peak Power	Up to 375W
Receiver noise figure	5 dB
Output power	1 W to 1 mW
Minimum Range	Very low

16. **SCOUT Radar**

Figure 20: SCOUT Radar (from [25])

The SCOUT is an LPI 2-D surface surveillance, navigation radar, which operates in I-band (8-10 GHz), manufactured by Thales Netherlands. It is an enhanced version of the PILOT radar, incorporating improved FMCW transmission techniques [26].

The SCOUT Mk3 is the latest version of the SCOUT family which will be installed on the new Joint Support Ship for the Royal Netherlands Navy. The Mk3 upgrade will employ Doppler processing techniques to ensure clutter suppression and high-range resolution against small surface targets for improved multihypothesis tracking. The

system will include fully automatic detection and tract initiation with fast track initiation and low false track rates [25].

Table 15: Technical Parameters of the SCOUT [25. 26]

Frequency	I-Band
	8-10 GHz
Waveform	FMCW
Output power	10 Mw – 1 W
Antenna rotation rate	10, 20, 40 rpm
Beamwidth, transmit	1.4°horizontal
Tracking capacity	Up to 500 targets

17. **SMART–L Radar**

Figure 21: SMART- L RADAR (from [27]

The SMART-L, manufactured by Thales, Netherlands, operates in the 1 to 2 GHz range (D Band, formerly L Band) and is used as an air and surface surveillance and target designation radar. The radar also has an integrated low probability of intercept (LPI) I/J-band surface surveillance mode, using FMCW techniques drawn from Signaal's Scout covert navigation radar program [28]. It is a multi-beam radar that provides medium-range detection of small “stealth” air targets, long-range detection of conventional aircraft, surface surveillance and maritime patrol aircraft guidance support. Some other important features of the SMART-L include the use of parallel receiver channels, digital beamforming, low antenna sidelobe values and a fast reaction mode with fast target alerts [27].

Table 16: Technical Parameters of the SMART-L Radar [26, 29]

Frequency	D-Band
	1-2 GHz
Waveform (in surface surveillance mode)	FMCW
Range	250 nm

Antenna rotation rate	12 rpm
Beamwidth, transmit	2.2°horizontal
Tracking capacity	>1000 air targets or >100 surface targets

B. GROUND SURVEILLANCE RADARS

18. DRS MSTAR V6

Figure 22: DRS MSTAR V6 radar antenna (from [30])

The U.S. DRS C3 & Aviation Company's Man-portable Surveillance and Target Acquisition Radar V6 is a ground surveillance radar system designed for border interdiction, surveillance, and force protection operations in harsh environments such as Iraq and Afghanistan [30]. As seen in Table 13, it is capable of detecting a walking person at 13 km, a light vehicle at 25 km, and aircraft at 13 km. There are currently more than 1,500 MSTAR units deployed worldwide. The system can be integrated into complex surveillance systems to detect and classify targets as personnel, tracked or wheeled vehicles, and rotor or fixed-wing aircraft [30].

Table 17: Technical Parameters of DRS MSTAR V6 [30]

Frequency	Ku band (6 selectable frequencies)
Transmit Power	5W peak
Target location accuracy	Range: ± 10m Azimuth: ± 10 mils

Input Power	<75 W
Typical Moving Target Detection Performance	Walking Person: >13 km Light Vehicle: >25 km Aircraft (gliders, ultra-light): >13 km
Waveform	FMCW

19. **DRS Squire Ground Surveillance Radar System**

Figure 23: Squire Radar Antenna (from [31])

DRS also produced the Squire, a rugged, man-portable, long range ground surveillance radar system. The Squire radar features a high Mean Time Between failures and low Mean Time to Repair, which reduces its lifecycle costs [31]. As shown in Table 14, it is capable of transmitting output powers of 10 mW, 100 mW, and 1W over 10 to 20 GHz [32]. This system is well suited for applications such as border surveillance, infrastructure protection, dignitary protection, force protection, and battlefield surveillance [31]. It can also be integrated with electro-optic and command and control systems.

Table 18: Technical Parameters of Squire [31, 32]

Frequency	J Band fixed, 10 GHz to 20 GHz
Transmit Power	10 mW, 100 mW, 1 W
Waveform	FMCW
Rotation Speed	7°/s or 14°/s
Instrumented Range	3, 6, 12, 24, or 48 km
Range Cells	512
Beamwidth	2.8° horizontal 8° vertical

20. **Pro Patria Electronics PGSR-3i Beagle**

The Hungarian Pro Patria Electronics manufactured PGSR-3i Beagle is a lightweight man-portable radar designed for ground surveillance in applications such as border guard, battlefield surveillance, civilian and military installation security, and combat operations duties [33]. The Beagle radar can be carried in backpacks by two man teams, mounted on vehicles, or mounted on fixed posts. It can be used as a standalone unit or be integrated in a network of radars. As shown in Table 15, the Beagle radar is capable of tracking over 300 targets at a rate of 10 plots per second [34]. It is capable of differentiating between moving and stationary targets, determining the exact parameters of the targets, and controlling adaptive detection in changing environmental conditions [33]. The radar can be set up and operating within five minutes and has a durable design that makes it well suited for harsh environments.

Figure 24: Pro Patria Beagle Transmitting and Receiving Antenna (from [33])

Table 19: Technical Parameters of Pro Patria PGSR-3i Beagle [34]

Frequency	8-12 GHz, 32 channels (fixed channels and automatic hopping)
Transmit Power	2 W
Waveform	FMCW
Antenna Gain	28 dB, horizontal polarization
Target Capacity	10 plots/sec, over 300 tracks, over 1000 displayed plots
Scan Rate	7°/s and 14°/s, operator selectable

21. **Pro Patria Electronics PSR-2i Doberman**

Figure 25: Pro Patria Electronics PSR-2i Doberman Antenna (from [35])

The Pro Patria Electronics PSR-2i Doberman is perimeter security radar that can be used as a standalone unit or integrated into a system of radars. It can be deployed as a fixed installation on walls, towers, or buildings, or it can be used as man-portable radar [35]. It features a scan rate of 30°/s, which allows for a high degree of situational awareness, and an integrated GPS and compass unit that provide accurate reference data for determining target position and direction, as seen in Table 16 [36]. It automatically classifies targets and continuously updates geo-position, velocity, direction, and target trajectories for detected targets.

Table 20: Technical Parameters of Pro Patria Electronics PSR-2i Doberman [36]

Transmit Power	200 Mw
Frequency	8-12 GHz
Waveform	FMCW Doppler
Scan Rate	30°/s
Scanning Modes	Azimuth Sector Scan (6° - 346°) Continuous Rotation (n x 360°)
Target Location Accuracy	Range: 2m Azimuth: <0.5°
Target Classification	Automatic

22. **Blighter Revolution 360**

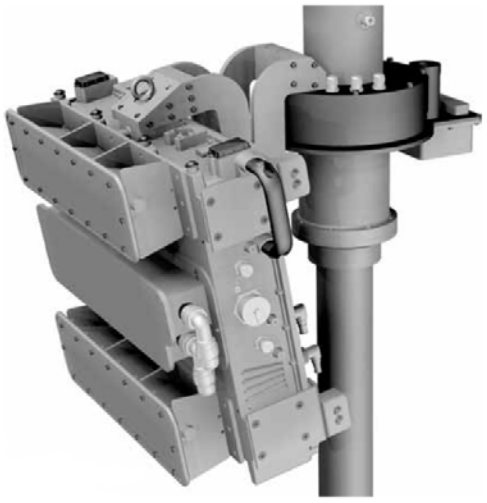

Figure 26: Blighter Revolution 360 Radar on Vehicle Mast (from [37])

The U.K. Blighter Surveillance Systems' Scout is a low cost, lightweight vehicle mountable ground surveillance radar, which supports both continuous scan & pan and stare surveillance modes.. It is a highly reliable, zero maintenance system for five years. The cable drive mechanism in the positioner is unaffected by temperature, dust, sand, ice, or snow. The Blighter Revolution 360 rotates around its mast, allowing it to sit beneath an integrated electro-optic camera without obstructing its view. As shown in Table 17, the Blighter Revolution 360 uses an FMCW Doppler waveform and transmits at either 1 W or 4 W. It is also capable of tracking up to 700 targets per scan [37].

Table 21: Technical Parameters of Blighter Revolution 360 [37]

Technical Specifications	
Frequency Band	Ku Band
Waveform	FMCW Doppler
Spectrum Occupancy	Wide Band: 15.7 – 17.2 GHz Narrow Band: 16.2 – 17.2 GHz
Transmitter Power	1 W (standard) 4 W (higher power version)
Maximum Targets per Scan	700
Elevation Beam Width	20° vertical
Scan & Pan Time for 360°	12.5 s
Maximum Detection Ranges	Crawling Person: 3.2 km Walking Person: 7.4 km Moving RIB: 14.2 km Moving Vehicle: 16.0 km Large Moving Vehicle: 22.1 km Large Moving Vessel: 32.0 km

23. **Blighter B400 Series Radar**

The Blighter B400 Series Radar are long range ground surveillance radar systems suited to fixed, mobile, and portable applications. They feature fully electronic scanning using PESA technology for ultra-high reliability, unsurpassed ground clutter suppression with low false alarm rate, and a choice of antennas for optimal terrain coverage [38]. The e-scan radars have no moving parts to wear out, maintain or replace and offer dramatic improvements in reliability over mechanically scanned radars. They are proven to withstand harsh environmental conditions and provide many years of maintenance free operation. Blighter radars have a very wide vertical elevation beam, allowing them to detect targets in the distance as well as close-up simultaneously. As shown in Table 17, the Blighter B400 series radar uses a FMCW waveform and can detect and track up to 700 targets per scan.

Figure 27: Blighter B402 shown with W2OS Antennas (from [38])

Table 22: Technical Parameters of Blighter B400 Series Radar [38]

Frequency Band	Ku Band
Waveform	FMCW Doppler
Spectrum Occupancy	Wide Band: 15.7 – 17.2 GHz Narrow Band: 16.2 – 17.2 GHz
Transmitter Power	1 W (standard) 4 W (higher power version)
Maximum Targets per Scan	700
Elevation Beam Width	5°, 10°, or 20° vertical
Fastest Scan Time for 90°	1 s
Maximum Detection Ranges	Crawling Person: 6.0 km Walking Person: 15.5 km Moving RIB: 19.1 km Moving Vehicle: 22.4 km Large Moving Vehicle: 27.9 km Large Moving Vessel: 32.0 km

24. **Blighter B303 Radar**

Figure 28: Blighter B303 Radar (180° azimuth scan angle) (from [39])

The Blighter B303 radar is lightweight and low cost ground surveillance radar suited to installation on masts or towers [39]. It is a fully integrated all-in-one unit comprising antennas, signal processing, plot extractor, GPS, and compass. The Blighter B303 features fully electronic scanning using PESA technology for ultra-high reliability. Blighter radars are designed to withstand harsh environmental conditions and can operate for several years without maintenance. Blighter radars also have a wide vertical elevation beam, which allows them to detect targets in the distance as well as close up simultaneously. As shown in Table 19, the Blighter 303 Radar uses an FMCW waveform and 1 W output power.

Table 23: Technical Parameters of Blighter B303 Series Radar [39]

Frequency Band	Ku Band
Waveform	FMCW Doppler
Spectrum Occupancy	Wide Band: 15.7 – 17.2 GHz Narrow Band: 16.2 – 17.2 GHz
Transmitter Power	1 W
Maximum Targets per Scan	700
Elevation Beam Width	20° vertical
Fastest Scan Time for 180°	1.3 s
Maximum Detection Ranges	Crawling Person: 1.5 km Walking Person: 3.3 km Moving Vehicle: 8.0 km Large Moving Vehicle: 8.0 km

25. **Blighter B202 Mk 2 Radar**

Figure 29: Blighter B202 Mk 2 Radar (from [40])

The Blighter B202 Mk 2 Radar is lightweight and a compact medium range ground surveillance radar with integrated Vortex fast-scan technology and fully electronic scanning technology for ultra-high reliability [40]. Blighter radars are designed to withstand harsh environmental conditions and can operate for several years without maintenance. Blighter radars also have a wide vertical elevation beam, which allows them to detect targets in the distance as well as close up simultaneously. As shown in Table 20, the Blighter B202 Mk2 radar uses a FMCW waveform and can detect a moving vehicle up to 8 km away. It also operates at 1 W transmitter power.

Table 24: Technical Parameters of Blighter B202 Mk 2 Radar [40]

Frequency Band	Ku Band
Waveform	FMCW Doppler
Transmitter Power	1 W
Maximum Targets per Scan	700
Elevation Beam Width	20° vertical
Fastest Scan Time for 90°	.66 s
Maximum Detection Ranges	Crawling Person: 1.5 km Walking Person: 3.3 km Moving Vehicle: 8.0 km Large Moving Vehicle: 8.0 km

26. **FLIR Ranger R2**

Figure 30: FLIR Ranger R2 Radome (from [41])

The U.S. FLIR Ranger R2 is a FMCW capable mid-range perimeter surveillance radar that provides accurate, high resolution detection of vehicles and personnel [31]. As shown in Table 21, the Ranger R2 completes one revolution per second, providing quick updates of the coverage area. The Ranger R2 is designed to work in virtually any climate, weather or lighting condition. Multiple units can be installed with overlapping coverage areas to protect large areas. They can also be networked with FLIR imagers to secure areas inside and outside a perimeter. Recommended applications include border security, monitoring ports, guarding industrial facilities.

Table 25: Technical Parameters of FLIR Ranger R2 [41]

Frequency Band	Ka Band
Waveform	FMCW/Doppler
Input Power	20 – 32 VDC, 24 nominal
Transmitter Power	Safe for Human Exposure
Scan Rate	60 rpm
Elevation Beam Width	6° (2 way)
Azimuth Beam Width	1° (2 way)
Target Velocity	.1 – 50 m/s
Operating Range	5 – 1400 m
False Alarm Rates	< 1 per 24 hours
Coverage area	6.16 km^2
Power Consumption	45 Watts

27. **FLIR Ranger R3D**

Figure 31: FLIR Ranger R3D Radome (from [42])

The FLIR Ranger R3D is a dual mode ground surveillance that leverages advanced FMCW technology and the extended range terrain adaptability of Doppler in a single lightweight package [42]. It supports radial and tangential movement detection in both Fast Scan and Doppler modes. The Ranger R3D has a low Minimum Detectable Velocity and high resolution. As shown in Table 22, it features FMCW modulation in both Fast Scan and Doppler modes, persistent wide area surveillance, continuous 360° wide area surveillance, early warning of intruders, low false alarm rates, slew-to-cue camera integration, annunciator integration, and a compact design. The Ranger R3D's recommended applications include border security, industrial facility security, monitoring ports, airports, and military bases, critical infrastructure protection, and force protection.

Table 26: Technical Parameters of FLIR Ranger R3D [42]

Frequency Band	Ka Band
Waveform	FMCW/Doppler
Input Power	20 – 32 VDC, 24 nominal
Transmitter Power	Safe for Human Exposure
Scan Rate	3-60 rpm, continuous or sector
Elevation Beam Coverage	6° , 12° option
Elevation Control	Up: 2°; Down: 5° (fixed settings)
Target Velocity	.1 – 50 m/s
Operating Range	5 – 6500 m
False Alarm Rates	< 1 per 24 hours
Coverage area	133 km^2
Power Consumption	40 Watts

28. **FLIR Ranger 5D**

Figure 32: FLIR Ranger 5D Receiving and Transmitting Antenna (from [43])

The Ranger R5D is a dual mode ground surveillance radar designed specifically to detect vehicles and personnel in environmental conditions common to the Middle East [43]. It is capable of detecting tangential movement in both Fast Scan and Doppler Modes. As shown in Table 23, it features an up to 10,000 m operating range with a 246 km^2 coverage area. The same antenna is used in both modes, but the scan rate, RF bandwidth, and PRFs are optimized according to the mode selected. In Doppler mode, improved clutter rejection provides for better detectability of small and slow targets. It features persistent wide area surveillance, FMCW modulation in both Fast Scan and Doppler modes, early warning of intruders, continuous 360° wide area surveillance, slew-to-cue camera integration, annunciator integration, and compact design. The Ranger R5D's recommended applications include desert environments, secure borders, force protection, industrial facility security, critical infrastructure security, and monitoring ports, airports, and military bases.

Table 27: Technical Parameters of FLIR Ranger R5D [43]

Frequency Band	Ka Band
Waveform	FMCW/Doppler
Input Power	20 – 32 VDC, 24 nominal
Transmitter Power	Safe for Human Exposure
Scan Rate	3-60 rpm, continuous or sector
Elevation Coverage	4°
Elevation Control	Up: 2°; Down: 5° (fixed settings)
Target Velocity	.1 – 50 m/s
Operating Range	5 – 10,000 m
False Alarm Rates	< 1 per 24 hours
Coverage area	346 km^2
Power Consumption	40 Watts

29. **IAI ELTA ELM-2105 Ground Surveillance Radar Family**

Figure 33: ELM-2105 Mounted on a Surveillance Vehicle (from [44])

Israel's ELTA System's ELM-2105 is a family of lightweight, all-weather, tactical Ground Surveillance Radars designed to provide 360 degrees coverage with just one rotating radar [44]. It features a high updated rate of targets and a solid state, continuously rotating Low Probability of Interception dual beam radar that is rapidly deployed. The ELM-2105 radar can be locally or remotely controlled either as a stand-alone radar or integrated in a larger ground surveillance radar system. As shown in Table 24, the ELM-2105 outputs 10W peak power and 1W average power, and operates in the X Band frequency range [44]. Its recommended applications include border monitoring, protection of military camps, bases, and sensitive sites, ambush or raid as early warning on movements of hostile forces, and support to border police at international passes: airports, harbors, and ground passes. It can also be used to protect civil sites such as power plants, communication centers, diamond mines, oil fields, prisons, and water reservoirs.

Table 28: Technical Parameters of ELM-2105 [44]

	ELM-2105	ELM-2105ER	ELM-2105LR
Frequency Band	X Band	X Band	X Band
Detection Range (max) Walking person Vehicle	 5000 m 9000 m	 8000 m 14000 m	 15000 m 25000 m
Min. Detection Range	50 m	50 m	50 m
Min. Detection Velocity	1 km/h	1 km/h	1 km/h
Range Resolution	4m, 8m	4m, 8m	8m, 16m
Range Accuracy	0.5 m	0.5 m	3m
Azimuth Beam Width	10°	7°	4°
Elevation Coverage	10°	8.5°	5°
Azimuth Coverage	360°	360°	360°
No. of Tracked Targets	200	200	200
Track Update Rate	4 sec	5 sec	6 sec

Transmitted Power	10w peak, 1W average	10w peak, 1W average	10w peak, 1W average

30. **IAI ELTA EL/M-2127**

Figure 34: 1. EL/M 2127 Ground Deployment with camera
2. EL/M-2127Z
3. Airport Deployment (from [45])

ELTA's El/M-2127 is a compact and lightweight, all weather ground surveillance and movement detection family of radars designed to detect and monitor intruders' movements in selected zones of interest [45]. These solid state radars operate automatically with electronic beam steering within the covered sector to provide fast response, high resolution, and high probability of target detection. They can be used as stand-alone units or integrated with other surveillance systems. The three available versions of this radar system are the EL/M-2127 regular version, EL/M-2127ER extended range version, and EL/M-2127Z low weight portable version. They operate in the X-Band frequency range and transmit 1.5W or 10W peak power, as seen in Table 24. Recommended applications include border monitoring, protection of military bases and sensitive sites, use in ambush or raid as early warning on movements of hostile forces, border police support at international passes: airports, harbors, and land passes, and site protection.

Table 29: Technical Parameters of ELM-2127 [45]

	EL/M-2127	EL/M-2127ER	ELM-2105LR
Frequency Band	X Band	X Band	X Band
Detection Range (max) Walking person Vehicle	 1300m 2000m	 3000 m 3000 m	 1300 m 2000 m
Min. Detection Velocity	0.6 km/h	0.6 km/h	0.6 km/h
Range Resolution	2m, 4m	4m	2m, 4m
Range Accuracy	1 m	1 m	1 m
Azimuth Beam Width	15ϒ	15ϒ	15ϒ
Elevation Coverage	10 ϒ	10 ϒ	10 ϒ
Sector Coverage	120 ϒ	120 ϒ	90 ϒ
Scan Time	1 sec	1 sec	1 sec
Transmitted Peak Power	1.5W	10W	1.5W

Transmitted Average Power	100 mW	1W	100mW
Power Consumption	55W @ 24V	65W @ 24V	55W @ 24V

C. LPI MOTION DETECTORS

31. **InnoSent IVS-148**

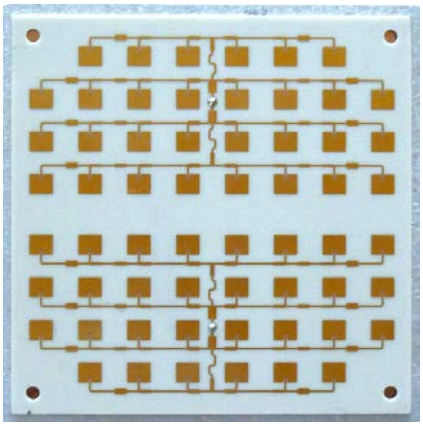

Figure 35: IVS-148 K-Band VCO Transceiver (from [46])

The German InnoSent IVS-148 is a FMCW/FSK capable K-band VCO Transceiver that operates centered at 24 GHz, as seen in Table 26. It features a RF pre-amplifier for lowest noise operation, split transmit and receive path for maximum gain, and stereo operation for direction of motion identification [46]. The IVS-148 is capable of detecting movement, velocity, direction, presence, and distance. Its recommended applications include long range traffic monitoring and industrial applications. It is also recommended as an upgrade to the IPS-144, which has identical dimensions but lacks FMCW/FSK capability.

Table 30: Technical Parameters of IVS-148 [46]

Frequency	24.000-24.250 GHz
Transmit Power	20 dBm
Waveform	FMCW/FSK
Beamwidth H/V	12° / 25°
Side lobe Suppression	15 dB
Bandwidth	50 Hz -100 kHz

32. **InnoSent IVS-465**

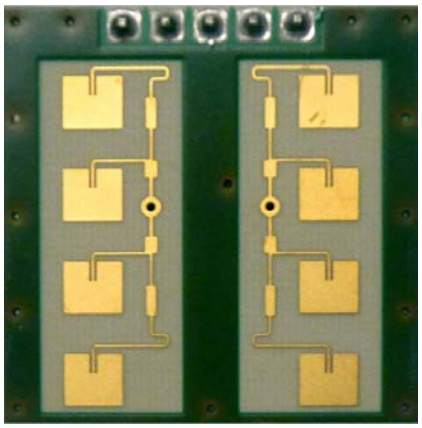

Figure 36: IVS-465 K-Band VCO Transceiver (from [47])

The InnoSent IVS-465 is a FMCW/FSK capable low cost K-band VCO transceiver. It features an advanced VCO-oscillator with low current consumption, split transmit and receive path for maximum gain, and dual channel operation for direction of motion identification [47]. As seen in Table 27, the IVS-465 has a maximum transmitting power of 16 dBm and transmits over 24.000-24.250 GHz. Its recommended applications include door openers, security applications, and industrial applications. The IVS-465 is capable of detecting movement, velocity, direction, presence, and distance.

Table 31: Technical Parameters of IVS-465 [47]

Frequency	24.000-24.250 GHz
Transmit Power	16 dBm
Waveform	FMCW/FSK
Beamwidth H/V	80° / 32°
Side lobe Suppression	13 dB

33. **InnoSent IVS-179**

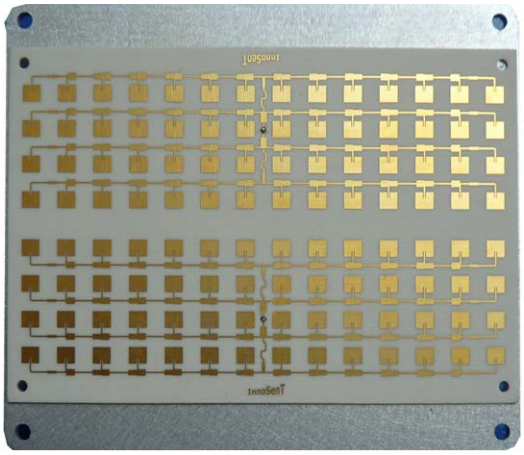

Figure 37: IVS-179 K-Band VCO Transceiver (from [48])

The InnoSent IVS-179 is a narrow beam FSK/FMCW capable K-Band VCO-Transceiver centered at 24 GHz, as seen in Table 28. It features a RF-pre-amplifier for lowest noise operation, split transmit and receive path for maximum gain, and stereo operation for direction of motion identification [48]. It is recommended for long range traffic monitoring and industrial applications.

Table 32: Technical Parameters of IVS-148 [48]

Frequency	24.000-24.250 GHz
Transmit Power	20 dBm
Waveform	FMCW/FSK
Beamwidth H/V	7° / 28°
Side lobe Suppression	15 dB
Bandwidth	50 Hz – 25 kHz

34. **InnoSent IVS-167**

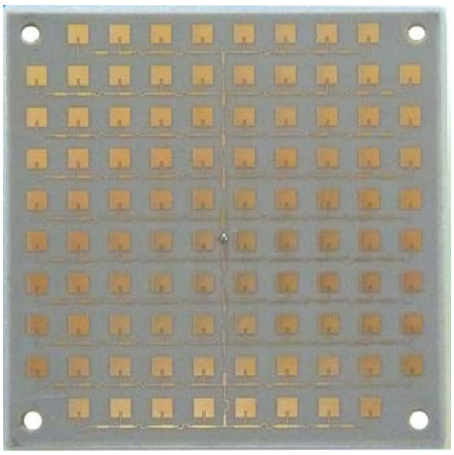

Figure 38: IVS-167 K-Band VCO Transceiver (from [49])

The InnoSent IVS-167 is a FMCW/FSK capable K-Band VCO transceiver centered at 24 GHz, as seen in Table 29. It features a narrow beam pattern, stereo operation for direction of motion identification and compact outline dimensions [49]. Its recommended applications include traffic monitoring, industrial applications, and level measurement.

Table 33: Technical Parameters of IVS-167 [49]

Frequency	24.000-24.250 GHz
Transmit Power	18 dBm
Waveform	FMCW/FSK
Beamwidth H/V	11° / 11°
Side lobe Suppression	15 dB

35. **InnoSent IVS-948**

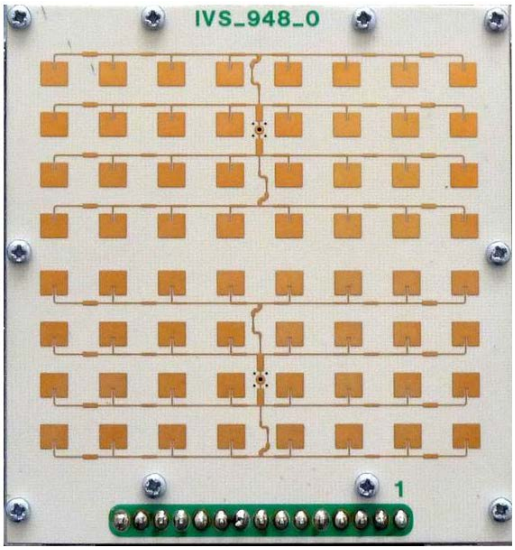

Figure 39: IVS-948 K-Band VCO Transceiver (from [50])

The InnoSent IVS-948 is a CW/FSK/FMCW capable K-Band VCO transceiver with advanced SiGe MMIC technology [50]. It transmit at either 20 or 26 dBm over 24.000-24.240 GHz, as seen in Table 30. It features a 1/x divider for reference frequency output, stereo operation to detect direction of motion, integrated RF-pre-amplifier, programmable IF-amplifier, and two selectable output power levels (ETSI/FCC). It is the advanced version of the IVS-148. Recommended applications for the IVS-948 include traffic monitoring and industrial applications.

Table 34: Technical Parameters of IVS-948 [50]

Frequency	24.000-24.250 GHz
Transmit Power	20, 26 dBm
Waveform	CW/FMCW/FSK
Beamwidth H/V	32° / 14°
Side lobe Suppression	25 dB
Bandwidth	20 Hz – 500 kHz

36. **InnoSent IVS-162**

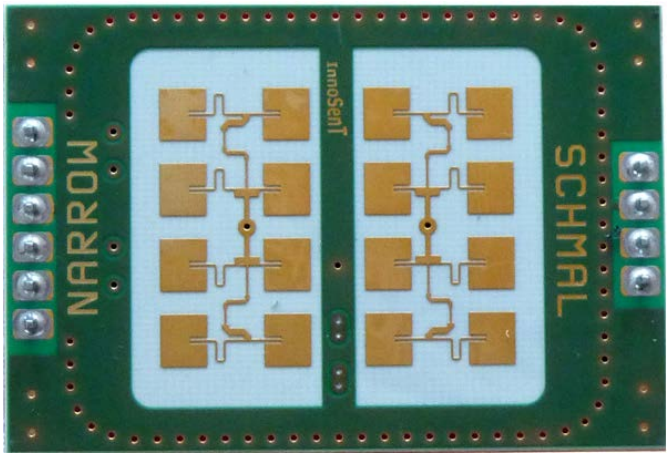

Figure 40: InnoSent IVS-162 K-Band VCO Transceiver (from [51])

The InnoSent IVS-162 is a FMCW/FSK capable K-band VCO transceiver centered at 24 GHz, as seen in Table 31. It features a split transmit and receive path for maximum gain, stereo operation for direction of motion detection, an IF-pre-amplifier, and compact outline dimensions [51]. Recommended applications for the IVS-162 include industrial applications and door openers.

Table 35: Technical Parameters of IVS-162 [51]

Frequency	24.000-24.250 GHz
Transmit Power	15 dBm
Waveform	FMCW/FSK
Beamwidth H/V	45° / 38°
Side lobe Suppression H/V	15 dB / 20 dB
Bandwidth	DC – 50 kHz

D. RESEARCH AND EDUCATIONAL RADARS

37. **SkyRadar ToGo**

Figure 41: SkyRadar ToGo Antenna, Receiver, and Laptop Computer (from [52])

The SkyRadar Togo radar is a close and medium range system designed for training and research applications in air traffic control, marine or homeland security, traffic analysis, object speed measurement, and distance measurement [52]. It is a low cost, all-in-one, ready-to-use system. It features FMCW, Doppler Radar, Frequency Shift Keying, and Mono Pulse radar modes. The system comes with a laptop computer pre-installed with necessary software for signal generation, analysis, and graphical user interfaces. The SkyRadar transmitter operates on 24 GHz with a 60 patch Doppler module, as shown in Table 32.

Table 36: Technical Parameters of SkyRadar ToGo [52]

Frequency	24.150 GHz
Transmit Power	18 dBm
Waveform	FMCW/FSK
Beamwidth H/V	12° / 25°
Antenna Gain	18.5 dBi
Diameter of Parabolic Dish	600 mm

38. **SkyRadar 5.0 FMCW**

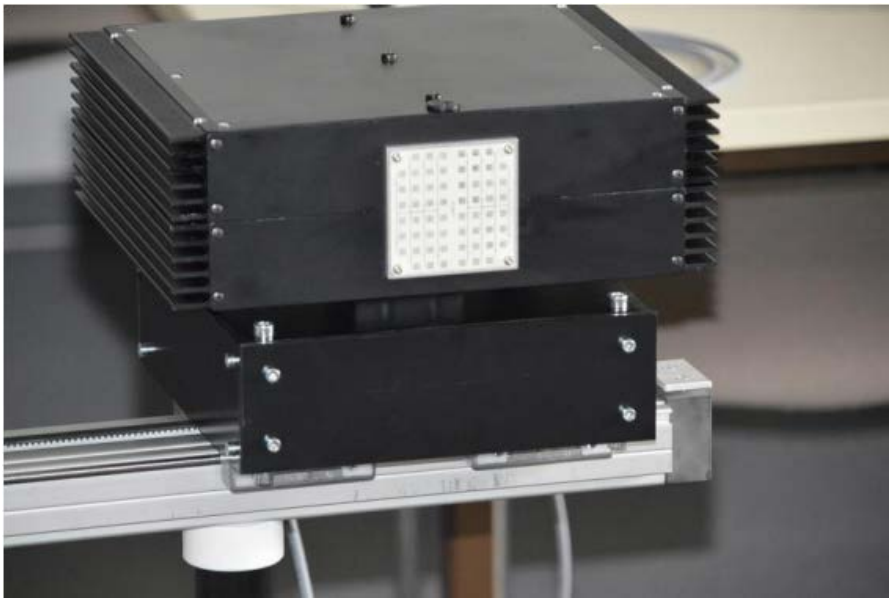

Figure 42: SkyRadar 5.0 Base Unit with Digital Signal Processing Unit and Transceiver (from [53])

SkyRadar's modular radar training system FMCW is a high resolution close range ground radar developed as a radar training system [53]. It supports Frequency Modulated Continuous Wave functionality along with Doppler, mono-pulse, and Frequency Shift Keying. The SkyRadar 5.0 was developed for didactical and research purposes, targeting aviation academies, military academies, and universities. It is safe for indoor and outdoor operation due to its low power technology. As shown in Table 33, the SkyRadar 5.0 FMCW operates at 24.05-24.25 GHz frequency and outputs a max power of 20 dBm. The FMCW base operates with a Phased Array antenna and provides multiple ways of visualization such as FMCW Fast Fourier Transform, Doppler, IF Signals, or the VCO Ramp.

Table 37: Technical Parameters of SkyRadar 5.0 FMCW [53]

Frequency	24.05-24.25 GHz
Transmit Power	16-20 dBm
Waveform	FMCW/FSK/Doppler/Monopulse
Beamwidth H/V	12° / 25°
Horizontal Sidelobe Suppression	-20 dB
Vertical Sidelobe Suppression	-18 dB
Supply Voltage	4.75-5.25 V
Frequency Tuning Range	180 MHz/°C
Antenna Gain	18.5 dBi

II. SECTION TWO: NON-COOPERATIVE INTERCEIPT RECEIVERS

Section Two of this report presents modern ES/ELINT systems and their sensitivities. It is organized based on the platforms these systems are deployed on; including airborne, submarine/surface ship and ground mobile systems.

E. NON-COOPERATIVE INTERCEPT RECEIVER OVERVIEW

In order to exploit LPI radar signals, non-cooperative intercept receivers must provide detection, parameter identification, and classification of the radar signals. Detection of LPI radar signals requires a large processing gain due to the wideband nature of LPI radars.

Characteristics critical to intercept receiver design are signal intercept performance, including recognition of the type of transmitter, and the capability to measure signal parameters. The frequency coverage of the antenna system and receiver front end must include all the frequencies expected to be encountered. Since the total potentially used radar frequency band is so broad (0.5 to 100 GHz), the coverage is divided into bands compatible with the hardware components used.

The bandwidth requirement of an intercept receiver is established by the waveform design used by the radar. The general rule for intercept receiver design is that the pre-detection RF bandwidth should be matched to the largest coherent radar bandwidth expected and the post-detection video bandwidth matched to the inverse of the smallest radar coherent integration time expected.

The instantaneous dynamic range is the ratio of the largest signal amplitude that the receiver can process to the smallest signal amplitude that the receiver can instantaneously process. The instantaneous dynamic range of a linear receiver is between 50 and 60 dB while that of a log-video receiver is about 80 dB. The sensitivity of an intercept receiver is defined as the minimum signal power required at the receiver input in the presence of receiver thermal noise and thermal radiation reaching the antenna (function of temperature in the direction the antenna is pointing).

Changing threats and operational demands have led to a requirement for enhanced receiver capabilities. By the radar adapting to stealth targets, the emitter frequency range to contend with is now below 0.5 MHz to 100 GHz. In addition, more emitters are taking on a low probability of intercept nature [28].

F. AIRBORNE INTERCEPT RECEIVERS

39. **DM/A-104 Radar Warning Receiver**

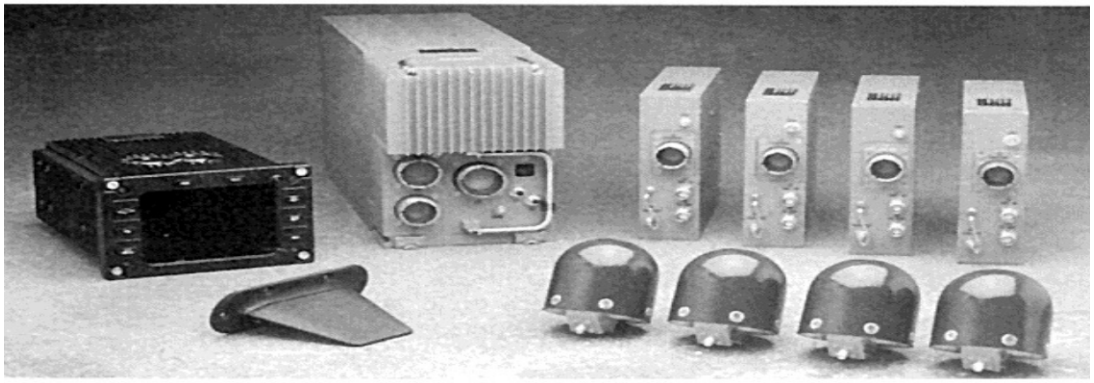

Figure 43: DM/A-104 Radar Warning Receiver (from [54])

The DM/A-104, manufactured in Chile, is a wideband, pulse, continuous wave, and pulse Doppler radar warning receiver (RWR) which is used in helicopters and combat aircraft to provide them detection of threat radar emitters. It provides 360 degrees coverage in the 2-18 GHz frequency range and provides an audio threat warning to the pilot about a surveillance radar, acquisition radar or a fire control radar in lock on mode, or whether the transmission if from a continuous wave radar [54].

Table 38: Technical Parameters of the DM/A-104 RWR [54]

Frequency Range	2-18 GHz (4 sub-bands); C/D-band (0.7-1.3 GHz)
Sensitivity	pulse, -50 dBm; C/D-band -50 dBm
Bearing (DF) Accuracy	>10° RMS

40. AN/ALR-95(V) Electronic Support/Radar Warning Receiver

Figure 44: AN/ALR-95(V) ES/RWR System (from [55])

The AN/ALR-95(V) is an Electronic Support (ES)/RWR system is designed to provide automatic signal intercept, identification and Direction Finding (DF). It contains a wideband receiver with a high-sensitivity set-on receiver channel, as well as other system features [55]. This system is used on the U.S. Navy P-3C Orion Maritime Patrol Aircraft, the German P-3C and the South Korean P-3B. The system has special signal processing and a 10,000-plus mode emitter library [55]. Other technical parameter information is classified. The manufacturer is Exelis Electronic Systems of Morgan Hill, California.

41. **ALR-2002 Radar Warning Receiver**

The Australian ALR-2002 Radar Warning Receiver system provides detection, direction finding, analysis and classification of radar emissions across the "standard" Radar Warning Receiver frequency range (assumed to be 2-18 GHz) with expansion capability to mm wave. The system is comprised of four quadrant receivers, a low-band receiver, a data processor, a track and interface processor and a visual display monitor [56].

Table 39: Technical Parameters for ARL-2002 RWR [56]

Frequency Range	Standard RWR coverage (2-18 GHz) to mm wave
Emitter types	Complex, CW, pulse-Doppler and low/high PRF

42. **AN/ALR-66(V)4 Electronic Support/Radar Warning Receiver**

Figure 45: AN/ALR-66 ES components (from [57])

The Northrop Grumman produced AN/ALR-66(V)4 is the latest U. S. upgrade to the AN/ALR-66 series. Its features include ultra-high RWR sensitivity, excellent DF accuracy and positive emitter identification in high-density environments [58]. Since it is software reprogrammable, the emitter library can be updated to recognize the identifying characteristics of new radar threats as they emerge. The AN/ALR(V)6 is the designation given to the AN/ALR-66 configuration that has been installed aboard the Norwegian P-3C maritime patrol aircraft [50]. Technical parameters for the AN/ARL-66(V)3 are provided in Table 10, as no parameters are available for the AN/ARL-66(V)4.

Table 40: Technical Parameters of the AN/ARL-66(V)3 [58])

Frequency Range	.05-20 GHz
Receiver Type	Crystal video
Emitter Types (Warning/ID)	CW, frequency agile, jitter/stager/LPI, pulse compression and pulse-Doppler emitters
Emitter library	More than 1,500 modes
Reprogramming time	90 seconds (on flight line)

43. **AN/ALR-67(V)3 Digital Radar Warning Receiver**

Figure 46: AN/ALR-67(V)3 Components (from [59])

The Hughes Aircraft Company's AN/ALR-67(V)3 Advanced Special Receiver (ASR) is a digital radar warning receiver designed to meet U.S. Navy requirements through the year 2020. This is an upgrade to the ALR-67 (V)2 system currently used on F/A-18 Hornet, AV-8 Harrier aircraft, and on the F-14 Tomcat until its retirement [59, 60].

The ASR collection frequencies include: high band pulse (2-40 GHz); high band continuous wave; low band pulse (less than 2 GHz); and millimeter wave MMW (28-40 GHz). The ASR provides signal detection, direction finding, and identification of radio frequency (RF) and MMW threat emitters including: scanning, pulse Doppler and continuous wave tracking, acquisition and early warning radars, and missile guidance. The software reprogrammable threat library user data file (UDF) development and

maintenance process and infrastructure for the ASR is intended to support improved operational timeliness of UDF updates (i.e.: tactical reprogramming) [60].

Table 41: Technical Parameters for AN/ALR-67(V)3 [59]

Frequency Range	2-40 GHz High band pulse High band CW Low band pulse (<2 GHz) MMW (28-40 GHz)
Emitter Types	Scanning; pulse-Doppler, CW, AQ, Early Warning Radar, Missile Guidance

44. AN/APR-39D(V)2 Radar Warning Receiver

Figure 47: AN/APR-39(V)2 Radar Warning Receiver (from [61])

The AN/APR-39D(V)2 is currently in development for the United States Navy and Army. It will provide will provide 360-degree coverage to automatically detect and identify threat types, bearing and lethality. With the increased receiver sensitivity, radar detection will include LPI and continuous wave emitters [61].

Table 42: Technical Parameters for AN/APR-39D(V)2 [61]

Frequency Range	C to M band; supports an optional low-band array for C/D band AOA
Emitter Types	Pulsed; Pulse-Doppler; CW; Scanning; Agile PRIs and RF; LPI
Weight	38.9 lb
Power	222 W, 28 VDC

45. **BOW-21 Radar Warning Receiver**

The SAAB BOW-21 is an E- through J-band (2-20 GHz) Radar Warning Receiver designed to operate in an extremely dense RF environment. The system features high sensitivity, high selectivity and a claimed 100 per cent Probability of Intercept (POI) [62]. The narrowband receiver can be used to detect not only CW and high PRF signals, but other signals that fall within its bandwidth.

Table 43: Technical Parameters for BOW-21 RWR [62 63]

Frequency Range	2-20 GHz (0.5-2 GHz and 20-40 GHz bands as options)
Coverage	±45° (elevation, -5 dB, baseline config); ±90° (elevation, option); 360° (azimuth)
Bearing (DF)°° Accuracy	1° RMS (interferometric option); 7° RMS (baseline config)
RF Accuracy	1 MHz (narrowband); 5 MHz (wideband)
Dynamic Range	75 dB
Pulse Density Capability	2 Mpps
Tracked Emitters	1000
Emitter Modes in Library	10,000
Reaction time	1 s (max)
Aircraft Interfaces	MIL-STD-1553B; RS-422

46. **Chinese BM/KZ 8608 ELINT System**

The Southwest China Research Institute of Electronic Equipment (SWIEE) in Chengdu, Sichuan developed the BM/KZ-8608 ELINT System which is reportedly an adaptation of Israeli equipment. The BM/KZ-8608 monitors the frequency spectrum of 1-18 GHz and has a high probably of intercept with high sensitivity and accurate measurement of parameters [64].

Table 44: Technical Parameters for the BM/KZ-8608 ELINT System [64]

Frequency Range	1-18 GHz

Frequency Accuracy	5 MHz
Azimuth Coverage	360°
Bearing Accuracy	5° (1-8 GHz); 3° (8-18 GHz)
Sensitivity	-100 dBW
Dynamic Range	50 dB
Signal Density	20,000 pps
PRF Range	100Hz-20kHz
PRF Accuracy	±1% (100 Hz-2kHz); ±2% (2-20 kHz)

47. **Chinese KM/KJ-8602 Radar Warning Receiver**

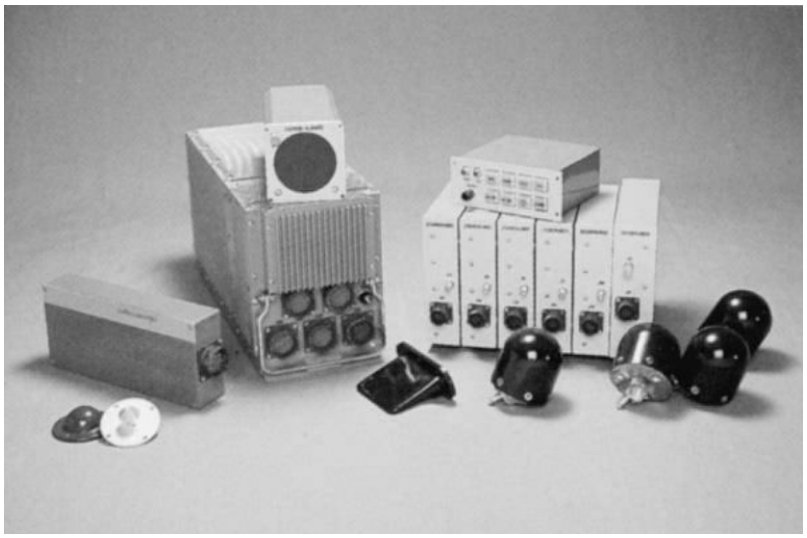

Figure 48: BM/KZ-8602 RWR (from [65])

The SEIEE has also developed the BM/KJ-8602 RWR, a wideband system covering frequency bands of 2-18 GHz, plus a second frequency band of .7 MHz to 1.4 GHz. It is capable of processing up to sixteen threat signals simultaneously from all types of pulsed and CW radars. Response time is around one second and bearing accuracy is 15° RMS [65].

Table 45: Technical Parameters for the BM/KJ-8602 RWR [58]

Frequency Coverage	.7-14 GHz and 2-18 GHz
Response Time	1 s
Capacity	16 threats simultaneously
Azimuth Coverage	360°
Elevation Coverage	-30 to +30°
Bearing Accuracy	15° RMS

48. **EL/L-8382 ES/ELINT Series**

There are two known EL/L-8382 ES/ELINT system configurations, one for airborne early warning platforms (EL/L-8382AEW) and the other for maritime patrol aircraft applications (EL/L-8882MPA [66]). Technical parameters for both are in Table 16.

Table 46: Technical Parameters for the EL/L-8382 System [66]

Frequency Coverage	.5-18 GHz (EL/L-8382AEW and -8382MPA, mmW option
Instantaneous Bandwidth	Up to 4 GHz
Probability of Intercept	Near 100%
Sensitivity	-70 to -85 dBm
Bearing Accuracy	Better than 2° (typical for both)
Selectivity	10, 50 or 250 MHz (both, but other bandwidths available for -8382MPA)
Azimuth Coverage	360°
Elevation Coverage	±35°

49. **ELINT-FD ELINT System**

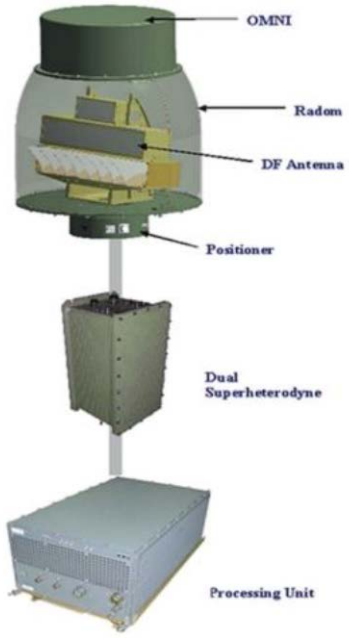

Figure 49: ELINT-FD Narrow-band ELINT System Schematic (from [67])

The 0.5 to 18 GHz band ELINT-FD is a narrow-band ELINT system that has system functionality which includes the detection of narrow-band CW, LPI and pulsed signals. It has been procured by the Spanish Army and Navy and Brazil for a maritime aircraft application [67].

Table 47: Technical Parameters for the ELINT-FD System [67]

Frequency Range	.5-18 GHz (extension to 40 GHz as option)
Reception Bandwidth	1, 5, 15, 50, 250, and 500 MHz
Frequency Measurement Accuracy	Better than 1 MHz RMS
System Sensitivity	Up to – 90 dBm
Emitter Frequency Types	agile, fixed, jump, PMOP (Barker, binary and code detection) and switch and FMOP (+ or - chirp, discrete shift

	and quadratic)
PRI Emitter Types	fixed, jitter, slide and stagger 32
Signal Analysis	agile, pulse Doppler, fixed, jitter, jump, slide, stagger and switch
Receiver Type	dual DLVA and DIFM analogue sensitivity; dual-band receiver with wideband high sensitivity for LPI intercept

50. **AN/ALR-56A/C Radar Warning Receiver**

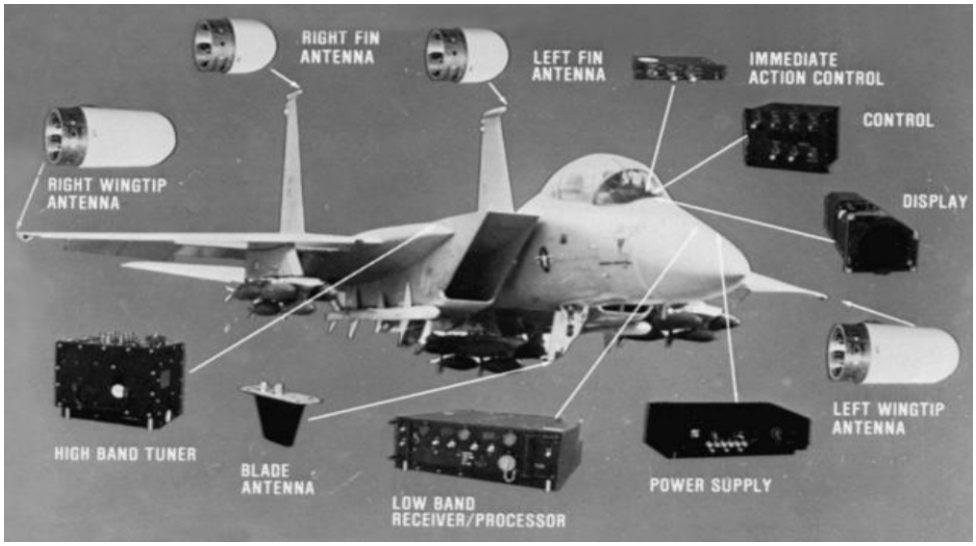

Figure 50: Schematic of F-15 Eagle with AN/ARL-56C components (from [68])

The AN/ALR-56 RWR is used with the AN/ALQ-135 Internal Countermeasures Set jamming equipment and forms part of the Tactical Electronic Warfare System (TEWS) installed aboard F-15 fighter and strike aircraft. The baseline AN/ALR-56 configuration incorporates the R-1867 processor/low-band receiver, the R-1866 high-band receiver, the IP-1164 display, the C-9429 immediate action control unit, the PP-6968 power supply, a TEWS controller and an antenna array. In more detail, the processor/low-band receiver

unit is made up of three major sections, namely a single-channel low-band superheterodyne receiver, a dual-channel Intermediate Frequency (IF) section and a processor. The low-band receiver is electronically tuned under the control of the processor while the dual-channel IF section operates with either the R-1866 dual-channel high-band receiver or the unit's own low-band receiver. Receiver selection for operation with the package's dual-channel IF section is under the control of the processor [61].
A major update of the baseline architecture (designated as the AN/ALR-56C) features an “improved” processor capable of handling 'new' threats, greater signal densities and other operational changes. As such, AN/ALR-56C is a digitally controlled, dual-channel superheterodyne receiver that covers the E- to J-bands (2-18/20 GHz - neither confirmed nor denied by BAE Systems) and is capable of sorting and identifying a “wide” range of threats [68].

Table 48: Technical Parameters of AN/ALR-56C RWR [28]

Frequency Range	2 – 18/20 GHz (E-J Bands)
Sensitivity	-50 dBm
Azimuth Coverage	360°
Elevation Coverage	3D
Antenna Gain	0 dB
Azimuth Accuracy	20°/quadrant

51. **ELT/750 Receiver**

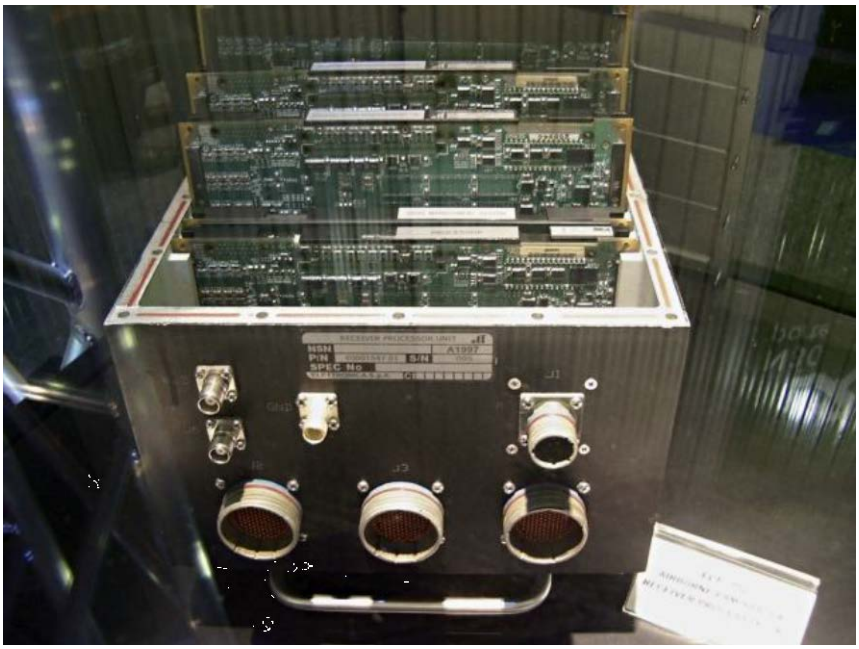

Figure 51: ELT/750 Receiver/processor unit (from [69])

The ELT/750 ES system family, developed by Elettronica SpA in Italy, is designed for fixed- and rotary-winged maritime patrol, tactical aircraft, search and rescue, transport aircraft and law enforcement applications. In its various configurations the system can provide 'full' radar warning, automatic ES surveillance/situational awareness, ELINT-type analysis (computer-aided and under operator control) and data collection capabilities [69].
The system provides very wide RF coverage, from C to J band, and is designed to provide a very high probability of intercept and can detect LPI emitters and detect and measure emitter side-lobes [69].

Table 49: Technical Parameters for the ELT/750 [69]

Frequency Range	.5 to 18/20 GHz (C to J band; supports an optional mmW)
Azimuth Coverage	360°
Emitter Types	Pulsed; Pulse-Doppler; CW; Scanning; Agile PRIs and RF; LPI

52. **ES-5080 Digital Receiver-based ELINT system**

Figure 52: ES-5080 (from [70])

The ES-5080, developed by ITT Electronic Systems, is a combined ELINT/ESM system that has been developed as an improved digital receiver-based replacement for the ES-5060 ELINT/ESM systems used on ships, on land, and on aircraft. The system architecture combines omnidirectional and high-gain spinning dish antennas with a radio-frequency preamplifier unit (RFPU), a wide-band synthesized superhet tuner, a signal processor, a server and a digital receiver, and an operator workstation. This combination provides the high system sensitivity and parameter measurement accuracy required for receiving modern complex low-power radars at long ranges. The ES-5080 will intercept, measure, analyze, identify, and associate radar signals to platforms in all operational environments. Identification is constrained by the national capability to populate the data library. The processing will cater for signals of significant complexity, including those with low-probability-of-intercept (LPI) characteristics. [70].

Table 50: Technical Parameters for the ES-5080 [70]

Frequency Range	.5-18 GHz
Bandwidth	70 MHz to 500 MHz (instantaneous)

Sensitivity	1° (min, RMS) 5° (max, RMS)
Omni Antenna Pulse Processing Sensitivity	-70 dBmi
Omni Antenna CW Processing Sensitivity	-100 dBmi
Respective Dish Antenna Processing Sensitivity	-90 dBmi (Pulse) -120 dBmi (CW)
Azimuth Coverage	360°
Pulse Length	5 NS (min)
Dynamic Range	60 dB

53. **Itata Airborne ELINT System**

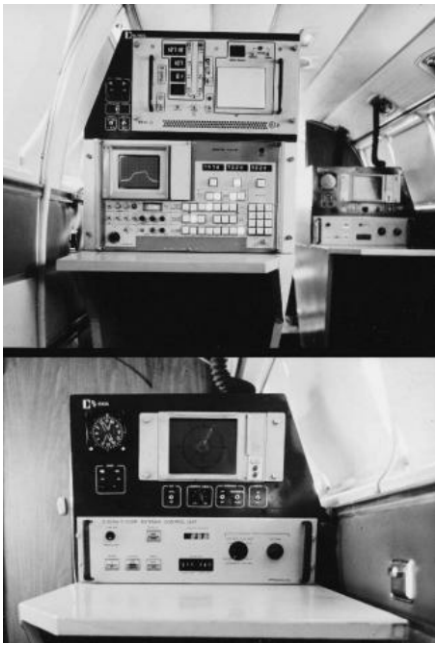

Figure 53: Itata ELINT System (from [71])

The Itata ELINT system has been developed by Desarrollo de Tecnologia y Sistemas (DTS) Ltd. and is a high-sensitivity electronic intelligence gathering system that can detect, locate and measure the parameters of emissions from search, acquisition and fire-control radars. Itata consists of a fully programmable super heterodyne receiver, a digital

pulse analyzer and a high-gain, wideband, rotating dish antenna which provides 360° coverage and bearing information to within a few degrees accuracy. Although intended primarily for light transport type aircraft, the equipment can also be installed in ship borne or ground vehicle configurations [71].

The receiver operates over the 30 MHz to 18 GHz frequency range with coverage divided into six system specific sub-bands. It can be used in either a wide open mode over the complete frequency range or in a selective mode over a single band. System function is either automatic or manually controlled and the operator can preprogrammed the equipment to search its entire frequency range or single or multiple sub-bands selected from the six sub-bands. After detection of a transmission of interest, the receiver locks onto it automatically and measures its frequency and other parameters. Digitized data of each intercepted signal can be recorded automatically for subsequent analysis [71].

Table 51: Technical Parameters of the Itata ELINT System [71]

Frequency Range	0.03-18 GHz in 6 bands
Sensitivity	-83 dBm
Dynamic Range	70 dB
Pulse-width Range	.05-24 μs
PRF Resolution	0.25 μs
PRF Range	0.092 – 12.83 kHz
Azimuth Coverage	360°
Polarization	circular
Azimuth beam-widths	8° E/F-band; 1.8° J-band

54. **French Phalanger ELINT System**

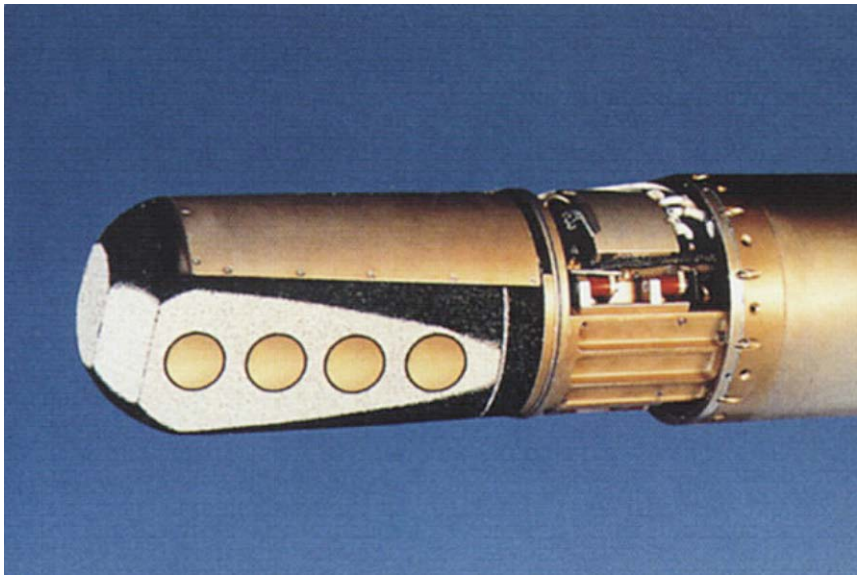

Figure 54: Phalanger ES/ELINT System Antenna head (from [72])

Phalanger is a new-generation ES/ELINT payload for airborne platforms such as unmanned aerial vehicles, helicopters or light multipurpose aircraft. Based on phase interferometry and digital receiver techniques, it is designed to offer high performance combined with “minimal” weight, volume and power consumption. The use of interferometry allows for “accurate” direction-finding while that of a digital receiver is used to facilitate long-range signal detection, “superior” parameter acquisition and “very short” acquisition times. Radar tracks can be preprocessed and Phalanger can either deliver track data for real-time display and analysis or record information for post-mission download. An associated battlefield tactical workstation can take the form of a stand-alone laptop computer or a `compatible ground workstation'. Data display formats include emitter maps and analysis histograms [72].

Table 52: Technical Parameters of the Phalanger [72]

Frequency Range	2-18 GhZ; 0.5-40 GHz (option)
Azimuth Coverage	360°
Bearing Accuracy	1°
Power Consumption	<300 W

55. **Kestrel**

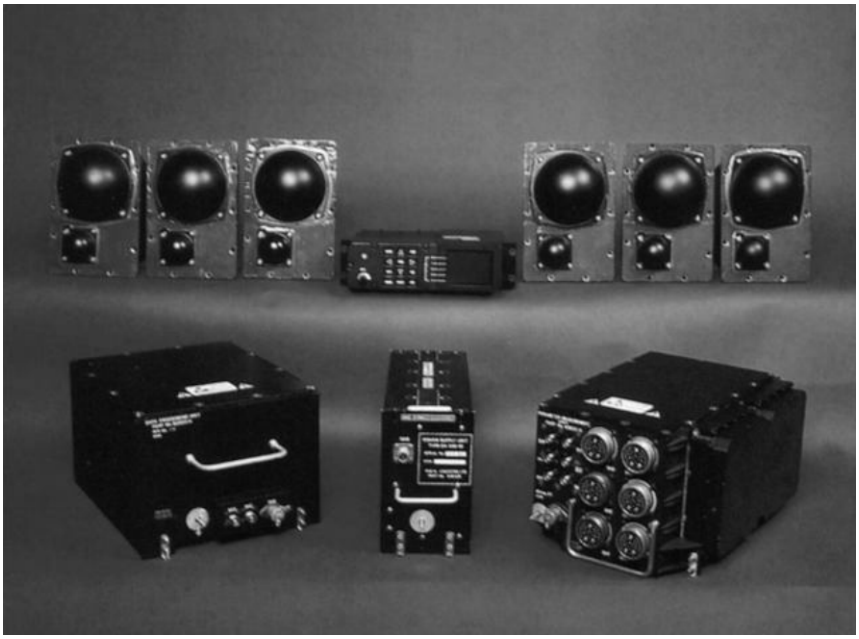

Figure 55: Kestrel System Components (from [73])

The Kestrel ES/ELINT system receives and processes pulse and continuous wave radar emissions within the 0.5 to 18/20 GHz frequency band and provides a “near” 100% probability of intercept those signals in “very dense” environments. Instantaneous bearing and frequency measurement are provided over the full 360° arc in azimuth. Functionally, Kestrel employs six antenna modules that are mounted around the host platform's airframe or in wingtip pods. Each module contains “high-sensitivity” receivers and derived radio frequency and video outputs are fed into a parameter measurement unit (PMU) for processing. The PMU incorporates super heterodyne receivers, undertakes digital instantaneous frequency measurement, establishes the time of arrival, direction of arrival, frequency, pulse repetition frequency, pulse-width and amplitude of received signals and digitizes the processed data for onward transmission to the system's data processing unit (DPU). For its part, the DPU performs “high pulse density” de-interleaving, analysis of “complex” pulse repetition intervals, scan types and frequency agilities and emitter identification. It is programmed before flight with a mission data package that includes an emitter library for automatic radar recognition. Emitter identification is achieved via library comparison using a software library with a capacity of “at least” 2,000 radar modes. Kestrel also incorporates a radar warning function that is capable of displaying threats within 1 second of receipt and interfaces with an onboard defensive aids suite (active radar jamming and chaff/infrared decoy flare dispensing subsystems) if available. Intelligence gathered during a mission can be recorded for post-flight analysis if required. Kestrel offers a number of tactical and ELINT display options (including fine grain measurement of “agile and complex radar signatures”) that are dependent on the type of aircraft in which the system is installed and the role it is being used for. As an alternative, analyzed data can be transmitted to the host platform's

mission computer or an aircraft recorder by means of a Military Standard (MIL-STD) - 1553B databus [73].

Table 53: Technical Parameters for the Kestrel [73]

Frequency:	0.5-18/20 GHz (20-40 GHz option)
Receiver Types:	Log video amplifier; digital log video amplifier; instantaneous frequency measuring; continuous wave super heterodyne
Azimuth Coverage:	360°
Elevation Coverage:	45°
DF Accuracy:	Better than 5° RMS
Bearing Accuracy:	±3.5° RMS
Frequency Accuracy:	5 MHz RMS
Warning/ID:	All pulse types including CW and 3-D LPI
Emitter Modes in Library	2,000 modes
Power:	1 KVA

56. **LR-100 Receiver**

Figure 56: LR-100 Receiver (from [74])

Northrop Grumman's LR-100 is light-weight all-in one, affordable, high-performance radar warning receiver (RWR)/electronic support measures (ESM)/electronic intelligence (ELINT) receiver system. The system's small foot-print and 73-pound weight make it ideally suited for installation on virtually any air, sea, or land-based platform, including light-weight unmanned air vehicles (UAVs) [74].

Table 54: LR-100 Receiver [75]

Frequency Coverage:	2-18 GHz (baseline -70 MHz or 18-40 GHz as growth options)
Frequency Range:	100ns-409 μs (CW)
Frequency Accuracy	2 MHz
Frequency Resolution:	25 ns
PRI Range:	2 μs-50 ms
PRI Resolution:	3 ns
Instantaneous Bandwidth:	20, 100 or 500 MHz

Standard FOV:	±45° (elevation); 360° (azimuth)
Sensitivity:	-71 dBm RMS
Dynamic Range:	45 dB (third order); 60 dB
DOA Accuracy:	0.8° RMS
Ranging:	Azimuth/elevation and bearing/triangulation
Revisit Time:	<300 ms (low density, <10 emitters); <2 s (high density, >40 emitters)
Reporting:	Average PRI/PRI type/deviation, average pulse width, DOA, frame rate, ID, Lat/Long, frequency rates, time of initial detection, time of last update and track number.
Power:	24 W (4 x azimuth antenna interferometer units, total 28 V DC); 35 W (antenna interface unit, 28 V DC); 160 W (receiver-processor/mounting tray, 28 V DC)

57. **SAGE Advanced Digital ESM**

Figure 57: S-100 flying trials with new SAGE ESM/ELINT Payload (from[76])

SAGE is a digital Electronic Support Measure (ESM) and Electronic Intelligence (ELINT) system for Radio Frequency (RF) Intelligence, Surveillance and Reconnaissance (ISR) missions. The system uses parallel wideband and channelized digital receivers to achieve enhanced sensitivity, fine frequency measurement, and very high probability of intercept in the frequency range 2-18 GHz (with options for C/D and K band extensions, and an adjunct communications ESM channel). The receiver architecture provides for instantaneous emitter detection and ELINT-grade measurement accuracy [77].

Table 55: Technical Parameters for SAGE [77]

Frequency Coverage:	0.5 – 40 GHz
RF Measurement Agility:	1 MHz typical, including RF characteristics
Sensitivity:	-60 dBmi wideband DRx sensitivity dependent on FFT better than -80 dbmi achievable
High Accuracy DF:	Typically 1° RMS
PRF Types:	Fixed, jittered, slide, stagger, random

	stagger, draft batch, irregular, nets
Geolocation:	Typically better than 5°
Fine Frequency Measurement:	<50 KHz RMS for pulse widths >1μs <100 Hz for coherent signals (using external 10 MHz ref.)
Intra-Pulse Measurements:	Frequency Modulation: FMICW, FMCW, FM Chirp
Phase Modulation:	Phase Shift Keying Barker Codes
Emitter Library Size:	16000 mode lines
Communication ESM:	VHF – D Band operation

58. **Sea Petrel RQH-5(V) ESM/ELINT System**

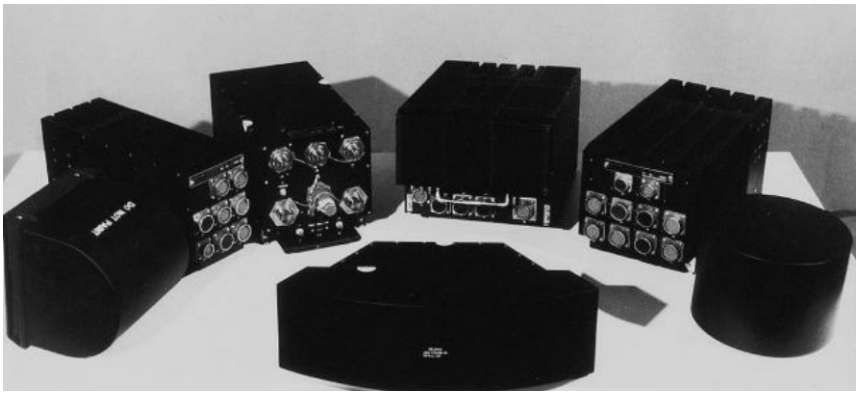

Figure 58: Sea Petrel RQH-5(V) (from [78])

The Sea Petrel RQH-5(V) is a family of systems which can meet EW requirements ranging from threat detection and analysis to electronic intelligence. The basic components are the antennas, direction – finder receiver, IFM receiver and data extractor. The following configurations are available [78]:

- The SL/ALR-730 Series offers electronic support measures and ELINT for all types of platforms including large and medium maritime patrol aircraft and large helicopters, but has also been installed onboard medium and small helicopters.
- The SL/ALR-733 and 735 Series represent the evolution of the original design. The internal hardware has been extensively re-

designed and various options (such as a new antenna model incorporating RF amplification for a significant increase of system sensitivity) give the possibility to enhance systems performance, extending the range of application of this product family.

- The SL/ALR-740 Series offers RWR functions combined with automatic signal analysis for post-flight intelligence, and is designed for installation on small aircraft or helicopters. Average DF accuracy of 10° RMS is provided, with automatic warning and emitter parameter measurements. The ALR-741-R uses multiple-IFM receivers.

Table 56: Technical Parameters for the Sea Petrel RQH-5(V) [78]

Frequency Coverage:	0.6 – 18 GHz (with option to 40 GHz)
Sensitivity:	-60 dBm
Bearing accuracy:	±2.5° RMS
Emitter Library:	3000 modes

59. **SEER**

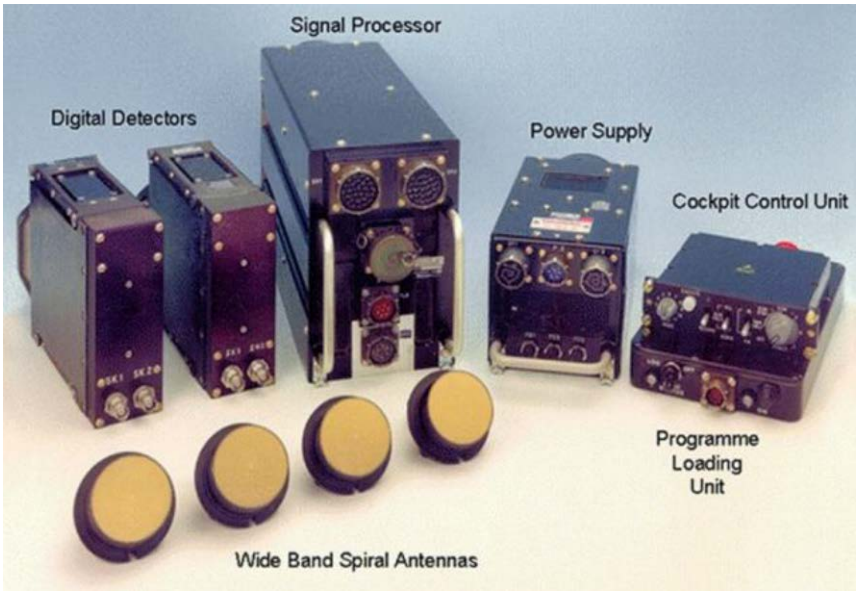

Figure 59: SEER RWR System Components (from [79])

The SEER is an advanced digital Radar Warning Receiver (RWR) with enhanced processing power, able to identify Radio Frequency (RF) threats. Because it uses digital receiver technology SEER is able to detect and accurately identify emitters at a tactically

significant range within dense, complex RF environments. SEER RWR can operate in E-J bands (2 GHz – 18 GHz) and has direction finding accuracy of <10°rms. It is able to detect pulse, pulse Doppler and continuous wave radar emissions, whether they are stable or agile [79].

Selex ES has enhancing the capability of the SEER RWR by extending the brand frequency range to incorporate C/D bands (0.5 – 2GHz) and K band (20 – 40 GHz). Work in this area is at an advanced stage and lab-based trials have been carried out successfully [79].

Table 57: Technical Parameters of the SEER RWR [80]

Frequency Coverage:	2-18 GHz (extendable to include the 500 MHZ – 2 GHz and 20-40 GHz subbands)
DF Accuracy:	<10° RMS
Detection:	CW, Pulsed and Pulse-Doppler
Pulse Characteristics:	All agile types and stable
Pulse width:	>50 ns (including agile)
Sensitivity:	<-55 dBmi
Frequency Measurement:	<10 Mhz

60. **Sky Guardian 2000 Radar Warning Receiver**

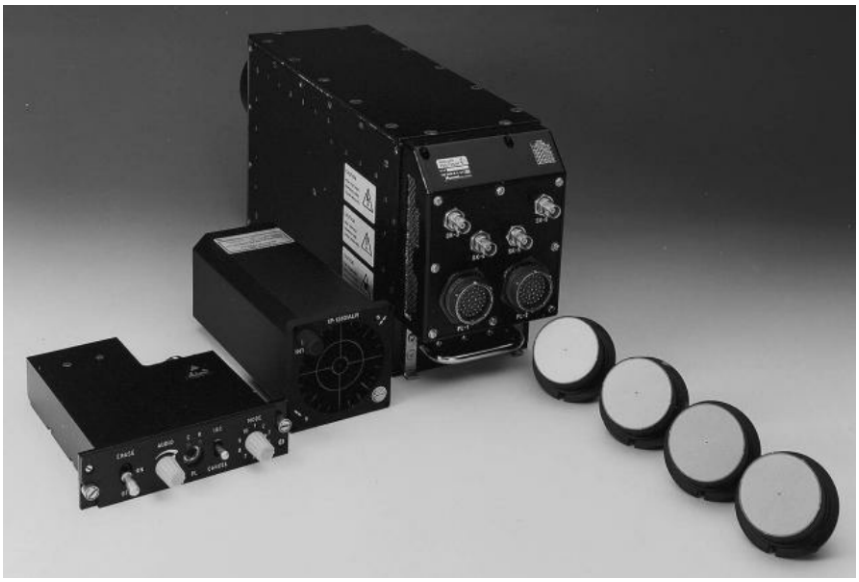

Figure 60: Sky Guardian 2000 RWR (from [81])

SKY Guardian 2000 is an airborne Electronic Counter Measures Radar Warning Receiver. Sky Guardian 2000 employs advanced signal processing algorithms and provides high sensitivity as well as accurate RF measurement. An emitter library of 4,000 emitter descriptions can be loaded by a PCMCIA smart card incorporated into the control unit. Sky Guardian 2000 has been designed from the outset as the core of a Defensive Aids System (DAS) and includes DAS control functions [81].

Table 58: Technical Parameters of the Sky Guardian 2000 [81]

Frequency Coverage:	E- to J-bands (c/D- and K-bands optional)
Frequency Measurement:	Pulse, pulse Doppler, CW and ICW
Azimuth Coverage:	360° instantaneous
Accuracy:	Better than 10°
Pulse Density:	>1 Mpps
Polarization:	Dual-polarization option
Emitter library:	Over 4000 emitter modes

61. **TOP-SCAN ES/ELINT System**

Figure 61: TOP-SCAN sensor module (from [82])

TOP-SCAN is an airborne ES/ELINT system designed to detect, identify and locate ground-based emitters operating within the 0.5-18 GHz frequency range. The system is a dual axis interferometer integrated sensor system and contains an on-board, reprogrammable emitter library [82].

Table 59: Technical Parameters of the TOP-SCAN System [82]

Frequency Coverage:	0.5-18 GHz (up to 40 GHz option)
Frequency Measurement:	1 MHz RMS (accuracy; 100 ns (measurement time)
Pulse Type:	Modern and complex (including modulation-on-pulse)
Dual-axis DF accuracy:	2° RMS and geolocation
Spatial Coverage:	>90° (elevation); 360° (azimuth)
Sensitivity:	-70 dBm
Bandwidth:	20, 800 and up to 4,000 MHz (selectable)
Dynamic Range:	40-60 dB (sampling, immediate; >55 dB (detection)
Power consumption:	<150 W
Receiver Recovery Time:	250 ns

62. **UltraEAGLE ALR-510**

Figure 62: UltraEAGLE ALR-510 (from [83])

The UltraEAGLE Airborne Tactical Elint System, is a family of Electronic Support (ES) systems technology designed to meet a wide array of Electronic Intelligence (ELINT) missions. Available in various models covering A through K band, UltraEAGLE represents a modern integrated digital ELINT receiver system for Intelligence, Surveillance and Reconnaissance (ISR) applications. The UltraEAGLE product line exploits the benefits of an open architecture with net-centric control and operation. Incorporating wideband software defined digital receiver technology; UltraEAGLE offers state of the art radar emitter intercept, analysis and recording capability. The ALR-510 can process conventional emitters as well as 'modern' types such as pulse compressed, pulse Doppler and multi-mode equipment [84].

Table 60: Technical Parameters of the ARL-510 [84]

Frequency Coverage:	2-18 GHz (extendable possibly to 0.5GHz and up to 40 GHz - unconfirmed)
Frequency Step:	>10 kHz
IF Center Frequency:	1 GHz
IF Bandwidths:	10, 50, 100, 250 and 500 MHz (predetermined)
Frequency Accuracy:	1.5 MHz RMS (or better)
Sensitivity:	-65 dBmi (or better, 100 MHz instantaneous bandwidth)
Angular Coverage:	35° (elevation, port and starboard, instantaneous FOV); 120° (azimuth, etc.)
DF Antenna Polarization:	Left- or right-hand circular
Bearing Accuracy:	:<1° (measured on steady pulsed or CW emitter)
RF Pulse Density:	>1 Mpps
TOA Resolution:	<6 ns
Active Emitter Capacity	>1000 emitters
Pulsewidth Range:	50 ns to 13 ms
Pulsewidth Resolution:	<± 6 ns
Programmable CW Flag Range:	100µ to 13 ms

PRI Range:	.500 ms to 100 ms/10 Hz to >2 MHz
PRI Resolution:	<6 ns
Amplitude Measurement Range:	60 dB
Emitter Library Storage:	10,000 emitters or better

G. SURFACE SHIP/SUBMARINE INTERCEPT RECEIVERS

Today's surface and sub-surface vessels continue to fulfill a major role gathering intelligence information, supporting direct military action, and combating piracy and terrorism. The electronic sophistication in both civil and military electronics domains has led to changes in the types and density of signals, requiring more sensitive intercept receivers for radar ESM capabilities. Radar electronic support measures equipment with a frequency band of 2-18 GHz, with the optional extension of up to 40 GHz , is no longer wide enough as new "stealth" emitters and LPI signals emerge. The frequency ranges of these emitters have increasingly come to be extended downwards (in some cases below 0.5 GHz). Thus the increased signal densities, in the radar and communication frequency bands, have heightened sensitivity demands for modern intercept receivers [85].

63. **Thales Sealion**

Figure 63: Thales Sealion Antenna (from [86])

The Thales Sealion ESM system is designed to provide rapid, dependable threat warning and situational awareness in dense, electromagnetic environments to aid command decision making [48]. It is primarily designed for use on submarines. This system features extensive use of commercial, off-the-shelf hardware and software. As seen in Table 35, it provides 100% probability of intercept over the 2 to 18 GHz frequency range [86].

Figure 64: Thales Sealion Console (from [86])

The system consists of an omnidirectional antenna, a receiver processor unit, and a low-volume/lightweight operator console. It is capable of automatically tracking more than 200 emitters simultaneously and comes equipped with an auxiliary library of 100 emitter modes. The Sealion's recommended applications include threat warning, tactical surveillance, assistance in targeting, and intelligence gathering. The masthead unit can accommodate a GPS unit and has provision for ultra-high-frequency communications antennas [48].

Table 61: Technical Parameters of Thales Sealion [86]

Frequency Coverage	2 – 18 GHz
Azimuth Coverage	360°
Elevation Coverage	45° to -10°
Dynamic Range	60 dB
Probability of Intercept	100%
Bearing Accuracy	2.25° RMS
Sensitivity (δ_I)	-65 dBm

64. **SAAB Electronics UME-100 and UME-200**

Figure 65: UME-100 System (Radar Warning Receiver Antenna, ESM Antenna, and Electronic Warfare Controller) (from [87])

Figure 66: UME-200 System (Radar Warning Receiver Antenna, ELINT Antenna, and Electronic Warfare Processor) (from [87])

Figure 67: UME-100 System installed onboard South African Navy Type 209 submarine (from [87])

The SAAB UME-100 is a surface/sub-surface tactical ESM system, with designated ELINT analysis capability and amplitude direction finding, whereas the UME-200 is a tactical ESM System with full parallel ELINT Analysis capability, and phase interferometer based direction finding [88]. These systems are designed for operation in blue water or littoral regions, with multi-receiver parallel architecture that provides rapid reaction time, at high pulse densities with high sensitivities, without jeopardizing platform safety. Both systems are capable of extracting and automatically recording basic parametric data, time varied frequency, phase amplitude, and PRI modulation schemes. As shown in Table 36, both systems operate over the 2-18 GHz band.

Table 62: Technical Parameters of SAAB UME-100 and UME-200 [87, 88]

	UME-100	**UME-200**
δ_I	-63 dBm	-83 dBm
Architecture:	ESM with ELINT functionality comprising parallel: Acquisition receiver, ESM receiver	Simultaneous ESM and ELINT System with parallel: Acquisition receiver, ESM receiver, ELINT receiver, Integrated LPI receiver
Frequency Range: Standard Options	 2-18 GHz 0.6-2.0 and 18-40 GHz	 2-18 GHz 0.6-2.0 and 18-40 GHz
Probability of Intercept:	100%	100%
Direction Finding: Method Accuracy	 Amplitude 5° RMS	 Phase and Amplitude 2° RMS

Pulse Density Processing	2.5 million pulses per second	2.5 million pulses per second
Shadow Time:	350 ns	350 ns
Reaction Time:	500 ms	500 ms
Frequency Resolution:	1.25 MHz	1.25 MHz
Pulse-Width Range:	50 ns-204's	50 ns-204's
PRI range:	2-26, 400's	2-26, 400's

65. **ITT/RSS ES-3601**

ITT/RSS (formerly EDO Reconnaissance and Surveillance Systems) produce the ES-3601 tactical radar ES and surveillance system. The ES-3601 system was designed for surface, subsurface, and land-based applications [89]. The frequency range is 2 to 18 GHz and with its As-950 acquisition/DF antenna for submarine mast installations, it provides a 3° to 5° accuracy with an automatic processing sensitivity of δ_I = -65 dBm [90].

Figure 68: ES-3601 AS-360 Acquisition and DF Antenna Assembly, SP-360 Receiver/Processor, and CP-360 Operator Workstation (from [89])

This system provides precise measurement and analysis of intercepted monopulse signals, including interception, signal measurement, classification, and DF to improve situational awareness, self-protection, and surveillance. The ES-3601 can track up to 500 signals simultaneously and compare them with a library of more than 10,000 radar emitter modes. As shown in Table 37, this system provides a frequency measurement accuracy of 3 MHz and a bearing accuracy of 3-5° RMS. The system is capable of multimode radar report-merging and multipath and reflection processing using an eight-element amplitude monopulse DF antenna array [89].

Table 63: Technical Parameters of ITT/RSS ES-3601 [89]

Frequency Range	2-18 GHz (1-2 and 18-40 GHz options)
Bearing Accuracy	3-5° RMS
Automatic Processing Sensitivity	-60 to -65 dBm
Dynamic Range	60 dB
Frequency Measurement Accuracy	3 MHz
Pulse Width Measurement	50-100 ns (minimum)
Signal Environment	1 million pulses/s
Reaction Time	< 1s
Emitter Library	More than 10,000 emitter modes
Track Capacity	Up to 500 signals simultaneously

66. **DR 200/3000/4000 RESM Suites**

Figure 69: DR 4000U IMF ESM System Console (from [93])

The DR 2000 Surface Ship and Submarine Radar Electronic Support Measures (RESM) radar intercept suite, was produced from about 1960 in France and was exported to several nations, some of whom continue to have the suite in service. The technology has been updated by the DR 3000 and the DR 4000 [92].

The DR 3000 was preceded by the digital RESM DR 4000 Series. The DR 3000 remains in active production and is in use by many countries around the world, including several Middle Eastern countries, such as the United Arab Emirates, Qatar, Saudi Arabia and Pakistan [92].

Table 64: Technical Parameters of DR 3000 Suites [92]

Frequency:	0.5 – 20 GHz
Azimuth Coverage:	<360° (subject to aearial location and design)
Elevation Coverage:	-10 to +45°
Sensitivity:	-68 dBm
Bearing Accuracy:	~3°
Dynamic Range:	Up to 60 dB
Radar Modes:	12,000+ in customer-defined data library

The DR 4000U ESM is the submarine variant of the DR 4000 series. It has an extremely fast reaction time and a high instantaneous data collection capability. High-sensitivity IFM receivers allow 100 per cent intercept probability, even on a short single pulse. Combining crystal video and IFM receiver technology on both omni-directional and DF channels, the system offers threat warning, surveillance, emitter identification, electronic intelligence, and automatic electronic warfare system control capabilities. The highly automated system has an instantaneous 360° DF capability with bearing accuracies of about 5°. Frequency coverage is over the C- to J-bands with the possibility of extension to the range as an option. The highly sensitive antenna system includes an omnidirectional unit for frequency measurements and two concentric six-port DF arrays, one for C- to G-bands (0.5 to 6 GHz) and the other for H- to J-bands (6 to 20 GHz) [92].

Table 65: Technical Parameters of the DR 4000U [92]

Frequency Coverage:	0.5 – 20 (with possible extension)
Azimuth Coverage:	360° (instantaneous)
Bearing Accuracy:	5°

67. **AN/BLQ-10 Submarine Electronic Warfare Support System**

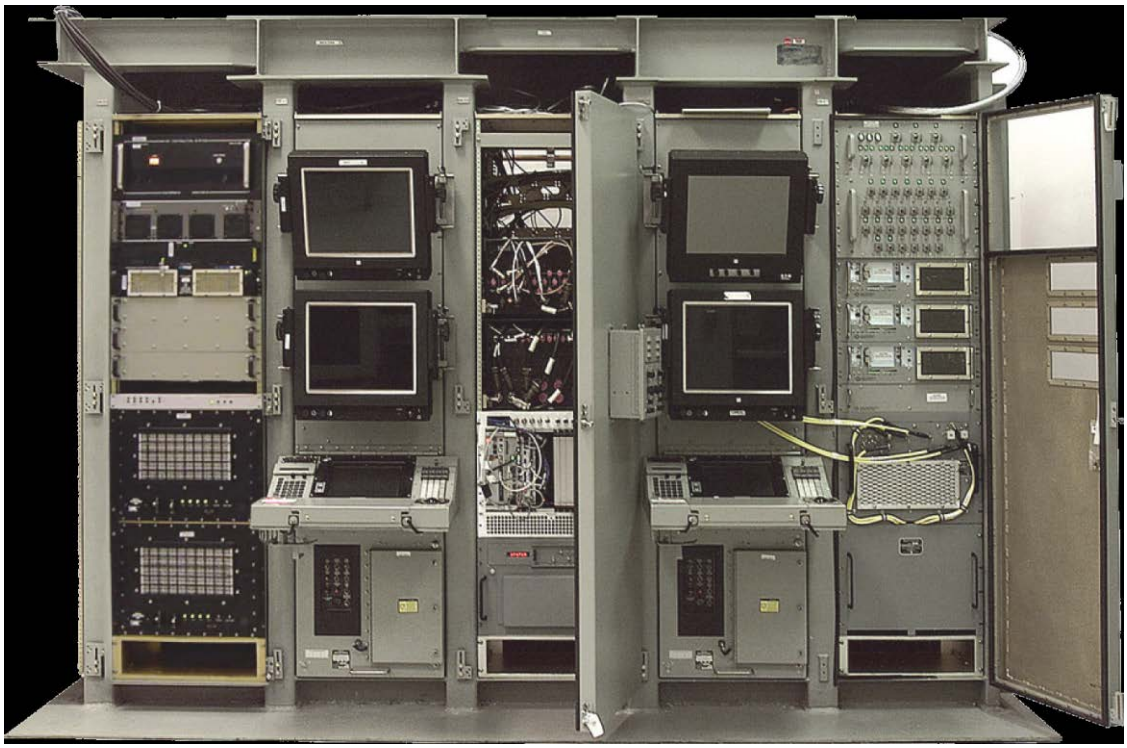

Figure 70: AN/BLQ-10 (from [94])

The AN/BLQ-10 system is an electronic warfare support system for U.S. submarines. It provides automatic intercept capability (detection, classification, localization, and identification) for both radar and communications signals. Separate subsystems process radar and communications signals. DOT&E issued a classified report on testing of the AN/BLQ-10 in September 2013 and concluded the TI-08 upgrade improves the system's intercept capability against LPI radars and the MMM provides communications signal accuracy sufficient for most missions. It assessed that the AN/BLQ10 system was not operationally effective for use in the collection of communications signals. Further work to develop the Test and Evaluation Master Plan (TEMP) and test the AN/BLQ-10 with the TI-10 upgrade is expected to take place during fiscal year 2014 (FY14). The AN/BLQ-10 is being integrated into Surface Electronic Warfare Improvement Program (SEWIP) upgrades for the US Navy [95]. Specific technical parameters of the system are classified.

68. **Chilean Naval ELINT and ES Systems**

Desarrollo de Tecnologías y Sistemas (DTS) a private company in Chile created in 1991 has produced a range of ELINT and ES systems for naval applications. Currently they are continuing to promote the DMA-302S, DMI-603 and DMI-604, although little specific information is known on the products and their customer [96].
The DMA-302S is an ES system for surface and subsurface as well as ground force applications. It is believed to cover a frequency range of 2-18 GHz and has a bearing accuracy of better than 5° RMS for direction finding. It has an emitter database storage capability of holding up to 10,000 emitters [96].

The DMI-603 ELINT system is a multipurpose, tri-service sensor that searches for, detects, analyses, records, and localizes radar emitters operating within the 100 MHz to 18 GHz frequency range. It is described as a multipurpose light ELINT system that employs small aerials and can be in a walk-on-board or permanent-fit configuration. Other system features include the ability to handle 'extremely complex' signals, 'high' sensitivity/'high' POI functionality, and use of a 'small' antenna array that facilitates the equipment's use in permanent or carry-on installations [96].

The DMI-604 is an ELINT system integrated with a ‘high accuracy” DF subsystem and is intended to be permanently installed on its host platform. It has a high POI fixed array and/or a high-gain spinning antenna to maximize its detection range [96].

Table 66: Technical Parameters for DMA-302S [96]

Frequency Range:	2-18 GHz (100 MHz to 18 GHz for DMI-603/4)
Azimuth Coverage:	360° (instantaneous, azimuth)
Bearing Accuracy:	Better than 5° (anechoic chamber)

69. **ES-3701 RESM Suite**

Figure 71: ES-3701 (from [97])

The ES-3701 was manufactured by ITT Exelis as an RESM suite for surface ships, providing 360° surveillance across the designed NATO I-/J-bands (2 to 18 GHz). The suite delivers precision measurement and analysis of intercepted monopulse signals, including interception, signal measurement, classification, and direction-finding (DF) on all detections to assist the command in compiling the tactical picture and improving situational awareness, self-protection, and surveillance [97].

Table 67: Technical Parameters for the ES-3701 [97]

Frequency coverage:	2-18 GHz (0.5-2 and 18-40 GHz options)
Azimuth coverage:	360° (instantaneous)
Sensitivity:	-65 dBm (automatic processing); -70 dBm (tangential signals); -80 dBm (with optional superhet receiver at 0,5-18 GHz)
Dynamic range:	60 dB (instantaneous processing)
Bearing (DF) Accuracy:	2° RMS (entire dynamic range)
Frequency measurement accuracy:	3 MHz
Pulse width measurement:	50 nm (minimum)
Signal environment:	1 million pulses/s
Emitter Library storage:	>10,000 emitter modes
Tract capacity:	Up to 500 Signals simultaneously
Notch filters:	2-18 GHz (tunable, CW/Omni/DF channels)

70. **MRBR-800/ MRSR-800 RESM/ELINT Suites**

Figure 72: Typical Components for the MRBR-800 RESM Suite (from [98])

The INDRA MRBR-800, the submarine variant and MRSR-800, the surface ship variant, share common components. The MRBR-800 suite is a scalable, combined RESM/ELINT suite designed for mast-mounting in submarine applications. The MRBR-800 suite benefits from the ability to re-site its antenna for increased detection ranges.. Both provide omni- and directional detection identification and classification of detected radar transmissions in the NATO I- to J-bands (2 to 18 GHz). This is expandable to cover 0.5 to 40 GHz [98].

The MRBR-800 family of radar ES equipment is based on wideband digital receiver technology. The BAS-B4 covers 2 to 18 GHz with an instantaneous bandwidth of 4 GHz. The antenna incorporates eight spiral antennas (3° accuracy) and an omnidirectional antenna (better than 5° accuracy). The BAS-B4 has good warning capability against pulsed emitters (δ_I = -85 dBm). The analysis processing is able to cope with complex signals, including those associated with LPI and CW radars [98].

Table 68: Technical Parameters for the MRBR-/MBSR-800 [98]

Frequency coverage:	2-18 GHz (0.5-2 GHz and 18-40 GHz options)
Instantaneous bandwidth:	16 GHz

POI:	100%
Azimuth Coverage:	360°
Automatic intra-pulse modulation classification:	yes

71. **SEAL**

Figure 73: SEAL on mast of Abu Dhabi-class FHS of the UAE Navy (from [99])

Elettronica SpA has designed the SEAL family of naval ESM equipment to form a complementary suite of systems that can be combined to form a comprehensive electronic warfare (EW) capability. The range of solutions was focused towards the needs of small- to medium-size vessels from offshore patrol vessels (OPVs) and corvettes to frigates. The selection of equipment provides different levels of performance, depending on ship role. The performance is targeted towards provision of EW capability for the whole range of maritime tasking, including high-end task force operations [87].
The equipment is promoted to have a high capacity to operate in high electromagnetic-density scenarios. The co-pulse signal-handling requires accurate differential-time-of-arrival measurement that is included in the wide-band digital receiver design. The sensitivity enables the detection of signals from emitters with LPI characteristics and provides fully automatic real-time analysis and tracking of each intercept. Passive ranging and location can be provided. The equipment is configured to deal with signals that may also include modulation on pulse (MOP), frequency modulation on a pulse (FMOP), pulse modulation on a pulse (PMOP), pulse-on-pulse (POP), continuous wave (CW) detection and pulse-on-CW (POCW) flag outputs, and detailed ELINT analysis for fingerprinting and recording [99]. No specific unclassified technical parameters are available.

72. **NS-9003A –V2/NS-9005A-V2 EW Suite**

Figure 74: Typical Configuration for the NS-9003A-V2/NS-9005A-V2 ES/ECM Suite (from [100])

The combined NS-9003A-V2 and NS-9005A-V2 equipment form an integrated EW suite is marketed by Elisra, which identifies it as 'IEWS' on its company website and describes it as a solution to provide ship safety with a combined passive ESM sensor and associated ECM jammer. Both subsystems are also advertised individually by the company. The NS-9003A-V2 is a development of the NS-9003A ESM radar intercept receiver, and the NS-9005A-V2 has similarly emerged from the NS-9005A design [100].

The NS-9003A-V2 and NS-9005A-V2 architecture has continued to be promoted on the Elisra website. However, in 2010 the next (fifth) generation of IEWS, marketed internationally under the name 'Aqua Marine', was announced at Farnborough Airshow in the United Kingdom. It is differentiated by the introduction of advanced wide-band digital receiver technology and is believed to have entered Israeli Navy service in 2008 as an upgrade to the Sa’ar 5 corvette [100].

Table 69: Technical Parameters of the ES Subsystem [100]

Frequency range:	1-18 GHz (instantaneous, 0.5-40 GHz option)
Frequency resolution:	2 MHz
Azimuth coverage:	360°
Bearing (DF) Accuracy:	2° RMS
Environment density:	>1 million pulses/s
Probability of Intercept:	100% (claimed)
Sensitivity:	-65 to -75 dBm
Dynamic Range:	>60 dB
Pulsewidth range:	0.05 μ to continuous wave
Continuous wave:	Full parametric measurement
Scan rate:	Simultaneous analysis of all detected emitters
Emitter ID library:	Up to 10,000 sets of emitter parameters

73. **NELTIS/SLQ-750 Integrated ES/ECM Suite**

The NELTIS family, manufactured by Elettronica SpA, can be configured with its ESM/ECM equipment to provide self-protection (including automatic initiation of active and passive countermeasures) and tactical surveillance. The ESM receivers are identified as being capable of enhanced performance for the detection of low probability-of-intercept (LPI) radars and passive emitter-ranging/location. The combinations of Elettronica equipment, including passive receivers, chaff/decoys, and active jammers, Nettuno-4100 ECM, and SEAL ES equipment (see separate SEAL entry) provide the components of a comprehensive EW suite [101].

Table 70: Technical Parameters for the ESM receiver [101]

Frequency range:	0.5-20 GHz
Probability of Intercept:	100% (nominal)
Bearing (DF) accuracy:	Sufficient for co-operative fixing
Pulse density:	Better than 1 million pulses/s
MOP detection:	Amplitude, frequency, and phase
Tracking channels:	>>100

74. **Timnex II ESM/ELINT Suite**

Figure 75: TIMNEX II System Components (from [102])

Timnex II is an advanced ELINT/ESM system based on a channelized IFM receiver. It provides omnidirectional detection, intelligence gathering and direction-finding in the 2 to 18 GHz band (0.5 to 40 GHz as an option), performing in-depth tactical analysis on up to 256 detected emitters in real-time. Bearing accuracy is in the region of 3° and the emitter library holds up to 10,000 parameters. The system's DF processor can handle both phase and amplitude comparison data, while its channelized receiver incorporates a multiple narrow frequency band blocking capability and the ability to handle co-pulse and low probability of intercept (option) emitters. The continuously open system provides instantaneous frequency coverage and direction finding with real-time signal processing and features automatic high amplitude, CW alarm and automatic identification of pre-defined targets [102].

Table 71: Technical Parameters for the Timnex II [102]

Frequency coverage:	2-18 GHz (0.5-40 GHz optional)
Frequency accuracy:	1.5 MHz (over complete freq. range)
Sensitivity:	-67 dBm

Bearing accuracy:	Better than 3° (phase comparison antenna array)
Real-time processing capacity:	Up to 256 emitters

75. **Vigile Electronic Support Systems**

Figure 76: Vigile APZ Receiver Array (from [103]

Vigile is a family of modular and scalable RESM equipment that, in combination, is suitable for surface, subsurface, maritime patrol aircraft (MPA), and ground-based applications. Vigile was designed as the successor to the earlier DR 3000 ESM (see previous entry). Vigile will process and analyze all emissions from multimode emitters, low effective radiated power (ERP) signals, agile transmissions (frequency, pulse repetition, etc), and high pulse repetition mode (PRF) such as pulse-Doppler. Basic frequency coverage is 2 to 20 GHz (NATO E- through J-bands) and the dual-polarized antenna array provides high DF accuracy (subject to precise ship fit) and 360° coverage. The processing is capable of single pulse detection and agile, multimode, and pulse-Doppler emitters will be detected and compared to details in the 'customer specified' data library for classification and identification. All systems have a high track capacity of more than 10,000 entries. The Vigile series (LW, 100, 200 and 400 versions) is also noted as being network-enabled and featuring an options package that includes frequency extensions ('high' -up to 40 GHz - and 'low band'), a LPI detection capability, a 'fine-grain' analysis capability, 'high-accuracy' DF, and passive geolocation [103].

VIGILE 400 is the ultimate version of the VIGILE family. It adds a high accuracy direction of arrival (DOA) measurement to a specific digital superhet receiver for - detection of LPI radar, operation in dense EW environments and enables advanced ELINT tasking through 'fine-grain' analysis of received signals. This system is designed for major warships, special auxiliaries and is also offered as a system for land-based electronic warfare centers. It provides accurate tactical situational awareness, self-protection and enables passive targeting. It delivers increased sensitivity with panoramic measurement, which enables more accurate identification and fingerprinting. The receivers are commercial off-the-shelf (COTS)-based. The Vigile 400 also offers a

frequency extension covering 0.5-2 GHz and the processing of CW and GSM radar signals [103].

Table 72: Technical Parameters (typical configuration) for Vigile 400 [103]

Frequency Coverage:	2-20 GHz (0.5 -2 extension)
Detection Modes:	FM/CW LPI radar
Direction Finding:	360° instantaneous
Bearing (DF) Accuracy:	1° RMS amplitude
Sensitivity:	-60 dBmi automatic wideband processing sensitivity over the entire freq. band
Signal Processing:	Fine Grain Analysis of intra-pulse and inter-pulse characteristics
Pulse Density:	1 million pps (pulse-to-Pulse parameter measurement)
Reaction time:	<1 second
Threat Emitter Library:	12,000 emitter modes

H. GROUND MOBILE INTERCEPT RECEIVERS

76. Chinese DZ9001 and ZJ93011 ELINT Systems

Figure 77: DZ901 ELINT Station (from [104])

The China National Electronics Import and Export Corporation builds the DZ9001 ground-mobile ELINT system that operates over 1 to 18 GHz and is a ground mobile ELINT system with a sensitivity of better than -70 dBm and a dynamic range of greater than 50 dD [105].

Table 73: Technical Parameters of DZ9001 ELINT System [105]

Frequency Range:	1-18 GHz
Dynamic Range:	>50 dB
Sensitivity:	-70 dBm
Bearing (DF) Accuracy:	>3° RMS
Frequency Accuracy:	2 MHz

They also build the ZJ9301-1 Radar Electronic Support Measures system which is a man portable battlefield ESM system. The ZJ93011 is available in variants covering the bands 18GHz and 818GHz. Its receiver sensitivity is 60dBm, and the signal processing facilities can handle three to five threat radars simultaneously. Accuracies are better than 4° RMS and 15MHz RMS [105].

Figure 78: Man-Portable ZJ9301-1 (from [104])

77. **CS-3360 ESM System**

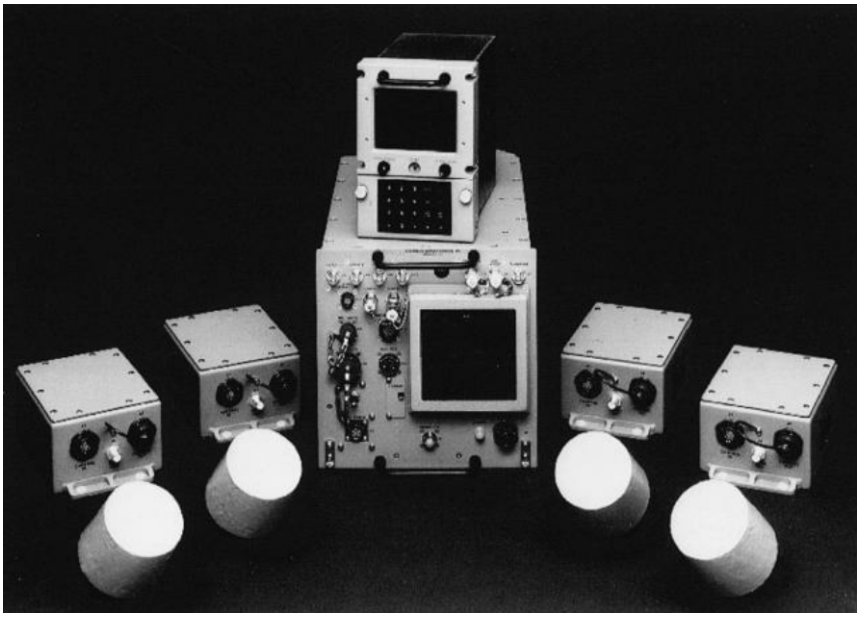

Figure 79: Condor CS-3360 ESM System (from [106])

The CS-3360 is a complete ESM system with antennas, receivers, pulse processor and multifunctional display. It combines the functions of radar warning, tactical surveillance and ELINT collection. It is designed for installation on aircraft, ships and land vehicles, where space is limited but high performance is required. Emitters are detected, identified and displayed with direction of arrival. The SP-2300 processor can process normal, stagger, jitter, multipulse, CW and complex radar signals [106].

Other systems in the series include: CS-3300 rapid deployment systems designed for applications requiring maximum capability, minimum weight and volume, and rapid set-up time. This includes the CS-3350 and CS-3360 systems. The latter is a lightweight, multiplatform equipment. Both systems operate over the 0.5 to 18 GHz band; CS-3500 tactical signal detection and classification systems; CS-3700 wideband ELINT intercept systems, latest version listed as CS-3701; CS-3900 remotely controlled ELINT receiver systems which can be used in remote fixed sites or unmanned aerial vehicles. They operate automatically or manually allowing remote control of frequency and pulse processing modes [106].

Table 74: Technical Parameters for CS-3360 [106]

Frequency Coverage:	0.5 to 18 GHz
Azimuth Coverage:	instantaneous
Types of signals processed:	Normal, stagger, jitter, multi-pulse, CW and complex
Emitter library storage:	>2,000 emitter modes

78. **Chinese ERR-107A Portable Radar Reconnaissance Receiver**

The ERR-107A portable radar reconnaissance receiver covers the 8 to 18 GHz frequency range and is described as being suitable for both frontline and border surveillance applications. The equipment is further noted as being primarily targeted against battlefield surveillance, “forward position”, airborne and armored fighting vehicle radars. Other system features are understood to include the ability to receive and process continuous wave signals, the ability to process high pulse repetition frequency signals and the use of miniaturized microwave components and large-scale integrated circuitry. As of 2006, the ERR-107A was still a live program [107].

Table 75: Technical Parameters for the ERR-107A [107]

Frequency Coverage:	8-18 GHz
Instantaneous space coverage:	45° (typical)
Sensitivity :	-42 dBm (pulse); -54 dBm (CW)
Dynamic Range:	50 dB (instantaneous); 80 dB (manual)
DF Accuracy:	3° RMS (fixed on tripod)
PRF:	200 Hz~200 Khz
Puslewidth:	0.1 ~ 200 μs

79. **ES-3000 ES/ELINT System**

Figure 80: ES-3000 ELINT/ESM System (from [108])

Manufactured by ITT (formerly EDO Reconnaissance and Surveillance Systems) the ES-3000 system, formerly designated CS-3000 system, is described as being a high-performance collection system designed to operate over the 0.5 to 18 GHz frequency range with an option to extend the frequency range up to 40 GHz. The system is designed to take advantage of the latest computer, receiver and signal processing technology to detect, analyze, and locate radar signals. It is believed that at least 12 ES-3000 systems, including six shelter-mounted ones for Egypt, are in operational service [108].
Other specific technical parameters are classified.

Table 76: Technical Parameters for the ES-3000 System [108]

Frequency coverage:	0.5 to 18 GHz (optional up to 40 GHJz)
Instantaneous bandwidth:	Up to 500 MHz

80. **INCE/Meerkat-S ES/ELINT System**

Figure 81: INCE/Meerkat-S Sensor Station Configuration (from [109])

The INCE/Meerkat-S is a three sensor station which was designed to meet the British Army's Interim Non-Communications Electronic support (INCE) requirement. At the time of supply, INCE was intended as an interim measure to bridge the gap between the existing Beady Eye and Pinemarten ES systems and the 'Soothsayer' electronic warfare architecture which was due to enter service in 2008, but was delayed and then

subsequently cancelled in 2009. The system incorporates a mast-mounted Antenna-Receiver Assembly (ARA), a Receiver Digitizer Unit (RDU), a Pulse Train Analyzer Unit (PTAU), main and auxiliary mode libraries and a single person operator's console. Of these, the ARA is noted as containing a rotating dish antenna/log video receiver subsystem for intercept and direction-finding and an omnidirectional antenna/receiver package for sidelobe suppression. A dedicated ELINT receiver for intrapulse and fine grain analysis is available. There is a claimed 100% probability of intercept within two seconds. [109].

INCE entered UK service in 2004 and is still in use and continues to be marketed by Thales.

Table 77: Technical Parameters for the INCE Meerkat-S [109]

Frequency Range:	0.4-18 GHz (40 GHz option)
Bearing Accuracy:	1.5° RMS (>2 GHz , average)
Sensitivity:	-86 dBmi at 9 GHz (76 dBW/m^2)
Dynamic Range:	60 dB
Azimuth coverage:	360°
Elevation coverage:	30° (typical)
Mode tracks:	Up to 500 emitters
Pulse density:	Up to 1 Mpps
Emitter Library:	Up to 1,000 modes (auxiliary); Up to 10,000 modes (main)

81. **Meerkat-SA ESM/ELINT System**

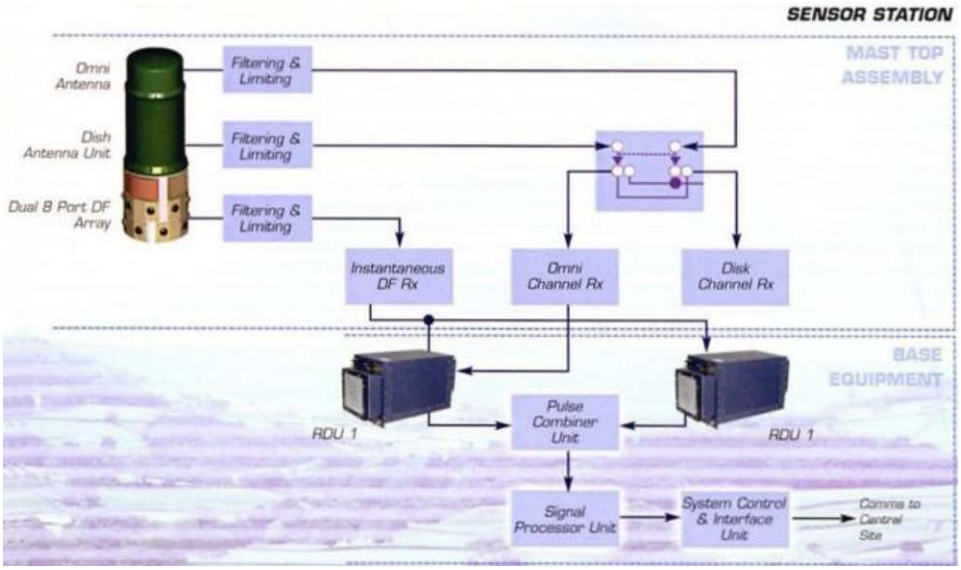

Figure 82: Meerkat-SA Components (from[110])

The Meerkat-SA ESM/ELINT system is a remote passive radio reconnaissance system. Meerkat-SA manufacturer Thales describes it as being a 'high-performance, very high-reliability ESM-ELINT system' that is designed to detect, identify and locate hostile and 'other' types of radar emission and can function as an unattended sensor architecture within passive air defense and strategic intercept applications. It consists of a number of remote, fixed-site, sensor stations that feed into a central Control Site (CS). Multiple operators control the architecture's remote sensor stations and control processors that identify intercepts, fuse data and create and maintain a 'dynamic' Electronic Order of Battle (EOB). The system is scalable, with each CS being capable of operating with up to 12 sensor stations. Communication between the architecture's various elements is by means of trunk radio or cable connection into a wide area network [110].

Table 78: Technical Parameters for the Meerkat-SA [110]

Frequency Coverage:	2-40 GHz (0.4 GHz option)
Bearing Accuracy:	1.5° RMS (>2 GHz average)
Sensitivity:	-85 dBmi @ 9 GHZ (76 dBW/m^2)
Dynamic Range:	60 dB
Azimuth coverage:	360°

Elevation coverage:	$Cosec^2$
Mode tracks:	Up to 500 emitters
Pulse Density:	Up to 1 Mpps
Emitter mode Library:	At least: 1,000 emitter modes (auxiliary); 1,000 platform types; 10,000 emitter modes (main)

82. **MUR-20 ELINT System**

Figure 83: MUR-20 (from [111])

The MUR-20 system is described as an 'advanced', land-based, radar-band, mobile, ES/ELINT detection and identification sensor operating in the 0.5 to 18 GHz frequency range, designed to provide 'fast and accurate' data collection in a 'dense' signal environment. MUR-20 is believed to be currently in service with the Polish Army and is known as ELINT BREN [111].

Table 79: Technical Parameters for MUR-20 [111]

	SEARCH Receiver	**Analysis System**
Operating Frequency	0.5 – 18 GHz	0.5 – 18 GHz (40 GHz option)
Sensitivity:	-45 to -55 dBm	-57 to – 90 dBm (depending on

		measuring channel)
Azimuth coverage:	360°	360°
Elevation coverage:	-15° to +30°	-2° to +7°
Frequency measurement resolution	<250 MHz	1 MHz (acousto-optic) 200 kHz (compression)
Time measurement resolution:	0.05 {ohm}s	0,05 μs
Bearing accuracy:	10° RMS	0.5° RMS at f <=10 GHz; 1 RMS at f >=10 GHz

83. **PRD-13(V)3 Tactical SIGINT System**

Figure 84: PRD-13(V)3 Tactical SIGINT System (from [112])

L-3 Linkabit's PRD-13(V)3 man packable Signals Intelligence (SIGINT) capability incorporates sophisticated RF intercept and Direction-Finding processing capabilities in an intuitive and functional package. The PRD-13(V)3 system provides a low-power, lightweight, ruggedized, versatile and scalable capability to support expeditionary decisive actions. It is capable of demodulating continuous wave signals as well other signals while doing a manual, directed search or wideband scan, as noted in the table below [112].

Table 80: Technical Parameters for the PRD-13(V)3 [112]

Frequency Coverage:	2 to 3000 MHz for intercept
Bearing (DF) accuracy:	3° RMS typical; 15 °for on-the-march
DF resolution:	1°
Demodulators:	NBFB, WBFM, AM, CW, LSB, USB, 2ISB
Modes:	Manual, directed search and wideband scan

84. **UltraEagle ULR-501 ESM/ELINT System**

Figure 85: UltraEAGLE URL-501 (from [113])

The UltraEAGLE ULR-501 system is Canada's Ultra Electronics TCS' advanced ELINT and ESM system for ground mobile operations. The ULR-501 frequency coverage is from 0.5 to 18 GHz (optional 40 GHz) utilizing a high Probability of Intercept (POI) Situational Awareness (SA) ESM receiver channel as well as an independent high sensitivity ELINT receiver channel [113].

Both channels of the ULR-501 provide de-interleaving, pulse characteristics in the form of Pulse Descriptor Words (PDWs), and PDW recording. The ELINT channel also provides (emitter) Direction Finding (DF) and digitized samples of the collected pulses [113].

Table 81: Technical Parameters of the ULR-501 [113]

Frequency Coverage:	0.5 – 18 GHz
Frequency measurements:	250 kHz (rms) for ELINT; 3 MHz (rms) for ESM
PRI Accuracy:	10 ns (rms) – ELINT; 50 ns (rms) - ESM
PW Accuracy:	10 ns (rms) – ELINT; 50 ns (rms) - ESM
Sensitivity:	-85 dBm – ELINT; -55 dBm ESM
Dynamic Range:	85 dB - ELINT (total Switched); 70 dB – ESM (total Switched)
Bearing Accuracy (ELINT):	2° (2-18 GHz) ; 6 ° (<2 GHz)

85. **UltraEagle URL-543 Man Portable**

Figure 86: UltraEagle URL-543 Man-Portable (from [114])

The ULR-543 system features a narrowband high sensitivity superhet based receiver, an advanced Receiver Pulse Processor (RPP) and a laptop running TCS' TALON server software. The ULR-543 system is specifically designed for man portable operations. It is also suited for installation in a variety of vehicles, shelters or buildings and for use with customer-supplied antenna systems [114].

Table 82: Technical Parameters for the URL-543 [114]

Frequency Coverage:	0.5 – 18 GHz (40 GHz option)
Frequency measurement:	<250 kHZ (rms)
Sensitivity:	-65 dBm (500 MHz IBW, TSS)
PW Accuracy:	50 ns to 13 ms (range); <10 ns (resolution)
CW Flag programmable range:	100us to 13 ms
PRI/PRF accuracy:	500 ns to 100 ms (range); <6 ns

Collected PDW Parameters:	
RF Carrier Modulation Types Automatic:	CW, Stable Pulsed
RF Carrier Modulation Types:	CW, Stable Pulsed, Frequency, Agile, Hopping, FMOP, PMOP, AMOP, Period Switching, Complex
Inter-pulse:	PRI Modulation (Tyte and values); Scan Modulation (circular, Sector, Sine
Intra-pulse:	Modulation on Pulse (FMOP, PMOP and AMOP, Flags)
Emitter Library Storage:	10,000 emitters or better

86. **VEGA (Orion) 85V6-A ELINT System**

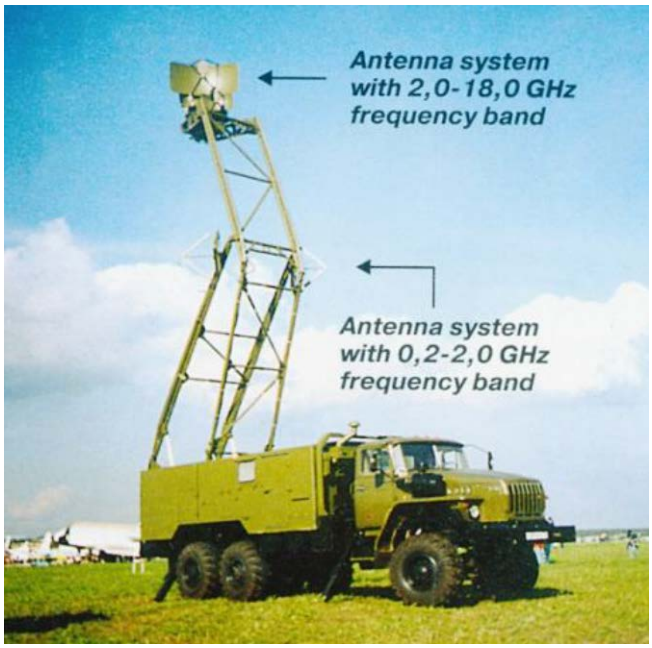

Figure 87: ORION 85V6-A ELINT Station (from [115])

The VEGA 85V6-A ELINT system is designed to operate within electronic warfare, air defense and other army units. The system can be used within early warning and air traffic control systems and to identify and locate jamming sources as well as an ESM asset. The system is capable of simultaneously detecting, identifying and tracking up to 100 ground, naval surface and air targets with a reported over horizon target detection range of at least 400 km. A typical 85V6-A system would consist of three ORION 85V6 detection, location and identification stations and a 85V6-A Control Post (CP). Typically, the ORION stations are located up to 30 km from each other with the control post being near one of them. DF and signal parameter data from the ORION stations are transmitted through the data link channels to the CP, where target positions and tracks are determined

and displayed on an electronic map of the area of interest. The system is noted as being able to handle 'burst-type' and 'complex frequency and time structure' radars and jammers. It is being used in the Russian Army and may also have been supplied to Algeria.[115].

Table 83: ORION 85V6 ELINT Station [115]

Frequency Coverage:	.02 – 18 GHz (40 GHz option)
Snap detection band:	500 MHz
Frequency resolution measurement:	1 MHz
Pulse duration Accuracy:	0.1 μs
Pulse repetition period measuring accuracy:	1.0 μs
Azimuth measuring accuracy:	0.2-2.0 GHz 1-2°; 2-18 GHz 0.2°
Maximum scanning speed:	180°/s
Data update rate:	10 s
Location error:	not more than 5° RMS (150 km range, with individual stations 30 km apart)
Azimuth coverage:	360°
Elevation coverage:	0-20°
Track capacity:	up to 60 (simultaneous and reported to a higher level authority)
Detection range:	at least 400 km (above the horizon)
Deployment time:	40 min ('on-the-run')

87. **Turkish Land-Based Transportable ESM/ELINT System**

Limited information is available on the ASELSAN Land-Based Transportable Radar ESM/ELINT System designed to search, intercept, analyze, classify and DF conventional and complex radar signals in a dense electronic environment. The system reportedly has a “wide” operating frequency range and a ‘high’ probability of intercept. Its various types of receivers provide “wide instantaneous bandwidth, high parameter accuracy, and high sensitivity” [116]. The contractor, ASELSAN A.S. from Ankara, Turkey, is the same contractor for the ALPER LPI Radar noted in section one of this report.

I. SUMMARY OF RECEIVER SENSITIVITIES

Table 84 summarizes the key parameters of the intercept receivers in the order in which they were discussed in this section.

Table 84: Summary of Deployed Intercept Receiver Sensitivities

System Name	Developer/ Country	Sensitivity (dBm)	Frequency Coverage (GHz)	Bearing Accuracy (RMS)	Use
DM/A-104	DTS/Chile	-50	2-18; 0,7-1.3	>10°	Airborne
AN/ALR-95(V)	ITT/U.S.				Airborne
ALR-2002	BAE/Australia		2-18 (with option to mm wave)		Airborne
AN/ALR-66 Series	NG/ U.S.		0.5-20		Airborne
AN/ALR-67(V)3	Raytheon/U.S.		2-40		Airborne
AN/APR-39D(V)2	NG/U.S		0.5-40		Airborne
BOW-21	Saab/Sweden		0.5-40	1° (IF) 7°(baseline)	Airborne
BM/KZ-8608	SW China Institute	-100 dBW	1-18	5° (1-8 GHz); 3° (8-18 GHz)	Airborne Surface
KM/KJ-8602	SW China Institute		.7-18	15°	Airborne
EL/L-8382	Elta Systems/Israel	-70 to -85	0.5-18	Better than 2°	Airborne

ELINT-FD	Indra/Spain	-90	0.5-18 (option to 40)		Airborne
AN/ALR-56A/C	BAE/U.S.	-50	2-18/20		Airborne
ELT/750	Elettronica/Spain		0.5-18/20 (with mmW option)		Airborne
ES-5080	ITT/ U.S.	-70dBmi (omni antenna) -120dBmi (CW)	0.5 - 18	1° (min) 5° (max)	Airborne Surface Ground
Itata	DTS/Chile	-83	0.03 - 18		Airborne
Phalanger	Thales/France		2-18 (0.5-40 option)	1°	Airborne
Kestrel	Thales/UK		0.5-18/20 (20-40 option)	±3.5° RMS	Airborne
LR-100	NG/U.S.	-71	2-18 (0.07 or 18-40 options)		Airborne Surface Ground
SAGE	Selex/UK	-60 to -80	0.5-40	1°	Airborne
Sea Petrel RQH-5(V)	Elettronica/Spain	-60	0.6-18 (to 40 option)	±2.5° RMS	Airborne Surface Ground
SEER	Selex/UK	-55dBmi	2-18	<10°	Airborne

			(extendable to 0.5– 2 and 20-40 subbands)		
Sky Guardian 2000	Selex/UK		0.5-18 (20-40 option)	<10°	Airborne
Top-Scan	Rafael ADS/Israel	-70	0.5-18 (to 40 option)	2°	Airborne
UltraEagle ALR-510	TCS/Canada	-65dBmi	2-18 (option 0.5-40 unconfirmed)	<1°	Airborne
Sealion	Thales/UK	-65	2-18	2.25°	Submarine Surface
UME-100	Saab/Sweden	-63	2-18	5°	Submarine Surface
UME-200	Saab/Sweden	-83	2-18	2°	Submarine Surface
ES3601	ITT/U.S.	-65	2-18	3-5°	Submarine Surface Ground
DR 2000S/2000U	Thales/France	-68	0.5 to 20	~3°	Submarine Surface
DR 4000U	Thales/France	-68	0.5-20	5°	Submarine

			(with option)		
AN/BLQ-10 (TI-08 LPI Upgrade)	LHM/U.S.	Classified	Classified	Classified	Submarine
DMA-302S/ DMI-603/ DMI604	DTS/Chile		2-18 (0.1 to 18 for DMI 603/4)	Better than 5° (DMA-302S)	Submarine Surface
ES-3701	ITT/U.S.	-65	2-18 (0.5-2 and 18-40 options)	2°	Submarine Surface
MRBR-800/ BAS-B4	Indra/Spain	-71 (pulsed)/ -85 (CW)	2-18 (0.5-2 and 18-40 options)	3° (spiral) 5° (omni)	Submarine
NS-9003A/ NS09005A	Elisra/Israel	-65 to -75	1-18 (0.5-40 option)	2°	Surface
SLQ750	Elettronica/Italy	'sufficient to facilitate sidelobe jamming'	0.5-20	'Sufficient for co-operative fixing'	Surface
Timnex II	Elbit/Israel	-67	2-18 (0.5-40 option)	Better than 3°	Surface
Vigile 400	Thales/France	-60 dbmi	2-20 (0.5-2 option)	1°	Surface
ZJ9301 DZ9001	China Nat. Elec.	-60 -70	1-18 1-18	3° 4°	Ground - mobile
CS-3900	Condor//U.S.		0.5-18		Ground
ERR-107A	Nanjing	-45 (pulse)	8-18	3°	Ground -

	Corad/China	-54 (manual)			portable
ES-3000	ITT/U.S.		0.5-18 (to 40 option)		Ground-mobile
Meerkat-S	Thales/UK	-86dBmi (at 9 GHz)	0.4-18 (to 40 option)	1.5°	Ground-mobile
Meerkat-SA	Thales/UK	-85dBmi	2-40 (0.4 option)	1.5°	Ground-mobile
MUR-20	Bumar/Poland	-45 to -55 (search) -57 to -90 (analysis)	0.5-18 (to 40 option)	10°	Ground-mobile
PRD-13(V)3	L3/U.S.		2-3000 MHz	3°	Ground-portable
UltraEagle URL-501	TCS/Canada	-85 (EIINT) -55 (ESM)	0.5-18	2°	Ground-mobile
ORION 85V6	Spetz-Radio/Russia		0.2-18 (to 40 option)	5°	Ground-mobile
ASELSAN	Aselsan/Turkey	“high”	“wide”		Ground-mobile

THIS PAGE INTENTIONALLY LEFT BLANK

IV. LIST OF REFERENCES

SECTION ONE: LPI RADARS

[1] P.E. Pace. *Detecting and Classifying Low Probability of Intercept Radar*. Norwood, MA: Artech House, 2009.

MARITIME RADARS

[2] ALPER English Marketing Brochure [Online]. Available: http://www.aselsan.com.tr/en-us/capabilities/radar-systems/reconnaissance-surveillance-radars/alper-naval-lpi-radar [Accessed August 25, 2014]

[3] Elektronika Polish Defense Holding. (2008). *CRM-203 Maritime Surface Surveillance FMCW Radar* [Online]. Available: http://www.bumar.com/elektronika/wp-content/uploads/2012/03/CRM-203-Maritime-Surface-Surveillance-FMCW-Radar.pdf [Accessed July 2, 2014].

[4] Plata S., Wawruch R. (2009). CRM-203 Type Frequency Modulated Continuous Wave (FMCW) Radar. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*. [Online]. *3* (*3*), pp. 311-314. Available: http://www.transnav.eu/Article_CRM203_Type_Frequency_Modulated_Plata,11,171.html [Accessed July 2, 2014].

[5] IHS Jane's C4ISR & Mission Systems: Maritime. (2014, May 5). *CRM-203*. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1505139&Pubabbrev=JC4IM [Accessed June 26, 2014].

[6] International Research Centre for Telecommunications and Radar-Indonesia. (2009). *Indera CX-3AH Coastal LPI Radar*. [Online]. Available: http://irctr-i.com/INDERA_CX-3_brochure.pdf [Accessed June 25, 2014].

[7] International Research Centre for Telecommunications and Radar-Indonesia. (2009*). Indera MS-2AM Low-Power S-Band Naval Radar*. [Online]. Available: http://irctr-i.com/INDERA_MS-2_brochure.pdf[Accessed June 25, 2014].

[8] International Research Centre for Telecommunications and Radar-Indonesia. (2009). *Indera MS-2AH X-Band Naval LPI Radar*. [Online]. Available: http://irctr-i.com/INDERA_MX-2_brochure.pdf[Accessed June 25, 2014].

[9] GEM Elettronica. (2008). *LPI-2000 Low Probability of Intercept Naval Radar*. [Online]. Available: http://www.gemrad.com/download/LPI.pdf [Accessed June 27, 2014].

[10] Detection Monitoring Technologies. (2012). *Dorado Marine and Security Radar*. [Online]. Available: http://dmtradar.com/products/radar/dorado/ [Accessed June 26, 2014].

[11] Thales Netherland B.V. (2013). *Scout Mk3 Unrivalled Small Target Detection*. [Online]. Available: https://www.thalesgroup.com/sites/default/files/asset/document/0002_a4_datasheet_scout_mk3_09-2013.pdf [Accessed June 25, 2014].

[12] IHS Jane's C4ISR & Mission Systems: Maritime. (2014, Jul. 1) *Scout.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1505078&Pubabbrev=JC4IM [Accessed July 3, 2014].

[13] Thales Netherland B.V. (2012). *Variant Lightweight Short-to-Medium Range 2D Surveillance Radar*. [Online]. Available:https//www.thalesgroup.com/en/canada/defence/variant-lightweight-2d-short-medium-range-surveillance-radar\ [Accessed June 30, 2014].

[14] Simrad Yachting. (2013). *Broadband 4G Radar*. [Online]. Available: http://www.simrad-yachting.com/en-US/Products/Radar/Broadband-4G-Radar-en-us.aspx [Accessed June 24, 2014].

[15] SAAB Technology. (2014). *Sea Giraffe AMB Multi-role Naval Surveillance Radar*. [Online]. Available: http://www.saabgroup.com/Global/Documents%20and%20Images/Land /Force%20Protection/sea%20giraffe/SeaGiraffe%20AMB%20product%20folder%202014-05.pdf [Accessed July 1, 2014].

[16] IHS Jane's C4ISR & Mission Systems: Maritime (2014, Jun. 20). *Sea GIRAFFE AMB (AN/SPS-77)/ Sea GIRAFFE LT/ Sea GIRAFFE 4A Radars.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1512850&Pubabbrev=JC4IM [Accessed July 1, 2014].

[17] Bumar Elektronika Polish Defense Holding (2013). *RM-100 Mobile Radar*. [Online]. Available: http://www.bumar.com/elektronika/wp-content/uploads/2012/03/RM-100-Mobile-Radar.pdf [Accessed June 24, 2014].

[18] Kelvin Hughes Marine Systems. (2014). *SharpEye Solid-State Radar Systems*. [Online]. Available: http://www.kelvinhughes.com/marine/products/sharpeye [Accessed July 8, 2014].

[19] Kelvin Hughes Marine Systems (2014). *Multifunction by Design MantaDigital Radar*. [Online]. Available: http://www.kelvinhughes.com/upload/pdf/brochures/radars.pdf [Accessed July 8, 2014].

[20] Aegean Electronics. (2014). *KH SharpEye*. [Online]. Available: http://www.aegean-electronics.gr/en/site/products/shipping_products/navigation/radar/kh_sharpeye.html [Accessed July 8, 2014].

[21] Kelvin Hughes Marine Systems. (2014). *SharpEye Technology*. [Online]. Available: http://www.kelvinhughes.com/upload/pdf/brochures/sharpeye.pdf [Accessed July 8, 2014].

[22] IHS Jane's Radar and Electronic Warfare Systems (2014, May 7). *ARIES* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1380928&Pubabbrev=JREW

[23] Defense and Security Indra Company (2014). *Aires-Low Probability of Intercept (LPI) Radar* [Online]. Available: http://www.indracompany.com/sites/default/files/ARIES%E2%80%93LOW%20PROBABILITY%20OF%20INTERCEPT%20(LPI)%20RADAR_0.pdf [Accessed August 28, 2014]

[24] SAAB PILOT ENG PRINT BROCHURE (2014). *PILOT LPI RADAR* [Online]. Available : www.saabgroup.com/Global/.../PILOT/PILOT_Short_100422.pdf [Accessed August 21, 2014].

[25] IHS Jane's C4ISR & Mission Systems: Maritime (2014, July. 01) *SCOUT*. [Online] Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1380193&Pubabbrev=JREW [Accessed August 8, 2014].

[26] IHS Jane's Defence Weekly (2014, Feb 07) T*hales wins SCOUT Mk 3 radar contract for new Dutch JSS* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=News&ItemId=+++1701882&Pubabbrev=JDW [Accessed August 28, 2014].

[27] IHS Jane's Radar and Electronic Warfare Systems: Naval/Coastal Surveillance and Navigation Radars (2014, July 01) *SMART-L Multibeam Rada*r [Online] Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1380194&Pubabbrev=JREW [Accessed August 28, 2014].

[28] Denk, Aytug, 2006. Detection and Jamming Low Probability of Intercept (LPI) Radars. M.S. Thesis in Systems Engineering. Naval Postgraduate School.[Online] Available: http://hdl.handle.net/10945/2541 (Accessed August 28, 2014).

[29] Thales Netherland B.V. (2012). *Smart-L 3D Long Range Surveillance Radar*. [Online]. Available: https://www.thalesgroup.com/en/worldwide/defence/smart-l-3d-long-range-surveillance-radar [Accessed August 28, 2014].

GROUND SURVEILLANCE RADARS

[30] DRS Technologies. (2011). *Manportable Surveillance and Target Acquisition Radar*. [Online]. Available: http://www.drs.com/Products/C3A/PDF/MSTAR.pdf [Accessed June 25, 2014].

[31] DRS Technologies. (2013). *Squire Ground Surveillance Radar System*. [Online]. Available: http://www.drs.com/Products/c3a/PDF/SQUIRE.pdf[Accessed June 27, 2014].

[32] IHS Jane's C4ISR & Mission Systems: Land. (2013, Oct. 16). *SQUIRE Ground Surveillance Radar*. [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1504692&Pubabbrev=JC4IL [Accessed July 2, 2014].

[33] Pro Patria Electronics. (2013). *PGSR-3i Beagle Portable Ground Surveillance Radar*. [Online]. Available: http://www.propatria-inc.com/pdf/ppe_pgsr3i_datasheet_en.pdf [Accessed July 1, 2014].

[34] IHS Jane's C4ISR & Mission Systems: Land. (2014, Jul. 7). *PGSR-3i Beagle*. [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1716149&Pubabbrev=JC4I[Accessed July 1, 2014].

[35] Pro Patria Electronics. (2013). *PSR-2i Doberman Perimeter Security Radar*. [Online]. Available: http://www.propatria-inc.com/pdf/ppe_psr2i_datasheet_en.pdf [Accessed July 1, 2014].

[36] IHS Jane's C4ISR & Mission Systems: Land. (2014, Jul. 7). *PSR-2i Doberman*. [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1716156&Pubabbrev=JC4IL[Accessed July 1, 2014].

[37] Blighter Surveillance Systems. (2014). *Blighter Revolution 360*. [Online]. Available: http://www.blighter.com/images/pdfs/fact-sheets/blighter-revolution-360-radar-fact-sheet-bss-0205.pdf [Accessed July 3, 2014].

[39] Blighter Surveillance Systems. (2014). *Blighter B400 Series Radar*. [Online]. Available: http://www.blighter.com/images/pdfs/fact-sheets/blighter-b400-series-radar-fact-sheet-bss-0802.pdf [Accessed July 3, 2014].

[39] Blighter Surveillance Systems. (2014). *Blighter B303 Radar*. [Online]. Available: http://www.blighter.com/images/pdfs/fact-sheets/blighter-b303-radar-fact-sheet-bss-0702.pdf
[Accessed July 3, 2014].

[40] Blighter Surveillance Systems. (2014). *Blighter B202 Mk 2 Radar*. [Online]. Available: http://www.blighter.com/images/pdfs/fact-sheets/blighter-b303-radar-fact-sheet-bss-0702.pdf
[Accessed July 3, 2014].

[41] FLIR Systems, Inc. (2012). *Ranger R2 Mid-Range Perimeter Surveillance Radar*. [Online]. Available: http://gs.flir.com/uploads/file/products/brochures/ranger_r2_ltr.pdf
[Accessed July 7, 2014].

[42] FLIR Systems, Inc. (2012). *Ranger R3D Dual Mode, Perimeter Surveillance Radar*. [Online]. Available: http://gs.flir.com/uploads/file/products/brochures/ranger_r3d_ltr.pdf
[Accessed July 7, 2014].

[43] FLIR Systems, Inc. (2012). *Ranger R5D Dual Mode, Perimeter Surveillance Radar*. [Online]. Available: http://gs.flir.com/uploads/file/products/brochures/ranger_r5d_ltr.pdf
[Accessed July 7, 2014].

[44] IAI ELTA (2012). *Ground Surveillance Radar Family – ELM-2105*. [Online]. Available: http://www.iai.co.il/sip_storage/FILES/2/39832.pdf [Accessed July 9, 2014].

[45] IAI ELTA (2009). *Smart Miniature Detection Radar Family – EL/M-2127*. [Online]. Available: http://www.iai.co.il/sip_storage/FILES/0/36840.pdf [Accessed July 9, 2014].

LPI MOTION DETECTORS

[46] InnoSent Innovative Sensor Technology (2013). *IVS-148*. [Online]. Available: http://www.innosent.de/fileadmin/media/dokumente/datasheets/IVS-148.pdf [Accessed June 27, 2014].

[47] InnoSent Innovative Sensor Technology. (2013). *IVS-465*. [Online]. Available: http://www.innosent.de/fileadmin/media/dokumente/datasheets/IVS-465.pdf [Accessed June 27, 2014].

[48] InnoSent Innovative Sensor Technology. (2013). *IVS-179*. [Online]. Available: http://www.innosent.de/fileadmin/media/dokumente/datasheets/IVS-179.pdf [Accessed June 27, 2014].

[49] InnoSent Innovative Sensor Technology. (2013). *IVS-167*. [Online]. Available: http://www.innosent.de/fileadmin/media/dokumente/datasheets/IVS-167.pdf [Accessed June 27, 2014].

[50] InnoSent Innovative Sensor Technology. (2013). *IVS-948*. [Online]. Available: http://www.innosent.de/fileadmin/media/dokumente/datasheets/IVS-948.pdf [Accessed June 27, 2014].

[51] InnoSent Innovative Sensor Technology. (2014). *IVS-162*. [Online]. Available: http://www.innosent.de/fileadmin/media/dokumente/datasheets/greenline/140521_Datenblatt_IVS-162_V4.2.pdf [Accessed June 27, 2014].

EDUCATIONAL AND RESEARCH RADARS

[52] The SkyRadar Consortium. (2013). *SkyRadar To Go V2.2*. [Online]. Available: http://www.skyradar.com/downloads/SkyRadar%20ToGo.pdf[Accessed July 7, 2014].

[53] The SkyRadar Consortium. (2014). *SkyRadar Modular Radar Training System FMCW and SAR*. [Online]. Available: http://www.skyradar.com/downloads/SkyRadar%20Radar%20Training%20System%20FMCW%20FMCW%20SAR.pdf [Accessed July 9, 2014].

SECTION TWO: INTERCEPT RECEIVERS

AIRBORNE

[54] IHS Jane's Radar and Electronic Warfare Systems. (2007, October 05). *DM/A Radar Warning Receiver*.[Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1339470&Pubabbrev=JAV_ [Accessed August 26, 2014].

[55] IHS Jane's Radar and Electronic Warfare Systems. (2013, November 29). *AN/ALR-95(V)*. [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1381082&Pubabbrev=JREW [Accessed August 21, 2014].

[56] IHS Jane's Radar and Electronic Warfare Systems. (2013, November 29). *ALR-2002 ComBat Radar Warning Receiver*. [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1380564&Pubabbrev=JREW [Accessed August 21, 2014].

[57] IHS Jane's Radar and Electronic Warfare Systems. (2013, January 15). *AN/ALR-66 series Electronic Support (ES) and Radar Warning (RW) systems* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1380681&Pubabbrev=JREW [Accessed September 3, 2014].

[58] IHS Jane's Radar and Electronic Warfare Systems. (2005, October 21). *AN/ALR-66(V)4 high-sensitivity ESM system*. [Online]. Available:

https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1339695&Pubabbrev=JAV_ [Accessed September 3, 2014].

[59] IHS Jane's Radar and Electronic Warfare Systems. (2014, January 07). *AN/ALR-67(V)3*. [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1380683&Pubabbrev=JREW [Accessed September 3, 2014].

[60] Military Analysis Network (FAS) (January 09, 1999). *AN/ALR-67(V)3 Advanced Special Receiver*.[Online]. Available: http://fas.org/man/dod-101/sys/ac/equip/an-alr-67.htm [Accessed September 3, 2014].

[61] Northrop Grumman Corporation RF Combat & Information Brochure (2013). *APR-39D(V)2 Radar Warning Receiver/Electronic Warfare Management System*.[Online]. Available: http://www.northropgrumman.com/capabilities/anapr39rwr/pages/default.aspx [Accessed September 3, 2014].

[62] IHS Jane's C4ISR & Mission Systems: Air (2013, November 28). *Bow-21*. [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1496957&Pubabbrev=JC4IA [Accessed August 21, 2014].

[63] IHS Jane's Radar and Electronic Warfare Systems. (2013, November 29). *BOW series Radar Warning Receivers/Electronic Support systems* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1380865&Pubabbrev=JREW [Accessed August 21, 2014].

[64] IHS Jane's C4ISR & Mission Systems: Joint & Common Equipment (2007, July 31) *BM/KZ 8608 ELINT system*.[Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1540930&Pubabbrev=JC4IL [Accessed August 21, 2014].

[65] IHS Jane's C4ISR & Mission Systems: Air (2008, December 03). *BM/KJ 8602 airborne radar warning system.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1565442&Pubabbrev=JC4IA [Accessed September 3, 2014].

[66] IHS Jane's Radar and Electronic Warfare Systems. (2013, December 24). *EL/L-8382 series.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1381243&Pubabbrev=JREW [Accessed August 21, 2014].

[67] IHS Jane's C4ISR Systems (2013, November 20). *ELINT-FD.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1347671&Pubabbrev=JC4I [Accessed August 21, 2014].

[68] IHS Jane's Radar and Electronic Warfare Systems. (2013, November 30). *AN/ALR-56A/C.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1380679&Pubabbrev=JREW [Accessed September 4, 2014].

[69] IHS Jane's C4ISR & Mission Systems: Air (2010, March 10). *ELT750.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1347591&Pubabbrev=JC4I [Accessed August 21, 2014].

[70] IHS Jane's Radar and Electronic Warfare Systems. (2012, January 13). *ES-5080.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1381289&Pubabbrev=JREW [Accessed August 21, 2014].

[71] IHS Jane's C4ISR Systems (2012, November 20). *Itata airborne ELINT system.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1346684&Pubabbrev=JC4I [Accessed September 4, 2014].

[72] IHS Jane's Radar and Electronic Warfare Systems. (2001, November 06). *Phalanger Electronic Support (ES)/ELectronic INTelligence (ELINT) system.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1381932&Pubabbrev=JREW [Accessed September 4, 2014].

[73] IHS Jane's C4ISR Systems (2013, December 23). *Kestrel* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1346748&Pubabbrev=JC4 I [Accessed September 4, 2014].

]74] Northrop Grumman Corporation RF Combat & Information Brochure (2009). *LR-100 Receiver* [Online]. Available: http://www.northropgrumman.com/Capabilities/LR100/Documents/pageDocuments/lr100.pdf [Accessed September 4, 2014].

[75] IHS Jane's Electronic Mission Aircraft. (2011, January 11). *LR-100* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1309833&Pubabbrev=JEMA [Accessed September 4, 2014].

[76] IHS Jane's International Defense Review (2013, December 23). S-*100 lofts new ESM package on trial.* [Online]. Available:

https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=News&ItemId=+++1596647&Pubabbrev=IDR [Accessed September 4, 2014].

[77] Selex ES Electronic Warfare Brochure (2014) . *Sage Advanced Digital ESM.* [Online]. Available: http://www.selex-es.com/documents/737448/20466420/body_Copy+of+mm07738_SAGE_LQ_.pdf [Accessed August 11, 2014].

[78] IHS Jane's C4ISR & Mission Systems: Air (2013, December 13). *Sea Petrel RQH-5(V) airborne ESM/ELINT systems.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1496814&Pubabbrev=JC4IA [Accessed September 4, 2014].

[79] Selex ES Press Backgrounder (March 2014). *SEER – Advanced Digital RWR.* [Online]. Available: http://www.selex-es.com/documents/737448/10910582/body_EW_Backgrounder_SEER.pdf [Accessed September 4, 2014].

[80] IHS Jane's C4ISR & Mission Systems: Air (2013, December 13). *SEER* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1525657&Pubabbrev=JC4IA [Accessed September 4, 2014].

[81] HIS Jane's Avionics (2010, October 01) *Sky Guardian 2000 Radar Warning Receiver (RWR).* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1339647&Pubabbrev=JAV_ [Accessed September 6, 2014].

[82] IHS Jane's C4ISR & Mission Systems: Air (2013, December 23). *TOP-SCAN.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1497021&Pubabbrev=JC4IA [Accessed September 6, 2014].

[83] Ultra Electronics TCS Brochure (2010, October 13). *UltraEAGLE ALR-510 Airborne Tactical ELINT System.* [Online]. Available: http://ultra-tcs.com/files/Ultra_TCS_UltraEAGLE_ALR-510.pdf [Accessed August 11, 2014].

[84] IHS Jane's C4ISR & Mission Systems: Air (2013, November 13). *UltraEAGLE ALR-510* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1592986&Pubabbrev=JC4IA [Accessed August 11, 2014].

SUBMARINE/SURFACE

[85] Pengelley, R., "Reading the signals: RESM evolves for submarines," Jane's Navy International, June 2007.

[86] IHS Jane's Underwater Warfare Systems. (2014, Feb. 2). *Sealion.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1391889&Pubabbrev=JUWS [Accessed July 15, 2014].

[87] SAAB Group. (2010). *Submarine Tactical ESM and ELINT Systems.* [Online]. Available: http://www.saabgroup.com/Global/Documents%20and%20Images/Naval/Electronic%20Warfare/UME100/UME100%20-%20UME200%20product%20sheet.pdf[Accessed July 15, 2014].

[88] IHS Jane's Radar and Electronic Warfare Systems (2011, November 08). *UME Series* [Online}. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1381253&Pubabbrev=JREW [Accessed September 11, 2014]

[89] EXELIS Brochure (2013) *ES-3601Tactical Radar ESM and Surveillance System.* [Online}. Available: http://www.exelisinc.com/solutions/ES-3601-3701/Pages/default.aspx [Accessed August 20, 2014].

[90] IHS Jane's Underwater Warfare Systems. (2014, June 16). *ES-3601.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1393228&Pubabbrev=JUWS [Accessed July 15, 2014].

[91] IHS Jane's Underwater Warfare Systems. (2014, May 02). *DR2000S/2000U ESM.* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1391879&Pubabbrev=JUWS [Accessed August 21, 2014].

[92] IHS Jane's Underwater Warfare Systems. (2014, June 13). *DR3000/ARBR21/ARUR 12/13 ESM* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1391881&Pubabbrev=JUWS [Accessed September 6, 2014].

[93] IHS Jane's Underwater Warfare Systems. (2014, June 13). *DR400U ESM* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1391880&Pubabbrev=JUWS [Accessed September 6, 2014].

[94] DOT&E Office of Secretary of Defense Public Reports Navy Programs (2013). *AN/BLQ-10 Submarine Electronic Warfare Support System.*[Online]. Available:

http://www.dote.osd.mil/pub/reports/FY2013/pdf/navy/2013anblq10.pdf [Accessed September 6, 2014].

[95] IHS Jane's Underwater Warfare Systems. (2014, June 03). *AN/BLQ-10(V)* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1392718&Pubabbrev=JUWS [Accessed September 7, 2014].

[96] IHS Jane's Radar and Electronic Warfare Systems (2013, November 01). *DTS naval electronic intelligence (ELINT) and electronic support (ES) systems* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1381513&Pubabbrev=JREW [Accessed September 7, 2014].

[97] IHS Jane's Underwater Warfare Systems. (2014, June 17). *ES-3701*[Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1392612&Pubabbrev=JUWS [Accessed August 21, 2014].

[98] IHS Jane's Radar and Electronic Warfare Systems (2014, April 17). *MRBR-800/MRSR-800* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1381386&Pubabbrev=JREW [Accessed August 21, 2014].

[99] IHS Jane's C4ISR & Mission Systems: Maritime (2014, March 04). *SEAL* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1526272&Pubabbrev=JC4IM [Accessed August 21, 2014].

[100] IHS Jane's Radar and Electronic Warfare Systems (2014, May 04). *NS-9003A-V2/NS-9005A-V2 electronic warfare (EW) suite* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1380519&Pubabbrev=JREW [Accessed September 8, 2014].

[101] IHS Jane's Radar and Electronic Warfare Systems (2014, February 25). *NELTIS/SLQ-750* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1381276&Pubabbrev=JREW [Accessed August 21, 2014].

[102] IHS Jane's C4ISR Systems (2011, January 20). *Timnex II ELINT/ESM system* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1347072&Pubabbrev=JC4I [Accessed August 21, 2014].

[103] IHS Jane's Radar and Electronic Warfare Systems (2014, April 09). *Vigile electronic support (ES) systems* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1381113&Pubabbrev=JREW [Accessed August 21, 2014].

GROUND

[104] IHS Jane's International Defense Review (1997, June 01). *CHINA MARKETS ELECTRONIC WARFARE EQUIPMENT [*Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=News&ItemId=+++1616427&Pubabbrev=IDR [Accessed August 21, 2014].

[105] IHS Jane's C4ISR & Mission Systems: Land (2005, June 22). *DZ9001 ELectronic INTelligence (ELINT) system* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1532863&Pubabbrev=JC4IL [Accessed August 21, 2014].

[106] HIS Jane's Avionics (2005, October 21). *CS-3360 lightweight ESM system* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1339682&Pubabbrev=JAV_ [Accessed August 21, 2014].

[107] IHS Jane's C4ISR & Mission Systems: Land (2007, March 26). *ERR-107A* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1532475&Pubabbrev=JC4IL [Accessed September 8, 2014].

[108] IHS Jane's Underwater Warfare Systems (2010, December 06). *ES-3000* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1393229&Pubabbrev=JUWS [Accessed August 21, 2014].

[109] IHS Jane's C4ISR & Mission Systems: Land (2014, February 02). *Meerkat-S (Interim Non-Communications Electronic support (INCE))* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1497742&Pubabbrev=JC4IL [Accessed August 21, 2014].

[110] IHS Jane's C4ISR Systems (2013, February 19). *Meerkat-SA* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1347473&Pubabbrev=JC4I [Accessed August 21, 2014].

[111] IHS Jane's C4ISR & Mission Systems: Land (2014, February 17). *MUR-20 ELINT system* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1497761&Pubabbrev=JC4IL [Accessed August 21, 2014].

[112] L3 Linkabit Brochure (2014, February 14). *PRD- 1 3 (V) 3 TACTICAL SIGINT SYSTEM* [Online]. Available: http://www2.l-3com.com/linkabit/pdf/Data_Sheets/PRD-13(V)3%20System-Final%202-14-2014.pdf [Accessed August 25, 2014].

[113] Ultra Electronics TCS Brochure (2014, March 15). *UltraEAGLE ULR-510 Ground Mobile Tactical ESM/ELINT System.* [Online]. Available: http://ultra-tcs.com/files/datasheets/Ultra_TCS_UltraEAGLE_ULR-501.pdf [Accessed August 11, 2014].

[114] Ultra Electronics TCS Brochure (2014, March 15). *UltraEAGLE ULR-543 Man Portable ELINT System.* [Online]. Available: http://ultra-tcs.com/files/Ultra_TCS_UltraEAGLE_ULR-543.pdf [Accessed August 12, 2014].

[115] IHS Jane's C4ISR & Mission Systems: Land (2014, February 17). *VEGA 85V6-A ELINT system* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1497744&Pubabbrev=JC4IL [Accessed August 21, 2014].

[116] IHS Jane's C4ISR & Mission Systems: Land (2014, July 03). *Land-Based Transportable Radar ESM/ELINT System* [Online]. Available: https://janes.ihs.com.libproxy.nps.edu/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1715897&Pubabbrev=JC4IL [Accessed August 21, 2014].

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Research Sponsored Programs Office, Code 41
   Naval Postgraduate School
   Monterey, CA 93943

4. LCDR James B. Vernon
   Deputy Program Manager
   HQ USSOCOM/J24-S
   7701 Tampa Point Blvd
   MacDill AFB, FL 33621-5323l

5. Phillip E. Pace, Ph.D
   Center for Joint Services Electronic Warfare, SP-543B
   Electrical & Computer Engineering Department
   1 University Circle
   Naval Postgraduate School, 93943

6. John McEachen, Ph.D.
   Electrical & Computer Engineering Department
   1 University Circle
   Naval Postgraduate School, 93943