APPENDIX E

RADAR CALCULATIONS

Summary

Radar calculations were completed on several radars from various countries of origin including: EL/M-2207 (Israel), SPS-49 (US), FAST (US), Castor II (France), SMART (Netherlands), SPY-1D (US), and X-band Phased Array Radar (XPAR). The XPAR is a conceptual radar design utilized by the CPCX design team to achieve high performance radar characteristics combined with the advantage of low weight and reduced volume. XPAR has many of the features and capabilities of a SPY-1D radar, however the XPAR utilizes a X-band operating frequency instead of the SPY's S-band to achieve weight reduction in many system components including: array size, waveguide dimensions and computers.

The calculations utilized each radar's specific characteristics including power output, beamwidth, pulse width, and frequency to calculate the signal excess in terms of range. Each threat missile's radar cross section (RCS) was then used with the signal excess vs range plot to determine the maximum detection range. These calculations were performed for each radar against each missile flying either a beam centered or sea skimming attack trajectory. An example of these calculations for the SPY-1D radar is located in tables (E-1) and (E-2) respectively. A summary of all radars and their maximum detection range for each missile is located in table (E-3).

Table E-1: SPY-1D Radar Calculation, Beam Centerline Target

Constants								
h=	20		c=	3E+08		TS=	0	
d=	3.75		DT=	-1.53		t=	2.17E-03	
Pt=	5.00E+06		Pavg=	3230.77				
Parameters								
T=	1.40E-06		f=	3.30E+09		alpha=	8.00E-06	
BWh=	1.70		Lv=	2.71		Phi(cl)=	10	
Lh=	2.71		BWv=	1.70		AG=	38.54	
rpm(max)	130.77		rpm=	60			Pulses/look=	2.18
Noise Level								
NL(amb)	-148.00		NL(int)	-132.46		NL(tot)=	-132.34	
Source Level								
Slt=	94.52561							
Range	SLt	2*AR	2*TL	TS	SLr	DT	SLr*	
10	94.53	-1	-40.00	0	53.53	-1.53	55.06	
30	94.53	-1	-59.09	0	34.44	-1.53	35.97	
100	94.53	-1	-80.00	0	13.52	-1.53	15.05	
300	94.53	-1	-99.09	0	-5.56	-1.53	-4.03	
1000	94.53	-1	-120.02	0	-26.49	-1.53	-24.96	
3000	94.53	-1	-139.13	0	-45.61	-1.53	-44.08	
10000	94.53	-1	-160.16	0	-66.63	-1.53	-65.10	
22583.18	94.53	-1	-174.51	0	-80.99	-1.53	-79.46	
45166.36	94.53	-1	-180.92	0	-87.39	-1.53	-85.86	
100000	94.53	-1	-186.60	0	-93.07	-1.53	-91.54	
200000	94.53	-1	-201.24	0	-107.72	-1.53	-106.19	
300000	94.53	-1	-211.88	0	-118.36	-1.53	-116.83	
400000	94.53	-1	-220.48	0	-126.96	-1.53	-125.43	
Reverberation Level			rmax=	22583.18				
Range	SLt	2*TL	Area	Phi	RSs	EAR	2*AR	RLs
30	94.53	-59.09	45.98	-90.00	-15	-23.26	-35	8.16
100	94.53	-80.00	51.20	-17.46	-48	-23.26	-8	-13.53
300	94.53	-99.09	55.98	-5.74	-57	-23.26	-4	-32.85
1000	94.53	-120.02	61.20	-1.72	-64	-23.26	-2	-53.54
3000	94.53	-139.13	65.98	-0.57	-77	-23.26	-1	-79.89
10000	94.53	-160.16	71.20	-0.17	-92	-23.26	-1	-110.69
22583.18	94.53	-174.51	74.74	-0.08	-100	-23.26	-1	-129.50

Table E-1: SPY-1D Radar Calculation, Beam Centerline Target

Signal Excess

Range	RLs	NL(tot)	NL+RLs	SLr*	SE
10	28.00	-132.34	28.00	55.06	27.06
30	8.16	-132.34	8.16	35.97	27.81
100	-13.53	-132.34	-13.53	15.05	28.58
300	-32.85	-132.34	-32.85	-4.03	28.81
1000	-53.54	-132.34	-53.54	-24.96	28.58
3000	-79.89	-132.34	-79.89	-44.08	35.81
10000	-110.69	-132.34	-110.66	-65.10	45.55
22583.18	-129.50	-132.34	-127.68	-79.46	48.23
45166.36		-132.34	-132.34	-85.86	46.48
100000		-132.34	-132.34	-91.54	40.80
200000		-132.34	-132.34	-106.19	26.16
300000		-132.34	-132.34	-116.83	15.51
400000		-132.34	-132.34	-125.43	6.91

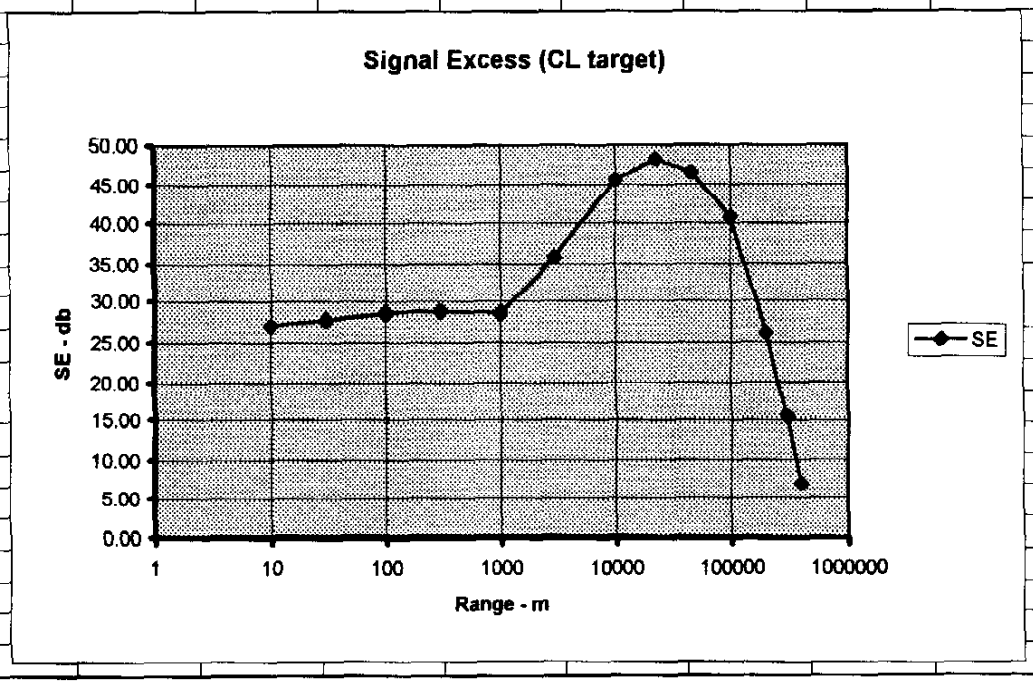


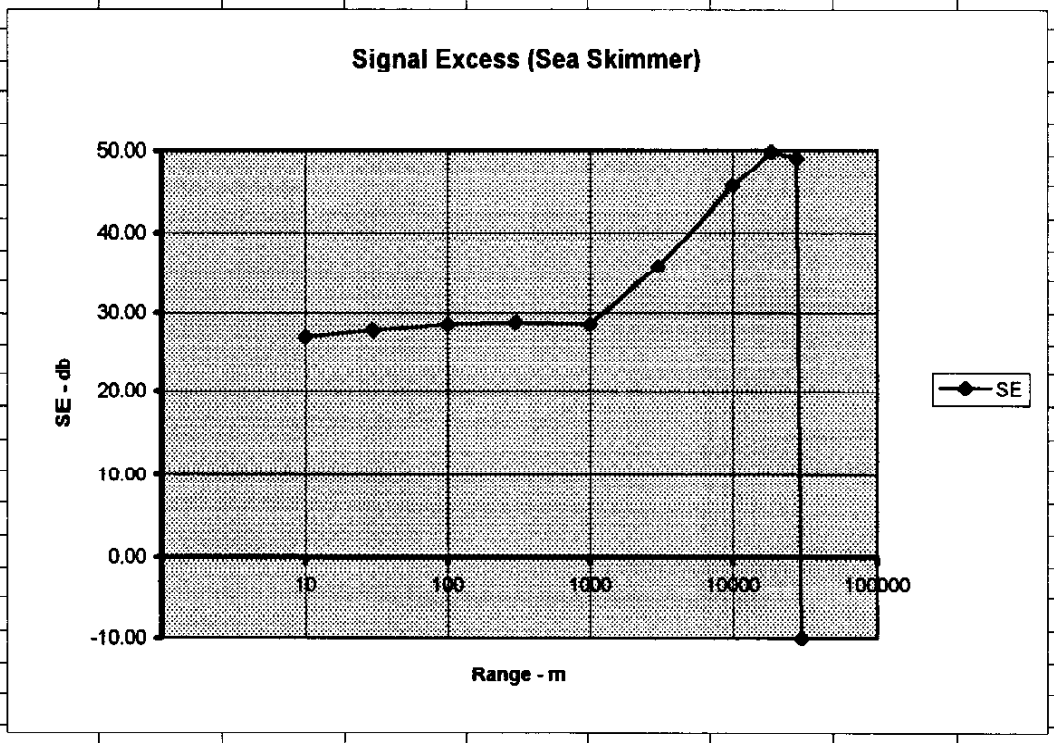
Table E-2: SPY-1D Radar Calculation, Sea Skimming Target

Constants								
h=	20		c=	3E+08		TS=	0	
d=	3.75		DT=	-1.53		t=	2.17E-03	
Pt=	5.00E+06		Pavg=	3230.77				
Parameters								
T=	1.40E-06		f=	3.30E+09		alpha=	8.00E-06	
BWh=	1.7		Lv=	2.71		Phi(cl)=	10	
Lh=	2.71		BWv=	1.70		AG=	38.54	
rpm(max)	130.77		rpm=	60			Pulses/look=	2.18
Noise Level								
NL(amb)	-148.00		NL(int)	-132.46		NL(tot)=	-132.34	
Source Level								
Slt=	94.52561							
Range	SLt	2*AR	2*TL	TS	SLr	DT	SLr*	
10	94.53	-1	-40.00	0	53.53	-1.53	55.06	
30	94.53	-1	-59.09	0	34.44	-1.53	35.97	
100	94.53	-1	-80.00	0	13.52	-1.53	15.05	
300	94.53	-1	-99.09	0	-5.56	-1.53	-4.03	
1000	94.53	-1	-120.02	0	-26.49	-1.53	-24.96	
3000	94.53	-1	-139.13	0	-45.61	-1.53	-44.08	
10000	94.53	-1	-160.16	0	-66.63	-1.53	-65.10	
18439.09	94.53	-1	-170.92	0	-77.40	-1.53	-75.87	
36878.18	94.53	-1	-178.26	0	-84.74	-1.53	-83.21	
Reverberation Level			rmax=	18439.09	tarh=	5	range=	9219.544
Range	SLt	2*TL	Area	Phi	RSs	EAR	2*AR	RLs
30	94.53	-59.09	45.98	-90	-15	-23.26	-35	8.16
100	94.53	-80.00	51.20	-17.4576	-48	-23.26	-8	-13.53
300	94.53	-99.09	55.98	-5.73917	-57	-23.26	-4	-32.85
1000	94.53	-120.02	61.20	-1.71913	-64	-23.26	-2	-53.54
3000	94.53	-139.13	65.98	-0.57297	-77	-23.26	-1	-79.89
10000	94.53	-160.16	71.20	-0.17189	-92	-23.26	-1	-110.69
18439.09	94.53	-170.92	73.86	-0.09322	-100	-23.26	-1	-126.80

Table E-2: SPY-1D Radar Calculation, Sea Skimming Target

Signal Excess

Range	RLs	NL(tot)	NL+RLs	SLr*	SE	
10	28.00	-132.34	28.00	55.06	27.06	
30	8.16	-132.34	8.16	35.97	27.81	
100	-13.53	-132.34	-13.53	15.05	28.58	
300	-32.85	-132.34	-32.85	-4.03	28.81	
1000	-53.54	-132.34	-53.54	-24.96	28.58	
3000	-79.89	-132.34	-79.89	-44.08	35.81	
10000	-110.69	-132.34	-110.66	-65.10	45.55	
18439.09	-126.80	-132.34	-125.73	-75.87	49.86	
27658.63		-132.34	-132.34	-83.21	49.14	
30000					-10	(Target not visible)



Radar Summary Chart*

CL is a beam centered target
SS is a sea skimming target

	A-1 (-40)		A-2 (-40)		A-3 (-30)		A-4 (-20)		M-1 (-45)		M-2 (-40)		weight (kg)
	CL	SS**	CL	SS	CL	SS	CL	SS	CL	SS	CL	SS	
EL/M-2207 (Israel)	20	-	20	5-15	37	30	65	30	-	-	20	5-15	ant=245
SPS-49 (US)	60	-	60	-	107	2-30	180	1-30	50	-	60	-	1425 above deck 6325 below deck
SPS-65/ER (US)	-	-	-	-	28	5-30	50	3-30	-	-	-	-	-
FAST (S band) (US)	75	-	75	5-15	120	1-30	200	3-30	60	-	75	5-15	antenna=3182 total=9227
Castor II (France)	30	-	30	10-30	55	5-30	95	3-30	23	15-30	30	10-30	antenna=620
SMART (Netherlands)	-	-	-	4-25	25	30	45	30	-	7-20	-	4-25	antenna=1200
XPAR	85	-	85	15-30	140	4-30	230	15-30	65	-	85	15-30	est. 25000
SPY-1D (US)	110	-	110	3-30	180	2-30	260	30	80	10-30	110	3-30	antenna=7400 36000 below deck

* All ranges in Km
** Missile A-1 is not sea skimming

Table E-3: Radar Summary