AIRSERVICES AUSTRALIA

Infrastructure Support Services

Port Botany Expansion

Impact on Airservices Radar and Navigation Systems at Sydney Airport

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1 Scope

This report will discuss the impact of the proposed redevelopment on the accuracy and performance of the various Radars and Navigation Systems providing services to Sydney Airport and if required, propose a strategy to mitigate any deleterious effects.

2 Sydney Airport Radar Services

The existing Radar services at Sydney Airport are:

2.1 Surface Movement Radar

Operating Range	5 Nautical Miles
Operating Frequency	9410 MHz
PRF	approx. 4000 Hz
Critical Areas	Thresholds and airport movement areas, see Figure 1
Main Tasks: -	- Airport surface surveillance - Correlation of airborne targets over the thresholds

2.2 Terminal Approach Radar (PSR)

Operating Range	40 Nautical Miles
Operating Frequencies	2770 and 2850 MHz
PRF	1000 Hz
Critical Areas	20 nm around Sydney Airport
Coverage	See Figure 2
Main Tasks:	- Intruder detection within 30nm of Sydney Airport - Tracking of non-transponder equipped aircraft

2.3 Terminal Approach Radar (SSR)

Operating Range	255 Nautical Miles
Operating Frequencies	1030 and 1090 MHz
PRF	333 Hz
Critical Areas	20 nm around Sydney Airport
Coverage	See Figure 7
Main Tasks:	- Approach control within 40nm Sydney Airport - Intruder detection within 30nm of Sydney Airport - Tracking of transponder equipped aircraft along Eastern Seaboard

2.4 Route Surveillance Radar, Mount Boyce (SSR)

Operating Range	255 Nautical Miles
Operating Frequencies	1030 and 1090 MHz
PRF	333 Hz
Critical Areas	40 nm around Sydney Airport
Coverage	See Figure 10
Main Tasks:	- Control within 40 nm of Sydney Airport - Tracking of transponder equipped aircraft along Eastern Seaboard

2.5 Precision Approach Runway Monitor (PARM)

Operating Range	32 Nautical Miles
Operating Frequencies	1030 and 1090 MHZ
PRF	Variable

Critical Areas and Coverage see Figure 12

Main Tasks:
- Precision Radar Approach control to the parallel runways
- Approach control within 30 nm of Sydney Airport.

3 Radar Coverage Calculations Assumptions

3.1 Line Of Site Obstruction

For calculations involving the radar line of site coverage, the height used in the calculations is taken as the height of the top of the crane top (50 metres), as this is the worst case. The cranes occupy all positions along the wharf front at some time.

3.2 Reflection

For calculations involving reflection of radar targets, the height used in the calculations is taken as the height of the vessel container stack, or container stack on the ground. The crane contributes little to the reflection environment.

4 Sydney Airport Radar Coverage

4.1 Surface Movement Radar

4.1.1 Surface Movement Radar Coverage

The Surface Movement Radar coverage is limited to the airport movement area, the area inside the yellow line in Figure 1. It is sited on the Control Tower (TWR).

4.1.2 Surface Movement Radar Accuracy

Azimuth	4.0 Metres
Range	4.0 Metres

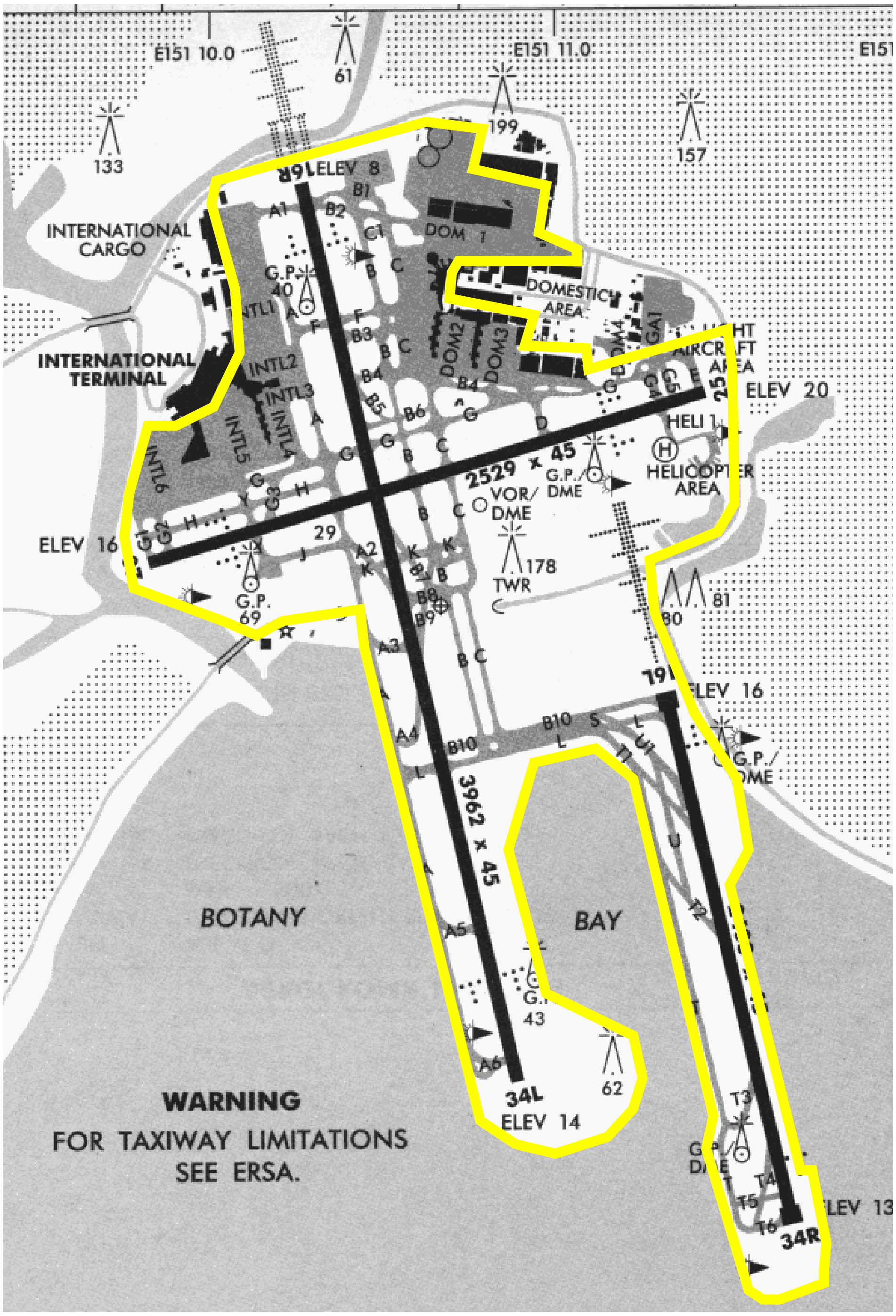
4.1.3 Expected Impact of Development

1) Minimal adverse affects, as the development is outside the coverage area.
2) Primary reflections will cause no problems.
3) Provided the berthing ships do not transit the approach path for 34R the threshold detection will be unaffected.

4.1.4 Mitigation Strategy

None required, provided 3) above is adhered to.

Figure 1 SMR Coverage



4.2 Terminal Approach Radar (Primary)

4.2.1 TAR Primary Radar Coverage

This radar sensor is located on the airport, near the junction of taxiways “C” and “B10”, see Figure 3 and is co-mounted with the TAR Secondary (Section 4.3 below). Data from the two sensors are processed in the same Track Processor. Where the tracks are combined tracks, (P+S) the position information from the most accurate sensor is used.

The coverage radius is 50 nautical miles from the TAR at position:

S33^{o} 56’ 59.70”   E151^{o} 10’ 52.65”   WGS 56.9m   AHD 34.5m

The guaranteed coverage is 40 nautical miles.

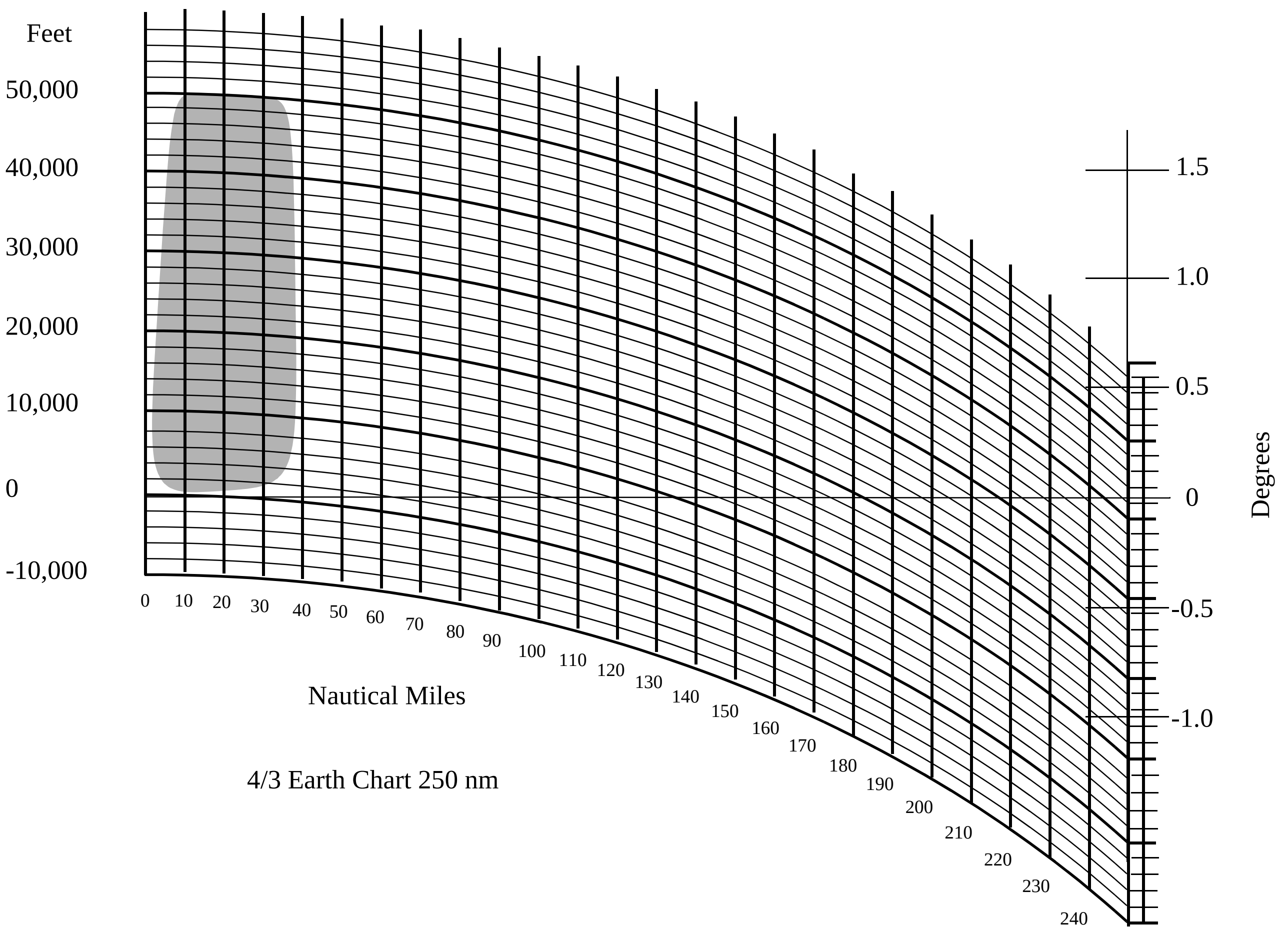
The antenna is set with the main low beam at 3^{o} above the horizon, see Figure 4.

4.2.2 TAR Primary Radar Accuracy

Azimuth ±0.15^{o} RMS (primary only target)

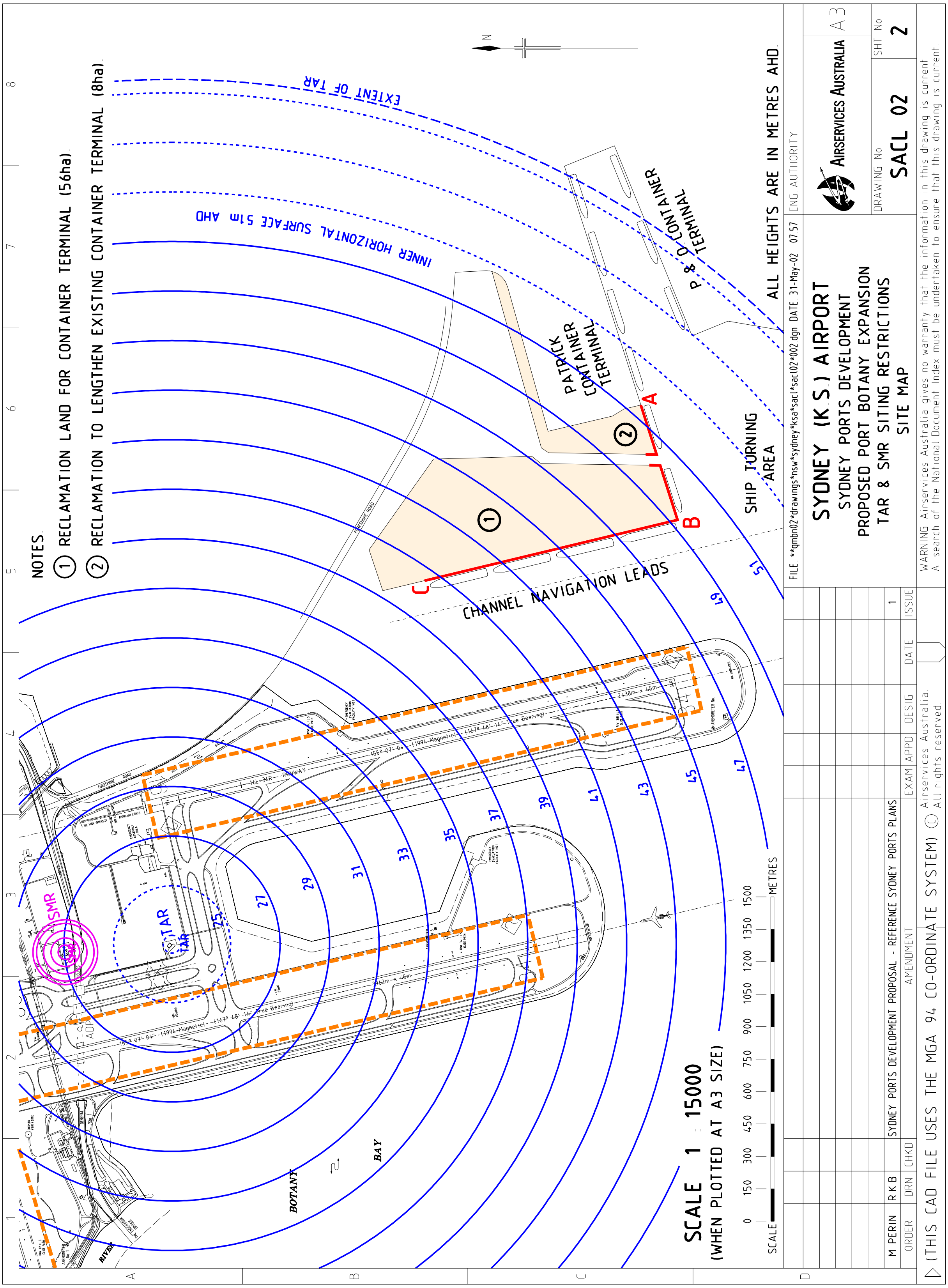
Range ±0.03 nm RMS (primary only target)

Figure 2 TAR Vertical Coverage Envelope



Primary Radar Coverage Envelope

Figure 3 TAR Siting Restrictions



4.2.3 Expected Impact of Development

1) Reduction in Primary coverage at low altitudes in the direction of development, Figure 9, between T1 and T2. The low level cutoff will be about 600' at 10 nm from the radar, due to masking by the new structures and vessels. Currently the coverage is to 100' at this range. See Figure 17 to Figure 19 and Figure 21. Vessels in transit to the dock along the normal navigation leads show only minor disturbances to the primary vertical radiation pattern, see Figure 20 and Figure 22.

   Figure 21 shows that the performance of the second primary transmitter frequency is substantially the same as that used for calculation of the other primary vertical patterns.

   Due to lack of consistent detection this may cause some tracking problems with aircraft below 600 feet AMSL in the coastal aircraft lane.

2) Large moving primary targets, typically any large maritime vessel, see Figure 6, within 10 to 15 nm that is illuminated by the radar may cause "ring around" due to side lobe detection, see the horizontal radiation pattern in Figure 5. This can result in suppression of real targets at the same range, and generation of "false" targets at all azimuths. The radar siting and height, limit this affect to vessels in Botany Bay or in transit through the Heads.

   The sidelobes of the antenna, see Figure 5, detect the vessel due to the large reflecting area and the short range, these returns are not coherent with the energy received by the antenna main beam causing a pseudo moving target to be generated. The primary processor (TVD900), will suppress most of these false targets by increasing the detection thresholds, but:

   a) A percentage of the false targets will be displayed adding to the clutter near the airport.

   b) The detection sensitivity under the "ring around" will be reduced.

   c) Primary azimuth disturbances may occur in the "ring around", due to plot width modulation by false targets.

   The largest target expected represents a Cross Sectional Area, (CSA) of 40-60 square metres in its best aspect and typically a CSA of 10-15 square metres in its worst aspect, the smallest targets expected are Ultralight aircraft or Robinson R22 helicopters, these have a CSA of 0.2 square metres.The maritime vessels expected in Botany Bay, see Figure 6, can have areas of between 3200 square metres and 9900 square metres and although not at optimum angles, probably have a reflection rate of more than 10% making them 6-10 times the size of the largest "normal" targets.

3) Reflection of Kurnell coast will reduce sensitivity over the La Perouse Peninsula and in the area bounded by T1 and T2 of Figure 9.

   The large size of the vessels allows for reflection of the primary main beam from any vessels berthed at the dock or in transit to the dock. Causing detection of targets along the line of the reflection Figure 9, between TR1 and TR2. The "reflected path" will be via the water increasing the attenuation, but large targets, (other maritime vessels and the coastline), will be detected and superimposed over the real targets. The TVD900 will suppress most of these effects, but:

   a) There will be a reduction in detection sensitivity where these super impositions occur.

   b) There will be an increase in clutter, angels and short lived false targets.

   The beam width of the antenna is 1.1^{o} at the 3dB points, at the range of the docked vessels, say 3km this represents 55 metres wide, as the vessels are 250 metres plus in length, the whole of the beam is reflected in the side of the vessel and/or the container stack.

4.2.4 Mitigation Strategy: -

The TAR antenna has been set with the main beam at +3.0^{o} reference the horizon, see Figure 4. This setting is a compromise between the clutter levels, detectability over the thresholds and long range performance. Increasing the radiation angle to reduce reflections will result in a reduction in performance over the thresholds and at long range and is therefore not recommended. This setting can not be altered without a complete flight test of the sensor.

1) No solution available. The reduction in primary coverage is entirely due to masking, the only remedy is to increase the height of the radar, or relocate the radar to a more benign position.

2) No solution available. Blanking and non-initialisation areas can be used to limit the initiation of false tracks, but they do not discriminate between wanted and unwanted targets. There is only 7 of each type of zone available, most of which are already in use to suppress false targets generated by road traffic in the Sydney Basin.

   a) No method exists to discriminate between the targets detected by the main lobe and those detected by the sidelobes. The TVD900 will automatically increase the thresholds to minimise the false tracks and clutter.

   b) The desensitisation is a result of the automatic increase in the thresholds due to the increased clutter levels.

   c) No method exists to discriminate between the false targets and the real targets.

3) No solution available.

   a) The reflections increase the automatic threshold levels decreasing the sensitivity.

   b) Clutter and angel activity increase as a result of the non-coherent replies, the automatic thresholding will eliminate most of this activity, but at the cost of detection sensitivity.

4.2.4.1 Summary

Any performance adjustment will be an operational compromise between:

a) Increased false primary tracks and track seduction to clutter

b) Use of blanking areas to suppress all primary tracks

4.2.4.2 Technology Upgrade

The current primary processing equipment at the Sydney TAR is relatively old (technologically speaking) and is a candidate for upgrading to later model processing. Preliminary discussions with potential suppliers have occurred, but no time frame has been discussed or proposed. The updated processing system generally improves the performance under adverse conditions as those described above.

Figure 4 TAR Vertical Radiation Pattern (Primary)

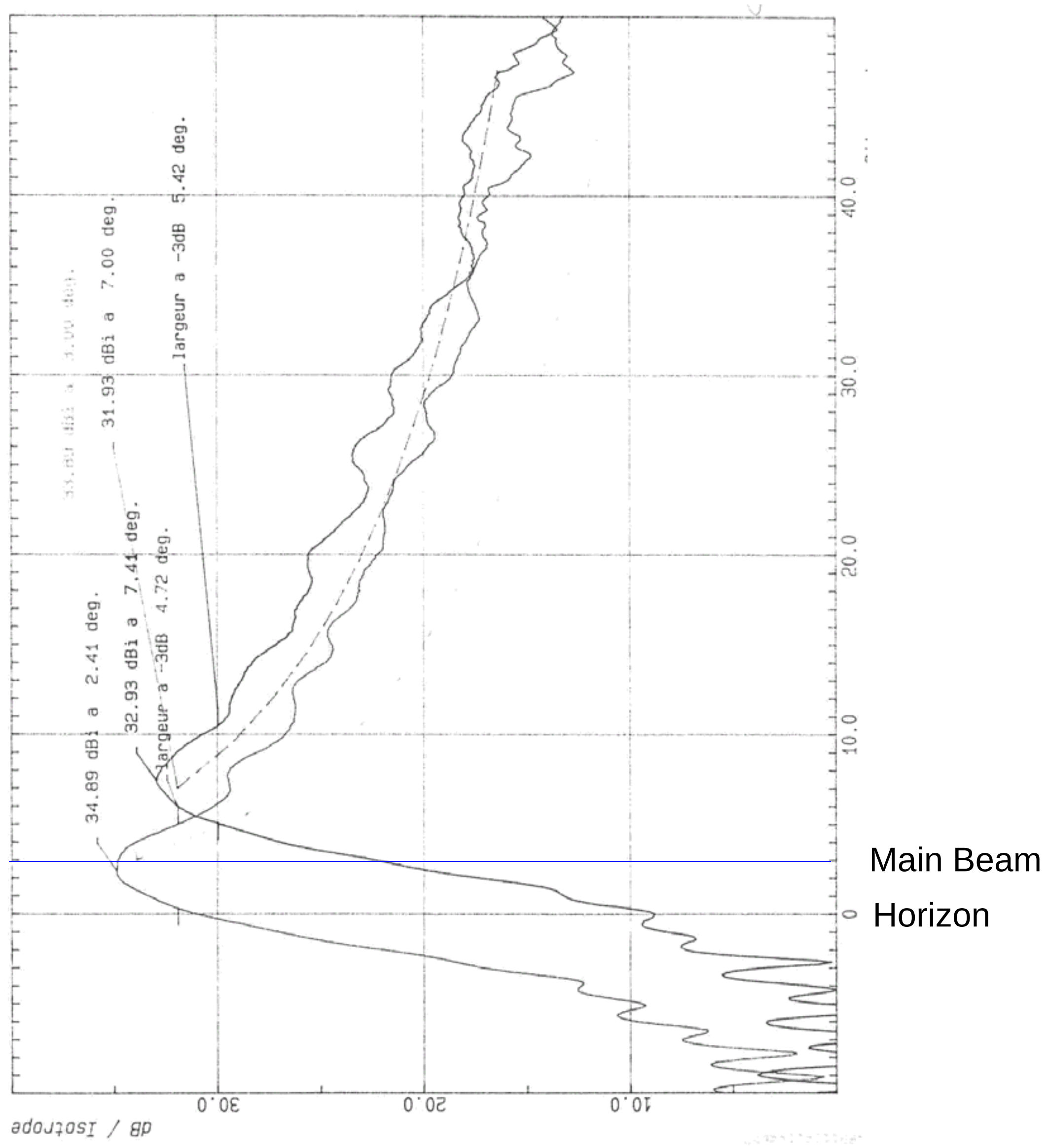


Figure 5 Tar Horizontal Radiation Pattern (Primary)

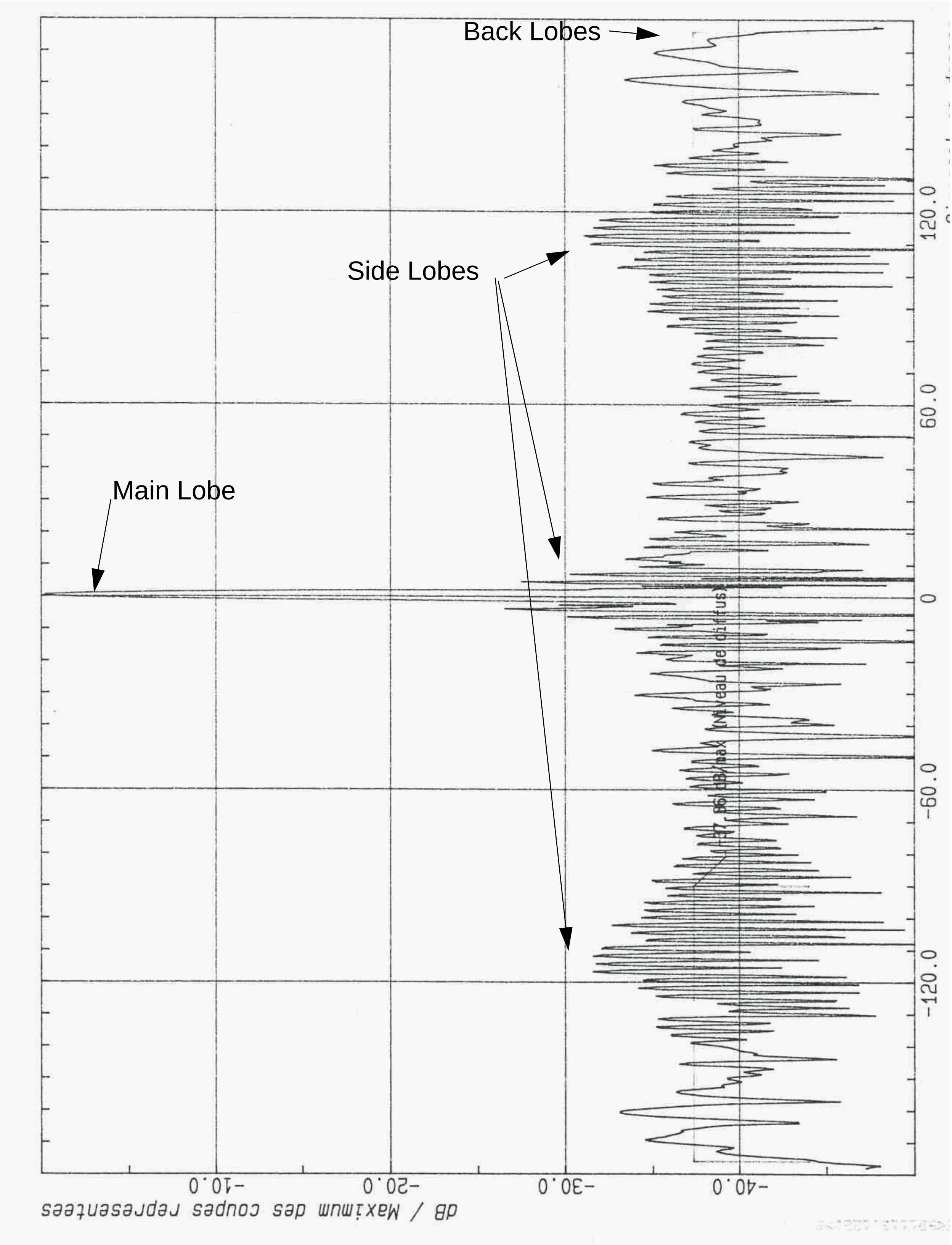
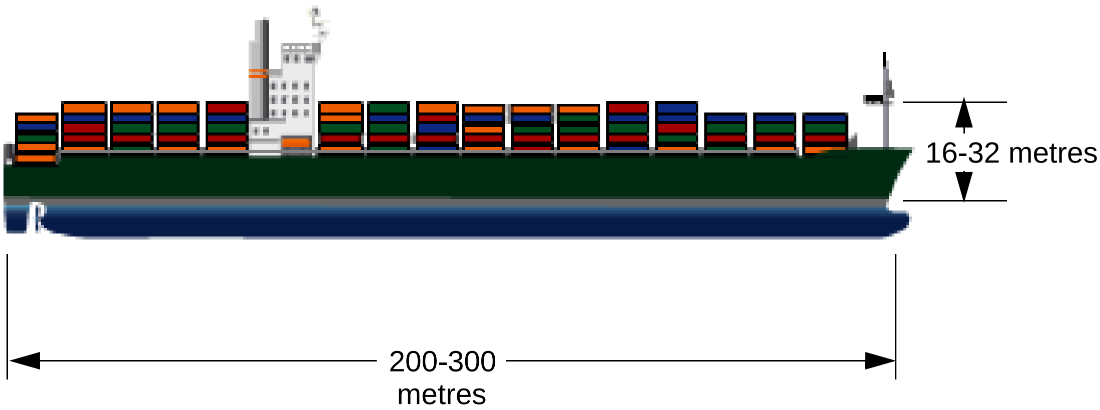
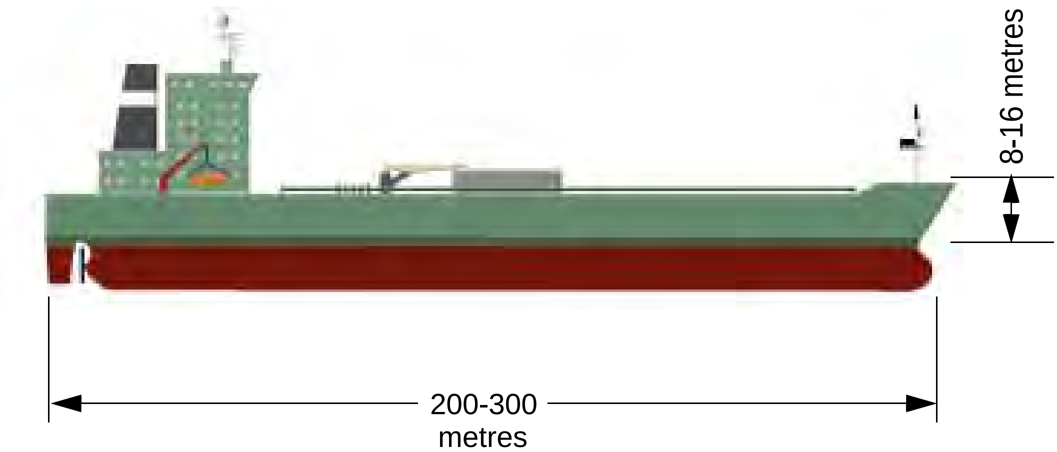


Figure 6 Vessels expected in Botany Bay



Reflector Size:-

1500 TEU	200 x 16 = 3200□ Metres
3000 TEU	260 x 23 = 5980□ Metres
4500 TEU	300 x 27 = 8100□ Metres
6000 TEU	320 x 31 = 9920□ Metres
Oil Tanker	260 x 10 = 2600□ Metres



4.3 Terminal Approach Radar (Secondary)

4.3.1 Terminal Approach Radar Coverage

This sensor is located on the airport, near the junction of taxiways “C” and “B10”, see Figure 3. It is co-mounted with the TAR Primary (Section 4.2 above). Data from the two sensors are processed in the same Track Processor. Where the tracks are combined tracks (P+S), the position information from the most accurate sensor is used.

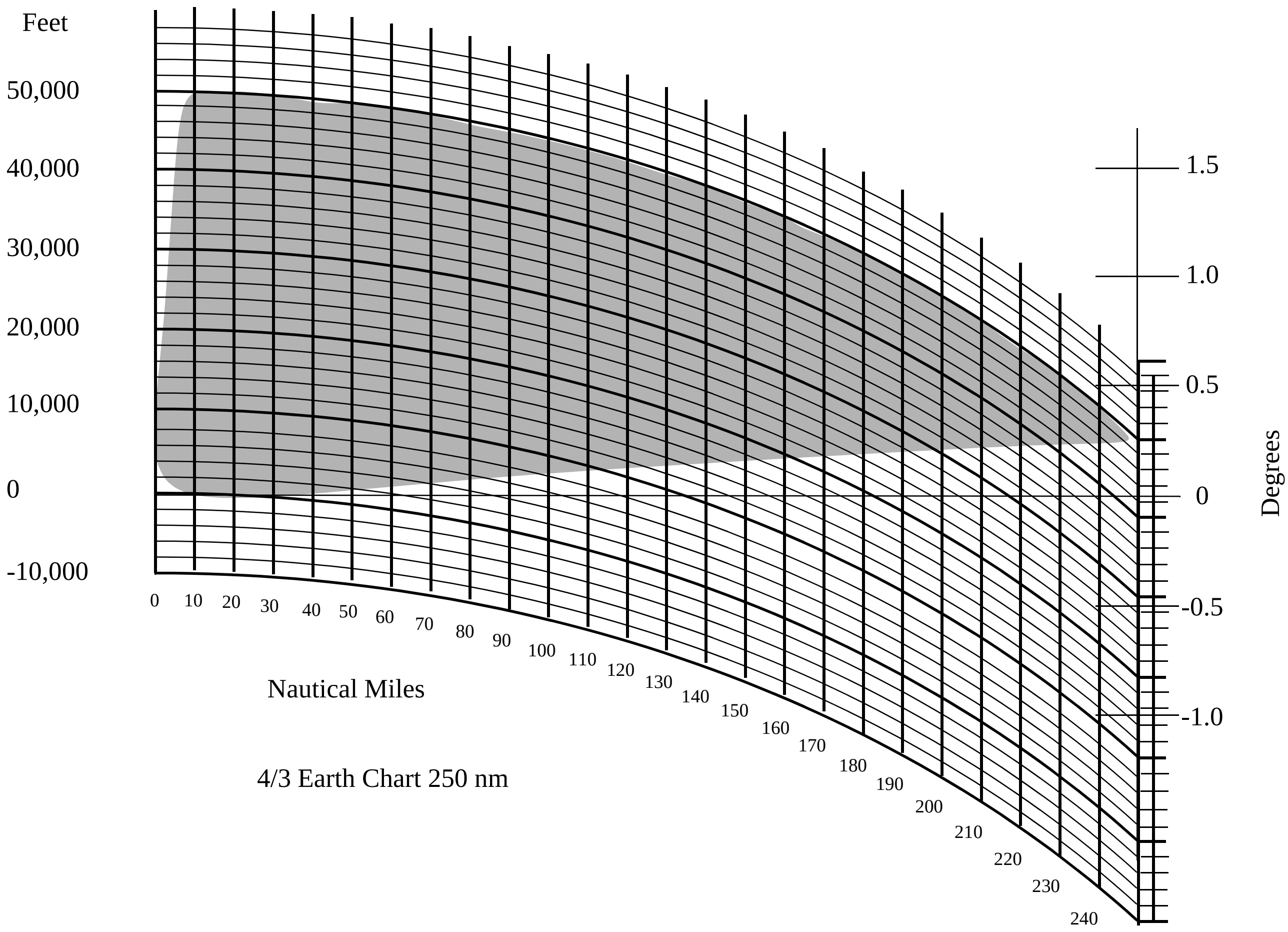
The coverage radius is 255 nautical miles from the TAR at position: -

S33^{o} 56’ 59. 70” E151^{o} 10’ 52.65” W56.9M AHD34.5M

The guaranteed coverage is 255 nautical miles.

The main beam of the SSR is set at +10^{o} reference the horizon. See Figure 8

Figure 7 TAR SSR Vertical Coverage Envelope



Secondary Radar Coverage Envelope

Figure 8 SSR Vertical Radiation Pattern

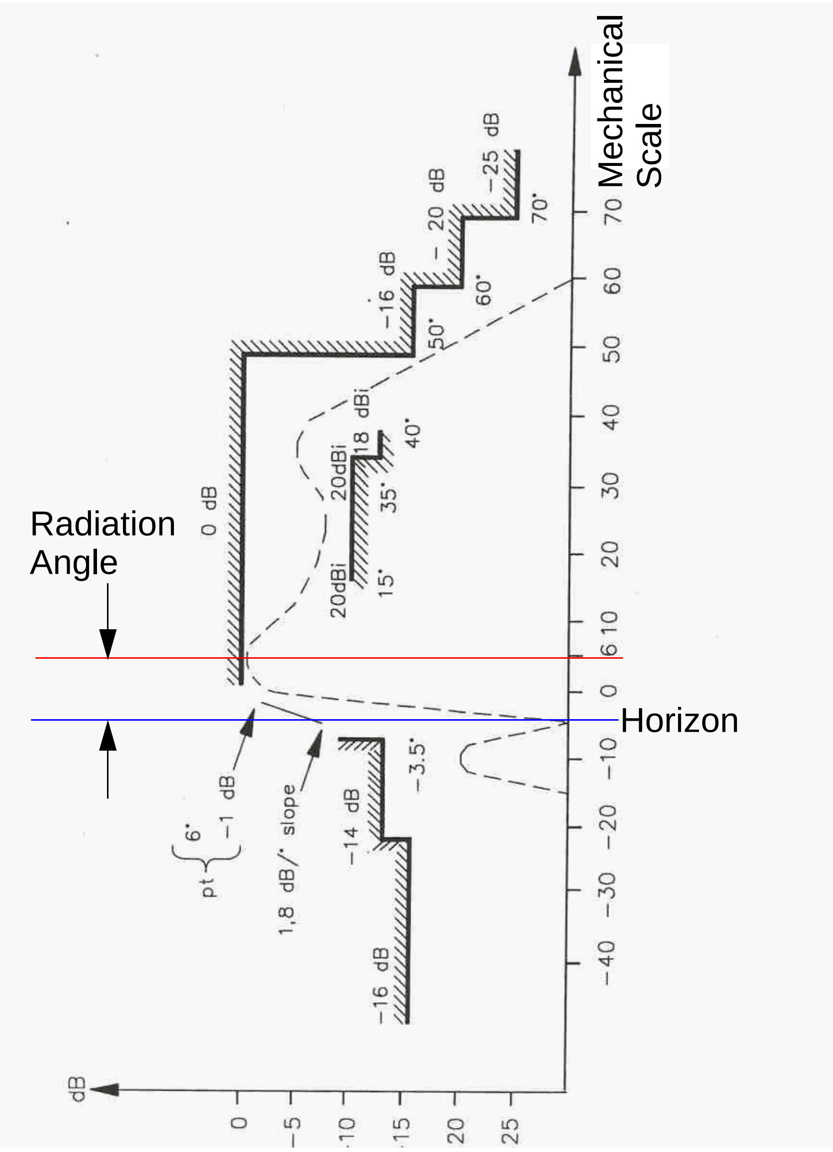


Figure 9 TAR Reflection Geometry (SSR)

4.3.2 Terminal Approach Radar Accuracy (Secondary)

1) Azimuth ±0.05^{o} RMS

2) Range ±0.03 nm RMS

4.3.3 Expected Impact of Development

1) Reduction in secondary coverage at low altitudes in the direction of the development, between Figure 9, T1 and T2. Coverage below 600' at 10 nm from the radar will be patchy due to diffraction over the Port. Currently the coverage is to 100' at this range. See Figure 23 to Figure 27.

Due to lack of consistent detection this may cause some tracking problems with aircraft below 600 feet AMSL in the coastal aircraft lane.

Vessels in transit to the dock along the normal navigation leads show only minor disturbances to the secondary vertical radiation pattern, see Figure 26 and Figure 28.

2) Increased reflections between Figure 9, T1 and T2 at all ranges, caused by aircraft in the southern sector, between Figure 9, TR1 and TR2, and north eastern sector Figure 9, TR3 and TR4.

The track processor uses three criteria for discriminating between real and reflecting targets. They are: -

a) Targets must be the same discrete reply code

b) the reflected target will have a longer range than the real target.

c) The reflected target should have a lower received field strength than the real target. This level is adjustable from "zero" difference to any negative level desired.

The large size of the vessels will allow the reflection of the SSR main beam and interrogation of aircraft that are off azimuth. The reflection path will be via the water for at least one path, so the path loss will be increased over the direct path, this should enable the tracking processor to discriminate between real and "reflected" tracks. Targets in this group should meet all three criteria.

When the reflection angle is small it is possible to interrogate via the reflector and reply direct to the radar antenna, thus making the reflection identification process more difficult. Targets in this group should meet two of the criteria, (a) and (b).

The beam width of the antenna is 2.2^{o} at the 3dB points, at the range of the docked vessels, say 3km this represents 110 metres wide, as the vessels are 250 metres plus in length the whole of the beam is reflected in the side of the vessel and/or the container stack.

3) All Aircraft on approach to runways 34L and 34R will transit through the new reflection zone. See Figure 9.

4.3.4 Mitigation Strategy

The TAR/SSR antenna has been set with the main beam at $+10.0^{o}$ reference the horizon, see Figure 8, this antenna is a sharp cutoff array minimising the radiation at angles below the peak of the beam. The setting is a compromise between the level of reflections and long range detectability. Increasing the radiation angle to further reduce reflections will result in a reduction in performance at long range and is therefore not recommended. This setting can not be altered without a complete flight test of the sensor.

1) No solution available. The coverage reduction is caused by masking, the only remedy is to increase the height of the radar, or relocate the radar to a more benign position.

2) There are several improvements that can be made to improve the reflection performance. They are:

a) Retuning of the Track Processors to ensure optimum reflection processing.

b) Adjustment of SSR Interrogators to reduce interrogate power in the sectors concerned.

c) Adjustment of SSR Receivers to reduce receive sensitivity in the sectors concerned.

Items (b) and (c) reduce the long range performance of the sensor, a balance will have to be met in making these adjustments.

Note: There are no secondary non initialisation or blanking zones used by the SSR processing. Replies originate from a transponder and any valid replies MUST create a track. The later processing must differentiate between real and reflected tracks.

3) Any reflections in this zone MUST be infrequent as they will cause problems with flight plan processing in the display system, for departing aircraft.

4.4 Route Surveillance Radar (Secondary) Mount Boyce

4.4.1 Route Surveillance Radar Coverage

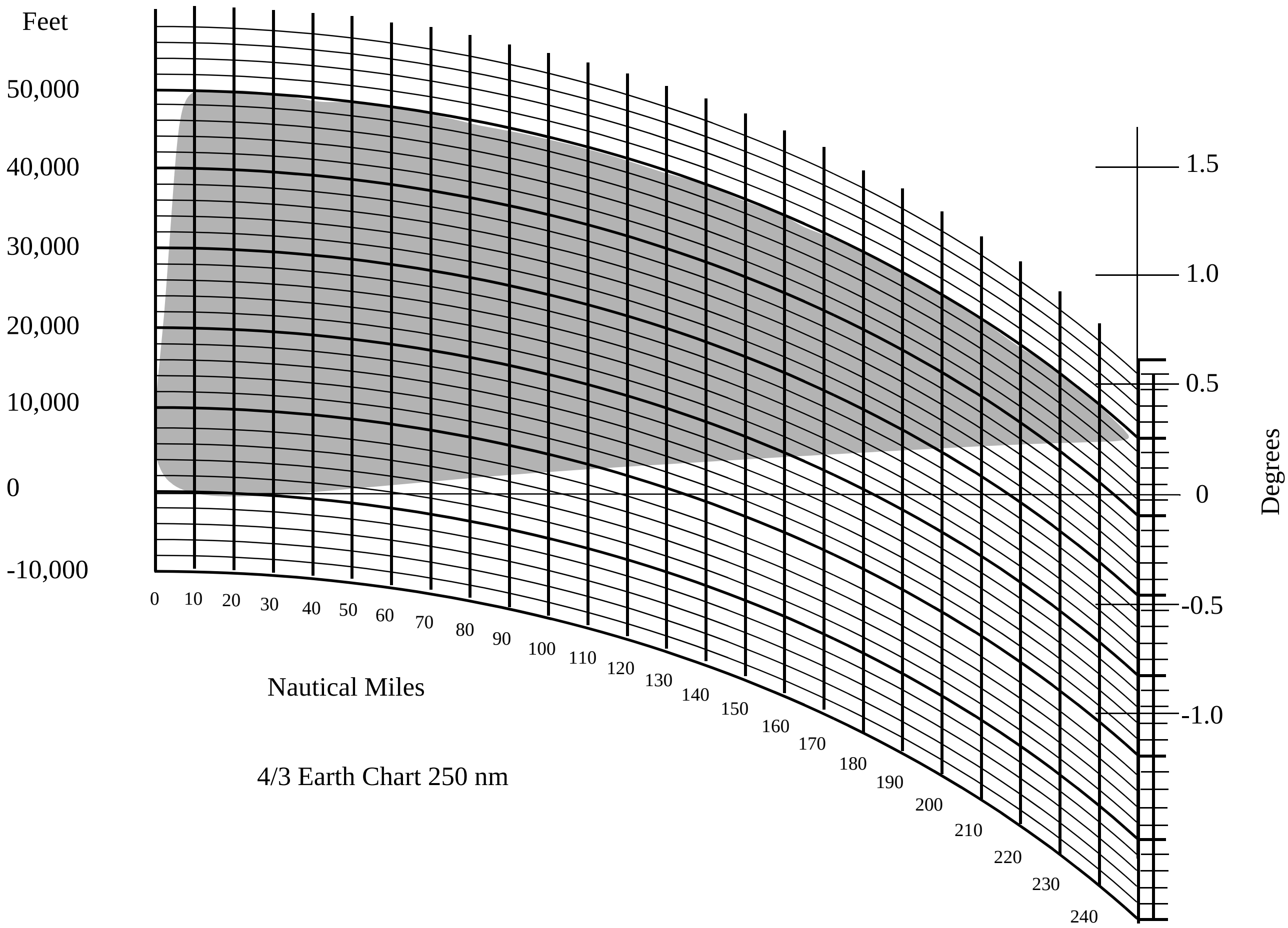
The coverage radius is 255 nautical miles from the RSR at position:

S33° 36' 47. 61" E150° 16' 10.15" W1144.0M AHD1118.6M
(this position is approximately 50 nautical miles bearing 293° from Sydney Airport, near Blackheath in the Blue Mountains)

The guaranteed coverage is 255 nautical miles and to runway level at Sydney Airport.

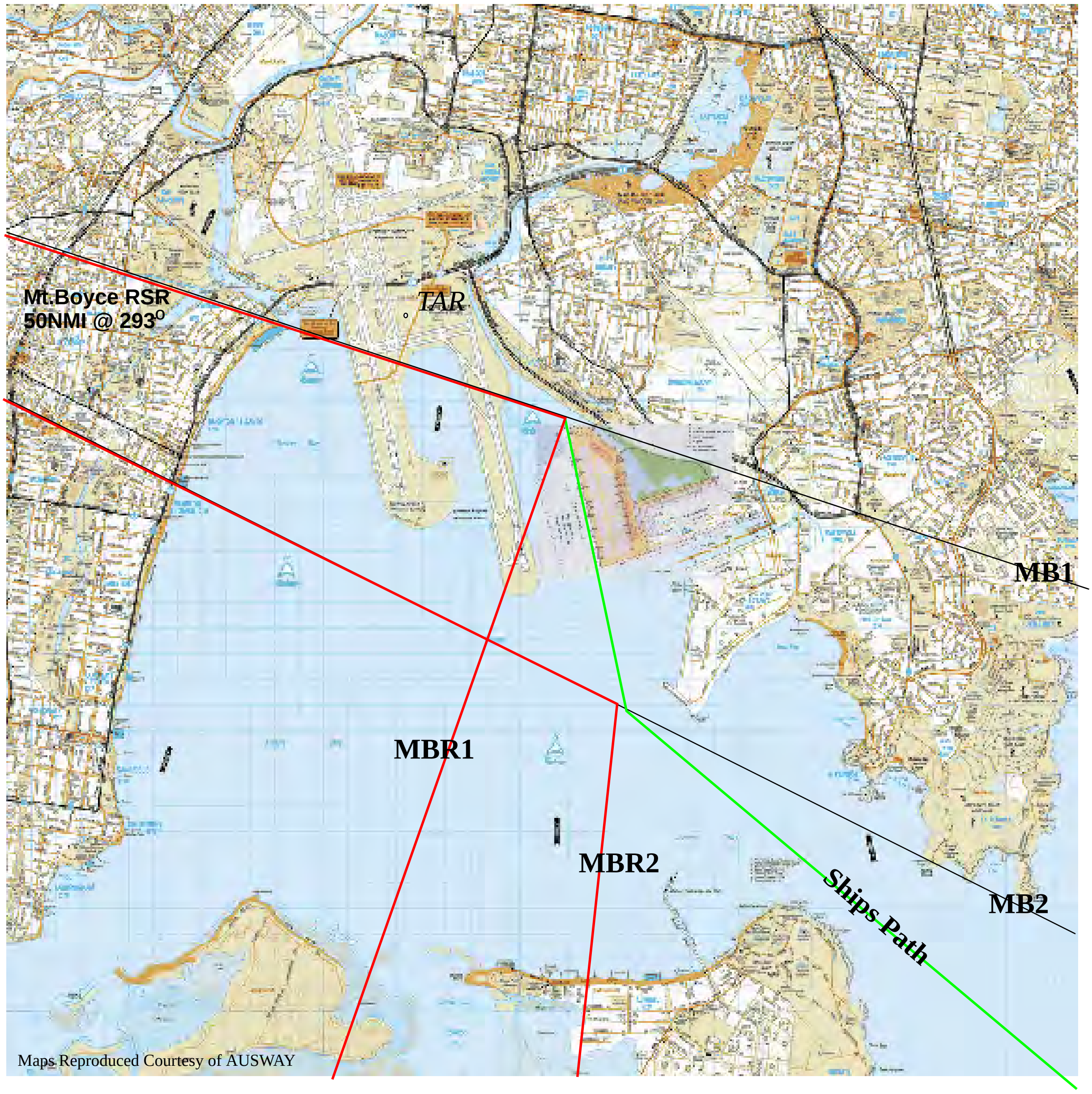
The antenna main beam is set to +9°. See Figure 8

Figure 10 RSR SSR Vertical Coverage Envelope



Secondary Radar Coverage Envelope

Figure 11 Mt.Boyce Reflection Geometry (SSR)



4.4.2 Route Surveillance Radar Accuracy

Azimuth	±0.05^{o} RMS
Range	±0.03 nm RMS

4.4.3 Expected Impact of Development

1) Increased reflections between, Figure 11, MB1 and MB2, from aircraft in the southern sector between, Figure 11, MBR1 and MBR2, at all ranges exceeding 50 nm.

   The reflection path will be via the water and the increased path loss via the reflector should be significant.

   The beam width of the antenna is 2.2^{o} at the 3dB points, at the range of the docked vessels, say 100km this represents 1.8 km wide, as the vessels are 250 metres in length only part of the beam is reflected in the side of the vessel and/or the container stack. When 4 vessels are berthed a larger reflecting surface will be present.

2) All Aircraft on approach to runways 34L and 34R will transit through the new reflection zone. See Figure 11, between MBR1 and MBR2.

4.4.4 Mitigation Strategy:

The RSR/SSR antenna has been set with the main beam at +9.0^{o} reference the horizon, see Figure 8. This antenna is a sharp cutoff array. The setting is a compromise between the level of reflections and long range detectability. Increasing the radiation angle to further reduce reflections will result in a reduction in performance at long range and is therefore not recommended. This setting can not be altered without a complete flight test of the sensor.

1) There are several improvements that can be made to improve the reflection performance. They are:

   a) Retuning of the Track Processors to ensure optimum reflection processing.

   b) Adjustment of SSR Interrogators to reduce interrogate power in the sectors concerned.

   c) Adjustment of SSR Receivers to reduce receive sensitivity in the sectors concerned.

   Items (b) and (c) reduce the long range performance of the sensor, a balance will have to be met in making these adjustments.

   Note: There are no secondary non initialisation or blanking zones used by the SSR processing. Replies originate from a transponder and any valid replies MUST create a track. The later processing must differentiate between real and reflected tracks.

2) Any reflections in this zone MUST be infrequent as they will cause problems with flight plan processing in the display system, for departing aircraft.

4.5 Precision Approach Runway Monitor (Secondary)

4.5.1 Precision Approach Runway Monitor Coverage

The coverage radius is 32 nautical miles from the Radar at position:

S33^{o} 56' 37.71" E151^{o} 10' 57.34" W55.0M AHD32.6M

The PARM is sited on the airport, adjacent the Control Tower Complex.

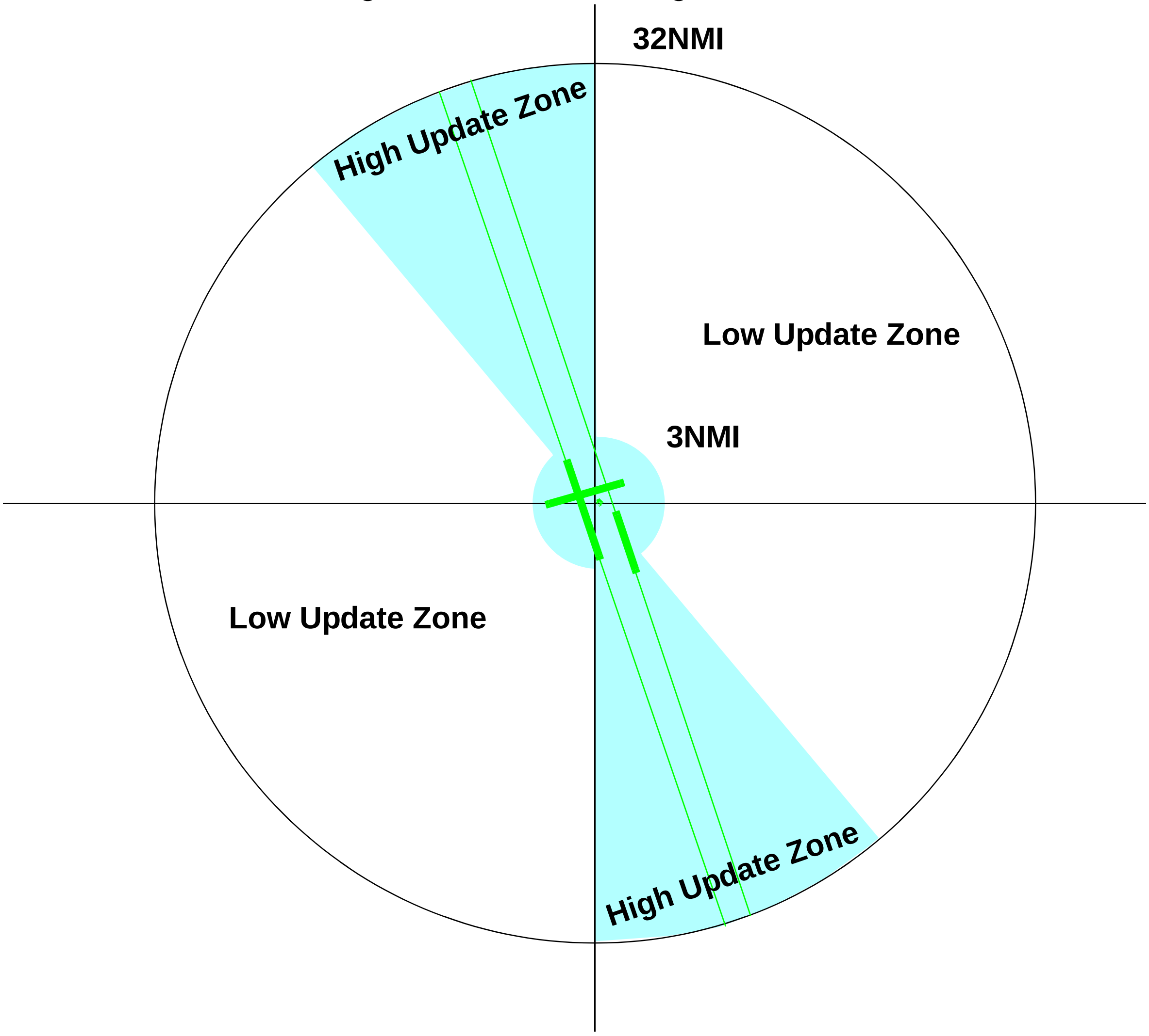
The guaranteed coverage is 32 nautical miles.

In Figure 12, the area inside the 32 nm circle is used for Multi Radar Tracking (MRT) in the Sydney TMA display. The area in blue is the zone in use for simultaneous approaches, high update rate zone.

4.5.2 Precision Approach Runway Monitor Accuracy

Azimuth	Better than 1 milliradian, (0.06^{o})
Range	±0.01 nm RMS

Figure 12 PARM Coverage Area.



4.5.3 PARM Licensing Requirements: -

Extract from the CASA Manual of Operational Standards, Part 3. Aerodromes;

4. Parallel Runway Standards

Approved by Assistant Director, Aviation Safety Standards Version 3.3: March 2002

4.3 Instrument Departures from Parallel Runways

4.3.1 Parallel runways may be used for independent departures provided:

a. The runway centre lines are separated by at least 760 m.
b. The departure tracks diverge by at least 15^{o} immediately after take-off.
c. Suitable radar capable of identification of the aircraft within 1.0 nm from the end of the runway is available.
d. ATS operational procedures ensure that the required track divergence is achieved.

4.4 Instrument Arrivals to Parallel Runways

4.4.1 Use for Independent and Dependent Arrivals

4.4.1.1 Parallel runways may be used for independent and dependent arrivals subject to the following described in ensuing paragraphs:

* Independent Parallel Approaches
* Dependent Parallel Approaches.

4.4.2 Independent Parallel Approaches

4.4.2.1 Independent parallel approaches may be conducted to parallel runways with centre-lines separated by at least 1035 m, provided that:

a. For runways separated by greater than 1525 m, suitable surveillance radar with a minimum azimuth accuracy of 0.3º (one sigma) and update period of 5 seconds or less is available.

b. For runways separated by less than 1525 m, suitable surveillance radar with a minimum azimuth accuracy of 0.06º (one sigma) and update period of 2.5 seconds or less and a high resolution display providing position prediction and deviation alert, is available.

c. Instrument landing system (ILS) approaches are being conducted on both runways.

d. The aircraft are making straight-in approaches.

e. Aircraft are advised of the runway identification and ILS localizer frequency.

Note: Para 4.4.2.1 b applies as the runway separation is less than 1525 metres.

Figure 13 PARM Reflection Geometry.

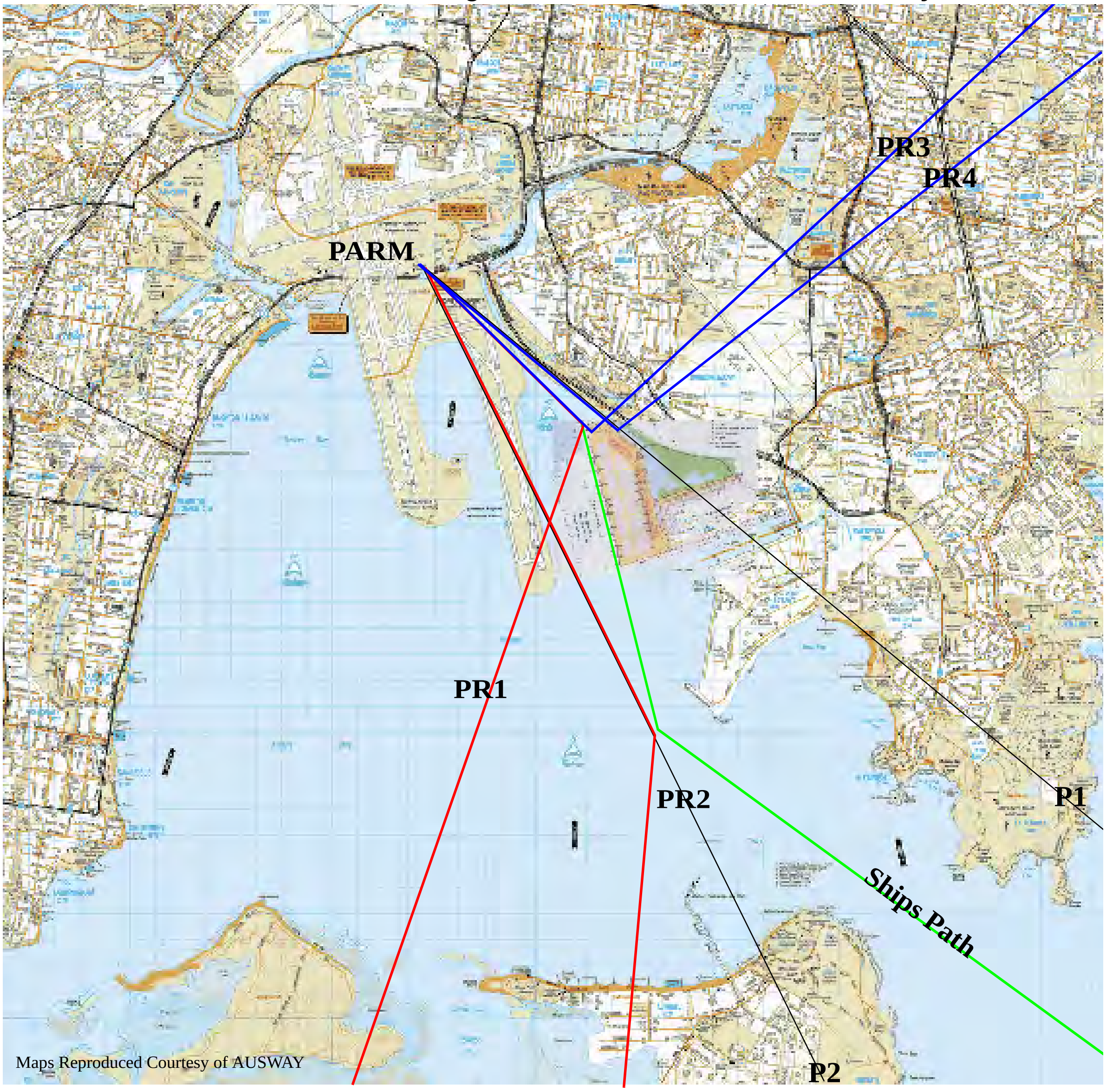
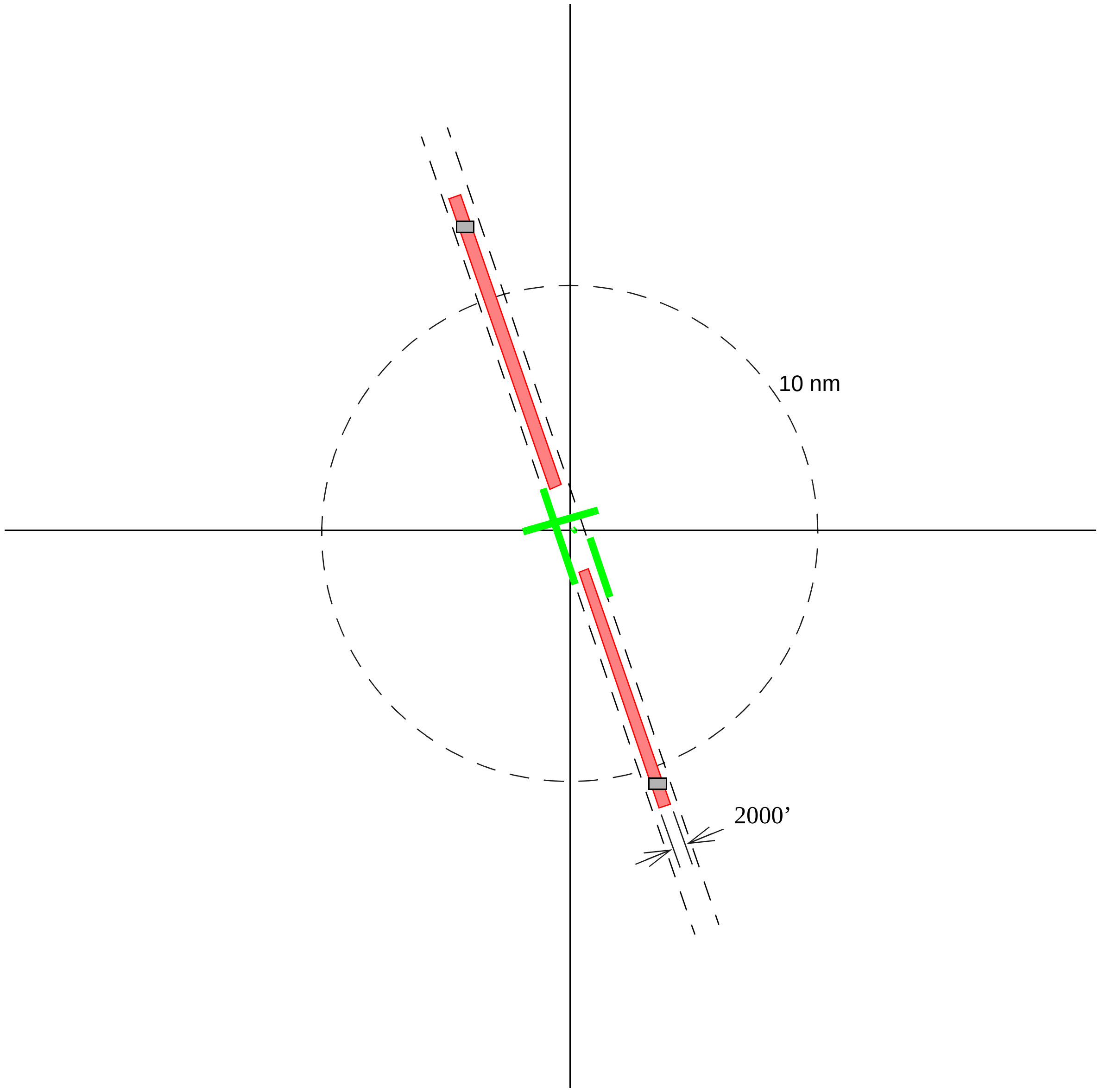


Figure 14 PARM No Transgression Zones



4.5.4 Expected Impact of Development.

1) Reduction in PARM accuracy for precision approaches to runways 34L and 34R. Particularly affecting the "No Transgression Zone", Figure 14. The PARM accuracy could be reduced to the point where its performance is outside the requirement for simultaneous approaches to be conducted.

2) Increased reflections between Figure 13, P1 and P2 at all ranges, caused by aircraft in the southern sector between Figure 13, PR1 and PR2, and north eastern sector Figure 13, PR3 and PR4.

   The track processor uses three criteria for discriminating between real and reflecting targets. They are:-

   a) Targets must be the same discrete reply code

   b) The reflected target will have a longer range than the real target.

   c) The reflected target should have a lower received field strength than the real target. This level is adjustable from "zero" difference to any negative level desired.

The large size of the vessels will allow the reflection of the SSR main beam and interrogation of aircraft that are off azimuth. The reflection path will be via the water for at least one path, so the path loss will be increased over the direct path, this should enable the tracking processor to discriminate between real and "reflected" tracks. Targets in this group should meet all three criteria.

When the reflection angle is small, it is possible to interrogate via the reflector and reply direct to the radar antenna, thus making the reflection identification process more difficult. Targets in this group should meet two of the criteria, (a) and (b).

3) All Aircraft on approach to runways 34L and 34R will transit through the new reflection zone. See Figure 13

4.5.5 Mitigation Strategy

1) There are several actions that can be made to resolve PARM accuracy problem. They are:

   a) Do not use Independant parallel approaches. This will restrict the capacity of Sydney Airport.

   b) The azimuth accuracy reduction is caused by multiple horizontal paths to the target. The impact of these multiple paths can be minimised by relocating the radar to a more benign position. This may involve a PARM at each end of the North /South Runways.

   Note: The above statement does not imply availability of alternative sites for the PARM.

2) There are several improvements that can be made to improve the reflection performance. They are:-

   a) Retuning of the Track Processors to ensure optimum reflection processing.

   b) Adjustment of SSR Interrogators to reduce interrogate power in the sectors concerned.

   c) Adjustment of SSR Receivers to reduce receive sensitivity in the sectors concerned.

3) Any reflections in this zone MUST be infrequent as they will cause problems with simultaneous approaches and flight plan processing in the display system, for departing aircraft.

   Note: The reduction in accuracy is due to the multiple horizontal paths to the target. The analysis tools supplied by the sensor manufacturer give a go/nogo result. The manufacturer has advised Airservices that these tools are only a reliable guide. Later modelling software now available can predict the sensor performance reliably. This software is available to manufacturer, and they are willing to perform the analysis, (cost approx $US 65,000).

   Note: If the performance prediction was favourable, the sensor would need to be flight tested to confirm the accuracy with the development in place.

5 Sydney Airport Navigation Services

Navigation systems are provided for the safe and efficient operation of aircraft in terminal areas, including approach and landing at airports. To ensure their proper operation, most of these facilities have associated restricted or clearance areas. Details of these can be found in Rules and Practices for Aerodromes (RPA) Volume 1, Book 2, Chapter 20.

Components of Airservices Instrument Landing Systems at Sydney Airport that potentially could be impacted upon by the expansion of Port Botany are:

- Runway 16L Localizer
- Runway 34R Localizer
- Runway 34R Glide Path

The normal site restrictions for these systems are shown in Figure 15.

5.1 Introduction to ILS

Instrument Landing Systems (ILS) is the international standard system for approach and landing guidance. ILS was adopted by ICAO (International Civil Aviation Organisation) in 1947 and will be in service until at least 2015. Because of the worldwide adoption of ICAO's technical specifications, any ILS equipped aircraft can expect to satisfactorily use the system at any airport.

An ILS normally comprises of a "Localizer" aligned with the runway centreline and providing azimuth guidance, a "Glide Path" for elevation guidance, and either "Marker Beacons" or DME for providing distance to touchdown information along the approach path.

The Localizer (LLZ), which provides lateral guidance, produces a course formed by the intersection of two antenna radiation patterns. One pattern is modulated by 90Hz and the other by 150Hz. The runway centreline is the vertical plane where the 90Hz and 150Hz modulation is equal.

The signal received by the airborne receiver produces a "fly right" indication for the pilot when the aircraft is to the left of centreline in the predominately 90Hz region. Similarly a "fly left" indication will be produced for the pilot on the opposite side of the centreline in the predominately 150Hz region.

The Glide Path (GP) produces two radiation patterns in the vertical plane which intercept at the decent angle, namely the 3 degree glide slope. Below the glide slope angle, 150Hz predominates giving a "fly up" indication. Above the glide slope angle a "fly down" indication will be produced by the 90Hz predominance. The GP is sited about 300m behind the runway threshold to give a threshold crossing height of between 15m and 18m.

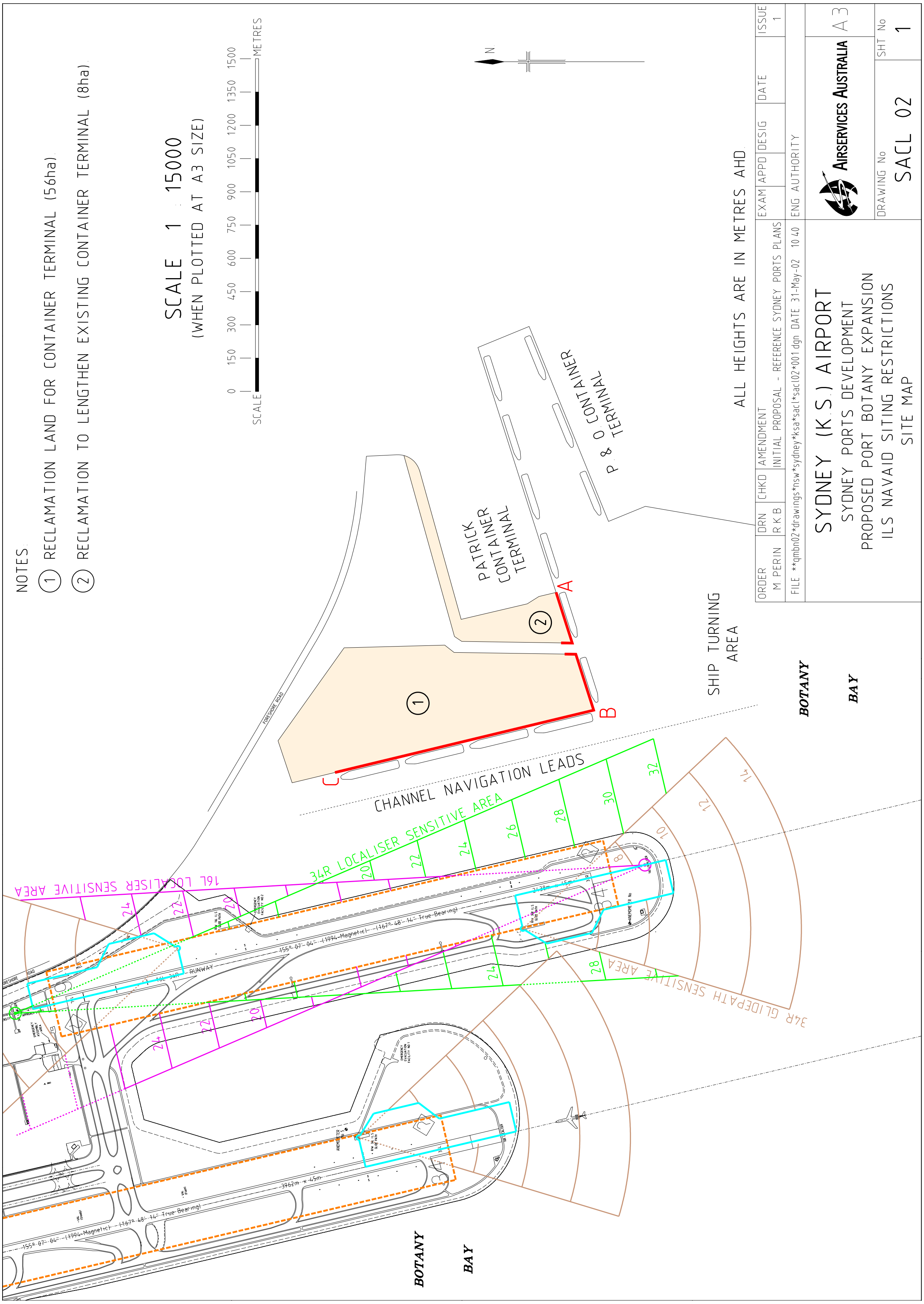
All elements of the ILS are carefully monitored, and any malfunction causes a warning signal to alert the ground controller. The ILS is automatically switched off if the system is not functioning correctly.

5.2 ILS Approach Procedure

An ILS procedure begins with the transition from enroute to final approach. The aircraft intercepts the Localizer course in level flight at an altitude and distance (specified by the approach plate of the pilot's flight manual) that places the aircraft below the 3 degree glide slope. This allows the pilot to become stabilised on the localizer before starting the descent. As the aircraft intercepts the glide slope sector, the indicator starts to move towards the centre and the pilot then makes the necessary power and trim adjustments to give a rate of descent consistent with the glide slope angle.

If the approach is being made to Category one weather minima (down to 200ft above the airport), the pilot must have in view an element of the approach lights, runway lights or markings by the time he reaches the minimum decent altitude. If he reaches this decision height and does not have adequate visual reference, he must abort the approach and execute a missed approach procedure.

Figure 15 ILS Site Restrictions



5.3 ILS Modelling of Port Botany Development

Analysis of the Port Botany development indicates that interference to the ILS will most likely be caused by container ships, particularly while they are transitting to the dock.

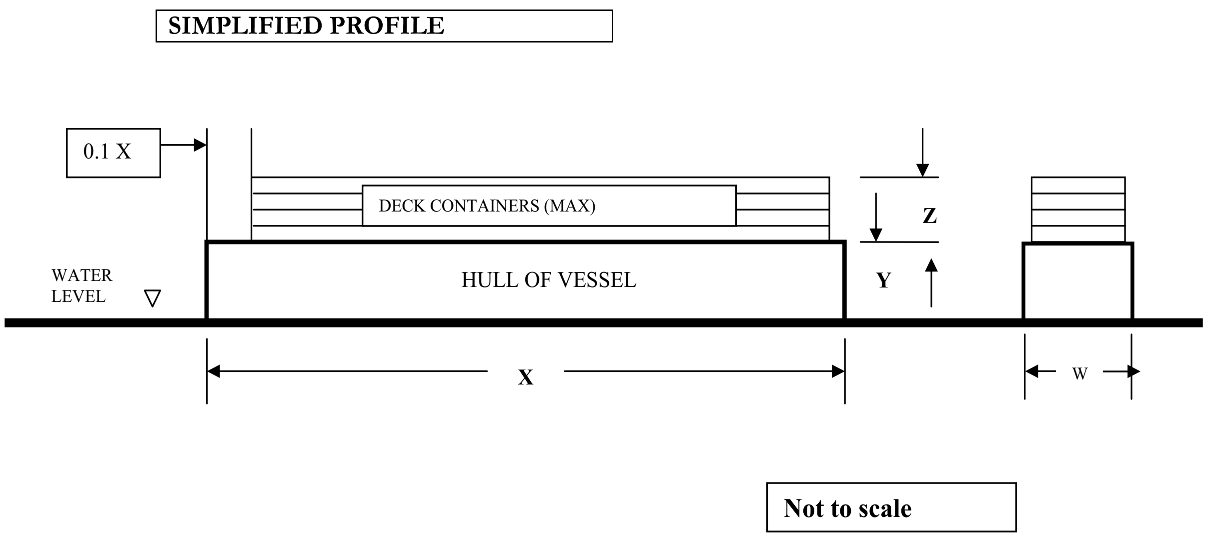
The proposed new crane and dock area, because of its distance from the 16L/34R runway centreline, and its substantially open lattice structure are considered unlikely to impact on the ILS.

Modelling of the Port Botany development therefore focused on the impact the various size container ships will have on the ILS. Container ships were modelled in several. positions and orientations with respect to the effected ILS components described earlier.

The classes of container ships that were considered, together with their dimensions are shown in Figure 16.

Figure 16 Class of Container ships

Class of Ship (TEU)	Simplified Dimensions (metres)					
	X	Y	Z	Y + Z	W	Water level to AHD
1500	200	7.5	8.0	15.5	25	+1.0m
3000	260	10.0	13.0	23.0	32	+1.0m
4500	300	12.0	15.5	27.5	37	+1.0m
6000	320	13.5	18.0	31.5	43	+1.0m



Computer modelling was undertaken using the Localizer AXIS 110 and Glide Path AXIS 330 programs. AXIS uses the same formulae as the GEC-Marconi VLOC. The validity of VLOC has been confirmed on United Kingdom Government Contracts and on work for the UK CAA.

Interference to either the Localizer or Glide Path course structure of about ± 10 µA or greater is considered as unacceptable.

5.4 Runway 16L Localizer

The Sydney Runway 16L Localizer is located on the extended runway centreline, approx 250m beyond the stop end of runway 16L.

The 16L Localizer co-ordinates are:

S33^{o} 58’ 23.88” E151^{o} 11’ 40.07” WGS 26.1 m AHD 3.7 m

Flight tests show that the Runway 16L Localizer course structure currently exhibits bends and deviations of ± 2 μA as a result of existing structures and objects on the airport.

5.4.1 Modelling

The impact on the 16L Localizer was assessed by modelling the various classes of container ships in the positions, and with orientations as shown in Table 5.1.

Table 5.1 Runway 16L Localizer

Distance offset from runway centreline	Distance forward of facility	Class of Ship	Orientation of ship wrt to runway centreline *				
500m east	400 m north 800 m north 1200 m north 1600 m north	1500	0^o	5^o	10^o	20^o	45^o
		3000	0^o	5^o	10^o	20^o	45^o
		4500	0^o	5^o	10^o	20^o	45^o
		6000	0^o	5^o	10^o	20^o	45^o

* 0^o indicates parallel to runway centreline

5.4.2 Results

The modelling results indicate that the TEU 1500 class of ship will have negligible impact on the 16L Localizer if they are maintained at least 500m east of the 16L/34R runway centreline.

For the TEU 3000 class of ship, the impact will be negligible if the ship is maintained at least 550m from the 16L/34R runway centreline.

For both the TEU 4500 and TEU 6000 classes of ships, an unacceptable level of interference will occur to the 16L Localizer, when those ships are transitting or docked at the Port.

Annex B 1.1 to 1.6 show typical results from modelling the impact of the different class of ships on the Sydney 16L Localizer.

5.4.3 Mitigation Strategy

Interference to the 16L Localizer from the TEU 4500 and TEU 6000 classes of ships can be reduced to an acceptable level by upgrading the current Localizer antenna system to a higher category, such as a 24 element antenna system. The current antenna system is a 12 element antenna array and is capable of being upgraded to a 24 element array without replacing the existing transmitter and building.

The cost of upgrading the existing 16L Localizer antenna, testing and re-commissioning is estimated to be $600,000.

Annex B 4.1 shows the typical radiation pattern of a 12 element Localizer antenna array. Shown in Annex B 4.2 is a the typical radiation pattern of a 24 element Localizer antenna. Note the smaller beam width which reduces the amount of side radiation, and the therefore the susceptibility of the Localizer to interference from lateral sources.

Annex B 1.7 to 1.8 show typical results for the interference caused by TEU 6000 class of ships on the SY 16L Localizer, if upgraded to a 24 element array. The interference, while still discernible, is reduced to an acceptable level of less than ± 10 μA.

5.5 Runway 34R Localizer

The Sydney Runway 34R Localizer is located on the extended runway centreline, approx 240m beyond the stop end of runway 34R.

The 34R Localizer co-ordinates are:

S33^{o} 56' 51.04" E151^{o} 11' 15.97" WGS 27.1 m AHD 3.1 m

Flight tests show that the Runway 34R Localizer course structure currently exhibits bends and deviations of ± 2 μA as a result of existing structures and objects on the airport.

5.5.1 Modelling

The impact on the 34R Localizer was assessed by modelling the various classes of container ships in the positions and with orientations as shown in Table 5.2.

Table 5.2 Runway 34R Localizer

Distance offset from Runway Centreline	Distance of facility	Class of Ship	Orientation of ship wrt to runway centreline *				
500 m east 600 m east	1600 m south 2000 m south 2400 m south 2800 m south 3200 m south	1500	0^{o}	5^{o}	10^{o}	20^{o}	45^{o}
		3000	0^{o}	5^{o}	10^{o}	20^{o}	45^{o}
		4500	0^{o}	5^{o}	10^{o}	20^{o}	45^{o}
		6000	0^{o}	5^{o}	10^{o}	20^{o}	45^{o}

* 0^{o} indicates parallel to runway centreline

5.5.2 Results

Modelling results indicate that the TEU 1500 class of ships will have negligible impact on the 34R Localizer, providing they are maintained at least 500m from the 16L/34R runway centreline.

However, for the TEU 3000, TEU 4500 and TEU 6000 classes of ships, an unacceptable level of interference will occur to the 34R Localizer, when those ships are either transitting to, or docked at the Port.

Annex B 2.1 to 2.8 show typical results of modelling the impact from the different class of ships on the Sydney 34R Localizer.

5.5.3 Mitigation Strategy

The interference to 34R Localizer from the TEU 3000 class of ships can be reduced to an acceptable level by upgrading the current Localizer antenna system to a higher category such as a 24 element antenna system. The current 34R Localizer antenna system is a 12 element array and is capable of being upgraded to a 24 element array without replacing the existing transmitter and building.

For the TEU 4500 and TEU 6000 classes of ships, in addition to upgrading the existing 34R Localizer antenna to a 24 element array, these ships would need to be maintained a distance greater than 550m from the 16L/34R runway centreline, in order to reduce the level of interference to an acceptable level.

The cost of upgrading the existing 34R Localizer antenna, testing and re-commissioning is estimated to be $600,000.

Annex B 4.1 shows the typical radiation pattern of a 12 element Localizer antenna array. Shown in Annex B 4.2 is a the typical radiation pattern of a 24 element Localizer antenna. Note the smaller beam width which reduces the amount of side radiation, and the therefore the susceptibility of the Localizer to interference from lateral sources.

5.6 Runway 34R Glide Path

The Sydney Runway 34R Glide Path is located on the western side of the 16L/34R runway centreline, 152m from the centreline and backset 350m from the 34R runway threshold.

The 34R Glide Path co-ordinates are:

S33^{o} 58' 05.77" E151^{o} 11' 29.31" WGS 25.1 m AHD 2.7 m

The 34R Glide Path course structure currently exhibits bends and deviations of ± 4 μA as a result of existing structures and objects in the airport environment.

5.6.1 Modelling

The impact on the 34R Glide Path was assessed by modelling the various classes of container ships in the positions, and with orientations as shown in Table 5.3.

Table 5.3 Runway 34R Glide Path

Distance offset from Runway Centreline	Distance of facility	Class of Ship	Orientation of ship wrt to runway centreline *				
500 m east	400 m south 800 m south 1200 m south 1600 m south	1500	0^{o}	5^{o}	10^{o}	20^{o}	45^{o}
		3000	0^{o}	5^{o}	10^{o}	20^{o}	45^{o}
		4500	0^{o}	5^{o}	10^{o}	20^{o}	45^{o}
		6000	0^{o}	5^{o}	10^{o}	20^{o}	45^{o}

* 0^{o} indicates parallel to runway centreline

5.6.2 Results

Modelling results indicate that the TEU 1500 class of ship will have negligible impact on the 34R Glide Path, provided they are maintained at least 400m east of the 16L/34R runway centreline.

For the TEU 3000, TEU 4500 and TEU 6000 classes of ships, these will have negligible impact on the 34R Glide Path if they are maintained at least 500m east of the 16L/34R runway centreline.

Annex B 3.1 to 3.8 show typical results of modelling the impact from the different class of ships on the Sydney 34R Glide Path.

5.6.3 Mitigation Strategy

None are required if the TEU 1500 class of ships is maintained at greater than 400m east of the 16L/34 Runway centreline, and the TEU 3000, TEU 4500 and TEU 6000 are maintained at least 500m east of the runway centreline.

The above lateral separations from the 16L/34R runway centreline are required to be maintained for at least 1000m south of the 34R Glide Path facility.

5.7 Future Technologies

Current forecasts indicate that ILS will be required at Sydney Airport until 2015, and possibly as late as 2020. Satellite based landing systems are emerging as the replacement technology for ILS. An alternative, but rarely used ground based landing system, is MLS (Microwave Landing System).

Both MLS and satellite based landing systems require significantly less site restrictions than does ILS. In circumstances where these technologies are installed on Runway 16L and 34R, and the existing ILS on these runways is decommissioned, it is not expected that the expansion of Port Botany will have as significant an impact on the navigation systems at Sydney Airport.

6 Conclusion

6.1 Sydney Airport Terminal Approach Radar (Primary)

The main effect on the TAR Primary will be obstruction of low altitude targets along the azimuth of the Port Botany Expansion. Currently, targets at sea level are visible to 20 nm. After the expansion, targets will not be visible below 1200’ at 20 nm. Some target detection sensitivity reduction over the La Perouse Peninsula because of primary reflection and increased false targets inside 10 nm due to “ring around”.

6.2 Sydney Airport Terminal Approach Radar (Secondary)

Similarly the TAR Secondary will suffer obstruction of low altitude targets along the azimuth of the Port Botany Expansion. Currently, targets at sea level are visible to 14 nm. After expansion, targets will not be visible below 1200’ at 14 nm. There will be an increase in reflections due to the large flat sides of the ships and containers. The reflection path will be via the surface of the water, increasing the path attenuation and improving the possibility of detecting the reflecting signals and removing them.

6.3 Mount Boyce Route Surveillance Radar (Secondary)

The Mount Boyce Secondary will suffer an increase in reflections due to the large flat sides of the ships and containers. The reflection path will be via the surface of the water, increasing the path attenuation and improving the possibility of detecting the reflecting signals and removing them.

6.4 Sydney Airport Precision Approach Runway Monitor (Secondary)

Based on the results of the initial analysis, the proposed developments are not within the normal siting guidelines for PARM operation. Initial results indicate that the proposed structure could have a major impact on PARM operations in terms of azimuth accuracy due to horizontal multipath degradation.

PRM operation and PARM’s radar as a backup to Sydney TAR will be affected by the proposed development. Further investigation is required to examine the impacts of such structures. Several factors can influence the operation of the PARM and the construction, including proposed development timing and operation of the port and required operation of the PARM. Since the proposed container vessels are not static structures, the impact can be small or large depending on time of usage for the PARM and the ships, and also the orientation of the vessels – either broadside or head-on when viewed by the PARM.

6.5 Sydney 16L Localizer

Modelling indicates that the proposed expansion will significantly interfere with the operation of the Sydney 16L Localizer. The interference can be mitigated by upgrading the existing 16L Localizer antenna system to a 24 element array, estimated to cost $600,000. All classes of container ships will also be required to be maintained at a distance greater than 500m east of the 16L/34R runway centreline.

6.6 Sydney 34R Localizer

Modelling indicates the proposed expansion will significantly interfere with the operation of the Sydney 34R Localizer. The interference can be mitigated by upgrading the existing 34R Localizer antenna system to a 24 element array, estimated to cost $600,000. In addition, TEU 1500 and TEU 3000 classes of container ships will be required to be maintained at a distance greater than 500m east of the 16L/34R runway centreline. TEU 4500 and TEU 6000 classes of ships will be required to be maintained at a distance greater than 550m from the 16L/34R runway centreline.

6.7 Sydney 34R Glide Path

Modelling indicates the proposed expansion will not interfere with the operation of the Sydney 34R Glide Path, providing all classes of container ships are maintained at a distance greater than 500m east of the 16L/34R runway centreline, for a distance of 1000m south of the 34R Glide Path facility (equivalent to 650m south of the 34R runway threshold).

6.8 Summary

The level of radar sensor performance degradation caused by the Port Botany Expansion is manageable using system tuning and site operating condition adjustments that are available for the various radar systems. The effects on the operational performance of the radar coverage will be minor and the system safety will not be compromised.

The only exception to this is the Precision Approach Runway Monitor, the azimuth errors introduced to the southern approach path will compromise the system safety margins. No remedy is available at this time.

The PARM is scheduled for replacement around 2009, this is about the commissioning time of the first berth in the Port Botany Expansion. There is no other type of sensor or alternative technology currently approved by either the FAA or CASA that meets the licensing requirements for independant parallel approaches at this time.

Both the 16L and 34R instrument landing systems will be required to be upgraded at a total cost of $1.2 million. In addition the TEU 1500 and 3000 classes of ships will be required to me maintained at more than 500m from the 16L/34R runway centreline, and TEU 4500 and TEU 6000 classes of ships at greater than 550m from the runway centreline. The lateral separations will be required to be maintained for 650m south of the 34R runway threshold.

7 Definitions

4/3 Earth Chart

A graphical representation of the earths surface with respect to the radio frequency propagation path, RF travels in a curve with a radius of 4/3 that of the earth. The RF path is drawn as a straight line so the earths surface is a curve falling away from the RF path.

AEI

Airways Engineering Instruction, a document describing the standards, maintenance procedures and operation of any navigational aid in use by Airservices Australia.

Angels

unwanted primary radar echoes that cannot be explained.

Blanking Zone

an area defined in the radar tracker in which all primary tracks are suppressed.

Boresight

The horizontal centre of the antenna interrogate pattern in space, 0^{o} of the SUM pattern.

CASA

Civil Aviation Safety Authority, the regulatory and licensing agency

Clutter

Unwanted primary radar targets from any source.

Combined Track

A track that contains both primary and secondary radar information.

Coverage

the area in which the radar detects targets.

CSA

Cross Sectional Area, the equivalent spherical surface area of a target.

Difference Pattern

The part of the SSR antenna pattern that supplies the off boresight information

FAA

The Federal Aviation Agency, the United States regulatory and licensing agency.

MRT

Multi Radar Tracking, a process in the display software that combines tracks from more than one radar to produce a single system track

Monopulse Azimuth

the process by which the aircraft azimuth is calculated from the antenna pointing angle (boresight) ± the measured OBA.

Multipath

The radar energy arrives at the targets by diverse paths, caused by either horizontal or vertical reflections.

NM

Nautical Mile (international, 1853 metres).

Non Initialisation Area

an area defined in the radar tracker that does not allow the creation of a primary track, existing primary tracks may transit the area.

NTZ

No Trangression Zone, an area between parallel runways that is forbidden to aircraft during simultaneous approaches. Predicted entry causes visual alarms and entry to the NTZ causes audio and visual alarms.

OBA

Off Boresight Angle, the angle difference between the target angle and the boresight of the antenna system. Measured by comparing the phase of the energy in the SUM pattern to the phase of the energy in the DIFFERENCE radiation pattern.

PARM

Precision Approach Runway Monitor, a specialized high update rate, high accuracy secondary surveillance radar, maximum range usually 40NMI. Specifically designed for parallel runway operations.

Parrot

a secondary surveillance radar test target, commonly an aircraft transponder located at a known ground position. Used for system alignment and accuracy monitoring.

PRF

Pulse Repetition Frequency, the interrogation rate of the radar.

Primary

The PSR, a radar system that relies on reflected energy for target detection.

PSR

Primary Surveillance Radar, a radar system that relies on reflected energy for target detection.

Reflection

An unwanted image radar return, either primary or secondary, caused by the energy travelling along an abnormal path to and from the target, usually occurs on the wrong azimuth.

Reply

The aircraft transponder’s answer to an SSR interrogation.

Ring Around

A primary target that due to its large physical size generates a ring of received energy at the target range. The ring may or may not be a full circle.

RSR

Route Surveillance Radar, a radar used for enroute guidance of aircraft. Usually an SSR.

Secondary

Secondary Surveillance Radar, A radar system requiring a transponder on board the aircraft.

SMR

Surface Movement Radar, specifically designed for surveillance of the airport surfaces, and detection of landing aircraft at the runway thresholds.

SSR

Secondary Surveillance Radar, A radar system requiring a transponder aboard the aircraft.

STC

Swept Time Constant, a predetermined system attenuation, usually variable in distance. Used to compensate for large signal amplitudes close to the sensor.

SUM Pattern

The part of the SSR antenna pattern that is the reference for OBA measurement.

TAR

Terminal Approach Radar, a radar used for terminal guidance of aircraft, IE close to airports. Usually a P+S Radar.

Target

An aircraft, that is candidate for radar detection.

Tracker, Track Processor (TPR1000).

A piece of radar equipment whose task is to correlate the target with its history to ensure that the same target is considered each time.

Tracking

The process of relating targets to their positional history, by prediction and association of the previous positions, performed by the track processor.

Annex A Radar Coverage Effects

1 Annex Scope

The aim of these graphs is to demonstrate the changes in radar performance that will occur when the Port Botany expansion is operational.

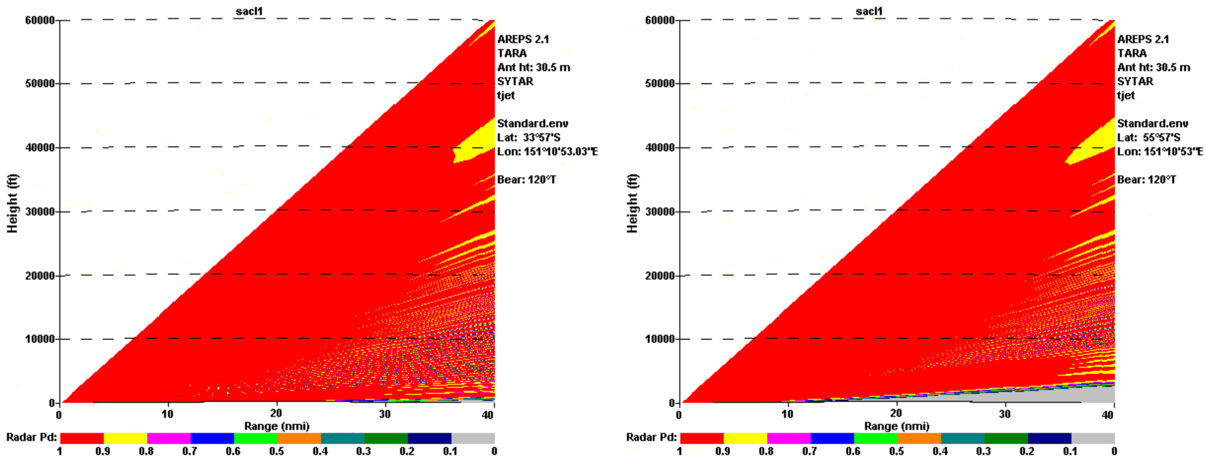
1.1 Coverage Software:

These antenna patterns are produced using Advanced Refractive Effects Prediction System, Version 2.1.200, using APM Version 1.30.0.5. Supplied by SPAWAR NAVAL Systems San Diego.

AREPS is intended for performance prediction of military radar systems, the following vertical patterns are representative of the changes in performance that will occur, but not intended to be exact predictions.

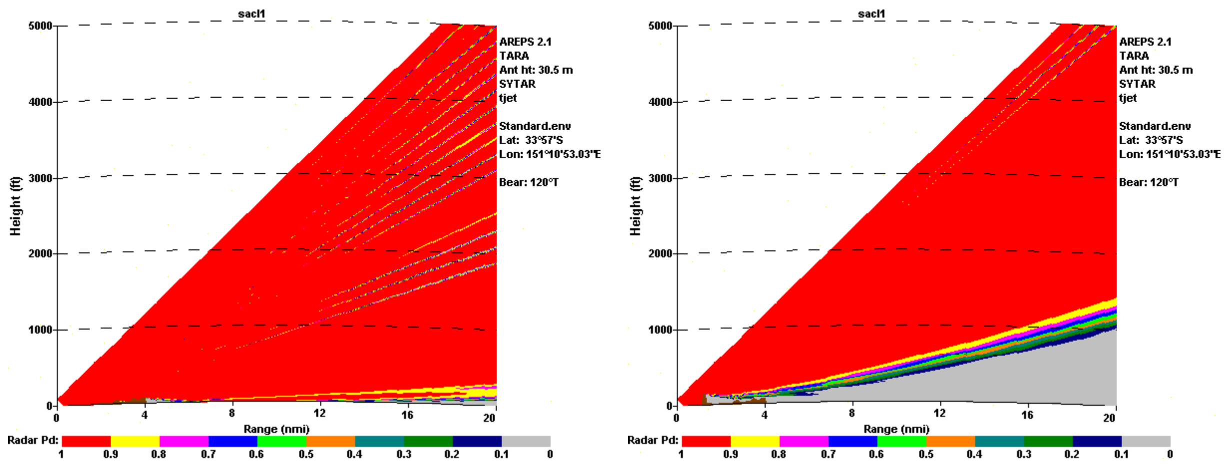
2 Terminal Approach Radar (Primary)

Figure 17 Vertical Coverage TAR Primary: 120º Radial



Pre Port expansion

Post Port expansion

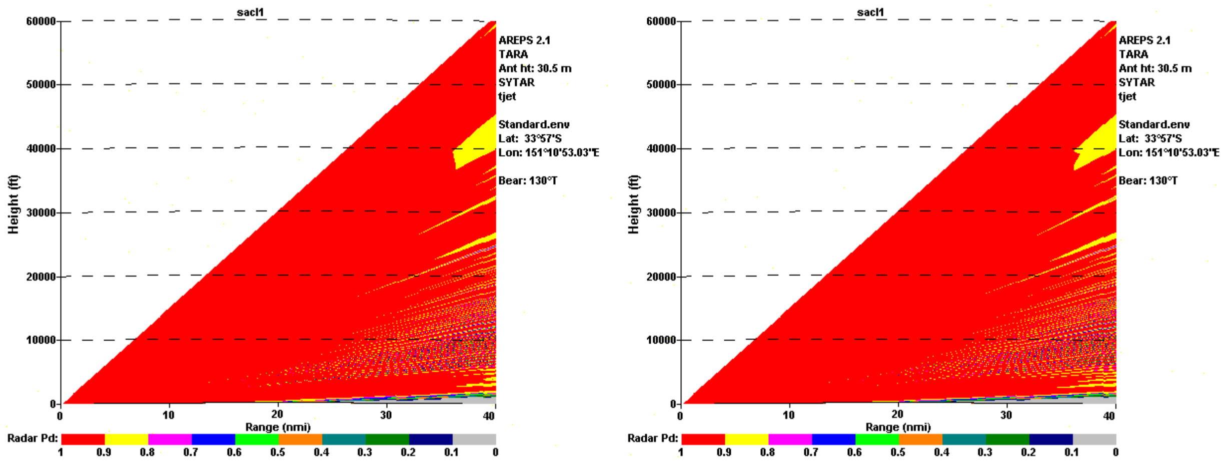


Coverage changes:

1) an increase in the minimum detection altitude at 16NMI from 200 feet to 1000 feet.

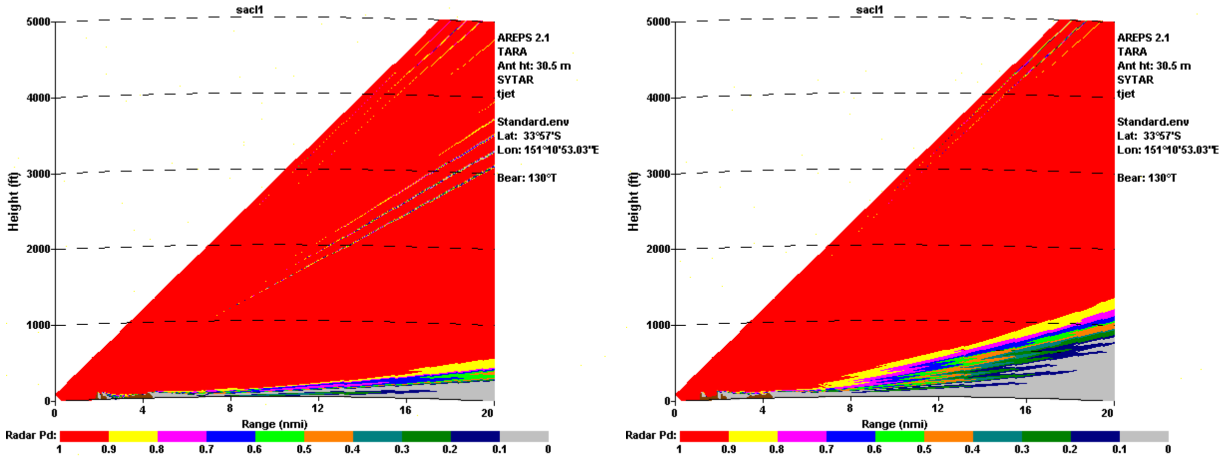
2) - no significant changes in the upper coverage.

Figure 18 Vertical Coverage TAR Primary: 130º Radial



Pre Port expansion

Post Port expansion

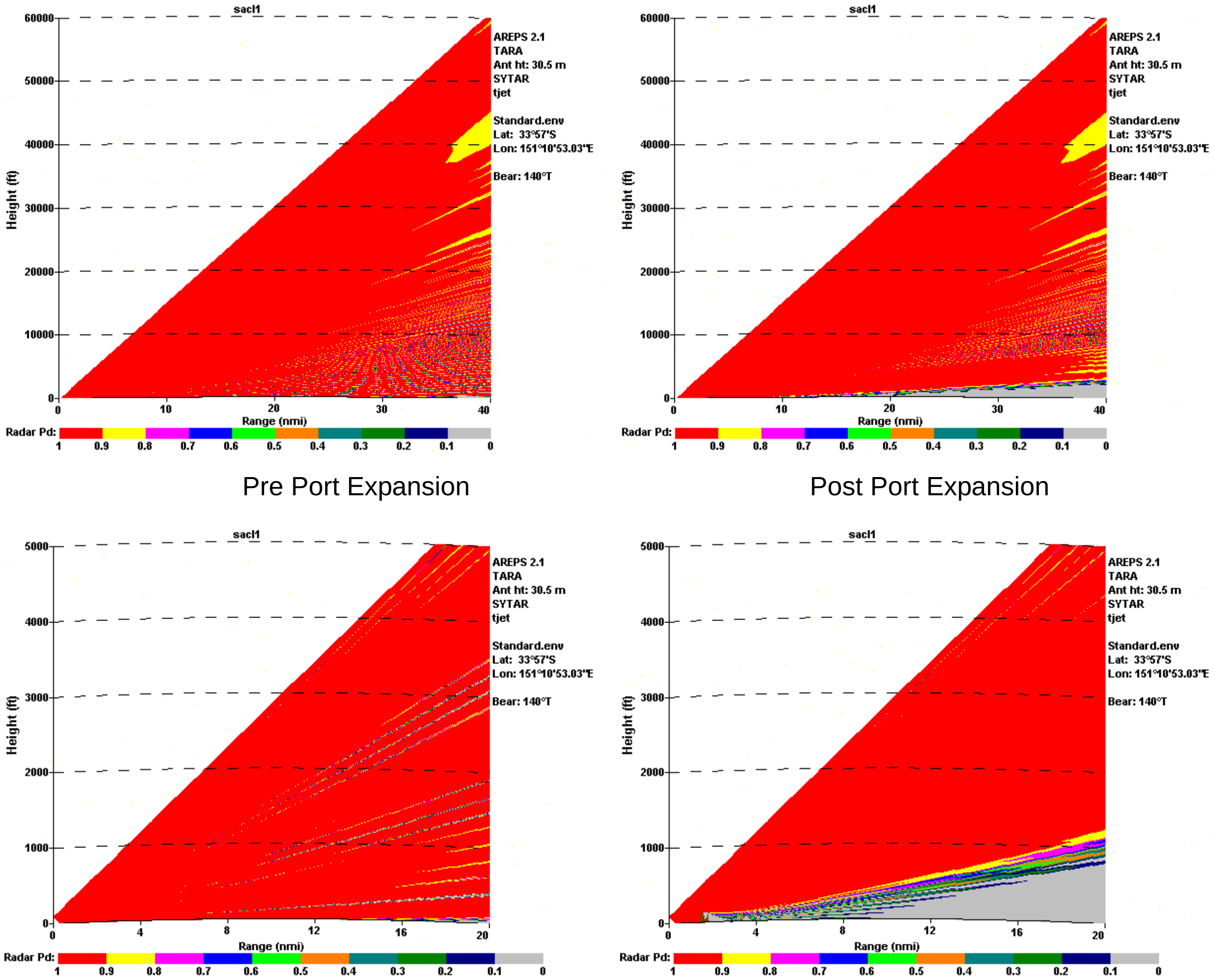


Coverage changes: -

1) an increase in the minimum detection altitude at 16NMI from 400 feet to 1000 feet.

2) no significant changes in the upper coverage.

Figure 19 Vertical Coverage TAR Primary: 140º Radial

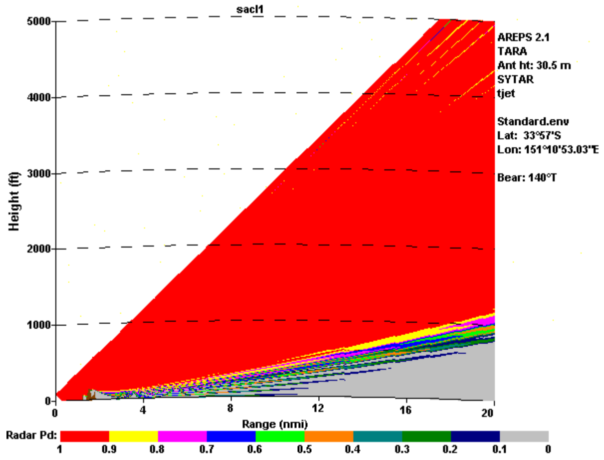


Coverage changes: -

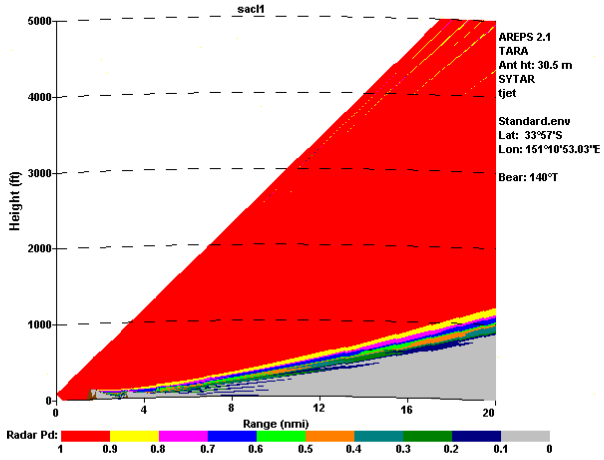
1) an increase in the minimum detection altitude at 16NMI from 100 feet to 800 feet.

2) no significant changes in the upper coverage.

Figure 20 Vertical Coverage TAR Primary: Vessels In Transit 140º Radial

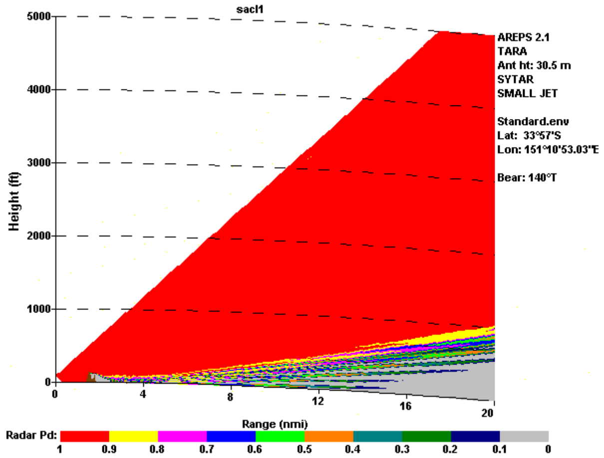


Vessel in transit abeam turning bay

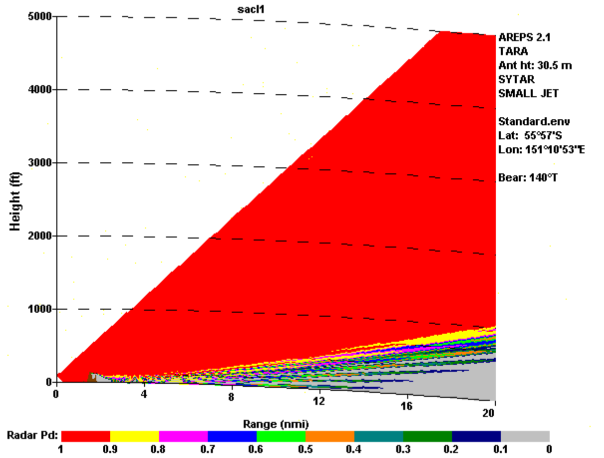


Vessel in transit abeam Molineaux Point

6000 TEU Vessel

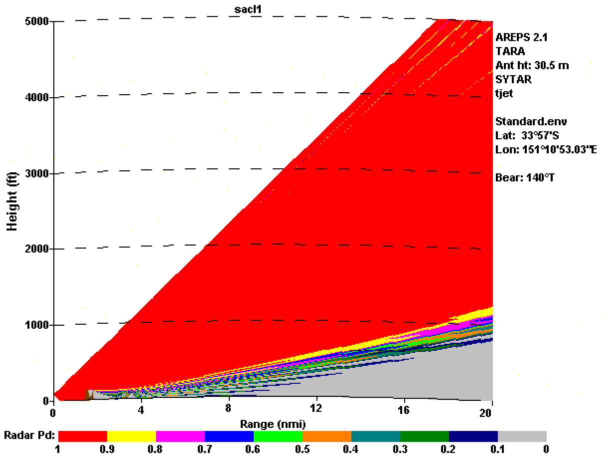


Vessel in transit abeam turning bay



Vessel in transit abeam Molineaux Point

1500 TEU Vessel



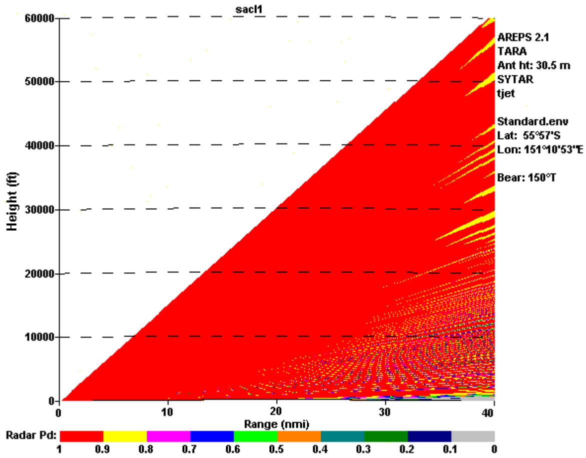
140^{O} Radial Post Development

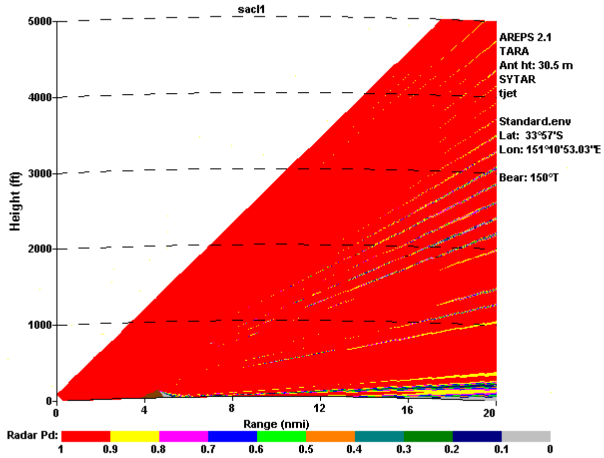
Coverage changes, reference post port expansion coverage,: -

1) no significant changes in the upper coverage.

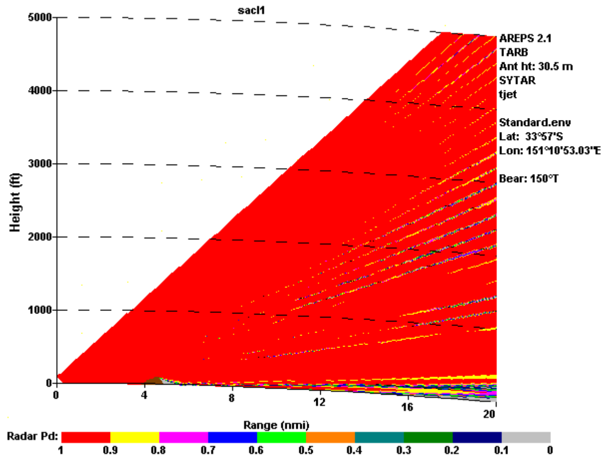
2) no significant changes in the upper coverage.

Figure 21 Vertical Coverage TAR Primary: 150º Radial





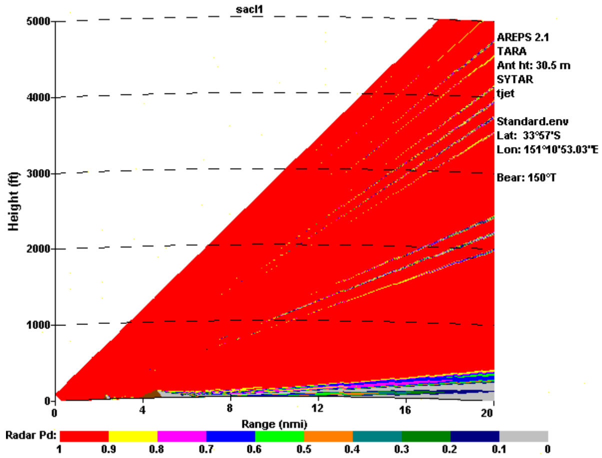
A comparative plot of the second primary radar transmitter to show that the differences are minor.



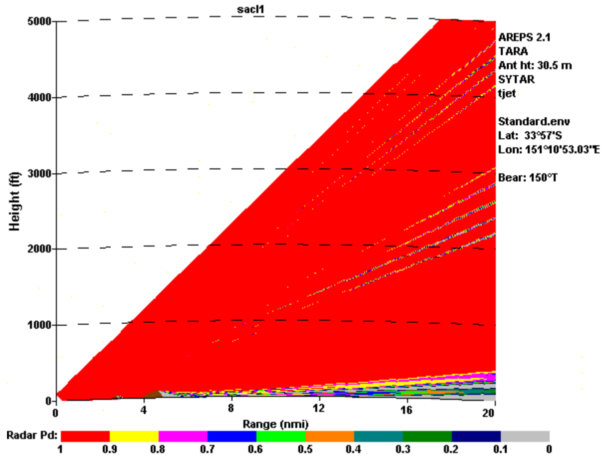
Coverage changes: -

1) Nil, the development is not in the line of site for this radial, shown for comparison with vessels in transit.

Figure 22 Vertical Coverage TAR Primary: Vessels In Transit 150º Radial

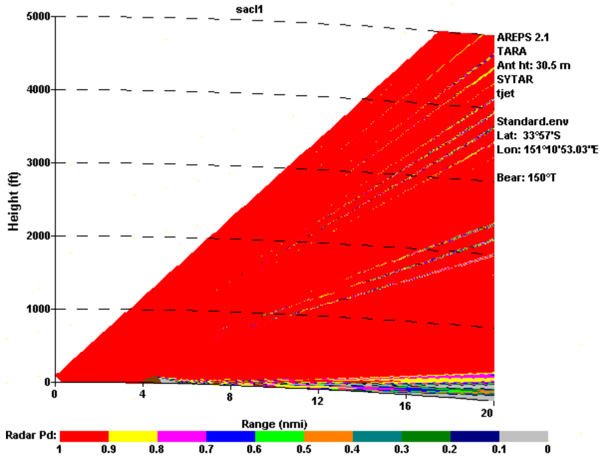


Vessel in transit abeam turning bay

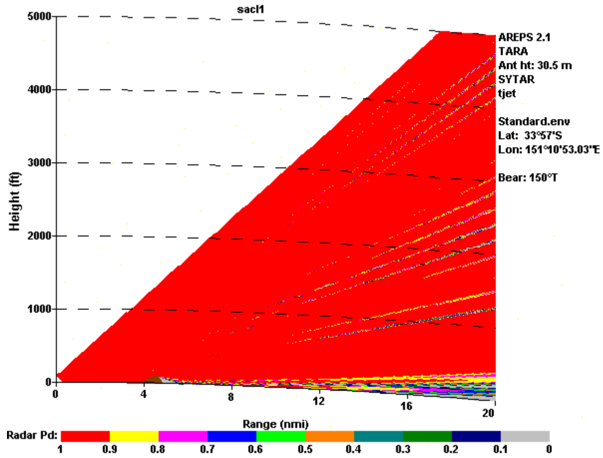


Vessel in transit abeam Molineaux Point

6000 TEU Vessel

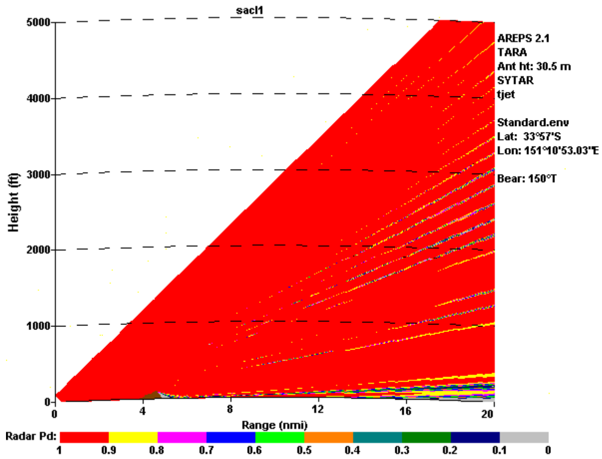


Vessel in transit abeam turning bay



Vessel in transit abeam Molineaux Point

1500 TEU Vessel



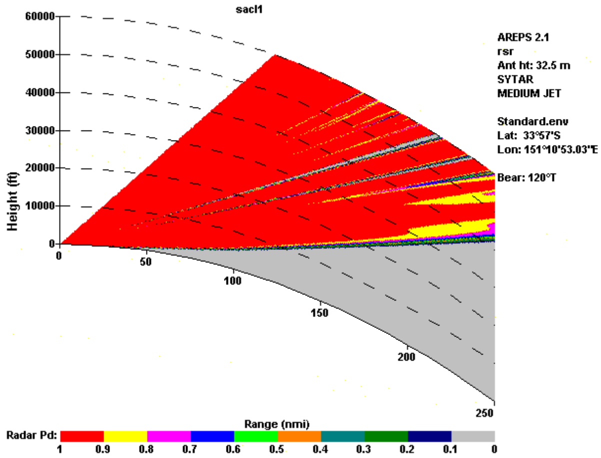
150^{0} Radial Pre and Post Development

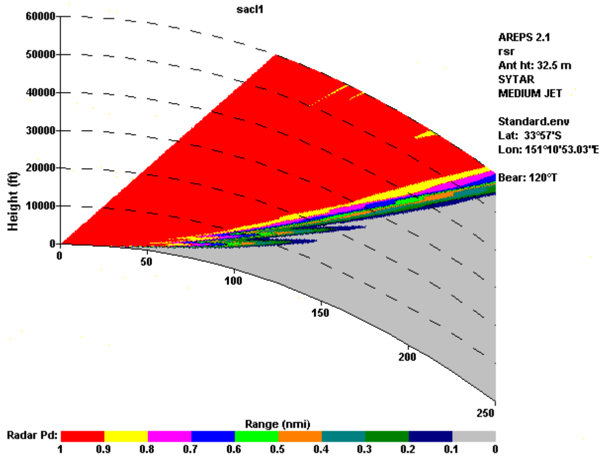
Coverage changes, reference post port expansion coverage: -

1) a change in the lobing structure at low altitude for both vessel types, not significantly altering the detection altitude.

3 Terminal Approach Radar (Secondary)

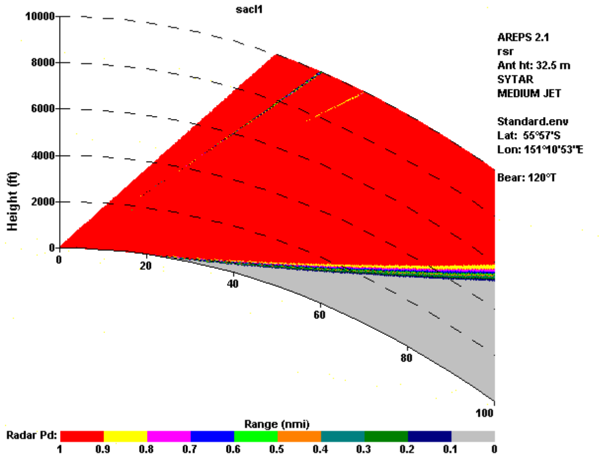
Figure 23 Vertical Coverage TAR SSR: 120º Radial

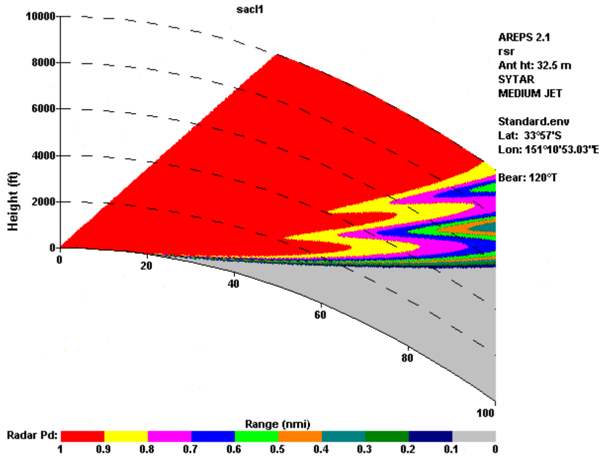




Pre Port Expansion

Post Port Expansion



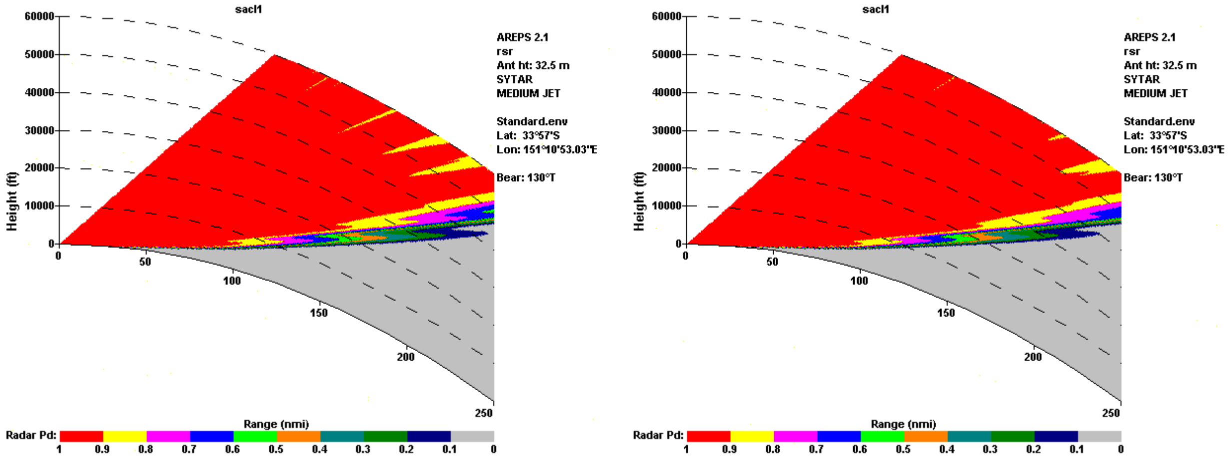


Coverage changes:

1) minor change in coverage inside 40NMI.

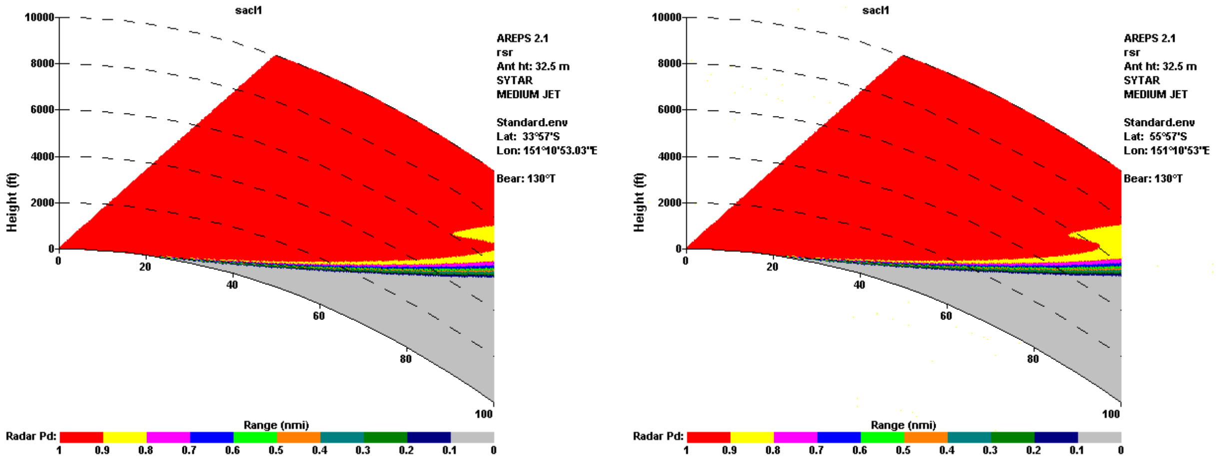
2) an increase in the minimum detection altitude at all ranges, the changes in coverage are in the lower 0.5 of the coverage and may result in a range reduction of 2-5NMI at maximum range.

Figure 24 Vertical Coverage TAR SSR: 130º Radial



Pre Port Expansion

Post Port Expansion

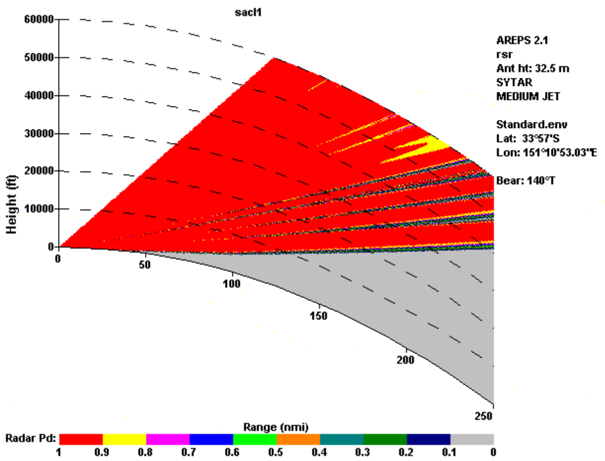


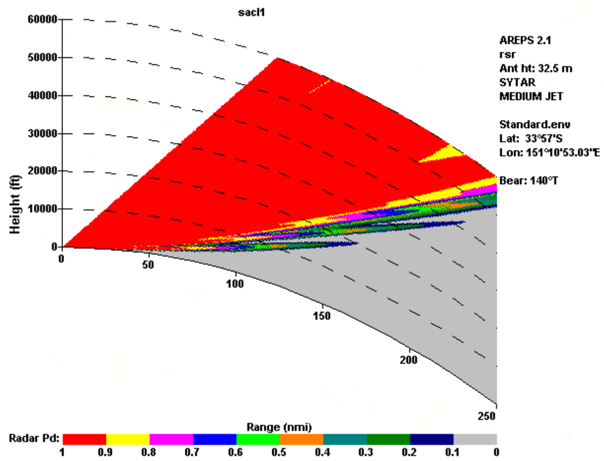
Coverage changes: -

1) no significant changes in the lower coverage.

2) no significant changes in the upper coverage.

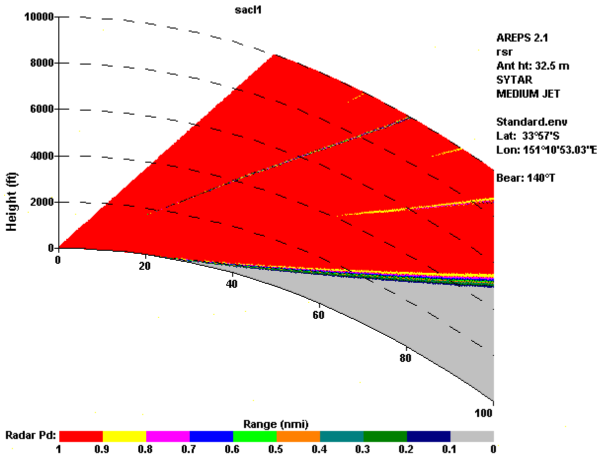
Figure 25 Vertical Coverage TAR SSR: 140º Radial

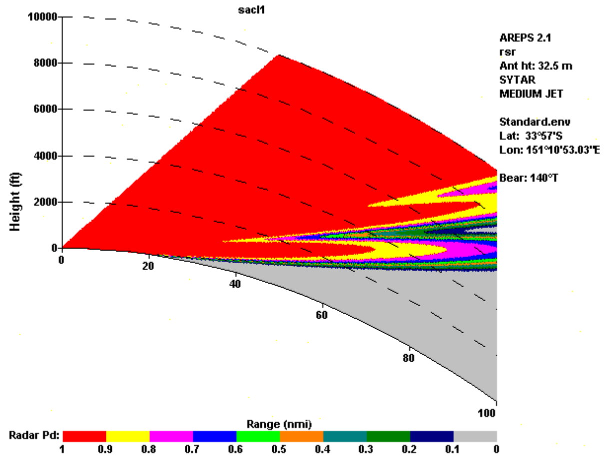




Pre Port Expansion

Post Port Expansion



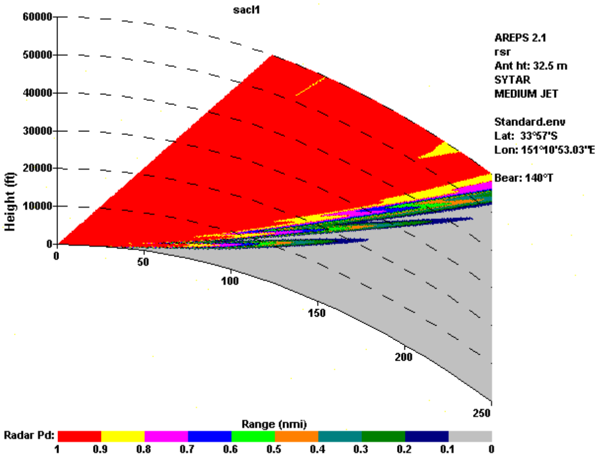


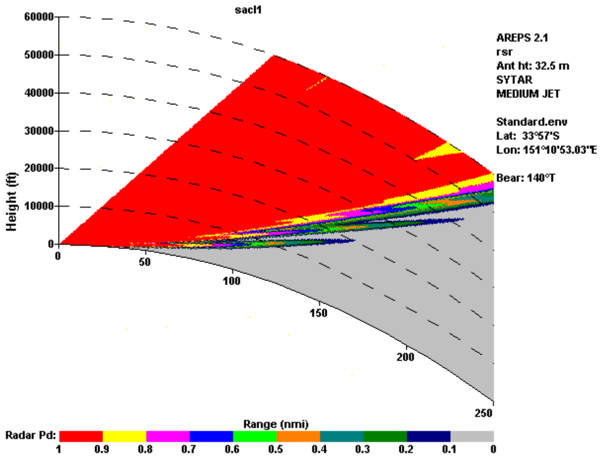
Coverage changes: -

1) minor changes in the lower coverage inside 40NMI.

2) an increase in the minimum detection altitude at all ranges, the changes in coverage are in the lower 0.5 of the coverage and may result in a range reduction of 2-5NMI at maximum range.

Figure 26 Vertical Coverage TAR SSR: Vessels In Transit 140º Radial

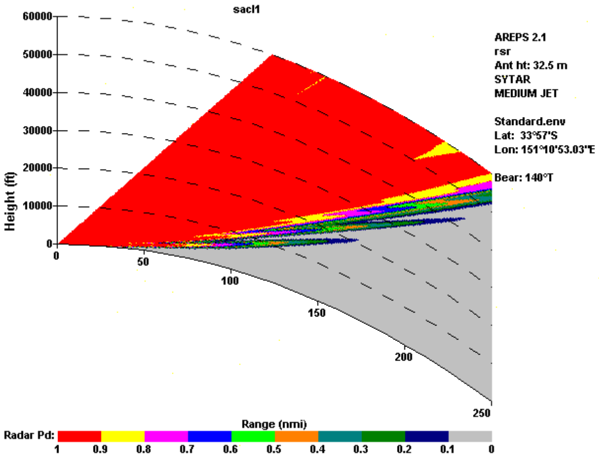


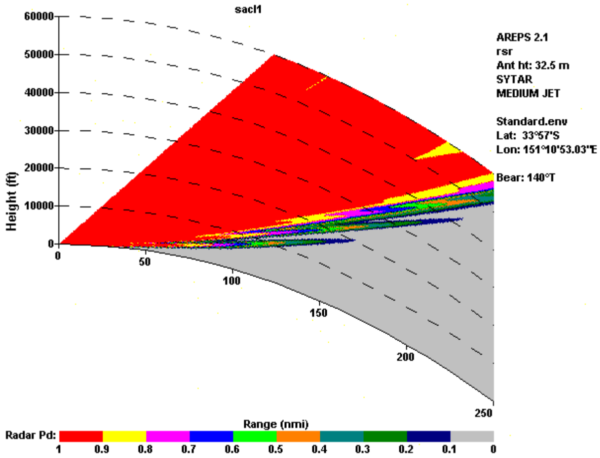


Vessel in transit abeam turning bay

Vessel in transit abeam Molineaux Point

6000TEU Vessel

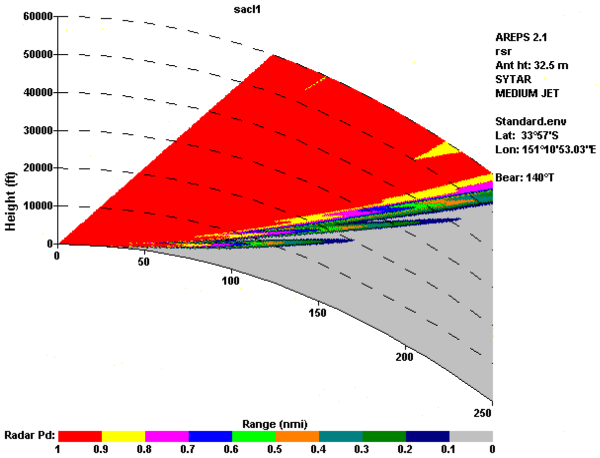




Vessel in transit abeam turning bay

Vessel in transit abeam Molineaux Point

1500TEU Vessel

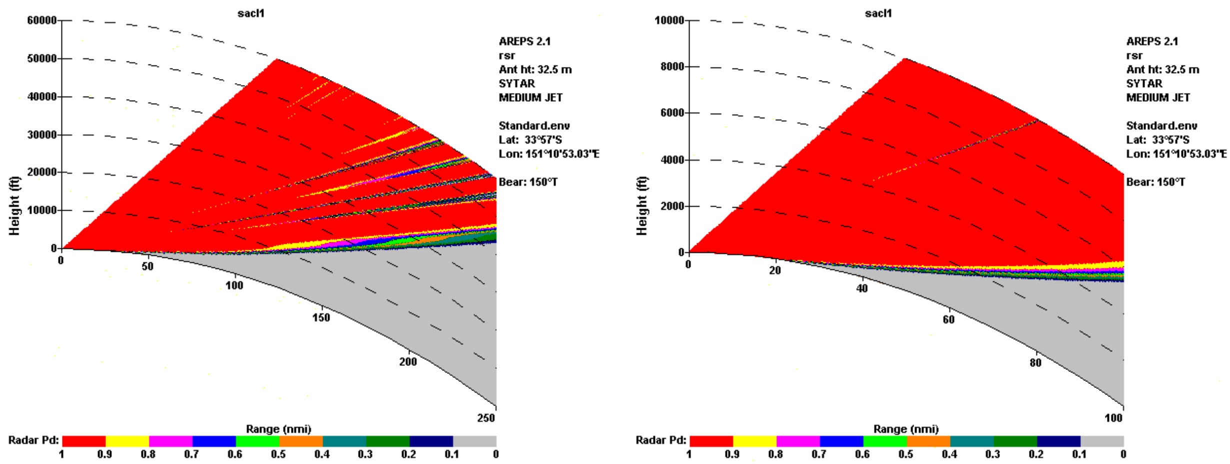


140^{o} Radial Post Expansion

Coverage changes, reference post port expansion coverage:

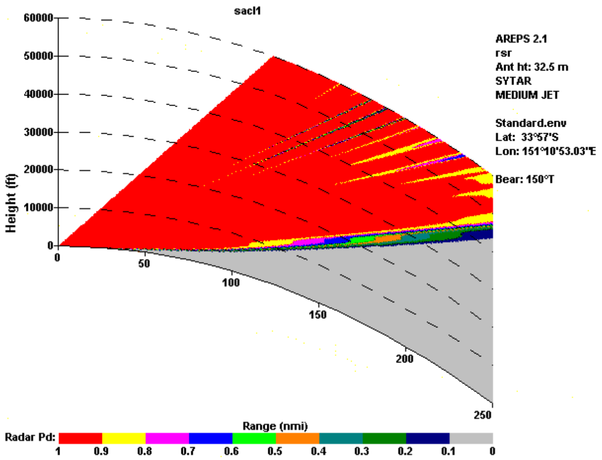
1) changes in the lobing structure of the lower 0.5^{o} of the coverage, no significant performance change.

Figure 27 Vertical Coverage TAR SSR: 150º Radial

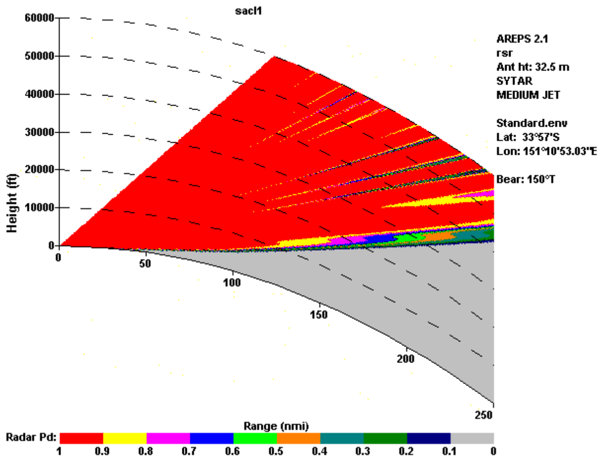


This radial is not line of site for the port expansion so the only coverage changes are due to vessels transiting this radial.

Figure 28 Vertical Coverage TAR SSR: Vessels In Transit 150º Radial

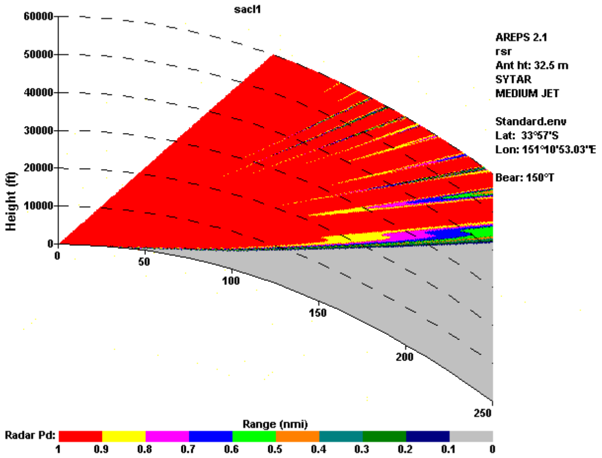


Vessel in transit abeam turning bay

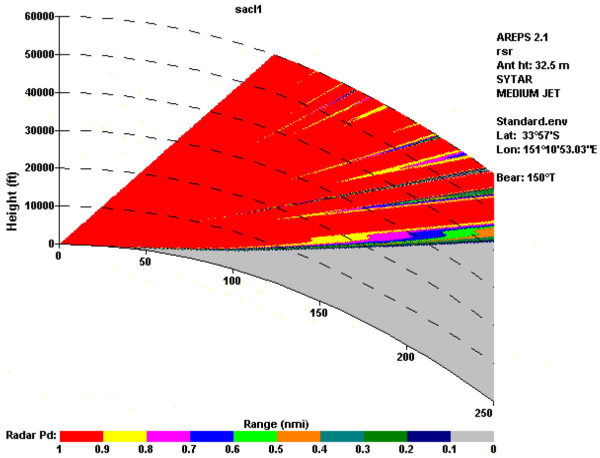


Vessel in transit abeam Molineaux Point

6000TEU Vessel

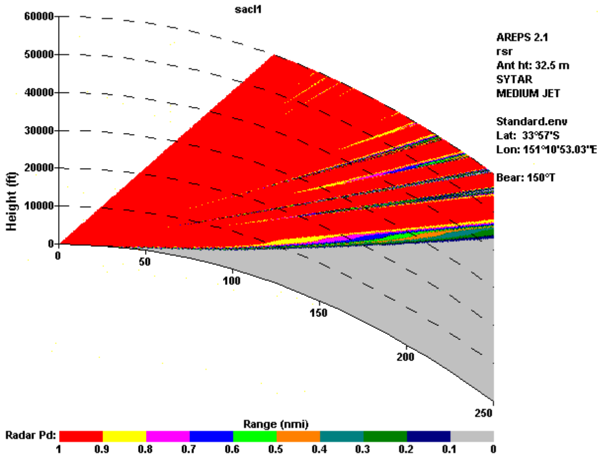


Vessel in transit abeam turning bay



Vessel in transit abeam Molineaux Point

1500TEU Vessel



150^{0} radial Pre and Post Development

Coverage changes, reference post port expansion coverage:

1) changes in the lobing structure of the lower 0.5^{0} of the coverage, no significant performance change.

4 Precision Approach Runway Monitor (PARM).

4.1 Reference background:

The PARM impact zones and analysis are based on the requirement of the PARM system which are defined in AEI-7.1609 – PRM Site Restrictions (Issue No.3). PRM Performance Requirements include Azimuth accuracy, airspace for PRM operation (line-of-sight), airspace requirement when used as a backup to the Sydney TAR, and clear line of sight to the two parrots.

4.2 Signal Multipath

4.2.1 Purely vertical multipath has no effect on the azimuth performance of the PARM, as the signal only adds and subtracts from the sum and difference signals by the same amount.

4.2.2 If however the multipath is horizontal (lateral), the sum and difference signals are perturbed differently corresponding to the amplitude difference between the sum and difference antenna patterns at the azimuth angle at which the reflector is located.

4.2.3 Horizontal (lateral) multipath can cause severe monopulse angle errors. Figure 30 shows the maximum error possible. In computing these error curves, the target of interest was located at the antenna beam boresight, while a reflector was rotated clockwise from the target (0^o) through 180^o in azimuth. Each curve corresponds to a different reflection curve magnitude. This is the magnitude of the indirect signal relative to the direct signal. At each reflector position, the phase angle of indirect (reflected) signal relative to the direct reply signal was set to a value which maximised the error.

4.2.4 For reflection that are at least 20dB down on the direct signal the angle error is significant only when the reflector is within $\pm 20^o$ of boresight.

4.3 Analysis:

The analysis examines the effects of reflections and obstructions from building structures on the PARM's azimuth accuracy – the determining parameter for PRM operation.

4.4 Analysis method:

Line-of-sight from the PARM to the proposed structure(s) were taken to analyse the impact of objects on the incident power of the antenna. The analysis uses radials (angles from True North) of 141^o, 145^o, 146^o+, 152^o and 157^o. These radials are classified as Zone2.2 and Zone 3.2 in the Site Restriction's manifest (AEI-7.1609).

For the given radial, the PARM elevation angle looking toward the proposed structure, was calculated and the incident power (Reflect), see Figure 29, was compared to the antenna gain 50 ft above the threshold (Target), see Figure 29. The analysis criteria requires that the ratio of Target power to Reflect power be greater than 6dB to ensure azimuth accuracy is maintained for PRM operation, see Figure 30.

The results of the analysis at the projected radials are summarised in Table 4.1.

Table 4.1 PARM Reflection Analysis

Table 1:

PARM Ant. Ht. (m):	31.2					
Target Power @ 50 Feet (dB):	-9					
Structure	**Range**	**Obj Ht (m)**	**PRM Eleva-tion**	**Relected Pwr (dB)**	**Target/Reflect r (dB)**	**Impact**
141 deg from PARM	2100	20	-0.31	-8	1	Az Error
145 deg from PARM	2100	20	-0.31	-8	1	Az Error
146+ deg from PARM	2400	51	0.47	-7	2	Az Error
152 deg from PARM	3350	51	0.34	-7	2	Az Error
157 deg from PARM	3900	32	0.01	-7.5	1.5	Az Error

Note: All heights shown are in AHD (Australian Height Data).

Note: PARM Antenna Height (m) is taken at the base of the antenna.

Note: Target Power (dB) [Ant Gain] & Ant Gain 50 ft Threshold are taken from the graph of PARM Elevation Pattern (1030 MHz). Reference: Figure 3.4.1.2.1-1 of the PARM Schedule of Technical Data - G - Volume 1A. (See Figure 29)

Note: Target/Reflect power ratio should be 6 dB or more to meet the operational requirement of the PARM's azimuth accuracy.

The above table (Table 1) shows the antenna elevation gain when looking in the direction of the structures (cargo ships). When this Gain is compared to that for an aircraft 50 ft above 34R threshold, the Target power to Reflected power ratio is relatively small. The analysis criteria implied that any ratio less than about 6dB can result in errors in excess of the requirement for PARM's operation (accuracy).

Figure 29 PARM Vertical Radiation Pattern

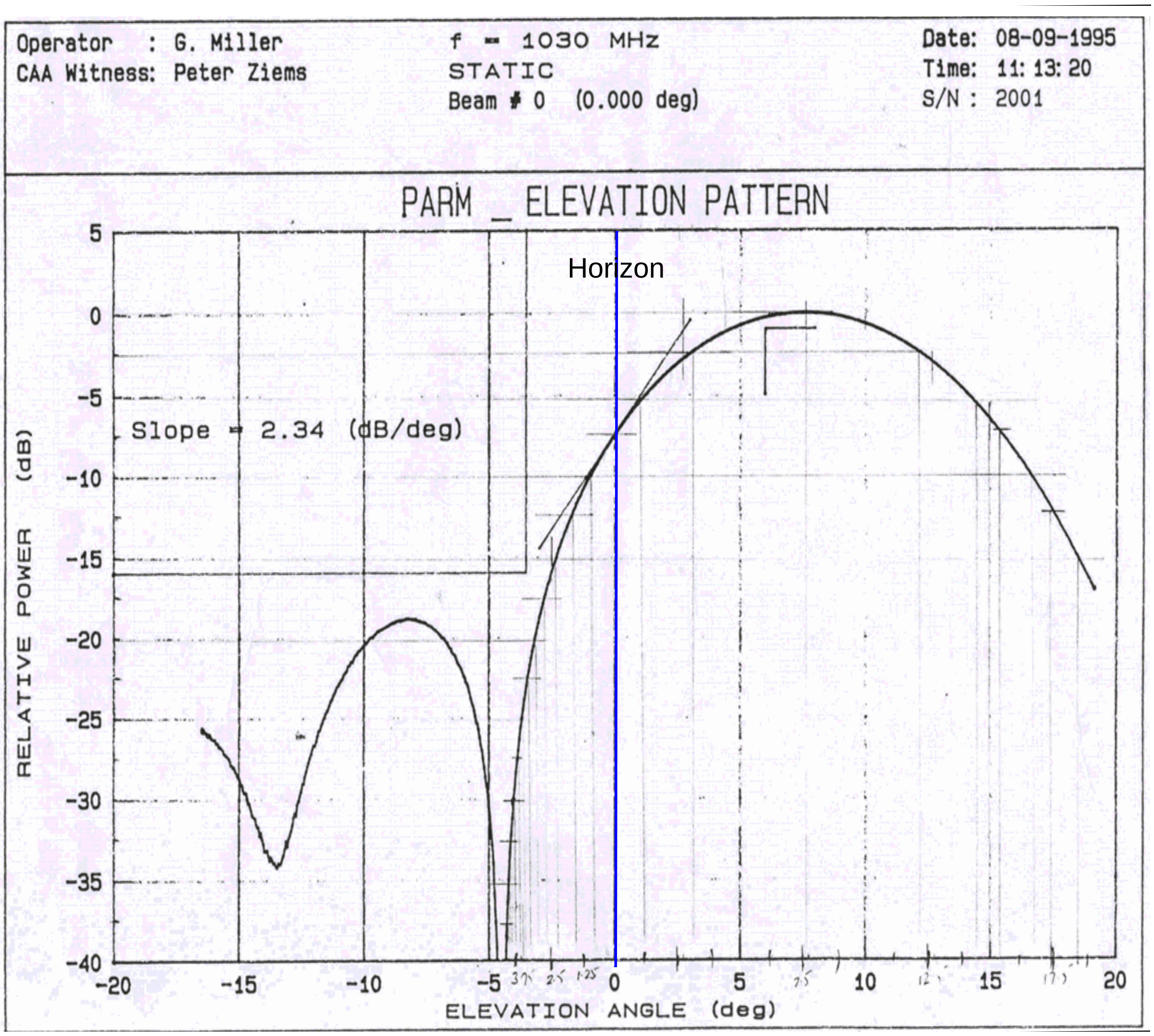


Figure 30 PARM Multipath Monopulse Azimuth Errors

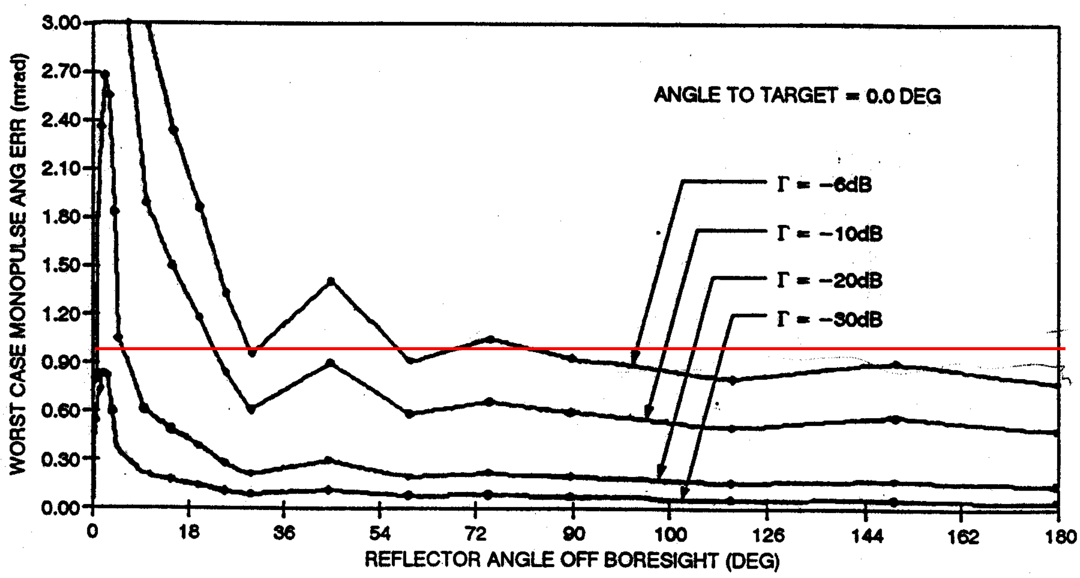


Figure C-3. Monopulse Angle Error Due to Horizontal Multipath

Figure 31 PARM Siting Restrictions

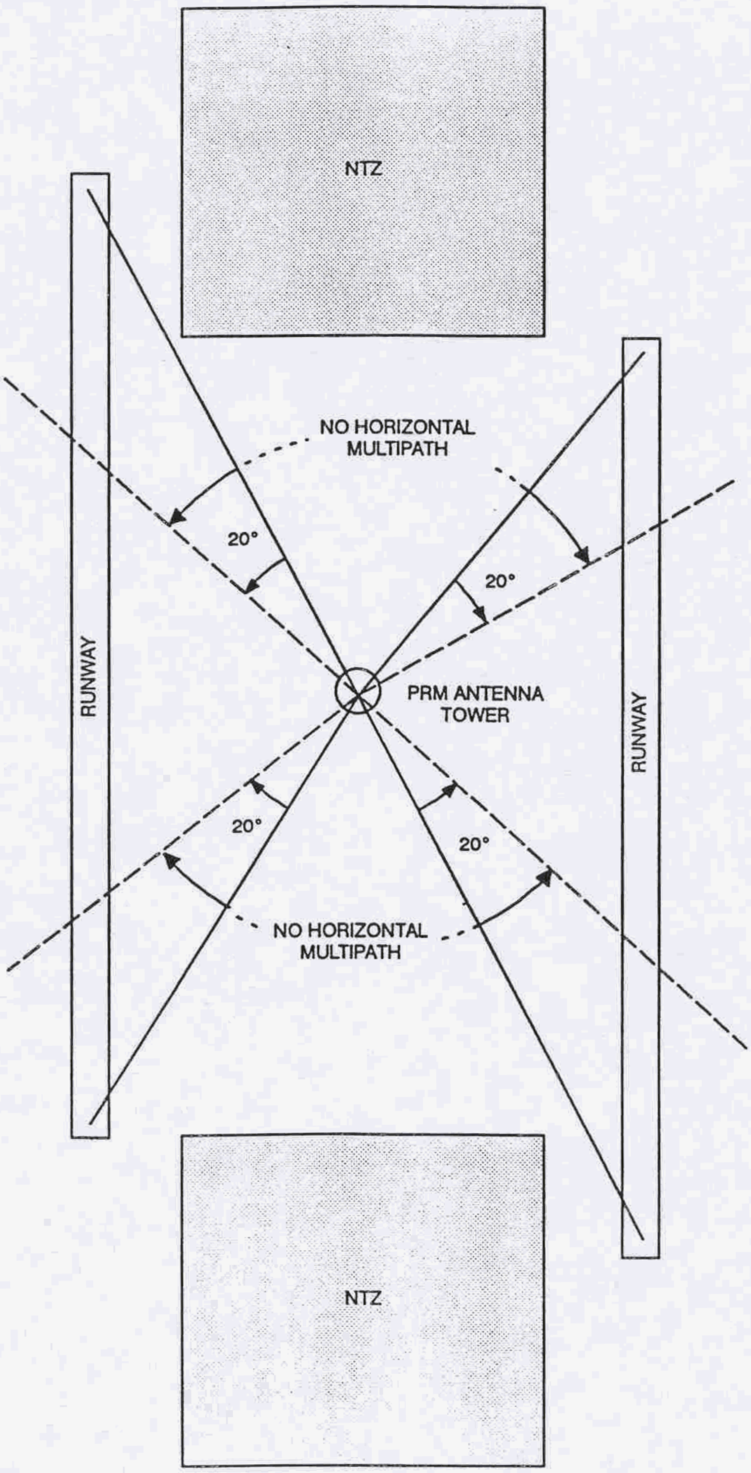
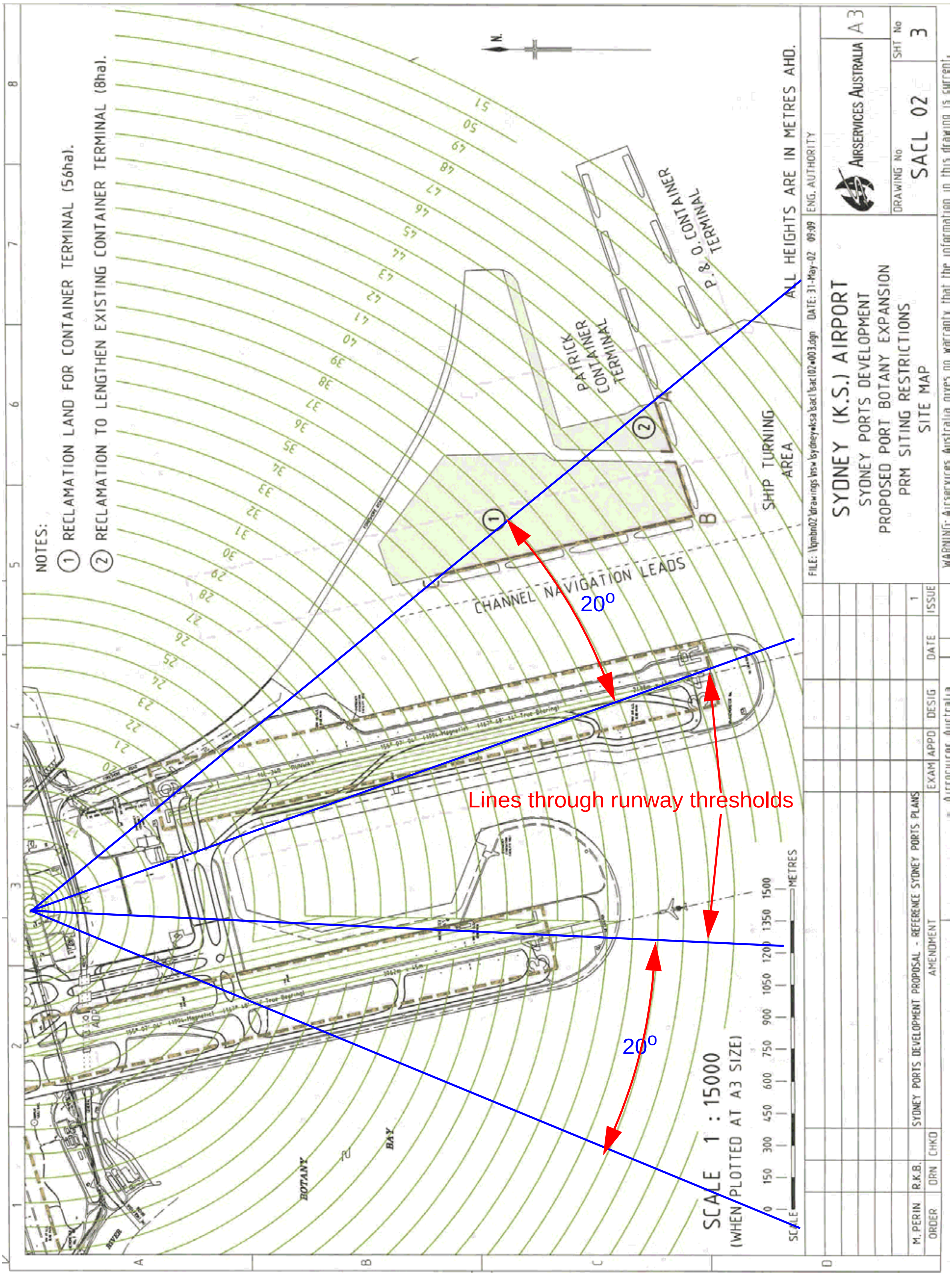


Figure C-4. PRM Antenna Tower Siting

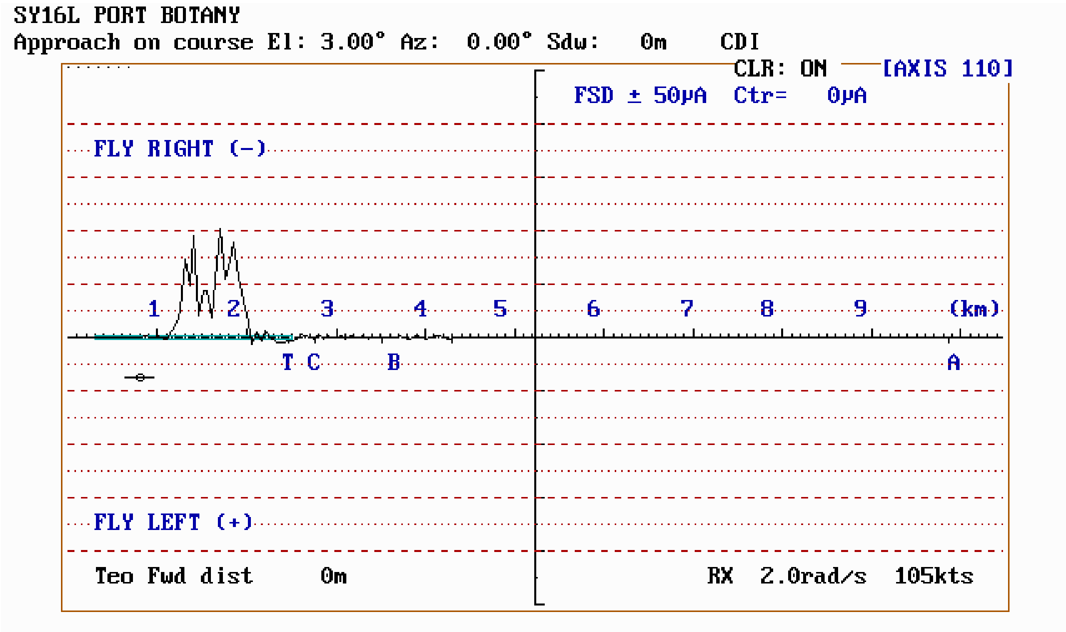
Figure 32 PARM Areas of Interest: Southern Approaches



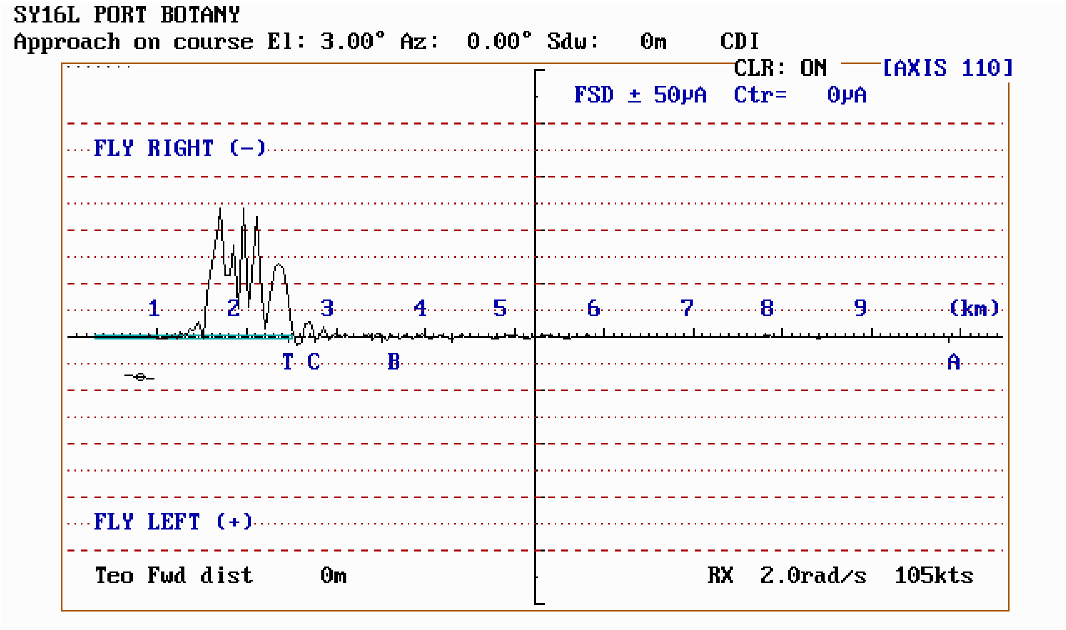
Annex B ILS Modelling Results

1 Sydney Runway 16L Localizer

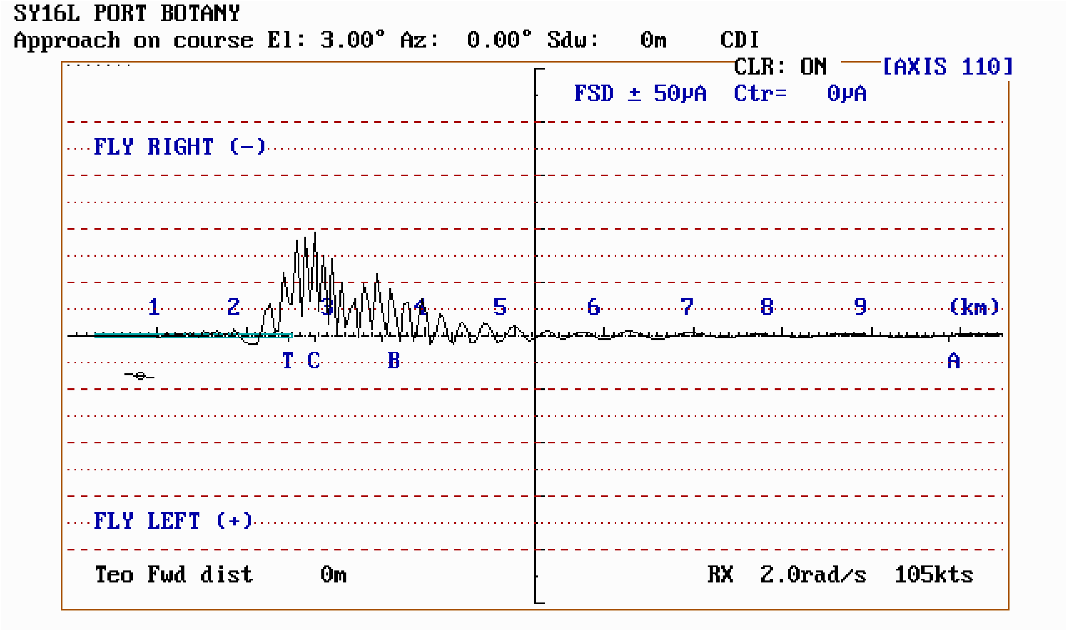
1.1 TEU 6000, Offset = 500m, Forward 800m, 0 deg rotation



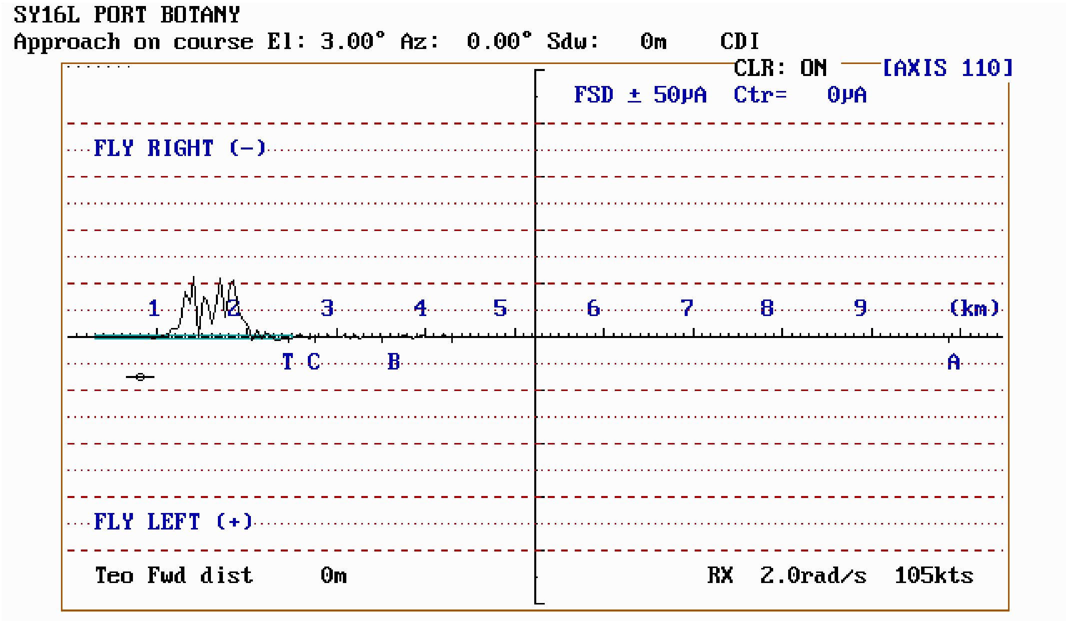
1.2 TEU 6000, Offset = 500m, Forward 800m, 5 deg rotation



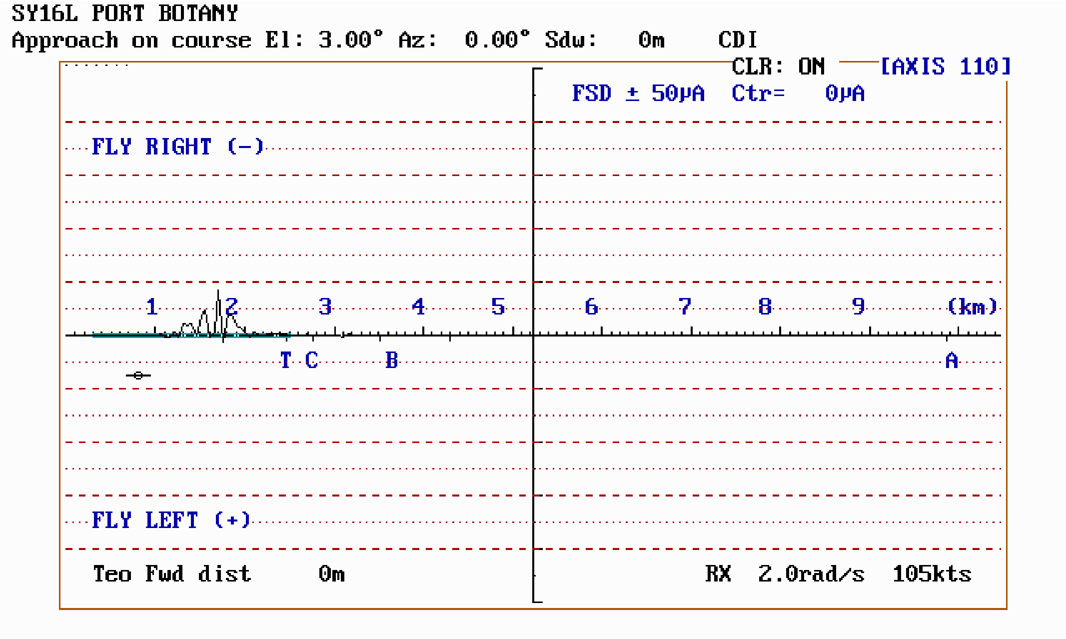
1.3 TEU 6000, Offset = 500m, Forward 800m, 10 deg rotation



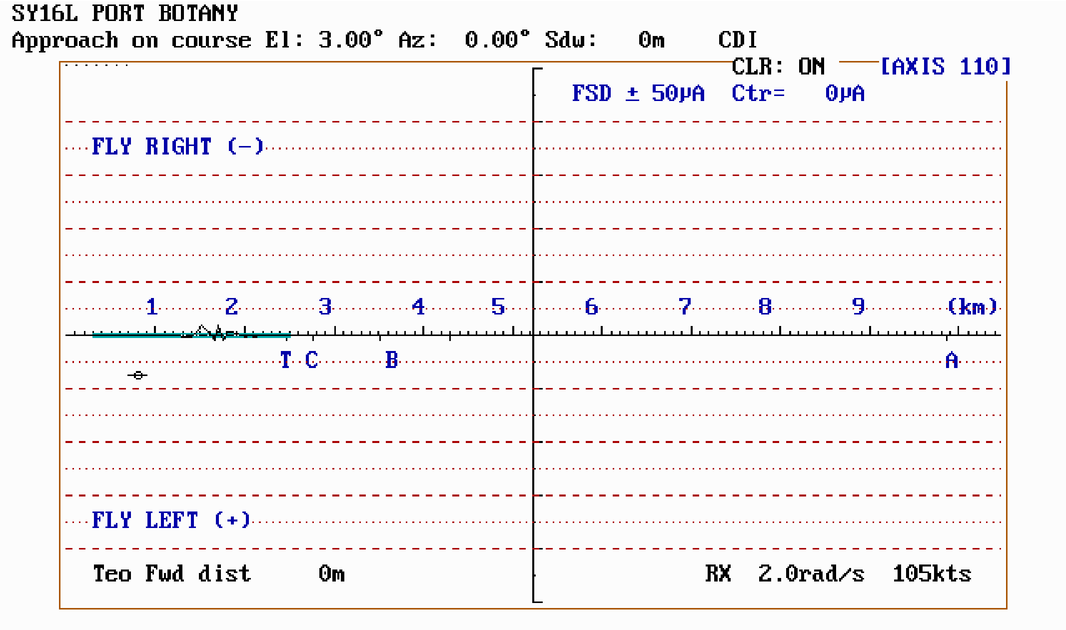
1.4 TEU 4500, Offset = 500m, Forward 800m, 0 deg rotation



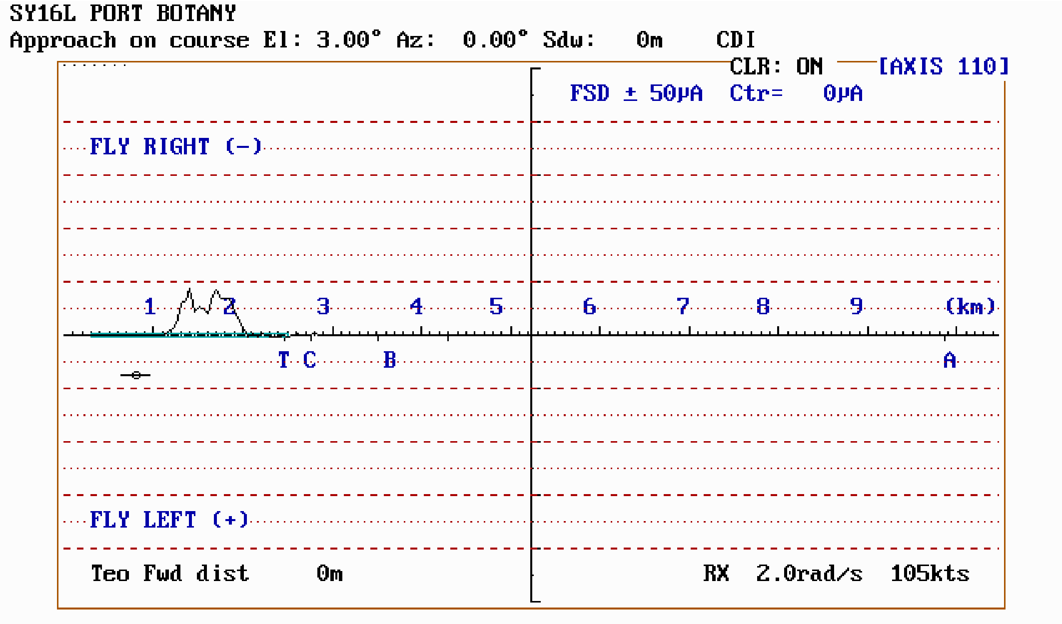
1.5 TEU 3000, Offset = 500m, Forward 800m, 0 deg rotation



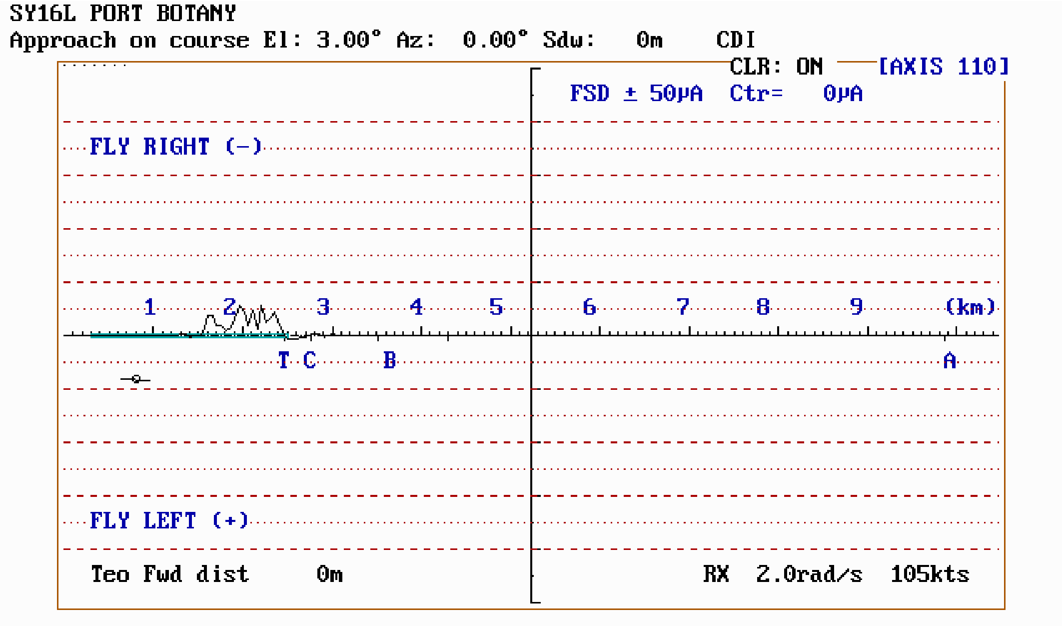
1.6 TEU 1500, Offset = 500m, Forward 800m, 0 deg rotation



1.7 TEU 6000, Offset = 500m, Forward 800m, 0 deg rotation (24 elment array)

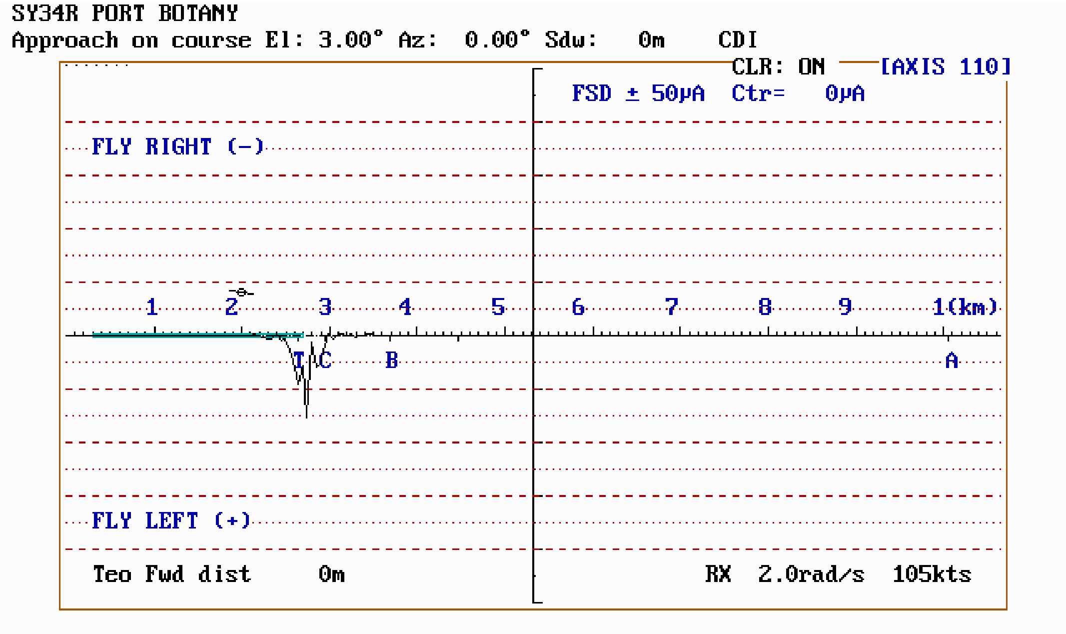


1.8 TEU 6000, Offset = 500m, Forward 800m, 5 deg rotation (24 elment array)

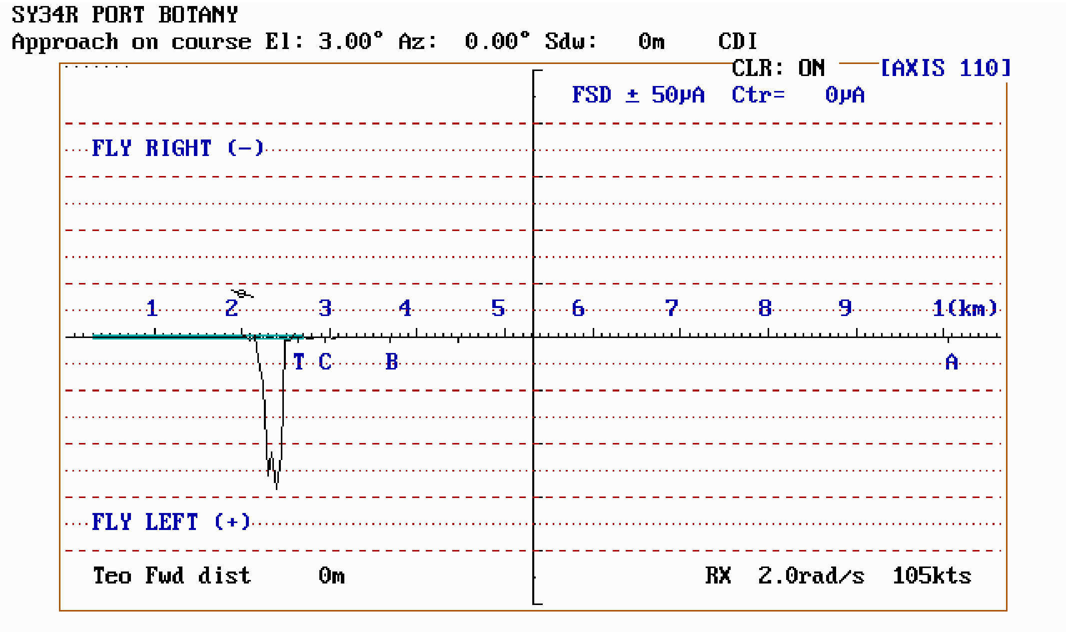


2 Sydney Runway 34R Localizer

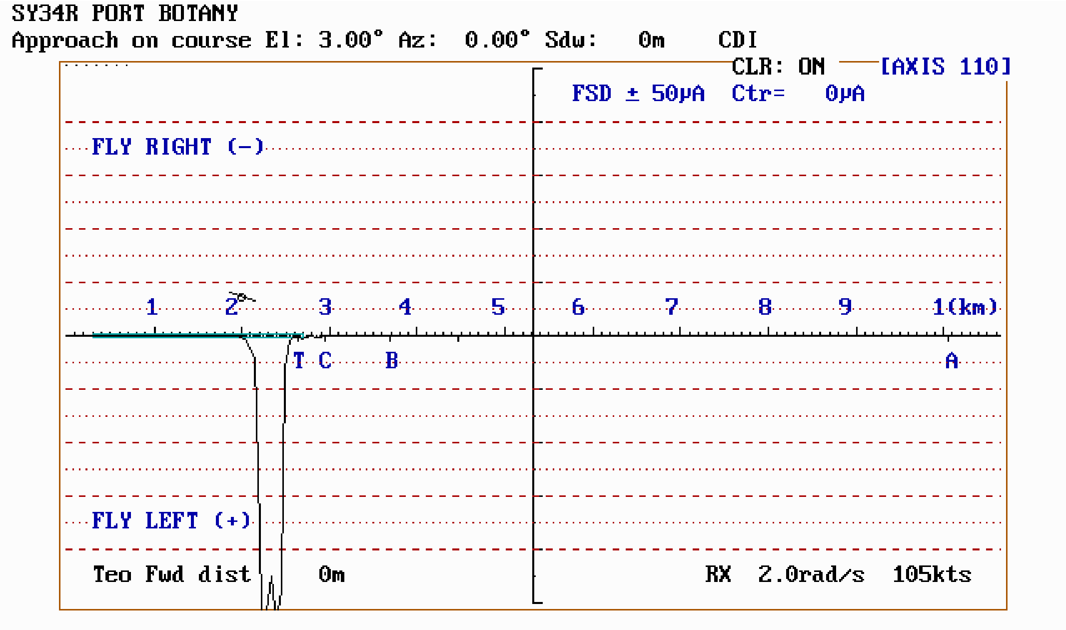
2.1 TEU 3000, Offset = 550m, Forward 2000m, 10 deg rotation



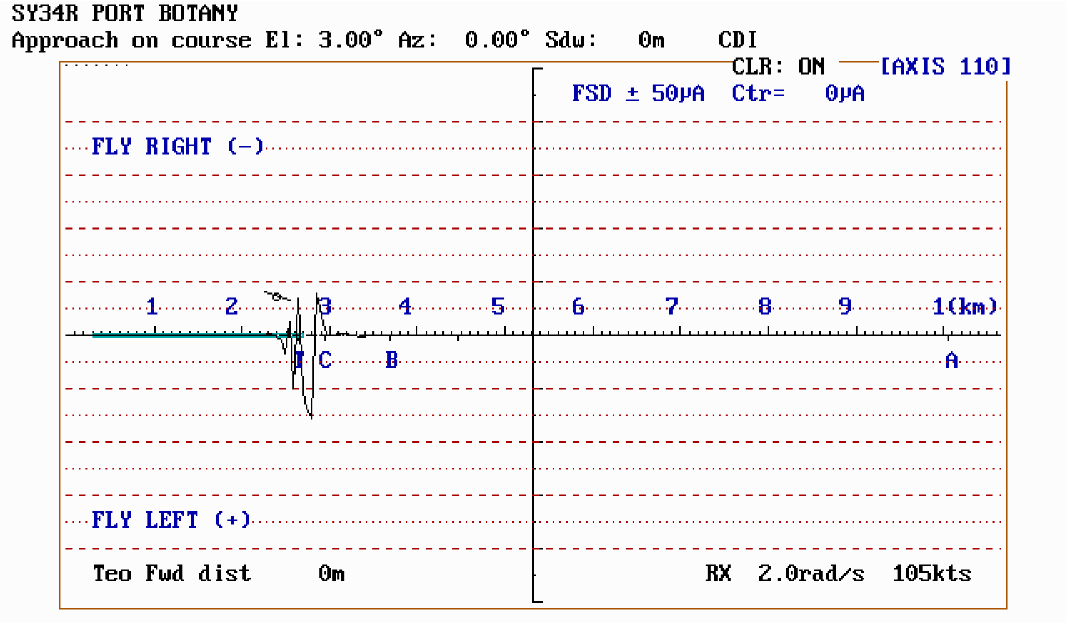
2.2 TEU 3000, Offset = 550m, Forward 2000m, 20 deg rotation



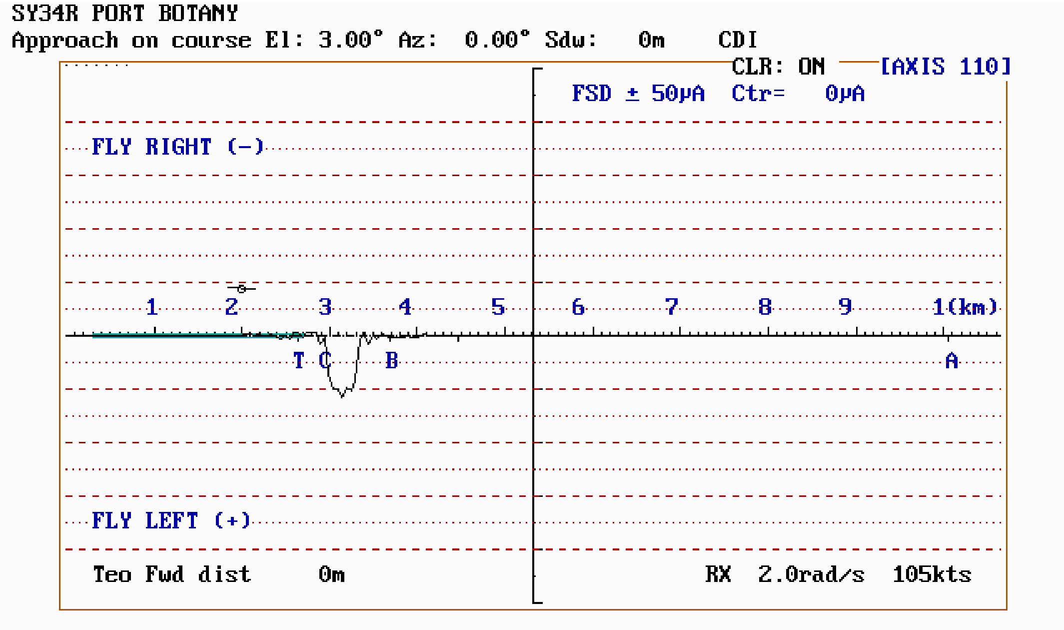
2.3 TEU 4500, Offset = 500m, Forward 2000m, 20 deg rotation



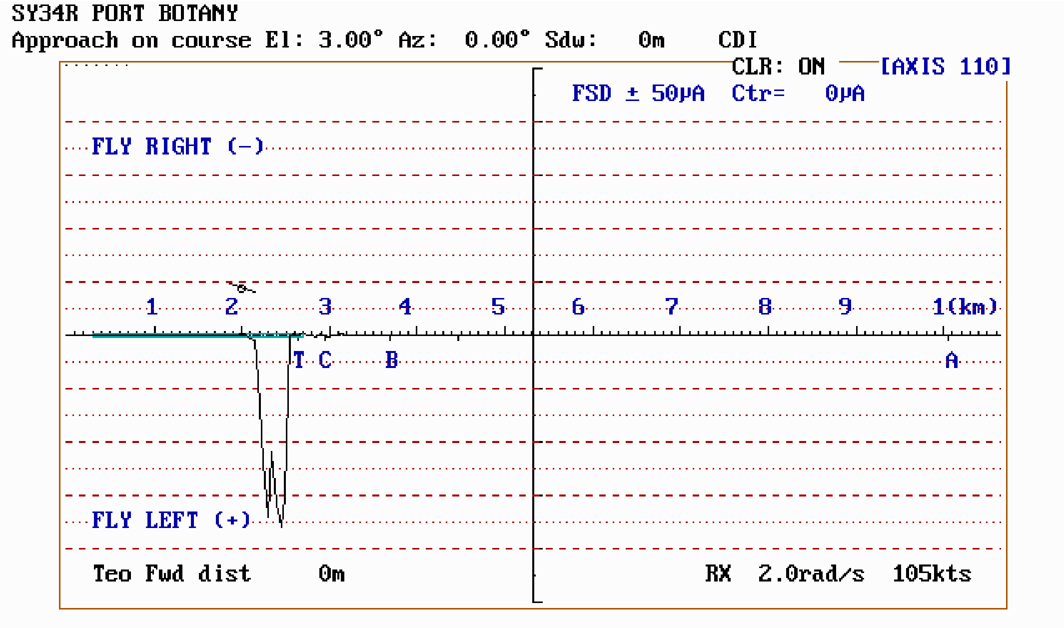
2.4 TEU 4500, Offset = 500m, Forward 2400m, 20 deg rotation



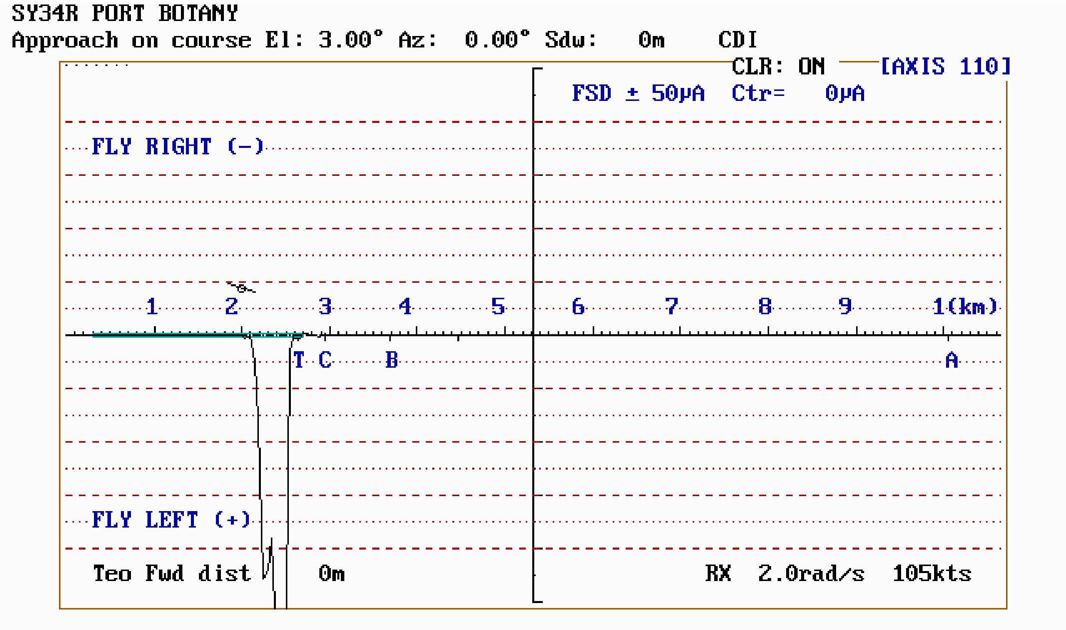
2.5 TEU 4500, Offset = 600m, Forward 2000m, 5 deg rotation



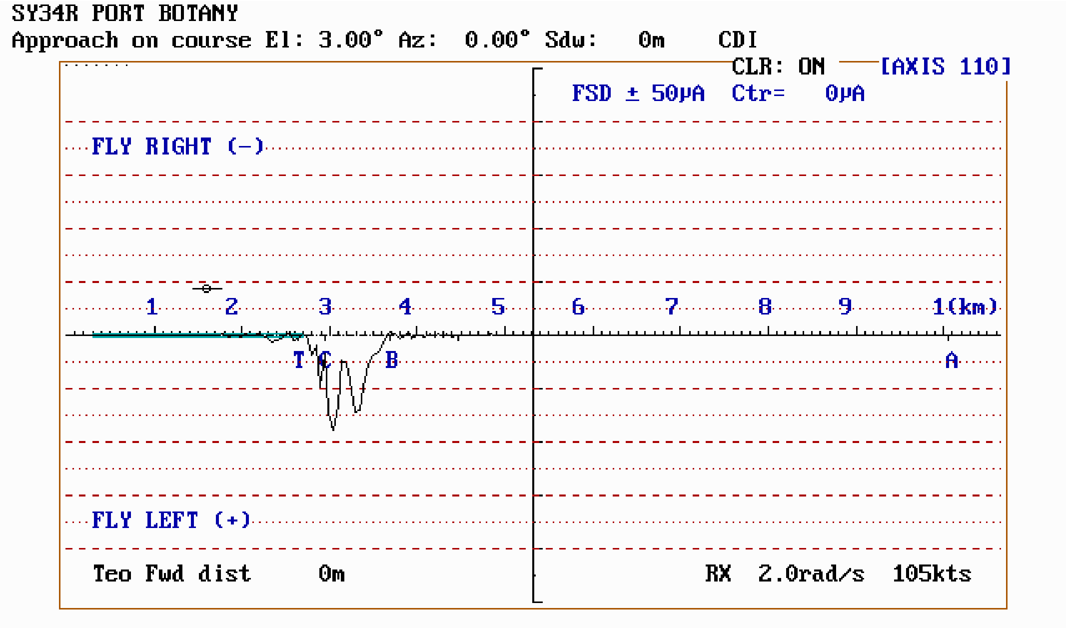
2.6 TEU 4500, Offset = 600m, Forward 2000m, 20 deg rotation



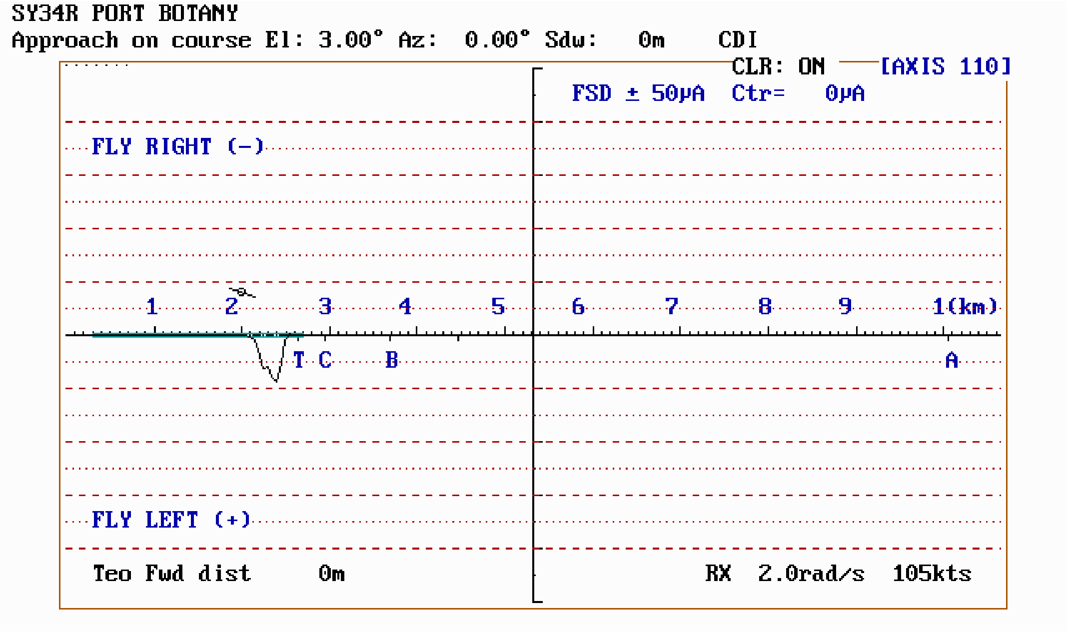
2.7 TEU 6000, Offset = 600m, Forward 2000m, 20 deg rotation



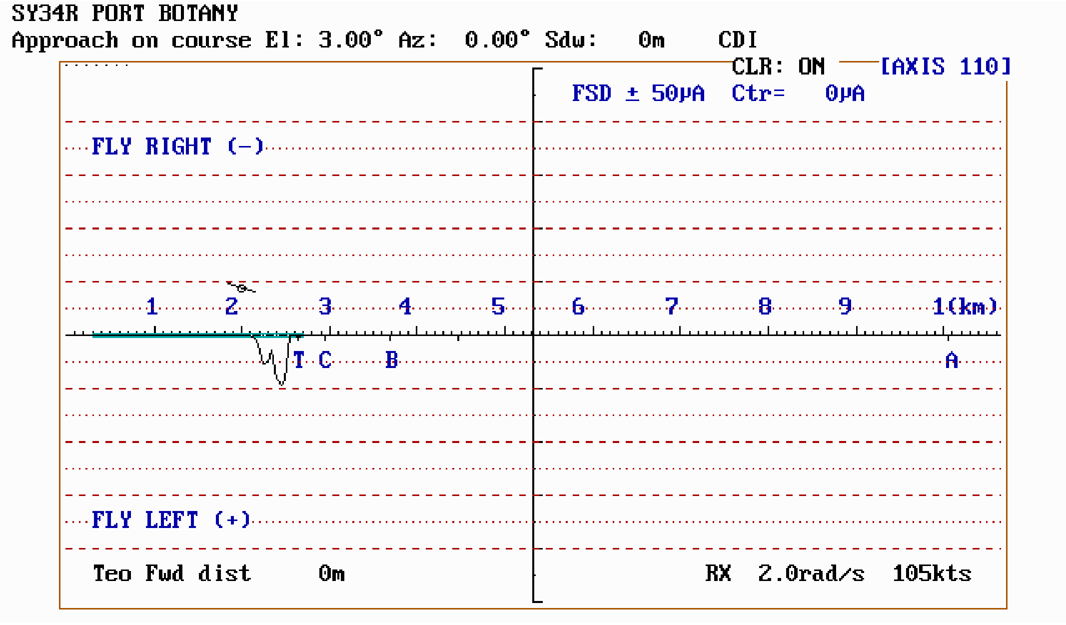
2.8 TEU 6000, Offset = 600m, Forward 2000m, 20 deg rotation



2.9 TEU 4500, Offset = 550m, Forward 2000m, 20 deg rotation (24 elment array)

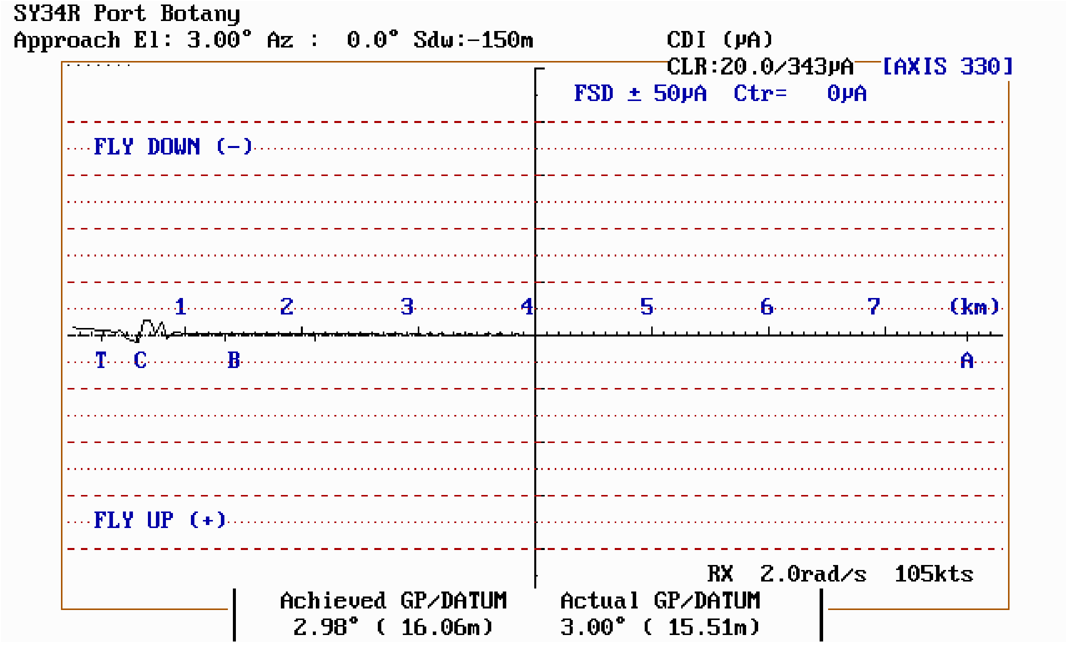


2.10 TEU 6000, Offset = 600m, Forward 2000m, 20 deg rotation (24 elment array)

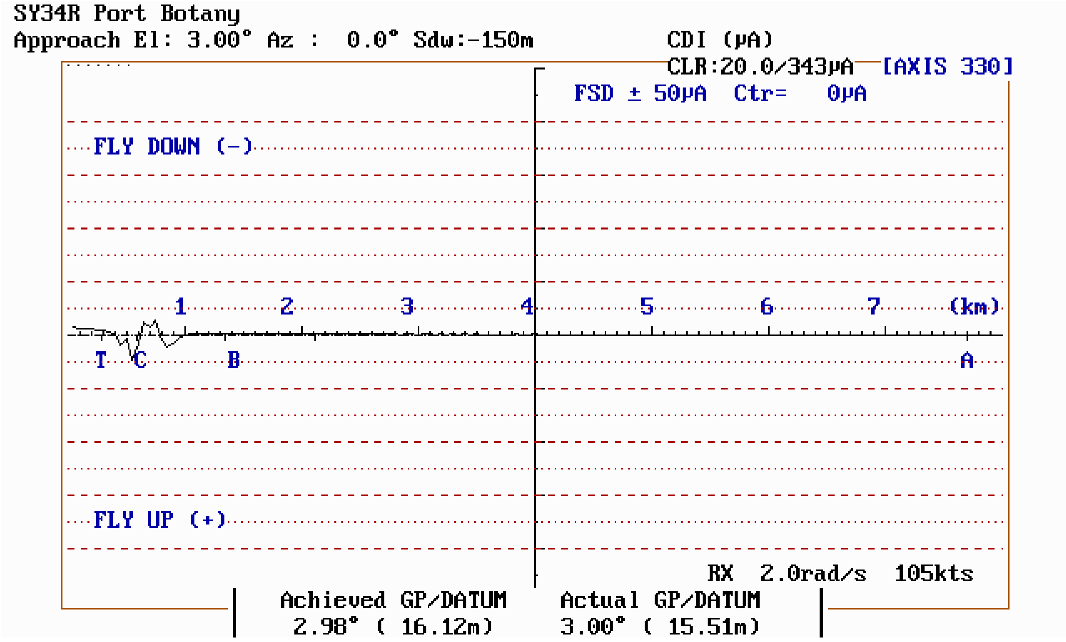


3 Sydney Runway 34R Glide Path

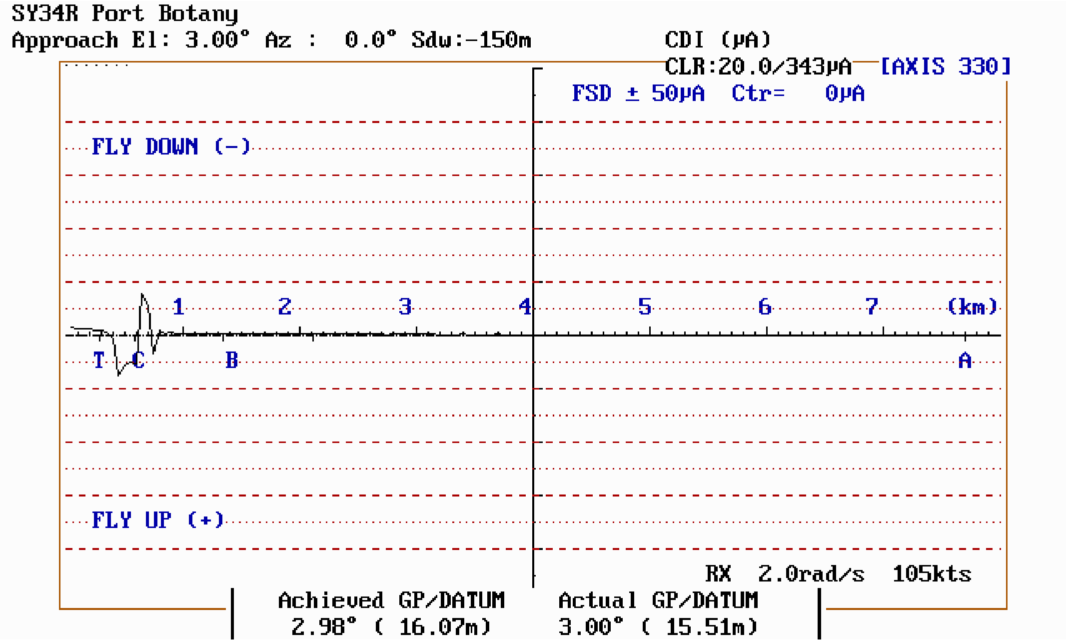
3.1 TEU 1500, Offset = 400m, Forward 400m, 0 deg rotation



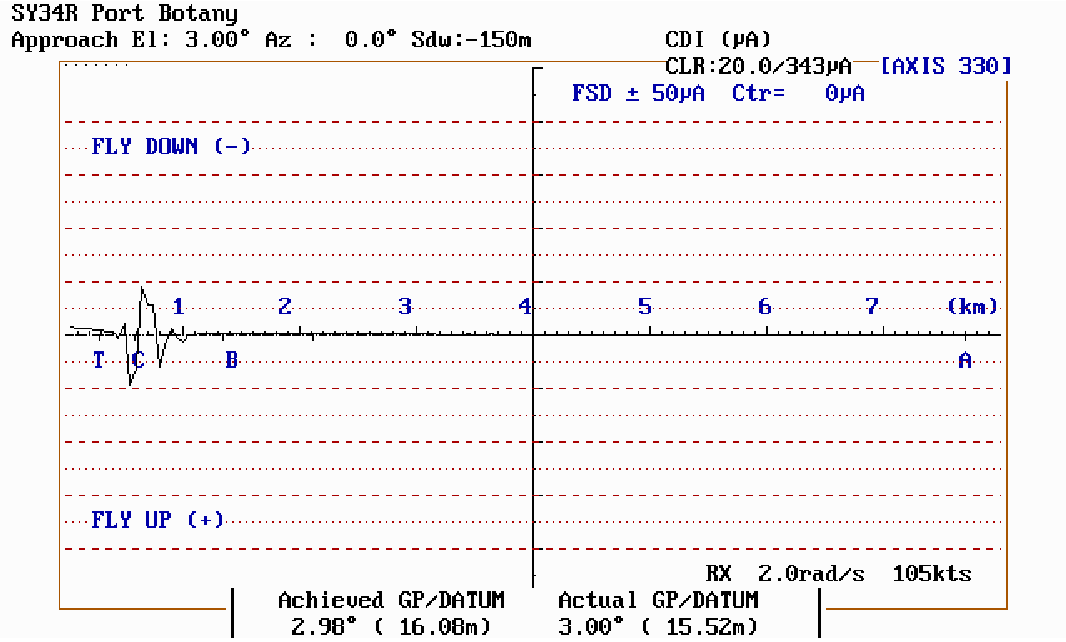
3.2 TEU 3000, Offset = 400m, Forward 400m, 0 deg rotation



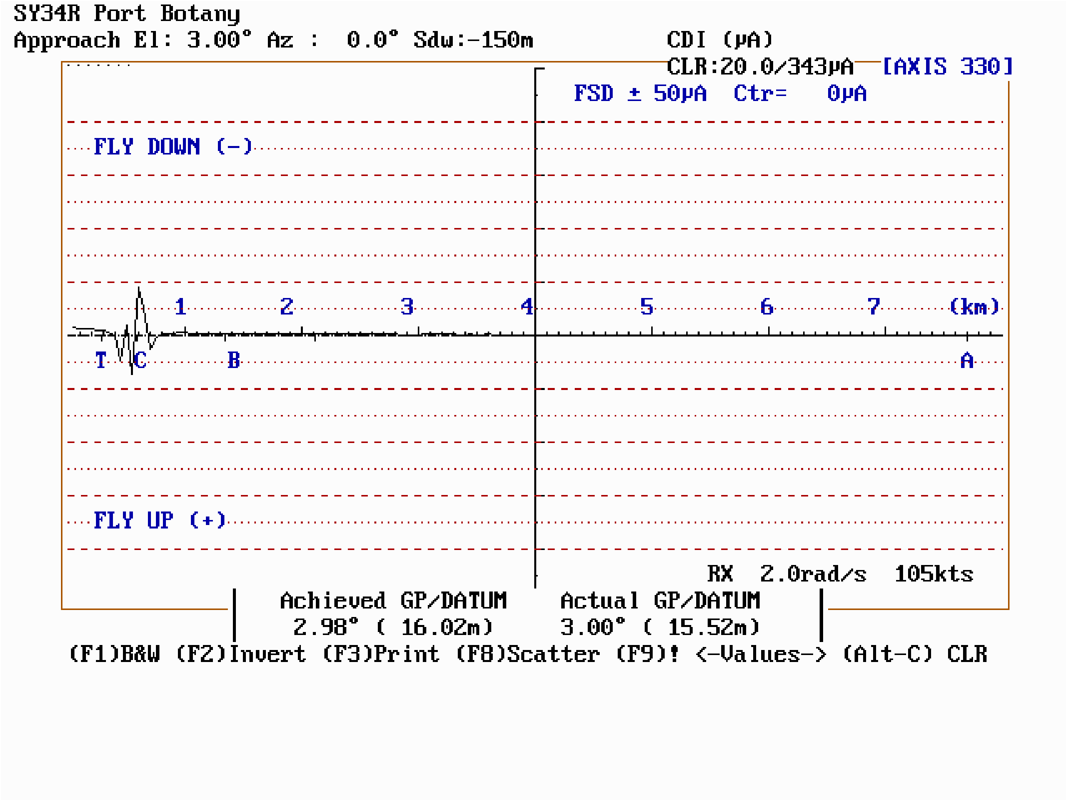
3.3 TEU 4500, Offset = 500m, Forward 400m, 5 deg rotation



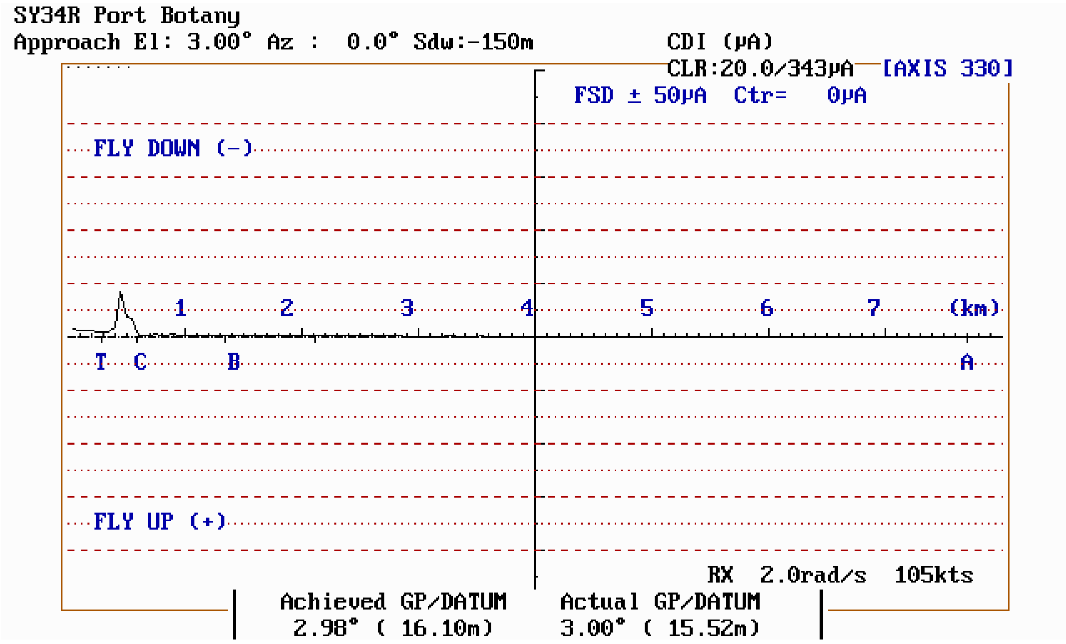
3.4 TEU 6000, Offset = 500m, Forward 400m, 0 deg rotation



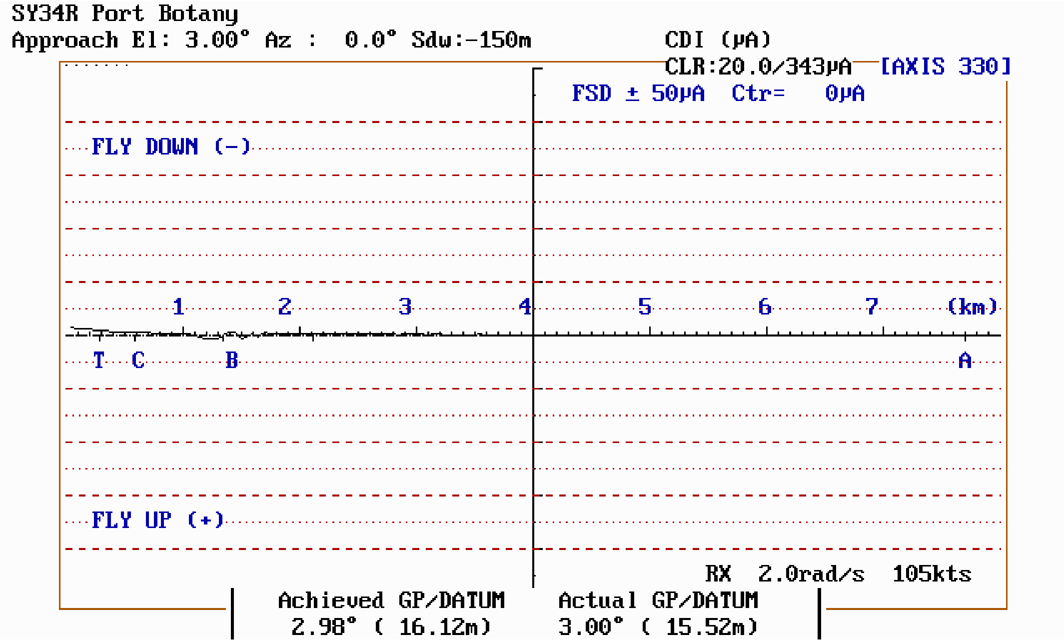
3.5 TEU 6000, Offset = 500m, Forward 400m, 10 deg rotation



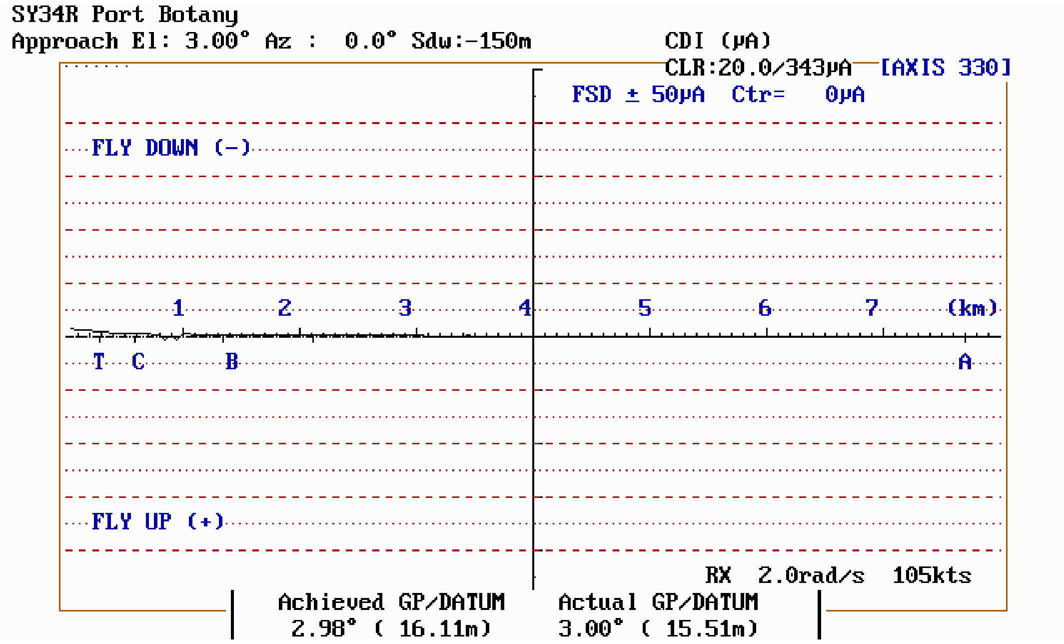
3.6 TEU 6000, Offset = 500m, Forward 400m, 20 deg rotation



3.7 TEU 6000, Offset = 500m, Forward 800m, 0 deg rotation

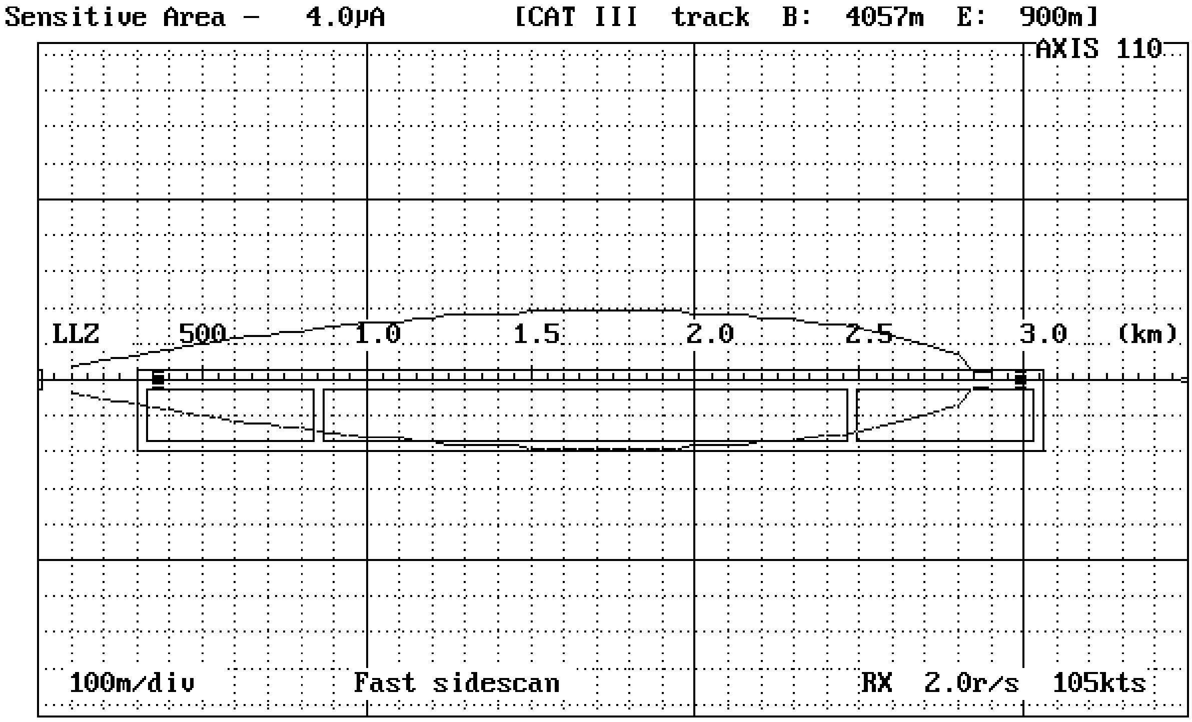


3.8 TEU 6000, Offset = 500m, Forward 800m, 20 deg rotation



4 Localizer Antenna Systems

4.1 12 Element Antenna Array Radiation Pattern



4.2 24 Element Antenna Array Radiation Pattern