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ENGINEERS AUSTRALIA

Aerospace Systems/Sensors I

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RAR Compensation by Genetic Algorithm based SAR Antenna Beam Forming

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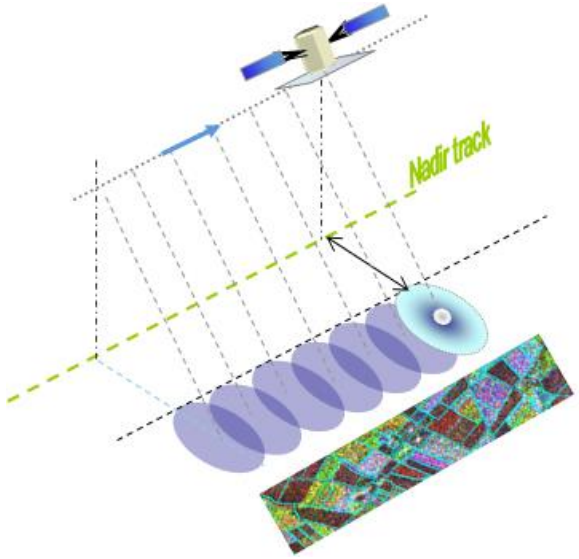
AUSTRALIAN DIVISION

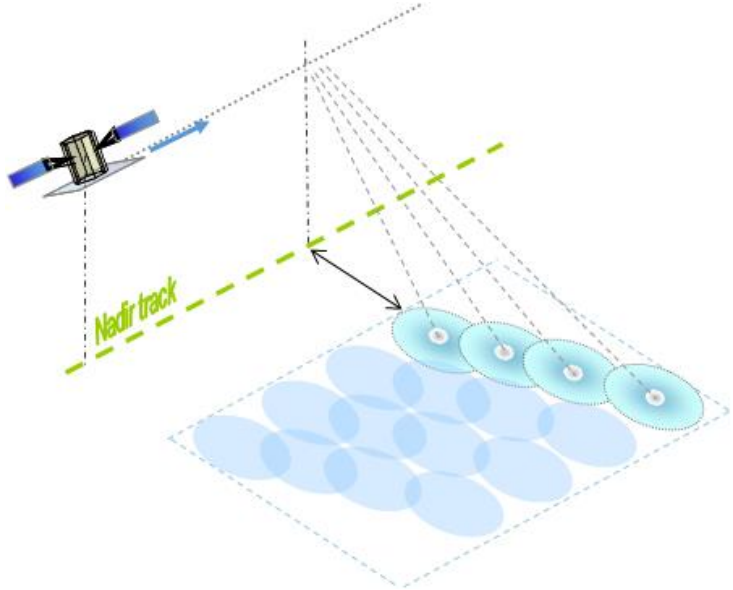
Introduction

- For the Range Ambiguity Ratio (RAR) compensation of spaceborne synthetic aperture radar (SAR) system, an operation concept of spaceborne SAR and an Active Phased Array Antenna (APAA) are considered.
- Among the various operation modes, the strip mode which is the basic operation mode for acquiring spaceborne radar imagery is focused. The beam forming of this mode is optimally produced via the Genetic Algorithm (GA) approach.
- However, even if antenna beams are optimally formed with GA, a partial failure of Transmit/Receive Module (TRM) by an unforeseen reason in APAA directly affects side-lobe, for example, a significant increase of its level, finally resulting in the degradation of RAR which is one of the important performance parameters of spaceborne SAR system.
- Due to this reason, compensation for the degradation of a damaged array pattern has to be made for nominal mode of operation.
- As a criterion for the compensation for performance degradation of spaceborne SAR, the RAR of requirement value is met.

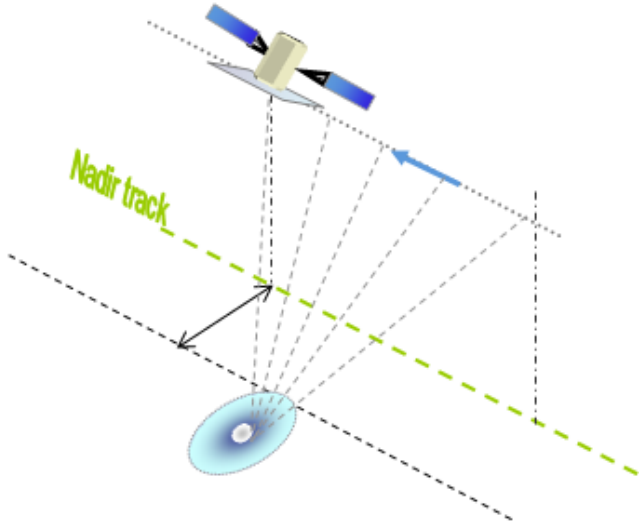
Spaceborn SAR System Operation Mode



Strip mode



Scan mode



Spotlight mode

Spaceborn SAR System Performance

Requirement	Strip Mode	Scan Mode	Spotlight Mode
Incidence Angle	20° ~ 45°	20° ~ 45°	20° ~ 45°
Swath Width	≥ 30km @45°	≥ 100km @45°	≥ 5km @45°
Resolution	≤ 3m @45°	≤ 20m @45°	≤ 1m @45°
NESZ	≤ -17 dBm2/m2	≤ -17 dBm2/m2	≤ -17 dBm2/m2
PSLR	≤ -19 dB	≤ -19 dB	≤ -19 dB
ISLR	≤ -13 dB	≤ -13 dB	≤ -13 dB
RAR	≤ -17 dB	≤ -17 dB	≤ -17 dB
RA	≤ 1 dB	≤ 1 dB	≤ 1 dB

Spaceborn SAR System Active Phase Array Antenna

$$E(\theta) = \sum_{n=0}^{N-1} A_n \cdot \exp(-j \cdot k \cdot d \cdot n \cdot \sin\theta_n + j \cdot \varphi_n)$$

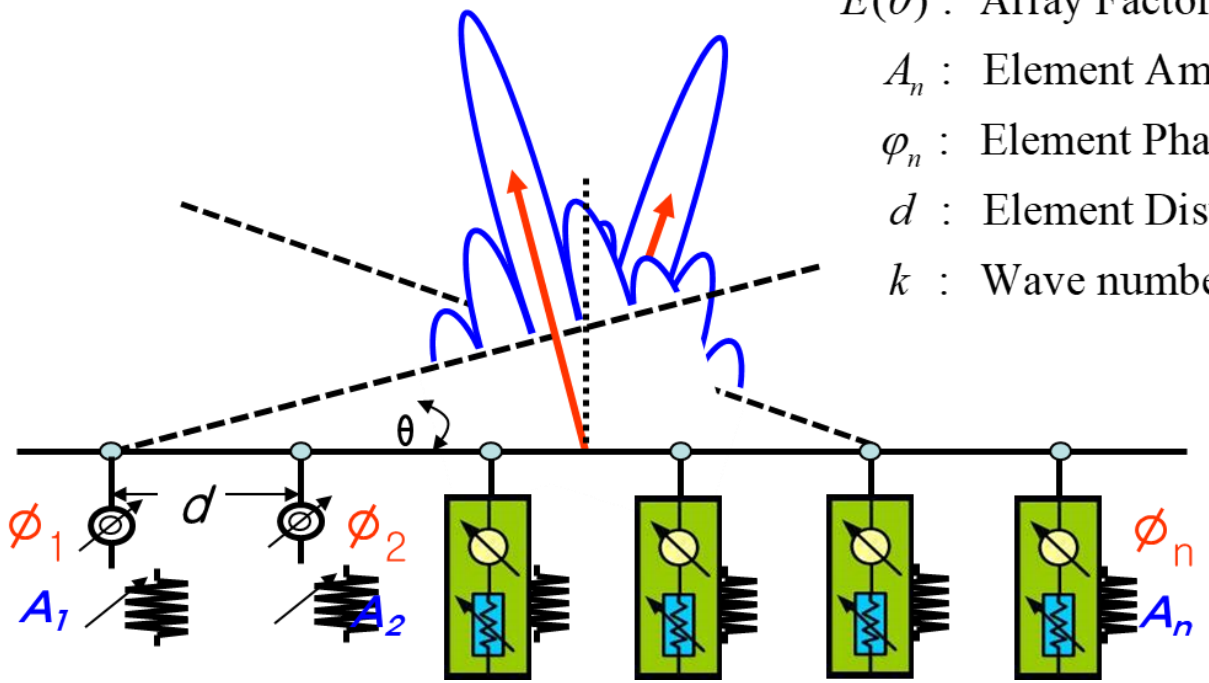
$E(\theta)$: Array Factor

A_n : Element Amplitude

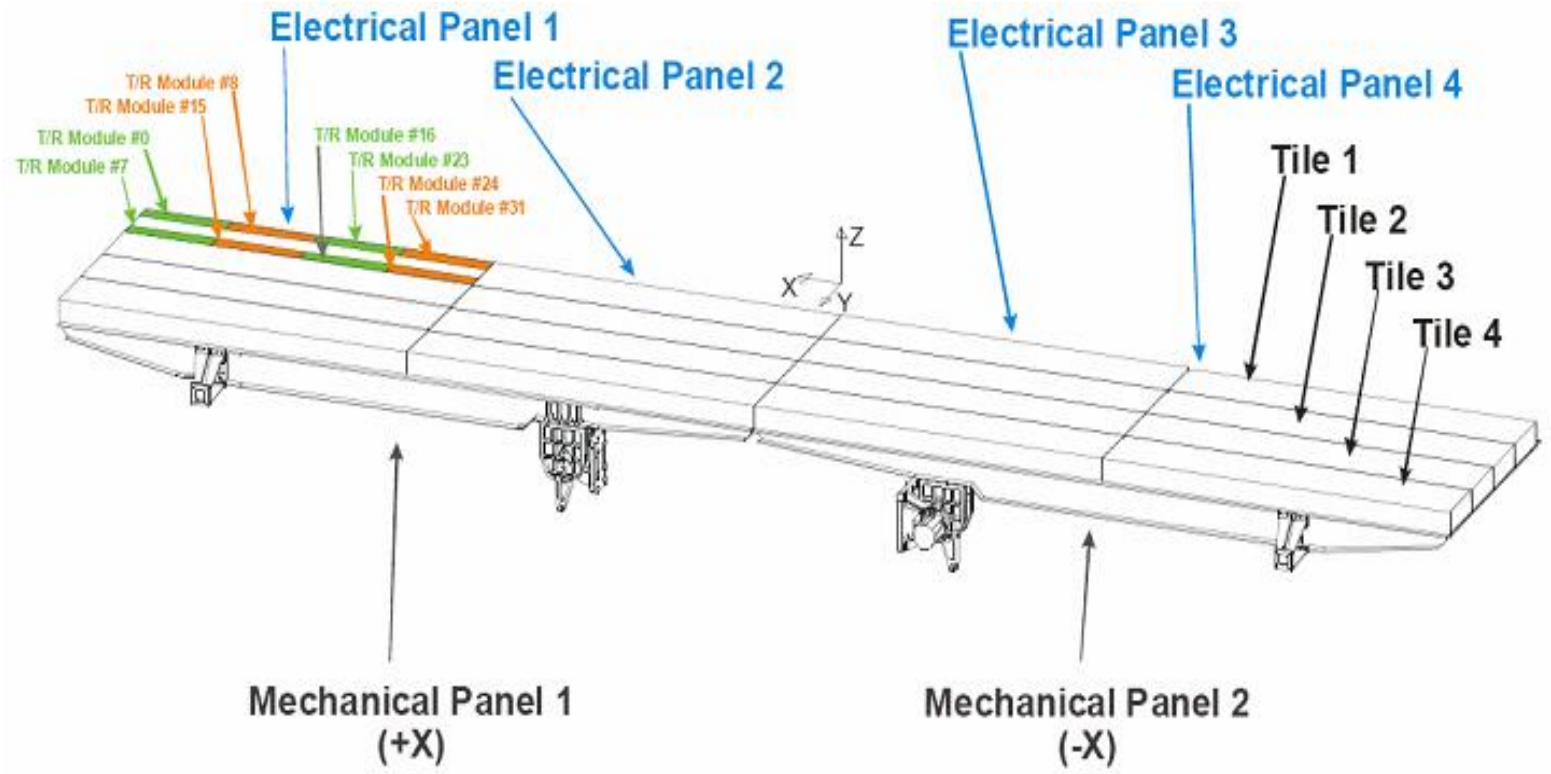
φ_n : Element Phase

d : Element Distance

k : Wave number



Spaceborn SAR System APAA Modeling

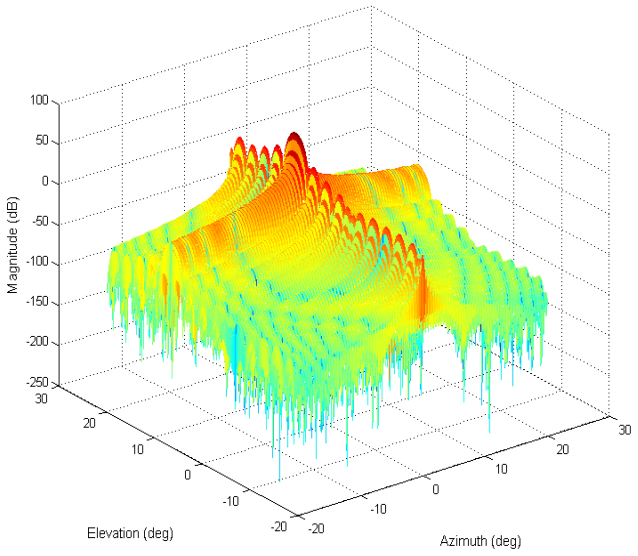


Spaceborn SAR System APAA Modeling

Requirement	Capability
RF frequency carrier	9.66 GHz ± 100 KHz
Band width	240 MHz
Polarization	HH, HV, VH, VV
Azimuth beam width	0.37 °
Azimuth max. steering angle	± 1.2 deg
Azimuth grating lobe	≤ -12 dB
Elevation beam width	2.3 ° ~ 4.6 °
Elevation max. steering angle	± 17.5 °
Elevation grating lobe	≤ -15 dB
Transmitted peak power	≥ 1800 W

APAA Beam Patterns Using Genetic Algorithm

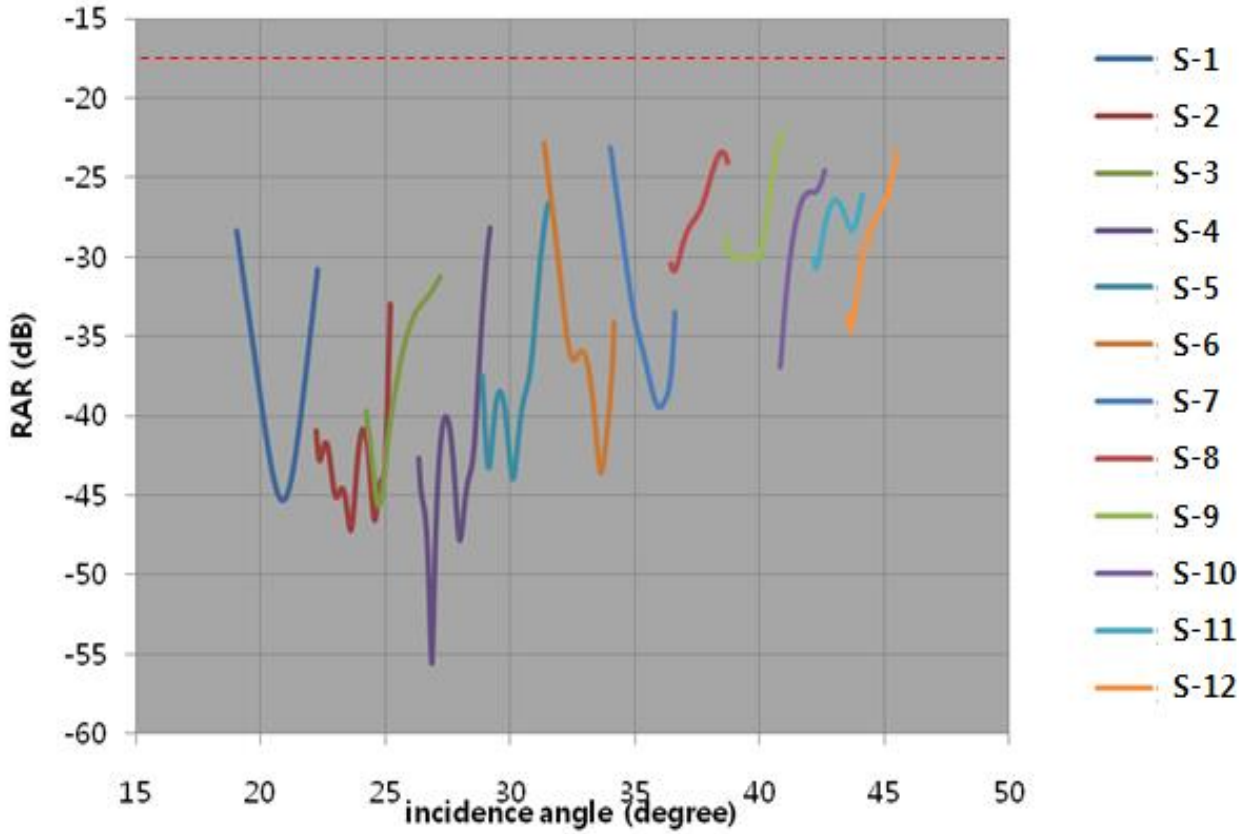
- Antenna beam patterns for strip mode



Example. S-12

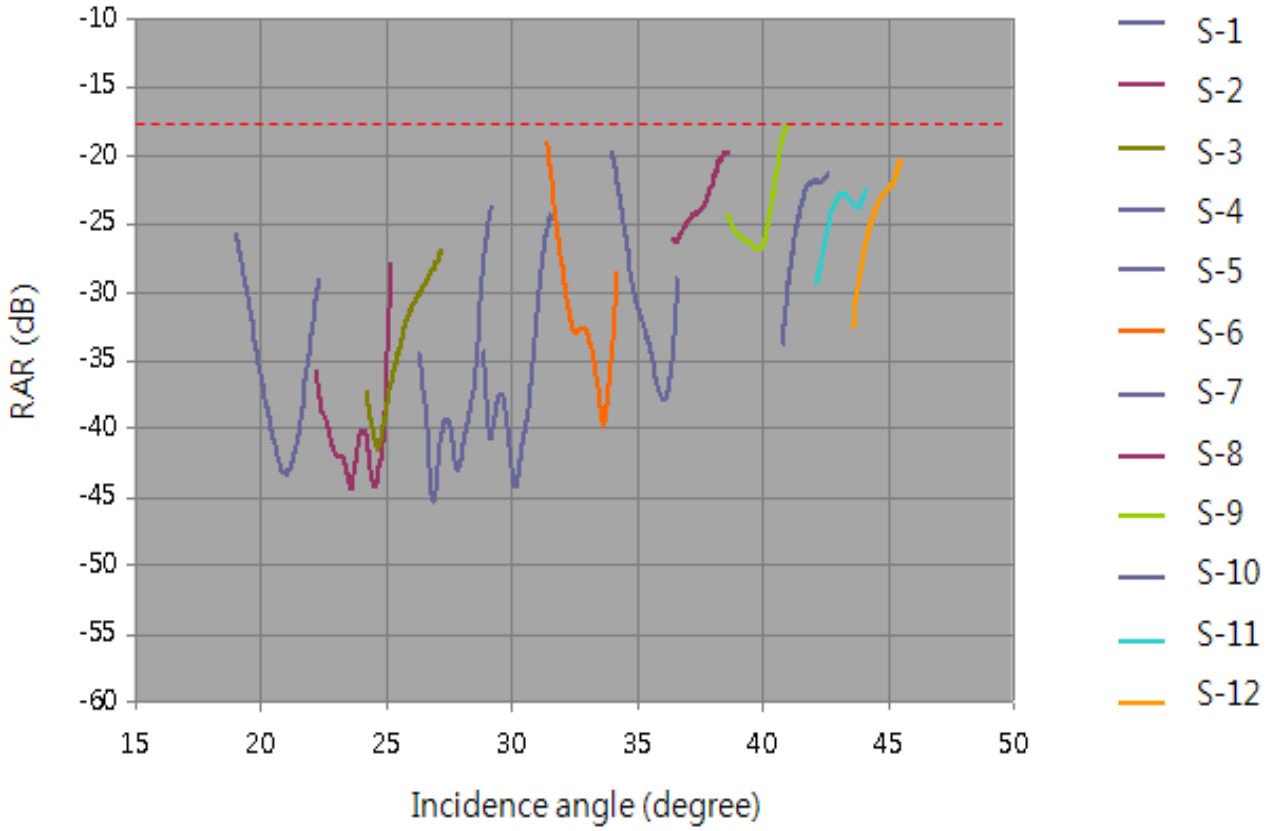
No.	Incidence angle (°)			W_gr (Km)	Overlap (Km)	T (us)	B (MHz)	PRF [Hz]
	Near	Center	Far					
S-1	19	20.66	22.31	32.9	0	30	58.94	3490
S-2	22.19	23.69	25.19	30.9	1.2	32	70.3	4400
S-3	24.2	25.69	27.19	31.8	10.4	32	63.53	4088
S-4	26.3	27.79	29.29	32.8	9.7	30	52.06	3770
S-5	28.85	30.2	31.55	30.8	5	32	58.12	3470
S-6	31.36	32.78	34.2	33.8	2.2	30	49.79	3840
S-7	34	35.29	36.6	32.7	2.5	34	47.04	3507
S-8	36.4	37.54	38.7	30.3	2.6	34	66.45	4088
S-9	38.6	39.79	40.99	33.3	1.4	32	52.1	3543
S-10	40.8	41.69	42.59	26.1	2.8	32	77.57	4088
S-11	42.16	43.15	44.15	30	6.5	32	68.35	3800
S-12	43.55	44.53	45.51	30.6	9.1	40	73.24	3530

RAR Analysis for 12 Beam Patterns of Strip Mode



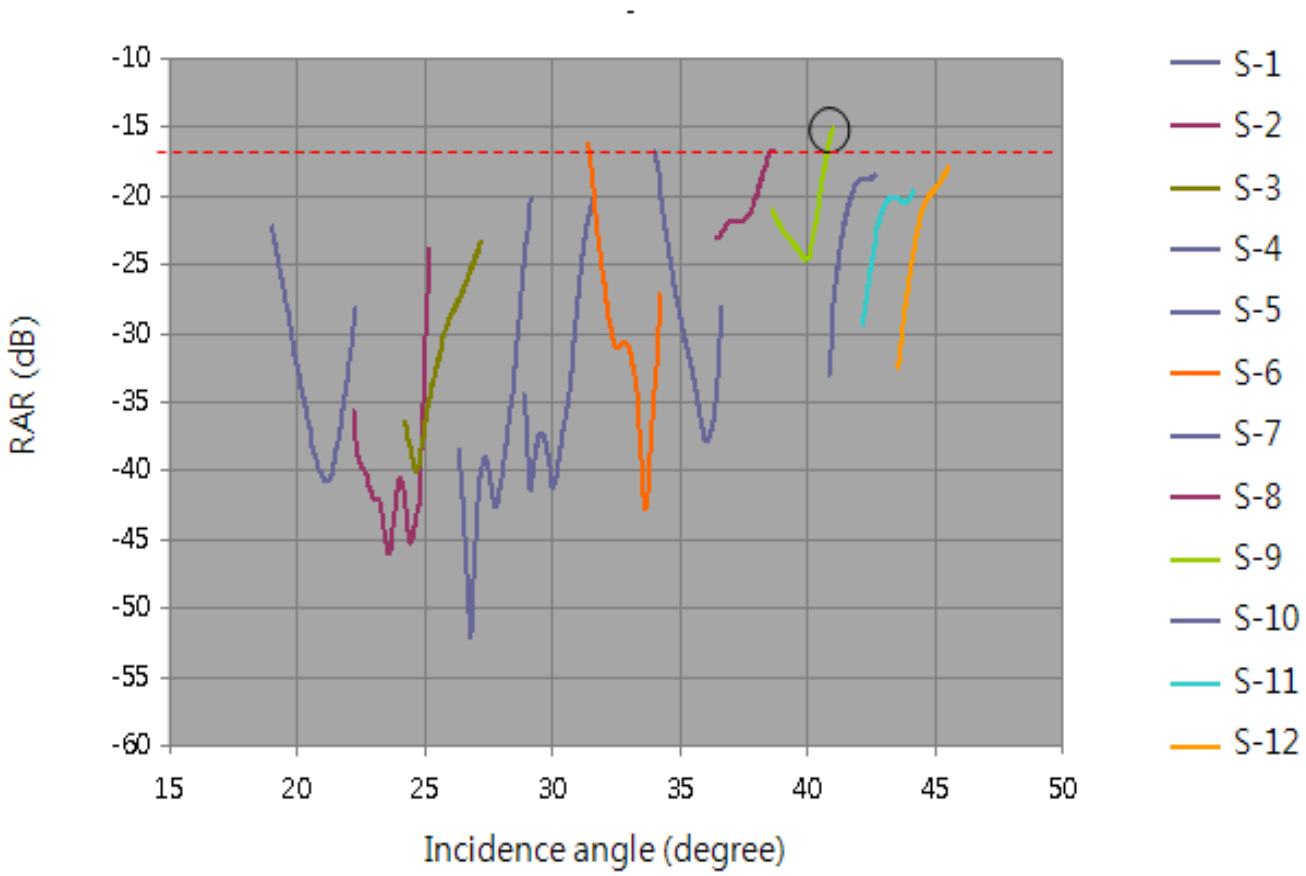
RAR Analysis for 12 Beam Patterns of Strip Mode

RAR of 1 Tile failure case



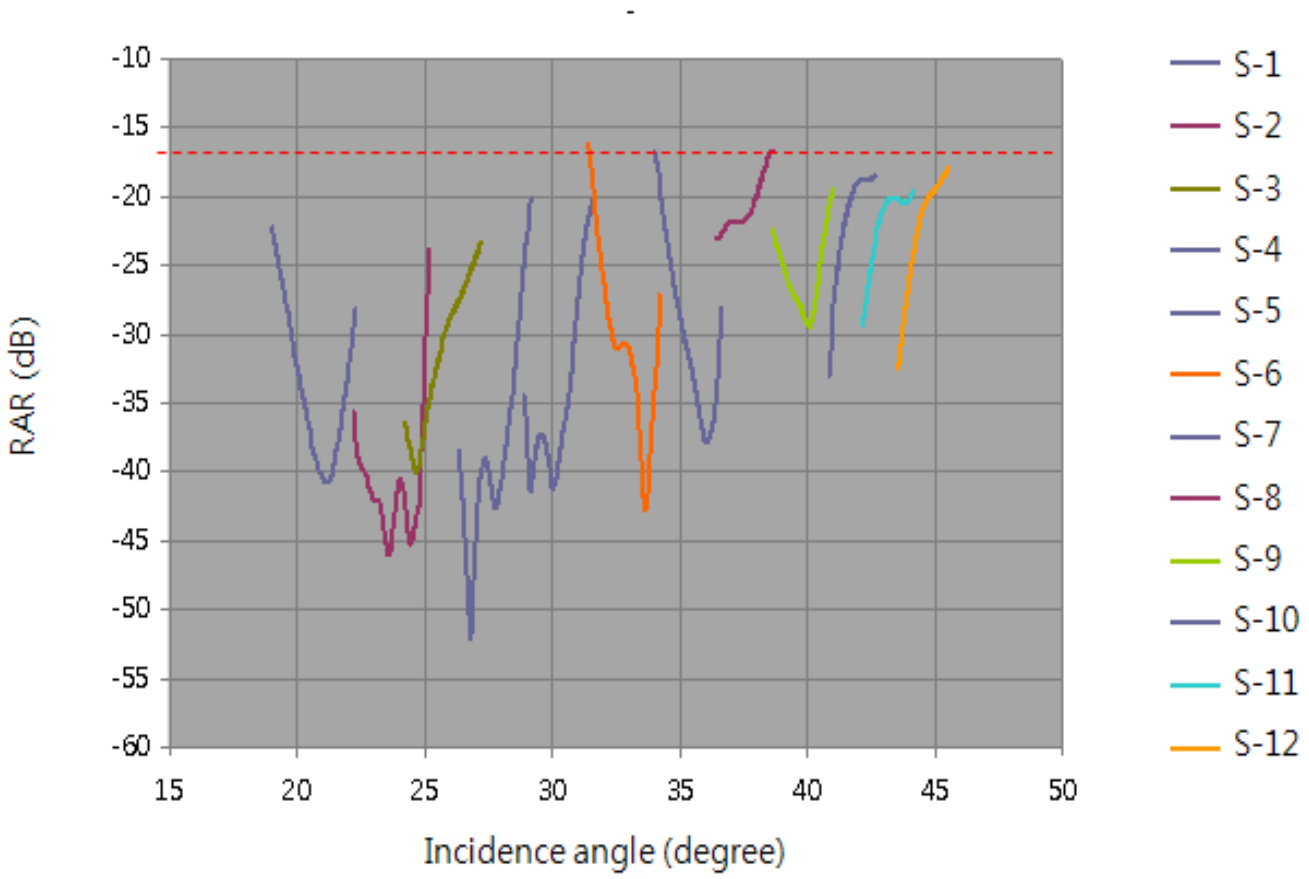
RAR Analysis for 12 Beam Patterns of Strip Mode

RAR of 2 Tile failure case



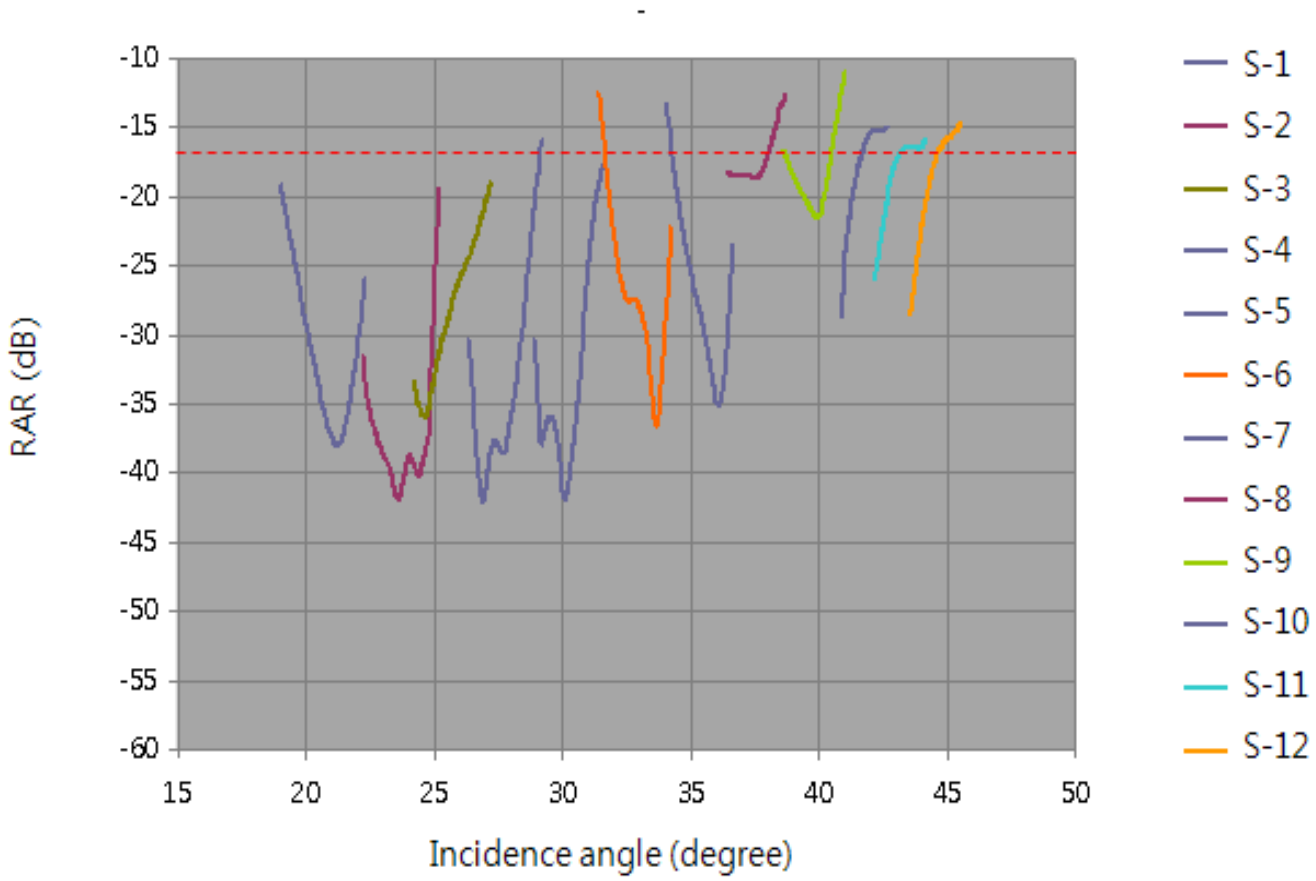
RAR Analysis for 12 Beam Patterns of Strip Mode

RAR of 2 Tile failure case
After re-generation



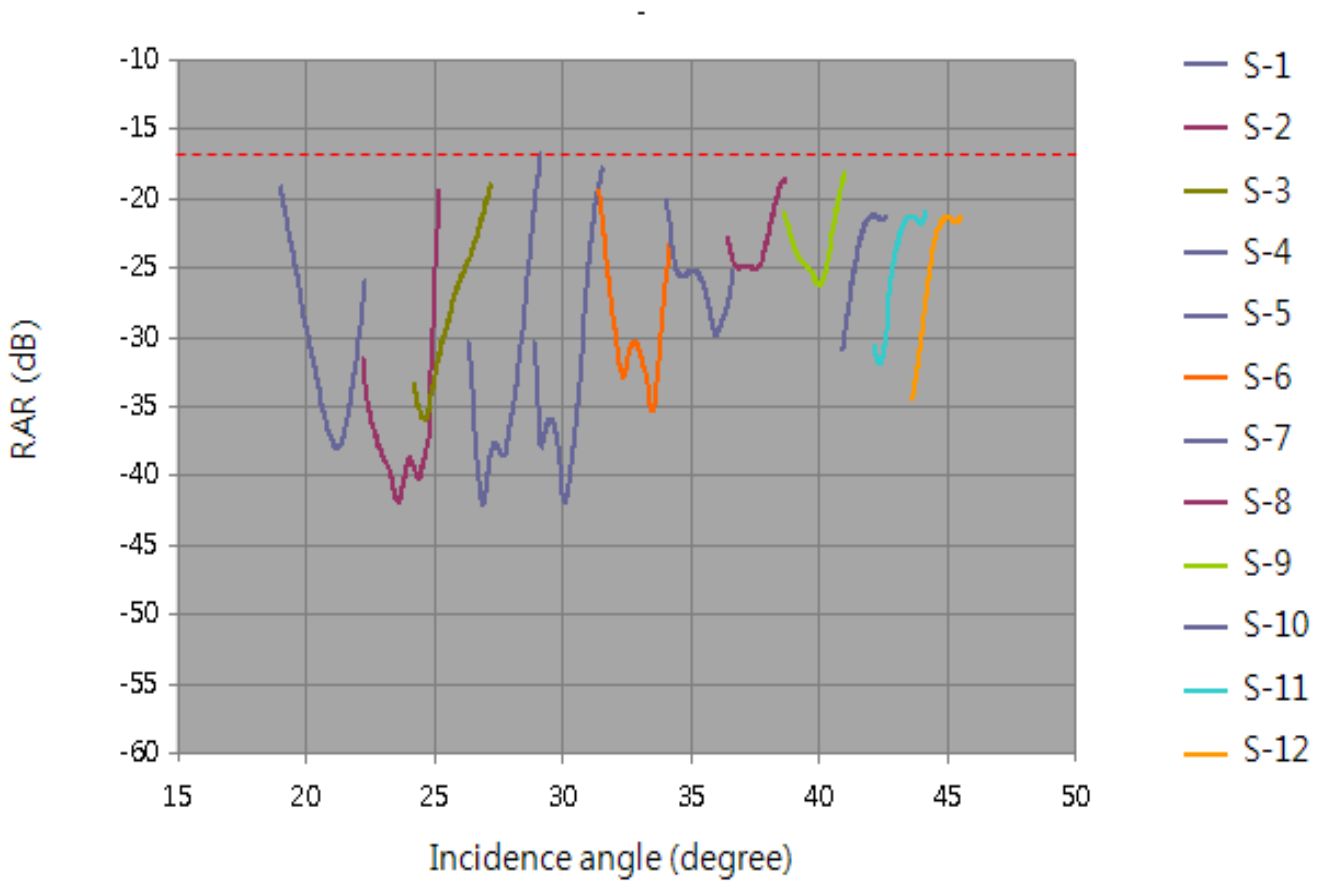
RAR Analysis for 12 Beam Patterns of Strip Mode

RAR of 3 Tile failure case



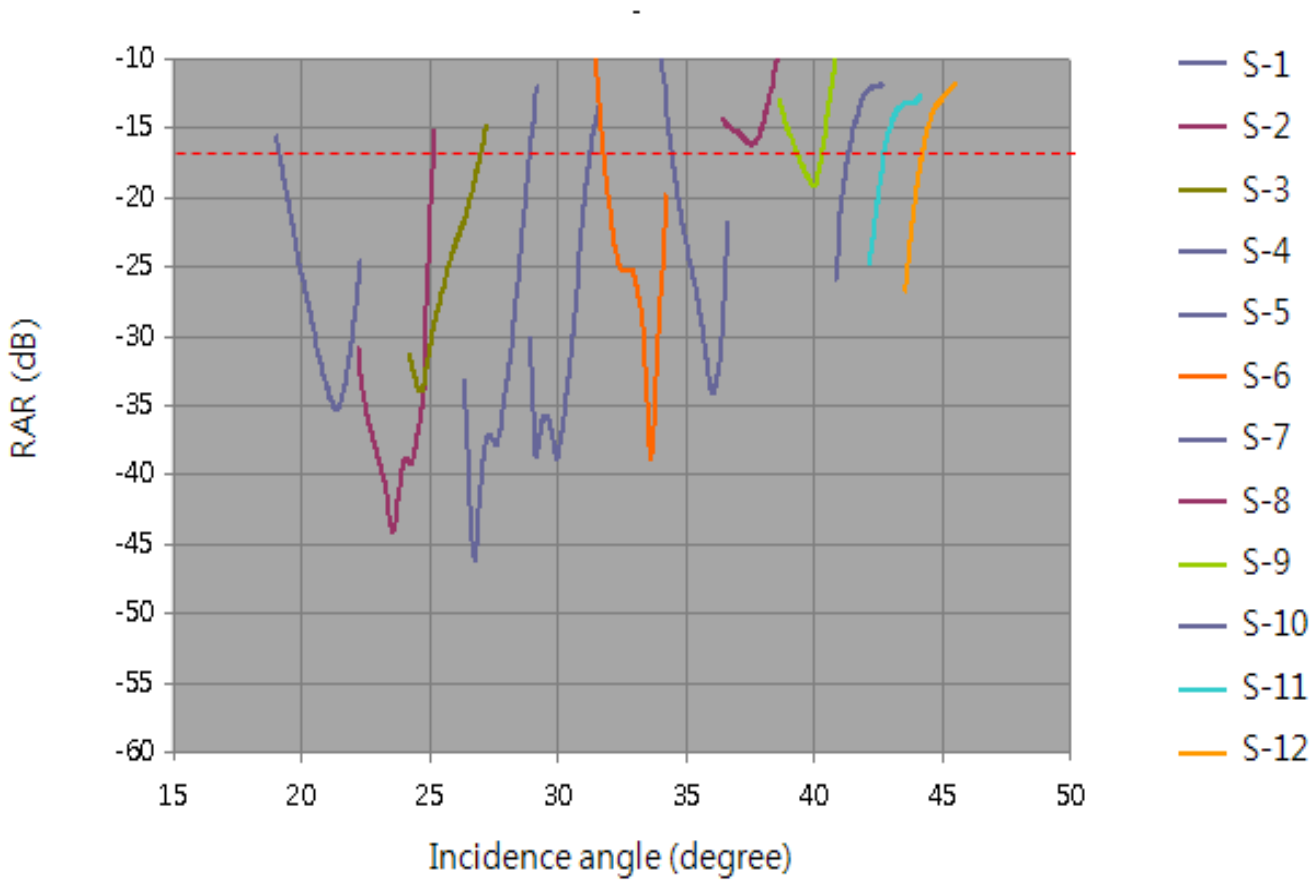
RAR Analysis for 12 Beam Patterns of Strip Mode

RAR of 3 Tile failure case
After re-generation



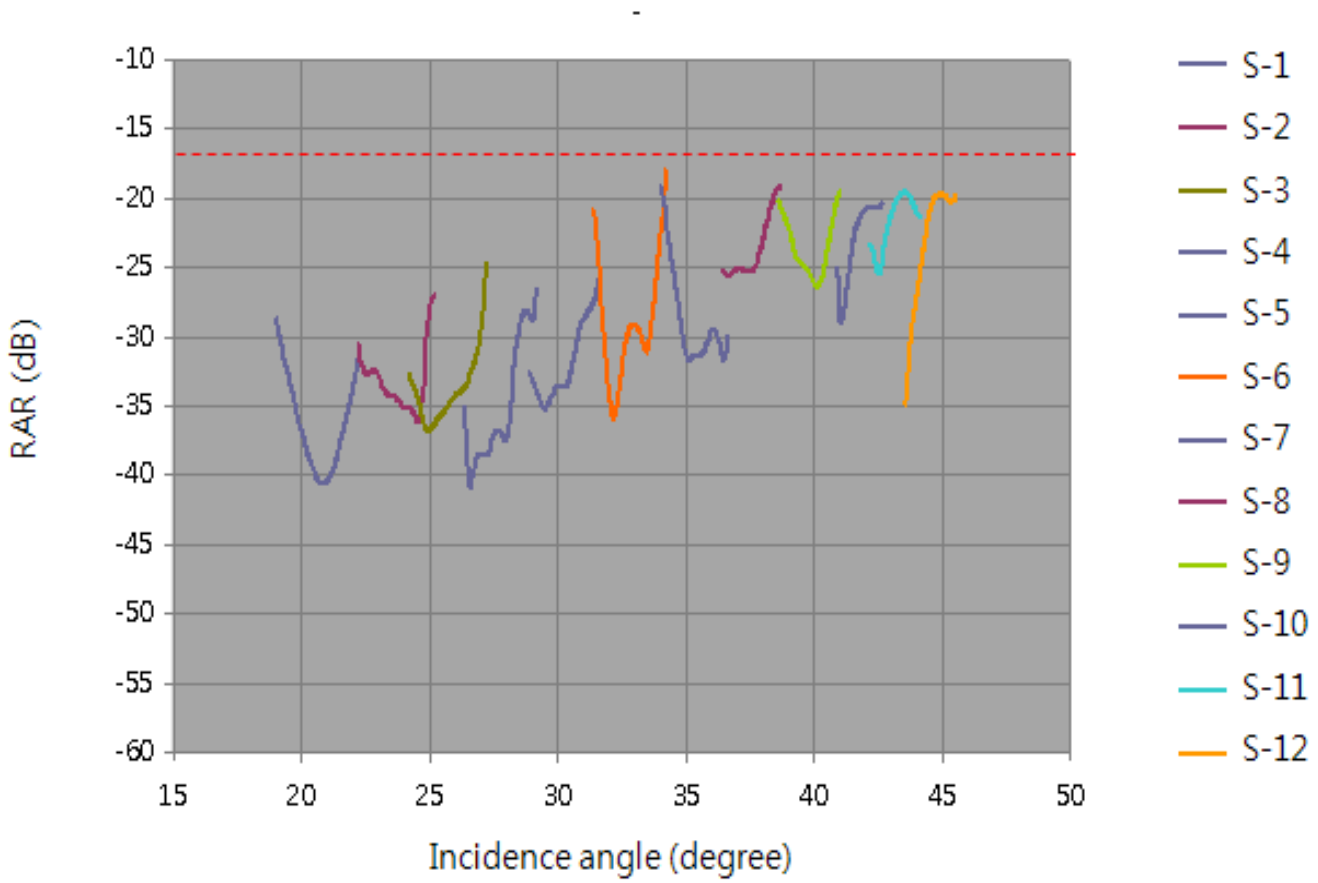
RAR Analysis for 12 Beam Patterns of Strip Mode

RAR of 4 Tile failure case



RAR Analysis for 12 Beam Patterns of Strip Mode

RAR of 4 Tile failure case
After re-generation



Conclusion

- The APAA considered in this study consists of 16 tiles in total, and one tile has 32 TRMs.
- Partial faults are set to not operate in tile units, and it is assumed that from one to four tiles gradually become faulted.
- After analyzing all antenna beam patterns by genetic algorithm and analyzing RAR, it was found that all antenna beam patterns can satisfy the requirement of -17dB or less.
- The result of this study can be used to compensate for degraded RAR performance by regenerating the antenna beam pattern by applying the genetic algorithm when the APAA operating in the stripe mode has a mission life of 5 years or more and the TRM of the APAA is partially faulted.