Active Radar Cross Section Reduction

Theory and Applications

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To

Professor R. Narasimha

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List of Abbreviations

ACM	Array correlation matrix
AMC	Artificial magnetic conductors
AWGN	Additive white gaussian noise
CFRP	Carbon fibre reinforced polymer
CLAS	Conformal load-bearing antenna structure
CNT	Carbon nanotube
DC	Direct current
DDD	Direct data domain
DF–GSC	Decision feedback sidelobe canceller
DNG	Double negative
DOA	Direction-of-arrival
DOF	Degree of freedom
DPS	Double positive
EBG	Electronic band gap
ECM	Equivalent currents method
EM	Electromagnetic
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
ENG	Epsilon negative
ERAKO	Electronic radar with conformal array antenna
ESPRIT	Estimation of signal parameters via rotational invariance techniques
FDMA	Frequency division multiple access
FDTD	Finite difference time domain
FEM	Finite element method
FHC	Filled-hole-compression
FHR	Fraunhofer institute for high frequency physics and radar techniques
FPGA	Field programmable gate array
FSS	Frequency selective surface
GA	Genetic algorithm
GA-CG	Genetic algorithm and conjugate gradient
GFRP	Glass fibre reinforced polymer
GO	Geometrical optics
GSC	Generalised sidelobe canceller
GTD	Geometrical theory of diffraction
HF	High frequency
INR	Interference to noise ratio
LCMP	Linearly constrained minimum power
LCMV	Linearly constrained minimum variance
LHM	Left handed material
LMS	Least mean square
LP	Linear programming
LS	Least squares
MMSE	Minimum mean square error
MNG	Mu negative
MoM	Method of moments
MSE	Mean square error
MUSIC	Multiple signal classification
NLMS	Normalised least mean square
NU	Non-uniform
NURBS	Non-uniform rational B-spline

OHC	Open-hole-compression	RLS	Recursive least square
OML	Outer mould line	RMIM	Receiving-mutual impedance method
PEC	Perfect electric conductor		
PMC	Perfect magnetic conductor	SINR	Signal-to-noise-interference-ratio
PO	Physical optics	SLL	Sidelobe level
PSLL	Peak sidelobe level	SMI	Sample matrix inversion
PSO	Particle swarm optimisation	SMILE	Scheme for spatial multiplexing of local elements
QFRP	Quartz fibre reinforced polymer		
QPSK	Quadrature phase-shift keying	SNR	Signal to noise ratio
QRD	QR decomposition	TDMA	Time division multiple access
RAM	Radar absorbing material	TE	Transverse electric
RAS	Radar absorbing structure	TM	Transverse magnetic
RCS	Radar cross section	UAV	Unmanned aerial vehicle
RCSR	Radar cross section reduction	UHF	Ultra high frequency
RF	Radio frequency	UTD	Uniform theory of diffraction
RHM	Right handed material	UWB	Ultra wideband

Preface

Logic will get you from A to Z; imagination will take you everywhere.

- Anonymous

Evading detection by radar has been one of the fascinating topics in aerospace engineering. Initial intuitive attempts towards achieving low-observable platforms, such as fighter aircraft, unmanned aircraft, missiles and even battle ships, came from the application of radar absorbing materials (RAM) and shaping to reduce the radar cross section (RCS) of the platform.

These efforts on RAM design have continued since 1940s. Likewise, the efforts on shaping have run parallel to the developments in the theory of electromagnetic (EM) scattering and diffraction. The edge-diffraction EM formulations of 1960s resulted in the ongoing efforts in 1970s towards eventual realisation of the Lockheed F-117 *Nighthawk*; this fighter aircraft was characterised by the faceted planar exterior for RCS reduction. Likewise, the subsequent standardisation of the EM curved surface-diffraction formulations reflected in the blended Northrop Grumman B-2 *Spirit* bomber aircraft structure in 1980s.

However, it must be understood that both the shaping and RAM were in the domain of passive RCS reduction (RCSR).Once these concepts were formalised, it became apparent that these essentially catered to the narrowband RCSR. The radar had to merely switch or scan over a wider frequency range to overcome the stealth strategies of the low observables.

Thus there is a need for broadbanding the electromagnetic design for airborne and naval structures. The desire is to evade detection for any incoming radar frequency, polarisation and direction of arrival. Indeed, the fervent wish list is to "some-how" sense and generate an anti-wave for cancellation. This is the essence of active radar cross section reduction (RCSR).

Active RCSR towards realisation of low-observable platforms hinges on the integration of (i) active antenna elements, (ii) onboard/airborne antenna analysis, and (iii) conformal EM analysis.

The onboard/ airborne antenna analysis formulations have matured over the last three decades. The conformal antennas provide the advantage of least obscuration and conflict with competing aerodynamic requirements. Conformal antenna studies have been actively carried out for last four decades. However, over the last ten years, the modern conformal antenna theory appears to have been systematised.

The active antenna elements have been extensively studied over the last two decades. Indeed the phased antenna arrays provide one, albeit not the only, route to generate adaptive patterns

towards active RCSR. Thus, it is our contention that active RCSR is an idea whose time has come!

The Centre for Electromagnetics (CEM), to which these authors are affiliated, has an active commitment towards RCS studies. Since RAM was once considered as a "highly classified area", we at the CEM took the initiative to demystify this topic in the form of a book:

> Vinoy, K.J. and R.M. Jha, *Radar Absorbing Materials: From Theory to Design and Characterisation*. Kluwer Academic Publishers, Norwell, Boston, USA, ISBN: 0792 397 533, 209 p., 1996.

The book in your hand is the second in this trilogy.

For the reasons discussed above, the emphasis in this book is on the phased antenna array analysis and algorithms as applied to active RCSR. All aspects, including mutual coupling, which takes one towards viable technological realisation of active RCSR, are discussed in details.

However, the end goal of this book is the low-observable platforms. Hence apart for the phased antenna arrays, advancement in the RAM design, plasma stealth, active FSS elements and metamaterial designs are also discussed as a parallel stream of concept.

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