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STEALTH, CAMOUFLAGE & COUNTERMEASURE TECHNOLOGIES

Technology Focus focuses on the technological achievements in the organization covering the products, processes and technologies.

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From the Desk of Guest Editor

Defence Laboratory, Jodhpur located at the gateway to Great Thar Desert, is a multi-disciplinary R&D laboratory of DRDO under Naval Systems & Materials cluster. The laboratory is working on the strategically important areas of Stealth, Camouflage, Countermeasures, Desert Operational Support Technologies and Nuclear Radiation Management & Applications to cater the requirements of Tri Services and paramilitary forces.

In the area of stealth technologies, the laboratory has established expertise in Radar signature measurement and analysis, Diagnostic RCS imaging, Electromagnetic analysis, Infrared signature measurement & prediction etc. Advanced materials and products have been realized towards signature management of legacy platforms. The laboratory is currently working on stealth solutions to futuristic platforms.

Camouflage, Concealment & Deception (CCD) is a major challenge in Desert Warfare. The systematic R&D activities undertaken by the laboratory resulted in establishment of camouflage infrastructure test facilities for signature acquisition of airborne and ground-based platforms in Microwave, Visual and Near Infra-red (NIR) & IR spectrum. Special type of multispectral coatings, paints, stickers and prototype adaptive camouflage add-ons have been developed to distort and suppress target signatures of strategic platforms and assets. Decoys for Tanks & Aircrafts and Thermal Targets for missile testing have been realized and deployed.

To improve survivability of fighter aircrafts and warships against hostile RF seeking missiles, the laboratory has successfully developed microwave chaff. For chaff characterization, state-of-art test and evaluation facility, virtual reality-based chaff application and training center &pilot plant chaff production facility have been established. Three variants of Naval chaff & 118/I chaff cartridges for IAF have been realized and Transfer of Technology given to industry partners for bulk production. Presently the laboratory is working on innovative Microwave Obscurant Chaff Technology to reduce the Radar Cross Section of platforms.

In the area of Nuclear Radiation management several products viz Dosimeters, Roentgenometer, Gamma Flash Sensor, CBRN Hazard Prediction Software, Environment Survey Vehicle, Modernized NBC Protection System for BMP, NBC reconnaissance vehicle (Tracked), Mobile Reconnaissance Laboratory (Wheeled) have been developed and inducted into the services. A mobile CBRN water purification system Mk-II has been developed to produce potable water

in chemical, biological, radiological & nuclear contamination zones. The system has been extensively exploited by Indian Army and cleared for quantity production.

In the area of Material technology, several advanced materials like Thermoelectric materials, Phase change materials, Artificial Engineered materials, Ferro-magnetic materials, Magnetic alloys, Graphene, Exfoliated Graphene, Reduced Graphene Oxide, Nano titanates, Gamma radiation sensors etc. have been successfully developed for myriad applications.

The laboratory with an excellent pool of human resources, R &D infrastructure and facilities complimented with academia and industry collaboration, has shown an exponential growth over the years.

The laboratory has drawn-up a technological road-map, identified niche technologies and accordingly focusing on the developmental activities.

The present issue of Technology Focus highlights the technology status, achievements made and R &D facilities established in the laboratory.

JAI HIND ....

RV Hara Prasad
Outstanding Scientist & Director, DLJ

STEALTH, CAMOUFLAGE & COUNTERMEASURE TECHNOLOGIES

Stealth and camouflage technologies are highly guarded and classified domains. Defence Laboratory, Jodhpur (DLJ) is working and providing comprehensive stealth, camouflage, and countermeasure solutions for the legacy as well as futuristic platforms of all types over the multi-spectral frequency range. The areas of focus include R&D in materials and process establishment, multi-spectral camouflage schemes in visual, thermal, and microwave frequency bands, radar signature diagnosis, measurements, and management.

Stealth Technology for Airborne Platforms

In the present war scenario, it is essential to defy the detection of military aircraft by minimizing the effectiveness of radar trackers by suppressing reflections from aircraft structure, which in turn reduce the probability of success of attacking missiles or weapons.

Aircraft geometrical shaping, material engineering, use of radar absorbing materials, and electromagnetic designs are the main constituents of stealth technology.

Low-observable Materials

Radar absorbing materials are based on the fact that some substances absorb energy from electromagnetic waves passing through them due to their lossy dielectric and magnetic characteristics, and reduced energy bounces off.

DLJ is involved in the development of radar-absorbing materials and their bulk production. The end-use products developed out of these materials, in the form of coatings and structures, are at the advanced level of evaluation for Radar Cross Section (RCS) reduction of specific airborne targets.

Magnetic Flakes

Specific shapes and sizes of magnetic flakes have been prepared by adopting the mechanical attrition process. Further, bulk production technology has been established while optimising various process parameters with reproducible physical and microwave absorption properties.

Ferrites

To absorb microwave energy, particularly over low-frequency bands, ferrite materials are promising candidates as functional filler materials. DLJ has successfully established the processes for the production of spinel and hexaferrites in bulk quantity to cater to the bulk requirement of ferrite for aircraft applications.

These potentially identified materials have been processed for the formulation of Radar-absorbing Paint (RAP), Radar Absorbing Structures (RAS), and flexible rubber sheets for the reduction of RCS on various platforms.

Radar-Absorbing Paints

DLJ has developed a two-pack coating system using in-house-developed functional filler materials. The coating has been designed with respect to filler concentration and thickness to obtain maximum absorption in the desired frequency range. Further, it can be applied to many portions of airframes, such as the air intake duct, wing skin, radome bulk heads, pylon, leading edge, splitter gap, etc.

RAP Coated Objects of Different Geometries

Demonstration of System Level RCS Reduction

For the demonstration of RCS reduction on legacy-aircraft in static mode, the developed RAP coating was exercised inside air intake ducts and adjoining sections of aircraft. RAP-coated aircraft shows a significant reduction in radar signatures over a multi octave frequency range.

RAP Application inside Air Intake Duct

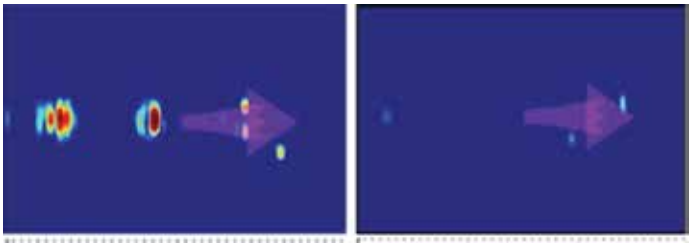
RAP Coated Glide Bomb

Flight Testing of RAP-coated Payload

Lightweight Flake-based Radar Absorbing Structures

The RAS based on magnetic flakes has also been developed, and their loading fraction has been optimized for the desired RCS reduction. A model aircraft duct was fabricated using the developed RAS, and its RCS measurement was carried out.

Model Duct Fabricated with Magnetic Flakes

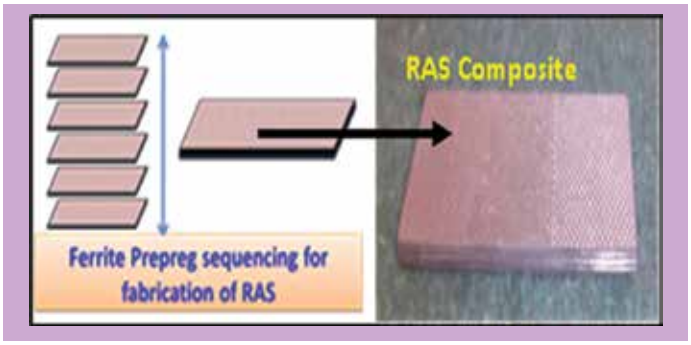


RCS Image of Duct (Left) Without RAS, (Right) With RAS

Prepreg-based low frequency Radar Absorbing Structures

Indigenous prepreg technology is established with the industry for large-area fabrication of filler-impregnated GFRP prepreg in roll form. The technology holds promise for the fabrication of RAS-based components aimed at realizing low-frequency microwave absorption.

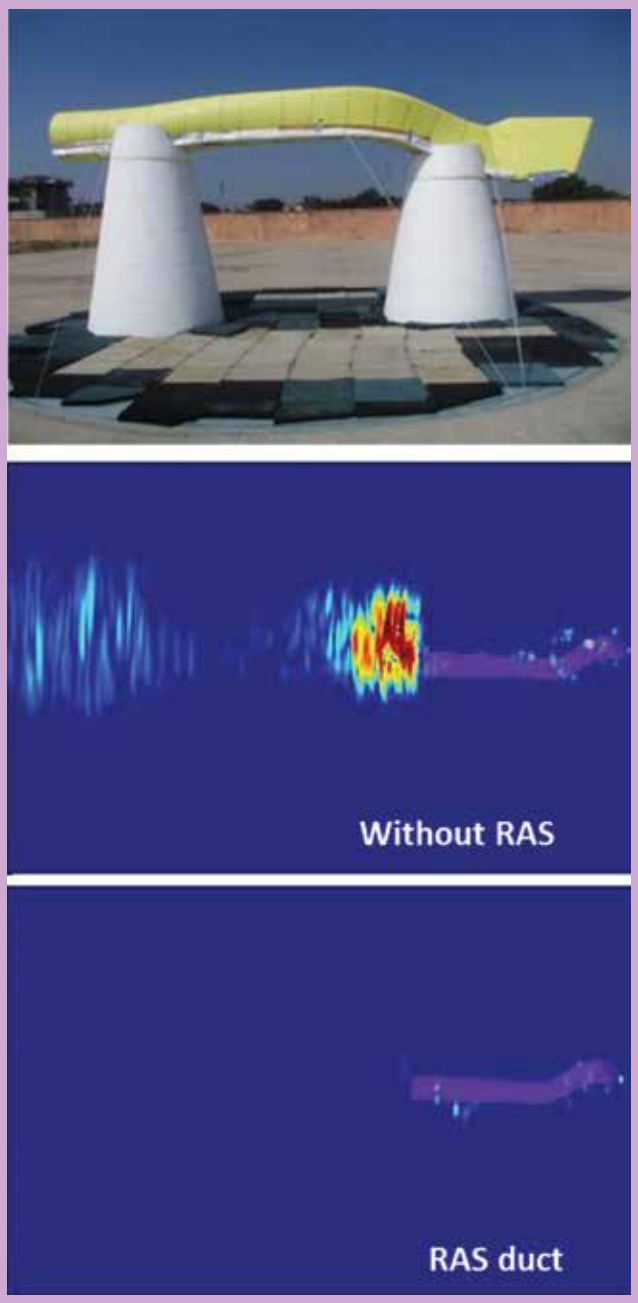
A full-scale duct model was cladded with the ferrite RAS as per the scheme shown in the figure.



Filler-based RAS

Flexible Sheets

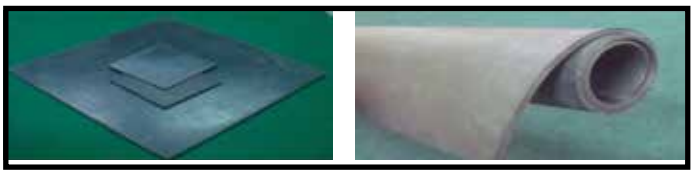
Flexible radar-absorbing sheets have been developed using in-house synthesized materials. These sheets can be easily cut and pasted onto curved



RAS Cladded Full-scale Duct Model and its RCS Images

surfaces, as well as custom-molded to any shape. The technology for the fabrication of these sheets has been established in industry.

Flexible RAM sheets pasted on the selective locations of the superstructure of the warship successfully altered the ISAR image of the ship.



Flexible Rubber Sheet

ISAR Imaging Modification of Warship Using Radar Rubber Absorbing Sheet

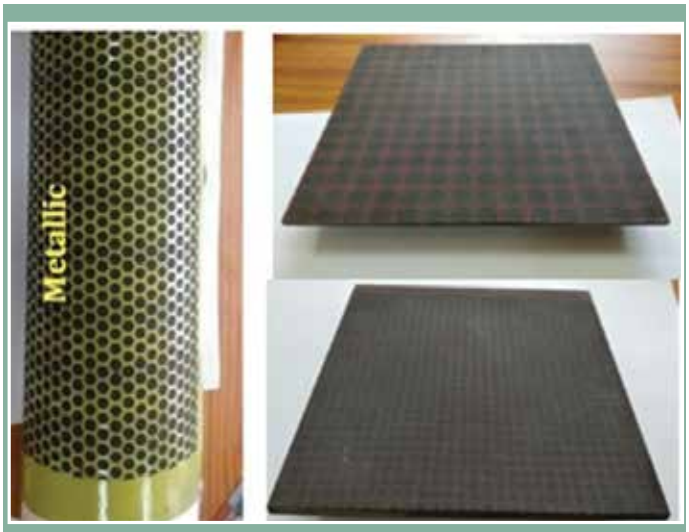
Artificial Engineered Materials

AEM-based radar absorbers consist of a periodic array of resistive printed patterns to achieve absorption and are placed over a grounded dielectric slab. The core of this technology is the development of suitable inks for different substrates.

The required physical properties of the printed pattern, such as conductivity, optical transparency, stability to bending, and adhesion (especially important for flexible patterns), along with the physiochemical properties of the ink, such as aggregation and stability, and its compatibility with the printing device, mainly determine the choice of the functional material.

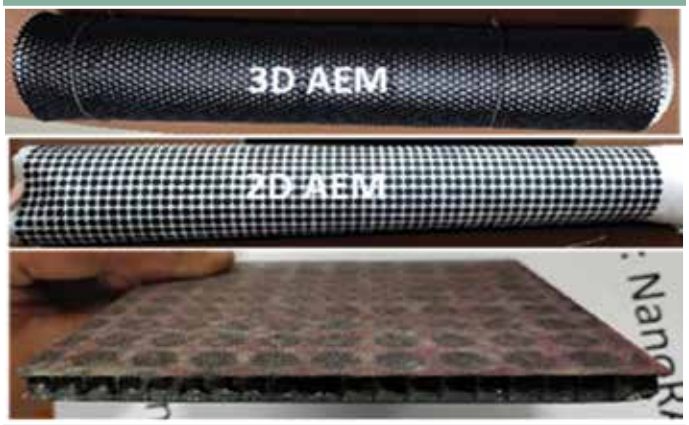
DLJ has developed nano-carbon-resistive inks suitable for different substrates. The developed ink has been utilized for the preparation of different classes of radar stealth materials, viz.

- Monolithic Radar Absorbing Structure (MRAS)
- Sandwich RAS (SRAS)
- Multilayer Filler-based RAS (FRAS)
- Flexible Radar-Absorbing Rubber Sheet



Monolithic RAS

Flexible Rubber-based Absorber



3D & 2D AEM-based SwRAS

EM Design Capability of Nose Cone Radomes

The laboratory has successfully established the following EM design capabilities, towards the design of nose cone radomes:

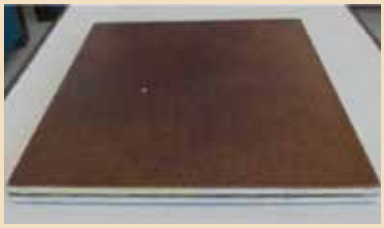
- Electron Microscopy (EM) characterization of materials
- Radome EM design and analysis
- Exact solver-based validation
- EM design capability of a monolithic radome

A nose cone radome has been successfully designed and prototyped for airborne applications

Low-observable FSS Radome

The realisation of low-observable radome is a critical and strategically important technology for the realization of stealth aircraft. The feasibility study on planar and conformal design has been carried out. Planar test samples are fabricated and tested.

FSS Pattern Development



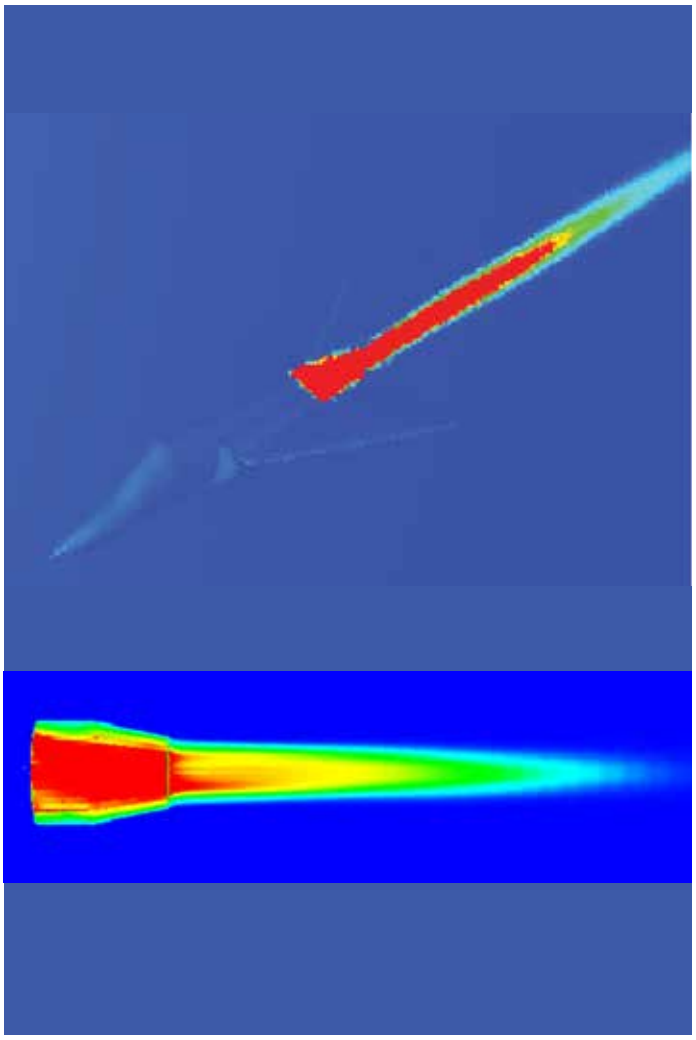
Fabricated FSS Radome Panel

Prototype of Scale Model of Multilayer Radome

Infrared Signature Management

IR stealth focuses on changing the IR radiation characteristics of the target. Signature management and stealth are possible only when a precise signature estimate is carried out. Signature estimation is possible in two ways: either through measurements on target or by predicting signature characteristics through simulation or prediction.

The laboratory has established both signature prediction and measurement capabilities in the IR domain. A signature prediction tool that simulates IR radiation distribution using geometry, computational fluid dynamics, and radiative heat transfer has been developed. Such a tool can simulate both solid surfaces and gaseous plumes.



Simulated IR Images Using Prediction Tool

Mini GT Engine Test Bench

The biggest challenge in signature simulation is its validity. To establish the validity of the developed tool with controlled measurements, a scale-down GT engine test bench facility has been established at DLJ. The measurement, analysis, and signature estimation of various aerial platforms have also been sucesssfully established in the laboratory.

Mobile Laboratory for Field Measurement

IR Emission of Aircraft

For futuristic aircraft the IR signature of the platform at multiple altitudes with various engine operating conditions has been worked out to carry out signature management on these platforms.

Camouflage Technologies for Ground-based systems

In the visible (VIS) region of the electromagnetic spectrum(400–700nm wavelength), the human eye, without and with aids (such as binoculars), is the primary sensor for detecting man-made objects in a natural background. Cam-IRR coatings are specially designed for low gloss and color-matching with the natural surroundings, such as sand and vegetation.

In the NIR region (700nm–1000nm wavelength),a variety of sensors, such as Passive Night Vision Devices (PNVD), Night Vision Goggles (NVG), and satellite-borne NIR cameras, seek to differentiate military targets from their natural surroundings.

Similarly, in Thermal Infrared (TIR) region, Handheld Thermal Imagers (HHTI) as well as platform-mounted imagers seek to detect objects in the field.

Cam-IRR Paints

The CAM-IRR coatings have been developed to cater to the requirements of camouflage of military targets in visible and near-infrared regions. These coatings can replace the normally used paints using conventional painting techniques. The cam-IRR paints are applied on the military tanks and served as an import substitution and accepted by the user. Additionally, these paints have also been applied to different tactical platforms and buildings by user agencies.

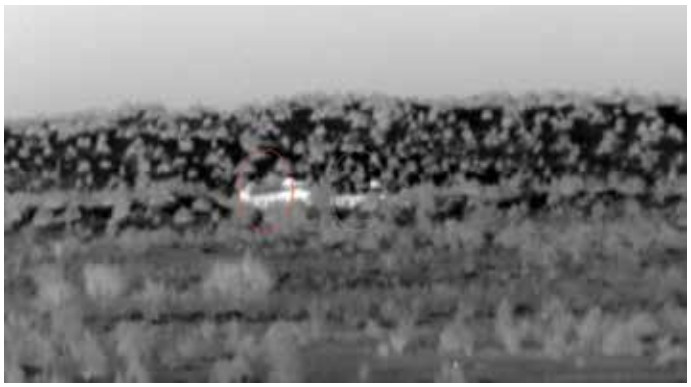
Tank with CAM-IRR Coatings

Low-Emissivity Multi-spectral Camouflage Paints

Low-emissivity Multi-spectral Camouflage Paints (LE-MSCP) coatings offer camouflage in the thermal infrared region. Additionally, they also provide effective blending with terrain features, such as camouflage, to provide surface protection and durability. The LE-MSCP coatings, comprising primer and topcoat, have low emissivity values to reduce the thermal signature due to solar loading.

Visual Image of Military Tank with MSCP Coatings

NIR Image of Military Tank with MSCP Coatings



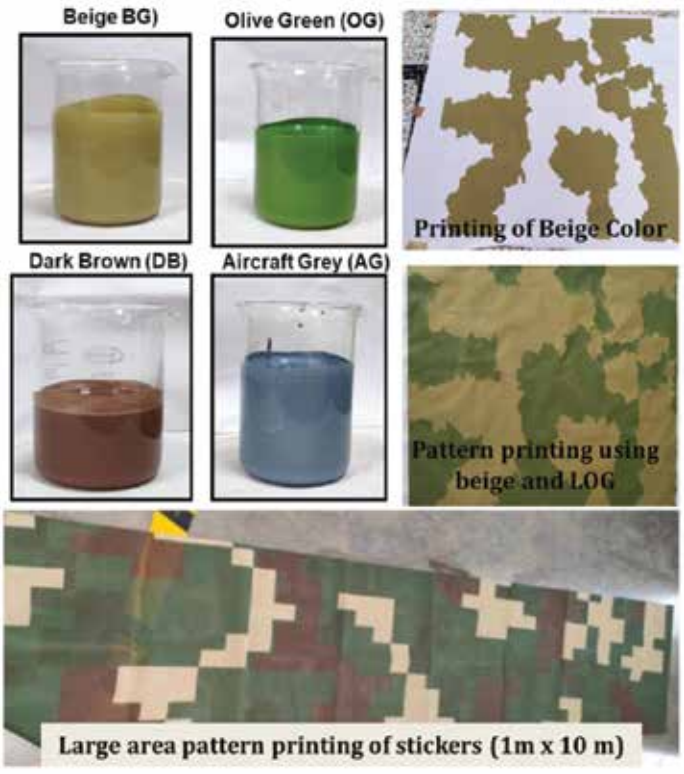
Thermal Image of Commercial Paint Coated (L), and MSCP Coated (R) AFV Against Natural Background

Multi-spectral Camouflage Stickers

DLJ has developed prototype multi-spectral camouflage stickers to meet user requirements. These stickers with multi-spectral properties, viz., visible, NIR, and TIR, will offer the following advantages:

- Ease of application
- Time-saving (paste and go, no down time)

Stickers can be used to camouflage objects just before a mission, adding an element of surprise.



Multispectral Camouflage Stickers

The technology for roll-to-roll fabrication of the stickers has been established with the help of industry.

Adaptive Add-on for AFV

DLJ has also developed technology for adaptive visible camouflage and successfully carried out its functional demonstration. The envisaged system generates visual colour patterns adaptively onto the vehicle to match the deployment background colour so that the vehicle merges with the background and makes it difficult to be identified during movement or change in the background features. The system is made up of flexible, active panels. The background image is captured by the camera, and with the help of control electronics, corresponding pixels on the object are activated that generate colours and patterns of the background on the object.

The panels are suitably fastened over the fabric substrate without hindering vehicle movement.

Visible Adaptive Add-on for AFV to Adapt to Changes in Colour and Patterns

Software for Camouflage Pattern Generation & 3D Visualisation

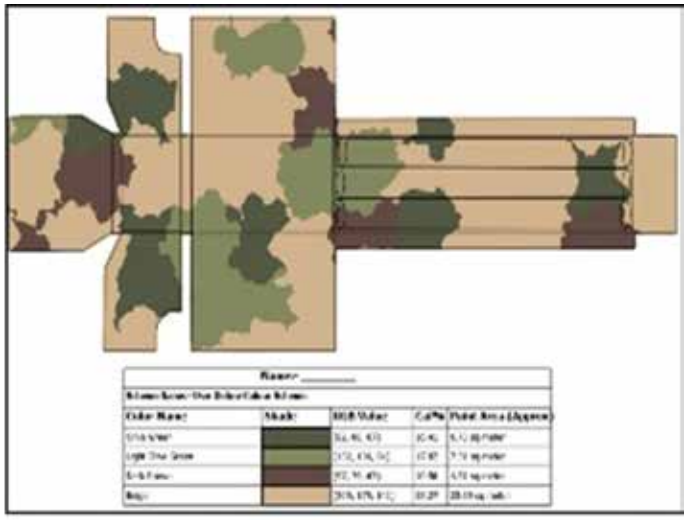
The simple and most effective way of camouflaging military objects in a visual range is camouflage painting. The camouflage painting is done using patterns, where more than one colour is used in inhomogeneous terrain. The software Sigma was specifically made at DLJ to meet the requirements of the Indian Armed Forces for computer-aided design of camouflage patterns for painting on moving or static military assets.

The software can generate a wide variety of camouflage patterns required by services, depending upon terrain features and the user's requirements.

Thermal Target System

DLJ has developed Thermal Target System (TTS), which is a low-cost solution and simulates the thermal signature equivalent of an operational tank in field conditions for test evaluation of IR-based Anti-Tank Guided Missiles (ATGM). TTS are a special class of thermal targets with controlled thermal characteristics, specifically tuned to provide a spatial

Sigma 3.1 Login Window



Colour Percentage Calculation

Camouflage Patterns Generated Using Sigma Software

Visualization of Tank with Camouflage Patterns

thermal signature profile equivalent to the actual size of the tank object. TTS has been successfully utilised in the test firing of IR seeker-based missiles.

Military Decoy Systems

Military decoys are strategically important objects for camouflage deception in modern warfare. Decoy enhances the survivability of actual equipment and personnel. The laboratory has successfully developed an inflatable decoy (1:1 scale) of a military tank with multi-spectral signature simulation capability in the optical, thermal IR, and Microwave (MW) spectrums. The inflatable decoys offer ease of operation in field conditions.

Inflatable Decoys

Frontal Aspect TTS of Tank

COUNTERMEASURES TECHNOLOGIES

Chaff Technologies

Chaff is a passive electronic countermeasure consisting of electrically conducting fine fiber of resonant length to act as a microwave dipole. Chaff products have been successfully realised and inducted in sevices.

Chaff Cartridge-118/I

It forms part of a Countermeasure and Dispersing System (CMDS) to protect the host aircraft from radar-guided missile threats by providing a suitable alternative and preferred target, or 'decoy' (as chaff cloud). DLJ has successfully indigenised the 1"x1"x8" chaff cartridges. After obtaining the Airworthiness Certificate and FCN from RCMA, user flight trials have been successfully completed. TOT is given to three industry partners for bulk production of chaff cartridges.

Chaff Cartridges (118/I)

Chaff Cartridges (26 mm & 50 mm)

These are circular chaff cartridges with a metallic covering that dispenses chaff fibers on firing to act as radar decoys. The development is complete, and airworthiness clearance has been obtained from RCMA (AA).

Chaff Cartridges (50 mm)

Naval Chaff Payloads

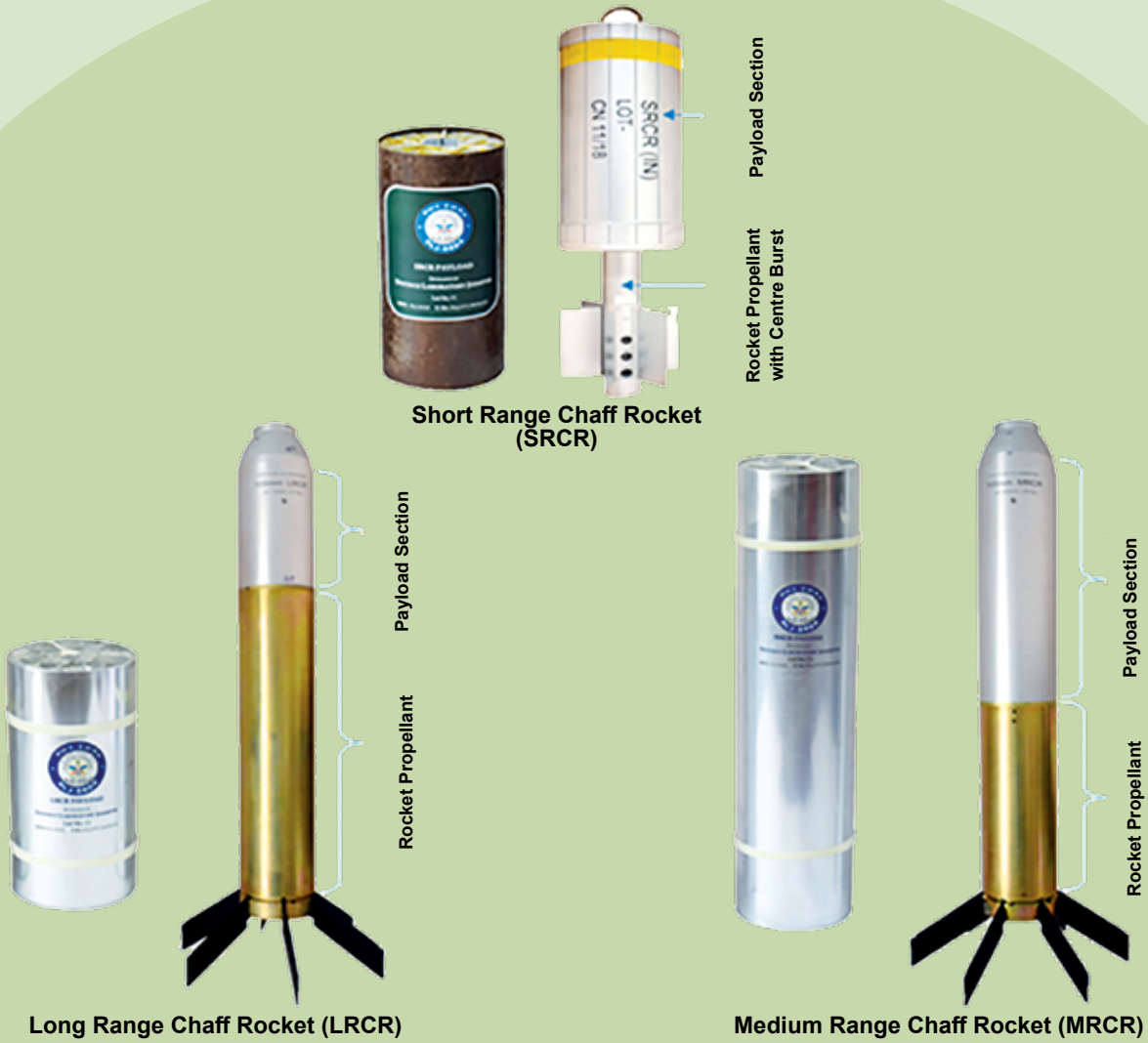
Defence Laboratory Jodhpur has also developed Advanced Chaff Technology for Indian Navy.

- The Short Range Chaff Rocket (SRCR) is a mortar-launched center burst system that is intended for very short ranges.
- Medium Range Chaff Rocket (MRCR) is a rocket-launched piston-based system that is intended for a few kilometers.
- Long Range Chaff Rocket (LRCR) is a rocket-launched piston-based system that is intended for long ranges.

Naval chaff payloads contain very fine-conducting fibers and produce high RCS over the broadband frequency range. The other features include a high retention time for chaff fibers, a rapid dispersal bloom rate, a cost-effective manufacturing process, and a high operational life.

Microwave Obscurant Chaff Technologies

MOC obscures radar signals and creates a microwave shield around strategic platforms and assets, reducing radar detection. The research on this technology is contemporary to such development internationally, and it is a niche technology.



DLJ successfully synthesized Microwave Obscurant Chaff (MOC) materials and has developed a continuous MOC coating process. DLJ has demonstrated the proof-of-concept of MOC technology to IN. The Navy user has successfully completed initial trials of the MOC rockets on IN ships to assess visual expansion, persistence time, and bloom time.

Coatings and Technologies Against Laser Threats

High-Energy Laser (HEL) weapons offers a potential threat to airborne platforms such as UAVs and aircrafts. The laboratory has initiated R&D to develop materials and coatings that protect military platforms against high power laser.

Editors are thankful to Dr Yojana Janu, Sc 'E', and Laboratory Correspondent of DLJ, Shri DK Tripathi, for preparing the write-up for this issue of *Technology Focus*.

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