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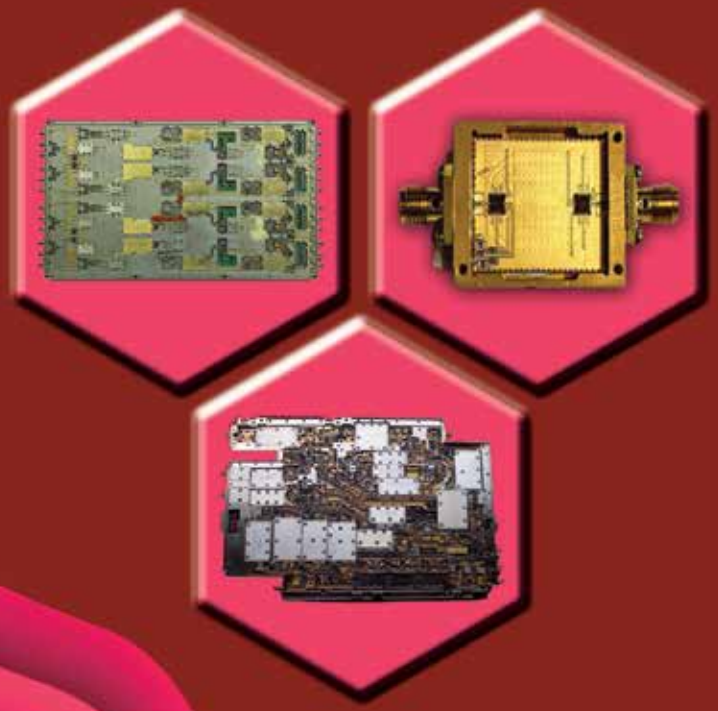
# MICROWAVE TECHNOLOGIES FOR ELECTRONIC WARFARE



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

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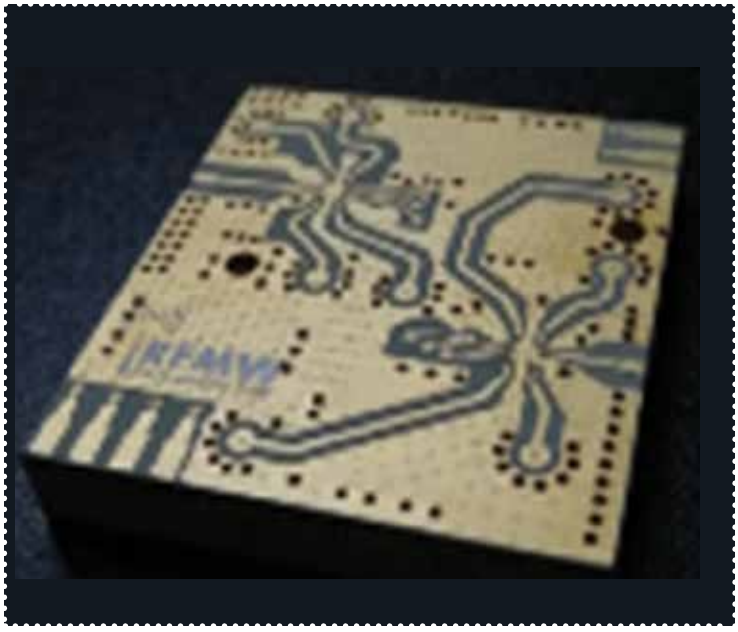

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# From the Desk of Guest Editor

Electronic Warfare (EW) is the use of electromagnetic and directed energy to control the electromagnetic spectrum. The present day EW systems have demanding requirements for the use of Armed Forces on land, air, sea, and also in space. Threats are becoming more and more agile and moving higher in the spectrum, thereby especially putting stringent design criticalities on various technologies for EW systems.

Defence Electronics Research Laboratory (DLRL), Hyderabad is indulged to meet the requirements of EW systems of Indian Armed Forces. The laboratory has designed, developed, and produced a large number of ruggedised systems meeting the state-of-the-art requirements of Army, Navy and Air Force in a dynamically changing operational scenario.

The EW system configuration comprises of antenna, microwave frontend modules followed by digital signal processing hardware, software, and man-machine interface modules. The laboratory developed the expertise in design and development of each of these functional technologies and also subsequently integrating them towards rugged field deployable systems for user exploitation and induction into the Services.

Microwave modules are heart of any EW system configuration in achieving the desired performance. The state-of-the-art challenges and advancements in microwave and millimetre wave circuits and system design place a heavy demand for highly reliable, SWaP-optimised, fully configurable, and sophisticated modular broadband RF solutions.

Over five decades, DLRL has developed the expertise and technical competence towards custom indigenous design, development, and productionisation of critical MW technology modules over multi-octave bandwidths meeting the requirements of the Services. Towards this wide range of MW technologies ranging from components, RF frontend modules and multi-channel receiver modules were successfully realised, productionised, field installed, and being exploited by the tri-services. State-of-the-art technologies like LTCC modules, multi-chip modules, T/R modules, core-chip, T/R chips and phased-array systems are also being developed and proposed to configure future systems with enhanced performance features.

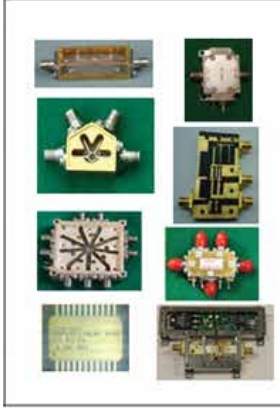
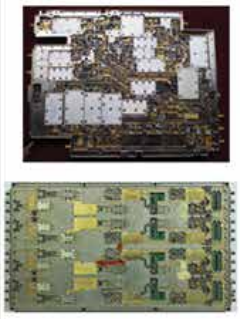
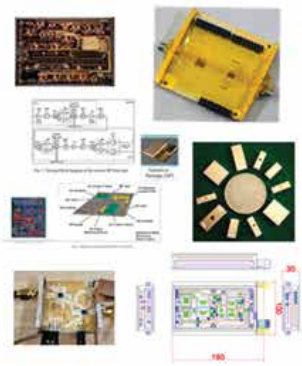
The present issue of *Technology Focus* highlights the contributions and various technological advancements that DLRL has brought in the field of microwave and millimetric wave area for EW. An effort is made to show the technology evolution from the early days to the present state-of-the-art SOC-based systems. Hope the readers will enrich their knowledge and appreciate the efforts by having glimpse of these technology modules, their salient features, application, and mapping to various EW systems.

**N Srinivas Rao**
**OS & Director, DLRL**

# MICROWAVE TECHNOLOGIES FOR ELECTRONIC WARFARE

Defence RF frontend applications are very versatile from the beginning. This has seen several advancements and steady emergence with the help of continuous progress of innovation in terms of performance, miniaturisation, wider bandwidths, etc. Over the last five decades' microwave technology has progressed by migration from large, heavy, waveguide, and discrete components to the integrated subsystems in Microwave Integrated Circuit (MIC) and Monolithic Microwave Integrated Circuits (MMICs) and presently marching towards Microwave Chip Modules (MCM), Low Temperature Co-Fired Ceramic (LTCC) and System on Chips (SOCs), etc.

## Microwave Technology Evolution at DLRL

| | | | | |
|---|---|---|---|---|
| Indigenous design & development of passive, active discreate components | Individual components connected to make subsystems | Super component approach as IMA | Integrated receivers using MMICs and indigenous design | MCM, LTCC System in package (Corechip/T/R Chip), 3U formfactor standard Open system Architecture (SOSA) |
| Legacy Systems | | Current & Advanced | | Next Generation |
|  |  |  |  |  |

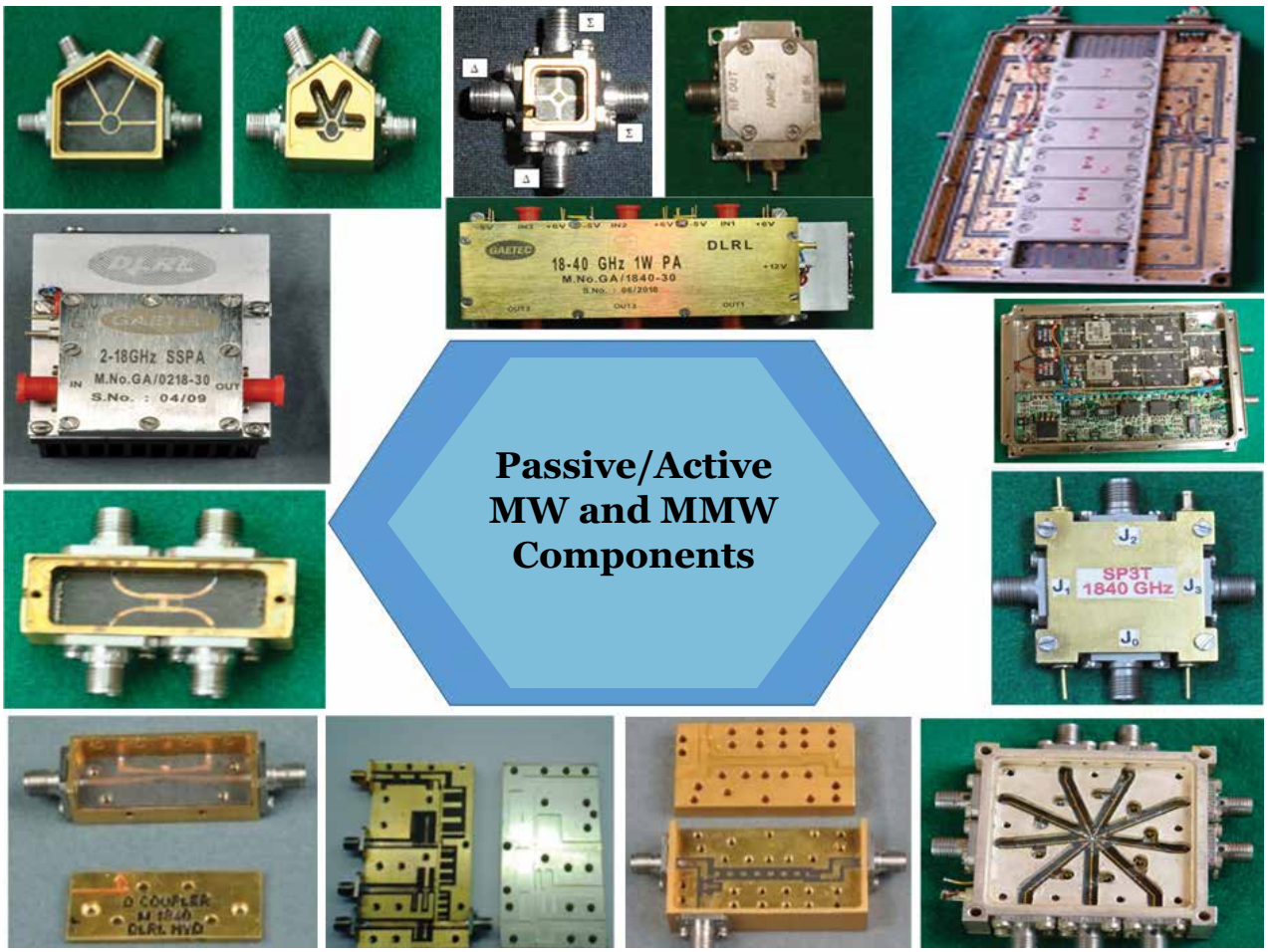
Initially microwave research was limited to individual components in which DLRL has established its strengths of design and development of complete range of passive components starting from filters, multiplexers, power dividers, couplers, hybrids, active, and control components like switches, amplifiers, attenuators, phase-shifters, phase-detectors, mixers, modulators, DTOs, etc., over the entire frequency spectrum upto 40 GHz. The EW system frontends are configured by connecting these components through cables and connectors. Later the super components were evolved with ease of integration, small size, lightweight with cableless and connector less configuration.

Further advancements have shown realising the complete receiver modules as single units as integrated receiver designs by employing MMICs and in-house designed components. This has drastically reduced the size, weight, and integration criticalities

and enhanced the performance. The next generation systems employing LTCC, MCM, SOC, AESA-based systems, etc. were also attempted as a part of technology development.

## Active and Passive Components (0.5-40 GHz Band)

Microwave wave and millimeter wave components both active and passive form the important constituents of the traditional RF receiver chains. In passive components family, filters like low-pass, high-pass, band-pass, notch-filters for interference suppression were indigenously designed, developed, and successfully employed in the EW receivers. Pass-band flatness, stop-band rejection, low-insertion loss and return loss above 10 dB are important specifications. Another group of passive components is power-dividers, hybrids directional-couplers multiplexers, circulator and isolators. Active components family has low-noise amplifiers, driver amplifiers, limiting amplifiers and power amplifiers, control components like multi-port switches, attenuators, mixers, Phase Lock Dielectric Resonator Oscillator (PLDRO), synthesisers, etc. Multiport multi-through switches upto 16 ports covering multi-octave bands both high-speed, high-power, more isolation between the ports were designed and developed inhouse. The complete range of microwave and millimeter wave components, subsystems and systems were designed, realised, assembled, tuned, and tested inhouse and the required skills and experience was well established. All or most of these were productionised as components, subsystems and systems or integrated modules through production partners.

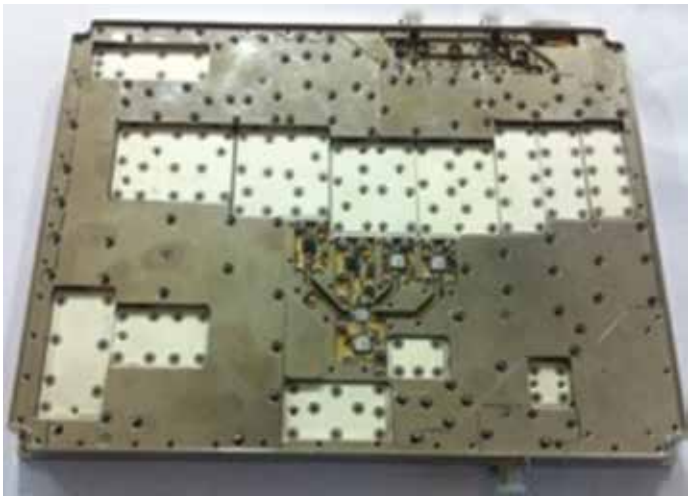


# Integrated Microwave Modules as Frontend Modules

Integrated microwave modules perform specific function by integrating several components in super component approach by employing direct integration of individual components as drop in versions and MMIC modules.

## Frontend Modules

Frontend Modules (FEMs) are the first components in the receiver chain, connected directly from the antenna. Their purpose is to provide initial gain for preconditioning, noise swapping of the signal and best control the harmonics to achieve the required dynamic range and sensitivity of the system. Design of the FEMs is very important to achieve the system performance. Based on the requirements, preselection filter banks are also provided to control or reject the unwanted high-power signals entering the system. These are designed to meet the platform, system specific functionalities, and RF mapping requirements. The several configurations were designed and successfully developed for airborne, shipborne, and ground-based system requirements covering multioctave bandwidths upto 40 GHz.



Frontend Receiver

RF Conditioning Units


Frontend Modules

### Salient Features:

- Indigenous custom design to meet platform specific requirements
- Frontend preconditioning and noise swapping.
- Pre-selection filter banks/Notch filters for interference suppression
- Optimise/improves sensitivity and dynamic range
- Better harmonics and spurious rejection

**Technology Mapping:** Ground-based, airborne and shipborne systems

**Status:** User evaluation on respective platforms is completed and quantity production is in progress.

## Built-in Test Equipment Modules

System Built-in Test Equipment (BITE) will be employed for testing and monitoring the health status of total EW system. These BITE modules provide a method of injecting test signal for establishing the functionality of the EW receiver. In the BITE mode of operation, the antenna input in each of chain will be de-selected and an RF BITE signal will be injected at respective frontend receiver to evaluate the output. The performance of the system is tested at regular intervals and also at power on time. Different modules covering 0.5-40 GHz band were designed, developed, and successfully evaluated. The Environmental Stress Screening (ESS), Safety of Flight Test (SOFT), and Qualification Test (QT) qualified units are employed in various projects after successful evaluation.

### Salient Features:

- Super component-based approach
  - System configuration specific design
  - Internal BITE signal generation
  - Provision for external mode for system calibration
  - QT qualified units

**Technology Mapping:** Airborne, ground-based and shipborne platforms

BITE Modules

BITE Modules

## Switch-Matrix Modules

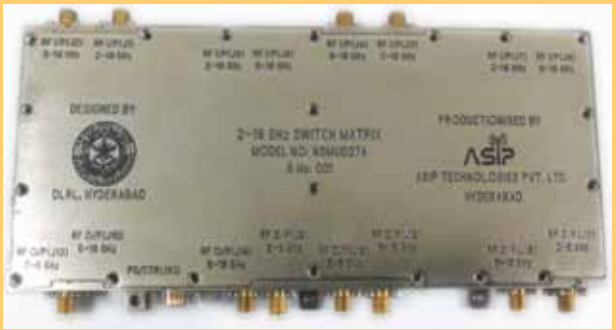
Integrated EW systems for tri services function over wide open band with 360⁰ coverage in space by positioning number of antennas. To configure the systems meeting the requirements, switching matrix is envisaged. These switching matrix units will switch the antenna outputs to the RF frontends as per the requirements. Hence these switching matrix units are very important units in the overall system configuration.

The switch matrix is used immediately after antennae to reduce the noise figure of the total ESM system as well as reducing the hardware of using number of RF frontend units. The switch matrix receives the antenna inputs from all four quadrants (look direction) and select one particular quadrant 90⁰ segment (look direction) at a time to the receiver frontend units for measurement of Phase-based Direction Finding (PDF). It also selects the antenna inputs simultaneously from one antenna in each quadrant based on the algorithm for the measurement of Amplitude-based Direction Finding (ADF) signals. It also provides BITE signal injection for the system.

### Salient Features:

- Multi-octave frequency band coverage
- High Isolation of 60 dB among ports
- Gain matched and phase matched for ADF and PDF Systems.

**Technology Mapping:** Airborne, shipborne projects.

Switching Matrix

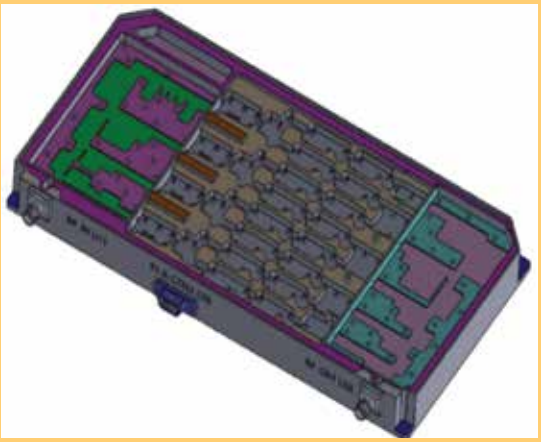
## Switch Multiplexer Module

The unit has a switched selection of multiplexer having 8 channels of 2 GHz bandwidth. Any of these 2 GHz channel or multiple combination of any 2 GHz can be selected or blocked as per the requirement. This prevents a channel having strong CW signal from saturating the weak signal. Also the switch multiplexer arrangement removes the extra crossover loss at the crossover frequencies ensuring almost flat amplitude response over 16 GHz bandwidth.

### Salient Features:

- Pre-selector and FER
- Excellent selectivity, good isolation
- Simultaneous multiple interference rejection
- Channel optimisation with flatness over the broad bandwidth

**Technology Mapping:** Developed as technology development module for ES/ELINT systems

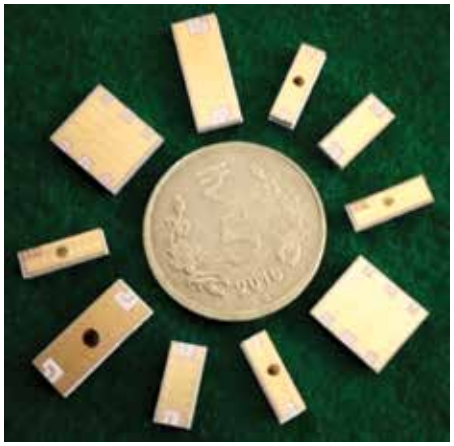


3-D Solid Model and Realised Switch Multiplexer Unit

## LTCC-based Filters and Switch Filter Banks

The demand of modern microwave receivers for high performance small size, low cost, lightweight, and high reliability is ever increasing. The passive components like filters and switch filter banks which form crucial part of the receivers add considerable size and volume in addition to increasing the weight of the receivers. It is difficult to reduce the size and weight of these passive components using simple planar designs.

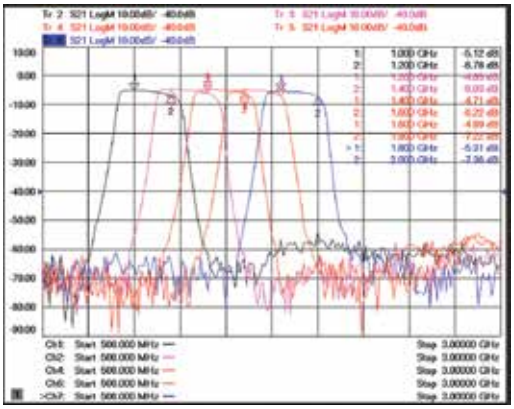
Advanced Low Temperature Co-Fired Ceramic Technology (LTCC) that allows multi-layer structures with high level of 3D integration is a promising solution for realising small size and lightweight passive components with high performance and reliability. Due to high dielectric constants, multilayer approach with smaller diameter and layer thickness option miniaturises passive microwave circuits and also increases its reliability and repeatability. The important feature is, once the design is proved, it becomes a surface mount component and can be mass produced. There is a considerable size reduction to an extent of 40 per cent to that of conventional filters and provides performance enhancements in terms of ease of production ability, excellent repeatability, etc. As the passives are buried inside layers the entire top layer area is free for MMIC integration which is best suited for SWaP optimisation. These filters and switch filter banks in various bands are designed inhouse and fabricated through Indian and foreign foundries and established the performance.



### Salient Features:

- Multilayer technology
- SWaP optimisation to an extent of 40 %
- Repeatability and productionability
- Inherent tracking performance
- Ease of integration

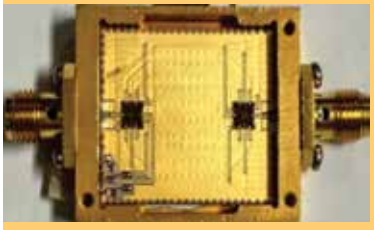
**Technology Mapping:** As drop in for future receiver modules and integrated receiver frontends.
**Status:** Design and fabrication established with both Indian and foreign foundries.



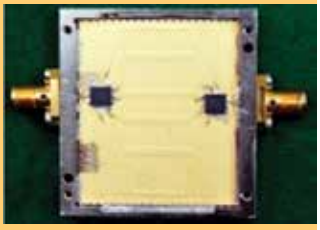
Measured response of 1.0 - 2.0 GHz SFB

Filter 3.0-3.5 GHz 15 X 4.5 X 1.6 mm³

Filter 2.75-3.25 GHz 14.4 X 5.9 X1.6 mm³



1-10 GHz and 1-2 GHz



Switch Filter Bank

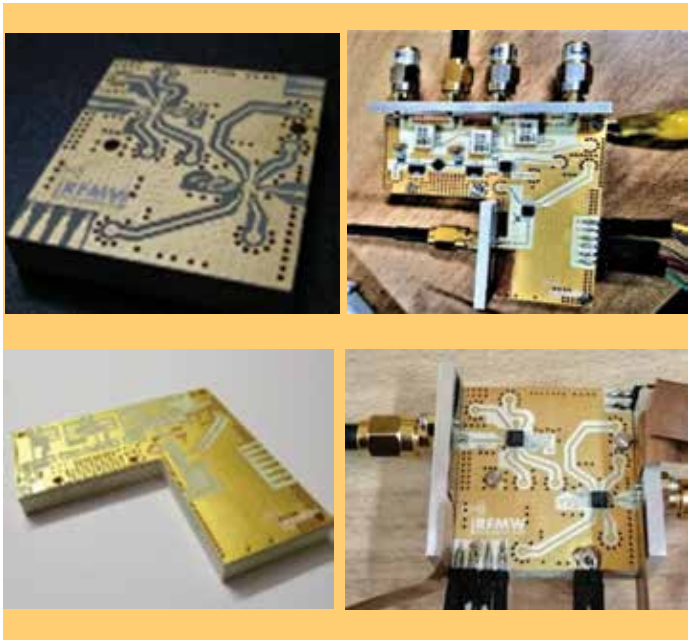
## Multifunction / Chip and Modules

Multi-chip modules are next generation microwave modules employing multilayer technologies for SWaP optimisation and integrating several MMIC functions into single chip. These are attempted to establish the feasibility by replacing several of these frontend module functions into single module. Towards this LTCC, multilayer technology are addressed and IF converter modules, filterbank modules, frontend modules were realised and performance tested.

### Salient Features:

- SWaP optimisation
- Excellent reliability and improved RF performance
- No tuning involved and ease of integration
- Good amplitude and phase tracking

**Technology Mapping:** To be employed in future integrated receiver modules and small form factor systems.



Multifunction Chip and Modules

# EA/ ES/ELINT/ COMINT Receiver Technologies

## EDLVA Super Component 0.5-18 GHz/18-40 GHz

Extended Detector Log Video Amplifier (EDLVA) performs an essential function in modern radars and EW systems. EDLVA is used to find the fine bearing information of the received signal using amplitude comparison method. EDLVA super component is an RF frontend receiver subsystem consisting of RF functional modules for signal conditioning upto video output. The functional modules required to develop 0.5-18 GHz, 18-40 GHz super component are single-pole Double-throw switch, high-pass filter, power-divider, low-noise amplifiers, detectors, and log-video amplifier. DC coupling is used in a DLVA when it is necessary for the circuit to respond to CW signals by producing a continuous DC output that is proportional to the CW input level. In the proposed scheme, RF detection takes place before the logging action. The output of the detector is then compressed to simulate a logarithmic input/output relationship in the log amplifier section. The dynamic range of a DLVA is limited by the linear/square law range of the input diode detector. The overall dynamic range of the DLVA can be extended by using two or three parallel detectors circuits with proper preamplifiers. Each detector can be operated over 20 to 30 dB dynamic range and the response of LVA is adjusted for linearity over the complete dynamic range. These modules were indigenously designed, developed, and successfully productionised through industry partners.

### Salient Features:

- MMIC-based EDLVA and compact RF frontend
- Notch filter banks for interference suppression
- Direct integration for coarse DF and frequency measurement
- In house design and development

**Technology Mapping:** RWR, ESM for ground-based, heliborne and shipborne platforms.




EA/ ES/ELINT/COMINT Receiver Technologies

## Channelised Receiver Technology (0.5- 40 GHz)

Indigenously designed and developed by the laboratory to meet the ES system configurations of airborne, shipborne systems. The unit has been realised using state-of-the-art MMIC/super component approach and airborne, shipborne qualified.

Channelised receiver technology is required for high sensitivity and high accuracy ELINT systems to intercept present and future threats over wide frequency coverage. These subsystems are developed in modular approach in different layers as RF module, LO synthesiser module, power supply module, and control module. This functional partition supports to configure the unit for N-channel coherent DF application by making use of BLI (Phase-based) and ADF (amplitude-based) techniques. this unit as single channel finds application for high performance microwave tuner that require demanding tuning performance in terms of tuning accuracy, resolution, speed, and phase noise in compact size and lightweight. It employs double down conversion and switch filter banks for better image and spurious harmonic rejection. It also employs indigenous syntheiser developed from micro synth module and multiplication and filtering approach upto 36 GHz.

### Salient Features:

- Indigenous design development
- High performance ES/ ELINT systems
- Modularity in design and compact multichannel frontend
- Integrated LO scheme in single housing
- Excellent amplitude and phase tracking
- Qualified product for the Services

**Technology Mapping:** Airborne, shipborne and ground-based ES/ELINT system configurations

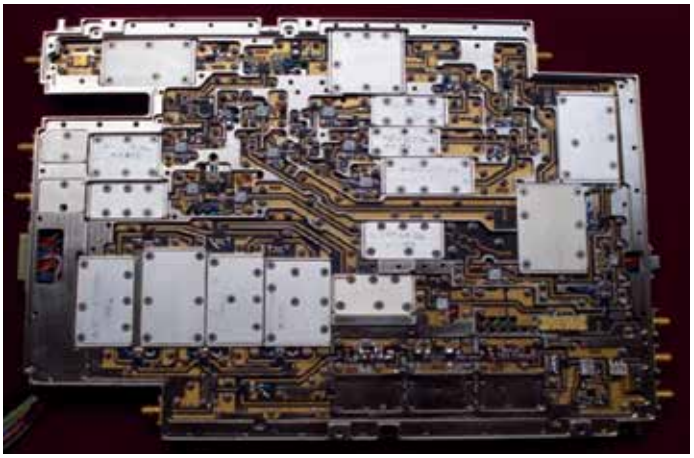
**Industry Partners:** M/s BEL, Bangalore, M/s ADTL and M/s AMPL, Hyderabad

**Status:** Field evaluated and presently being exploited.

Quad-channelised Receiver (0.5-18 GHz)

Single Channel as RF Tuner (0.5-18 GHz)

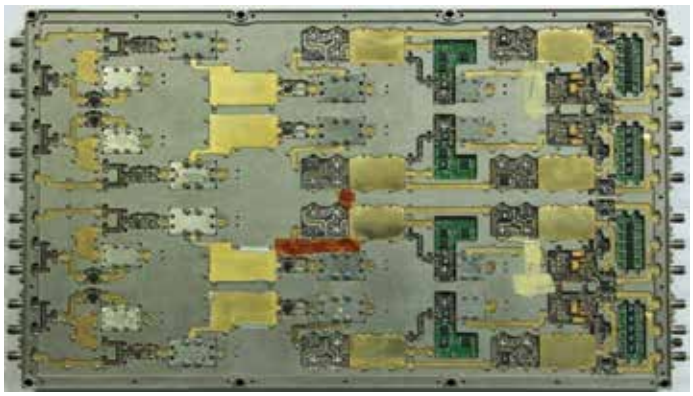
Channelised Receiver 18-40 GHz Single, Dual, and Quad Configurations



Inside View of Single Channel RF to IF Section

## 0.5-18 GHz Quad Superhet Receiver

Superhet receiver is an important constituent of Electronic Intelligence (ELINT) system to achieve enhanced sensitivity to intercept LPI-radars operating with low transmitting power. It offers superior sensitivity, frequency stability, and selectivity. QSR, developed using state-of-the-art super component integration approach, consists of four identical superhet channels in a single mechanical housing of 340 x 240 x 30 $mm^3$ to achieve high accuracy DF measurement using Baseline interferometric technique with higher sensitivity. Multifold reduction in size and volume has been achieved with respect to the conventional approach.



0.5 GHz -18GHz Quad Superhet Receiver

### Salient Features:

- Triple down conversion approach
- High accuracy DF with high sensitivity
- Indigenous design in modular and compact size
- Excellent phase and amplitude tracking among channels

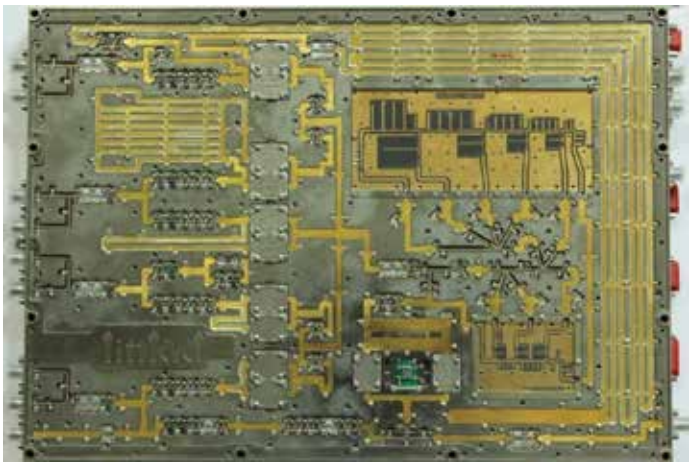
**Technology Mapping:** Ground-based, airborne, shipborne and space-based ES/ELINT configurations

**Industry Partners:** M/s BEL, Bangalore and M/s. AMPL, Hyderabad

**Status:** More than 150 numbers are productionised till date and are being used across various airborne, shipborne, ground-based and space-borne platforms.

## Homodyne Receiver Technology in 2.2-18 GHz, 1.2-18 GHz and 0.4-2.2 GHz

Homodyne receiver is a broadband ESM system, for measuring amplitude, frequency and DF of the intercepted radar signal. It employs homodyne based down conversion to convert entire RF frequency range to an IF of 160 MHz. It also incorporates channelised receiver for better selectivity and superhet receiver for better sensitivity along with the homodyne receiver. This receiver configuration employs EDLVA for amplitude, delay line-based instantaneous frequency measurement technique for frequency and BLI-based high accuracy DF technique for DF.



### Salient Features:

- Homodyne-based EW receiver with wide instantaneous bandwidth
- High accuracy DF, IFM, and amplitude in a single receiver
- 5-tier assembly for achieving compactness
- Indigenous design in modular and compact size

**Technology Mapping:** Airborne, shipborne, and ground-based systems

**Industry Partners:** M/s BEL, Bangalore and M/s. AMPL, Hyderabad

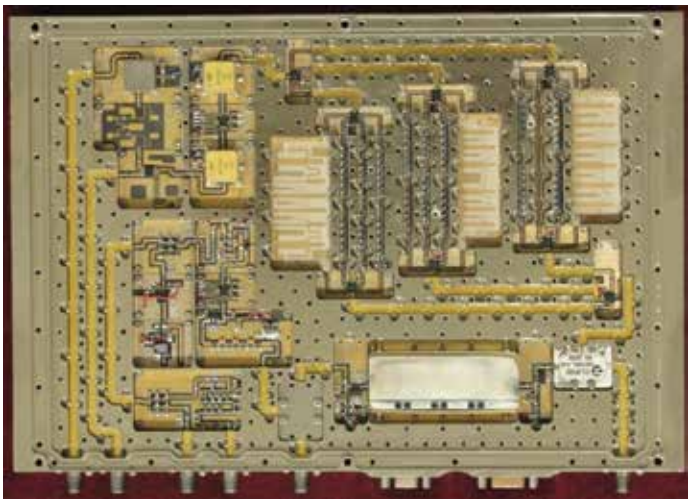
**Status:** More than 230 numbers (HB and LB) for shipborne are productionised.

## V/UHF Tuners

V/UHF tuned receivers are configured to convert RF input (70-500 MHz, 175-2200 MHz, and 400-2200 MHz) into 160 MHz IF, with an instantaneous bandwidth of 20/10 MHz (switchable). It employs a double conversion super heterodyne technique. The tuner consists of a built-in Switch Filter Bank (SFB). It consists of suboctave band-pass filters. Depending on the incoming signal frequency only one filter shall be selected at a time. This tuner finds application in communication ESM direction finding, search and analysis and non-com EW applications.

### Salient Features:

- Double down conversion approach
- High sensitivity and extended dynamic range
- Indigenous design
- Modular and compact size



V/UHF Tuner

**Technology Mapping:** As technology development and later mapped to shipborne and airborne systems.

**Industry Partners:** M/s BEL, Hyderabad and M/s. FLIC, Hyderabad

**Status:** 66 numbers each of tuners and FERs are productionised under project Samudrika.

# Down/DownUp Converters (5-18 GHz for EA Receivers)

RF Modules for EA application needs receive and transmit chains with excellent phase coherency of the signal to better mimic the threat signal. This requires down and up conversion of the input RF signal. This module generates IF signal and provides as input to the low power jammer programming module. The output is further up converted back to the baseband signal to the high power units to generate the jamming signal. These modules are indigenously designed and developed to meet the airborne system requirements.

**Salient Features:**

- Wideband operation for EA application
- Super component-based approach
- SWaP optimised realisation
- Single down/up conversion approach
- Qualified modules

**Technology Mapping:** Airborne, shipborne ECM systems

**Industry Partners:** M/s ADTL, Hyderabad and M/s. AMPL , Hyderabad

**Status:** Integration checks and platform trials are in progress.

# Downconverter Subsystem 18-40GHz

The module is developed indigenously employing the state-of-the-art MMIC and super component approach to extract emitter parameters in ES/ ELINT configurations. The 18-40 GHz downconverter subsystem receives 18-40 GHz signal from the antenna and down converts to 6-17 GHz (11 GHz instantaneous bandwidth). It generates two video signals for DF processor and two RF outputs which are used for parameter measurement in wideband and narrowband modes. The qualified units are developed for airborne and shipborne requirements. Platform trials are completed successfully and EW system handed over to the user and is operational.

**Salient Features:**

- MMIC and super component-based approach for SwaP optimisation
- High RF and BITE isolation for calibration
- Signal interception 100 % and truly instantaneous
- High sensitivity ESM system for airborne and shipborne platforms

**Technology Mapping:** Airborne, shipborne EW systems


18-40 GHz Downconverter Subsystem

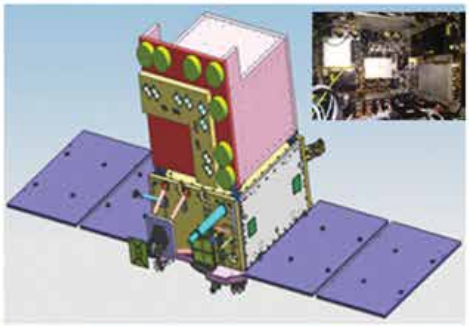
**Industry Partners:** M/s ADTL, Hyderabad and M/s. AMPL, Hyderabad

**Status:** 26 nos integrated and completed platform trials.

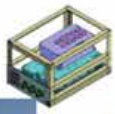
# Integrated EW Systems/Platforms

All these modules as components, frontend modules and/or as integrated receiver units are qualified, integrated on the respective platforms and field tested successfully. Many of these are being exploited by users. Integrated EW suites, ESM, ELINT configurations by employing various modules described above were deployed for the Services. Broadband, Narrowband applications for tactical and strategic missions were proved with the indigenous custom designed modules. Parameter extraction in terms of frequency, PW, PRF, direction and type of modulations, etc., were the measurements on the emitter signal. Land, air, sea, and space-based systems were successfully field evaluated.

EMISAT with the Payload Interface Module



AEW&C ESM System



ARC, NTROELINT System

Channelised Receiver 18-40 GHz, BITE Module, Switch Matrix, Homodyne Receivers, Superhet Receivers

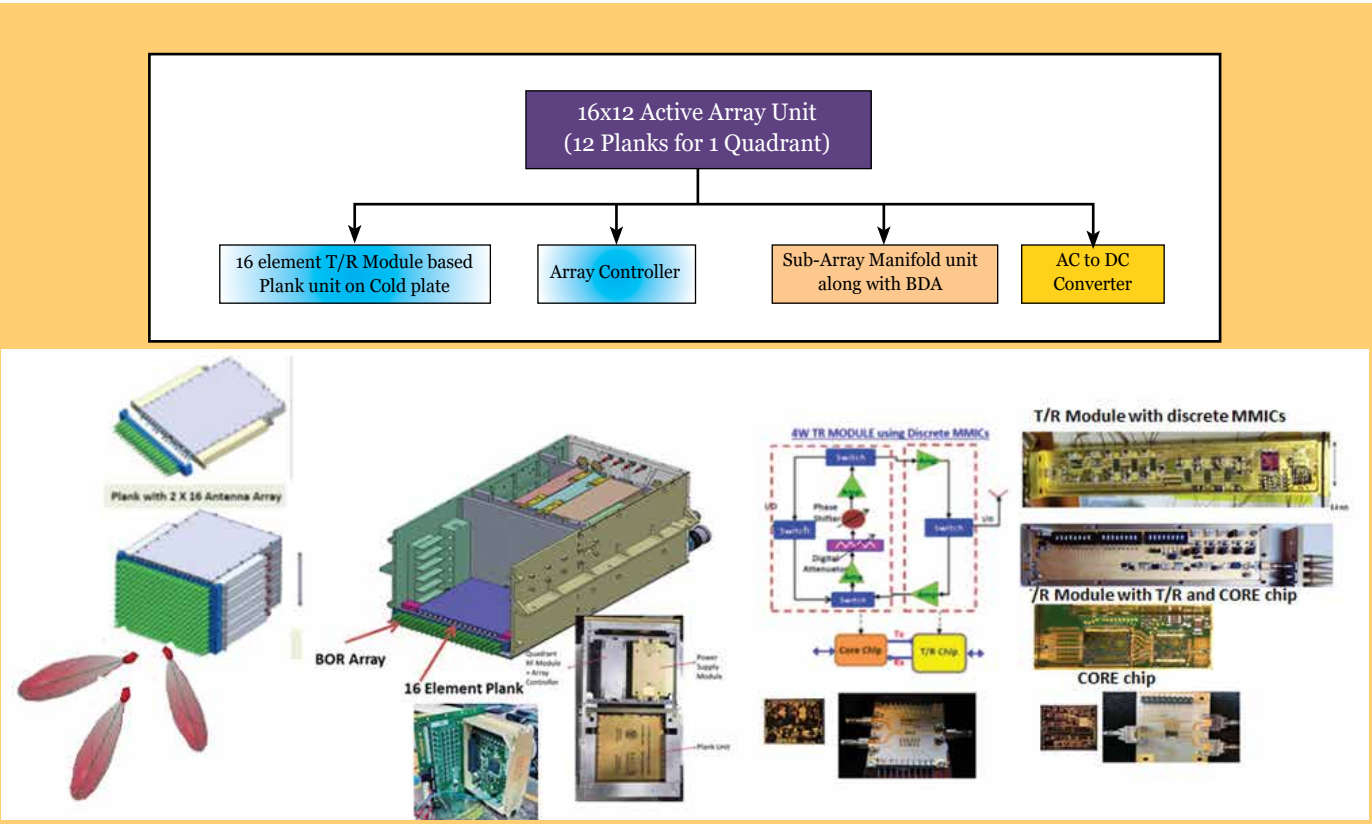
HIMRAJ—Low, Mid and High Band

Superhet Receivers, Channelised Receiver 18-40 Ghz BITE modules

Channelised Receiver 18-40 GHz, BITE Module, Switch Matrix, Homodyne Receivers, Superhet Receivers

# Active Phased Array for EW Applications

High Effective Radiated Power (ERP), fast reaction times, High DF accuracies and ability to handle multiple threats are the essential requirements of present day jammer systems. Conventional jammers using TWTs as transmitters along with high gain antenna are mounted on a servo pedestal to achieve wide angular coverage. State-of-the-art next generation EW systems are configured with an active electronic scanned planar antenna array where, each element of the antenna is driven with a low power solid-state amplifier and the phase and amplitude of each element is controlled to form a single sum beam of narrow beamwidth, with high gain using spatial combination technique. The active electronic planar antenna array facilitates to form the beam that can steer both in azimuth and elevation planes.




**Technology Modules of AESA-based EW System**

As a technology development, wideband T/R module-based 12X16 active array covering 5-18 GHz is being developed in DLRL. The approach is based on individual MMIC chips, TR, and CORE chips for 28 dBm, 2 w and 4 w respectively. The individual T/R modules are tested and iterations are in progress. Complete AESA system modules comprising of antenna array, plank controller, quadrant RF module, power supply, and other electronics for integration are in advanced stage of development and testing.

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