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Production Criticalities of Microwave Subsystems for UWB Systems

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ABSTRACT

Electronic Warfare (EW) systems are Ultra Wideband Systems (UWB) since the operating frequency ranges are in the order of few GHz. EW systems are built with modern electronic circuits, installed on different varieties of military platforms that guards country's security continuously. The three major armed forces i.e., Navy, Army & Air-force are equipped with EW systems that are capable of searching, identifying, classifying and jamming of wide variety of hostile radars including special types of radars like LPI radars. EW systems are complex in nature and the operational requirements keep changing rapidly due to advancements in radar technologies, signal processing techniques, unpredictable field conditions, etc.,. Therefore EW engineers are continuously upgrading the technology to effectively design, develop, manufacture, evaluate and deploy the systems in the field. The accuracies of measurement for the radars parameters are critical for tactical purposes and hence advanced measurement techniques are used in EW systems. The important characteristic of EW systems is Ultra Wide Band operation. The front processing requires RF & MW subsystem, which are UWB, to meet the operational requirements. Modern EW systems are built with many UWB MW subsystems based on the system specifications. The specifications and ruggedness of these MW subsystems used are also critical, to meet the stringent system specifications. Hence most of the MW modules used in EW systems are custom made, complex and limited in numbers and hence the production of these items is one of the challenges for industry. The criticalities of manufacturing of these modules for EW applications are brought in the current paper for the benefits of EW community.

Key words; EW, ERP, ESM, ECM, LPI, MW, RF, UWB

I INTRODUCTION

The function of EW system is to receive, measure & identify the Electromagnetic waves radiated by radars around it and create an intentional interference in the enemy's electromagnetic environment. Thus the capability to measure the parameters of the radars and jamming techniques are the key performance factors of an EW system. Further, the EW system measures and analyzes the radar signal parameters before radar does, thus provides better capability to use in military applications for tactical warfare [1 - 5]. To achieve this important task for defense forces, EW system capabilities and specifications (i.e., mainly frequency of operation, antennas parameters, detection capability, sensitivity, noise performance, processing speed & high Effective Radiated Power (ERP) are very much important to achieve good performance in deployed condition. The receiver specifications are characterized by antennas, RF front end, digital hardware and the measurement techniques, the jamming performance depends on the RF front end, power amplifier, antennas and the technique generator. Thus in the performance of EW systems, UWB MW components play major role in achieving the satisfactory performance of EW Systems. Of course, in addition many other parameters like processor speed, blanking, look-through, installation on targeted platforms, etc., are also defines the final performance of the system installed on designated platform. The production criticalities of MW subsystems used in EW systems are brought in the current paper.

II EW – ULTRA WIDE BAND SYSTEMS

The WB operation of an electronic system is defined by its Band Width Ratio [6] and is mathematically, given by

$$BWR = \frac{2(f_h - f_l)}{f_h + f_l}$$

$$> 0.2 \text{ (FCC)}$$
$$> 0.25 \text{ (DARPA)} \quad \textbf{(1)}$$

& the band width of operation should be greater than 500 KHz. The definition is pictorially shown at Figure-1.

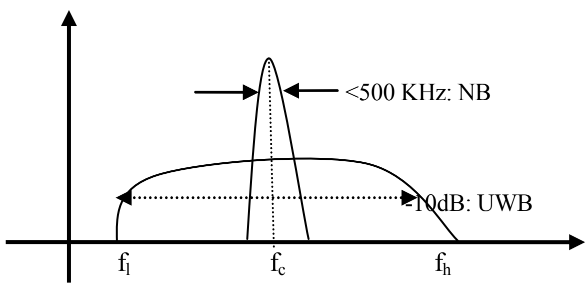

Figure-1: FCC definition of NB & UWB systems

EW systems practically, operate in few thousands of MHz bandwidths, for example, 16000 MHz or 18000

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MHz (BWR>8), are truly UWB systems. Antennas and RF & MW front end hardware used in these systems are also UWB components, operating with the same BWR.

III EW - MW SUB-ASSEMBLIES

1 SYSTEM CONSTITUENTS

Typically, an EW system consists of both Electronic Support Measures (ESM) and Electronic Counter Measures (ECM). ESM system receives radar signals present in the free space environment (Z_0 = 377Ω), at any instance of time, converts RF power in to a 50Ω system, measures and identifies the radar characteristics for tactical applications. On the other hand, ECM system provides jamming capability for the particular radar based on information from ESM. The function of ESM and ECM together termed as EW. ESM system mainly constitutes a wide open receiver with reasonably high sensitivity and hence the hardware of ESM system consist of UWB antennas to detect the radar signals, RF processing circuits, high speed digital measurement circuits as receiver unit, on pulse to pulse basis, high end processor unit for de-interleaving of pulses and Display for presenting the radar parameters to the EW operator along with suitable Man Machine Interface (MMI) commands. In most of the systems, Receiver and processor units are combined to optimize the resources. ECM consists of high power / high gain transmitter antenna, Control unit and high power Travelling Wave Tube (TWT) amplifier, Digital Radio Frequency Memory (DRFM) or Frequency Memory Loop (FML) and a Technique generator. An additional the functionalities, like blanking, Navigation Data, CMS, etc., are also interfaced with EW Systems. Therefore EW system performance depends on the MW subsystems used in antenna and receivers.

2 CHARACTERISTICS

Generally, ESM systems provide high sensitivity over wide operating frequency ranges with very good Angle of Arrival (AOA) accuracy. The processing of radar pulses should be instantaneous, all most in real time, and cater for reception and analysis of many types of radars [7] like pulse, CW, MTI, Agile, LPI, etc., and broad ESM system specifications from open literature are given below.

2.1 TYPICAL SPECIFCATIONS - ESM

Frequency range	: B/K Band (Wide band)
Sensitivity	: -65 dBm Min
AOA accuracy	: 1-8° RMS
Frequency accuracy	: 3-10 MHz
Antenna polarization	: VP, HP, Slant & RHCP
Gain	: 0 dBi (Typ.) for omni
	: 5 dBi (Typ.) for directional
PW range	: few ns to few µs
PW accuracy	: 50ns max
PRF range	: few Hz to few hundreds of KHz
PRF accuracy	: Few Hz max
Dynamic range	: 50 dB min
Amplitude accuracy	: 2 – 4 dB rms max
Modulations	: Frequency Agile, wobbling, Chirp, Barker, Jitter, Stagger, QPSK, etc
Shadow time	: less than few µs
No of radars	: few hundreds
Interface with	: Gyro, radar blanking, CMS
BITE facility	: up to PCB level
Power supply	: platform compatible

2.2 TYPICAL SPECIFICATIONS - ECM

Similarly, an ECM system shall have following typical specifications, extracted from open literature.

Frequency range	: I/Ku Band
Tracking accuracy	: Few degrees
Self screening range	: few tens of KM
Transmitter power	: Few hundreds of KW
Antenna gain	: 25-30 dBi Min
Polarization	: Slant 45°
BW of Tx antenna	: 6° x 6° (typ.)
No of emitters	: few nos. simultaneously
Jamming types	: Noise and Deception
Interface with	: Gyro, radar blanking, CMS
BITE facility	: up to PCB level
Power supply	: platform compatible

3 IMPORTANCE OF MW SUBSYSTEMS / COMPONENTS IN EW SYSTEMS

Based on the specifications, it is understood that the RF Subsystems / Components, operating in Microwave frequency ranges are critical for EW systems and require wide variety of these items. Some of the microwave components used in various EW systems is tabulated in Table-1.

Age	MW technologies	MW components / Subsystems
Few decades back	All discrete components	LNA, MW Switches, power dividers, Limiters, Detectors, Limiting amplifiers, Band Pass / Low pass / High Pass filters, attenuators, Frequency / Phase discriminators, Delay lines, TWTA, FML, Rotary joints, wave guides, etc.,
Around 2000	Mix of discrete components and Super components	DIFM unit, FE receivers, FML, RF FE components TWT, etc.,
Current	Custom made Subsystems	Homodyne Receivers, Bite Modules, SHR, Channelized Rs etc.,

Table-1: MW Subsystems in EW systems

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Thus over the years, the microwave components used in EW systems, transformed from discrete components Subsystems. These subsystems include complete functionality built on to a single module. These microwave components are both wide band and narrow band. Further, the advances of digital processor technologies have enhanced the capabilities of these MW modules. These subsystems are configured as super components which are made up of many discrete MW components in single unit (both RF & Digital capability) and hence production of these subsystems is very critical.

4 CHARACTERISTICS OF MW SUBSYSTEMS USED IN ESM

Following are some of the characteristics of MW subsystems used in ESM systems.

4.1 Wide / Narrow frequency coverage
4.2 High sensitivity
4.3 Power handling ranging from 2 to 5Watts
4.4 Switching capabilities
4.5 Very good Signal Noise Ratio (SNR)
4.6 Very good Dynamic Range (DR)
4.7 Low harmonic characteristics
4.8 Linear characteristics over DR
4.9 Good Voltage Standing Wave Ratio (VSWR)
4.10 Matching (Phase & amplitude matching)
4.11 EMI/EMC capability
4.12 Environmental specifications

5 CHARACTERISTICS OF MW SUBSYSTEMS USED IN ECM

Following are the typical characteristics of MW components used in ESM systems.

5.1 Wide / Narrow frequency coverage
5.2 Medium sensitivities
5.3 Power handling range from 2 to 1000 Watts
5.4 Multi-port controlling capabilities
5.5 Good SNR
5.6 Reasonable Dynamic Range
5.7 Low harmonic characteristics
5.8 Linear & Non Linear characteristics over DR
5.9 Good VSWR
5.10 Matching (Phase & amplitude matching)
5.11 EMI/EMC capability
5.12 Environmental specifications

Therefore, the MW subsystems used in EW systems should have same or better characteristics than listed above.

IV PRODUCTION OF MW SUBASSEMBLIES

1 PRODUCTION – CRITICAL STAGES

The production of MW Subsystems has following critical requirements.

1.1 Manufacturing process
1.2 Engineering Packaging
1.3 Testing
1.4 Infrastructure (Assembly, Inspection & Testing)
1.5 Experienced human resources

1.1 Manufacturing of MW subsystems

The manufacturing process of Microwave sub-systems required for EW applications is very complex, needs lot of experience and very expensive infrastructure facilities (explained later). The critical stages of manufacturing process are given as follows.

1.1.1 Procurement of raw material & components
1.1.2 Inward inspection
1.1.3 Fabrication & inspection of mechanical items
1.1.4 Screening of components
1.1.5 Assembly of module
1.1.6 Preparation of RF cables
1.1.7 ESS during assembly
1.1.8 Inspection
1.1.9 Testing & Tuning
1.1.10 Final ESS
1.1.11 Acceptance Test procedure
1.1.12 Storage

1.2 Engineering Packaging of MW subsystems

Though the packaging is part of manufacturing process, the due importance is given in EW applications for engineering packaging of MW subsystems. The packaging is one of important task of EW manufacturing company as many varieties of configurations are required to suit the today's end user requirements. Also, as the complexity is increased in these microwave subsystems, there is a huge challenge in packaging these subsystems, especially meeting electrical and environmental specifications of the end users. Following are critical issues are taken care while packaging these items.

1.2.1 Modularity
1.2.2 Weight & Volume constraints
1.2.3 Thermal Management
1.2.4 Testing & Tuning requirements
1.2.5 Connectivity within units
1.2.6 Connectivity to External units
1.2.7 Environmental conditions
1.2.8 EMI / EMC requirements

1.3 Testing MW subsystems

1.3.1 Electrical Testing

The testing of MW subsystems is one of the important stages of MW subsystem production activities. Though the concept of testing MW subsystems is not very new,

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it is one of the critical stages to ensure the performance of MW subsystems before proceeding to next stages of EW production. The testing normally includes manual and / or automated testing. The special requirement for testing of EW subsystems, in specific, is phase and amplitude matching among set of many numbers. Many types of test jigs and test instruments are needed to perform complete testing of these subsystems. To emphasize the importance of testing for MW subsystems, the test results of few specifications of UWB EDLVA (2 to 18 GHz) module used in ESM is given below.

Test Condition	Test Freq (GHz)	Spec. (dBm)	TSS in dBm
1. a) PW: 1 µSec b) PRF: 10 KHz 2. Video BW: 20 MHz	1.8	-72	-73.5
	2.0	-72	-74.5
	4.0	-72	-74.9
	6.0	-72	-73.5
	8.0	-72	-73.5
	10.0	-72	-73.6
	12.0	-72	73.6
	14.0	-72	72.7
	18.0	-72	72.8
	18.2	-72	-72.6

Table-2: Tangential Signal Sensitivity

Test Condition	Specification	Measured video level (mV)
Minimum: Freq : 10 GHz, RF Power : -65 dBm Pulse width: 1 µSec, PRF: 10 KHz Video BW: 20 MHz, With 75 ohm load	Pin-1: 190 to 210 mV Pin-2: -190 to -210 mV (invert of each)	209 -200.5
Maximum: Freq : 10 GHz, RF Power : 0 dBm Pulse width: 1 µSec, PRF: 10 KHz Video BW: 20 MHz, With 75 ohm load	Pin-1: 1.28 V Max Pin-2: -1.28 V Min (invert of each)	1.14 -1.09

Table-3: Video Measurements

Test Condition	Specification	Measured video level (mV)
Freq : 10 GHz, RF Power : 0 dBm CW in J3 port, 75 Ohm load	<150 mV	64

Table-4: CW immunity measurements

Test Condition	RF Power level dBm	Spec. nS) (Max.)	Measured value (nS)
Freq : 10 GHz Pulse width: 50 nSec, PRF: 500 KHz	-60	40	32
	-30	40	35
	-10	40	30
Freq : 10 GHz Pulse width: 1 µSec PRF: 10 KHz	-60	40	34
	-30	40	32
	-10	40	35

Table-5: Rise time

Test Condition	RF Power level dBm	Spec. (nS) (Max.)	Measured value (n Sec)
Freq : 10 GHz Pulse width: 50 nSec PRF: 500 KHz	-60	30	30
	-30	30	30
	-10	30	30
Freq : 10 GHz Pulse width: 1 µSec PRF: 10 KHz	-60	30	30
	-30	30	30
	-10	30	30

Table-6: Setting Time

Test Condition	Required Spec. (n S)	Measured value (nS)
RF Power : 0 dBm, RF Freq. 10 GHz, PW: 1µSec & PRF: 1 KHz	410 Max.	356

Table-7: Recovery Time

Test Condition	Required Spec. (nS)	Measured value (nS)
RF Power : - 30 dBm RF Freq. 10 GHz TTL Pulse width: 1 µSec PRF: 100 KHz	≤ 125	50

Table-8: Switching Time

Test Condition	Spec. of spike level (dBm)	Measured value (dBm)
RF Power : - 66 dBm, RF Freq. 10 GHz, PW: 1 µSec & PRF: 100 KHz	≤ -66	OK

Table-9: Video Spike Leakage

Test Condition	Freq. (GHz)	Spec. (dB) Min	Measured value (dB)
RF Power Level @ RF IN Port: +4 dBm for J3 port	2.0	74	77
	6.0	74	78
	10.0	74	78
	14.0	74	78
	18.0	74	76

Table-10: Switch Isolation

Test Condition	Test Freq. (GHz)	RF O/P Pwr for -50 dBm I/P Spec: Min -25 dBm)	RF O/P Pwr for 0 dBm I/P (+17 dBm Max)
RF Power Level (CW) for selected port	1.8	-16.8	15.2
	2.0	-16.6	15.2
	6.0	-20.6	14.1
	10.0	-21.8	13.3
	14.0	-23.9	12.4
	18.0	-25.4	11.0
	18.2	-25.7	11.1

Table -11: Minimum & Maximum RF Output Power

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Test Condition	RF O/P Noise Power (Spec <= -40 dBm)	RF Gain for -60 dBm I/P Sweep from 1.8-18.2 GHz) (Spec 25 dB Gain Min)
RF measurements (Select J1 Port) Mode: CW	<=-40 dBm	27.2 dB

Table-12: RF Noise Power O/P & RF Gain

Test Condition	Required Spec. (dB)
I/P Signal Power Level 500 MHz MHz @ RF IN Port: 0 dBm	Video: NA RF: NA
I/P Signal Power Level 18500 MHz MHz @ RF IN Port: 0 dBm	Video: NA RF: NA

Table-13: Filter Rejection

Test Condition	Test Freq. (GHz)	Required Spec. (dBc)	Measured 2nd harmonic level (dBc)
RF Power Level 0 dBm	1.8	-14	-17.2
	2.0	-14	-18.5
	3.0	-14	-19.49
	4.0	-14	-20.29
	5.0	-14	-17.67
	6.0	-14	-18.44
	7.0	-14	-19.5
	8.0	-14	-15.12
	9.0	-14	-14.2

Table-14: Second Harmonic

Test Condition	Spec. (nS)	Measured value
Frequency : 10 GHz Power level: -25 dBm PW 50nS PRF = 500 KHz	45 Max	18 ns

Table-15: Differential delay

Test Condition	Spec. (nS)	Measured value
Frequency : 10 GHz Power level: -30 dBm PW 50nS, PRF = 10 KHz	50 Max	14ns

Table-16: Propagation Delay

Test Condition	Test Port	Spec.	Measured value
Freq. 1.8 to 18.2 GHz (Sweep) RF Power Level: -20 dBm	RF IN (J1)	2:1	1.95:1
	RF IN (J2)	2:1	1.9:1
	RF IN (J3)	2:1	1.94:1
	RF OUT (J5)	2:1	1.9:1

Table-17: VSWR

Test Condition	Required Spec. (mV)	Measured value (mV)
RF IN, BITE, RF OUT Ports terminated with 75 Ω load.	±50	35

Table-18: DC Offset

Test Condition	Spec.	Measured value
RF Power level 0 dBm @ 10 GHz BITE, RF OUT Ports terminated with 50Ω load.	+ 12V @ 600 mA (max.) - 12V @ 400 mA (max.)	480 mA 200 mA
Short Circuit protection test BITE, RF OUT Ports terminated with 50 Ω load. RF Freq. @ 10 GHz.	Log linearity ≤ ± 1.5 dB @ 10 GHz.	=± 1.3 dB
Over voltage protection test BITE, RF OUT Ports terminated with 50 Ω load. RF Freq. @ 10 GHz.	Log linearity ≤ ± 1.5 dB @ 10 GHz.	=± 1.2 dB
Reverse voltage protection test BITE, RF OUT Ports terminated with 50 Ω load. RF Freq. @ 10 GHz.	Log linearity ≤ ± 1.5 dB @ 10 GHz.	=± 1.3 dB
Linearity @ RF Freq. @ 10 GHz. & + 9V & -9V DC	Log linearity ≤ ± 1.5 dB @ 10 GHz.	=± 1.25 dB

Table-19: DC Power Supply

Test Condition		Spec.	Measured value
Frequency 10 GHz Power level – 45 dBm.	PRF 600 KHz PW 25nSec.	600 KHz ± 1% 50nSec (max.)	OK
	PRF 33 Hz PW 300 μ sec.	33 Hz ± 1% 300 μ S ± 100 nS	OK

Table-20: PRF & Pulse Width Range

Parameter	Specification	Measured Value
Log Linearity over -65 to 0 dBm	<±1.5 dB	<±1.2 dB
Monotonicity	Video shall increase over DR	OK
Log slope	15 mV/dB	14.66 mV/dB
Frequency flatness	<±1.5 dB	<±1.4 dB
DC offset tracking among set of 6	10 mV	OK
Video matching among set of 6	<±1.5 dB	OK

Table-21: Log Slope / Log Linearity / Monotonic / Logging Range / Logging Accuracy / Freq. Flatness / Matching. (Extracts of Test data from Computer printout)

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Spec.	Parameter		Spec.	Measured value (mV)
RF Power level – 65 dBm	Min. Video output at		190-210 mV	
		2.0 GHz		210
		6.0 GHz		204
		10.0 GHz		198
		14.0 GHz		194
		18.0 GHz		202
RF Power level 0 dBm	Max. Video output at		1.28 V	
		2.0 GHz		1135
		6.0 GHz		1135
		10.0 GHz		1155
		14.0 GHz		1065
		18.0 GHz		1145
All port terminated with 50 Ω load	Base line noise		70 mV	50 mV

Table-22: Video signal amplitude

1.3.2 ESS Testing

Environmental Stress Screening (ESS) of MW subsystems is essential part of production activities. This is also important to weed out manufacturing defects and ensure reliable products. ESS has to be done on 100% of items used in EW products. ESS guidelines are promulgated by service headquarters and updated from time to time [8 - 9]. ESS tests include following tests.

a) Thermal cycling: POWER ON condition:
b) Random Vibration: POWER ON condition

Pre and post ESS measurements are carried out to ensure the reliability of the production process of the units.

1.4 Infrastructure

The following Table-2 provides list of some of the infrastructure required for production of MW subsystems required for EW Systems.

S. No.	Description	Area
1	Pick and Place Machine	Assembly
2	X-Ray inspection system	Assembly
3	Laser welding machine	Assembly
4	Laser cutting machine	Assembly
5	Thermosonic Wire Bonder	Assembly
6	Bond pull and shear Pull Tester	Assembly
7	Vapor Degreaser	Assembly
8	Screen Printer	Assembly
9	Plasma Cleaner	Assembly
10	Parallel Gap Welder	Assembly
11	Reflow Furnace	Assembly
12	Curing & baking ovens	Assembly
13	Deep Freezer (-40°C)	Assembly
14	Microscopes 100X (assembly)	Assembly
15	Rework Station	Assembly
16	Argon Gas Bank	Assembly
17	Temperature controlled Hot Plates	Assembly
18	Epoxy Dispenser	Assembly
19	Surface Resistivity meter	Assembly
20	Static Charge meter	Assembly
21	Refrigerator	Assembly
22	Soldering Stations along with fume absorbers	Assembly
23	Set of Small Tools & Fixtures	Assembly
24	Particle counter	Assembly
25	Microscope 150X with camera (Inspection)	QA
26	MRTP (Thermal Plate)	Testing
27	Wrist strap tester	Testing
28	Class 10000 / Class 100000 Rooms with ESD Flooring, & doors (1000 & 500 SFT)	Assembly / Testing
29	Computers	Assembly / Testing
30	ESD garments	Assembly / Testing
31	ESD accessories	Assembly / Testing
32	Assembly Tables	Assembly / Testing
33	Testing Tables	Assembly / Testing
34	ESD Chairs	Assembly / Testing
35	Temperature & humidity controlled Desiccators	Assembly
36	Shoe Racks polypropylene	Assembly
37	Mobile pedestal	Assembly
38	Temperature & humidity controlled storage unit small	Assembly
39	Vertical storage unit Big	Assembly
40	SS Clean room Trolley	Assembly
41	Laminar Flow Stations	Assembly
42	Signal generators	Testing
43	Spectrum analyzer	Testing
44	Network analyzer	Testing
45	Power meter with sensors	Testing
46	Noise figure meter	Testing
47	RF test jigs	Testing
48	Terminations	Testing
49	Frequency Counters	Testing
50	Automatic Test Equipment	Testing
51	Controllers	Testing
52	RF cables and adapters	Testing

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1.5 Human expertise

Since the production of MW subsystems is critical and repeatability is required in the electrical performance (amplitude and phase matching) for EW applications, skilled and experienced human resources are mandatory. To ensure the matching requirements (amplitude and phase matching over wide frequency coverage), one has to assemble the modules very carefully. Few precautions have to be taken while assembling / packaging of the MW modules.

- 1.5.1 Maintaining Soldering temperature
- 1.5.2 Proper Connectorization
- 1.5.3 Cutting of materials (Ex. RT duroid)
- 1.5.4 Preparation of cables
- 1.5.5 Usage of mandrel
- 1.5.6 Fabrication of large quantities at a time for obtaining uniform characteristics
- 1.5.7 ESD precautions
- 1.5.8 Operator skills

The above operations are skilled activities, though automated to great extent; the final outcome depends on human expertise.

V CONCLUSION

The production criticalities of MW subsystems are presented in this paper. The infrastructure and the expertise required for manufacturing MW systems to meet the EW functionality were brought out based on the experiences of the production team. Further EW systems are UWB and hence special care is required while manufacturing these items. The electrical and environmental specifications and achieving these specifications for amplitude and phase matching over wide frequency ranges, is utmost requirement for EW Systems. Though automation of the processes is available, human expertise is one of the key factors in production of these systems.

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VIII BIO DATA OF AUTHOR (S)

Ch Viswanadham, born in Ampolu, a village in suburbs of Srikakulam, Andhra Pradesh, India joined Bharat Electronics Limited, a premier defense electronics industry in 1990 immediately after B Tech (ECE) from Nagarjuna University, Guntur, Andhra Pradesh. He worked in various Naval EW Systems from design to field trails. He has received internal R&D award for developing light weight ESM system for Indian Naval Ships. He has been deputed to Israel, Spain & South Korea to participate in technical discussions on EW systems with international companies. He has completed Master's degree in Digital Systems from Osmania University, Hyderabad in 1997, while working at BEL. Presently he is working as Senior Deputy General Manager (D&E) and heading RF & MWP group. He has presented many technical papers in BEL-House journal, national & international journals and conferences. He is Fellow of IETE & IE (I), Life member of SEMCE (I) & CSI and MIEEE. He is pursuing PhD in Andhra University, Visakhapatnam. His areas of interest are antennas, radomes, RF & Microwave designs and wide band / narrow band receivers.

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