ALION
SCIENCE AND TECHNOLOGY
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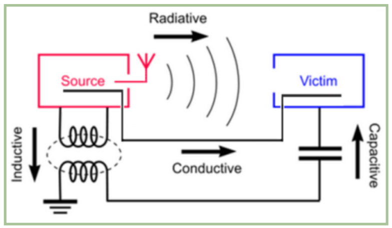
Shipboard Electromagnetic Compatibility

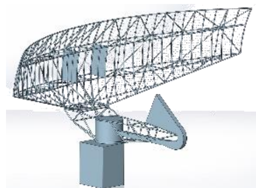
University of British Columbia

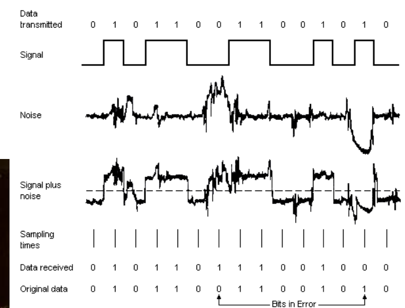
Session 2 - Shipboard Electromagnetics (Wireless/EMC)

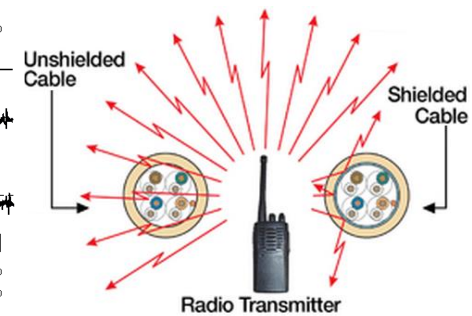
Mark Oakes - March 15, 2019

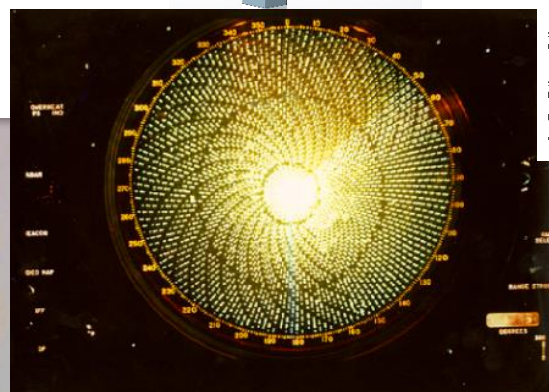
The Undesired Effects of EMI

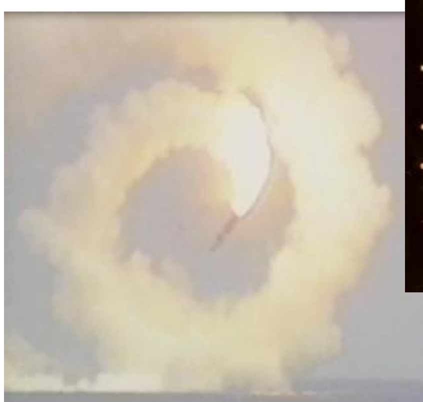


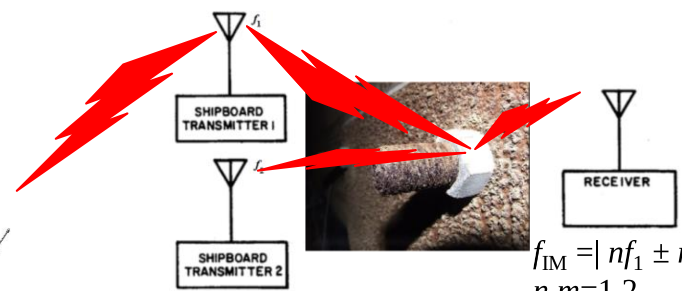




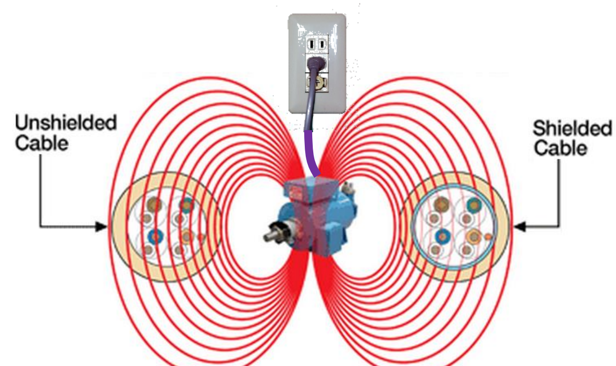








$f_{IM} = | nf_1 \pm mf_2 |$
$n,m = 1,2,\ldots$



Some Recorded Marine and Naval EMI Mishaps

HMS Sheffield Disaster

The Sheffield's search radar was switched off when the satellite communication system was used, because of interference from the radar. Without its search radar the Sheffield's anti-missile defenses could not be used, and this allowed an Exocet missile to hit the ship on 4 May 1982.

Radar Interferes with Ship Steering Gear

Two navy warships nearly collided when the radar beams of one disabled the steering of the other. The minehunter HMAS Huon went out of control and veered across the bow of the frigate HMAS Anzac.

Vessel Collisions, Sinkings

- In the Rotterdam harbor there is an 'old case' of about 15 years ago: X-band (1 kW) radars for Vessel Traffic Control influenced the steering gear of a small towing ship in such a way that it hit the quay.
- There is some evidence that EMI may have contributed to two boat capsizes, via autopilot malfunctions. One was the 16 meter fishing vessel the "Dalewood Provider" which capsized on August 17 1989, the other was the 64 tons "Martin N", which sank on April 25th 1987

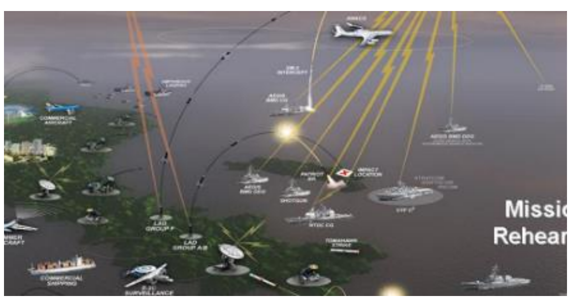
ALION'S CORE COMPETENCIES

Alion delivers agile engineering solutions — from the lab to the battle space — across six core capability areas

WEAPONS PLATFORMS

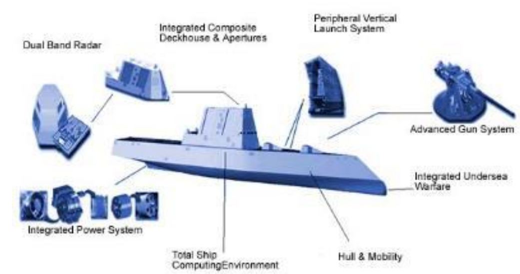
MODERNIZATION & SUSTAINMENT

LIVE, VIRTUAL, CONSTRUCTIVE TRAINING



NETWORK & SOFTWARE ENGINEERING

INTEL, SURVEILLANCE & RECON (ISR)



SYSTEMS ENGINEERING & INTEGRATION

ALION SCIENCE AND TECHNOLOGY
Overview

- Purchased John J. McMullen Associates, Inc. (JJMA) in 2005
  - JJMA founded 1957

- Added maritime/ship design capability to Alion
  - Largest ship design entity in the US
  - Largest NAVSEA engineering support contractor
  - Significant non US surface combatant ship design support

- Long history of support to Canadian programs
  - Part of SCAN Marine Team that competed for the CPF project
  - Performed over 50% of the HALIFAX Class detail design for Saint John Shipbuilding
  - Design Agent to SNC Lavalin for first JSS program
  - Competed for the CSC program

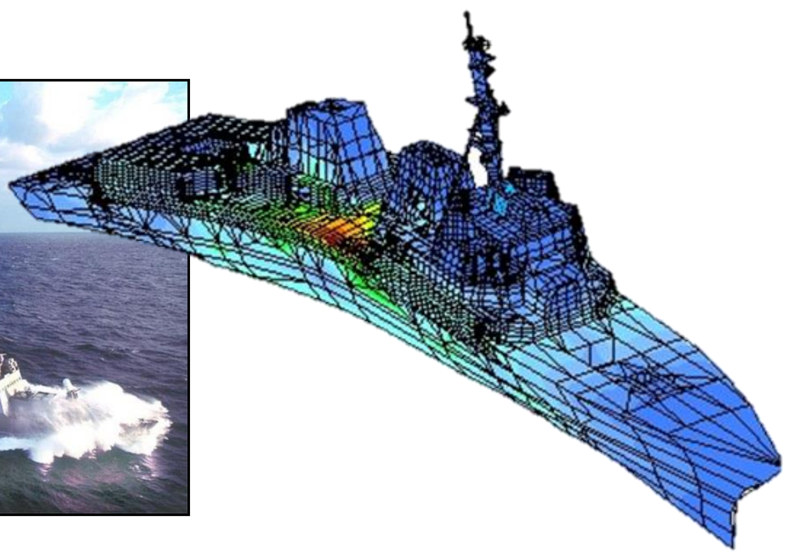
- Started Alion Canada in early 2009
  - OFSV preliminary design for CCG
  - R/V INVESTIGATOR design, built for Australia's CSIRO
  - JSS design agent for Seaspan
  - MoT Ontario owner's expert for three ferry build projects
  - ~60 staff

DESIGN ENGINEERING EXPERTISE

Full Scope Design Agent Skill-set:

Traditional Skills

- Naval Architecture
  - ✓ Hydrodynamics
  - ✓ Structures
  - ✓ Weights/Stability
  - ✓ Outfitting
  - ✓ Propulsor Design
- Marine Engineering
  - ✓ Propulsion
  - ✓ Auxiliary/Fluid Systems
  - ✓ Electrical
  - ✓ Controls
  - ✓ HVAC
  - ✓ Materials



Specialty Skills

- Combat Systems Engineering
  - ✓ Mission and Threat Analysis
  - ✓ Combat System Definition
  - ✓ Combat Systems Engineering and Integration
  - ✓ Ship Integration
  - ✓ Test and evaluation
- Simulation Based Design
  - ✓ Topside Design
  - ✓ **EMC/EMI/RADHAZ Analysis**
  - ✓ Modeling and Simulation
  - ✓ Total Ship Survivability
  - ✓ Signatures (Stealth)
  - ✓ Equipment Design/Failure Analysis
  - ✓ Environmental Engineering
- Systems Engineering
  - ✓ Reliability Engineering & Analysis
  - ✓ Human/Systems Integration
  - ✓ System Safety
  - ✓ Requirements Management

Alion Proprietary

ALION'S EMC EXPERIENCE

Alion has managed and was the technical lead of EMC analysis, design, and integration of major combatants and coast guard ships both at the contract and detail design levels, as well as the construction phase and testing.

The following major domestic and international navy ships and programs were supported by Alion in EMC design, analysis, integration, construction, and testing:

- Indian Navy NEC Lead EMC Contractor
- Turkish, Coast Guard Search and Rescue Vessel (RMK Marine)
- Indian NOPV (Pipavav Shipyard)U
- ROKN Ulsan-I Corvette (Hyundai Shipyard)
- USCG FRC-B fast response cutter (Bollinger Shipyard)
- Indian OPV (Pipavav Shipyard)
- ROKN KDX-III destroyer (Hyundai Shipyard)
- ROKN PKX fast attack ship (Hanjin Shipyard)
- ROKN LPX amphibious ship (Hanjin Shipyard)
- SES LCS
- Canadian Navy first JSS program (2006-2008)
- Israeli MPC
- ROKN KDX-II Corvette (Daewoo Shipyard)
- Planner and leader of EMC surveys of Tx-Rx co-existence and radiation safety to personnel, ordnance, and fuel as part of the ship acceptance testing (SAT) for all future Indian Naval Surface Ships
- Business case analysis (BCA) and participation in the EMC specification development for the future MSC T-AO(X)
- LCC(R) (topside antenna placement)
- CGX (topside antenna placement)
- CVN-77 and CVN-78 (topside cosite analyses).

THE E3 PROBLEM ON NAVAL PLATFORMS

Major Causes Of E3 Problems On Naval Platforms:

- High Density of Complex Electronic Systems
- Highly Sensitive Narrowband (NB) and Broadband (BB) Sensors
- High Power NB and BB Intentional Radiators
- Broad Frequency Operation Range - DC to millimeter Waves (MMW)
- Device Non-Linearity

Shipboard EMI Threats

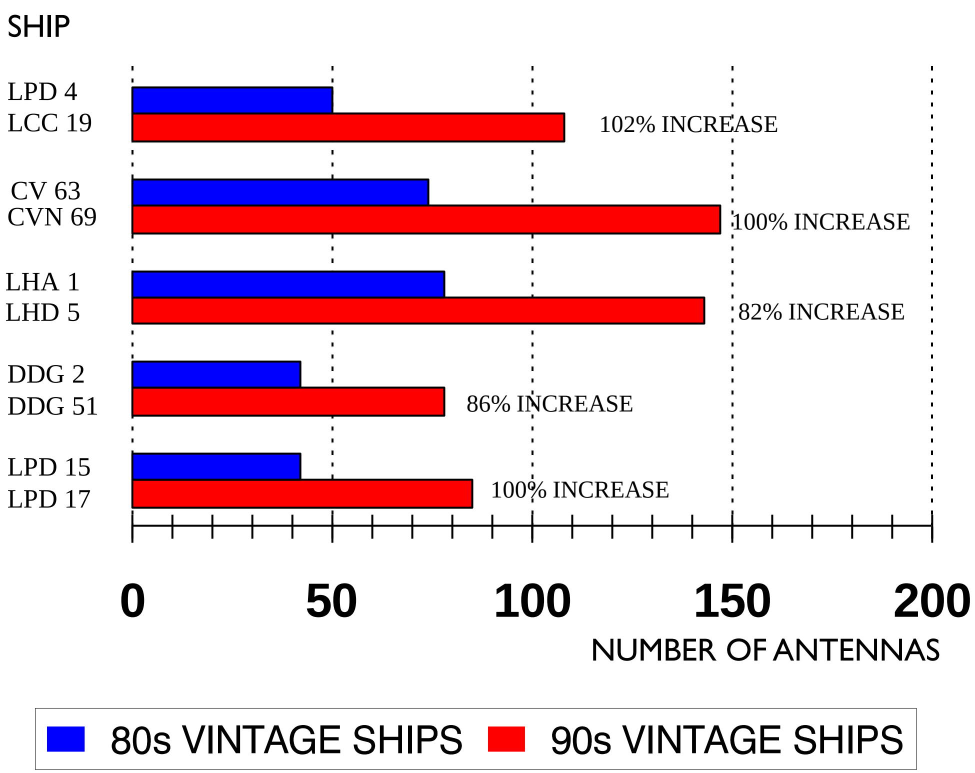
BAND (IEEE)	FREQUENCIES	THREAT
DC and Low Frequency	$0<f< 100$ kHz (LF)	Magnetic Fields
Medium and High Frequencies (MF, HF, and VHF)	100 kHz$<f<$ 200 MHz	Emissions from nearby transmitters, Machinery, Electrical and Electronic Equipment
Ultra High Frequencies and above (UHF and up)	$f>$ 200 MHz	Emissions from nearby Transmitters

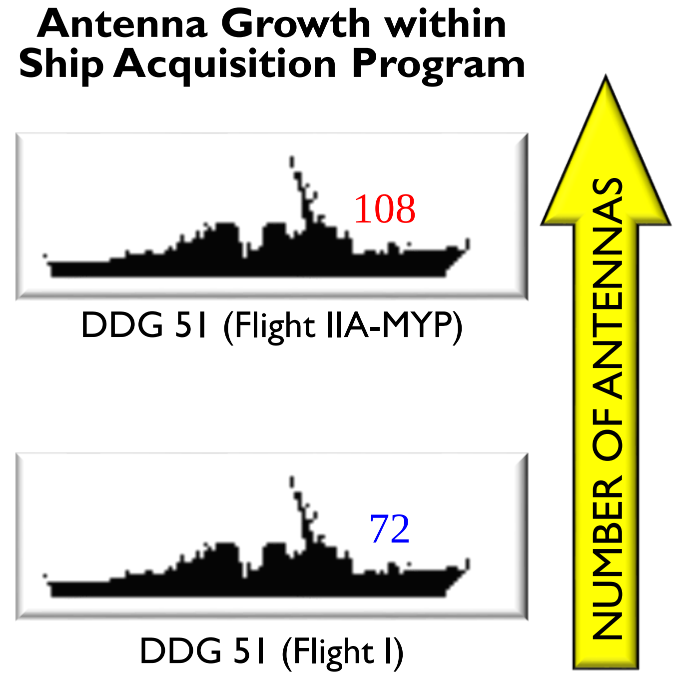
Primary Source-Victim Interactions

EMI Source (Emitter)	Primary Coupling Mechanism	EMI Victim (Receptor)
Transmitters	<u>Radiated</u> Antenna-to-Antenna	Receivers
	<u>Radiated</u> Antenna-to-Cable Antenna-to-Case	Electronic Equipment
Electrical and Electronic Equipment	<u>Radiated</u> Cable-to-Antenna Case-to-Antenna	Receivers
	<u>Radiated</u> Cable-to-Cable Cable-to-Case Case-to-Cable Case-to-Case	Electronic Equipment
	<u>Conducted</u> Power Lines Signal Lines Ground	

Antenna Number Growth - Topsides of a US Warship

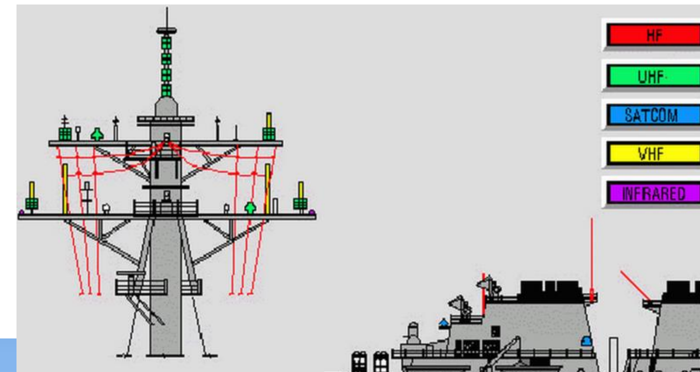
(Indicative of the increase of the number of onboard systems)





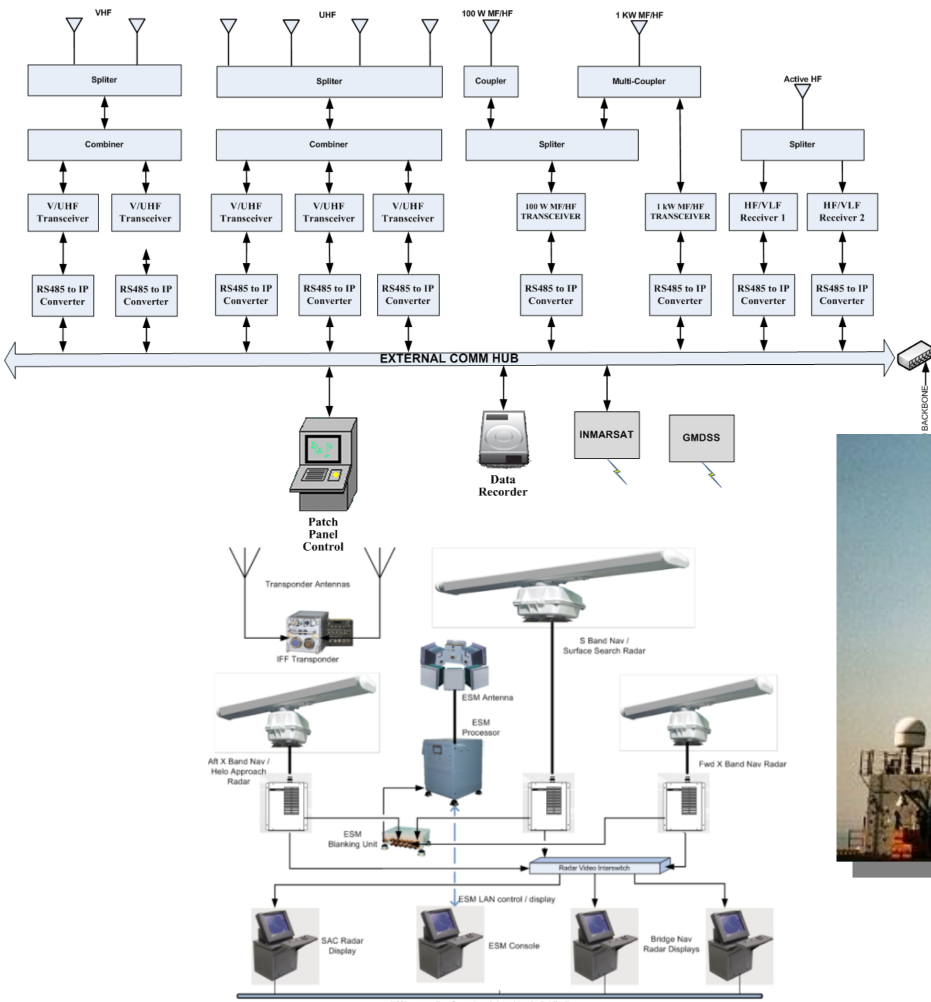
TIGHTER PHYSICAL CONSTRAINTS ⇒ AUGMENTED EMC REQUIREMENTS

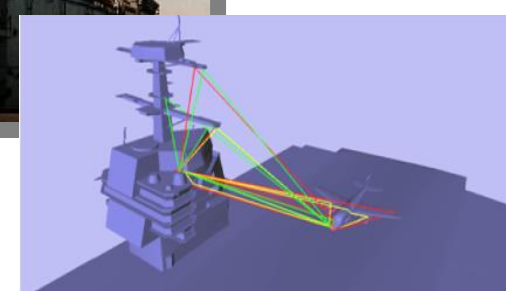
Antenna Number Growth - Topsides of a US Warship (cont.)



The Ship Spectrum Management Problem

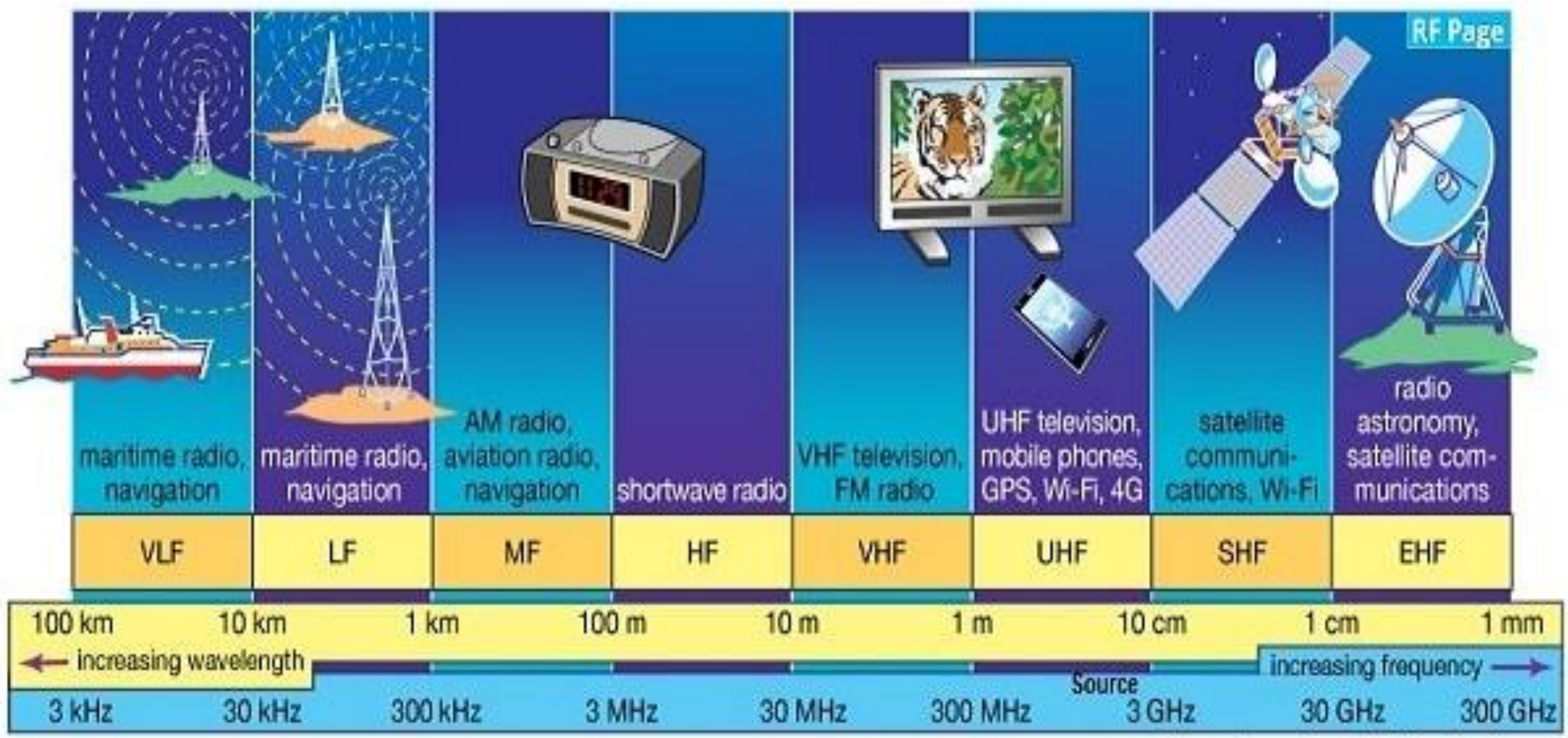
Shipboard Systems Having Topside Sensors and Effectors:





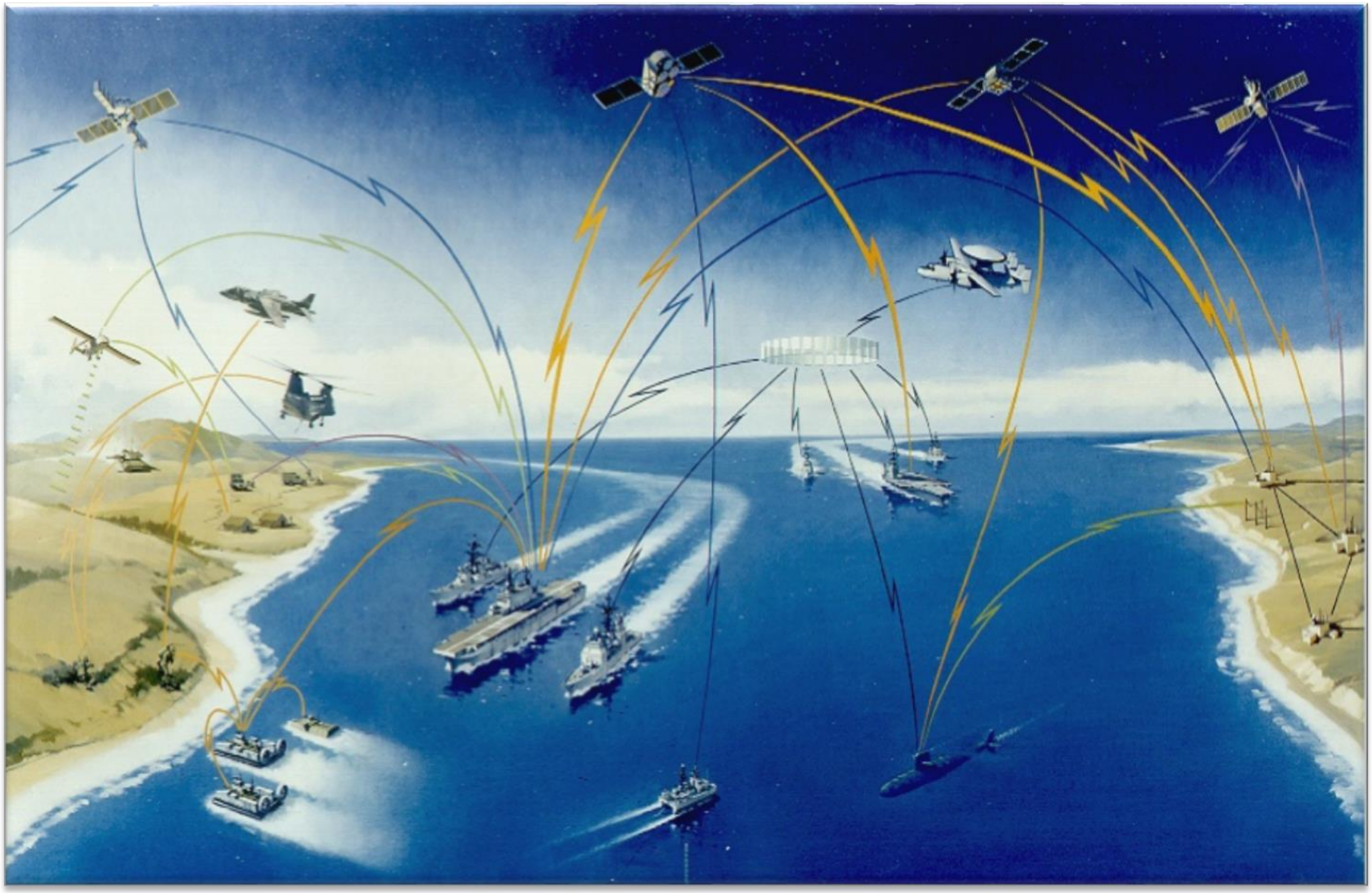
THE ELECTROMAGNETIC SPECTRUM

The RF Spectrum Utilization



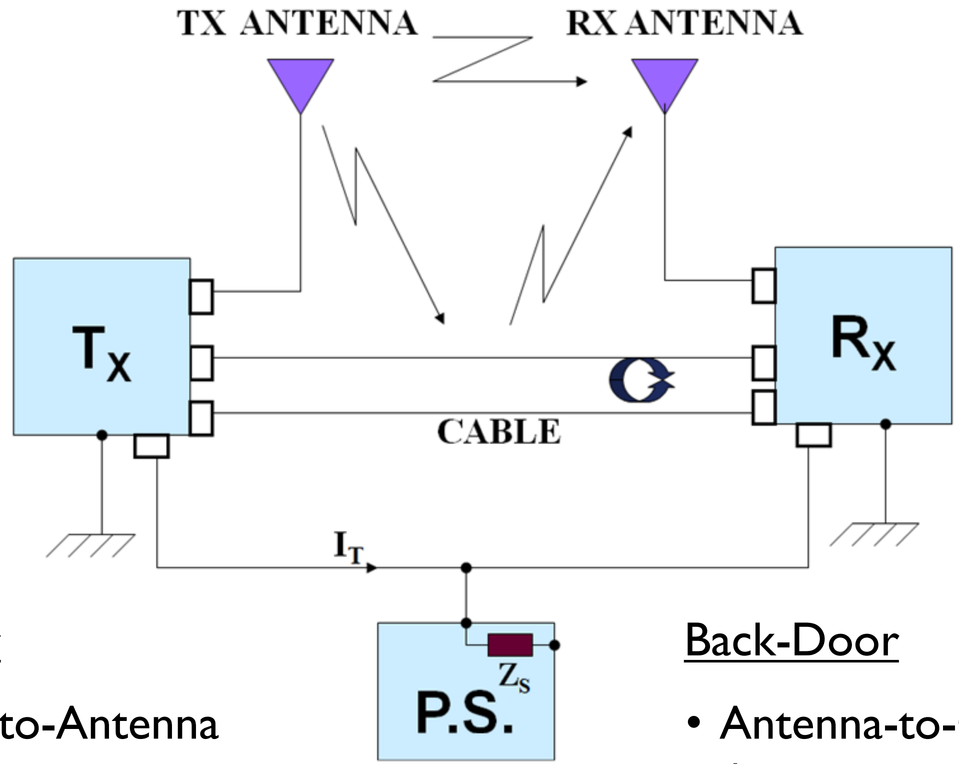
Source: Encyclopaedia Britannica, Inc.

The Fleet Spectrum Management Problem



Basic Coupling Mechanisms

Coupling - The transfer of electromagnetic energy between fields, wires, circuits, equipment, and/or systems



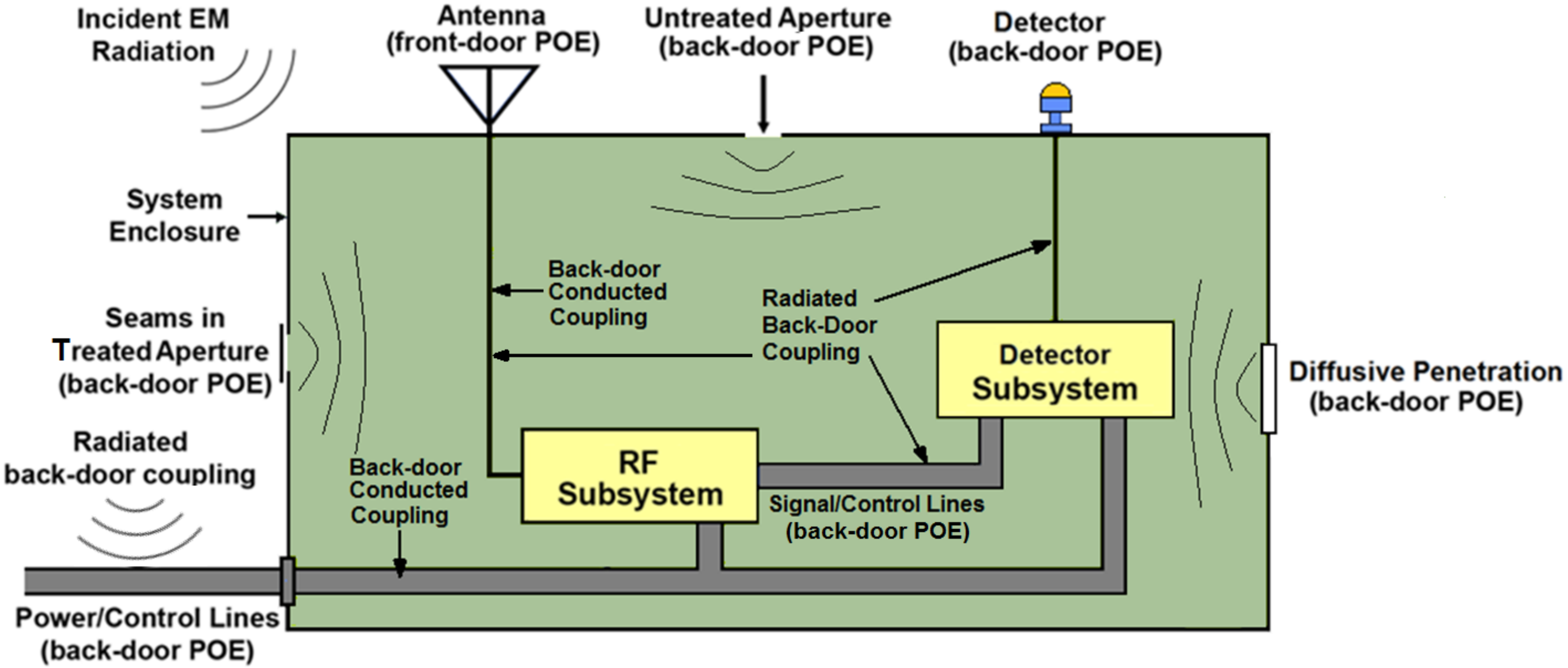
Front-Door

- Antenna-to-Antenna

Back-Door

- Antenna-to-Cable
- Antenna-to-Device
- Cable-to-Cable
- Cable-to-Device
- Device-to-Cable

Basic Coupling Mechanisms (cont.)

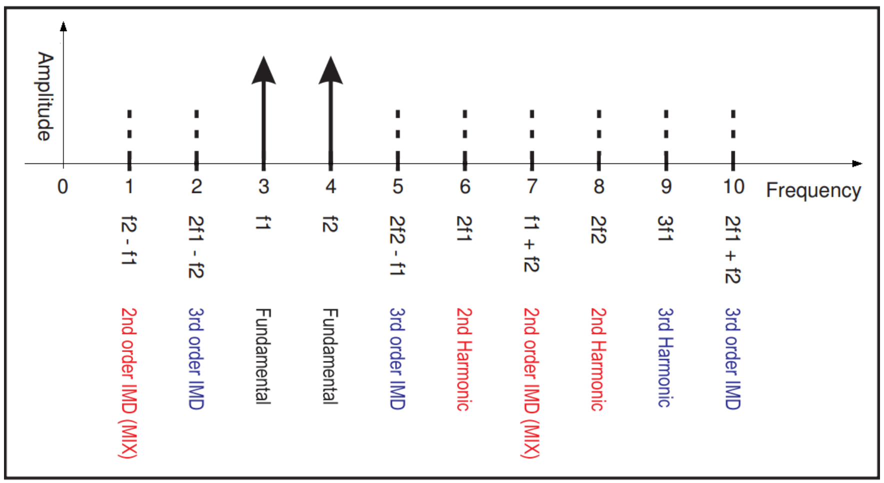


EME inside the enclosure is chaotic due to internal reflections

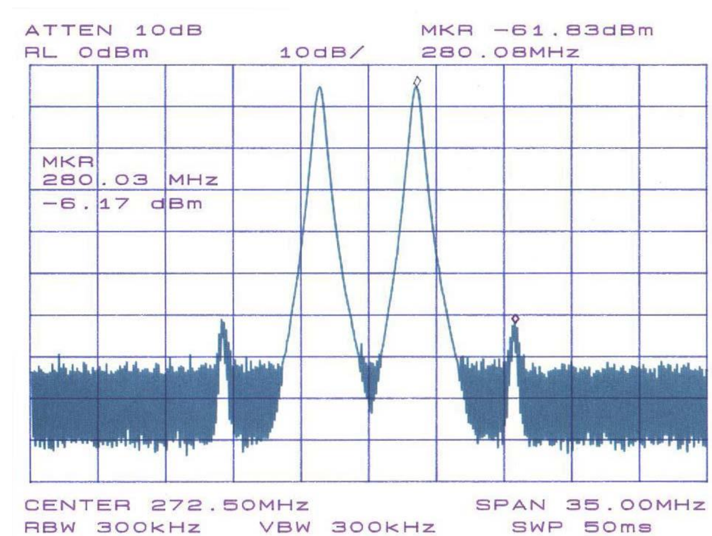
Basic Time-Harmonic System Responses (cont.)

Two or more sinusoidal inputs to linear systems are processed separately. Two or more sinusoidal inputs to nonlinear systems generate intermodulation.

Intermodulation - The "mixing" of two or more time-harmonic signals to produce new frequencies of sums and differences of multiples of the original signals



Two Time-Harmonic Signal Intermodulation

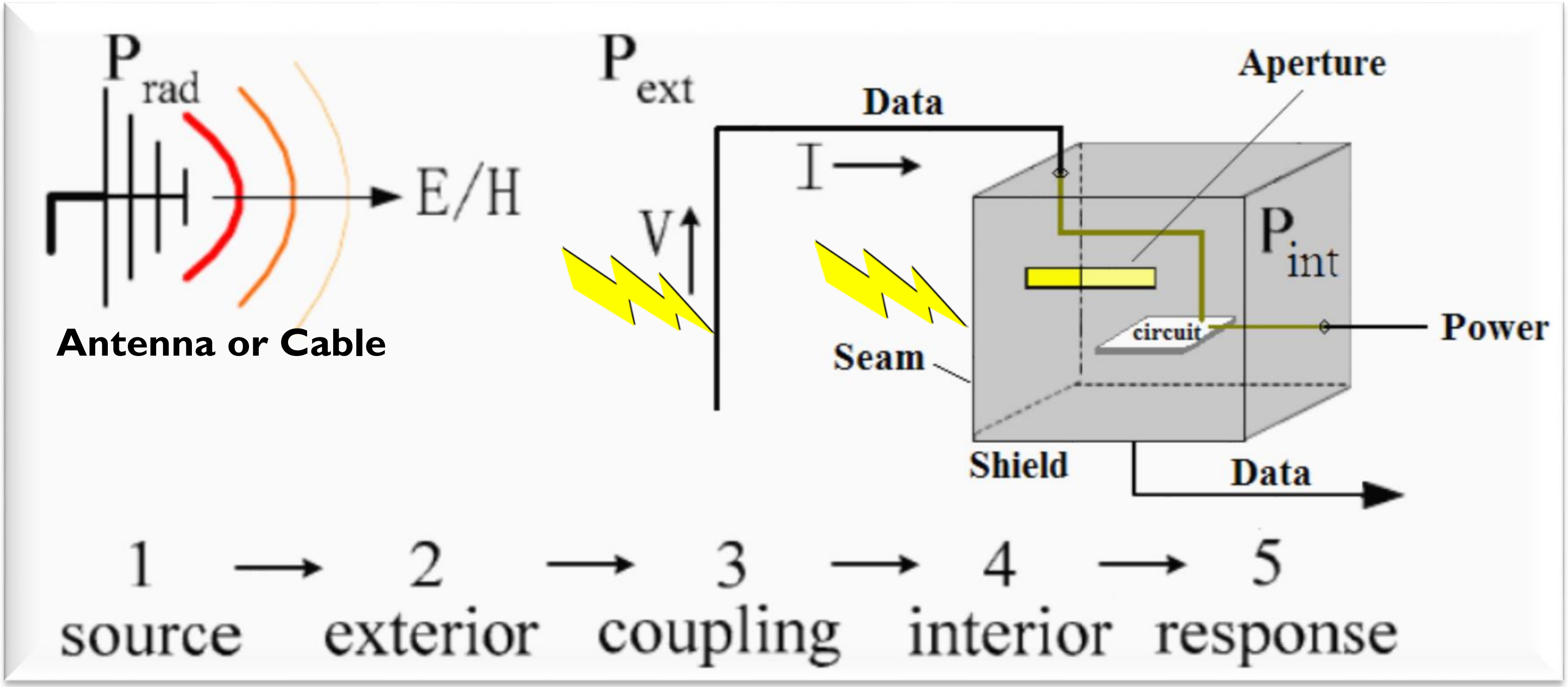


Intermodulation Product of Two Signals of Different Frequency Inputs to Nonlinear Systems:

$$f_{IM} = |nf_1 \pm mf_2|, \quad n,m = 1,2,\ldots$$

Topside Back-Door Coupling

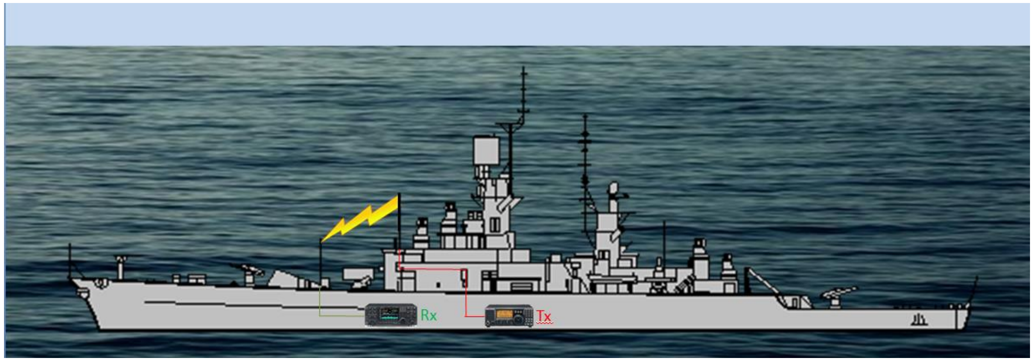
The Problem: Ship Own Source-to-Cable/Device Interference



TOPSIDE INTRASYSTEM EMI

The Problem: Ship Own Interference Due to Antenna-to-Antenna Coupling (Coexistence)

Transmitter-to-Receiver Front-Door Coupling

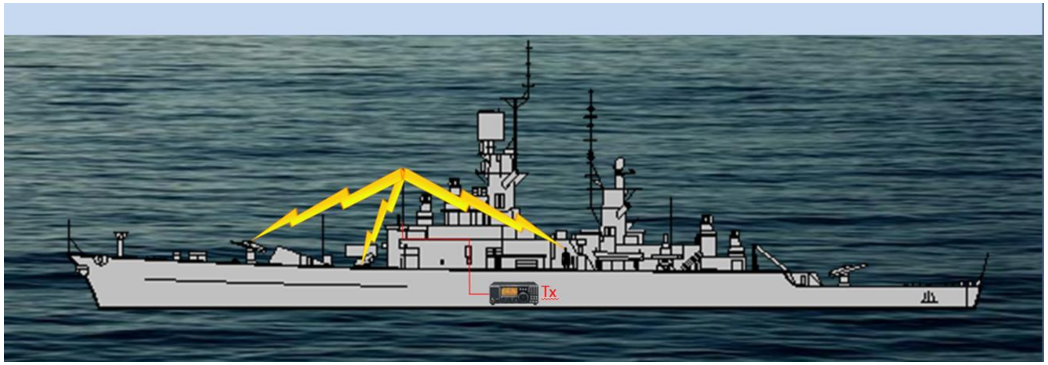


The Problem: Ship Own Transmitters RADHAZ to Personnel, Ordnance, and Fuel

Topside RADHAZ Categories:

- HERP - Hazards of EM Radiation to Personnel
- HERO - Hazards of EM Radiation to Ordnance
- HERF - Hazards of EM Radiation to Fuel

Topside Radiation Hazard (RADHAZ)



The Ever Increasing Below-Deck Shipboard EMI Problem

- Increased use of electrical and electronic equipment aboard naval ships introduces EMI problems to ship operation and performance
- As systems are added, they all contribute and become susceptible to an intense onboard electromagnetic environment (EME)
- The corrosive salt water environment and the interaction of a ship's electrically conductive metallic superstructure, topside hardware, antenna systems, etc., increase significantly the potential for interoperability problems
- Potential EMI and safety to personnel problems as related to electronic equipment operating in these environments are magnified because of the:
  - Need to establish and maintain a low impedance, common reference ground for all electrical/electronic equipment, and
  - EMI effects of several noise sources and types:
    - Natural and manmade,
    - Unintentional and intentional,
    - Radiated and Conducted,
    - Off-ship and own-ship electromagnetic (EM) energy

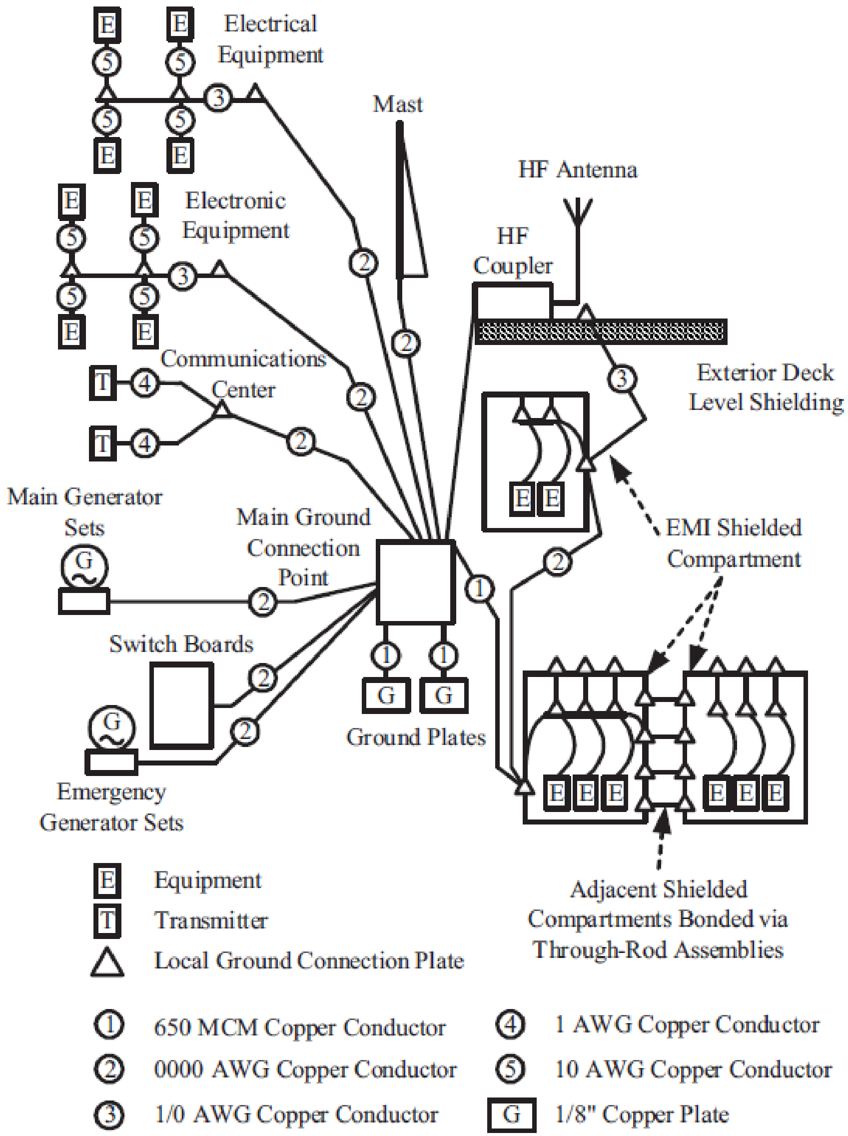
Equipment-to-Equipment Coupling

The Problem: Own Ship Device/Cable-to-Device/Cable Interference

- Bridge
- Cable Runs
- Control Rooms
- Electronic Equipment Rooms

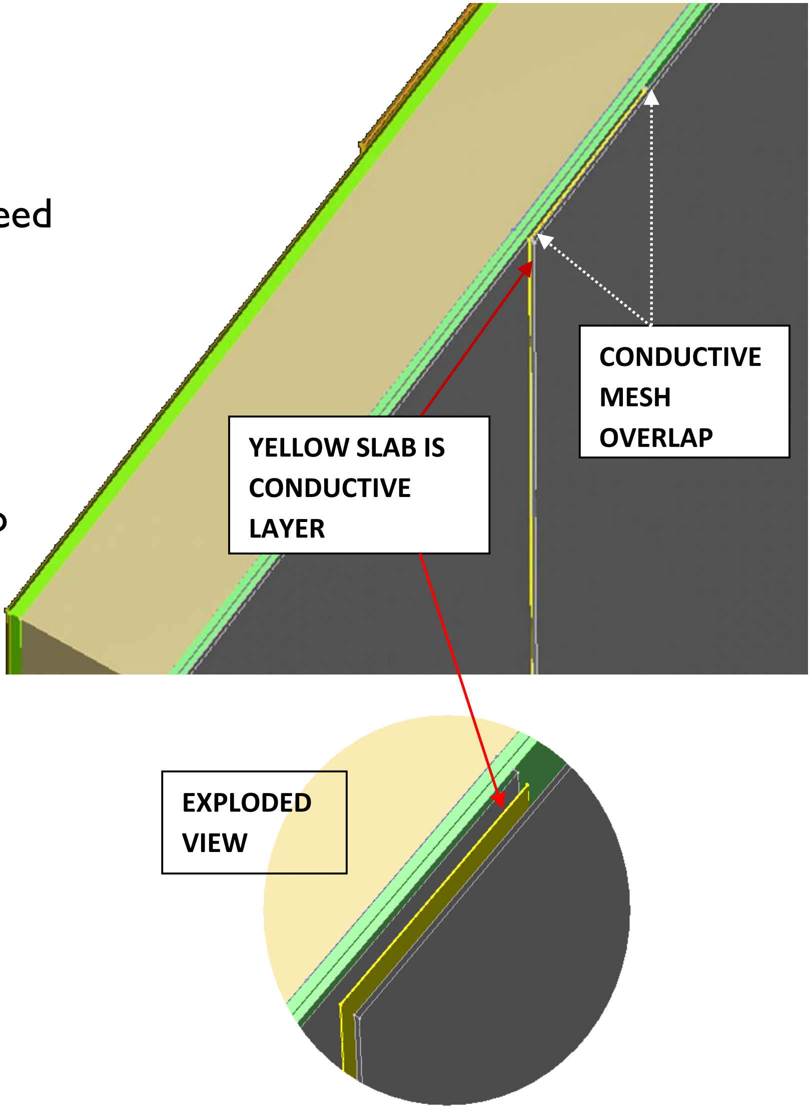
Composite Ship Considerations

- Grounding and an efficient Ground Plane are most important in achieving EMC on naval ships.
- Metallic ships intrinsically provide this feature, but non-metallic or composite ships are more problematical.
- On these ships, a "natural" equipotential ground reference structure does not exist and must, therefore, be artificially created.
- Ground plate(s) are installed at the lowest point of the structural hull, as close as possible to the vertical of the mast, in order to provide an earth ground connection via contact with seawater.
- From the ground plates stems a cable grounding system, with branches and branch extensions, forming a multi-tree grounding scheme, intended to provide a common reference to all equipment onboard the ship



Composite Ship Considerations

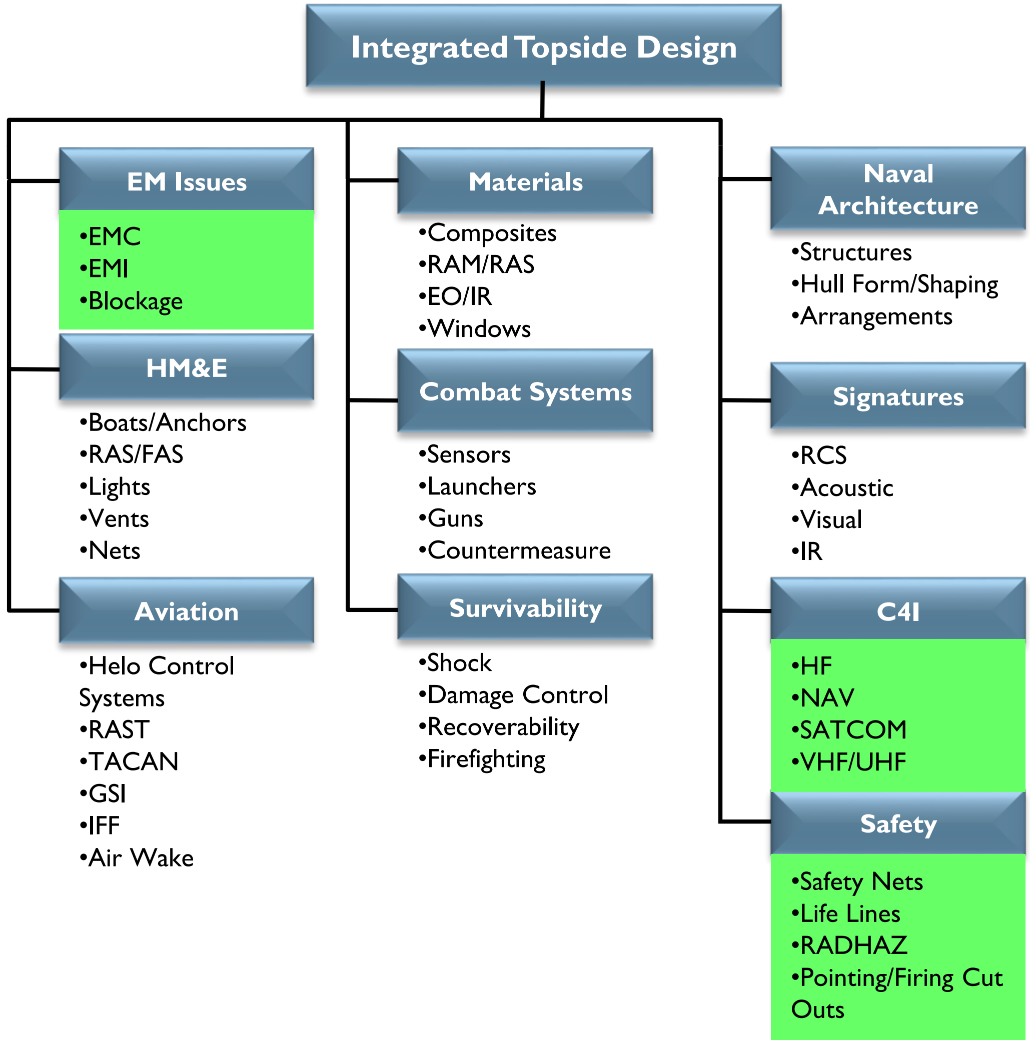
- Composite ships and superstructures in particular, need to incorporate a ground plane in the composite.
  - Typically a conductive mesh is incorporated
  - This mesh is incorporated as a layer into the composite as it is laid up.
  - If it is not continuous, it must be overlapped to retain continuity
  - If traditional antennas are incorporated, EMC design and problem resolution are similar to metallic ships



Shipboard EMC is a Component of the Integrated Topside Design Process

EMC/EMI Management

- Control Plan
  - Analysis
  - Mitigation
  - Monitoring Design Process
  - Monitoring Construction Process
- Integrated Topside Design Process
- Ship Specifications
  - Equipment Design
  - Bonding
  - Grounding
  - Shielding
  - Cable Types

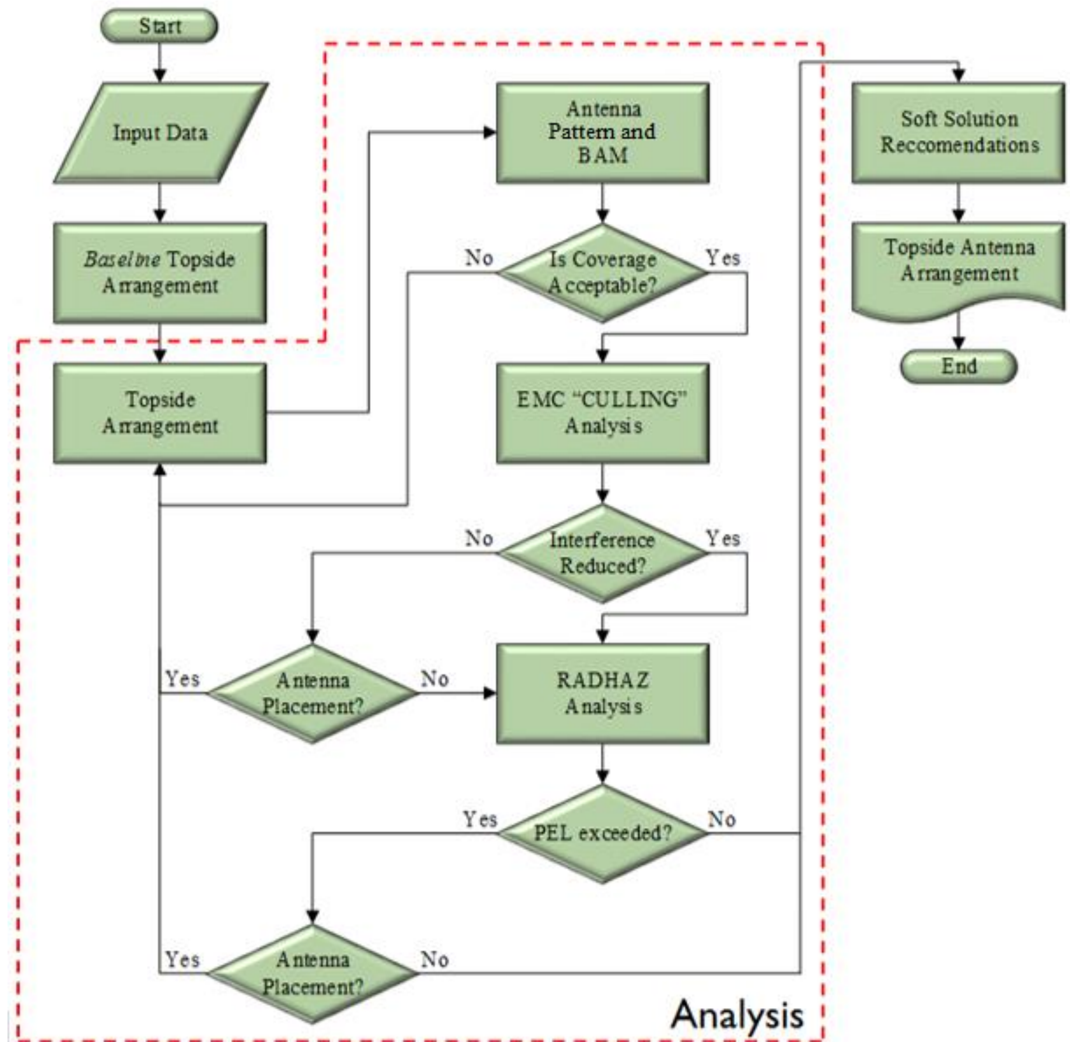


Alion Approach to Effective Early Stage EMC Ship Design

- Assemble Transmitter, Receiver, and Antenna Data
- Use "Good Engineering Practices" to Develop Initial Topside Design
  - Based on Knowledge and Experience, Control Plan and Ship Specifications
- Use Blockage Analysis Model (BAM) to Refine Topside Coverage for High Frequency Antennas
- Create Antenna Patterns for Lower Frequency Antennas (Rx and Tx)
- Use "Culling" Process to Eliminate Source / Victim Pairs with Low Likelihood of Interference
- Analyze Potentially Interfering Pairs
  - Culling Process Greatly Reduces Computation Time
  - Relocate Interfering Antennas (Hard Solutions) until EMI can be Mitigated Soft Solutions
  - Reduced Computational Time Allows Refinements to Arrangement in Earlier Stage of Ship Design
- Continue Refining Arrangement Based on New or Corrected Data
- Perform Ship Survey on Suspected Interfering Pairs
- Make Recommendations to Resolve Interference by Soft Solutions

Alion Approach to Ship EMC

Good Engineering Practices



TRANSMITTER-TO-RECEIVER FRONT DOOR COUPLING

The Topside EMC Analysis Approach

The Culling Analysis Stages

1. Frequency Cull – Eliminate from the analysis antenna pairs of non-overlapping bands
2. Amplitude Cull – Eliminate antenna pairs of 0 dB coupling after each of the stages:
   a. Compute no obstruction line of sight Rx frontend amplitudes
   b. Compute temperature noise for the remaining pairs
   c. Compute attenuation due to obstruction and diffraction
   d. Compute attenuation due to polarization mismatch for the remaining pairs
   e. Compute bandwidth mismatch for the remaining pairs
3. Criticality Cull – Eliminate pairs of acceptable interference

In case that excessive levels of interference are predicted at the end of the amplitude culling stage,

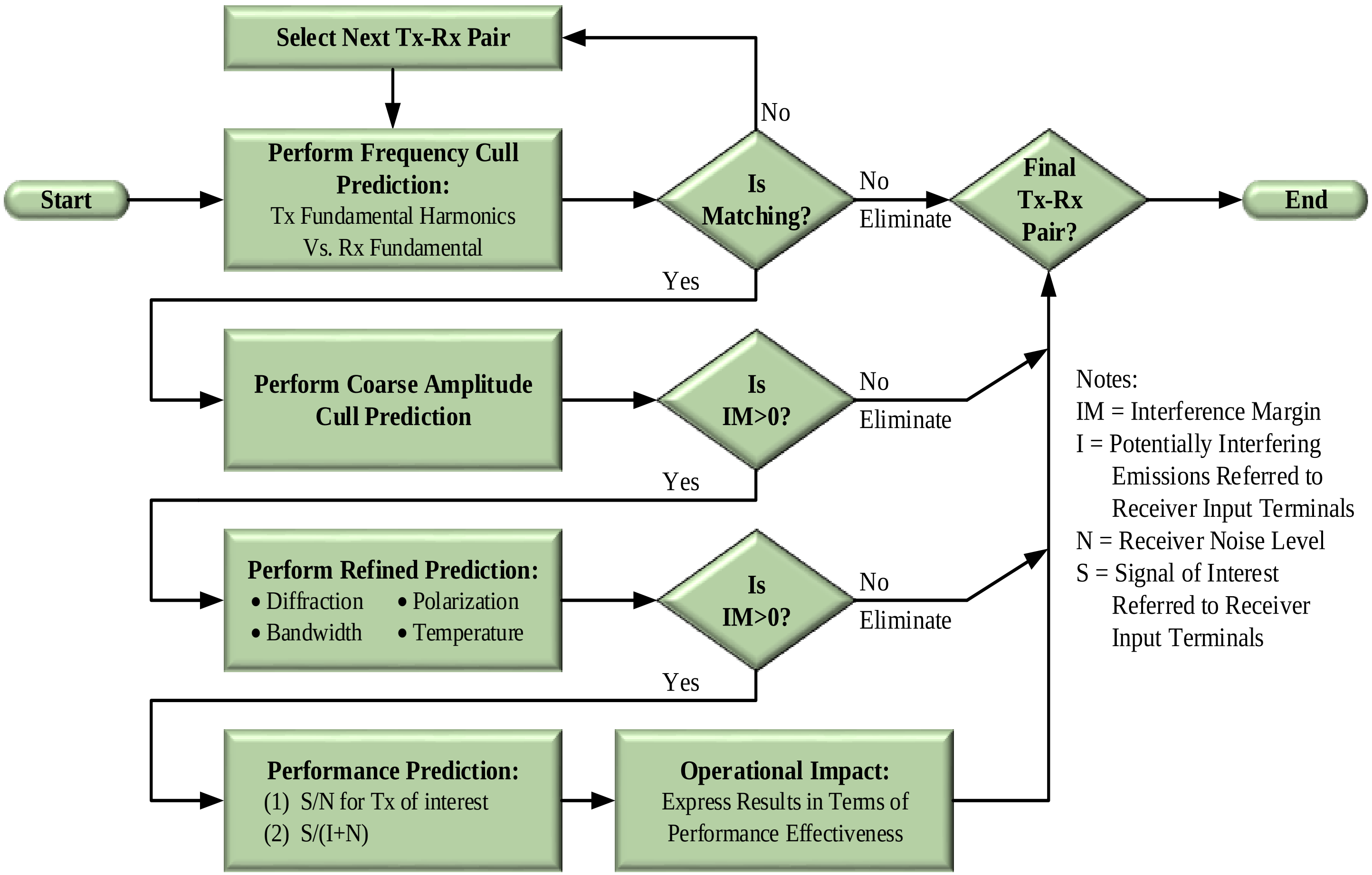
- Rearrange the transmitter or receiver antennas of the problematic pairs,
- Verify the optical coverage of high frequency antennas via BAM analysis, and
- Repeat the coupling analysis.

In case that the interference levels are acceptable, issue soft solutions to mitigate them.

TRANSMITTER-TO-RECEIVER FRONT DOOR COUPLING

The Topside EMC Analysis Algorithm

The Topside Culling Analysis Procedure:



The Culling Process - At each stage eliminate non-interfering Tx-Rx pairs from the analysis

TRANSMITTER-TO-RECEIVER FRONT DOOR COUPLING

The Frequency Culling Stage

Putting it all together - the frequency cull source-victim matrix:

TX \ RX	H2	H3	H4	A1	A2	V1	V2	V3	V4	V5	V6	U1	U2	U3	U4	U5	PH1-1	PH1-2	PH2-1	PH2-2	S1	S2	S3	S4	N1	N2
H1	1	1	1	1	1	2	2	2	5	6	6	8	8	8	--	8	--	--	--	--	--	--	--	--	--	--
H2	-T-	1	1	1	1	2	2	2	5	6	6	8	8	8	--	8	--	--	--	--	--	--	--	--	--	--
H3	1	-T-	1	1	1	2	2	2	5	6	6	8	8	8	--	8	--	--	--	--	--	--	--	--	--	--
H4	1	1	-T-	1	1	2	2	2	5	6	6	9	9	9	--	9	--	--	--	--	--	--	--	--	--	--
V1	--	--	--	--	--	-T-	1	1	2	2	2	3	3	3	5	3	10	--	10	--	--	--	--	--	--	--
V2	--	--	--	--	--	1	-T-	1	2	2	2	3	3	3	5	3	10	--	10	--	--	--	--	--	--	--
V3	--	--	--	--	--	1	1	-T-	2	2	2	3	3	3	5	3	10	--	10	--	--	--	--	--	--	--
V4	--	--	--	--	--	--	--	--	-T-	1	1	2	2	2	3	2	5	--	5	--	--	--	--	--	7	8
V5	--	--	--	--	--	--	--	--	1	-T-	1	2	2	2	3	2	--	--	--	--	--	--	--	--	--	8
U1	--	--	--	--	--	--	--	--	--	--	--	-T-	1	1	2	1	3	5	3	5	--	--	--	--	4	4
U2	--	--	--	--	--	--	--	--	--	--	--	1	-T-	1	2	1	3	5	3	5	--	--	--	--	4	4
U3	--	--	--	--	--	--	--	--	--	--	--	1	1	-T-	2	1	3	5	3	5	--	--	--	--	4	4
U4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	--	2	5	2	5	--	--	--	--	3	3
U5	--	--	--	--	--	--	--	--	--	--	--	1	1	1	2	-T-	3	5	3	5	--	--	--	--	4	4
PH1-1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	-T-	--	--	9	--	--	--	--	--
PH1-2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	-T-	--	--	4	--	--	--	--	--
PH2-1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	-T-	9	--	--	--	--	--
PH2-2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	-T-	4	--	--	--	--	--
S1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	--	--	--	--	--
S2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	--	--	--	--
S3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	--	--	--
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Legend: 1 = Adjacent Channel Interference Natural # = Harmonic Order -B- = RX blanking -T- = TRx -- = No Interference

TRANSMITTER-TO-RECEIVER FRONT DOOR COUPLING

Interference Criticality

The Criticality Matrix:

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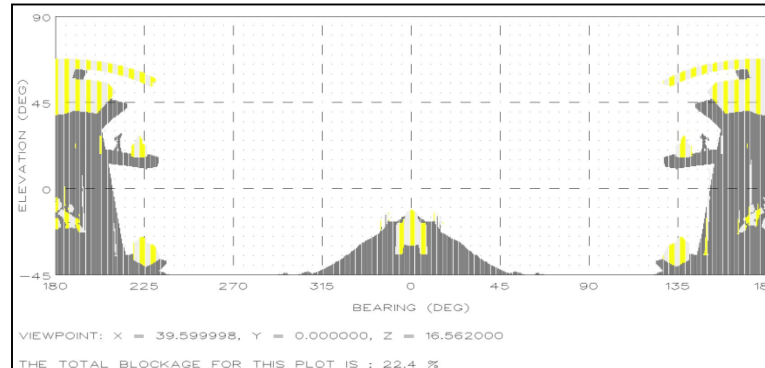
R5-U	--	--	--	--	--	--	(U)	(U)	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	--	--	--	-B-	-T-	-T-	--	--	--
R6	--	--	--	--	--	--	--	--	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	--	--	--	--	--	-T-	--	-B-
R7	--	--	--	--	--	--	--	--	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	--	--	--	--	--	--	-T-	-B-
R8	--	--	--	--	--	--	--	--	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	-B-	--	--	--	--	--	-B-	-B-	-T-

Legend: -U- = Unacceptable -M- = Marginal -A- = Accept/Nuisance -B- = RX blanking -T- = TRx ( ) = Based on Default Criteria O = Operational Experience

Alion Integrated Topside Design - EMI/EMC

- Products
  - Blockage Analysis Model
    - EMENG
  - Antenna Radiation Patterns and Coverage
    - FEKO
  - Coupling Analysis
    - NEC-4, CULLING, FEKO
  - RADHAZ Analysis
    - TRIGO



		RX																															
		H2	H3	H4	H5	A1	V2	V3	V4	V5	V6	U1	U2	U5	U6	S1	S2	S3	S4	N1	N2	N3	N4	N5	N6-1	N6-2	N7	R1	R2	R3	R5		
	H1	-M-	-M-	-U-	-M-	(A)	-U-	-U-	-A-	--	--	--	--	-A-	--	--	--	--	--	--	--	--	--	(M)	(U)	--	--	--	--	--	--	H1	
	H2	-T-	-A-	-A-	-A-	--	-U-	-U-	-A-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	(U)	(M)	--	--	--	--	--	--	H2	
	H3	-A-	-T-	-A-	-A-	--	-U-	-U-	-A-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	H3	
	H4	-A-	-A-	-T-	-A-	--	-U-	-U-	--	--	--	--	--	-A-	--	--	--	--	--	--	--	--	--	--	(M)	--	--	--	--	--	--	H4	
	H5	-M-	-M-	-M-	-T-	--	-U-	-U-	-A-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	(U)	(U)	--	--	--	--	--	--	H5	
	V1	--	--	--	--	--	-U-	-M-	-U-	-U-	-M-	-U-	-M-	-A-	--	--	--	--	--	--	--	--	--	(U)	(U)	--	--	--	--	--	--	V1	
	V3	--	--	--	--	--	-M-	-T-	-U-	-A-	-A-	-A-	-A-	-U-	--	--	--	--	--	--	--	--	--	(U)	(U)	(A)	--	--	--	--	--	V3	
	V4	--	--	--	--	--	--	--	-T-	-A-	-A-	-M-	-M-	-A-	-A-	--	--	--	--	(U)	(U)	(U)	--	(U)	--	(U)	(A)	--	--	--	--	V4	
	V5	--	--	--	--	--	--	--	-U-	-T-	-M-	-U-	-U-	-A-	-M-	--	--	--	--	--	--	(U)	--	(U)	--	--	--	--	--	--	--	V5	
	U1	--	--	--	--	--	--	--	--	--	--	-T-	-U-	-M-	--	--	--	--	--	-A-	-A-	(U)	--	--	--	--	-A-	--	--	--	--	U1	
TX	U2	--	--	--	--	--	--	--	--	--	--	-U-	-T-	-M-	--	--	--	--	--	-A-	-A-	(U)	--	--	--	--	-A-	--	--	--	--	U2	TX
	U3	--	--	--	--	--	--	--	--	--	--	-U-	-U-	-M-	--	--	--	--	--	-M-	-M-	(U)	-M-	--	--	--	-U-	(M)	--	--	--	U3	
	U4	--	--	--	--	--	--	--	--	--	--	-U-	-U-	-M-	--	--	--	--	--	-A-	-A-	(M)	--	--	--	--	-A-	(A)	--	--	--	U4	
	S1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S1	
	S2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	S2	
	S3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	--	--	--	--	--	--	--	--	--	--	--	--	--	S3	
	N4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	(U)	--	--	--	--	--	--	-T-	--	--	--	--	(U)	--	--	--	N4	
	R1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	(U)	(U)	(M)	--	--	--	--	--	--	--	--	-T-	--	--	(A)	R1-2	
	R2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	--	(U)	R2	
	R3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	-T-	--	R3	
	R5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	(U)	--	-T-	R5	
		H2	H3	H4	H5	A1	V2	V3	V4	V5	V6	U1	U2	U5	U6	S1	S2	S3	S4	N1	N2	N3	N4	N5	N6-1	N6-2	N7	R1	R2	R3	R5		
		RX																															

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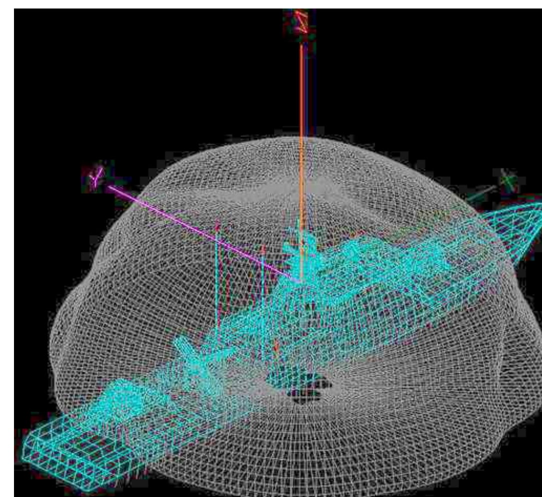

Alion Integrated Topside Design - EMI/EMC

- **Tools**
  - NEC4 - Numerical Electromagnetic Code, antenna modeling code for wire and surface antennas and scatterers.
  - NEC-BSC - NEC - Basic Scattering Code
  - CULLING – Alion Proprietary Code to eliminate the non interfering pairs from lengthy analysis
  - TRIGO - Alion Proprietary Code to analyze RADHAZ
  - EMENG – Develops the Blockage Analysis Model (BAM)
  - FEKO - Computational Electromagnetics Software to develop antenna patterns

- Real Ship Testing
  - Tests only Suspected Interfering Pairs from Culling Process
  - Quantitative Measurement
  - Reports
    - Test Plan and Test Procedures Report
    - Test Results Report

Test Point No.	Transmitter Name	Frequency Ranges (MHz)	Above PEL (dB)
TP1	E1	1626.5-1660.5	3.4
	H1, H3, H4, H5	2-30	12.8
	H3	2-30	28.8
	H4	2-30	8.4
	H5	2-30	8.2
	U1	291-318.3	2.6
TP2	E1	1626.5-1660.5	5.6
	H1	2-30	20.6
	H3	2-30	37.8
	H4	2-30	11
	H5	2-30	10.8
	U1	291-318.3	4.2
	V1-H	118	0.9
	V4	137	0.9

UBC and other Research Organizations can help Industry by

- Acquiring an understanding of the considerations and requirements essential for achieving electromagnetic compatibility (EMC) compliant ships by design.
- Getting familiar with the characteristics of the system and shipboard electromagnetic environment (EME) and the relevant electromagnetic phenomena.
- Contributing to the ingredients of a systematic approach for the proper implementation of electromagnetic interference (EMI) control measures and maintenance.
- Assisting in developing a systematic approach to shipboard EMC design and integration.
- Contributing to new techniques of EMC component testing and topside system coexistence surveying.
- Developing whole ship EMC/EMI prediction tools similar to those developed to predict other signatures such as RCS, IR, and Acoustics
    - Topside
    - Intra-System
    - Below Decks
- Characterization and development of best practices for deploying shipboard internal wireless communications for sensors, equipment health monitoring, personnel safety, etc.,

QUESTIONS?

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