Integrated Top Side Design
Topics

- Network Centric Operation
- Integrated Top Side Design
- Top Side Design Communications
- Impact on the Communications System Design
- Recapitulation

Integrated Top Side Design

Network Centric

- Network Centric
  - Warfare
  - Operations
  - Capability
- **Network Centric Operations** seeks to translate an information advantage, enabled in part by information technology, into a competitive warfighting advantage through the robust networking of well informed geographically dispersed forces.

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Network Centric Operations

Specifically, the theory contains the following four tenets in its hypothesis:

- A robustly networked force improves information sharing;
- Information sharing enhances the quality of information and shared situational awareness;
- Shared situational awareness enables collaboration and self-synchronization and enhances sustainability and speed of command; and
- These, in turn, dramatically increase mission effectiveness.

Going back to bottom line principles, Network Centric Operations is a strategy to move from a situation of single awareness to a situation of shared awareness across all involved forces.

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Network Centric Operations

Is Network Centric Operations all about networks? No.

Network Centric Operations is more about networking.

However, the “networks” or better lines of communications are one of the critical areas that needs to be considered for Network Centric Operations .

- Integrated Top Side Design
- Top Side Design Communications
- Impact on the Communications System Design

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Some Basics to Kick-of

4. The applied voltage that excites the antenna is $V_g = E_g b$ and the input impedance is given by

$$Z_a = \frac{E_g b}{I(0)}$$

The formal solution for the vector potential $A_z(x, y, z)$ may be found from a superposition of the contribution from each current-filament element $I(z')\,dz'$ using Eq. (2.24), and is

$$A_z(x, y, z) = \frac{\mu_0}{4\pi} \int_{-l_0}^{l_0} \frac{e^{-jk_0 R}}{R} I(z')\,dz' \qquad (2.63)$$

where $R = [r^2 + (z - z')^2]^{1/2}$ and r is the cylindrical radial coordinate $(x^2 + y^2)^{1/2}$. The z component of the electric field is given by

$$E_z = -j\omega A_z + \frac{1}{j\omega\epsilon_0\mu_0} \frac{\partial^2 A_z}{\partial z^2} = \frac{1}{j\omega\epsilon_0\mu_0}\left(k_0^2 + \frac{\partial^2}{\partial z^2}\right) A_z \qquad (2.64)$$

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The Kick-Of

- What does Integrated Top side Design mean?
- What are we confronted with?
- Answer: Top side design a special for communications is a discussion point for many years!
- To cover this in the required depth, we would need to spend at least a whole day.
- This forum does not allow for this, so we must focus on the basics, the physics behind it and a little bit of maths.
- Of course, we will not completely ignore the practice.

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Challenges in Topside Design

Typical areas of observation

- Performance
- Stealth
- Electronic Support Measures (ESM)
- Radars
- Weapons

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Challenges in Topside Design

Interference Problems

- Collocation of antennas
- Obstruction by other topside elements
- Transmission and reception at the same time

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Challenges in Topside Design

Network Centric Operation (Warfare)

- Collection of Information
- Distribution of Information
- Processing of Information
- Utilise Information

Simultaneously, Accurate, Understandable & Error Free.

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Challenges in Topside Design

Serious Incidents:

- EMI caused by radar
- Helicopter moves through Radar Beam
- Exocet Hits Warship
- Loss of Target

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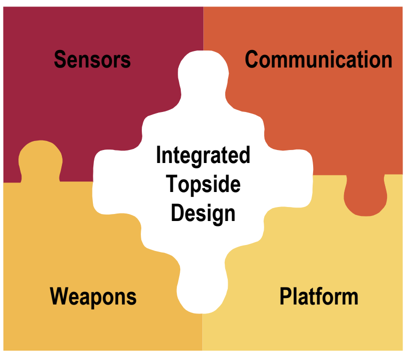
The core of ITD



Integrated Top Side Design

From Concept to Operational Platform

Integrated Project Team

- Defence material Organisation (Program Requirements)
- Navy (Operational Requirements)
- Shipyard (Platform Designer)
- Combat System Integrator (Design Weapons & Sensor Systems)
- Communications System Integrator
  (Design Fully Integrated Information & Communications System

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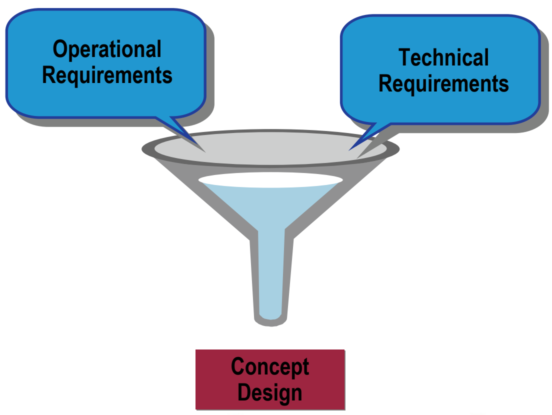
From Concept to Operational Platform



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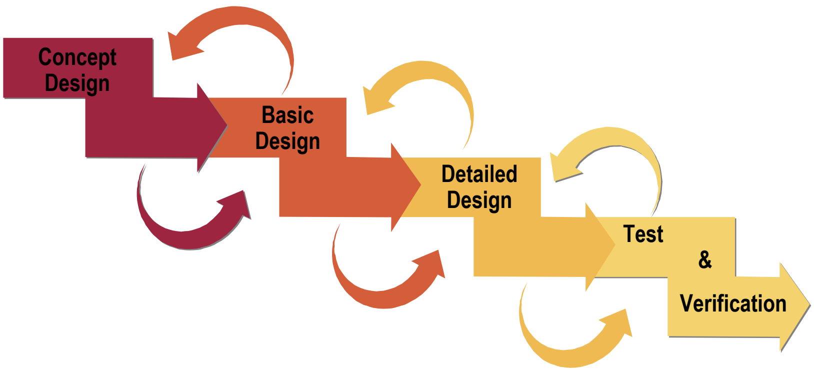
From Concept to Operational Platform



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From Concept to Operational Platform

Integrated Topside Design
Areas of Concern (Communications)

- Electromagnetic Engineering
- Signature Management
- Time Frequency Power and Polarisation Control (TFP^2)
- Antenna Integration

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Electromagnetic Engineering

- Radiation Hazard
  - Hazards from Electromagnetic Radiation to Ordnance (HERO)
  - Hazards from Electromagnetic Radiation to Personnel (HERP)
  - Hazards from Electromagnetic Radiation to Fuel (HERF)
- Electromagnetic Interference
- Antenna Coverage & Performance
- Blocking

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Signature Management

- Radar Cross section (RCS)
- Infrared (IR) Signature
- Electro-Optical (E/O) Signature
- RF Emission

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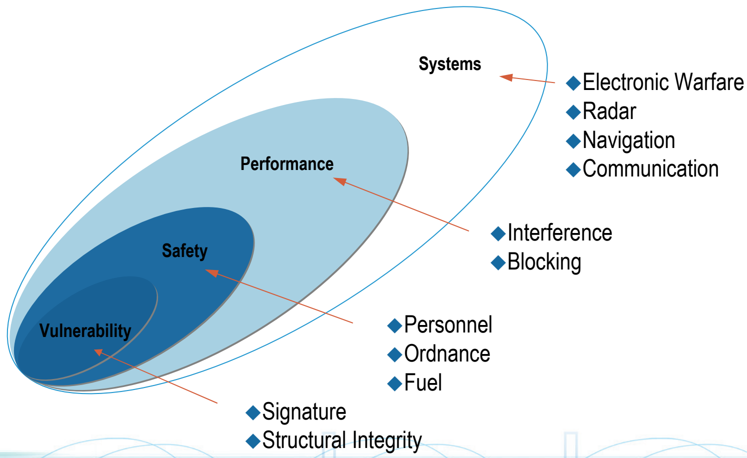
Time Frequency and Polarisation Control

- Time management
- Frequency Management
- Power Management
- Polarisation Management

Integrated Topside Design
Time Frequency and Polarisation Control



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Antenna Integration

- Antenna Location
- Topside Impact
- Special-to-Type (vessel) antenna design
- Antenna Coverage (V/H Diagram)

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Operational Requirements

HF Communications
1.5 – 30 MHz
Use full Frequencies @

- **Δf 5%** **62 freq.**
- **Δf 10%** **34 freq.**
- **Δf 15%** **24 freq.**
- **Δf 20%** **17 freq.**

Integrated Topside Design
Operational Requirements

VHF Tac. Communications
30 – 108 MHz
Use full Frequencies @

- **Δf 1%** **99 freq.**
- **Δf 3%** **34 freq.**
- **Δf 3%** **34 freq.**
- **Δf 5%** **21 freq.**
- **Δf 10%** **12 freq**

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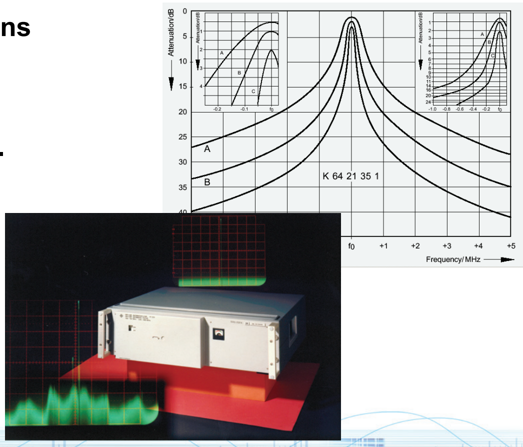
Operational Requirements

UHF Communications
225 – 400 MHz
Use full Frequencies @

- **Δf 0.5%** **116 freq.**
- **Δf 1%** **58 freq.**
- **Δf 3%** **20 freq.**
- **Δf 5%** **12 freq.**
- **Δf 10%** **7 freq.**



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Antenna Collocation, Radiation & Propagation

- Our collocation point of view assumes that the mutual influencing takes place via the involved antennas only.
- Knowing the decoupling (i.e. the attenuation) between the associated antennas is a indispensable prerequisite for the collocation assessment.
- The process of radiation and hence the field distribution around an antenna is able to be described with reasonable technical effort only for the so called far field.
- As a rule of thumb, the transition from near field to far field can be presumed at a distance of $\lambda/(2\pi)$ from the antenna.

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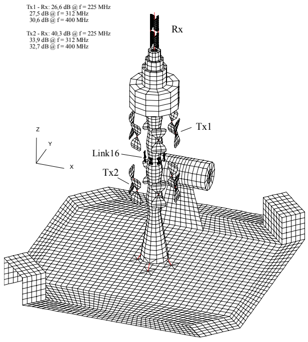
Special to Vessel Antenna Design

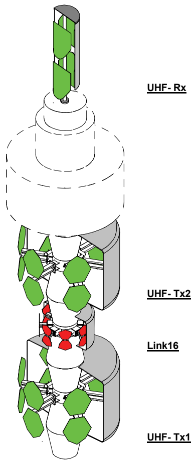
Isolation:

Tx1 - Tx2: 23,5 dB @ f = 225 MHz
23,2 dB @ f = 312 MHz
29,5 dB @ f = 400 MHz

Tx1 - Rx: 26,6 dB @ f = 225 MHz
27,5 dB @ f = 312 MHz
30,6 dB @ f = 400 MHz

Tx2 - Rx: 40,3 dB @ f = 225 MHz
33,9 dB @ f = 312 MHz
32,7 dB @ f = 400 MHz





UHF / Link16 - Antenna System

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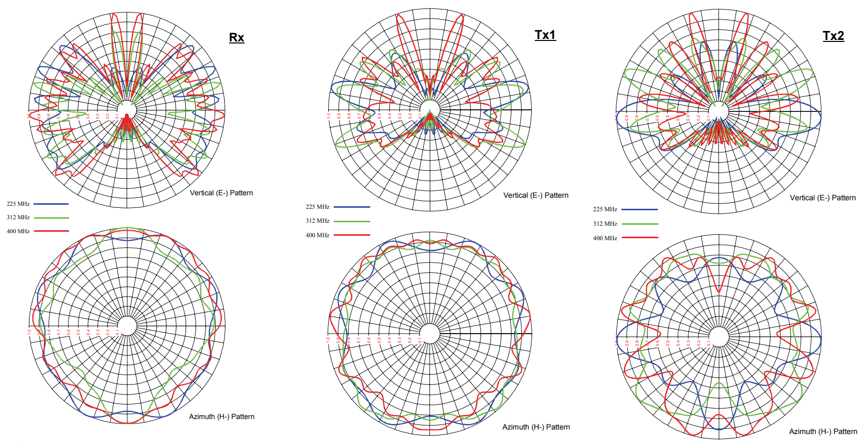
Special-to-Type (Vessel) Antenna Design



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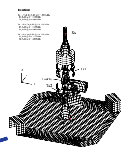
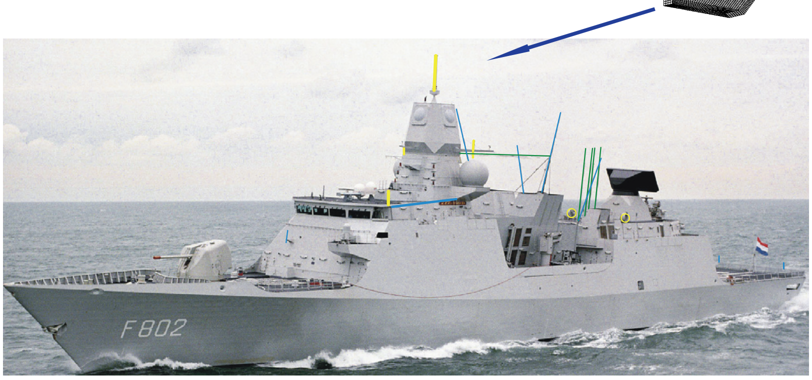
Modelling of HF Antenna Collocation





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Antenna Collocation, Radiation & Propagation

- For frequencies > 100 MHz (i.e. λ = 3m) - In almost all practical cases, a calculation of antenna decoupling is permissible as we are normally in the far field.
- In contrast to this, for 1.5 MHz (i.e. λ =200m) - A measurement of antenna decoupling will be the normal case due to the previously mentioned near field problem.

Integrated Topside Design
Modelling of HF Antenna Collocation

Integrated Topside Design
Calculating of Antenna Decoupling

The attenuation between two λ /2- dipole antennas is described by the formula:

A[dB] = 17,7 + 20∗log (d[m]/l[m])

Since the frequency is usually better known than the wavelength, the adapted formula runs as follows:

A[dB] = 17,7 + 20∗log (d[m]∗f[MHz]/300)

Note:

- The two dipoles "point to each other". (See next foil).
- A λ /2-dipole has a gain of 0 dBd respectively 2.14 dBi.
- Antenna gain in excess of 0 dB reduces the decoupling figures by the gain (in main lobe).
- Example: Two dipoles 5m apart in the VHF-ATC-range have a decoupling of around 25 dB.

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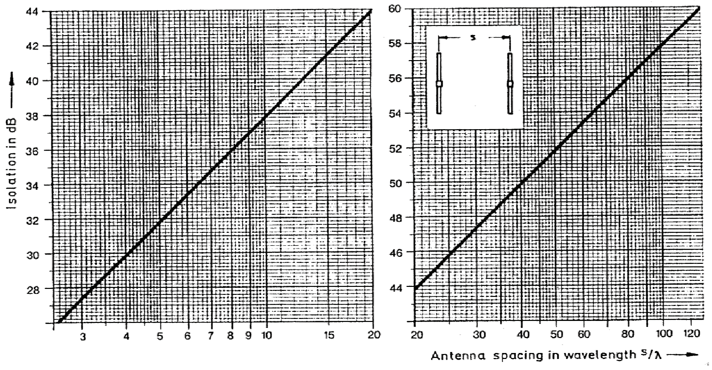
Antenna Decoupling Graphical

Isolation by horizontal separation

of two vertical polarized half wave dipoles with horizontal spacing



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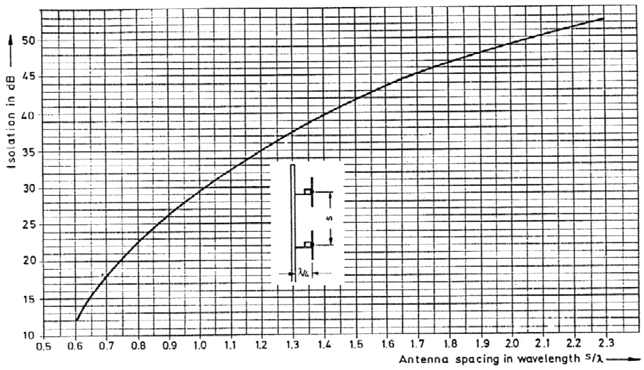
Antenna Decoupling Graphical

Isolation by vertical separation

of two vertical polarized half wave dipoles, vertically positioned in line on a common mast



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Collocations Mechanisms

Phenomenon	Spot of Origin	Effect	Occurrence at Sites with	Appearance	Theory
TX-noise floor	**TX, Synthesizer**	**RX-desensitization**	**2 or more installed Channels**	**Broadband**	Noise
RX reciprocal mixing	**RX, Synthesizer**				
RX blocking	**RX, Front-end**				
TX backdoor-IM	**TX, Power Amplifier**	**RX Squelch-opening, Beat with wanted signal, "Ghost reception"**	**3 or more installed Channels**	**Discrete frequency(ies)**	Nonlinearity
RX IM	**RX, Front-end**				

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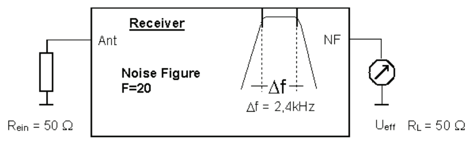
Basic of Noise

- **How does an engineer handle noise?**

  He/she prefers simple math and dB!

  Let's look into a receiver



What does Nyquist tell us?

The noise power related to the input terminal is

$$P_R = k * T * \Delta f * F$$

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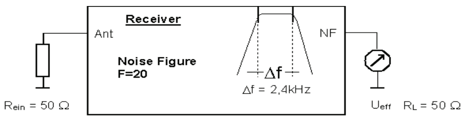
Receiver Noise

Question: Which equivalent noise power is present at the input terminals of the previous receiver?



$$P_R = k * T * \Delta f * F$$

Nyquist:

k	**Boltzmann constant = 1,38∗10^{-23} Ws/K**	
T	**Absolute temperature, normally 290 K (=17° C)**	
Δf	**Noise bandwidth of receiver, 2,4 kHz in example**	
F	**Noise factor of receiver, 20 in example**	

Result of calculation: 1,92∗10^{-16} W

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Receiver Noise

However, engineering uses a different calculation approach namely:

logarithmic

k ∗T (1,38∗10-23 Ws/K) ∗290 K = 4 ∗10-21 W/Hz

in logarithmic scale (dBm)

10 ∗ log(4 ∗10-21 ∗1000) = -174 dBm/Hz

(That's the noise power generated by Rin in 1Hz bandwidth at room temperature.)

Noise bandwidth in logarithmic scale

10 ∗ log 2400 = 33,8 dB

(That's the "noise window".)

Integrated Topside Design
Receiver Noise

Conversion of the (linear) noise factor F into logarithmic noise figure

10 ∗ log 20 = 13 dB

(That's the "internal" noise contribution of the receiver.)

Now our general "logarithmised Nyquist-formula" runs as follows:

PN[dBm]= -174 dBm/Hz+ Df [dB] + F [dB]

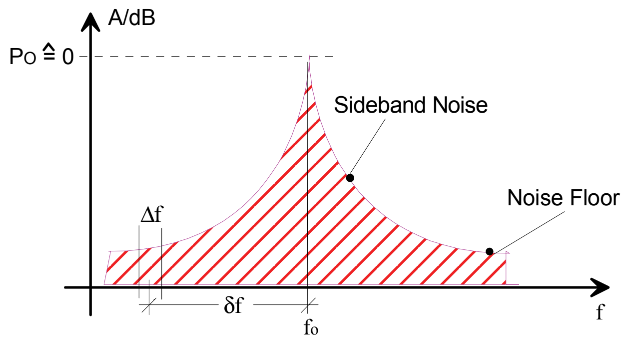
Result of calculation with values above:

PN= -174 dBm/Hz+ 33,8 dB + 13 dB = - 127,2 dBm

(That's identical with 1,92∗10-16 W).

Integrated Topside Design
Transmitter Noise

Connecting a spectrum analyser to the transmitters RF output terminal displays the following picture:



Integrated Topside Design
Transmitter Noise

What does the specification (e.g.) **"150 dB$_c$/Hz"** mean?

1. The "$_c$" tells us that the measured noise power (in Δf) is referred to the carrier (i.e. P_0).
2. The " /Hz " describes the (practically fictitious) measuring bandwidth of 1 Hz

Practical consequences:
•All data (incl. TX power) are to be logarithmic.
•The measurement (i.e. noise-) bandwidth has to be converted to 1 Hz.
•The further ("δf") we go away from the carrier frequency f_0, the better (normally) the specification for sideband noise suppression will be.

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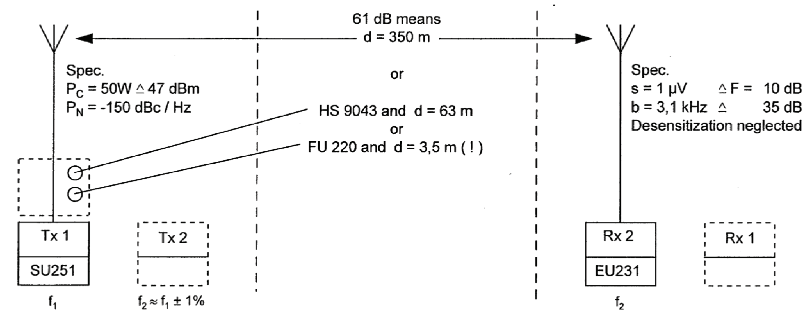
TX Noise Floor



A Rx-desensitization of 3 dB occurs, if Tx noise at Rx antenna input and Rx internal noise are identical.

Tx noise radiated in 3,1 kHz bandwidth
P_N = 47 - 150 + 35 = **- 68 dBm**

P_N = - 68 dBm
P_R = - 129 dBm

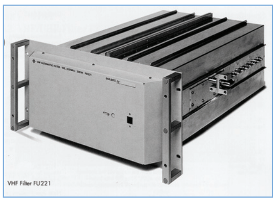
61 dB
are missing

Rx internal noise
P_R = - 174 + 10 + 35 = **- 129 dBm**

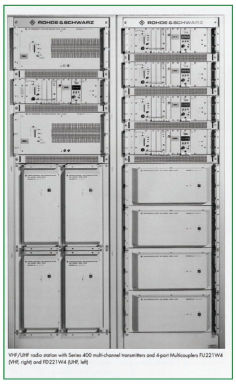
Integrated Topside Design

Solutions for V/UHF Antenna Collocation

Cavity Resonator
Manually Tuned
Single Circuit



Cavity Resonator
Automatically Tuned
Two-Section Bandpass Filter



Cavity Resonator
Automatically Tuned
Two-Section Bandpass Filter in
Combiner Configuration

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Antenna Collocation, Radiation & Propagation

- The previous consideration deals with Line Of Sight propagation.
- For frequencies above 100MHz this type of propagation holds true in most cases.
- For long distance communications in the HF frequency range however, ionospheric propagation needs to be considered. This type of propagation is far more complex.

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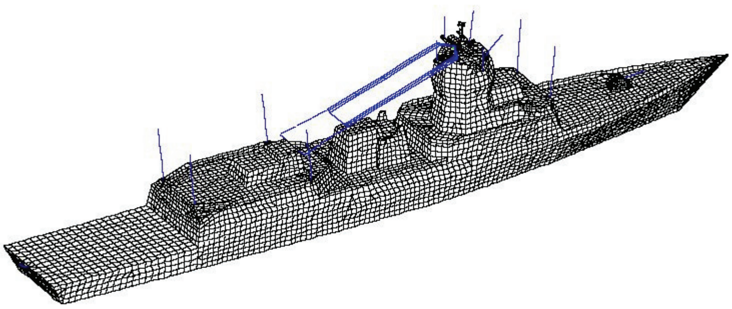
Modelling of HF Antenna Collocation

- Computer modelling (estimation)
- Brass Modelling
  - Model 1 : 50 → VSWR < 2
  - Real world VSWR < 3
- Model verification on First of Class
- Influence of small constructional changes in the super structure
  - Influence on HF Broadband antennas
  - RADHAZ

Integrated Topside Design
Modelling of HF Antenna Collocation



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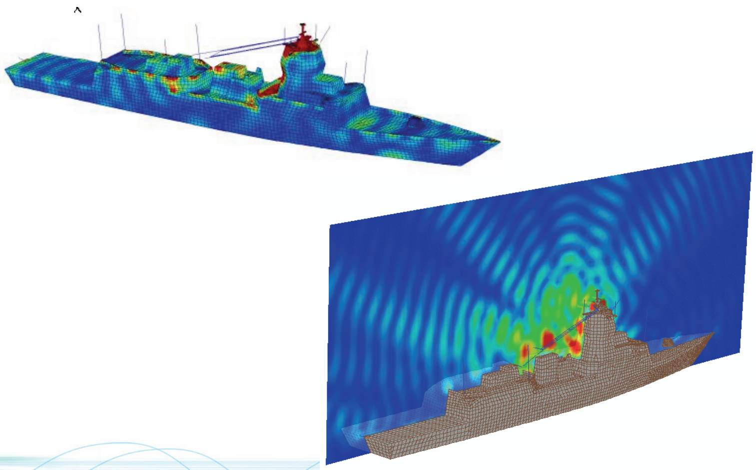
Modelling of HF Antenna Collocation



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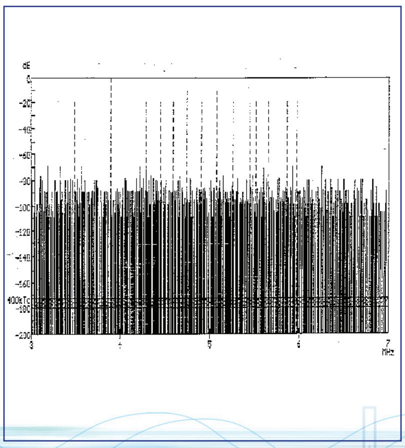
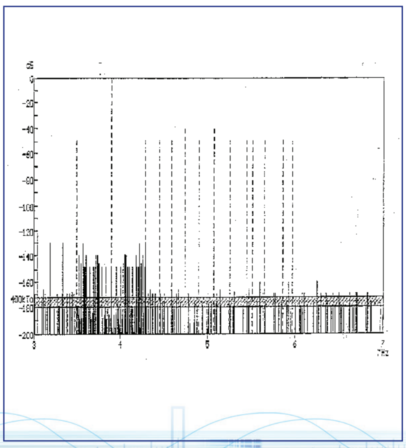
Modelling of HF Antenna Collocation





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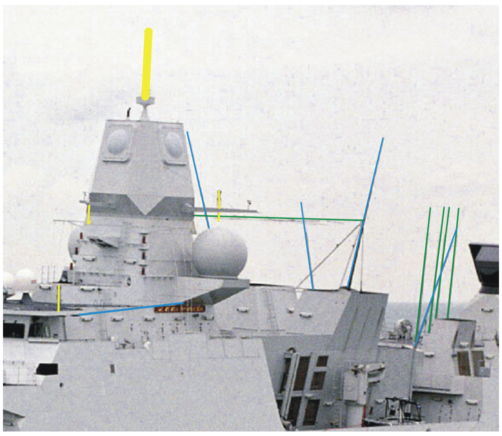
Modelling of HF Antenna Collocation

Integrated Topside Design
Modelling of HF Antenna Collocation



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Recapitulation

- All Stakeholders involved in the early stages
- All solutions are compromises
- Balanced priorities of operational tasks
- Matching requirements - Operational Capabilities / Technical Possibilities

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Recapitulation

- The topic "Integrated Topside Design" is far too extensive to be covered within 90 minutes.
- ROHDE & SCHWARZ has always given their attention to Integrated Topside Design and the related issues. This statement holds true for decades of Naval communications integration.
- Due to the permanent analysis and treatment of Integrated Topside Design issues, a wealth of experience (even in the resolution of "nasty" designs problems) exists within the company.
- ROHDE&SCHWARZ is pleased to share this knowledge with you.
- Please don't hesitate to contact us for assistance in the resolution of your Topside Design issues. Whenever possible, we will help.

Integrated Topside Design

Thank you for your attention!

Questions ?

Integrated Topside Design

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Photo Sources

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Spanish Navy

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