MILCIS

RF Systems for Naval Applications

Integrated Antenna Systems (IAS) for Naval Ships for Communication, CESM and RESM

Focus on VHF/UHF Communication Antennas

Presented by

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75 Years of Driving Innovation

ROHDE&SCHWARZ

Introduction

Part A: Basics on Antennas

Part B: RF Coupling Networks

Example of Integrated Antenna (IAS)

Necessity of a New Concept

Shipboard Antennas for Military Purposes

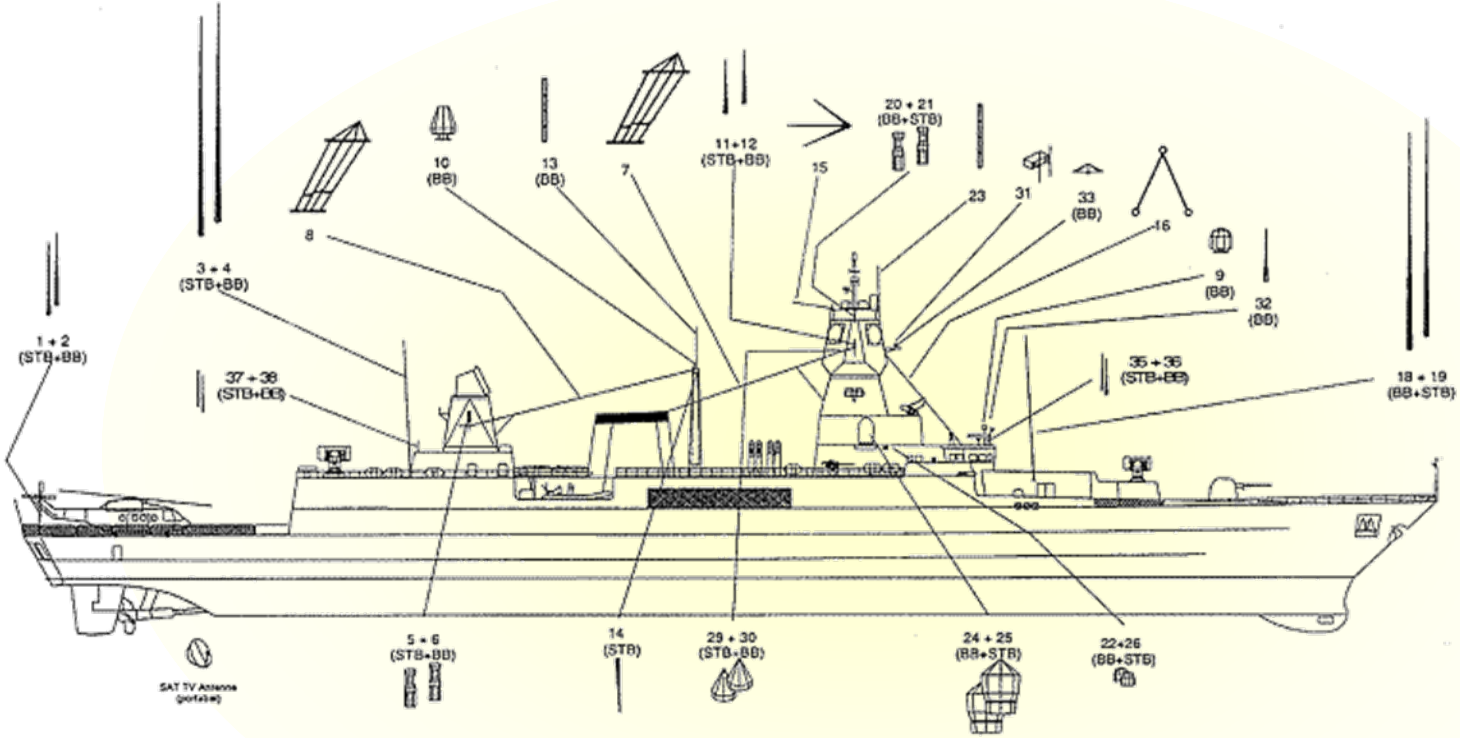
are used for

- communications
- direction finding
- monitoring
- radar and data links
- ...

These applications are in the frequency range from 10 kHz to currently 40 GHz.

Necessity of a New Concept

Today‘s Antenna Arrangement (an example)



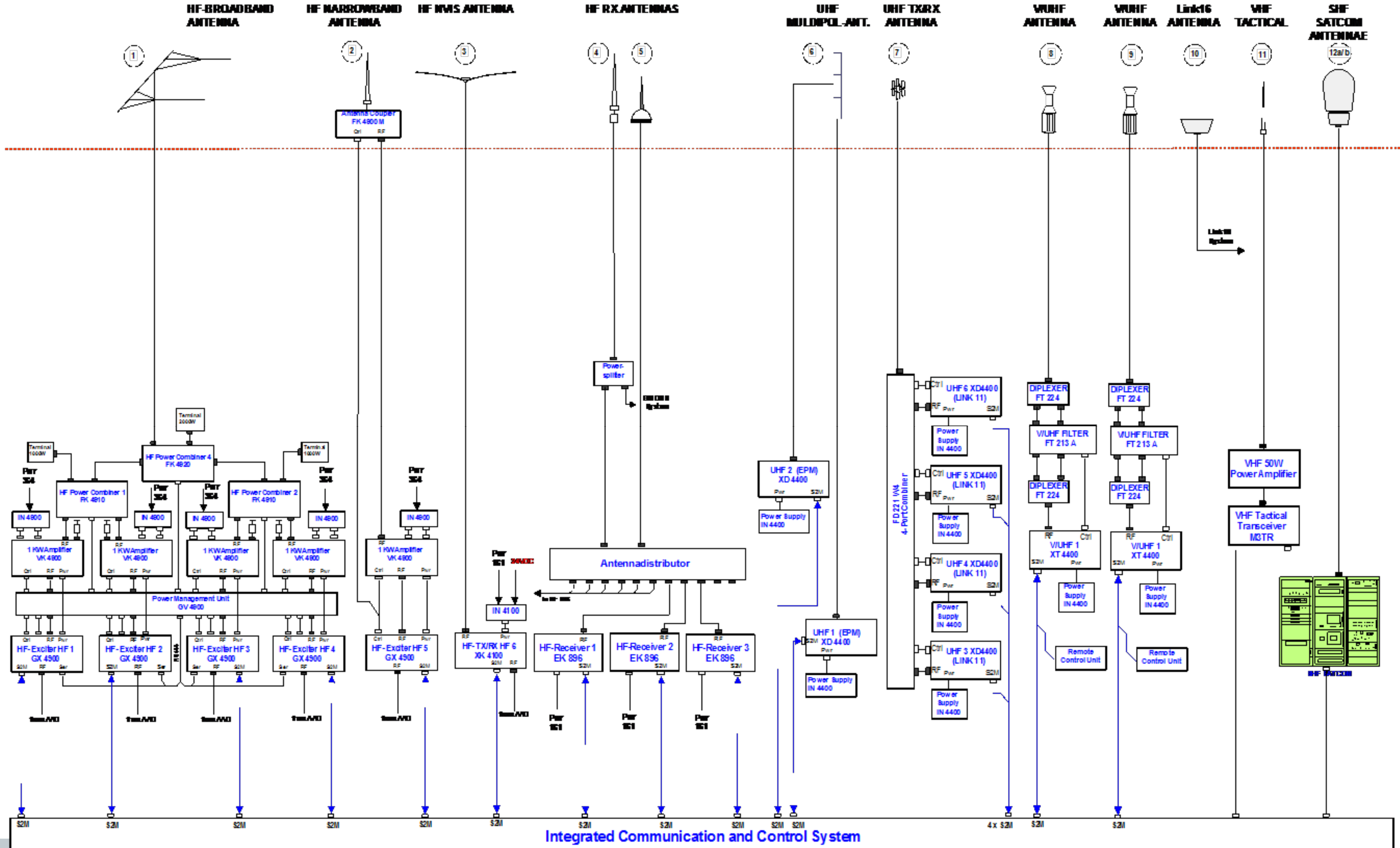
xy radar antennas and xy ESM/ECM antennas

10 antennas for HF/MF/LF Tx/Rx, 11 antennas for UHF / VHF Tx/Rx and xy antennas for SATCOM

Source : MTG Marinetechnik GmbH

Necessity of a New Concept

Shipboard Communications System for a Corvette (typ.)



Necessity of a New Antenna Concept

Points of Criticism of Conventional Antenna Concepts

- Due to the number of antennas required only some of them can be mounted in respect of proper radiation aspects.
- The required omnidirectional coverage especially in the VHF-/UHF-range can not be fulfilled for each communication line.
- The large number of antennas at limited space leads to strong interferences in between the individual communication lines.
- Competition of the sensors for the best location on the mast
- Ships have limited real estate available for antennas, especially at their pinnacles

Necessity of a New Antenna Concept

Points of Criticism of Conventional Antenna Concepts

Analysis of Link Budget for Radiotelephony AM

Antenna height at ship 1:	34 m above water linie
Antenna height at ship 2:	34 m above water line
Optical horizon:	41 km
Radio horizon:	55 km (approx. 30 nautical miles)
Frequency:	400 MHz

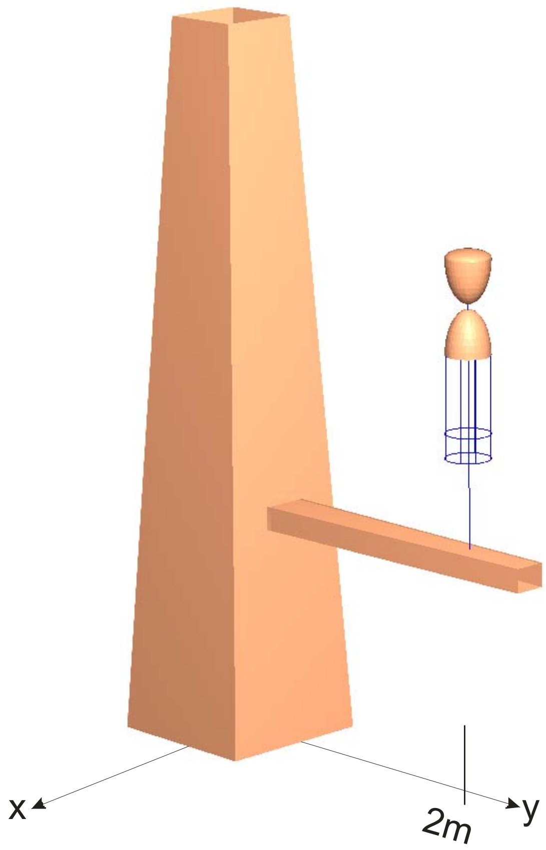
Tx power (30W) at transmitter output:	45 dBm	Tx
Attenuation between Tx antenna and transmitter:	3 dB	
Gain of Tx antenna:	1 dB	
Propagation loss between ship1 and ship 2:	115 dB	
Gain of Rx antenna:	1 dB	Rx
Attenuation between Rx antenna and receiver:	3 dB	
Sensitivity at minimum modulation depth of 30%:	- 100 dBm	

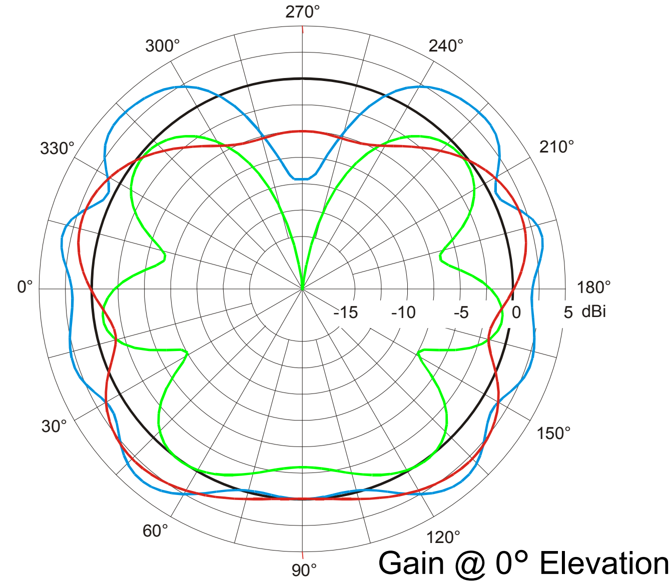
System reserve: 26 dB

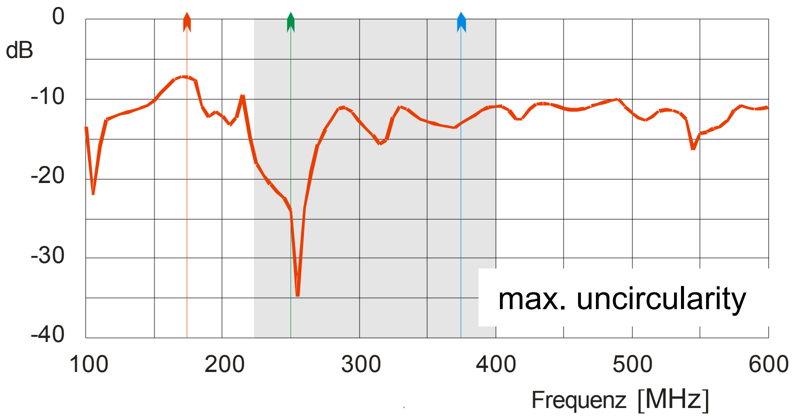
Necessity of a New Antenna Concept

Points of Criticism of Conventional Antenna Concepts

Example: Omnidirectional coverage







Necessity of a New Antenna Concept

Main Reasons for a New Antenna Concept

- Reduction of number of antennas despite increasing number of communication lines
- Reduction of interference between the individual antennas/communication lines
- Design and setup of antennas in respect to requirements for better radar cross section by reduction of superstructures

} Integrated Antenna System

IAS Requirements

- Reduction of total number of antennas
- Ease of integration into given ship structures for easy installation respectively retrofitting
- Avoidance of radiation gaps (nulling) in the azimuth to improve operational characteristics
- Reduction of Radar Cross Section (RCS)

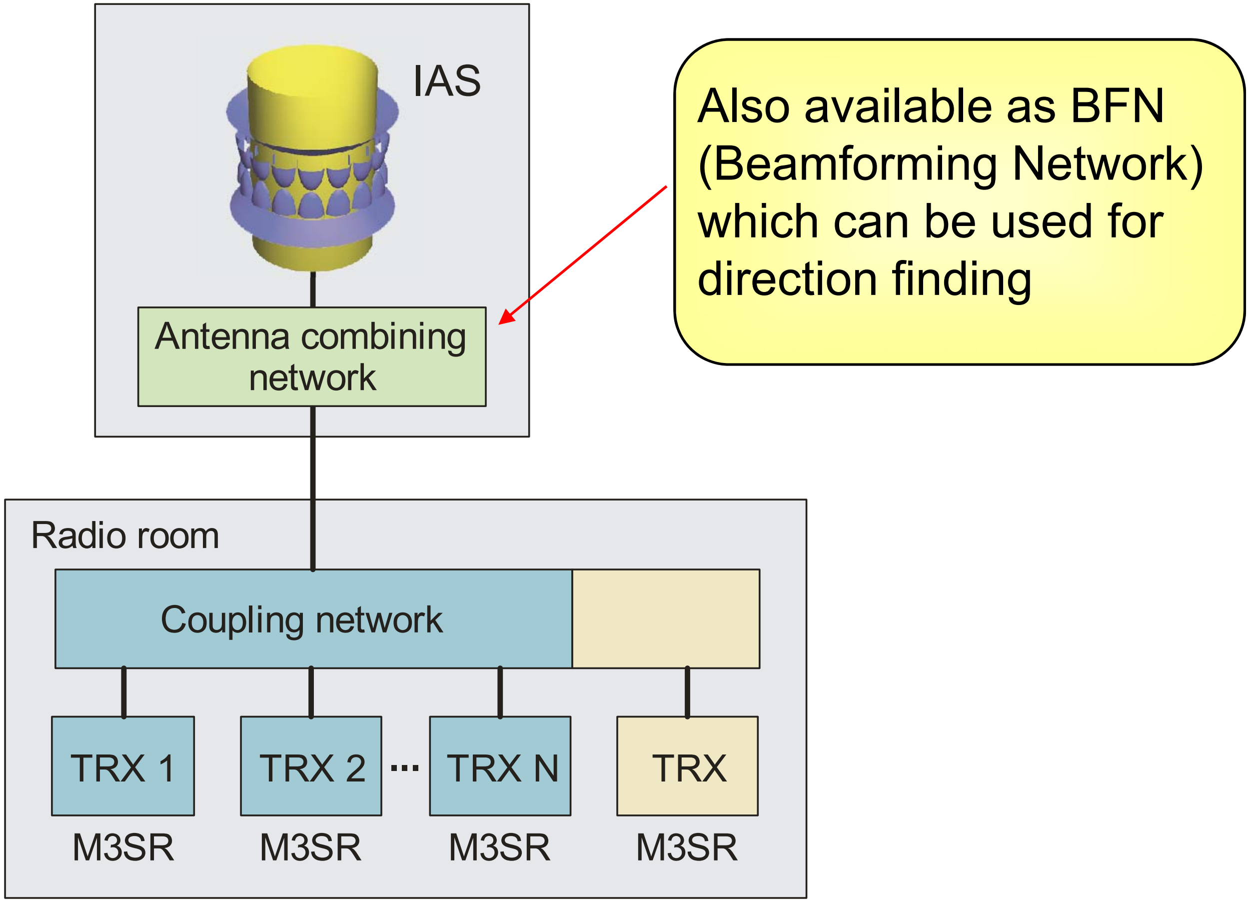
Multiple Use of Antennas

- Increasing the antenna bandwidth
  - Coverage of e.g. VHF and UHF with one antenna only

- Combining of n x radios to one antenna
  - Number limited due to losses of coupling network

Multiple Use of Antennas

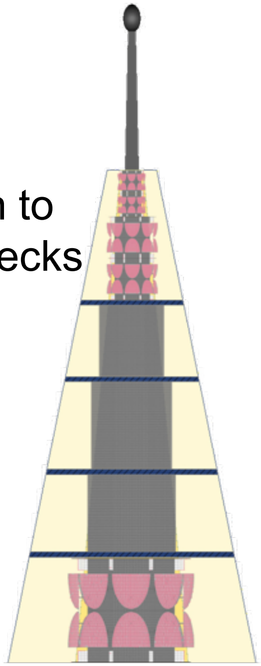
Example of a Coupling Network for Connecting of n x Radios



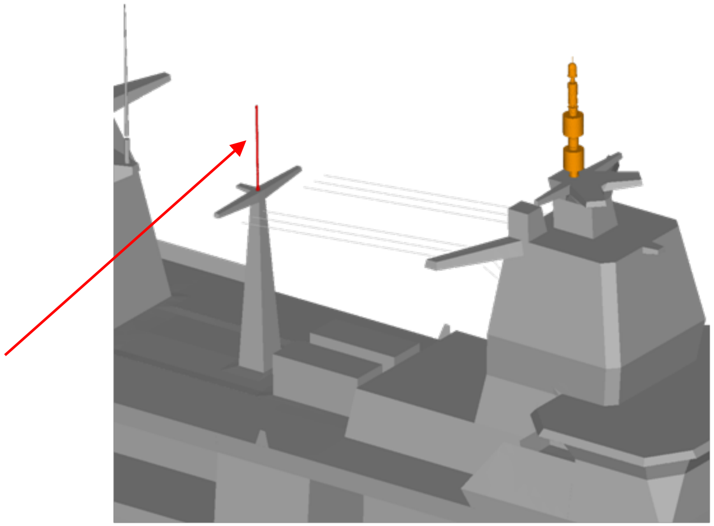
Integration in Ship Structure

Assembly Alternatives

Distribution to separate decks



Compact stacking (wrap around) of VHF/UHF/Link16 communications, and C/RESM antennas



Use of multiple masts by separation of EPM lines

Integration in Ship Structure

Basic Requirements:

- Antennas must be able to be mounted around masts of various diameters (wrap-around)
- High decoupling in between antennas

Wish:

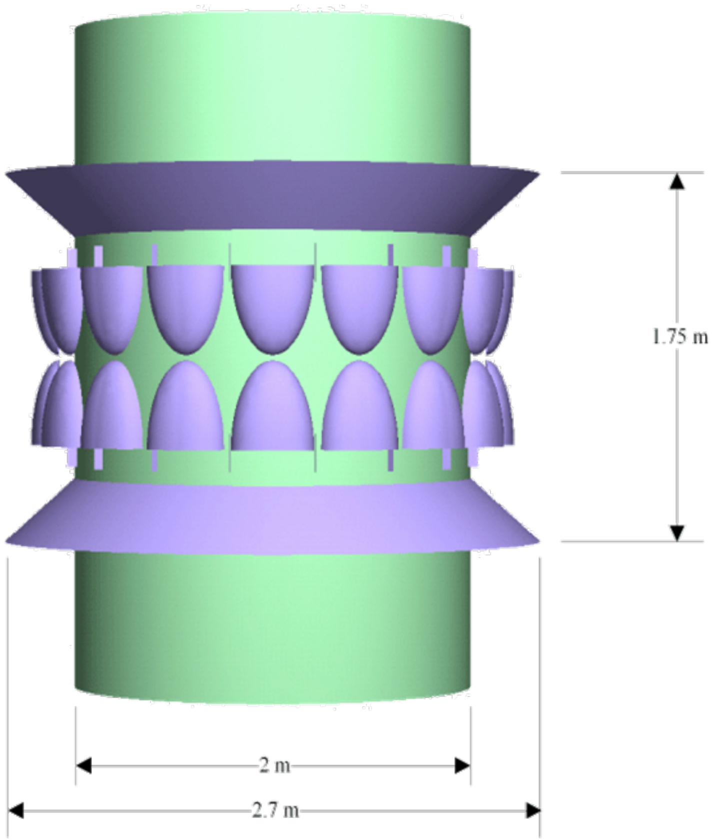
- Arbitrary distribution of antennas for using free areas

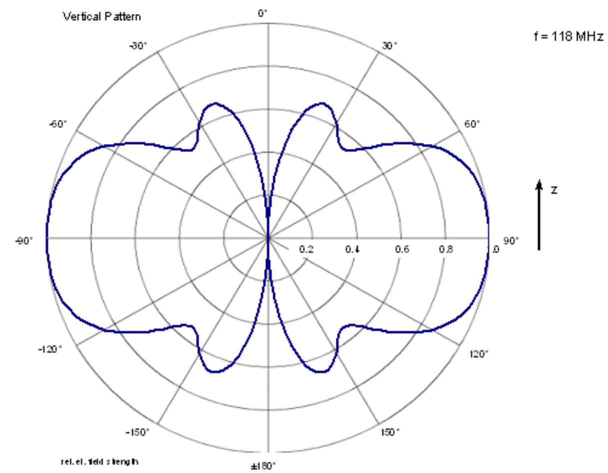
Investigated in line with a couple of studies for the German MOD

Integration in Ship Structure

Investigation of Various Mast Diameters up to 8 m

(Example of free inner diameter 2 m)



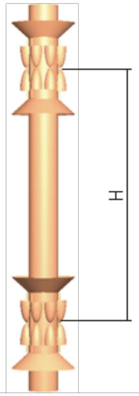


Frequency range	118 MHz to 453 MHz
Impedance	50 Ω
VSWR	≤ 2:1
Gain	≥ 2 dBi
Uncircularity	<± 1dB
Permissible input power	600 W AV (max.)
Polarization	vertical
Polarization decoupling	> 20 dB

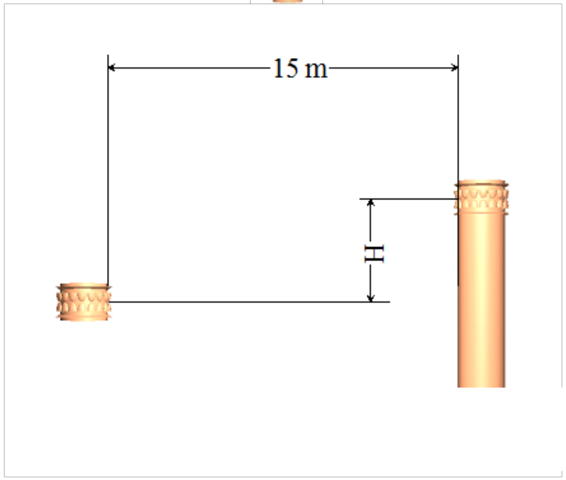
Integration in Ship Structure

Investigation of Simultaneous Use (Decoupling)

- One-Mast-Arrangement
  - Coupling of two identical antennas on the same mast with differing distances in between



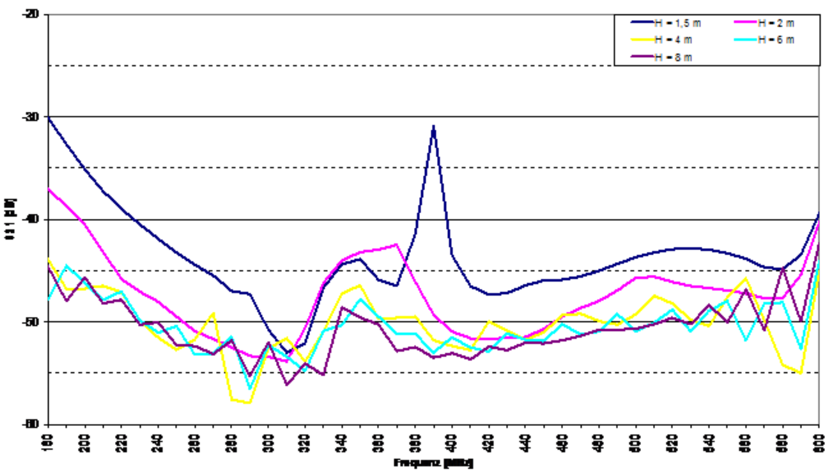
- Two-Mast-Arrangement
  - Coupling of two antennas with a distance of 15 m and differing height offset
  - Shadowing of second mast



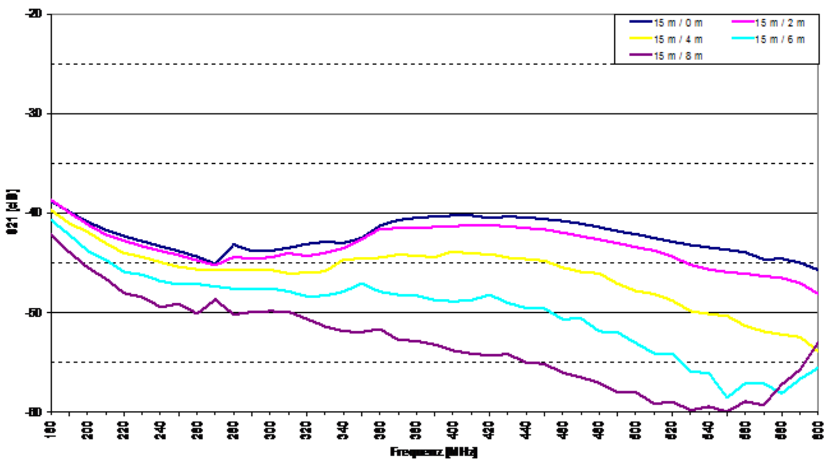
Integration in Ship Structure

Investigation of Decoupling

One-Mast-Arrangement
(mast diameter: 2 m)



Two-Mast-Arrangement
(mast diameter: 2 m)



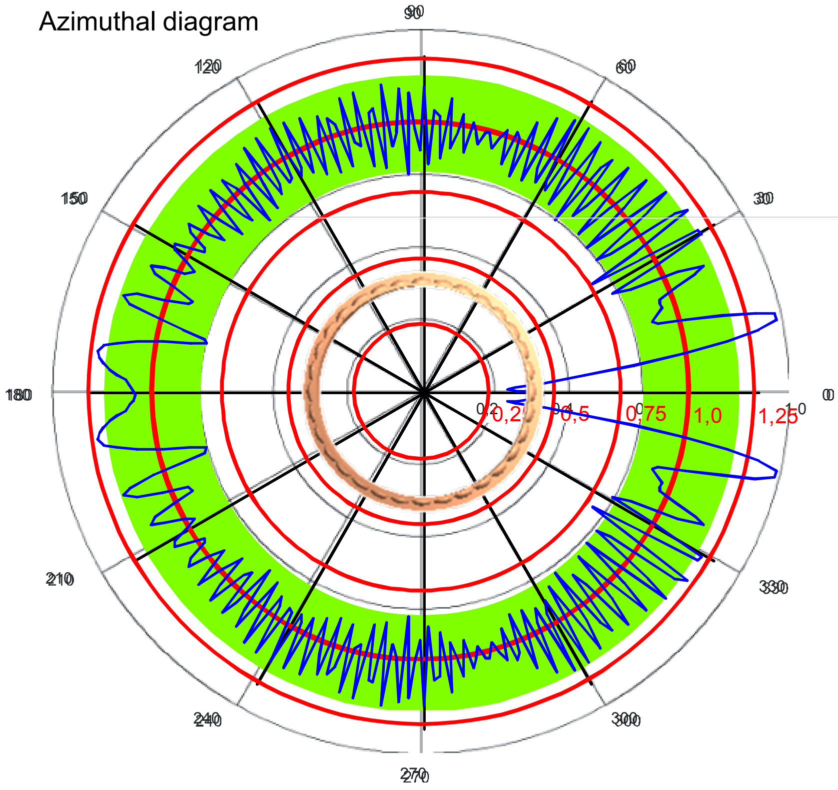
Remark:

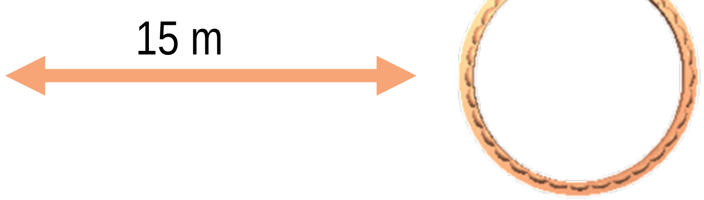
No additional attenuation measures

Integration in Ship Structure

Investigation of Shadowing

(Example: Two-Mast-Arrangement with 15 m Distance)





Radiation diagram for mast diameter 2 m and f = 400 MHz

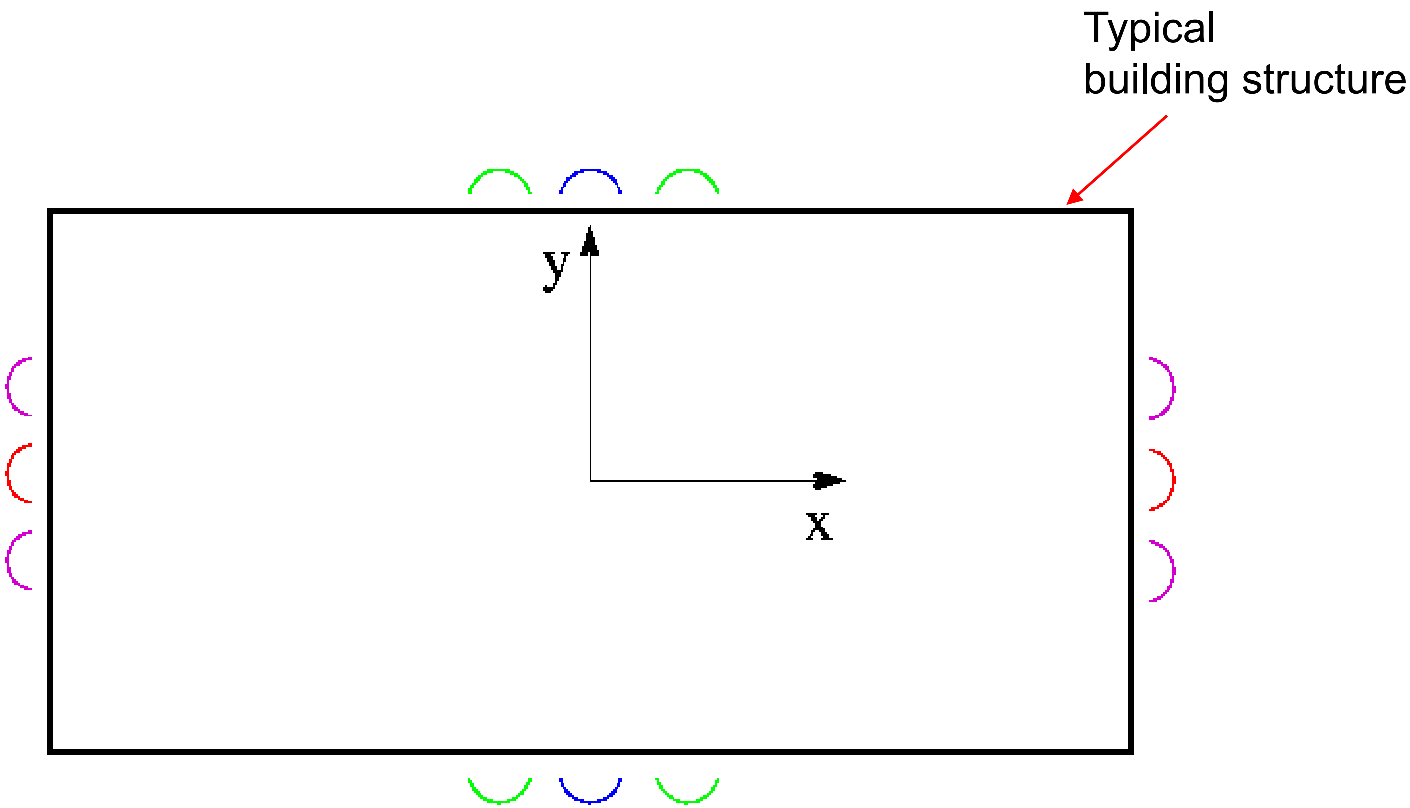
Integration in Ship Structure

Further on, the behavior of n dipoles laterally arranged around typical superstructures (e.g. deck/mast house) have been investigates in respect to following criteria

- achievable circularity
- required number of antenna elements
- Sustainment/quality of an optional direction finding functionality

Avoidance of Radiation Gaps

Example of a Principle Arrangement of Dipoles



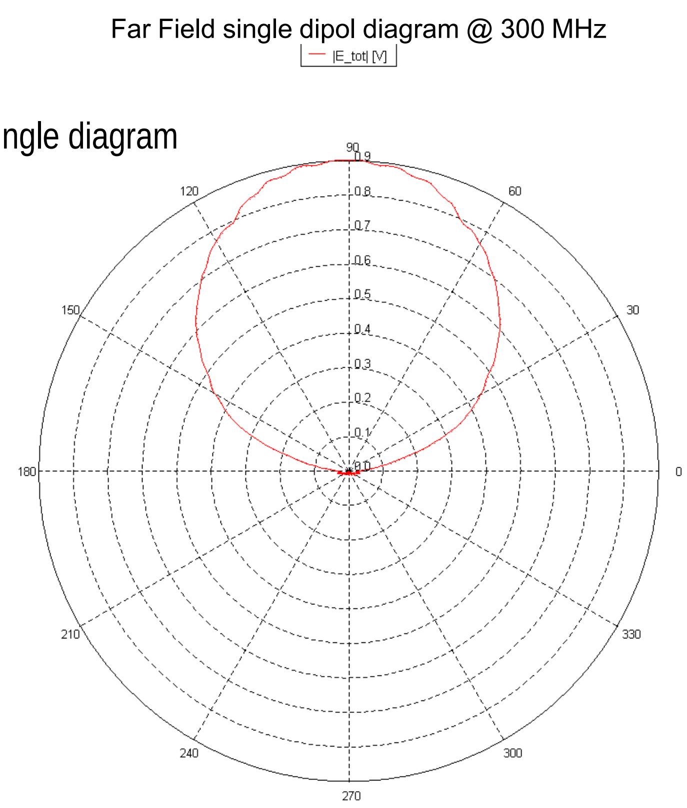
Dipoles of the same color are fed by identical amplitude and phase

Avoidance of Radiation Gaps

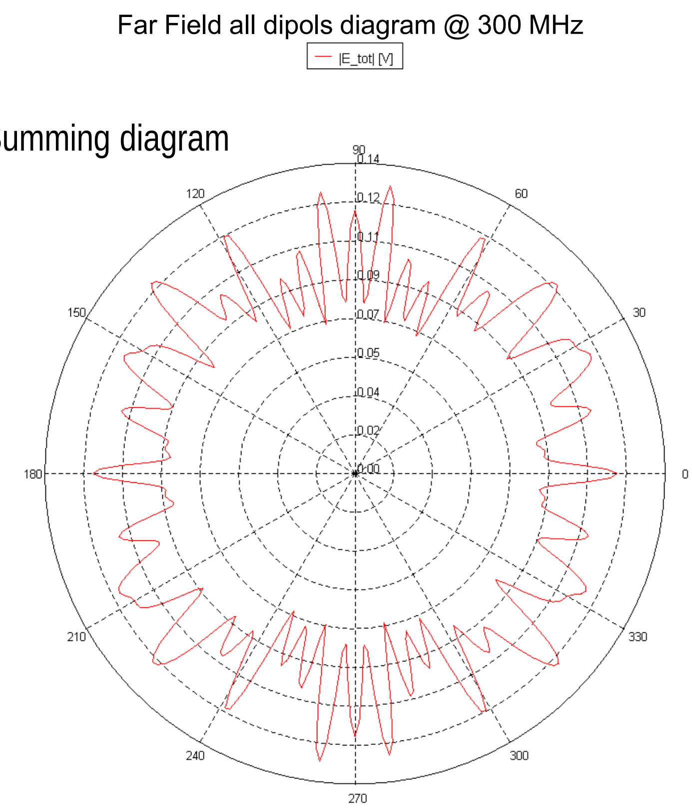
Distribution at Surfaces of Buildings and Ships

Achievable Circularity at 300 MHz

Single diagram



Summing diagram



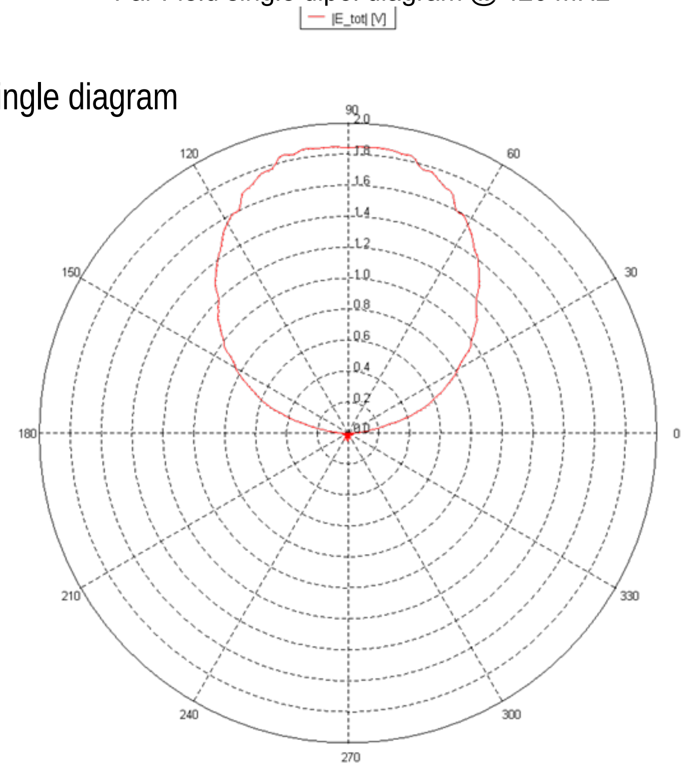
Avoidance of Radiation Gaps

Distribution at Surfaces of Buildings and Ships

Achievable Circularity at 420 MHz

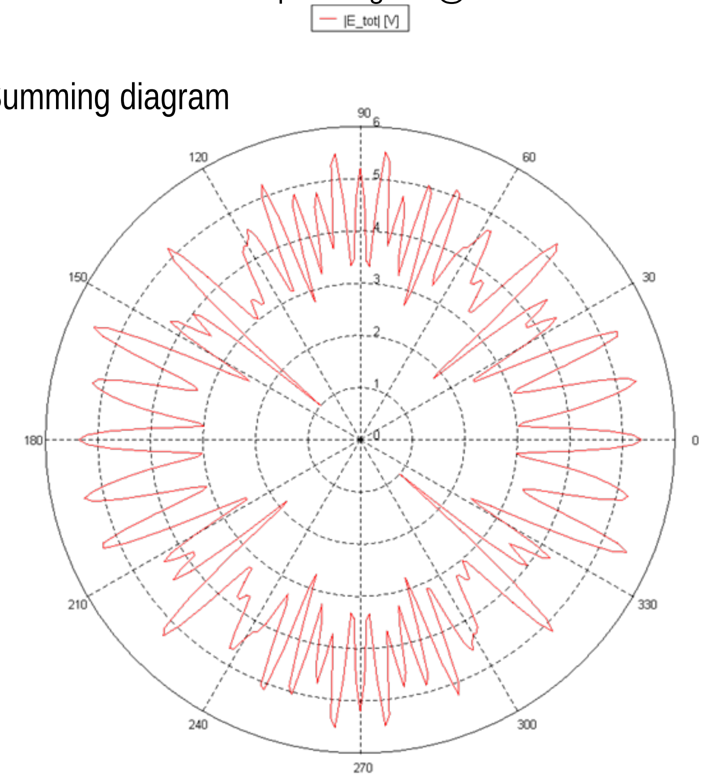
Far Field single dipol diagram @ 420 MHz

Single diagram



Far Field all dipols diagram @ 420 MHz

Summing diagram



Avoidance of Radiation Gaps

Summary

- Sufficient gain values towards azimuth direction can only be achieved at an appropriate and frequency depending dipole spacing towards each other (approx. half wave length)
- Real superstructures prohibit an homogenous distribution of the single radiators, which makes it even more difficult to generate acceptable omnidirectionality
- The phase differences required for single radiator feeding are quite high, additionally they have to be generated very accurately

With arbitrarily distributed antennas onboard ships, omnidirectional diagrams can just be achieved for <u>low frequencies</u> and only for <u>narrow bands</u>.

Reduction of RCS Value

The shaping of modern antennas or antenna systems follows the shipbuilding trend of „sloped areas“, because

- a broadband absorption of radar signals is merely possible and additionally for frequencies << 10 GHz extremely elaborate
- „frequency selective surfaces“ (FSS) of radomes behave like „normal“ superstructures (metal) beyond their RF penetrable frequency bands

Reduction of RCS Value

Typical Mechanical Design

(Example only: Link16 Antenna)

The RCS value will be reduced by approx. 20 dB when all surfaces are sloped by > 7°.

Necessity of a New Antenna Concept

Conclusion

The **I**ntegrated **A**ntenna **S**ystem features

- optimized omnidirectionality
- multiple use of antennas limited only by the coupling network
- reduced interference of the communication lines
- adaptable to (almost) every existing ship design
- installation of different antennas within close space in respect to proper radiation aspects

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RF Systems for Naval Applications

Part B

Coupling Networks for broadband and frequency agile Communication Systems

Example of Integrated Antennas for ships

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Content

- **Typical naval Radio - Requirements**
  - Number of Communication Lines
    - With EPM
    - Broadband Waveforms
    - Fix Frequency only
  - Design of Antenna configurations
    - Number of available mounting positions
    - Minimizing the number of mounting positions
    - Radiation Patterns
  - Operational Requirements
    - Range
    - Simultaneous Operation

- **Coupling Networks**
- **Example**

Typical Requirements for Ships

- Number of Comm Lines - up to 10 – 15 V/UHF Lines

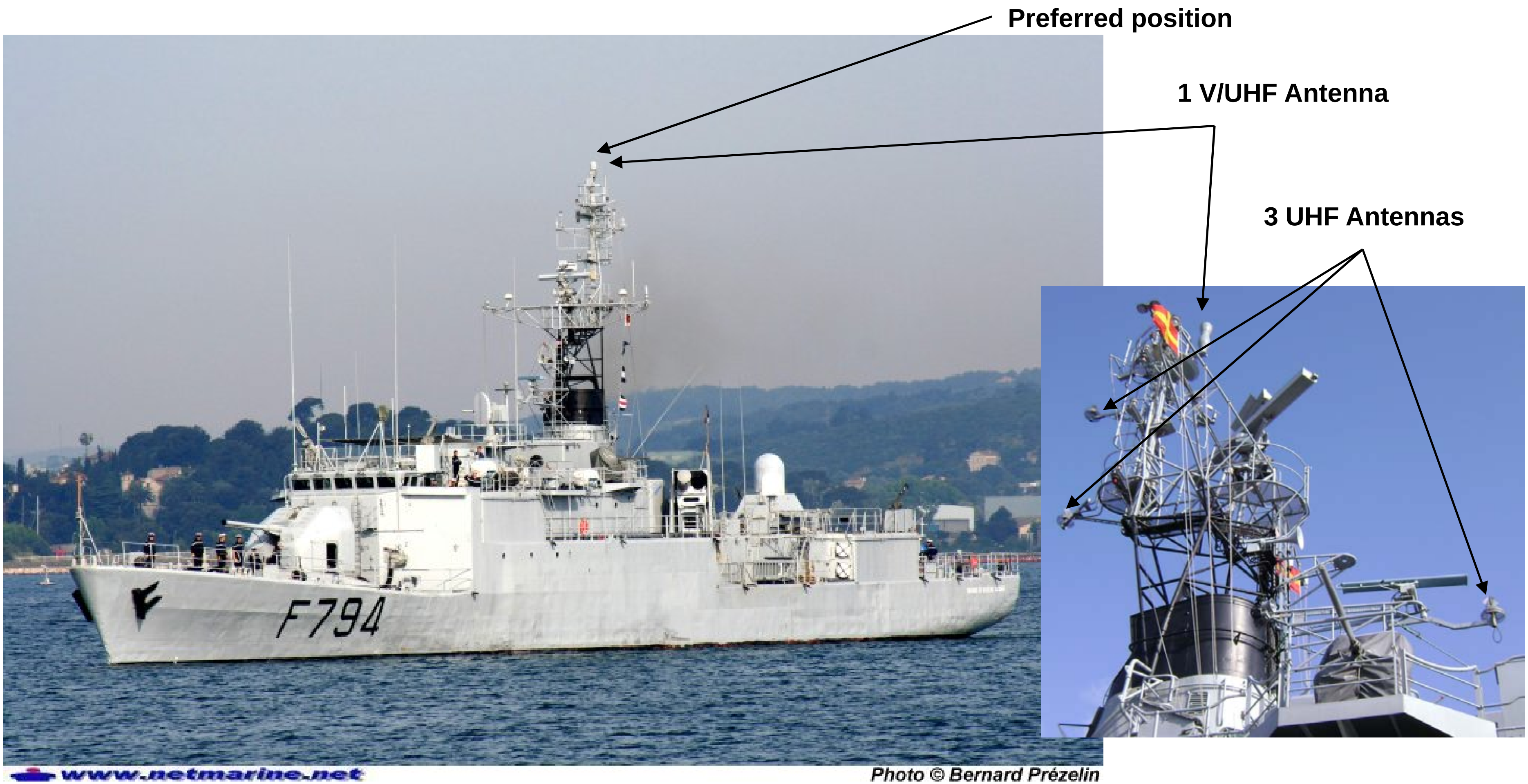
– EPM	- 30-50 %	Some lines can switch between modes
– Broad band Waveforms	- 25%	
– Fix Frequency	- 75%	

- Some Examples for Waveforms :

– EPM	- HQII, SATURN incl. Link 22 (NATO)
– Broadband Waveforms	- Subnet Relay, Bandwidth approx. 100kHz
– Fix Frequency	- Voice, Data (Link 11, Link 22 (FF part)…)

Typical Requirements for Ships

- Design of Antenna Configurations



Small Systems: **2 V/UHF Lines,** **2 Antennas**

Big Systems: **15 V/UHF Lines,** **5 - 10 Antennas**

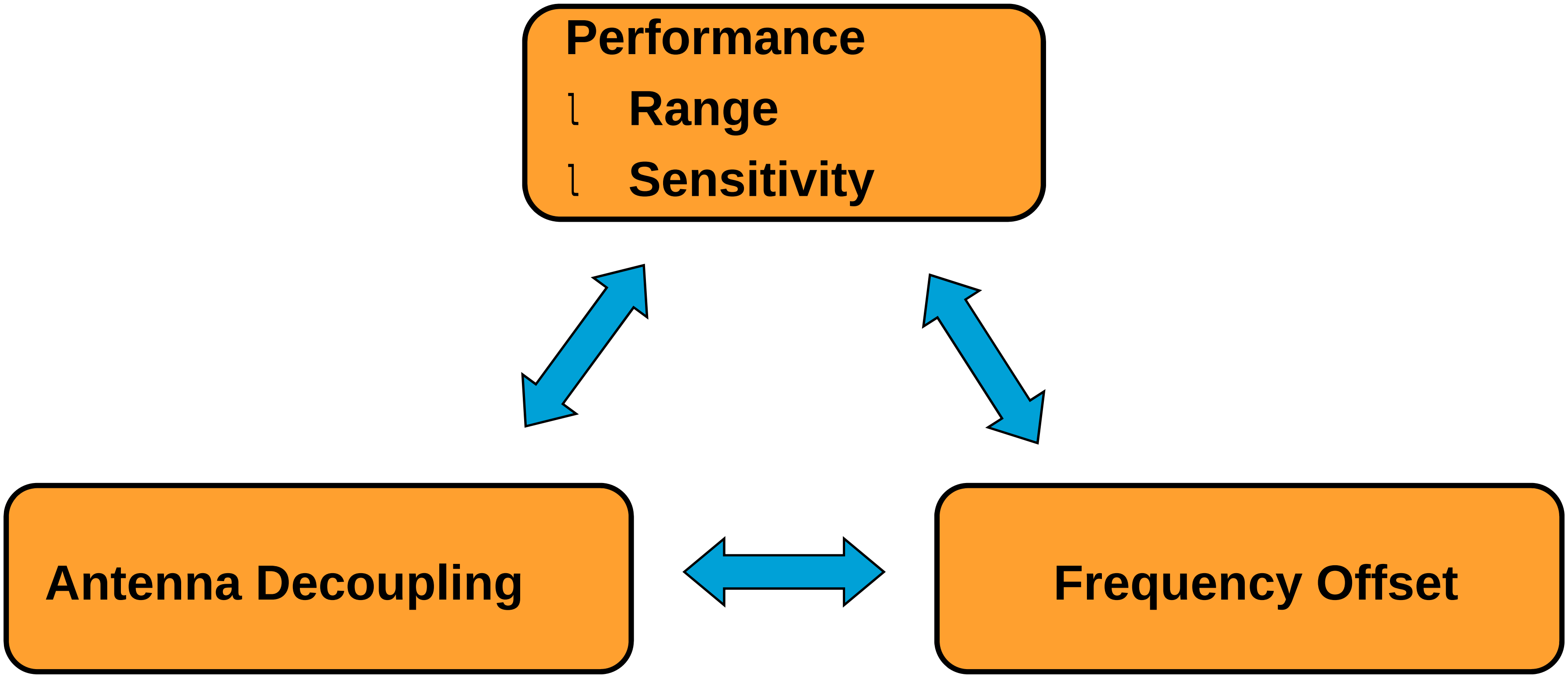
Typical Requirements for Ships

- **Simultaneous Operation means:**

→ All radios must be usable at the same time and independently to all others with full performance (= range)

- **This means:**
- **→ Transmission with one or more radios**
  - and simultaneously
- **→ Reception of weak radio signals with other radios**
  - without loosing the receiver sensitivity
  - with small antenna decoupling and small frequency offsets.
  - Typical Values are :
    - **Frequency Offsets 1-2%**
    - **Antenna Decoupling > 30dB**

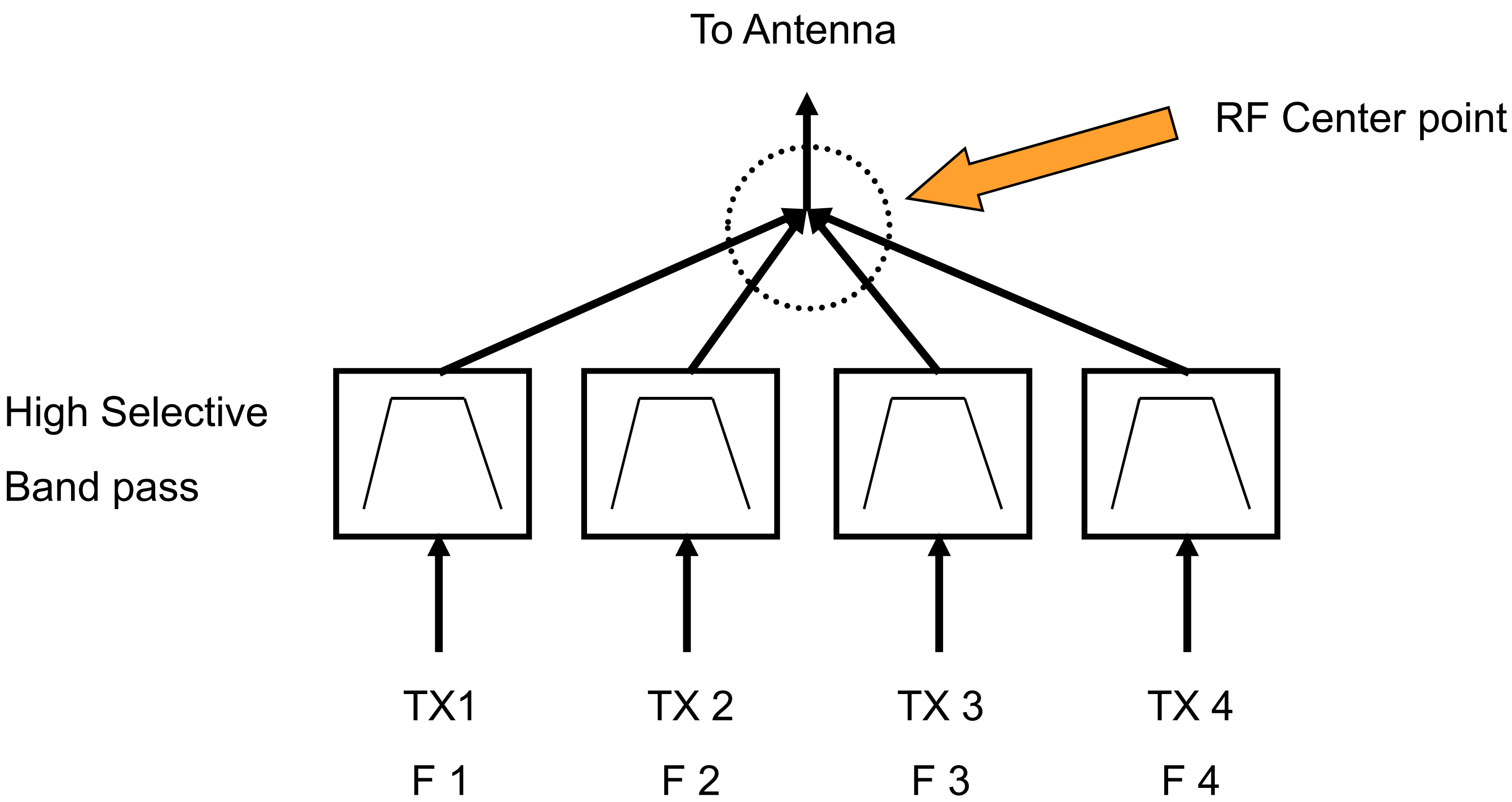
System Optimization



Coupling Networks

Example 1:

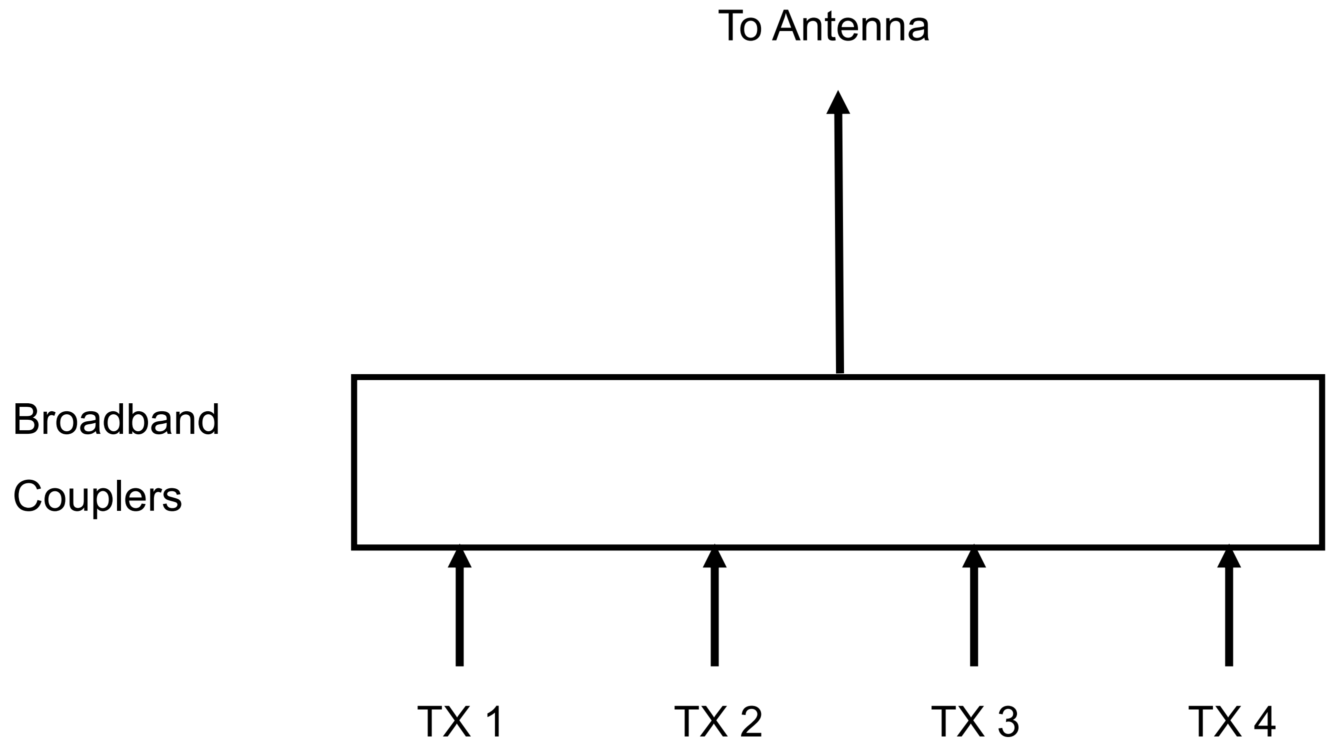
→ 4 Fix Frequency Transmitters to 1 Antenna



Coupling Networks

Example 2:

→ 4 EPM Transmitters to 1 antenna



Examples for complete systems

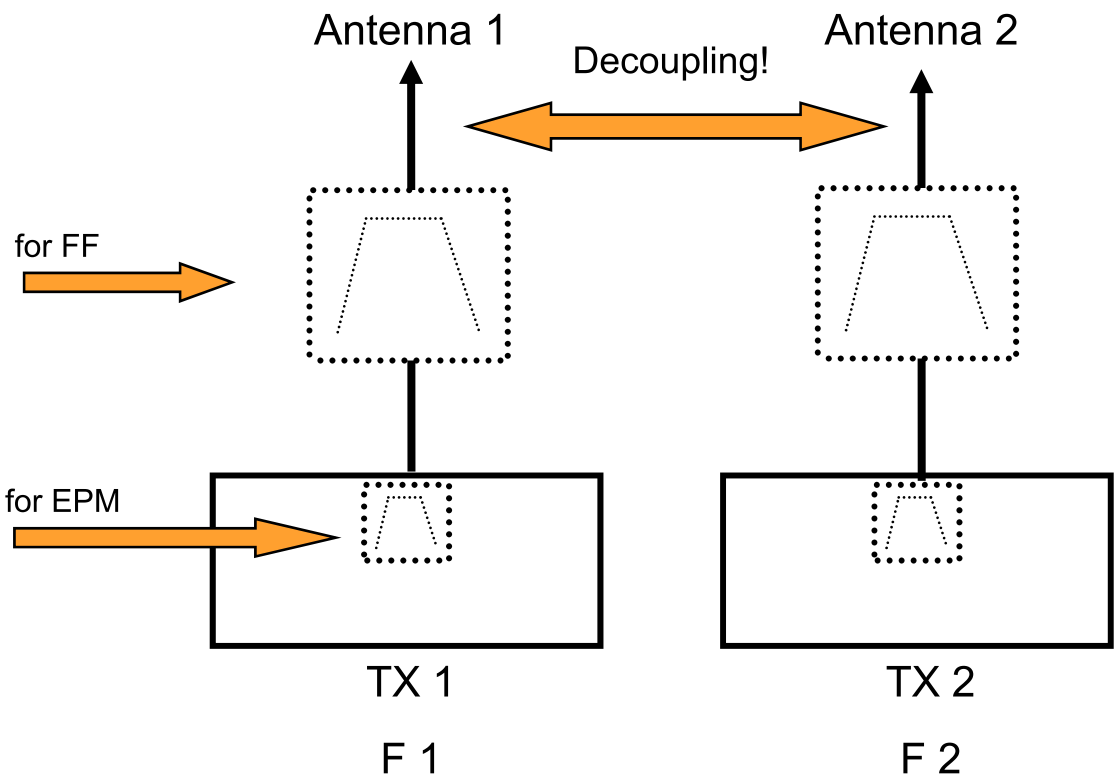
Example 1: **Small Installation: 2 Lines (TX only) on 2 Antennas**

Filter options

Depending on decoupling values

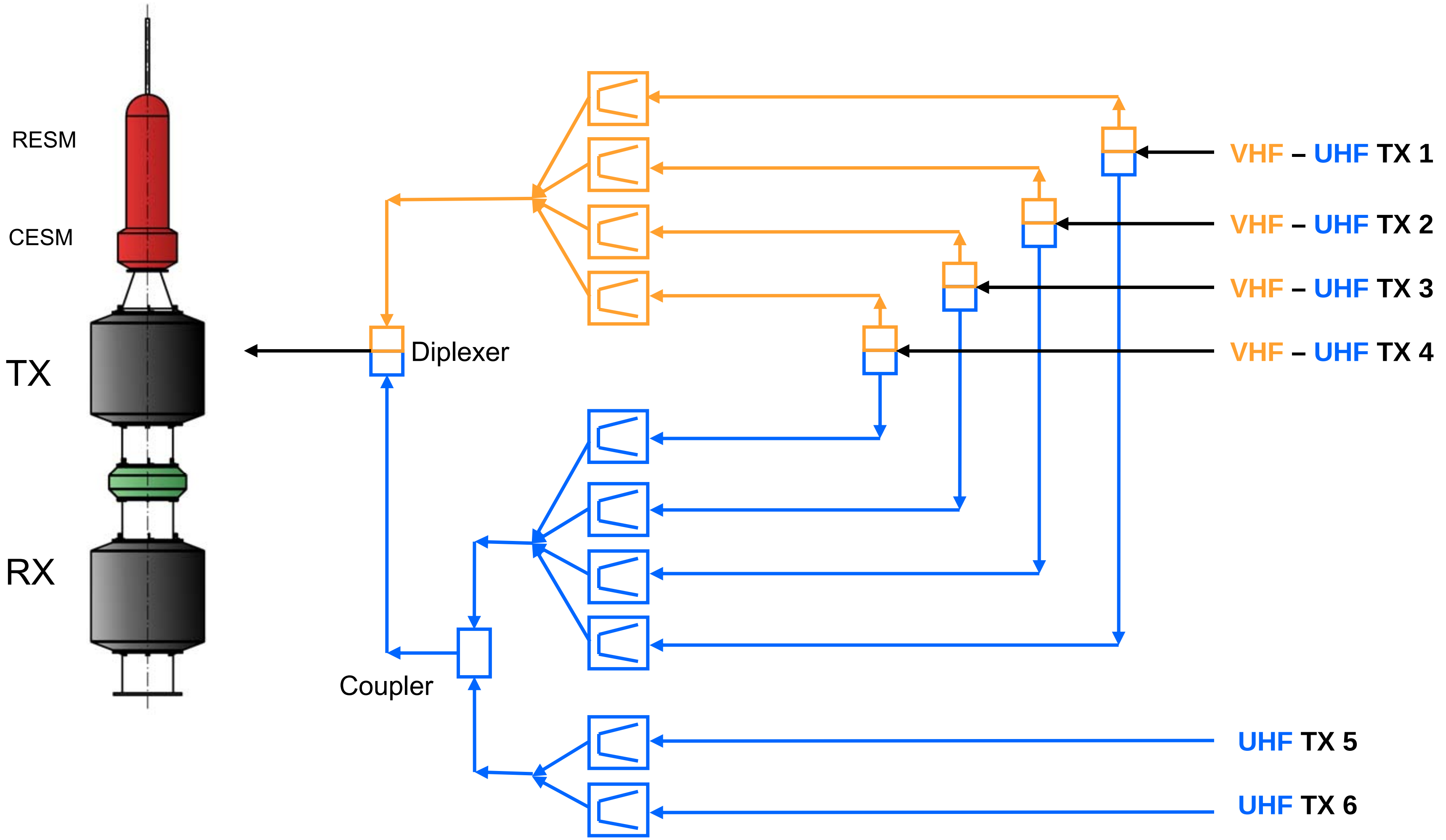
External
Co site Filters
- mechanical
- Fix Frequency

Internal
Co site Filters
- electronic
- agile



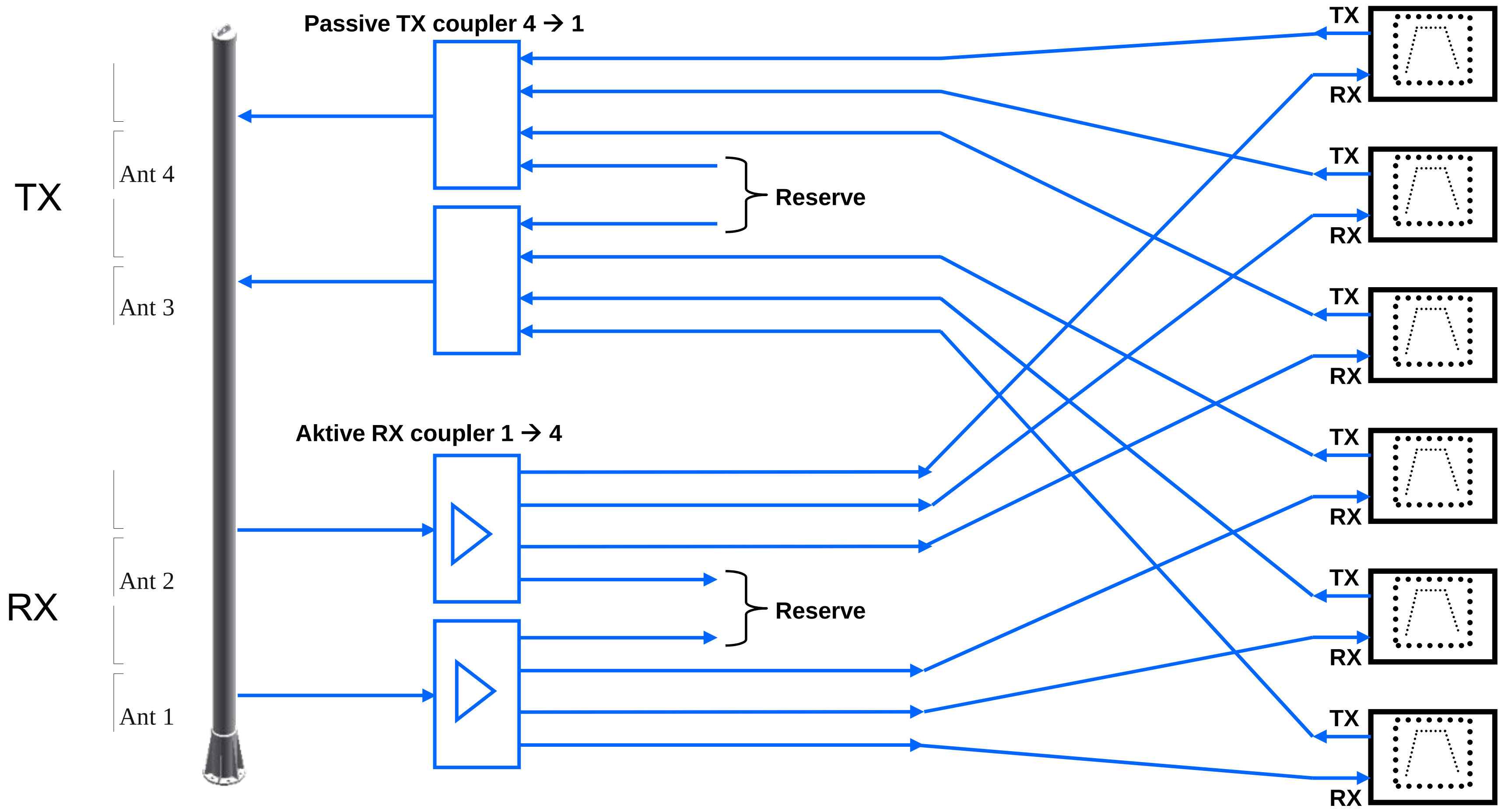
Examples for complete systems

Example 2: **4 V/UHF + 2 UHF Transmitters on 1 antenna → TX Fix Frequency only**



Examples for complete systems

Example 3: 6 transceivers to one stacked antenna system → EPM



6 x UHF EPM Radios with internal frequency agile Co site - Filter

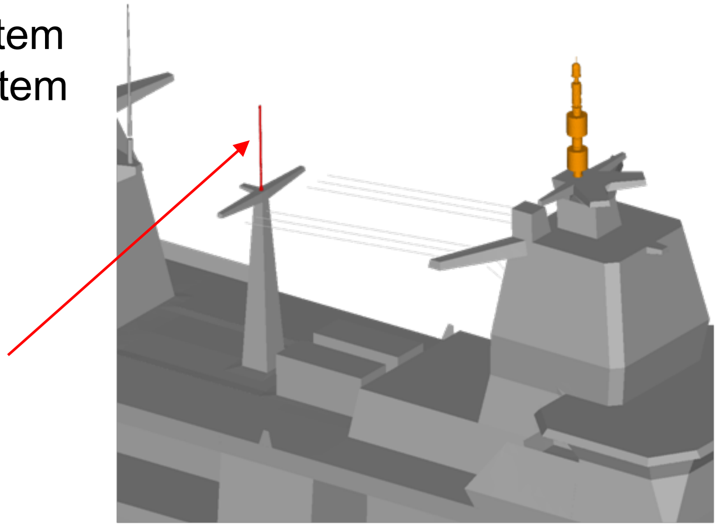
Integration in Ship Structure

Assembly Alternatives

<u>Example of IAS on Frigate :</u>

- 4 x VHF/UHF — Transmit/Receive lines
- 2 x UHF — Transmit/Receive lines
- 6 x UHF EMP — Transmit/Receive lines
- 1 x Link 16 — Transmit/Receive line
- Communication — CESM Antenna system
- Radar — RESM Antenna System

Compact stacking (wrap around) of VHF/UHF/Link16 communications, and C/RESM antennas



Use of multiple masts by separation of EPM lines

Thank you!