Evolution of VLF and LF Systems

How to Improve Legacy VLF/LF Communication Technology

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Agenda

Introduction

VLF / LF Belongs to Submarines

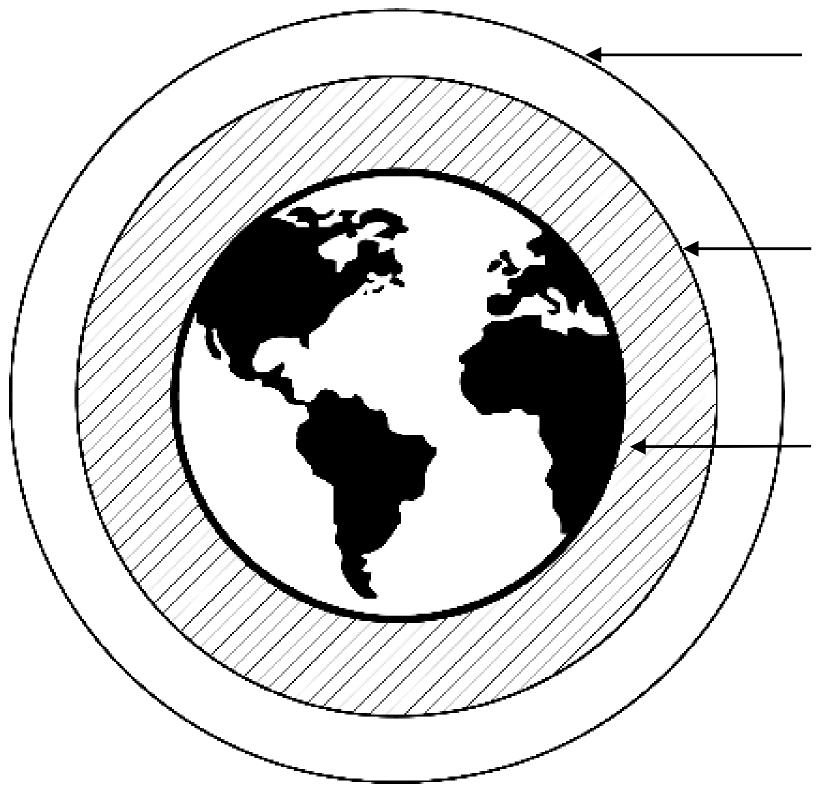
Submarines operate:

- Alone
  - Cut off from outer world
- All over the world
  - Including pole regions
- As covert as possible
  - Submerged
  - Short period of being surfaced

VLF / LF Wave Propagation

The Physical Environment Lead to Various Advantages for VLF/LF Communication

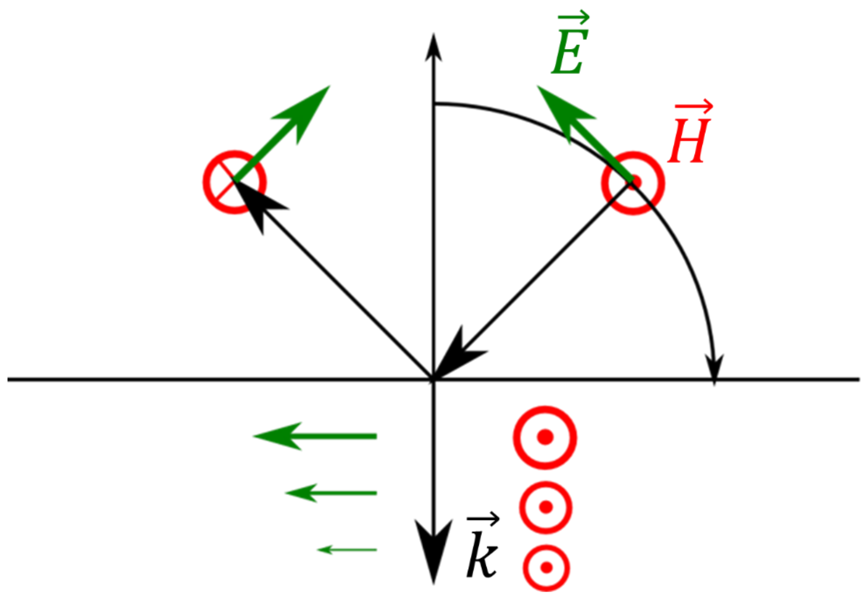
- Very low frequency
  - VLF: 3 – 30 kHz
  - LF: 30 – 300 kHz
- The earth as a cavity resonator



Cit. J. R. Johler, Propagation of the Low-Frequency Radio Signal, IRE 1961, P.405

VLF/ LF Advantages

- Stable energy level
- Robust communication
- Under water reception



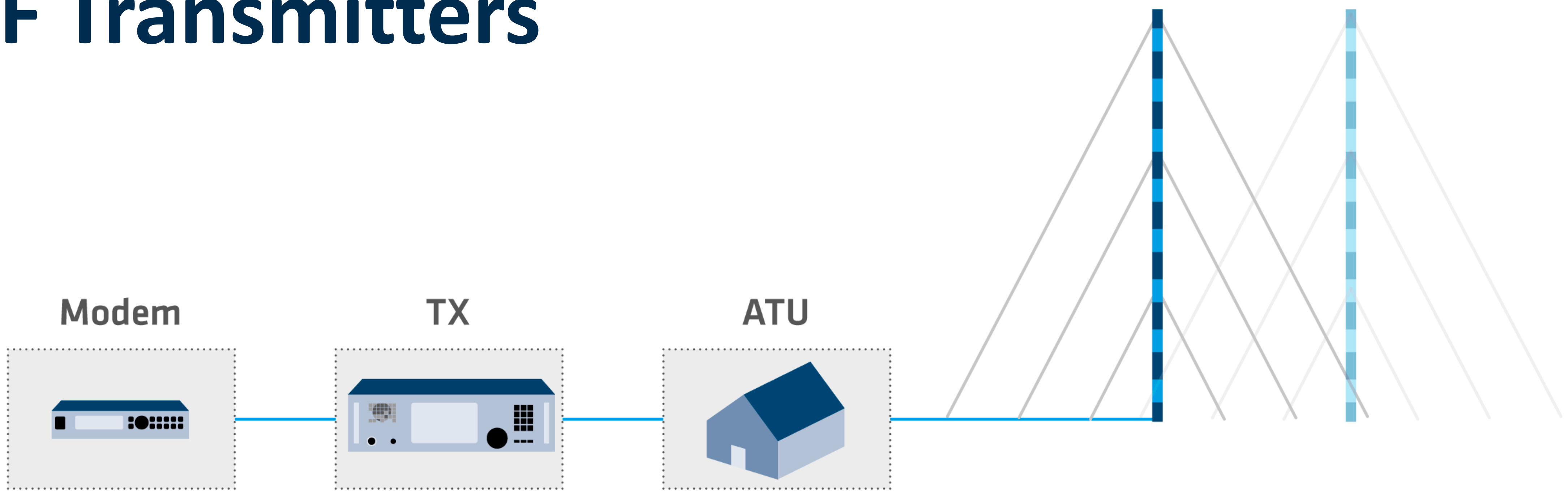
VLF / LF Disadvantages

- Low bandwidth
- Large antennas for VLF transmission
- On naval vessels reception only

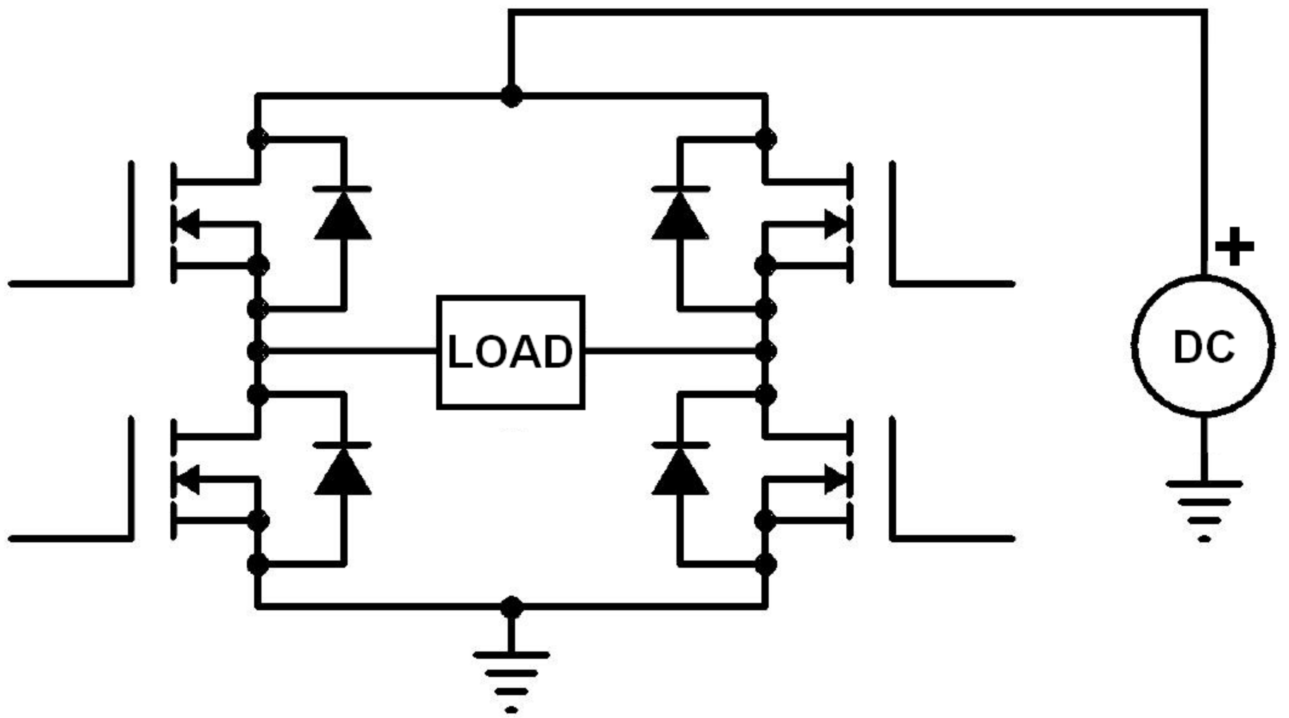
VLF / LF Transmission

Requirements for VLF/LF Transmitters

- Level of efficiency
  - Energy saving
  - Cooling
  - Infrastructure
- Reliability
  - Maintenance / Service
  - High MTBF
- Robustness



- Need for solid state amplifiers
  - Amplifier architecture with switched H-bridge technology
  - Extreme high level of efficiency
  - Low source resistance (<< 1 Ohms)



Characteristic of Current VLF/LF Antennas

- Radiation power: 100 kw – 1000 kW
- Wavelength: 10 km – 100 km

- Also large antennas are electrically short
- Electrical short antennas
  stand in contrast to high level of efficiency
- Limited Bandwidth of antenna

- Limitation in data rate
  - Bandwidth: 50 Hz to 120 Hz
  - 4-MSK Signal → 200 Bit/s

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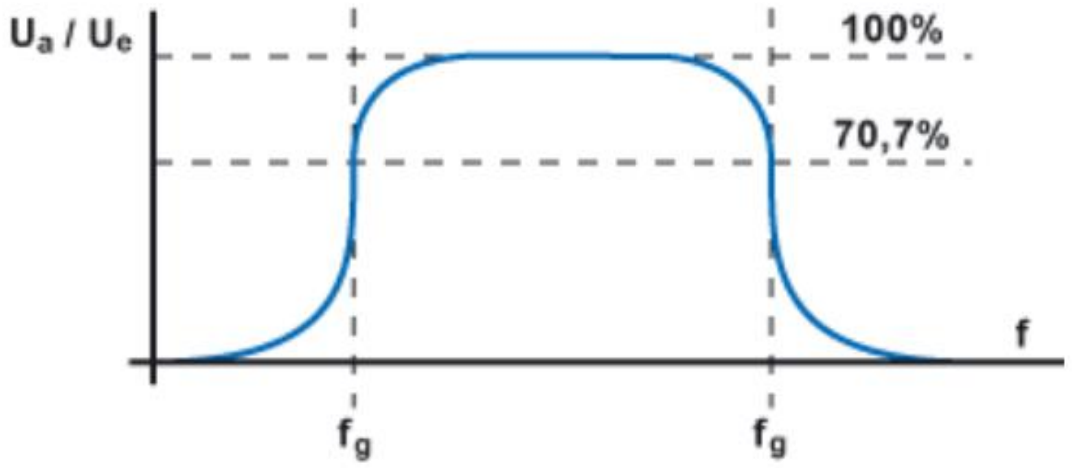
High Efficiency Transmitters on Current VLF/LF Antennas

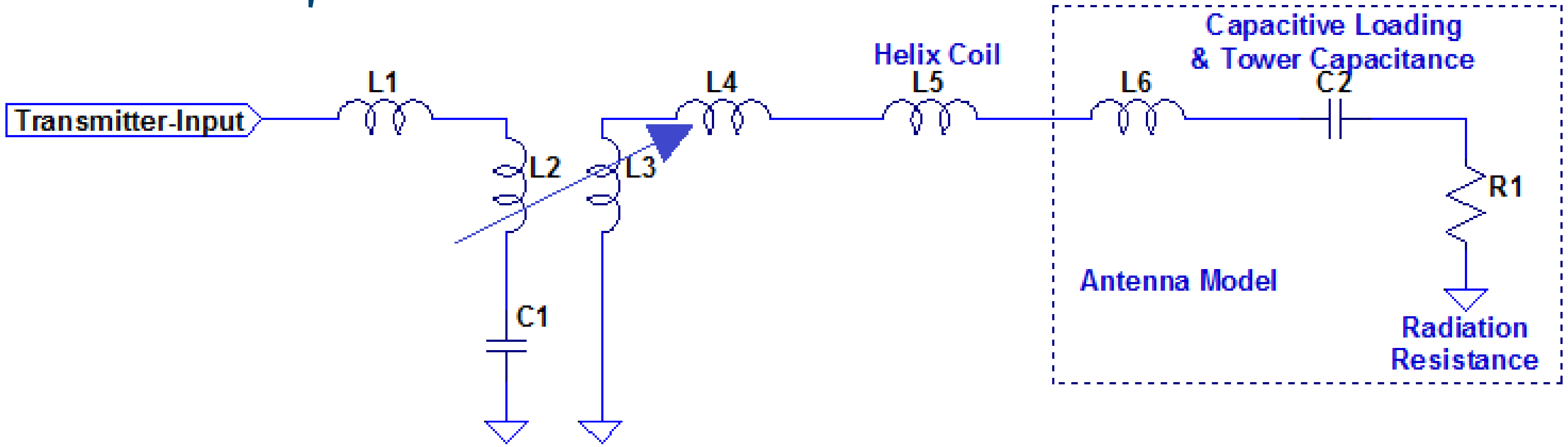
- Extreme impact of VLF Antenna characteristic on transmitter
  - Influence of antennas narrowband characteristic
  - Compared to classical 50 Ohms transmitters
- Extreme impact of narrowband characteristic
- Linear distortion
  - Distortion of transmit signal
  - Limitation in Bandwidth
  - Response of transmitted signal on the air is limited



Double Tuned Matching Networks

- Tuning out capacitive reactance from electrically short antennas.
- Transformation of the antenna impedance to a value suitable for the transmitter.
- Increase the usable bandwidth.
- Suppress harmonics and out of band emissions.

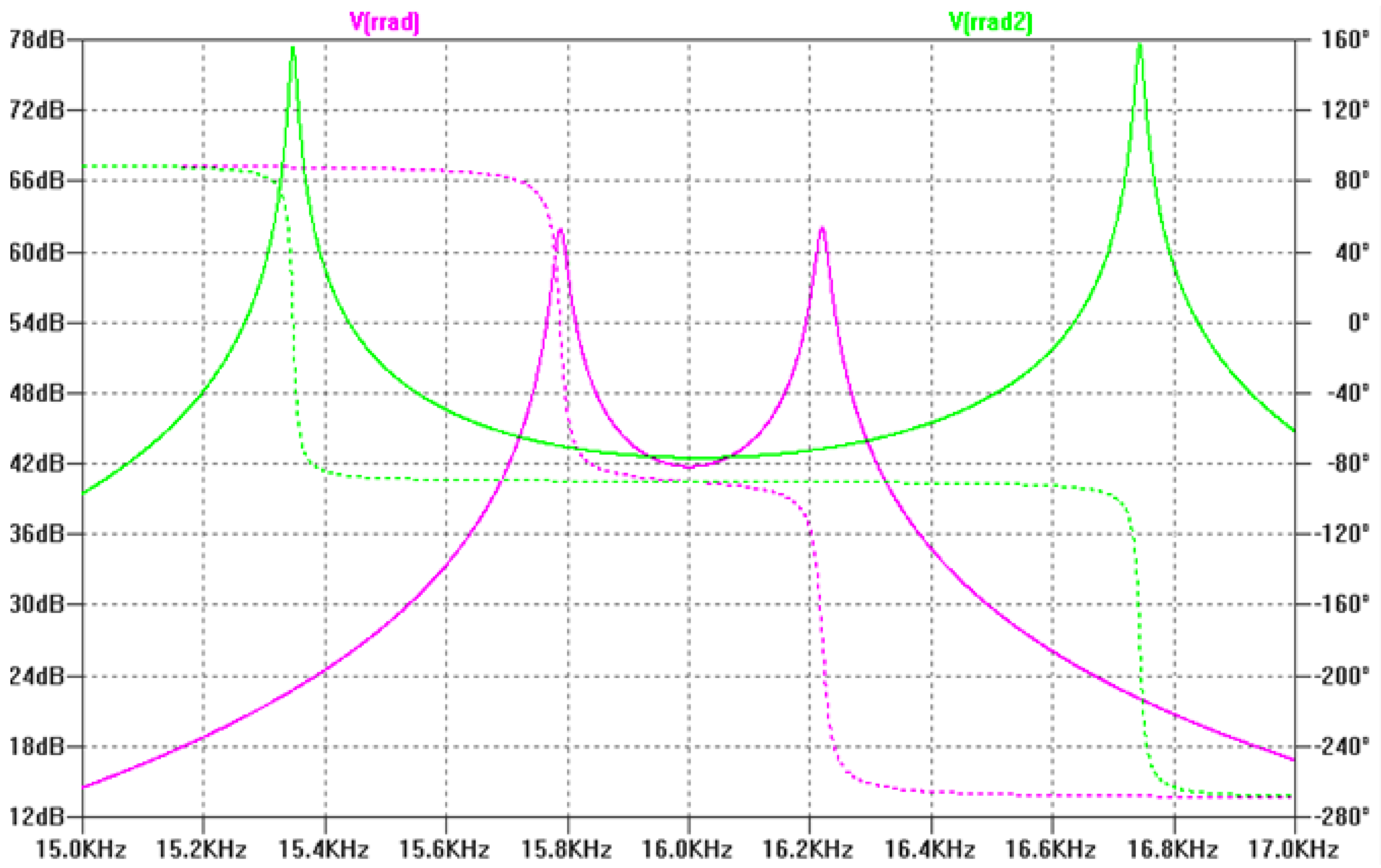
- Independent adjustment of coupling
- Increase in bandwidth



Cit. US patent 9,571,132 by Dave Hershberger, Continental Electronics

Linear Pre-Distortion

- Linear pre distortion
  - Digital equalizer → add inverse antenna system response to the signal
  - Equalization flattens both:
    - Amplitude response
    - Group delay
  - Better signal quality over a wider bandwidth
- Legacy matcher
  - bandwidth 308 Hz
- Wideband matcher
  - bandwidth 1110 Hz

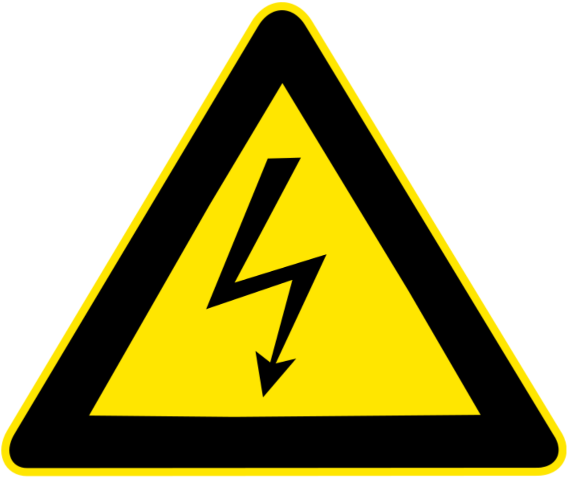


Cit. Dave Hershberger, IEEE APS/URSI 2017

Tradeoffs for Wider Bandwidth

- Transmitter must be sized appropriately
- More reactive power required
- Power supply does NOT increase in proportion to reactive power
- Transmitter efficiency remains high

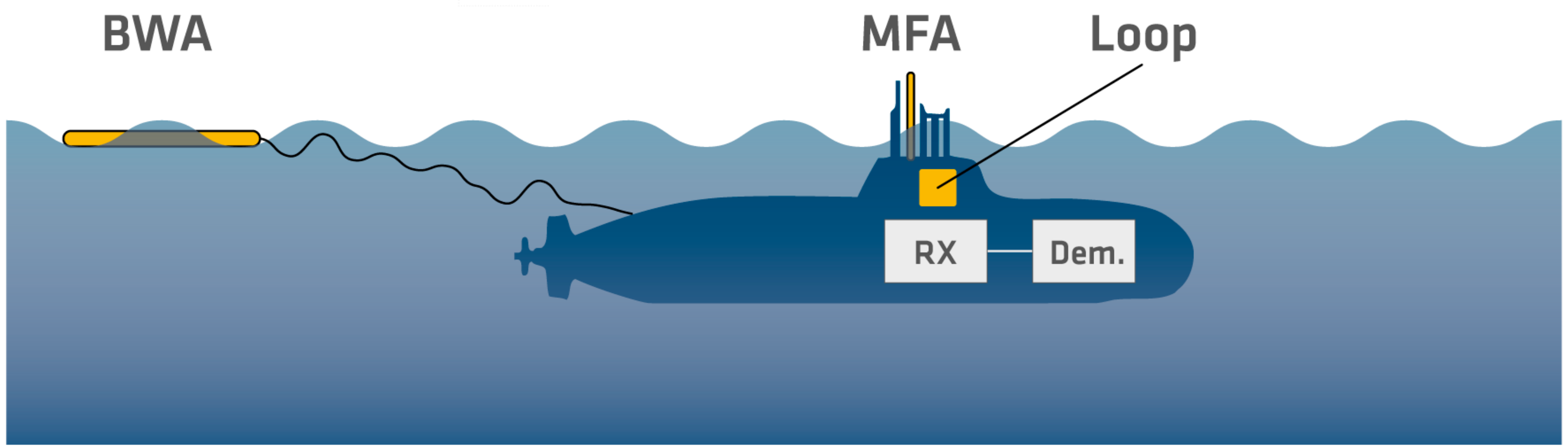
- Tuning components must support higher currents and voltages



VLF / LF Reception

Three Ways for VLF/LF Reception

- Different ways of VLF reception
  - Buoyant wire
  - Multifunctional antenna
  - Fin mounted loop antenna
- Electrically short antennas
- Antennas can not be matched to wavelength
- Mismatched Antennas have a wideband characteristic



- Requirements for Antenna:
  - High SNR despite extremely low field strength
- Requirements for Receiver:
  - Optimized channel filter and gain control

Easy implementation for VLF wideband reception in current systems

Conclusion

Operational Advantages Through VLF Wideband Technology

Combination of 3 technological approaches

- Solid state amplifiers
- Adaptive equalization
- New matching network topology

Data rate to be improved by factor 3 - 10

- Depending on
  - antenna system
  - infrastructure
  - high voltage robustness

Approx.:

- 600 Bit/s – 2 kBit/s

Legacy Data Rate 200 Bit/s

- 1h reception → 720 kBit

Enhanced Data Rate 800 Bit/s

- 1h reception → 2.88 MBit
- 15 min → 720 kBit

Contact

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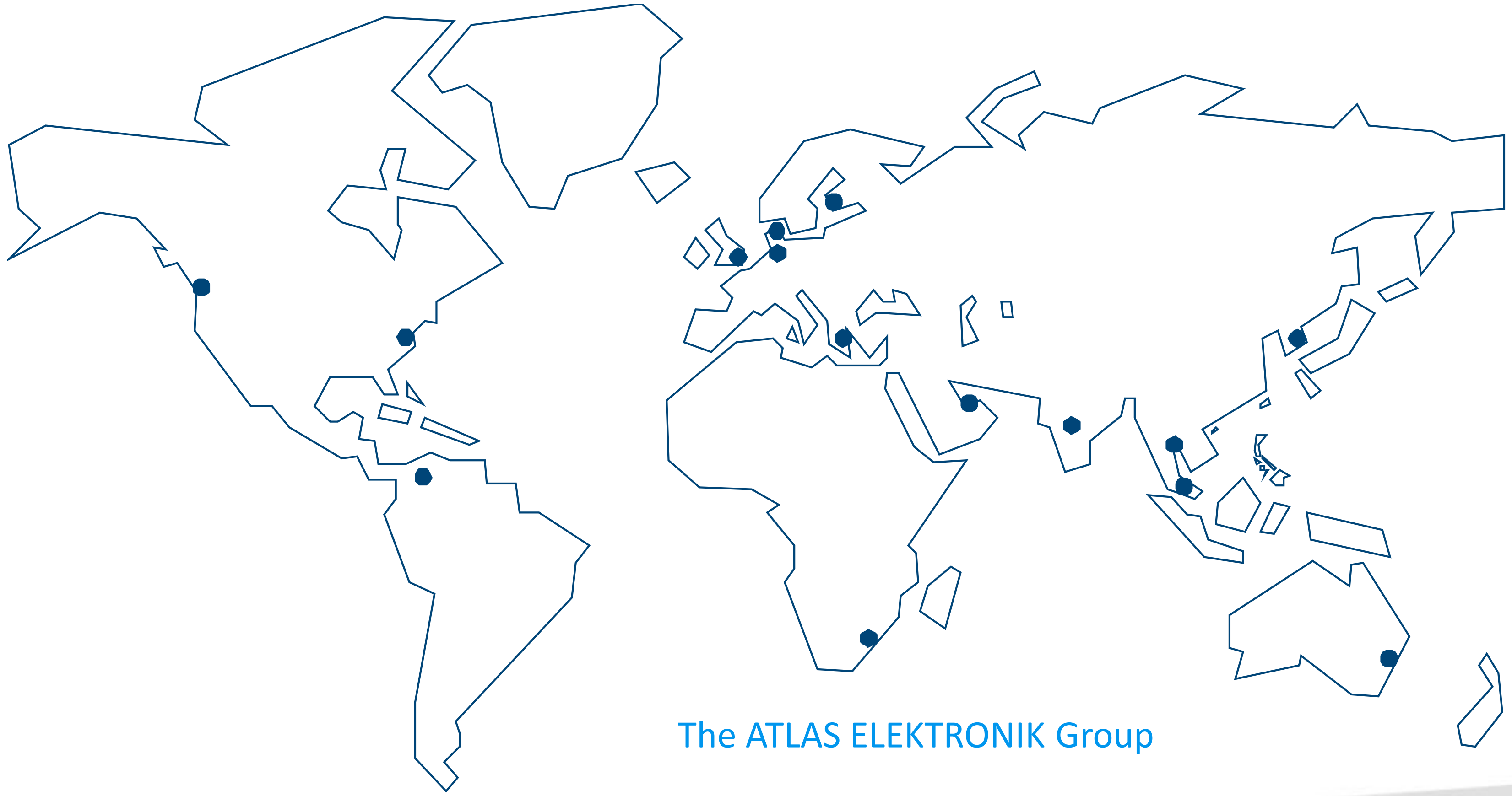

Thank you for your kind attention !

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