Powerline Communications in Sonar Sensor Networks

V. Burstein and W. Henkel

... a sound decision

JACOBS UNIVERSITY

ATLAS ELEKTRONIK
A joint company of ThyssenKrupp and Airbus DS

WSPLC2016: PLC in Sonar Sensor Networks

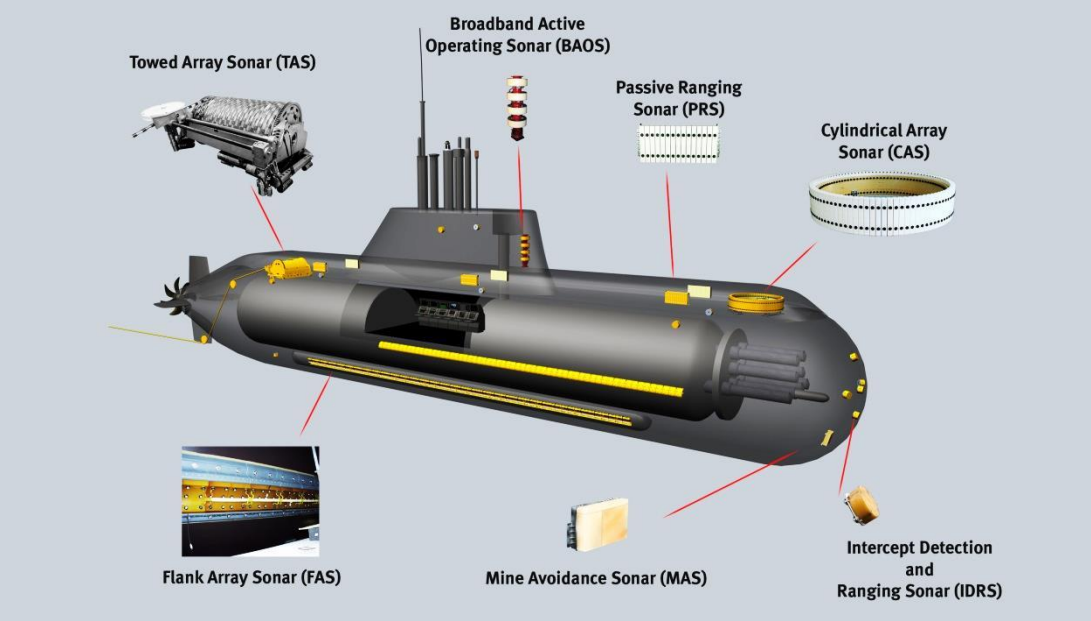
Presentation Overview

- Introduction
- DC-PLC for an Broadband Sensor Network
  - Channel
  - Physical Layer
  - TEQ
- MC-TP Bus: Design Prototype

WSPLC2016: PLC in Sonar Sensor Networks

Introduction

- Using sonar is a typical way to navigate and detect other vessels or obstacles under water
- Acoustic sensors or hydrophones are commonly used to build up the sensor array of a sonar system



- The amount of sensors and array dimensions grow constantly and an efficient method to aggregate and transmit the data ***and*** reduce the cabling is needed
- The sensors' DC power bus can be used for the data transmission – a "typical" PLC application

WSPLC2016: PLC in Sonar Sensor Networks

Presentation Overview

- Introduction
- DC-PLC for a Broadband Sensor Network
  - Channel
  - Physical Layer
  - TEQ
- MC-TP Bus: Design Prototype

WSPLC2016: PLC in Sonar Sensor Networks

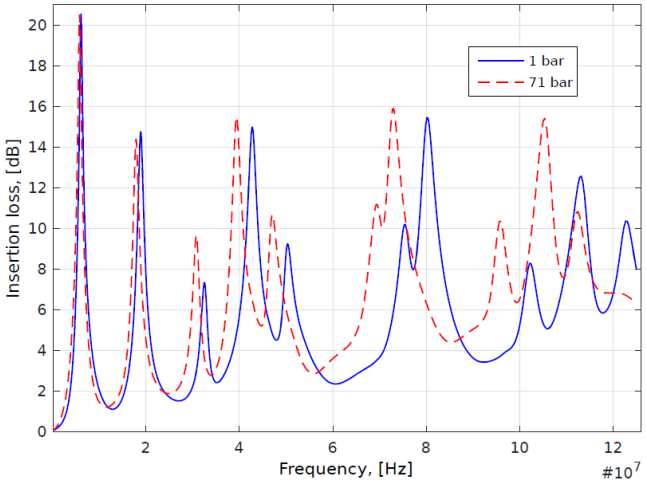
DC-PLC for a Broadband Sensor Network: Channel

- Similar to other PLC system topologies, a linear bus of DC power can be utilized
- The underwater cabling can be optimized for both power *and* data transmission:
  - Twisted pair for differential signaling
  - Increased wire diameters for power (e.g. AWG20)
- No electromagnetic emissions due to the natural shield – wide bandwidth is available

- Noise is mostly due to DC/DC converters and variable power consumption profile

- The channel of a linear bus is frequency selective due to multi-path – but quite stable

- The harsh underwater environment introduces some fading due to changing pressure/temperature



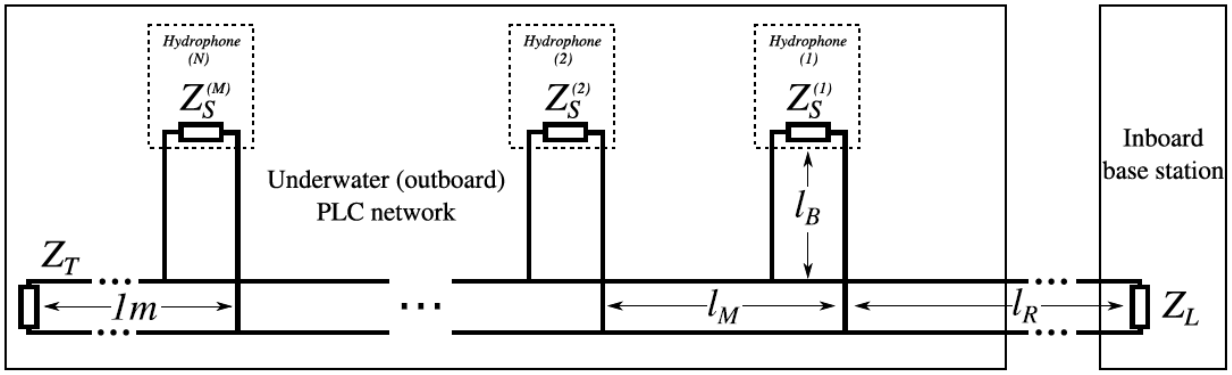
ATLAS ELEKTRONIK
A joint company of ThyssenKrupp and Airbus DS

WSPLC2016: PLC in Sonar Sensor Networks

DC-PLC for a Broadband Sensor Network: Channel Sharing

- Full duplex transmission is required for fast feedback – asymmetric FDD is preferred:
  - Low bitrate and low latency downstream ***broadcast*** channel (e.g. up to 1 MHz)
  - High bitrate upstream ***multi-access*** channel (1 MHz-100 MHz)

- The sharing in the upstream channel is TDMA:
  - Lower bus load due to different active/passive node impedances
  - Straightforward and relatively low complexity protocol implementation



WSPLC2016: PLC in Sonar Sensor Networks

DC-PLC for a Broadband Sensor Network: Physical Layer

- Bandwidth is not limited by interference, but:
  - Higher attenuation at higher frequencies
  - Pressure influence at higher frequencies is more pronounced
  - Cabling and analog hardware cost

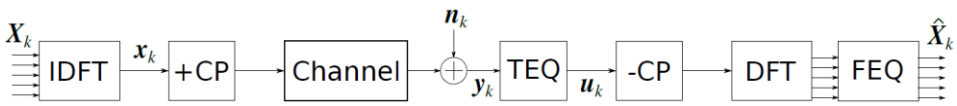
- An obvious choice of modulation is the baseband DMT/OFDM:
  - Very effective on a frequency-selective channel of the multi-path linear bus
  - Low complexity well-known implementation (FFT)
  - Flexible and scalable, depending on channel conditions and bus configuration

- Bit- and energy loading:
  - The channel is rather stable, pressure dependent fading is slow: bit-swapping
  - Energy consumption is of concern: less energy on better channels

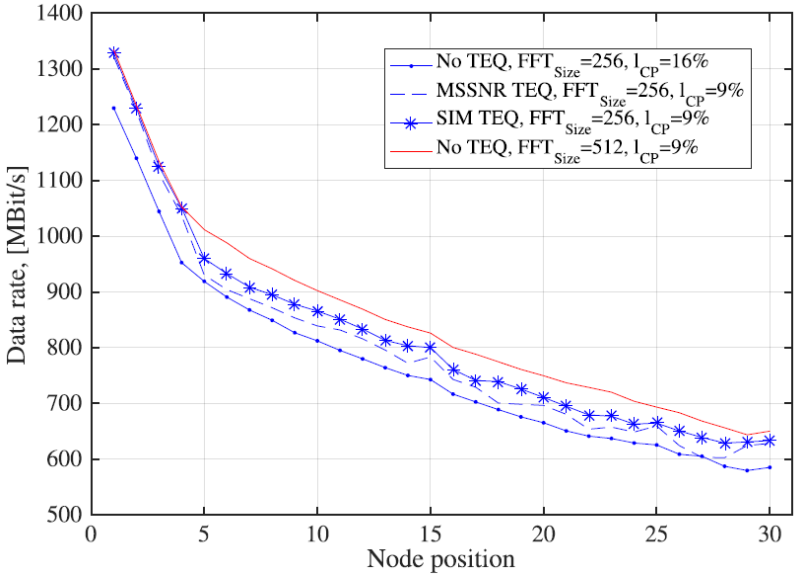
WSPLC2016: PLC in Sonar Sensor Networks

DC-PLC for a Broadband Sensor Network: Cyclic Prefix and TEQ

- Choosing cyclic prefix length equal to the length of impulse response zeroes the ISI/ICI
- The effective data rate of sensor (node) i is then $R_i = \frac{2N + \mathrm{CP}_{\mathrm{Size}}}{f_S} \sum_{j=1}^{N} b_j$, with N carriers
- An optimum cyclic prefix would be $\hat{\mathrm{CP}}_{\mathrm{Size}}^{\mathrm{opt}} = \arg \max_{\hat{\mathrm{CP}}_{\mathrm{Size}}} \sum_{i=1}^{M} R_i$, which tolerates some ISI/ICI
- Time-domain equalization helps to reduce the cyclic prefix or ISI/ICI by shortening the impulse response



- A rate-optimizing TEQ maximizes the data rate and can be used to reduce the hardware cost



WSPLC2016: PLC in Sonar Sensor Networks

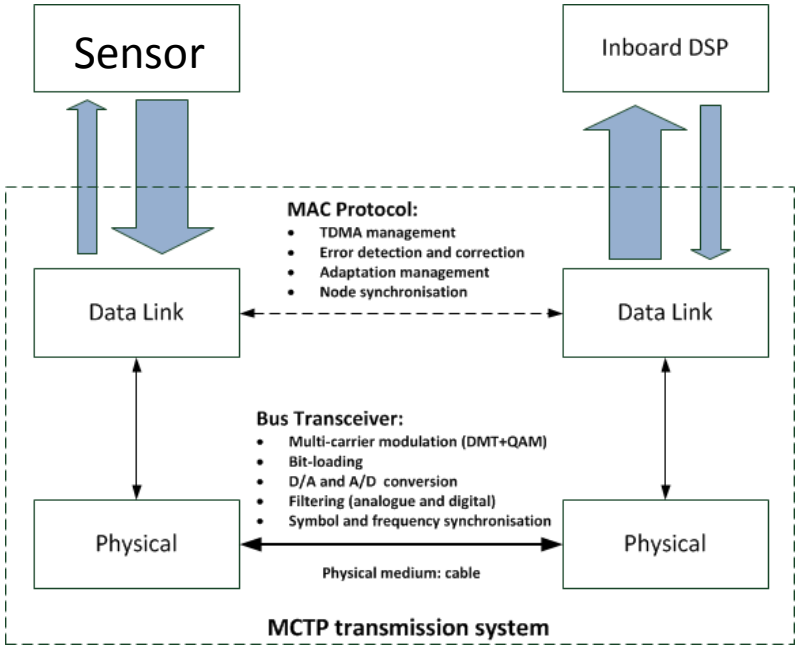
Presentation Overview

- Introduction
- DC-PLC for a Broadband Sensor Network
  - Channel
  - Physical Layer
  - TEQ
- MC-TP Bus: Design Prototype

WSPLC2016: PLC in Sonar Sensor Networks

MC-TP Bus: A DC-PLC Transmission System

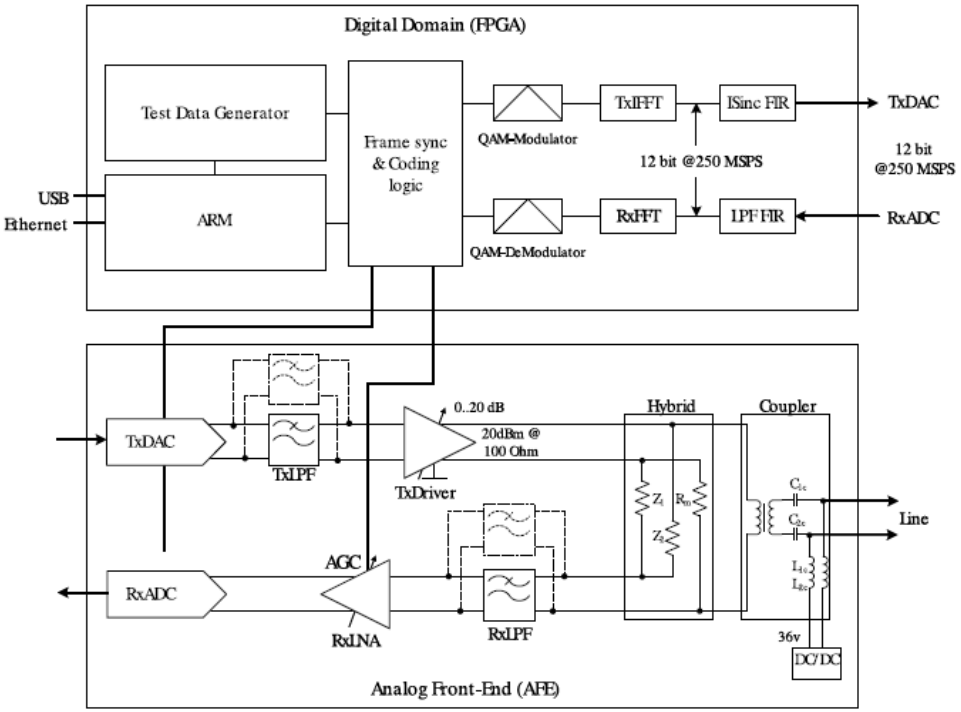
- (M)ulti-(C)arrier (T)wisted-(Pair) Bus with a target bandwidth of 100 MHz
- A minimum of 300 Mb/s upstream per node is guaranteed over a single twisted-pair:
  - Up to 100 m main cable length, 1 m branch length, at any pressure
  - Up to 5 matched connectors
  - Up to 64 nodes on a single bus
- DC power combined: 128 W @ 48 V
- Node synchronization accuracy ~ 1 µS
- Galvanic isolation of the transceiver

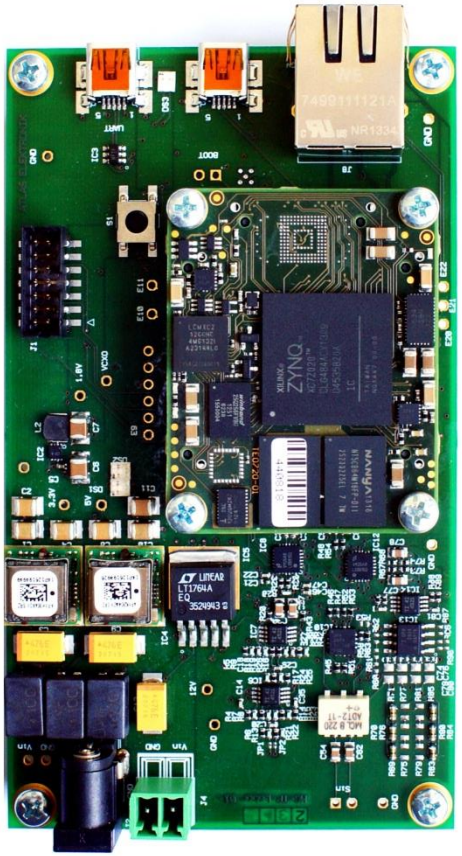


WSPLC2016: PLC in Sonar Sensor Networks

MC-TP Bus: Modem Design

- No integrated solution yet – discrete analog part, digital part on an FPGA
- High-speed 12 bit ADC/DAC @ 250 MHz sampling rate
- Passive reconstruction and anti-aliasing filters
- Transformer-based AC-coupling





ATLAS ELEKTRONIK
A joint company of ThyssenKrupp and Airbus DS

Contact

ATLAS ELEKTRONIK GmbH
Sebaldsbruecker Heerstrasse 235
28309 Bremen | Germany
Phone: +49 421 457-02
Telefax: +49 421 457-3699

www.atlas-elektronik.com

... a sound decision

ATLAS ELEKTRONIK
A joint company of ThyssenKrupp and Airbus DS