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# Single-chip mmW Radar for Marine and Industrial Applications

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## Motivation

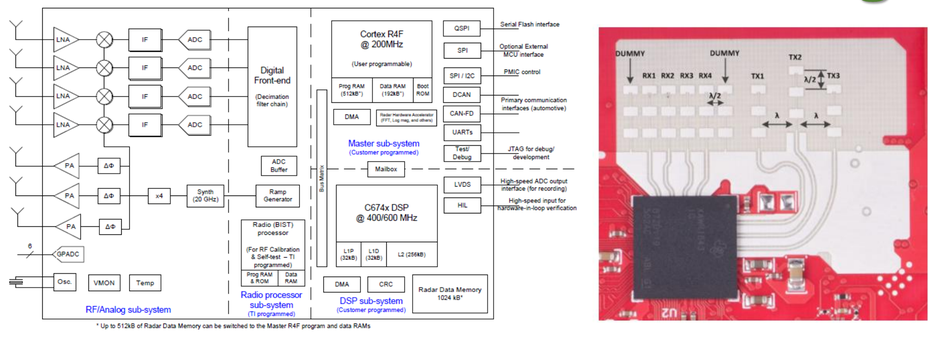
Recent maritime accidents have been red flag for maritime community. Possibility of increasing safety at sea and saving lives using novel technology of 76-81 GHz radar on the chip has been presented. Measurable step change in boosting navigation safety has been witnessed by author during testing of first solid state radar on cruise vessel in 2017. M/S Costa Concordia evacuation chaos in 2012 call for lost person and life signs onboard detection system, M/S Viking Sky blackout and lost of propulsion near cost of Norway in 2019 call for precise engine sump lvl monitoring, M/S Brilliance of The Seas extreme/parametric roll in 2010 and numerous ships and containers lost at sea, call for oscillatory and parametric roll prediction and alert system. Medium/short range TI AWR1843 76-81 GHz SoC radar has been evaluated onboard cruise vessel for concept purpose.

## Radar design

AWR 1843 is integrated single-chip FMCW radar sensor for 76-81 GHz band with 3 parallel Tx chains, each with independent phase and amplitude control and 4 parallel Rx channels with complex baseband architecture. 4Rx/3Tx allows 2D and 3D objects detection.

Complex baseband architecture allows calibration/digital compensation for mismatches in a radar system. Signal delay and/or RF phase response mismatch across channels are digitally compensated (before beat signal 1D FFT processing) by digital frequency/phase de-rotations on the I and Q data for each RX channel.

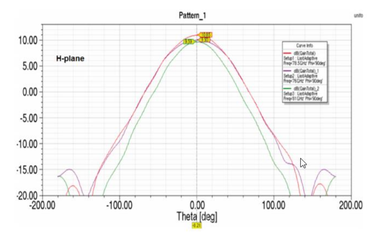
Built-In Self-Test subsystem configures and monitors the on chirp RF baseband components in real time. It is also able to detect interferer and to provide Chirp Quality report on a chirp-to-chirp basis that helps localization of interferer and try to reduce probability of multiple chirps impacted by pseudo random chirp setting and/or binary phase chirp modulation, up to 512 chirps/frame.



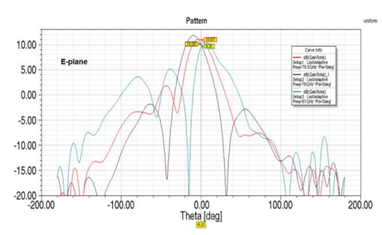




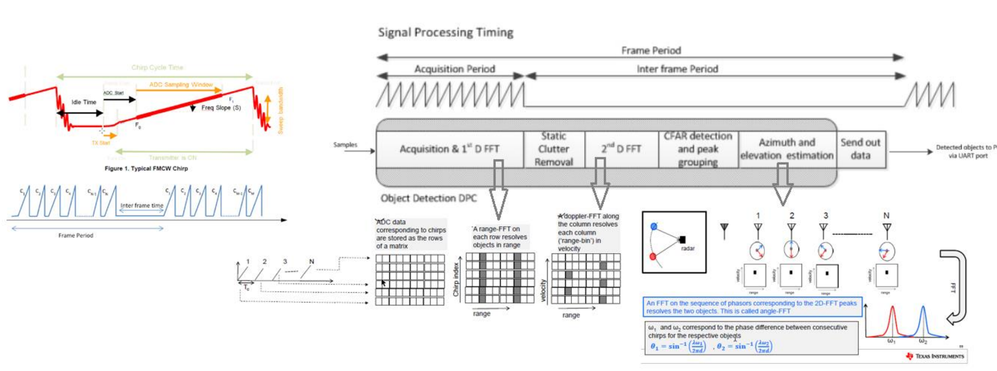
Antenna Horizontal plane beam width: ±28° |3dB ±50° |6dB

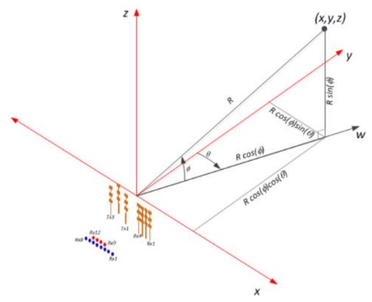


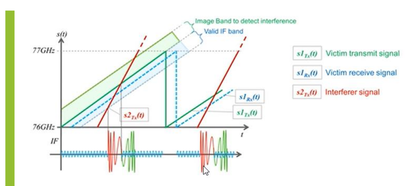

Antenna Vertical plane beam width: ±14° |3dB ±20° |6dB



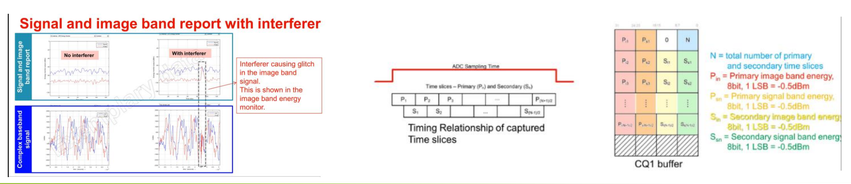

## Radar signal processing




## Chirp Quality report




## Marine accidents and radar applications

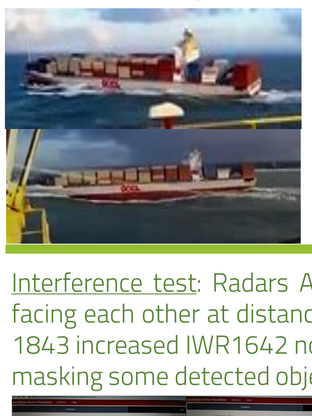
### Parametric roll

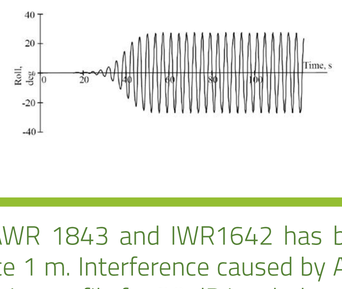
The stability of the ship depends on the waterline buoyancy ship dynamics and influences of the encounter frequency and wave height on the vessel stability regions.

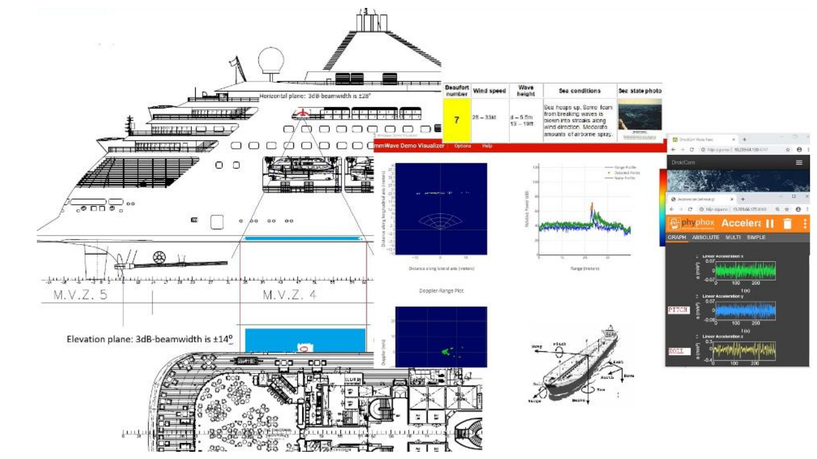

Vessel Model describe parametric roll resonance as an auto parametric system. It is a three degree of freedom model that combines the primary (heave and pitch) and secondary (roll) system into one model. The primary system is externally exited by wave motion. The secondary system is parametrically excited by the primary system.

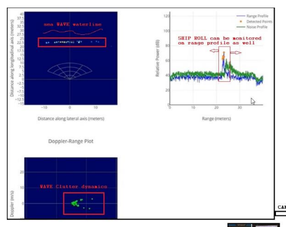
Conditions for parametric roll:

- The excitation / encounter frequency of the ship and waves must be approximately two times the natural roll frequency of the ship.
- Length of the waves should be approx.. 0.8 to 1.2 length of the ship coming from bow/stern direction.
- The wave height needs to be larger than a ship dependent height threshold value.

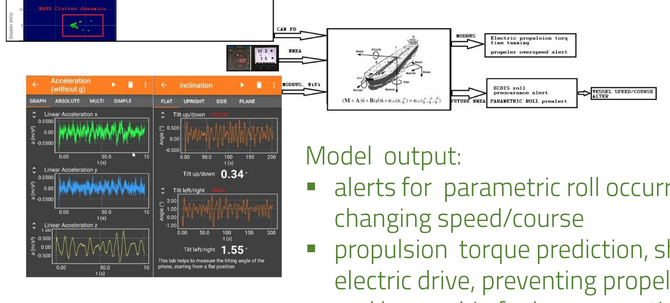





Radar measures wave waterline shape and wave clutter dynamics
accelerometers measures ship dynamics and feed it to ship stability model:

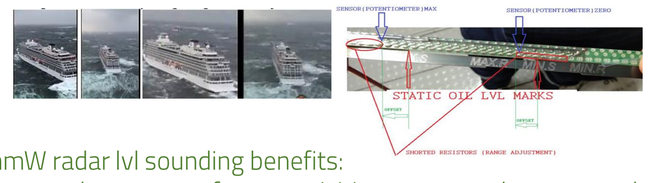



Model output:

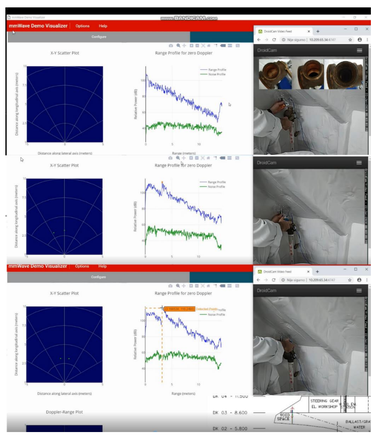
- alerts for parametric roll occurrence → advising changing speed/course
- propulsion torque prediction, short term tuning electric drive, preventing propeller over speed and lower ship fuel consumption.

### Radar tank level and void spaces sounding

Max roll angle vessel limits are lowered in case of inaccurate engine oil sump tank level (reed relay linear potentiometer) causing engine shutdown/blackout. Viking Sky too low engine sump tank lvl and vessel roll in ruff sea resulted in lub oil pressure shutdown on all engines/blackout/loss of propulsion.

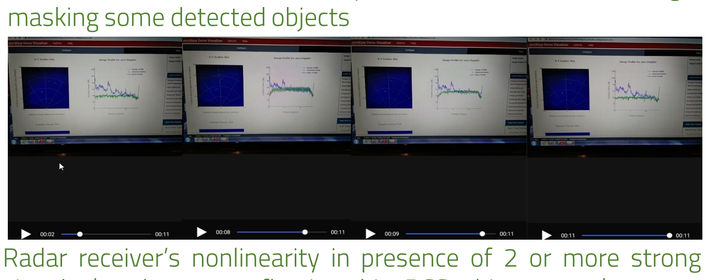



mmW radar lvl sounding benefits:
increased accuracy, fast acquisition compared to manual sounding presently used, in case of vessel grounding time gained to abandon vessel decision improve survival chances.



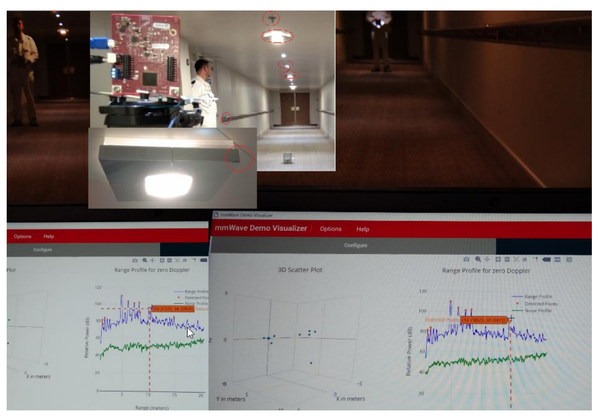

## Radar concerns

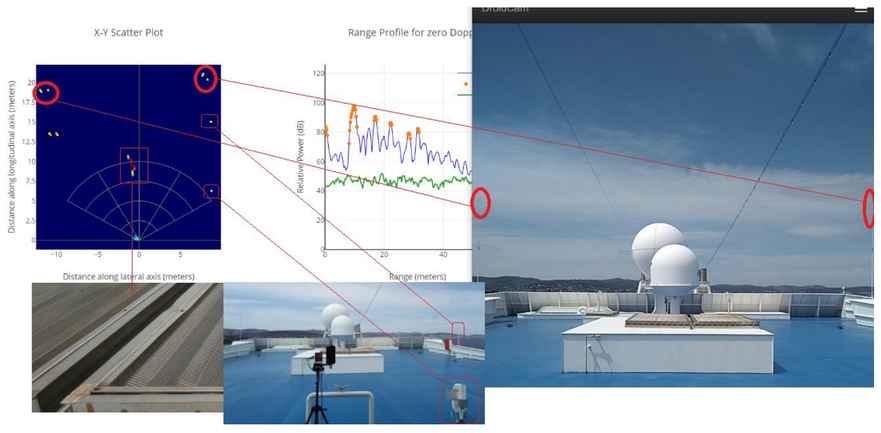
Interference test: Radars AWR 1843 and IWR1642 has been facing each other at distance 1 m. Interference caused by AWR 1843 increased IWR1642 noise profile for 20 dB in whole range masking some detected objects




Radar receiver's nonlinearity in presence of 2 or more strong signals (car bumper reflection, big RCS objects, etc..) creates Intermodulation products that may result in ghost objects.

Strong multipath and specular reflections (first Fresnel reflections) antennas, sharp edges, ventilation grid




## References

[1] AWR 1843 Product documentation, Texas Instruments
[2] Sergio Ribeiro e Silva, Anton Turk, C. Guedes Soares, Jasna Prpić-Oršić, On the Parametric Rolling of Container Vessels
[3] Matjaž Vidmar, ARM DSP Vertical Navigation radar
[4] B.J.H. van Laarhoven, Stability Analysis of Parametric Roll Resonance,