SFP Level Instrumentation

Radar:
Through-Air or Guided Wave?

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The debris, steam and moving water capability of the AREVA/VEGA Through-Air Radar system were demonstrated in front of customers.

**Written customer summary:**

“In conclusion, the demonstrations offered compelling evidence that the Through-Air Radar measurement technology is a viable candidate.”

The 27ft ‘Moving Wall’ allowed the simulation of quickly rising and falling water level. Large debris was introduced in the beam area at different heights - with no effect.

The attendees can see the display at all times.
Radar: Through-Air vs. Guided Wave

How It Works

Through-Air Radar
- Radar pulses generated by electronics travel through air, which is enclosed in a ‘waveguide pipe’ (standard stainless steel pipe).
  - The waveguide was demonstrated by AREVA with 180° and 90° bends and multiple flanges.
- The waveguide ends in a stainless steel horn antenna, which emits the pulses.
- Water (ideal reflector) reflects the pulses (echo). They return through the same enclosed air path.
- The electronics receive and filter the echo.
  - Lesser reflections (e.g. from steam or smoke particles, from debris) get ignored.
- Pulse run time is converted to level information

Guided Wave Radar
- Radar pulses get emitted into a rad-proof coax cable, continue via a rad-proof coax-to-stainless steel cable connector to a wire guide that extends into the water.
- Pulses reflected by the water surface travel back through the same connection.
- Pulse run time is converted to level information.
- Any objects touching the wire guide above water lead to a false measurement. To prevent that, the wire guide can be protected by a stilling tube.
- Coax cable should be protected by metal conduit.

Basic Principle, with obvious lower complexity.

Waveguide pipe ends in a horn antenna above water.

Exposed cable or cable in stilling well extends to the desired depth.
Radar: Through-Air vs. Guided Wave

**Simplicity**

**Through-Air**
- Three (3) Main Components:
  1. Electronics
  2. Stainless steel pipe (waveguide pipe)
  3. Stainless steel horn antenna above water
- About half the component count.
- Simpler, less expensive, more rugged components.
- No components in the SFP room that need to be protected from radiation or high temperatures.
- Nothing in the water.
- Simple in-situ calibration with swivel horn antenna, no calibration ever needed.

**Guided Wave**
- Min. five (5) Main Components:
  1. Electronics (same size as through-air)
  2. Stainless steel pipe (conduit)
  3. Rad-proof coax cable
  4. Rad-proof coax to stainless cable connector (sensitive high-quality h/w)
  5. Waveguide cable hanging in pool
     - Stilling well extending into water
     - Rad-proof spacers to keep wire guide from touching stilling well
     - Mounting structure for heavy stilling well
- Higher implementation risk, e.g. need to qualify rad-proof components, regulatory reviews.
- More delicate components (e.g. mineral insulated coax cable, connector coax/steel cable)
- Waveguide cable outside of stilling tube exposed to forces of water
- Challenging stilling well size and weight
- Calibration in situ more challenging

**Simpler. → More Reliable. → Lower Cost.**
Radar: Through-Air vs. Guided Wave

**Installation**

**Through-Air**

- Simple pipe installation
- No *relevant* limitation of permissible bends or flanges
  - Typically six (6) 90° Bends
  - Plant standard or AREVA's qualified mounts can be used
  - Power supply is simple, just 0.5W needed

**Guided Wave**

- After installation of conduit pipe, mineral insulated cable needs to be pulled through.
- Sensitive coax-to-stainless connector needs to be installed at pool, may require work above water.
- If a stilling well is used, a very strong support will be needed at the pool edge and pipe will have to be supported at fuel rack.
  - Fuel racks can move under seismic stress
  - Forces of moving water when excited by an earthquake have been shown to be very significant

**Guided Wave Radar Installation is More Challenging.**
Radar: Through-Air vs. Guided Wave

**Handling of Debris**

**Through-Air**
- Every object in the radar beam causes a reflection (echo), however all but the strongest reflection get ignored.
- Water is an ideal reflector. Objects with a lesser dielectric constant (i.e. concrete) are less reflective to the signal. Even with much of the radar beam looking at pool deck concrete, the system still displays the water level correctly (proven during demonstration by AREVA).
- Objects (incl. metal) located not perpendicular to the beam direction cause a lesser echo and get ignored as the radar pulses don’t get reflected back to the antenna entirely. Proven during demonstration: 1000 sq. inch size metal debris.
- Even large metal objects can return small echoes compared with the very large echo from the water surface.
  - The lower the water level, the larger the area the radar beam occupies.

**Guided Wave**
- Any object touching the waveguide cable above water causes a reflection that can distort the signal.
- If an object leans against the waveguide cable and makes it touch the liner above water, it causes a distorted signal.
- Issues with handling of debris have required adding a stilling well design.

One of the AREVA Debris Test Setups
Handling of Steam, Dust, Smoke, Foam, Moving Water Surface

Through-Air

- Through-Air Radar comes in different versions, specifically designed for different environments.
- The offered system (VEGAPULS 66) has been designed for level measurement in liquids with strongly agitated media.
- Saturated steam conditions are no issue for the measurement, as demonstrated by AREVA.
- Likewise, smoke, foam and dust do not provide a strong reflection and will not cause corruption of the measurement.

Guided Wave

- Steam, Dust, Smoke and Foam don’t normally cause an issue.
- A moving water surface could be an issue, if the wire guide cable touches the liner or other objects above the water line.

Through-Air Radar’s Capability has been demonstrated in front of several US nuclear utilities.

AREVA Saturated Steam & Smoke Test Setups.
Radar: Through-Air vs. Guided Wave
Event Survivability

Through-Air

- Significantly less exposed length.
- Through-Air Radar waveguide pipe is standard stainless steel. Thicker walled pipe could be chosen for additional protection.
- Using two Through-Air Radar systems in physically diverse locations will help to ensure SFP level information following the beyond design basis event.
- Proven ‘high/low’ strategy (combined floor and ceiling mounting) can be used only with Through-Air Radar, lowering the risk of loss in an event.
- Moderate deformation of the waveguide would be ignored by the system.
- Forces of moving water would not affect the Through-Air Radar.

Guided Wave

- Guided wave radar has the same structure as through-air outside of the pool plus an additional exposure on a length of about 24ft of cable and potentially a stilling well in the pool. The cable or stilling well could be affected by something dropping on top of it or by indirect impact of pieces dropping in the pool and then falling against these parts, as happened at Fukushima.
- Conduit provides protection comparable to Through-Air Radar’s waveguide pipe.
- Coax-to-stainless steel connector has to be protected through a separate structure.

Through-air radar’s survivability will be easier to justify.
Radar: Through-Air vs. Guided Wave

Operation and Maintenance

**Through-Air**

- For Through-Air Radar there will never be a need for moving parts in the water.
- Calibration for Through-Air Radar achieved by $90^\circ$ swivel flange (bolts just to be loosened, none to be removed) and moving target.
- OEM guarantees less than 0.5% drift in 10 years, accuracy is 0.3 in. No recalibration is ever needed, just verification.

**Guided Wave**

- For in-situ calibration verification, the cable in the pool may have to be lifted by a defined amount.
  - No stress must be placed on the sensitive coax-to-stainless steel connector.
  - Neither the cable in the pool nor the mineral insulated coax cable are very flexible.
- A stilling well further complicates calibration.
- Same high accuracy and low drift as Through-Air Radar.
Radar: Through-Air vs. Guided Wave

Cost

Through-Air

- Less and simpler components.
  - Less need for testing and documentation.
- No special mounting structures.
- Complete solution is produced in large quantities.
- AREVA can provide EPC solution using AREVA DZ.
- Through our contractual relationship with VEGA, AREVA procures the hardware at a very competitive rate.

Guided Wave

- On top of the components needed for Through-Air Radar, Guided Wave Radar requires:
  - Rad-proof coax cable
  - Rad-proof coax-to-stainless steel connector
  - Stainless steel wire guide with weight
  - Stilling well, spacers, mounting
- Installing mineral insulated cable is more challenging than standard cable.
- Calibration may be more complicated, increasing overall lifecycle cost.

More components and higher complexity lead to higher installation and maintenance costs for guided wave radar.
Radar: Through-Air vs. Guided Wave

References

Through-Air

- >300,000 VEGA Through-Air Radar devices in the field including:
  - Nuclear
  - Military
  - Industrial
- Hawaii Lava Level Meas.

Guided Wave

- Unknown

VEGA Through-Air Radar Installation with ‘wetted’ waveguide pipe (no horn antenna)
Radar: Through-Air vs. Guided Wave

Bottom Line

**Through-Air**

- **Completely fulfills** the hardware requirements per EA-12-0051 and NEI 12-02.
- **Easier** to apply due to less need for testing, justifying documentation, less components.
- **Simpler** overall design with fewer critical components.
- Makes the AE’s and Licensee’s life easier.
- **More reliable** due to low component count and debris ignoring operating principle.
- **Proven** to work in saturated steam and with large size debris.
- **Saves money** on the hardware and on the engineering side.

**Guided Wave**

- Higher complexity design.
- More exposure to damage in an event due to exposure to forces of moving water.
- More challenging installation.
- Harder to calibrate in situ.
- Higher overall cost.

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**Through-Air Radar is the More Reliable and Lower Cost Choice for SFP Instrumentation.**