H-FIELD OR E-FIELD RECEIVER ANTENNA?

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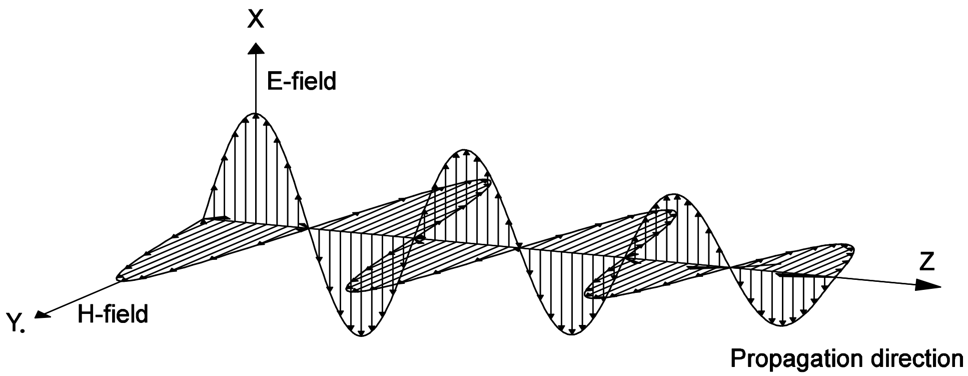
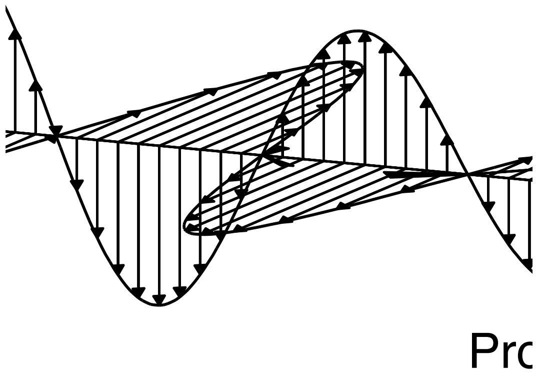
Far-field propagation





- In the far field, the E-field and H-field component of an Electro-Magnetic wave have a fixed relation
- The EM-wave can be probed equally well with an E-field or H-field antenna

Overview E-field vs. H-field

- EM signal
  - Receiver can be equipped with E-field (whip) or H-field (loop) antenna
- Far-field propagation: fixed relation between E and H
  - Performance differences between E-field and H-field antennas
  - Practical differences (for example: size, integration with GPS antenna, grounding, costs)
- Near-field phenomena: no fixed relation between E and H
  - Local interference
    - P-static
    - Power electronics
    - Engine noise
  - Local propagation phenomena (local structures)
    - TOA and positioning accuracy / Re-radiation
    - Signal strength

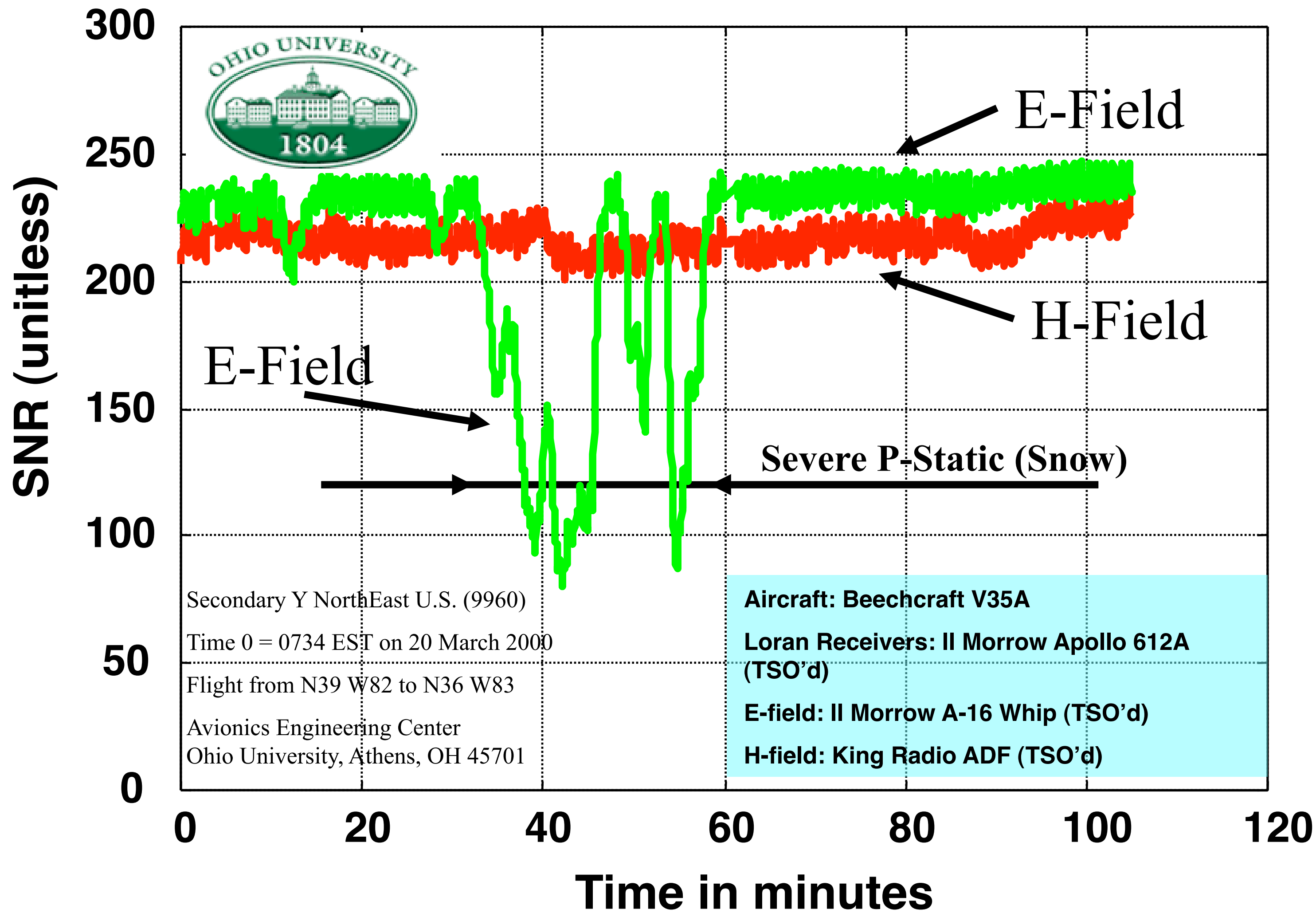
E-field vs. H-field in the far field

	E-field	**H-field**
Low noise design	*Easy*	*Hard*
Radiation pattern	*Omni-directional*	*Figure-8*
Required RX processing	*Easy*	*Harder*
Antenna form	*Whip*	*Flat*
Integration with GPS patch	*Hard*	*Easy*
Compass functionality	*No*	*Yes*
Re-radiation detection	*No*	*Yes*

Under favorable (far-field) conditions, the E-field antenna offers similar performance but with less implementation challenges

→ Legacy Loran-C uses E-field ←

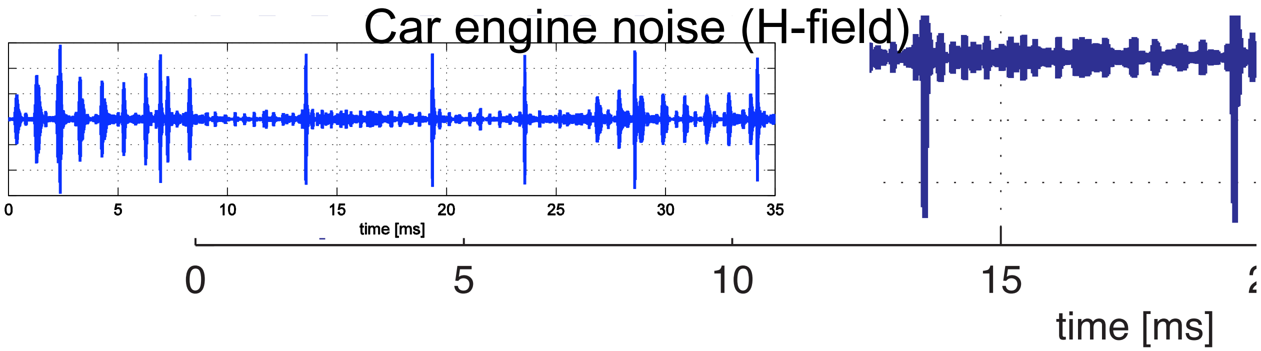
In-Flight SNR comparison between E-Field and H-Field Antennas

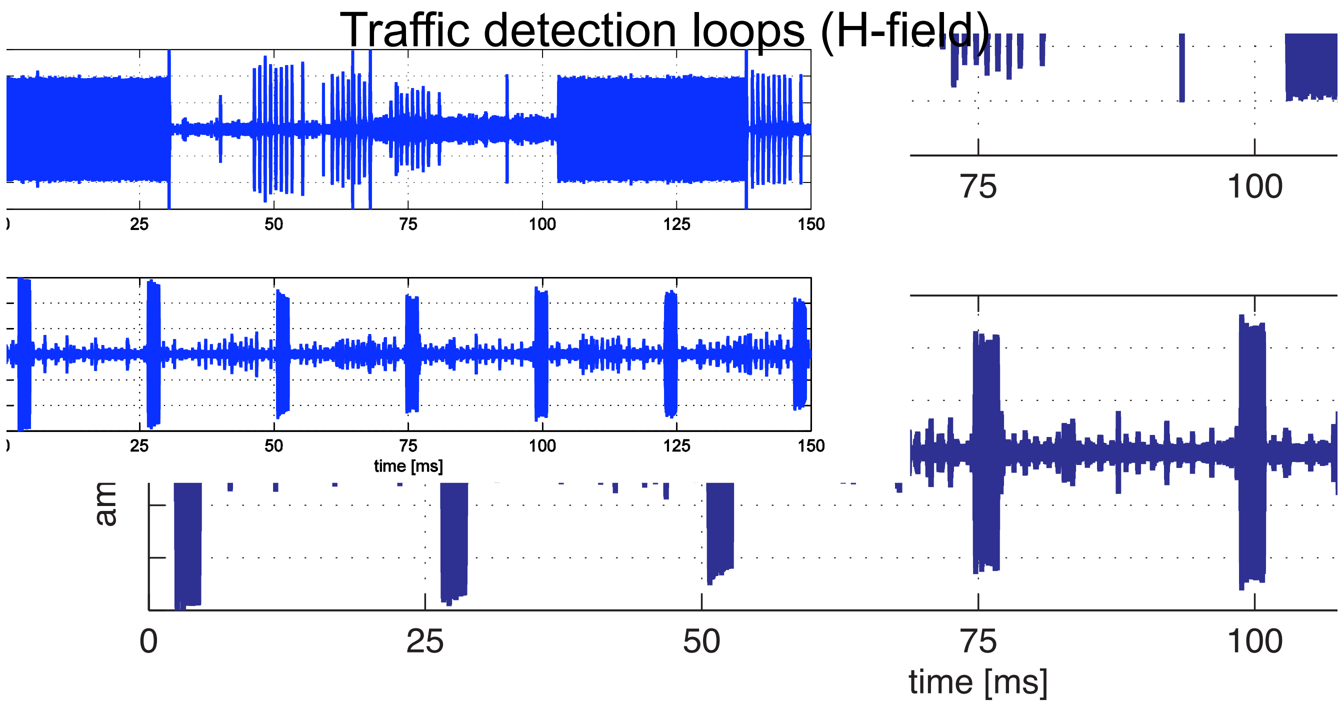


P-static susceptibility *unacceptable* for aviation applications

→ THE motivation to go H-field ←

E-field vs. H-field: local interference (1)



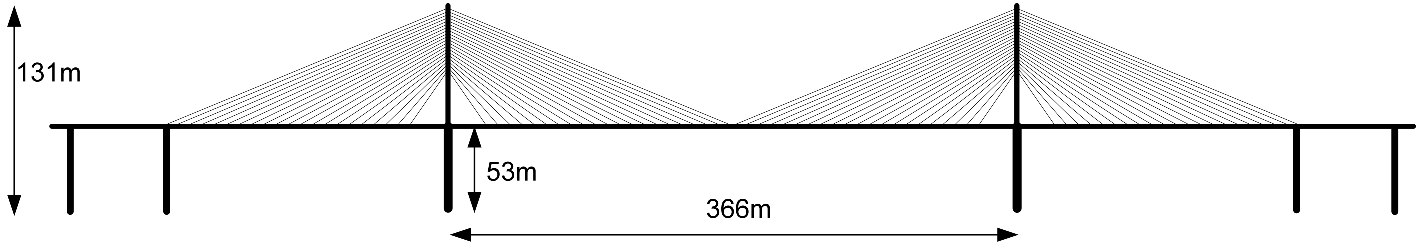


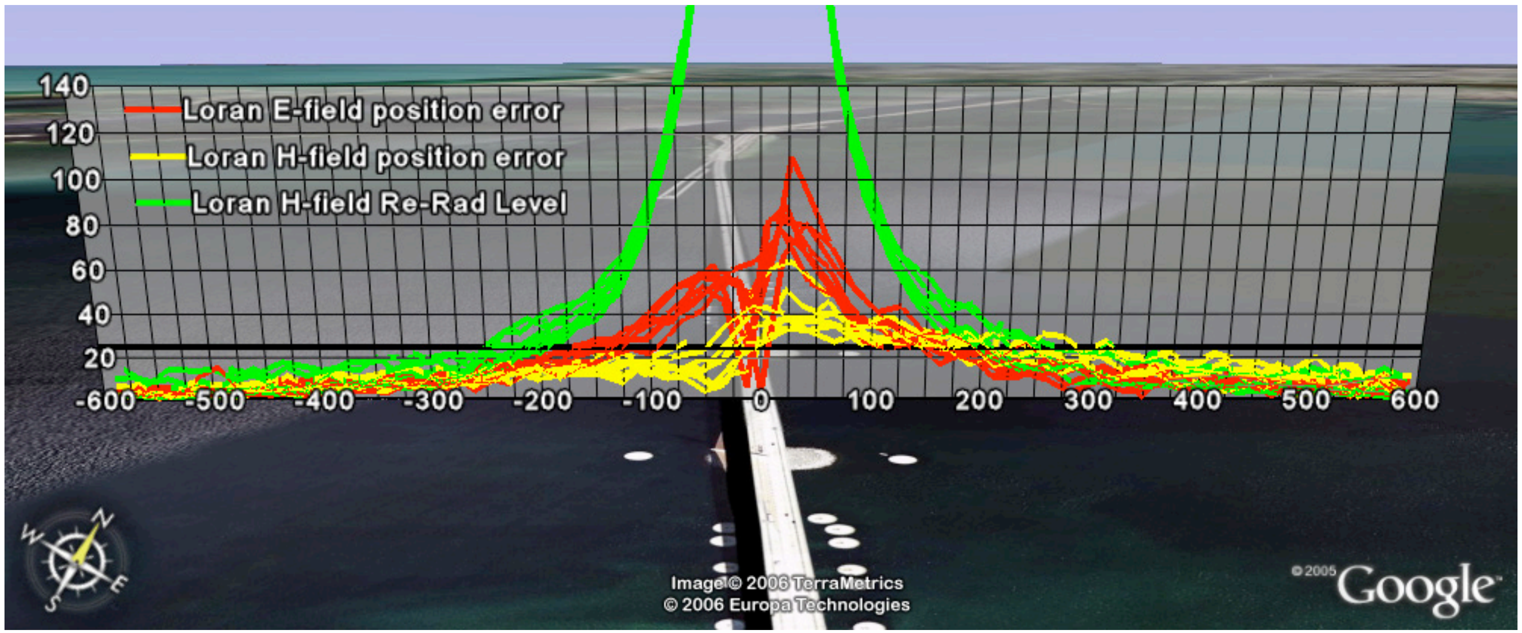
E-field vs. H-field: local interference (2)

Local Interference	E-field	H-field
Precipitation static	- - ?	+ +
Power electronics	+ -	- -
Engine/generator	+ -	-
Traffic detection loop	+	-

- Some local interferers can be mitigated in the time and/or frequency domain
  - traffic loops, …
- Better select the best type for the given application

Local propagation phenomena (1): Sunshine Skyway bridge (Tampa, FL)

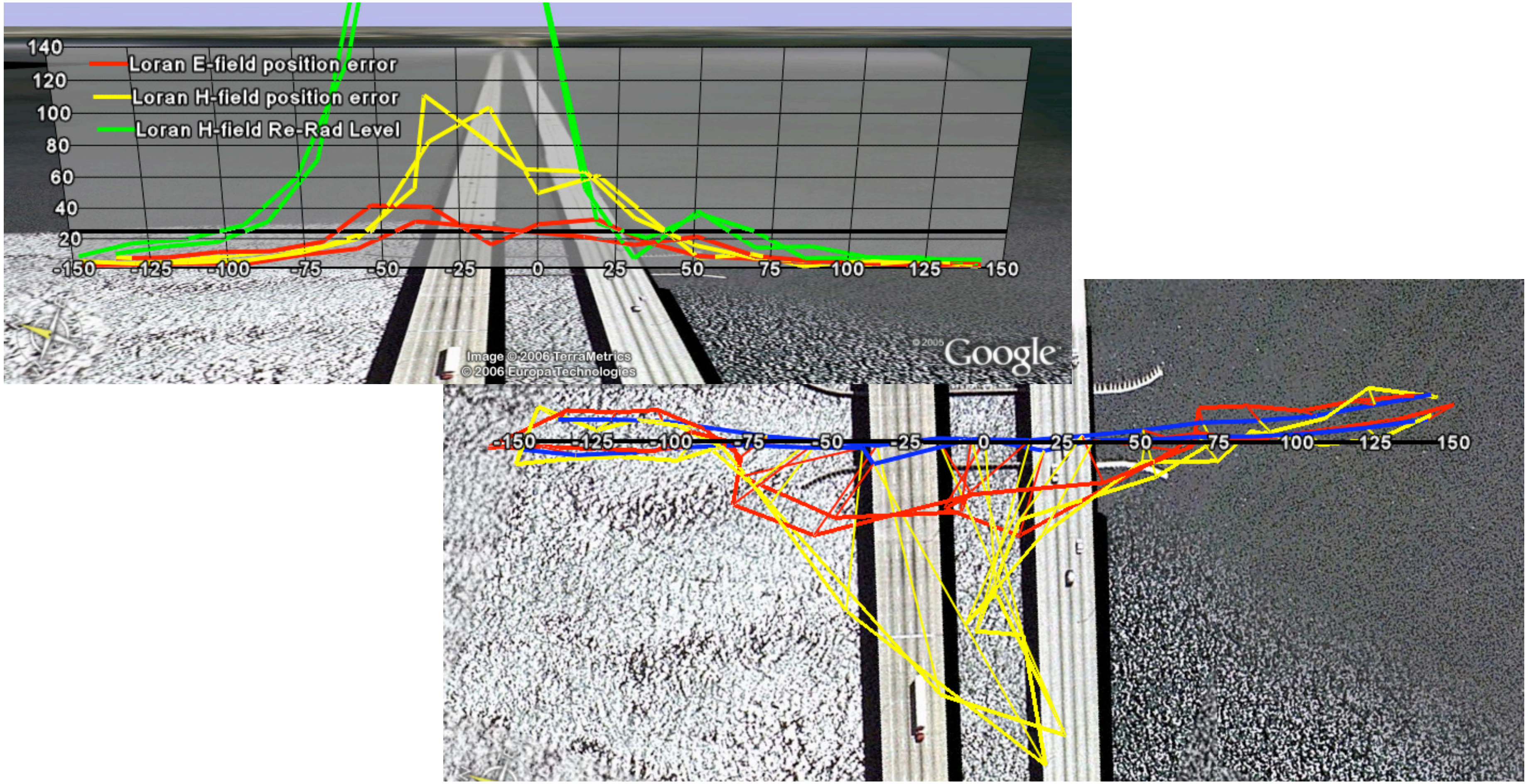




H-field positioning errors much smaller than E-field

H-field provides re-radiation detection, warning for potential position errors

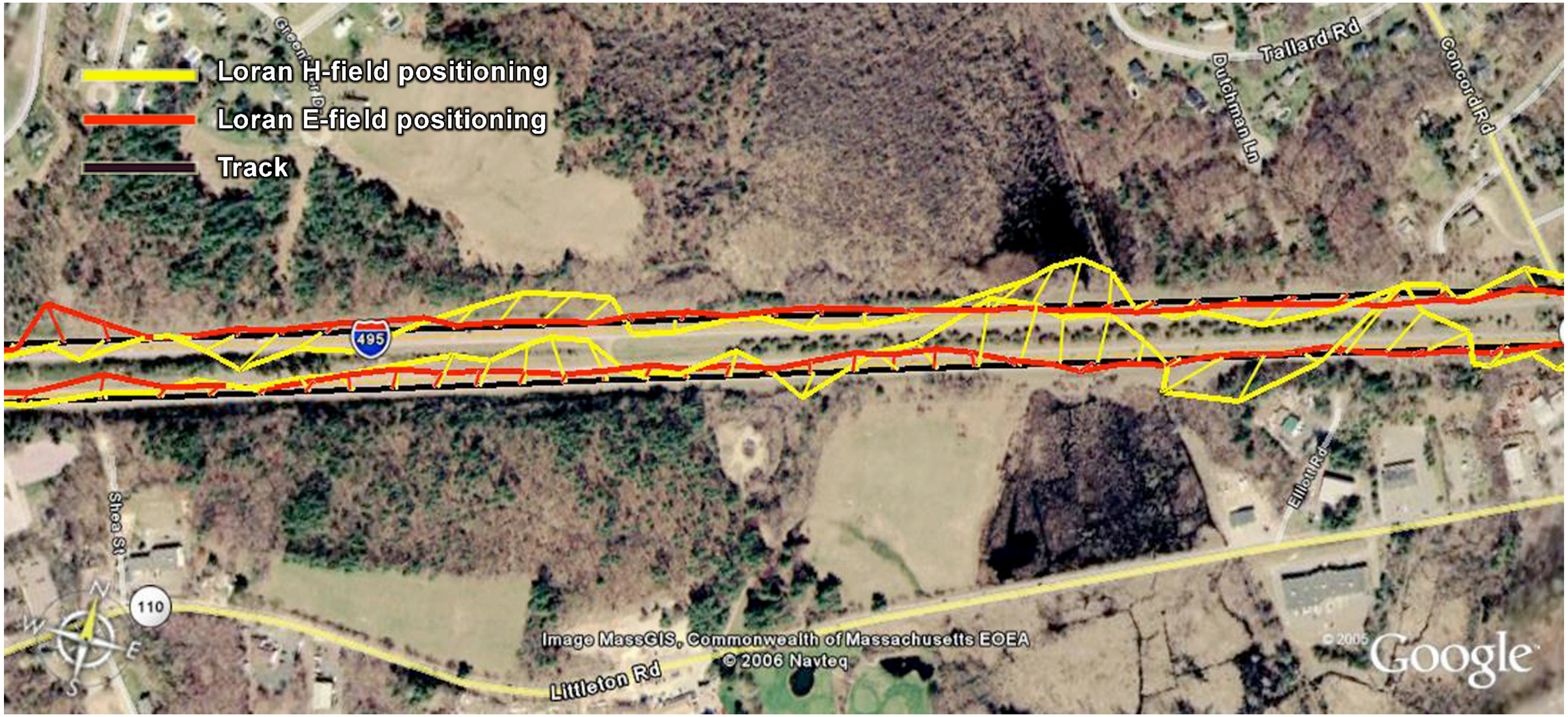
Local propagation phenomena (2): Howard Franklin Bridge (Tampa, FL)



E-field positioning errors much smaller than H-field

H-field provides re-radiation detection, warning for potential position errors

Local propagation phenomena (3): 495 highway (near Boston, MA)



E-field positioning errors much smaller than H-field

Note repeatability of H-field between back and forth: it's not noise, it is local propagation!

E-field vs. H-field recap

- Aviation: P-static unacceptable, so use H-field
- Other modalities:
  - Performance considerations (interference, local propagation phenomena)
  - Integrity considerations (H-field antenna provides re-radiation detection capability)
  - Practical considerations (size, cost, compass functionality)
  - in some situations H-field more applicable, in other situations E-field
- Still a business-case for E-field eLoran !
- Question: ***How far can we push E-field eLoran antennas with modern technology?***

From Large to Small

- 1950 – 1985
  - Large 10 ft whip E-field antennas
    - Excellent sensitivity
    - Omni-directional
    - Some bandpass filtering
    - P-static ☹ ☹
- 1985 – now
  - H-field antennas
    - Good sensitivity
    - Omni-directional with two perpendicular loops with two receiver channel
    - No P-statics ☺ ☺
    - Compass ☺ ☺
- 2008 – now
  - Miniature E-field antennas
    - Excellent sensitivity ☺
    - Improved P-static rejection
    - Very low-cost ☺ ☺
    - Single receiver channel ☺ ☺

H-field antenna nuisances and solutions

- **Noise**
  - High-performance double-loop amplifier
- **Figure-8 radiation pattern**
  - Two orthogonally placed loop antennas, combined with a dual-channel receiver and advanced signal processing
- **E-field susceptibility**
  - Shielding and/or balancing of the loops
- **Cross-talk**
  - Design & calibration
- **Tuning**
  - Design & calibration

Problems solved !

high-quality H-field antennas are possible and are currently on the market!

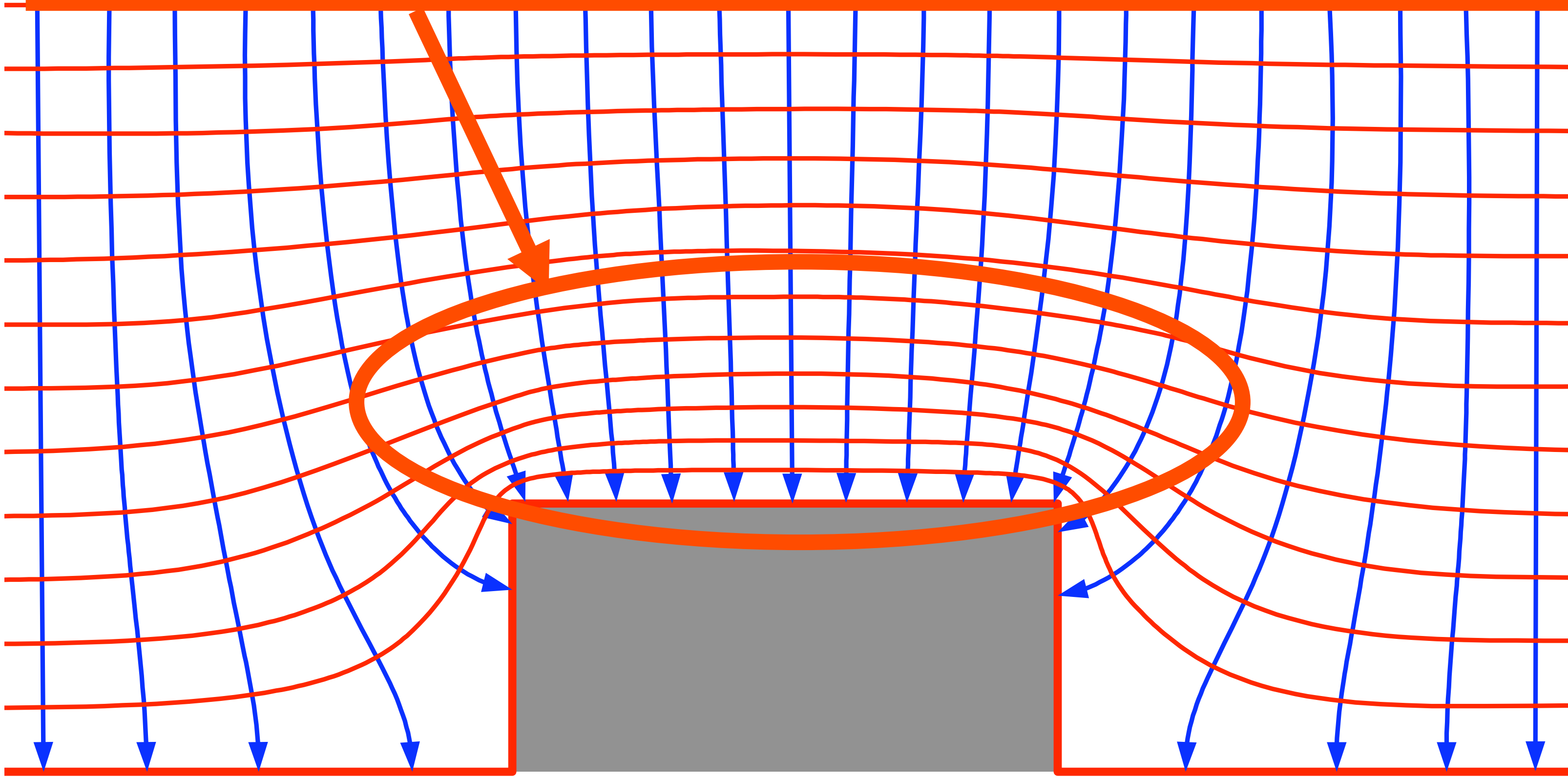
Modernized LF E-field antenna

- Charge-coupled amplifier
  - Low noise, high bandwidth, large dynamic range
  - Insensitive against (salt) water splashing against antenna
  - Robust and easily protected against lightning discharges
- Costs and size
  - Low component count
  - Simple production and low-cost components
- Low-noise amplifier leads to very small antennas
  - Possible to use plastic “dome” around antenna to reduce dQ/dt and thereby P-static sensitivity*

*only effective against charged raindrops/snow, not against local discharges on airframe

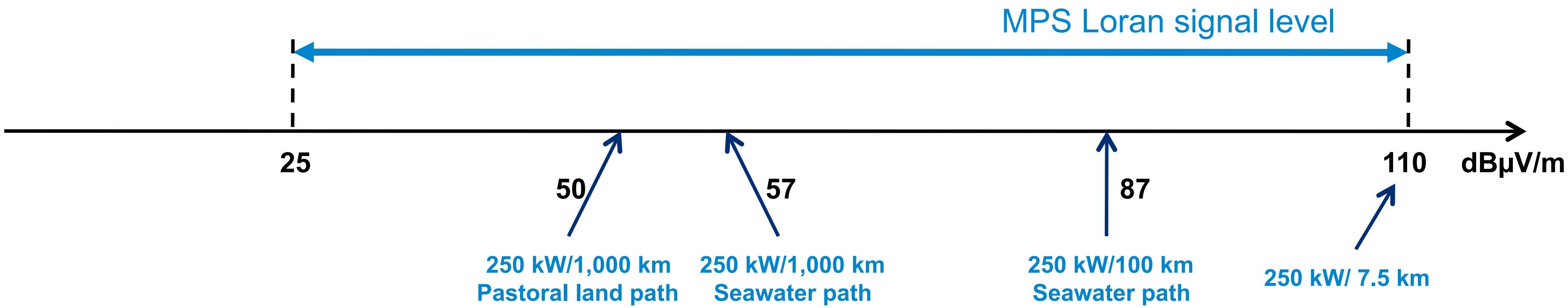
E-field equi-potential lines around conduction object

- Apparent local increase of E-field strength
- Increase depends on height and slenderness of object

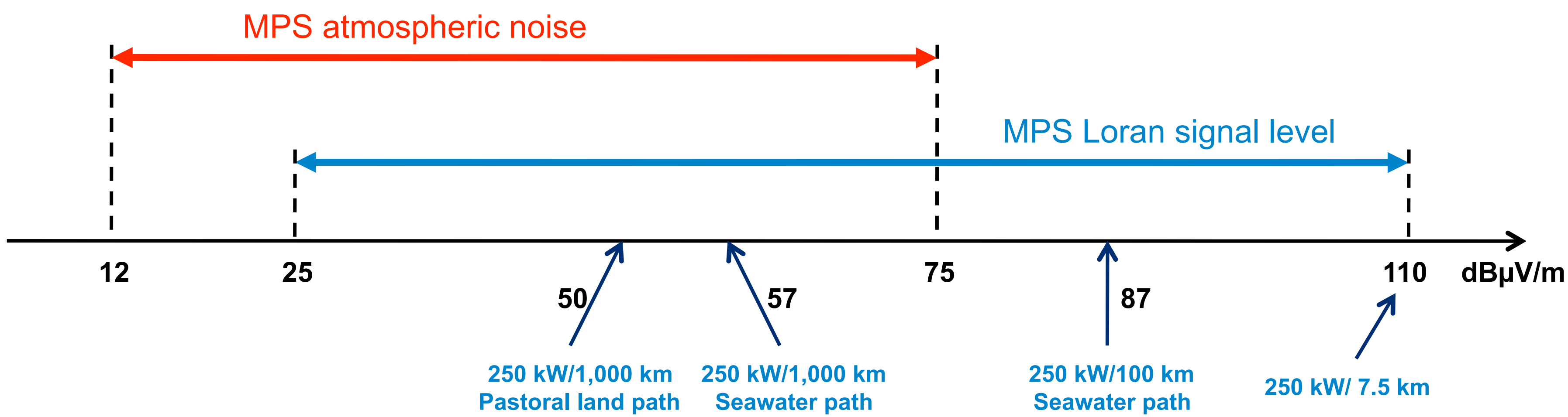


Loran Signal Levels (MPS)

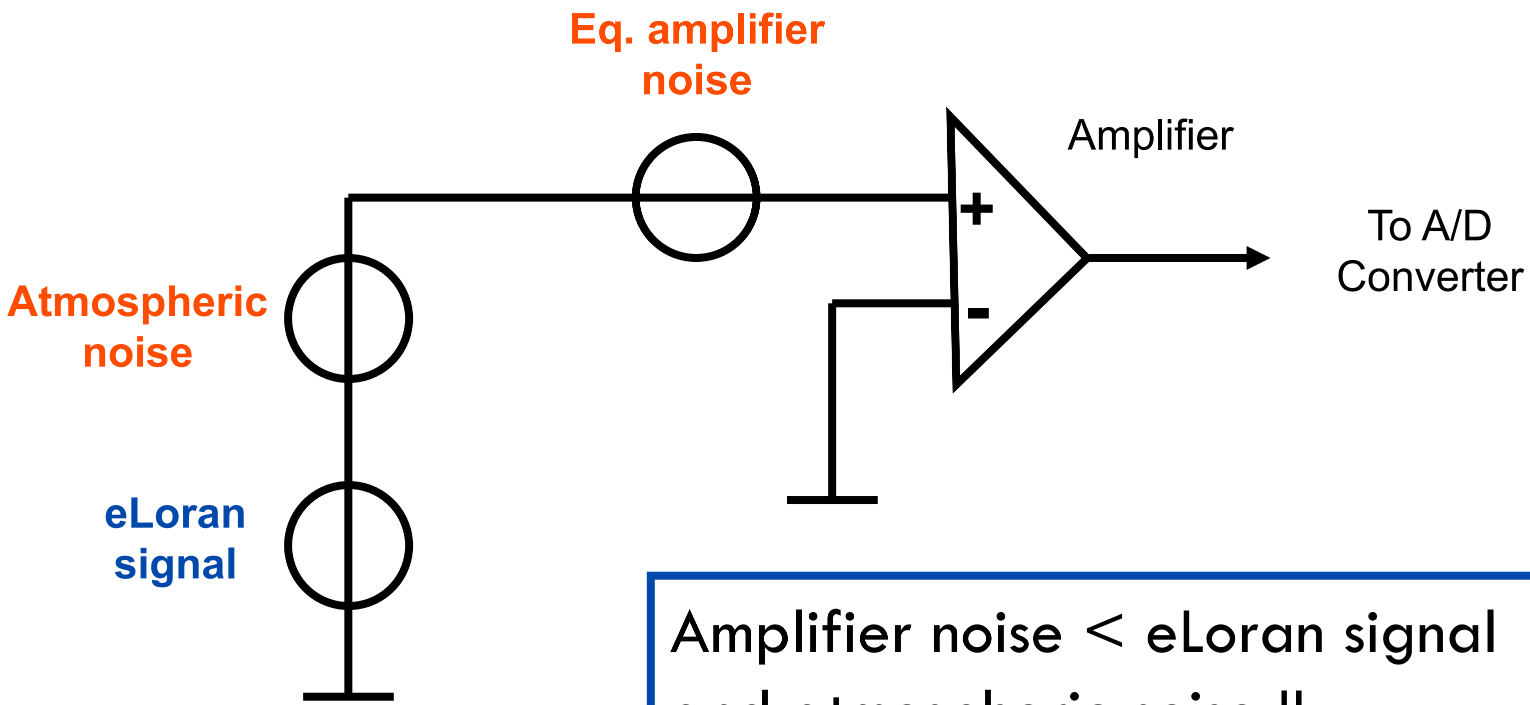
MPS = RTCM SC70 Minimum Performance Standards Marine Loran-C Receiving Equipment



Loran Signal Levels + Noise 1

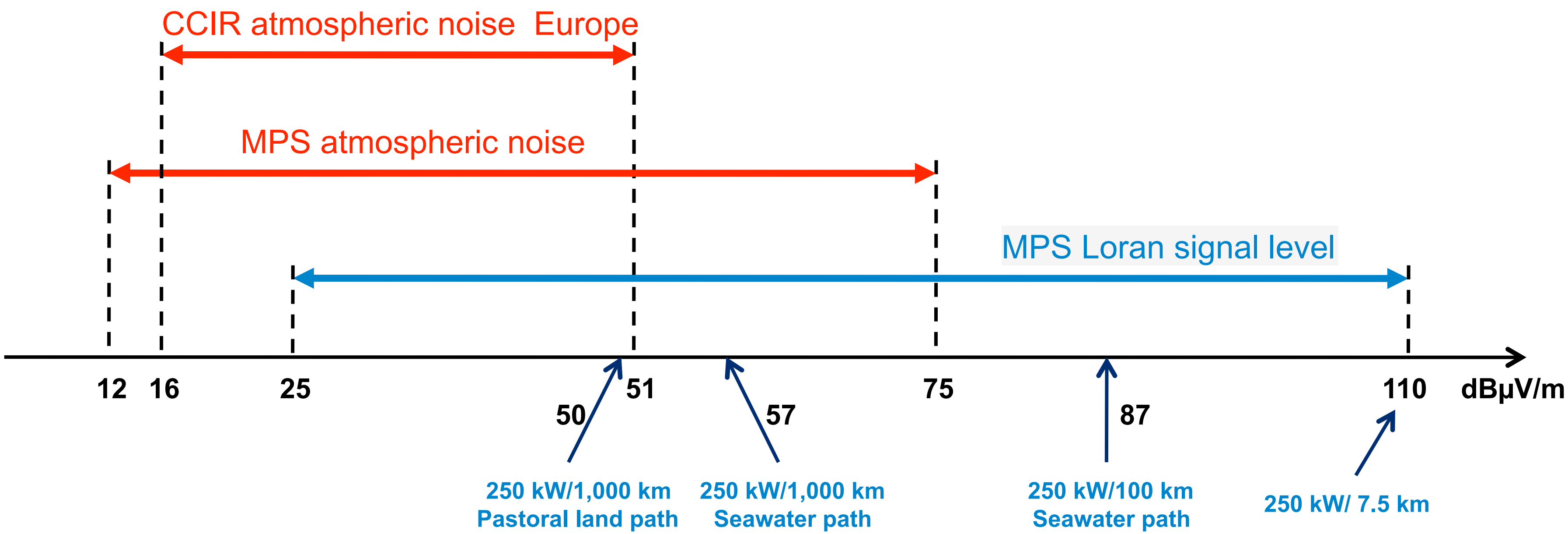


Active Antenna & Noise Sources

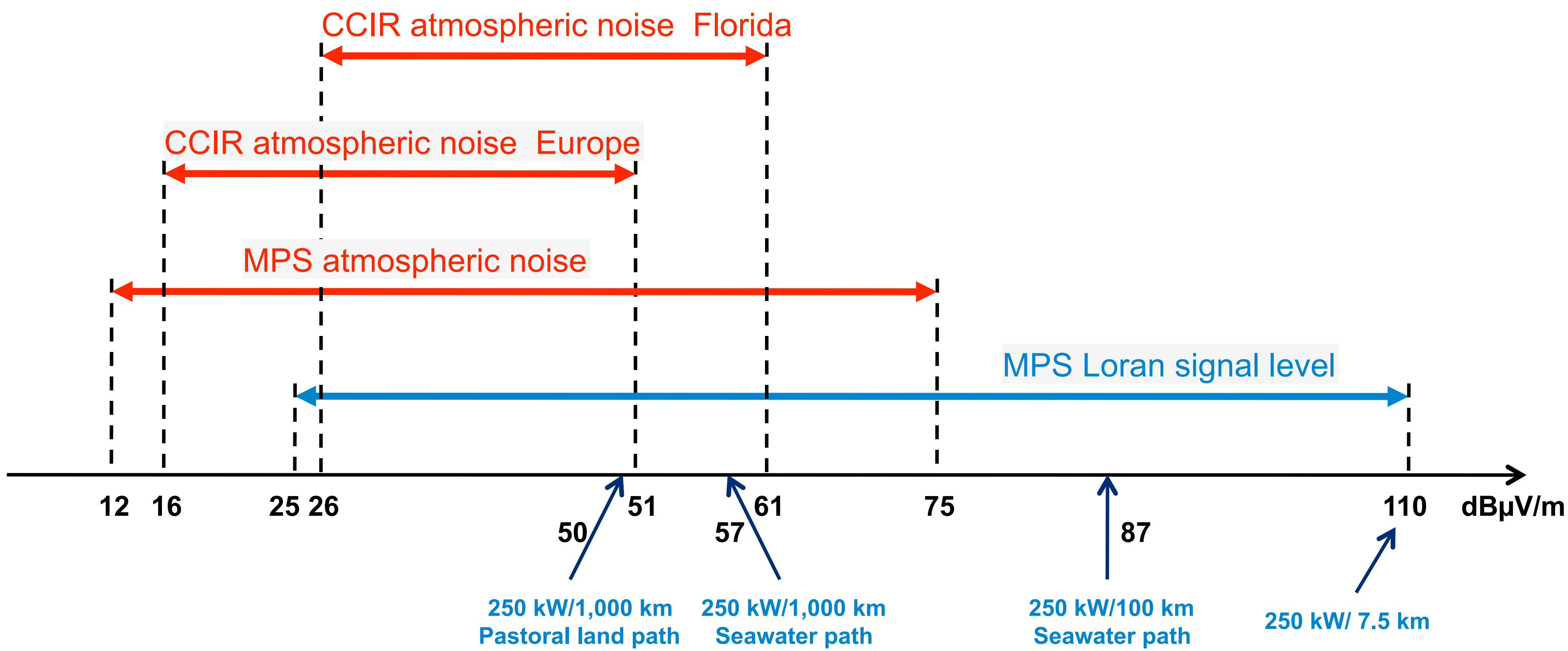


Amplifier noise < eLoran signal and atmospheric noise !!

Loran Signal Levels + Noise 2



Loran Signal Levels + Noise 3



E-field Antenna Characteristics

- Minimum physical length determined by atmospheric and amplifier noise levels
  - Very useful results with antenna length of 50 mm or less

    Antennas of 200 mm show excellent noise figures
- E-field strength may increase up to 20 dB on top of masts
- Perfect omni-directional pattern
- Antenna has large bandwidth which may introduce inter-modulation due to non-linearities in amplifier
- Very low components costs and easy manufacturing
- Single channel receiver reduces overall costs

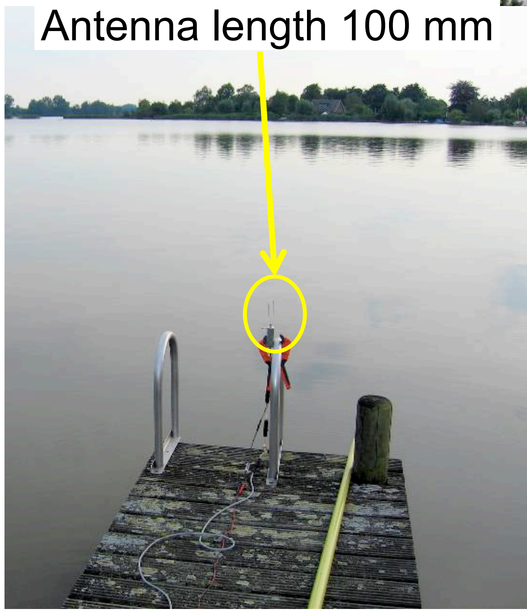
Real-life Testing

Prototype amplifier

100 mm antenna on top
of 5 meter mast

Antenna length
of 50 mm

0.5 meter above water
Antenna length 100 mm



Production prototype
30 x 300 mm outside

Comparing Measurements

Station	Distance to Reelektronika	H-field		E-field @ 1 m		E-field @ 5 m	
		SS (dB)	SNR (dB)	SS (dB)	SNR (dB)	SS (dB)	SNR (dB)
6731M	546.6 km	51.0	18.3	58.7	22.1	72.5	27.7
6731X	1,028.2 km	38.4	4.0	46.1	9.4	59.9	15.0
6731Y	621.6 km	45.9	11.6	53.4	16.7	67.5	22.7
6731Z	387.5 km	55.6	21.4	62.3	25.6	76.5	31.7
7499M	387.5 km	55.6	21.4	62.6	25.9	76.6	31.8
7499X	546.6 km	51.0	18.3	58.4	21.7	72.5	27.7
7499Y	1,030.3 km	38.7	4.7	46.1	9.4	59.9	15.1

Standard Reelektronika H-field antenna as reference
E-field antenna length **20 cm** mounted at 1 or 5 meter above ground
SS = Relative fieldstrength (dB)
SNR = Signal-to-Noise ratio (dB)

Some Preliminary Conclusions

H-field Antenna

Pro

- Accurate true-North Compass
- Beam Steering
- Re-radiation detection
- No ground needed
- Height independent gain
- Effective length definable

Con

- H-field interference
- Very low-noise amplifiers
- Dual-channel receiver

E-field Antenna

Pro

- Small size
- Very low production costs
- Omni-directional
- Single-channel receiver

Con

- Ground needed
- No re-radiation detection
- Height dependent gain
- Effective length difficult to establish
- P-static ?

Type selection depends on number of specific user requirements

More results to come on ILA-38 and NAV09!

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