Progress in Mitigation of WLAN Interference at Weather Radar

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I. Wireless/radio local area networks (WLAN/ RLAN) [1]

- ❑ are widely used,
- ❑ co-exist in traditional frequency bands of weather radars (WR), and
- ❑ their signals often contaminate weather radar observations:
  - ➢ **significant false echo → "precipitation" in fair weather**
  - ➢ superimposed with true echo → distortions in measurements and in identification
  - ➢ weak background → ambiguity in ambient noise power (calibration)

Management of WLAN/RLAN interference in WR is a diverse activity:

1. enforcement of standards, e.g. dynamic frequency selection (DFS),
2. localization of individual sources in daily operations, authorization,
3. quality control of radar observations and mitigation of effects.

All these call for good understanding of the WLAN/RLAN 'noise'

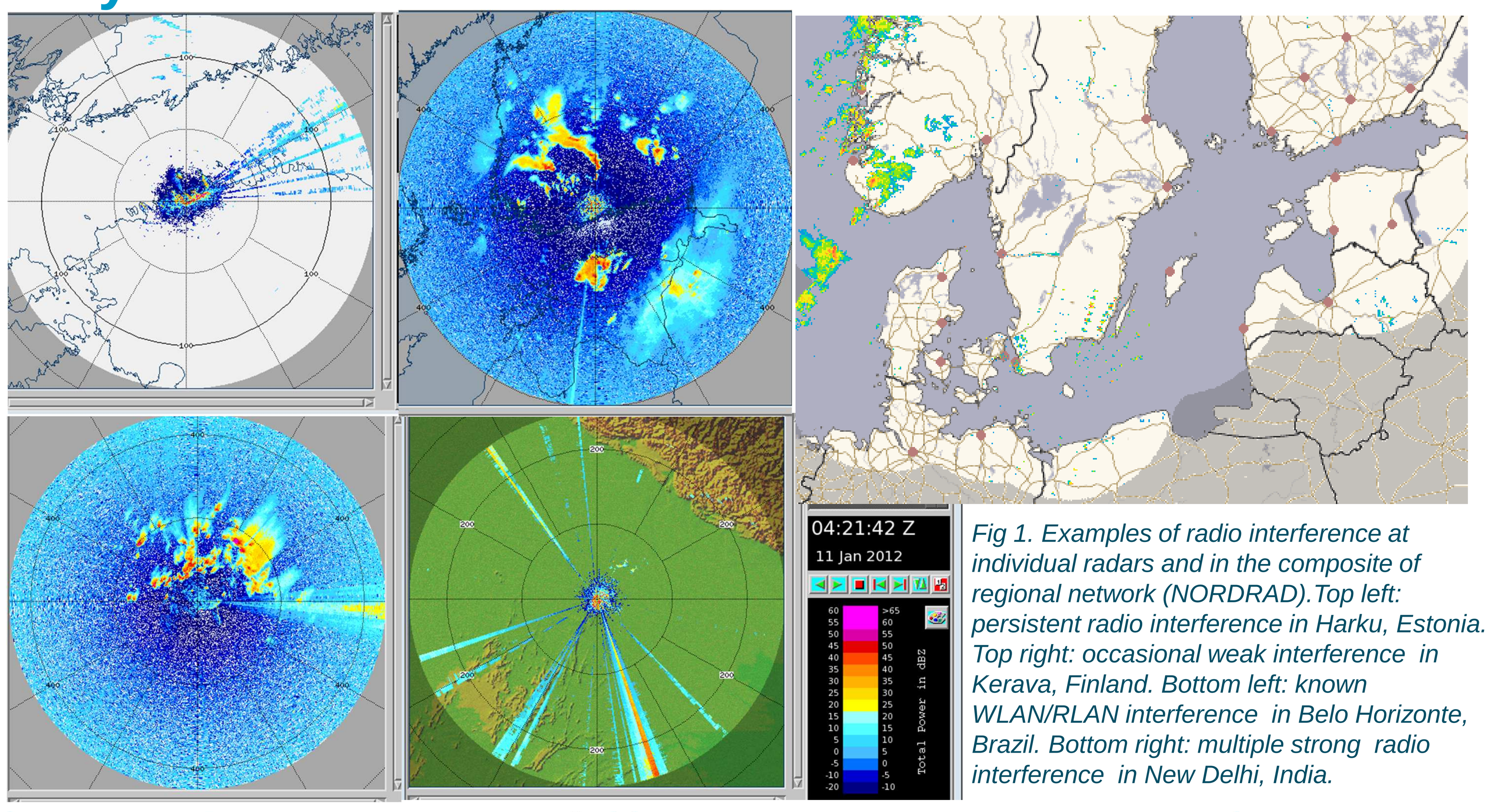

Fig 1. Examples of radio interference at individual radars and in the composite of regional network (NORDRAD).Top left: persistent radio interference in Harku, Estonia. Top right: occasional weak interference in Kerava, Finland. Bottom left: known WLAN/RLAN interference in Belo Horizonte, Brazil. Bottom right: multiple strong radio interference in New Delhi, India.

II. WLAN input to the radar receiver in a controlled set-up (Ref. [2])

- D-link DAP-2553 access points (AP)
- Wireless distribution system (WDS) at channel 48 (5240 MHz)
- CW RF generator at 389 MHz (Agilent E4438C) as local oscillator
- RF spectrum analyzer (Agilent E4407B)
- UDP or TCP/IP data traffic generated between the Radar PC and a PC using iperf software
- Pemitted: 7dBm Preceived: -85dBm
- Mimics a stationary antenna & AP@100m

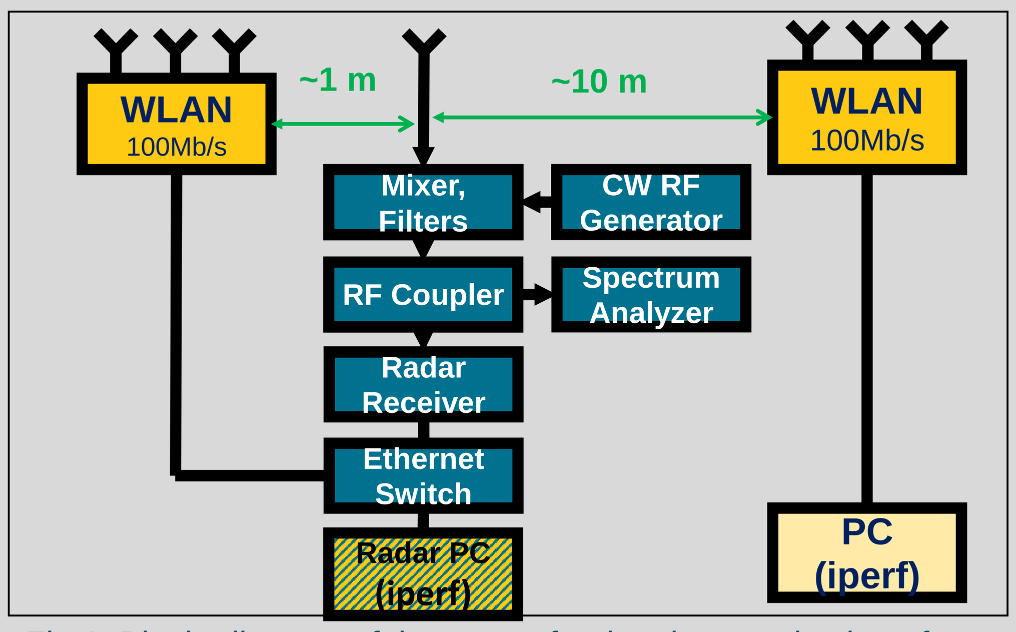

Fig 1. Block diagram of the set-up for the characterization of WLAN/RLAN interception in controlled conditions.

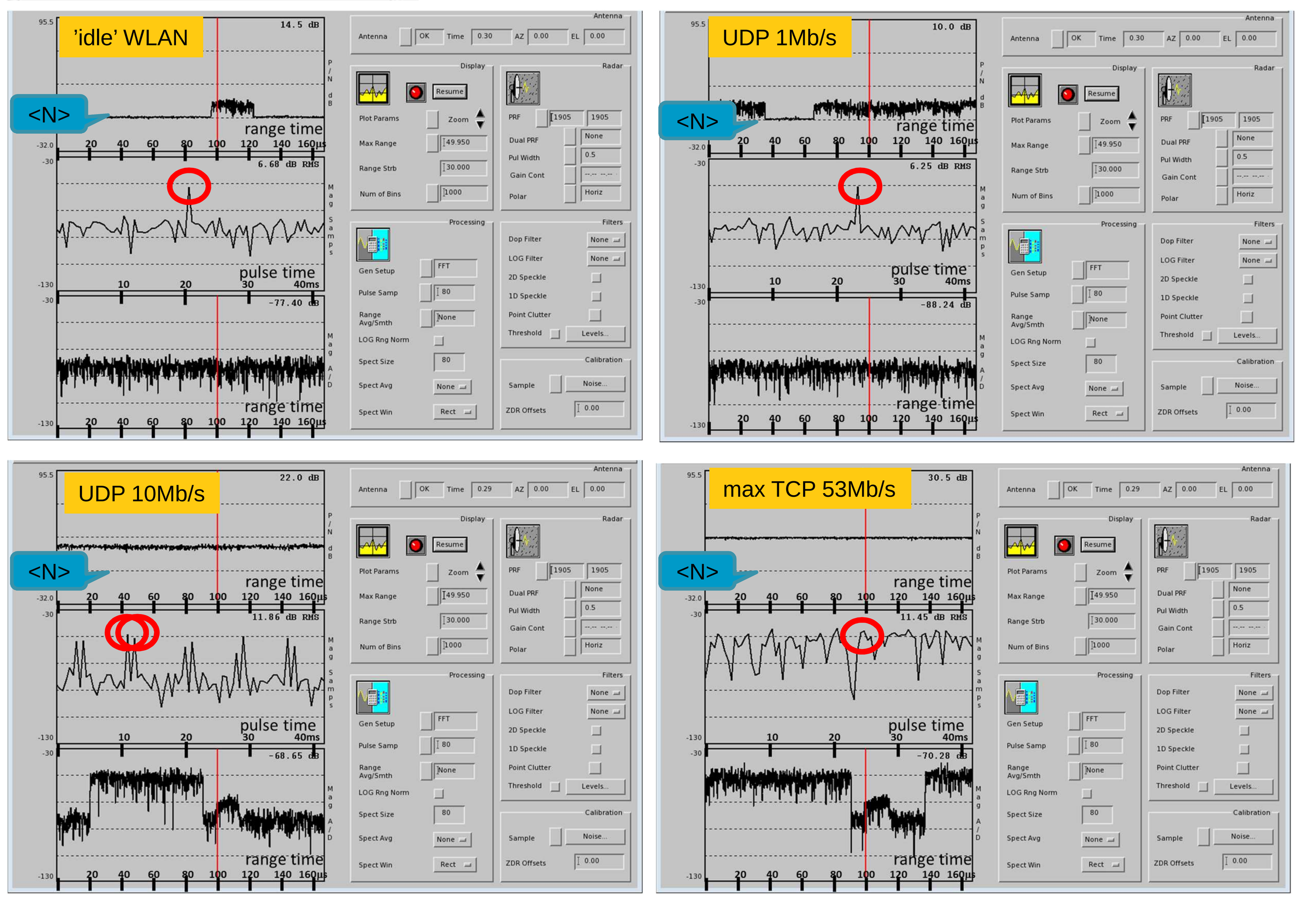

Fig 4. WLAN communications intercepted by the radar receiver. In each screen, the power estimates (P/N) from 80 samples are shown as function of the range-time (top), the amplitudes of the voltages in pulse-times at the gate marked with red (middle), and the amplitudes of the voltage time series in range-time (bottom). Upper left: idle WLAN, upper right: UDP at 1Mb/s, lower left: UDP at10Mb/s, lower right: max throughput of TCP/IP.

III. Basics of the WLAN/RLAN complex 'noise'

Recall: complex voltages from **precipitation echo** and additive **thermal noise** are **Gaussian distributed random variables; the powers are Rayleigh distributed**

WLAN (IEEE802.11a,g,n):

I. Orthogonal Frequency Division Multiplexing (OFDM) -> flat spectrum

II. Standard packet structure [2]: a multiple of symbol times of 4 µs

802.11a,g:

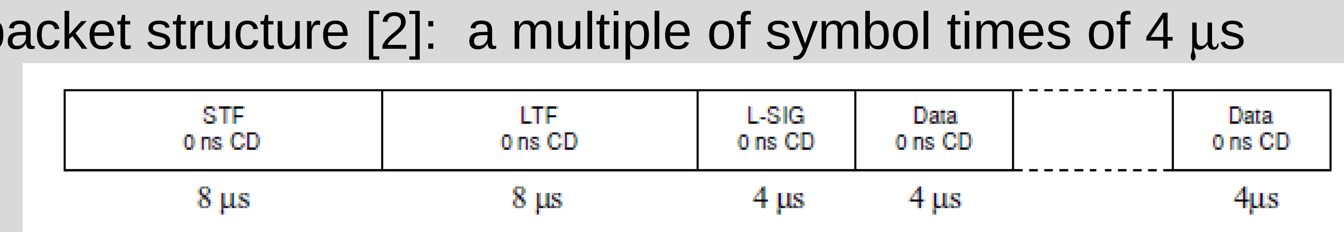

Fig 2. The packet frame structure in the standards of IEEE802.11a,g. The first three frames are header frames of WLAN, followed by the data frames. All transfers are a multiple of symbol times of 4 ms with a minimum length of 20 ms.

802.11n: an extension from 802.11a,g.

III. Request for Send/Clear for Send and other overheads in time

→ bursts of 20µs + Nx4µs with variable idle times (throughput ~50% max)

OFDM 'noise' at weather radar

Property / Input	Power [SNR]	Pulse power statistics	Doppler spectrum	Co-polar correlation
WLAN/RLAN	Anything, varies rapidly, bursts	Irregular	Flat	Variable
Precipitation	Anything, varies slowly	Rayleigh	Variably peaked	High
Thermal noise	A small constant (+/- 2dB)	Rayleigh	Flat	Zero

Table 1. Gross features of the OFDM interference, precipitation and thermal noise.

IV. Tests for a non-Rayleigh component in time series

- pulse-to-pulse checks for anomalous spikes (Ref. [7])
- χ^2-test for the hypothesis of Rayleigh distributed pulse powers

An operational approach:for each received channel and gate

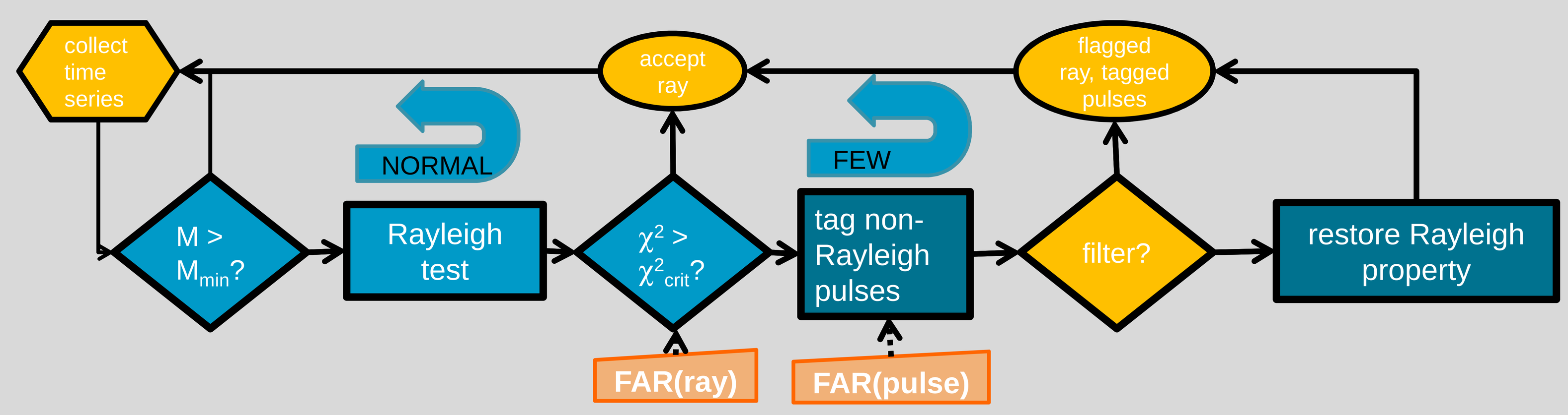

Fig 3. Block diagram for recognizing the presence of OFDM interference as a non-Rayleigh component in the received voltages squared. Subsequently, the anomalous pulses can be tagged. Optionally, the non-Rayleigh component can be filtered out in time domain. The objects "FAR(ray)" and "FAR(pulse)" indicate the configurable parameters in the method. Computationally, the loop "NORMAL" dominates in absence of interference.

Evaluations in laboratory and at radars

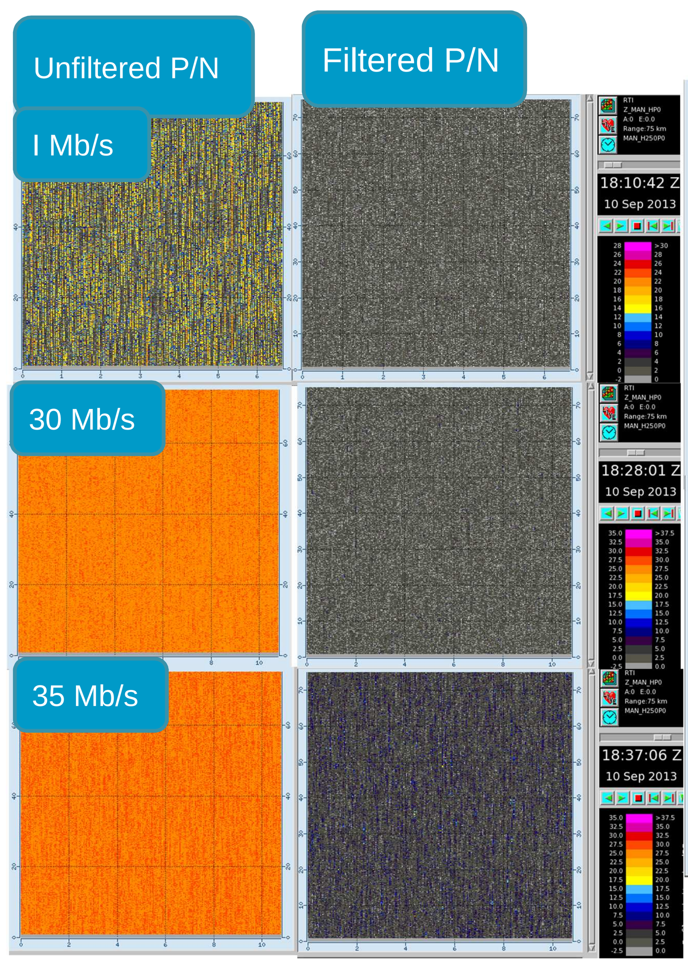

Fig 5. Range-time displays of the total sample powers (left) and sample powers, in which the non-Rayleigh components have been recognized and filtered out.

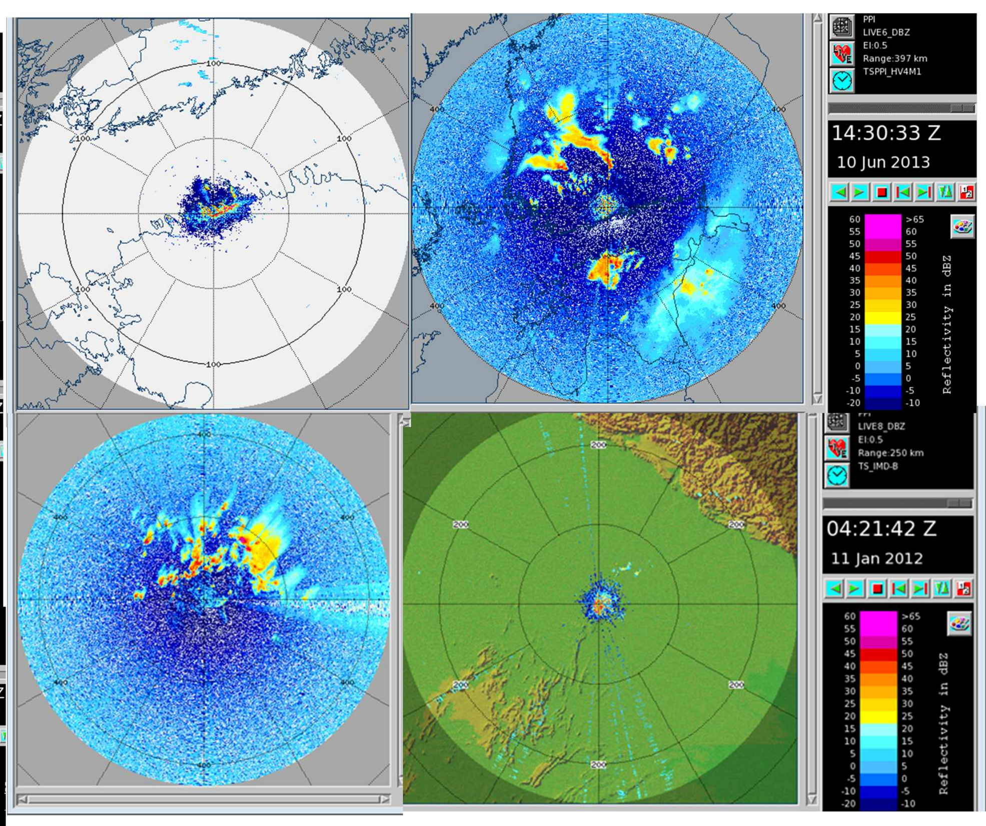

Fig 6. Field evaluations of the recognition and the filtering of radio interference based on Rayleigh testing. Top left: a case of persistent radio interference at the WRM200 radar in Harku, Estonia . Top right: a case of occasional weak interference at the WRM200 radar in Kerava, Finland. Bottom left: a case of known WLAN/RLAN interference at the WRM200 radar in Belo Horizonte, Brazil. Bottom right: a case of multiple aggressive radio interference at the WRK200 radar in New Delhi, India. The non-filtered powers are displayed in Figure 1.

V. Conclusions

- ✓ OFDM intereference are distinct from Rayleigh distributed precipitation echo and thermal noise;
- ✓ spikes in pulse time series can be recognized, flagged and removed in real-time;
- ✓ Rayleigh components appear recoverable within OFDM transmissions upto ~70% of the maximum throughput.

Bibliography

[1] IIEEE 802.11™ Wireless Local Area Networks, the Working Group for WLAN Standards http://www.ieee802.org/11/#.

[2] Paul Joe, John Scott, John Sydor, Andre Brandão and Abbas Yongacoglu (2005): Radio Local Area Networks (RLAN) and C-Band Weather Radar Interference Studies. *32nd AMS Radar Conference on Radar Meteorology.* Albuquerque, New Mexico.

[3] Miurel Tercero, Ki won Sung and Jens Zander (2011): Impact of Aggregate Interference on Meteorological Radar from Secondary Users. *IEEE WCNC 2011-Service and Application*, 2167-2172.

[4] Zoltán Horváth and Dávid Varga (2009): Elimination of RLAN interference on weather radars by channel allocation in 5 GHz band. *International Conference on Ultra Modern Telecommunications & Workshops*, (pp. 1-6).

[5] Laura C.Rojas, Dmitri Moisseev, V. Chandrasekar, Jason Sezler, Reino Keränen (2012): Dual-polarization spectral filtering for radio frequency interference suppression. *The seventh European Conference on Radar in Meteorology and hydrology.* Toulouse, France.

[6] Richard. van Nee, V.K. Jones, Geert. Awater, Allert. van Zelst, James Gardner and Greg Steele (2007): The 802.11n MIMO-OFDM Standard for Wireless LAN and Beyond. *Wireless Personal Communications* 37, pp. 445–453.

[7] Vaisala Oyj: RVP900™ Digital Receiver and Signal Processor, User's Manual ftp://ftp.sigmet.com/outgoing/manuals/

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