Coexistence of weather radars and telecommunication systems

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   1. Arpa Piemonte mobile radar
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## Introduction

### RFIs at C-band

- In-band emissions from HIPERLAN systems (*HI*gh *PE*rformance *Ra*dio *LAN*)
- Towers location available from Arpa database of electromagnetic sources
- In-field measurements to retrieve RFIs SSID.
- Method to identify the RFI sources. Check of standards requirements compliance.
- Time series analysis for RFI removal.

### RFIs at X-band

- Likely spurious emissions from 1.8GHz mobile communication systems
  - RFIs day-night pattern → Base Station radiated power
  - Towers location available from Arpa database of electromagnetic sources
  - Time series analysis show RFI duration comparable to LTE symbol duration
Introduction

- Frequency allocation defined in the International Telecommunication Union (ITU) radio regulations (latest version 2016).
- C-band weather radars widely used in Italy and Europe. These radars share the frequency spectrum with RLAN and WLAN, especially HIPERLAN systems.
- The 5GHz RLAN were authorized in the 5150-5350MHz and 5470-5725MHz band after World Radiocommunication Conference 2003 (WRC-03).
- Dynamic Frequency Selection (DFS) is a mandatory feature for WLAN/HIPERLAN systems to mitigate interferences with weather radars.

- No civil communication allowed in the 9300-9500MHz band.
- Spurious emissions defined from standards (e.g. 3GPP – LTE, Table 9.2.1.2.1-1)
Growth of HIPERLAN towers transmitting in Piemonte region (from Arpa database).

May 2018: about 1100 towers
C-band radar -0.1° elevation

PPI acquired the 9 December 2010 at -0.1° elevation from Bric della Croce radar (TO). The same radar scan, acquired after four year is reported in figure b. It is remarkable the interference increase.
PPI acquired the 9 December 2010 4.4° elevation from Bric della Croce radar (TO). The same radar scan, acquired after four year is reported in figure b. It is remarkable the interference increase.
C-band RFI Identification

Location of towers transmitting in the C-band (green points) and Bric della Croce radar (violet pentagon).

The figure shows the towers selected by the interference zones model:
1. Antennas pointing to the radar
2. Tower location is visible from the radar.

Amount of selected towers: 256

Focus on this particular tower.
C-band RFI Identification

Example of tower in optical visibility with Bric della Croce radar. During the 2015 in-field measurements with the Italian Ministry of Economic Development, comparing the SSID with the available information, these sources were found to interfere the Bric della Croce radar.
C-band RFI time series

Time series of \( I_h \) and \( I_v \) of the selected interference.
C-band RFI time series

1st row: $I_v$ vs $I_h$ and $Q_v$ vs $Q_h$ plots. Note that the data are distributed along the -45° slope line. The RFI source is slant polarized. Antennas slant polarization reduces interferences and increase performances in dense wireless environments.

2nd row: scattergram $I$ vs $Q$ for h-pol and v-pol. Unable to see any pattern.
X-band radar

Mobile radar used for research purposes. Currently located near Vercelli, 60km North-East of Turin
Operational frequency: 9.366GHz

RFIs started from 2014, continuously increasing.
Day-night pattern: RFIs received from approximately 6 a.m. to midnight
X-band RFI

Maximum of echoes received during a day (in colors) overlapped on the map.
The black dots represent the Base Station of a mobile operator transmitting the LTE 1.8GHz.
The lines represent the ray between the radar and the B.S.

Note that the radar range has been divided by 2.
X-band RFI – LTE signal

OFDM based signal. Basic unit in which data are transmitted is the LTE symbol with QAM, QPSK a CAZAC sequences as possible modulations. Total duration of the symbol is 71.3μs and 71.9μs for special symbols.

Down-link of the 1860-1880MHz LTE signal:
1.8732GHz x 5 = 9.366GHz which is the radar operating frequency

Maximum spurious level at X-band: -30dBm ETSI-TS 136 106 V10.0.0

This particular signal is not transmitted from midnight to 6 a.m. in the radar area.
X-band RFI – time series

Z (dBZ)

I_h (V)

km North

km East

pulse number

time (μs)
X-band RFI – time series

Scattergram $I$ vs $Q$ for $h$-pol and $v$-pol. Data distributed along a circle. Is this modulation comparable to LTE symbols?

$I_v$ vs $I_h$ and $Q_v$ vs $Q_h$ plots. Note that the data are distributed elliptically along the $-45^\circ$ slope line. Linearly polarized signal reflected by the environment surfaces during its path to the radar.

RFI duration: 71.7 $\mu$s
Reference Signals (RS) and Primary Synchronization Signals (P-SS) may be constructed from a **Constant Amplitude Zero AutoCorrelation** sequence named Zadoff-Chu sequence.

**ZC properties:**
1. Constant amplitude
2. Cyclic auto-correlation of each ZC sequence results in a single impulse at time offset zero.

1. RFI amplitude vary less than 5%;
2. RFI H-pol. autocorrelation is a single pulse at time lag zero.
DFW X-band radars network

Cleburne radar

Addison radar
DFW X-band radars network

DFW RFIs features:
- Few interferences received per day
- High time and spatial variability

What is the RFI source?

Could telecommunications affect CASA radars as Arpa X-band radar?

<table>
<thead>
<tr>
<th></th>
<th>f (MHz)</th>
<th>Uplink (MHz) (Mobile to Base)</th>
<th>Downlink (MHz) (Base to Mobile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>1800</td>
<td>1710.2 – 1784.8</td>
<td>1805.2 – 1879.8</td>
</tr>
<tr>
<td>North America</td>
<td>1900</td>
<td>1850.2 – 1909.8</td>
<td>1930.2 – 1989.8</td>
</tr>
</tbody>
</table>

No downlink communication allowed in the 1800MHz band.
Uplink of the LTE, user devices → low power.
Conclusions

**C-band** radar:
- Broadband internet access towers cause severe interferences
- I-Q data show high variability in the interference duty cycle
- SSID may help to identify the interference sources using the regional database of electromagnetic sources
- ITU standards compliance

**X-band** radar:
- Day-night pattern of the received interferences
- No in-band transmissions allowed → out-of-band or spurious emissions
- I-Q data analysis show high correlation due to artificial source. The polarization state (slant-pol) is widely used in mobile Base Stations.
- Likely due to 4G mobile communications
- In-field measurement to identify which are the interfering base stations.

First step of the enhanced RFI removal tool
Thank you!
Bibliography


Bibliography

• http://webgis.arpa.piemonte.it/campi_elettromagnetici_webapp/