Coherent Scatterers in Urban Areas: Characterisation and Information Extraction

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Method to detect coherent scatterers

Hamming

Unhamming

Sublooks

\[ f^{-1} \]

Correlation
**Test site: Dresden Germany**

**Baselines:**
- 10, 30, 40m
- Only 2 independent

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<table>
<thead>
<tr>
<th>RF-Band</th>
<th>X-Band</th>
<th>C-Band</th>
<th>S-Band</th>
<th>L-Band</th>
<th>P-Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF-centre frequency</td>
<td>9.6 GHz</td>
<td>5.3 GHz</td>
<td>3.3 GHz</td>
<td>1.3 GHz</td>
<td>450 MHz</td>
</tr>
<tr>
<td>Transmit peak power</td>
<td>2500 W</td>
<td>750 W</td>
<td>2 kW</td>
<td>400 W</td>
<td>200 W</td>
</tr>
<tr>
<td>Receiver noise figure</td>
<td>4.0 dB</td>
<td>4.0 dB</td>
<td>5 dB</td>
<td>8.5 dB</td>
<td>4.0 dB</td>
</tr>
<tr>
<td>Antenna gain</td>
<td>17.5 dB</td>
<td>17 dБ</td>
<td>16 dБ</td>
<td>15 dБ</td>
<td>12 dБ</td>
</tr>
<tr>
<td>Azimuth beamwidth</td>
<td>17°</td>
<td>19°</td>
<td>12°</td>
<td>18°</td>
<td>30°</td>
</tr>
<tr>
<td>Elevation beamwidth</td>
<td>30°</td>
<td>33°</td>
<td>32°</td>
<td>35°</td>
<td>~ 60°</td>
</tr>
<tr>
<td>Antenna Polarization</td>
<td>H and V</td>
<td>H and V</td>
<td>H and V</td>
<td>H and V</td>
<td>H and V</td>
</tr>
<tr>
<td>IF-centre frequency</td>
<td>300 MHz</td>
<td>300 MHz</td>
<td>300 MHz</td>
<td>300 MHz</td>
<td>300 MHz</td>
</tr>
<tr>
<td>Max. Signalbandwidth</td>
<td>100 MHz</td>
<td>100 MHz</td>
<td>100 MHz</td>
<td>100 MHz</td>
<td>50 or 18 MHz</td>
</tr>
<tr>
<td>System bandwidth</td>
<td>120 MHz</td>
<td>120 MHz</td>
<td>120 MHz</td>
<td>100 MHz</td>
<td>60 or 25 MHz</td>
</tr>
</tbody>
</table>
HH Polarisation

Pauli Decomposition

RGB-Coding
HH-VV
2HV
HH+VV
Coherent Scatterers in the Pauli basis
Polarimetry

Entropy

Alpha angle

Polarimetric entropy

Polarimetric alpha angle

- Surface
- Dipol
- Dihedral

Normalised histogram

Entropy

Alpha angle (degrees)
Orientation angle estimation

Cameron's Decomposition

Degree of Symmetry

LOS orientation of the symmetry axis
Orientation angle estimation
(Cameron's Decomposition)

\[
[S] = \begin{bmatrix}
S_{HH} & S_{HV} \\
S_{VH} & S_{VV}
\end{bmatrix} = \begin{bmatrix}
a + b & c \\
c & a - b
\end{bmatrix}
\]

\(a, b, c = \text{Pauli components}\)

Two symmetric contributions:

\[
[S] = A \left( \cos(\tau)[S_{\text{max}}^{\text{sym}}] + \sin(\tau)[S_{\text{min}}^{\text{sym}}] \right) \quad 0 \leq \tau \leq \pi / 4 \quad A = \text{Total power}
\]

Maximum symmetric component:

\[
[S_{\text{sym}}^{\text{max}}] = a[S_a] + \epsilon[S_b] = a \begin{bmatrix}
1 & 0 \\
0 & 1
\end{bmatrix} + \epsilon \begin{bmatrix}
1 & 0 \\
0 & -1
\end{bmatrix}
\]

\(\epsilon = b \cos(\theta) + c \sin(\theta)\)

Maximizing the symmetric component:

\[
\tan(2\theta) = \frac{bc^* - b^*c}{|b|^2 - |c|^2}
\]

Degree of symmetry:

\[
DoS := \cos(\tau) = \frac{|a|^2 + |\epsilon|^2}{|a|^2 + |b|^2 + |c|^2}, \quad 0 \leq DoS \leq 1
\]

Orientation angle:

\[
\psi_a = -\theta / 2
\]
Histograms of the degree of symmetry and orientation angle of CSs

surface: $0 < \alpha < 30$  
dipol: $42 < \alpha < 48$  
dihedral: $70 < \alpha < 90$
Oberpfaffenhofen Dihedral Experiment

Dihedral Size:
Vertical: 80 x 80 cm
Horizontal: 80 x 80 cm

Orientation of first dihedral: 0°
Orientation of second dihedral: 5°
Oberpfaffenhoffen CSs Detection

RGB-Coding
Dihedral
Dipol
Surface
**Dihedrals Parameters Estimation**

Estimated orientation of first dihedral: $-10.21^\circ$

Estimated orientation of second dihedral: $-6.181^\circ$

Degree of Symmetry: $\text{DoS} = 0.994$

Dielectric constant: $\varepsilon_g \rightarrow \infty$

Shh/Svv = 0.978

Orientation difference: $\psi_{a2} - \psi_{a1} = 4.03^\circ$
L and X-Band CSs Comparison

DRESDEN

L-Band

X-Band

Polarization: VV
$L$- and $X$-Band CSs detected in VV polarization

$L$-Band

Number of CSs: 184.673

$X$-Band

Number of CSs: 78.581
Common CSs to L- and X-Band in VV polarization

Number of common CSs: 13.297
Number of Surface CSs: 2.230
Number of Dipol CSs: 1.329
Number of Dihedral CSs: 3.687
OBERPFAFFENHOFEN

L-Band

X-Band

Polarization: VV
L- and X-Band CSs detected in VV polarization

Number of CSs: 19.513

Number of CSs: 4.040
Common CSs to L- and X-Band in VV polarization

Number of common CSs: 1.116
Number of Surface CSs: 570
Number of Dipol CSs: 61
Number of Dihedral CSs: 124
Dresden Histograms

X-band amplitude histograms

Polarimetric entropy histograms

Alpha angle histograms
Oberpfaffenhofen Histograms

X-band amplitude histograms

Polarimetric entropy histograms

Alpha angle histograms
Conclusions

Coherent Scatterrs (CS’s) are strongly polarised (low entropy scatterers). Therefore: (S-Matrix) Polarimetry plays an key role in characterisation and information extraction.

The availability of the full scattering matrix allows (examples):

1. to increase the density of detected CSs (up a factor of 10).
2. the estimation of the Line of Sight (LOS) Orientation of coherent scatterers.
   - Line of Sight (LOS) Orientation estimation - by using Camerons approach - has been demonstrated over the Dresden test site and validated in terms of a controlled dihedral-CR experiment.
   - Dihedral CSs show, in general, a strong orientation behavior while dipoles and surface like CSs have a wider orientation distribution.
3. the estimation of the dielectric properties of coherent scatterers.
   - Dielectric constant (DC) estimation has been demonstrated on dihedral scatterers (light posts).

The CSs in X- and in L-band have been compared:

- More CSs (in general) have been detected at L-band than at X-band (using the same thresholds).
- Only very “ideal” CSs are common in X- and in L-band (in their majority dihedrals scatterers).