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Impact of Effective Antenna Pattern on Radio Frequency Exposure Evaluation for 5G Base Station with Directional Antennas

Kamil Bechta, Christophe Grangeat, Jinfeng Du

Scope of the presentation

1. Extrapolation of the EMF exposure from mMIMO antennas according to IEC 62232
2. What do nominal and effective antenna pattern mean?
3. Accuracy of the EMF extrapolation factor based on simulations
4. Accuracy of the EMF extrapolation factor based on closed-form formula
5. Conclusion & recommendations

Extrapolation of the EMF exposure from mMIMO antennas according to IEC 62232

Section B.5.5 Extrapolation for massive MIMO and beamforming BS

In new technologies like LTE-TDD and NR different signals can be transmitted on different beams. The power, gain, steering direction, beam shape and polarization plane of the different beams may vary over time.
The measurement of a stable reference signal, called broadcast signal, transmitted independently of the traffic load and user behaviour (e.g. CRS in LTE or SSS in NR BS), two EIRP envelopes shall be known for implementing the corresponding extrapolation methods. In general these two EIRP envelopes are functions of the azimuth ϕ and elevation θ angle and depend on the configuration of the cell:

- The first EIRP envelope is the EIRP envelope of the broadcast signal. It is defined as the maximum EIRP due to the broadcast signal for all beams which are used to transmit the broadcast signal. For the EIRP envelope of the broadcast signal it is assumed that all resource elements of the complete resource grid transmit the same power as a resource element which is indeed transmitting a part of the broadcast signal;
- The second EIRP envelope is the EIRP envelope of all signals. It is defined as the maximum EIRP due to all signals for all beams which may be used to transmit all signal types. This EIRP envelope describes the configured maximum EIRP as a function of the azimuth and elevation angle.

The ratio of the EIRP envelope of all **traffic beams** to the EIRP envelope of the **broadcast signal** at a given azimuth and elevation angle is the **extrapolation factor** F_{extBeam} at this azimuth and elevation angle.

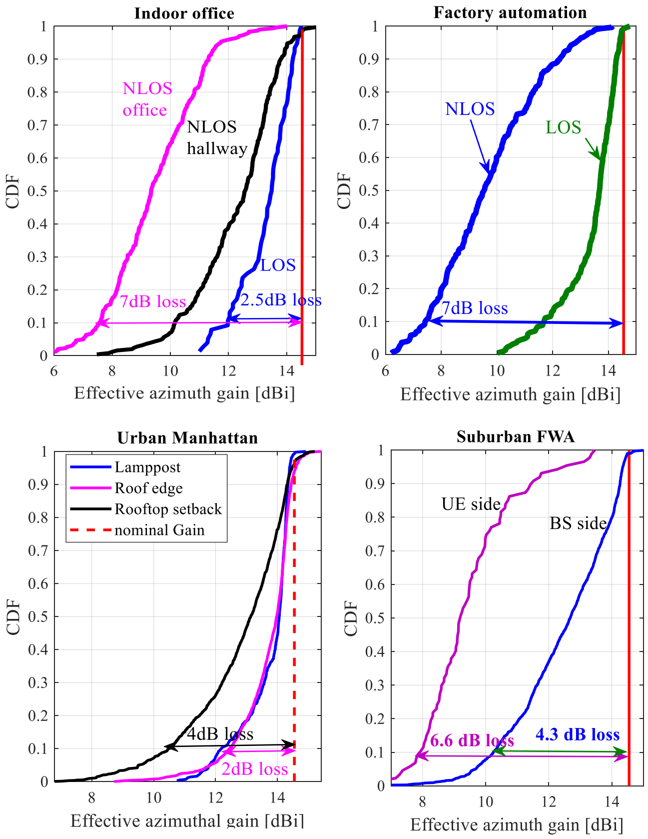
What do nominal and effective antenna pattern mean?

With increasing number of antenna elements (N) in the array **the nominal** gain ($g_{max}{}^{Nom}$) of the antenna array, as measured in anechoic chamber, increases and the half-power beam-width (B_{ho}, B_{vo}) decreases.

$$g_{\max}^{Nom} = \frac{2}{B_{ho} \cdot B_{vo}} = N \cdot G_e$$

In scattering environment, the maximum realizable **effective** antenna array gain (g^{Eff}) , the effective beam pattern and its associated half-power beam-width differ from nominal values. Difference between the nominal and the effective patterns in the radio channel with scattering depends on the angular spread introduced by the real deployment scenarios.

$$g^{Eff}(\phi_0,\theta_0) = \int_{-180^\circ}^{180^\circ} \int_{0^\circ}^{180^\circ} g^{Nom}(\phi,\theta) \cdot p(\phi-\phi_0,\theta-\theta_0)\, d\phi d\theta$$



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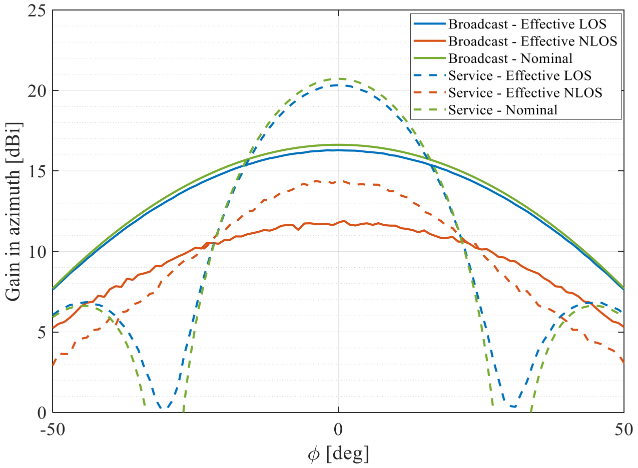
Accuracy of the EMF extrapolation factor based on simulations

Comparison of extrapolation factor for nominal and effective antenna patterns

Parameter	Value
Channel model	3GPP Urban Macro
Frequency [GHz]	3.5
Broadcast/signaling beam	
Nominal gain [dBi]	20.8
Horizontal HPBW [°]	58
Vertical HPBW [°]	6.6
Service/traffic beam	
Nominal gain [dBi]	16.7
Horizontal HPBW [°]	24
Vertical HPBW [°]	6.6

Simulation assumptions



Simulation results of nominal and effective antenna patterns of broadcast and service beams

Beam type	Nominal max gain [dBi]	Simulated effective max gain [dBi]	
		LOS	NLOS
Broadcast/signaling	16.7	16.3	11.9
Service/traffic	20.8	20.4	14.5
Approximated extrapolation factor [dB]	**4.1**	**4.1**	**2.6**

Maximum antenna gains and approximated extrapolation factor according to statistical simulations

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Accuracy of the EMF extrapolation factor based on closed-form formula

Comparison of extrapolation factor for nominal and effective antenna patterns

The effective antenna pattern is assumed to be convolution of two gaussian signals, i.e. nominal antenna pattern with variance indicate by B_{ho}^2, B_{vo}^2 and PAS with variance indicated by σ_h^2, σ_v^2 , where σ_h is RMS azimuthal angular spread and σ_v is RMS elevation angular spread, respectively, in given propagation environment. The resulting effective antenna pattern is also gaussian signal with variance indicated by $B_{ho}^2 + \sigma_h^2$ and $B_{vo}^2 + \sigma_v^2$ .Therefore, the maximum effective antenna gain can be determined by following formula:

$$g_{\max}^{Eff} = \frac{2}{\sqrt{B_{h0}^2 + \sigma_h^2} \cdot \sqrt{B_{v0}^2 + \sigma_v^2}}$$

Beam type	Nominal max gain [dBi]	Simulated effective max gain [dBi]	
		LOS	NLOS
Broadcast/signaling	16.7	16.4	13.8
Service/traffic	20.8	19.5	15.9
Approximated extrapolation factor [dB]	**4.1**	**3.1**	**2.1**

Maximum antenna gains and approximated extrapolation factor according to closed-form formula calculations

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Conclusion & recommendations

- The maximum effective antenna gain in realistic propagation environment is lower than maximum nominal antenna gain measured in anechoic chamber or ideal free space conditions
- Difference between nominal and effective gains depends on the scattering intensity in the radio channel between transmitting antenna and the point of investigation and is noticeable especially in case of NLOS conditions
- The analysis has been performed using a representative commercially available antenna for which the ratio of service beam gain and broadcast beam gain has been calculated
- EMF exposure extrapolation factor defined by IEC for mMIMO and beamforming antennas can be overestimated by 1.5 dB to 2.0 dB for NLOS conditions, and assumed simulation parameters, if nominal antenna patterns are used instead of effective antenna patterns
- It is important to consider using the effective antenna gains in extrapolation factor to reduce overestimation of RF exposure

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Thank you!