Modelling Inter-Floor Radio-Wave Propagation in Office Buildings

A. C. M. Austin*, M. J. Neve and G. B. Rowe

Department of Electrical and Computer Engineering
The University of Auckland, Auckland, New Zealand

Motivations

- Performance and capacity of wireless systems limited by interference
- Interfering power levels are heavily influenced by the environment
- Propagation in indoor environments is not well understood
- Coverage/interference prediction tools are required

How does the energy travel between the floors?

and

How can we model this behaviour?

Features of a Desirable Solution

- Deterministic Electromagnetic basis
- Explains experimental results
- Transportable (i.e. can be used in other buildings)
- Provide a basis on which to build approximate, yet reliable/efficient models for system design purposes

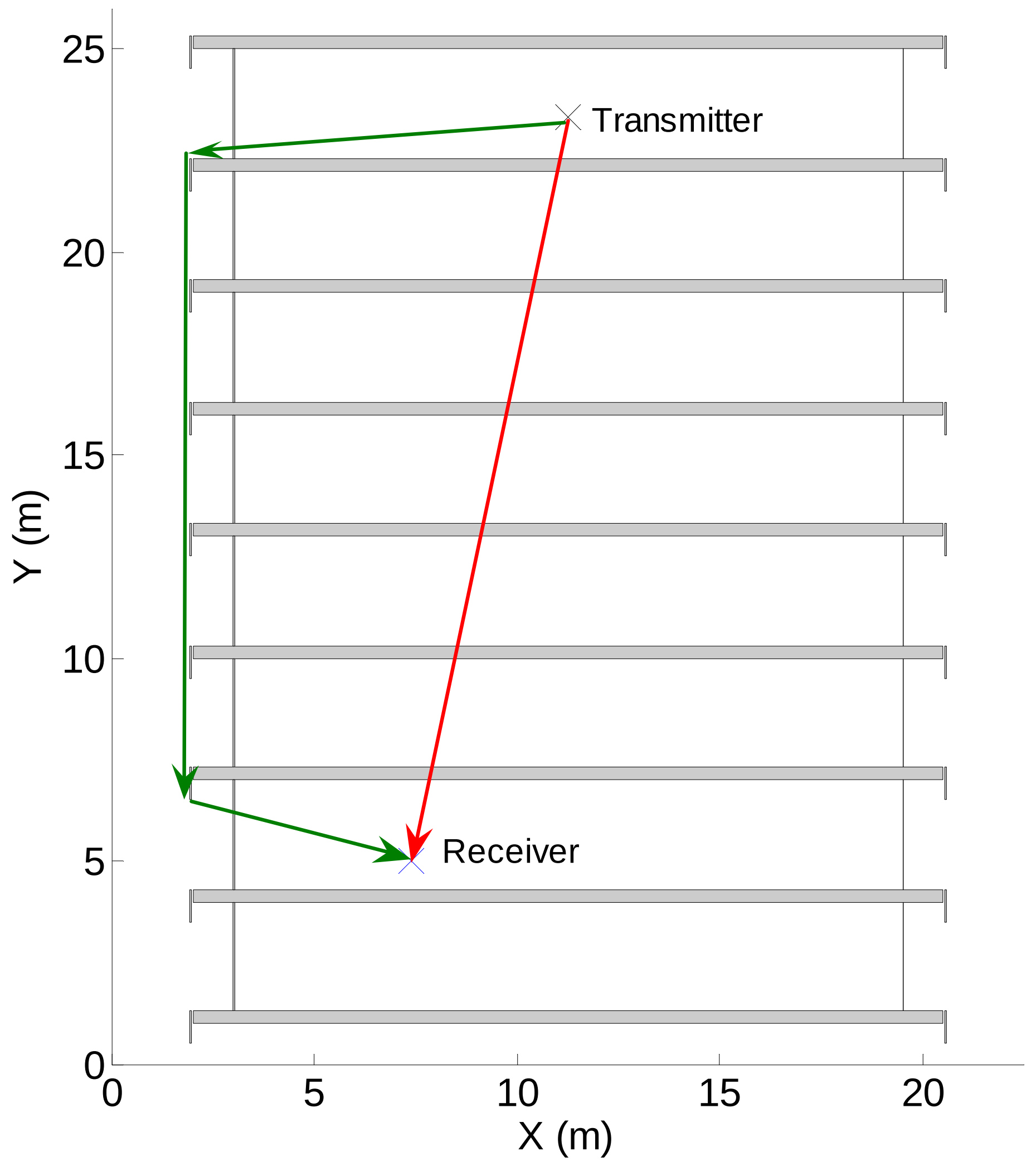
Identifying the Mechanisms

- A 2D implementation of the Finite-Difference Time-Domain algorithm is used to determine the mechanisms governing inter-floor propagation
- A vertical slice through the problem is analysed at 1.0GHz for TM polarization
- The concrete floors are modelled as dielectric slabs:
  - $\varepsilon_r = 6.0$
  - $\sigma = 50$ mS/m
  - Floor thickness: 0.30 m
  - Floor-ceiling separation: 2.70 m
- External building features, e.g. windows and hanging panels have also been modelled

Inter-Floor Propagation

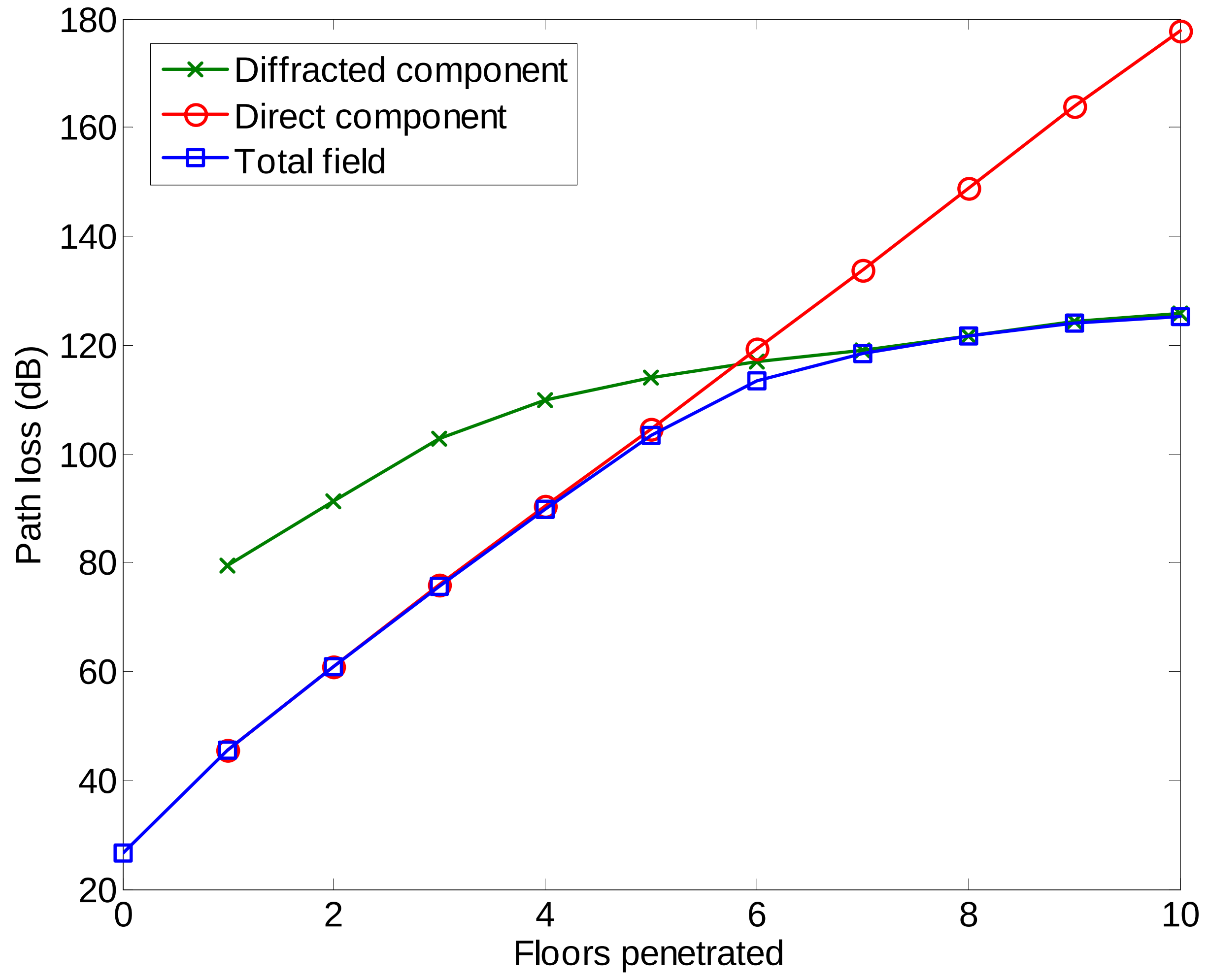
- Results show two propagation paths: Direct Penetration and Floor-Edge Diffraction
- A simple mechanistic model takes both components into account

What level of accuracy will this model provide?



Results – 1.0 GHz TM$_z$ Polarization

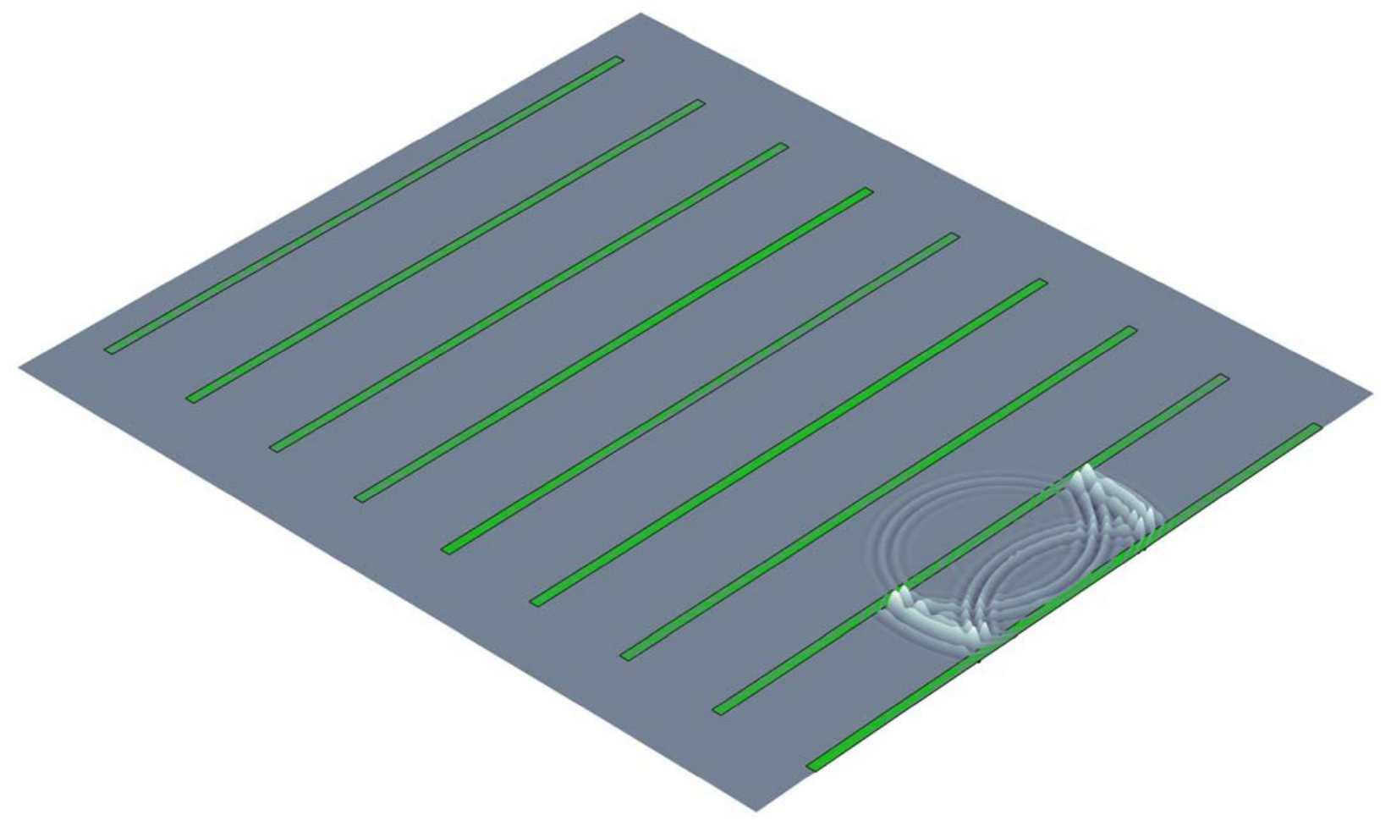
- The received power is averaged across small sectors to remove multipath fading



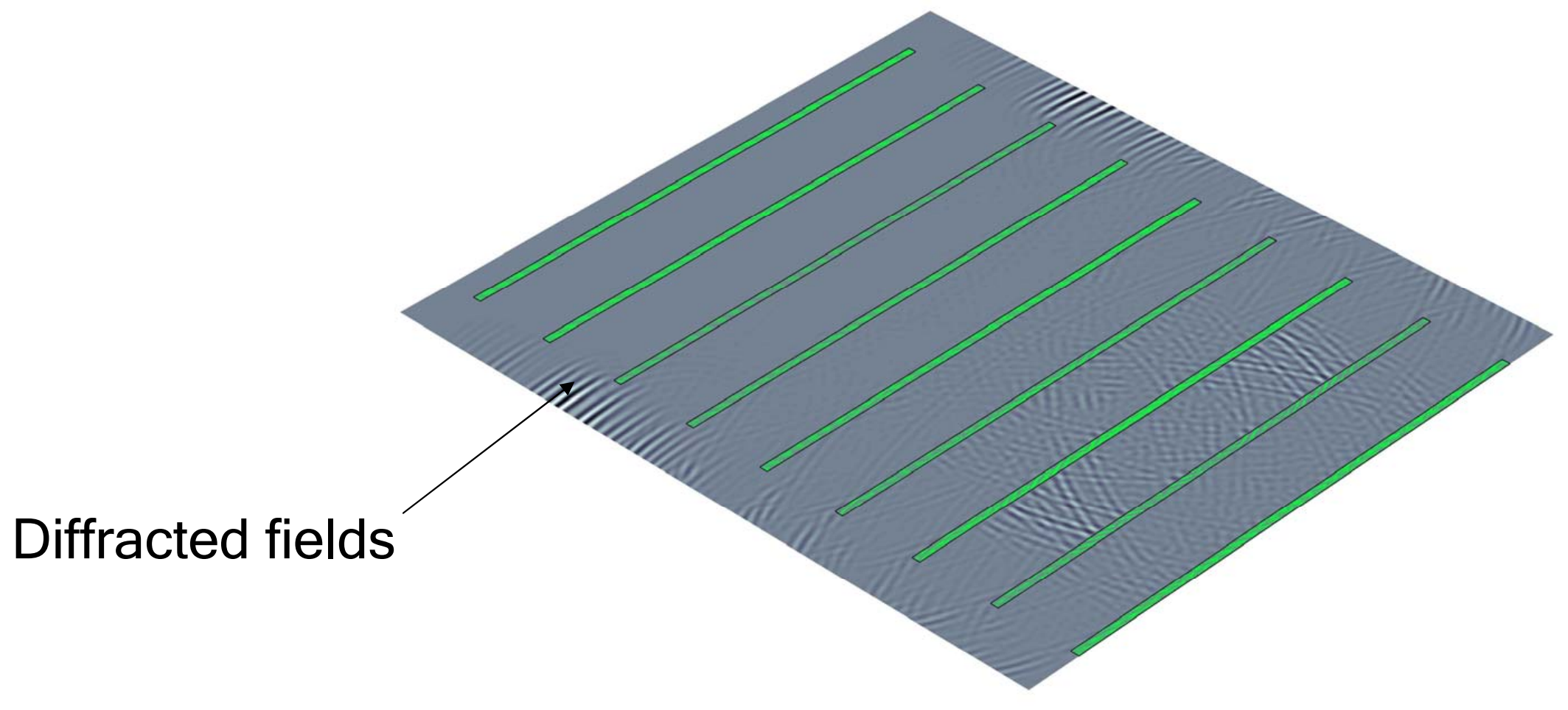
- Diffraction dominates the total power after 5-6 floor penetrations
- This finding agrees well with previously unexplained experimental results

Visualisation

- The lattice is excited with a modulated Gaussian pulse, and the wave fronts observed

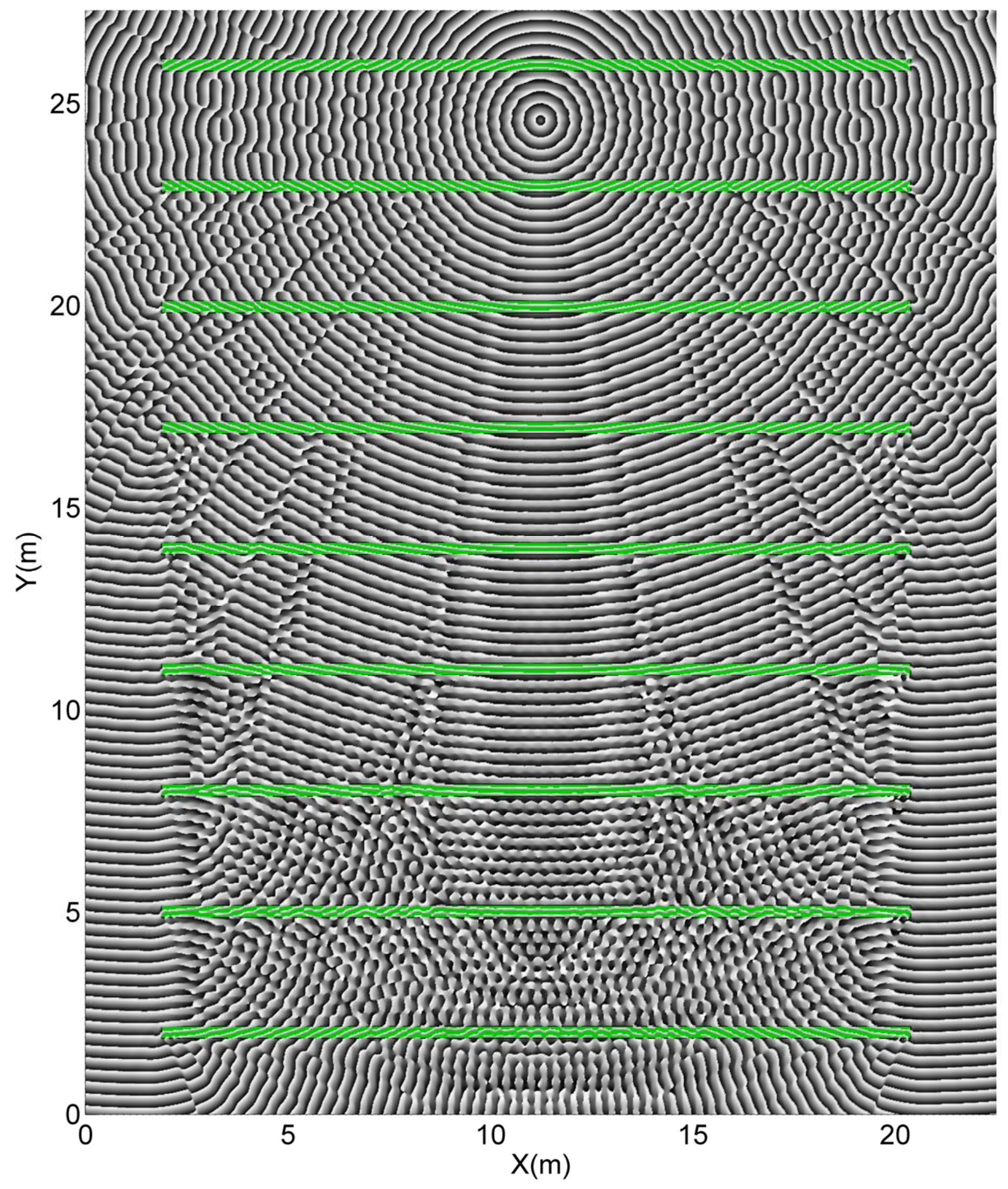


(a) Re(E_z), t = 8.3ns



(b) Re(E_z), t = 100ns

- The steady-state electric field phase at 1.0GHz is extracted with a Fourier transform

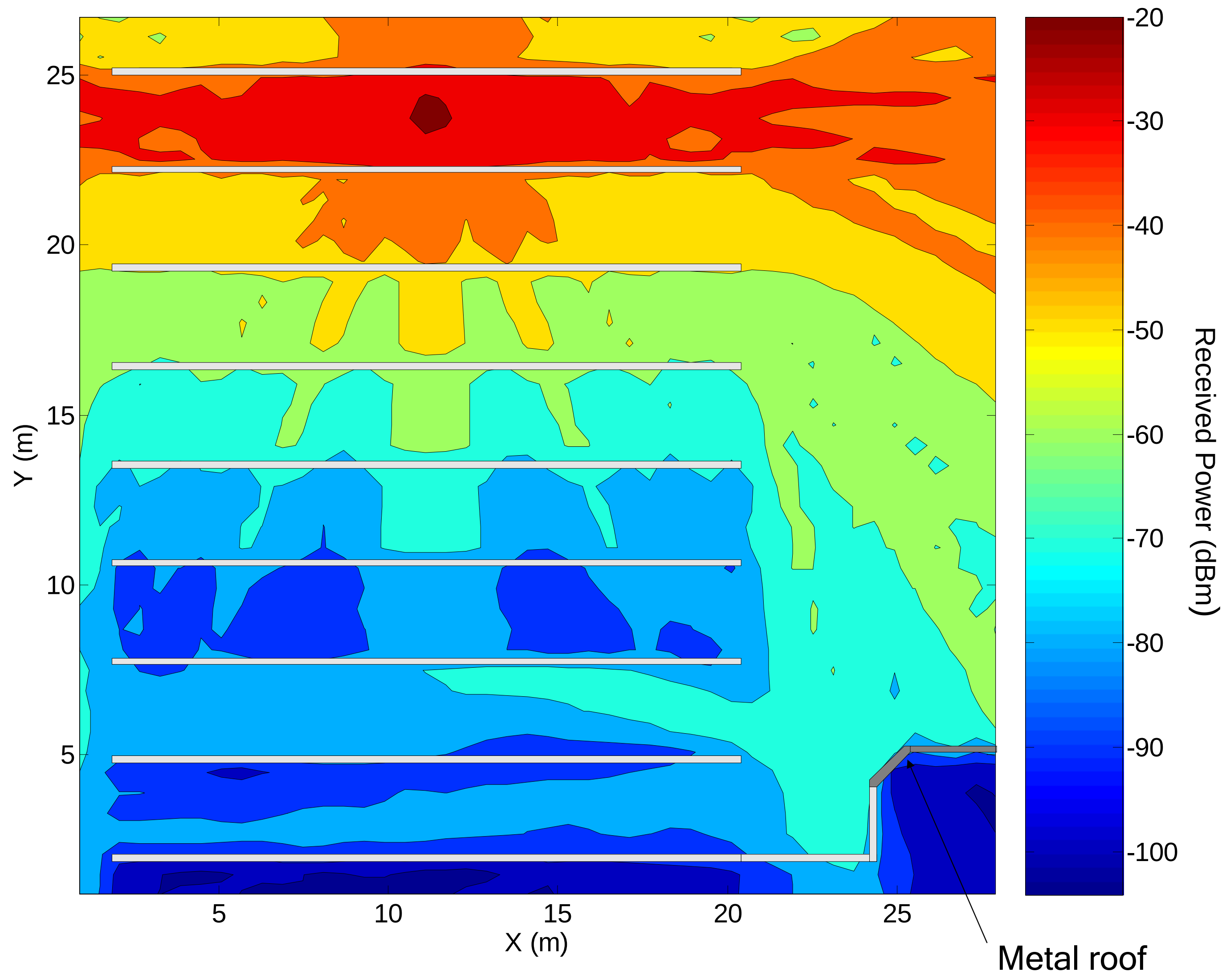


Steady-state electric field phase

- The curvature of the steady-state electric field phase remains centred on the source point for < 6 floor penetrations
- Diffraction at the floor edges is clearly visible after 5 floor penetrations

Effects of Nearby Buildings

- Nearby buildings can reflect significant levels of power back onto lower floors
- The increase is up to 22 dB over the case where no nearby building is present



Sector-averaged received power (dBm)

- Results suggest external reflection offers a low loss propagation mechanism

Mechanistic Model

FDTD results suggest:

- The direct component can be modelled as free space with an appropriate (linear) floor attenuation factor

$$P_{\text{direct}} = P_{\text{free space}} + N \cdot FAF \quad \text{(dB)}$$

- The diffracted component is best modelled by multiple diffraction at the floor edges
- Initial results suggest an additional distance dependency term of:

$$20\log_{10}\left(\frac{1}{N+1}\right) \quad \text{(dB)}$$

Conclusions

- Direct penetration through the floors dominates the total received power for less than five floor penetrations
- The dominant mechanism changes to diffraction after six floor penetrations
- Results suggest a simple two-component model will be appropriate to predict area coverage
- Nearby buildings must also be considered, as preliminary results show the received power can be increased by 22 dB