Zaggoulos, G., Doufexi, A., & Nix, A. R. (2007). WiMAX system performance in highly mobile scenarios with directional antennas. In IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications, 2007 (PIMRC 2007) , Athens. (pp. 1 - 5). Institute of Electrical and Electronics Engineers (IEEE). 10.1109/PIMRC.2007.4394335

# WIMAX SYSTEM PERFORMANCE IN HIGHLY MOBILE SCENARIOS WITH DIRECTIONAL ANTENNAS

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## Presentation Outline

- Wireless Communications and Mobility
- Challenges and Limitations
- Proposed Solution to Increase Mobility
- Conclusions

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# Wireless Communications and Mobility

- Wireless Market Demands:
  - Faster Connections (Higher Transfer Rates)
  - Increased Availability of Service (Geographically)
  - Service that supports Highly Mobile users
- Wireless Services Available:
  - Mobile Telephony – 2G/3G
  - WiFi
  - WiMAX

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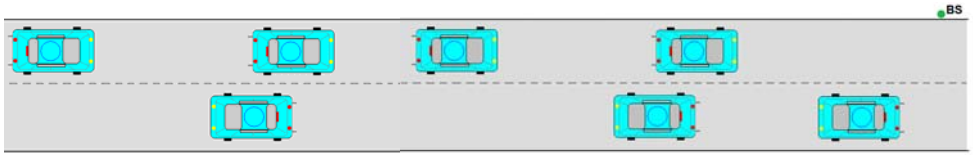
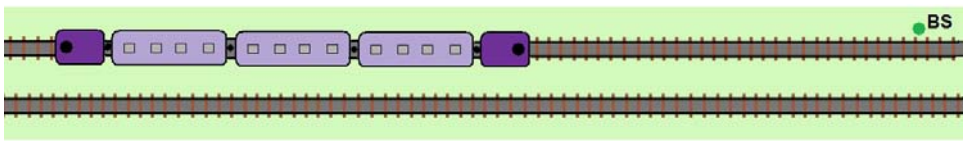
# High Mobility Users Include:

- Vehicles moving at high-speeds on motorways




- High-Speed Trains moving along fixed tracks




- Rally cars with rapid acceleration and braking

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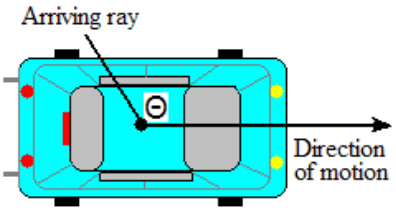
# Mobility Limitation

- How can WiFi and WiMAX technologies support users travelling at high speeds without increased Signal Processing?

- Higher Doppler Shifts:
  - Increase Channel Fading
  - Reduce Coherence Time
  - Introduce Aging Problem

$$f_\theta = f_m * \cos(\theta)$$

$$f_m = u / \lambda$$




$f_m$: *Max. Doppler Shift*
$u$ : *Mobile speed*
$\lambda$ : *Carrier Wavelength*

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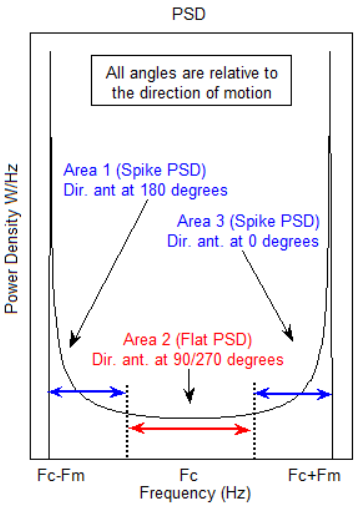
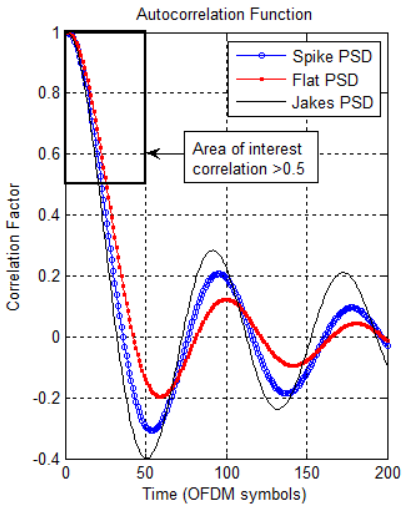
# Power Doppler Profile and Coherence Time




- Coherence Time

$$R(\tau) = FT^{-1}\{S(f)\}$$

$$T_c = \frac{\lambda / 2}{u} = \frac{0.5}{f_m}$$

- Coherence time is relatively insensitive to the shape of the Power Doppler Profile, but strongly related to the rms Doppler Spread.
- For antennas with a front-to-back ratio of 12 dB or higher, signals outside the main beam do not affect the coherence time.

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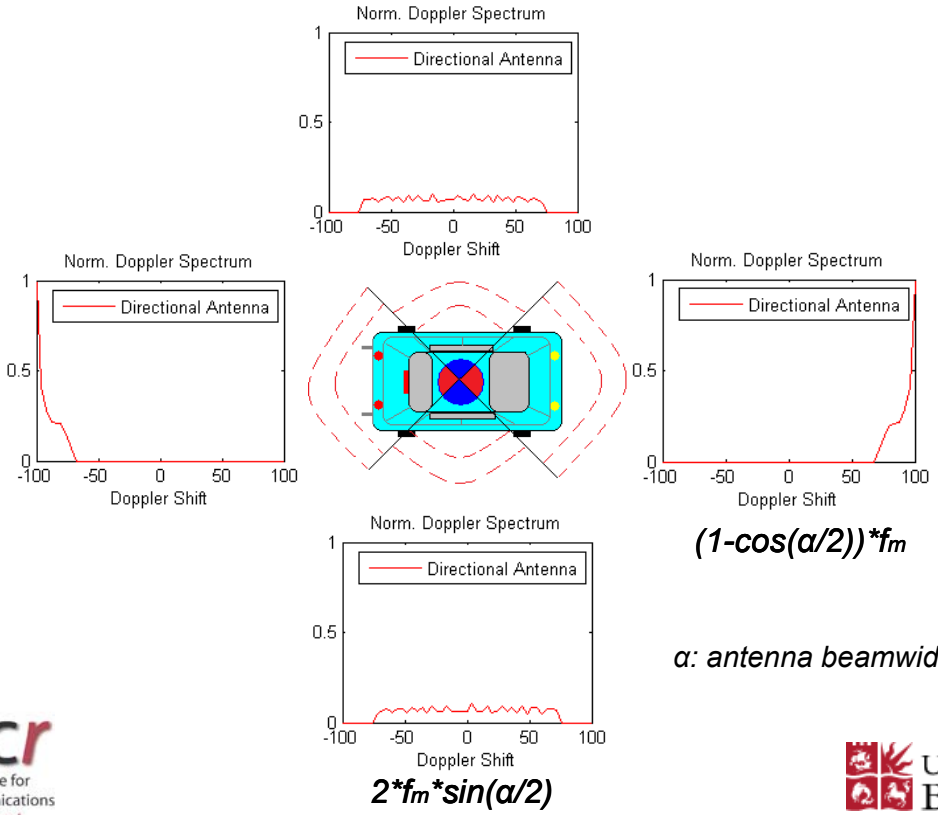
# Can Directional Antennas Increase Mobility?

- Directional Antennas are used as Spatial Filters
- When correctly aligned, Directional Antennas offer:
  - Enhanced Signal Levels,
  - Reduced Doppler Spread,
  - Reduced Delay Spread,
  - Reduced Co and Adjacent Channel Interference.





# Proposed Solution



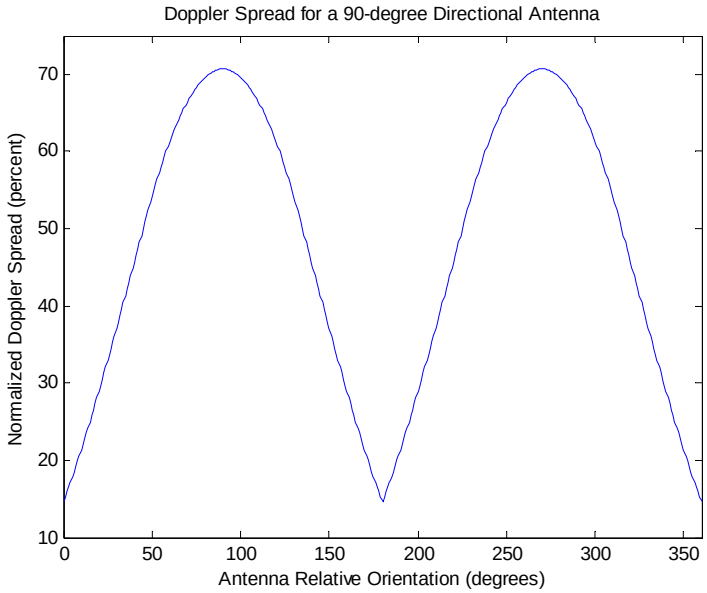

$(1-\cos(\alpha/2))*f_m$

$\alpha$: antenna beamwidth

$2*f_m*\sin(\alpha/2)$

# Proposed Solution

Doppler reduction with a 90 degree sector

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# Simulation Parameters

802.16-2004 PHY-Layer simulator parameters:

| | |
|---|---|
| Operating Frequency | 3.5 GHz |
| Bandwidth | 5 MHz |
| FFT Size | 256 |
| Useful Sub-carriers | 192 |
| Guard Interval Length | 64 |
| Sub-carrier Spacing | 22.5 kHz |
| Useful Symbol Duration | 44.4 μs |
| Total Symbol Duration | 55.5 μs |
| Channel Coding | Punctured 1/2 rate convolutional code, constraint length 7, $\{133,171\}_{octal}$ |
| Mode | BPSK ½ |

Channel Parameters

| | Tap 1 | Tap 2 | Tap 3 |
|---|---|---|---|
| K-factor | 0 | 0 | 0 |
| Delay (ns) | 0 | 500 | 1000 |
| Power (dB) | 0 | -10 | -20 |
| Max. Doppler Spread (Hz) | 450 | 450 | 450 |
| PSD | Jakes | Jakes | Jakes |

Frame Structure

| | | | | |
|---|---|---|---|---|
| Preamble | Data 1 | Data 2 | Data 3 | Data 4 |

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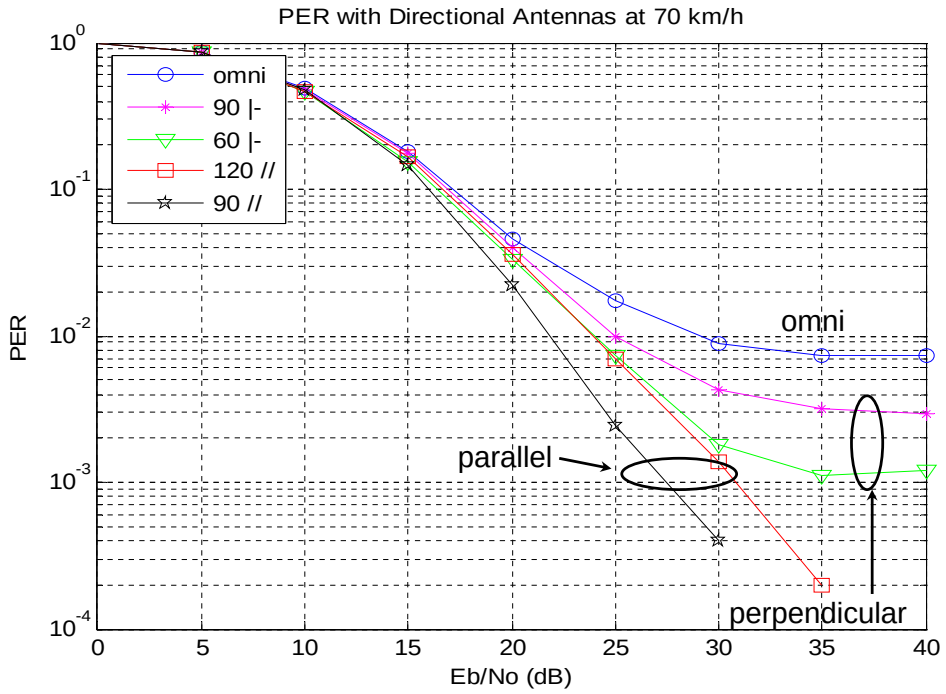
# Simulation Results 70 km/h

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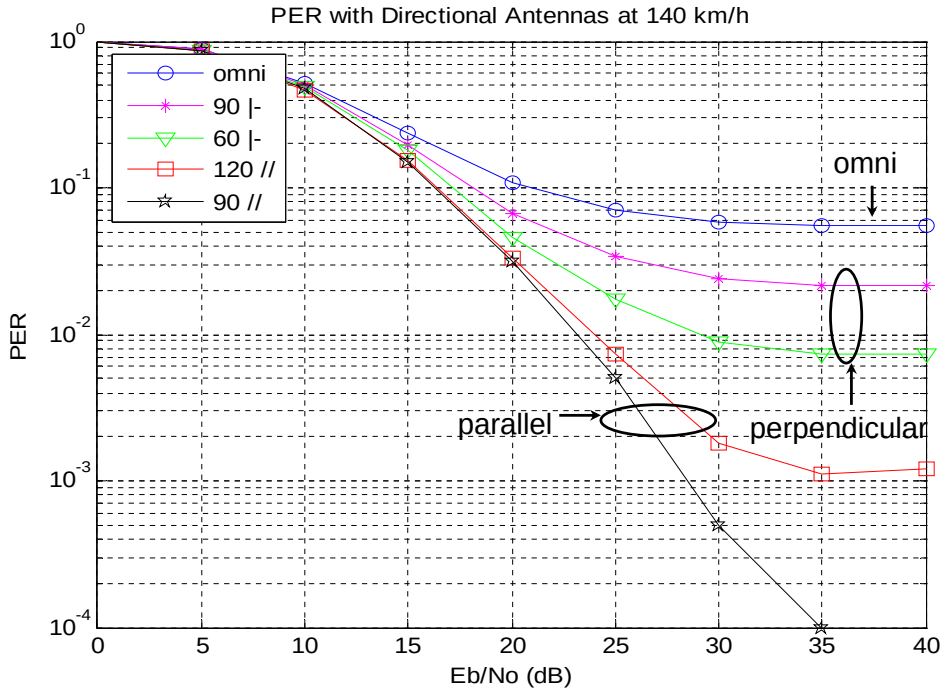
# Simulation Results 140 km/h

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# Conclusions

- Performance is relatively insensitive to the shape of the Power Doppler Profile, but strongly related to the value of the rms Doppler Spread.
- The use of directional antennas (aligned parallel to the direction of motion) improves performance without the need for increased digital signal processing.
- Antennas with at least a 12 dB front-to-back ratio result in a channel coherence time that is independent of the side lobe structure.

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# Questions?

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