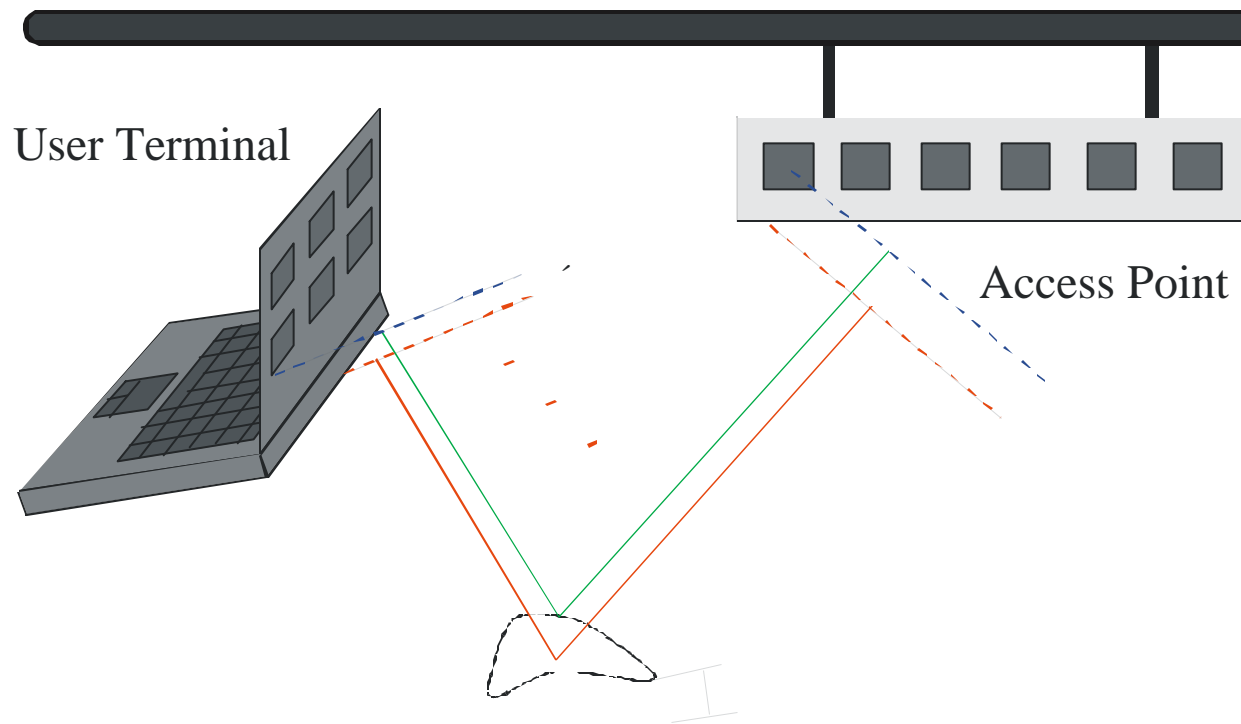


Gbit/s over radio

- Not without MIMO (Multiple-Input Multiple Output)

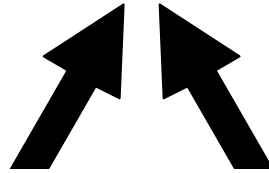


Beware: $\text{MIMO} > \text{SIMO} + \text{MISO}!$

Benefits of MIMO

Array Gain

- increase power
- beamforming



But will the propagation channel support
what you devise?



**Spatial
Multiplexing**

- multiply data rates
- spatially orthogonal channels

Diversity

- mitigate fading
- space-time coding

Exploit the spatial domain!

Propagation is at the heart of any wireless system;
it sets the ultimate limits for other fields of communications engineering

A Myth

~~„The unpredictable wireless channel“~~

?

Mäihonen et al., “Hop-by-Hop Toward Future Mobile Broadband IP”,
IEEE Communications Magazine, Vol. 42, March 2004

What channel model would the systems engineer like to have?

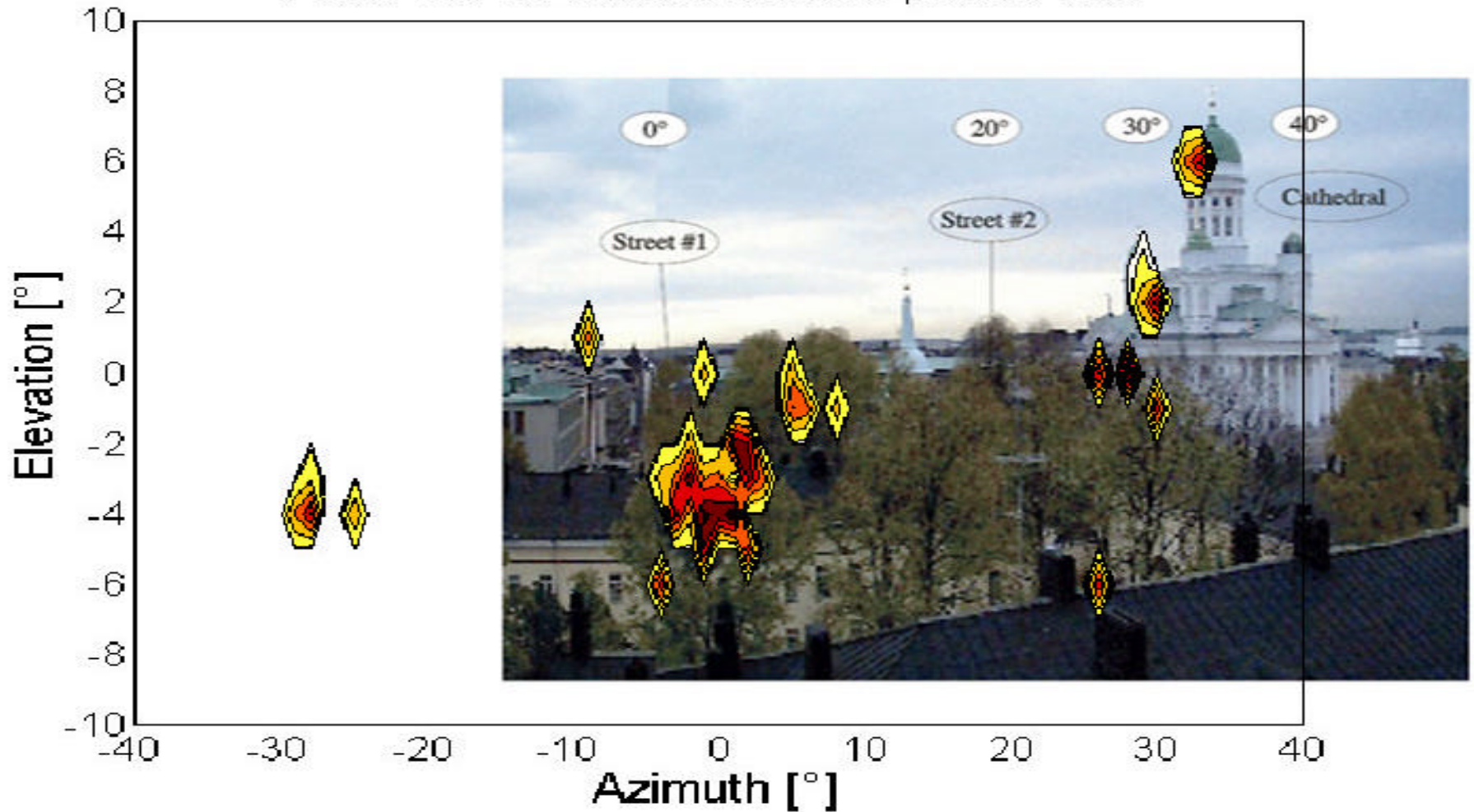
“AWGN”

But...

We need to know **spatial** properties of the channel!

Channel „Photograph“ at 15 cm Wavelength

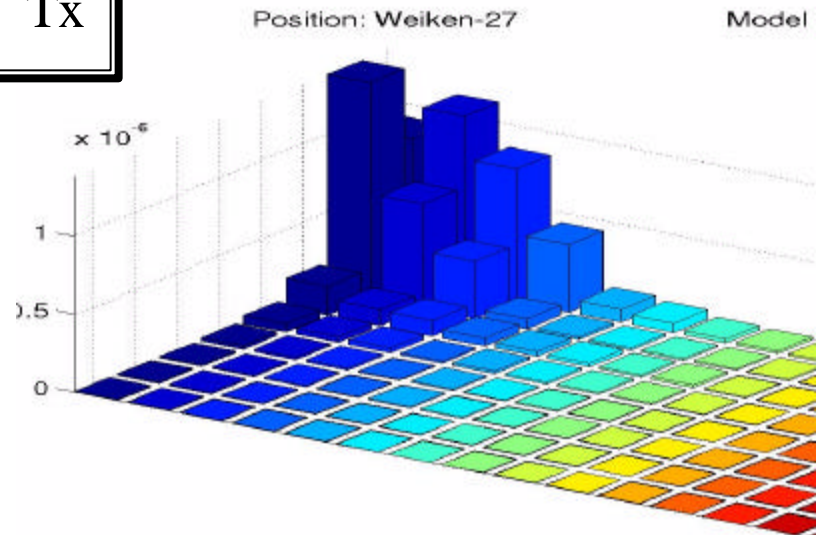
Power over the Azimuth-Elevation-plane of TX 3



Weichselberger Model

- Eigenmode description of MIMO channel
- will turn a MIMO measurement campaign into a meaningful ensemble of MIMO channel matrices for system design

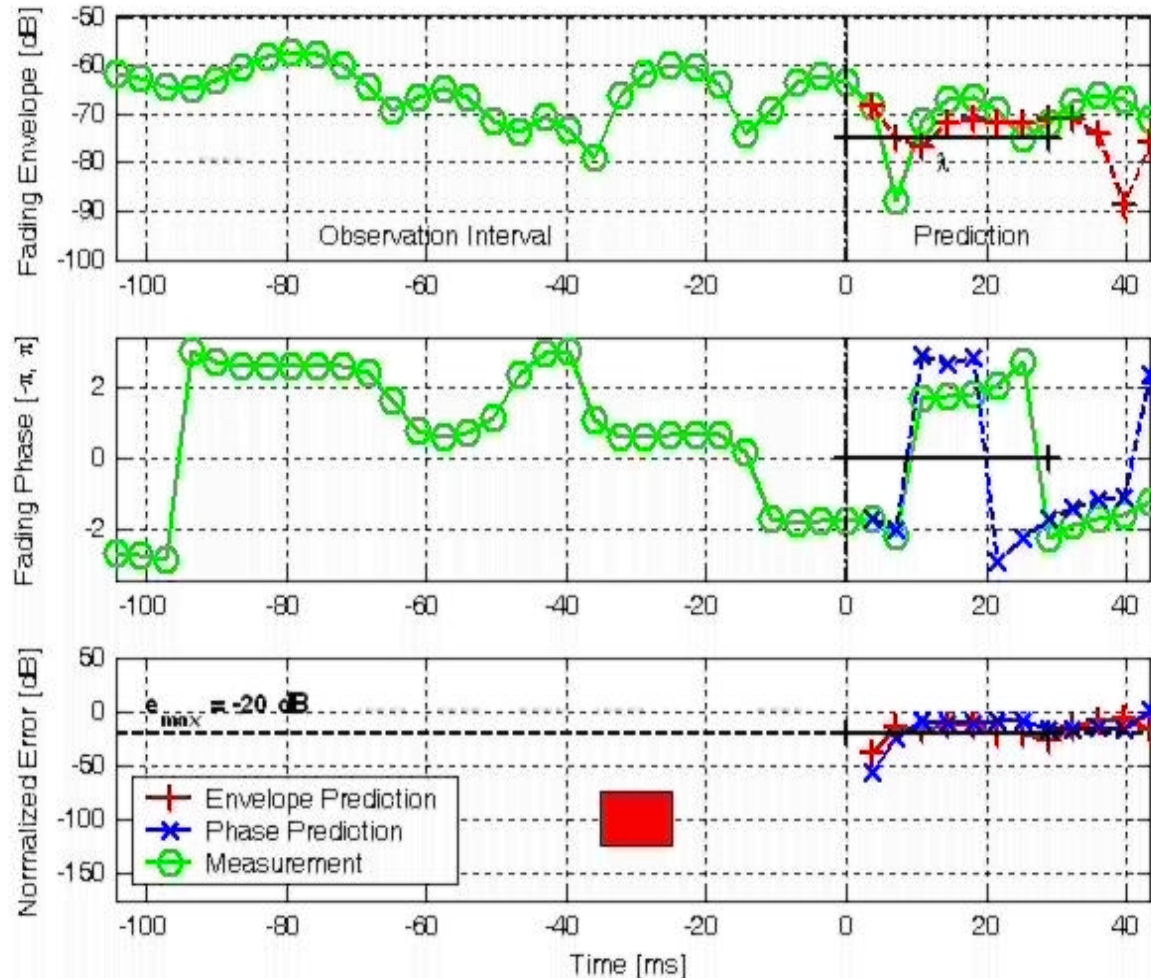
$$H = U_{\text{Rx}} \left(\tilde{\mathbf{O}} \odot \mathbf{G} \right) U_{\text{Tx}}^T$$



Weichselberger et al, IEEE Trans
Wireless Communications, to appear



A Fading Forecast Using the RLS-Algorithm



The Future of MIMO

- MIMO will NOT solve all problems on the way to Gbit/s
- Ridiculous channel models
- 4x4? Capacity increase is too modest
- 8x8? too expensive
 - Antenna selection!

We cannot predict the future

- Go 15 years back: 1990
- Iridium or GSM?
- TDMA or CDMA?
- First international GSM call still to be made (1991 Telecom Geneva)

Worldwide Mobile Subscriber Growth

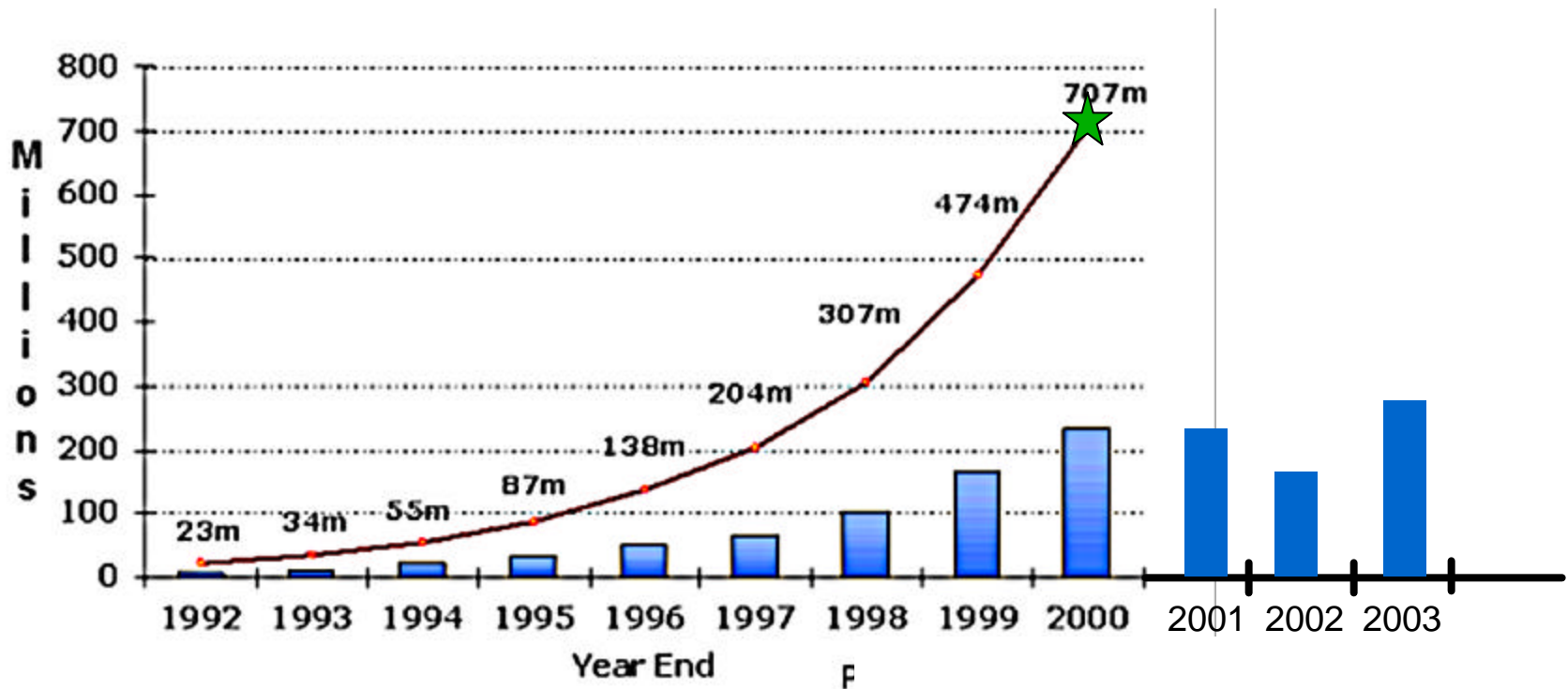
~1400m ★

- Never in history of mankind has a technical device reached 1 billion people in such a short time

1134m ★

- >70% GSM

955m ★



Source: www.gsmworld.com

Why was GSM successful?

- addresses a basic human need
- conceived by operator-vendor cooperation
- international and open standard
- SIM
- roaming
- secure
- trusted operators

What do we have today?

- Open Mobile Alliance (OMA)
- "multi-standard interoperability"

- The same analysts that are responsible for the Internet bubble now advise investors about participating in the mobile telecomms value chain

Unresolved Problems

- Handset energy
 - solar, mechanical, hydrogen?
- QoS in IP
- If telecommunications is supposed to become cheaper and cheaper and cheaper... who will pay for the development of all the gadgets we are promised today?
- Telecommunications is **too cheap!**

Unresolved Problems 2

- Ubiquitous wireless sensors
 - What about privacy?
- Read „1984“ by G. Orwell again and carefully

„1984“

by George Orwell

How to enforce compliant behavior:

„Big Brother is watching you“

Anti-Sex-League

„Ignorance is strength“

„War is Peace“

„...he loved Big Brother.“

Find all slides in a few days at

<http://www.nt.tuwien.ac.at/mobile>

Ernst Bonek (ernst.bonek@tuwien.ac.at)