Spatial Modulation Explained and Routes for Practical Evaluation

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Outline

- UK-China bridges project
  - Aims, Members and outcomes
- Spatial Modulation
  - Introducing SMod as a concept
- Project Objectives
  - Collaborative work to develop SMod for B4G

UK-China Science Bridges UC4G Project

- **Aim:** To create a *UK-China Joint R&D Centre for Future Wireless Communication Networks*, enabling long-term sustainable collaboration between the UK and China
- **Duration**: 3 years (01/08/2009-31/07/2012)
- **Funding**: £1,174,258 from Research Council UK (RCUK) => EPSRC

10 UK Universities

7 Chinese Universities

UK Company (Mobile VCE, with 13 Industrial members)

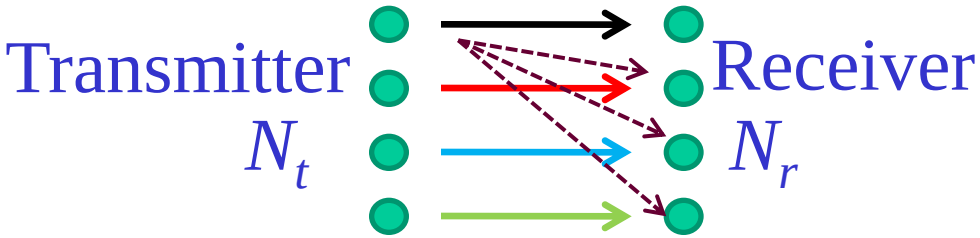
6 Chinese Companies/Institutes

R&D on (B)4G Wireless Mobile Communications (UC4G)

The project is designed to enable full interaction among the project members through diverse activities including visits, staff exchanges, and workshops. It also facilitates knowledge transfer from academia to industry through technical demonstrations and commercial engagements. The activities are organised into 6 work packages (WPs):

- **WP1:** 'Kick-off' workshop with UK researchers visiting their Chinese partners.
- **WP2:** Exchange of 30 researchers between the UK and Chinese academic consortium members.
- **WP3:** Jointly-hold international workshops.
- **WP4:** Prototype development and test of (B)4G wireless mobile communication technologies.
- **WP5:** Commercialisation of mature (B)4G technologies.
- **WP6:** Summary workshop with Chinese researchers visiting their UK partners.

Classical Spatial Multiplexing MIMO

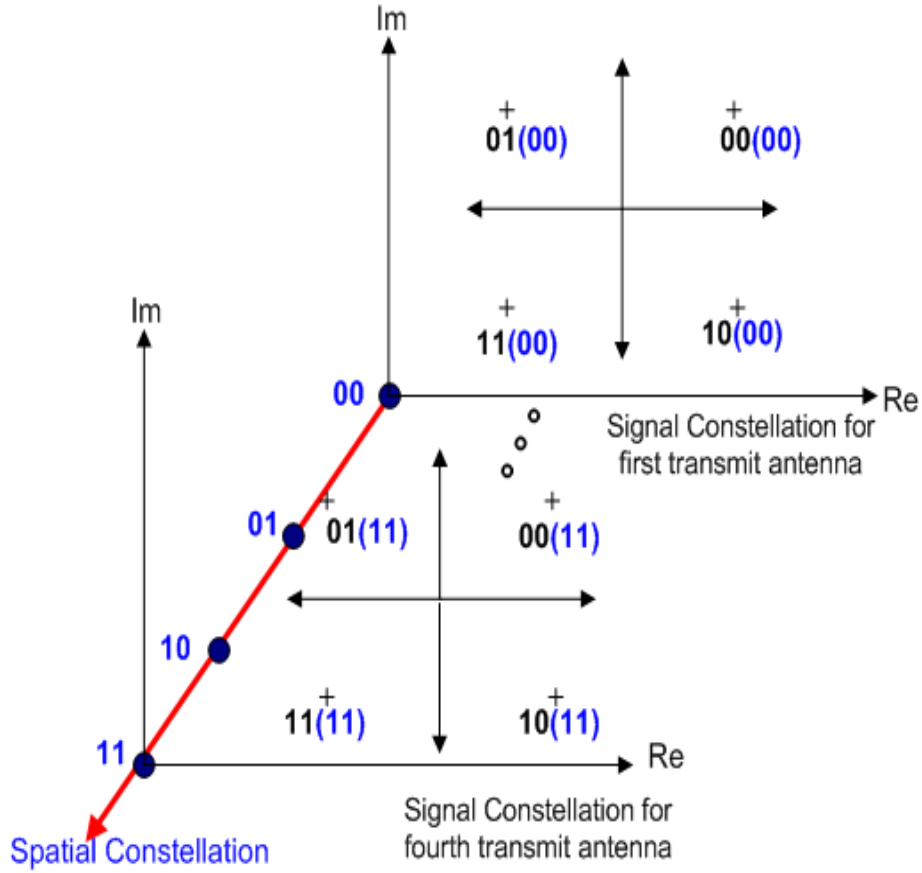


Significantly improve spectral efficiency (~min(N_t,N_r)), **but**:

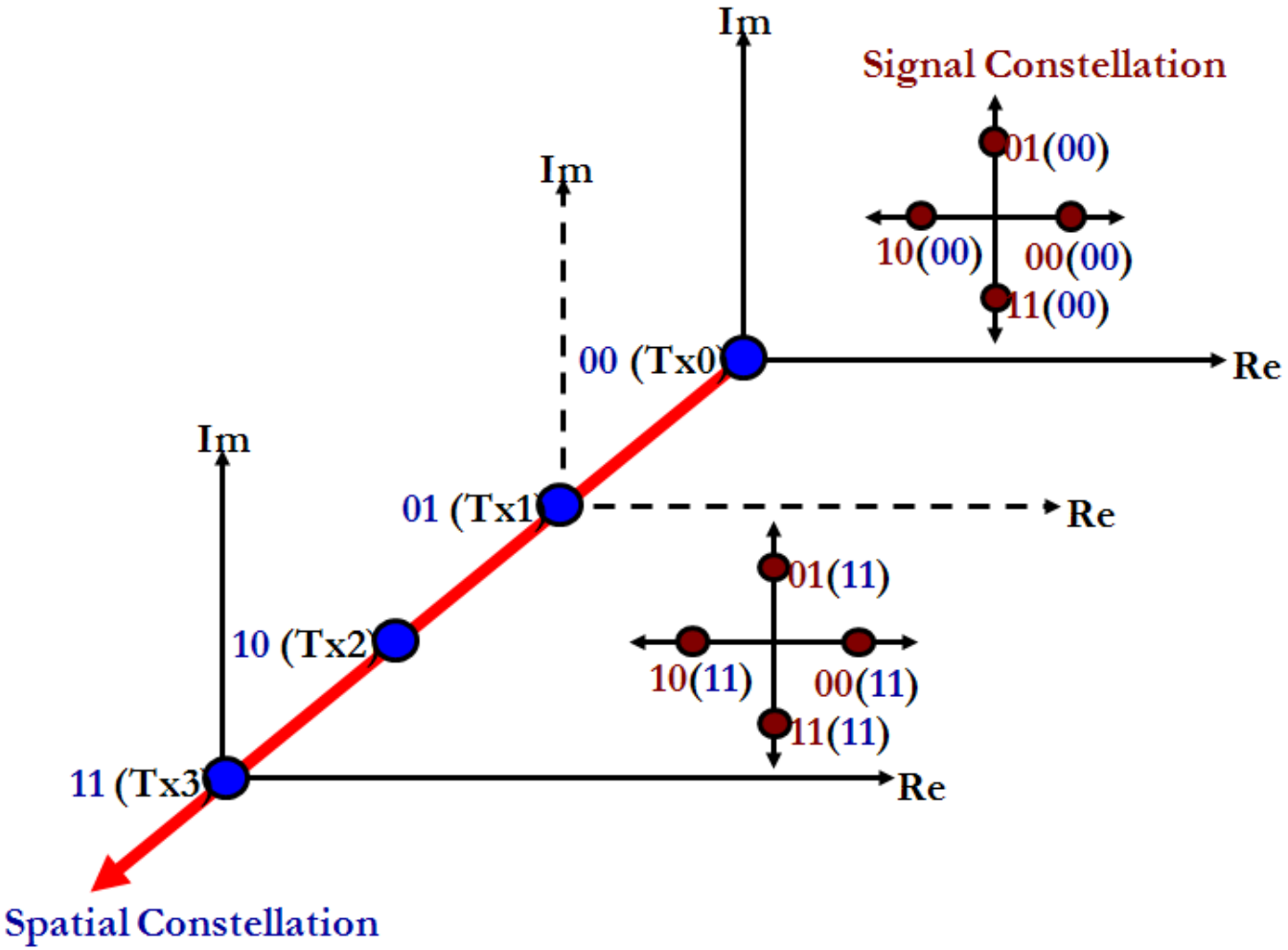
- Suffer from inter-channel interference (ICI) resulting in high computational complex algorithms (*e.g.*, V-BLAST)
- Suffer from antenna correlation
- Require inter-antenna synchronisation (IAS)
- Require multiple RF-chains (→ expensive)
- Typically require $N_r > N_t$ which, especially in the downlink, is problematic due to the space limitations at the mobile terminal

Spatial Modulation

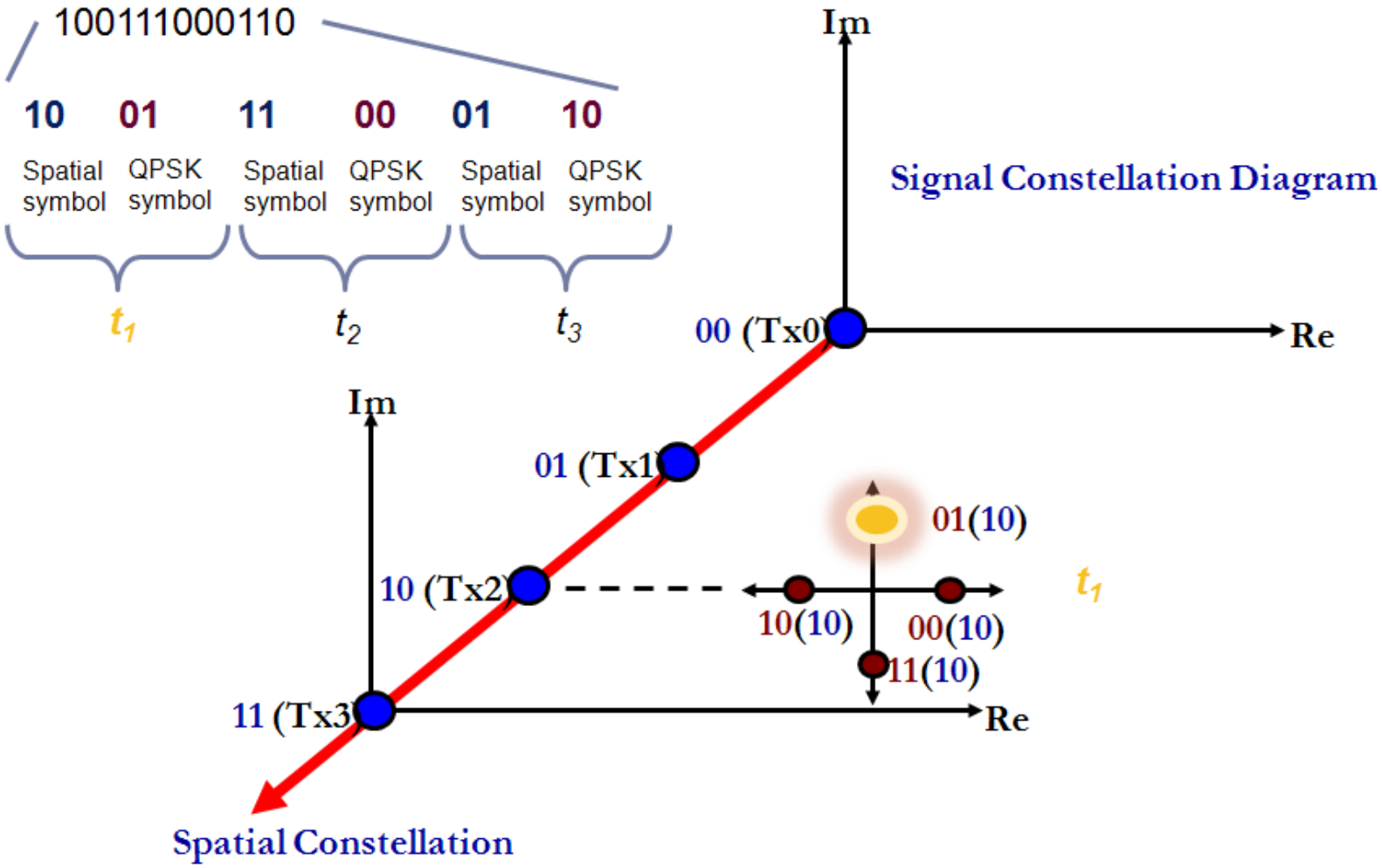
- **Claims for Spatial Modulation:**
  - A novel technique that utilises multiple–antenna transmission to realise an entirely new modulation concept
  - Only one Tx antenna is activated at a time: a '**green**' MIMO solution
  - Low system complexity than many existing MIMO techniques
  - Expected to be a key contender for physical layer techniques for B4G wireless communications standards
  - The UC4G project has been the first to demonstrate this new technique experimentally.



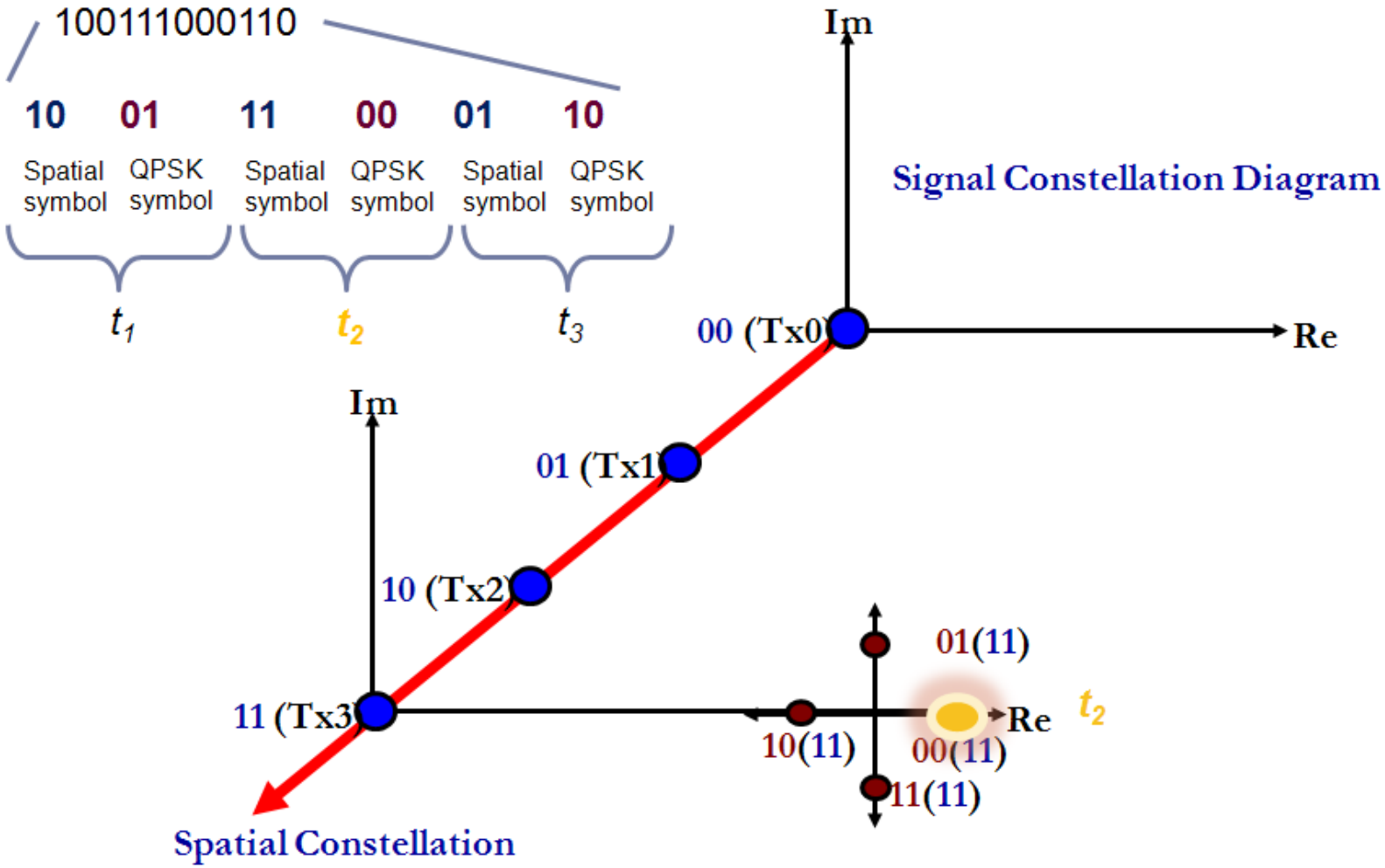
SM Principle – How does it work?



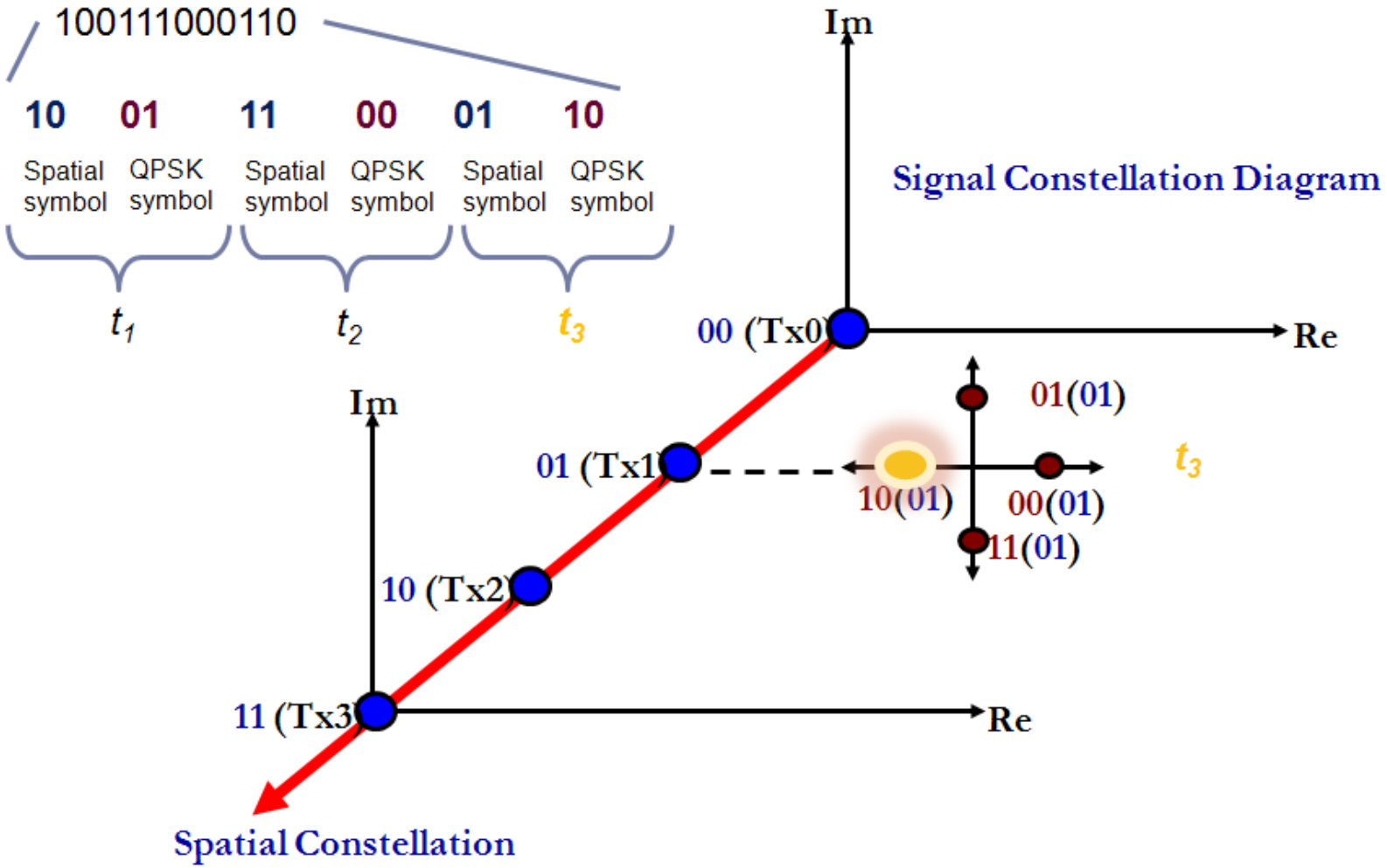
SM Principle



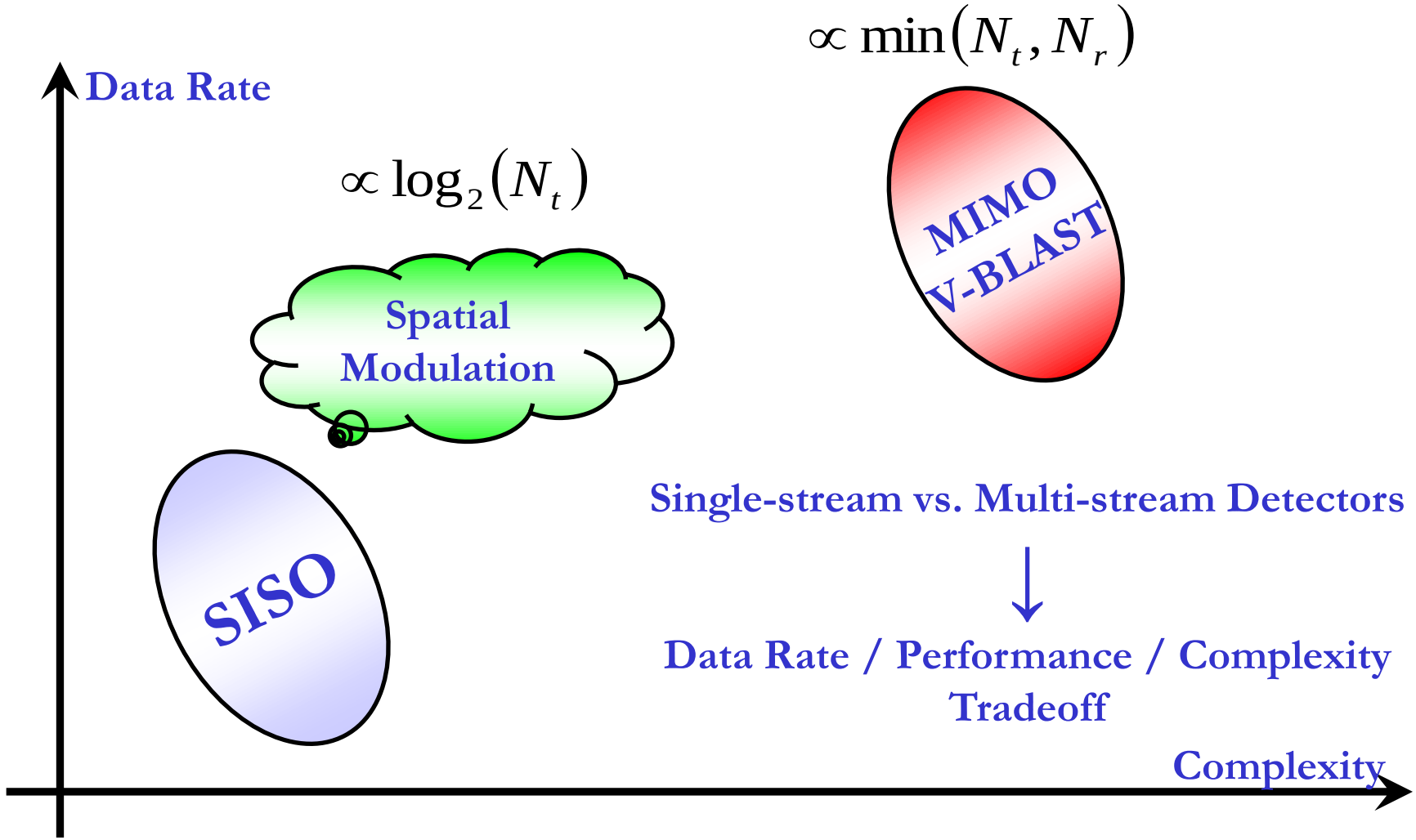
SM Principle



SM Principle



SMod Complexity vs. Performance



Key Advantages

- Avoids inter-channel interference (ICI)
- Low computational complexity
- Spatial multiplexing gains are achieved with a **single** Rx antenna
- No constraints on the number of Rx antennas (particularly beneficial for DL transmission)
- Only a **single** RF chain is required at the Tx (yielding low cost and high energy efficiency)
- No antenna synchronisation is required making it a very strong candidate for distributed MIMO and Coordinated Multi-Point
- SM efficiently supports multiple access

UK-China Bridges SMod Evaluation

Three partners:

- University of Edinburgh
  - Key developer of SMod techniques
- University of Bristol
  - Extensive MIMO urban channel measurements
  - Hardware evaluation, including Ebit C8
- Heriot Watt University
  - National Instruments MIMO testbed.

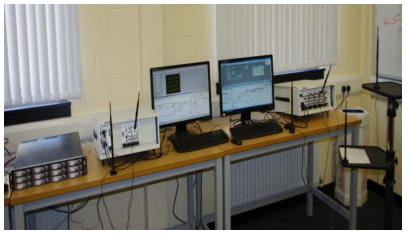
UK-China Science Bridges WP4
Goals

- Show world's first Spatial Modulation (SMod) demonstrator as a result of UK-China Science bridge activities
- Demonstrate that SM is a viable LTE Advanced technique for combining CoMP and relaying
- Demonstrate that SM can solve some of the existing problems of proposed LTE Advanced techniques especially with respect to signaling overhead and complexity
- Liaise with industrial partner, for LTE Advanced standardisation
- Demonstrate that UK-China science bridge activities has had an impact on LTE standardisation

Spatial Modulation Evaluation

MATLAB SIMULINK

SMod Simulator



Test Bed

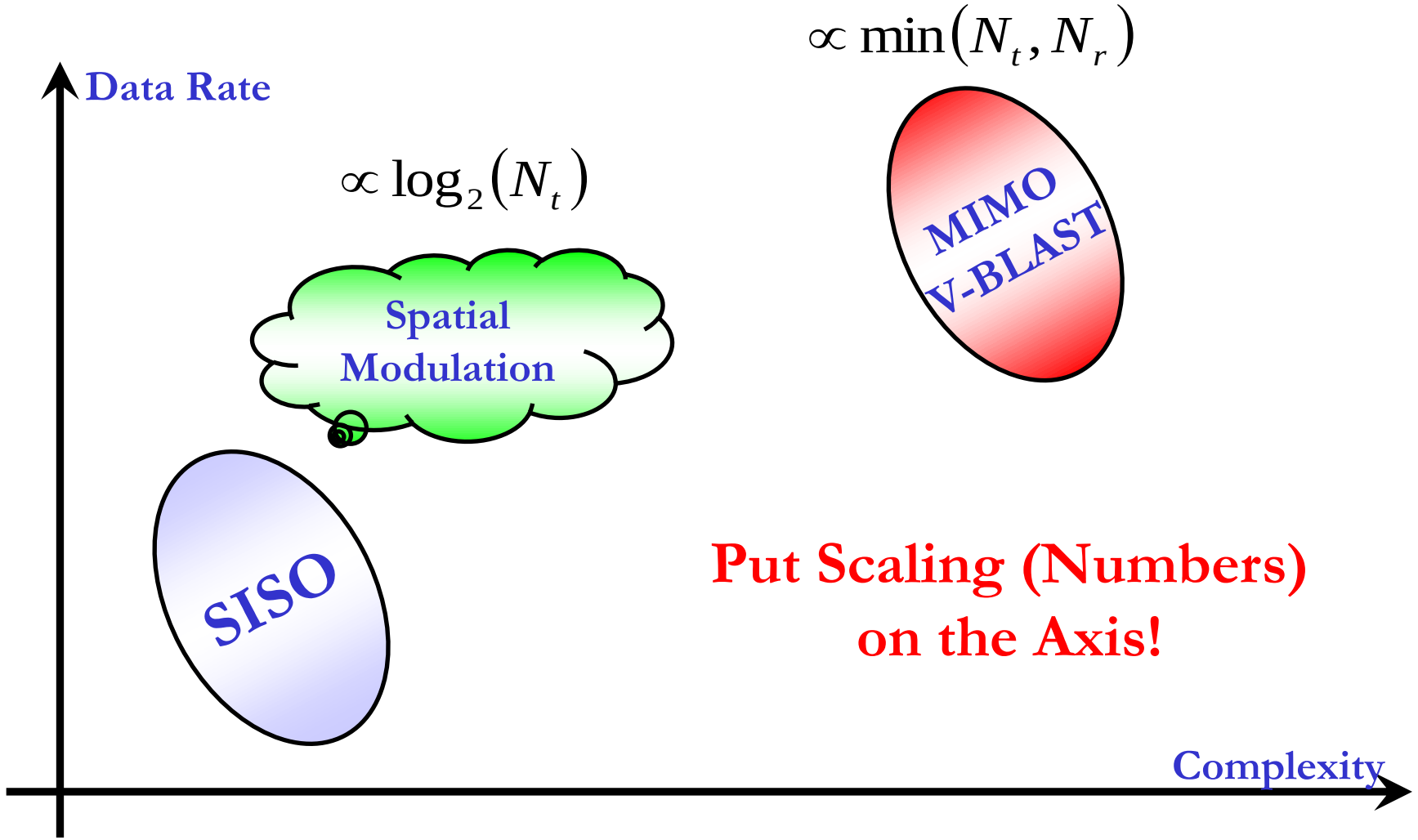
Channel Measurements

THE UNIVERSITY OF EDINBURGH

University of BRISTOL

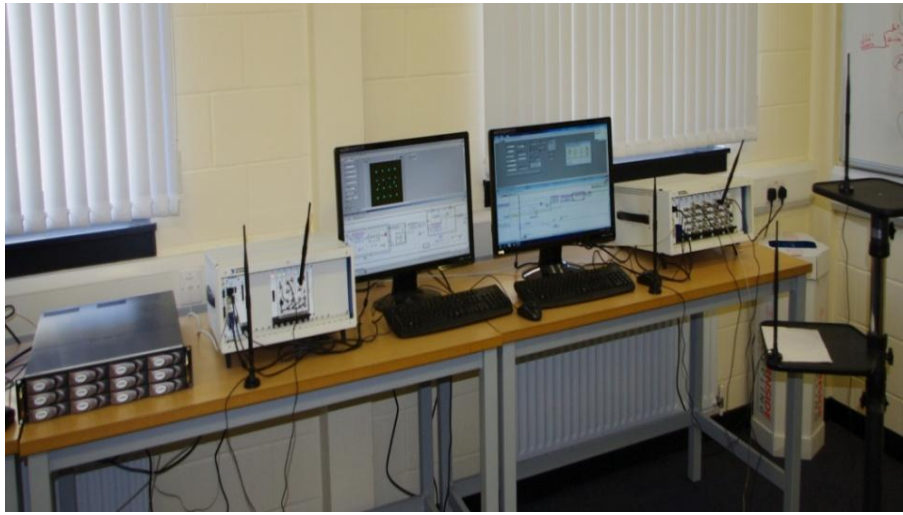
HERIOT WATT UNIVERSITY

SMod Complexity vs. Performance



NI PXi MIMO Test Bed

- **Hardware specifics (NI PXI products):**
  - Tx → 4 RF chains
  - Rx → 2 RF chains
  - Hard-drive array (RAID)→6TBs memory
  - Tx frequency range (85 MHz – 6.6 GHz)
  - Rx frequency range (10 MHz – 6.6 GHz)
  - Tx RF bandwidth: 100 MHz
  - Rx bandwidth (3dB): 50 MHz
  - Embedded FPGA (Xilinx Virtex 5) at the Tx & Rx for real-time signal processing
  - Embedded PCs at the Tx & Rx with Windows 7, LabView , Matlab, & NI software



UK-China Science Bridges WP4

- **Current capabilities/demos:**
  - Offline ‘Spatial Modulation’ system
  - Offline 4 x 2 MIMO-LTE system
  - Real-time simplex SISO-WLAN system
- **Developing:**
  - Novel ‘Spatial Modulation’ techniques with testing in Real Channels (off line)
  - Integration of Elektrobit C8 channel simulator for real time testing

- **Project Tasks**
  - Application of candidate decoding methodologies
  - Sensitivity analysis
    - Channel estimation errors
    - Channel correlations
  - Performance benchmarking
    - Alamouti, spatial multiplexing
  - Reporting Results to the Community

Thank you for your attention