Spatial Modulation Testbed

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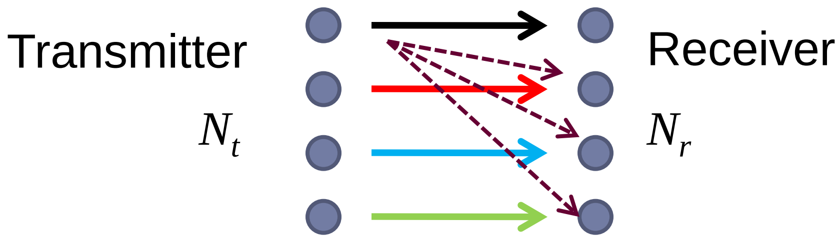
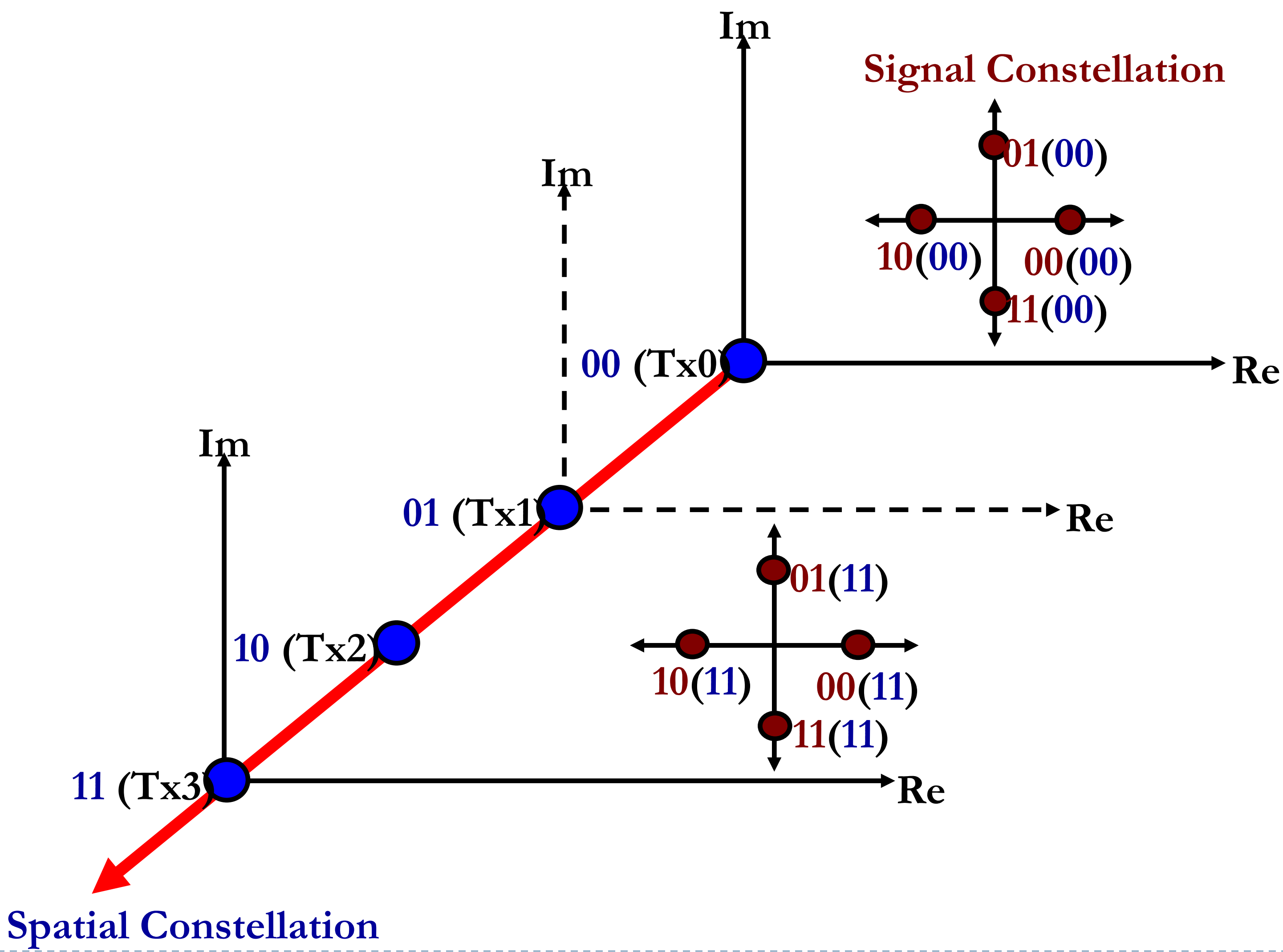
Classical Spatial Multiplexing MIMO



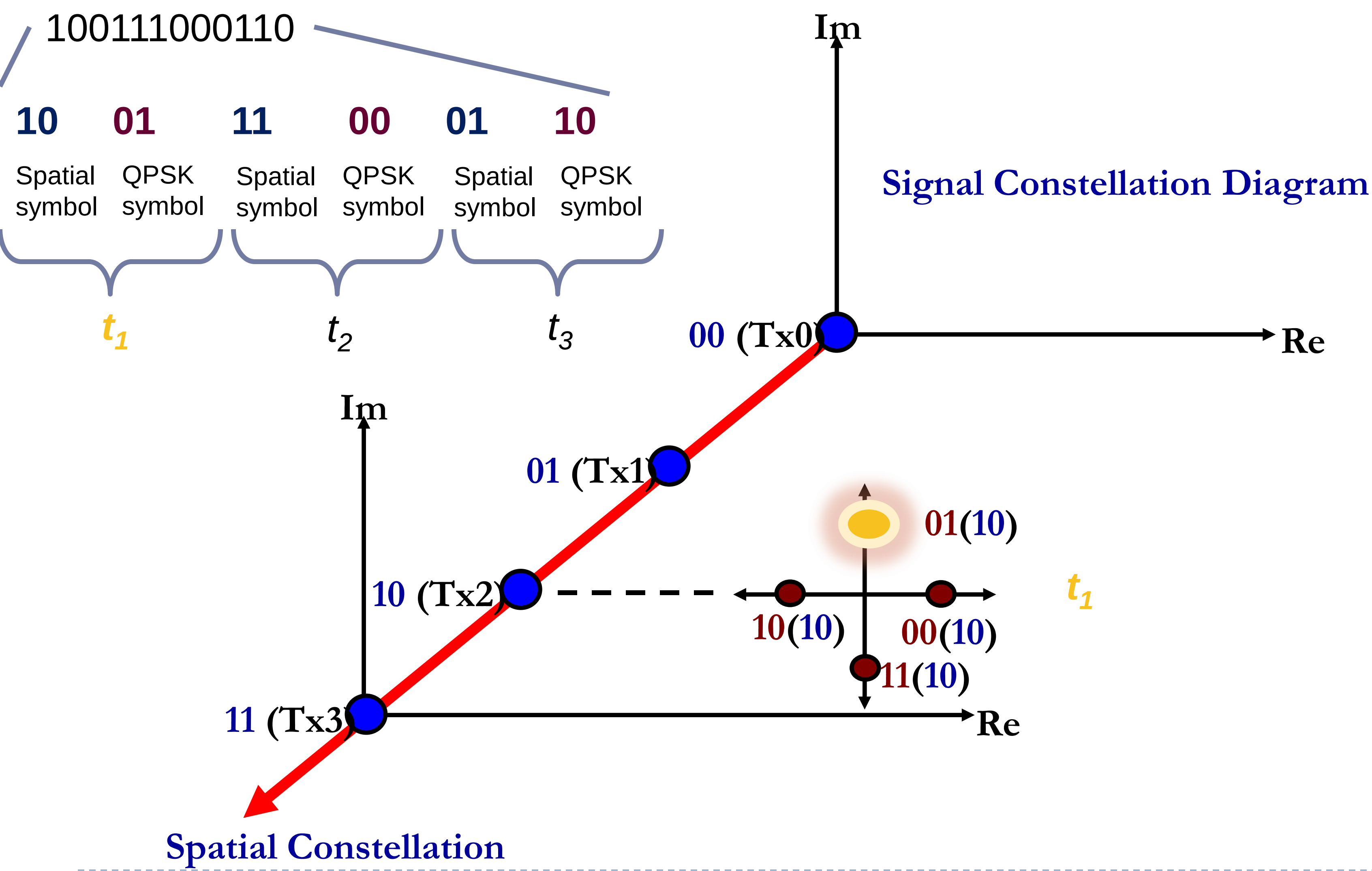
Significantly improve spectral efficiency (~min(N_t,N_r)), **but**:

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

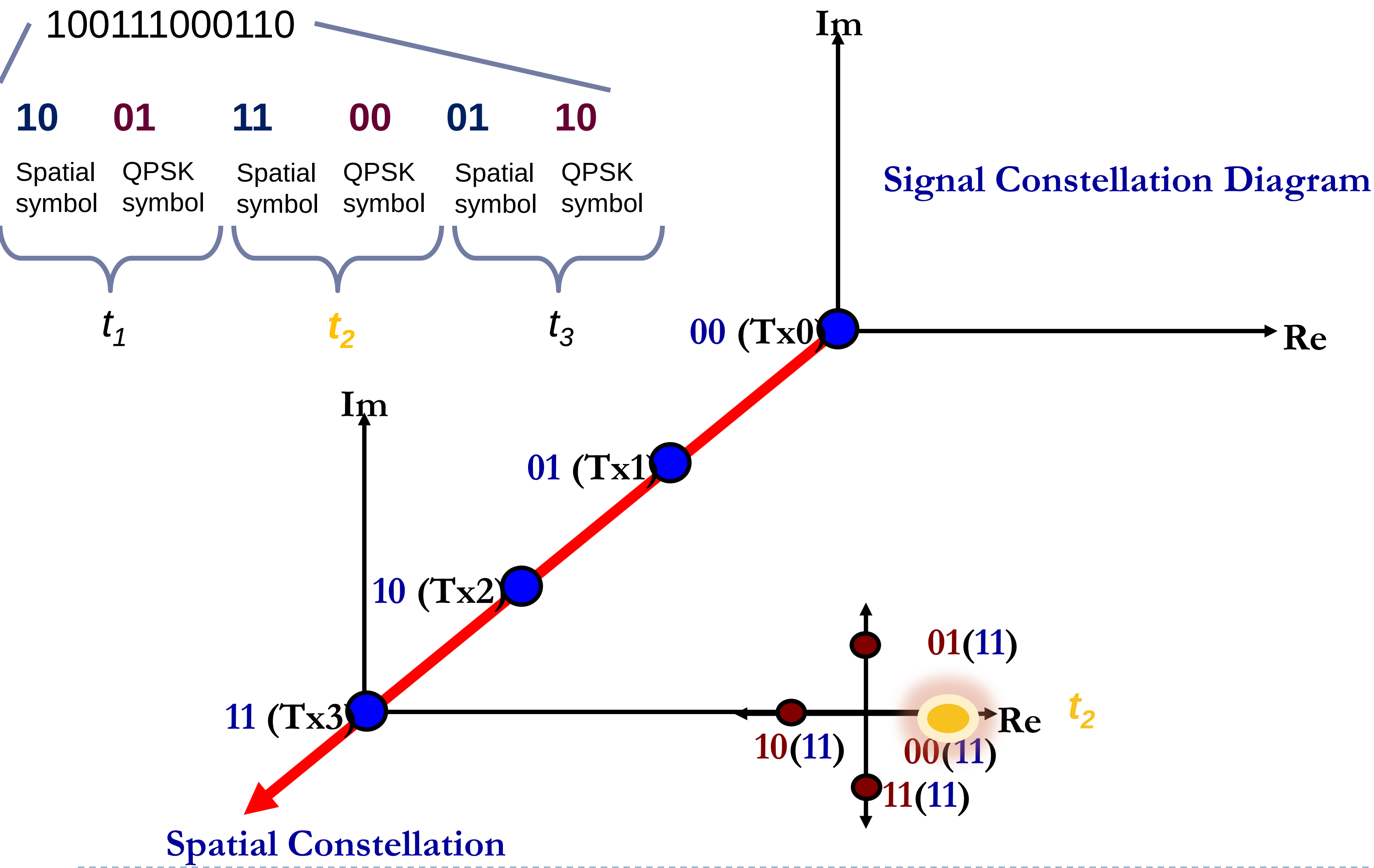
SM Principle – How does it work?



SM Principle



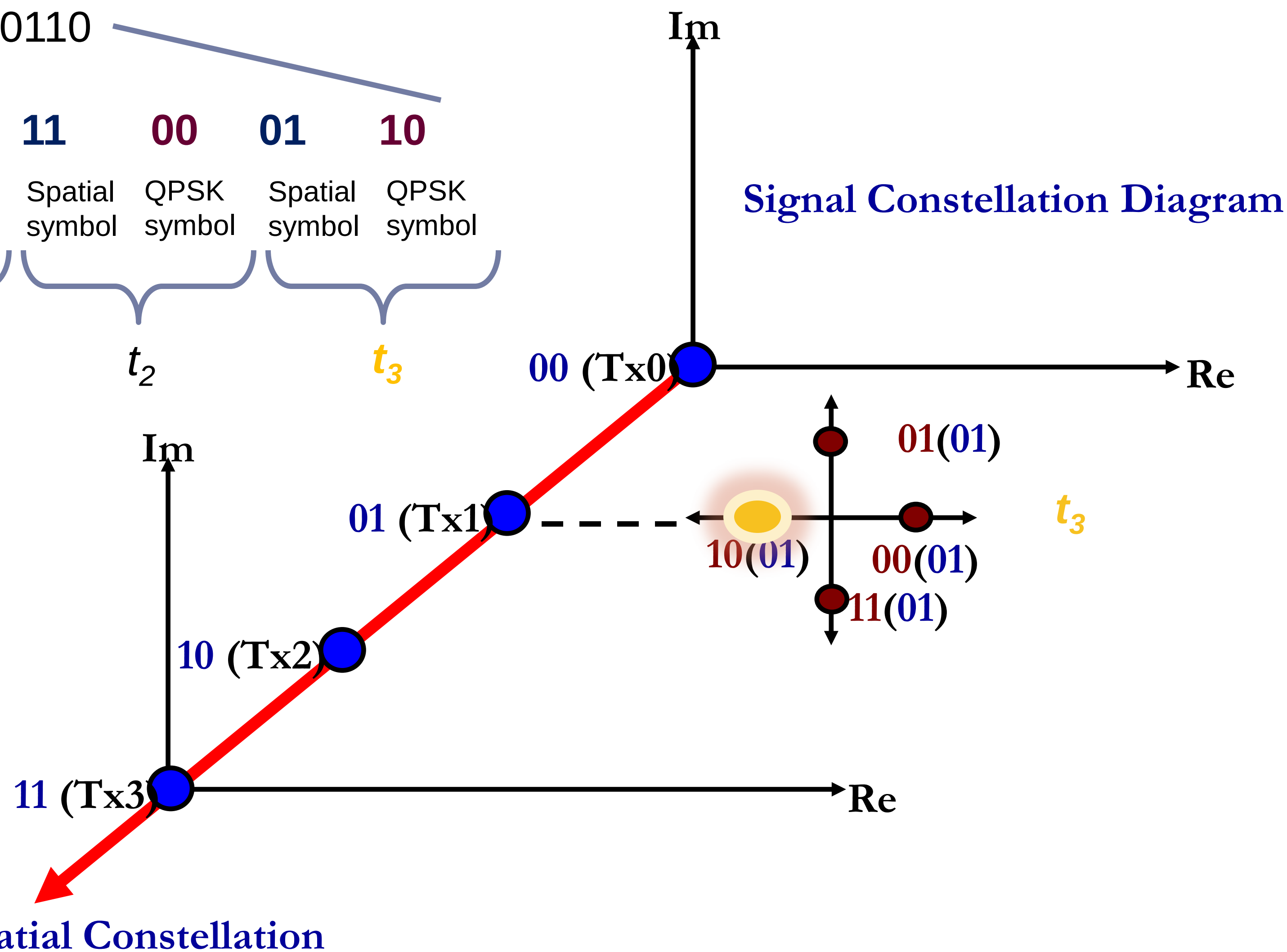
SM Principle



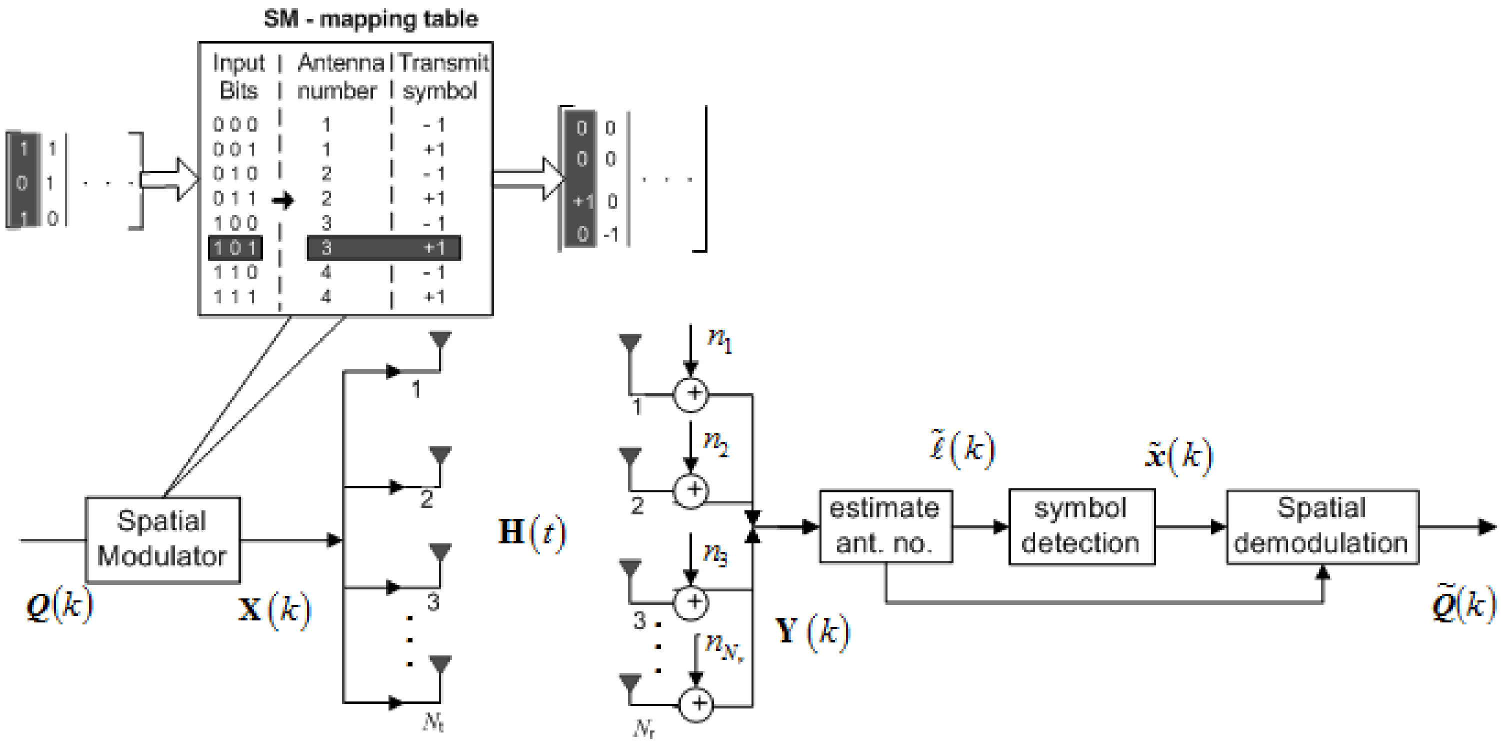
SM Principle

100111000110

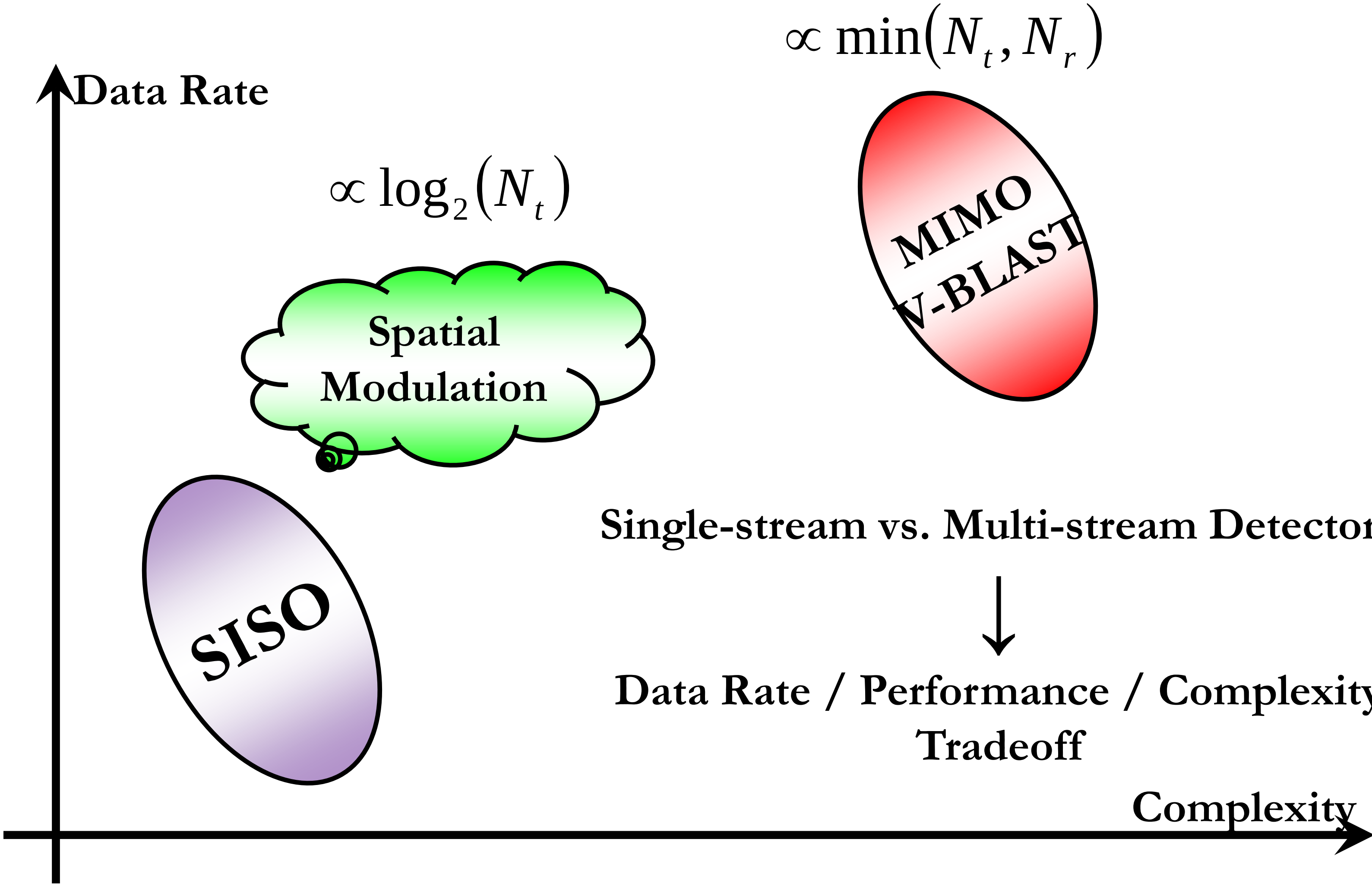
10	01	11	00	01	10
Spatial symbol	QPSK symbol	Spatial symbol	QPSK symbol	Spatial symbol	QPSK symbol
t_1		t_2		t_3	



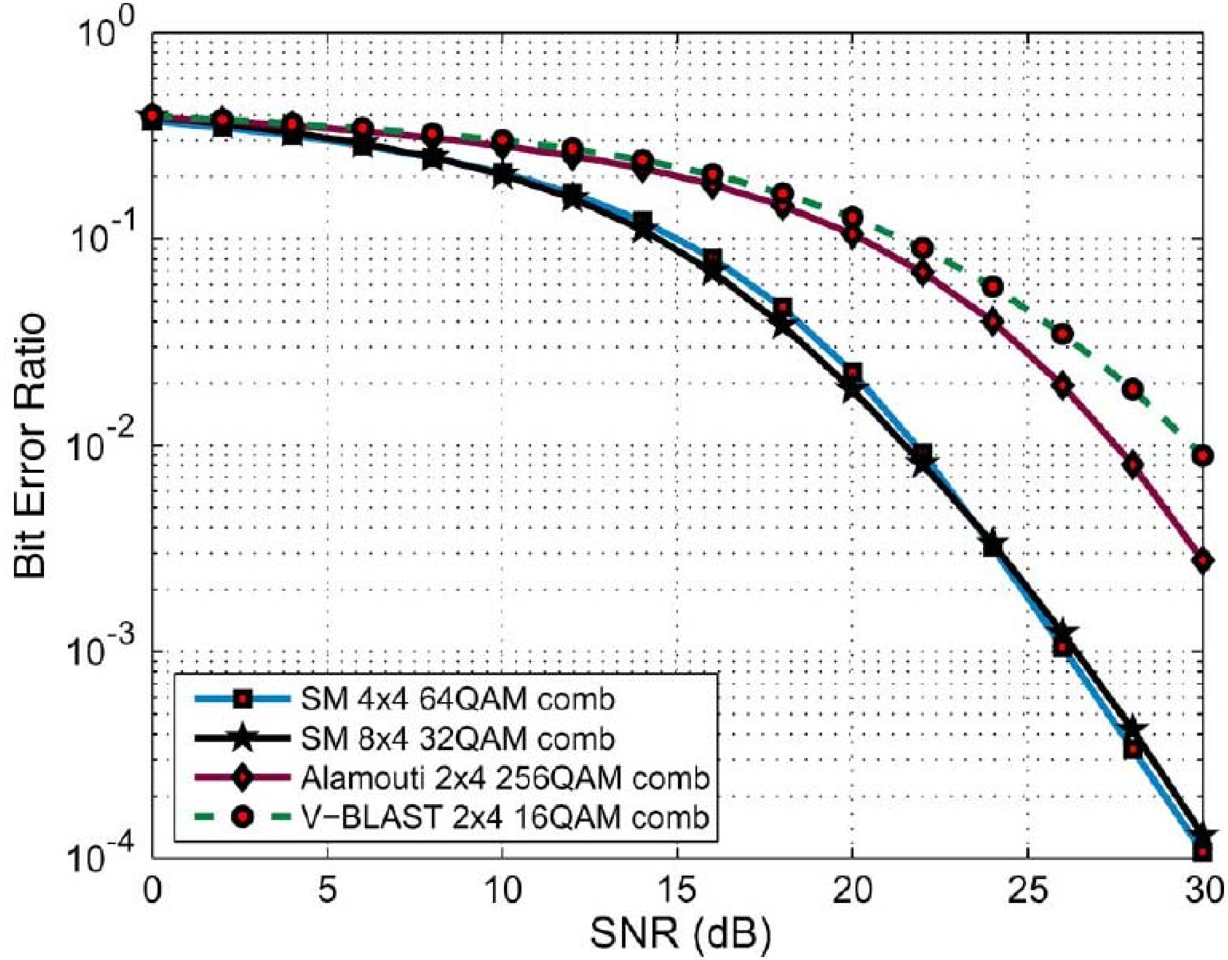
SM Essential Building Blocks



SM Complexity vs. Performance



SM vs. V-BLAST and Alamouti



R. Y. Mesleh, H. Haas, S. Sinanovic, C. W. Ahn, and S. Yun, "Spatial Modulation", IEEE Transactions on Vehicular Technology, vol. 57, no. 4, pp. 2228-2241, July 2008.

Computational Complexity

TABLE III
RECEIVER COMPLEXITY COMPARISON FOR 6 B/S/HZ TRANSMISSION

V-BLAST				SM		Alamouti
MMSE		QR		MRRC		ML
2x4 8QAM	3x4 4QAM	2x4 8QAM	3x4 4QAM	4x4 16QAM	2x4 32QAM	2x4 64QAM
110	560	85	140	28	14	15

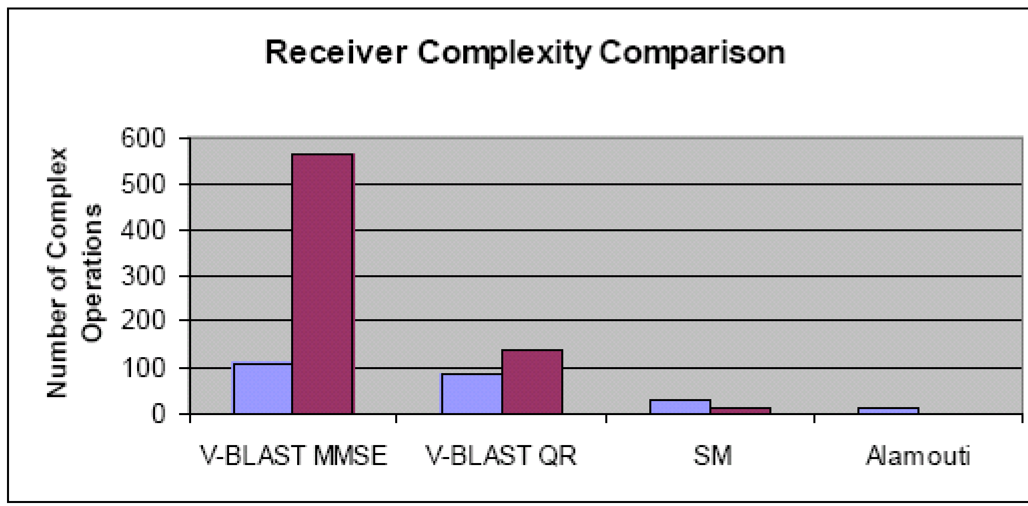
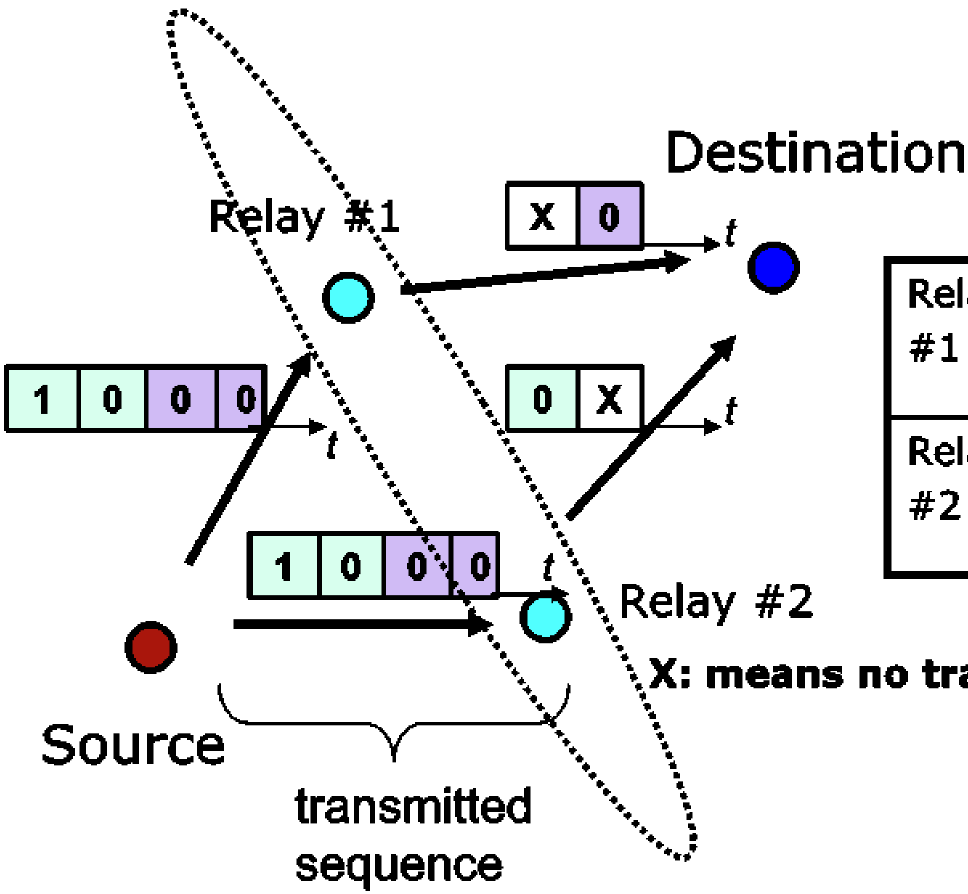


Fig. 14. Receiver complexity comparison for 6 b/s/Hz transmission using MMSE V-BLAST, V-BLAST based QR decomposition, SM and Alamouti algorithms.

Combined CoMP and relaying through SM

SM combines CoMP and relaying in a novel fashion



Relay #1	0	0	→	0
	0	1	→	1
Relay #2	1	0	→	0
	1	1	→	1

X: means no transmission

SM is well researched and understood

M. Di Renzo, H. Haas, and P. M. Grant, "Spatial Modulation for Multiple–Antenna Wireless Systems – A Survey", *IEEE Communications Magazine*, (to appear)

Mesleh, R., Haas, H., Sinanović, S., Ahn, C. W. and Yun, S., "Spatial Modulation," *IEEE Transactions on Vehicular Technology*, vol. 57, no. 4, DOI 10.1109/TVT.2007.912136, 2008, pp. 2228 – 2241

M. Di Renzo, H. Haas, "A General Framework for Performance Analysis of Space Shift Keying (SSK) Modulation for MISO Systems over Correlated Nakagami-m Fading Channels", *IEEE Trans. Commun.,* vol 58, iss. 9, DOI 10.1109/TCOMM.2010.09.090565, 2010, pp.: 2590 – 2603

R. Y. Mesleh, M. Di Renzo, H. Haas, P. M. Grant, "Trellis Coded Spatial Modulation", *IEEE Trans. Wireless Commun.*, DOI 10.1109/TWC.2010.07.091526, 2010, pp.: 2349 - 2361

M. Di Renzo, H. Haas, "Space Shift Keying (SSK) Modulation with Partial Channel State Information at the Receiver: Optimal Detector and Performance Analysis over Correlated Fading Channels", *IEEE Trans. Commun.*, vol. 58, iss. 11, DOI 10.1109/TCOMM.2010.091710.090598, 2010, pp.: 3196 – 3210

M. Di Renzo, H. Haas, "Improving the Performance of Space Shift Keying (SSK) Modulation via Opportunistic Power Allocation", *IEEE Commun. Lett.,* vol. 14, iss.: 6, DOI 10.1109/LCOMM.2010.06.100163, 2010, pp.: 500 – 502

N. Serafimovski, M. Di Renzo, S. Sinanovic, H. Haas, R. Y. Mesleh, "Fractional Bit Encoded Spatial Modulation (FBE-SM)", *IEEE Commun. Lett.*, vol. 14, iss. 5, DOI 10.1109/LCOMM.2010.05.092270, 2010, pp.: 429 – 431

M. Di Renzo, H. Haas, "SSK-MIMO over Correlated Rician Fading Channels: Performance Analysis and a New Method to Achieve Transmit-Diversity Gains", *IEEE Trans. Commun*., vol. PP, iss. 99, DOI 10.1109/TCOMM.2011.111710.090775, 2010, pp.: 1 – 14

M. Di Renzo and H. Haas, "Performance Comparison of Different Spatial Modulation Schemes in Correlated Fading Channels", in Proc. of *ICC 2010*, DOI 10.1109/ICC.2010.5501948, 2010, pp.: 1 – 6

M. Di Renzo and H. Haas, "On the Performance of Space Shift Keying MIMO Systems over correlated Rician Fading Channels", in Proc. of *ICC 2010*, DOI 10.1109/ICC.2010.5501936, 2010, pp.: 1 – 6

Younis, H.Haas, and P. Grant, "Reduced Complexity Sphere Decoder for Spatial Modulation Detection Receivers", in Proc. *IEEE Globecom (2010)*, (Miami, Florida, USA), 2010

M. Di Renzo and H. Haas, "On the Performance of SSK Modulation over Multiple–Access Rayleigh Fading Channels", in Proc. *IEEE Globecom (2010),* (Miami, Florida, USA), 2010

Younis, R. Mesleh, and H. Haas, "Generalised Spatial Modulation" in Proc. of *Asilomar 2010*

M. Di Renzo, H. Haas, "Performance Analysis of Spatial Modulation (SM) over Nakagami–m Fading Channels" IEEE *Conference on Communications and Networking in China (ChinaCom 2010)*, (**invited**)

S. Sugiura, H. Haas, P. M. Grant, S. Chen, and L. Hanzo "Coherent Versus Non-Coherent Decode-and-Forward Relaying Aided Cooperative Space Time Shift Keying" IEEE Trans. Commun. (submitted

Key Advantages

- 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)
- Better robustness to channel estimation errors compared to V-BLAST
- Better robustness to channel correlation compared to V-BLAST
- Low signaling overhead and simple channel estimation
- No antenna synchronisation is required making it a very strong candidate for distributed MIMO and CoMP
- SM efficiently supports multiple access

Proposed Demonstrator

- 4x2 MIMO link level setup (scalable to 2x1)
- FDD or TDD dependent on availability of spectrum
- Fixed power allocation
- FECC – e.g., novel FECC tailored for SM such as *trellis coded spatial modulation*
- Detector, e.g., novel sphere decoder tailored for SM
- At least four units to be able to demonstrate CoMP and relaying
- *Optional:* Feedback channel for advanced SM concepts

Available Equipment

- Agilent Sepctrum Analyser (27 GHz)
- Agilent Vector Signal Generator
- Agilent Signal Analyzer

as well as

- Matlab code for the various building blocks

Envisaged Investigations

- Confirm theoretical BER results
- Evaluate SSK (space shift keying) a special form of SM
- Confirm theoretical results of the computational complexity of novel algorithms
- Confirm trade-offs between signaling overhead and BER performance
- Investigate performance under various channel conditions
- Demonstrate multiple access capability of SM
- Demonstrate relaying and CoMP capability using a setup of 1 Tx, 2 relays and 1 Rx

UoE support for testbed development

- Currently 1 Postdoctoral Research Fellow funded through EPSRC
- Currently 2 PhD students (self-funded and EPSRC funded)
- Two more ESR (Early Stage Researchers) funded through Maire Curie Inital Training Network starting early 2011
- In addition: £25k UoE IKTF award

Development support required:

- 24 MM of experienced development engineer

Goals

- Show world's first SM 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 is a practical scheme that strikes a good balance between implementation complexity and achievable spectral efficiency
- Demonstrate that SM can solve some of the existing problems of proposed LTE Advanced techniques especially with respect to signaling overhead and complexity
- Hope to liaise with industrial partner for LTE Advanced standardisation
- Demonstrate that UK-China science bridge activities has had an impact on LTE standardisation
- Combine KT activities, e.g., utilise £25k UoE IKTF award