THE SPATIAL MODULATION SAGA: SINGLE- *VS.* MULTIPLE-RF CHAINS AND ALL THAT...

Lajos Hanzo

School of ECS, Univ. of Southampton, S017 1BJ, UK.
Tel: +44-(0)23-80-593 125, Fax: +44-(0)23-80-594 508
Email:lh@ecs.soton.ac.uk;http://www-mobile.ecs.soton.ac.uk

Abstract

The classic Shannon-Hartley law suggests that the achievable channel capacity increases logarithmically with the transmit power, which is not a 'good deal'!

More beneficially, the MIMO capacity increases linearly with the number of transmit antennas, provided that the number of receive antennas is equal to the number of transmit antennas. With the further proviso that the total transmit power is increased proportionately to the number of transmit antennas, a linear capacity increase is achieved upon increasing the transmit power, which justifies the spectacular success of MIMOs...

However, there are huge challenges, which have to be tackled, before these 'massive MIMOs' might become an off-the-shelf reality. For example, estimating all the (N x M) MIMO channels imposes a potentially excessive complexity, hence - perhaps somewhat surprisingly owing to its potential performance erosion - non-coherent detection might become an attractive low-complexity solution, as demonstrated in this lecture.

Another challenge is the provision of numerous Radio-Frequency (RF) chains, which is THE most costly part of a transceiver. This problem might be circumvented wiht the aid of Spatial Modulation (SM), where only a single one or a limited fraction of the transmit antennas is activated during any symbol interval. This 'win-win saga' continues, since apart from the potential benefit of requiring only a single RF chain, SM also has the potential of implicitly conveying extra bits by inferring say $log_2(M)$ bits from the specific index of the activated transmit antenna, as discussed in this light-hearted overview...

Lajos Hanzo FREng, FIEEE, FIET, RS Wolfson Fellow, received his 5-year Master degree in electronics from the Technical University of Budapest in 1976, his doctorate in 1983 and his Doctor of Sciences (DSc) degree in 2004. During his career in telecommunications he has held various research and academic posts in Hungary, Germany and the UK. Since 1986 he has been with the School of ECS, University of Southampton, UK, where holds the Chair in Telecommunications. His current research interests are featured at (http://www-mobile.ecs.soton.ac.uk)

1. REFERENCES

[1] Di Renzo, M. ; Haas, H. ; Ghrayeb, A. ; Sugiura, S. ; Hanzo, L.: Spatial Modulation for Generalized MIMO: Challenges, Opportunities, and Implementation, Proceedings of the IEEE, Volume: 102 , Issue: 1, 2014, pp 56 - 103

[2] S. Sugiura, S. Chen, and L. Hanzo, "A universal space-time architecture for multiple-antenna aided systems," *Communications Surveys Tutorials, IEEE*, vol. 14, pp. 401 –420, 2012.

[3] M. Kadir, S. Chen, S. Sugiura, L. Hanzo: Unified MIMO-Multicarrier Designs: A Space-Time Shift Keying Approach Communications Surveys & Tutorials, IEEE, Year: 2015, Volume: 17, Issue: 2 Pages: 550 - 579, DOI: 10.1109/COMST.2014.2375321

[4] Ping Yang; Di Renzo, M.; Yue Xiao; Shaoqian Li; Hanzo, L.: Design Guidelines for Spatial Modulation Communications Surveys & Tutorials, IEEE Year: 2015, Volume: 17, Issue: 1 Pages: 6 - 26, DOI: 10.1109/COMST.2014.2327066

[5] Yang, P.; Xiao, Y.; Li, S.; Hanzo, L.: A Low-Complexity Power Allocation Algorithm for Multiple-Input Multiple-Output Spatial Modulation Systems, IEEE Transactions on Vehicular Technology, 2015, IEEE Early Access, DOI: 10.1109/TVT.2015.2410252

[6] Yang, P.; Xiao, Y.; Yin, L.; Tang, Q.; Li, S.; Hanzo, L.: Hybrid Bit-to-Symbol Mapping for Spatial Modulation, IEEE Transactions on Vehicular Technology, IEEE Early Access, DOI: 10.1109/TVT.2015.2453216

A “SPOOKY PHENOMENON AT A DISTANCE” OR A POTENT WIRELESS TOOL DR EINSTEIN? QUANTUM-SOLUTIONS IN COMMUNICATIONS

Lajos Hanzo

School of ECS, Univ. of Southampton, S017 1BJ, UK.
Tel: +44-(0)23-80-593 125, Fax: +44-(0)23-80-594 508
Email:lh@ecs.soton.ac.uk;http://www-mobile.ecs.soton.ac.uk

Abstract

Since Marconi demonstrated the feasibility of radio transmissions, researchers have endeavoured to fulfill the dream of flawless wireless multimedia telecommunications, creating the impression of tele-presence - at the touch of a dialling key...

However, making this dream a reality required ’quantum’ leaps both in digital signal processing and in its nano-electronics based implementation, facilitated by advances in science both in Edinburgh and farther afield. This process has been fuelled by a huge consumer market. Moore’s laws has indeed prevailed since he outlined his empirical rule-of-thumb in 1965, but based on this the scale of integration is set to depart from classical physics obeying the well-understood rules revealed by science and enter into a new world, where the traveller has to obey the sometimes strange new rules of the quantum-world.

The quest for quantum-domain communication solutions was inspired by Feynman’s revolutionary idea in 1985: particles such as photons or electrons might be relied upon for encoding, processing and delivering information. During the last three decades researchers and engineers often considered a pair of open problems. Firstly, classic systems relying on the efficient processing capability of quantum-search algorithms were considered in the area of quantum-assisted communications, while the branch of quantum-domain communications relies on quantum channels.

In wireless communications we often encounter large-scale search problems, some of which may be efficiently solved with the aid of bio-inspired random guided algorithms or quantum-search techniques. For example, Grover’s algorithm is capable of searching through an N-element data-base with the aid of $\sqrt{N}$ cost-function evaluations. Commencing with a brief historical perspective, a variety of efficient quantum-assisted solutions will be exemplified.

Lajos Hanzo FREng, FIEEE, FIET, RS Wolfson Fellow, received his 5-year Master degree in electronics from the Technical University of Budapest in 1976, his doctorate in 1983 and his Doctor of Sciences (DSc) degree in 2004. During his career in telecommunications he has held various research and academic posts in Hungary, Germany and the UK. Since 1986 he has been with the School of ECS, University of Southampton, UK, where holds the Chair in Telecommunications. His current research interests are featured at (http://www-mobile.ecs.soton.ac.uk)

1. REFERENCES

[1] P. Botsinis, SX Ng, L. Hanzo: Quantum Search Algorithms, Quantum Wireless, and a Low-Complexity Maximum Likelihood Iterative Quantum Multi-User Detector Design, IEEE Access, Volume: 1, Issue 1, 2013, pp 94 - 122

[2] Botsinis, Panagiotis ; Ng, Soon Xin ; Hanzo, Lajos: Fixed-Complexity Quantum-Assisted Multi-User Detection for CDMA and SDMA IEEE Transactions on Communications, Volume: 62 , Issue: 3, 2014, pp 990 - 1000

[3] Alanis, D.; Botsinis, P.; Babar, Z.; Ng, S.X.; Hanzo, L.: Non-Dominated Quantum Iterative Routing Optimization for Wireless Multihop Networks, Access, IEEE Early Access, DOI: 10.1109/ACCESS.2015.2478793

[4] Botsinis, P.; Alanis, D.; Babar, Z.; Ng, S.X.; Hanzo, L.: Iterative Quantum-Assisted Multi-User Detection for Multi-Carrier Interleave Division Multiple Access Systems, IEEE Transactions on Communications, Early access, DOI: 10.1109/TCOMM.2015.2458857

[5] Alanis, D. ; Botsinis, P. ; Soon Xin Ng ; Hanzo, L.: Quantum-Assisted Routing Optimization for Self-Organizing Networks: IEEE Access, Volume: 2, 2014, pp 614 - 632