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Title: **Cost-related requirements for future massive MIMO systems on the cost of massive MIMO systems**
Agenda Item: **9.2.1**
Document for: **Discussion**

1 Introduction

Massive MIMO systems comprising a large number of antennas at the base station represent one of the most promising solutions to increase the area spectral efficiency in NR. The effective application of simple linear precoding strategies is attractive for operators in terms low complexity, but it is desirable to take a closer look at the RF specifications in order to prevent this approach to lead to a dramatic increase in the cost of the analogue hardware in order to fulfil RF requirements. Given the large number of antennas, it is reasonable to investigate how much one can relax some RF specifications without compromising the overall performance in order to support low-cost massive MIMO setups. Similarly, it is also desirable to state limitations in the maximum transmit powers to be handled by the individual RF chains, in order to prevent the presence of costly power amplifiers for transmission of broadcast control signals.

2 Discussion

RF requirements can have significant impact on the cost of the analogue subsystems in massive MIMO technology. The large number of antennas makes it desirable to explore new MIMO performance requirements different to current ones, where all individual RF chains must meet stringent in-band and out-of-band characteristics. Among these, out-of-band emissions (OOBE) can have a direct impact on cost because tight OOBE limits demand highly-linear power amplifiers with low power efficiency. Another driver for cost reductions is the maximum transmit power that must be handled by each of the RF chains.

2.1 OOBE requirements in massive MIMO

One of the claimed advantages of massive MIMO systems is the simplicity in baseband processing brought by application of linear, yet effective, precoding techniques. However, this simplicity in baseband design should be followed by similar principles in RF analogue design in order for the system to be cost-effective.

OOBE requirements as specified in current MIMO systems put limits on the maximum leakage power as measured on the adjacent frequencies of the desired signal carrier. OOBE requirements can only be met by sufficiently linear transmit amplifiers, which leads to reduced PA efficiency and increased cost. In massive MIMO systems, this requirement could lead to an excessive overall cost if the number of RF chains is high.

Given the large beamforming gain provided by massive MIMO systems, intended users in a cell will experience an increased received power given by the beamforming gain, but non-served users will in general receive a superposition of non-coherent waves that do not add constructively. If the OOBE distortion behaves in the same way as the in-band signals ([1]), intended users will receive a signal whose level is above the OOBE level of victim users by a magnitude equal to the beamforming gain (thorough studies on massive MIMO topics can be found in MAMMOET & Massive MIMO Info P, used as

foundation for this contribution). Hence, the actual OOBE limits of the whole system will be equal to the OOBE characteristics of the RF chains plus the beamforming gain.

As a consequence of the above, it seems reasonable to study up to which point the OOBE requirements can be relaxed on the RF chains, in order to meet a given overall OOBE at victim users. These considerations may be essential when trying to develop cost-effective massive MIMO solutions, especially when targeted at underserved areas in which massive MIMO solutions could save deployment costs by replacing multiple traditional sites. Based on these statements, Telefónica propose the following recommendation.

Recommendation 1: Include, in section 10.9 "cost-related requirements" a reference to the need of deeper study in a relaxation in the RF specifications of massive MIMO systems, in order to enable economically viable deployments.

2.2 Maximum transmit power of the RF chains in massive MIMO

Massive MIMO systems can operate with low transmit powers per RF chain in the data plane, thanks to the enhanced spatial resolution provided by the extra number of antennas. However, control plane physical signals such as broadcast control channels or cell reference signals require sector-like radiation patterns. Achieving broad spatial patterns is easy if transmission is concentrated over a few antennas, but becomes a non-trivial task if the transmit power is to be uniformly spread over all the available antennas. Whilst being an implementation decision, the implications in terms of cost can be very significant as the former approach requires over-dimensioning the power amplifiers of certain RF chains in charge of transmitting broadcast control signals.

In order to ensure that cost considerations are taken into account in the design of the control plane physical signals, Telefonica propose the following recommendation.

Recommendation 2: Include, in section 10.9 "cost-related requirements" a reference to the need to study the overall versus individual power distribution among RF chains in massive MIMO systems, without compromising system performance.

3 Conclusion

Accordingly with the current SoTA of massive MIMO, Telefónica propose the following recommendations for section 10.9 in [2]:

- **Recommendation 1: Include, in section 10.9 "cost-related requirements" a reference to the need of deeper study in a relaxation in the RF specifications of massive MIMO systems, in order to enable economically viable deployments.**
- **Recommendation 2: Include, in section 10.9 "cost-related requirements" a reference to the need to study the overall versus individual power distribution among RF chains in massive MIMO systems, without compromising system performance.**

References

[1] C. Mollén, U. Gustavsson, T. Eriksson, and E. G. Larsson, "Out-of-Band Radiation Measure for MIMO Arrays with Beamformed Transmission", arXiv: 1510.05513v1.

[2] TR 38.913 V 0.4.0, "Study on Scenarios and Requirements for Next Generation Access Technologies", Release 14, June 2016.