

**Title:** Proposal for Downlink LTE MIMO Scheme  
**Source:** Alcatel  
**Agenda Item:** 8.5 (MIMO)  
**Document for:** Discussion

## 1. Introduction

In the 3GPP study item on Long Term Evolution, MIMO schemes have to be evaluated. Important criteria for the evaluation of these schemes are now given in [1].

## 2. Coding Options

The combination of multi-antenna systems with OFDM transmission offers four coding and modulation options when no usable channel knowledge at the transmitter is assumed, as depicted in Figure 1: Each codeword can span over all or only one subcarrier (SC) and across all or only one Tx antenna.

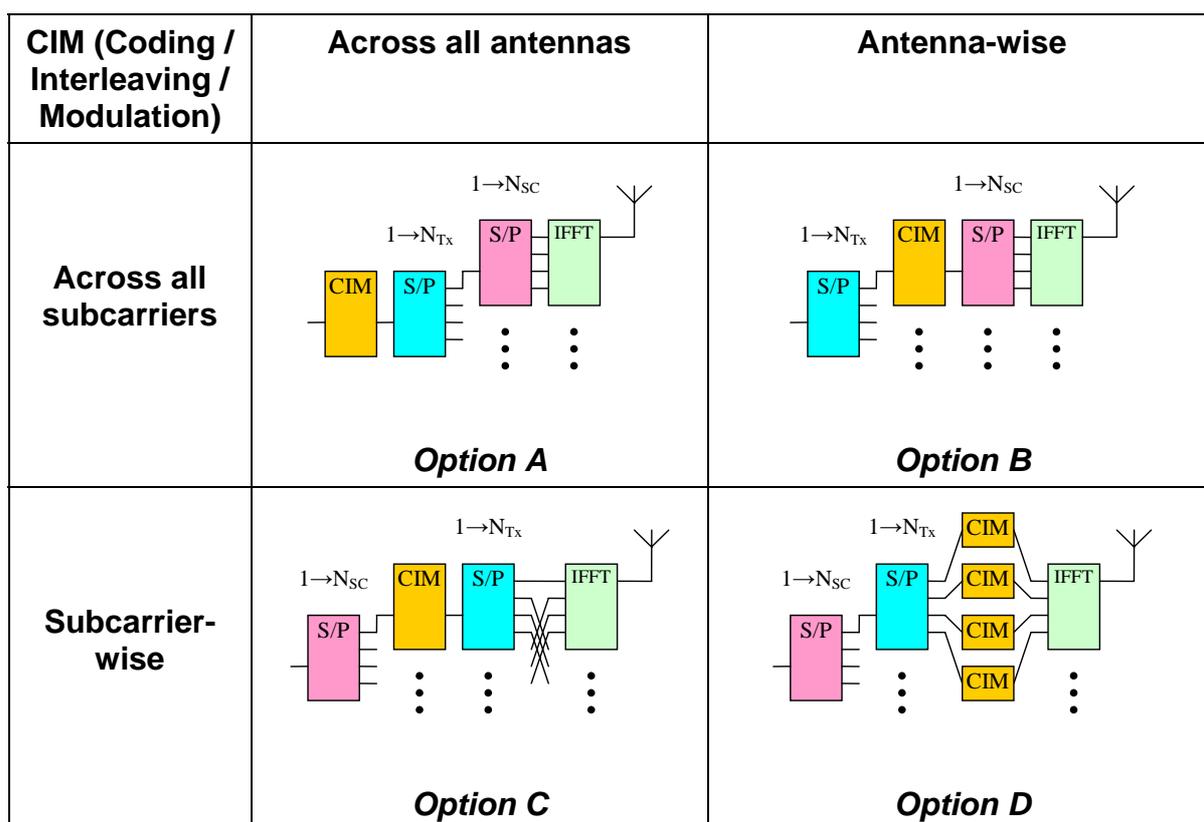


Figure 1

In Figure 1, options C and D do not utilize frequency diversity inside a codeword. Also, both options can only be realized with very short codeword lengths or alternatively with high latency times, which makes these options less favorable to be selected.

Thus options A and B remain. Of these options, option B enables the usage of different code rates for each Tx antenna. This may be favorable in case the transmitter has knowledge about the different channels between the Tx antennas and the UEs. If such information is not available with enough reliability and actuality, the distribution of the codeword over more than one Tx antenna as depicted in option A will provide Tx diversity. At the same time, option A enables the maximum length of codewords for a given latency, which improves FEC performance.

Thus, of the options given by Figure 1, option A is preferred, especially when channel information is limited.

A more detailed view of option A for >1 users is shown in Figure 2. This scheme supports the well-known Vertical BLAST (V-BLAST) receiver structure.

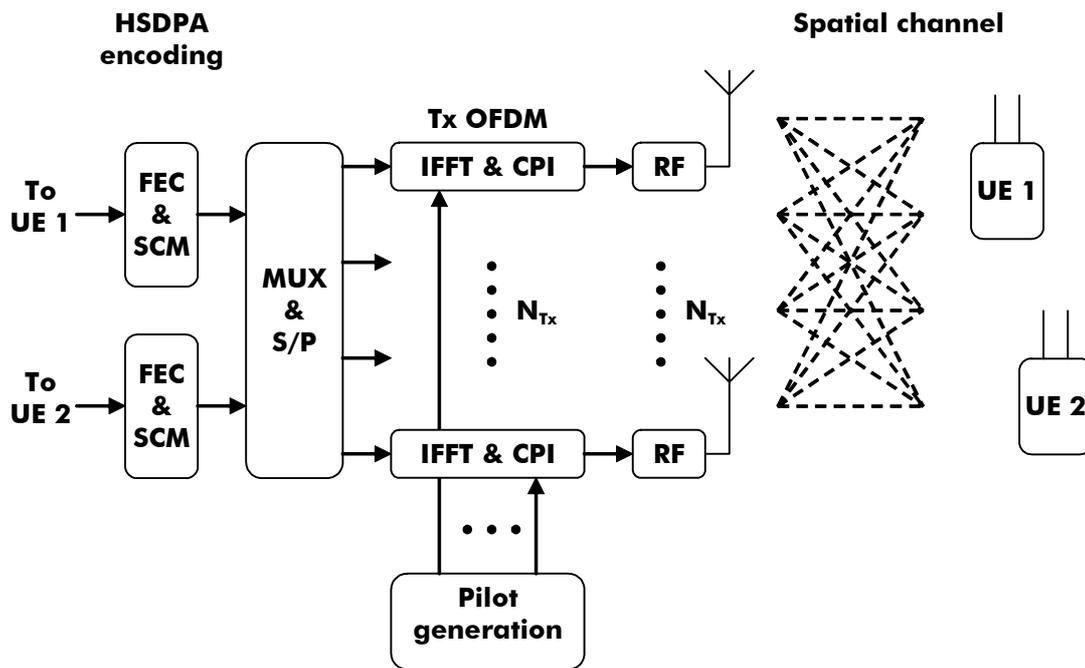
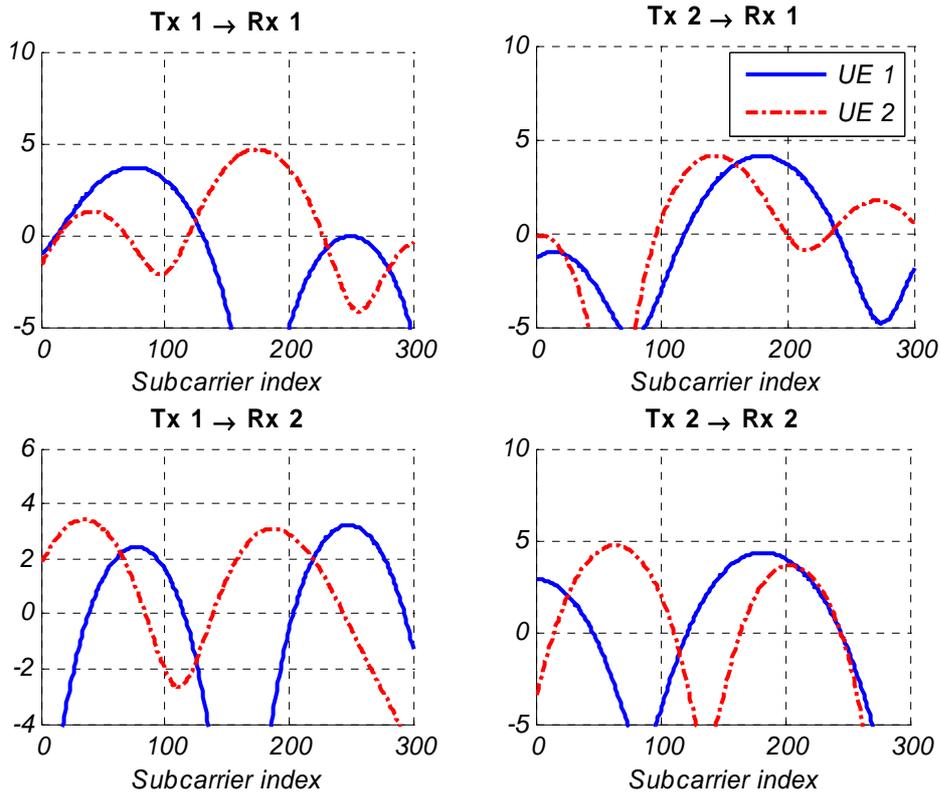


Figure 2

### 3. Frequency-Selective Scheduling

One of the main advantages of OFDM over other multiplexing methods (like e.g. WCDMA) is its ability to exploit the frequency-selective properties of the mobile channel, see e.g. our former document [2]. With frequency-selective scheduling, those parts of the spectrum where the channel transfer function shows high power values are selected while avoiding the spectrum parts with relatively low SNR. This advantageous feature can also be applied in MIMO, where apart from the relative signal power at the receiver, also correlation effects have to be taken into account.

This is illustrated by the following example:



**Figure 3**

Figure 3 shows snapshots of power spectra of the 4 transfer functions which appear in a typical  $2 \times 2$  MIMO arrangement in a multipath environment with a relatively short maximum path delay (e.g. Pedestrian A). In each diagram, "good" and "bad" subcarriers can be distinguished. However, signals from different Tx antennas which arrive with high SNR at one receiver antenna may be deteriorated because of high correlation between the different channels. Thus, the monitoring of the different subcarriers for the purpose of frequency-selective scheduling has to consider MIMO detection performance. This monitoring may be dependent on the type of MIMO detection actually used in the receiver. After feedback from the different UEs to the Node B, the Node B may allocate different spectrum parts to different UEs. One possibility to perform this is to allocate the same set of subcarriers to the same UE over all Tx antennas, such as proposed by [3]. However, it may be advantageous to increase flexibility by allocating subcarriers differently from one Tx antenna to the other, as illustrated in Figure 4 (using the same channel snapshots as in Figure 3).

Note that the signal detection accuracy is not reduced in this case as in downlink all pilots are available to all UEs, see also Section 4.

A refinement of the frequency-selective scheduling is to use different types of modulation for selected subcarriers according to their channel quality, e.g. to use 16-QAM (or 64-QAM) for those subcarriers showing (very) high quality, while using QPSK for selected subcarriers with medium quality. Self-evidently, this "waterfilling" principle can only be used in the presence of stationary or slowly varying channels.

In case the channel to a given UE shows fast variations, which is typical for high-speed users, no useable channel information is available at the transmitter. In that case, the transmitter shall utilize the complete available spectrum and apply both frequency and space diversity, according to option A in Figure 1. Note that the frequency-selective scheduling is also supported by option A.

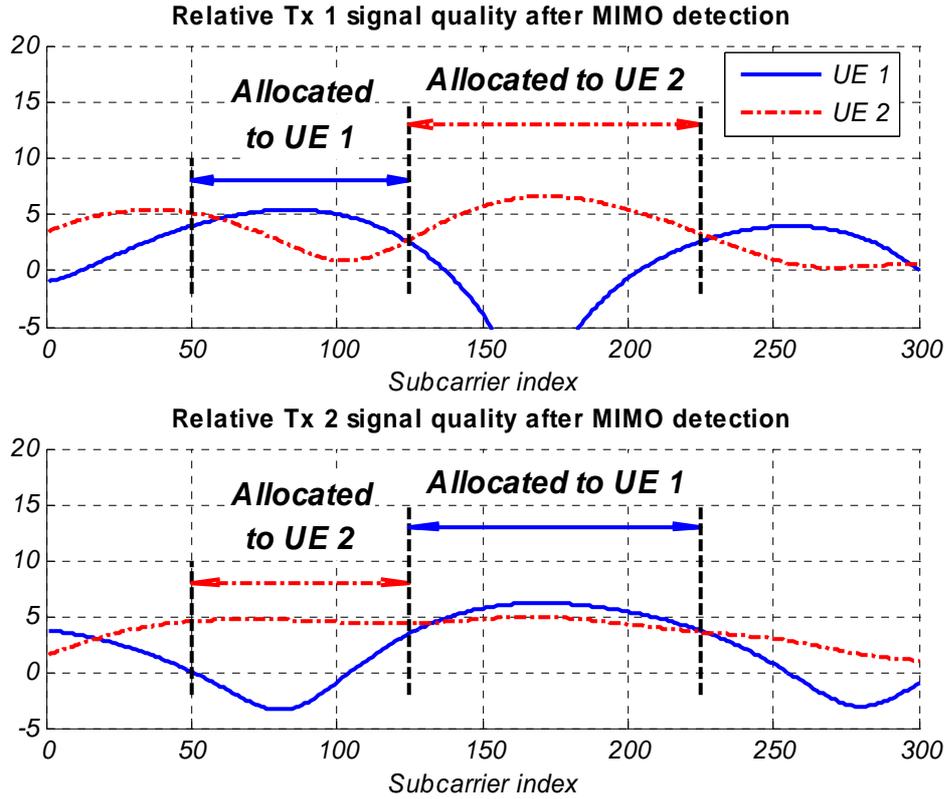


Figure 4

#### 4. Pilot setting

It is recommended to have a regular pilot pattern which supports IFFT-based channel estimation, e.g. as described in [4], as IFFT-based channel estimation clearly shows superior performance over channel estimation e.g. by linear interpolation, while keeping complexity at an acceptable level. This requires the pilots to be cyclically equidistant over the subcarriers. Between the different Tx signals, the pilots have to be orthogonal. A straightforward method to reach this is to place pilots at different positions for each Tx antenna and for each pilot in a given Tx antenna, leaving the parallel subcarrier signal-free at the other Tx antennas (i.e., occupied by "empty pilots") or at least with reduced signal level (FFS), in order to enable accurate channel estimation for MIMO detection.

With the "empty pilot" method, the distance in the frequency domain  $\Delta f_{PP}$  between pilots for IFFT-based channel estimation depends on the FFT size  $N_{FFT}$  and the expected maximum path delay  $\tau_{max}$  in the channel and can be computed by evaluation of the sampling theorem, which leads to the following inequality to be satisfied:

$$\Delta f_{PP} \leq \frac{N_{FFT}}{\tau_{max}}$$

Dividing  $\Delta f_{PP}$  by the frequency distance between two adjacent subcarriers and rounding down to the nearest integer leads to the maximal inter-pilot distance  $D_{PP}$  as a number of subcarriers. Division of the number of used subcarriers by  $D_{PP}$  results into the number of pilots  $N_P$  in the signal at one Tx antenna. In the same signal,  $(N_{Tx} - 1)N_P$  positions have to be reserved for "empty pilots", which brings the total of pilot positions to  $N_{Tx}N_P$  [5].

## 5. Summary and Conclusion

A downlink LTE MIMO scheme has been proposed based on OFDM, thereby highlighting a coding structure which combines potentially large codewords with small latency and utilizes space diversity as well as frequency diversity inside codewords (i.e., option A in Figure 1).

An approach to include frequency-selective scheduling also in MIMO-OFDM scheme has been illustrated, thereby indicating that it is expected that a scheduling which is optimized for each Tx antenna separately is advantageous in comparison to a scheduling which uses the same subcarriers over all Tx antennas for the same user.

The pilot configuration should be such that IFFT channel estimation at the receiver is supported.

## References

- [1] 3GPP TSG-RAN, "TR 25.814: "Physical Layer Aspects for Evolved UTRA", Version 0.3.1, October 2005
- [2] REV-WS029, "OFDM Air Interface for 3G Broadband Evolution", Alcatel, 3GPP RAN Future Evolution Workshop, Toronto, Canada, November 2004
- [3] R1-050942, NTT DoCoMo, NEC, SHARP, "AMC and HARQ Using Frequency Domain Channel-dependent Scheduling in MIMO Channel Transmission", 3GPP TSG-RAN WG1, meeting 42, August/September 2005
- [4] R1-050714, Motorola, "EUTRA Downlink Pilot Requirements and Design", 3GPP TSG-RAN WG1, meeting 42, August/September 2005
- [5] Hongwei Yang, Alcatel Shanghai Bell, "A Road to Future Broadband Wireless Access: MIMO-OFDM-Based Air Interface", IEEE Comm. Mag., January 2005, pp. 53-60