Chapter 7

Conclusions

In Chapter 2, a method for multi-user channel estimation was presented. Utilizing the pulse shaping information in the transmitter and receiver reduces the number of parameters to be estimated. Only parameters associated with the unknown part of the channel need to be estimated. Also, the number of channel parameters do not increase when fractional sampling is performed. Since the number of equations do increase, this gives potentially improved channel estimates.

When estimating the channels to multiple users jointly, with a short training sequence, it is important to reduce the number of parameters per user. This is because the number of parameters increases linearly with the number of users while the number of equations remains constant, determined by the length of the training sequence. In the multi-user channel estimation example we can see that the method improves the channel estimate considerably, especially as the number of users increases.

In Chapter 3 an array antenna was introduced. The channel estimate obtained in Chapter 2 was projected in a spectrum norm sense onto the subset parameterized by the incoming angles and relative gains. The resulting channel estimate was compared to other estimates in terms of relative channel error and bit-error-rate. Not surprisingly, the spatio-temporal estimation methods outperform the purely temporal ones as the number of antennas increases. A notable improvement can also be seen when comparing the proposed method to the method where an unparameterized initial LS-estimate is used, see [8], both for various SNR and various number of antennas.

In Chapter 4 an adaptive antenna built for uplink use according to the DCS-1800 standard was experimentally evaluated. Both laboratory measurements and outdoor field-trials were performed. The laboratory tests show that the adaptive antenna presented is capable of improving the carrier-to-interference ratio more than 30 dB. When the angle between the desired and the interfering signal is decreased the C/I improvement is reduced, mainly due to a loss in carrier gain. With C/I=-20 dB the minimum separation between the desired and the interfering mobile for an error-free transmission is 10 degrees. It has been verified that diagonal loading is a way to improve the estimation of the covariance matrix, giving lower sidelobes and a distinct mainlobe towards the desired signal. Low sidelobe levels are of great importance, particularly in downlink implementations where the spreading of interfering ”noise” must be kept low. Assuming an existing downlink, a comparison with a traditional base station antenna gives a spectral efficiency gain of G=6, thus a significant improvement over existing base station systems.

Chapter 5 demonstrated by means of mathematical derivation, computer simulation and practical experiment, the impact of inaccuracies in the weight settings and the quantization in A/D converters for the adaptive antenna analyzed in Chapter 4. Only the uplink and one co-channel interferer was considered in this study and also line-of-sight propagation without multipath was assumed. The ABF (analog beamformer), utilizing weighting at the air interface frequency has substantial drawbacks compared to the DBF (digital beamformer) where the weighting is performed in a digital signal processor. The inaccuracies in the weights are in the derivations replaced by an equivalent noise source that affects the output SINR. The mean power of this quantization noise is seen to be proportional to the sum of the desired signal power and the interferer power. It also depends on the type of weights that are used. In this work the log-PA weighting technique was described and analyzed. The signal power dependent noise causes the SINR improvement provided by the adaptive antenna to saturate at high signal power levels, setting the limit of maximum interferer suppression attainable.

Due to the high degree of accuracy and control of the antenna patterns, the DBF looks more promising for the future. The DBF software can handle more users, even at different frequencies, which is necessary in a future implementation of adaptive antennas in cellular systems. The number of hardware weighting units increases rapidly as the number of users in a cell increases in an ABF system. For each new user there is a need for N new weighting units, where N is the number of antenna elements. Considerable amount of research have been performed on receiving algorithms. These algorithms need high capacity signal processors for implementation, which is another reason for choosing DBF.

However, it has been verified that even with a limited accuracy in the weights, an adaptive array antenna gives substantial suppression of co-channel interferers, a fact which can be used to improve the utilization of the available spectrum, and thereby increase the number of users in cellular systems.

In Chapter 6, two algorithms designed to mitigate temperature drift in adaptive antennas, utilizing analog beamforming were proposed. The first method used the calculated SMI-weights to create a reference signal. An LMS-like algorithm adjusts the hardware weights for the output of the adaptive antenna to follow the reference. The second method attempts to track the drift due to temperature variation, and then use this information to compensate the SMI-weights, steered out to the hardware weighting units. Simulations show that the signal-to-interference ratio (SIR) of the two auto-calibration methods remains constant when a temperature drift generated as an integrated random-walk is introduced. The variance of the SIR for the tracking approach is of the same order as that of the off-line calibrated array. This is not surprising, since both methods suffer from the batch estimate of the weight vector, calculated by means of the SMI-algorithm. The low-pass filtering of the tracked parameters improves the tracking, but the variance of the SIR is only decreased to the level of the variance of the input signal and the weight vector. The SIR of the LMS-like method is low due to the smoothing effect introduced by the recursive algorithm.

It is believed that the tracking approach is superior to the LMS-like algorithm, since the demand for a stationary signal environment is not as apparent as in the LMS-case. More computations are however required in the implementation of the tracking method.