A POLARIZATION FLEXIBLE PHASED ARRAY ANTENNA FOR A MOBILE COMMUNICATION SDMA FIELD TRIAL

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ABSTRACT

An 8x8 element array antenna for 1.71 - 1.785 GHz frequency range suited for an adaptive antenna system has been built. Elements are broadband microstrip patches, which are optimized for large angular coverage. Antenna can digitally be switched between 16 different polarizations to enhance polarization-diversity-gain. Calibration ports allow precise phase and amplitude adjustment of element coefficients.

INTRODUCTION

Spatial division multiple access (SDMA) techniques are expected to significantly increase the capacity of cellular mobile communication systems [1]. The ACTS TSUNAMI (II) research project, which is sponsored by the European Union, aims at demonstrating this performance gain in a real operating mobile communication network and at promoting the utilization of SDMA in third generation mobile communication systems (e. g. UMTS). During this project an adaptive antenna system has been developed and a field trial in an operating network will be performed. The DCS-1800 standard has been chosen as a basis in order to have a real network available and because the frequencies are similar to those allocated for 3rd generation mobile systems.

Figure 1 illustrates the SDMA-principle and shows the polarization flexible receive antenna array which is part of the adaptive antenna system. Horizontally arranged subarrays build the array antenna. It is connected to a modified DCS 1800 base transceiver station (BTS) and a

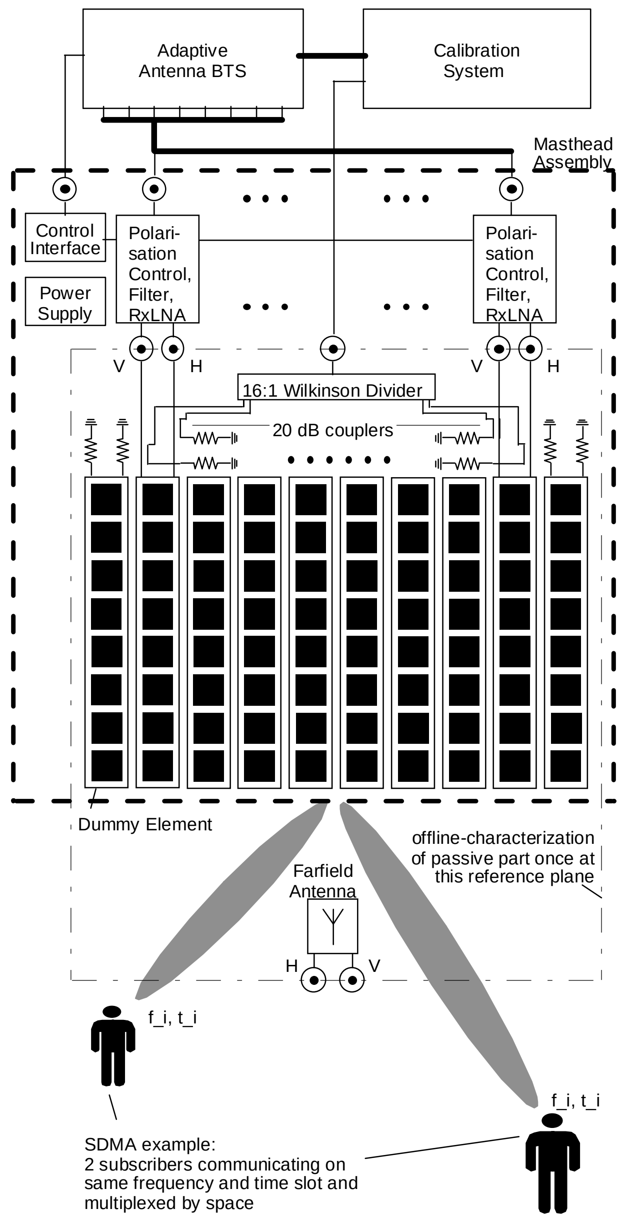

Fig. 1: Adaptive Antenna System with Polarization Flexible Receive Array and Example for SDMA

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calibration system. The BTS is extended to 8 transceivers to enable digital beamforming at baseband. ASICS perform complex weighting of the 8 subarray signals and DSP´s run the algorithms for beamforming.

Calibration of the complex element weighting factors is crucial for the success of the field trial. An important function of the adaptive beamformer algorithms to be investigated is to improve the carrier to interferer ratio (C/I) by placing nulls of the radiation pattern into the direction of strong co-channel interferers. Depth and angular position of these nulls are very sensitive to phase errors $\Delta\varphi$ and amplitude errors Δa of the weighting factors. The post-calibration targets for these errors are $\Delta\varphi < 3°$ and $\Delta a < 0.5$ dB.

Further improvement of C/I can be obtained using the polarization diversity concept. Therefore, a new polarization control unit has been designed, which allows to switch between 16 different polarizations.

RX ANTENNA ARRAY

The receive antenna array shown in Figure 1 consists of 10 linearly arranged subarrays, of which the outer 2 act as dummy elements to increase the similarity of the subarray radiation patterns in the azimut. For the required azimutal scan coverage of 120° a maximum horizontal antenna element spacing of 0.535 λ is allowed to supress grating lobes.

Each subarray consists of 8 vertically separated single antenna elements in order to increase directivity in elevation. The vertical spacing between the antenna elements has been chosen to 0.87 λ to obtain 11 dBi minimum subarray gain. The geometry of a subarray is shown in Figure 2.

Microstrip patch antennas have been selected for the single elements, as these are low cost,

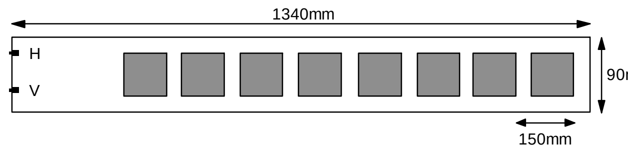

Fig. 2: Geometry of a Subarray

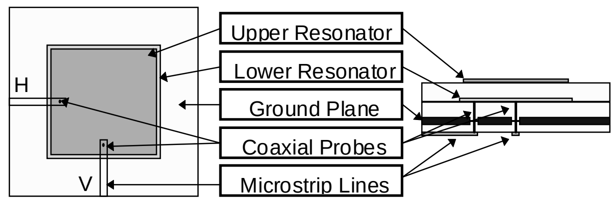

Fig. 3: Stacked-Patch Antenna Element with Ports for Horizontal and Vertical Polarization

easy to fabricate, low weight, small dimension devices and it is easy to couple out the two orthogonal polarizations required for the polarization flexibility.

Also, gain and size of a patch antenna can easily be reduced by choosing a high permittivity substrate. A low element gain is important because a broad main lobe is required for the 120° azimut coverage. For the polarization flexibility it is advantageous because the radiation patterns for horizontal and vertical polarization are more similar than with a high gain and low ε_r patch. The E-plane radiation pattern that corresponds to horizontal polarization has a stronger decay towards greater azimut angles than the H-plane pattern that corresponds to vertical polarization. The horizontal element spacing of 0.535 λ makes an element size smaller than $\lambda/2$ favourable to limit coupling between neighbour elements.

Therefore, the convenient strip-slot-foam design [2] cannot be used to obtain the necessary bandwidth because the usual foam material (e. g. ROHACELL HF) has an ε_r of about 1 and the element gain and size would be too large. Instead, a substrate with an $\varepsilon_r = 3.4$ and a $\tan\delta = 0.002$ has been chosen. To meet the required bandwidth of 5% a very thick substrate could be chosen, which is unpractical because of weight and cost. Therefore a stacked-element design has been applied, which is shown in Figure 3. Above a lower patch resonator, which is fed conventionally by two coaxial probes for horizontal and vertical polarization, is a slightly smaller patch resonator, which produces a second resonance frequency and thus increases the bandwidth.

Measurement results of all components show good performance. Bandwidth of antenna elements is about 6% (SWR < 2). Single element gain is about 6 dBi. Radiation pattern of a subarray demonstrates a narrow beam in elevation (6°, -3 dB) and a fairly wide beam in azimuth (120°, -5 dB). Crosspolarization level in the sector of interest is below -25 dB.

ACTIVE RX AND POLARIZATION CONTROL

The passive part of the antenna array is succeeded by an active circuitry, which is shown in Figure 4.

Two input ports are for the V- and H-signals received by each subarray. Firstly, these signals are amplified by LNA´s to minimize the composite noise figure. For the LNA´s HP MGA82583 have been chosen. Their fairly high dynamic range (1 dB compression point: +17 dBm) allows them to be connected directly to a subarray before any RX bandpass filter.
To achieve the polarization flexibility a new digitally configurable polarization control unit has been designed. It uses two switches and a 4-bit phase shifter equally distributed on both signal paths in order to get balanced attenuation. The unit allows to switch between 16 different polarization settings including horizontal, vertical, left-handed circular and right-handed circular polarization and it can account for phase differences possibly occurring between the RX-LNAs.

The phase shifters are realized using a switched delay line approach, which is acceptable as the relative bandwidth of operation is only 5%. GaAs-switches HP MGS71008 are utilized as these are well matched, fast, easy to drive and employ high isolation (36 dB) and low attenuation (1.2 dB). Switching time is less than 30µs to allow switching in the odd-numbered DCS-1800 time slots. Thus, the antenna can online be adapted to the polarization of the received signals.

A Wilkinson power divider combines the two signal paths for horizontal and vertical polarization. Another amplifier is placed before the output port of the active RX-unit to obtain the required overall amplification and to compensate for the losses of the phase shifters. It is preceeded by a protecting bandpass filter.
The performance of the RX-unit remains well within the specifications. The overall-amplification is 16 dB. Phase shifters have a typical accuracy of 2% at design frequency, which provides for a high polarization purity.

CALIBRATION

Calibration of the element signal paths is performed by an offline calibration after manufacture and an online calibration during operation.

The online calibration is performed by a special calibration system that measures the transfer function of each element signal path in opera-

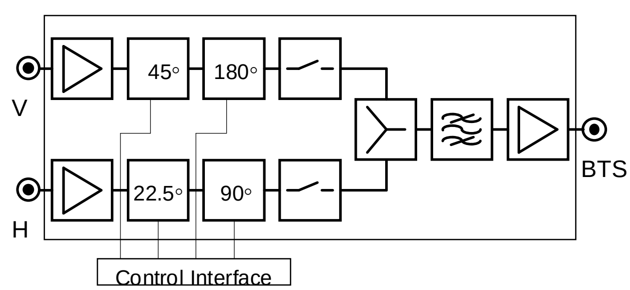

Fig. 4: Active RX and Polarization Control Unit

tion and therefore can account for amplitude and phase errors occuring from temperature variations, aging, changing cable connections and so on. This is achieved by injecting a calibration signal into every signal path by means of the 16-to-1-Wilkinson-divider and the 20-dB-directional-couplers shown in Figure 1 and measuring the response at digital baseband. The Wilkinson-divider and the couplers are designed to provide a symmetric and equal distribution of the calibration signal to every signal path.

The offline calibration assumes that the passive components including the single antenna elements preceeding the active RF-circuitry in the signal paths from the antenna elements to the digital beamformer behave stable over time and temperature. Thus a precise measurement of scattering parameters is performed at the ports which are on the reference plane indicated in Figure 1. All offline calibration measurements are performed with the completely assembled and fixed array to include also influences from mutual coupling between subarrays and the housing and to have a stable characterization of the passive parts.

Since it is not practicable to measure the whole 19x19 S-matrix, which would completely describe the antenna system, a reduced set of measurements is performed. Firstly, the transmissions regarding magnitude and phase between the central calibration signal port and the 16 ports for the V- and H-signals from the subarrays are measured. Secondly, the magnitude and phase radiation patterns or the transmissions between the farfield antenna ports and the V- and H-ports of each subarray are measured over the azimut angle. Thus, also magnitude and phase imbalances of the radiation patterns between subarrays can be accounted for in the beamforming algorithms.

CONCLUSION

A polarization flexible receive antenna array for an SDMA field trial has been presented. A single antenna element for large angular coverage and bandwidth has been developed. A new polarization control device has been introduced. A calibration method consisting of an online and an offline calibration is described. The antenna assembly is prepared for the SDMA field trial to be performed within the TSUNAMI project.

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