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"System-theoretical considerations on RIS-supported radio communication systems"

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Kirchoffbau, K2001

6G or IMT-2030 is currently a major research topic for the next major step in mobile and wireless communications. According to the ITU-R Recommendation "Framework and overall objectives of the future development of IMT for 2030 and beyond" very wideband systems with an aggregated throughput in the order of several hundred Gbps are proposed as target for research and innovation. The necessary bandwidth will only be available in the millimeter and sub-terahertz domain, which is heavily affected by shadowing conditions. The communication link is blocked without any additional technical means. Coverage improvements can be provided by using reflectors, RIS arrays, and repeaters to direct radio waves around corners or obstacles.

Reconfigurable Intelligent Surfaces (RIS) are proposed as a means to improve coverage.

An additional advantage is investigated, whether in multipath propagation environment the overall channel capacity can be increased by constructive superposition of the different multipath components at the receiver by appropriate settings of different RIS arrays. It is shown that the increased channel capacity can only be achieved within a small bandwidth much smaller than needed in 6G depending on the radio channel delay spread. This approach is very sensitive with respect to displacements of the mobile station.

The comparison of reflectors, RIS arrays, and repeaters shows different performance and complexity levels affecting their network deployment. Overall, the repeater solution provides either the largest radio range or the lowest necessary total transmit power compared to reflectors or RIS arrays and, thereby, is the most sustainable approach.

It is claimed that by means of RIS the radio channel can be programmed. In the equalizer approach at the receiver basically any transfer function can be approximated. However, for increasing system bandwidth and radio channel delay spread the equalizer length and signal processing effort is growing very fast. In the RIS-supported approach only the tap factors of the multipath propagation channel can be adjusted, where the delays of the different multipath components remain. This corresponds to the scalar product between the vector of the radio channel impulse response and the vector of the complex reflection coefficients of the different RIS arrays. Therefore, the possibilities to program the radio channel is rather limited.

The RIS array can be regarded as an antenna array, where the phase of each RIS element can be adjusted with phase shifters in the range of maximum 0 to 2π to provide beamforming. Due to the physical size of the RIS array ranging from about 100 cm^2 to 5 m^2 depending on the carrier frequency and other factors with hundreds to thousands of RIS elements the RIS array is adding frequency dependency to the overall radio transmission.

The targeted frequency-independent transmission channel for very wideband systems requires ideally a single path channel. This can be approximated in radio propagation by Rice channels with one dominating path. Multipath propagation results in frequency-selective fading, which is characterized by the coherence bandwidth and the time variation by the coherence time. Especially a repeater with signal amplification and potentially also regeneration can provide such a dominating path. The coherence bandwidth of the radio channel follows from the correlation function of fading functions at different frequency deviations. With the proposed correlation criterion based on the well-known approach for Rayleigh channels, the coherence bandwidth and time tend to infinity from a Rice factor around $K' \geq 4 \mathrel{\hat{=}} 6\ \mathrm{dB}$.

The different effects are investigated by system-theoretical concepts.

Short biography

Werner Mohr graduated from the University of Hannover, Germany, with a Master Degree in electrical engineering in 1981 and a Ph.D. degree in 1987.

Dr. Werner Mohr joined Siemens AG, Mobile Network Division in Munich, Germany in 1991. He was involved in several EU-funded projects and ETSI standardization groups on UMTS and systems beyond 3G. Werner Mohr coordinated several EU and Eureka Celtic funded projects on 3G (FRAMES project), LTE, and IMT-Advanced radio interface (WINNER I, II, and WINNER+ projects), which developed the basic concepts for future radio standards. Since April 2007 he was with Nokia Solutions and Networks (now Nokia) in Munich Germany, where he was Head of Research Alliances. In addition, he was chairperson of the NetWorld2020 European Technology Platform until December 2016. Werner Mohr was Chair of the Board of the 5G Infrastructure Association in 5G PPP of the EU Commission from its launch until December 2016. He was chair of the "Wireless World Research Forum – WWRF" from its launch in August 2001 up to December 2003. He was a member of the board of ITG in VDE from 2006 to 2014. He is co-author of a book on "Third Generation Mobile Communication Systems" a book on "Radio Technologies and Concepts for IMT-Advanced" and a book “Mobile and Wireless Communications for IMT-Advanced and Beyond”. In December 2016 Werner Mohr received the IEEE Communications Society Award for Public Service in the Field of Telecommunications and in November 2018 he received the VDE ITG Fellowship 2018. In May 2019 Werner Mohr received the WWRF Fellowship.

In March 2021 he retired from Nokia and is now active as a consultant (mainly for 6G Infrastructure Association in the Smart Networks and Services Joint Undertaking of the European Commission) and lecturer at the Technical University of Berlin, Germany.

Currently, his research interests in the 6G context are on sub-Terahertz radio systems, radio propagation, and RIS-systems.