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Phase Shift Beamformer for Millimeter Wave Hybrid Receiving

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ABSTRACT
This study looks at millimeter-wave orthogonal frequency division multiplexing's uplink transmission using a wide bandwidth and hybrid receiving. Analysis of the spectral efficiency of the system is made possible by the channel model's treatment of the spatial- and frequency-wideband effects. The beam squint effect brought on by wideband effects is demonstrated by the study and simulation results. The phase shift beamforming method aids in reducing this impact. The results suggest that the technique produces better results when compared to base results.

Keywords : Millimeter-wave (mm-wave), wideband, beam squint, orthogonal frequency division multiplexing (OFDM), hybrid.

I. INTRODUCTION

Millimeter-wave (mmWave) communications, which is a highly acknowledged promising technology, are anticipated to improve future wireless networks. mmWave communications can produce previously unheard-of gigabits-per-second data speeds and fulfil the ever-growing need for wireless traffic when used in dynamic micro-cell or pico-cell (IEEE 802.11ad) systems. However, radio signals in mmWave frequencies have trouble passing through barriers due to their weak diffractive properties and significant path loss. In this case, route loss is compensated by massive multiple-input multiple-output (MIMO) technology, which also improves spectral and energy efficiency and makes it simpler to exploit channel sparsity for mmWave communications. Recent years have seen a lot of study in mmWave communications on massive MIMO. Massive MIMO provides a large number of spatial degrees of freedom, making it possible to eliminate inter-user interference and achieve high data speeds using relatively modest computing linear precoding techniques like zero-forcing and maximal ratio combining. Since channel state information is crucial for large MIMO systems, many channel estimation techniques have been created for mmWave communications to take advantage of the channel sparsity in the angle domain and delay domain. A minimum mean-squared error (MMSE) estimator has been presented using channel covariance. Recent years have seen a lot of study in mmWave communications on massive MIMO.

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On the other hand, if beam squint is neglected and the same beam-steering vector is used for each subcarrier, signals will point in distinct physical directions. Therefore, the beam squint effect should be carefully considered while estimating channels, especially for physical angles-based approaches. Beam squint poses yet additional challenge in downlink channel estimation and precoding for FDD systems with hybrid transceivers. The analogue precoder is unable to produce the frequency-dependent steering vectors required to account for the beam squint effect since the phase configuration in phase shifters is fixed for one OFDM block. We suggest using several RF chains to jointly create frequency-dependent steering vectors for each path by adjusting the digital precoder for each subcarrier. To the best of our knowledge, this is the first attempt to tackle the issue. Since mmWave communications mainly rely on the precise alignment of beams between the transmitter and the receiver, beam squint will significantly reduce performance. An investigation has been made into a combining pattern for high-dimensional receivers with beam squint for mmWave MIMO channels in the line-of-sight (LoS) situation. For analogue phased arrays, the algorithms increase the codebook size during beam generation to partially adjust for beam squint. Based on the massive MIMO-OFDM channel model, we have developed a quick Fourier transform-based channel estimation approach that takes into account the spatial-wideband effect. In wideband communications, this approach can address the beam squint issue, although it encounters error floors in high SNR regions. In order to estimate uplink channels with the beam squint effect for single-user mm Wave systems with hybrid transceivers, a compressive sensing-based channel estimation technique has been developed.

II. RELATED WORKS

[1] J. Rodrıguez-Fernandez and N. Gonzalez-Prelcic: The gathering of channel information is necessary for the design of the precoders and combiners in hybrid MIMO (Multiple-Input Multiple-Output) systems operating at millimetre waves (mmWave). The beam-squint effect, which appears when the system bandwidth is relatively large, is mostly ignored in earlier research on hybrid MIMO designs for channel estimation. The requirement to assume frequency-dependent array steering vectors in order to account for beam-squint significantly complicates the estimation of the mmWave wideband channel. In this study, we present a method for frequency-selective mmWave channels that accounts for frequency-

dependent array responses and approaches the optimal ML estimator under dictionary constraints. We also develop a suboptimal channel estimation technique that accounts for the beam squint effect. The simulation results based on channel realisations received from Quadriga show the effectiveness of the proposed solutions at the low Signal-to-Noise Ratio (SNR) regime without assuming that the channel sparsity is known. Studied the Maximum-Likelihood (ML) estimator for mmWave channels.

[2] X. Gao, L. Dai, S. Zhou, A. M. Sayeed, and L. Hanzo: Beam space channel estimate is crucial for millimeter-wave MIMO systems that rely on lens antenna arrays to achieve much greater data rates despite using a constrained number of radio-frequency links. However, the majority of existing beam space channel estimation schemes were developed for narrowband systems, whereas the relatively few wideband solutions usually rely on the assumption that the sparse beam space channel exhibits a common support in the frequency domain, which has limited validity due to the impact of beam squint caused by the wide bandwidth in actual use. In this paper, we examine the wideband beam space channel estimation problem without using the common support assumption. By utilizing the impact of beam squint, we specifically show that each path component of the wideband beam space channel exhibits a separate frequency-dependent sparse structure. Then, driven by this structure, we present a successive support detection (SSD) based beam space channel estimation method. SSD progressively estimates all of the sparse path components in line with the traditional idea of successive interference cancellation. The support of each path component at multiple frequencies is jointly calculated using the demonstrated sparse structure to improve accuracy, and its influence is then removed to estimate the remaining path components. The suggested SSD-based approach can accurately estimate the wideband beam space channel at a low complexity, according to the performance analysis. The suggested SSD-based system has a lower pilot overhead and, according to simulation findings, improves channel estimate accuracy. Studied about successive support detection (SSD) based beam space channel estimation scheme.

[3] B. Wang, F. Gao, S. Jin, H. Lin, and G. Y. Li,: Massive MIMO systems' numerous antennas generate the spatial-wideband effect, which makes the transmitted wideband signal susceptible to the actual electromagnetic wave propagation delay over the sizeable array aperture. In contrast to most other efforts, the transceiver design presented here ignores the spatial-wideband effect, assumes that the transmitted signals' bandwidths are not exceptionally wide, and concentrates only on frequency selectivity. In this paper, we investigate dual-wideband effects, also known as spatial and frequency wideband effects, in large MIMO systems from the viewpoint of array signal processing. We provide the transmission method to handle the effects of dual-wideband in mmWave-band communications. Utilizing the channel sparsity in the angle domain and the delay domain, we develop efficient uplink and downlink channel estimation algorithms with minimal training overhead and no pilot contamination. Due to the array signal processing techniques, the suggested channel estimation works with both TDD and FDD huge MIMO systems. The dual-wideband effects may be successfully handled by the suggested transmission architecture for large MIMO systems, as demonstrated by numerical examples. Studied about TDD and FDD massive MIMO systems.

III. Methodology

In proposed method, the spectral efficiency of wideband mm-wave orthogonal frequency division multiplexing (OFDM) uplink transmission with hybrid receiving is analyzed. The base station (BS) is equipped with a large array and employs a hybrid receiving structure. The dual-wideband effects are considered in the channel model. By analyzing the norm of the beam space channel, the spectral efficiency of the system is derived, which shows the deterioration caused by the beam squint effect. Moreover, the impacts of the bandwidth and the number of subcarriers on the beam squint effect are revealed by analyzing the spectral efficiency, which provide guidance for designing the system. The considered system is depicted in Fig. 1. In this system, a user equipment (UE) with an antenna is transmitting signals to the BS. The BS is equipped with a uniform linear array of M antennas. The BS antennas are connected to a phase shift network which conducts analog receiving. The phase shift network is connected to N_RF radio frequency (RF) chains. The received signal at the BS at the t-th slot can be expressed as

$$y(t) = x(t) * h(t) \in C \ (1)$$

where x(t) is the transmitted signal, h(t) ∈C^M ×1 is the channel between the UE and the BS, n(t) ∈ $C^{M\times1}$ is the received noise. As the system works with wide bandwidths and mm-wave bands, the channel is of multipaths and is frequency selective. By considering the dual wideband effects. In order to simplify the BS structure and save power in mm-wave systems with large arrays, the hybrid structure is employed at the BS. The received signal is first processed with analog beamforming, which is further converted to the digital domain with RF chains.

Phase Shift Beamforming Technique:

The phased. $PhaseShiftBeamformer$ object implements a narrowband phase-shift beamformer. A phase-shift beamformer approximates a time-delay beamformer for narrowband signals by phase-shifting the arriving signal. A phase shift beamformer belongs to the family of conventional beamformers. The phase shift beamformer uses the conventional delay-and-sum beamforming algorithm. The beamformer assumes the signal is narrowband, so a phase shift can approximate the required delay. The beamformer preserves the incoming signal power.

To beamform signals arriving at an array:

A simple phase shift beamforming structure is developed. Aiming at highly parallel implementation of the phase-shift beamformer a matrix formulation of its operations has been developed and simulated.

Create the $phased.\ PhaseShiftBeamformer$ object and set its properties.

Call the object with arguments, as if it were a function.

Apply phase-shift beamforming to a sinewave signal received by a 7-element ULA. The beamforming direction is 45° azimuth and 0° elevation. Assume the array operates at 300 MHz. Specify the beamforming direction using the Direction property.

The time delay operation, fundamental for beamforming, has been replaced by the phase-shift, which for the complex valued signals is equivalent to rotation of signal. This removes limitations on the steering directions inherent for the time-delay beamformers. A simple phase shift beamforming structure is developed. Aiming at highly parallel implementation of the phase-shift beamformer a matrix formulation of its operations has been developed and simulated.

Advantages:

1. We analyzed the spectral efficiency of wideband mm-wave OFDM systems with a large antenna array at the BS.
2. By increasing the number of subcarriers the beam squint effect can be alleviated.
3. By considering the spatial- and frequency-wideband effects in the channel model, the spectral efficiency of the system is analyzed.

Applications:

1.Radio astronomy,
2. Remote sensing,
3. Automotive radars,
4. Military applications

IV. Results and Discussion

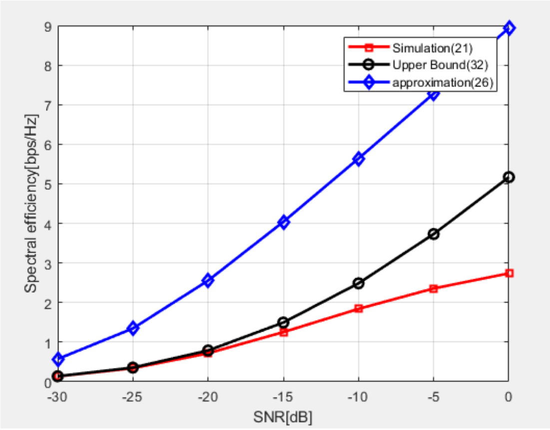

Figure 2: Graph for Spectral Efficiency

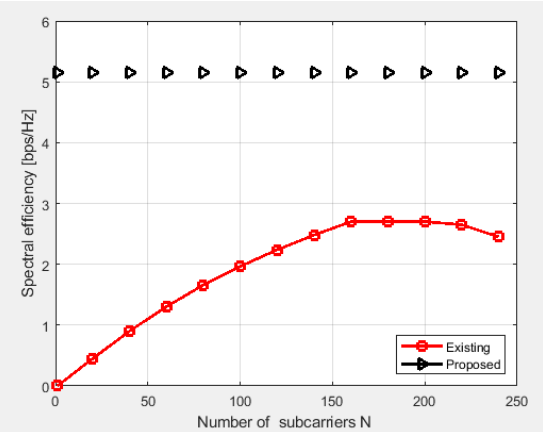

Figure 3: Spectral Efficiency Vs Number of Subcarriers

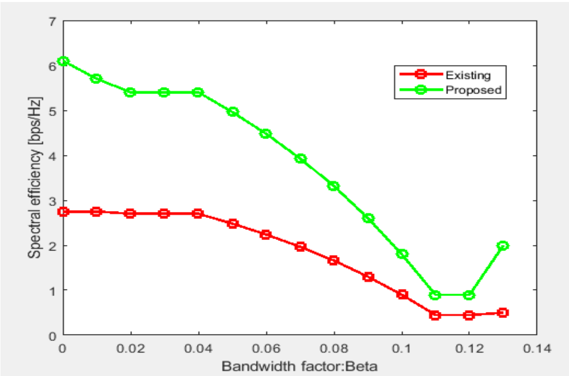

Figure 4: Spectral Efficiency Vs Bandwidth Factor

V. Conclusion

At the BS, we examined the spectral effectiveness of systems using a big antenna array for wideband mm- wave OFDM. The research and simulation demonstrate that the wide bandwidth leads the beam to squint, or point in a direction away from the path. We demonstrate that the beam squint effect can be lessened by increasing the number of subcarriers.

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