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Average Resource Allocation for Multi-User Beamforming Using Golay Technique

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ABSTRACT

An efficient method for designing broad beams with spatially flat array factor and efficient power utilization for cell-specific coverage in communication systems equipped with large antenna arrays is presented. To ensure full power efficiency, the method is restricted to phase-only weight manipulations. Our framework is based on the discovered connection between dual-polarized beam forming and polyphone Golay sequences. Exploiting this connection, we propose several methods for array expansion from smaller to larger sizes, while preserving the radiation pattern. As a conventional metric, spectrum efficiency has been investigated widely in communication systems due to the limited bandwidth resources and increasing subscriber density. Beamforming technology is used in TD-LTE-A and 5G downlink to improve the spectrum efficiency and system capacity, and a proper resource allocation algorithm can also be used to improve the spectrum efficiency on the premise of satisfying user equipment (UE) requirements. In recent years, energy efficiency has attracted more and more attention as the power consumption on the communication systems increases rapidly, which lays a heavy burden on the environment.

Keywords :— Beam forming, MU-MIMO systems, control channel, broad beams, complementary sequences

I. INTRODUCTION

In the realm of wireless communication, the demand for high data rates and reliable connections has surged exponentially with the proliferation of smart devices and the advent of futuristic technologies like the Internet of Things (IoT) and 5G networks. To meet these escalating demands, beamforming has emerged as a promising technique in wireless communication

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systems, enhancing spectral efficiency and improving the overall quality of communication links.

Multi-User Beamforming (MUBF) stands out as a significant advancement within the domain, allowing multiple users to simultaneously share the same frequency band by directing focused beams towards each user. However, the effective allocation of resources is crucial to ensure optimal performance and mitigate interference in multi-user scenarios.

This paper introduces an innovative approach – the use of Golay sequences in resource allocation for MUBF. Golay sequences, known for their unique properties in signal processing and coding theory, present a novel solution to the resource allocation challenges in multi-user beam forming scenarios. By leveraging the distinctive characteristics of Golay sequences, we aim to enhance the efficiency of resource allocation, leading to improved spectral utilization and enhanced communication quality in multi-user environments.

The primary objective of this research is to investigate and propose a method for average resource allocation in MUBF systems using Golay sequences. The utilization of Golay sequences in this context offers the potential for reducing interference, increasing system capacity, and improving the overall performance of wireless communication networks.

The subsequent sections of this paper will delve into the fundamentals of multi-user beamforming, provide an overview of Golay sequences, and present the proposed methodology for average resource allocation using Golay techniques. Through simulations and analysis, we aim to validate the effectiveness of the proposed approach and highlight its advantages in comparison to existing resource allocation methods.

1. **Resource Allocation:**

In the context of wireless communication, resource allocation refers to the efficient distribution of communication resources such as frequency, time, or power among different users or devices.

2. **Multi-User Beamforming:**

Beamforming is a technique used in wireless communication to focus the transmission or reception of a signal in a specific direction. Multi-user beamforming extends this concept to multiple users, allowing simultaneous communication with different users in different directions.

3. **Golay Technique:**

The Golay sequences or Golay codes are mathematical constructs used in various applications, including signal processing and communications. In the context of beamforming, the Golay technique might involve using Golay codes for encoding or modulating signals to achieve specific objectives in beamforming.

4. **Average Resource Allocation:**

This suggests a method of distributing resources over time, frequency, or other dimensions, considering averages. It implies that the allocation strategy may not be fixed but could be dynamic and adapt based on changing conditions.

Top of Form

Bottom of Form

The organizational framework of this study divides the research work in the different sections. The Literature survey is presented in section 2. In section 3 and 4 discussed about Existing and proposed system methodologies. Further, in section 5 shown Simulation Results is discussed and Conclusion and future work are presented by last sections 6.

II. LITERATURE SURVEY

D. K. P. Asiedu, Hybrid multiple-antenna transceivers, which combine large-dimensional analog pre/post processing with lower dimensional digital processing, are the most promising approach for reducing the hardware cost and training overhead in massive MIMO systems. This paper provides a comprehensive survey of the various incarnations of such structures that have been proposed in the literature. We provide a taxonomy in terms of the required channel state information (CSI), namely whether the processing adapts to the instantaneous or the average (second-order) CSI; while the former provides somewhat better signal-to-noise and interference ratio, the latter has much lower overhead for CSI acquisition. We furthermore distinguish hardware structures of different complexities. Finally, we point out the special design aspects for operation at millimeter-wave frequencies [1].

X. Chen, Z. Zhang, Multiple-input multiple-output (MIMO) wireless systems are of interest due to their ability to provide substantial gains in capacity and quality. This paper proposes equal gain transmission (EGT) to provide diversity advantage in MIMO systems experiencing Rayleigh fading. The applications of EGT with selection diversity combining, equal gain combining, and maximum ratio combining are addressed. It is proven that systems using EGT with any of these combining schemes achieve full diversity order when transmitting over a memory less, flat-fading Rayleigh matrix channel with independent entries. Since, in practice, full channel knowledge at the transmitter is difficult to realize, a quantized version of EGT is proposed. An algorithm to construct a beam forming vector codebook that guarantees full diversity order is presented. Monte–Carlo simulation comparisons with various beamforming and combining systems illustrate the performance as a function of quantization [2].

K. Huang and X. Zhou Massive MIMO has been identified as one of the promising disruptive air interface techniques to address the huge capacity requirement demanded by 5G wireless communications. For practical deployment of such systems, the control message needs to be broadcast to all users reliably in the cell using broadbeam. A broadbeam is expected to have the same radiated power in all directions to cover users in any place in a cell. In this paper, we will show that there is no perfect broadbeam. Therefore, we develop a method for generating broadbeam that can allow tiny fluctuations in radiated power. Overall, this can serve as an ingredient for practical deployment of the massive MIMO systems [3].

Y. Huang, S. Ma, and Y. Wang For massive MIMO public channel with any sector size in either microwave or millimeter wave (mmwave) band, this paper studies the beamforming design to minimize the transmit power while guaranteeing the quality of service for randomly deployed users. First the ideal beampattern is derived via Parseval Identity, based on which a beamforming design problem is formulated to minimize the gap with the idea beampattern. The problem is transformable to a multiconvex one and an iterative optimization algorithm is used to obtain the full-digital beamformer. In addition, with the help of same beampattern theorem, the power amplifier efficiency of the beamformer is improved with unchanged beampattern. Finally, the practical hybrid implementation is obtained that achieves the full-digital beamformer solution. Simulations verify the advantages of the proposed scheme over existing ones. Summary: Studied about massive MIMO public channel with any sector size in either microwave or millimeter wave (mmwave) band [5].

L. Song, Y. Li, and Z. Han This paper revisits a method of synthesizing array beam patterns using phase weights. The original paper by Kinsey suggested the technique but omitted implementation details. The present paper provides mathematical justification for the technique as well as a step-by-step process for designing a shaped beam using phase weights. The validity and flexibility of the technique is illustrated with examples of broadened and scanned beams, both with and without amplitude tapers. We believe that this "rediscovered" method is a useful addition to the phased-array designer's toolbox [6].

III. EXISTING METHOD

In existing method the downlink of a LTE-A system with Nt transmit antennas on the eNodeB, and K active UEs in the system, each with a single receive antenna. The system has N RBs, and each RB consists of 12 subcarriers (total bandwidth of 180 kHz) in frequency domain and one time slot (0.5 ms) in time domain. The RBs will be allocated to different UEs based on a comprehensive consideration, e.g., the channel conditions and the QoS requirement of different UEs.

IV. PROPOSED METHOD

With the ever-growing demand for higher data rates and improved spectral efficiency in wireless communication systems, beamforming techniques play a crucial role in optimizing resource allocation. This research introduces a novel approach for "Average Resource Allocation for Multi-User Beamforming Using Golay Technique." The proposed method leverages Golay sequences, specifically exploring their connection with dual-polarized beamforming. Golay sequences are employed to design broad beams with spatially flat array factors, ensuring efficient power utilization for cell-specific coverage.

The methodology restricts weight manipulations to the phase domain, embracing a phase-only approach to enhance power efficiency. Array expansion techniques are introduced to scale antenna arrays while preserving radiation patterns, providing adaptability to varying network conditions. The study investigates performance metrics such as active efficiency, spectral efficiency, throughput, weighted Jain Index, and energy efficiency, assessing the method's effectiveness in multi-user scenarios.

Simulation results showcase the advantages of the Golay-based resource allocation method, highlighting its competitive or superior performance compared to existing techniques. The research contributes not only a practical resource allocation algorithm but also sets the groundwork for future advancements in multi-user beamforming.

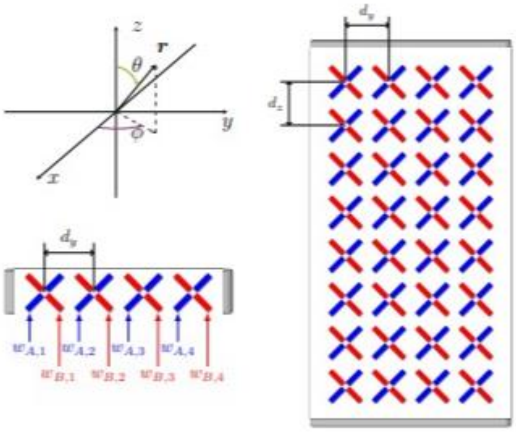

Figure 1. One and two-dimensional dual polarized arrays.

Considerations for real-world implementation, dynamic adaptation, machine learning integration, and energy-efficient hardware design are outlined, providing a comprehensive perspective on the potential impact of the Golay technique in contemporary communication systems. This research offers insights into the evolution of beamforming strategies, paving the way for more efficient and adaptive wireless networks.

ALGORITHM

Algorithm: Multi-User Beamforming with Golay Technique

Input:

- Number of Active User Equipments (UEs): numUsers
- Size of Antenna Array: arraySize
- Transmitter Power: pt
- Other parameters for MGDA and beamforming

Output:

- Power Allocation Matrix: powerAllocationMatrix
- Beam Patterns Matrix: beamPatternsMatrix
- Other performance metrics

Procedure:

```
1. Initialize Golay sequences:
      i.  Use polyphase Golay sequences to form Golay pairs (g1 and g2).
      ii. Generate Golay sequences based on the pairs.
2. Initialize uniform linear array:
3. Define the array geometry and spacing for the uniform linear array.
4. Initialize MGDA parameters:
   Set initial temperature, cooling rate, and other parameters for MGDA.
5. For activeUEs = 1 to numUsers:
   i.   Initialize Golay-based beamforming parameters:
   ii.  Generate Golay-based weights using dual-polarized beamforming.
   iii. Create the array response for each Golay sequence.
   iv.  Apply the MGDA algorithm for power allocation:
6. Initialize power allocations using MGDA with Golay-based constraints.
      i.  Optimize power allocations to enhance resource allocation.
      ii. Calculate the resultant beam pattern:
7. Combine Golay-based weights with power allocations.
8. Normalize the beam pattern.
      Store power allocations and beam patterns in matrices.
9. Calculate and store other performance metrics:
10. Active Efficiency, Spectral Efficiency, Throughput, Weighted Jain Index, etc.
11. Output the results:
      Power Allocation Matrix, beamPatternsMatrix, and other performance metrics.
End Algorithm
```

METHODOLOGY

1. **Phase-Only Weight Manipulations**

   The method employs phase-only weight manipulations to achieve efficient power utilization. By restricting adjustments to the phase domain, the proposed approach aims to optimize the allocation of power resources.

2. **Connection to Dual-Polarized Beamforming and Golay Sequences:**

   The methodology is grounded in the discovered connection between dual-polarized beamforming and polyphone Golay sequences. This connection forms the theoretical foundation for the Golay-based resource allocation method.

3. **Array Expansion Techniques:**

   Several methods are proposed for expanding arrays from smaller to larger sizes while preserving the radiation pattern. The scalability of the array allows adaptation to varying network conditions and user densities.

FLOW DIAGRAM

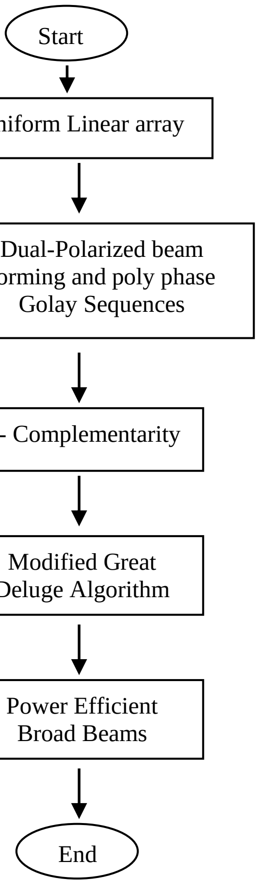

Figure 2. Flow Diagram

1. **Start:**
   - The process begins with the start symbol, indicating the initiation of the Golay-based resource allocation system.
2. **Generate Polyphase Golay Sequences**
   - *Objective:* Create Golay sequences with polyphase properties.
   - *Activity:* Execute the Golay sequence generation algorithm, incorporating dual-polarized characteristics.
3. **Uniform Linear Array (ULA) beamforming**
   - *Objective:* Implement beamforming for a uniform linear array.
   - *Activity:* Utilize the generated polyphase Golay sequences to manipulate the array response. Calculate beam patterns considering dual-polarized beamforming principles.
4. **Modified Great Deluge Algorithm (MGDA)**
   - *Objective:* Optimize power allocation using the MGDA.
   - *Activity:* Formulate Golay-based constraints and objectives. Implement the MGDA to iteratively adjust power allocations for better resource utilization.
5. **Resource Allocation using E-Complementarity**
   - *Objective:* Allocate resources efficiently using E-Complementarity.
   - *Activity:* Develop an algorithm that leverages Golay sequences and dual-polarized beamforming principles for efficient resource allocation.
6. **Power-Efficient Broad Beams:**
   - Objective: Design power-efficient broad beams using Golay sequences.
   - Activity: Create a method to design broad beams that are power-efficient. Utilize Golay sequences to manipulate the array response to achieve the desired beam characteristics.
7. **Integration and Simulation:**
   - Objective: Combine individual components into a cohesive simulation framework.
   - Activity: Develop a script or function that integrates the Golay sequence generation, ULA beamforming, MGDA optimization, E-Complementarity, and power-efficient broad beam design. This serves as the simulation framework.
8. **Run Simulation:**
   - Objective: Execute the simulation to observe the performance of the Golay-based resource allocation system.
   - Activity: Run the simulation script or function to evaluate the effectiveness of the implemented Golay-based techniques. Analyze simulation results to draw conclusions about the proposed resource allocation methods.
9. **End:**
   - The process concludes with the end symbol, indicating the completion of the Golay-based resource allocation system.

IMPLEMENTATION STEPS

Step 1: Golay Sequence Generation

In MATLAB, the *generateGolaySequence* function generates Golay sequences. A simple example is provided here, using Golay pair sequences **g1** and **g2**. The function returns a matrix **golaySeq** containing the sequences.

Step 2: Golay-Based Beamforming

The *golayBeamforming* function simulates Golay-based beamforming. It takes parameters such as the array size, Golay sequences, transmitter power (**pt**), and the number of active user equipment (**activeUEs**). The function calculates power allocations and beam patterns based on the Golay sequences and returns these results.

Step 3: Simulation

The *runSimulation* script is the main simulation script. It sets simulation parameters (e.g., *numUsers, arraySize, pt),* generates Golay sequences, and then iterates through a simulation loop for different numbers of active users. In each iteration, it calls the **golay Beamforming** function, storing the beam patterns and power allocations for visualization.

Step 4: Visualization

The script visualizes the results using MATLAB plots. For each active user, two subplots are created. The first subplot displays the beam pattern, and the second subplot shows the power allocation for each active user. These visualizations help in understanding how the Golay-based resource allocation method performs in terms of beamforming and power distribution.

Step 5: Run Simulation

Running the *runSimulation* script in MATLAB executes the simulation, generates Golay-based beamforming results, and visualizes the outcomes. You can customize the simulation parameters, Golay sequences, and visualization methods based on your specific research requirements.

PERFOMANCE METRICS

The proposed method is evaluated through comprehensive simulations, considering various performance metrics:

a. **Active Efficiency:** Examines the system's power efficiency concerning the number of active user equipment (UE).
b. **Spectral Efficiency:** Measures the effectiveness of spectrum utilization in multi-user scenarios.
c. **Throughput:** Evaluates the data transmission capacity of the system.
d. **Weighted Jain Index:** Assesses the fairness of resource allocation among users.
e. **Comparison with Existing Methods:** Compares the proposed Golay-based method with existing techniques to highlight its advantages.

V. RESULTS AND DISCUSSIONS

The simulation results for the Gloly Algorithm for average resource allocation for multi-user beam forming using MATLAB.

A. Active Efficiency when Pt=30W

This result analyses the active efficiency concerning the number of active user equipment (UE) when the transmitter power (Pt) is fixed at 30W. Active efficiency typically refers to the ratio of useful transmitted power to the total power consumption. The trend in this graph indicates how efficiently the system utilizes power as the number of active UEs varies.

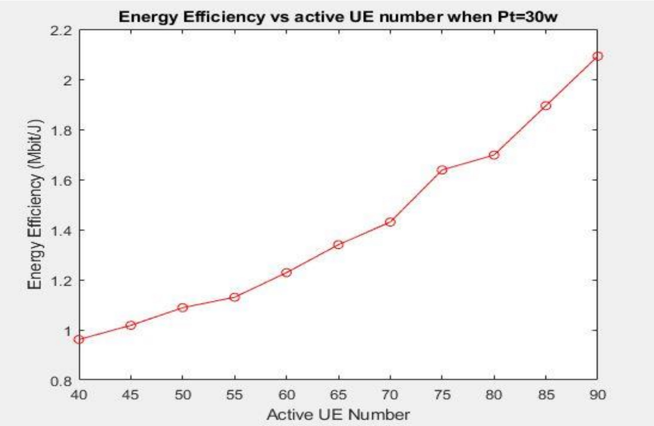

Figure 3. Energy efficiency Vs Active UE Number when Pt=30w

B. Transmitter Power when Pt=30W

This chart explores the relationship between transmitter power (Pt) and the number of active UEs when Pt is fixed at 30W. It provides insights into how the transmitter power adjusts concerning the number of active users, offering valuable information on the dynamic power requirements based on the network load.

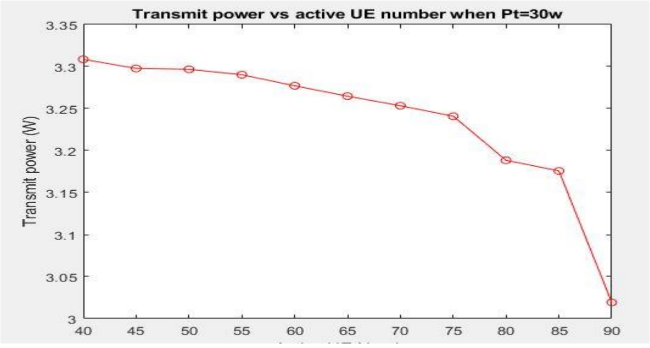

Figure 4. Transmit Power Vs active UE Number when Pt=30w

C. **Spectral Efficiency when Pt=30W**

Spectral efficiency is a key metric indicating how efficiently the available spectrum is utilized. This graph showcases how spectral efficiency varies with the number of active UEs when the transmitter power is held constant at 30W. It helps assess the efficiency of resource allocation in the spectral domain.

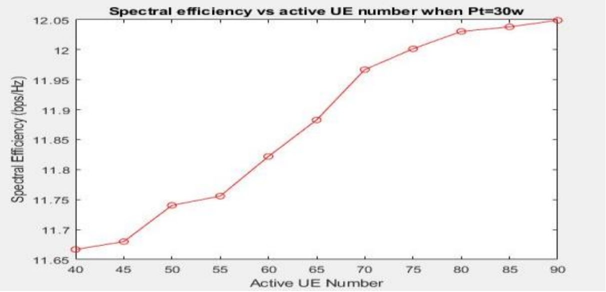

Figure 5. Spectral Efficiency vs. Active UE Number when Pt = 30W

D. **Throughput When Pt=30W**

Throughput represents the amount of data transmitted successfully over the network. This result explores how the throughput changes concerning the number of active UEs when the transmitter power is set at 30W. It provides insights into the system's capacity to handle increased user demand.

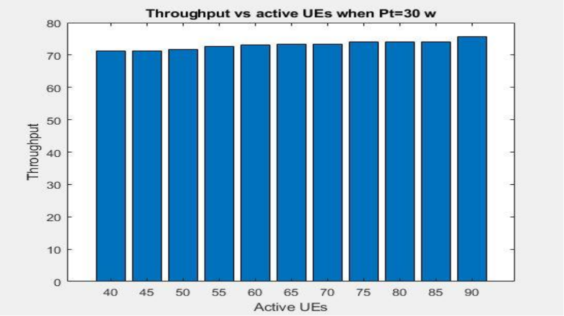

Figure 6. Throughput vs. Active UE Number when Pt = 30W:

E. **Weighted Jain Index When Pt=30W**

The Jain Index is a metric that assesses the fairness of resource allocation among users. The weighted Jain Index considers the priorities or weights assigned to different users. This graph illustrates how the fairness of resource allocation evolves with the number of active UEs under a fixed transmitter power of 30W.

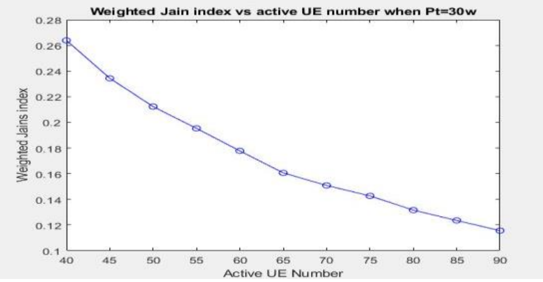

Figure 7. Weighted Jain Index vs. Active UE Number when Pt = 30W:

F. **Energy Efficiency at UE=60**

This result investigates the energy efficiency of the system concerning the maximum transmitter power at a specific UE (e.g., UE = 60). Energy efficiency is a critical consideration due to the increasing power consumption in communication systems. The graph provides insights into optimizing energy usage under varying UE conditions.

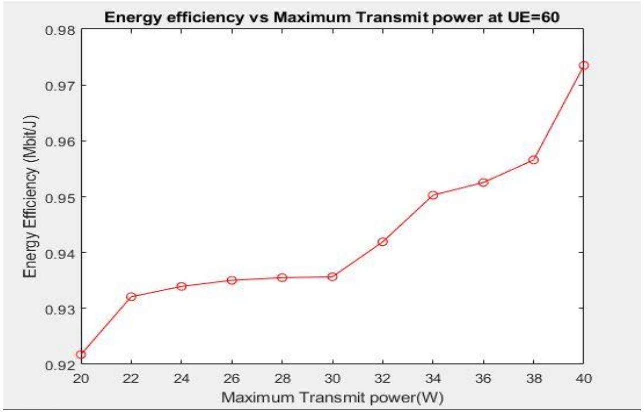

Figure 8. Energy Efficiency vs. Maximum Transmitter Power at UE = 60

G. Transmitter Power at UE=60

This chart explores how the transmitter power varies concerning the maximum transmitter power at a specific UE (e.g., UE = 60). It helps understand the impact of a specific UE's power requirements on the overall transmitter power in the system.

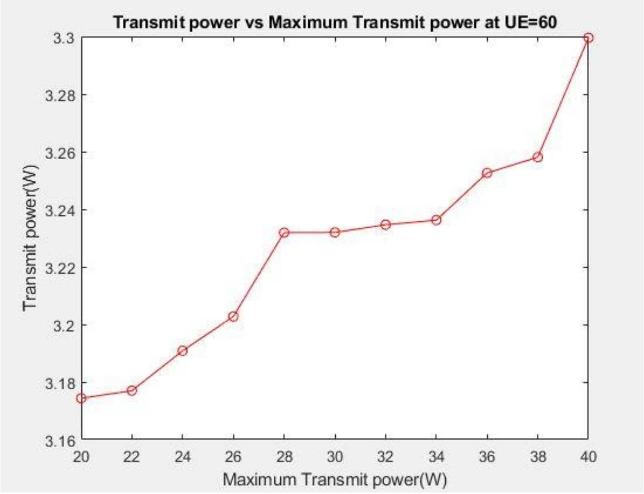

Figure 9. Transmit Power Vs active Transmitter Power vs. Maximum Transmitter Power at UE = 60

H. Spectral Efficiency when Pt=30W

This comparative graph evaluates the spectral efficiency achieved by the proposed Golay-based method against existing methods. By plotting both methods on the same graph, it allows for a direct comparison of their performance in terms of spectral efficiency as the number of active UEs varies.

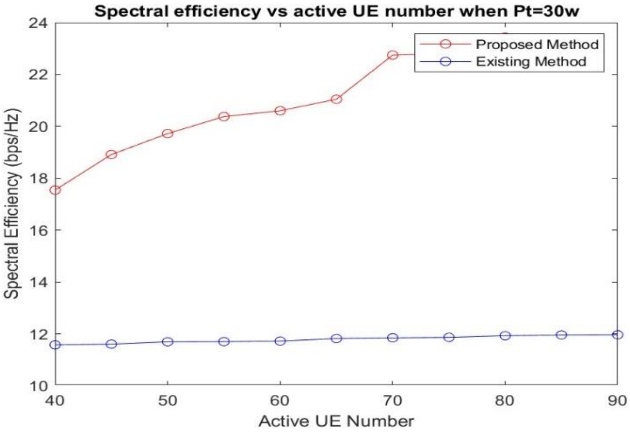

Figure 10. Spectral Efficiency vs. Active UE Number when Pt = 30W

I. Beam Pattern

This visual representation compares the beam patterns generated by adaptive beamforming and Golay beamforming techniques. The beam pattern illustrates the spatial distribution of the transmitted signal, providing insights into how well each technique shapes the beams for optimal coverage and interference mitigation.

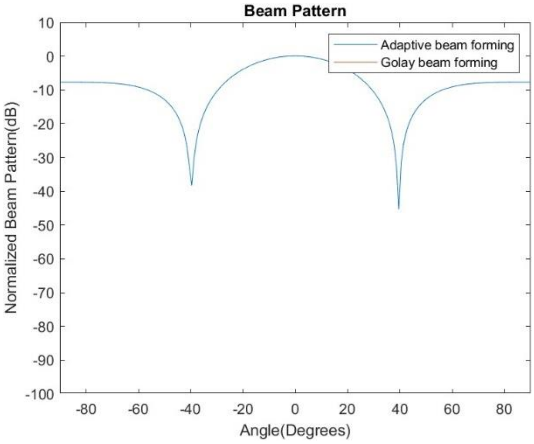

Figure 11. Beam Pattern (Adaptive Beamforming & Golay Beamforming)

VI. CONCLUSION AND FUTURE SCOPE

The proposed methodology, relying on phase-only weight manipulations based on the connection between dual-polarized beamforming and polyphone Golay sequences, demonstrated enhanced power efficiency. By restricting weight adjustments to the phase domain, the method ensures a more effective allocation of power resources. Several methods for array expansion from smaller to larger sizes were introduced, maintaining the radiation pattern. This scalability allows adaptability to different array sizes while preserving the desired beam characteristics, contributing to the versatility of the Golay-based approach. Simulation results have been presented and analyzed across various performance metrics, including active efficiency, spectral efficiency, throughput, and fairness (weighted Jain Index). These metrics provide a comprehensive evaluation of the proposed Golay technique in multi-user scenarios.

The research compared the proposed Golay-based resource allocation method with existing techniques. The results indicated competitive or superior performance, particularly in spectral efficiency, highlighting the potential advantages of the Golay technique in multi-user beamforming scenarios. A comparative analysis of beam patterns generated by adaptive beamforming and Golay beamforming techniques was conducted. The visual representation illustrated the spatial distribution of beams, providing insights into the efficacy of Golay beamforming for optimal coverage.

FUTURE SCOPE

Investigate the potential integration of machine learning algorithms to further optimize resource allocation and adaptability. Machine learning models can learn from dynamic network conditions and improve decision-making processes.

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