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Reconfigurable Antennas and Link Adaptation Algorithms for MIMO-OFDM Wireless System

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***Abstract:*— In this paper, adaptive MIMO-OFDM (Multiple Input multiple Output-Orthogonal Frequency Division Multiplexing) wireless system is used to increase the efficiency of spectrum and it enhance the data rates. In this system reconfigurable antenna is used which is capable of dynamically changing their radiation properties or pattern according to wireless channel characteristics. This system can be implemented to increase the post processing signal-to-noise ratio. This technique reduces the complexity of the modulation.**

This system uses the coding algorithm that uses the advantages of pattern reconfigurable antenna in concern with link adaptation to improve the MIMO-OFDM link throughput.

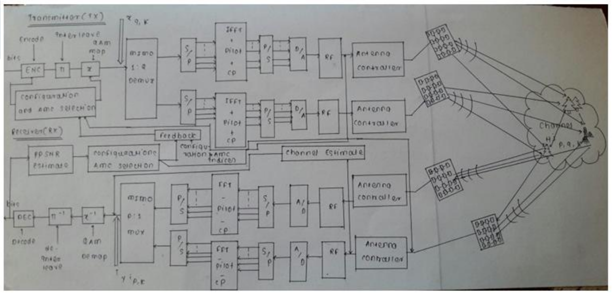
I.INTRODUCTION

Adaptive multiple input-multiple output (MIMO) wireless system have been explained to increase spectral efficiency and provide flexible data rates in multipath fading channel [1-2]. Recent research in this area has either focused on adaptive antenna systems such as pattern reconfigurable antennas [1-8] or adaptive physical layer(PHY) techniques such as link adaptation [9-12] to enhance data rates.

Several studies [2-4] have proposed pattern reconfigurable antennas for MIMO- orthogonal frequency-division multiplexing (OFDM) systems. These antennas are capable of dynamically changing theirradiation properties or patterns according to the wireless channel characteristics. Pattern reconfigurability has been shown to be effective in improving signal-to-noise ratio (SNR) at the receiver[3] and the channel capacity[4] in MINO-OFDM systems.

Although several work [3,4,8] have demonstrated the benefits of reconfigurable antennas, translating the benefits of these antennas into a practical realizable MIMO communication system is very challenging the use of reconfigurable antennas also introduce the need for efficient selection algorithm to leverage the radiation pattern diversity resulting from the different antenna states to improve diversity gain. In this work, we attempt to correct this issue by employing a low-complexity spatially adaptive scheme for joint antenna state selection.

II. SYSTEM MODEL



The system is built by connecting a convolution encoder with an interleaver and a symbol mapper. After the mapping, the symbols in M-ary quadrature amplitude modulation (M-QAM) are modulated by the inverse fast Fourier transform (IFFT) and

The appropriate cycle prefix is added to minimize inter-symbol interference. The data are then split into two spatial streams that are fed into the antenna controller before transmission; the controller sets the correct antenna transmission configuration of mode. The two streams are separately transmitted from the two transmit antennas over the radio channel using spatial multiplexing technique. At the receiver, the cycle prefix is removed and the signal is transformed back into frequency domain with an FFT prior to de-interleaving and subsequently decoded to reconstruct the received symbols.

The receiver forecast the post-processing signal-to-noise ratio(ppSNR) to be used for adaptation and them, runs the spatially modulation (M-QAM) are modulated by the invers fast Fourier transform (IFFT) and

Adaptive modulation and coding (SAMC) control algorithm to determine the antenna configuration and transmission rates. The controller uses the lookup tables to select the indices of the configuration and AMC model that considts of a modulation type and coding rate. It sends this indices to the transmitter via the feedback channel and transmitter uses its lookup tables to match the selected parameters. Each of the reconfigurable antennas used in this MIMO system is able to adaptively modify its radiation characteristics and thus leverage pattern diversity to impact the manner in which the transmitter and receiver perceive the wireless channel. As established in [4] two co-located antennas with different patterns 'see' differently weighted multipath components so that they interfere differently for the two antennas resulting in better reception'. This observation motivated us to merge the benefits of antenna diversity and antenna reconfigurability to improve link capacity and SNR at the receiver [3]

III SPATIALLY ADAPTIVE MODULATION AND CODING

Spatially adaptive modulation and coding is carried out in two main stages,
1) antenna configuration selection and
2) AMC selection

1) Antenna configuration selection:- During this stage the algorithm selects an optional configuration J* that yields the highest average ppSNR. This process requires channel training and is carried out during one of the following training intervals: i) initial training interval and ii) re-training interval.

i) Initial training interval:- The initial training interval is necessary when no prior channel training has been done. Conversely, the re-training interval prior to some initial training is only used in order to some initial training is only used in order to abate the effects of channel fading over time and for up-to-date channel adaption.

ii) Re-training interval:- In this interval, we re-train over the top five configurations stored in interval i) and transmit onetraining packet per condiguration-thus, a total of five training packets. We then select the configuration that yields the highest average ppSNR out of these top five configurations. 2) AMC selection:- in this stage the algorithm selects the AMC scheme using the (text[ppSNR]^[j^[*]]/) associated with the optimal configuration in stage 1.

The selected antenna configuration and AMC scheme are then used to transmit a scheduled number of packets. In order to minimize the loss of throughput during the training interval in stage 1 of the algorithm we append a payload of 1 KB to each training packet. The size of the training packet is reduced to 32 bytes. Additionally, if the optimal configuration found during the training interval is consecutively selected, the number of packets scheduled for transmission and AMC scheme is doubled. These measures helped reduce the negative impact of training overhead on throughput gains, and not only minimized training time but provided data transmission opportunity is achieved through optimization of the AMC mode selection.

The Selection Antenna Configuration And Amc Mode

AMC Mode	**Modulation Type**	**Overall Coding rate**	**Data rate (bps/Hz)**
AMCI	BPSK	½	0.5
AMC2	4-QAM	½	1
AMC3	4-QAM	¾	1.5
AMC4	16-QAM	½	2
AMC5	16-QAM	¾	3
AMC6	64-QAM	2/3	4
AMC7	64-QAM	¾	4.5

Table 1 Mode Selection

3.1.1 Highest rate Selection

Each AMC mode will be denoted by χ, where χ=1,…..., χmax and χmaxis the total number of modes. For each χ, a convolutional encoder($\varsigma\chi$) with coding rates Rc($\varsigma\chi$) and constellation size Mχ.

3.1.2 Robust rate selection algorithm

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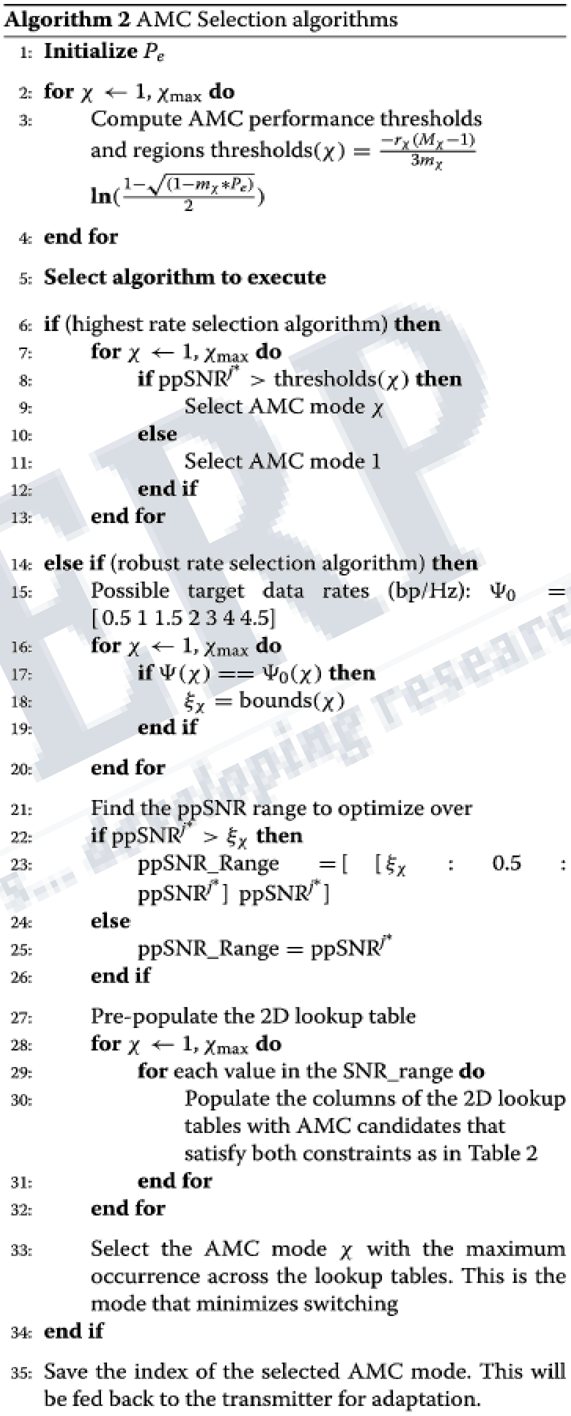
In the design of this algorithm, we observed that the feedback information is often transmitted through a fading channel and is therefore itself prone to errors. There is a non-zero probability of feedback packet loss which may result in a mismatch of loss which may result in a mismatch of switching decisions (the transmitter may not be able to determine the correct AMC mode that the receiver sent). As an example, suppose the target BER is 10-3, target data rate equals 1.5 bps/Hz and the measured ppSNR is 10dB. From Table 1, we determine that AMC3 (QPSK and coding rate ¾) is the minimal AMC mode that would satisy the specified target data rate.



Algorithm 2 AMC Selection algorithms

```
Initialize $P_e$

for $\chi \leftarrow 1, \chi_{\max}$ do
    Compute AMC performance thresholds
    and regions thresholds($\chi$) = $\frac{-r_\chi(M_\chi-1)}{3m_\chi}$
    ln($\frac{1-\sqrt{(1-m_\chi * P_e)}}{2}$)
end for

Select algorithm to execute

if (highest rate selection algorithm) then
    for $\chi \leftarrow 1, \chi_{\max}$ do
        if ppSNR$^{j^*}$ > thresholds($\chi$) then
            Select AMC mode $\chi$
        else
            Select AMC mode 1
        end if
    end for

else if (robust rate selection algorithm) then
    Possible target data rates (bp/Hz): $\Psi_0$ =
    [0.5 1 1.5 2 3 4 4.5]
    for $\chi \leftarrow 1, \chi_{\max}$ do
        if $\Psi(\chi) == \Psi_0(\chi)$ then
            $\xi_\chi$ = bounds($\chi$)
        end if

    end for

    Find the ppSNR range to optimize over
    if ppSNR$^{j^*}$ > $\xi_\chi$ then
        ppSNR_Range = [ [$\xi_\chi$ : 0.5 :
        ppSNR$^{j^*}$] ppSNR$^{j^*}$]
    else
        ppSNR_Range = ppSNR$^{j^*}$
    end if

    Pre-populate the 2D lookup table
    for $\chi \leftarrow 1, \chi_{\max}$ do
        for each value in the SNR_range do
            Populate the columns of the 2D lookup
            tables with AMC candidates that
            satisfy both constraints as in Table 2
        end for
    end for

    Select the AMC mode $\chi$ with the maximum
    occurrence across the lookup tables. This is the
    mode that minimizes switching
end if

Save the index of the selected AMC mode. This will
be fed back to the transmitter for adaptation.
```

IV. EXPERIMENTAL SETUP AND IMPLEMENTATION

4.1Software defined radio (SDR) testbed

We use the wireless open-access radio platform (WARP) designed at Rice University for protocol implementation at the PHY layer. Three main components of the WARP testbed are of interest: (a) Xilinx Virtes-II Pro Field-Programmable Gate Array (FPGA), (b) MIMO-capable radios, and (c) 10/100 Ethernet port. The FPGA allows for MAC protocols to be written in C code. The platform supports up to four radio boards which can be configured for applications similar to the 802.11g/n standards. Source/sink traffic and feedback of the protocols is handled over the Ethernet port[20].

4.2 Reconfigurable printed dipole array(RPDA) antenna:-

We use the reconfigurable printed dipole array[7] shown in Fig. 4 for both signal transmission and reception. These antennas have beam configurations that can be electronically controlled by adjusting the length of each dipole in the two-element array.

A change in length is ingenious by biasing PIN diodes embedded in the structure of the antenna.

Multiple radiation patterns are generated as a result of varying the levels of mutual coupling between array element when the array geometry is changed [4]. We note in passing that although changing the electric length of the antenna changes the resonant frequency of the antenna, the configuration states of the array elements have been shown to resonate at a common frequency and reflection coefficient. Figure 6 in [4] illustrates a reflection coefficient of -12.5 dB at a common resonant frequency of 2.484 GHz.

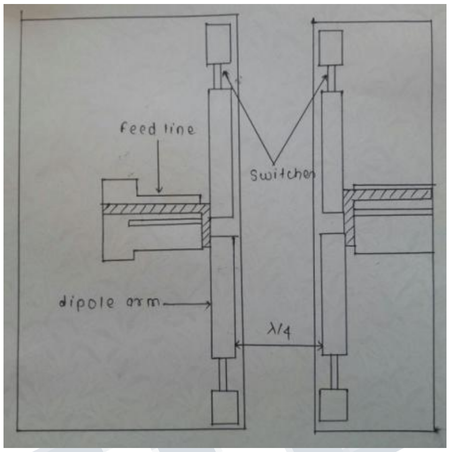


Fig.2
RECONFIGURATION PRINTED DIPOLE ARRAY (RPDA) [7]

The RPDA antennas PIN diode switches to achieve four different operating states. The “short” (S) configuration is used when the switches on the antenna are inactive. The active switches cause the antenna to operate in a “long” (L) configuration. One array at each end of the link therefore uses a combination of the individual antenna states to form different configurations. Shows the 16 possible combinations for the 2 x 2 antenna structure; Fig. 3 shows four different radiation pattern combinations for a two-antenna array system. The blue radiation pattern corresponds to antenna 2 of the array. The radiation patterns on the left of Fig. 3 are generated from the short-short configurations, for antenna 1 and antenna 2, respectively.

Possible configurations for 2 x 2 MIMO-OFDM system

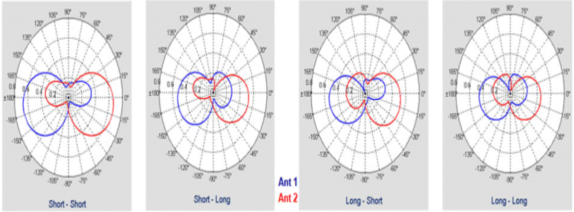


Fig. 3 Radiation Patterns Combinations For A Two-Antenna Array System For All The Possible Antenna Configurations

To determine the pattern diversity of these antenna configurations, we evaluated the correlation coefficients based on the approach proposed by Vaughan et al. in [11, 12]. This approach uses the radiation patterns of the antenna system and numerical integration to obtain the envelop correlation for a two-antenna system. However, it has been shown that the complex envelop correlation(ρ_c) derived in [12] yields a more accurate result when correlation is included in the channel modeling estimation of capacity.

V CONCLUSIONS

A spatially adaptive modulation and coding algorithm was proposed and implemented in a software-defined radio testbed. Multiple techniques of link adaptation were employed to develop a low computational complexity, throughput improving model. The capabilities of reconfigurable printed dipole array (RPDA) antennas in MIMO-OFDM systems were is to improve spectral efficiency. It was shown via field implementation that our model can increase post processing signal-to-noise ratio and therefore system reliability over a multipleantenna slow fading channel. Future work will investigate the effects of feedback delay on the proposed algorithm.

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