Polarized modulation and receivers for wireless communication

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Abstract. Achieving increase in spectral efficiency has always been a major aspect in communication systems. Our work emphasizes the application of dual polarized modulation in a wireless environment. Our main goal is to increase the throughput of the system. We aim to increase the spectral efficiency and throughput without an increment of radiated energy without any Channel State Information at Transmitter (CSIT) and feedback at the transmitter. The proposed dual Polarized Modulation (DPMOD) scheme exploits the polarization diversity reducing the required SNR (Eb/N0) and adding an extra bit and achieves the same Bit Error Rate (BER) carrying extra information.

1. Introduction

Spectrum Scarcity is a serious problem in communications. Especially with wireless communications taking the mantle, the users of communications have also increased multifold. The demand on the network is to support tens of Gbps of data rates if not hundreds of Gbps of data rates. The upcoming 5G is bent upon fulfilling these type of challenges. Polarized modulation transmits the symbol s using one of the polarizations depending on an extra bit c. The symbol s is conveyed through polarization 0, if c = 0 or through polarization 1 if c = 1. (For eg: polarization 0 can refer to horizontal polarization and polarization 1 can refer to vertical polarization.) When compared with the single polarization scenario, DPMOD is particularly striking that although the single polarization scenario has less Spectral Efficiency, it achieves higher BER. On the contrary, DPMOD carries more information and achieves low BER values. Hence, we are able to conclude that the DPMOD obtains better results of lower BER and higher SE.
Hierarchical modulation, also called layered modulation, is one of the signal processing techniques for multiplexing and modulating multiple data streams into one single symbol stream, where base layer symbols and enhancement layer symbols are synchronously overplayed before transmission. The inner or the outer circles determines the Most Significant Bit (MSB). It is clear that HPQ only decides between inner and outer circles, whereas LPQ decides among the quarters. DPMOD[1]-[6] is the superposition of binary phase shift keying (BPSK) plus the modulation used by symbol ‘s’ while the high priority queues (HPQ) are often composed of lower modulations in order to be decoded in poor SNR margins. The low priority queues (LPQ) offer higher throughput even though they require higher SNR values. As the transmitted signal is conveyed with DPMOD, the receiver sees the constellation S in two copies with radius ||h0|| and ||h1|| respectively. The total Spectral Efficiency of the DPMOD is given by the Spectral Efficiency of the transmission of symbol s plus the extra bit conveyed through the switching polarization step.

Cross polarization discrimination can be specified as a signal mean level difference between two orthogonal polarized signal components - horizontal and vertical ones. It is the antenna’s ability to maintain radiated or received polarization purity between horizontally and vertically polarized signals. This is called cross-polar discrimination, or XPD. XPD is defined as

\[ XPD = 20 \log \left( \frac{|y_c|}{|y_{1-c}|} \right) \]

Where, \( y_c \) is the amplitude of the signal received at the polarization where the symbol is transmitted and \( y_{1-c} \) is the other signal. For low XPD values, both polarizations carry the same symbol and the probability of error of detecting the bit \( c \) increases as XPD decreases but the probability of error of detecting the symbol \( s \) remains the same. Even if the \( c \) bit is erroneous and the detected polarization is wrong, it contains the symbol \( s \) and is able to detect it. For high XPD values, only one polarization carries the data symbol whilst the other only carries noise. The system will detect the symbol \( s \) and the switching bit \( c \) correctly. In any case, the system is able to detect the symbol \( s \). XPD impact can also be related to HM. Even if we
are unable to make out whether the signal belongs to inner or outer circle it may be possible for us to find out which quadrant it belongs to so info can be retrieved even if ‘c’ is detected wrongly. This work is based on conjunction to VBLAST and PTC, with polarized modulation(Pmod). Pmod becomes the favourite trade-off between the robustness of the PTC schemes and the higher SE schemes such as VBLAST.

Figure 2 VBLAST over MIMO

Figure 3. Simulation Procedure
As depicted in the diagram, the simulation of the generation of the random vector, \( y=Hz+w \) which is output of the single correlator and input to the detector is done. First the two-bit symbol generated is generated from a uniform random number of the range(0,1) and then this symbol is then compared with the 4 phase signal points(00,01,10,11). Here the addition of AWGN noise takes place and then it is send to the optimal detector where it is then compared and the symbol error rate or SER is calculated.

3. Simulation results and discussion
Channel configurations of \( H_1=[0.2,0.5; 0.7, 0.2] \), \( H_2=[0.2, 0.5; 0.7, 0.02] \), \( H_3=[0.9, 0.7; 0.8, 0.5] \), \( H_4=[0.2, 0.5; 0.07, 0.02] \), \( H_5=[0.6, 0.4, 0.3, 0.1] \) are chosen. (The choice is purely random so as to assure all permutations and combinations). SNR vs SER curves for 5 different invariant channel matrices when \( 10^7 \) symbols are transmitted. For \( H_1=[0.2,0.5; 0.7, 0.2] \), the SER is calculated and plotted against SNR as in Figure 4.

![SER vs SNR](image)

Figure 4. SER vs SNR for \( H_1 \)

For \( H_2= [0.2, 0.5; 0.7, 0.02] \), the SER is calculated and plotted as in Figure 5.
For \( H_3 = [0.9, 0.7; 0.8, 0.5] \), the SER is calculated and plotted as in Figure 6.

For \( H_4 = [0.2, 0.5; 0.07, 0.02] \), the SER is calculated and plotted as in Figure 7:
For $H_5 = [0.6, 0.4, 0.3, 0.1]$, the SER is calculated and plotted as in Figure 8.

Figure 8: SER vs SNR for $H_5$

Comparing all the five time invariant channel matrices:
Figure 9. Comparison of all the time invariant channels considered. Figure 10 represents the SNR vs SER curve for Time Varying channel matrices when $10^7$ symbols are transmitted.

Figure 10. SER vs SNR for time varying channel.
4. **Employing GMSK modulation and its performance evaluation**

GMSK (Gaussian minimum shift keying) modulation is based on MSK, which is itself a form of continuous-phase frequency-shift keying. Here the carrier signal is first smoothened with a Gaussian low-pass filter and then fed to a frequency modulator, which greatly reduces the interference in the neighboring channels. This is used in GSM because of its good spectral efficiency, and better immunity to noise. (It is reflected from its constellation diagram in figure 11)

![GMSK constellation diagram](image)

The new idea proposed here is GMSK modulation is used for symbol’s’ and is combined with the ‘c’ bit which is of BPSK modulation which gives the conveyed signal ‘x’. This ‘x’ is then encoded using the alamouti scheme and later is multiplied with H matrix where AWGN noise is added and then is sent through an combiner and later into optimal detector where the SER calculation is performed to give a 2bit symbol. The following is the SNR vs SER graph for GMSK modulation using a channel matrix. Here channel H1 = [0.2 0.5; 0.7,0.2] is considered.

The SER can be calculated and plotted against SNR as in figure 12.
Comparison between alamouti and without alamouti scheme is shown in figure 13.

5. **On employing circular polarization**
Employing circular polarization is a more convenient method; normally the horizontal polarization can be changed to vertical polarization and vice versa when we employ horizontal /vertical polarization because of channel impairments. When circular polarization is employed, we are not affected by the depolarizing effect due to the wireless channel. Hence, the symbol could undergo either right hand circular polarization (RHCP) or left hand circular polarization (LHCP). As in previous case a single ‘c’ bit can denote either RHCP or LHCP.
6. Conclusion

Our work introduced a novel application of the dual Polarized Modulation in wireless communications. The results demonstrated that the DPMOD consumes less energy to increase the Spectral efficiency and improves the robustness in the presence of cross-polarization when compared with single polarization scenarios. This work can also be extended using OSTBC with that of the GMSK modulation and its necessary parameters. It can also be modelled based on mobile environment. The concept explained here can be applied to various demodulating schemes.

References
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