## LINEAR EQUALIZATION THEORY IN DIGITAL DATA TRANSMISSION OVER DUALLY POLARIZED FADING RADIO CHANNELS

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## Summary

Communications via dually polarized radio channels is an effective means of reusing existing bandwidth. It is a well known fact that one can transmit and receive two orthogonally polarized waves, e.g., linear, circular, or elliptical. Information can be conveyed by independently modulating the signals carried by each of these waves. In conventional terrestrial microwave radio systems, linear orthogonal polarizations, i.e., horizontal and vertical, are usually employed.

Digital communications over a single radio channel (single polarization) is adversely effected by multipath fading which causes intersymbol interference (ISI). In dually polarized digital radio communications one has to contend, in addition, with cross-polarization interference (CPI). This interference, which is dispersive in general, is due to antenna misalignments, imperfect waveguide feeds, fading and other propagation path anomalies. In order to utilize the dually polarized radio channels to their maximum capacity, it is necessary to mitigate the deleterious effects of ISI and CPI.

Various approaches to this problem have been suggested. Some of them address the problem of CPI cancellation only, some minimize CPI and noise, and others treat non-dispersive channels only. Often these methods are based on cross-channel frequency response estimations, thereby facilitating at least a partial cancellation of CPI.

The chief purpose of this paper is to establish a sound theoretical base for realizing effective algorithms and devices for the simultaneous and optimal compensation of cross-polarization and intersymbol interferences in the presence of noise. The dually polarized channel is modeled as a two-by-two complex matrix with frequency dependent elements followed by an additive noise vector. The diagonal entries

represent the co-channel (in-line) frequency transfer characteristics while the off-diagonal terms represent the cross-channel transfer characteristics. The four entries in this matrix channel can be viewed as a sample from a random collection of frequency functions. The presence of noise implies that each matrix channel in the collection is limited to a maximum data rate, for a given error rate and specific communication method. Due to the random nature of the matrix channel, a meaningful performance measure for a particular communication method is the probability distribution of data rates that can be supported at a certain error rate objective.

Figure 1 depicts the problem considered. Two data sources are first passed through a matrix transmitting filter. The diagonal entries control the co-channel signal shaping while the off-diagonal terms control the cross-channel signal shaping as well as a possible power distribution (transfer) between the two channels. The two emerging output signals, represented by a vector, are then transmitted over the matrix channel. At the receiver, independent noise sources are added, and the resultant vector signal is processed by a linear matrix filter which acts as a linear equalizer/canceler.

We pose these general questions. How does one choose the matrix receiving filter so as to minimize a reasonable cost function? Next, how does one choose an optimum matrix transmitter filter under a reasonable power constraint? Finally, how does the performance of these optimum structures compare with the ultimate performance predicted by information theory (Shannon limit).

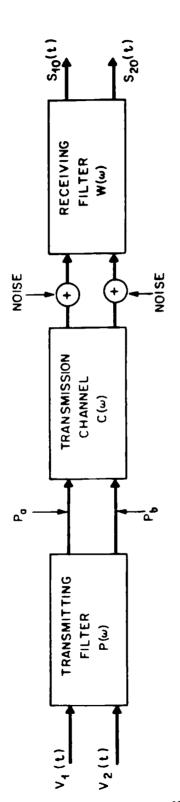
We shall discuss the receiver optimization problem as well as the theory for joint transmitter-receiver optimization. In addition, we shall also present the matched filter bound on performance and the information theory limit.

Results of extensive numerical work (simulation) will be presented. These results are based on our suggested propagation model of the dually polarized radio channels. This model is rich enough to allow meaningful performance comparisons of the various equalization/cancellation methods and their ultimate limits.

Some of the major conclusions are:

 The effects of cross-polarization interference (CPI), contributed by the antennas and their feeds, can be practically eliminated by the linear equalizer/canceler structures discussed herein. This may have a significant bearing upon the cross-polarization requirements placed on the antennas.

- 2. In principle, the random components of CPI can provide partial diversity reception. They could be exploited to increase the total data rates supported by the channels relative to the case where CPI is absent.
- 3. A jointly optimized transmitter-receiver equalizer/canceler is effective when low outage probabilities are required. At relatively high outage probabilities it is of marginal benefit.



Pa+ Pb # TOTAL AVERAGE POWER

FIGURE 1 DUALLY POLARIZED RADIO TRANSMISSION