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Date:3/4/2020

Paper Title: A Simple Transmit Diversity Technique for Wireless Communications

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Year Published: 1998

Open questions for discussion in class:

-How does diversity order affect the accuracy of receiving a signal?

-Are pilot symbols the same thing as a training sequence for something like a linear feedback equalizer?

The topic areas covered by the paper are:

-The Problem of Time-Varying Multipath Fading

-A New Transmit Diversity Technique

-Transmission and Receiving Schemes

-Diversity Order and Diversity Gain

-Pros and Cons of the Technique

The previous approaches to this problem were:

-The previous approaches to reducing BER caused by time-varying multipath fading were:

-Pre-distort the transmitted signal to overcome channel effects. This is limited by radiation power and the fact that the transmitter does not know what the channel is like

-Time and frequency diversity, which put constrictions on time delays and bandwidth

-Antenna diversity, which involves adding antennae to base stations or to remote stations. Of the two, the first one is definitely more economical as there are fewer base units. Then apply a maximum likelihood sequence estimator or minimum mean squared error at the receiver

-Space-time trellis, which requires considerably more processing power

Outline the basic new approach or approaches to this problem:

-Use 2 antennae at the transmitter and M antennae of the receiver. Processing at the receiver includes channel estimation, combiner for the 2 separate signals, and a maximum likelihood detector to differentiate between two signals. The resulting diversity order is 2M, which is equal to applying a maximal-ratio receiver combining (MRRC) with 2M (double the amount) antennae at the receiver and 1 transmit antenna.

-The basic model of this technique is 2 antennae at transmitter and 1 antennae and receiver, but the technique is shown capable of being generalized to M antennae at receiver.

-In terms of error performance, the diversity gain of this technique is about 3 dB worse than the diversity gain of normal MRRC, with 1 transmit antenna and 2M receive antennae. However, this is because the 2 transmit antennae used by the technique both have half the power of the 1 transmit antenna of normal MRRC. If the power of each antennae were equal to the power the 1 antenna of normal MRRC, the diversity gain would be equal. However, the power reduction of a half can be desirable in some cases, and 2 antennae with half power can be cheaper than 1 antenna with full power.

-In terms of sensitivity to channel estimation errors, Normal MRRC would require M pilot sequences for M receive antennae to estimate M channels. For the new technique with M receive antennae, 2 times as much pilot sequences are required since there are 2 transmit antennae and thus 2M channels.

-Decoding delay is two symbol periods.

-In terms of antennae configuration, the transmit antennae have to be placed on the order of ten wavelengths apart to provide the same diversity at the receiver. This is the same as normal MRRC where the receive antennae have to be placed on the order of ten wavelengths apart. This also means 2 receive antennae at a base station can also be used for transmitting.

-The new technique also provides the same soft failure as normal MRRC. Soft failure is when one receiver antenna fails to get a signal, but the signal is preserved due to the presence of multiple receive antennae. What happens instead is that diversity is lost. This new technique achieves the same effect.

Critical assumptions made include:

-Noise is AWGN

-Different cases were discussed, such as if there was no power limitation or no cost limitation,

The performance of the techniques discussed in the paper was discussed in what manner:

-Metrics included were: Diversity order at receiver and diversity gain at the same total transmit power. Sensitivity to channel errors, antennae configuration, soft failure.

-The author made some discussion about the case when the total transmit power is not limited. In this case, the technique would have equal diversity gain just by doubling the total transmit power.

The following terms were defined:

-Diversity order: how many different signals there are at the receiver, which can improve performance.

-Diversity gain: Value of the decrease of the required SNR in order to achieve same BER as a scheme with no extra diversity (1 transmit 1 receive)

-Maximal ratio receiver combining: Using more receivers and 1 transmitter in order to improve diversity order and gain.

-Maximum likelihood decision rule: Condition to pick between two received signals. Equation in paper.

-Pilot sequence: A known sequence transmitted periodically across a time-varying channel to allow receiver to estimate the channel

-Soft failure: When one receiver antenna fails to get a signal, the other antennas can make up for it. Generally, the signal is preserved but diversity gain is lost.

I rate and justify the value of this paper as:

-Very concise and clear paper to read, and it provides a new technique that uses roughly the same resources but has the potential of greatly reducing remote station size while limiting the change in size to larger and fewer base stations. 9/10