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Transmit Diversity Technique for Wireless Communication over Raleigh/Flat Channels using M-ary Modulation Schemes

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ABSTRACT

This paper presents a simple two-branch transmit diversity scheme using two transmit antennas and one receive antenna. It is also shown that the scheme may easily be generalized to two transmit antennas and M receive antennas to provide a diversity order of 2M. This scheme does not require any bandwidth expansion any feedback from the receiver to the transmitter and its computation complexity is similar to MRC.

Keywords: Antenna Diversity, Fade Mitigation, Maximal Ratio Combining, Raleigh Fading, Space-time Coding, Transmit Diversity.

1. INTRODUCTION

The most effective technique for mitigating multipath fading in a wireless radio channel is to cancel the effect of fading at the transmitter by controlling the transmitters power that is, if the channel conditions are known at the transmitter (on one side of the link),then the transmitter can pre–distort the signal to overcome the effect of the channel at the receiver (on the other side). However ,there are two fundamental problems with this approach .The first problem is the transmitters dynamic range .For the transmitter to over come an x dB fade, it must increase its power by x dB which, in most cases, is not practical because of radiation power limitations and size and cost amplifiers. The second problem is that the transmitter does not have any knowledge of the channel has seen by receiver (except for time division duplex system, where the transmitter receives power from a known other transmitter over the same channel). Therefore, if one wants to control a transmitter based on channel characteristics channel information has to be sent from the receiver to the transmitter which results in through put degradation and added complexity to both the transmitter and the receiver.

Other effective techniques are time and frequency diversity .Using time interleaving together with coding can provide diversity improvement. The same holds for frequency hopping and spread spectrum. However, time interleaving results in unnecessarily large delays when the channel is slowly varying. Equivalently, frequency diversity techniques are ineffective when the coherence bandwidth of the channel is large (Small delay spread).

It is well known that in most scattering environments antenna diversity is the most practical and effective technique for reducing the effect of multipath fading. The classical approach to antenna diversity is to use multiple antennas at the receiver and perform combining to improve the quality of the received signal.

The major problem with using receiver diversity approach in current wireless communication systems, such as IS-136 and GSM, is the cost, size and power consumption constraints of the receivers. For obvious reasons, small size, weight and cost are paramount. The addition multiple antennas and the RF chains in receivers is presently not be feasible .As a result, diversity technique have often been applied only to improve the uplink (receiver to base) transmission quality with multiple antennas (and receivers) at the base station .Since a base station often serves thousands of receivers, it is more economical to add equipment to base station rather than the receivers.

2. MODEL FOR TRANSMISSION

Considering a wireless communication system with n antennas at the base station and m antennas at the remote. At each time slot t signals c_t^i , $i = 1, 2\ldots\ldots n$ are transmitted simultaneously from n transmit antennas. The channel is assumed to be a flat fading channel and the path gain from transmit antenna i to receive antenna j is defined to be $\alpha_{i,j.}$

The path gains are modeled as samples of independent complex Gaussian random variables with variance 0.5 per real dimension. This assumption can be relaxed without any change to the method of encoding and decoding. The wireless channel is assumed to be quasi-static so that the path gains are constant over a frame of length l and vary from one frame to another. Basic wireless system block diagram as shown in fig 1.

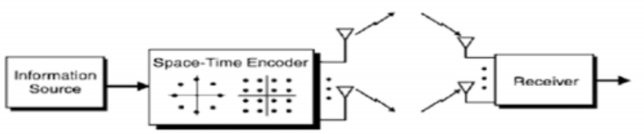

Fig 1: System Block Diagram

At time t the signal r_t^j, received at antenna *j*, is given by

$$r_t^j = \sum_{i=1}^{n} \alpha_{i,j} c_t^j + \eta_t^j$$

where the noise samples h^j_t are independent samples of a zero-mean complex Gaussian random variable with variance η/(2 SNR) per complex dimension. The average energy of the symbols transmitted from each antenna is normalized to be one, so that the average power of the received signal at each receive antenna is *n* and the signal-to-noise ratio is SNR.

3. THE SCHEME FOR TRANSMIT DIVERSITY

A. Two-Branch Transmit Diversity with One Receiver Fig. 2 shows the base band representation of the new two branch transmit diversity scheme. The scheme uses two transmit antennas and one receive antenna and may be defined by the following three functions:

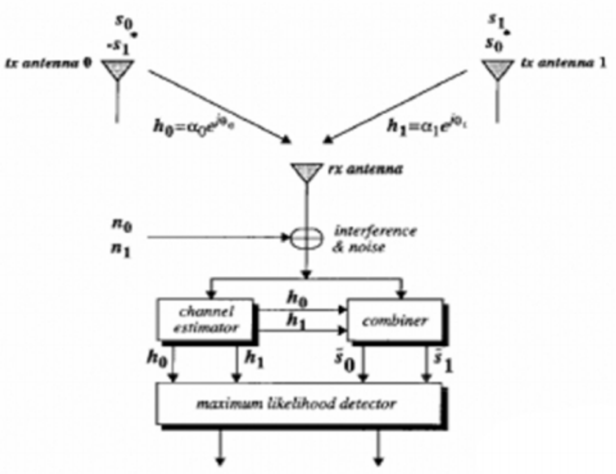

Fig 2: The Two-branch Transmit Diversity Scheme with One Receiver

1. The Encoding and Transmission Sequence: At a given symbol period, two signals are simultaneously transmitted from the two antennas. The signal transmitted from antenna zero is denoted by s_0 and from antenna one by s_1. During the next symbol period signal ($-s_1^*$) is transmitted from antenna zero, and signal s_0^* is transmitted from antenna one where * is the complex conjugate operation. This sequence is shown in Table I.

In Table1 the encoding is done in space and time (space–time coding). The encoding, however, may also be done in space and frequency. Instead of two adjacent symbol periods, two adjacent carriers may be used (space–frequency coding).

Table 1
The Encoding and Transmission Sequence for the Two-branch Transmit Diversity Scheme

	Antenna 0	*Antenna 1*
Time *t*	S_0	S_1
Time *t* + *T*	$-S_1^*$	S_0^*

The channel at time t may be modeled by a complex multiplicative distortion $h_0(t)$ for transmit antenna zero and $h_1(t)$ for transmit antenna one. Assuming that fading is constant across two consecutive symbols, we can write]

$$h_0(t) = h_0(t+T) = h_0 = \alpha_0 e^{j\theta 0}$$

$$h_1(t) = h_1(t+T) = h_1 = \alpha_1 e^{j\theta 1} \qquad \ldots(1)$$

Where *T* is the symbol duration. The received signals can then be expressed as

$$r_0 = r(t) = h_0 s_0 + h_1 s_1 + n_0$$

$$r_1 = r(t+T) = -h_0 s_0^* + h_1 s_0^* + n \qquad \ldots(2)$$

Where r_0 and r1 are the received signals at time *t* and *t* + *T* and n_0 and n_1 are complex random variables representing receiver noise and interference.

2. The Combining Scheme: The combiner shown in Fig. 2 builds the following two combined signals that are sent to the maximum likelihood detector:

$$\tilde{S}_0 = h_0^* r_0 + h_1 r_1^*$$

$$\tilde{S}_1 = h_1^* r_0 - h_0 r_1^* \qquad \ldots(3)$$

Substituting (1) and (2) into (3) we get

$$\tilde{S}_0 = (\alpha_0^2 + \alpha_1^2) S_0 + h_0^* n_0 + h_1 n_1^*$$

$$\tilde{S}_1 = (\alpha_0^2 + \alpha_1^2) S_1 - h_0 n_1^* + h_1^* n_0 \qquad \ldots(4)$$

3. The Maximum Likelihood Decision Rule: These combined signals are then sent to the maximum likelihood detector.

Assuming n_0 and n_1 are Gaussian distributed, the maximum likelihood decision rule at the receiver for these received signals is to choose signal si if and only if

$$d^2(r_0, h_0 s_i) + d^2(r_1, h_1 s_i) \le d^2(r_0, h_0 s_k) + d^2(r_1, h_1 s_k) \forall i \ne k \qquad \ldots(5)$$

Where $d^2(x, y)$ is the squared Euclidean distance between signals x and y calculated by the following expression:

$$d^2(x, y) = (x - y)(x^* - y^*) \qquad \ldots(6)$$

Expanding (5) and using (6) and (4) we get Choose si if

$$(\alpha_0^2 + \alpha_1^2)|s_i|^2 - \tilde{s}_0 s_1^* - s_0^* s_i \le (\alpha_0^2 + \alpha_1^2)|s_k|^2 - \tilde{s}_0 s_k^* - s_0^* s_k \forall i \ne k \qquad \ldots(7)$$

or equivalently choose s_i if

$$\begin{aligned} &(\alpha_0^2 + \alpha_1^2 - 1)|s_i|^2 + d^2(\tilde{s}_0, s_i) \le \\ &(\alpha_0^2 + \alpha_1^2 - 1)|s_k|^2 + d^2(\tilde{s}_0, s_k) \forall i \ne k \end{aligned} \qquad \ldots(8)$$

For PSK signals (equal energy constellations)

$$|s_i|^2 = |s_k|^2 = E_S \forall i \ne k \qquad \ldots(9)$$

Where is the E_s energy of the signal. Therefore, for PSK signals, the decision rule in (8) may be simplified to choose s_i if

$$d^2(\tilde{s}_0, s_i) \le d^2(\tilde{s}_0, s_k) \forall i \ne k \qquad \ldots(10)$$

The combiner may then construct the signal $\tilde{s}_0$, and $\hat{s}_1$ as shown in Fig. 2, so that the maximum likelihood detector may produce, which are a maximum likelihood estimate of s_0 and s_1.

5. IMPLEMENTATION ISSUES

So far it has been shown, mathematically, that the new transmit diversity scheme with two transmit and receive antennas is equivalent to MRRC with one transmit antenna and receive antennas. From practical implementation aspects, however, the two systems may differ. This section discusses some of the observed difference between the two schemes.

a. Power Requirements

If the system is radiation power limited, in order to have the same total radiated power from two transmit antennas the energy allocated to each symbol should be halved. This results in a 3-dB penalty in the error performance. However, the 3-dB reduction of power in each transmit chain translates to cheaper, smaller, or less linear power amplifiers.

b. Channel Estimation Errors

Throughout this paper, it is assumed that the receiver has perfect knowledge of the channel. The channel information may be derived by pilot symbol insertion and extraction Known symbols is transmitted periodically from the transmitter to the receiver. The receiver extracts the samples and interpolates them to construct an estimate of the channel for every data symbol transmitted. There are many factors that may degrade the performance of pilot insertion and extraction techniques, such as mismatched interpolation coefficients and quantization effects. The dominant source of estimation errors for narrowband systems, however, is time variance of the channel. The channel estimation error is minimized when the pilot insertion frequency is greater or equal to the channel Nyquist sampling rate, which is two times the maximum Doppler frequency.

c. Delay Effects

With branch transmit diversity; if the transformed copies of the signals are transmitted at distinct intervals from all the antennas, the decoding delay is symbol periods. That is, for the two-branch diversity scheme, the delay is two symbol periods.

d. Antenna Configurations

For all practical purposes, the primary requirement for diversity improvement is that the signals transmitted from the different antennas is sufficiently uncorrelated (less than 0.7 Correlation) and those they have almost equal average power (less than 3-dB difference). Since the wireless medium is reciprocal, the guidelines for transmit antenna configurations are the same as receive antenna configurations.

e. Soft Failure

One of the advantages of receive diversity combining schemes is the added reliability due to multiple receive chains. Should one of the receive chains fail, and the other receive chain is operational, and then the performance loss is on the order of the diversity gain. In other words, the signal may still be detected, but with inferior quality. This is commonly referred to as soft failure.

f. Impact on Interference

The scheme requires the simultaneous transmission of signals from two antennas. Although half the power is transmitted from each antenna, it appears that the number of potential interferers is doubled, i.e., we have twice the number of interferers, each with half the interference power. It is often assumed that in the presence of many interferers, the overall interference is Gaussian distributed.

6. CONCLUSIONS AND DISCUSSIONS

In this paper a transmit diversity scheme has been presented. It is shown that using two transmit antennas and one receive antenna, this scheme provides same diversity as MRC with one transmit antennas and two receive antennas. The figs.3-6 shows the performance of the system using M-ary modulation Techniques. The performance curves are obtained over Rayleigh and flat channels using 2 transmitting antennas and different receiving antennas it is observed that whenever the number of receiving antennas are increased the performance of system is increasing i.e. the error probability of system decreases. It is also observed that the bit error rate increases as the M increases. If the total radiated power remains same the transmit diversity scheme has a 3-dB disadvantage because of the simultaneous transmission of two distinct symbols from two antennas.

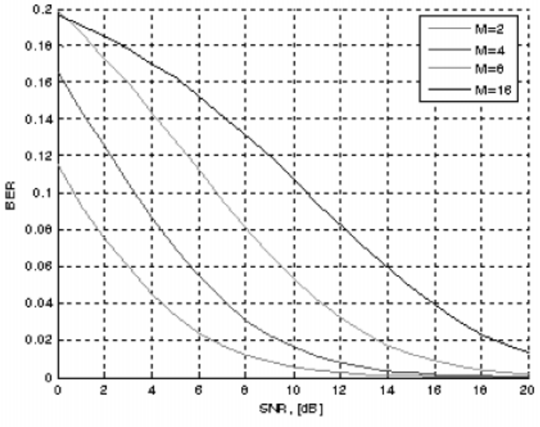

Fig 3: Performanceof Wireless System one Rx Antenna and Two Transmitting Antennas over Rayleigh Channel

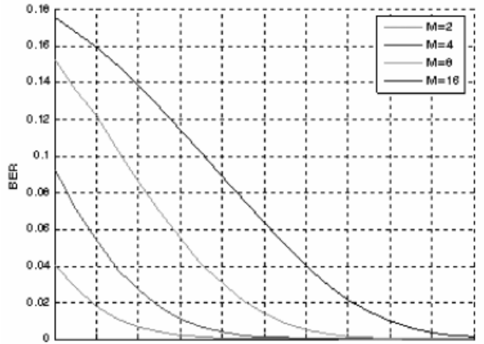

Fig 4: Performanceof Wireless System two Rx Antenna and Two Transmitting Antennas over Rayleigh Channel

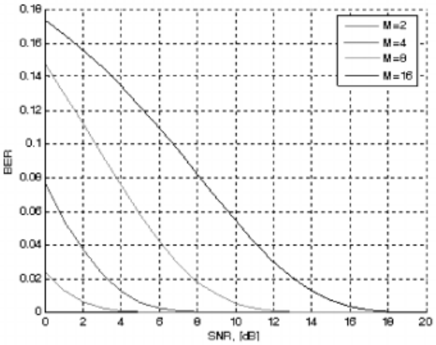

Fig 5: Performanceof Wireless System two Rx antenna and Two Transmitting Antennas over Flat Channel

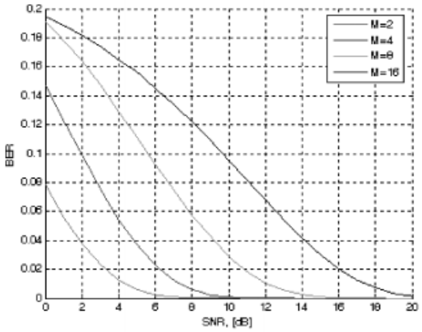

Fig 5: Performanceof Wireless System one Rx Antenna and Two Transmitting Antennas over Flat Channel

REFERENCES

[1] J. H. Winters, "The Diversity Gain of Transmit Diversity in Wireless Systems with Rayleigh Fading," in *Proc. 1994* ICC/SUPERCOMM, New Orleans, LA, May 1994, **2**, pp. 1121–1125.

[2] A. Wittneben, "A New Bandwidth Efficient Transmit Antenna Modulation Diversity Scheme for Linear Digital Modulation," *in Proc. 1993 IEEE International Conf. Communications (ICC'93)*, May 1993, pp.1630–1634.

[3] N. Seshadri and J. H. Winters, "Two Signaling Schemes for Improving the Error Performance of FDD Transmission Systems using Transmitter Antenna Diversity," *in Proc. 1993 IEEE Vehicular Technology Conf. (VTC 43rd)*, May 1993, pp. 508–511.

[4] V. Tarokh, N. Seshadri, and A. R. Calderbank, "Space-time Codes for High Data Rate Wireless Communication: Performance Criteria and Code Construction," *IEEE Trans. Inform. Theory*, Mar. 1998.

[5] V. Tarokh, A. Naguib, N. Seshadri, and A. R. Calder Bank, "Space-time Codes for Wireless Communication: Combined Array Processing and Space Time Coding," *IEEE Trans. Inform. Theory,* Mar. 1998.