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Comparative Analysis of Maximum Ratio Combining Technique on SISO and SIMO and receiver diversity techniques

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ABSTRACT

In this paper, we compare the diversity combining technique . Here, in this paper we applied the Maximum ratio combining technique on . We also discussed the comparative analysis of SISO and SIMO. Here, we plot the result with respect to the bit error rate (BER) and signal to noise ratio (SNR) and also give the comparison between SISO and SIMO Comparison SNR Vs BER for 16-QAM with Selection Combining Technique, Equal Gain Combining & Maximum Ratio Combining..

KEYWORDS: Bit Error Rate(BER), Maximum Ratio Combining(MRC), Multiple Input Multiple Output(MIMO)

The simplest form of radio link can be defined in MIMO terms as SISO - Single Input Single Output. This is effectively a standard radio channel - this transmitter operates with one antenna as does the receiver. There is no diversity and no additional processing required. The advantage of a SISO system is its simplicity. SISO requires no processing in terms of the various forms of diversity that may be used. However the SISO channel is limited in its performance. Interference and fading will impact the system more than a MIMO system using some form of diversity, and the channel bandwidth is limited by Shannon's law - the throughput being dependent upon the channel bandwidth and the signal to noise ratio.

The SIMO or Single Input Multiple Output version of MIMO occurs where the transmitter has a single antenna and the receiver has multiple antennas. This is also known as receive diversity. It is often used to enable a receiver system that receives signals from a number of independent sources to combat the effects of fading. It has been used for many years with short wave listening / receiving stations to combat the effects of ionospheric fading and interference. SIMO has the advantage that it is relatively easy to implement although it does have some disadvantages in that the processing is required in the receiver. The use of SIMO may be quite acceptable in many applications, but where the receiver is located in a mobile device such as a cellphone handset, the levels of processing may be limited by size, cost and battery drain.

Diversity is a powerful communication receiver technique that provides wireless link improvement at a relatively low cost. Diversity techniques are used in wireless communications systems to primarily to improve performance over a fading radio channel. In such a system, the receiver is provided with multiple copies of the same information signal which are transmitted over two or more real or virtual communication channels. Thus the basic idea of diversity is repetition or redundancy of information. In virtually all the applications, the diversity decisions are made by the receiver and are unknown to the transmitter Diversity is the technique used in wireless communications systems to improve the performance over a fading radio channel. Here receiver is provided with multiple copies of the same information signal which are transmitted over two or more real or virtual communication channels. Thus the basic idea of diversity is repetition or redundancy of information. In virtually all the applications, the diversity decisions are made by the receiver and are unknown to the transmitter..

In MRC all the branches are used simultaneously. Each of the branch signals is weighted with a gain factor proportional to its own SNR. Co-phasing and Summing is done for adding up the weighted branch signals in phase. In this method produces an output with an acceptable SNR even when none of the individual signals are themselves acceptable.

EGC-It is not convenient to provide for the variable weighting capability required for true maximum ratio combining. In such cases, the branch weights are all set to unity. but the signals from each branch are co-phased to provide equal gain combining diversity. Performance is only marginally inferior to maximal ratio combining and superior to selection diversity

The combining method of selection diversity is by picking the best branch of the set of received branches by comparing each one with every other branch.

II. RECEIVER DIVERSITY COMBINING TECHNIQUE

A. Maximum Ratio Combining

In MRC, all the branches are used simultaneously. Each of the branch signals is weighted with a gain factor proportional to its own SNR.

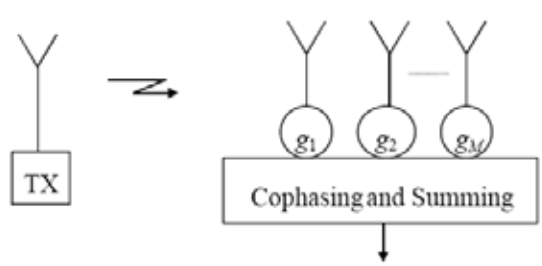


Fig. 1. Maximum Ratio Combining [11]

Co-phasing and summing is done for adding up the weighted branch signals in phase.

The gain associated with the ith branch is decided by the SNR of the corresponding branch. i.e.

gi=(S/N)i (1)

The MRC scheme requires that the signals be added up after bringing them to the same phase, If ai is the signal envelope, in each branch then the combined signal envelope is given as

$$a = \sum_{i=1}^{M} a_i g_i \quad (2)$$

Assuming that the noise components in the channel are independent and identically distributed in each branch,total noise power is

$$N_t = N_0 \sum_{i=1}^{M} g_i^{\,2} \qquad (3)$$

The resulting SNR is thus given by

γ = a2 Eb/N0= (Eb/N0) (Σgi ai)2/(Σ gi2)2 (4)
γ ≤ (Eb/N0)(Σ ai2) (5)

The equality in this case is obtained when gi=k * ai, k being some constant. The maximum value of the output SNR after MRC is given by γ = (Eb/N0)(Σ ai2)

i.e., γ = Σ (Eb/N0)(ai2) = Σ γi (6)

(All summations between i=1,2,....M).

Thus we notice that the sum of the SNRs of the individual branches yields the final SNR of the output

To obtain the distribution of the combined signal, observe that

γi = (Eb/N0) ai2= (Eb/N0) *(xi2+yi2) (7)

γi is χ2 distributed with degree 2 which is the same as an exponential distribution.Let γ = Σγi. Then we can see that γ is χ2 distributed with degree 2M. Then the PDF of γ is given by

p (γ) = 1/(M-1)! * γ M-1/γ0M* exp(-γ/γ0) (8)

with γ≥0;

γ0 is the mean SNR in each branch and is given by 2σ2 Eb/N0.

The CDF of γ is in [11]

$$P(\gamma) = \int_0^{\gamma} \frac{1}{(M-1)!} \frac{x^{M-1}}{\gamma_0^{\,M}} \exp\left(-\frac{x}{\gamma 0}\right) dx$$

$$1 - \exp\left(-\frac{\gamma}{\gamma_0}\right) \sum_{i=1}^{M} \frac{1}{(i-1)!} \left(\frac{\gamma}{\gamma_0}\right)^{i-1} \qquad (9)$$

It can be noticed that as compared to selection combining, the fall of the probability is more rapid. Eg: at a level of 10 dB below γ0,

M=1 Probability=0.1

M=2 Probability=0.005

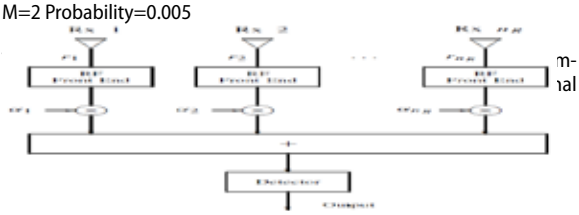


Fig. 2. Maximum Ratio Combining(MRC)[11]
B Equql Gain Combining

The third type of combining method is the Equal Gain combining wherein the gi.s of the MRC scheme are all made equal to 1, for all i=1,2,..M. Thus co-phasing and summing is done on the branches which are received directly.

$$a = \sum_{i=1}^{M} a_i \qquad [10]$$

γ =a2 Eb/(M*N0). =(Eb/M*N0)*(Σ ai)2 (11)

Since γ can be represented the square of the sum of M Rayleigh distributed random variables, there is no closed form expression to it. The performance of the Equal Gain Combining is worse than the MRC.

The expected value of the SNR is given by,E[γ] = (Eb/MN0) E[(Σ Ai)2] where Ai is a Rayleigh variable.

= (Eb/MN0) E[ΣΣ Ai Aj]

= (Eb/MN0) ΣΣ E[Ai Aj]

For uncorrelated branches, we have E[Ai Aj]=E[Ai]E[Aj]

Further, we assumed each of them to be Rayleigh,

Thus, E[Ai2] = 2σ2 which implies that E[Ai] = √ (πσ2 /2)

E[γ] =(Eb/MN0)*[2Mσ2 + M(M-1) πσ2/2]

=γ0[1+(M-1) π/4]

where γ0= (Eb/N0) 2σ2

For large M,

E[γ] = π M γ0/4

Thus, Equal gain combining is worse than MRC approximately by a factor of π/4 ≈ 0.8. Comparison between MRC, Equal Gain Combining and Selection Diversity is as shown in the graph below. The analysis is done using the expected SNR value E[γ].

C.Selection Combining
Consider M branches assuming that the signal to noise ratio achieved on each branch is γi (i=1, 2..M). Further, assume that the received signal on each branch is independent and Rayleigh distributed with mean power of 2σ2. This type of diversity is microscopic in nature and is designed to combat small scale fading. Each of γi are thus distributed exponentially.

The pdf of γi is given by

P(γi) = (1/γ0) exp(-γi/γ0) (12)

Where i=1,2...M

γi ≥ 0

and γ0 = 2σ2 (Eb/N0) is the mean signal to noise ratio. Eb/N0 is the SNR without

fading. The CDF of the SNR is thus,

$$P\{\gamma_i \le \gamma\} = \int_0^{\gamma} p(x)dx = 1 - \exp\left(-\frac{\gamma}{\gamma_0}\right) \qquad [13]$$

The combining method of selection diversity is by picking the best branch of the set of received branches by comparing each one with every other branch. In short, it picks the maxi{γi}. Then the probability that the selected SNR of the branch is less than γ is

P(γ) = Pγ(maxi γi ≤ γ)

= Pγ(γ1 ≤ γ,γ2 ≤ γ,γ3 ≤ γ,..γM ≤ γ) [14]

The above given expression is the resulting CDF when selection diversityis used. The performance of diversity systems is usually measure by comparing the CDFsof various combining methods. From the given graph above, we can notice thatthe probability of γ falling a particular value below γ0 reduces as M increases.Thus the receiver looks at M different branches and chooses the best of γi. Alsonote that the probability of a very low SNR decreases quite rapidly (for example, 10 dB below the mean γ0) when diversity is used as opposed to the non-diversity case.

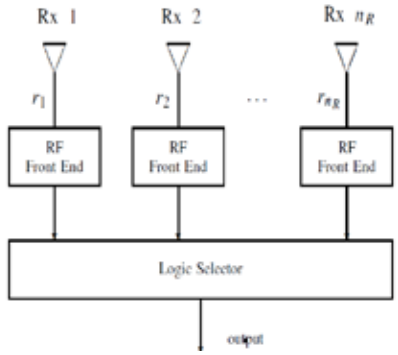


Fig. 3. Selection Combining Diversity [11]

III.SIMULATION RESULTS

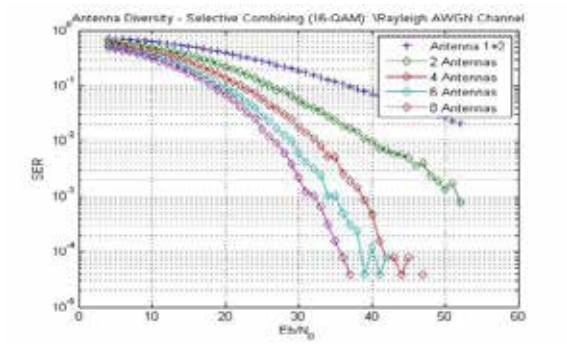


Fig. 4Selective Combining Techniques

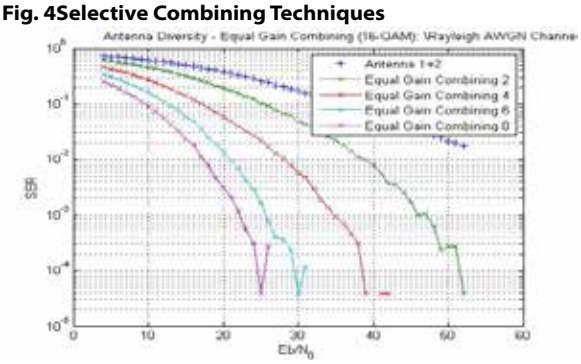


Fig. 5Equal Gain combining Techniques

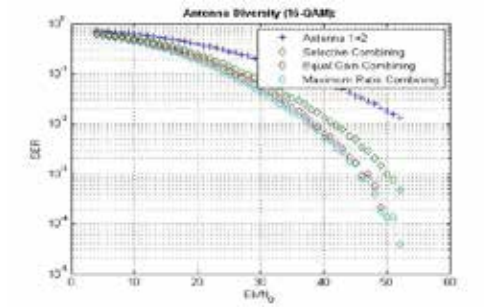


Fig. 6Three techniques

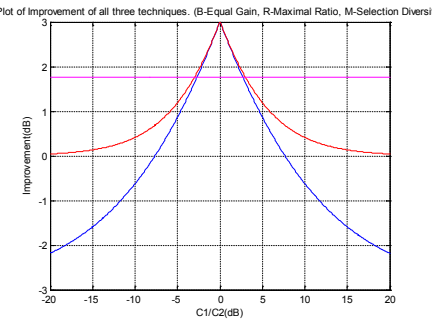


Fig. 7Comparing of different techniques

Conclusion

Diversity technique is a powerful communication technique which improves the link performance. In this paper we discussed the performance of SISO and SIMO with respect to

AWGN channel and Maximum ratio combining technique. Here, we achieved the bit error rate (BER) 10^-2 for SISO, bit error rate 10^-4 for SIMO (TX antenna 1, RX antenna 2), and bit error rate 10^-6 for SIMO (TX antenna 1, RX antenna 4). So, as increased the number of antenna, bit error rate is reduced with respect to the same SNR.

As expected the best improvement is for the maximal ratio combiner, while the worst is for the selection diversity technique. Note that the improvement in the case of equal gain combining is comparable to that of maximal ratio combining.In terms of the required processing, the selection combiner is the easiest - it requires only a measurement of SNR at each element, not the phase or the amplitude, i.e., this combiner need not be coherent. Note, however, that the results presented use a coherent receiver (the phase of channel is removed after the fact). Both the maximal ratio and equal gain combiners, on the other hand, require phase information. The maximal ratio combiner requires accurate measurement of the gain too. This is clearly difficult to implement, as the dynamic range of a Rayleigh fading signal may be quite large.

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