Selection Combining Receiver with Two and with Four Input Branches

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Abstract: This paper focuses on comparing performances of the diversity system which consists of selection combining receiver (selective SC combiner) with two input branches and performances of the diversity system which consists of SC combiner with four input branches. Supposition is that the signal has Rice distribution. The probability density function of the output signal from SC combiner with two inputs, the probability density function of the output signal from SC combiner with four inputs, and bit error rate probability either are determined. Derived results are compared mutually.

Key-Words: selective SC combiner, Rice distribution, probability density function, bit error rate probability

1 Introduction
Diversity techniques can include different combining forms. They are used in order to accomplish better quality of transmission in wireless telecommunication systems. The influence of many factors on transmission quality is minimized with those techniques. Those factors imply presence of fading, shadowing and interference. The aim of applying diversity techniques with different combining forms is to achieve best, maximal, effective signal at the diversity system output, when there are two or more copies of the same input signals, carriers of useful information.

Diversity combining techniques mainly discussed in many previous studies are: MRC (Maximal Ratio Combining) technique [1], EGC (Equal-Gain Combining) technique [2], SWC (Switched Combining) technique [3] and SC (Selection Combining) technique [4], [5]. Hybrid techniques like GSC (Generalized Selection Combining) [6] are proposed recently.

Selection combining is the technique of signal combining in diversity systems, where selection of the instantly strongest signal among the diversity signals is accomplished [7]. Selection combining is carried out in the receiver. The selection combiner estimates instantly value of signal-to-noise ratio, SNR, from all input signals and chooses the one with maximal value.

This paper is organized as follows: first section is introduction. In the second section model of SC combiner with two input branches is defined. Subsection 2.1 is dedicated to numerical results for SC combiner with two inputs. The model of SC combiner with four input branches is given in section three. In the subsection 3.1 numerical results for SC combiner with four inputs are represented. The next, fourth section, compares numerical results from previous sections. The last section is conclusion.

2 SC combiner with two inputs
Selection combining receiver with two input branches is shown at Fig.1. Signal $r_1$ is at first SC combiners input, and at second SC combiners input is signal $r_2$. Signals $r_1$ and $r_2$ have Rice distribution. Variances of those signals are $\sigma^2$.

The probability density functions of the signals $r_1$ and $r_2$ are:

$$p_{\rho_{1}}(r_1) = \frac{r_1}{\sigma^2} e^{-\frac{r_1^2 + A^2}{2\sigma^2}} I_0 \left( \frac{r_1 A}{\sigma^2} \right) \quad r_1 \geq 0$$

$$p_{\rho_{2}}(r_2) = \frac{r_2}{\sigma^2} e^{-\frac{r_2^2 + A^2}{2\sigma^2}} I_0 \left( \frac{r_2 A}{\sigma^2} \right) \quad r_2 \geq 0$$

Output signal of the SC combiner with two inputs is:

$$r = \max \left\{ r_1, r_2 \right\}$$

Cumulative distribution functions are necessary to determine probability density functions of output signal from SC combiner with two inputs and bit error rate probability:
The probability density function of output signal from SC combiner with two inputs is:

\[ F_n (r) = \int_0^r p_n (r_1) dr_1 = \int_0^r \frac{2}{\sigma^2} e^{-\frac{r_1^2 + A^2}{2\sigma^2}} I_0 \left( \frac{r_1 A}{\sigma^2} \right) dr_1 \] (4)

\[ F_{r_2} (r) = \int_0^r p_{r_2} (r_2) dr_2 = \int_0^r \frac{2}{\sigma^2} e^{-\frac{r_2^2 + A^2}{2\sigma^2}} I_0 \left( \frac{r_2 A}{\sigma^2} \right) dr_2 \] (5)

The probability density function of output signal from SC combiner with two inputs is:

\[ p_r (r) = p_n (r) F_n (r) + p_{r_2} (r) F_{r_2} (r) \] (6)

Bit error rate probability, when SC combiners output is connected with coherent system, is:

\[ P_e = \int_0^\infty \frac{1}{2} erfc(\alpha r^2) p_r (r) dr \] (7)

2.1 Numerical results

Fig.2. shows plots of the probability density function versus SC combiners output signal for different values of \( \sigma \) and \( A=4 \). The probability density function of SC combiners output signal for different values of amplitude \( A \) and \( \sigma =1 \) is shown in Fig.3. Plots of bit error rate probability are represented in Fig.4, when SC combiners output is connected with coherent system and \( \sigma \) varying.

![Fig.2. Probability density function of SC combiners output signal for different values of \( \sigma \) and \( A=4 \).](image)

![Fig.3. Probability density function of SC combiners output signal for different values of amplitude \( A \) and \( \sigma =1 \).](image)

3 SC combiner with four inputs

Fig.5. shows selection combining receiver with four input branches. Input signals of SC combiner \( r_1, r_2, r_3 \) and \( r_4 \), have Rice distribution. Variances of those signals are \( \sigma^2 \).

![Fig.5. SC combiner with four inputs.](image)

The probability density functions of SC combiners input signals are:

\[ p_{r_1} (r_1) = \frac{r_1}{\sigma^2} e^{-\frac{r_1^2 + A^2}{2\sigma^2}} I_0 \left( \frac{r_1 A}{\sigma^2} \right) \] (8)

\[ p_{r_2} (r_2) = \frac{r_2}{\sigma^2} e^{-\frac{r_2^2 + A^2}{2\sigma^2}} I_0 \left( \frac{r_2 A}{\sigma^2} \right) \] (9)

\[ p_{r_3} (r_3) = \frac{r_3}{\sigma^2} e^{-\frac{r_3^2 + A^2}{2\sigma^2}} I_0 \left( \frac{r_3 A}{\sigma^2} \right) \] (10)

\[ p_{r_4} (r_4) = \frac{r_4}{\sigma^2} e^{-\frac{r_4^2 + A^2}{2\sigma^2}} I_0 \left( \frac{r_4 A}{\sigma^2} \right) \] (11)

Output signal of the SC combiner with four inputs is:

\[ r = \max \{ r_1, r_2, r_3, r_4 \} \] (12)

Cumulative distribution functions are also necessary to determine probability density functions of SC combiners with four inputs output signal and bit error rate probability:
The probability density function of SC combiners with four inputs output signal is:

\[ F_{r_i}(r) = \int_{0}^{r} p_{r_i}(r_i) dr_i = \int_{0}^{r} \frac{r_i^2 + r^2}{2 \sigma^2} I_0 \left( \frac{r A}{\sigma^2} \right) dr_i \]  \hspace{1cm} (13)

\[ F_{r_2}(r) = \int_{0}^{r} p_{r_2}(r_2) dr_2 = \int_{0}^{r} \frac{r_2^2 + r^2}{2 \sigma^2} I_0 \left( \frac{r A}{\sigma^2} \right) dr_2 \]  \hspace{1cm} (14)

\[ F_{r_3}(r) = \int_{0}^{r} p_{r_3}(r_3) dr_3 = \int_{0}^{r} \frac{r_3^2 + r^2}{2 \sigma^2} I_0 \left( \frac{r A}{\sigma^2} \right) dr_3 \]  \hspace{1cm} (15)

\[ F_{r_4}(r) = \int_{0}^{r} p_{r_4}(r_4) dr_4 = \int_{0}^{r} \frac{r_4^2 + r^2}{2 \sigma^2} I_0 \left( \frac{r A}{\sigma^2} \right) dr_4 \]  \hspace{1cm} (16)

The probability density function of SC combiners with four inputs output signal is:

\[ p_{r}(r) = p_{r_1}(r)F_{r_1}(r)F_{r_2}(r)F_{r_3}(r)F_{r_4}(r) + \]
\[ + p_{r_2}(r)F_{r_1}(r)F_{r_2}(r)F_{r_3}(r)F_{r_4}(r) + \]
\[ + p_{r_3}(r)F_{r_1}(r)F_{r_2}(r)F_{r_3}(r)F_{r_4}(r) + \]
\[ + p_{r_4}(r)F_{r_1}(r)F_{r_2}(r)F_{r_3}(r)F_{r_4}(r) \]  \hspace{1cm} (17)

If SC combiners output is connected with coherent system,bit error rate probability is determined according to the next formula:

\[ P_e = \int_{0}^{\infty} \frac{1}{2} \text{erfc}(\alpha r^2) p_{r}(r) dr \]  \hspace{1cm} (18)

3.1 Numerical results

Fig.6. shows the probability density function of SC combiners output signal, when amplitude is constant \( A=4 \), and \( \sigma \) varying. Plots of the probability density function of SC combiner output signal for different values of amplitude \( A \), and constant \( \sigma = 1 \) are given in Fig.7. Plots of bit error rate probability when SC combiners output is connected with coherent system, and when \( \sigma \) varying, are shown in Fig.8.

4 Comparing previous numerical results

Fig.9. shows probability density function of the SC combiners with two inputs output signal (dashed curve) and probability density function of the SC combiners with four inputs output signal (solid curve), when amplitude of effective signal is \( A=4 \) and \( \sigma = 1 \). It is obvious that red curve is wider and has lower maximum.
Plots of bit error rate probability for SC combiner with two inputs (solid curve) and bit error rate probability of SC combiner with four inputs (dashed curve) are shown at Fig.10. This results are accomplished in case that there is coherent system, connected at SC combiners output. We note that bit error rate probability of SC combiner with four inputs is almost size range lower than bit error rate probability of SC combiner with two inputs.

Fig.10. Bit error rate probability for SC combiner with two inputs (solid curve) and bit error rate probability for SC combiner with four inputs (dashed curve), for $\sigma = 1$.

5 Conclusion

Selection combiners are often applied in diversity systems because they are so simple. It is necessary to determine bit error rate probability in order to estimate performances of diversity systems in which is used selection combining technique. In this paper, with assumption that input signal has Rice distribution, the probability density functions of SC combiners with two and with four input branches output signal are determined.

According to those results bit error rate probabilities are obtained in case that there are coherent systems at output of SC combiners with two and with four input branches. Comparison of obtained results leads to conclusion that diversity system which contains SC combiner with four inputs has much better performances than diversity system which contains SC combiner with two inputs.

References:


