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Measurement of MF Receiver Performance Deviation Using Conventional and Practically Derived Threshold for Binarised Image Signals

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Abstract: Matched filter based receiver (MF receiver) are designed to achieve reliability at physical layer of TCP/IP model. Signal detection in this receiver is based on the use of threshold which is logarithmic function of input signal parameters, r_0 and $r_{1.}$ Usually, at the receiver, r_0 and r_1 are assumed as 0.5. This leads to $\lambda = 0$. But in many practical situations such as transmission of image signals through AWGN channel, $r_0 \neq r_1$ and hence $\lambda \neq 0$. The objective of this work is to find the performance deviation using $\lambda^{0.5,0.5}$ and λ^{r_0,r_1} when image signal are transmitted through AWGN channel. This is done for different considered window lengths and by using appropriately defined methodology. The simulation analysis study is carried out using MATLAB 7.6.0.324 (R2008a) version. For different considered signal, various results are plotted in the form of percentage BER deviation vs. SNR curves. From the results it is found that substantial performance deviations do exist when considering (i) $\lambda^{0.5,0.5}$ (ii) λ^{r_0,r_1} for image categories especially at low SNR values and smaller window length.s

Keywords: MF Receiver, TCP/IP, AWGN, BER, MATLAB, SNR.

I. INTRODUCTION

Global communication systems have not only changed the world but are also advancing at an exceptional rate. Future communication systems will form the foundation for a sustainable and intelligent society where people and equipment can be connected anywhere, anytime with anything. A high degree of connectivity will be a key enabler for new innovative technologies and applications that can benefit from information sharing.

Evolving technologies are e.g. 5G [5] mobile communications, machine communications, fiber optical links and networks, and sensor network communication, with emerging new applications such as remote and assisted medical diagnosis and treatment, traffic and vehicle safety, environmental monitoring, maximizing efficiency and reliability [6] in smart grid infrastructure, and tele-presence systems that reduce the need for energy consuming transportation of people [7].

Society today is firmly rooted in electronic communication systems, and it is hard to imagine life without them. In the near future, we will see rapid development of e.g. sensor network communication, algorithms to decrease energy consumption of communication networks, tele-presence systems that reduce the need for transportation of people, communication as it becomes an increasingly prominent aspect of vehicles and transportation and many more areas. Exactly what the future will bring is unknown, but some things are almost certain: there will still be advanced communication systems. Global systems such as TV, radio, the Internet and wired and mobile telephones have a fundamental impact on the way we live and work [7].

A. General Block Diagram of Communication System

The three basic elements of every communication systems are Transmitter, Receiver and Channel. The overall purpose of this system is to transfer information from one point called Source to another point, the user destination. The first block is source of information[4] in which we can use two types of information sources analog information sources like microphone actuated by a speech, TV Camera scanning a scene, continuous amplitude signals and digital information sources like teletype or the numerical output of computer which consists of a sequence of discrete symbols or letters [4].

The source encoder (source coder) converts the input i.e. symbol sequence into a binary sequence of 0's and 1's by assigning code words to the symbols in the input sequence. At the receiver, the source decoder converts the binary output of the channel decoder into a symbol sequence [4].

Error control is accomplished by the channel coding operation that consists of systematically adding extra bits to the output of the source coder. These extra bits do not convey any information but helps the receiver to detect and/or correct some of the errors in the information bearing bits.

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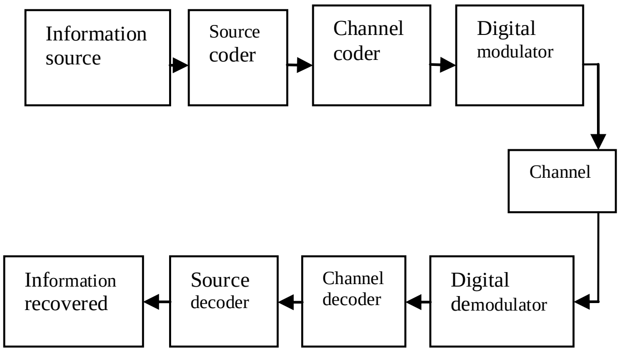

Fig. 1. Block Diagram of Digital Communication system [4]

There are two methods of channel coding block coding and convolution coding. The channel decoder recovers the information bearing bits from the coded binary stream [4].

The Modulator converts the input bit stream into an electrical waveform suitable for transmission over the communication channel. Modulator can be effectively used to minimize the effects of channel noise, to match the frequency spectrum of transmitted signal with channel characteristics, to provide the capability to multiplex many signals. The extraction of the message from the information bearing waveform produced by the modulation is accomplished by the demodulator. The output of the demodulator is bit stream [4].

The Channel provides the electrical connection between the source and destination. The different channels are: Pair of wires, Coaxial cable, Optical fibre, Radio channel, Satellite channel or combination of any of these [4].

B. Reliability: An Important Communication Aspect

Reliability theory describes the probability of a system completing its expected function during an interval of time. It is the basis of reliability engineering, which is an area of study focused on optimizing the reliability, or probability of successful functioning of systems, such as airplanes, linear accelerators, and any other product. It developed apart from the mainstream of probability and statistics [8].

There are different parameters at different layers for reliability. A number of mechanisms help provide the reliability TCP guarantees. First one is checksums all TCP segments carry a checksum, which is used by the receiver to detect errors with either the TCP header or data. Secondly, duplicate data detection is possible for packets to be duplicated in packet switched network; therefore TCP keeps track of bytes received in order to discard duplicate copies of data that has already been received [9].

Thirdly, retransmissions in order to guarantee delivery of data, TCP must implement retransmission schemes for data that may be lost or damaged. The use of positive acknowledgements by the receiver to the sender confirms successful reception of data. Fourth one is sequencing in packet switched networks, it is possible for packets to be delivered out of order [22]. It is TCP's job to properly sequence segments it receives so it can deliver the byte stream data to an application in order. Lastly timers in which TCP maintains various static and dynamic timers on data sent. The sending TCP waits for the receiver to reply with an acknowledgement within a bounded length of time. If the timer expires before receiving an acknowledgement, the sender can retransmit the segment [9].

Reliability is an important user requirement today. Reliable physical layer network coding takes this idea one step further: using judiciously chosen linear error-correcting codes, intermediate nodes in a wireless network can directly recover linear combinations of the packets from the observed noisy superposition of transmitted signals [10].

C. BER-Reduction Methods

Bit error rate, BER [11] is a key parameter that is used in assessing systems that transmit digital data from one location to another. As the name implies, a bit error rate is defined as the rate at which errors occur in a transmission system. This can be directly translated into the number of errors that occur in a string of a stated number of bits. The definition of bit error rate can be translated into a simple formula as ratio of number of errors and total number of bits sent.

If the medium between the transmitter and receiver is good and the signal to noise ratio is high, then the bit error rate will be very small possibly insignificant and having no noticeable effect on the overall system However if noise can be detected, then there is chance that the bit error rate will need to be considered. There are three methods of BER reduction like increase power transmission, use of channel coding especially analogue to digital converter type and efficient design of receiver. BER can be affected by a number of factors. This is normally undertaken in the design stages of a data transmission system so that the performance parameters can be adjusted at the initial design concept stages [11].

The first factor is interference which present in a system is generally set by external factors and cannot be changed by the system design. However it is possible to set the bandwidth of the system. By reducing the bandwidth the level of interference can be reduced [11]. Second one is increase transmitter power which is also possible to increase the power level of the system so that the power per bit is increased [12][13].

Thirdly, Lower order modulation schemes that can be used, but this is at the expense of data throughput. Lastly, reduce bandwidth which is another approach that can be adopted to reduce the bit error rate is to reduce the bandwidth [14].

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II. SIGNAL CONSIDERED AND METHODOLOGY ADOPTED

A. Image signals

Here we have considered four categories of images like nature image, animal image, human image and uniform image. A brief description about each image category is as follows:

Non uniform image

Non uniform images are those image which don't have uniformity like image of nature, animal, human etc

Fig. 2. Example of non uniform image

Uniform image

Uniform image are those image which have uniformity everywhere like image of single color green, yellow, blue etc.

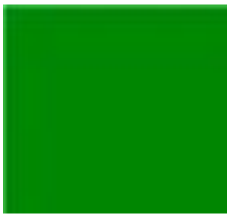

Fig. 3. Example of uniform image

B. Methodology Adopted

The next step is to discuss the methodology that is adopted for the evaluation of the performance deviation of matched filter based receiver. The step-wise methodology for the evaluation of performance deviation is as follows:

Step 1: Initialize parameters; i=0, j=0, k=0, l=0, I=0, J=0, K=0, L=0.

Step 2: Take a sample of sound/image signal. Increment counter; i = i + 1.

Step 3: Select a particular SNR. Increment counter; j = j+1.

Step 4: Convert the test signal into binary form using appropriate A/D converter.

Let $L^{'}$ is the length (in number of bits) of this binarized sound/image.

Step 5: Consider a window-length N_w, and define $\lfloor L = L^{'} / N_W \rfloor$; k = k+1.

Step 6: If l=1, take first N_w bits of the binarized sequence. Else, take next N_w bits of this binarized sequence. Increment counter; l = l + 1.

Step 7: Modulate using polar NRZ line coding scheme.

Step 8: Transmit through AWGN channel.

Step 9: Receive the noisy signal at the receiver.

Step 10: Demodulate using conventional Matched filter based receiver with assumption $r_0 = r_1 = 0.5$ ($\lambda^{0.5,0.5} = 0$) and find BER at the receiver output.. Name this as $BER^{0.5,0.5}$ and store it at some memory location.

Step 11: Using r_0 & r_1 in Eq. (1), find out λ^{r_0,r_1} .Use this threshold to evaluate BER^{r_0,r_1} at the receiver output and store it at some memory location.

Step 12: Check if l < L? If 'YES', go to Step 6 & repeat the procedure. If 'NO' then find out $BER_{avg}^{\ 0.5,0.5}$ & $BER_{avg}^{\ r_0 r_1}$ by averaging all the BER that were stored previously. Further, find BER deviation as per Eq. (2) & go to the next step.

Step 13: Is j < J? If 'YES' then go to Step 3 & repeat the procedure for different SNR values. Else, go to the next step.

Step 14: Is k < K? If 'YES', go to the Step 5 & repeat the procedure for other window sizes. Else, go to the next step.

Step 15: Is i < I? If 'YES', go to Step 2 & repeat procedure for different test samples. Else stop the simulation & go to next step.

Step 16: Plot percentage BER deviation vs. SNR curve for different window sizes (N_w) & different test signals.

III.RESULTS AND DISCUSSION

A. Evaluation of Performance Deviation For Image Category

First of all, let us consider the evaluation of the performance deviation using image signals. For this various images have been sub-divided into four distinct categories. These are: Nature image, Animal images, Human images and Uniform images. The results are plotted in the form of percentage BER deviation (%η) vs. SNR curves for all the considered N_w values. Different parameters that are considered for the evaluation of performance deviation are as follows:

- MATLAB 7.6.0.324 (R2008a) version is used for the simulation purpose.
- Channel is assumed to be AWGN channel. Further the considered range of SNR is -30 dB ≤ SNR ≤+10 dB.
- Following three window sizes (N_w) has been considered for the analysis, N_w = 10, 100 and 1000.
- Standard A/D converter without A-Law and μ-law is used for the image binarization.
- The size of each considered image is 80x80 pixels.

From the result shown in Fig. 4, following conclusions can be drawn:

- As can be seen Fig. 4 (a) that, for all considered SNR values and at N_w=10, BER vs. SNR curve corresponding to $\lambda^{0.5,0.5}$ is much higher than BER vs. SNR curve corresponding to λ^{r_0,r_1}. Further, this shows that the

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conventional matched filter based receiver become suboptimal when threshold $\lambda^{0.5,0.5}$ is used for the detection of practical digital signals, which is image here.

- This deviation in BER is decreases with increase in N_w.
- BER deviation appears to decrease with increase in SNR.

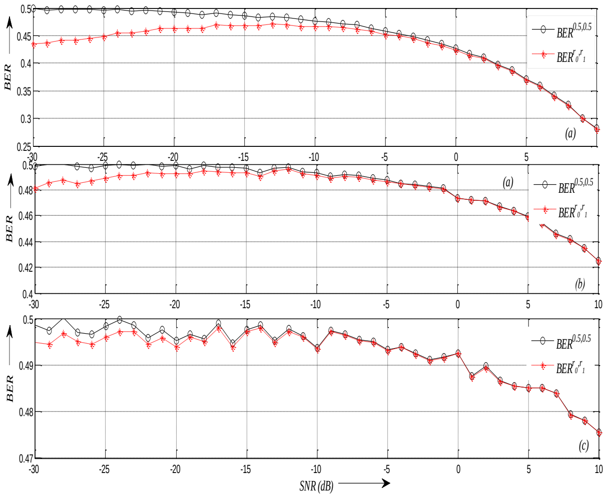

Fig. 4. BER vs. SNR curve corresponding to image of Fig. 1, for a) N_w = 10 b) N_w = 100 c) N_w = 1000

In order to compare the results corresponding to all the image categories that are considered, percentage BER deviation (average) vs. SNR (dB) curves are plotted for a given window sizes i.e. N_w = 10, 100 & 1000 , as shown in Fig. 5, 6 & 7 respectively. Further, all the results of Fig. 5 to Fig. 7 are averaged and plotted in Fig. 8.

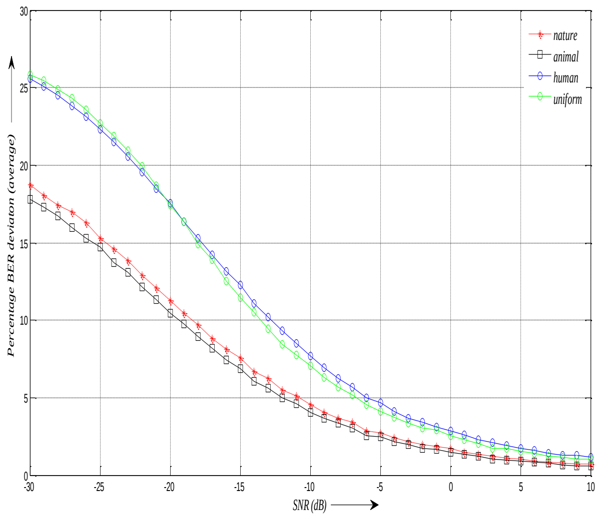

Fig5 Comparison of average percentage BER deviation for all considered image categories, corresponding to N_w =10

- As shown in Fig. 5, for given SNR, more deviation in average BER is observed corresponding to human and uniform image categories than for the case of nature and animal image categories.

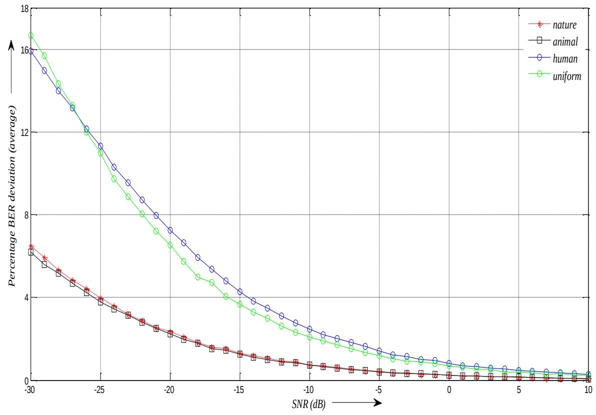

Fig6 Comparison of average percentage BER deviation for all considered image categories, corresponding to N_w =100

- As shown in Fig. 6, corresponding to N_w = 100, at SNR = -30 dB, maximum percentage BER deviation of approx. 16.5 % is observed for the case of uniform image category, and, minimum of approx. 6% is observed for the case of Nature and Animal image categories. As SNR increases, this deviation decreases further.

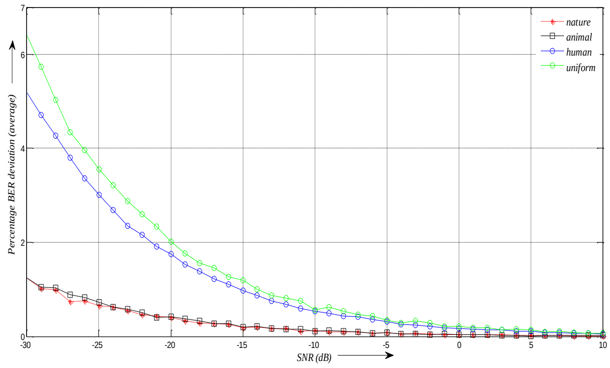

Fig7 Comparison of average percentage BER deviation for all considered image categories, corresponding to N_w =1000

- As shown in Fig. 7, corresponding to N_w = 1000, at SNR = -30 dB, maximum percentage BER deviation of approx. 6.5 % is observed for the case of uniform image category, and, minimum of approx. 1% is observed for the case of Nature and Animal image categories. As SNR increases, this deviation decreases further.

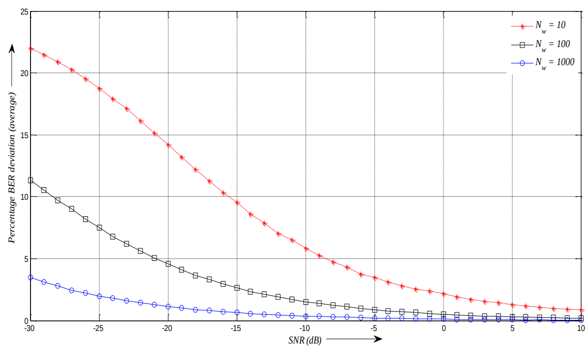

Fig. 8. Final average percentage BER deviation curve for all images

• From Fig. 8, it is clear that, for a given SNR, maximum percentage average BER deviation of approx. 23% is observed for the case of $N_w = 10$ and minimum deviation of approx. 4% is observed for the case of $N_w = 1000$.

IV. CONCLUSION

In this work, the performance deviation at the receiver output is evaluated for the case when i) $\lambda^{0.5,0.5}$ and ii) λ^{r_0,r_1} are used as thresholds for the signal detection, at the receiver. For this, practical signal such as different image are transmitted, window-wise. As practical signals, four categories, of image , have been considered. For example, image categories consist of nature images, animal images, human images and uniform images. Five samples from within each of these sub categories have been taken up for the evaluation of performance deviation. Various results obtained are plotted in terms of percentage performance deviation vs. SNR curves, for a given window size (N_w). Further, in order to generalize these results for a given category, results corresponding to each category are averaged to obtain average percentage BER deviation and is plotted as % performance deviation vs. SNR curve, for a given N_w. Using extensive simulation results that is carried out using MATLAB 7.6.0.324 (R2008a), it is found that a substantial performance deviation do exist, when digitized image signals are transmitted window-wise. Further, corresponding to these categories, higher performance deviation is observed at lower SNR values, and, corresponding to smaller window size (N_w). For a given SNR and N_w, the performance deviation is seen higher for uniform image samples as compared to that of non-uniform. The maximum average performance deviation of 27% is observed for the case of uniform image samples, while, it is 19% for the case of non-uniform image samples. Since a considerable performance deviation is seen when λ^{r_0,r_1} is used over $\lambda^{0.5,0.5}$, for bits detection at the receiver, this study and analysis will certainly be useful in optimizing the performance of MF based receivers. Further, this work can be extended for carrying out the performance deviation of MF based receivers, other than considered here.

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