# Algorithm for SNR Estimation and Signal Power Variation of Wireless Channel

Chanda V Reddy
Asst. Prof. Department of TC Engg
K. S. Institute of Technology, Bangalore – 62,
Karnataka, India
Email:cvr.badami@gmail.com

Dr Padmaja K. V
Prof. & Associate Dean,
Department of Instrumentation Engg
R. V. College of Engineering, Bangalore.
Karnataka, India
Email:padmajakv@rvce.edu.in

**Abstract:** In this paper, an algorithm is developed to estimate Signal to Noise Ratio (SNR) of wireless channel for Racine, Rayleigh and Gaussian noises. Algorithm varies power of the Transmitting signal ($T_{SIG}$) comparing the estimated SNR with Threshold SNR (SNRth) of the channel. Power variation of the Received signal ($R_{SIG}$) can also be varied at the receiver. SNRth is defined by the acceptable noise effect in the channel. Simulation results for both variations of $T_{SIG}$ and $R_{SIG}$ has been shown using MATLAB.

*Key words: Signal-to-noise ratio (SNR), Transmitting signal ($T_{SIG}$), Received noise signal ($R_{SIG}$). SNR estimation, power variation, Threshold SNR (SNRth).*

## 1. Introduction

Wireless communication is the means of transfer of information between two or more points that are not connected by an electrical conductor. A communication channel, or channel, refers to a physical transmission medium, such as a wire, or a logical connection between multiplexed media, such as a radio channel. A channel is used to transmit information signal, for example a digital bit stream, from one or several senders (or transmitters) to one or several receivers. A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in bits per second.

A high speed wireless network must satisfy the increasing bandwidth demand to support multimedia applications. A promising solution is the OFDM (Orthogonal Frequency Division Multiplexing) technology which is a form of a multicarrier modulation scheme designed to meet the demands of high data rate traffic for wideband wireless communications.

Noise variance and hence SNR estimates of the received signal are very important parameters for the channel quality control in communication systems [2]. The search for a good SNR estimation technique is motivated by the fact that various algorithms require knowledge of the SNR for optimal performance. For instance, in OFDM systems, SNR estimation is used for power control, adaptive coding and modulation, turbo decoding etc. [2] -[5].

Signal-to-noise ratio (SNR) is defined as the ratio of the desired signal power to the noise power. SNR estimation indicates the reliability of the link between the transmitter and receiver which may be wired or wireless. SNR estimation is commonly used for measuring the quality of the channel. Then, the system parameters are changed adaptively based on this measurement. For example, if the measured channel quality is low, the transmitter adds some redundancy or complexity of the information bits
(More powerful coding), or reduces the modulation level (better Euclidean distance), or increases the spreading rate (longer spreading code) for low data rate transmission. Therefore, instead of fixed information rate for all levels of channel quality, variable rates of information transfer can be used to maximize system resource utilization with high quality of user experience [3]. The power of the signal is another parameter which can be varied.

In many SNR estimation techniques, noise is assumed to be white and Gaussian distributed. However, in wireless communication systems, Rayleigh and Racine noises are also added into the channel.

In this paper we estimate the SNR of the channel with respect to all (Gaussian, Rayleigh and Racine) types of noises in the channel and then by comparing with a threshold value of SNR the power of the signal is variable.

This paper is organized as follows:-
II. Problem definition
III. Explanation
IV. Algorithms
V. Simulation Results
VI. Conclusion.

## 2. Problem definition

In wireless channel some noises that are added to the signal are Gaussian, Rayleigh and Racine noises. The additive thermal and ambient noise in the channel can be modeled by a Gaussian distribution and is defined as Gaussian noise. If the multiple reflective paths are large in number and there is no line-of-sight signal component, the envelope of the received signal is statistically described by a Rayleigh Distribution i.e., the Rayleigh fading model assumes that the magnitude of a signal that has passed through transmission medium will vary randomly, or fade, according to a Rayleigh Distribution [1]. The term Rayleigh fading channel refers to a multiplicative distortion h (t) of the transmitted signal s (t), as in y (t) = h (t)· s (t) + n (t), where y (t) is the received waveform and n (t) is the noise. Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. Rayleigh fading is most applicable when there is no dominant line-of-sight propagation between the transmitter and receiver. The Russian model considers that the dominant wave can be a poser sum of two or more dominant signals, e.g. the line-of-sight, plus a ground reflection. The Russian model considers that the dominant wave can be a poser sum of two or more dominant signals, e.g. the line-of-sight, plus a ground reflection [1].

SNR measures the quality of a transmission channel, the greater the ratio, the easier it is to identify and subsequently isolate and eliminate the source of noise. A SNR of zero indicates that the desired signal is virtually indistinguishable from the unwanted noise.
In a wireless communication system when the signal is transmitted it may undergo all three types of noises before reaching the receiver antenna. So we consider basic three noise models and estimate there SNR values individually, average it and compare it with a threshold (i.e., acceptable) value. If SNR of the received signal is not acceptable according to the application requirement increases the power of the $R_{SIG}$ or increase the power of the $T_{SIG}$ before transmitting it into the channel.

## 3. Explanation.

In wireless channel it is impossible to estimate the SNR of the channel at an instant and consider it to be constant for the system throughout the transmission time. So we transmit the known data (signal) for n number of times and calculate SNR for each time. Latter average n SNRs and compare it with the acceptable SNR of the channel for the application.

The proposed technique is divided into two parts. In the first part we estimate the SNR of the channel and compare it with a threshold for individual noise model. In the second part we average SNRs and noise signals then compare it with threshold SNR ($SNR_{TH}$) of the channel. Power variation is done accordingly either at receiving or transmitting end.

**Part I**
In the first part of algorithm, estimation of SNR for an analog cosine signal is considered with frequency (F). It is transmitted for n times through the channel. At the receiver SNR of the signal is calculated each time with respect to the Rayleigh noise model. Average SNR (SNRav) of n SNRs is calculated and compared with SNRth of the respective noise model, if it is lesser or equal to, then the received signal power is incremented in the range of 0.1 to 0.5 else the same signal is considered. Obtained signal is termed as Ya. Similarly Yb for Racien model and Yc for Gaussian model is obtained.

**Part II**
In the second part, Algorithm, averages all received noise signals and their respective SNRs as SNRavg and compares it with a threshold value of the channel of all noises ($SNR_{TH}$). If SNRavg is lesser or equal to $SNR_{TH}$ then the power of the average noise signal is incremented by 0.5dB for all the further $R_{SIG}$ at the receiver is the same average noisy signal is processed further as considered in algorithm 2.
The power of the next $T_{SIG}$ can also be if the SNRavg is lesser or equal to $SNR_{TH}$ which is dealt in algorithm in 1 else transmission is continued without variations in the power of the $T_{SIG}$. This can be done by a handshake signal process of considering whether to increase the power or retain same for further transmission.

## 4. Algorithm

### *i) Algorithm (change the power at the transmitter)*

1. Initialization of i/p signal
   a) Frequency of i/p signal -- F
   b) Sampling frequency-- Fs
   c) Define i/p signal & PLOT — X=Acos (2*pi*F*t)
   d) Define incremental power -- inc_power =0.1 to 0 .5
   e) Define Threshold SNR for noise model – SNRth
   f) Define Threshold SNR for channel – $SNR_{TH}$

2. Obtain signal power– sig_power

3. Obtain mean SNR (SNRmean) of Channel by the handshaking process
   a. Define channel noise
   b. Obtain signal with noise through channel --Y
   c. Plot the signal Y
   d. Obtain SNR by calling SNR function.
   e. Obtain mean SNR by passing the signal for 'n' times -- n = 100
   f. Obtain the signal with mean SNR --Ya
   g. Compare mean SNR with SNRth
      **If** mean SNR < = SNRth
      Increment power
      Obtain Ya for mean SNR with inc_ power
      *Ya =signal (y, mean SNR, signal power, inc_ power)*
      **Else** Obtain Ya for mean SNR without inc_ power
      *Ya =signal (y, mean SNR, signal power)*
   h. Plot Ya

4. Repeat step 3. for different channel noises & obtain respective mean SNR signals and plot them.
Ya — for Rayleigh noise of the channelYb — Racian noise channel
Yc – with Gaussian noise

5. Obtain an average output
a. Average noise signal h
*h=avg (Ya, Yb, Yc,)*
b. Plot h
c. Calculate SNR of h
d. Compare SNR of h with Threshold SNR of the channel
**If** SNRh < = $SNR_{TH}$
Increment power
Obtain Yav for mean SNR with inc_ power
*Yav =signal (X, mean SNR, signal power, inc_ power)*
**Else** Obtain Yav for mean SNR without inc_ power
*Ya =signal (X, mean SNR, signal power)*
e. Plot Yav

6. Transmit the next signal with the required incremented power.

### *ii) Algorithm (change the power at the receiver)*

1. Initialization of i/p signal
a) Frequency of i/p signal -- F
b) Sampling frequency-- Fs
c) Define i/p signal & PLOT — X=Acos (2*pi*F*t)
d) Define incremental power -- inc_power =0.1 to 0 .5
e) Define Threshold SNR – SNRth

2. Obtain signal power– sig_pow

3. Obtain mean SNR (SNRmean) of Channel by the handshaking process
a. Define channel noise
b. Obtain signal with noise through channel -Y
c. Plot the signal Y
d. Obtain SNR by calling SNR function
e. Obtain mean SNR by passing the signal for ‘n’ times -- n = 100
f. Obtain the signal wrt mean SNR --Ya
g. Compare mean SNR with SNRth
If mean SNR < = SNRth
Increment power
Obtain Ya for mean SNR with inc_ power
*Ya =signal (y, mean SNR, signal power, inc_ power)*
Else Obtain Ya for mean SNR without inc_ power
*Ya =signal (y, mean SNR, signal power)*
h. Plot Ya

4. Repeat step 3. for different channel noises & obtain respective mean SNR signals and plot them.
Yo — for Rayleigh noise of the channel
Yb — racing noise channel
Yc – with Gaussian noise

5. Obtain an average output
f. Average noise signal h
*h=av (Ya, Yb, Yc,)*
g. Plot h
h. SNR of h
i. Compare SNR of h with Threshold SNR
**If** SNRh < = $SNR_{TH}$
Increment power
Obtain Yav for mean SNR with inc_ power
*Yav =signal (**h**, mean SNR, signal power, inc_ power)*
**Else** Obtain Yav for mean SNR without inc_ power
*Ya =signal (**h**, mean SNR, signal power)*
j. Plot Yav

### *iii) SNR estimation algorithm:*
### *(A function called in main algorithm to find SNR)*

1) Select input signal (x) and choose the SNR value and pass it through the Gaussian channel.
2) Receive the noisy signal (y)
3) Noise (n) = x-y
4) Find the number (n) of elements in input signal (x).
5) Define Welch power spectral density functions
6) Obtain the PSD objects by using the Welch power spectral density functions for the input signal and Noisy signal (n). Here PSD objects represent
   a. Spectrum Type — 'one-sided' or 'two sided'
   b. Normalized Frequency — normalizes frequency between 0 and 1
   c. Fs — sampling frequency in Hz
   d. NFFT — number of FFT points
   e. Center DC — shifts data and frequencies to the center DC component
   f. FreqPoints — 'All' or 'User Defined'
   g. FrequencyVector – frequencies at which to compute spectrum
7) By using the PSD objects calculate the PSD of input signal (x) and noisy signal (n).
8) From PSD obtain the average powers Signal power (Px) and Noise power (Pn) noisy signals respectively.
9) The find the ratio SNR = Pin/Pn. So SNR is estimated.

## 5. Simulation results

Simulation was done for radio frequency (20hz) signal with SNR 10dB as noise model threshold and 15dB for average acceptable, as from Table.1 [9], with respect to random data values. Man made noise consists of all type noises in atmosphere. Here we are considering the unmodulated signal for simplicity. The same algorithm can be considered for a modulated signal which is applied before modulation at the transmitter and after demodulation at receiver.

| Category | Decile | Variation with time (dB) | Variation with location (dB) |
|---|---|---|---|
| City | Upper<br>Lower | 11.0<br>6.7 | 8.4<br>8.4 |
| Residential | Upper<br>Lower | 10.6<br>5.3 | 5.8<br>5.8 |
| Rural | Upper<br>Lower | 9.2<br>4.6 | 6.8<br>6.8 |

Table-1: Values of decile deviations of man –made noise

### Initial values for the simulation were as follows:

```
% Define Input Signal Frequency
F = 20;
% Define the sampling rate
Ts = 0.001;
% Define the time duration
t = 0:Ts:1;
% define the input signal
X = 10*cos (2*pi*f*t);
% incremental power
inc_power =0.5; % 0.01; %  0 to 0.4 with an increment of 0.01
%% compare with throsheld
threshold_SNR = 10; %for individual noise model
threshold_SNR_AV = 15;
```

During simulation, for cos wave the estimated SNR of Rayleigh noise and Gaussian noise were lesser than SNRth. There by the power of the signal was incremented. Racine noise had grater estimated SNR than SNRth, so the noise signal power was unaltered. (See Figure 1 and Figure 3)

With the effect of lesser estimated SNR with respect to SNRth of the channel algorithm 1 incremented Tsig and received the noisy signal through channel for the incremental effect.(See Figure 2)

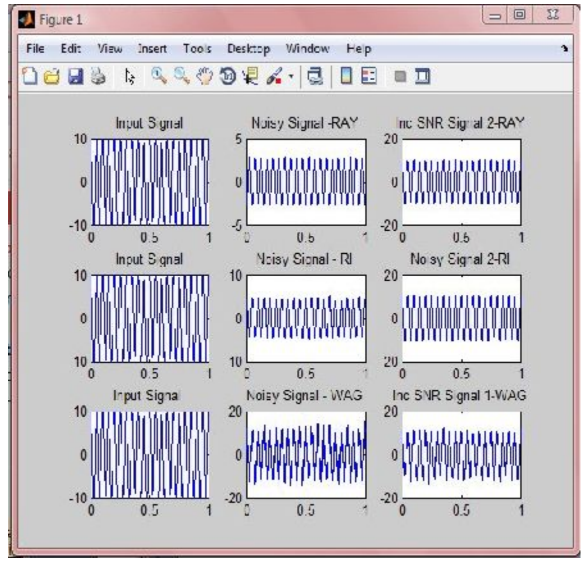


Figure 1: I/P *($T_{SIG}$)*, noise signal output and compared SNR output write three noise model-
i) Rayleigh ii) Racine iii) Gaussian (For algorithm 1)

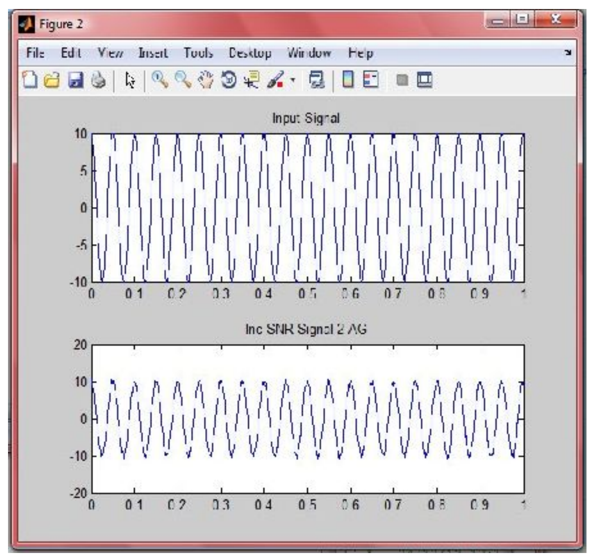


Figure 2: Input signal *($T_{SIG}$)* and incremented power output (For algorithm 1).

The simulation results for algorithm 1 are shown in Figure 1 and Figure 2

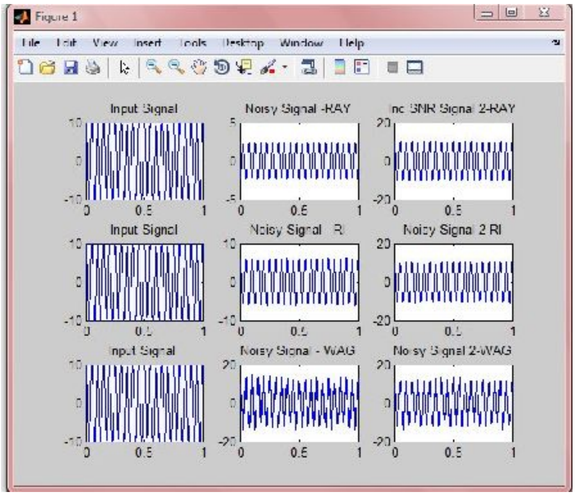


Figure 3: I/P $(T_{SIG})$, noise signal output and compared SNR output write three noise model-
i) Rayleigh ii) Racine iii) Gaussian (For algorithm 2)

Considering the average of the 3 noisy signals and their estimated SNRs Algorithm 2 incremented average noisy signal which had better signal. (See Figure 4)

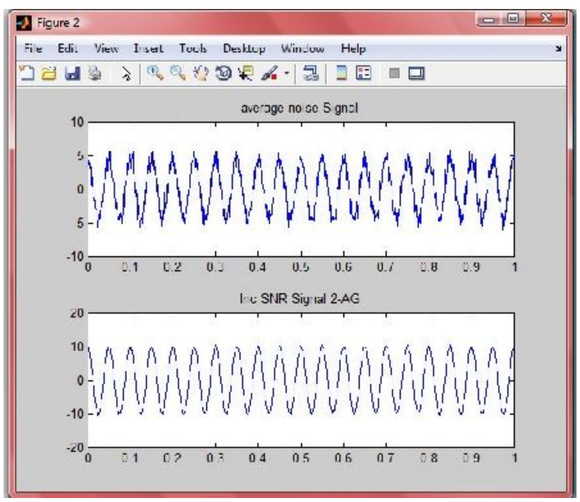


Figure 4: Average noise signal output and incremented power output (For algorithm 2)

Simulation results for algorithm 2 are shown Figure 3 and Figure 4.

## 6. Conclusion.

In this paper, we have proposed algorithms which are used to estimate the SNR of the channels for three different noise models. Rayleigh, Racine and Gaussian are considered. SNRs of individual noises are compared with threshold value and power of the noise signal is incremented if necessary. Average of all the SNRs is considered and again compared with acceptable threshold SNR of the wireless channel. In the first algorithm the power of the TSIG is varied and transmitted which is better than the average noise $R_{SIG}$. In the second algorithm at the receiver itself we can increase the power for the analog signal and then send for further process. This will increase throughput of the system.

## 6. Acknowledgment.

The satisfaction and euphoria that accompany the completion of any task would be but incomplete without the mention of the people who made it possible, whose constant guidance and encouragement crowned my efforts with success. We consider it a privilege to express our gratitude and respect to all those who guided me in the completion of this task.

## References

[1] ]. M.S. Chavan, R.H. Chile and S.R. Sawant (2011) “Multipath Fading Channel Modeling and Performance Comparison of Wireless Channel Models’-International Journal of Electronics and Communication Engineering. ISSN 0974-2166 Volume 4, Number 2 (2011), pp. 189-203

[2] Shahid Manzoor, Varun Jeoti, Nidal Kamel and Muhammad Asif Khan (2011) ‘‘ Novel SNR Estimation Technique In Wireless OFDM Systems’’International Journal of Future Generation Communication and Networking Vol. 4, No. 4, December, 2011

[3] H¨useyin Arslan, Sharath Reddy 2003 ‘‘Noise Power and SNR Estimation for OFDM Based Wireless Communication Systems’’ Proc. of 3rd IASTED International Conference

[4] L. Hanzo, C. Wong, and M. -S. Yee (2002) “Adaptive Wireless Transceivers: Turbo-Coded, Turbo-Equalized and Space-Time Coded TDMA, CDMA and OFDM Systems,” New York: John Wiley & Sons, 1st Ed., 2002.

[5] T. Keller and L. Hanzo, (1998)“ Adaptive orthogonal frequency division multiplexing schemes,” in *ceedings of ACTS Mobile Communications Summit*, June 1998, pp. 794-799.

[6] T. Keller, L. Hanzo, “Adaptive Multicarrier Modulation: A convenient framework for time-frequency

[7] Gautam Kulkarni, Sachin AdlakhaI, and Mani Srivastava, (2005) ‘Subcarrier Allocation and Bit Loading Algorithms for OFDMA-Based Wireless Networks’- IEEE 2005

[8]. Mathuranathan Viswanathan (2013) “Simulation of Digital Communication Systems Using Matlab [eBook]” – Second Edition Published: Feb. 18, 2013

[9].ITU-R (2009) “Radio Communication sector ITU” Published: October 2009, P.327-10.