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SIMULATED DESIGN OF CHANNEL NOISE REDUCTION MODEL FOR EFFECTIVE COMMUNICATION

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Abstract- In this paper, the Simulated Design of Channel Noise Reduction Model for effective Communication has been achieved. It is the comparative study of noise reduction technique using Simulink in Matlab work environment.The study is based on simulation of noise behavior in communications channel by varying the input parameters (Message Signal Amplitude, Noise Power, Input Power of Channel and Signal to Noise Ratio(SNR)); and the output:signal (strength and noise amplification) and measurements taken. The ODE3 (Bogacki-Shampine) solver with fixed step was used to model simple sine wave function for the message signal and Band-limited White Noise as the source. The signals were passed through the Additive White Gaussian Noise Channel and the parameters varied. The output signal was connected to a display block and scope for proper measurement. Again, Gaussian filter was introduced at the output of the channel for noise filtration and reduction; and a gain block added to improve the signal output. Transitional delay was also added to smooth out the final signal output. The results obtained from the measurement confirm that introducing the Gaussian filter offers significant improvement in signal strength over communication channel

Keywords: Noise, Channel, Reduction, Model, Gaussian Filter, Matlab/Simulink

Introduction

Noise is the major impairment to smooth transmission of message signal from one point to another in a communication system. Several studies have been carried out in the field of noise reduction technique in Communication.**[1]**refers to noise as disturbances due to environmental factor, thermal agitation, effect of temperature changes etc. These distortions superimpose itself on the message signal and introduce unwanted signals that impair signal quality [2-3]**.**As the signal is transmitted along the channel, the original signal is amplified along with the noise. For effective communication to be established between two points, noise in communication channel must be eliminated or reduced as low as possible [4].

In this study, key elements that are contributed to noise behavior in communication system were simulated. These are: 1. message signal, 2. noise source, 3. channel and 4. filter. In the model, thebehavior of additive white Gaussian noise (AWGN)channel was simulated using external band-limited noise, sinusoidal waveform (message signal) and the output of the channel characteristics passed through a Gaussian Filter to evaluate its effect in smoothening out the noise ripples that travels along with the message signal. An amplifier (Gain) circuit was placed at the output of the filter to improve on the signal quality; and a transition delay block added to provide some delay for the noise ripples.The overall output of the model was compared to the behavior of the noise model prior to introducing the filter.

For effective study of noise reduction technique in communication, it is important to evaluate the properties and characteristic of a channel. A communication channel can be defined as the medium used for transport of message signal which could be wire, optical fiber or free space. Channel is comprised of the source, transmitter, channel, receiver and the sink **[5-6].**

Channel properties could be definedby random variables:

Let Xand Ybe the random variables representing the input and output of the channel, respectively. Let $p_{Y|X}(y|x)$be the conditional distribution function of Ygiven$X$, which is an inherent fixed property of the communications channel. Then the choice of the marginal distribution$p_X(x)$completely determines the joint distribution$p_{X,Y}(x,y)$due to the identity

$$p_{X,Y}(x,y) = p_{Y|X}(y|x)\,p_X(x)$$

--------------------Equation 1

which, in turn, induces a mutual information$I(X;Y)$. The channel capacity is defined as

$$C = \sup_{p_X(x)} I(X;Y)$$

---------------------Eqn. 1

where the supremum is taken over all possible choices of $p_X(x)$.

Fig.1: Simple Communications Channel

2.0 Noise in Communications Systems

Noise is broadly defined as unwanted or undesirable signal in a communication circuit **[5].**There are several types of noise such as Thermal Noise, Intermodulation Noise, Crosstalk, Impulse, Jitter, Echo etc.

This simulation was based on analysis of band-limited noise inter-modulated with inherent white noise in the additive Gaussian White noise and superimposed on the message signal of a continuous sine wave form [7].

Gaussian noise is statistical noise having a probability density function (PDF) equal to that of the normal distribution, which is also known as the Gaussian distribution [8].

The probability density function $p$of a Gaussian random variable z is given by eqn 2

$$p_G(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}}$$

-----Eqn. 2

Where: z represents the grey level, μ the mean value and $\sigma$the standard deviation.

In this study, Gaussian noise was used as additive white noise for the channel and Band-limited Noise for the external noise source [9-10].

3.0 Noise Reduction Model

The design approach is based on the use of Simulink in Matlab work environment to analysis the impairment of noise on communication; and thereby developing a model to reduce its effect as low as possible.

The signal sources comprising of message signal and the band-limited noise source were passed through Additive Gaussian White Noise Channel to generate the effect of noise through a channel. The entire Model is shown in Fig.2

The combine noise and message signal were further passed through a Gaussian filter of ±3dB cutoff. A gain block and transport delay were further introduced to improve the signal output. The output was connected to a display block and scope for measurement of the parameters.

The amplitude of the message signal was varied and measurement taking. The process was repeated for the noise power, channel input power and the signal to noise ratio(SNR). Results from the output display block1 (after the AGWN) and block 2(after the filter) were recorded and tabulated for further analysis.

Some designed considerations were made to achieve the expected results.

3.1 Sine wave Block generating message signal of x(t)=Amp*sin[w(t)+θ].

In this study, a simple sine wave of varying amplitude, frequency and phase was used to represent the messaging signal. Amplitude of a sine wave is the maximum distance it ever reaches from zero.The amplitude was varied from 1 to 10 and measurement taken to verify the system behavior.

3.2 Band limited white noise with noise power of 0.1watt

The Band-Limited White Noise block generates normally distributed random numbers that are suitable for use in continuous or hybrid systems. Theoretically, continuous white noise has a correlation time of 0, a flat power spectral density (PSD), and a total energy of infinity. In practice, physical systems are never disturbed by white noise, although white noise is a useful theoretical approximation when the noise disturbance has a correlation time that is very small relative to the natural bandwidth of the system.

$tc \approx {}_{11002\pi \mathrm{fmax}}$’

wheref_{max} is the bandwidth of the system in rad/sec.

Additive Gaussian White Noise Channel signal to noise ratio of 10dB.

Additive White Gaussian Noise (AWGN) is a noise model used in Information theory to mimic the effect of many random processes that occur in nature. It is often used as a channel model in which impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. However, it produces simple and tractable mathematical models which are useful for gaining insight into the underlying behavior of a system before these other phenomena are considered (**Anon,2015).**

The relative power of noise in an AWGN channel is typically described by quantities such as Signal-to-noise ratio (SNR) per sample and ratio of symbol energy to noise power spectral density (Es/N0) **(Anon, 2015).**

Mathematically, a Gaussian filter modifies the input signal by convolution with a Gaussian function; this transformation is also known as the Weierstrass transform.

Display output Block.

The output of the AWGN was connected to a display to measure the signal strength and noise amplification.

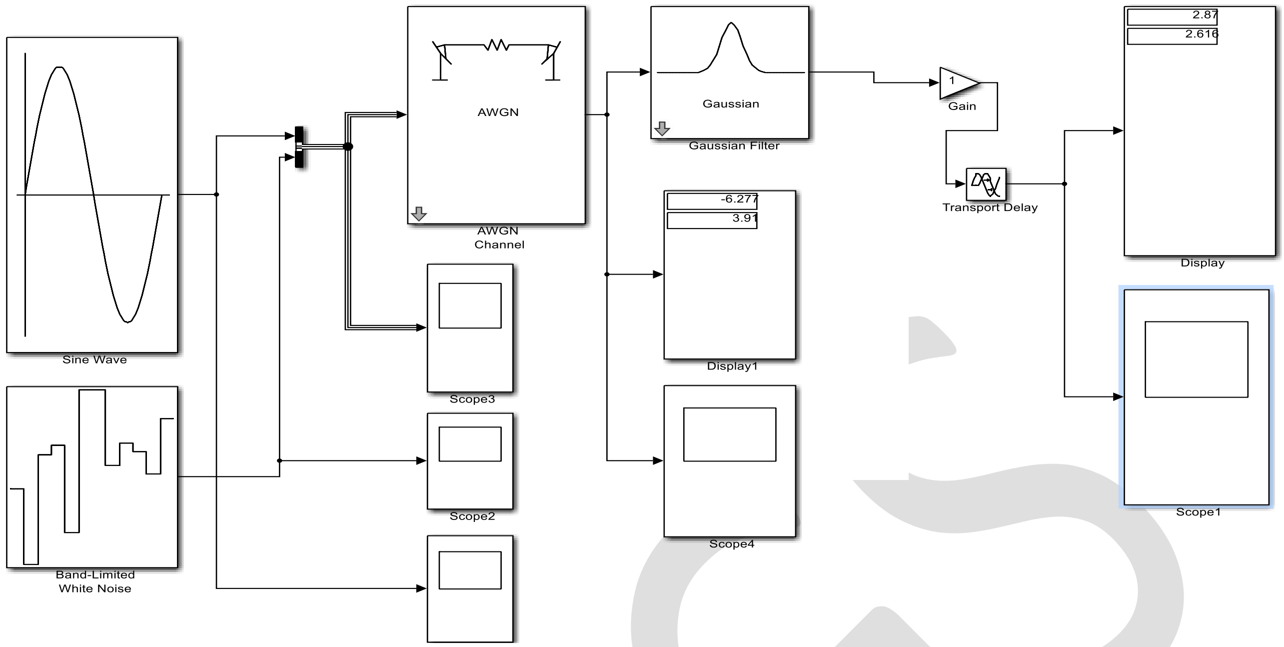

Fig.2: Simulated Design of Channel Noise Reduction Model

Results and Discussion

Test was carried out by varying the following parameters: (i) Amplitude of the Message Signal.

Input power of the Band-Limited Noise Source (iii) Signal to Noise Ratio(SNR) of the Additive Gaussian White Noise Channel (iv) Input Signal Power of the AWGN

And the following results obtained after simulation are shown in Fig. 3; 4; 5; 6;7

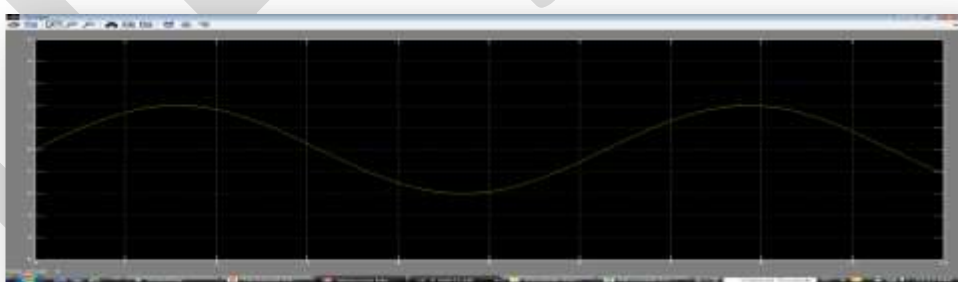

Fig.3: Output waveform of Message Signal without noise

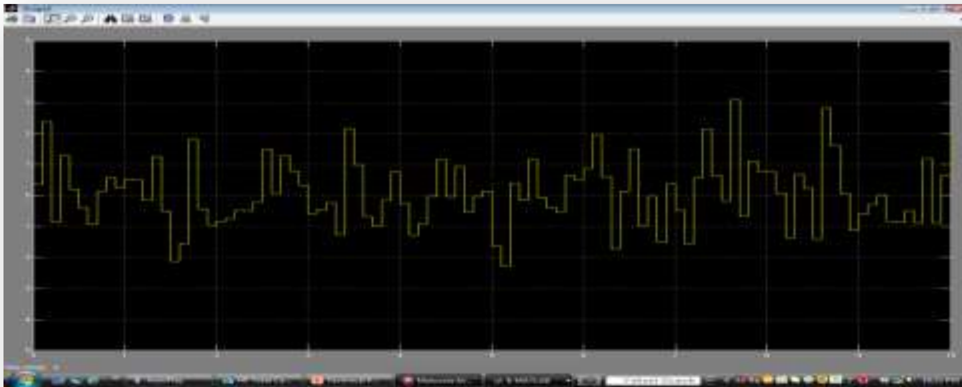

Fig.4: Output waveform of Noise Signal

Fig.5: Output waveform of Noise and Message Signal without Channel

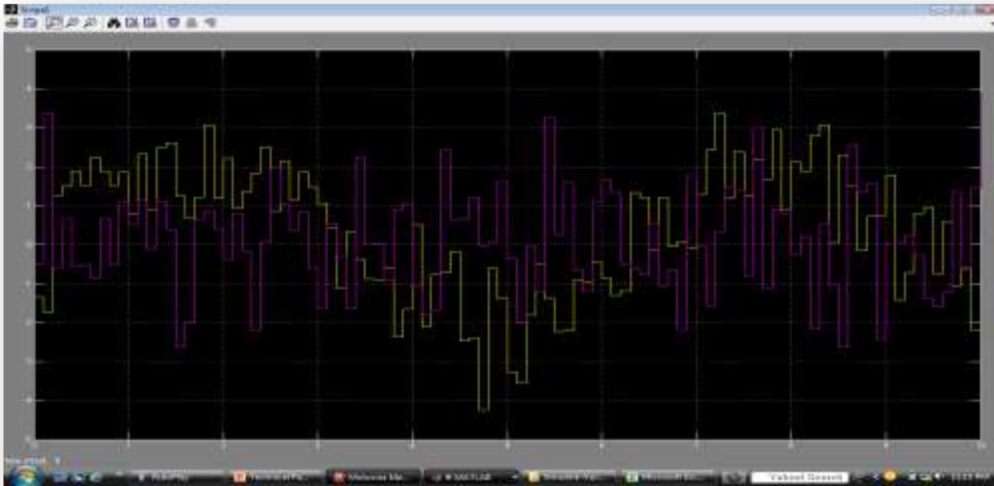

Fig.6: Output of AGWN Channel showing Message and Noise signal waveform

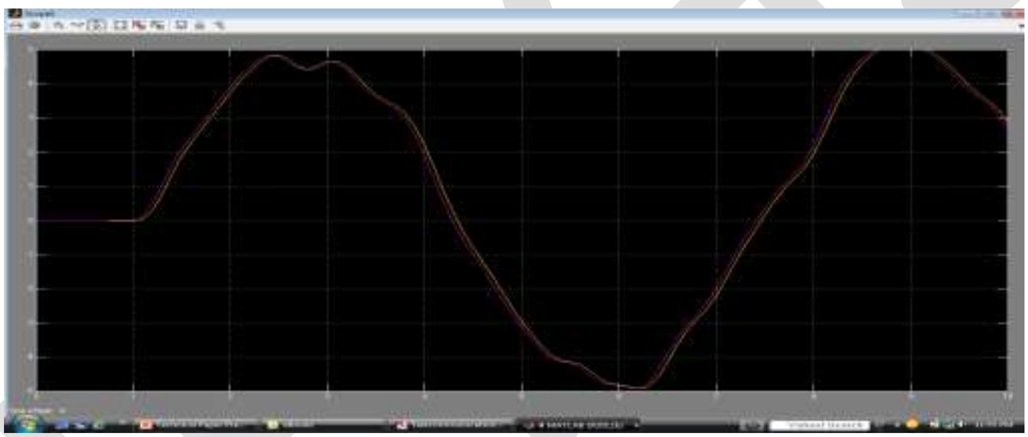

Fig.7: Output Waveform of Gaussian Filter

Table 1: Result of increasing amplitude of message signal

S/N	Sine Wave Message Signal Amplitude	Display1 Signal Strength1	Display1 Noise Amplification1	Display2 Signal Strength2	Display2 Noise Amplification2
1	1	-1.38	3.91	2.786	2.071
2	2	-1.924	3.91	5.466	4.748
3	3	-2.468	3.91	8.545	7.424
4	4	-3.013	3.91	11.42	10.1
5	5	-3.557	3.91	14.3	12.78
6	6	-4.101	3.91	17.18	15.45
7	7	-4.645	3.91	20.06	18.13
8	8	-5.189	3.91	22.95	20.8
9	9	-5.733	3.91	25.82	23.48
10	10	-6.277	3.91	28.7	26.16

From Table 1, display 1 shows the signal strength and noise amplification after the AWGN, While Display 2 shows signal Strength and noise amplification after the Gaussian Filter

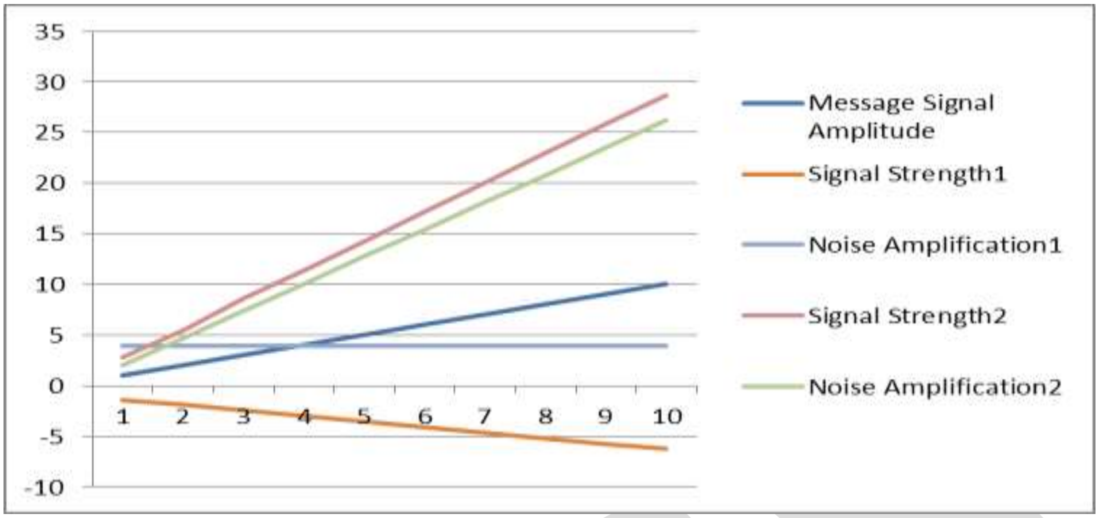

Fig.8: Graph Showing result of increasing Message Signal Amplitude

Table 2: Result of increasing Input Noise Power

	Band-Limted White Noise	Display1		Display2	
S/N	Input Noise Power	Signal Strength1	Noise Amplification1	Signal Strength2	Noise Amplification2
1	0.1	-1.38	3.91	2.786	2.071
2	0.2	-1.38	4.812	3.73	2.643
3	0.3	-1.38	5.504	4.455	3.082
4	0.4	-1.38	6.087	5.065	3.452
5	0.5	-1.38	6.601	5.603	3.778
6	0.6	-1.38	7.066	6.09	4.072
7	0.7	-1.38	7.794	6.537	4.343
8	0.8	-1.38	7.891	6.953	4.595
9	0.9	-1.38	8.265	7.344	4.832
10	1	-1.38	8.818	7.714	5.056

From table 2, Display 1 shows the signal strength and noise amplification after the AWGN while Display 2 shows the signal strength and noise amplification after the Gaussian Filter

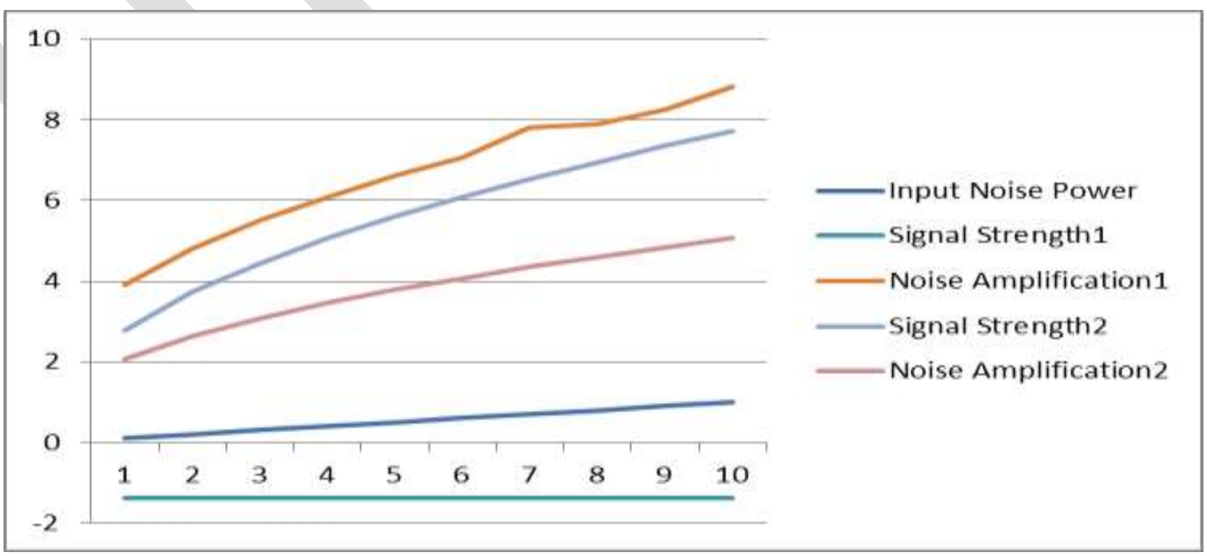

Fig.9: Graph showing increase in Input Noise Power

Table 3 Result of increasing Input Signal Power

		Display1		Display2	
S/N	Input Signal Power(watt)	Signal Strength1	Noise Amplification1	Signal Strength2	Noise Amplification2
1	1	-1.38	3.91	2.786	2.071
2	2	-1.727	4.627	1.804	1.249
3	3	-1.993	5.178	1.05	0.6182
4	4	-2.217	5.642	0.4143	0.08623
5	5	-2.414	6.05	-0.1456	-0.3824
6	6	-2.593	6.42	-0.6518	-0.8061
7	7	-2.757	6.76	-1.117	-1.196
8	8	-2.91	7.067	-1.551	-1.558
9	9	-3.053	7.374	-1.958	-1.899
10	10	-3.189	7.655	-2.343	-2.221

From table 3, Display 1 shows the signal strength and noise amplification after the AWGN, while Display 2 shows the Signal Strength and noise amplification after the Gaussian Filter.

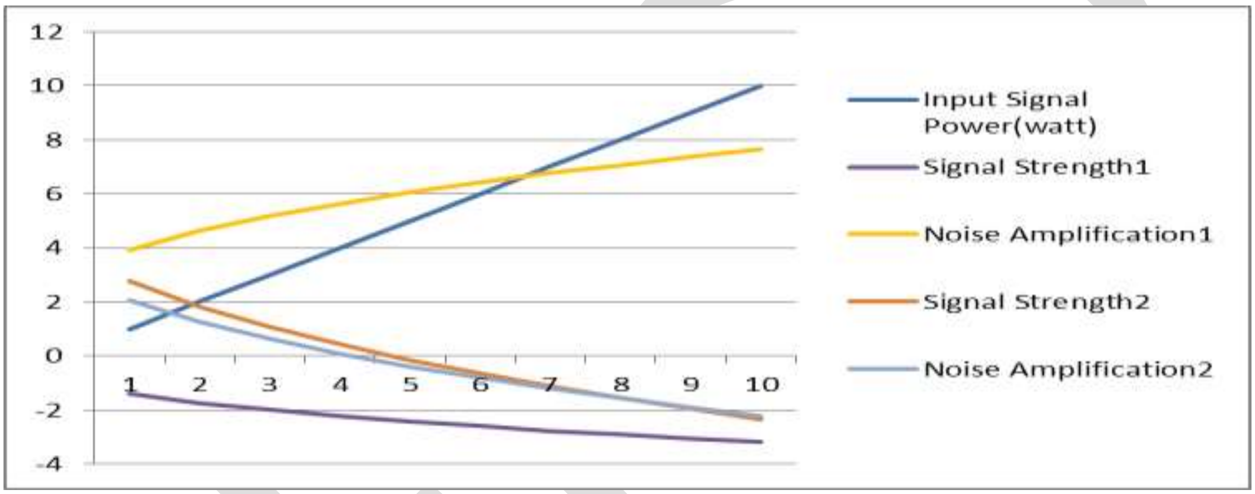

Fig.10: Graph showing effect of increasing Input Signal Power of Noise

Table 4: Test showing increase in Signal to Noise ratio

		Display1		Display2	
S/N	SNR(dB)	Signal Strength1	Noise Amplification1	Signal Strength2	Noise Amplification2
1	1	-1.38	3.91	2.786	2.071
2	2	-1.289	3.721	3.044	2.287
3	3	-1.208	3.553	3.274	2.48
4	4	-1.136	3.404	3.479	2.651
5	5	-1.072	3.27	3.662	2.804
6	6	-1.04	3.152	3.824	2.94
7	7	-0.9632	3.046	3.969	3.062
8	8	-0.9176	2.951	4.099	3.17
9	9	-0.877	2.867	4.214	3.266
10	10	-0.8408	2.792	4.317	3.352

From table 4, Display 1 shows the Signal Strength and Noise Amplification after the AWGN while Display 2 shows the signal strength and noise amplification after the Gaussian Filter

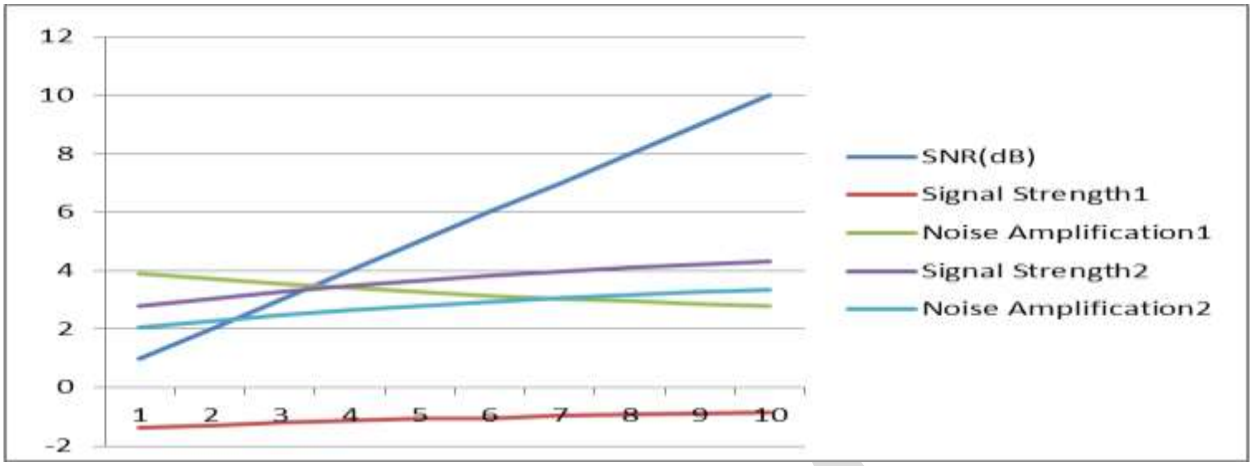

Fig 11: Graph showing effect of increasing Signal to Noise Ratio versus Signal Strength and Noise Amplification

Table 5: Test result of increase in all Parameters

Table 6.5 Test showing Proportional increase in all the parameters					
		Display1		Display2	
S/N	SNR(dB)	Signal Strength1	Noise Amplication1	Signal Strength2	Noise Amplification2
1	1	-1.38	3.91	2.786	2.071
2	2	-2.142	5.263	5.992	4.802
3	3	-2.783	6.155	9.322	7.688
4	4	-3.36	6.808	12.72	10.65
5	5	-3.9	7.313	16.15	13.67
6	6	-4.416	7.72	19.59	16.7
7	7	-4.917	8.058	23.04	19.75
8	8	-5.049	8.348	26.48	22.81
9	9	-5.895	8.602	29.53	25.62
10	10	-6.379	8.83	33.34	28.9

From table 5, Display 1 shows the signal strength and noise amplification after the AWGN, while Display 2 shows the signal strength and noise amplification after the Gaussian Filter.

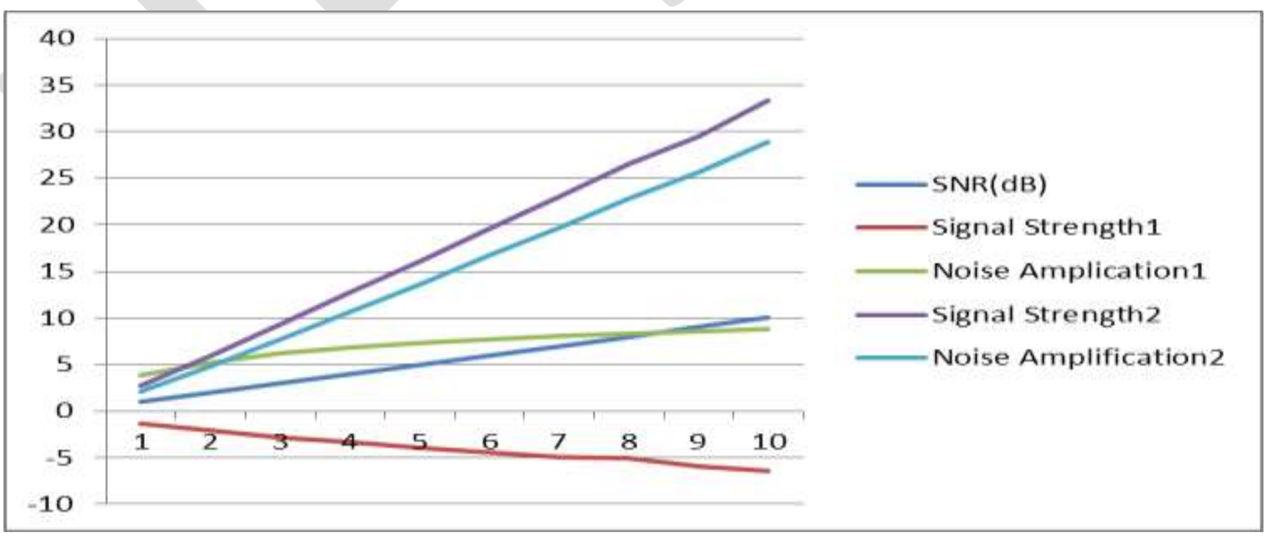

Fig.12Graph Showing effect of proportional increase in all Noise Parameter

Discussion

The noise and messaging signals do not interfere with each other without a channel. See Fig.5

There is significant improvement in signal strength after the Gaussian Filter compared to the degradation observed as you increase the amplitude of messaging signal in a noise channel. See Fig. 7 and Fig. 8

Increasing the input noise power shows proportional degradation in noise amplification and signal strength at the output of the Gaussian Filter as compared to the significant increase in noise amplification obtained at the output of the AWGN Channel. See Fig.9

Increasing the input signal power of the channel shows proportional decrease in signal.

Strength and noise amplification after the Gaussian Filter as compared to degradation in signal strength and increased noise amplification as obtained in the output of AWGN Channel. See Fig.10

Increase in the signal to noise ratio(SNR) improves the signal strength and noise amplification of the Gaussian Filter proportionally as compared to the increase o signal strength and decrease in the noise amplification as observed in the output of the AWGN Channel. See Fig.11

Increase in all the parameters shows proportional increase in signal strength and noise amplification. Never the less, it was observed that the signal strength shows significant improvement over the noise amplification. See Fig.12

Conclusion

The simulated design of a channel noise reduction model has been achieved. It was strongly observed that Increase in Signal to Noise Ratio (SNR) significantly improves signal strength and reduces noise amplification in channel but do not show significant improvement when applied to Gaussian Filter. The Gaussian Filter significantly improved signal strength and reduced noise in communication system

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