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Transimpedance Amplifier Receiver with Variable Gain Amplifier

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Abstract: A 'Transimpedance Amplifier Receiver with Variable Gain Amplifier' has been designed to detect the gain and amplitude of the transmitted signal. Two different configurations of receivers had been designed using LMH6624 and LMH6642 as the front-end transimpedance amplifier. The output frequency response achieved by LMH6624 is 73.0 MHz to 85.9 MHz and LMH6642 is 59.9 MHz to 60.6 MHz.

Keywords: Transimpedance; Amplifier; Variable Gain

1. Introduction

Optical wireless is a complementary technology for short range communications where it can be used for indoor and outdoor environments [1-3]. It is also used to provide telecommunication to clusters of end points which are geographically distant [4-5]. Optical wireless can also referred as the combined use of two technologies that is conventional radio-frequency (RF) wireless and optical fiber for telecommunication. Compared with radio frequency, the optical signal carrier considered for wireless communication does not fall under the FCC regulation and there is no interference with the electromagnetic spectrum.'Transimpedance Amplifier Receiver with Variable [6-7]. Gain Amplifier' is a receiver that detects the gain or the amplitude of a signal that is transmitted by a transmitter [8]. This receiver uses an Automatic Gain Control (AGC) which allows it to control the gain or the amplitude of the signal [9-10]. An AGC is a circuit that automatically controls or normalizes the output of an electronic component by boosting or lowering incoming signals to match a preset level so that the output signal level is virtually constant. The AGC is used to reduce or increase the dynamic range of a signal [11].

1.1 Objectives

- To design an optical wireless receiver that is capable of controlling the gain of the incoming signal automatically.
- To maintain the bandwidth of the received signal at the receiver.

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- To reduce the noise and distortion that has occurred in the received signal during the transmitting of the signal.

Control the gain of an incoming signal automatically. This system consists of a photodiode, transimpedance amplifier and AGC unit. The AGC unit will detect the signal that is received and then change the gain of the amplifier so the bandwidth of the system will be constant.

2. Literature Review

A photodiode is a type of photodetector that is capable of converting light into either current or voltage. It could also be either of the visible light type or the type essentially sensitive to infra-red radiation. The front-end of an optical receiver responds to an optical signal by generating a photocurrent with a photodetector. An optical receiver's front-end design can usually be grouped into one of three basic configurations:

- Low-impedance voltage amplifier
- High-impedance amplifier
- Transimpedance amplifier

Transimpedance amplifier or TIA [12] is a front-end architecture that provides a good compromise between the low-noise characteristics of the high-impedance front-end and the wideband nature of the low-impedance voltage-amplifier front-end. TIA is also known as a transresistance amplifier and a current-to-voltage converter. This device will convert an input current into an output voltage [13]. The conversion is linear, so when the input current doubles, so will the output voltage be. The transimpedance design uses a feedback to reduce input impedance, where this will permit fast response due to the low effective input RC-time constant and low thermal noise since Rf can be made large [14]. The result is that the RC-time constant limitation is multiplied by the amplifier gain and the signal output is a function of the size of the feedback resistance. The transimpedance amplifier has a wide range but is limited in noise performance or frequency response as shown in Fig. 1.

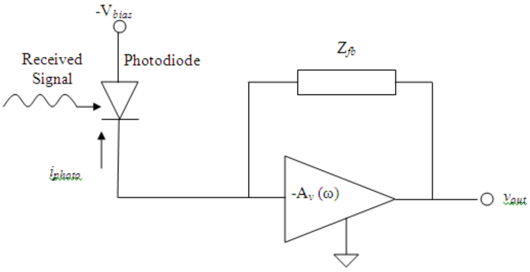

Fig. 1 - Typical circuit configuration of TIA

The transimpedance amplifier comprises of an op-amp of gain, A with feedback resistor, Rf and feedback capacitor, Cf. The gain of the transimpedance amplifier can be expressed as below as in Eq. 1 [15]:

$$A = 1 + \frac{R_f}{R_1} \tag{1}$$

Automatic Gain Control or AGC is an automatic time-varying gain of a signal according to the input signal level. An AGC is typically made up of a signal detector, a gain computer, where the signal detector detects the signal level of the input signal and the gain computer controls the gain or output signal level depending on the output of the signal detector. If the AGC is used to reduce the dynamic range of a signal, it is called compression [16], while if it is used to increase the dynamic range, it is called expansion as in Fig. 2.

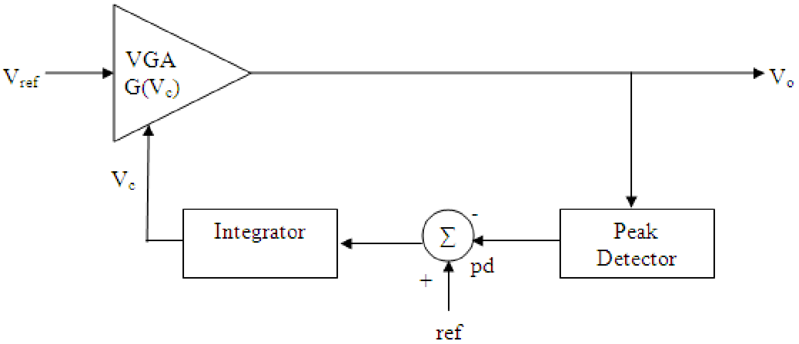

Fig. 2 - Block diagram of an AGC

Typical applications of an AGC are compressors and limiters. Compressors and limiters perform similar tasks, but one essential point makes them different between one another. Limiters abruptly limit the signal above a certain level, while compressors control the signal more gently over a wide rage.

3. Methodology

In this work, the simulation of the circuit is done by using the 'Micro-Cap 9 Spectrum Software' before proceeding on doing the prototype. This is to ensure that the circuit is functional before the fabrication of the circuit is done as shown in Fig. 3

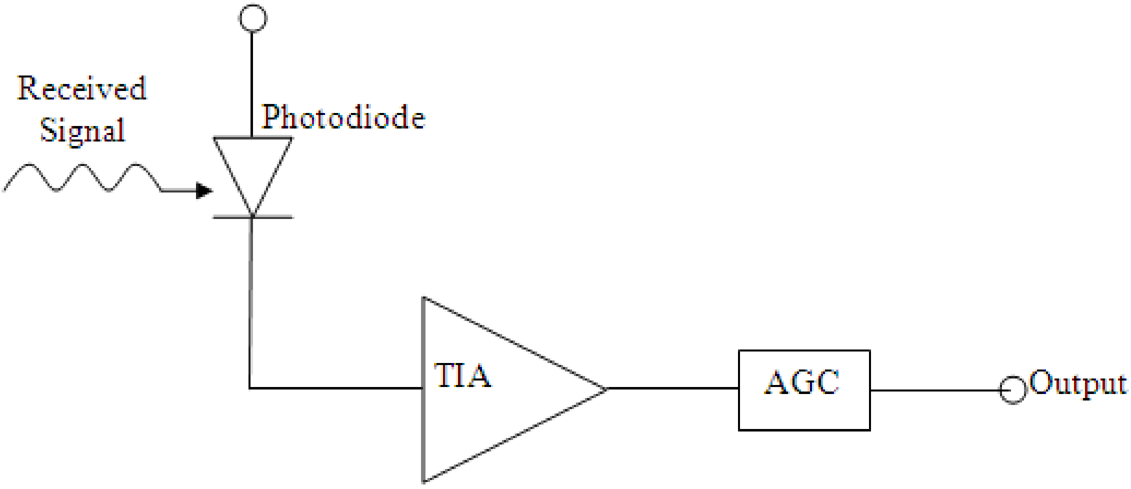

Fig. 3 - Block diagram of 'Transimpedance Amplifier Receiver with Variable Gain Amplifier'

'Transimpedance Amplifier Receiver with Variable Gain Amplifier' consists of three main parts which is a photodiode, a transimpedance amplifier and an automatic gain control. The photodiode will detect detect the gain or the amplitude of a signal that is transmitted by a transmitter and change it to current. The transimpedance amplifier will then convert the current input into voltage output. The output is then given to automatic gain control where it will control the gain or the amplitude of the signal as in Fig. 4.

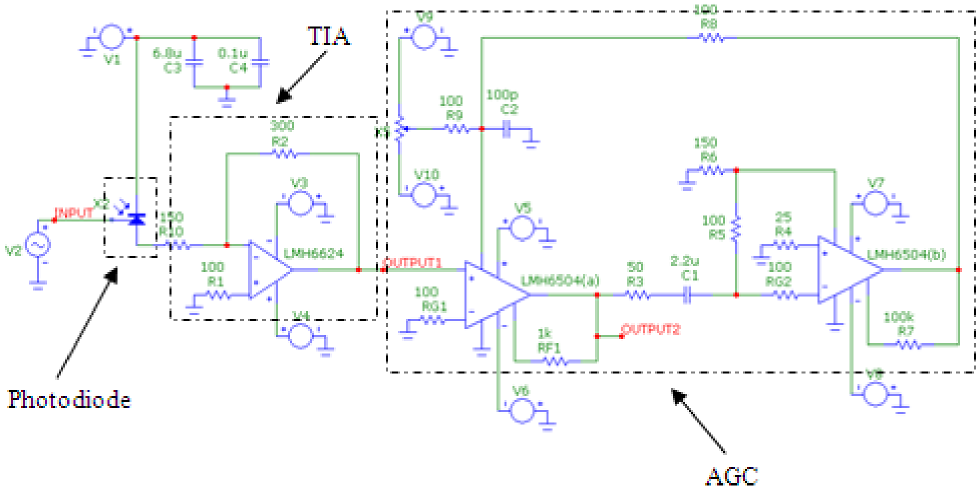

Fig. 4 - Blocked circuit of 'Transimpedance Amplifier Receiver with Variable Gain Amplifier'

The automatic gain control (AGC) circuit employs two LMH6504. In the circuit, LMH6504(a) receives the input signal and produces an output signal of constant amplitude. LMH6504(b) is configured to provide negative feedback. LMH6504(b) generates a rectified gain control signal that works against an adjustable bias level which may be set by the potentiometer and X3. C1 integrates the bias and negative feedback. The resultant gain control signal is applied to the LMH6504(a) gain control input VG. The bias adjustment allows the LMH6504(a) output to be set at an arbitrary level less than the maximum output specification of the amplifier. Rectification is accomplished in LMH6504(b) by driving both the amplifier input and the gain control input with the LMH6504(a) output signal. The voltage divider that is performed by R2 and R3 sets the rectifier gain.

4. Results and Discussion

The receiver receives a sinusoidal input signal. When the signal passes through the transimpedance amplifier stage, the signal is oscillated at some high frequency above the bandwidth cut-off as shown in Fig. 5.

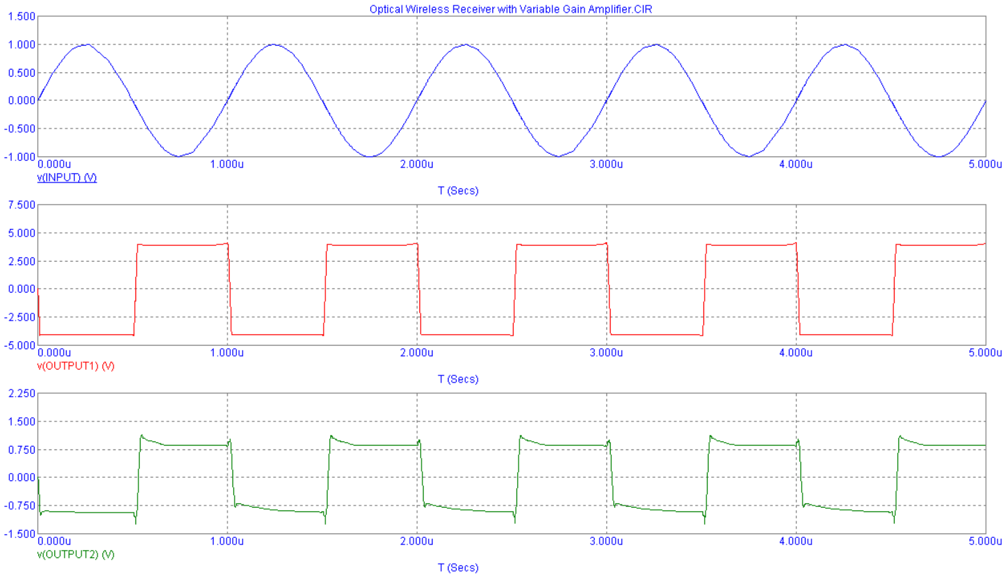

Fig. 5- Transient analysis waveform for 'Transimpedance Amplifier Receiver with Variable Gain Amplifier'

The signal from the final stage of the main amplifier in the AGC circuit is compared with a preset reference level and fed back to adjust the high voltage bias supply in order to maintain a constant signal level as in Fig. 6.

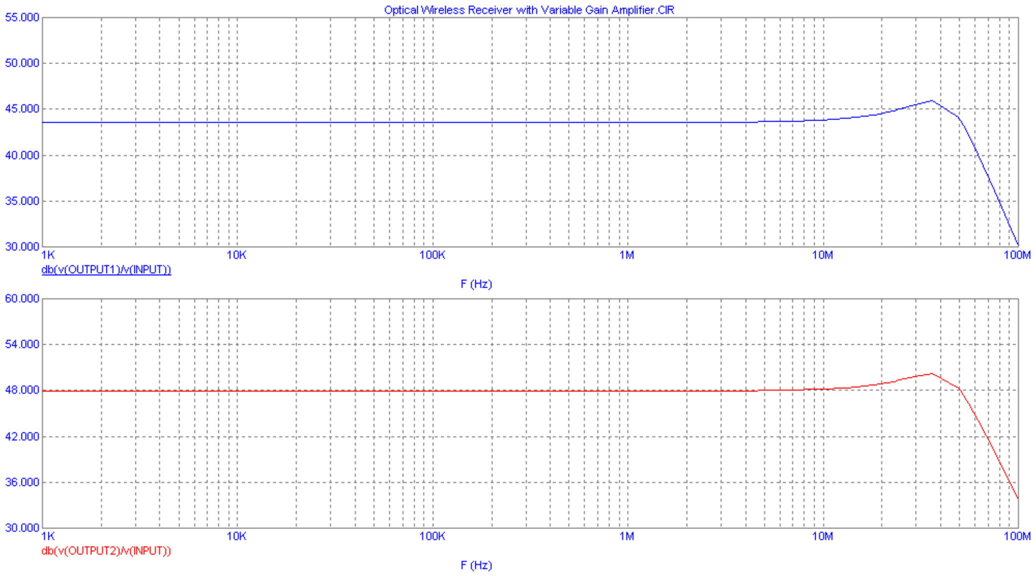

Fig. 6 - Frequency response of ‘Transimpedance Amplifier Receiver with Variable Gain Amplifier’ using LMH6642

The cut-off frequency and gain of the optical wireless receiver using LMH6642 are summarized in Table 1 and in Fig. 7

Table 1 – Summarized out-off frequency and gain

	OUTPUT1	OUTPUT2
Cut-off Frequency	60.587 MHz	59.851 MHz
Gain	40.59 dB	44.91 dB

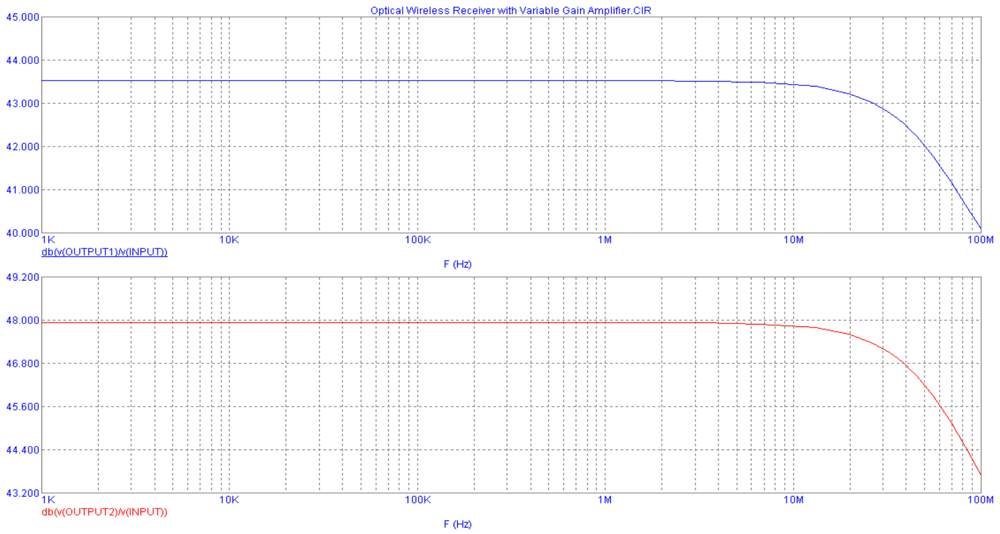

Fig. 7 - Frequency response of ‘Transimpedance Amplifier Receiver with Variable Gain Amplifier’ using LMH6624

The cut-off frequency and gain of the optical wireless receiver are summarized in Table 2.

Table 2 – Summarized out-off frequency and gain

	OUTPUT1	OUTPUT2
Cut-off Frequency	85.918 MHz	73.024 MHz
Gain	40.53 dB	44.94 dB

The cut-off frequency for the first stage is higher than cut-off frequency after the AGC stage. This is because at the first stage, the signal is amplified by the transimpedance amplifier but when the signal passes through the AGC, the signal's dynamic range is reduced and is applied to the preamplifier giving increased optical dynamic range at the receiver input as in Fig. 8.

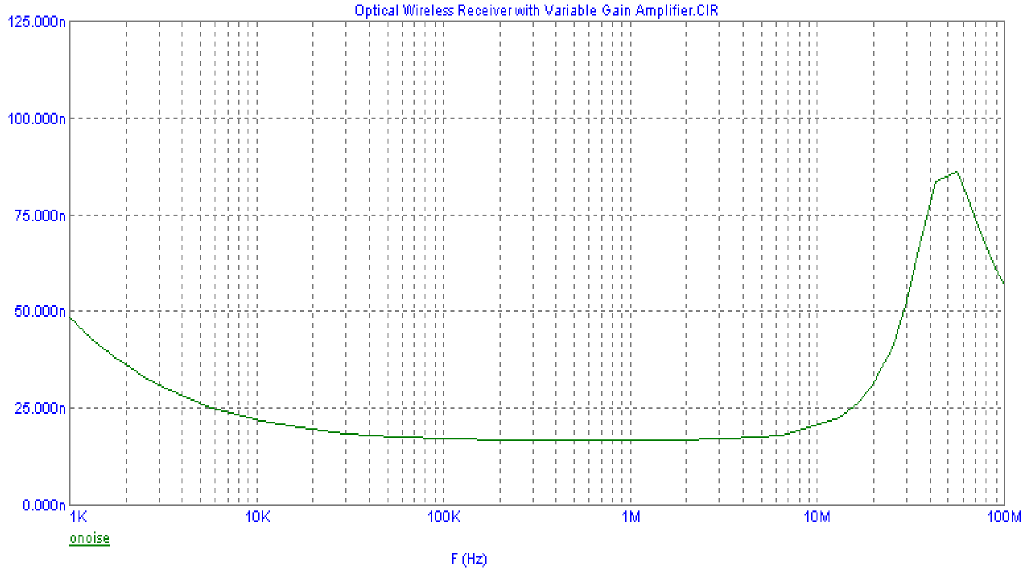

Fig. 8 - First stage output noise of the 'Transimpedance Amplifier Receiver with Variable Gain Amplifier' using LMH6642

The output noise is 48.315 np/A at low impedance whereas the output noise in 56.912 np/A at high impedance as in Fig. 9.

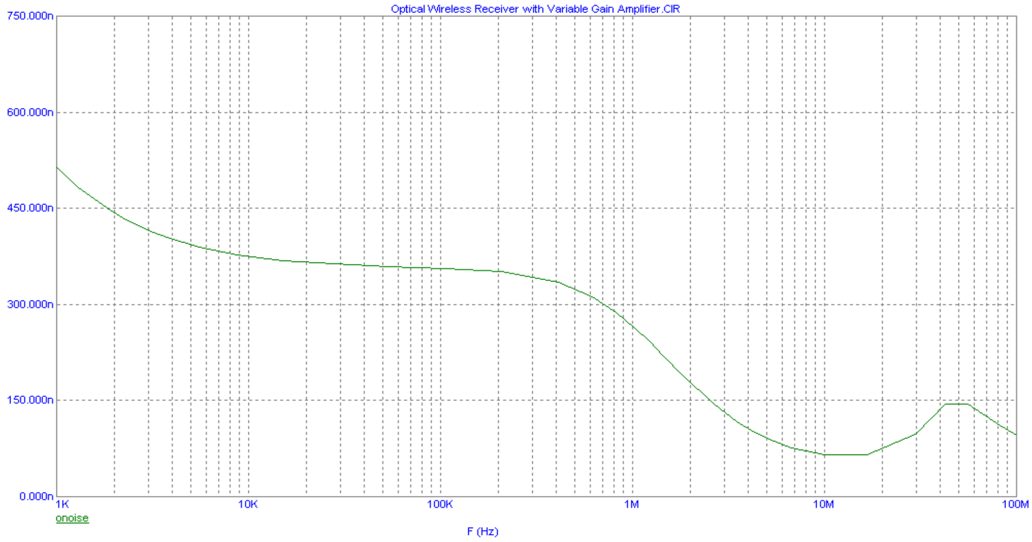

Fig. 9 - Second stage output noise of the 'Transimpedance Amplifier Receiver with Variable Gain Amplifier' using LMH6642

The output noise is 514.856 np/A at low impedance whereas the output noise in 65.810 np/A at high impedance as in Fig. 10.

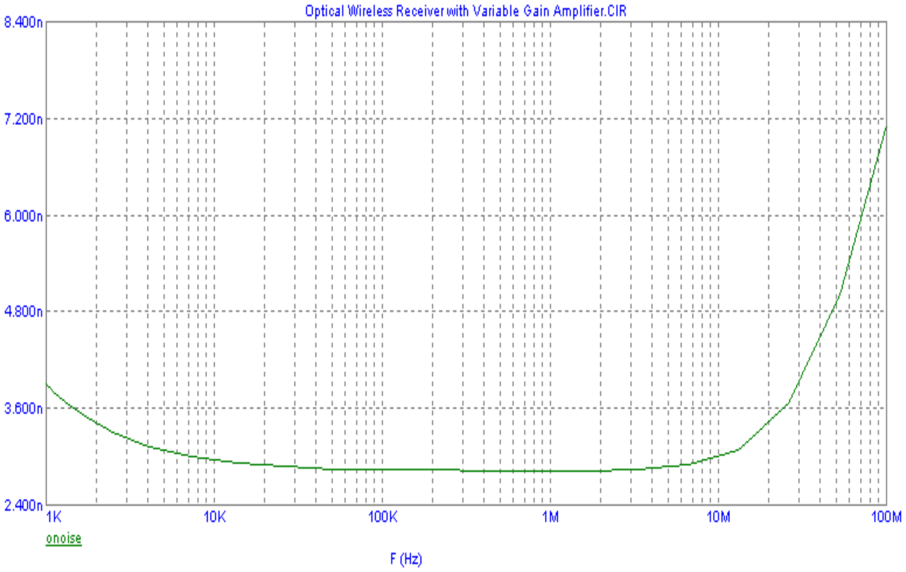

Fig. 10 - First stage output noise of the 'Transimpedance Amplifier Receiver with Variable Gain Amplifier' using LMH6624

The output noise is 3.898 np/A at low impedance whereas the output noise in 7.122 np/A at high impedance as in Fig. 11.

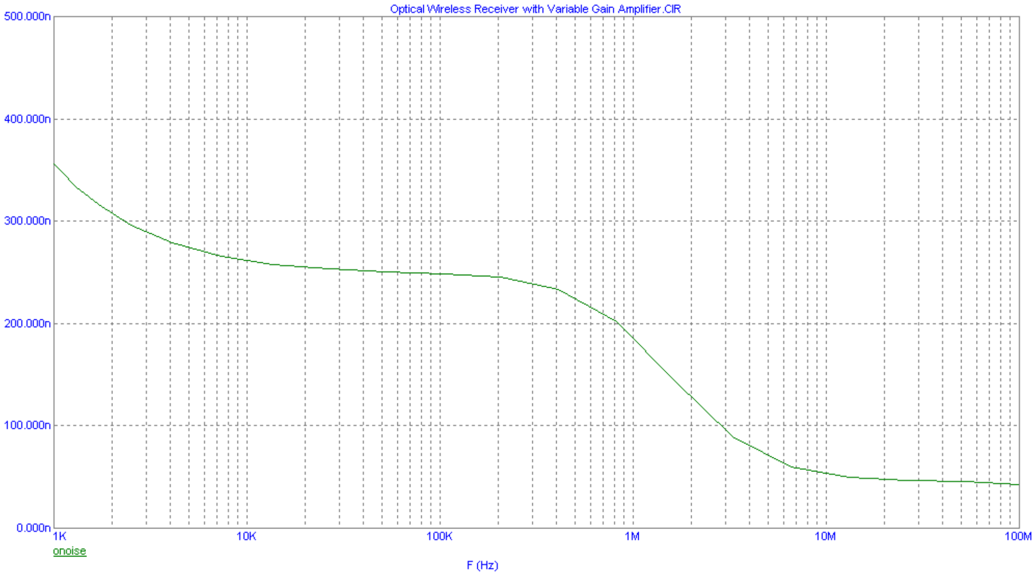

Fig. 11 - Second stage output noise of the 'Transimpedance Amplifier Receiver with Variable Gain Amplifier' using LMH6624

The output noise is 355.856 np/A at low impedance whereas the output noise in 42.638 np/A at high impedance. Comparing the simulated results, LMH6624 is chosen for practical experimental work because it gives a better performance and cut-off frequency response. It also gives a lesser output noise compared to LMH6642.

5. Conclusion

A ‘Transimpedance Amplifier Receiver with Variable Gain Amplifier’ has been designed and fabricated to meet the objectives. It is an optical wireless receiver that is capable of controlling the gain of the incoming signal automatically and maintains the bandwidth of the received signal.

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