Mini Signal Booster for LTE Network

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Abstract
In this project, we evaluate and design a mini-antenna for mobile network amplification to boost the cellular signal for better network in that region. The current LTE network is necessary in most of the places and time, but everyplace does not necessarily have strong network to carry out daily video demands and internet surfing. This mini-antenna system consists of high gain outdoor Yagi Uda antenna to receive the LTE signal of 1800 MHz and a patch panel indoor antenna, the signal received by the high gain antenna will go into a directional signal booster system where the signal enters into amplification process and comes out of greater strength and power. The patch panel antenna then retransmit it in an Omni directional radiation pattern in demand for that area, hence boosting the network of that area. Since the system receives the weaker signal and amplifies it, it is not implemented in the area with no signal occurrence at all.
Key Words : *LTE Network, Signal Booster, Radiation Pattern, High Gain antenna, High Gain Amplifier*

1. INTRODUCTION

The devices with the ability to increase the amplitude of the input signals are termed as ‘amplifiers. The amplifiers are classified into different types based on their construction of operating characteristics. Their operating characteristics can be seen in their output waveforms. Linearity, signal gain, efficiency and power output are the main operating characteristics of an ideal amplifier. Amplifiers are capable of only increasing the amplitude and the other parameters such as frequency and shape of the waves remain constant and can be used to vary the output signals.
Amplifier plays a vital role in the world of telecommunication. Wireless communication to longer distance were made possible only because of the amplification of the signal transmitted carrying the information or the message. Due to attenuation and other loses, the signal transmitted becomes weaker as it travels through different mediums resulting in weak signal coverage to few places. The attenuation arises due to the factor such as the geographical conditions, high rise building causing severe diffraction [no direct line of sight between transmitter and receiver] and etc. Hence the amplification of the signal is required to maintain the signal strength.
The amplifier is connected with an antenna system to receive the weak signal. The antenna helps capture signals and provide an input signal to the amplifier circuit. It also helps broadcast the amplified signal as desired. Hence both the component combined together with other necessary components such as filters can act and behave as an LTE network booster which is a vital system in telecommunication.

2. METHODOLOGY

For the purpose of this report, the research method adopted would be qualitative to study the papers already carried out on this topic. The report will highlight a detailed calculated and simulated results of the designed system and will explore possibilities of the improvement of the given system.
The flow chart below clearly represents all the procedure or the steps followed to complete the project. It includes all the blocks necessary to successfully complete the project. Hence the entire project will follow this flow chart from the start till the end.

3. LITERATURE REVIEW

1. Signal Booster (P.Kavipriya, M.R Ebenzar Jebarani, G.Jegan, P.Chitra, S.Lakshmi, Department of ECE, Sathyabama Institute of Science and Technology, Chennai-119, 2020)
   In this paper, it has designed the simple network booster which works on the present 4G network. It discusses the idea on improving the signal strength at the longer distance. In this signal booster design, it uses two antennas i.e., the outdoor antenna

(Tx/Rx) and the indoor antenna (Tx/Rx). The type of antenna used is the patch panel antenna because it is omni directional. The main component used in the booster are the bandpass filter and the power amplifier. The bandpass filter allows only 4G band to pass through rejecting other signals and power amplifier amplifies the strength of the weak signal into original message signal.

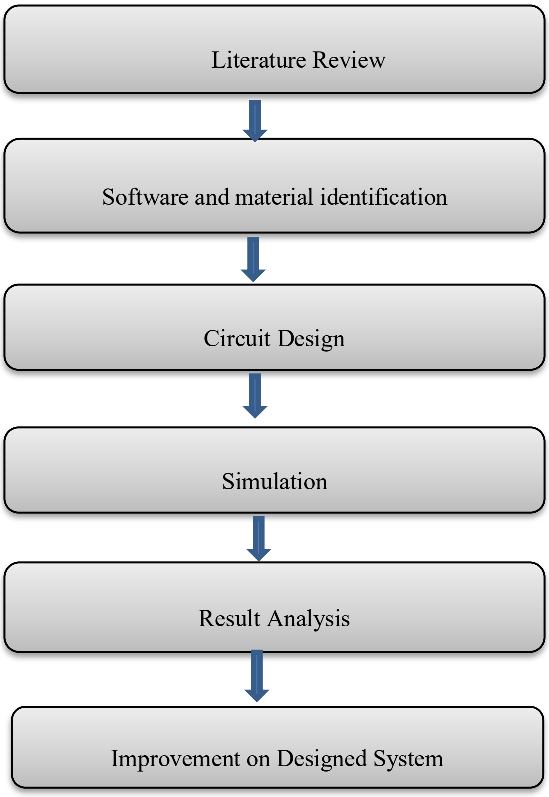

Fig. 1: *Methodology*

2. Design of Yagi-Uda Antenna for CDMA modems of 800MHz(Adik Putra Andika, Vinesunsius Letsoin, Rapha Nichita Kaikatui, Paulus Mangera, Damis Hardiantono,Department of Electrical Engineering, Musamus University, Indonesia, 2019)
   This paper designed the Yagi-Uda antenna for CDMA modems which operates at the frequency of 800MHz. In this antenna design, the number of elements used are 1 reflector, 1 driven and the 16 numbers of directors. The antenna was designed using the software, NEC win pro 1.6 and the Ansoft HFSS 13.0. The simulation using NEC win gets VSWR value as 1.59 and S11 as 13dB using MATLAB. Whereas using Ansoft HFSS simulation, VSWR obtained was 200000 and S11 as -9dB.We will design the Yagi-Uda antenna using the CST STUDIO SUITE which is available for us.
3. Design of Wideband Micro-strip Antenna with Parasitic Element for 4B/LTE Application. (Yulianto La Elo, FitriYaliZulkifia, EkoTjiptoRahardjo, Electrical Engineering Department, University Indonesia)
   This paper aims to design a wideband micro-strip antenna which is for mobile communication especially for 4G/LTE long term evolution. The wideband antenna is designed to support frequencies band of 850MHz, 900MHz, 1800MHz and 2300MHz which are commonly used by 4G/LTE application. By adding parasitic elements in a rectangular micro-strip patch antenna, it can work as wideband antenna since it achieves the characteristic of wideband. Using such technique, the frequency band is obtained at 793.66MHz up to 2501.34MHz with bandwidth of 1707.64MHz. Increasing the frequency, the gain of the antenna can be increased. The result of the antenna design can be used for 4G/LTE applications due to its antenna characteristic. The CST STUDIO SUITE software is used for designing the antenna.
4. The internal GSM/DCS patch Antenna for a portable mobile Terminalby W.Kinlu, L.Yuan-chih, T.Ting-Chih (Kin-Lu Wong, Senior Member, IEEE, Yuan-Chin Lin, and Ting-Chih Tseng). This paper presents the demonstration of a novel in portable patch antenna suitable for GSM/DCS operation in a portable mobile terminal. The proposed antenna has a thin air-layer substrate of 3mm. The impedance bandwidth of modes (lower mode and upper mode) of the proposed antenna over the required bandwidth of GSM and DCS system with a volume of 2.7 cm3 (3*15*60mm3). For the proposed antenna, the radiation characteristics over the two modes have also been obtained. The proposed antenna shows a thickness of 6-10mm for operating in 900/1800MHz bands for GSM (890-960MHz) and DCS (1750-1880MHz) operations. Therefore, the proposed antenna is suitable for the application in thin mobile phones as an internal antenna. In their paper they make use of software called Ansoft HFSS (High Frequency structure Simulator) simulation software for designing patch antenna. In our project we make use of CST MICROWAVE STUDIO SUITE software to design patch antenna.

4. SOFTWARE AND MATERIALS IDENTIFICATION

The technique used for designing the mini antenna for network amplification is solely based on software design. The project takes two parts, where first one is to design an antenna (for receiving the weak signal and transmitting the amplified signal) using CST STUDIO SUITE software and the second one is to design an amplifier (to amplify the received weak signal received by the antenna) using OrCAD Capture CIS Lite software.

5. OVERALL BLOCK DIAGRAM

The Mini Signal Booster for LTE Network will enhance the network strength at places where the LTE network coverage is poor. The Poor Signal which cannot be received by smartphones will be captured/received by the antenna system of the signal booster and feed to the rest of the system lock as the input source. The Input signal will then be passed through the Low Pass Filter which will filter out any noise of higher frequency with the input signal. Next the signal enters the LNA where the amplitude of the signal is boosted which then passes through the bandpass filter for further noise clearness. The power of the signal is then amplified and fed to the patch antenna to be broadcast indoor.

6. DESIGN ASPECT

The system will be designed individually as presented in the above block diagram. The antenna system will be able to receive the signal from the base station which are very weak. A signal strength of (-65 to -50) dBm is considered Excellent, (-85 to 75) dBm as very good, (-95 to -85) dBm as Good, (-105 to -95) as fair and (-120 to -105) dBm as poor. Hence the places with the signal of only fair and poor strength will be unusable and provide a very bad network connectivity. Therefor the antenna will collect this signal and pass down to the LNA for amplification. The LNA will be designed with a minimum sensitivity of -105dBm so that it can efficiently detect the poor signal and amplify it. Every other individuals' blocks are designed as per the requirement.

All the blocks including the filter, LNA and power amplifier after being designed individually are collectively implemented in the orcad simulation circuit for testing and to produce required output. Every block will be replaced by its individual circuit diagram and implemented and hence the output is verified.

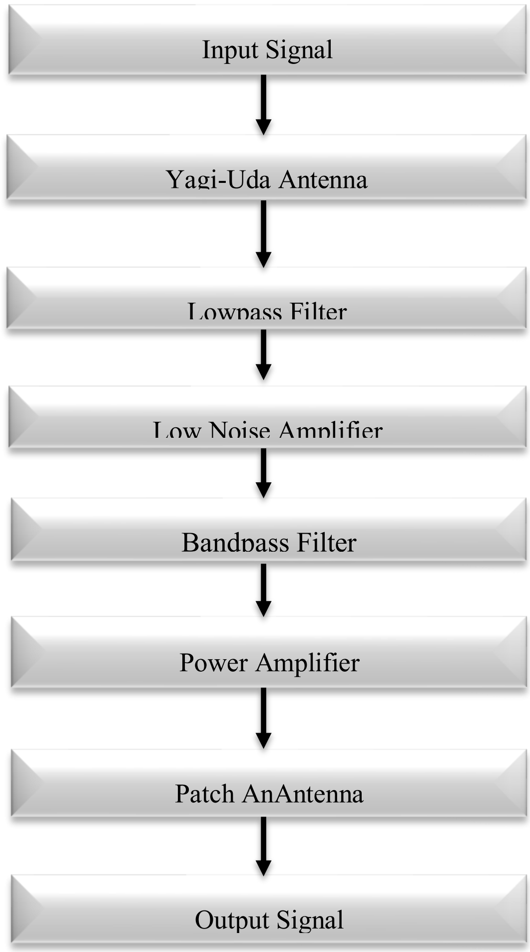

Fig. 2: *Overall block Diagram*

7. YAGI-UDA ANTENNA

The Yagi–Uda antenna is the highly RF directional antenna that is widely used in the VHF and UHF bands where its frequency is ranging from 30 MHz to 3 GHz. This type of antenna is widely identified for its high directivity and high gain. It is formed by the combinational of three major elements in which the elements are hold by horizontal rod like structure called boom. The Driven element having the feeding point is the main element which is used to radiate the power/signal and is placed in the center. The element which is placed behind the main element is called a Reflector and it is usually longer in length which suppressed the backward radiation. Whereas the element which are placed in front of driven element is called director and it is shorter than any other element of the antenna, it enhances radiation in one direction. It has become popular for signal reception in television, but it is also used in many other areas where high directivity and gain is required. Therefore, this antenna is best suitable for this project for orienting in any direction to capture the weak signal.

7.1 Simuation Result Output

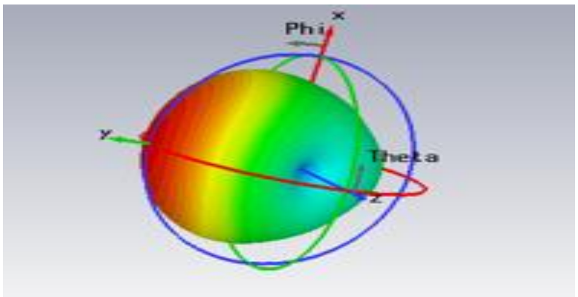

Fig. 3: *Radiation pattern of Yagi-Uda Antenna*

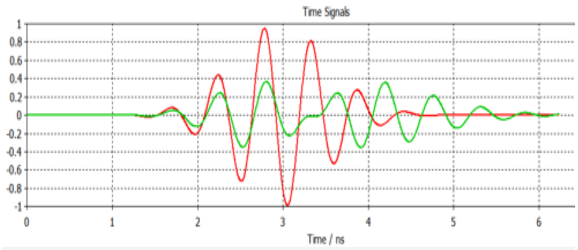

Fig. 4: *Port Sig*

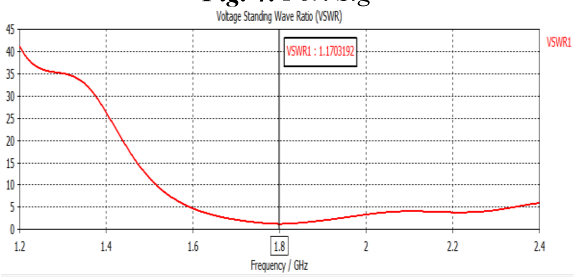

Fig.5: *VSWR*

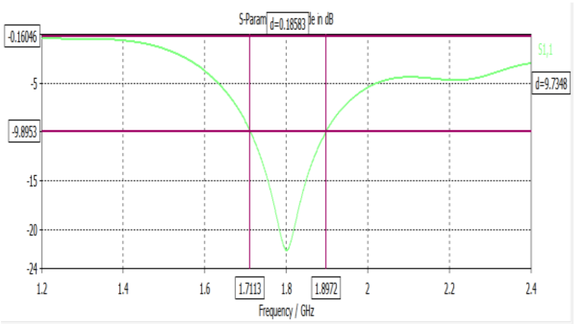

Fig. 6: *S-Parameter*

8. INTEGRATION OF AMPLIFIER CIRCUIT

The individual design blocks of components are integrated and the results are analyzed in this chapter. Due to the limitation of the Orcad Simulation Software for a maximum of 60 elements in the design, the integration was done in two parts. First the Low Pass Filter and the Low Noise amplifier were integrated together. The output of which was fed as the input to the integration of Band pass filter and the power amplifier and the results was obtained as follows from all the system.

8.1 Circuit Diagram

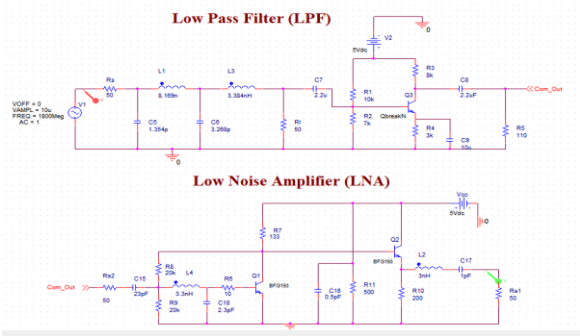

Fig. 7: *Lowpass Filter and Low Noise Amplifier*

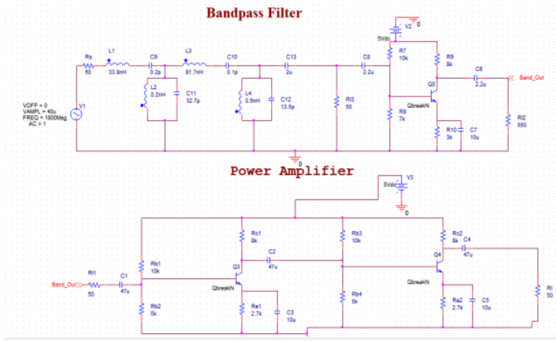

Fig. 8: *Bandpass Filter and Power Amplifier*

8.2 Simulation Results Output

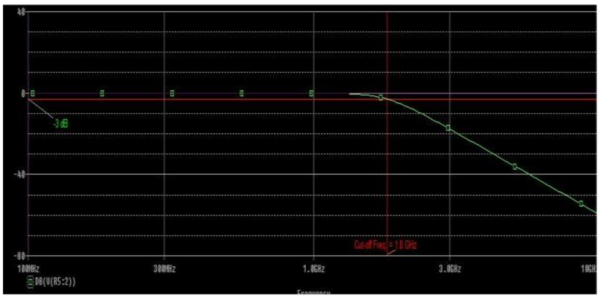

Fig. 9: *Lowpass filter gain response*

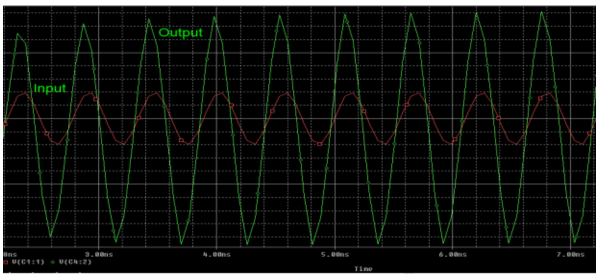

Fig. 10: *Output from LNA*

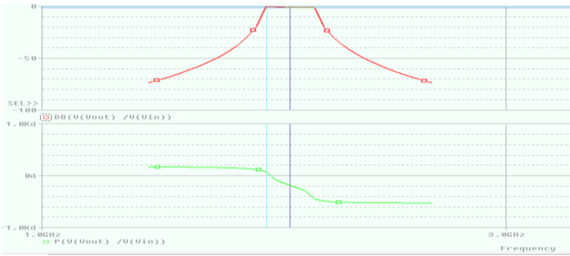

Fig. 11: Bode plot of Bandpass filter

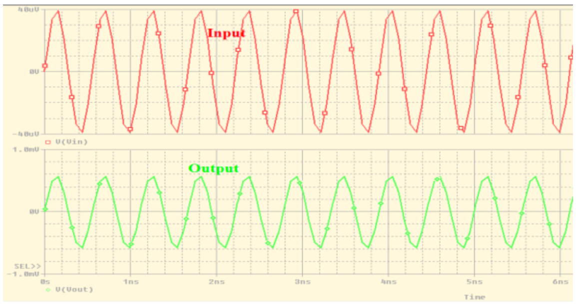

Fig. 12: Input-Outut waveform from power amplifier

9. PATCH ANTENNA

A microstrip patch antenna is the type of antenna that is mostly used for the narrowband applications. It has got an omnidirectional radiation pattern with wider beam which is produce by designing the radiating metallic surface called patch over a dielectric substrate. A thin metal layer which is placed bottom of the substrate forms the ground plane. This type of antenna can be found in different shapes, such as Rectangular, Triangle, Square, L-shape, circular, elliptical, dipole etc. But the most commonly used regularly shapes are like Square and Rectangular. This is due to its low cross radiation properties, ease of fabrication, ease of analysis and attractive radiation characteristics. This chapter is mainly focused on designing of a rectangular patch antenna. The design and simulation of Patch antenna is created in CST STUDIO SUITE software using theoretical values obtained by considering the operating frequency of 1.8GHz. The table shows theoretical values used for the initial design.

9.1 Simulation Result Output

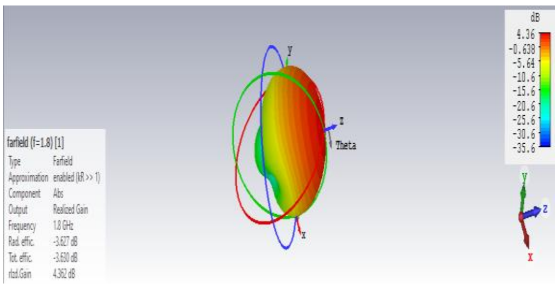

Fig. 13: Radiation Pattern

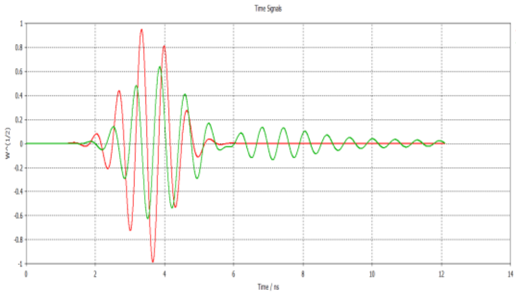

Fig. 14: Port Signal

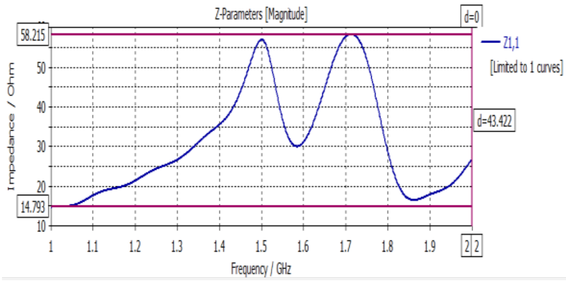

Fig. 15: Z-Parameter

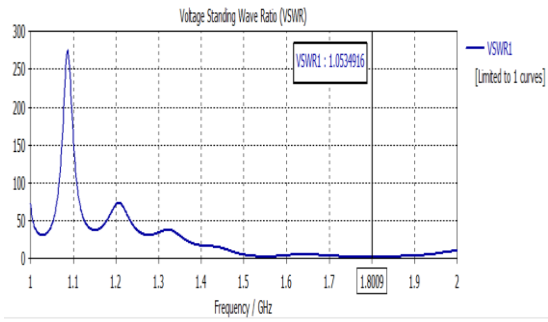

Fig. 16: VSWR

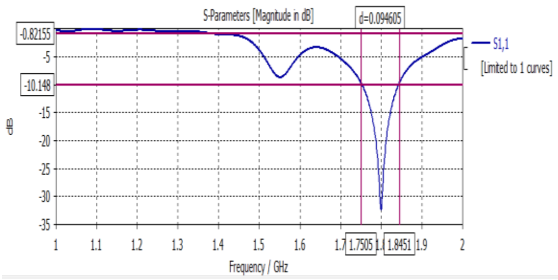

Fig. 17: S-Parameter

10. RESULT ANALYSIS

The result obtained, such as the output and input graph from the simulation analysis and the characteristics parameters obtained from the antenna design helped us to verify if the design is applicable to be implemented in the desired way. It also provides the necessary information to calculate the gain obtained and the type of radiation pattern of the signal, allowing to generalize how and where the system can be implemented.

The high directivity and gain of the Yagi-Uda antenna receives the poor signal of LTE and pass to the LNA. The antenna system is capable of receiving the weak signal of strength -120dBm to -90dBm or even the strong signal. Since the minimum receiver sensitivity of the LNA is -120dBm, the received signal of the antenna can hence be amplified successfully by the LNA.

The RG-8 type transmission line coaxial cable of 12 m was used for the system. The attenuation for the cable was 8 dB/100feet (30.5m). The connector used in the system accounts a total loss of 0.4 dB. Hence the total transmission loss we have for the system is 3.52 dB.The gain of Yagi-Uda and patch antenna as measured were 7.36dB and 4.36dB respectively.

Table.1 Overall Result Analysis including comparison between theoretical and simulation result

TWO CASES								
	CASE-I (-120dBm)				CASE-II (-90dBm)			
Methods	Received Power (dBm)	Output Power (dBm)	Input Signal (uV)	Output Signal (uV)	Received Power (dBm)	Output Power (dBm)	Input Signal (uV)	Output Signal (uV)
Theoretical Values	-120	-82.63	0.32	23.37	-90	-52.73	10	730.3
Simulation Values	-120	-84.54	0.32	18.73	-90	-54.65	10	585.4

From the above table it can be seen that the weak and fair signal of strength -120dBm to -90 dBm are amplified to good and excellent signal of strength -85dBm to -50 dBm.

Hence the system of mini antenna for mobile network amplification can be used in the places where the mobile network is weak and doesn't provide a good connectivity for the user. The system will receive this weak signal at that place through the antenna and amplify it to greater strength. With this benefit from the system, the underground houses, places at narrow valley, high altitude region and etc. with weak connectivity of mobile network could be solved.

11. CONCLUSION

The technology of amplification has improved to a great extent over the course of time. Amplifiers are able to convert small and weak signal in actual into amplified and powerful signal. In this Project a poor signal of strength up to -120 dBm is captured by the Yagi-Uda antenna and fed into the amplification system to achieve a stronger/boosted Signal. The aim was to a design the 4G network booster for implementation in the places where there is weak signal coverage. The LNA provides a gain of 3.6 and the power amplifier with a gain of 17.65 which is sufficient enough for the amplification process. However, the simulation gain was 3 and 14.4 respectively which is able to amplify the poor signal strength -120 dBm received by the Yagi-Uda antenna of gain 7 dB and broadcast indoor by the patch antenna. The design of the amplification circuit was a success. Further exploration can be also done to achieve higher gain and improve the system. Basic components such as copper annelid, resistors, capacitors and transistors were used in this design. Hence a LTE network booster is designed which is able to improve stability of communication in required places.

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