**An improved Adaptive Beam Forming Algorithm for 5G Interface-coexistence communication**

**ABSTRACT**

Multiple wireless systems coexisting in a 5G network may cause interference in the same frequency range, affecting the performance of the received signal. In this paper, a new antenna array processing algorithm is developed to manage interference-coexistence communication. A QAM modulator acts as a translator, converting digital packets into analogue signals for flawless data transport. Maximum-Likelihood Sequence Estimation (MLSE) equalizers enable optimal equalization of time fluctuations in the propagation channel characteristics, and QAM is used to achieve high levels of spectrum consumption efficiency. We apply a log-sum penalty to the coefficients and include it into the cost function, which is based on the standard singly linearly restricted least mean square method (LC-LMS). Filter weights are calculated using an iterative algorithm. Using simulations in an antenna environment with a signal of interest, noise, and interferences, we show that the novel method's convergence rate is faster than the traditional one. The mean-square-error (MSE) of the suggested approach is also confirmed. According to the results of the experiments, our approach has a lower MSE than the standard LC-LMS algorithm. To deal with signal and interference coexistence in a 5G system, the suggested adaptive beam forming approach can be implemented.

**Keywords:** Interference-coexistence, LC-LMS, Log-Sum Penalty, Maximum-Likelihood Sequence Estimation (MLSE), Quadrature amplitude modulation (QAM).

**CHAPTER 1**

**INTRODUCTION**

Extensive deployment of fifth generation (5G) communication started to take place in few countries around the world. Therefore, extensive studies on channel modelling and signal measurements with respect to the physics fundamentals are needed to properly design the architecture whereby such signals are precisely transmitted and received. The motivation of using such technology is that it promises higher data rates and enhanced network performance relative to the existing ones. This is typically achieved by exploiting wider ranges of bandwidth in higher frequency bands, for example 30 Gigahertz (GHz). For instance, millimetre wave (mmWave) communication provides up to 10 Terabits data rates and spectral efficiency (SE) of approximately 100 bps/Hz over a bandwidth of about 270 Megabits per second (Mbps) (30–300 GHz frequency band). The Federal Communication Commission (FCC) initiative of bandwidth allocation in 5G. Clearly, the existing long-term evolution (LTE) system will no longer be able to embrace the network demands such as data rates and spectrum needed neither solve for the challenges such as the excessive interference. Given that, investigations on the performance of the system with respect to the operating frequency and bandwidth such as the Terahertz (THz) bandwidths are already ongoing because of the high capacity figures it provide. On the other hand, higher frequencies are extremely fragile especially in wider distances which enforces the fact that higher frequencies are best for indoor communications. This has encouraged researchers to investigate the possibility of designing transmitters that are able to radiate stronger signals without increasing the power, examples of such techniques are beamforming, and multiple input multiple-output (MIMO). These techniques enable high signal gains and may extend the reach of the signals but it also increases antenna sizes, and the complexity of antenna designs at both transmitters and receivers. This is evidenced by the study which concluded that performance degradation is proportional to antenna size. The study has also highlighted some of the technical challenges that researchers should realize before approaching the technology. While massive MIMO and cell-free technologies are deemed to be some of the exciting innovations for the 5G communication paradigm, beamforming extends the use of such technologies by exploiting the broad range of antenna elements to provide high security, enhanced energy efficiency (EE), good communication reliability, and low signal processing complexity. Cell-free technology is one of the areas that could adopt the beamforming technology to enhance the directivity and connectivity in wireless networks whereby a user is connected to several distributed antennas instead of the conventional systems to insure maximum sum rate reception. Subsequently, interference is considered the most destructive factor to wireless communication systems. Therefore, the availability of proper channel models of the conventional LTE communication system such as Rayleigh, Okumura-Hata etc. has made it easy for researchers to investigate andpropose innovative ways to overcome the interference issue.Nevertheless, the existence of limited channel representation that precisely model 5G channels may have limited the availability of realistic simulation models. In that regard, two famous channel models were developed to visualise and understand the signal behaviour, namely: the third generation partnership project (3GPP) and New York university simulation(NYUSIM). On the other hand, electromagnetic radiations are generally categorised into non-ionising radiations such as infra-red, microwave, radio frequency etc., and ionising radiations such as X-rays. The non-ionising radiations define the ones that have insufficient energy to break the atoms and turn them into ions, that is it does not cause any damages to the human body. Whereas the ionising radiations at high doses increase the risksof cancer, birth and DNA defects etc.. However, concerns of thermal heating caused by the electromagnetic radiations were raised. Therefore, the FCC limits the maximum exposure to radio frequency energy measured by the specific absorption ratio (SAR) to 1.6 watts per kilogram for mobile phones. The FCC approval indicates that the device will never exceed the maximum exposure levels, but it does not describe the consumers exposure during normal use. Given that, consumers may accidentally overheat a specific part of their body, for example head, torso, legs etc. while using their phones, for example talking for long durations on the phone. Therefore, manufacturers advise to keep phone conversations short, use of plug-in earpieces, and that a minimum distance of 5–20 mm to be maintained between the consumer’s body and his/her phone. These recommendations make us wonder about the extent of the maximum exposure that human tissues can tolerate especially when considering cellular base stations that are deployed on top of houses and at the middle of residential areas. And while many people are happy with the pays of telecommunication companies for deploying cellular base stations on top of their houses, some are worried about the threats posed by these especially if the number of base stations is to be increased, for example in 5G communication systems. Despite the claims of the harmfulness of the electromagnetic signals, it can be said that through directional transmission, consumers’ concerns will be put to rest. Not only this, but quality of service will also be improved. Therefore, the motivation is to address the efforts of some researchers on beamforming methods which contribute to minimizing the radiations in all directions and enhance the network performance. The contributions are summarized as follows:

1. Enhanced understanding of interference in 5G communication and beamforming methods that achieves less interference(i.e. green communication).

2. Summarized, yet efficient presentation on the important 5G channel modelling models.

3. The evaluations of different interference mitigation techniques provide clearer understanding of the effectiveness of beamforming techniques.

4. The presentation of different works on this issue promotes the work to be a reference for beamforming in future 5G systems.

All signals in its basic form experience fading and undergo huge losses in the channel. To illustrate this, we look in which the wave propagation is described. In Figure 4a, the base station has an omnidirectional antenna in which signals are propagating in all directions equally. In that sense, the user equipment’s are supposed to receive equal signal powers. However, it is not achievable due to the unequal distance at which the users are located. On the other hand, user equipment’s receive much more improved signal powers when beams are not radiated equally in all directions which is done using different types of antennas. The terminology of forming the beams to a specific direction is familiarly known as beamforming .The function used in beamforming determines the shape and the direction at which the beam is directed, that is number of antenna elements, their arrangement, the separation of elements, and the phase of each signal fed into each antenna element.

In that regard, the work presented in proposed a hybrid beamforming approach that is able to utilize the channel state information and come up with a beamsteering map codebook. The approach attempts to mitigate the interference between the sub bands caused by the carrier offsets of the orthogonal frequency division multiplexing (OFDM). Although the design seem to be complex, a digital beamformer with regulated channel inversion was used to lower the complexity. In a 5G-IOT smart virtual antenna array is designed to eliminate the interference by precisely directing the generalized frequency division multiplexing (GFDM) beams towards the targeted angles. Although the interference is mitigated, the performance raises few concerns due to the availability of limited higher frequencies channel models. On the other hand, the authors of analyzed the end-fire arrangement arrays to combat interference in MIMO infrastructure in 12.9 GHz frequency band. OFDM techniques were also used to suppress the interference of in-band dull duplex channels. However, both reports did not discuss the performance in terms of bit error rates and throughput ratios. The smart antenna is another approach in which the antenna is able to construct a different beam for each user at the simultaneously.

The antenna can hop to any beam at any given time. With the aid of smart antennas, other techniques can be used to suppress the interference such as zero-forcing (ZF) of, or time division multiple access (TDMA) techniques. In a combined beam antenna that operates in 28 GHz frequency band is proposed. The design relies on combining two different radiating elements to obtain a wider beam that has a high gain. On the azimuth plane, wider beams are obtained by micro strip patches while the higher gain is achieved using a wave-guide aperture in the elevation plane. Besides the reduced antenna size, the antenna can also constructively reduce interference by optimizing the radiation of the two radiating parts. In an uplink interference computation algorithm was designed for 70 and 80 GHz frequency bands to mitigate the interference by sectoring the cell zones and exclude certain zones from the transmission via switching off certain beams. Moreover, the spatial power control method helps in elevating the coverage area affects resulting from the beam on/off method. This also supports the fact that no coordination between the current and the 5G systems is needed. In the interference in 2.6 GHz frequency band is mitigated using beamforming whereby an array antenna consisting of 4 antenna elements that gives a 40 beamwidth was used. The proposed scheme relies on estimating the locations of the users by obtaining the angles of the users in relation to their respective femtocells. Subsequently, the users are re-associated to the femtocell that gives the highest interference plus noise ratio (SINR). Although the spectral efficiency and throughput were considerably enhanced, the interference occurrence probability can inflate in dense deployment environments. The same authors in improved the performance by utilising TDMA to time the transmissions instead of re-associating the users which improved the throughput even further and mitigated the outage probability to less than 5%.

The deployment of wireless cellular networks back in the early 1980s made feasible communications via portable devices, thus decoupling call establishment from existing location. In the next decades, technological achievements such as data exchange, which was introduced in second generation (2G) wireless cellular networks, or multimedia communications, which was a key concept of third generation (3G) networks, enabled the delivery of even higher data rates to mobile users (MUs) and a more efficient spectrum utilization compared to second generation systems. In March 2009, the International Telecommunications Union-Radio communications sector (ITU-R) specified a list of requirements for fourth generation (4G) systems, named the International Mobile Telecommunications Advanced (IMT-Advanced) specification, setting peak speed requirements for 4G services at 100 Mbs for high mobility communications (such as from trains and cars) and 1 Gbs for low mobility communications (such as pedestrians and stationary users). The era of 3G and 4G networks coincided with scientific progress in other related fields, such as micro and power electronics, as well as hardware minimization and related improvements. This in turn made feasible the development of advanced transceiver architectures able to support among others large bandwidth operations and multiple Radio Frequency (RF) chains. Therefore, a quite popular transmission technique that has been studied thoroughly over the previous two decades is the use of antenna arrays at both ends of a wireless orientation, also known as multiple input multiple output (MIMO). Research on MIMO systems was mainly boosted after the pioneering work of Alamouti. MIMO systems can provide, among other benefits, diversity and spatial multiplexing gain. In the first case, the same symbol information is sent and received over multiple antennas; hence, the mean Bit Error Rate (BER) is reduced, due to the presence of multiple diversity branches. In the spatial multiplexing mode, individual data streams are sent from different Transmit antennas. Therefore, overall network throughput can be improved, at the cost, however, of increased hardware complexity, as the diversity order of the orientation is reduced. Although MIMO systems were incorporated in 3G and 4G standards the increasing demand for even higher data rates as well as traffic congestion (i.e., total requested throughput per area) led the scientific community to seek additional bandwidth efficient solutions [9]. Observing the evolution of generations of mobile communication systems, one easily realizes that there is an endless quest for an equilibrium between serving the exponentially increasing user needs (global wireless traffic volume in 2013 increased 30 times compared to that in 2008 [10]), and developing innovative technologies to enhance operational capabilities and network capacity given the scarce spectrum (wireless communications capacity in 2008 has increased by one million times compared to 1957).

In this context, various solutions have been proposed for the deployment of 5G networks, such as mmWave transmission, massive MIMO systems, non-orthogonal multiple access (NOMA) schemes as well as flexible network deployment along with nomadic nodes (e.g., drones, uav, etc.). In the first case, mmWave spectrum covers the range from 30 GHz to 300 GHz (with equivalent wavelengths from 10 to 1 mm). This spectrum area is of particular interest for various reasons, as there is one order of magnitude of more spectrum available in this band than in lower bands. In addition, larger bandwidth channels can be now achieved (i.e., of 2 GHz, 4 GHz, 10 GHz, or even 100 GHz). Massive MIMO is an extension of multiuser MIMO, in which the base station (BS) transmitter simultaneously communicates with multiple mobile station (MS) receivers using the same time-frequency resources, improving the spectrum efficiency. Massive MIMO systems can have hundreds or even thousands of antenna channels in the array. Finally, in NOMA schemes multiple users can share non-orthogonal resources in a synchronous way, thus achieving a higher spectral efficiency by allowing some degree of multiple access interference at mobile receivers. It becomes apparent from the above that accurate performance evaluation and radio network planning of 5G systems can be a quite challenging and computationally demanding procedure, since a considerable number of novel technologies is introduced compared to previous wireless protocols. In general, prior to the actual deployment of a wireless cellular network, it is important to estimate a number of associated parameters, such as total capacity, maximum transmission rate both in uplink and downlink, delay, latency, outage probability, etc. Due to the large number of associated parameters (i.e., the number of active users, number of transmit/receive antennas, propagation environment, requested service per user, etc.), there are no analytical solutions for such complex wireless cellular orientations. Hence, parameter estimation can be performed only numerically, via Monte Carlo (MC) simulations. Therefore, the goal of this review article is to provide all latest achievements on simulation platforms and techniques for 5G interfaces. In this context, channel modeling issues for massive MIMO systems and mmWave transmission are discussed, along with simulation and evaluation procedures. Additional issues, such as Radio Network Planning (RNP) and integration of high bandwidth zero latency applications (e.g., autonomous driving in future electrical smart grids, network recovery after physical disasters, or bandwidth on demand in crowded areas) are discussed as well.

With the demand increase of the capacity to mobile communication systems and scarce spectrum resources, smart antennas are used to resolve co-channel interference, multiple access interference, multipath fading and other issues, as a new application to airspace resource development. The future fifth generation (5G) mobile network is aiming to provide a significant capacity increase compared to any current cellular solutions. The demand for increased capacity in wireless networks motivated recent research toward wireless systems that exploit space selectivity. A smart antenna consists of several antenna elements, whose signal is processed adaptively in order to exploit the spatial domain of the mobile radio channel. The smart antenna technology can significantly improve wireless system performance and economics for a range of potential users. It enables operators of cellular and wireless local loop networks to realize significant increase in signal quality, network capacity and coverage. Smart antennas have been widely applied in radar, sonar, mobile and satellite communication, which inhibit the interference from different directions by beamforming and efficiently improve cell coverage and system capacity. Smart antenna has played a part in the 3rd Generation of Mobile Communication Systems (3G) standard, and the technique can also find applications in the next generation (5G) cellular systems. Many researchers have been designed. For example, research on antenna design has focused in the selection of attractive radiating elements and antenna architecture.

Beamforming is a signal processing technique used in sensor arrays for directional signal transmission or reception. Adaptive beamforming is techniques in which arrays of antennasare used to achieve maximum reception in the direction of desired user while signals of same frequency form other directions are rejected. The user signal is multiplied by complex weights that adjust the magnitude and phase and amplitudes are adjusted to optimize the received signal. This causes the output of arrays of antenna to form transmit or receive in a particular direction and minimize the output in other direction. To change the directionality of the array when transmitting, a beamformer controls the phase and relative amplitude of the signal at each transmitter, in order to create a pattern of constructive and destructive interference in the wave front., adaptive beamforming algorithms LMS and RLS operation in MIMO smart antennas system is proposed. Moreover different convergence factors are used for the adaptive beamforming algorithms, and forgetting factors are also applied to each algorithm.

5G COMMUNICATION SYSTEM:

The motivation behind the development of 5G system (i.e. the rapid unprecedented growth of the network, and the increasing network demands) has triggered the researchers to approach the limitations of the fourth generation (4G) communication systems to underlay the new 5G system specifications and services. This network growth can be illustrated in which the network supports numerous kinds of communications (e.g. agricultural monitoring services, medical services etc.). In such environments, the amount of information exchanged is impressively large which requires advanced technologies to cater for such. The relation between the frequency and the data rate is a major concern whereas low frequencies will not be able to support such demands and high frequencies cannot support wider coverages. Various studies concluded that the traffic is expected to grow to 24.3 Exabytes per month by 2019 on top of the requirements of emerging new services such as cloud computing, smart homes, drone systems, multimedia streaming, point-to-point communication etc. which has now been exceeded already. Therefore, 5G communication system is the revolution of wireless communication in which impressive applications and exceptional data rates and performance are supported. This necessitates fundamental changes in communication infrastructure and innovative realisation of the expected performance. Some of the 5G applications, services, and major challenges are described in the subsequent subsections.

The deployment and commercial operation of 5G systems are speeding up to meet the anticipated demands of next decade in data transmission. 5G networks are emerging intelligent systems which involve the application of advanced signal processing, D2D, internet of things (IOT), edge computing, and wireless access technologies that have drawn much attention in recent years. In a 5G network, coexistence of multiple wireless systems can cause interference in the same frequency band and deteriorate the received signal. The anti-interference communication will still play an important role in the network. The adaptive beamforming technology has always been an import part in antenna processing to handle interference problem. The direction information is added into the transmitted signal with the technology and then the mixed signal, including signal of interest(SOI), interferences and noise, is received at receive end. Actually, SOI have different Direction of Arrival (DOA) compared with interferences. Adaptive algorithms ensure to produce null points towards the directions of interferences while maintain the gain of SOI.

**CHAPTER 2**

**LITERATURE SURVEY**

**[1] S. Wang, Y. Wang, B. Xu, Y. Li, and W. Xu:** In this paper, we investigate the capacity performance of an in-band full-duplex (IBFD) amplify-and-forward two-way relay system under the effect of residual loop-back-interference (LBI). In a two-way IBFD relay system, two IBFD nodes exchange data with each other via an IBFD relay. Both two-way relaying and IBFD one-way relaying could double the spectrum efficiency theoretically. However, due to imperfect channel estimation, the performance of two-way relaying is degraded by self-interference at the receiver. Moreover, the performance of the IBFD relaying is deteriorated by LBI between the transmit antenna and the receive antenna of the node. Different from the IBFD one-way relay scenario, the IBFD two-way relay system will suffer from an extra level of LBI at the destination receiver. We derive accurate approximations of the average end-to-end capacities for both the IBFD and half-duplex modes. We evaluate the impact of the LBI and channel estimation errors on system performance. Monte Carlo simulations verify the validity of analytical results. It can be shown that with certain signal-to-noise ratio values and effective interference cancellation techniques, the IBFD transmission is preferable in terms of capacity. The IBFD two-way relaying is an attractive technique for practical applications.

**Summary:**

Analysed about the For both the IBFD and half-duplex modes, we get accurate approximations of average end-to-end capacity. The impact of the LBI and channel estimate errors on system performance is investigated. Monte Carlo simulations are used to test the accuracy of analytical results.

**[2] Z. Zhao, M. Xu, Yong Li, and M. Peng,:** A key problem of content caching networks is that extra radio resource blocks are consumed to push content objects, which leads to a decline of spectrum efficiency. To solve this problem, a non-orthogonal multiple access-based multicast (NOMA-MC) scheme is proposed in this paper, where pushing and multicasting content objects can be accomplished simultaneously, and thus the spectrum efficiency can be improved significantly. To evaluate the performance of the NOMA-MC scheme, an explicit expression of outage probability is derived, which shows that full diversity gains can be achieved in the single-cell scenario. Moreover, the theoretical results can be extended to the multi-cell scenario by establishing a stochastic geometry-based network model, which show that the NOMA-MC scheme can achieve better performance than the conventional orthogonal multiple access-based multicast scheme. Then, the joint design of power allocation and content matching is studied to enlarge the performance gains of the NOMA-MC scheme, and two distributed optimization algorithms are proposed by solving a hospitals/residents matching problem. Finally, simulation results are provided to verify the analytical results, and also demonstrate the performance gains of the NOMA-MC scheme.

**Summary:**

Studied about enlarge the performance gains of the NOMA-MC scheme, and two distributed optimization algorithms are proposed by solving a hospitals/residents matching problem.

**[3]**  [**D.L. Duttweiler,**](https://ieeexplore.ieee.org/author/38289214500) : On typical echo paths, the proportionate normalized least-mean-squares (PNLMS) adaptation algorithm converges significantly faster than the normalized least-mean-squares (NLMS) algorithm generally used in echo cancelers to date. In PNLMS adaptation, the adaptation gain at each tap position varies from position to position and is roughly proportional at each tap position to the absolute value of the current tap weight estimate. The total adaptation gain being distributed over the taps is carefully monitored and controlled so as to hold the adaptation quality (misadjustment noise) constant. PNLMS adaptation only entails a modest increase in computational complexity

**Summary:**

Studied about the adaptation gain in PNLMS adaptation varies from tap position to tap position and is typically proportional to the absolute magnitude of the current tap weight estimate at each tap location.

**[4] Y. Chen,Y. Gu,and A. O. Hero**: We propose a new approach to adaptive system identification when the system model is sparse. The approach applies ℓ1 relaxation, common in compressive sensing, to improve the performance of LMS-type adaptive methods. This results in two new algorithms, the zero-attracting LMS (ZA-LMS) and the reweighted zero-attracting LMS (RZA-LMS). The ZA-LMS is derived via combining a ℓ1 norm penalty on the coefficients into the quadratic LMS cost function, which generates a zero attractor in the LMS iteration. The zero attractor promotes sparsity in taps during the filtering process, and therefore accelerates convergence when identifying sparse systems. We prove that the ZA-LMS can achieve lower mean square error than the standard LMS. To further improve the filtering performance, the RZA-LMS is developed using a reweighted zero attractor. The performance of the RZA-LMS is superior to that of the ZA-LMS numerically. Experiments demonstrate the advantages of the proposed filters in both convergence rate and steady-state behavior under sparsity assumptions on the true coefficient vector. The RZA-LMS is also shown to be robust when the number of non-zero taps increases

**Summary:** Studied that further improve the filtering performance, the RZA-LMS is developed using a reweighted zero attractor. The performance of the RZA-LMS is superior to that of the ZA-LMS numerically.

**[5]** **Emmanuel J. Candès · Michael B. Wakin:** Stephen P. Boyd: It is now well understood that (1) it is possible to reconstruct sparse signals exactly from what appear to be highly incomplete sets of linear measurements and (2) that this can be done by constrained 1 minimization. In this paper, we study a novel method for sparse signal recovery that in many situations outperforms 1 minimization in the sense that substantially fewer measurements are needed for exact recovery. The algorithm consists of solving a sequence of weighted 1-minimization problems where the weights used for the next iteration are computed from the value of the current solution. We present a series of experiments demonstrating the remarkable performance and broad applicability of this algorithm in the areas of sparse signal recovery, statistical estimation, error correction and image processing. Interestingly, superior gains are also achieved when our method is applied to recover signals with assumed near-sparsity in overcomplete representations—not by reweighting the 1 norm of the coefficient sequence as is common, but by reweighting the 1 norm of the transformed object. An immediate consequence is the possibility of highly efficient data acquisition protocols by improving on a technique known as Compressive Sensing.

**Summary:** Learned that reweighted 1 minimization outperforms plain 1 minimization in a variety of setups. Therefore, this technique might be of interest to researchers in the field of Compressive Sensing and/or statistical estimation as it might help to improve the quality of reconstructions and/or estimations.

**CHAPTER 3**

**EXISTING METHOD**

Uniform linear array (ULA) is used to simplify the optimization problem and analyze algorithm performance. The signals are narrow band and can be seen as plane wave at receive end. In the model, the arrays are arranged in a line with equal intervals. The angle of incidence θ is the angle between DOA and y axis. The ULA model is shown as Fig.

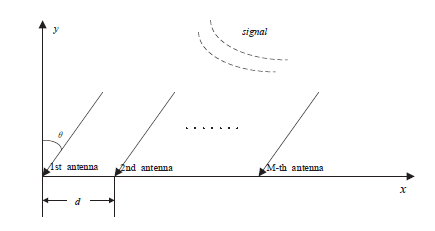
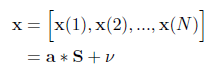


Fig.: ULA

The array consists of M antennas and is used to receive m signals, including SOI, interferences and noise. We assume there are one SOI and  interferences. The incident angles of SOI and interferences  and are expressed as and respectively.

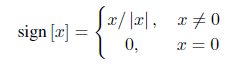
In the ULA, it is assumed that the distance between two adjacent antennas d is  (is the signal wavelength). Then the phase difference between the two adjacent antennas is 

We use the first antenna as a reference. When the incident angle is the corresponding steer vector can be written as  Then the whole steer vector is. In order to construct transmitted signal, we use N denote signal length and x(n) denote the n-th snapshot with n ranges from 1 to N. Then the whole signal x is expressed as below



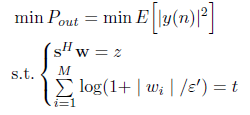
where S is a signal matrix that contains one SOI and m interferences  donates the additive white Gaussian noise(AWGN). It is assumed to be independent from SOI and interferences.

. In this paper, we propose a new algorithms in LCMV. LCMV criterion takes the output power as cost function. It was first proposed by Frost[10]. And it works well in anti-interference. But the convergence rate contradicts with steady state. Many researchers have done a lot to improve the algorithm. However, there still needs more works to push it further. On this point, motivated by [9], we propose a new method on the basis of LCMV. Log-sum penalty is imposed on the cost function. We get the final formulation through mathematical derivation. Compared with traditional singly linearly constrained LMS, simulations are carried out toprove the new method’s superiority. The method outperforms other methods in convergence rate and steady state. Notations: In the following parts, the superscripts and denote the transpose and inverse operators, respectively. denotes the expectation operator and is the component-wise sign function defined as below

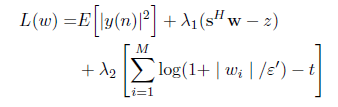


**The linearly constrained least mean square (LC-LMS) Algorithm:**

On the basis of traditional, singly linearly constrained least mean square (LC-LMS), we introduce a log-sum penalty on the coefficients and add it into the cost function. We derive the iterative formula of filter weights.By simulations in antenna environment with signal of interest, noise and interferences. In this part, we give the specific derivations of the new algorithm. The newly proposed algorithm adds log-sum penalty to the object function on the basis of LC-LMS. The optimization problem is expressed as follows



 is the i-th element of the vector w(n).  is a parameter that determines how much each element contributes to the penalty t. Then the Lagrange function can be written as



Similarly, through steepest descend method, we get



Where and Pre-multiplying equation (14) with and using the constraint 





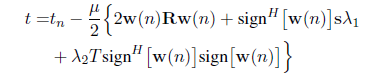
In order to reduce the complexity, we make an approximation



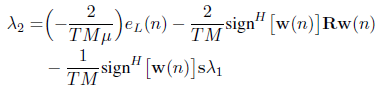
The approximation is on the basis of  n is large enough. Now we define and make another approximation



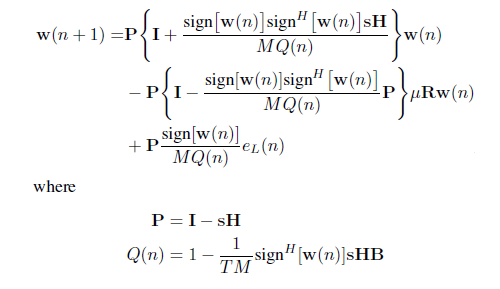
Then pre-multiply equation (14) with and eliminate w(n + 1)



Where   can be denoted as



Where ), we can obtain the solutions of Finally, can be rewritten as



**Disadvantages:**

* It is not readily applicable to censored data.
* It is generally considered to have less desirable optimality properties than maximum likelihood.
* It can be quite sensitive to the choice of starting values.
* LC-LMS algorithm is not effective in the case of convergence rate
* LC-LMS algorithm is also not effective in the case of steady state.

**CHAPTER 4**

**PROPOSED METHOD**

### **QAM (Quadrature Amplitude Modulation):**

### What is QAM (quadrature amplitude modulation)?

QAM (quadrature amplitude modulation) is a method of combining two amplitude [modulation](https://www.techtarget.com/searchnetworking/definition/modulation) (AM) signals into a single [channel](https://www.techtarget.com/searchdatacenter/definition/channel). This approach helps double its effective [bandwidth](https://www.techtarget.com/searchnetworking/definition/bandwidth). QAM is also used with pulse AM ([PAM](https://www.techtarget.com/whatis/definition/pulse-amplitude-modulation-PAM)) in digital systems, like [wireless](https://www.techtarget.com/searchmobilecomputing/definition/wireless) applications.

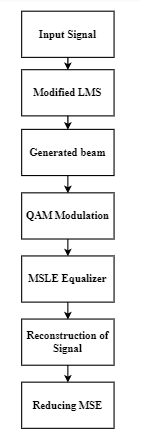


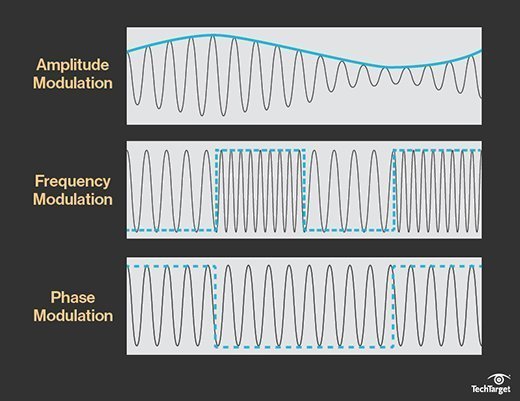
Fig: Block Diagram of Proposed System

A QAM modulator works like a translator, helping to translate digital [packets](https://www.techtarget.com/searchnetworking/definition/packet) into an analog [signal](https://www.techtarget.com/searchnetworking/definition/signal) to transfer data seamlessly.

QAM is used to achieve high levels of spectrum usage efficiency. This is accomplished by utilizing both the amplitude and phase components to provide a form of modulation. In this scenario, the QAM signal comes with two [carriers](https://www.techtarget.com/whatis/definition/carrier-network). Each has the same [frequency](https://www.techtarget.com/whatis/definition/frequency) but differs in phases by 90 degrees, or one-quarter of a cycle, which is the basis for the term quadrature.

One signal is called the I signal, and the other is called the Q signal. Mathematically, one of the signals can be represented with a sine wave and the other by a [cosine wave](https://www.techtarget.com/whatis/definition/cosine-wave). The two modulated carriers combine at the source for transmission.

At the destination, the carriers separate, and the data is extracted from each. Then, the data is incorporated into the original modulating information.



Examples of three types of modulation

### What is the difference between analog and digital QAM?

Some analog transmissions, like AM stereo, use QAM systems. However, QAM comes into its own in data applications. This is because it offers a highly effective form of modulation for data when used in anything from mobile phones to [Wi-Fi](https://www.techtarget.com/searchmobilecomputing/definition/Wi-Fi). QAM is found in most forms of high-speed data transmission.

Analog QAM also enables carriers to transmit multiple analog signals. For example, QAM is used in Phase Alternating Line and [National Television Standards Committee](https://www.techtarget.com/whatis/definition/National-Television-Standards-Committee-NTSC) systems. In this case, different channels provided by QAM enable the signal to carry components of color or chroma data.

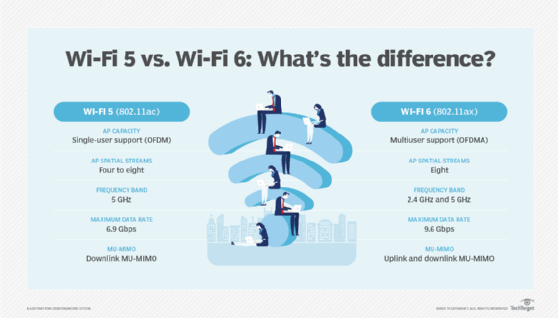
A system known as [Compatible QUAM](https://dbpedia.org/page/C-QUAM) is found in AM stereo radio applications. In this scenario, the different channels enable the required two channels for stereo to be carried by a single carrier. Digital versions of QAM are often called quantized QAM. They are built into most radio communications systems that use data.

For example, radio communications technologies ranging from [Long-Term Evolution](https://www.techtarget.com/searchmobilecomputing/definition/Long-Term-Evolution-LTE) to Worldwide Interoperability for Microwave Access and Wi-Fi use different types of QAM. As the field evolves, expect to see an increase in QAM systems in radio communication technologies.

### What is quadrature amplitude modulation in Wi-Fi?

Since the inception of [Wi-Fi 5](https://www.techtarget.com/searchnetworking/feature/A-deep-dive-into-the-differences-between-Wi-Fi-6-vs-Wi-Fi-5), networking devices use 256-QAM. Whenever 256 combinations are possible for 8 [bits](https://www.techtarget.com/whatis/definition/bit-binary-digit), it's referred to as 256-QAM. When you use a single time period to communicate 10 bits, then it is known as 1024-QAM.

This technology works well in home applications, and the improvements, like 1024-QAM, in Wi-Fi 6 have slightly enhanced bandwidth utilization. This is especially true for high-speed [Gigabit Ethernet](https://www.techtarget.com/searchnetworking/definition/Gigabit-Ethernet) connections.

Wi-Fi 5 vs. Wi-Fi 6 both use QAM.

### What are the advantages and disadvantages of using QAM?

The primary benefit of QAM variants is efficient usage of bandwidth. This is because QAM represents more bits per carrier. For example, 256-QAM maps 8 bits per carrier and 16-QAM maps 4 bits per carrier.

Although QAM uses both the amplitude and phase variations to boost the efficiency of radio communication transmissions, there are some significant disadvantages. For example, QAM is more susceptible to [noise](https://www.techtarget.com/whatis/definition/noise). This is because the transmission states are close together and a lower level of noise is required to move the signal from one point to another.

Unlike QAM systems, receivers equipped with phase or frequency modulation can limit [amplifiers](https://www.techtarget.com/whatis/definition/frequency) and remove any amplitude noise. This approach improves its noise reliance. Furthermore, amplification of the phase or frequency modulated in a radio transmitter eliminates the need for linear amplifiers.

However, in QAM that contains an amplitude component, linearity must be maintained. Unfortunately, these linear amplifiers fall short when it comes to efficiency, and they consume more power. QAM receivers are also more complex when compared to those of other modulation types and systems. Therefore, they are not the best solution for mobile applications.

### What is QAM in cable TV?

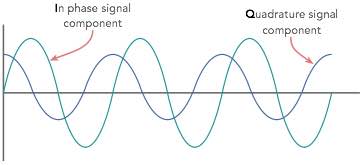
QAM systems are popular in the cable television industry.

[Multiple system operators](https://channelnomics.com/2112-channel-dictionary/multiple-system-operator/) (MSOs) and other network operators use QAM to deliver data, video and voice services. QAM systems provide formatting services in hubs where signals are processed and distributed over the cable operator's network. Once at the subscriber's home, cable [modems](https://www.techtarget.com/searchmobilecomputing/definition/modem) and set-top boxes convert QAM signals back into their original format.

There's been an increasing need for QAM channels among network operators. This explosion in demand is being driven by consumers using [high-definition televisions](https://www.techtarget.com/whatis/definition/HDTV-high-definition-television), high-speed data, [video conferencing](https://www.techtarget.com/searchunifiedcommunications/definition/video-conference) and more. From an overall cost perspective, MSOs need QAM.

Quadrature Amplitude Modulation, QAM utilizes both amplitude and phase components to provide a form of modulation that is able to provide high levels of spectrum usage efficiency.

QAM, quadrature amplitude modulation has been used for some analogue transmissions including AM stereo transmissions, but it is for data applications where it has come into its own. It is able to provide a highly effective form of modulation for data and as such it is used in everything from cellular phones to Wi-Fi and almost every other form of high speed data communications system.



Quadrature amplitude modulation concept

## What is QAM, quadrature amplitude modulation

Quadrature Amplitude Modulation, QAM is a signal in which two carriers shifted in phase by 90 degrees (i.e. sine and cosine) are modulated and combined. As a result of their 90° phase difference they are in quadrature and this gives rise to the name. Often one signal is called the In-phase or “I” signal, and the other is the quadrature or “Q” signal.

The resultant overall signal consisting of the combination of both I and Q carriers contains of both amplitude and phase variations. In view of the fact that both amplitude and phase variations are present it may also be considered as a mixture of amplitude and phase modulation.

A motivation for the use of quadrature amplitude modulation comes from the fact that a straight amplitude modulated signal, i.e. double sideband even with a suppressed carrier occupies twice the bandwidth of the modulating signal. This is very wasteful of the available frequency spectrum. QAM restores the balance by placing two independent double sideband suppressed carrier signals in the same spectrum as one ordinary double sideband supressed carrier signal.

## Analogue and digital QAM

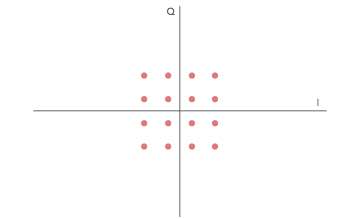
Quadrature amplitude modulation, QAM may exist in what may be termed either analogue or digital formats. The analogue versions of QAM are typically used to allow multiple analogue signals to be carried on a single carrier. For example it is used in PAL and NTSC television systems, where the different channels provided by QAM enable it to carry the components of chroma or colour information. In radio applications a system known as C-QUAM is used for AM stereo radio. Here the different channels enable the two channels required for stereo to be carried on the single carrier.

Digital formats of QAM are often referred to as "Quantised QAM" and they are being increasingly used for data communications often within radio communications systems. Radio communications systems ranging from cellular technology as in the case of LTE through wireless systems including WiMAX, and Wi-Fi 802.11 use a variety of forms of QAM, and the use of QAM will only increase within the field of radio communications.

## Digital / Quantised QAM basics

Quadrature amplitude modulation, QAM, when used for digital transmission for radio communications applications is able to carry higher data rates than ordinary amplitude modulated schemes and phase modulated schemes.

Basic signals exhibit only two positions which allow the transfer of either a 0 or 1. Using QAM there are many different points that can be used, each having defined values of phase and amplitude. This is known as a constellation diagram. The different positions are assigned different values, and in this way a single signal is able to transfer data at a much higher rate.



Constellation diagram for a 16QAM signal showing the location of the different points

As shown above, the constellation points are typically arranged in a square grid with equal horizontal and vertical spacing. Although data is binary the most common forms of QAM, although not all, are where there constellation can form a square with the number of points equal to a power of 2 i.e. 4, 16, 64 . . . . , i.e. 16QAM, 64QAM, etc.

By using higher order modulation formats, i.e. more points on the constellation, it is possible to transmit more bits per symbol. However the points are closer together and they are therefore more susceptible to noise and data errors.

The advantage of moving to the higher order formats is that there are more points within the constellation and therefore it is possible to transmit more bits per symbol. The downside is that the constellation points are closer together and therefore the link is more susceptible to noise. As a result, higher order versions of QAM are only used when there is a sufficiently high signal to noise ratio.

To provide an example of how QAM operates, the constellation diagram below shows the values associated with the different states for a 16QAM signal. From this it can be seen that a continuous bit stream may be grouped into fours and represented as a sequence.

Bit sequence mapping for a 16QAM signal

Normally the lowest order QAM encountered is 16QAM. The reason for this being the lowest order normally encountered is that 2QAM is the same as binary phase-shift keying, BPSK, and 4QAM is the same as quadrature phase-shift keying, QPSK.

Additionally 8QAM is not widely used. This is because error-rate performance of 8QAM is almost the same as that of 16QAM - it is only about 0.5 dB better and the data rate is only three-quarters that of 16QAM. This arises from the rectangular, rather than square shape of the constellation.

## QAM advantages and disadvantages

Although QAM appears to increase the efficiency of transmission for radio communications systems by utilising both amplitude and phase variations, it has a number of drawbacks. The first is that it is more susceptible to noise because the states are closer together so that a lower level of noise is needed to move the signal to a different decision point. Receivers for use with phase or frequency modulation are both able to use limiting amplifiers that are able to remove any amplitude noise and thereby improve the noise reliance. This is not the case with QAM.

The second limitation is also associated with the amplitude component of the signal. When a phase or frequency modulated signal is amplified in a radio transmitter, there is no need to use linear amplifiers, whereas when using QAM that contains an amplitude component, linearity must be maintained. Unfortunately linear amplifiers are less efficient and consume more power, and this makes them less attractive for mobile applications.

## QAM vs PSK & other modes

When deciding on a form of modulation it is worth comparing AM vs PSK and other modes looking at what they each have to offer.

As there are advantages and disadvantages of using QAM it is necessary to compare QAM with other modes before making a decision about the optimum mode. Some radio communications systems dynamically change the modulation scheme dependent upon the link conditions and requirements - signal level, noise, data rate required, etc.

Typically it is found that if data rates above those that can be achieved using 8-PSK are required, it is more usual to use quadrature amplitude modulation. This is because it has a greater distance between adjacent points in the I - Q plane and this improves its noise immunity. As a result it can achieve the same data rate at a lower signal level.

However the points no longer the same amplitude. This means that the demodulator must detect both phase and amplitude. Also the fact that the amplitude varies means that a linear amplifier si required to amplify the signal.

**MLSE Equalizers:**

Maximum-Likelihood Sequence Estimation (MLSE) equalizers provide optimal equalization of time variations in the propagation channel characteristics. However, MLSE equalizers are sometimes less appealing because their computational complexity is higher than Adaptive Equalizers.

In Communications Toolbox™, the mlseeq function, comm.MLSEEqualizer System object, and MLSE Equalizer block use the Viterbi algorithm to equalize a linearly modulated signal through a dispersive channel. These features output the maximum likelihood sequence estimate of the signal by using an estimate of the channel modeled as a finite input response (FIR) filter.

To decode a received signal, the MLSE equalizer:

1. Applies the FIR filter to the symbols in the input signal. The FIR filter tap weights correspond to the channel estimate.
2. Uses the Viterbi algorithm to compute the trace back paths and the state metric. These values are assigned to the symbols at each step of the Viterbi algorithm. The metrics are based on Euclidean distance.
3. Outputs the maximum likelihood sequence estimate of the signal as a sequence of complex numbers corresponding to the constellation points of the modulated signal.

An MLSE equalizer yields the best theoretically possible performance, but is computationally intensive.

For background material on MLSE equalizers, see Selected References for Equalizers.

**Equalize a Vector Signal in MATLAB**

You can use the mlseeq function or comm.MLSEEqualizer System object for MLSE equalization in MATLAB®. The examples in this section call the mlseeq function. A similar workflow applies when using the comm.MLSEEqualizer System object. For examples that use the System object, see the comm.MLSEEqualizer System object reference page.

The mlseeq function has two operation modes:

* Continuous operation mode enables you to process a series of vectors by using repeated calls to mlseeq. The function saves its internal state information from one call to the next. To learn more, see Equalizing in Continuous Operation Mode.
* Reset operation mode enables you to specify a preamble and postamble that accompany your data. To learn more, see Using a Preamble or Postamble.

If you are not processing a series of vectors and do not need to specify a preamble or postamble, the operational modes are nearly identical. They differ in that continuous operation mode incurs a delay, while reset operation mode does not. The following example uses reset operation mode. If you modify the example to run using continuous operation mode, there will be delay in the equalized output. To learn more about this delay, see Delays in Continuous Operation Mode.

**Use mlseeq to equalize a Vector Signal**

In its simplest form, the mlseeq function equalizes a vector of modulated data when you specify:

* The estimated coefficients of the channel (modeled as an FIR filter).
* The signal constellation for the modulation type.
* The Viterbi algorithm traceback depth. Larger values for the traceback depth can improve the results from the equalizer but increase the computation time.

**Maximum likelihood sequence estimation** (**MLSE**) is a mathematical algorithm to extract useful data out of a noisy data stream.

Theory

For an optimized detector for digital signals the priority is not to reconstruct the transmitter signal, but it should do a best estimation of the transmitted data with the least possible number of errors. The receiver emulates the distorted channel. All possible transmitted data streams are fed into this distorted channel model. The receiver compares the time response with the actual received signal and determines the most likely signal. In cases that are most computationally straightforward, root mean square deviation can be used as the decision criterionfor the lowest error probability.

Background

Suppose that there is an underlying signal {*x*(*t*)}, of which an observed signal {*r*(*t*)} is available. The observed signal *r* is related to *x* via a transformation that may be nonlinear and may involve attenuation, and would usually involve the incorporation of random noise. The statistical parameters of this transformation are assumed known. The problem to be solved is to use the observations {*r*(*t*)} to create a good estimate of {*x*(*t*)}.

Maximum likelihood sequence estimation is formally the application of maximum likelihood to this problem. That is, the estimate of {*x*(*t*)} is defined to be sequence of values which maximize the functional

{\displaystyle L(x)=p(r\mid x),}

where *p*(*r* | *x*) denotes the conditional joint probability density function of the observed series {*r*(*t*)} given that the underlying series has the values {*x*(*t*)}.

In contrast, the related method of maximum a posteriori estimation is formally the application of the maximum a posteriori (MAP) estimation approach. This is more complex than maximum likelihood sequence estimation and requires a known distribution (in Bayesian terms, a prior distribution) for the underlying signal. In this case the estimate of {*x*(*t*)} is defined to be sequence of values which maximize the functional

{\displaystyle P(x)=p(x\mid r),}

where *p*(*x* | *r*) denotes the conditional joint probability density function of the underlying series {*x*(*t*)} given that the observed series has taken the values {*r*(*t*)}. Bayes' theorem implies that

{\displaystyle P(x)=p(x\mid r)={\frac {p(r\mid x)p(x)}{p(r)}}.}

In cases where the contribution of random noise is additive and has a multivariate normal distribution, the problem of maximum likelihood sequence estimation can be reduced to that of a least squares minimization.

**CHAPTER 5**

**ADVANTAGES AND APPLICATIONS**

**Advantages:**

* The major benefit of QAM modulation variants is efficient usage of bandwidth. This is due to the fact that QAM represent more number of bits per carrier.
* Maximum-Likelihood Sequence Estimation (MLSE) equalizers provide optimal equalization of time variations in the propagation channel characteristics

**Applications:**

* Applied in 5G system.
* System Identification.
* Inverse Modeling.
* Prediction.
* Echo Cancellation.

**CHAPTER -6**

**HARDWARE & SOFTWARE REQUIREMENTS:**

**Software:** Matlab R2018a.

**Hardware:**

**Operating Systems:**

• Windows 10

• Windows 7 Service Pack 1

• Windows Server 2019

• Windows Server 2016

**Processors:**

Minimum: Any Intel or AMD x86-64 processor

Recommended: Any Intel or AMD x86-64 processor with four logical cores and AVX2 instruction set support

**Disk:**

Minimum: 2.9 GB of HDD space for MATLAB only, 5-8 GB for a typical installation

Recommended: An SSD is recommended a full installation of all Math Works products may take up to 29 GB of disk space

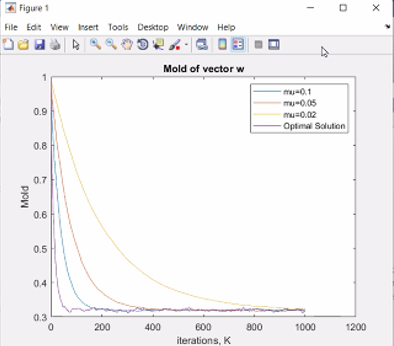
**RAM:**

Minimum: 4 GB

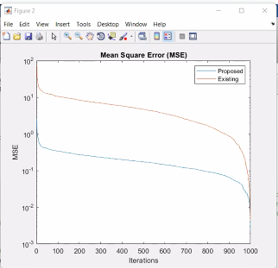
Recommended: 8

**CHAPTER 7**

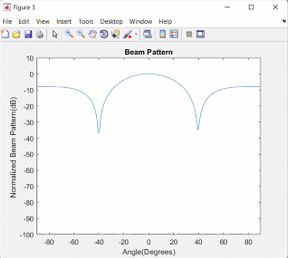
**RESULTS**

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**Figure 1: Mold of Vector w**

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**Figure 2: MSE Error**

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**Figure 3: Beam Pattern**

**CHAPTER 8**

**CONCLUSION**

Multiple wireless systems coexisting in a 5G network may cause interference in the same frequency range, affecting the performance of the received signal. In this proposed method, a new antenna array processing algorithm is developed to manage interference-coexistence communication. Using the Modified LMS, a beam is generated and sent to a QAM modulator and MLSE Equalizer, after which the signal is reconstructed and the MSE Error is calculated. MSE error is decreased when QAM modulator and MLSE Equalizer are used.

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[4] Z. Zhao, M. Xu, Yong Li, and M. Peng, “A non-orthogonal multiple access-based multicast scheme in wireless content caching networks,” IEEE J. Sel. Areas Commun., vol. 35, no. 12, pp. 2723–2735, July 2017.

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**BIBLIOGRAPHY**

**Introduction To Matlab**

What Is MATLAB?

The name MATLAB stands for Matrix Laboratory. The software is built up around vectors and matrices. This makes the software particularly useful for linear algebra but MATLAB is also a great tool for solving algebraic and differential equations and for numerical integration. MATLAB has powerful graphic tools and can produce nice pictures in both 2D and 3D. It is also a programming language, and is one of the easiest programming languages for writing mathematical programs. These factors make MATLAB an excellent tool for teaching and research.

MATLAB was written originally to provide easy access to matrix software developed by the LINPACK (linear system package) and EISPACK (Eigen system package) projects. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. MATLAB has many advantages compared to conventional computer languages (e.g., C, FORTRAN) for solving technical problems.

MATLAB abilities a family of add-on software program utility software application software program software utility software-unique solutions called toolboxes. Very essential to maximum customers of MATLAB, toolboxes assist you to studies and observe specialized technology. Toolboxes are entire collections of MATLAB abilities (M-files) that increase the MATLAB surroundings to remedy precise schooling of problems. Areas in which toolboxes are to be had embody signal processing, manipulate systems, neural networks, fuzzy correct judgment, wavelets, simulation, and hundreds of others.

It has powerful built-in routines that enable a very wide variety of computations. It also has easy to use graphics commands that make the visualization of results immediately available. Specific applications are collected in packages referred to as toolbox. There are toolboxes for signal processing, symbolic computation, control theory, simulation, optimization, and several other fields of applied science and engineering. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. The software package has been commercially available since 1984 and is now considered as a standard tool at most universities and industries worldwide.

**Brief History of MATLAB:**

Cleve Moler, the chairman of the computer science department at the University of New Mexico, started developing MATLAB in the late 1970s. The first MATLAB® was not a programming language; it was a simple interactive matrix calculator. There were no programs, no toolboxes, no graphics and no ODEs or FFTs. He designed it to give his student’s access to LINPACK and EISPACK without them having to learn FORTRAN. It soon spread to other universities and found a strong audience within the applied mathematics community. The mathematical basis for the first version of MATLAB was a series of research papers by J. H. Wilkinson and 18 of his colleagues, published between 1965 and 1970 and later collected in Handbook for Automatic Computation, Volume II, Linear Algebra*,* edited by Wilkinson and C. Reinsch. These papers present algorithms, implemented in Algol 60, for solving matrix linear equation and Eigen value problems.

In the 1970s and early 1980s, I was teaching Linear Algebra and Numerical Analysis at the University of New Mexico and wanted my students to have easy access to LINPACK and EISPACK without writing FORTRAN programs. By “easy access,” I meant not going through the remote batch processing and the repeated edit-compile-link-load-execute process that was ordinarily required on the campus central mainframe computer. Jack little, an engineer, was exposed to it during a visit Moler made to Stanford University in 1983. Recognizing its commercial potential, he joined with Moler and Steve Bangert. They rewrote MATLAB in C and founded Math Works in 1984 to continue its development. These rewritten libraries were known as JACKPAC. In 2000, MATLAB was rewritten to use a newer set of libraries for matrix manipulation, LAPACK. MATLAB was first adopted by researchers and practitioners in control engineering, Little's specialty, but quickly spread to many other domains. It is now also used in education, in particular the teaching of linear algebra and numerical analysis, and is popular amongst scientists involved in video processing**.**

## **EISPACK and LINPACK**:

In 1970, a group of researchers at Argonne National Laboratory proposed to the U.S. National Science Foundation (NSF) to “explore the methodology, costs, and resources required to produce, test, and disseminate high-quality mathematical software and to test, certify, disseminate, and support packages of mathematical software in certain problem areas.” The group developed EISPACK (Matrix Eigen system Package) by translating the Algol procedures for Eigen value problems in the handbook into FORTRAN and working extensively on testing and portability. The first version of EISPACK was released in 1971 and the second in 1976.

In 1975, four of us Jack Dongarra, Pete Stewart, Jim Bunch, and myself proposed to the NSF another research project that would investigate methods for the development of mathematical software. A byproduct would be the software itself, dubbed LINPACK, for Linear Equation Package. This project was also centered at Argonne. LINPACK originated in FORTRAN; it did not involve translation from Algol. The package contained 44 subroutines in each of four numeric precisions. In a sense, the LINPACK and EISPACK projects were failures. We had proposed research projects to the NSF to “explore the methodology, costs, and resources required to produce, test, and disseminate high-quality mathematical software.” We never wrote a report or paper addressing those objectives. We only produced software.

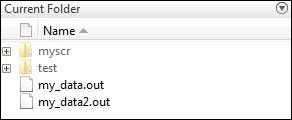
So, I studied Niklaus Wirth’s book Algorithms + Data Structures *=* Programs and learned how to parse programming languages. I wrote the first MATLAB an acronym for Matrix Laboratory in FORTRAN, with matrix as the only data type. The project was a kind of hobby, a new aspect of programming for me to learn and something for my students to use. There was never any formal outside support, and certainly no business plan. This first MATLAB was just an interactive matrix calculator. This snapshot of the start-up screen shows all the reserved words and functions. There are only 71. To add another function, you had to get the source code from me, write a FORTRAN subroutine, add your function name to the parse table, and recompile MATLAB.

**Starting MATLAB:**

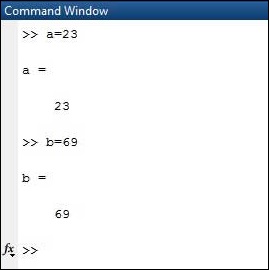
After logging into your account, you can enter MATLAB by double-clicking on the MATLAB shortcut icon (MATLAB 7.0.4) on your Windows desktop. When you start MATLAB, a special window called the MATLAB desktop appears. The desktop is a window that contains other windows. The major tools within or accessible from the desktop are:

* The Command Window
* The Command History
* The Workspace
* The Current Directory
* The Help Browser

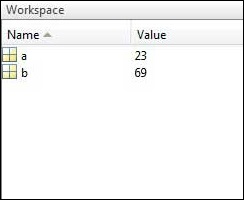
**Current Folder:** This panel allows you to access the project folders and files.



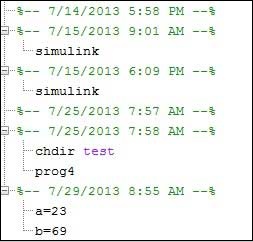
**Command Window:** This is the main area where commands can be entered at the command line. It is indicated by the command prompt (>>).



**Workspace:**  The workspace shows all the variables created and/or imported from files.



**Command History:** This panel shows or return commands that are entered at the command line.



**Help Browser:**

The critical way to get assist online is to use the MATLAB help browser, opened as a separate window every through clicking at the question mark photograph (?) on the computing tool toolbar, or through manner of typing assist browser on the spark off in the command window. The assist Browser is an internet browser blanketed into the MATLAB computing tool that shows a Hypertext Markup Language (HTML) files. The Help Browser consists of panes, the help navigator pane, used to find out information, and the show pane, used to view the information. Self-explanatory tabs apart from navigator pane are used to performs are searching out.

**MATLAB language:**

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

**MATLAB working environment:**

This is the set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files, MATLAB's applications.

**MATLAB mathematical function library:**

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

**MATLAB Application Program Interface (API):**

This is a library that allows you to write C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

**MATLAB DESKTOP:**

MATLAB Desktop is the precept MATLAB utility window. The computing tool includes five sub home windows, the command window, the workspace browser, the modern-day-day list window, the command records window, and one or greater decide domestic windows, which is probably confirmed high-quality on the identical time due to the truth the client suggests a photo. The command window is in which the character types MATLAB instructions and expressions at the spark off (>>) and in which the output of these commands is displayed. MATLAB defines the workspace because the set of variables that the client creates in a bit consultation. The workspace browser suggests those variables and some facts about them. Double clicking on a variable within the workspace browser launches the Array Editor, which may be used to gain statistics and profits instances edit exceptional homes of the variable.

The modern-day-day-day Directory tab above the workspace tab suggests the contents of the cutting-edge list, whose path is shown inside the modern-day list window. For example, in the home windows on foot machine the path is probably as follows: C: MATLAB Work, indicating that listing “artwork” is a subdirectory of the number one list “MATLAB”; WHICH IS INSTALLED IN DRIVE C. Clicking on the arrow within the modern list window suggests a listing of these days used paths. Clicking at the button to the right of the window permits the individual to trade the present day listing. MATLAB uses a seeking out path to find out M-documents and one-of-a-type MATLAB associated documents, which can be put together in directories within the computer document tool. Any report run in MATLAB need to be dwelling in the modern-day-day listing or in a list that is on is looking for course. By default, the documents supplied with MATLAB and math works toolboxes are included inside the searching out direction. The first-rate manner to look which directories are on the searching out route. The satisfactory manner to appearance which directories are speedy the quest route, or to characteristic or regulate a searching for course, is to pick out outset path from the File menu the computing device, and then use the set course talk discipline. It is proper exercise to feature any generally used directories to the hunt route to avoid again and again having the exchange the cutting-edge-day listing.

The Command History Window contains a file of the instructions a person has entered in the command window, together with every contemporary-day and former MATLAB periods. Previously entered MATLAB instructions can be determined on and re-completed from the command statistics window thru proper clicking on a command or series of commands. This movement launches a menu from which to select numerous options similarly to executing the commands. This is useful to select out abilities options in addition to executing the instructions. This is a beneficial feature at the equal time as experimenting with numerous commands in a piece session.

**Using the MATLAB Editor to create M-Files:**

The MATLAB editorial manager is a literary substance proofreader particular for growing M-facts and a graphical MATLAB debugger. The supervisor can seem in a window through command facts technique for itself, or it is probably a right-clicking inside the PC. M-information this gadget signified through the use of the expansion .M, as in pixel up.M. The MATLAB editorial supervisor window has a few draws down menus for obligations collectively with sparing, seeing, and troubleshooting facts. Since it plays more than one easy test and furthermore affects utilization of shade to separate among exclusive variables of code, this article editorial supervisor is often supported due to reality the system of a need for composing and altering M-talents. To open the manager, type at enact opens the M-document filename. M in a supervisor window, sorted out for enhancing. As stated earlier than, the file should be inside the cutting-edge posting, or in a posting in the seeking out direction.

## **Features of MATLAB:**

Following are the basic features of MATLAB.

* It is a high-level language for numerical computation, visualization and application development.
* It also provides an interactive environment for iterative exploration, design and problem solving.
* It provides vast library of mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, numerical integration and solving ordinary differential equations.
* It provides built-in graphics for visualizing data and tools for creating custom plots.
* MATLAB's programming interface gives development tools for improving code quality maintainability and maximizing performance.
* It provides tools for building applications with custom graphical interfaces.
* It provides functions for integrating MATLAB based algorithms with external applications and languages such as C, Java, .NET and Microsoft Excel.

## **Uses of MATLAB:**

MATLAB is widely used as a computational tool in science and engineering encompassing the fields of physics, chemistry, math and all engineering streams. It is used in a range of applications including

* Signal Processing and Communications
* Video and Video Processing
* Control Systems
* Test and Measurement
* Computational Finance
* Computational Biology

**Applications of MATLAB:**

MATLAB can be used as a tool for simulating various electrical networks but the recent developments in MATLAB make it a very competitive tool for Artificial Intelligence, Robotics, Video processing, Wireless communication, Machine learning, Data analytics and whatnot. Though it’s mostly used by circuit branches and mechanical in the engineering domain to solve a basic set of problems its application is vast. It is a tool that enables computation, programming and graphically visualizing the results. The basic data element of MATLAB as the name suggests is the Matrix or an array. MATLAB toolboxes are professionally built and enable you to turn your imaginations into reality. MATLAB programming is quite similar to C programming and just requires a little brush up of your basic programming skills to start working with.

Below are a few applications of MATLAB –

* **Statistics and machine learning (ML)**

This toolbox in MATLAB can be very handy for the programmers. Statistical methods such as descriptive or inferential can be easily implemented. So is the case with machine learning. Various models can be employed to solve modern-day problems. The algorithms used can also be used for big data applications.

* **Curve fitting**

The curve fitting toolbox helps to analyze the pattern of occurrence of data. After a particular trend which can be a curve or surface is obtained, its future trends can be predicted. Further plotting, calculating integrals, derivatives, interpolation, etc. can be done.

* **Control systems**

Systems nature can be obtained. Factors such as closed-loop, open-loop, its controllability and observability, Bode plot, NY Quist plot, etc. can be obtained. Various controlling techniques such as PD, PI and PID can be visualized. Analysis can be done in the time domain or frequency domain.

* **Signal Processing**

Signals and systems and digital signal processing are taught in various engineering streams. But MATLAB provides the opportunity for proper visualization of this. Various transforms such as Laplace, Z, etc. can be done on any given signal. Theorems can be validated. Analysis can be done in the time domain or frequency domain. There are multiple built-in functions that can be used.

* **Mapping**  
  Mapping has multiple applications in various domains. For example, in Big Data, the Map Reduce tool is quite important which has multiple applications in the real world. Theft analysis or financial fraud detection, regression models, contingency analysis, predicting techniques in social media, data monitoring, etc. can be done by data mapping.
* **Deep learning**

It’s a subclass of machine learning which can be used for speech recognition, financial fraud detection, and medical video analysis. Tools such as time-series, Artificial neural network (ANN), Fuzzy logic or combination of such tools can be employed.

* **Financial analysis**

An entrepreneur before starting any endeavor needs to do a proper survey and the financial analysis in order to plan the course of action. The tools needed for this are all available in MATLAB. Elements such as profitability, solvency, liquidity, and stability can be identified. Business valuation, capital budgeting, cost of capital, etc. can be evaluated.

* **Video processing**

The most common application that we observe almost every day are bar code scanners, selfie (face beauty, blurring the background, face detection), video enhancement, etc. The digital video processing also plays quite an important role in transmitting data from far off satellites and receiving and decoding it in the same way. Algorithms to support all such applications are available.

* **Text analysis**

Based on the text, sentiment analysis can be done. Google gives millions of search results for any text entered within a few milliseconds. All this is possible because of text analysis. Handwriting comparison in forensics can be done. No limit to the application and just one software which can do this all.

* **Electric vehicles designing**

Used for modeling electric vehicles and analyze their performance with a change in system inputs. Speed torque comparison, designing and simulating of a vehicle, whatnot.

* **Aerospace**

This toolbox in MATLAB is used for analyzing the navigation and to visualize flight simulator.

* **Audio toolbox**

Provides tools for audio processing, speech analysis, and acoustic measurement. It also provides algorithms for audio and speech feature extraction and audio signal transformation.

**COMMUNICATION:**

Communications System Toolbox™ offers algorithms and gear for the layout, simulation, and analysis of communications systems. These capabilities are furnished as MATLAB ® features, MATLAB System gadgets™, and Simulink ® blocks. The machine toolbox includes algorithms for source coding, channel coding, interleaving, modulation, equalization, synchronization, and channel modeling. Tools are supplied for bit blunders charge evaluation, producing eye and constellation diagrams, and visualizing channel characteristics. The machine toolbox additionally provides adaptive algorithms that allow you to version dynamic communications structures that use OFDM, OFDMA, and MIMO techniques. Algorithms support fixed-point facts arithmetic and C or HDL code era.

**Key Features**

▪ Algorithms for designing the physical layer of communications systems, which includes supply coding, channel coding, interleaving, modulation, channel fashions, MIMO, equalization, and synchronization

▪ GPU-enabled System objects for computationally intensive algorithms together with Turbo, LDPC, and Viterbi decoders

▪ Interactive visualization equipment, consisting of eye diagrams, constellations, and channel scattering capabilities

▪ Graphical tool for evaluating the simulated bit mistakes rate of a machine with analytical outcomes

▪ Channel models, consisting of AWGN, Multipath Rayleigh Fading, Rician Fading, MIMO Multipath Fading, and

LTE MIMO Multipath Fading

▪ Basic RF impairments, along with nonlinearity, section noise, thermal noise, and section and frequency offsets

▪ Algorithms available as MATLAB features, MATLAB System objects, and Simulink blocks

▪ Support for fixed-point modeling and C and HDL code technology

**System Design, Characterization, and Visualization:**

The layout and simulation of a communications gadget requires analyzing its reaction to the noise and interference inherent in real-world environments, reading its behavior the usage of graphical and quantitative manner, and determining whether the resulting overall performance meets requirements of acceptability. Communications System Toolbox implements a selection of obligations for communications machine layout and simulation. Many of the functions, System objects™, and blocks inside the device toolbox perform computations associated with a specific thing of a communications gadget, consisting of a demodulator or equalizer. Other talents are designed for visualization or evaluation.

**System Characterization**

The system toolbox offers several standard methods for quantitatively characterizing system performance:

▪ Bit error rate (BER) computations

▪ Adjacent channel power ratio (ACPR) measurements

▪ Error vector magnitude (EVM) measurements

▪ Modulation error ratio (MER) measurements

Because BER computations are fundamental to the characterization of any communications system, the system toolbox provides the following tools and capabilities for configuring BER test scenarios and accelerating BER simulations:

**BER tool**— A graphical user interface that enables you to analyze BER performance of communications systems. You can analyze performance via a simulation-based, semi analytic, or theoretical approach.

**Error Rate Test Console** — A MATLAB object that runs simulations for communications systems to measure error rate performance. It supports user-specified test points and generation of parametric performance plots and surfaces. Accelerated performance can be realized when running on a multi core computing platform.

**Multi core and GPU acceleration** — A capability provided by Parallel Computing Toolbox™ that enables you to accelerate simulation performance using multi core and GPU hardware within your computer.

**Distributed computing and cloud computing support** — Capabilities provided by Parallel Computing Toolbox and MATLAB Distributed Computing Server™ that enable you to leverage the computing power of your server farms and the Amazon EC2 Web service. Performance Visualization. The system toolbox provides the following capabilities for visualizing system performance:

**Channel visualization tool** — For visualizing the characteristics of a fading channel

**Eye diagrams and signal constellation scatter plots** — for a qualitative, visual understanding of system behavior that enables you to make initial design decisions

**Signal trajectory plots** — for a continuous picture of the signal’s trajectory between decision points

**BER plots** — for visualizing quantitative BER performance of a design candidate, parameterized by metrics such as SNR and fixed-point word size

**Analog and Digital Modulation**

Analog and digital modulation strategies encode the facts circulation into a sign this is appropriate for transmission. Communications System Toolbox presents some of modulation and corresponding demodulation abilities. These talents are available as MATLAB features and gadgets, MATLAB System Modulation sorts provided by the toolbox are:

**Source and Channel Coding**

Communications System Toolbox affords source and channel coding talents that can help you develop and compare communications architectures fast, enabling you to discover what-if eventualities and avoid the need to create coding competencies from scratch.

**Source Coding**

Source coding, also referred to as quantization or signal formatting, is a manner of processing facts a good way to lessen redundancy or prepare it for later processing. The system toolbox offers a diffusion of styles of algorithms for imposing source coding and interpreting, inclusive of:

▪ Quantizing

▪ Companding (*µ*-law and A-law)

▪ Differential pulse code modulation (DPCM)

▪ Huffman coding

▪ Arithmetic coding

**Channel Coding**

▪ orthogonal area-time block code (OSTBC) (encoder and decoder for MIMO channels)

▪ Turbo encoder and decoder examples

The gadget toolbox offers application functions for developing your personal channel coding. You can create generator polynomials and coefficients and syndrome deciphering tables, in addition to product parity-take a look at and generator matrices.

The system toolbox additionally presents block and convolutional interleaving and deinters leaving functions to reduce facts errors as a result of burst mistakes in a conversation machine:

**Block,** including General block interleaver, algebraic interleaver, helical scan interleaver, matrix interleaver, and random interleaver.

**Convolutional,** including General multiplexed interleaver, convolutional interleaver, and helical interleaver

**Channel Modeling and RF Impairments**

Channel Modeling

Communications System Toolbox provides algorithms and tools for modeling noise, fading, interference, and different distortions which might be commonly found in communications channels. The system toolbox supports the subsequent styles of channels:

▪ Additive white Gaussian noise (AWGN)

▪ Multiple-enter multiple-output (MIMO) fading

▪ Single-enter single-output (SISO), Rayleigh, and Rician fading

▪ Binary symmetric

A MATLAB channel object provides a concise, configurable implementation of channel models, enabling you to

specify parameters such as:

▪ Path delays

▪ Average path gains

▪ Maximum Doppler shifts

▪ K-Factor for Rician fading channels

▪ Doppler spectrum parameters

For MIMO systems, the MATLAB MIMO channel object expands these parameters to also include:

▪ Number of transmit antennas (up to 8)

▪ Number of receive antennas (up to 8)

▪ Transmit correlation matrix

▪ Receive correlation matrix

To combat the effects noise and channel corruption, the system toolbox provides block and convolutional coding and decoding techniques to implement error detection and correction. For simple error detection with no inherent correction, a cyclic redundancy check capability is also available. Channel coding capabilities provided by the system toolbox include:

▪ BCH encoder and decoder

▪ Reed-Solomon encoder and decoder

▪ LDPC encoder and decoder

▪ Convolutional encoder and Viterbi decoder

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**RF Impairments**

To model the effects of a non-ideal RF front end, you can introduce the following impairments into your communications system, enabling you to explore and characterize performance with real-world effects:

▪ Memory less nonlinearity

▪ Phase and frequency offset

▪ Phase noise

▪ Thermal noise

You can include more complex RF impairments and RF circuit models in your design using SimRF™.

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**Equalization and Synchronization**

Communications System Toolbox lets you discover equalization and synchronization strategies. These techniques are usually adaptive in nature and tough to design and symbolize. The machine toolbox affords algorithms and tools that will let you swiftly select the proper approach on your communications machine. Equalization To compare one-of-a-kind techniques to equalization, the device toolbox offers you with adaptive algorithms which include:

▪ LMS

▪ Normalized LMS

▪ Variable step LMS

▪ Signed LMS

▪ MLSE (Viterbi)

▪ RLS

▪ CMA

These adaptive equalizers are available as nonlinear decision feedback equalizer (DFE) implementations and as

Linear (symbol or fractionally spaced) equalizer implementations.

**Synchronization**

The device toolbox provides algorithms for each service segment synchronization and timing phase synchronization. For timing section synchronization, the machine toolbox presents a MATLAB Timing Phase Synchronizer object that offers the following implementation techniques:

▪ Early-late gate timing method

▪ Gardner’s method

▪ Fourth-order nonlinearity method

**Stream Processing in MATLAB and Simulink**

Most verbal exchange structures cope with streaming and frame-primarily based statistics using a aggregate of temporal processing and simultaneous multi frequency and multichannel processing. This form of streaming multidimensional processing can be visible in superior communication architectures consisting of OFDM and MIMO. Communications System Toolbox enables the simulation of advanced communications structures via helping move processing and frame-based simulation in MATLAB and Simulink. In MATLAB, circulate processing is enabled by way of System items™, which use MATLAB objects to symbolize time-based and facts-driven algorithms, sources, and sinks. System objects implicitly manipulate many information of flow processing, including information indexing, buffering, and management of set of rules state. You can mix System gadgets with fashionable MATLAB functions and operators. Most System items have a corresponding Simulink block with the identical abilities. Simulink handles circulation processing implicitly with the aid of coping with the float of information thru the blocks that make up a Simulink model. Simulink is an interactive graphical environment for modeling and simulating dynamic systems that uses hierarchical diagrams to symbolize a machine version. It includes a library of widespread-reason, predefined blocks to represent algorithms, resources, sinks, and device hierarchy.

**Implementing a Communications System**

Fixed-Point Modeling Many communications systems use hardware that requires a fixed-point representation of your design.

Communications System Toolbox supports fixed-point modeling in all relevant blocks and System objects™ with tools that help you configure fixed-point attributes.

Fixed-point support in the system toolbox includes:

▪ Word sizes from 1 to 128 bits

▪ Arbitrary binary-point placement

▪ Overflow handling methods (wrap or saturation)

▪ Rounding methods: ceiling, convergent, floor, nearest, round, simplest, and zero

Fixed-Point Tool in Simulink Fixed Point™ facilitates the conversion of floating-point data types to fixed point. For configuration of fixed-point properties, the tool tracks overflows and maxima and minima.

**Code Generation**

Once you've got advanced your set of rules or communications device, you can robotically generate C code from it for verification, rapid prototyping, and implementation. Most System gadgets, functions, and blocks in Communications System Toolbox can generate ANSI/ISO C code the use of MATLAB Coder™, Simulink Coder™, or Embedded Coder™. A subset of System gadgets and Simulink blocks also can generate HDL code. To leverage present highbrow belongings, you can choose optimizations for specific processor architectures and integrate legacy C code with the generated code.

You can also generate C code for both floating-point and fixed-point data types.

DSP Proto typing DSPs are used in communication system implementation for verification, rapid prototyping, or final hardware implementation. Using the processor-in-the-loop (PIL) simulation capability found in Embedded Coder, you can verify generated source code and compiled code by running your algorithm’s implementation code on a target processor. FPGA Prototyping

FPGAs are used in communication systems for implementing high-speed signal processing algorithms. Using the FPGA-in-the-loop (FIL) capability found in HDL Verifier™, you can test RTL code in real hardware for any existing HDL code, either manually written or automatically generated HDL code.