# Enhancement of Data Speed with the Application of CAP Coding in DSL Modem

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**ABSTRACT**
Today's, high-speed Internet access has become quite a necessity, not only in the advanced nations but also in many of the third world countries. Thanks to the fast growing economies, technologies have opened up many of the homes and offices to a new realm of possibilities for network connectivity and applications. Video on demand, Multi-media conferencing and on-line gaming are just a few examples of the services on the Internet that have become quite common these days. DSL and Cable Modem are two parallel technologies in broadband communications, each having its own pros and cons. This article provides a CAP modulation techniques used in DSL modem for enhancement of data speed in the broadband communication.

**IndexTerms—DSL, QAM, CAP etc…**

## INTRODUCTION

The voracious demand for fast domestic Internet access has spurred the development of several new technologies for delivering improved data rates to consumers at ever-decreasing prices [1]. As consumers increasingly find dialup services to be inadequate for modern applications such as voice and video over IP, high quality streaming media and interactive real-time on-line games, telecommunications service providers have progressively introduced new services to connect customers to their network via high bandwidth (broadband) and low latency links [2].

Broadband is the common term for a high bandwidth internet connection. The current definition of broadband in India is 'always on' with the speed of more than 256 Kbps. By this yardstick, India has around 9 million broadband customers. In western countries like Finland the 1 Mbps is already available to 90% of the citizens and the government is planning to provide 100 mbps by 2013 to all its citizens. TRAI has recommended raising the definition of broadband to 2 Mbps in India. If we consider 2 mbps speed the total broadband connections will come down to 200,000 subscribers. The high cost of providing broadband connection through wire line, contributed to this slower growth. With the launch of 3G and BWA, the country is now poised to witness huge growth in broadband connections. 3G is promising 14 Mbps speed and BWA could deliver 100 Mbps. The main driver for the growth of broadband will be applications like watching online video, using IP based telephony services, and downloading music files.

From an economic perspective, the DSL family of technologies frequently offer the most attractive short-term to medium-term solution to the growing demand for bandwidth. They are cheap to deploy, and in areas of medium-to-high population density can reach most residential customers (essentially everyone living within a few kilometers of a telephone exchange, which covers a surprisingly large fraction of the population). According to the Australian Consumer and Competition Commission's September 2003 snapshot of broadband services in Australia, all Australian state and territory central business districts and metropolitan areas have ADSL available, as well as a majority of state and territory regional centers [3]. The same report indicates that at the time of publication, ADSL was the fastest-growing broadband technology in Australia with some 128,100 residential and business customers, and 23,200 customers (less than one-fifth) subscribing to other DSL services (primarily HDSL).

At the time of writing, the most widely deployed member of the DSL family is Asymmetric DSL (ADSL), which is commonly used in many parts of the world to provide broadband connections to residential customers and small businesses. This technology provides a much greater downstream capacity than upstream capacity - theoretically up to 8 Mb/s downstream and 640 kb/s upstream although in practice, most Australian service providers limit this to 256, 512, 1500 or 8000 kb/s downstream and 64, 128, 256 or 384 kb/s upstream. ADSL is appropriate for customers who wish to primarily consume content rather than provide it themselves. Users hosting and managing their own servers services may require a symmetric DSL solution such as HDSL, but at present this represents a minority of customers, primarily business users who would otherwise use ISDN or dedicated leased lines.

It is expected that as the network providers progressively replace copper networks with optical fibres, ADSL will be replaced by a higher-speed but shorter-range successor - Very-high-speed DSL (VDSL), which is also asymmetric but with proportionally faster data rates in both directions (up to

50 Mb/s downstream and 12 Mb/s upstream). Although ADSL has been standardized for some time [4], the standards for VDSL are not yet finalized (however one group of interested parties has published a proposed basis for a standard [5]). Ultimately this, too, will be superseded by fibre-to-the-home, which can provide customers with enormous bandwidth, with the added benefit of neither generating nor being susceptible to electromagnetic interference. This will eventually eliminate many of the reliability issues which currently affect broadband services, but due to the cost of the infrastructure upgrade, it is still many years into the future.

The effectiveness of DSL systems varies significantly depending on customer location. The data capacity of DSL systems decreases as distance from the exchange increases [4,6]. This inverse relationship is a result of the increase in high-frequency attenuation with increasing distance, and the degradation in Signal-to-Noise Ratio (SNR) with increasing distance (due to greater ingress of impulsive noise and crosstalk noise events)

## II MOTIVATION

CAP modulation is a multidimensional and multilevel modulation scheme proposed in mid 70s by Falconer et al. at Bell Labs [7]. CAP displays certain similarities to QAM in its ability to transmit two streams of data in parallel. In contrast to QAM, however, CAP does not rely on a carrier, but uses filters with orthogonal waveforms to separate the different data streams. This makes CAP receivers simpler than QAM receivers while achieving the same spectral efficiency and performance, a quality that made it very popular for digital subscriber lines (DSLs) during the 90s [8], [9]. As bandwidth demands raised and high speed electronics became more affordable, there were strong efforts put into exploiting the available bandwidth of deployed copper cables [10], but CAP was proven to be very sensitive to non-flat spectral channels, and required very complex equalizers [11], sacrificing the inherent simplicity of CAP. Therefore, in 1999 the international telecommunications union (ITU) deprecated it in favor of DMT [12]. By dividing the available bandwidth into many subchannels, DMT could increase total throughput and performance. Although the complexity of this scheme was still higher than in case of un-equalized CAP, the electronics needed to make it work at these bitrates were inexpensive, and DMT remains the most widely used modulation format in most asynchronous digital subscriber lines (ADSLs).

Lately, CAP has been investigated for short range optical data links [13]–[15]. One of its most attractive features for this scenario is the ability to use analog filters to generate the CAP signal, allowing for low power consumption and footprint. In addition, a practical implementation of wide-band analog filters with linear and orthogonal phase response is very challenging.

DMT could provide a solution in the same way it did for ADSL, but in this case, the electronics needed to operate at these high bitrates are still far from affordable [16], especially considering the growing high volume sales on active optical cables for data-centers [17]. We propose to use a multiband approach to CAP signalling (MultiCAP), where the CAP signal is divided into smaller subbands. Thereby, the advantages of CAP such as lower peak-to-average power ratio (PAPR) and simple implementation, can be combined with the advantages of DMT. Additionally, the CAP filters become easier to realize, sincethe frequency bands covered by each pair of filters are narrowed down. The viability of MultiCAP is investigated in this paper.

## III LINE CODING WITH CAP MODULATION

Figure 1 shows CAP modulation scheme. Here I and Q filters have $90^0$differences in phase. This system is called CA or Carrierless AM/PM.

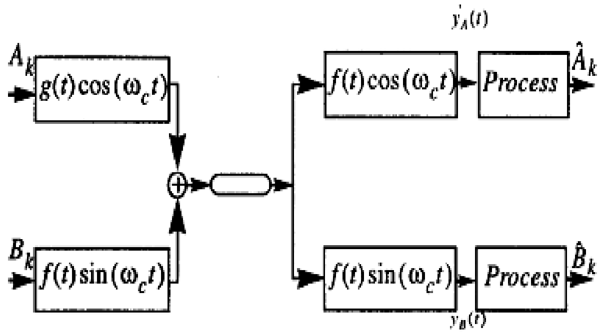


**Figure 1: CAP Modulation Scheme: Transmitter and Receiver**

It should be noted that this idea is practical whenever the carrier frequency is not very high, so we can reasonable filters. For example in the digital domain we approximate those filters by reasonable number of taps for low $f_c$, whereas it would not feasible for high values of $f_c$.

In the QAM modulation modulation-demodulation are linear and time variant system but in CAP both linear and time variant filters. So form the figure 1 we can write:

$$y_A(t) = y_I(t) + y_{IQ}(t) \quad [1]$$

OR

$$y_A(t) = \sum_k A_k h_I(t-kT) + \sum_k B_k h_{IQ}(t-kT) \quad [2]$$

And

$$h_I(t) = g(t)\cos(\omega_c t) \otimes f(t)\cos(\omega_c t) \quad [3]$$

$$h_{IQ}(t) = g(t)\cos(\omega_c t) \otimes f(t)\sin(\omega_c t) \quad [4]$$

Since we are interested in having zero interference at sampling time ($kT$), we look over $h_{IQ}(t)$ in more detail:

$$h_{IQ}(t) = \int_{-\infty}^{\infty} g(\tau)\cos(\omega_c \tau) \cdot f(t-\tau)\sin\omega_c(t-\tau)d\tau$$

$$h_{IQ}(t) = 0.5\sin(\omega_c t)\int_{-\infty}^{\infty} g(\tau) f(t-\tau)d\tau \quad [5,6]$$

$$+ 0.5\int_{-\infty}^{\infty} g(\tau) f(t-\tau)\sin\omega_c(t-2\tau)d\tau$$

The second term in (6) is negligible because it is similar to filtering a high-frequency signal (modulated *g(t)* around $2\omega_c$) by a low-pass filter *f(t)*. so we can write:

$$h_{IQ}(t) \cong \sin(\omega_c t)h(t) \quad [7]$$

In which:

$$h(t) = 0.5[g(t) \otimes f(t)] \quad [8]$$

Similarly it can seen that:

$$h_I(t) \cong \cos(\omega_c t) h(t) \quad [9]$$

Notice that in (7) $h_{IQ}(t)$ is zero at *t=0* which implies zero interference between corresponding symbols in I and Q paths. But we are interested in zero interference at other sampling times (i.e. $t = kT; (k \neq 0)$ . Once choice for this requirement is maintaining the Nyquist Property for *h(t)* which is the same condition as zero ISI in an equivalent PAM system. However. It should be noticed that this property here is more crucial because of its effect on interference between I and Q paths, whereas in PAM systems. Adaptive equalizer and maximum likely-hood detectors can correct for ISI.

The second choice is

$$\sin(\omega_c kT) = 0 \quad ; k = \text{integer} \quad [10]$$

$$2\frac{f_c}{F_s} = \text{integer} \quad [11]$$

In which $F_s = \frac{1}{T}$ is the baud-rate.

## IV SIMULATION & RESULT

Figure 2 shows the transmitter system for VDSL Modem, designed in the MATLAB environment. Here we use communication toolbox for the simulation of the system. The basic blocks used in the Simulink model is

- Random Integer Generator
- Rectangular QAM
- Impulse generator
- IIR Filter

Figure 3 shows the receiver system based on CAP modulation technique. The receiver is the reverse process of the transmitter. The major block for the simulink model is

- Matched Filter
- Rectangular Demodulator Base Band

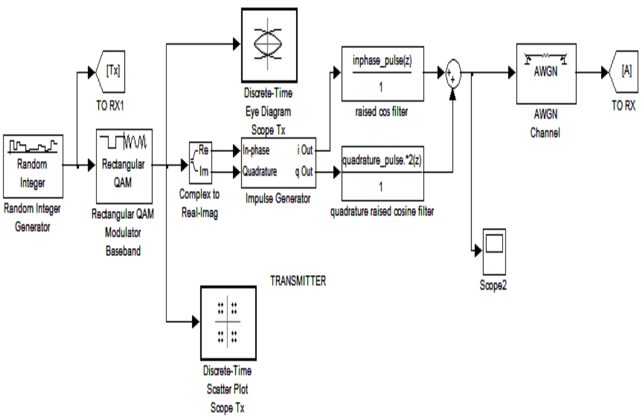

Figure 2 Simulink Model of Transmitter.

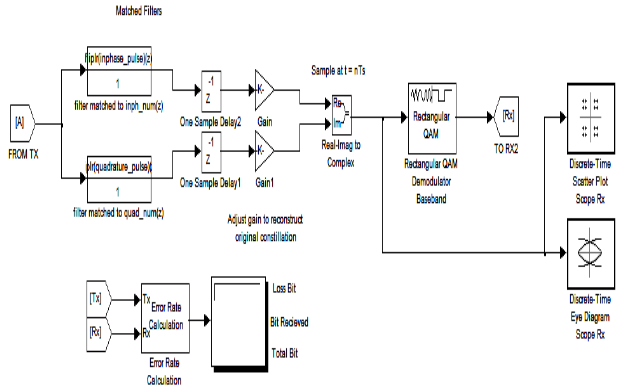

**Figure 3: Simulink model of Receiver system.**

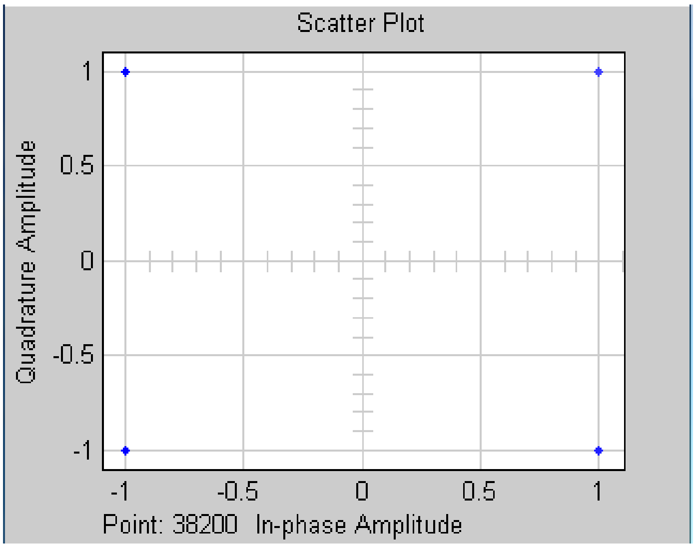


**Figure 4: Scatter Plot of 4QAM based CAP modulated signal for Receiver.**

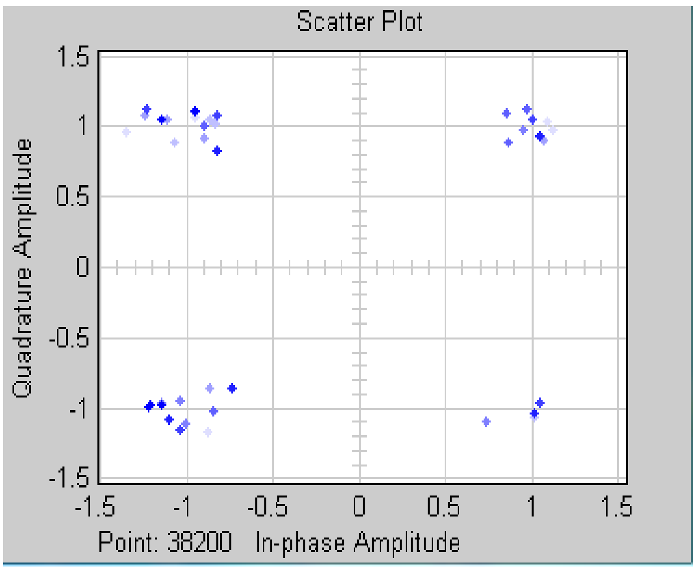


**Figure 5: Scatter Plot of 4QAM based CAP modulated signal for Receiver.**

Figure 4 & figure 5 shows the scatter plot of the transmission plot of 4 QAM of the CAP modulated DSL.

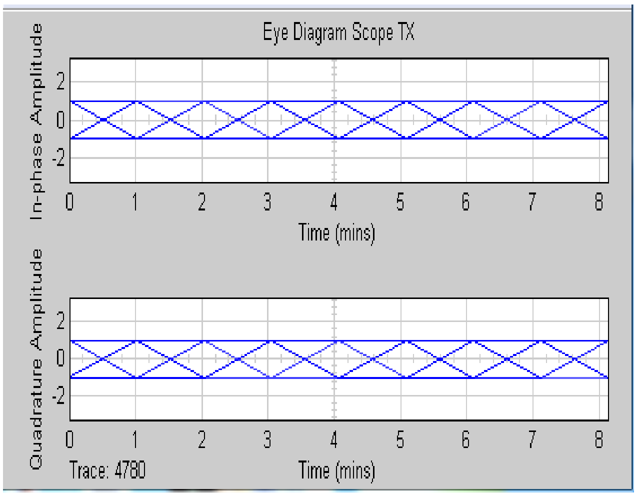


**Figure 6: Eye Diagram of 4QAM based CAP modulated signal for Transmitter.**

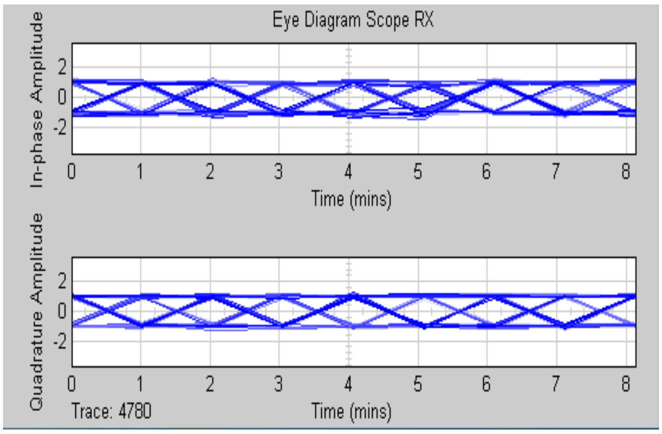


**Figure 7: Eye Diagram of 4QAM based CAP modulated signal for Receiver.**

Figure 6 & 7 shows the eye diagram of the transmitted and received signal of 4 QAM. Eye diagram shows the error free transmission.

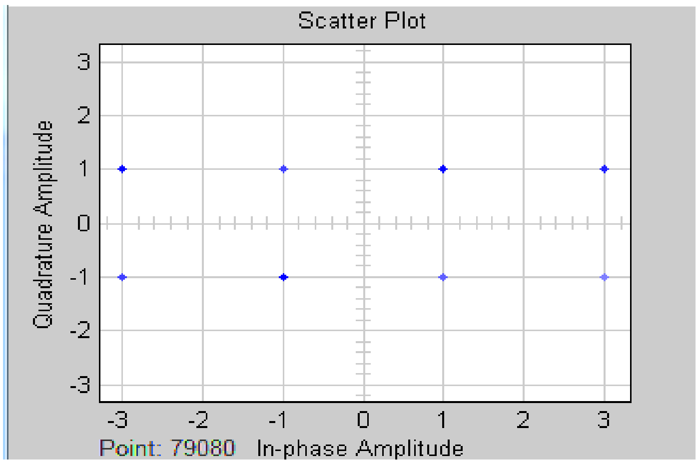


**Figure 8: Scatter Plot of 8QAM based CAP modulated signal for Transmitter.**

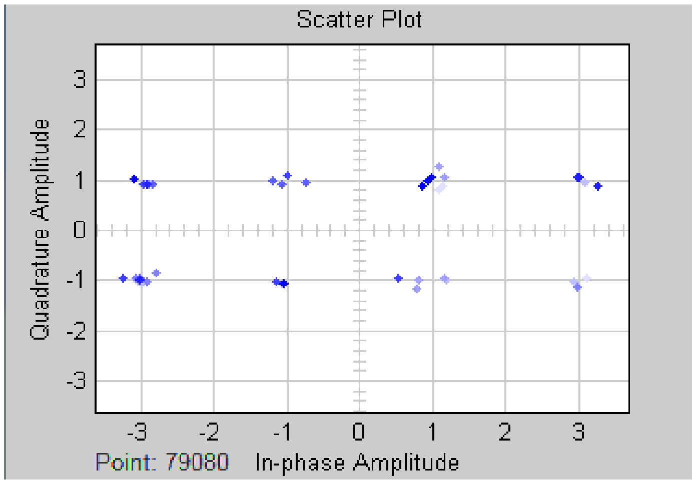


**Figure 9: Scatter Plot of 8QAM based CAP modulated signal for Receiver.**

Figure 8 & figure 9 shows the scatter plot of the transmission plot of 8 QAM of the CAP modulated DSL.

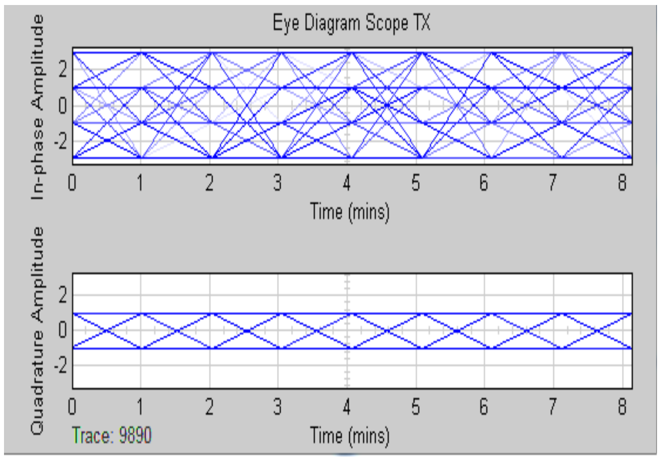


**Figure 10: Eye Diagram of 8QAM based CAP modulated signal for Transmitter.**

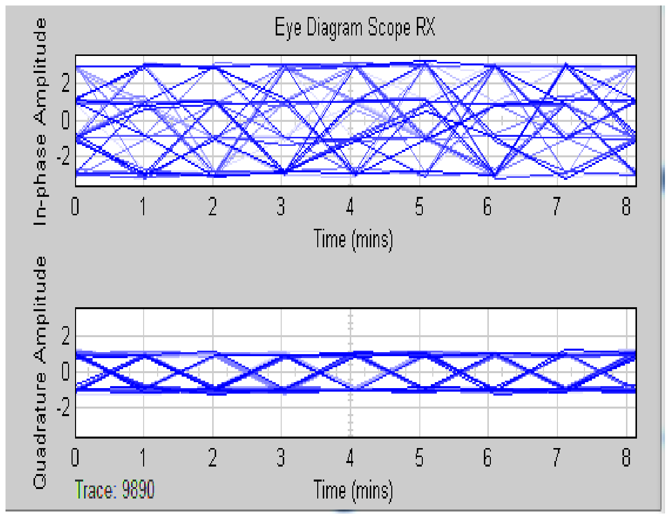


**Figure 11: Eye Diagram of 8QAM based CAP modulated signal for Receiver.**

Figure 10 & 11 shows the eye diagram of the transmitted and received signal of 8 QAM. Eye diagram shows the error free transmission.

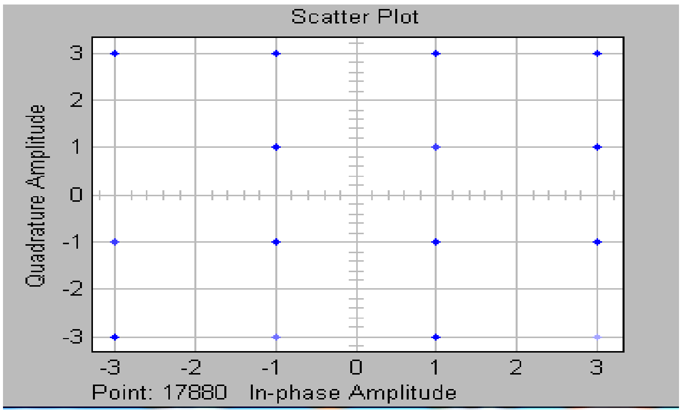


**Figure 12: Scatter Plot of 16QAM based CAP modulated signal for Transmitter.**

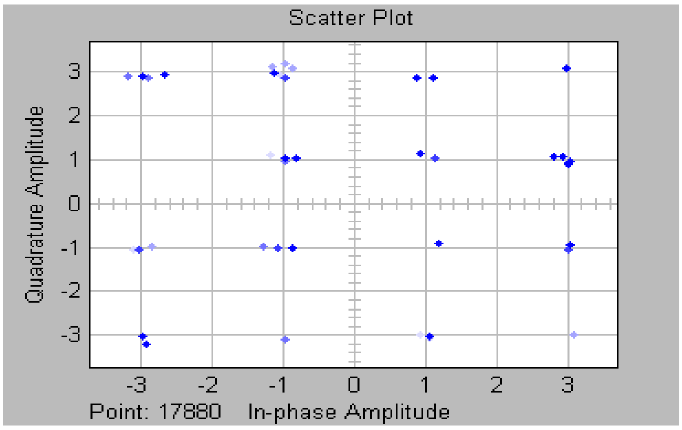


**Figure 13: Scatter Plot of 16QAM based CAP modulated signal for Receiver.**

Figure 12 & figure 13 shows the scatter plot of the transmission plot of 16 QAM of the CAP modulated DSL.

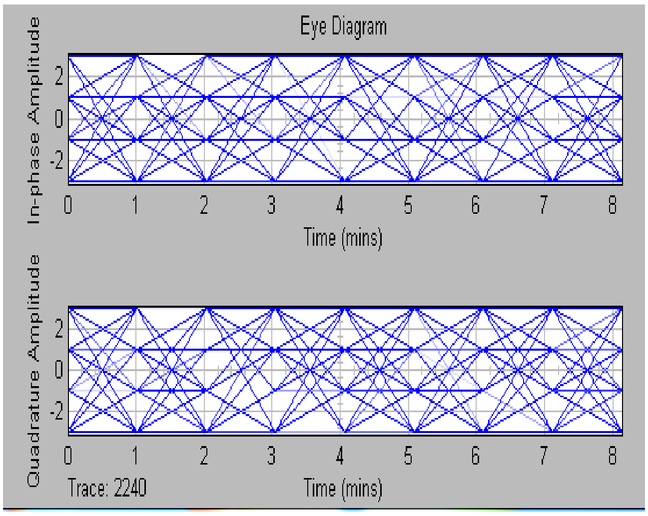


**Figure 14: Eye Diagram of 16QAM based CAP modulated signal for Transmitter.**

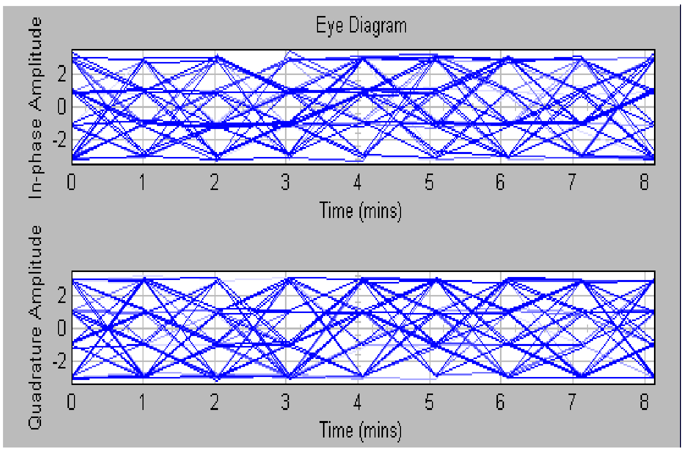


**Figure 15: Eye Diagram of 16QAM based CAP modulated signal for Receiver.**

Figure 14 & 15 shows the eye diagram of the transmitted and received signal of 16 QAM. Eye diagram shows the error free transmission.

**Table :I Summary of Results of Simulation**

| | Type of Modulation | | |
|---|---|---|---|
| | QAM-4 | QAM-8 | QAM-16 |
| Transmitted Bits (kbps) | 4161 | 4161 | 4161 |
| Received Bits (kbps) | 3057 | 3639 | 3897 |
| Upstream Data Rate (Mbps) | 3.05 | 3.63 | 3.89 |
| BER | 0.73 | 0.87 | 0.93 |
| Line Coding Technique | CAP | | |

Table: I show the summary of the results of simulation. Here, the BER for 4 QAM, 8QAM and 16QAM are 0.73, 0.87 and 0.93 and the upstream data rate of 16 QAM is 3.86 Mbps.

## V Conclusion

This high speed data transmission is very necessary in the current scenario. The whole data transmission system operates on the modulation techniques. A new approach of CAP modulated line coding scheme developed for high speed data transmission is discussed in this paper. The whole model is developed in the MATLAB software for verification of the system.

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