MiMOMax Wireless Ltd

About that MiMOMax Data Rate!

Background

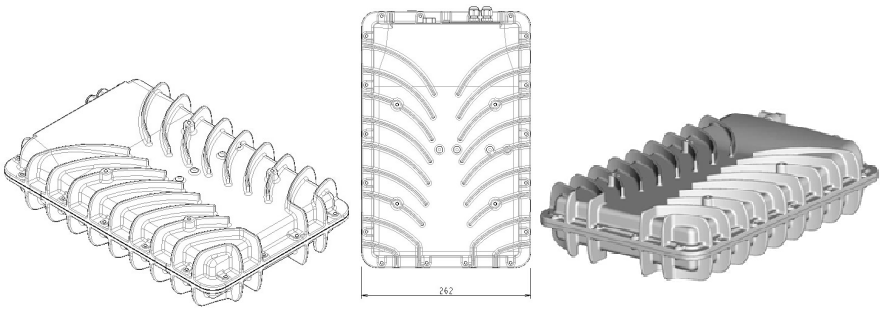
As a core point of distinction, MiMOMax Wireless has the ability to deliver a high data rate, ultra high spectrally efficient, low latency linking solution in narrow bandwidths. In short, MiMOMax linking products offer reliable broadband linking solutions in narrow band radio channels.

Customers occasionally ask for explanations of how MiMOMax equipment achieves such high maximum data rates and spectral efficiencies. The exact implementation is outside the scope of this paper and is best explained in detail during a MiMOMax training programme. However, this brief paper seeks to explain how the MiMOMax Team arrive at calculating system data rates and how these are derived for the various modulation schemes and bandwidth options available.

One main aim of this paper is to show that Raw Data Rate alone should not be used to determine suitability for a particular application. Hence, various types of system data rates are also introduced, to illustrate why the Raw (or Gross) Data Rate alone cannot be used to predict system performance.

It is of crucial importance to understand an application's data transport requirements in relation to how the MiMOMax link transports and manages data over-the-air. Understanding the data management of MiMOMax radios enables prospective customers to recognise how a MiMOMax solution will perform their application.

What follows, is an outline of the calculation of the various MiMOMax data rates and information regarding the MiMOMax Data Acceleration Protocols (M-DAP) options.



Summary

It is important to understand the data transport requirements of an application and how the MiMOMax radio can be integrated within the application, in order to maximise the performance of the final solution.

MiMOMax recognises at least four different types of data specifications for determining the data rates and capacity of a linking solution. All of which need to be considered when specifying a linking solution.

i) Raw (or Gross) Data Rate;

This is the total over-the-air system data rate, including all forward error correction, system management and maintenance data. It is a function of the symbol rate and the modulation scheme used.

ii) Net Data Rate;

This is the over the air data rate as specified in the MiMOMax data sheets. It is less than the Raw Data Rate as it excludes all of the overhead data defined above. The Net Data Rate specifies the minimum that can be expected, however, the typical measured data rate will generally be significantly higher.

iii) Effective Data Rate

The Effective Data Rate is the measured over-the-air rate, which can be achieved by using one or more of the MiMOMax M-DAP options. The Effective Data Rate can be greater than the Raw or Net Data Rate by a factor of several times depending on data types.

iv) Virtual Data Rate

This is a notionally “equivalent” data rate that can be achieved when compared to other systems that do not have the capability to manage the over-the-air data, in a spectrally efficient manner. It provides a notional performance equivalency.

The MiMOMax product family, because of its progressive data management, has demonstrated it is an effective narrow band linking solution, which significantly outperforms wideband linking solutions when servicing the same application. In determining the best fit, it is important that the characteristics of the data requirements are well understood and that Net Data Rate alone is recognised as not the best, and certainly not the only, determinant of performance for the total system.

Understanding the Various Data Rates on MiMOMax Systems

Gross Data Rate

The MiMOMax Radio Unit is a software flexible digital radio platform, capable of transmitting Raw (or Gross) Data Rates of up to 320kb/s, using 20k symbols per second. This provides an industry leading raw spectral efficiency of up to 16b/s/hz (when running in its highest modulation mode). In order to meet the various international radio compliance requirements, these radios are run in 25kHz or 12.5kHz channels, the latter (12.5kHz) option providing up to 160kb/s Gross Data Rate.

For the 25kHz implementation, this Gross Data Rate is derived by running the system at 20k symbols per second and then applying high order modulations to the data stream.

For example the gross bit rate is calculated as follows:

20k symbols per second

Modulation Scheme	Bits per Symbol	Data Rate Kilo Bits / Second	Multiply by 2 for MiMO Implementation
QPSK (4QAM)	2	40	80
16QAM	4	80	160
64QAM	6	120	240
256QAM	8	160	320

The highest modulation rate provides 8 x 20k symbols per second, which equals 160kb/s. This is then doubled again via the MiMO solution, to provide a radio linking Raw Data Rate of 320kb/s when using the 256QAM (Nitro) option. Please note that all MiMOMax data rates are full duplex and fully symmetrical.

At this point it is often pointed out that, while the theory may support this, the practical implementation of such high symbol rates in narrow bandwidths is not practically possible. Contrary to such opinions, this is exactly what MiMOMax radios do. Once more, the technical design is outside the scope of this paper but to summarise, MiMOMax products achieve this by implementing true MiMO, using very high levels of digital signal processing, dual ultra linear digital Cartesian loop transmitters, and dual high performance receiver line ups. This allows for transmission, receiving and recovery of separate data on each transmitter/receiver pair while only occupying a single radio RF channel.

Notably, while MiMOMax radios successfully and reliably achieve very high modulation rates, supplementing them with MiMO is the most efficient way possible to get these high levels of spectral efficiency. An extrapolation of the modulation schemes and possible data rates shows that it is not possible to approach the efficiency of the true MiMO implementation by further increasing modulation rates alone.

In 12.5kHz the symbol rate is halved as outlined below.

10k symbols per second

Modulation Scheme	Bits per Symbol	Data Rate Kilo Bits / Second	Times 2 for MiMO Implementation
QPSK (4QAM)	2	20	40
16QAM	4	40	80
64QAM	6	60	120
256QAM	8	80	160

This defines the Raw (or Gross) Data Rates available in the various configurations and modulation schemes (Raw Data = Gross Data).

Net Data Rates

The MiMOMax data sheets (located via: http://mimomax.com/network-digital-link-ndl/), quote the "Net data rates" for the various modulation schemes.

The difference between the Raw and the Net Data is the link overhead data, which is only accounted for within the Raw Data Rate. The overhead data is made up of;

- Forward error correction coding, to improve overall system performance
- Control data running over the link, to maintain control and synchronisation of the link
- Management and reporting data running over the link for diagnostics and maintenance purposes

The Net Data Rate equals the Raw (or Gross) Data Rate, less this link overhead data.

When quoting the performance of MiMOMax products, the MiMOMax team adopt a conservative perspective. While the data sheets quote the Net Data Rates, it is important to note that typically these are conservative numbers, and that "typical Net data rates" may at times be significantly higher (an example is outlined in the table below).

Typical Net Data Rates (25kHz System)

Modulation Scheme	Raw Data Rate Kilo Bits / Second	Net Data Rate Specified	Actual Typical Net Data Rate
QPSK (4QAM)	80	64	66
16QAM	160	128	132
64QAM	240	210	216
256QAM	320	256	264

As can be seen, the difference between the Net Data Rate and the typical Net Data Rates are significant. These figures are presented as an explanation, due to many users reporting that MiMOMax's commercially specified data rate numbers are too conservative. However, using the specified Net Data Rates ensures more robust implementations, although it is still useful to understand the MiMOMax link's actual typical net capacity.

Effective Data Rate

MiMOMax offer a number of options that significantly accelerate the effective data performance of MiMOMax links. These offerings are bundled under the headings of M-DAP (MiMOMax Data Acceleration Protocols, as mentioned above) and M-CAM (MiMOMax Cognizant Adaptive Modulation), which work to maintain high levels of modulation and increase the data throughput.

The question is often raised with respect to the speed of the MiMOMax link or the "effective maximum data rate" with all the data enhancement options turned "on". This is not a simple question as it can be dependent on many factors. It is an "it depends" question. The effective maximum data rate achievable with M-DAP is dependent on identifying the data type and the improvements that can be made to transport the data over the links. As an example, rate improvement can be up to a 1000%, depending on the type and characteristics of the data to be transported over the link.

As a rule of thumb and again dependant on the type of data, typically an improvement of approximately two times can be expected by engaging the M-DAP option on the IP interface. This has the potential to bump the "effective" spectral efficiency up to 32b/s/Hz. It should be also noted that engaging this option will not significantly increase the system latency.

25kHz System Typical Effective Data Rates (M-DAP Activated)

Modulation Scheme	Raw Data Rate Kilo Bits / Second	Net Data Rate Specified	Actual Typical Effective Data Rate
QPSK (4QAM)	80	64	128
16QAM	160	128	256
64QAM	240	210	420
256QAM	320	256	512

The Effective Data Rate is the data rate that can be measured as being transported across the link. It is important to note that the Effective Data Rate can be significantly higher than the Net Data Rates and potentially the Raw data rates, which is specified in the data sheets. Those applications[1] that can benefit from this feature should consider using the M-DAP feature.

Virtual Data Rate

In addition to the M-DAP, MiMOMax radios also use unique data traffic management techniques that have the potential to further improve a systems' ability to handle large amounts of peak data. Although this will not increase the "measured" data rate through the system, it provides a notional indicative number as a comparison to a system that does not efficiently manage the data streams over-the-air.

Typically the Virtual Data Rate increase is again, up to two times over the Effective Data Rate. Additionally, this is again an "it depends" number. However, practical experience has shown that the MiMOMax linking equipment, with all the data enhancement options enabled, and in the right circumstances, is capable of demonstrating superior "over the air" data performance in comparison to competitive wideband equipment, which uses up to 20 times the bandwidth of the MiMOMax narrowband radio[2].

The MiMOMax Team strongly believe spectrum is the most important and valuable resource in wireless communications, and therefore, will always work to bring maximum utility to the available spectrum. For this reason it is important to understand the nature of the data, and to match the linking solution with the application, in order to preserve spectrum and provide the most effective solution. Net Data Rate should not be the only consideration in determining the best linking solution.

[1] (as an example when transporting P25 data streams for linking digital radio sites together M-DAP will typically provide a 2 x improvement in the link data capability)

[2] (In controlled tests MiMOMax has measured and demonstrated superior performance in MiMOMax 12.5kHz Radio Units to other systems requiring up to 250kHz of spectrum)