Variable Modem Technology Provides Dramatic Solutions For Point-to-Point Microwave Market

by Radyne ComStream, Inc.

Today's digital communication is a quagmire of standards, styles and methods. Simple communication between two points can involve copper, fiber, cable, microwave, and satellite. In this environment, there is one thing that is always certain —and that is uncertainty itself. Cell phones, videos and the Internet have created an insatiable demand for bandwidth that has launched a goldrush mentality of sorts for new services, and with it a risk to the system designer that a system, planned today, may not make a return on investment before it is obsolete. Will the market change its mind and with it its requirements? Will one standard fall in favor of another? Will the equipment needed tomorrow be incompatible with the system being planned today?

In the early eighties, satellite modem technology took a major turn. System designers demanded that satellite modems contain as many features in one box as possible. This included demands to get away from fixed rate designs and go to variable data rate and code rate designs. The arrival of new technology like Field Programmable Gate Arrays (FPGAs), Direct Digital Synthesizers (DDSs) and digital filters allowed Radyne ComStream to meet the demands of the industry by designing what is now a prestigious line of variable rate modems.

Simply put, if you have the Microwave bandwidth, the MM200 can make money from it.

The point-to-point microwave market is primed to undergo the same revolution. A massive amount of fixed-rate equipment installed throughout the world is starting to feel the strains of inflexibility. One only has to look at the popularity of the new interface standards to see that the digital world is no longer a hierarchy of fixed-rate standards. MPEG encoded data changes data rate to suit its application. The DVB ASI and SPI interfaces, now emerging as standard interfaces, can handle any data rate over an extremely wide range of 0 to 216 Mbps. Couple these new data streams to a world of different regulations and licenses for microwave links and the need to change both data interface and radio interface becomes not just a desire but a necessity.

The MM200 Microwave Modem from Radyne ComStream is ready for these challenges. Taking a new approach to system design, the MM200 allows for solutions unavailable with other equipment. This approach allows the system designer to see their link as a variable commodity rather than just a fixed extension of a fixed data path. Microwave bandwidth becomes an essential ingredient defining what services can be added to the link.

Radyne ComStream has implemented a unique approach to increasing data rate while maintaining performance and variability. Using a technique that is well established as an excellent method of overcoming the multipath nature of microwave links, the MM200 transmits and receives multiple carriers. Multiple carriers allow the data transmitted to be comprised of multiple low rate paths instead of one high rate path. Refer to **Figure 1** for a functional block diagram of the MM200.

Reflections, or Multipath, commonly the primary limitation of a microwave link, cause the receiver to receive not just the line-of-site signal, but reflections from mountains, bodies of water and other objects. These reflections are delayed from the line-of-site signal because of their longer route from transmitter to receiver. If this delay is long enough compared to the period it takes to transmit one bit (symbol) the reflection(s) can cancel out most or all of the transmitted information. Since the bit period is easier to change than moving mountains or draining bodies of water, the MM200 divides the transmitted data into four paths, each having a symbol period four times longer than a conventional modem running at the same symbol rate. Critical to performance under multipath conditions, each demodulator has a 20-tap (8 FFE and 12 DFE) adaptive decision feedback equalizer. These powerful equalizers greatly reduce many of the degradations caused by the radio and the microwave path.

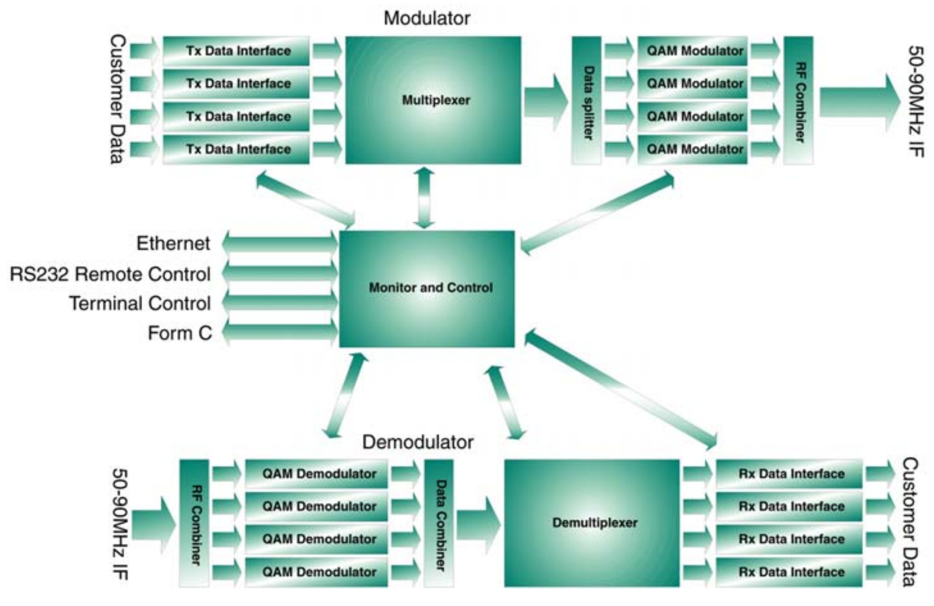

Figure 1. MM200 Functional Block Diagram

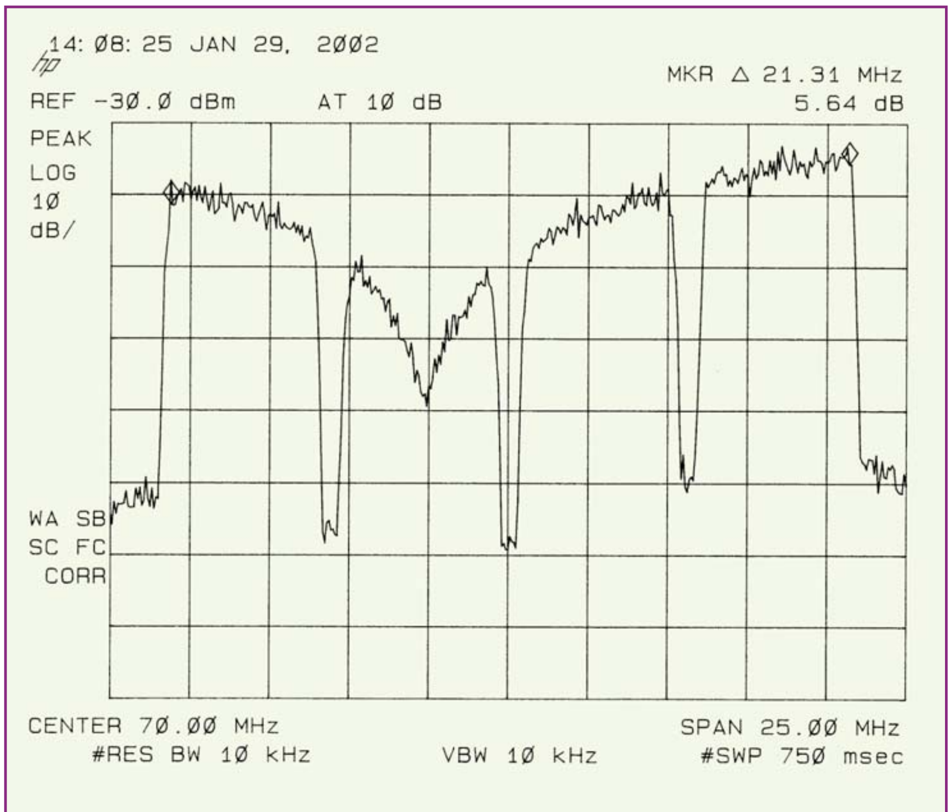

Figure 2. MM200 Signal Degradation

Utilizing their ability to automatically compensate for a distorted signal, the equalizers allow much greater distances to be spanned. With the possibility of greater distance between sites, yet another parameter becomes flexible to the system designer. A good example of the level of distortion that can be tolerated by the modem is shown in **Figure 2**. The modem was passing 100 Mbps of data without error under these harsh conditions. A measurement of the modem's Dispersive Fade Margin (DFM) performance at different symbol rates is shown in **Figure 3.**

For noise reduction, each demodulator has its own Reed-Solomon Forward Error Correction (FEC) (204,188 T=8). This form of FEC is ideal for microwave links with great power to remove errors without adding too much overhead to the bandwidth used. The performance of the modem when degraded by noise is shown in **Figure 4**. This graph shows measured Bit Error Rate (BER) versus C/N (carrier over noise) for all the modulation modes.

The typical output spectrum shown in **Figure 5** is from a modem running at the maximum 200 Mbps at 256 QAM. The almost ideal spectral filtering allows very close channel spacing keeping bandwidths only marginally wider than single carrier modems. In addition, the steep skirts fit any mask requirements with ease.

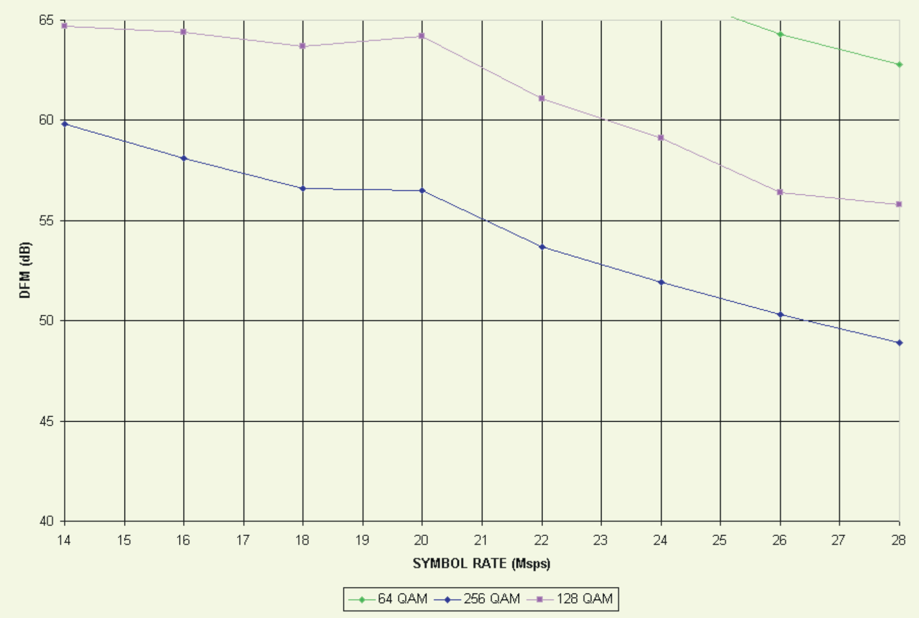

Figure 3. MM200 Dispersive Fade Margin

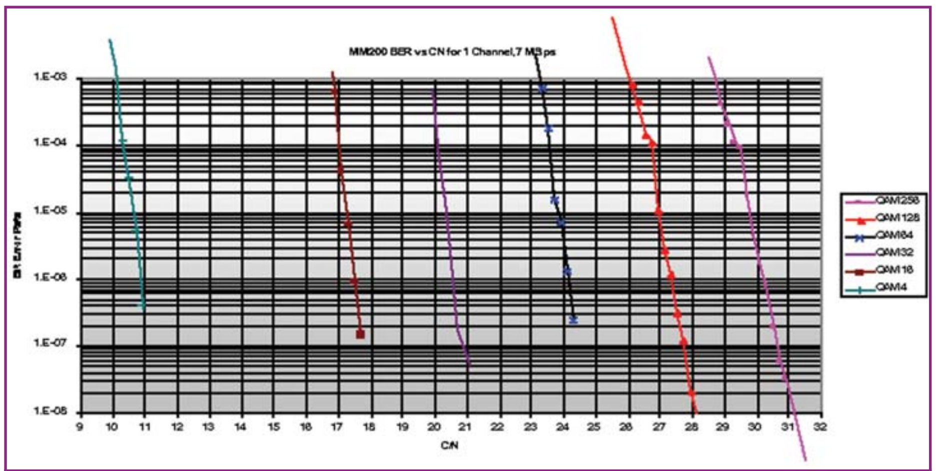

Figure 4. MM200 Bit Error Rate

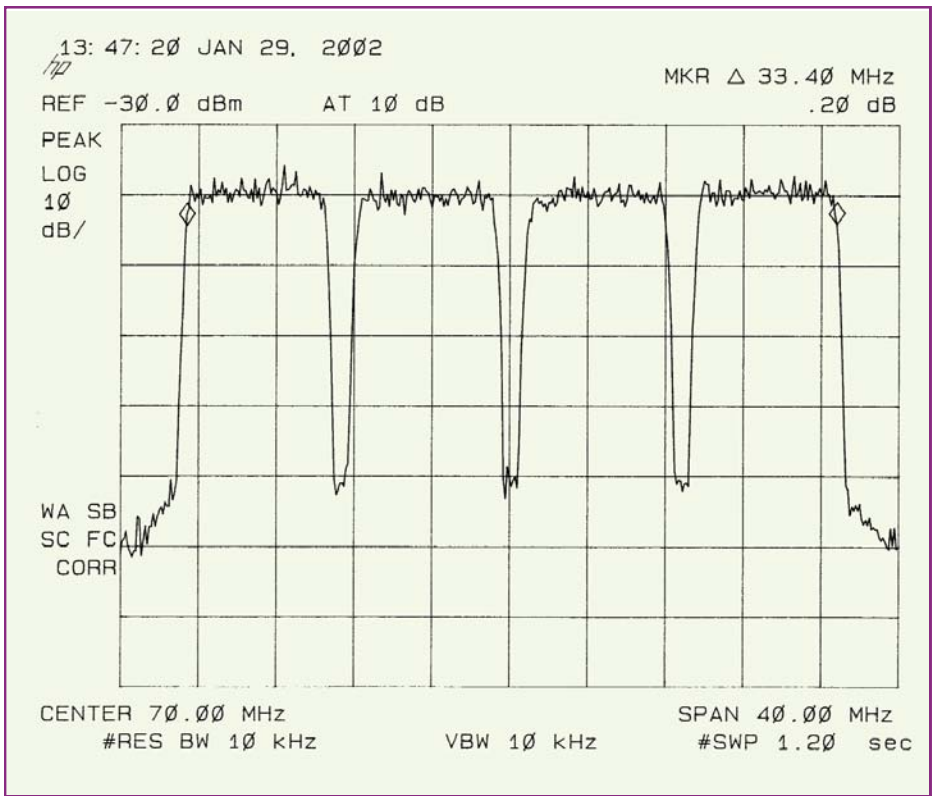

Figure 5. MM200 Typical Output Spectrum

All these features are wrapped around a completely variable architecture. Both modulators and demodulators can be set to 4, 16, 32, 64, 128 or 256 QAM with just the touch of a button. Symbol rates, data rates and frequencies can all be set in 1 Hz increments without any other user intervention.

To ensure a customer can tap into all this flexibility, Radyne ComStream has developed a data interface that is as flexible and variable as the modem. A variable rate bit stuffing multiplexer allows a multitude of interface standards to be combined into the chassis. Four interface slots can be populated with any combination of the twelve standard interface types shown in **Table 1**. Rates up to 200 Mbps can be achieved with the appropriate radio links. Unusual configurations like 10BaseT, DS3, ASI and Overhead are possible along with the more usual 3 X DS3 and Wayside. Of course, reducing the number of interfaces and lowering the number of channels can also cover lower rate applications.

Interface name	Interface Standards	Data Rate
Overhead	8 x 64kbps RS/422	512kbps
	7 x 64 kbps RS422 + 1 Audio Channel	512kbps
Wayside	T1 Balanced	1.544Mbps
	E1 Balanced	2.048Mbps
	E1 Unbalanced	2.048Mbps
SMPTE	SMPTE 310	19.392Mbps
G.703	E3	34.368Mbps
	DS3	45.736Mbps
	STS-1	51.84Mbps
OC3/STM-1	OC3 Optical	155.52Mbps
	STM-1 Electrical	155.52Mbps
DVB ASI	EN-50083-9 ASI-C	0 to 160Mbps
DVB SPI (LVDS)	EN-50083-9 SPI	0 to 200Mbps
DVB SPI (RS422)	EN-50083-9 SPI (modified to RS 422)	0-80 Mbps
10 Base T	IEEE 802.3 Ethernet v.2	0-10 Mbps

Table 1. MM200 Data Rates/Interfaces

Where multiple standards are listed interface can switch between standards via the MM200 Monitor and control.

A Powerful Monitor & Control (M&C) system keeps everything running and gives the user access to well over 100 monitor and alarm displays. Direct user interface can be from the front panel or a terminal/computer connected to the RS232 Terminal port. On the other hand, for remote M&C, the RS232/485 remote port or the 10BaseT Ethernet running SNMP can be used.

To appreciate the full impact a variable rate modem can have on a new or existing microwave link, it is important to understand the architecture and the implications on system performance when parameters are varied. As previously referenced, Figure 1 is a block diagram of a fully configured non-redundant MM200. The 2RU-rack mount unit can be supplied in many different configurations. The base chassis is available in Duplex or Simplex Configurations and world standard AC or DC prime power. In the back of the chassis are the four slots for optional data interface assemblies that form the connection between the modem and the customer's data equipment.

Inside the chassis, the modulator and demodulator cards are installed at the factory as options. With up to eight cards in total (four modulators and four demodulators), cost can be controlled when the application uses lower data rates. Each modulator or demodulator has a symbol rate of 3.5 to 7 MSps giving maximum rates of 7, 14, 21 or 28 MSps for 1, 2, 3 or 4 modulators/demodulators installed.

Following a data signal through a typical unprotected system, the customer data first arrives at the optioned interface card installed in the rear of the chassis. This card converts the industry standard interface to parallel data and clock. Internal to the modem, the next stage is a bit stuffing multiplexer whose output runs at a constant rate that is directly related to the symbol rate. Bits arriving at the interface card are buffered and taken by the bit stuffing multiplexer at the appropriate time. Because of this feature, the modem does not care about the speed of the incoming data providing the multiplexer output data (or symbol rate) is high enough so the interface buffers never overflow. Multiplexing overhead and Reed-Solomon FEC coding are also added giving a total overhead rate of 204/184. The difference between the bits sent by the customer and the bits modulated is taken up by stuffing bits that will be removed at the demodulator.

The multiplexer output data is then divided evenly into the number of IF channels that have been installed and activated. The number of IF channels has therefore no relationship to the number of interfaces. The modulators are programmed identically except for their output frequencies. The modulation modes can be set to 4, 16, 32, 64, 128 or 256 QAM. The M&C computer can set the frequencies automatically so carrier spacing is a percentage of the symbol rate, i.e. 120%. In this mode, the user simply enters the center frequency of the output spectrum. The 3 dB bandwidth of the total spectrum is displayed for convenience. A typical output spectrum is shown in Figure 5. An alternative mode allows the user to simply state the desired 3 dB bandwidth from which the computer will calculate the most efficient modulation settings. Complete manual settings are also available allowing any channel to be set to any frequency within the 50 to 90 MHz range. This can be especially useful if the MM200 is sharing the radio bandwidth with another service. Output power is adjustable in 1 dB increments.

The Demodulator side of the Modem is, for the most part, simply the reverse of the modulator side. After demodulation, Reed-Solomon error correction is applied and the R-S overhead bits removed. The corrected bits have the multiplexing overhead and stuffed bits removed during demultiplexing. The appropriate data is then channeled to the appropriate interface. The optional interfaces de-jitter the data and format it for the appropriate interface standard before it leaves the unit.

With many adjustments at hand, the system designer needs a key interest in the performance of the demodulators. The ideal solution can be designed based on a clear understanding of how each variable parameter has an effect on the overall system performance.

The Job of the Demodulator is to simply recover, without error, the data from the incoming IF signal. This IF signal has normally been degraded by the microwave path and to a lesser extent by the modulator and radio. To maximize the modem's ability to remove errors due to link performance, it is best to minimize equipment-caused effects. The desire to go to higher QAM modes, reaping the benefit of higher data rates or lower bandwidths can be tempered by the radio equipment.

Phase Noise and Microphonics

Phase noise and microphonics are important performance metrics when transmitting high order QAM signals. The best approach is to use 'Digital-Ready' radios, ensuring from the manufacturer that the equipment is capable of carrying the desired QAM signal. The performance on the radio link also limits how far up in the modulation scheme you can go. Flat fades and dispersive fades can, if deep enough, generate errors in the data path. Errors occur in the data path when the demodulator feeds the Reed-Solomon with so many errors that it basically gives up and passes out a block of uncorrected data. For the demodulator to get into such a poor state, the incoming signal must have enough distortion to put data bits so far away from their ideal demodulated vector position that a 1 pops out instead of a 0 or vice versa. As the modulation order gets higher, the distance between the ideal position and a neighboring vector gets smaller. This is obvious from observing the receive constellation and how the states or bit sequences are mapped. A 4 QAM signal is simply four dots in a square, each dot representing a two-bit sequence. For an error to occur, the received dot must be pushed far enough from the ideal so that it is seen as being one of the other three states.

Now take the same square and evenly fill it with 256 dots. This is 256 QAM, with each state representing a unique 8-bit sequence (2 to 8 bits, that's the data rate improvement). Now the distance between states is very small. This important point is why higher order modulations must be designed into the system before they can operate properly.

Redundancy is handled in a number of ways by a family of products associated with the MM200. Where dispersive fading restricts the length of the path, the MM200 diversity receiver can be used to reduce the number of errors and meet the reliability criteria of the link. The diversity receiver provides some equipment redundancy but mostly path redundancy. Another way to view the diversity receiver is as a way to increase QAM modes on a link to a level higher than the original design. The added diversity path overcomes the loss of DFM performance caused by the higher modulation mode.

Equipment redundancy is achieved through 1:1 or M:N (up to 2:8) hot standby configurations using Radyne ComStream's line of protection switches.

Now, to pick that optimum operating point.

Figure 6 is a graphical representation of the relationship between symbol rate and the data rate. Calculate the user data rate by adding all the rates of all the interfaces that will be used.

Now find the symbol rate(s) and channel combinations by moving across the graph horizontally at the user data rate; everywhere you cross a line there is a symbol rate and channel number solution. Move down vertically from the line to see the total symbol rate and the number of channels.

Knowing the number of channels and the total symbol rate, performance data can be reviewed for the best operation. **Figure 7** shows the normal bandwidth the modem will occupy.

The MM200 brings a new way of thinking to the Microwave point-to-point market and with it many new solutions to new problems. As a replacement for existing modems or new installations, the MM200 will provide the ability to change and grow with these uncertain times.

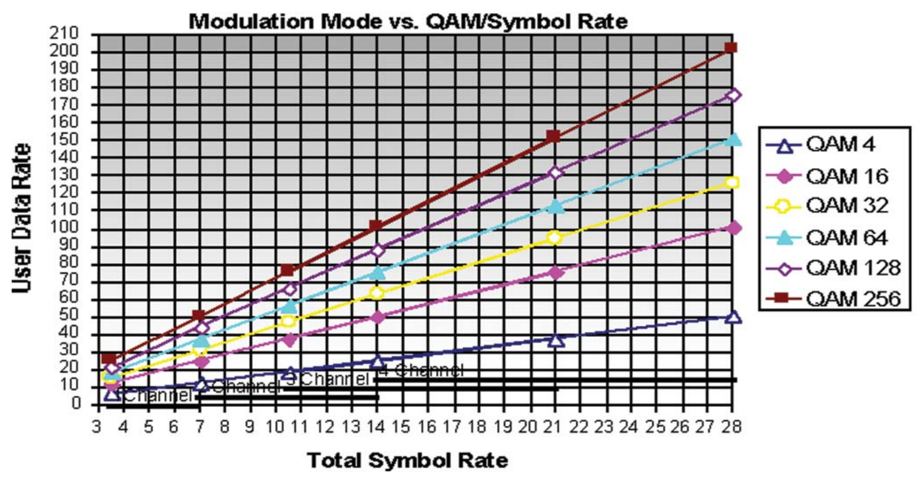

Figure 6. MM200 Modulation Mode vs. QAM/Symbol Rate

Example:
A user has an ASI interface running at 25 Mbps, an E3 and SPI running at 40 Mbps, and an overhead channel. That's 25+34.368+40+0.512 = 99.88 Mbps or approximately 100 Mbps.

Solutions are:
QAM 256—13.9 MSps 2 or 3 channels
QAM 128—15.9 MSps 3 or 4 channels
QAM 64—18.5 MSps 3 or 4 channels
QAM 32—22.2 MSps 4 channels only
QAM 16—27.7 MSps 4 channels only
QAM 4—No solution

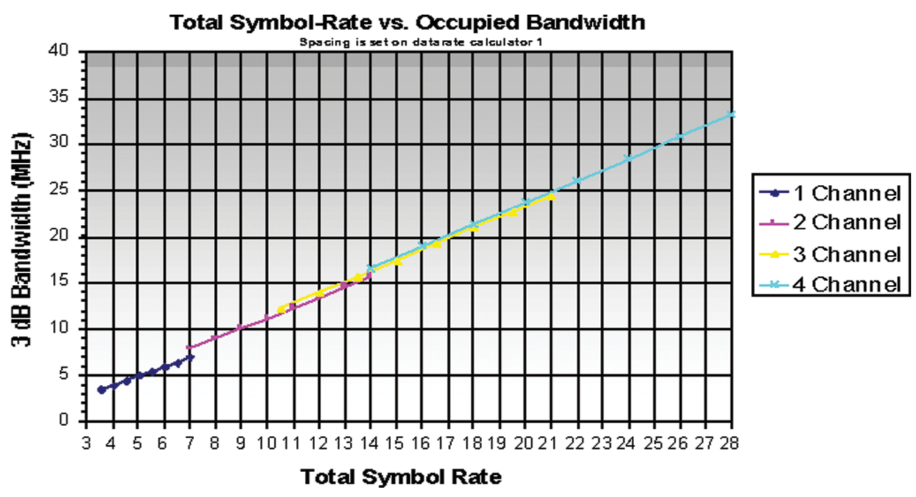

Figure 7. MM200 Total Symbol Rate vs. Occupied Bandwidth

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