COFDM versus QAM and VSB in ENG/ HD-ENG

The Real Deal on Single Carrier Solutions

The discussion of COFDM versus VSB is not new to TV broadcasters in the US or in Europe. The choice of 8VSB as the digital standard in the United States was a hotly debated topic at the start of the DTV build-out, particularly after the Europeans demonstrated COFDM. The debate was centered on the fact that DVB-T's COFDM transmission system performs substantially better in mobile applications, which some broadcast groups saw as a potential new revenue opportunity. In spite of the evidence, US broadcasters re-affirmed their choice of VSB, and the discussion appeared to be behind us. Some microwave vendors also chose VSB as an alternate to COFDM for high data rates, as required for airborne or stationary HD-ENG.

While some consider VSB as being viable for mobile applications, standards based single carrier digital microwave modulation formats have proven to be as robust, and easier to implement. At MRC, our engineers evaluated numerous methods of modulation for ENG, and chose to implement COFDM for its superior performance in a multipath environment. During the evaluation process, we documented the advantages and disadvantages of other digital transmission methods, and feel that our customers can benefit from this knowledge. In this discussion, we give you the "Real Deal" on modulation formats for ENG.

COFDM and VSB are very different

In light of the original discussions relative to COFDM and VSB, there is still a tendency among broadcast engineers to view the two as competitive forms of modulation for ENG, which is not at all the case.

The ETSI DVB-T standards for mobile operation were chosen specifically to avoid multipath fading and Doppler effects while operating from a moving platform. The 2K-carrier mode transmits 1705 individual carriers, in contrast to normal DVB-T, which uses the 8K-carrier mode, where 6817 carriers are transmitted. Both modes benefit greatly from the inherent multipath advantages that COFDM provides; if a few carriers are lost to multipath, the lost data can be easily recovered by error coding. In most cases, the implementation of COFDM in ENG follows the ETSI standards, however some systems use a proprietary non-standard implementation.

VSB is a single carrier transmission system, with no provisions for mobile operation, and no meaningful way to compare it to COFDM in a severe multipath environment. The typical ENG microwave implementation of VSB is 2VSB, which can support only 25% of the data capacity that 8VSB can support. This reduction in data rate capability is required to increase the robustness of VSB, which is still more susceptible to multipath than COFDM, even at the 2VSB level.

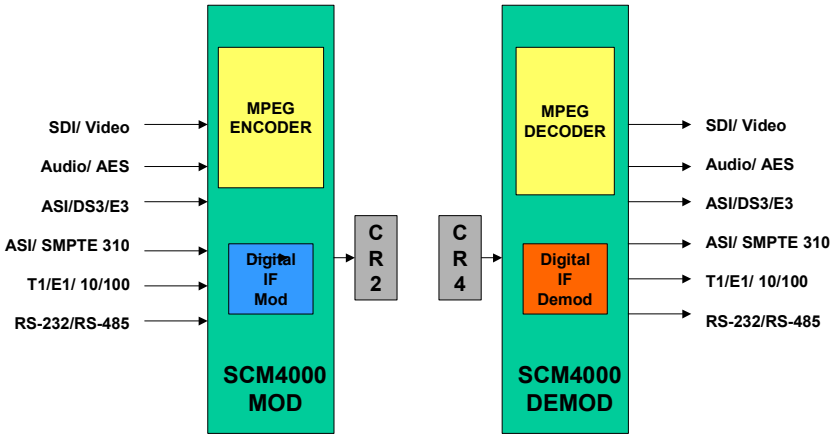
QPSK and QAM

A more appropriate comparison can be made however, between VSB and QPSK or QAM modulation, which are single carrier modulation schemes designed for microwave applications. QPSK and QAM are used routinely to modulate multicarrier systems, like COFDM, but are highly developed, stand-alone transmission formats for single carrier systems. Point to point digital microwave systems have favored QAM modulation for many years to transport up to 310 Mbps on a single carrier. The composite fading and multipath countermeasures in these radios have been highly developed, with extremely robust dispersive fade margins made possible by the use of multi-tap adaptive IF equalizers developed specifically for reflective microwave paths.

In the case of ENG microwave, COFDM is well documented as the best format where reflections are expected, or where the transmitter may be in motion. The trade-off is in total data capacity, which is limited by the need for heavy error correction.

For ENG and remote pick-up applications that are not plagued by severe reflections, a traditional single carrier system provides much greater throughput, while maintaining the high dispersive fade margin found in point to point digital paths. The MRC SCM-4000 single carrier high-speed modem was developed to addresses this need for broadcast ENG and fixed link applications.

The SCM-4000 supports QPSK, 16QAM, 32QAM, and 64QAM modulation, with data rates up to 65 Mbps in a 12 MHz channel, and up to 110 Mbps in a 25 MHz channel.



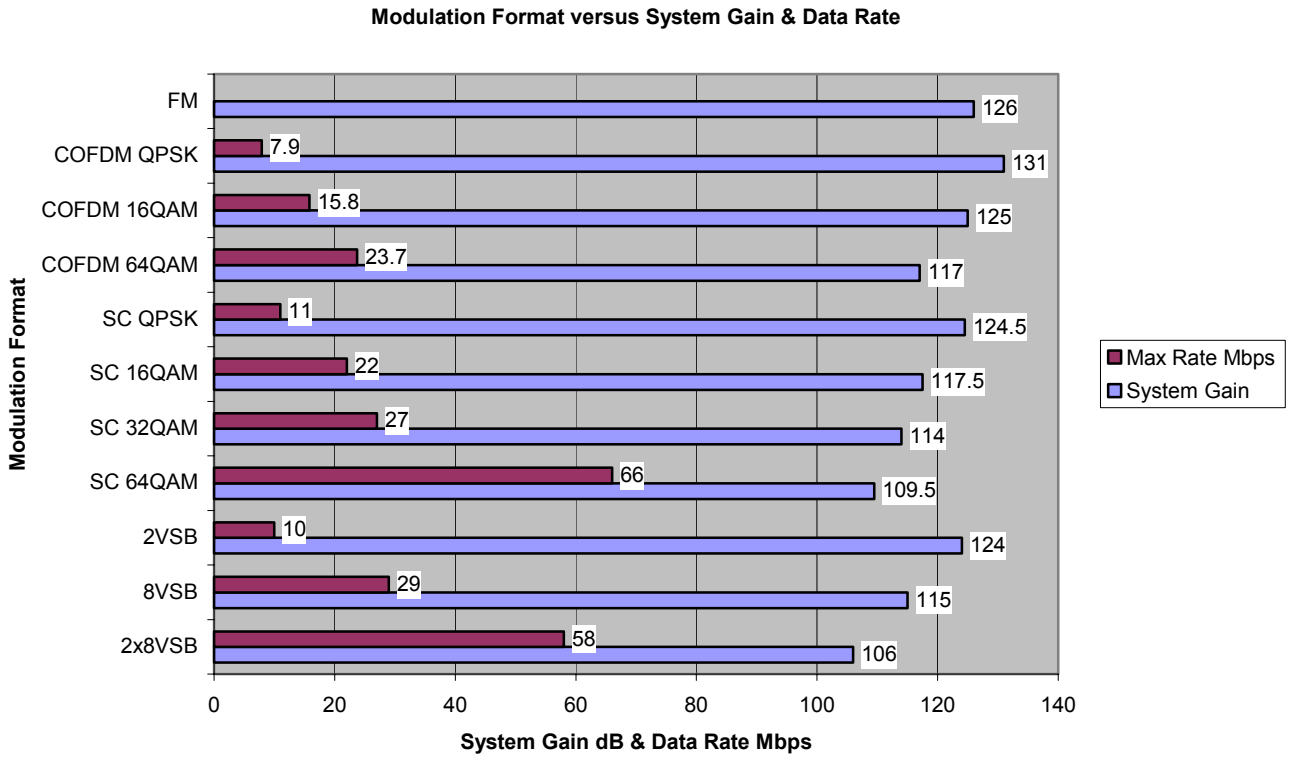
SCM4000 Single Carrier ENG Configuration

The true measure of microwave performance is system gain, which amounts to the total fade margin that a radio system offers, exclusive of the antenna system; the larger the system gain value, the better it performs in the environment. Digital modulation types require a trade-off between system gain and data rate, with the higher data rates yielding lower system gains. In the graph that follows, we show comparisons of system gain versus maximum data rates for three modulation formats. The COFDM and single carrier QPSK/QAM values are based on an MRC CodeRunner 2 ENG van transmitter and CodeRunner 4 central receiver with the capability of switching from COFDM to an SCM4000 single carrier system. These values are compared to a number of VSB schemes. When looking at the system gain values, it is important to remember that they are somewhat compressed due to the way the chart was scaled.

In analyzing the graph, a few key results stand out quickly:

1) COFDM – QPSK has a substantially higher system gain than 2VSB and FM analog, and should outperform both under any circumstances where signal strength is an issue.
2) Analog FM, CODFM-16QAM, single carrier QPSK, and 2VSB modes perform within 1.5 dB of each other with respect to system gain. The advantage in this case would go to COFDM-16QAM, as it supports about 50% more data throughput than either 2VSB, or single carrier QPSK, but with a much higher resistance to multipath.
3) 32QAM and 8VSB offer essentially identical performance in the mid ranges.
4) At the highest bit rates as needed for HD-ENG, single carrier 64QAM modulation has a 3.5 dB system gain advantage over dual carrier 8VSB, and can support an additional

14% in payload. The dual carrier 8VSB solution is more susceptible to interference and multipath, it complicates the modulation-demodulation scheme, and it adds cost.



System gain versus data rate for COFDM, QPSK/QAM, VSB, and analog modes
NOTES: 1) COFDM is 2K Carrier Mode; QPSK, QAM, 2VSB & 8VSB are single carrier, 6MHz B/W
2) 2xVSB is dual carrier, 12 MHz bandwidth
3) 64QAM is single carrier, 12 MHz bandwidth
4) Typical QPSK- COFDM data rates based on 1/8 Guard & ½ FEC
5) Typical 16 QAM-COFDM data rates based on 1/8 Guard & 7/8 FEC
6) Single Carrier digital values based on engineering calculations

In summary

The application of VSB modulation techniques to terrestrial microwave systems is an interesting concept, however it adds a significant level of complexity and expense, without adding meaningful improvements in performance. VSB receiver performance is limited to off-the-shelf solutions developed in response to ATSC recommendations for home entertainment. The pedestals and symbol rates are fixed, forcing microwave manufacturers to use multiple pedestals to achieve the same data rate that a single QAM carrier can achieve.

QPSK and QAM modulation have been used in terrestrial systems for decades, and are accepted standards for robust transmission of data rates up to 310 Mbps. Both transmitter and receiver performance are in the hands of microwave engineers, who can optimize the parameters based on actual path requirements.

A direct comparison of COFDM technology versus single carrier QPSK/ QAM, VSB, and FM reveals that COFDM is superior up to 16 Mbps; QAM and VSB are quite similar in mid-range data rates, however QAM shows a noticeable improvement over VSB at the highest data rates, and is based on accepted terrestrial microwave standards that are easier to implement.