THE MODULATION ARMS RACE – A CASE OF DIMINISHING RETURNS

INTRODUCTION

There's a new arms race in the microwave industry, and it's over who can claim support for the highest QAM level. Now two vendors are out in the market fighting it out over who had 2048QAM first, yet go back a little more than 12 months and 512 or 1024QAM had barely hit the market. We even are seeing mentions of 4096QAM in some conference presentations. We here at Aviat view these advances as a good thing for our industry, but this heavy marketing of 2048QAM does no-one any favors, as it focuses purely on only one aspect of high modulations – capacity, and ignores several others aspects that need to be understood, namely:

- Capacity improvement diminishes with every higher modulation set
- High modulations come with much lower system gain – requires shorter hops and/or larger antennas
- High modulations are much more sensitive to interference – creates difficult link coordination, reduced link density
- High modulations need higher Tx power, increased phase noise and linearity – increases radio design complexity cost

INCREASING CAPACITY WITH HIGHER MODULATIONS

So let's first look at the capacity claims. These are pretty clear, but can be misleading for the layman. Instead of doubling the capacity when you double the modulation level, say going from 1024 to 2048QAM, the increase is much less, with the improvement getting smaller the higher up you go in modulation. For example, moving from QPSK to 16QAM the capacity improvement is 50%, from 128 to 256QAM the improvement is 14%, and moving from 1024 to 2048QAM the improvement is barely 10%.

Modulation Level (QAM)	Bits/Symbol Bits/s/Hz	Incremental Capacity Gain
4 (QPSK)	2	-
8	3	50%
16	4	33%
32	5	25%
64	6	20%
128	7	17%
256	8	14%
512	9	13%
1024	10	11%
2048	11	10%

Table 1: Incremental Capacity Gain by Modulation Step

IMPACT ON RF SYSTEM PERFORMANCE

Now, the thing that no-one is talking about in their press releases is that with modest capacity improvements also come significant radio link performance trade-offs. For a radio to perform well at such high modulations requires backing of the transmitter power, while the receiver threshold is also degraded. This reduction of overall system gain happens with each step up in modulation. The actual reduction will vary depending upon the radio design, but it essentially equates to an antenna size - i.e.: with each step up in modulation you would need to increase the size of the antenna at one end of the link, two steps needs a bigger antenna at both ends. Bigger antennas equate directly to higher costs – larger antenna costs more, are more expensive to install, and more importantly can cost much more in recurring tower lease fees for operators who don't own their own tower assets. Moving from a 4ft to 8ft antenna could cost an operator in North America nearly an additional $100,000 in OPEX over a 10 year period, just on a single link. The alternative to larger antennas is to shorten the link, meaning potentially more links and more sites required in a network.

More Tx power would help, but today's microwave designs were never developed to support the kind of power needed for very high modulations with acceptable performance. Adding significant power improvement is difficult and expensive – to make up for the 3dB or so loss of system gain by going up one step in modulation you would need to double the Tx power output. Higher power output requires larger and more expensive devices, more heat dissipation and potentially reduced reliability.

INCREASED SENSITIVITY TO INTERFERENCE

The other major trade-off is increased sensitivity to adjacent links. When a licensed microwave link is planned, the operation needs to be 'coordinated' with other links in the area operating on close-by frequency channels. Coordination ensures that the new link will not create potential interference into the other existing links, but also that these links will not degrade the performance of the new link. A new 2048QAM link will need up to 10dB more protection from interference, compared to a 256QAM link, and in today's congested frequency bands that could mean that the new link will not work and cannot be deployed as planned. Ironically, the areas of higher link density and thus higher levels of interference will often be where mobile operators are seeking capacity improvement the most – in dense urban areas. Indeed there has been some skepticism with our industry that even 1024QAM will be practically viable for this reason. Interestingly, one vendor who last year questioned the viability of 1024QAM, but has since introduced 1024QAM capability, is now similarly questioning 2048QAM.

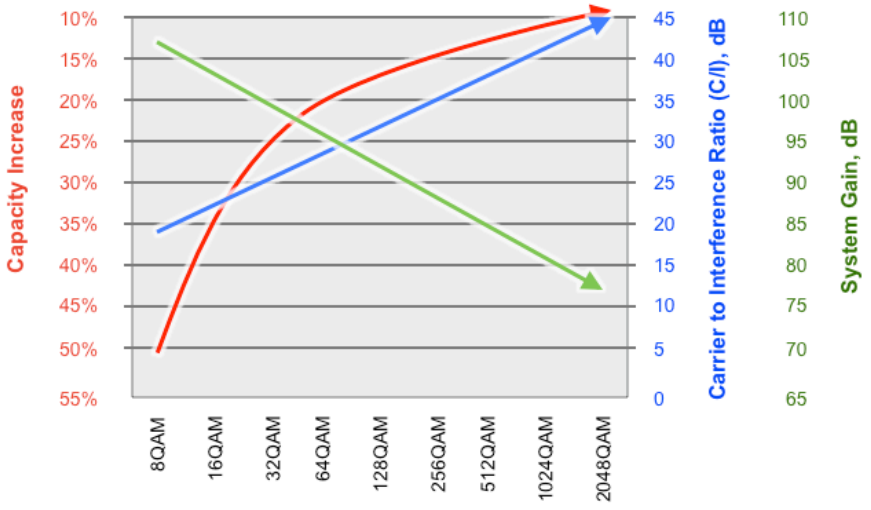

Figure 1: Effect on System Gain and C/I with increasing Modulation

USING ADAPTIVE MODULATION

Some will say that adaptive modulation (ACM) will mitigate the negative effects of higher modulations, and that is true for system gain degradation. Adaptive modulation allows the link to operate at a high modulation with a small fade margin, and then drop back to a lower modulation when conditions are poor to maintain the link for higher priority traffic.

However, due to the significant reduction in system gain you may wonder how long the link would be able to operate at the maximum modulation. To avoid constantly dropping lower priority traffic due to modulation down-shifts you would want the link to run at maximum modulation (and hence capacity) for at least 99.9% of the time, but this may not be practical with 2048QAM, or even 1024QAM, particularly for long haul trunking links. ACM will also not help with coordination, since interference analysis for the new link needs to be performed at the highest modulation level. Otherwise the link will never operate at the highest modulation level if existing interference is above the maximum level that can be tolerated by the radio.

CONCLUSION

As with most things that are presented as a cure-all, higher order modulations are a useful tool to help operators address their growing backhaul capacity needs, but the catch is in the fine print. Operators need to look at all the tools at their disposal, of which 1024/2048QAM is useful option, albeit one that will require very careful planning and strategic deployment.