Adaptive Modulation
TxPower Optimization

Abstract

RF power output has been a major planning aspect for engineers since the start of radio transmission. Undoubtedly important, RF Power level is only one of many factors that determine a successful wireless network. To effectively evaluate and differentiate between various microwave systems and link performance, operators should be able to examine several key aspects of RF power output. Propagation and antennas set aside, parameters such as receiver threshold, modulation type and RF power level are the most important to consider. However, deciphering the diverse range of often incomparable radio system data sheets may prove a challenge.

Adaptive Modulation schemes and ATPC (Automatic Transmit Power Control) already provide point-to-point microwave systems with a high degree of flexibility, ensuring better efficiency under changing weather conditions. This paper discusses how RF output power can now also be controlled dynamically so as to ensure the highest power efficiency under changing modulations. We will also present the various methods in which RF output power control is implemented by Ceragon's FibeAir® IP-10 point-to-point microwave solution.

Adaptive Modulation

The goal of Adaptive Modulation is to improve the operational efficiency of Microwave links by increasing network capacity over the existing infrastructure - while reducing sensitivity to environmental interferences.

Adaptive Modulation means dynamically varying the modulation in an errorless manner in order to maximize the throughput under momentary propagation conditions. In other words, a system can operate at its maximum throughput under clear sky conditions, and decrease it gradually under rain fade. Adaptive modulation is described in ETSI DTR/TM-4147 and in EN 302 217-2-2. In the US, the FCC plans to introduce similar functionalities, albeit with some restrictions.

The Benefits of Adaptive Modulation

Operators evaluate point to point microwave links according to capacity and availability parameters. This would in turn imply having a detailed plan of frequencies, channel bandwidth, modulation, antenna size, link configuration (1+1, N+1 etc.), diversity schemes, transmission power and more. Radio network planners can harness Adaptive Modulation in different ways. The obvious one is to increase capacity of any given link. Adaptive modulation may also flex radio design rules further, influencing availability per service, hop distance and antenna size. For more information on the advantages of Adaptive modulation see the Adaptive modulation white paper on Ceragon's web site.

Depending on the end to end expected service level agreement, a microwave link would be planned to maintain 4 or 5 9s availability (99.99% resulting in ~1 hour of outage a year – or -99.999% resulting in ~5minutes outage a year). Each link is designed with fade margins to maintain traffic at different fade conditions like rain fades.

In a single class of service - such as TDM voice - the use of Adaptive Coding & Modulation (ACM) is less relevant. However, since a great deal of new capacity requirements is associated with data, cost-per-bit must be optimized. Microwave links therefore should allow more bits per Hz for any give spectrum, antenna size and transmitter power. Assigning different availability classes to different types of service over a single radio link allows more efficient planning of link capacity for best case scenario rather than for worst case as it is done today. Voice and real-time video applications will continue to be assigned "five nines" availability, while non-real-time data packets can be reduced to four or even 3 nines availability with little or no sacrifice to user experience. By using ACM to drop some of the data under fading conditions and allow the constant flow of high priority bits at all time, the overall radio capacity can be maximized at no extra cost.

Ceragon's Adaptive Coding & Modulation (ACM)

Ceragon provides a unique, full range Adaptive Modulation with the widest, 8-step, modulation range - from QPSK to 256 QAM. This implementation includes a multi-level, real-time, hitless and errorless modulation that shifts dynamically according to environmental conditions to ensure zero downtime connectivity.

Ceragon's service aware Adaptive Modulation enabled FibeAir® systems ensure that high priority traffic is maintained according to each individual link design goals. This ensures that:

- High priority voice and data packets are never "dropped", thus maintaining even the most stringent service level agreements.
- TDM service does not suffer from interruption (ES, SES, UAS) and/or loss of synchronization and timing.

FibeAir solutions support fading rates of up to 90dB/sec, easily compensating for rain or multipath events. Ceragon system constantly estimate the signal to noise ratio and implement built-in hysteresis, determined by a 2dB over the predetermined threshold SNR to shift the modulation down – and a 3dB over the predetermined threshold SNR for modem configuration to shift the modulation up. This prevents repeated switching between modulations when the input signal hovers between two modem configuration thresholds.

The Modulation switching criteria is based on SNR estimation. Continuous monitoring of SNR, allows the system to switch modulations before errors are detected by the user.

Ceragon's Adaptive Modulation mechanism support Unidirectional Modulation Shift, which means that the shift between the different physical modes does not occur at the same time in both link directions.

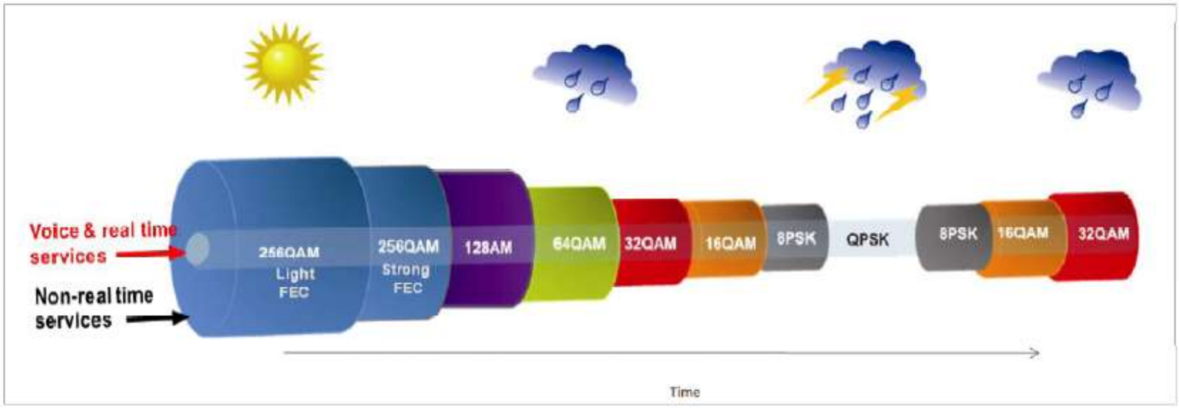

Figure 1: Ceragon's eight levels of Adaptive Modulation

Generally speaking, user bit rate – or "net" bit rate for user traffic - over a given channel with a given symbol rate is determined by two main factors; One is the modulation scheme efficiency (modulation bits/symbol), the other is the coding rate.

User bit rate = Symbol rate * modulation bits/symbol * coding rate.

Adaptive coding allows Ceragon's FibeAir solutions to use a light forward-error-correction (FEC) code under ideal weather conditions, thus gaining more bits for payload. Should the system detect an increase in errors over the link, it will automatically implement stronger FEC coding. By implementing full dynamic ACM (e.g. Adaptive Coding and Modulation), the overall user bit-rate can be improved significantly.

Modulation Scheme Efficiency is in fact the amount of bits that are carried by each transmitted symbol. For example: QPSK carries 2 bits/symbol, while 256QAM carries 8 bits/symbol. The Coding Rate determines the percentage of payload bits out of the total amount of transmitted bits - as opposed to redundancy bits which are used for coding. For example: a coding rate of 0.9 means that we add one redundancy bit for every nine bits of payload. In this particular case, the code consumes 10% of the bandwidth. When the system needs to use a stronger code (to make up for bit-errors for instance), the coding rate is changed to 0.8. This would ensure better quality of transmission on the one hand, but reduce the percentage of payload bits as more bandwidth is consumed by coding.

Modulation Scheme Efficiency and Coding Rate influence the radio system's signal-to-noise ratio (SNR) - or system gain. As the modulation bits/symbol increases there is a need for a higher SNR which results in lower system gain. As the coding rate decreases, by introducing a stronger code, SNR is lower, resulting in better system gain. So, by dynamically adjusting both the modulation efficiency and the coding rate using ACM, a FibeAir IP-10 solution for example, ensures the highest available per-channel bit rate. This automatic changing of channel coding and modulation gives operators more flexibility and a finer resolution on the curve of system gain verses delivered bandwidth.

RF power output and Multi-Modulation

It is important to note that every modulation, from QPSK up to 256QM, has a different optimal power output. Thus, a transmitter will operate at 20dBm in QPSK mode and at 14dBm to 16dBm in 256QAM mode - in order to maintain sufficient linearity.

In most Adaptive Modulation radios, the output power is fixed and does not change with the modulation type. Let us look for example at a system that is configured for 256QAM at 16dBm. Under ideal weather conditions, the modulation remains unchanged. Should the weather deteriorate, the system will be able to step down the modulation - but not the transmit power. Thus, even though the systems operate in QPSK, it will continue to maintain low power output of 16dBm.

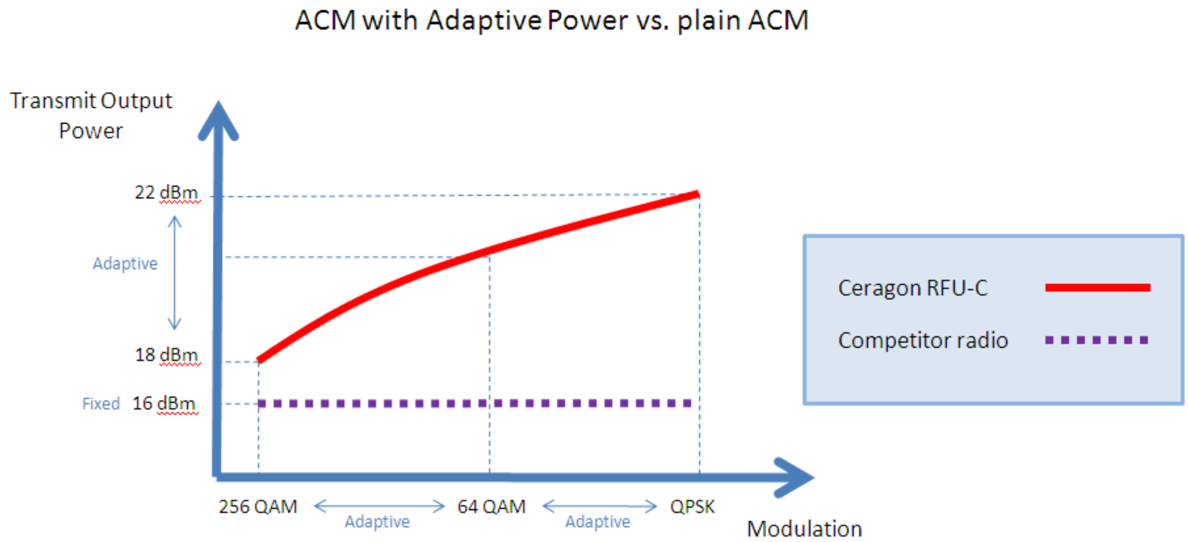

Figure 2: Adaptive-Modulation with Adaptive-Power feature Versus Adaptive-Modulation with a Fix Power level, over 18-23 GHz link

As the modulation type becomes more complex, the power "back-off" factor will become more pronounced. Therefore, in order to be able to truly compare competing microwave systems, it is important to know each system's power output under each and every specific modulation – not just "best case" (stating "power output = 20dBm" on a data sheet is meaningless and sometimes even misleading without a specific reference as to how this measurement was taken).

It is plain to see that Adaptive Modulation – and even Adaptive Coding and Modulation – are simply not enough. To maintain optimal per-link system gain and planned availability, operators should also apply an Adaptive Power mode.

Most microwave systems perform ACM while retaining a fixed low transmit output power even when going down in the modulation. Ceragon FibeAir IP-10 family on the other hand, offers an inherent Adaptive Power mode along with the advanced ACM schemes. This unique feature allows the radio transmitter to change the transmitted power according to the compatible modulation in order to maintain the wireless link system gain – as shown in table 1 below.

Transmit Power with RFU-C[1] (dBm)

Modulation	6-8 GHz	11-15 GHz	18-23 GHz	26-28 GHz	32-38 GHz
QPSK	26	24	22	21	18
8 PSK	26	24	22	21	18
16 QAM	25	23	21	20	17
32 QAM	24	22	20	19	16
64 QAM	24	22	20	19	16
128 QAM	24	22	20	19	16
256 QAM	22	20	18	17	14

Table 1: Ceragon's ADAPTIVE-POWER mode along with the ADAPTIVE-MODULATION in different frequencies

Automatic Transmit Power Control (ATPC)

Adaptive power techniques for microwave systems are not a new concept in itself. One such technique is ATPC which is used to lower the output power when environmental conditions are good in order to reduce power consumption and network interference. Under fading conditions the power is automatically increased to compensate for far end signal loss and to ensure the link continues to meet the required performance level.

Ceragon's ATPC implementation

Ceragon's ATPC feature is a standard configurable software option on all frequency bands. The algorithm, when activated, constantly monitors remote Receive Signal Level (RSL), sensing any deviation greater than 1dB from the "set level" - closing the gap exponentially at a maximum response speed of 90dB/sec until the monitored RSL is within 1dB of the "set RSL." Minimum TX power steps are 1dB. This process utilizes an inter-processor communication channel between local and remote terminals. The frequency of adjustment is once per 30ms.

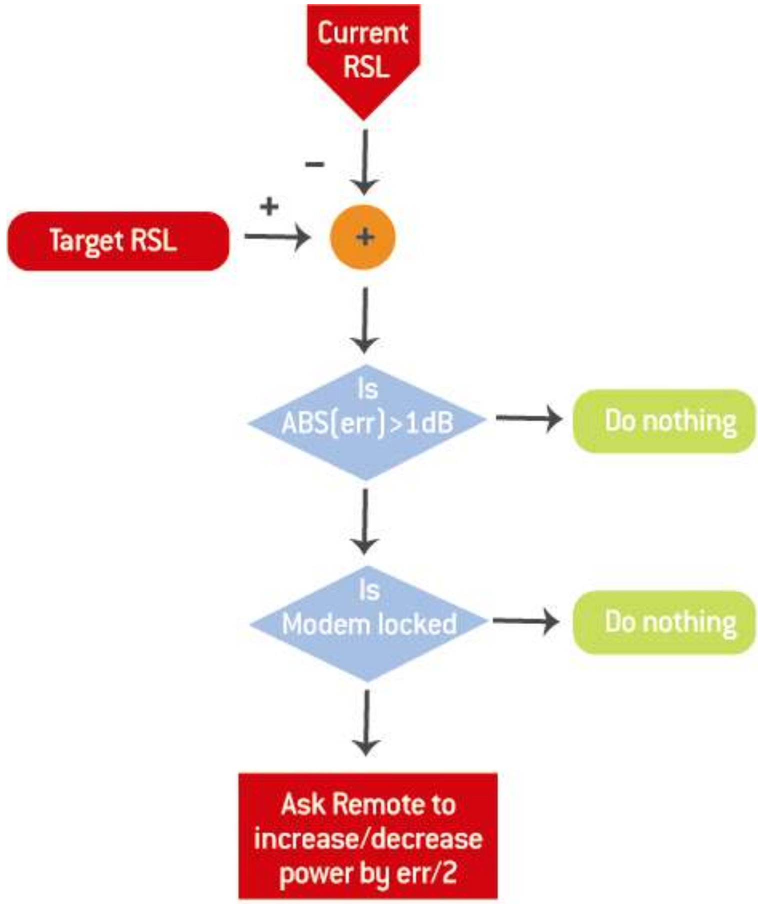

Figure 3: Diagram chart explaining the behavior of ATPC algorithm

How we can use ATPC and Adaptive Modulation together?

Ceragon's Adaptive Modulation takes ATPC a step further. By controlling both the power output and the modulation level dynamically, it adjusts the link capacity to suit the propagation conditions.

ATPC and Adaptive Modulation can be enabled simultaneously. When fading conditions occur, the ATPC loop increases the power to compensate for it until reaching the maximum allowed transmit power. If fading conditions worsen and the SNR degrades until it reaches the adaptive modulation threshold, the adaptive modulation mechanism will begin shifting the active modulation. Once fading conditions are cleared, the process is reversed and the highest possible modulation is restored. ATPC and Adaptive Modulation are therefore not contending but rather complimenting technologies.

Conclusion

RF output power is a significant measurement with respect to a transmitter -however it is more important to study all the RF parameters that effect microwave system performance, and how they are measured. Simply put, adaptive Modulation without Adaptive Power will not provide optimal link utilization.

In this paper we highlighted a number of methods in which operators can address the requirement for Adaptive-Power mode as an inherent feature of Adaptive Modulation schemes. We have also described how legacy ATPC schemes can be utilized in combination with Adaptive Modulation.

RF output power and ACM are highly important for optimizing high-capacity microwave links. Ceragon's advanced FibeAir IP-10 wireless backhaul solution offers a unique technological combination of both features and ensuring high availability and unmatched link utilization.

About Ceragon Networks

Ceragon Networks Ltd. (NASDAQ: CRNT) is the premier wireless backhaul specialist. Ceragon's high capacity wireless backhaul solutions enable cellular operators and other wireless service providers to deliver 2G/3G and LTE/4G voice and data services that enable smart-phone applications such as Internet browsing, music and video. With unmatched technology and cost innovation, Ceragon's advanced point-to-point microwave systems allow wireless service providers to evolve their networks from circuit-switched and hybrid concepts to all IP networks. Ceragon solutions are designed to support all wireless access technologies, delivering more capacity over longer distances under any given deployment scenario. Ceragon's solutions are deployed by more than 230 service providers of all sizes, and hundreds of private networks in more than 130 countries. Visit Ceragon at www.ceragon.com.