Rain Fade Management in
Third Generation Ka-band Satellite Systems

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Propagation of a radio-communication microwave signal from a transmitter, such as a microwave tower or a satellite, to a receiver, such as another microwave tower or a VSAT earth terminal, is attenuated (reduced in signal strength) by rain that the signal may pass through. The amount of attenuation increases both with the microwave frequency and the rain rate. That is, higher frequency microwave signals are subject to greater attenuation than lower frequency microwave signals, and the attenuation increases as the rain rate increases. Ka-band is higher frequency than Ku-band, which is higher frequency than C-band.

Microwave links, including links between a communication satellite and the gateway and VSAT earth terminals, are designed to accommodate the distribution of rain rates that are experienced locally by incorporating various types of margin and transmission robustness into the links to achieve the desired availability (percentage of time that the link and service are available per year). With the migration of broadband satellite networks from Ku-band to the higher frequency Ka-band, there is a natural concern that the increased rain attenuation at Ka-band will reduce the service availability to an unacceptable level, especially in high rain regions such as Darwin. The latest generation satellite networks, however, employ a combination of Adaptive Coding and Modulation (ACM) and an advanced Forward Error Correction (FEC) known as Low Density Parity Check (LDPC) to provide the necessary link margin against Ka-band rain fade even in high rain, tropical regions such as Darwin. These techniques, which have been well vetted by the satellite industry and have been incorporated as part of the ETSI DVB-S2 standard in 2006, provide typical margins against rain fade of 20 dB that yield a link availability of 99.8% in high rain regions such as Darwin. This means that typical consumer-grade Ka-band broadband satellite VSAT networks operating in these northern Australia tropical regions will have service available on average 99.8% annually. Small and medium enterprise (SME) networks would have even higher availability in these regions by deploying even more robust, albeit more expensive, VSAT equipment such as larger antennas.

A two-page technical tutorial is provided in the attachment to describe these rain-fade management techniques in greater detail. But perhaps the strongest confidence in the appropriateness and practicality of Ka-band for broadband satellite networks can be gained by looking to the commitment and deployment that current and future generation system operators have made to Ka-band in North America and Europe, including high rain regions in the southern United States such as Florida, Louisiana, Mississippi, and Georgia. Today, there are over 550,000 Ka-band consumer VSATs in operation in North America in all regions including the high rain regions in the southern United States. These consumers are paying on average US$50 per month for this Ka-band broadband satellite service, and the service is performing so well that ~15,000 consumers per month are adding the service.

KaComm is confident that by applying third generation technology and the rain fade management techniques described herein, it will deliver to all Australians, including those in high rain regions, a quality, high availability broadband satellite service.

Attachment:

Adaptive Coding and Modulation Increases Network Availability

Next Generation satellite network access systems employing an FDMA/TDMA air interface allocate bandwidth and timeslots to each access based on the requirements of the application requesting the access. When signal to noise, including interference, ratios are high, highly efficient modulations and weak coding algorithms are applied in order to increase the user's data rate while consuming a minimum amount of the air link resource. As the signal to noise ratio decreases, as in the case during a rain fade, the resource controller adjusts the modulation and coding to maintain the required Eb/No. Accesses are given additional air link resources to compensate for the allocated modulation and coding drop in data rate if the rate approaches the applications required minimum bit rate.

Typical forward link (from gateway to user terminal) carriers will be transmitted with a constant symbol rate (typically 200MS/s) but with variable modulation and error correction encoding. The symbols transmitted are a shared resource for the users assigned to that carrier. The modulation and FEC rate will remain fixed until enough bits have been transmitted to make up an FEC frame (64,800 bits). Individual users assigned to that mode will demodulate and decode the frame to produce a stream of information bits in the form of 188 byte packets. The user modem will then select the packets addressed to the user for further processing. The gateway resource controller will continue to transmit FEC frames in the same mode until all users assigned to that mode have received their allocated number of packets. The resource controller in the gateway allocates a switch (without interruption) to the next ACM mode and the process repeats. Messages embedded in the forward and return data streams between the gateway resource controller and the user modem report link quality and command mode changes.

The architectures of state of the art Ka-band Internet satellites systems currently under construction have been chosen to take advantage of advanced antenna designs and Adaptive Coding and Modulation (ACM). The net result of the new designs is a significant increase in availability and capacity compared to systems currently in operation.

The key technology that allows much of this improvement is the advanced ACM that is defined in the ETSI DVB-S2 standard of 2006 (available online). This standard defines performance for ACM modes that have a dynamic range of 18.4 dB in carrier to noise ratio while providing information data rates over a 9:1 ratio. The proposed system matches the applied modes to the individual beam coverage areas so that capacity and availability for the specific rain region reaches the desired balance. The mode assignments are adjustable at any time without modification to the satellite or the consumer premises equipment.

The DVB-S2 standard utilizes an advanced Forward Error Correction (FEC) method called Low Density Parity Check (LDPC). First conceived in the 1960s, LDPC has only recently become practical for the consumer market due to the amount of digital processing power required by the error correction decoder. Low cost, high density ASIC chipsets in consumer modems are now capable of economically providing this function. LDPC approaches the theoretical Shannon limit, providing significantly better performance than previously implemented Turbo codes resulting in higher capacity and an extended availability range.

The return link (from user terminal to gateway) carriers will also be transmitted with a constant symbol rate with variable modulation and error correction encoding. It should be noted that on the return link only 'uplink power control' is also implemented in modern CPE. This allows the CPE to increase the actual transmit power in response to rain fade in addition to ACM and FEC.

The following two figures are an example of one potential beam allocation applied to a northern territory rain region. This example uses a subset of the available modes that provides a 9:1 individual data rate range over an 18.4 dB ACM dynamic range with and additional 1.6dB of fixed margin added to provide a total margin of 20 dB. Figure 1 depicts an access initially allocated resources supporting 12 Mbps under a clear sky environment. As the rain attenuation increases, the modulation and the coding are autonomously adapted to maintain acceptable link margins. In this example the allocation policies for this application do not add air interface resources to maintain a minimum data rate which may be the case for accesses using other applications.

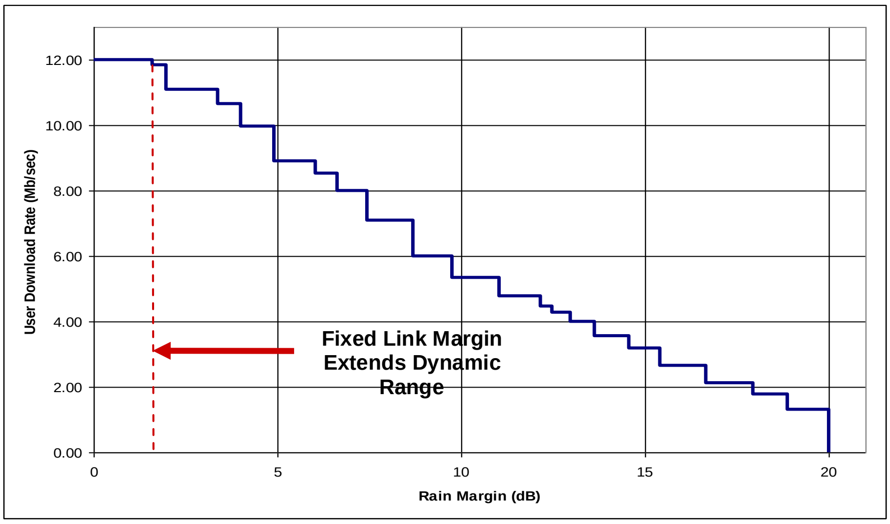

Figure 1. ACM Performance with Fixed Satellite Resource Allocation

Figure 2 depicts the same data as a function of the probability of the plotted attenuation. The link availability at data rates greater than 1.3 Mbps is 99.8%.

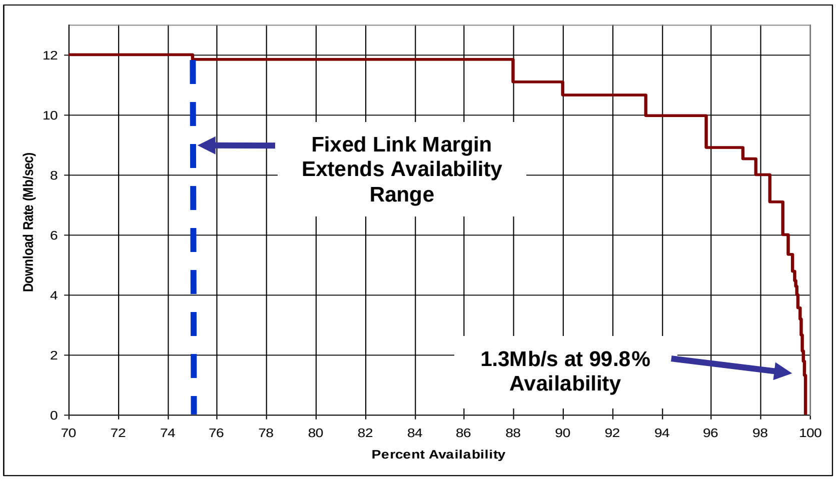

Figure 2. ACM Extends Availability: Typical Download Performance due to Rain in Darwin Region

In summary, policies are set for each beam that balance capacity with availability. These policies are managed and reconfigurable at any time to provide availabilities greater than 99.8% anywhere across Australia.