Making V-Band Ubiquitous

WHITE PAPER

Intelligent AGC for Millimeter Wave Radio Links

Maintaining Reliability without Impacting Throughput

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Introduction

In the world of microwave and millimeter wave radio transmission, especially for systems used for point-to-point link applications, one of the most important operating parameters is how the link adapts to changing path conditions. As temperature, humidity and especially rainfall change in the environment, the link needs to dynamically adapt in order to maintain reliable connectivity.

Environmental Factors

Environmental factors change how much radio transmission loss (path loss) there is between the link endpoints or terminals. If the links were deployed in free space, such as between satellites, the environment is not affected by weather conditions. In this case the free space path loss is very easy to define. But in the atmosphere and troposphere where real weather constantly changes, the radio frequency path loss, or RF path loss, changes with temperature, humidity and most drastically with rainfall.

At millimeter wave frequencies, such as 60 GHz (V-Band) and 70/80 GHz (E-Band), precipitation loss is well defined. The variable used for amount of rainfall is Rain Rate, and is measured in inches/hour or millimeters/hour. As the radio frequency increases, the attenuation or reduction in signal strength due to a given rain rate also increases.

Figure 1 is a graph of attenuation versus frequency for various rain rates. 60 GHz and 80 GHz are highlighted to show attenuation at these two frequencies. At 50 mm/hour (about 2 inches/hour) rain rate, 60 GHz is attenuated about 16 dB/km and at 80 GHz, about 19 dB/km. Note these attenuation numbers are in addition to the normal propagation path loss for the link.[1]

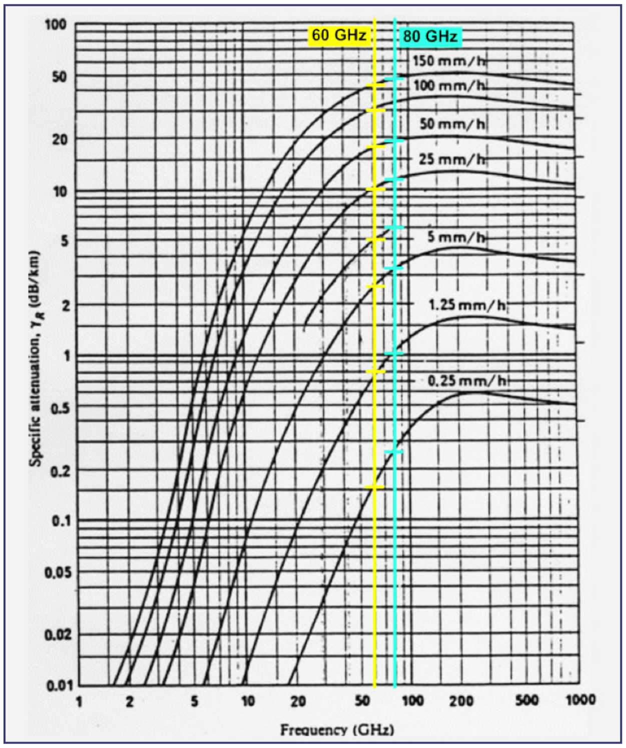

Figure 1. Attenuation due to Rain vs Frequency

As an example, for a 500 meter link at 60 GHz, 8 dB of additional margin is required for reliable operation for up to 50 mm or 2 inches per hour of rain rate. Rainfall, and other environmental factors, change in real time. Even though the link has the additional margin necessary to accommodate these changes, there are different approaches as to how the margin is utilized.

Adapting by Changing Modulation Bit Rate – the Old Way

One method for attempting to make a link more robust through the dynamic changes in the path loss is to adapt the modulation rate in order to create a higher margin. The modulation rate directly affects the bandwidth of the channel being used for transmission.

As an example, if the bandwidth is reduced by half or 50%, an additional 3 dB of margin can be added. A 50% reduction in bandwidth corresponds approximately to a 50% reduction in bit rate. In the case of simple modulation techniques, if a 1 Gbps link reduces its modulation bit rate to 500 Mbps, an additional 3 dB of margin results. At the system throughput level, the link will suffer a 50% throughput degradation as a result.

Typically the method used to determine if a reduction in bit rate is required is received signal strength indication (RSSI). Even though the RSSI may undergo a reduction during heavy rain, the packet error rate may still be fine depending upon the type of error correction that is used. But only relying on RSSI and quickly reacting by reducing bit rate can often be too aggressive, with the result that the link will suffer throughput degradation more often than necessary.

Note that a 50% reduction in throughput is a significant reduction, but at what expense? For the savings of only 3 dB of link budget, the throughput was cut in half. A well-designed millimeter wave link has much more link budget margin than 3 dB. Why not use the extra margin instead of sacrificing the digital bandwidth of the link?

There are also other collateral effects of reducing the link throughput.The bit rate, or digital bandwidth, sets the maximum throughput level that the link can provide. If the bandwidth is reduced, the throughput can no longer reach the same peak or burst speed levels that may be required by the link users.

With lower throughput, not only is the link affected, but the network in which the link is part of can start to experience other issues due to potential data buffer limits in switches and routers. This can ultimately result in the loss of packets. This behavior can ripple back through the network and create a greater loss in performance than just the problem at the radio link. Network management facilities will potentially report problems from other locations in the network, leading to the consequence of unhappy customers.

Figure 2 shows a graphic representation of throughput as a result of bandwidth reduction. Network congestion increases with less throughput.

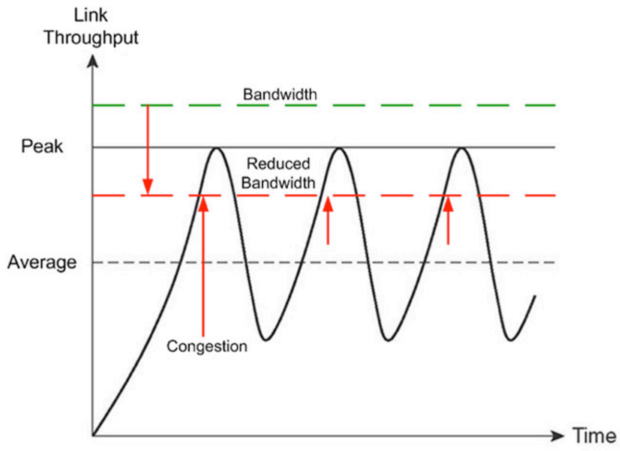

Figure 2. Impact on Link Throughput from Bandwidth Reduction

Maintaining Throughput with Intelligent AGC

A better approach to handling dynamic change in the path loss is to monitor bit error rate instead of RSSI, and to maintain minimal error rates by intelligently adjusting the gains at the receiver and transmitter.

Traditional systems that use RSSI to adjust gain are called automatic gain control or AGC. But using bit error rate allows a much finer adjustment mechanism than RSSI, and by adjusting the system gain with the error rate constantly monitored, the throughput is maintained with minimal errors.

This refined method of AGC through the use of digital system and error control is called Intelligent AGC. The end user wants reliable, high-throughput performance without suffering lower bit rates during bad weather. Maintaining high throughput packet delivery with minimal packet loss is the preferred approach.

Figure 3 shows the traditional technique of adjusting the gain at the receiver end of the link. The RSSI signal level is used to adjust the gain of the IF amplifier. Figure 4 shows how Intelligent AGC works by monitoring the digital BER with the ability to intelligently adjust the receiver gain based on the more important parameter of getting the high throughput packet payload delivered with minimal errors.

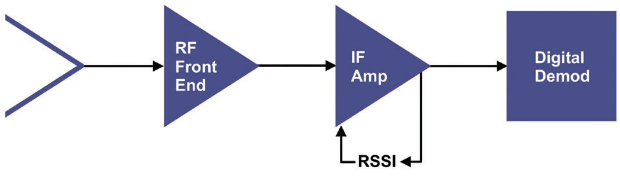

Figure 3. Traditional RSSI Gain Adjustment

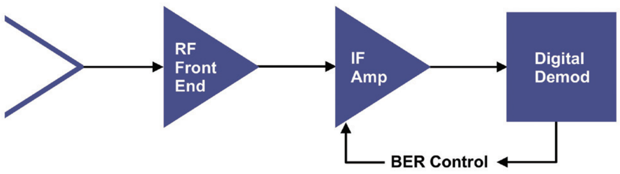

Figure 4. Intelligent AGC with Bit Error Rate Control

Conclusion

Millimeter wave digital radio links must operate in the real world of changing path conditions, especially due to rain fade. There are different approaches used to adapt link behavior in response to the dynamic path environment. The older technique of using RSSI as the indicator of link quality and then reducing the modulation rate in an attempt to maintain the link essentially throws away performance at the cost of a minimal improvement of link margin.

Through the use of Intelligent AGC, as opposed to simply turning down the link bandwidth, the network throughput of the system is maintained. High speed data services and internet bandwidth demand continue to rise, with industry predictions showing the trend will continue. Ultimately, maintaining high link throughput keeps the end users happy. Vubiq Networks' strategy for millimeter wave link design is to continue to increase digital throughput, not decrease it.

Footnote:

1. See the Vubiq Networks white paper, Rain Fade Considerations in the Design of Millimeter Wave Radio Links, July 2016

VUBIQ NETWORKS

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