THE NEED FOR SPEED:

BEST PRACTICES FOR BUILDING ULTRA-LOW LATENCY MICROWAVE NETWORKS

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TABLE OF CONTENTS

INTRODUCTION

In today's ultra-competitive High Frequency Trading markets, speed is everything, and recently wireless technologies, and specifically microwave networking, have recently been recognized as a faster alternative to optical transport for ultra-low latency financial applications.

Even though microwave technology has been in use in telecommunications networks around the world for more than 50 years, recent developments have optimized microwave products to drive down the latency performance to the point that microwave can significantly outperform fiber over long routes, for example between Chicago and New York. This has provided a new market opportunity for innovative service providers to venture into the microwave low latency business.

Although reducing the latency of the equipment is an important consideration, the most important metric is the end-to-end latency. Many factors that influence the overall end-to-end latency require deep understanding of the technology and how this is applied in practice.

This white paper will show that to achieve the lowest end-to end latency with the highest possible reliability and network stability not only requires a microwave platform that supports cutting edge low latency performance but also a combination of experience and expertise necessary to design, deploy, support and operate an microwave transmission network.

MICROWAVE: THE NEW DEFAULT TRANSPORT FOR LOW LATENCY APPLICATIONS

Although fiber optic transport latency has improved recently, the new frontier for ultra-low latency is microwave networking. Some of the reasons why microwave is becoming the new default transport for financial applications are:

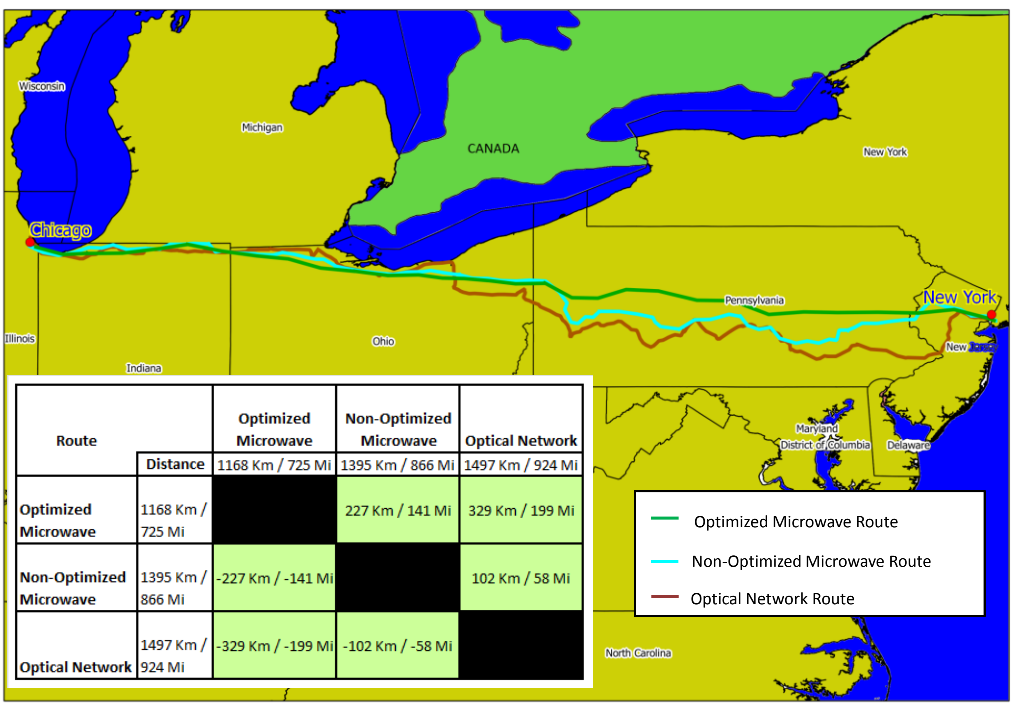
- **Microwave is faster than fiber:** Electromagnetic waves travel 50 percent faster through the air than through a fiber optic cable. The reason for this is that light in the fiber cable is traveling through a medium similar to glass that has a higher diffraction index than air, slowing it down. An electromagnetic wave traveling through air travels very close to the speed of light.
- **Shorter routes:** As optical networks cannot be deployed through geographical obstacles such as mountains, lakes, freeways, buildings, etc., they have to go around them, and this can add hundreds of miles to a network path for optical networks, with each additional mile adding to end-to-end latency. Microwave hops can easily overcome these obstacles since they can have a direct "as the crow flies" route, providing true speed-of-light benefits.
- **Flexibility:** Microwave networks, unlike installation of optical fiber, can be deployed, commissioned, expanded and upgraded quickly and cost effectively. This gives network operators flexibility to deal with unpredictable traffic demand allowing quick and flexible deployments that can adapt to changing markets. This also allows networks to evolve, finding newer shorter paths, or upgrading capacity as more bandwidth becomes available.

BUILDING AN ULTRA LOW MICROWAVE NETWORK

Even though a properly engineered microwave network has very low latency, planning, building, and operating a microwave network is a complex endeavor that requires experience to get right. Careful design and execution are required to deal with multiple technical, operational and logistical issues. Some of the considerations to build a successful ultra-low latency network include:

END-TO-END LATENCY

Although equipment latency has been the main focus of attention, it is not the only important consideration. The greater potential contributor to overall latency is a non-optimized network design. This means that during the design phase a judicious analysis of the factors that determine the overall end-to-end latency is required. Some of the factors that can help reduce overall end-to-end latency include:



Route	Distance	Optimized Microwave	Non-Optimized Microwave	Optical Network
	Distance	1168 Km / 725 Mi	1395 Km / 866 Mi	1497 Km / 924 Mi
Optimized Microwave	1168 Km / 725 Mi		227 Km / 141 Mi	329 Km / 199 Mi
Non-Optimized Microwave	1395 Km / 866 Mi	-227 Km / -141 Mi		102 Km / 58 Mi
Optical Network	1497 Km / 924 Mi	-329 Km / -199 Mi	-102 Km / -58 Mi	

Figure 1. Theoretical Chicago-NY microwave networks using existing towers compared to existing optical network

- **Selection of optimal route:** The minimization of the overall distance between the exchanges is one of the greatest contributors to reducing the overall end-to-end latency. The selection of the optimal route will depend on the location of the sites and towers to use. This selection will have to consider whether existing infrastructure will comply with network design objectives, or if construction of new sites is justified to reduce the overall distance. Figure 1 shows the approximate distance differences between two theoretical Chicago-to-New York ultra-low latency microwave networks routes that use existing towers and an existing optical network route.

- **Reducing the number of hops:** As more hops introduce more processing latency and noise to the network, decreasing the number of hops is a great contributor to reducing the overall end-to-end latency. The number of hops will directly depend on the maximum distance that can be achieved with a particular microwave equipment and antenna combination in each hop. The maximum distance will depend on the available frequency band, system gain and capability of the equipment to cope with atmospheric propagation anomalies. Atmospheric propagation will also depend on environmental conditions on each hop considered during network design. A balance will need to be reached between the total number of hops and a reliability objective that will ensure that the network is available when needed.
- **Using analog IF repeaters:** In order to reduce end-to-end latency new innovations are being developed to reduce equipment latency. An innovation recently introduced by Aviat Networks is the use of IF (Intermediate Frequency) repeaters. In this configuration the IF connection from the modem to the radio head is passed directly from node to node eliminating the digital processing latency. Using this technique, IF repeaters can have latency **as low as 170 ns**. At several points along the network path, regenerator nodes are employed that demodulate the signal all the way back down to baseband to "clean up" the transmitted signal, which ensures the required low Residual Bit Error Rate (RBER), at the expense of added latency.

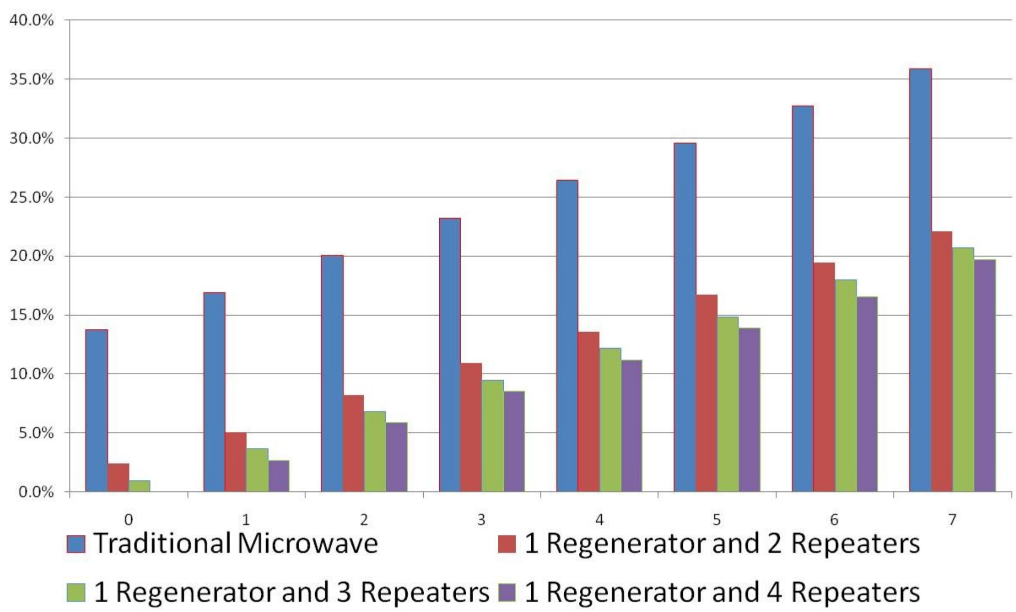


Figure 2. Latency impact of adding nodes to reference network

Figure 2 shows the impact on latency of adding links to a reference network between Chicago and New York (1168km, 725 miles) shown in Figure 1. Figure 2 shows the increase in latency for traditional microwave without the use of IF repeater technology, and the use of IF repeaters and regenerators in different ratios (1 regenerator to 2, 3 and 4 repeaters). There are many reasons why the number of hops needed can exceed an optimal design including non-optimal route, low system gain, etc. The bottom line is that each additional hop can increase the overall latency from 4 to 14 percent depending on the configuration for this particular example. This means that if the design is not meticulously done, all gains obtained using low latency equipment can be lost.

EQUIPMENT

The following features are fundamental for the design and implementation of a successful ultra-low latency network:

- **Smart low latency configurations:** In order to minimize latency the solution should have exceptional end-to-end latency, including IF repeater and regenerator configurations. The system should have the capability to smartly change from IF to repeater configuration depending on environmental conditions as shown in figure 3.

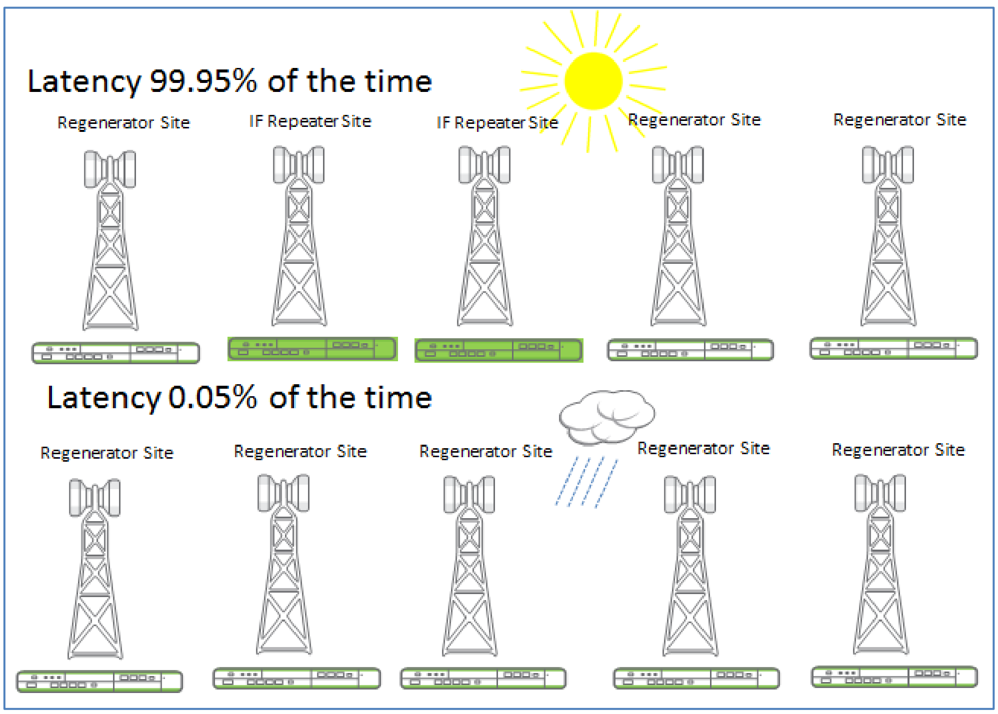


Figure 3. Smart low latency configurations

- **High system gain:** High transmission power, low receive threshold and resistance to difficult propagation conditions such as reflections and diffraction (high dispersive fade margin). Radios should be available in both all-indoor and split-mount/configurations to allow for the most optimal deployment scenarios.
- **Frequency band options:** Since lower frequencies can become congested, especially close to urban centers, the wireless solution should be available across a broad range of possible frequency possibilities (5, 6, 7, 11, 18, 23, 38 GHz).

- **Standards compliant:** The solution must comply with all relevant local regulatory entity standards for digital microwave radio in all modes of operation.
- **Reliability and security:** The underlying radio technology must also be rugged and field proven. Single chassis design, redundant power supplies, secure management interfaces, and NEBS compliant options are critical to ensure that your communications infrastructure can operate reliably and is always secure. Multi-box repeater solutions should be avoided due to increased management complexity, reduced system stability and increased points of failure.
- **Purpose-built Network Management System:**
  Operational visibility and control are critical in any communications network and to enable this a software-based management platform that provides the network operator with the ability to anticipate and diagnose problems related to a microwave network is essential.

ULTRA-LOW LATENCY MICROWAVE NETWORK DESIGN

The design of an ultra-low latency microwave network begins with understanding the necessary latency, capacity and availability objectives with which the ultra-low latency microwave network needs to comply to meet business requirements.

The network designer must plan a carefully laid out route that minimizes the overall distance, but also takes into account different factors such as available frequencies in the area, coordination with existing networks and the existence of suitable towers to minimize costs.

Possible equipment and antenna configurations will be used within candidate routes (employing software simulations) to weigh impact of different configurations on overall end-to-end latency and network reliability. These simulations need to consider the effect of environmental conditions such as:

- Annual rain probability
- Atmospheric propagation conditions that could create multipath fading
- Reflections if the hop traverses a body of water
- Diffraction in the presence of obstacles in the line of sight, etc.

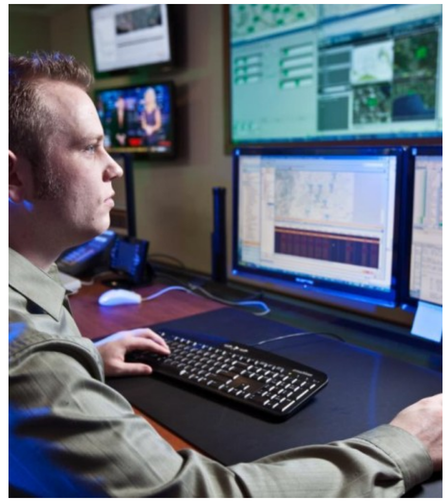
Additional factors to be considered during the design phase include the available bandwidth and whether this bandwidth is sufficient to meet the capacity requirement. Balancing all these factors and obtaining a suitable design is a complex process that requires a partner with the necessary engineering know-how to navigate through a series of obstacles in order to provide a reliable network with a competitive edge.

DEPLOYMENT

Time to market is often a key consideration, so a planned and systematic approach that minimizes risks and validates all assumptions made during the design phase is needed. Some of the considerations required during the deployment phase include:

- **Site surveys**: In order to validate the design, conditions in each site must be verified including:
    - Accuracy of coordinates used for intial design
    - Obstacles in the path not contempated in terrain and clutter database used for hop design
    - Tower condition and antenna clearance at designed height
    - Existence and condtion of equipment room and racks
    - Existence (or lack) of DC power and suitability of existing power to meet new radios requirements
- **Frequency coordination**: In order to minimize interference with existing networks, frequency coordination to obtain the proper licenses for the local regulatory entity is required. Spectrum management will also be required to optimize the use of acquired frequencies.
- **Site construction:** In some cases the construction of a new microwave site can be economically justified if it can significantly reduce the network path length, and hence latency. If construction is necessary, construction permits and coordination with local authorities will be necessary.
- **Installation and commissioning:** Installation must be performed by highly qualified technicians, as improper installation is often one of the main causes of deployment delays and can significantly degrade the performance of the network. Each hop needs to be commissioned and tested to verify that it meets design specifications.

OPERATION AND MAINTENANCE



Owning and maintaining an ultra-low latency microwave network should be as simple as possible. Even if with experience of operating an optical network, operating a microwave network requires specific understanding and expertise.

There are two approaches to solve the problem. Operators can hire staff dedicated to operate service and maintain the network. Although feasible it requires time and may well be outside the core competency of financial institutions, since maintaining a microwave network requires special skills—like climbing towers, for example.

A better approach is to work with an experienced partner that can offer a complete managed service, where the operation and maintenance of the network is outsourced to a specialist that can reduce OPEX, optimize network performance, and provide the flexibility to expand the network and meet unpredictable traffic demands. Even if the financial institutions deem it necessary to have some “in-house” capabilities to operate and maintain the network, the support of an experienced partner can make all the difference and ensure greater success in a competitive market.

CONCLUSIONS

Microwave is the new default transport solution for ultra low-latency applications for the following reasons:

- Microwave is faster than fiber (It’s physics!)
- Cutting edge microwave solutions are now available with extremely low latency and configurations and system reliability
- Microwave can significantly shorten routes by overcoming obstacles in the field
- Microwave can adapt to changing conditions, such as availability of new frequencies or shorter route alternatives

High performance and reliable low latency networks are critical, since down time can result in lost opportunities that impact the bottom line. Therefore, it is crucial to select an established and stable microwave vendor that not only provides exceptional and reliable technology but also is a partner you can trust and rely on to deliver continued support throughout the life-cycle of your network providing the lowest end-to-end latency.

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