BELL LABS INNOVATIONS

STRATEGIC WHITE PAPER

COMPLETE MICROWAVE SOLUTIONS FOR THE U.S. GOVERNMENT

Government Agencies and Departments can minimize the complexity, mitigate the risks, and reduce the costs of deploying wireless microwave systems by choosing a capable partner.

Choosing a partner with excellent experience and past performance reduces the overall project risks. LGS Innovations is:

» A partner that understands the complexities of microwave systems and has the skills to manage them allows for projects to be completed on time.

» A partner that uses sophisticated design tools to ensure that the deployed system will actually work.

» A partner that utilizes world class products and services, providing the flexibility and high availability that microwave solutions require.

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COMPLETE MICROWAVE SOLUTIONS

1. ABSTRACT

For 50 years, microwave transport has been the primary selection for transport technology. Wireless networks have proven to be more cost effective for areas exhibiting high terrain challenges and extreme remoteness, avoiding the high labor costs associated with deploying new wireline facilities in such areas. Key factors such as rights of way, availability of power along the right of way, trenching, and cable procurement do not become issues with microwave systems. However, microwave solutions do present some unique challenges that must be well understood, designed for, and considered during deployment. An experienced services team using proven product technologies is the best choice for providing the high quality and high bandwidth required for a transmission system that fulfills the Government's demands.

2. INTRODUCTION

Many government organizations have chosen microwave transport for network bandwidth, either for the entire network configuration or for portions of the network to complement or backup an existing wireline network. The majority of government systems have been deployed within what is called the "government band" which runs from 7.125GHz to 8.5GHz. This frequency spectrum provides enough network bandwidth to handle a variety of government applications such as voice channels, data applications, video transmission, sensor or surveillance camera data, and land mobile radio. Transmission capacities can range from DS-1 channels, DS-3 channels, OC-3 SONET transmission, and Ethernet network bandwidth up to 300 Mbps.

With the recent enactment of the Advanced Wireless Services (AWS) program, the FCC conducted a spectrum auction for microwave frequencies within the 1.7GHz spectrum. Many government agencies were operating in this frequency range and were instructed to evolve their microwave systems to a different frequency band such as the 7.125GHz to 8.5 GHz spectrum.

Some government agencies elected to shift to what is considered as the upper 2GHz band, which runs from 1.755 to 1.850GHz. This can be considered the second "government band" utilized by government agencies for microwave. This spectrum is smaller in size and can accommodate traffic demands up to 16-DS-1s.

3. SOLUTION ELEMENTS

A microwave solution generally consists of many distinct elements which together provide a complete and working system. No single company provides all of the elements of a complete microwave solution; thus the teaming of key companies and providers becomes essential. However, to ensure that this teaming results in a complete, working system requires detailed knowledge of each company's offerings, experience, and history of successful past performance, as well as extensive testing and characterization of functionality.

At the heart of any microwave solution is the microwave equipment. This equipment interfaces with the applications at a transmission rate of DS-1, DS-3, OC-3, or 10/100/1000 Ethernet. The equipment then modulates the data applications using

techniques such as Quadrature Amplitude Modulation (QAM), Trellis Coded Modulation (TCM), or some level of Phase Shift Keying (QPSK for example). These modulation/demodulation techniques have been in use over the last 25 years in coding digital waveforms for transmission over a carrier frequency and a set of frequencies known as a channel. As a rule of thumb, the higher the channel frequency, the shorter the microwave path; conversely, the lower the channel frequency, the longer the microwave path.

Besides incorporating the modulation/demodulation of digital signals, the microwave equipment incorporates power amplifiers to induce signal gain, thus accommodating the path loss that is derived from the atmospheric conditions of the microwave path as well as associated cabling losses from the microwave equipment to the transmitting or receiving antenna systems. Thus the longer the microwave path, the higher the atmospheric losses, which may lead to higher gain systems being required.

Microwave equipment comes in two configurations: an indoor package and a split package. Indoor configurations incorporate all of the active electronic circuits such as modulation/demodulation, application physical interfaces, and power amplification within the indoor microwave shelf. This shelf then transmits signals over a cable facility, known as waveguide, to a passive antenna parabolic. The split package has an indoor shelf that provides application interfacing, transmitting these signals over a cable system, typically coax, to an active unit on the back of the antenna called an Outdoor Unit (ODU). This element provides the modulation/demodulation and power amplification for the transmission.

Most deployments of microwave systems for government organizations have been of the indoor package type. These systems provide the benefits of higher signal amplification for longer paths. They also remove any active components near the antenna and therefore may reduce overall maintenance costs. Some government agencies prefer a split package design if their microwave paths are of short or medium length, particularly if they are concerned over microwave to antenna cable losses, which are higher using waveguide systems.

Microwave systems are line-of-site transmission systems requiring a transmitting antenna to be carefully aligned with a receiving antenna. Antennas are typically parabolic designs and can range in size from 1 foot diameter to 15 foot diameters. The rule of thumb is that the longer the microwave path, the larger the antenna requirement. Antennas can be standard performance, high performance, or ultra high performance based on how congested the frequency spectrum is within a given geographic area. They can be equipped with radomes, which are covers for the antenna that reduce affects of dust, rain, and snow, and also minimize wind loading.

Wind loading is an important aspect to antennas because of damage that can occur or miss-alignment in the line of site transmission. Antennas can support wind speeds, depending on antenna size, up to 200 mph. Microwave antennas are placed on towers and are located at a position called a “centerline”. This is the physical height on the tower. Towers can range from as little as 50 foot in height to 1000 feet. Tower height is defined by the overall microwave design which stipulates the antenna centerlines required for line of site transmission on a particular path. Antenna centerlines must always be less than the overall tower height.

There are various types of towers, including the monopole, which is a singular pole; the Self Supporting Tower (SST), which is a 3 or 4 legged tower affixed to a cement foundation; the Guyed tower, with some level of foundation mounting but including high tension wired guides; and the camouflaged tower, which can resemble objects such as trees.

There is a wide selection of additional equipment and system elements that comprise a complete microwave solution. Some of these elements are functional equipment such as multiplexors, switches or routers that are required for the transmission of applications. Others are not directly associated with the transmission path such as security lights, shelters or fencing. The following table highlights some of the elements that are considered part of a complete microwave solution:

Routers	Switches	SONET Multiplexors	LMR Equipment	Channel Banks
Media Converters	Battery plant	Rectifiers	ATS switches	Generators
Waveguide	Coax	Dehydrators	Flanges	Manifolds
Cable Entry Facilities	Twist flex	Hangers	Security fence	Shelters
Door entry systems	Fuel tanks	Audible alarm systems	Network management systems	Security lights
Radomes	Conduit	Racks		Landscaping

4. PRODUCTS

LGS Innovations is able to supply all of the products associated with a microwave solution. As noted, no one company produces all of these products; however, LGS is able to supply them directly or through carefully chosen strategic partnerships. All functional solution equipment has been tested and characterized and has been deployed in multiple designs and configurations worldwide, giving LGS customers the assurance that their microwave solutions will work.

The primary microwave system that LGS provides is the Alcatel-Lucent MDR-8000, the most widely deployed microwave equipment within the U.S. It is a flexible microwave system that can support either the upper 2GHz frequency band or the 7/8 GHz band. It is designed for medium to long distance microwave paths and can support path lengths exceeding 40 miles. It accomplishes this by supporting the highest signal power amplification in the industry at 32 db. It can also support lower amplification for shorter paths ranging from 15 db to 30 db.

The Alcatel-Lucent MDR-8000 is flexible in its application interfacing and growth capability. It utilizes software based Capacity Key modules to increase a systems transmission capacity without having to change out or upgrade circuit pack modules. At the low end it can support up to two DS-1s and can be grown to thirty-two DS-1s, DS-3, OC-3, or Ethernet based. It is also flexible in its supported configurations. It can operate as non-standby or Hot Standby, which provides one-for-one protection of all microwave equipment functional elements. In addition, Space Diversity, Frequency Diversity, and Quad Diversity options are available.

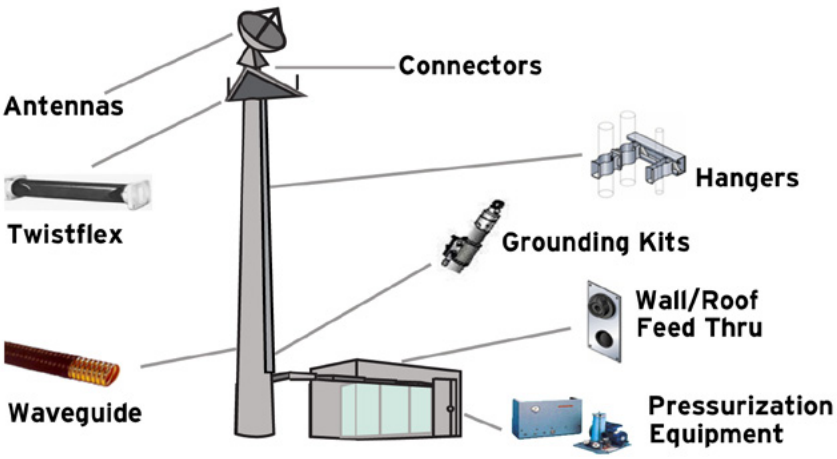
Automatic Transmitter Power Control (ATPC) is a standard feature of the Alcatel-Lucent MDR-8000 that improves the ability to coordinate radios in frequency-congested areas by allowing the radio to operate at lower power levels. ATPC can also be used to protect against up-fade conditions. Reducing the transmit power also provides an added benefit by increasing the life of the power amplifiers.

Key Features of the Alcatel-Lucent MDR-8000 include:

- Multiple Data Capacities - up to 8-, 12-, 24-, 50-, 150-, and 300-Mbps throughput
- Support of non-standby, non-standby space diversity, hot-standby, hot-standby space diversity, dual channel, and dual

channel space diversity configurations

- Combined data throughput of 300 Mbps in a single shelf
- Ethernet Port Switching
- Ethernet Port Aggregation



Microwave antenna systems including all miscellaneous equipment such as mountings, twist flex, manifolds, dehydrators, hangers, etc. are designed and directly supplied to LGS from its sister company, RFS. Antennas provided are a variety of types and sizes dependent upon the design requirements. Antenna sizes range from 1 foot to 15 foot diameters and can be standard performance, high performance, ultra high performance, or compact. Frequencies supported are 1.4 to 40 GHz for standard antennas, and up to 60 GHz for compact types. Antennas can be equipped with an optional spun back ring to provide additional support for high wind conditions. Antenna assemblies include all of the miscellaneous components to provide a complete design for the microwave to antenna transmission. All miscellaneous elements are carefully specified based on site-specific design requirements.

LGS supplies complete tower systems for a full turn-key approach for the outside plant elements. Tower types provided range from 50 feet to over 100 feet in height and can be monopole, self supporting, guyed, or camouflaged. Towers are specifically designed according to site conditions such as available land, soil conditions, microwave design requirements for antenna centerlines, antenna loading weight, and support for ANSI/TIA-222G standards and compliance of R56 grounding requirements.

LGS provides a wide selection of telecommunications shelters ranging in sizes from 4’ by 6’ to 24’ by 42’ and comprised of a variety of materials including steel, concrete, fiberglass, and composites. They can single elements or modular for those sites with minimal access. All shelters can include functional subsystems such as lighting, fire and smoke alarms, restricted door entry, attached HVAC systems, cable ladder racking, cable entrance facilities, and security lighting.

LGS also provides a wide selection of miscellaneous transmission equipment and systems to support the microwave solution. These elements consist of channel banks, multiplexors, power plant equipment, generators, automatic transfer switches, cement pads, conduit, routers, switches, alarm systems, and network management systems as required by the design.

A key element of a microwave solution is the network management system. LGS utilizes the TSM 8000 platform to manage the microwave equipment as well as SNMP-enabled telecommunications equipment within the design. TheTSM-8000 is a graphically oriented alarm monitoring and control fault management system. It automatically collects and stores alarm, status and performance data from the radio as well as SNMP alarms retrieved from the subtending equipment. It can also be used for remote provisioning of the microwave systems. Current network alarm status is displayed both graphically and textually. Automatic and on demand logically derived reports provide focused historical information.

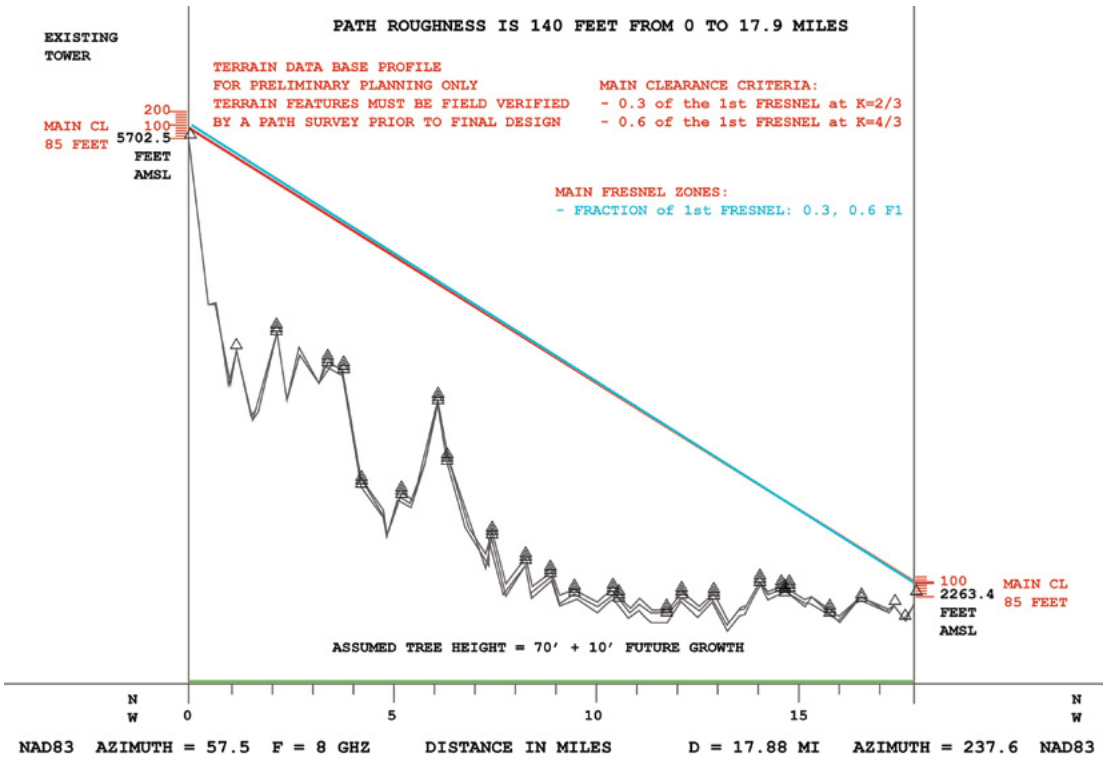
5. SERVICES

LGS provides the vast selection of support services that are required to successfully commission a microwave solution. The team skills that it conveys to a microwave project ensure that projects are designed and delivered correctly, on time, and within budget. Some of the various services are summarized in the following table:

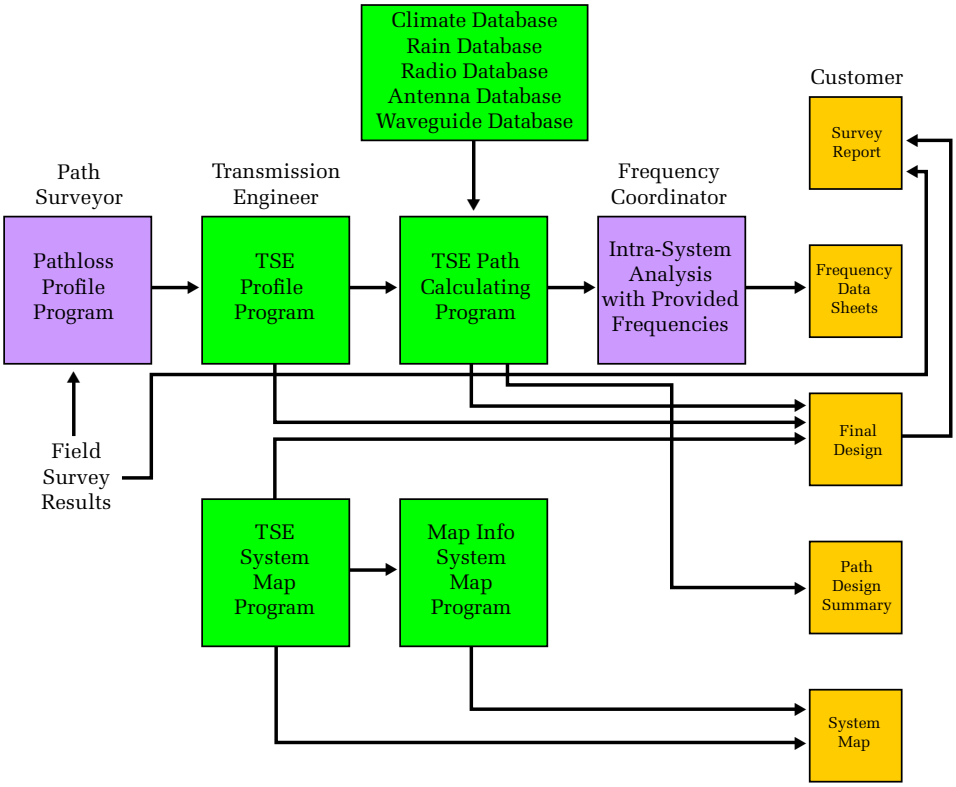
Path analysis design	Tower design	Tower foundation design	Foundation installation	Site surveys
Equipment engineering	Equipment and material procurement	Staging	Shipping and logistics	Factory test and integration
Detailed engineering drawings	Frequency coordination	Training	Equipment installation	Tower installation
Shelter installation	Antenna installation and sweeps	Program management	Management system installation	Maintenance and extended warranty
		Removal services		

5.1 Design Process

LGS Design Engineers use a structured approach in developing a microwave solution design. They begin this process with a full, detailed analysis of site specific requirements. They may couple this effort by conducting site surveys and assessments. They determine key understandings regarding the road access to the site, the site real estate and physical disposition, determine any removal of structures that are required, review available communications space, location of a power source, condition of existing shelters if available, and take GPS readings for the location of a new or existing tower. This effort allows them to develop a concise, site-specific bill of materials, to develop complete Statements of Work for each site, and provide key advice regarding the development of a program schedule.



With accurate GPS readings and a determination of specific transmission requirements such as path availability and bandwidth required, the LGS Design Engineers then initiate the development of a path analysis of the complete microwave solution. They utilize various software tools that provide the most accurate and stringent analysis of a microwave path design. The tools incorporate a 50-year database of regional rain coefficients, the most detailed and realistic in the industry. This database links to the North American Datum of 1983 (NAD83) data files for site coordinates as well as the U.S. Geological Survey (USGS) 30-meter terrain database to develop accurate path profiles to ensure the availability as specified. This analysis optimizes the system design parameters, transmitter power, antenna centerlines, tower height, and antenna size and polarization to minimize the total outage and interference for a given path and provides the most cost efficient overall design. The path profiles derived from this analysis are based on the main beam clearance for the first full Fresnel zone 1.0F1 for the standard effective earth's radius, K = 1.33, and for a worst case K = 1.



5.2 Detailed Engineering

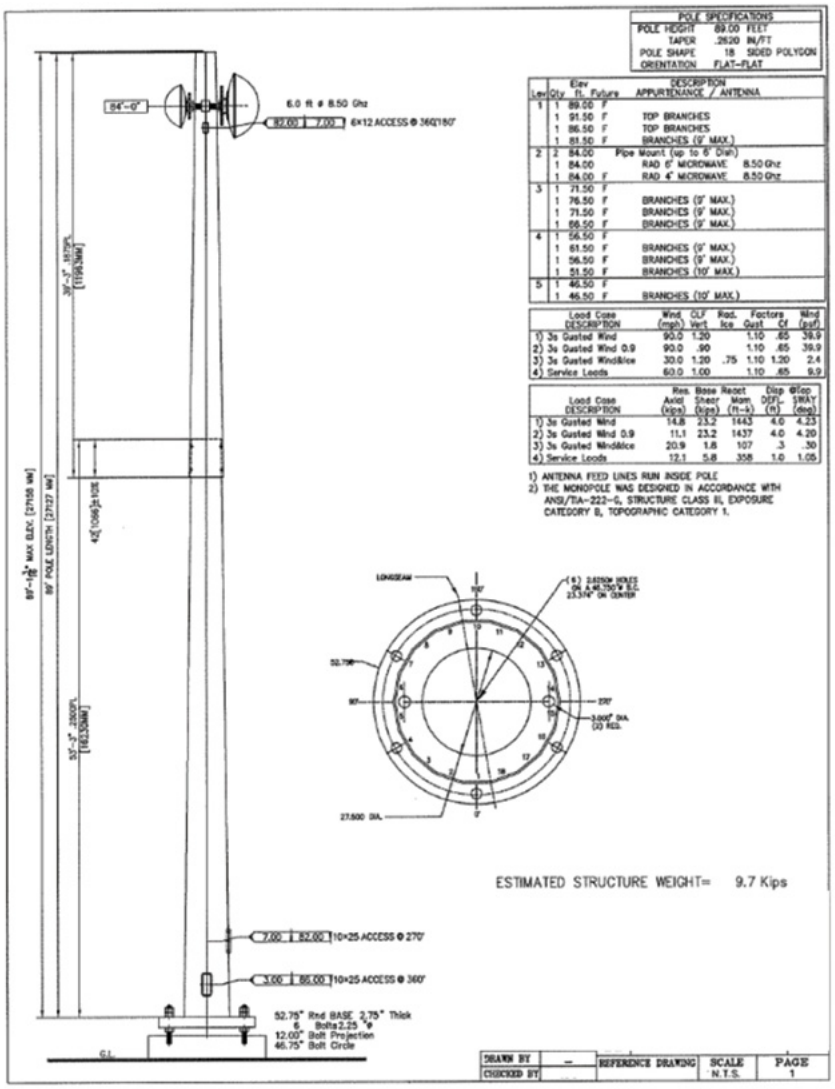
The LGS Design Team engages itself in the design effort of all outside plant elements such as tower design, tower foundation design, cable runs and conduit placement, fuel tank and generator sizing, power distribution and backup systems, and security elements such as lighting, door entry, and security fencing. They analyze site specific details and conduct site surveys and assessments to develop an accurate and complete material list and labor estimate for these areas.

The LGS Design Team utilizes the specifications for antenna sizes, weights, and centerlines defined in the path analysis report to develop a tower loading model. Load calculations include all antennas to be used in the system architecture, all antenna mounts and systems, including side arms for azimuth and elevation adjustment of each directional antenna, and all ancillary hardware such as ice shields, climbing ladders, waveguide ladders, and Radio Frequency (RF) transmission lines. Included in the tower design are site specifics derived from the site assessments. These load factor parameters are then utilized with the Tower Analysis software tool Guymast to assess strengths of members, guys, and twist and sway.

The output provides a detailed tower foundation design and tower design that conforms to all applicable tower standards including ANSI/TIA-222-G, Class/ Exposure Category and Topographic data as well as compliance with R56 grounding requirements.

The LGS Team also provides detailed configuration designs and drawings on all inside plant elements such as rack face layout designs, floor plan layouts, cabling diagrams, alarm configurations, and any IP addressing requirements. These designs and drawings are developed prior to any equipment deployment or installation to support required design reviews. All drawings are red lined as required to exhibit any modifications made to site requirements. The deliverable is a Professional Engineered Stamped drawing package that consists of the following:

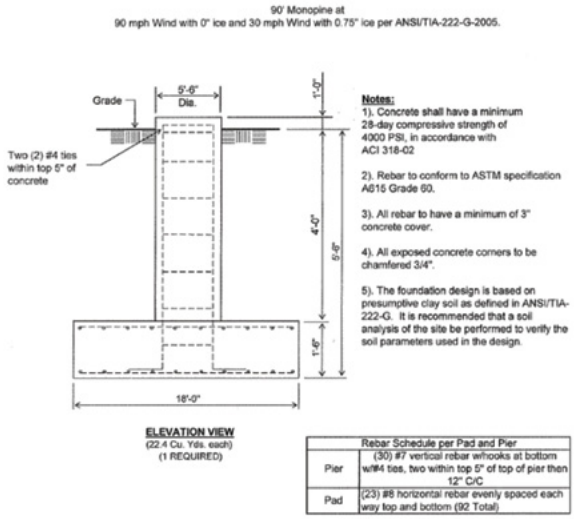
- Geotechnical Report and Site Survey Details
- Site Layout Drawings
- Tower Detail Drawing with calculations
- Tower Foundation Drawings with calculations
- Tower Installation Drawings
- Shelter Detail Drawing with calculations
- Shelter Foundation Drawings with calculations
- Shelter Installation Drawings
- Permits, as required



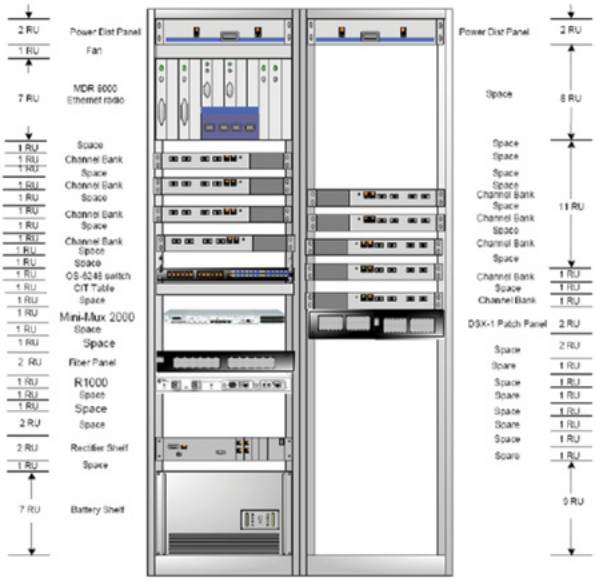
5.3 Deployment and Acceptance

The Deployment and Acceptance phase consists of all tasks required from a project award to final acceptance and turnover. These multiple tasks are managed by a certified LGS Project Manager and support a pre-defined program schedule to ensure completeness on time. The tasks involved are summarized as follows:

- Geotechnical analysis at each site
- Final path survey and path analysis
- Design modifications as required
- Final tower design and foundation design
- Finalize the Design Reviews and Program Schedule
- Begin equipment and material procurement
- Tower foundation installation
- Tower installation
- Factory testing of individual equipment
- Shipping and logistics plan



- Staging of all functional equipment
- Integration testing and network simulation
- Site specific shipment
- Site integration and field testing
  - Equipment inventory and check off as per the Bill of Material
  - Waveguide and antenna sweeps
  - Dehydrator Pressurization Test (4-hour test)
  - DC Power and battery backup test
  - Generator Test (Verify automatic transfer, frequency, and voltage)
  - Radio local and path testing including Power Supply, RF power out and LO Frequency, receive signal level, fade margin, ow, mcs-11 and elmc service channel verification, usi operation, transmitter, receiver and I/O switching, and 12-hour end-to-end Bit Error Rate (BER) tests
  - Add/Drop Mux Local Test if required
  - Fiber system testing if required
  - DS1 path end-to-end if required
  - Station Alarm Testing
  - Station Ground Test
- Site specific and network test results
- System acceptance



6. PAST PERFORMANCE

Proven experience in the design and deployment of microwave systems is an essential component for the evaluation of solution providers. As illustrated, microwave systems can be quite complex and only an expert team can assure a customer that the systems will operate correctly, that no surprises will occur, and that the overall project will be completed on time and within the defined budget. LGS and its team members have an extensive resume of successful design and deployment of microwave solutions. This experience extends world-wide and includes hostile regions where project schedules can be challenged. The following illustrates a sample of the LGS past performance through its parent company, Alcatel-Lucent:

- **Advanced First Responder Network (AFRN) Project**. Provided wireless communications at 70 sites to Iraqi First Responders, with an extensive microwave transport network for the interconnection of base stations, switching offices, and dispatch centers for the 16 largest cities.
- **FAA-LDRCL Project.** During the last 11 years, installed or supplied over 1,000 hops of microwave radio for the Federal Aviation Administration in the United States and its territories.
- **State of Florida (SLERS) Project**. Provided digital microwave backbone network for the State of Florida's statewide land mobile radio communications system consisting of 189 hops.
- **Central Iraq Microwave System (CIMS) Project.** Selected by prime contractor Galaxy Scientific Corp. to engineer and furnish a microwave system that provides connectivity between seven major U.S. Army sites in Iraq.
- **U.S. Bureau of Reclamation (USBR) Wyoming Project.** Provided engineering and technical services for seven backbone hops MDR-8708-155 OC-3 radios, 7270 Asynchronous Transfer Modes (ATMs), 3600/3620 Intelligent Channel Banks and seven spans of 7270 ATMs and 3620 Intelligent Channel Banks at the power plants, with connectivity to the local switchyards and connectivity back to the new USBR communications backbone.

- **U.S. Border Patrol Land Based Intelligence System.** Provided engineering and technical services supporting site preparation, installation, integration, testing, and final delivery of the system that replaced the 2 GHz system backbone and funnel back to Tucson Headquarters.
- **Okinawa Digital Microwave Upgrade (ODMU) Project.** Selected to provide the U.S. Army with microwave radios at 17 sites.
- **DISN-E Project.** DISA and the U.S. Army selected LGS for the replacement and capacity upgrade of the Defense Information System Network – Europe (DISN-E) microwave system. LGS has provided over 150 terminals of OC-3 radios that have been installed throughout Italy, Germany, and Belgium.
- **Operation Enduring Freedom.** Provided vital microwave connectivity in Kuwait for support of Operation Enduring Freedom. This project required turnkey systems implementation within 60 days of contract award and during the build-up weeks prior to the war in Iraq.
- U.S. Department of Energy PMA. Maintained a blanket purchase agreement for over seven years to facilitate the streamlined acquisition of microwave radios, ancillary equipment, and support services required throughout the Western United States.
- U.S. Air Force RSAII. Provided microwave upgrades for both the Eastern Range (Cape Canaveral Area) and the Western Range (Vandenberg AFB Area) launch complexes.
- Iraqi Republic Railroad. Engineered, furnished, installed, and tested a new Digital Microwave Radio Communications Network for the Iraqi Republic Railroad (IRR) that extends 1,200 kilometers interconnecting 33 railway stations from Turkey in the North (Rabiya) across Iraq to the Persian Gulf (Umm Qasr) in the South. Effort included microwave radios, 33 towers, 33 antenna systems, 33 environmentally controlled (transportable) equipment shelters, and 33 back up emergency generators. The project was a turn-key replacement of an existing seven-hop microwave system under the TIA/FCC Advance Wireless Service 2GHz Spectrum Relocations program. The tasks involved designing, installation, test, and activation of a new microwave point-to-point microwave network. The new system had to be developed and installed in parallel with the existing microwave to avoid interruption in mission-critical communication services.

7. CONCLUSION

Microwave transport solutions can be a cost effective selection for complete network designs or to complement or backup existing wireline networks. They are especially chosen for those sites that have terrain challenges or are considered remote. However, because of the complexities regarding the design and deployment of microwave solutions, solution providers should be selected based on their ability to provide world class products, provide a full compliment of design, deployment, and project management services, and have a proven track record on a global basis deploying microwave systems.

LGS with its key strategic partners delivers a world class suite of products to handle all types of application support and transport requirements. Our services offerings are extensive and utilize highly skilled personnel for the design, planning, scheduling, installation, commissioning, and overall management of a microwave solution program. LGS has demonstrated vast experience in all types of microwave deployments on a global basis and is indeed the partner of choice for microwave solutions.