MODEL COMPARISON OF LICENSED UHF AND SHF RF MESH COMMUNICATIONS IN SUPPORT OF DISTRIBUTION AUTOMATION

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ABSTRACT

This paper addresses the design and comparisons resulting from modeling two different wireless mesh communication systems in support of a distribution automation solution that utilizes communication enhanced coordination. The location of this distribution automation solution is a geographically remote isle and is rather unique, consisting of: farmland, developed areas, and coastline separated from the mainland by relatively small distances.

The two predominant radio types and spectrum choices are analyzed. The first is narrow channel UHF licensed band that provides good propagation characteristics but low throughput. The other is an SHF licensed band with much more challenging propagation characteristics but higher throughput capabilities, offering future performance demanding application support.

The problem addressed is the qualification and quantification of the capital equipment and operational expenditure required to adequately cover and operate the distribution automation field area network in the higher SHF band, versus the immediate and future advantages provided the radio system at the higher band.

Specifically, two separate radio subsystem designs are explained, and comparisons are made regarding projected performance expectations. The first system is a licensed 433MHz to 466MHz UHF OSI layer3 mesh that makes use of 4 independently tuned channels aggregated to provide 50KHz total occupied bandwidth. The other system is a licensed 5725MHz to 5850MHz Band C OSI layer2 mesh system with 20 MHz channel bandwidth that can also be used for Fixed Wireless Access services.

To address the problem in a timely, cost efficient, and risk tolerant manner, the different systems were modeled using industry proven mesh software tools, and the results compared.

The results indicate that use of the SHF band results in a 17% increase in radio site repeaters , a 40 times increase in throughput, and a 30 times decrease in latency. Such improvements could be used to facilitate remote location video monitoring and support future standards such as the IEC61850 protocol. This paper describes the specific field area network geography, the wireless mesh system modeling methodology, and the metrics provided such that an appropriate system and wireless band is chosen. Balancing these differences versus cost and future needs provides the utility operator with the information to make their best informed return on investment decision.

PROJECT REQUIREMENTS

The communication system must support the requirements pertaining to a smart grid communication network, comprising both SCADA traffic and support of a performance demanding smart grid distribution automation restoration application. The study consists of: 3 substations, 34 Pulseclosers and other switch locations, a peer to peer distributed intelligence smart grid application.

The performance requirements imposed on the communication system in support of distribution automation and communication enhanced coordination are:

- Peer to peer throughput of at least 100 kbps
- Peer-to-peer latency less than 100 msec
- Greater than 4 NINEs communication system network availability
- Power consumption < 15 W average
- 20 year viability, inclusive of equipment and spectrum support

The problem posed is to determine the best of 2 radio types, comparing a licensed 400MHz UHF and a 5.8GHz licensed SHF spectrum option. Of note, the more challenging propagation characteristics of the 5.8GHz spectrum will require additional repeater radios to ensure coverage is sufficient. The additional repeater radio volume required for the SHF band must then be compared to the UHF band radio volume (assuming their cost is similar), to arrive at an answer. This comparison is done with a RF mesh propagation and path analysis modeming tool (EDX) to arrive at answers for suitable system comparisons.

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A means to compare the UHF and SHF radio systems in terms of coverage and performance capabilities was sought. The most appropriate means to compare these were with an industry standard radio frequency propagation and path analysis tool.

The UHF licensed radio study was performed using actual site survey measurements taken over the geographical area on key radio links. The physical measurements were made with the UHF radios configured with the following frequencies: 454.44375, 454.45625, 454.61875, and 454.63125MHz. These physical measurements were then used to calibrate the EDX radio propagation and path modelling software package.

All key UHF radio paths were modelled with the following criteria:

- The conducted transmission power and antenna gains were tuned to be compliant with licensed frequency regulations for the licensed UHF spectrum
- Antenna heights were modelled from 3 to 8 meters above ground level
- A minimum of -110 dBm received signal strength indicator (RSSI) with 12 dB fade margin to provide over 100Kbps of throughput per radio link
- All radios are designed to have at least one alternate path to route the traffic in case of primary route failure, in order to achieve at least 4 NINES system availability

Utilizing the physical measurements, the RF path models were tuned and the model executed. It was determined that for sufficient coverage, 11 radio repeaters would be required for the UHF radio solution.

Therefore, the Total Sites and Distribution Automation assets required were determined to be the 11 radio repeater sites, 3 substation sites, and 34 Distribution automation end devices, for a total of 48 UHF radios. Each radio link in this design would provide support over its aggregate 50 KHz of bandwidth of at least 108 Kbps.

The SHF radio design was performed using the same desktop RF model (EDX) that employed 30 meter Digital Elevation Models (DEM), and land cover databases in the geographical project location, purchased from EGS Technologies Corporation. The primary purpose of this model was to understand the feasibility of using SHF licensed radio where the SHF 5.8 GHz band is licensed in the UK. Additionally, this study would also assist to determine the numbers of repeaters required and total bill of materials cost when comparing a higher SHF licensed band radio system with UHF licensed band radio system.

Radio site locations and distribution automation assets to be connected were defined as the same as with the UHF radio. Again, transmission power and propagation losses were considered to be at maximum 5.8GHz licensed conducted transmission power and antenna gain regulations.

All key SHF radio paths were modelled with the following criteria:

- All radio links were designed based on -90dbm RSSI in the 5.8GHz SHF band
- All links would have at least 12dB fade margin
- All radios are designed to have at least one alternate path to route the traffic in case of primary route failure, in order to achieve at least 4 NINES system availability
- One of the three primary substations pole heights had to be raised to 15 meters and other 2 substations pole to 8 meters height
- Suitable power sources for repeater locations utilized a best guess method to find new locations based on Google Earth and street view wherever available.

SF model results uncovered that an additional 8 repeaters for the SHF solution over the UHF solution are required.

Additionally, compared to the UHF 108 Kbps throughput, the SHF throughput per link would provide a minimum of 6 Mbps throughput per radio link.

Figure 1 illustrates an example of the SHF radio link locations, mesh topology model achieved.

Figure 1. SHF radio design system mesh

The link color in Figure 1 illustrates the resulting path loss over the radio link as indicated in Figure 2.

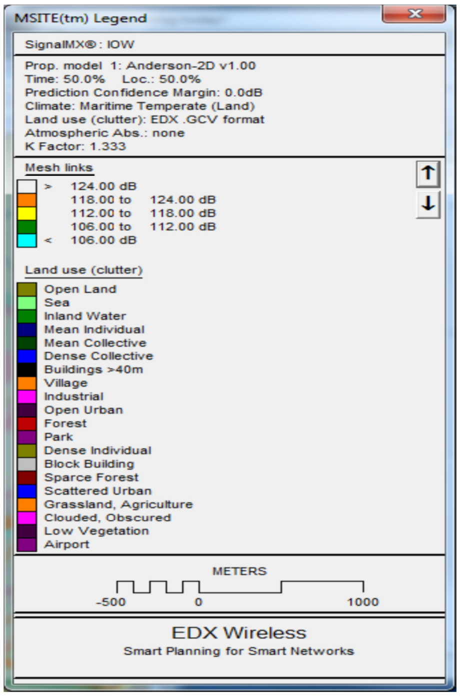

Figure 2. SHF radio design link path loss and clutter

In this model, the link color corresponds to:

- Orange: 118-124 dB path loss
- Yellow 112-118 dB path loss
- Green: 106-112 dB path loss
- Cyan: <106 dB path loss

Note that links with > 124 dB path loss are not shown.

STUDY CONCLUSION

Upon closely studying the RF design of both UHF and SHF licensed radios in this project, it is determined that higher band licensed SHF radio can be expected to provide similar radio coverage as UHF licensed with the addition of 8 repeaters sites (8 radios).

Assuming license cost for UHF and SHF bands are comparable, and a comparable radio cost, the additional capital investment for 8 additional SHF radios over the 48 UHF radios implies a 17% additional capital investment.

Further comparing the latency characteristics of the radios, the UHF latency is on the order of 40 msec per radio link, and the SHF radio is on the order of 1 msec latency per radio link. The improved latency of the SHF radio enables faster distribution automation isolation and restoration. Additionally, the improved latency also enables other applications such as VOIP, video surveillance, and IEC61850 latency – satisfying the requirements for future proofing the deployment for future application demands imposed on the communication subsystem.

Finally, the SHF radio with up to 20 MHz of spectrum can provide capacity from the minimum 6 Mbps at the lowest link speed, to 30 Mbps in better signal strengths. Such throughput would further support applications such as video surveillance, and would provide enhanced Return on Investment as security requirements and future application throughput demands penetrate the deployment.