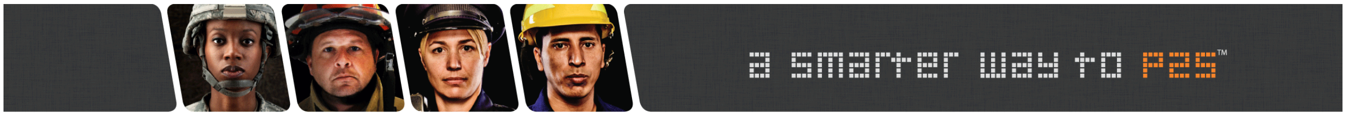


ATLAS™

Simulcasting Project 25

2013 April

EFJohnson TECHNOLOGIES

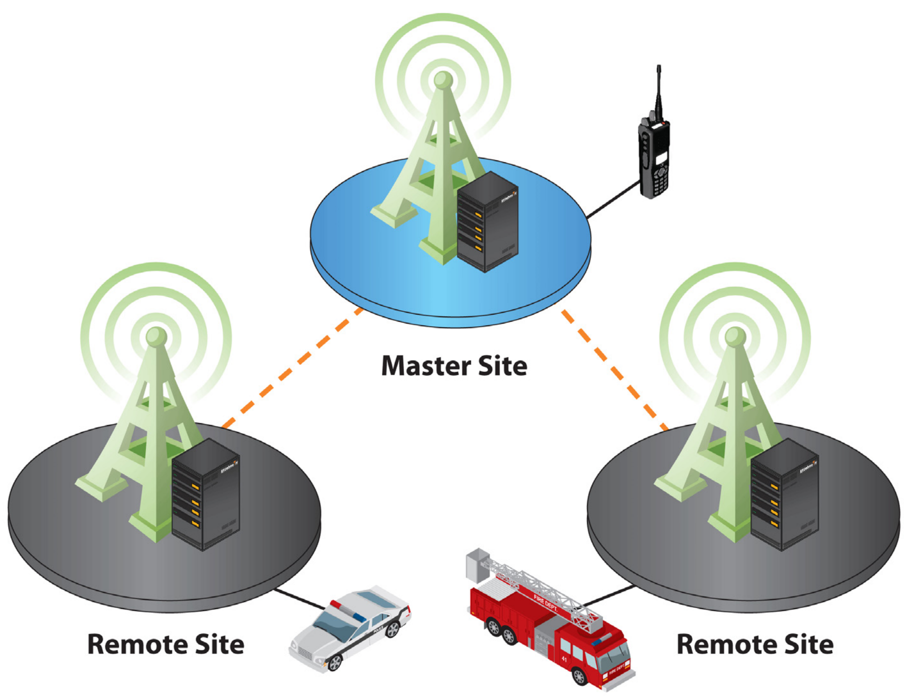
1440 Corporate Drive | Irving, TX 75038 | 972.819.0700 | www.efjohnson.com

Introduction

Simulcast is a technique used to provide Wide Area coverage from a radio system to subscriber radios. In a simulcast system, the same radio signal is transmitted by two or more transmitters on the same frequency from different locations. The intent of simulcast is to extend the radio coverage to an area larger than a single transmitter can cover, while utilizing a single frequency.

Simulcast systems have a single master site and multiple remote sites. The master site *synchronizes* the system timing, so calls are transmitted simultaneously to all sites for a given repeater channel. This synchronization reduces the quantity of frequencies needed for the system and simplifies frequency coordination.

Figure 1 *Simulcast System*



In locations where the signal level from one transmitter is much larger than from another transmitter, such as when a subscriber radio is close to one of the transmitters, the capture effect ensures that the signal from that close transmitter predominates, and the weak signals are rejected.

ATLAS™ supports analog conventional, P25 conventional, and P25 trunked systems

In an area where the subscriber radio is nearly equidistant from two or more transmitters, the received signal is a composite of all of the transmitters in range. This area is known as the overlap region. It is in this region that particular degradations can occur to the reception of the signals, due to signal addition and cancellation effects.

Often in the design of systems the overlap region, where practical, is purposely placed in areas where few radio users are located, such as over a lake or in areas of rugged terrain.

EFJohnson’s ATLAS™ simulcast systems support analog conventional, P25 conventional, and P25 trunked systems. Auto-discovery, tuning, and network delay compensation result in quicker system turn-up and reduced maintenance activities.

Conversion from an ATLAS P25 conventional simulcast system to an ATLAS P25 trunked simulcast system is made simple, primarily through a software upgrade to the ATLAS controllers.

ATLAS Simulcast System Benefits

No need for dedicated prime site or prime site controller

Typically, a simulcast subsystem is deployed in a separate prime site that hosts the voter comparators, simulcast controllers, and the simulcast subsystem controller. These subsystems rely on the constant availability of the prime site or require the deployment of expensive, redundant prime sites to provide communication, in case of a prime site failure.

The unique design of the EFJohnson ATLAS simulcast subsystem eliminates the need for a dedicated prime site or a prime site controller. The availability of a *simulcast controller* and *voter comparator* (together known as a *traffic manager*) in each repeater enables the distribution of the prime site functionality of each channel to different sites. Any repeater can become the prime for a channel.

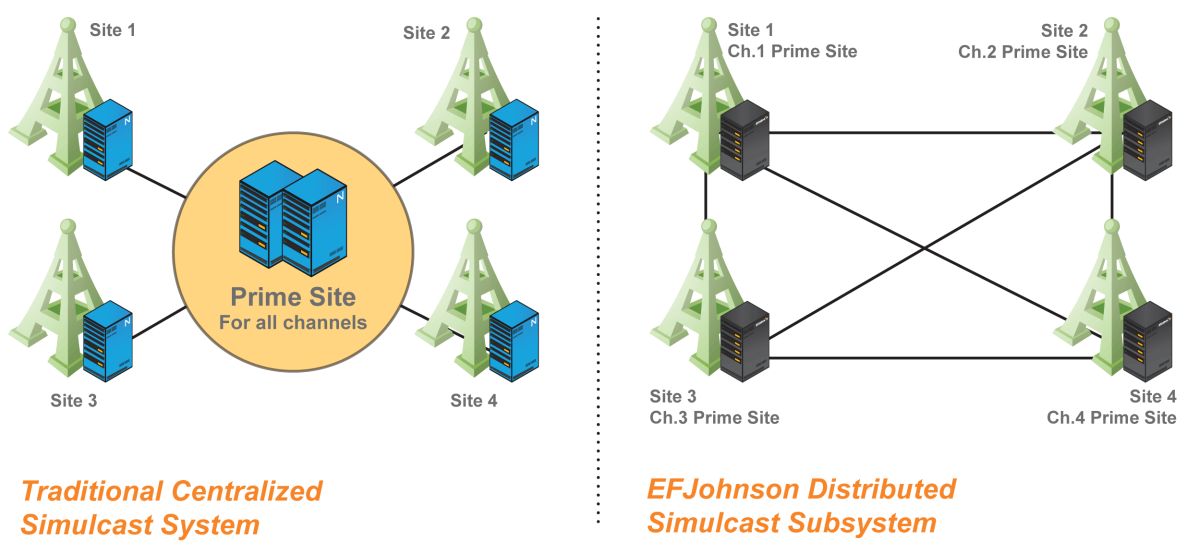
One of the repeaters is configured from the NMS to be the prime. Other repeaters are configured as standbys and only become prime if the primary voter comparator/simulcast controller fails.

The unique distributed architecture of the ATLAS solution also eliminates the need for a central controller to process calls. Instead, the simulcast subsystem controller performs control for all calls. If the primary subsystem controller fails, one of the hot standby redundant subsystem controllers becomes active.

Unlike a traditional simulcast system, the ATLAS system does not require any tuning of equipment to control the launch time. Auto-discovery, tuning, and network delay compensation result in quicker system turn-up and reduced maintenance activities.

The following figure illustrates a simulcast subsystem operation.

Figure 2 *Simulcast Subsystem Operation*



Simulcast Operation Aspects

Various aspects of simulcast operation are explained in the following sections:

- **Key Parameters**
- **Modulation Varieties**
- **Analysis of Delay on page 5**
- **Simulcast System Performance on page 5**

Key Parameters

These key parameters are important for proper operation of simulcast:

- **Transmitter Frequency Stability**: For proper operation, the frequency of each transmitter needs to be kept at nearly the same frequency. This is usually accomplished by employing high stability frequency references for the transmitters.
- **Modulation Balance**: This balance is an important factor where the individual modulation deviations are held to close tolerances.
- **Signal Launch Time**: The launch time of the modulation signal must be such that the signal arrives from the various transmitters at the receiver at nearly the same time.

Each of these parameters is integral to achieving good performance in both analog and digital simulcast systems.

Modulation Varieties

The modulation used for digital Project 25 is actually a family of modulations of the *Quadrature Phase Shift Keying* (**QPSK**) family. Since all of the modulations of the family are compatible, in the sense that they can all be received by the same receiver, the family of modulations is known as *Compatible Quadrature Phase Shift Keying* (**CQPSK)**.

Among the most commonly used modulations are:

- *Compatible Four-level Frequency Modulation* (**C4FM**).
- Variants of the QPSK modulation, for example, *Linear Simulcast Modulation* (**LSM**), may be optimized for particular characteristics, but remain compatible with the family of modulations.

The C4FM modulation is a constant envelope modulation most closely associated with Frequency Modulation. This is the modulation that is used by most, if not all, subscriber radios. Base station transmitters, however, use a variety of modulations including C4FM, or variants of CQPSK modulation. In particular, the CQPSK modulations require linear transmitters to faithfully transmit the non-constant envelope signals.

Analysis of Delay

Two signals transmitted at precisely the same time will arrive at a receiver at different times, depending on the distance that the signal travels. This difference in arrival times of the two signals time is known as *delay*.

Analyzing the effects of signal fading and delay is complex; however, a technique has been proposed to create a metric for analyzing the effects of delay [1]. The technique relies on a parameter known as *delay spread*, which is an rms average of the signal delay weighted by the power of that signal. This parameter provides a single-number metric related to the performance of the system.

Delay spread of signals and deployed modulation characteristics help predict system performance

Knowing the delay spread of the signals and the characteristics of the deployed modulation, system performance can be predicted. Using the delay spread model, performance characteristics can be measured on actual equipment.

Industry standard measurement methods have been developed to assess the delay spread performance of receivers under various modulations [2]. This measurement involves supplying a signal consisting of two independently-faded signal paths with different delays to the input of a receiver. The delays are adjusted until a reference *Bit Error Rate* (**BER**) is achieved. The associated delay gives a delay spread figure of merit. The delay spread capabilities of the various modulations are predominantly a function of the characteristics of that modulation.

In general, the QPSK linear modulations will have delay spread capabilities that exceed that of C4FM by a certain percentage. Given the delay spread capabilities of the various modulations, it is possible to predict system performance for the applicable modulation type and thereby design the system to meet coverage and propagation requirements.

Data and performance curves have been generated for the various modulations that are associated with Project 25 systems [3]. These show the relative performance differences between the various modulations.

Simulcast System Performance

Quality performance achieved using C4FM with delay spreads of ~ 40 µs

A well known figure of merit for simulcast system performance given in reference [3] is a *Delivered Audio Quality* (**DAQ**) score of 3.4. Curves of the various modulations show that this performance can be achieved using C4FM modulation with delay spreads of approximately 40 µs or below.

A similar figure of merit for some of the deployed QPSK modulations is on the order of 70 µs. When delay spreads are held below these respective numbers, any of the modulations within the family of Project 25 modulations can be used in simulcast systems with acceptable performance.

Outstanding simulcast performance with C4FM on systems designed with delay spread considerations

Often when designing system coverage, it is possible to optimize a system based on delay spread predictions. This can be done in a number of ways:

- Optimizing location and spacing of the various transmitter sites
- Tailoring antenna patterns
- Varying launch time of the signal on a site-by-site basis to minimize locations of large delay spreads.

Using these methods, system design is optimized to employ any of the possible Project 25 modulations, including C4FM. Field testing conducted with several systems at various locations has shown outstanding simulcast performance using C4FM modulation on systems that have been designed with delay spread considerations in mind.

Simulcasting P25: Myth vs Reality

This section contrasts five myths about simulcast P25 with the actual facts (reality) for each.

Myth #1

The Myth

Simulcast delay spread is most problematic in the overlap regions in a simulcast system.

The Reality

In reality, the overlap region in a simulcast system is the area in which delay spread is most predictable. Since this region generally occurs equidistant between two or more sites, the difference in signal delay is generally very small, and delay spread is not usually a concern.

Myth #2

The Myth

Delay spread is the only criteria for simulcast performance.

The Reality

In reality, there are many aspects to simulcast performance, of which delay spread is only one. With proper system design, frequently the effects of delay spread can be minimized.

Myth #3

The Myth

All transmitters transmit at the same time in a simulcast configuration.

The Reality

In reality, the launch delays of the various sites are individually programmable. Therefore, it is possible to analyze the simulcast system and optimize the individual site launch delays to minimize the effects of delay spread.

Myth #4

The Myth

The maximum distance between sites in a simulcast system cannot exceed 13 miles.

The Reality

In reality, distances of up to 20 miles are possible, with proper design and optimization of the various system parameters.

Myth #5

The Myth

LSM is the only modulation technology that can perform well in simulcast configuration.

The Reality

In reality, when a system is designed and optimized for delay spread, often a modulation, such as C4FM, can be quite effective for use in simulcast systems.

Simulcast System Case Study

Field trial performed to assess ATLAS P25 performance with C4FM modulation

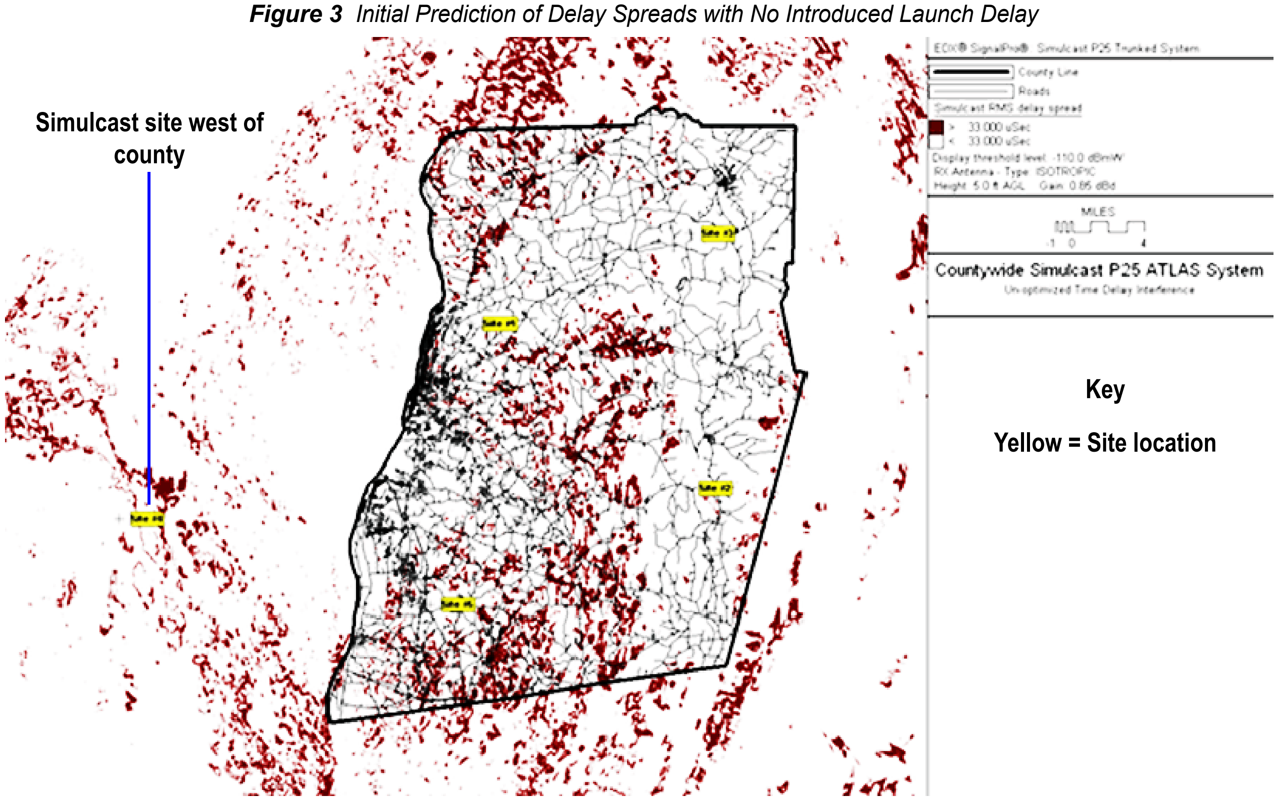
We present results from a field trial EFJohnson conducted (with the co-operation of the customer) in Rensselaer County, New York in October, 2012. This field trial was performed to assess the performance of the ATLAS P25 system using C4FM modulation.

Rensselaer County operates an 800 MHz six-site analog simulcast system, consisting of five channels per site. The trial involved replacing one of the channels at each of the simulcast sites with a single-channel Project 25 simulcast repeater. The resulting simulcast channel was used to evaluate the system performance. For convenience, the number of simulcast sites was reduced from six to five for the trial.

Prior to the trial, coverage prediction software was used to predict simulcast delay spreads throughout the county. **Figure 3** shows the delay spread predictions for the county. The red areas are where predicted delay spreads exceed 33 µs. The criterion of 33 µs was chosen to give a conservative value for meeting the DAQ 3.4 goal. Note that there are a fair number of areas where the delay spread does exceed 33 µs.

Coverage predictions showed that the simulcast site located *west* of the county will be responsible for causing the majority of the delay spread issues. The delay issues were attributed to the fact that the site is in a prominent location, and covers virtually the entire county.

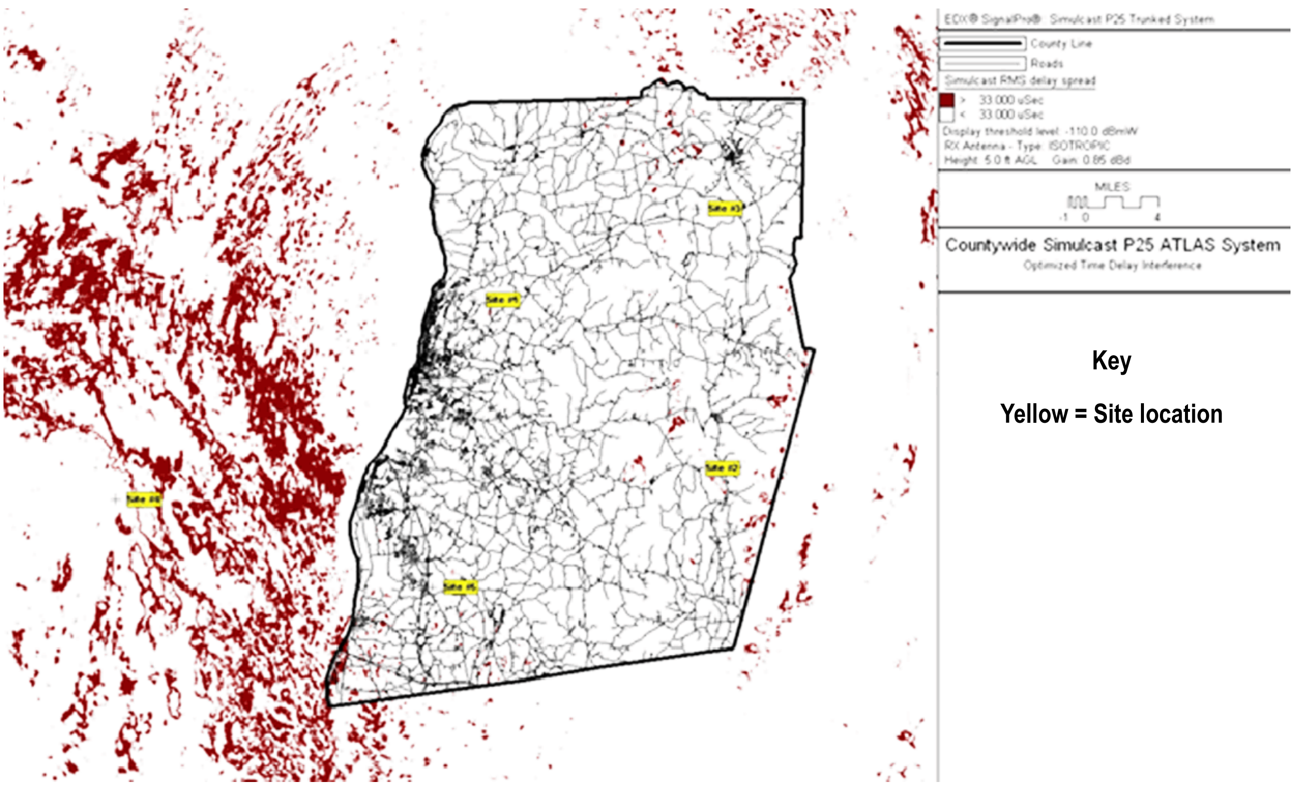
Figure 3 *Initial Prediction of Delay Spreads with No Introduced Launch Delay*



To optimize the design of the system, the EFJohnson and customer field trial team noted that if the western-most site signal were launched prior to the launches of the other sites, the result would be less delay spread throughout the county. The team accomplished this by adding delay to all sites within the county, while *not* delaying the launch of the western-most site.

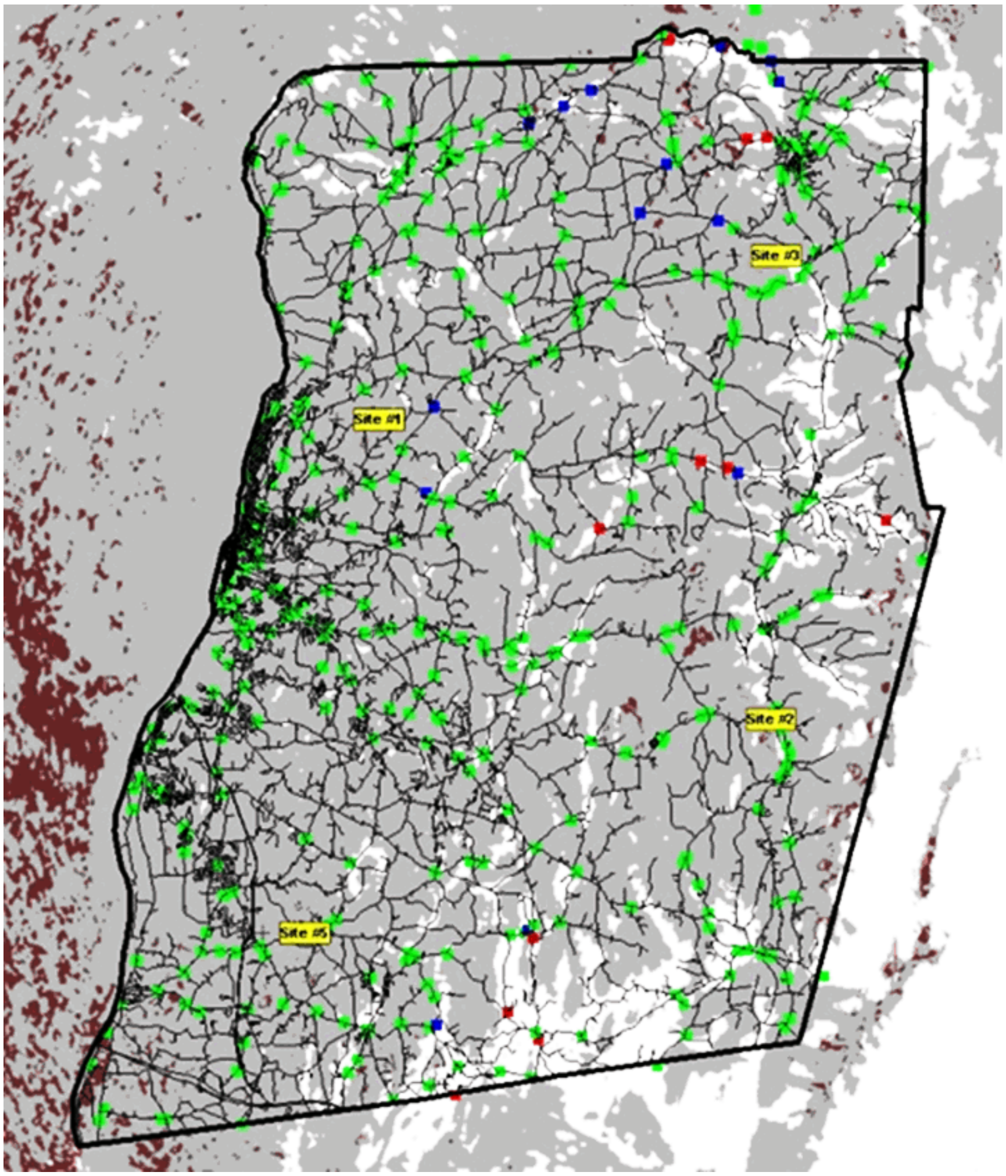
Applying a launch delay of 70 µs to the sites within the county resulted in the delay spread illustrated in **Figure 4**. This configuration was used for field trial implementation.

Figure 4 *Delay Spread Prediction with Optimized Launch Delay*



The field trial team tested the system coverage at various locations, to determine the resulting audio quality. The goal was to meet or exceed a DAQ value of 3.4. The results of these tests are illustrated in **Figure 5 on page 11**.

Figure 5 *Signal Quality Test Results*



Key

- **Green = DAQ 4 or 5**
- **Blue = DAQ 3.4**
- **Red = DAQ 1 or 2**
- **Yellow = Site location**
- **Gray = Predicted RF Coverage**
- **Maroon = Delay Spread > 33 µs**

Keeping delay spread predictions in mind when using C4FM modulation results in good simulcast system performance

As shown in the map in **Figure 5 on page 11**, a DAQ of 3.4 or better was obtained in the majority of locations throughout the county. The predicted coverage estimated that 95% of the area coverage would achieve a DAQ of 3.4 or better. Measured results exceeded this estimate with 97% acceptable coverage.

For the locations testing at DAQ 2 or lower (indicated by red dots in **Figure 5**), the perceived cause for poorer performance was attributed not to delay spread issues, but simply to inadequate signal strength. The signal strength issue was due primarily to terrain and site placement issues.

The results of the test show that good simulcast system performance can result from the use of C4FM modulation, provided the system is designed with attention paid to delay spread predictions.

Summary

There is a common (mistaken) idea that C4FM is not an acceptable modulation for use in simulcast systems. It is sometimes believed that the use of C4FM modulation will cause severe degradations, especially in the overlap regions. However, overlap regions are often those where delays between the various signals are minimal.

Judicious system design can result in minimal simulcast delay spread. When properly designed, any of the Project 25-compatible modulations may be used successfully in simulcast systems.

References

- [1] Hess, G., Land-Mobile Radio Systems Engineering, Norwood, MA, Artech House, 1993.
- [2] TIA Standard, "Digital C4FM/CQPSK Transceiver Measurement Methods", TIA-102.CAAA-C, September 2008.
- [3] TIA Standard, "Wireless Communications Systems Performance in Noise and Interference-Limited Situations, Part 1: Recommended Methods for Technology Independent Performance Modeling," TSB-88.1-D, April 2012.