Section 2 – Theory of Simulcast Operations

2.1 Criteria for Good Reception

When a receiver is in range of more than one transmitter operating at the same frequency, the criteria for good reception include relative signal strength and total transmission delay. Relative signal strength describes the relationship of two or more transmitted signals at a common receiver. In the case of transmitters with overlapping coverage areas, the relative signal strength varies depending on the geographic location of the receiver within the overlap area. Total transmission delay is the elapsed time interval calculated from the moment the signal leaves the origination point to the moment it reaches the receiver. This delay can differ from one transmitter to another, based on the signal path of the specific origination point-transmitter link.

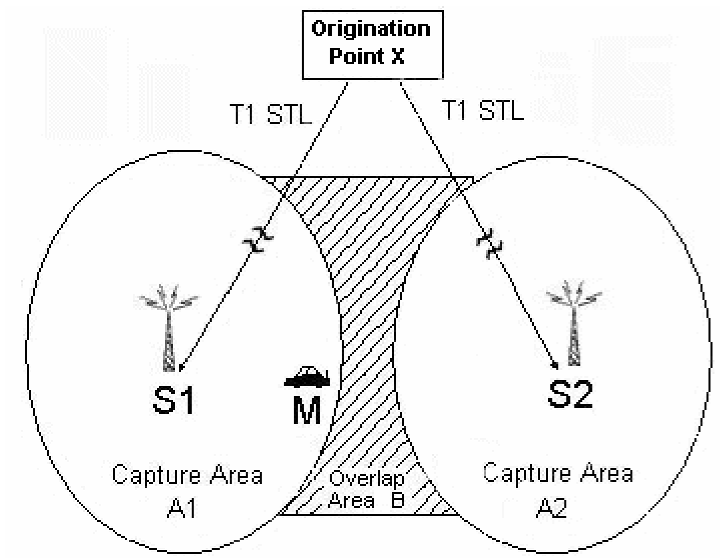

Figure 2-1. Impairment Compared to Relative Delay and Protection Ratio

Figure 2-1 illustrates the relationship between delay and relative signal strength. The figure shows an FM transmission system in which the same audio program is simultaneously transported from Origination Point X over communication links to two transmitter sites (S1 and S2). In this example, both sites have equal transmission power. The total transmission delay between the origination point and each transmitter is different, based on an unknown number of devices in the electrical path.

When the radio receiver "M" is located in capture area A1, the receiver locks in the transmission from site S1 due to the "capture effect" of FM receivers. This is because the signal from S1 is much stronger in Capture Area A1 than the signal from S2. When the receiver is located in Capture Area A2, the reverse situation occurs.

When the receiver is located in the Overlap Area B; however, it receives signals of almost equal strength from both transmitter sites. In this case, the receiver can jump between capture of either or admit both. Since the receiver is capturing both signals, it is critical that the signals be time-aligned so that the listener does not hear artifacts or a distorted audio signal.

Effective implementation of the SynchroCast3 system is based on successful balancing of relative signal strengths within the overlap areas and aligning the audio delay at the precise targeted geographic location. Figure 2-2 depicts the contours of relative signal strength from both sites. In Overlap Area B, the relative power levels differ by less than 6 dB.

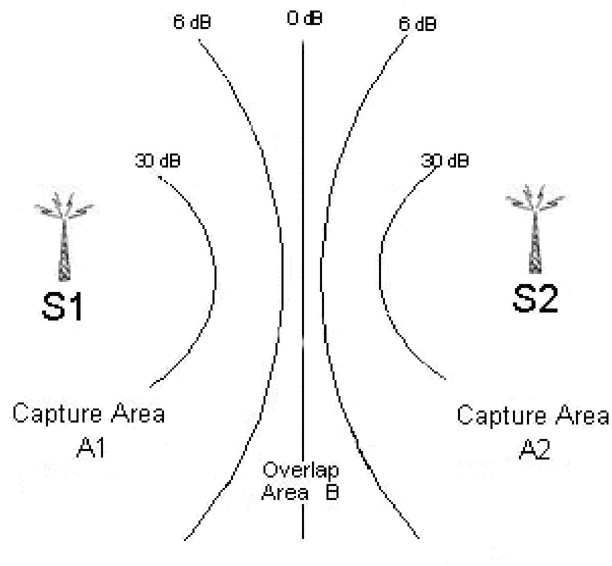

Figure 2-2. Overlap and Capture Areas

Because the origination point distributes the same FM audio program or voice traffic using IP, T1, or E1 circuits in the public-switched telephone network, different time delays occur between the origination point and the receiver in the overlap area, based on their locations. Factors affecting the total transmission delay time can include

- Audio processing equipment delay.
- IP, T1, or E1 network path delay.
- Air path delay.

In the overlap area between two adjacent transmission sites, good reception requires equalizing time delay and phase alignment of the audio.

Now, consider the relationship between the air path delay and the distance between the receiver and the two transmitter sites. Regardless of the signal power strength of the transmitter, the distance between the receiver and the transmitter determine the contours of the air path propagation delay.

As shown in Figure 2-3, if each transmission site gives the same signal at exactly the same time, there is a line of equal delay that lies exactly halfway between them, perpendicular to a line connecting them. A receiver located anywhere on this line gets exactly the same signal at exactly the same time from both transmitters because the RF propagation delay from each transmitter is exactly the same for all points located on this line.

Other lines can also be defined along which a receiver picks up the signal from one transmitter at a constant specified interval before the other. These lines are in the shape of mathematical hyperbolas, with one transmitter or the other at the focal point.

In cases of unequal transmitter power balance, where the point of equal field strength is not located at the equal distance point, the signal delay at one of the transmitters must be intentionally and precisely altered. This alters the position of the delay curves relative to the signal level curves, eliminating problem areas or allowing them to be shifted to unpopulated areas, such as mountaintops or over bodies of water.

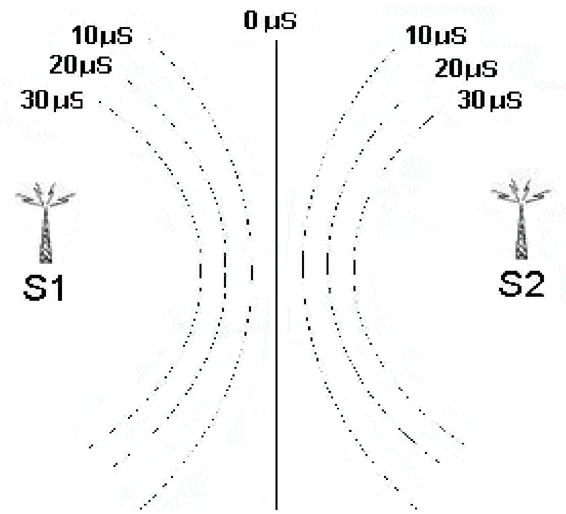

Figure 2-3. Propagation Delay Difference in Microseconds

2.2 Distribution Networks

A radio frequency transmission traverses about 981 feet (300 meters) in one microsecond (µS). If the time that a signal leaves a transmitter varies by 4 microseconds, the location of the equal-delay curve shifts by about a third of a mile (0.6 kilometers) from the reference line. This delay-curve change is equal to half of the transmitter signal propagation delay change. To maintain this degree of control, the delay of every element in the signal path, from the origination point to each antenna, must be controlled to the microsecond level of precision.

T1 and E1 circuits over dedicated radio links tend to have fairly stable delay characteristics, typically in the 3-8 millisecond range. Public networks and IP packet transmissions are subject to rerouting. This means that the phone company or service provider can shift the data to different physical network paths for many different reasons, such as hardware fault or excessive congestion. Rerouting can cause a sudden and dramatic change in the overall circuit delay and can happen as often as several times each day without warning.

Private networks or microwave links can also be subject to variable delays on the order of tens of microseconds, as a result of data buffering in modems or other equipment. Long microwave links can have unequal amounts of delay shift due to path differences.

The Intraplex SynchroCast3 system (Figure 1-1) solves these problems by automatically adjusting for any differences and variability in the path delay in three ways:

- The program is distributed over the air as a discrete-channel digital audio signal, which facilitates amplitude and frequency response matching.

- GPS receivers at all end points in the network provide extremely precise frequency and time references.
  The SynchroCast3 system uses the GPS frequency reference to calibrate the transmitter frequency directly, while using the time reference to adjust a variable time delay mechanism that automatically compensates for delay changes in the audio distribution network. The timing comparator (a function of the SNC-101T) receives input from a local timing reference from a GPS receiver located at the transmitter site plus the master timing reference that arrives over the link, with exactly the same network delay as its accompanying audio signal.

- The comparator measures the time offset between these two inputs and sends commands to the local system controller to create the overall delay required to compensate for any variations in the network delay.
  Overall, the system can control the path delay from the origination point to each transmitter to within 2 microseconds. This tolerance, if exceeded, drives slewing of the delay. Therefore, the

system can be considered locked if the actual delay is ± 2 microseconds of the target for TDM based links, or ± 1 microseconds for IP transports. The requested value of each individual path delay can be offset in steps of 0.1 microseconds to optimize the performance of the system in the overlap regions. You can also configure the system to absorb path delay variations of up to 84 milliseconds for T1 systems, 66 milliseconds for E1 systems, and hundreds of milliseconds for IP stream based systems.

The audio and other multiplexed signals are not interrupted or perturbed in any way, even when delay adjustments are made. This is called “hitless” operation and a patent has been issued covering the mechanism that accomplishes this. The system operates automatically once the initial installation and alignment are complete, keeping the total delay to each transmitter constant even if the actual path delay changes, as might occur if the network gets routed to an alternate path.

The system delivers the audio signals to each transmitter with the desired degree of precision. It is important that the signal chain from that point to the antenna at each transmitter maintain the same fixed delay or at least delays that track each other. The easiest way to assure these delays is by using identical processing and amplifying equipment at each transmitter site.

At the origination point, the GPS receiver feeds its clock signal to the SNC-101S module for each transport link, and each SNC-101S provides identical output reference signals for each link.

At each transmitter site, the GPS receiver provides a local version of the same reference clock for comparison. It also supplies an accurate 10 MHz reference signal to the transmitter itself. This slaves all transmitters to the same GPS controlled source, keeping all carrier frequencies precisely the same.

The Intraplex system transports the reference information from the origination point to each transmitter site by a user-selected portion of bandwidth within the data link that is paired with the audio signal. The SNC-101T module compares the incoming data signal with that obtained from the local GPS receiver and calculates the amount of delay it took for the signal to arrive from the origination point. It then calculates the amount of delay that must be added to the actual path delay to reach the desired total delay and sends signals to the system controller module which adjusts the delay accordingly.

The simulcast concept requires exact signal timing from all transmitters. Managing transmitted audio is an important factor for seamless reception in a simulcast system. While individual station operators have personal preferences when it comes to audio processing, it is important that the audio transmission be as consistent as possible, including density of processing and modulation levels, across all transmitter sites. One way you can achieve this consistency is to locate all audio processing equipment at the origination point and split its output to the various data links. You can employ some amount of final peak limiting at the transmitter, but take care to make this identical at each transmitter site. Modulation levels at all transmitters should exactly match.

2.3 Delay Measurement and Adjustment

You can use the SNC-101S and SNC-101T cards in the Intraplex STL-160, ACS-160, ADL-260, TDM-160, and TDM-260 series multiplexers and in NetXpress systems to provide a simulcast solution over digital data networks. SNC-101S card is installed into the multiplexer at the audio origination point and needs to be distributed to the transmitter site over the same transport path as the simulcast audio. In NetXpress systems, the SNC-101T module measures the IP network delay, jitter buffer delay, and NIM-1 processing delay and compares these to the customer’s requested delay. Any offset error is reported to the NIM-1 software and the controller readjusts the jitter buffer as necessary.

For TDM-based links, the transmitter site multiplexer requires a CM-5R-TD (T1) or CM-7R-TD (E1) Time Delay Common Module to artificially delay the network. The SNC-101T module continuously measures and dynamically controls the Time Delay Common Module to compensate for network changes and ensure that the play-out occurs at the customer’s requested delay value.