SIMULCAST - Lessons Learned

Simulcast Forum XII

Joe Blaschka Jr., P.E.
ADCOMM Engineering Company
Bothell, WA
Voice: 425-821-8827
www.adcommeng.com
j.blaschka@adcomm911.com
Basic Concepts

Definition

- Simulcast is the simultaneous operation of two or more transmitters with overlapping coverage on the same frequency
- Simulcast is controlled interference
Why Simulcast?

- The right technology to improve system operation.
- Spectrally efficient.
- Provides excellent coverage
- Few alternatives
Typical Simulcast Coverage

- TX1: Non-overlap
- Overlap #1
- Overlap #2
- TX2: Non-overlap
- TX3: Non-overlap
Signal Overlap Areas

Pay close attention to the signal overlap areas!

- Overlap areas are those where the RF levels are within 10-20 dB of each other.
  - Wideband 10-15 dB
  - Narrowband 15-20 dB
  - Digital 15-20 dB
Pay close attention to the signal overlap areas!

- Acceptable size of overlap area depends primarily on maximum audio frequency or bit rate being transmitted.
  - Voice Only - 80-100 µs
  - Plectron Tones 1500-2300 Hz - 40-50 µs
  - P25 Phase 1 Digital - 40-50 µs (2% BER)

- Plectron or any high frequency tone has smaller overlap area (30 degrees at 2000 Hz is ½ the time as 30 degrees at 1000 Hz.)

- Overlap effects are less pronounced in areas with high multipath and at higher frequencies

- CTCSS overlaps are not a problem due to low frequencies. Launch all sites at the same time/phase.
Signal Overlap Areas are Problem Areas

- Analog simulcast audio will never sound as good as non-simulcast in the overlap areas.
- Overlap areas outside main coverage areas may have significant distortion.
- Overlap areas = Interference control
- Digital may not work at all or may sound fine
Multipath and Simulcast

Simulcast increases multipath

Figure 1.1-1 Typical received signal variations at 836 MHz measured at a mobile speed of 15 miles/hr. Records taken on the same street with different recording speeds.
Controlled Interference Means:

- Controlled RF Frequency
- Controlled deviation
- Controlled audio phase
- Controlled bit timing/delay spread for digital

These three parameters must be controlled if simulcast is to work.
It is not as bad as it sounds.

- 80-90% of area in capture - sounds good
- 10-15% of area in overlap - sounds good
- 2-5% of area in overlap - some distortion but usable
- 1-3% of area in overlap - audio may be severely distorted
- Digital simulcast will generally sound good or not work at all
Remember FAST

F - Frequency
A - Amplitude
S - Signal Strength
T - Timing
RF Frequency/Phase

- Relative frequency between transmitters, not absolute frequency, is important
- No reason to use frequency offsets with current frequency control technology.

Methods
- GPS Locked XTAL or Rubidium can be used for all frequency bands depending on specifications
- 1 part in 10^{-11} minimum required.
- Rubidium will provide longer stability should GPS be lost
RF Frequency/Phase

- Frequency or phase changes can cause rolling fade in overlap area
- VCO phase instability in a base station could cause problems
• Deviation causes rapid frequency/phase changes
• Distortion is caused by different deviations in receiver
• Recovered audio from each transmitter must be within .2 dB
• Cannot be set by service monitor!!!!!!
• Set by using monitor receiver
• Digital deviations must also be matched to less than .1 kHz deviation. Usually, little control over adjustment.
Amplitude/Deviation Control

• Use digital transport if at all possible.
  – T1 Channel banks - External Audio Control
  – T1 Channel banks - Internal Audio Control
  – Special LAN/IP Channel Banks - Do not use low bit rate vocoders

• Analog transport if necessary
  – RF links
  – Analog phone lines - Use with extreme caution - High Risk.
  – Analog MW - Special Mux Cards - High Risk
  – Must use advanced technology for control.
Audio frequency response must be matched
- Each transport route should have the same elements
- Same type/vintage base stations should be used

Audio levels held to within .2 dB or better

Cannot adjust deviation with service monitor!!!!!!!

Digital simulcast levels generally adjusted by software

Digital simulcast levels are set by measurement of the digital waveform
Audio Phase

- Audio phase difference must not exceed 30 degrees
- Audio phase difference will be audio frequency dependent. Remember Plectron Tones
- Digital time difference measured in fractions of a bit time (symbol time) at the modulated level
- Digital delay spread should be less than 50 µs
Audio Timing/Phase Control

- Audio phase must be stable
- Audio phase should be adjustable 10-20 milliseconds, possibly greater depending on transport variability

**Methods**
- Digital delay lines
- Digital signal processing
- Time marked delay

- Phase/digital timing is adjusted for the overlap area
- Transport method must keep constant phase
Signal Strength

- Control your overlaps.
- Less is better.
- Think lower elevation not higher.
- Coverage control using lower power and directional antennas.
Calculations

RF Speed = 5.4 usec/mile
TX1 transit time 600 us + 54 us = 654 us
TX2 transit time 400 us + 81 us = 481 us
Overlap zone time difference = 27 us
30° @ 1000 Hz = 83 us allowed
Digital data tolerates less delay difference.
Overlap distance less than or equal to:
3600 bps = 11-13 miles
9600 bps = 6-9 miles
Delay Interference 83 uS, 6 dB Capture

RadioSoft Comstudy 2.2 used.
Delay Interference 83 uS, 10 dB Capture

RadioSoft Comstudy 2.2 used
Delay Interference 83 uS, 15 dB Capture

RadioSoft Comstudy 2.2 used.
Delay Interference 45 uS, 10 dB Capture

RadioSoft Comstudy 2.2 used.
Most Likely Server Analysis

RadioSoft Comstudy 2.2 used.
Maintenance Issues

- Individual components cannot be adjusted by themselves
- Standard test equipment cannot be used to make final adjustments
- Any maintenance action in the audio path requires system adjustments
- All measurements are made relative to other transmitters
Maintenance Issues

- Make sure monitor receiver is not receiving any interference (Watch scope display!)
- Make sure everything is operating in the linear mode (no clipping!)
- Avoid temptation to “tweak” with adjustments
- No “Hoot N’ Holler” adjustments
Maintenance Issues

- Use the Convex 806A TIMS
  - Provides standard TIMS measurements
  - Provides delay measurements
  - Allows measurements to be computer controlled.
  - Download measurement information into Convex equalizer cards
Narrowband Operation

- Main difference between wideband and narrowband FM
  - Narrow IF filters do not deal with impulse noise as well (multipath holes)
  - Capture effect less pronounced
  - Lower signal-to-noise ratio and reduced audio recovery
  - Equipment has lower hum and noise specifications
- Frequency stability requirements the same for simulcast
- Deviation control is more critical
- Overlap area control more critical
- Digital will help because audio distortion is reduced digital to analog conversion process
- Digital may be worse because coverage holes may develop in overlap areas
Digital Simulcast

- Some digital simulcast announced available now or soon
  - Motorola
  - Tyco Electronics (M/A-COM)
  - Tait
  - EADS
Digital Simulcast

- Site spacing distances may be reduced depending on technology.
  - Delay Spread less than 50 µs for 2% BER (Equivalent to 3.4 DAQ)
  - Do not use static sensitivity 5% BER (70 µs) as a standard
- Multipath and audio distortion virtually eliminated (other than typical digital distortion)
- Overlap areas out of the timing specification will likely have no audio
- "Gollywobbles" may be heard in overlap areas caused by higher bit error rate from multipath
What about low-band?

- Band of last resort
- Fewer equipment choices
- Overlap area is difficult to control
- Can be done but requires close transmitter spacing and possibly directional antennas
- Multipath null areas may be large - feet instead of inches
- Do not guarantee successful operation to client
Summary - Lessons Learned

- Consider all of the system requirements - Plectron tones, CTCSS, Digital, etc.
- Control user expectations - Do not promise simulcast will fix all of their problems
- Design for low maintenance - Cheap System = Higher Maintenance
- Use common RF equipment. All same brand and model
- Multi-vendor systems can easily be done with the right homework
- No matter how good you think you are. The transport (links) can kill you
- Use advanced technology - Do not try to outsmart obstacles
Summary - Lessons Learned

- Design to minimize overlap areas. Do not assume you can adjust them away.
- Consider using lower sites and/or directional antennas.
- Use GPS based frequency and timing references.
- Stage the equipment prior to taking it to the sites - Very important! Every hour spent troubleshooting in the shop saves a day or more in the field.
- No service monitors for final level adjustments - Invest in a monitor receiver.
Proper failure repair is critical for continued user satisfaction. A properly engineered and installed system requires little routine maintenance.

Equipment repair actions may require system realignment. Do not put it off until later.

Do not be afraid of the technology but realize it will require more precision and attention to detail.

Don’t worry - Be happy....if you do it right!
Questions?