Interoperability of FM Composite Multiplex Signals in an IP Based STL

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FM MPX Generation

- L+R
- 19 kHz pilot tone
- L-R – 38 kHz subcarrier
- Radio Data System (RDS) - low bit rate (1187 bps) digital data – 57 kHz subcarrier
FM MPX Frequency Spectrum

- Pilot tone decoded at receiver
- Subsidiary Communication Authorization – Low BW audio
- 67 and 92 kHz Subcarriers
- FM MPX BW
  - 53 kHz: L and R audio
  - 60 kHz: plus RDS
  - 75 kHz: plus one SCA
  - 99 kHz: plus one SCA
FM Processing Chain

- FM Audio Processing
  - Frequency Limiting (< 15 kHz)
  - Overshoot Limiting
  - Pre-emphasis
- Stereo Generation
- FM Exciter
- FM MPX
  - Analog MPX
  - Digital MPX over AES/EBU @ 192 ksps
MPX over AES3

- Introduced in 2013
- AES3 or AES/EBU
  - Two 32-bit sub-frames
  - Sub-frame 32 bits = 24 bit sample word + Parity, metadata, and synchronization
- 192 kHz sampling
- Left channel
- 192 kHz digital sampling = 80 kHz bandwidth due to Nyquist
MPX over AES3

• MPX over AES3 at 384 kHz
• Support for the entire 99 kHz MPX bandwidth
• Use left and right channel
• Multiplex L and R in odd even sequence
• Back compatible with MPX over AES @ 192 kHz
• Energy from 96 to 99 kHz aliased to 93 to 96 kHz
STL Topologies

- STL Transport
  - Baseband Audio
  - Analog MPX
  - Digital MPX
Analog MPX Codec STL

Studio Site

Transmitter Site
Analog MPX over a STL

- Stereo Audio + RDS < 60 kHz
- Stereo Audio + RDS + one SCA < 75 kHz
- Stereo Audio + RDS + two SCA < 99 kHz
- 132, 162 or 216 ksp
- 6 dB per bit
- 24-bit word = 144 dB dynamic range
- 16-bit word = 96 dB dynamic range
- 132 kHz sampling, 16-bit word has data rate of 2.11 Mbps
Digital MPX over a STL using Transparent Transport

- End-to-end, bit-by-bit copy
- Only transport the AES3 24-bit left sample word
- Regenerate parity, sync, metadata at the far-end
- One channel of 192 kHz, 24-bit has a data rate of 4.6 Mbps
Digital MPX over a STL with Reduced Bandwidth

- Reduce word size and use SRC to reduce bandwidth
- MPX over AES at 192 ksps supports 96 kHz bandwidth
- Stereo Audio and RDS < 60 kHz
- 132 kHz sampling, 16-bit word has data rate of 2.11 Mbps
Bridging
MPX Bridging

- Bridge between analog and digital domains for interoperability
- Interoperate between old and new equipment
- Dual domain input/output provides “future proof” solution
MPX Bridging – Digital to Analog

- Bridge between a newer digital FM stereo generator and older FM exciter
MPX Bridging – Analog to Digital

• Bridge between an older analog MPX stereo generator and a new digital FM exciter
MPX STL Bandwidth

- MPX is linear PCM – uncompressed
- MPX over AES/EBU is 192 ksps @ 24 bit sampling, one channel – 4.6 Mbps
- Analog MPX sampling is 132 to 216 ksps
- MPX IP transport uses RTP
- IP RTP/UDP header overhead is 40 bytes
- Tradeoff between delay and packing efficiency
Benefits of FM MPX over IP vs Audio over IP
• Enables baseband equipment (audio processor, stereo generator, RDS generator) to be located at the studio side
• Reduces CapEx when distributing the same signal to multiple transmit sites
• Simplifies operation for FM SFN
• However – MPX requires higher STL capacity than audio only transport
• Audio is amiable to lossy compression – AAC, MPEG, opus, etc
Analog MPX Codec Requirements

• Band from 0 to 53 kHz contains stereo audio
• Left: $2L = (L+R) + (L-R)$
• Right: $2R = (L+R) - (L-R)$
• Gain flatness of 0.05 dB across 0 to 53 kHz for >50 dB stereo separation
• Linear phase response
Linear Phase

- Linear phase = constant group delay
  \[ \tau_g(\omega) = -\frac{d\phi(\omega)}{d\omega} \]
- Use FIR filters for linear phase
- Use over-sampling at ADC to minimize effect non-linear phase response analog filters
- Use interpolation at DAC to minimize effect non-linear phase response analog filter
Single Frequency Simulcasting

- RF single frequency simulcasting uses multiple, geographically disperse RF transmitters operating on the same carrier frequency
- In simulcast, modulating signal undergoes a precision delay process
- MPX advantage vs audio only transport over STL
  - In MPX all components are equally delayed
IP Packet Loss

• Causes of IP packet loss: route flapping, transmission errors, congestion
• Unmanaged vs. managed network services
• In audio - packet loss concealment methods: frequency interpolation, replaying previous frame
• In MPX – no standardized concealment methods
• For MPX, use correction techniques for packet loss mitigation
Packet Loss Effects

• Audio compression algorithms keep spectral information – fill in missing data segment from previous data – error concealment
• MPX codec method is PCM coding – no spectral information is computed
• MPX codec – no error concealment
IP Packet Loss

- Random vs. Burst Packet Loss
- Random Losses
  - Uncorrelated
  - Appear to be spread out
FEC packets are generated from a matrix of RTP data packets
Both RTP data and FEC packets are sent to the receiver
FEC attempts recovery of lost data packets at the receiver
Effectiveness of recovery depends on type of packet loss
## FEC Matrix

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<th>Col 1</th>
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<th>Col 3</th>
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<td>3</td>
<td>4</td>
<td>XOR(1,2,3,4)</td>
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<tr>
<td>Row 2</td>
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<td>6</td>
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<tr>
<td>Row 3</td>
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<td>XOR(3,7,11,15)</td>
<td>XOR(4,8,12,16)</td>
<td></td>
</tr>
</tbody>
</table>
FEC Correction for Random Loss

![Graph showing FEC correction for different network loss percentages with lines for 4x6, 4x4, 3x3, and 2x2.]
Single Network Packet Protection

For burst loss, packet level FEC with interleaving – adds delay
Or, add redundant streams in a group with programmable time delay. Very effective for burst packet losses which are typically seen on public ISP connections
Time delay value based on network analytics
Multiple Network Packet Protection

- Network diversity
- Grouped streams sent across diverse network paths
- Scalable protection per network based on capacity
- “Hitless” operation with packet and network losses
Summary

• High bandwidth IP connections is an enabler for MPX transport
• MPX STL - advantage of centralization at studio and simulcasting
• Two methods of MPX – MPX over AES and analog MPX
• Interoperability possible with a bridging device
• For high quality MPX STL, IP packet loss must be mitigated
  • FEC
  • Redundant streaming
  • Network diversity
Thank You