Interoperability of FM Composite Multiplex Signals in an IP Based STL

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Featuring GatesAir's

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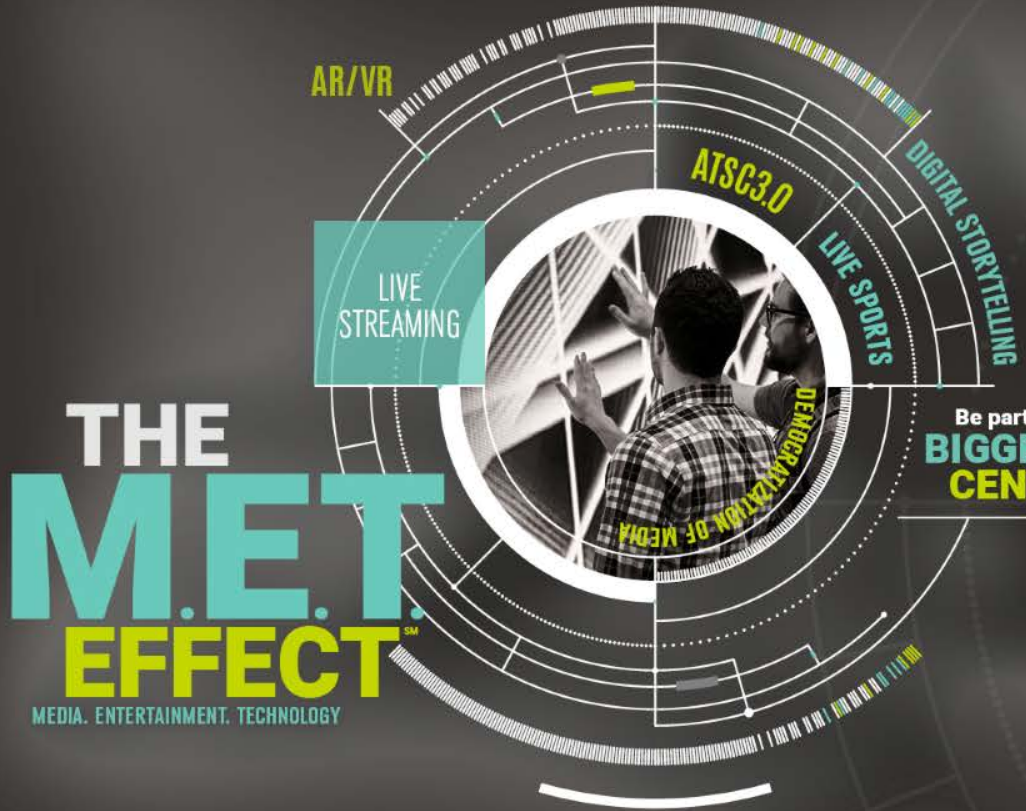

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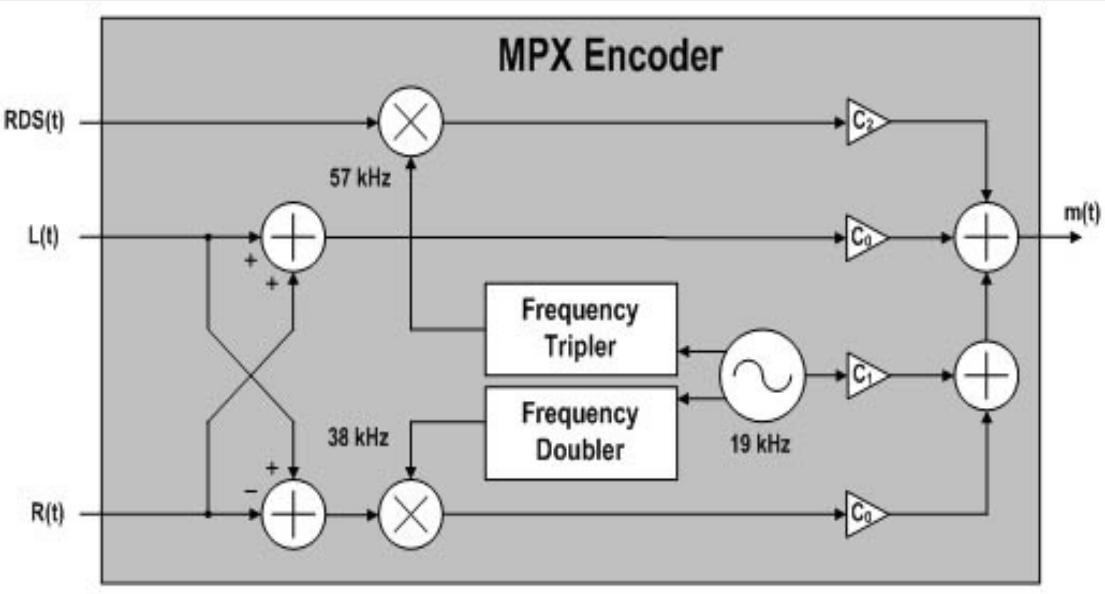
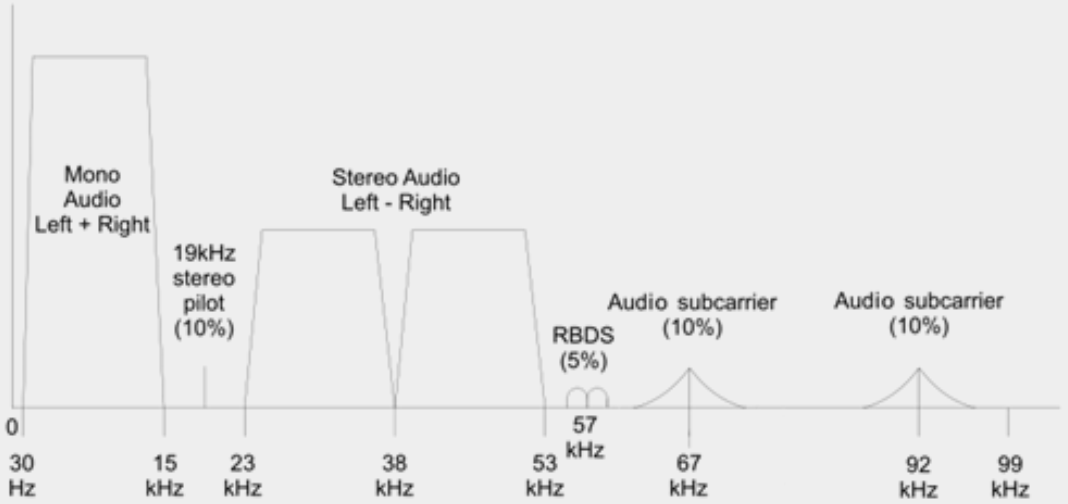
FM MPX Generation

- 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



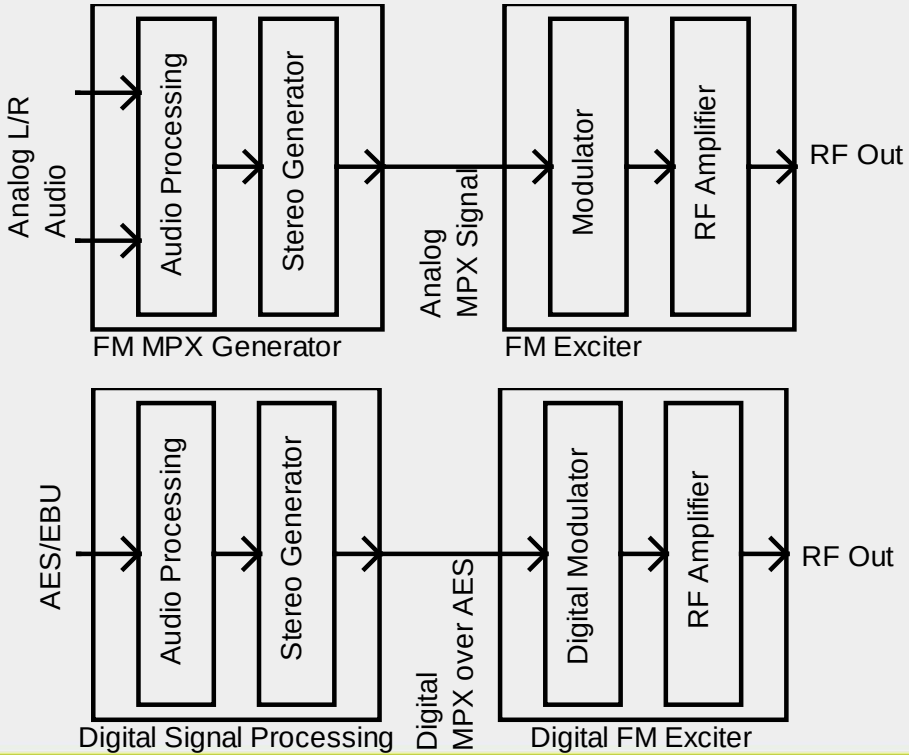
FM MPX Frequency Spectrum

- 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



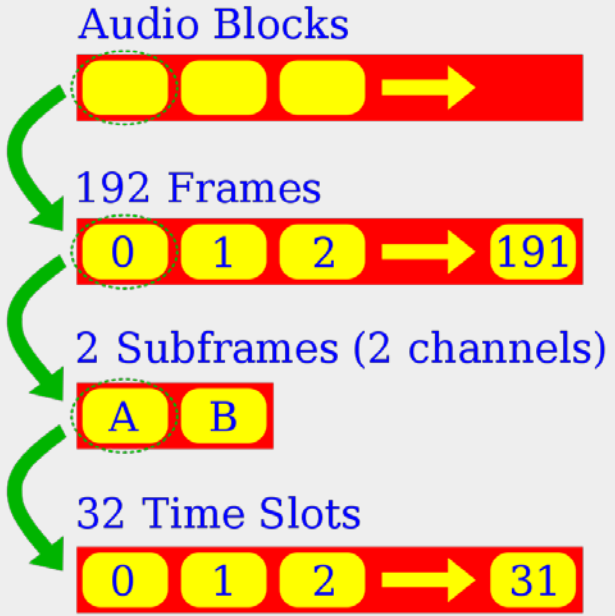
FM Processing Chain

- 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



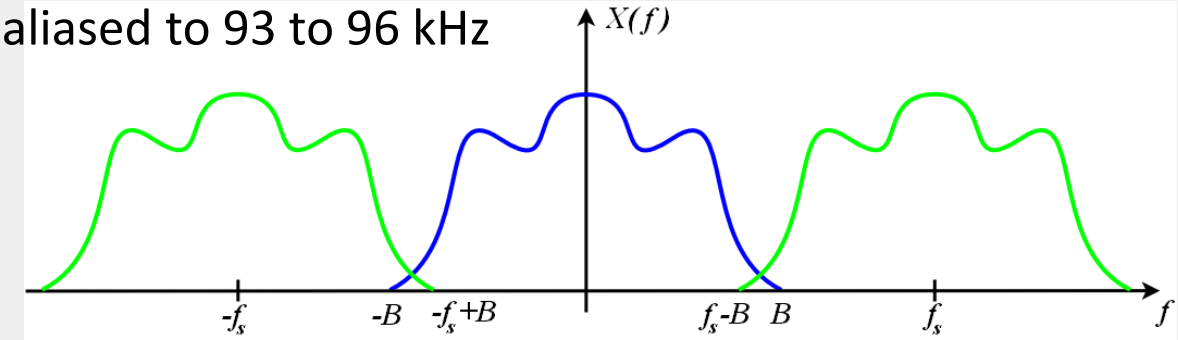
MPX over AES3

- 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



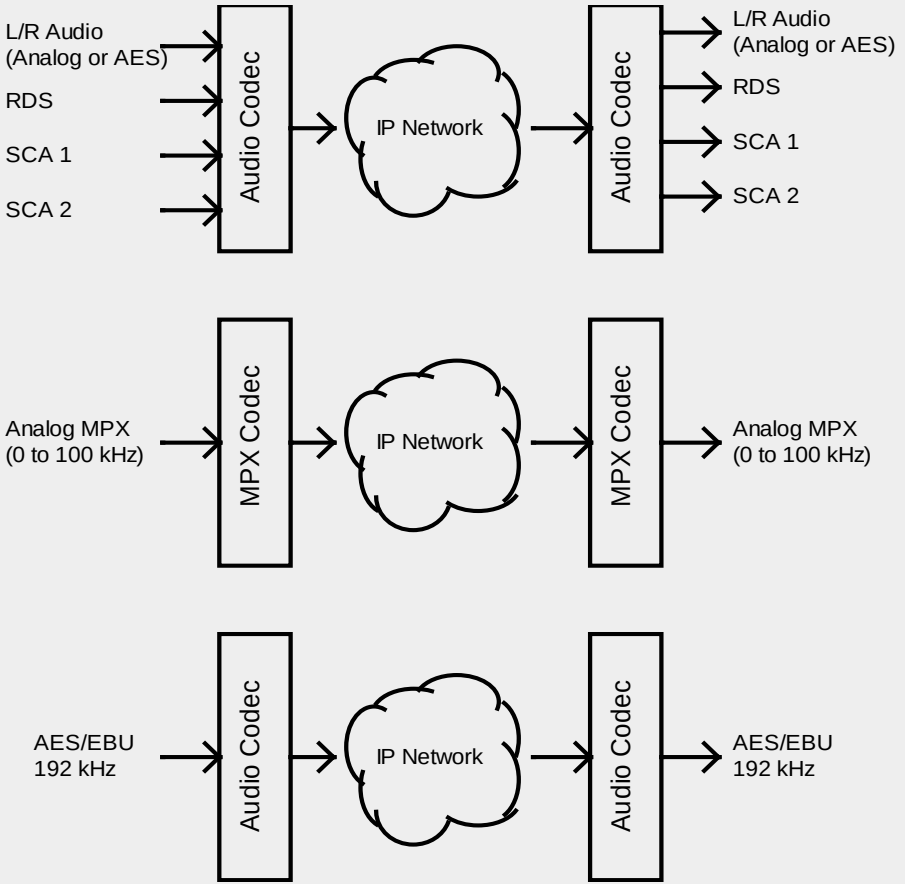
MPX over AES3

- 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

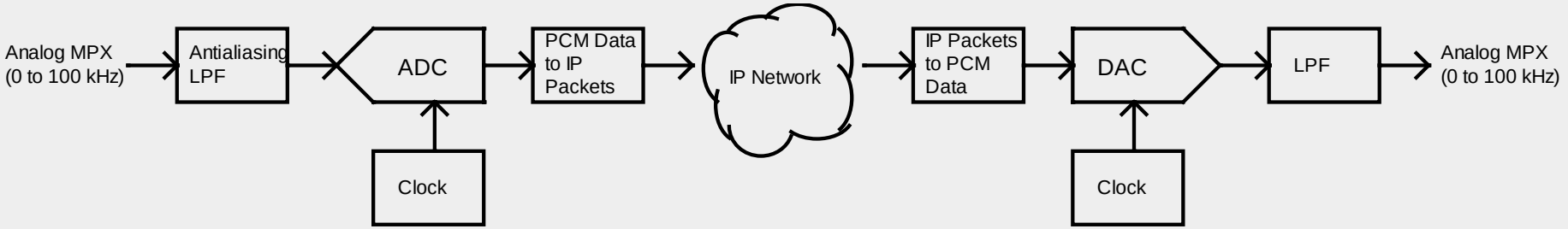


STL Topologies

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



Analog MPX Codec STL

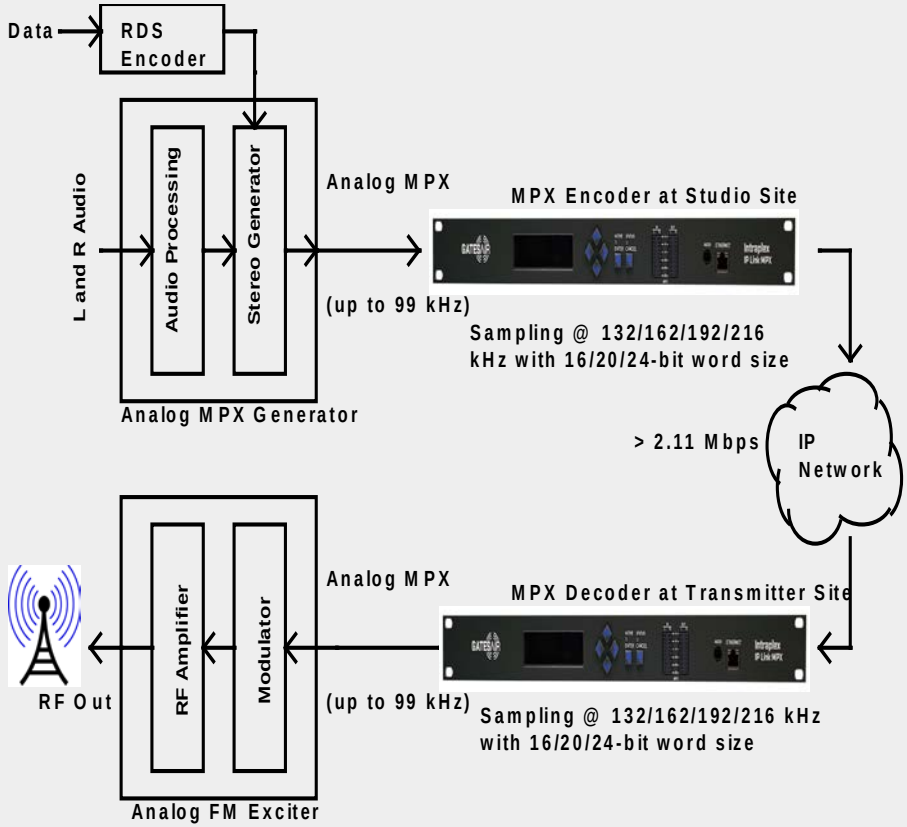


Studio Site

Transmitter Site

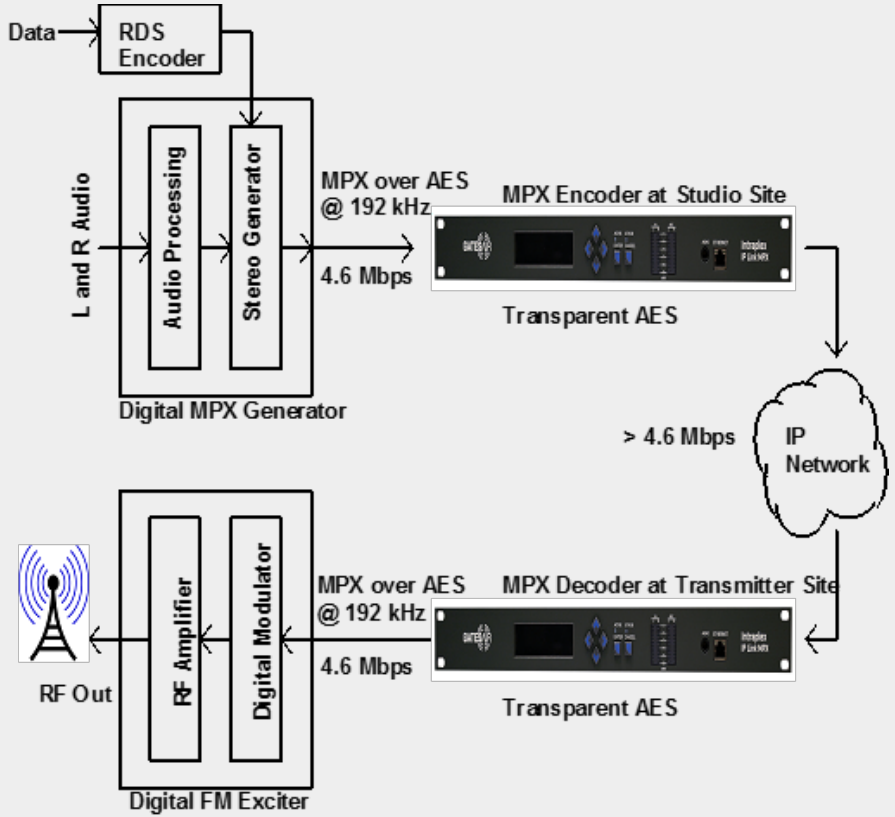
Analog MPX over a STL

- Stereo Audio + RDS < 60 kHz
- Stereo Audio + RDS + one SCA < 75 kHz
- Stereo Audio + RDS + two SCA < 99 kHz
- 132, 162 or 216 ksps
- 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



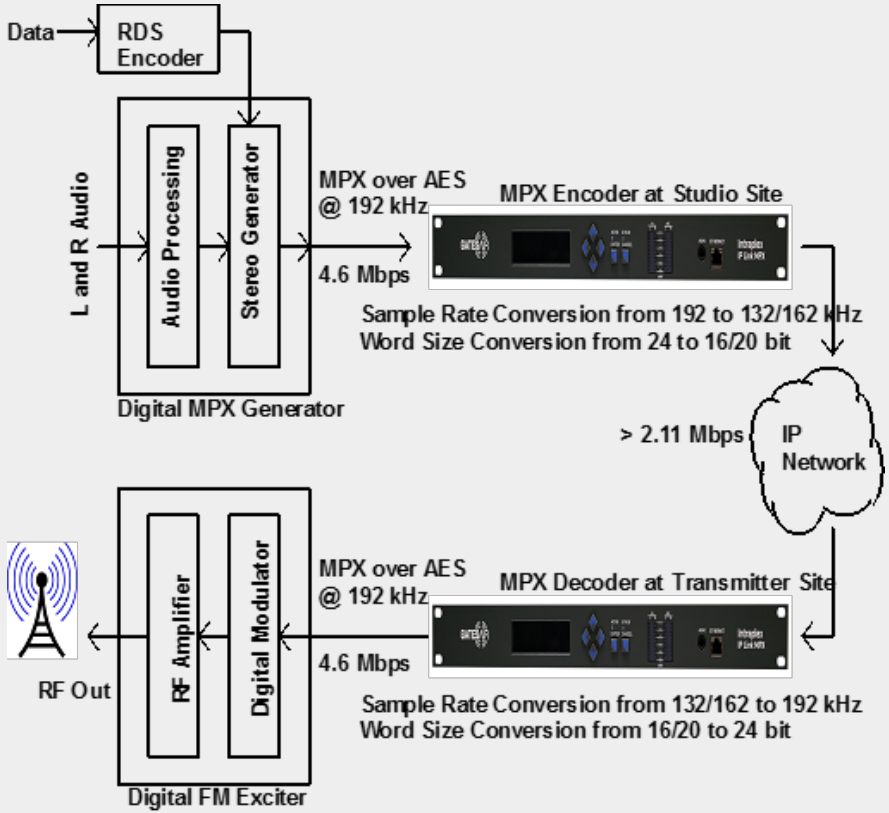
Digital MPX over a STL using Transparent Transport

- 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

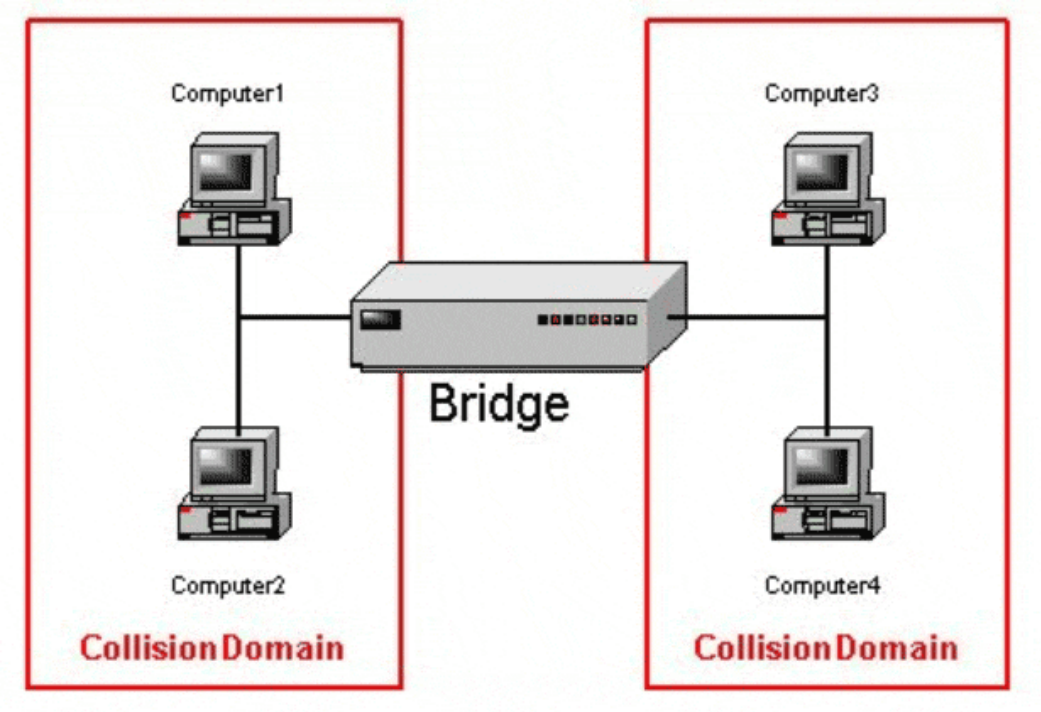


Digital MPX over a STL with Reduced Bandwidth

- 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

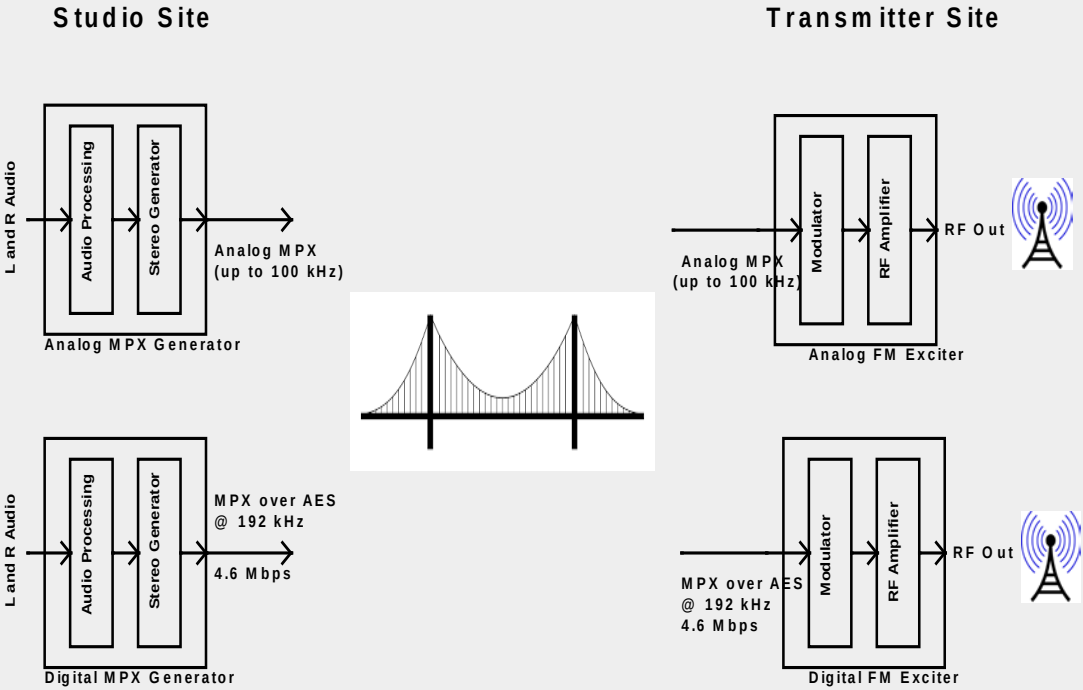


Bridging


Computer1
Computer3
Bridge
Computer2
Computer4
Collision Domain
Collision Domain

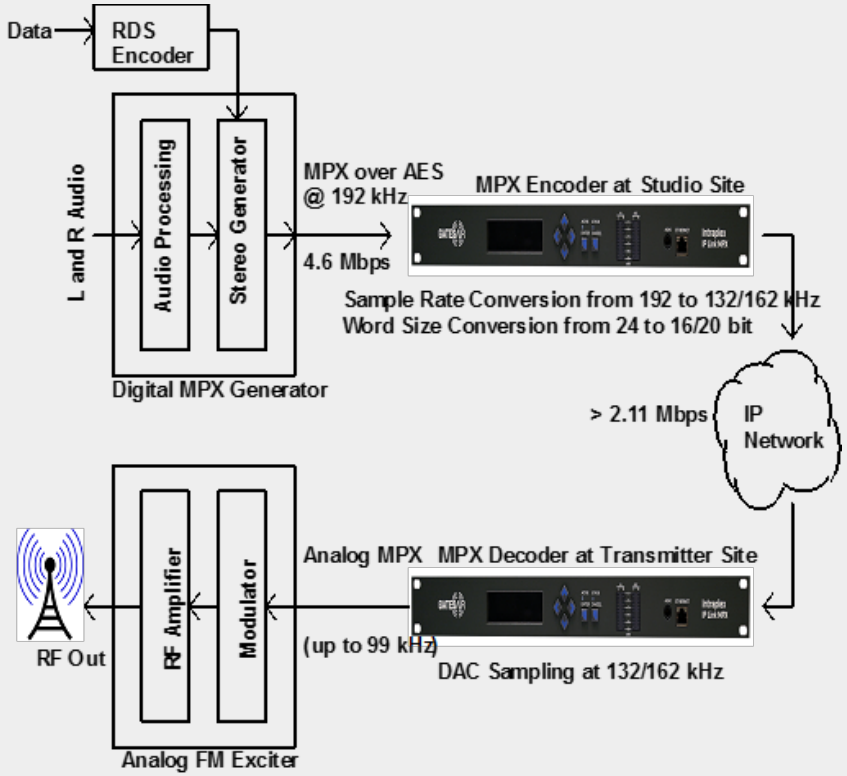
MPX Bridging

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



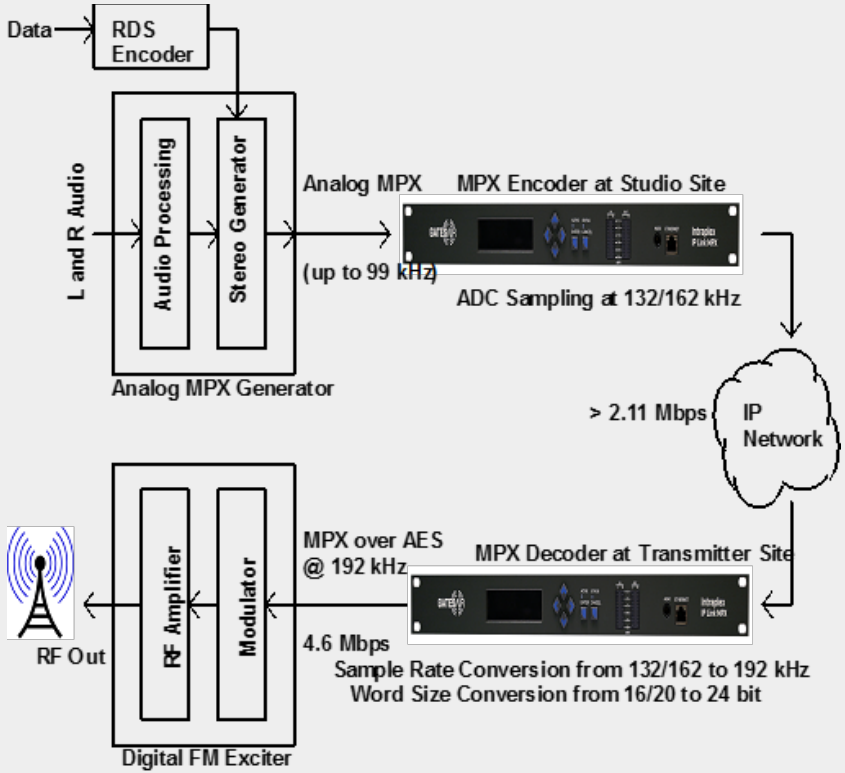
MPX Bridging – Digital to Analog

- Bridge between a newer digital FM stereo generator and older FM exciter



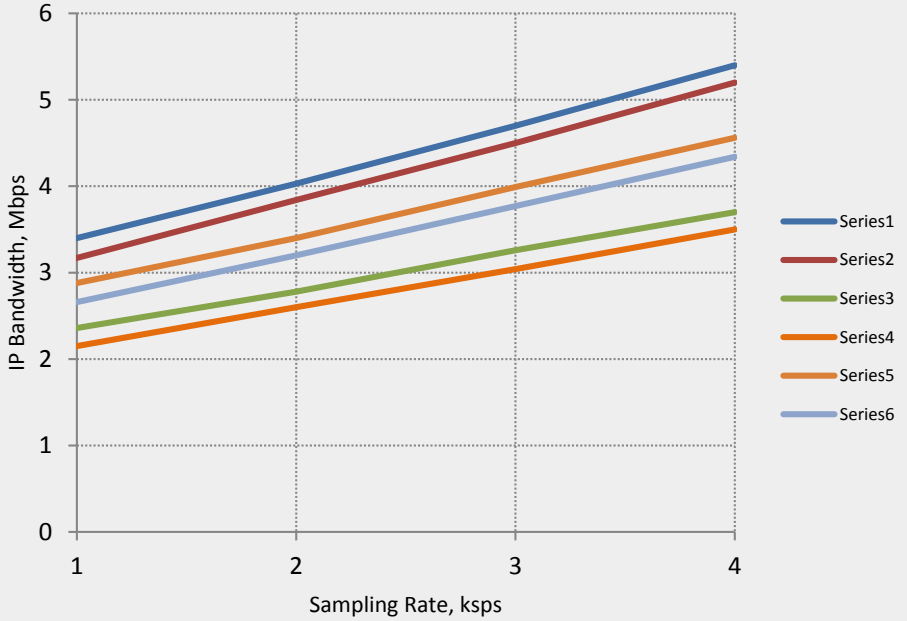
MPX Bridging – Analog to Digital

- Bridge between an older analog MPX stereo generator and a new digital FM exciter

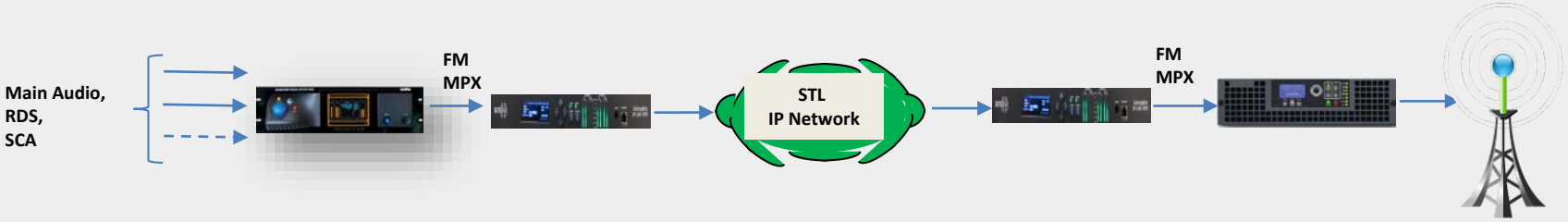


MPX STL Bandwidth

- 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



FM MPX over IP



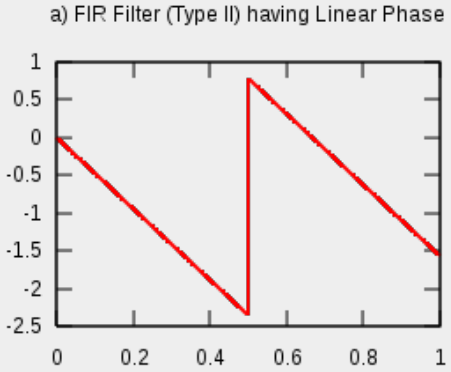
- Benefits of FM MPX over IP vs Audio over IP
  - Enables baseband equipment (audio processor, stereo generator, RDS generator) to be located at the studio side
  - Reduces CapEx when distributing the same signal to multiple transmit sites
  - Simplifies operation for FM SFN
- However – MPX requires higher STL capacity than audio only transport
  - Audio is amiable to lossy compression – AAC, MPEG, opus, etc

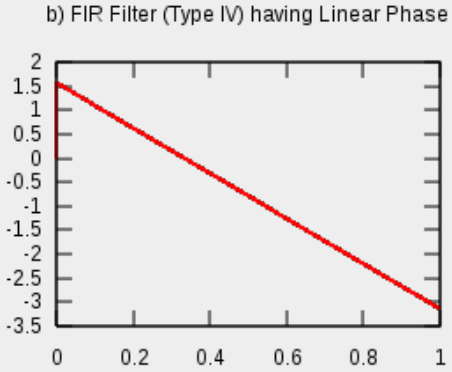
Analog MPX Codec Requirements

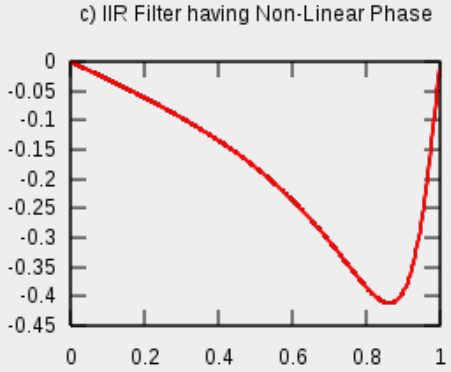
- Band from 0 to 53 kHz contains stereo audio
- Left: $2L = (L+R) + (L-R)$
- Right: $2R = (L+R) – (L-R)$
- Gain flatness of 0.05 dB across 0 to 53 kHz for >50 dB stereo separation
- Linear phase response

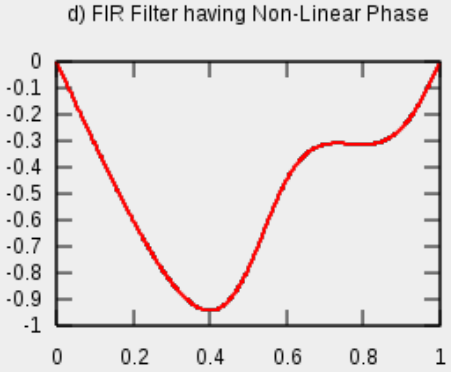
Linear Phase

- 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



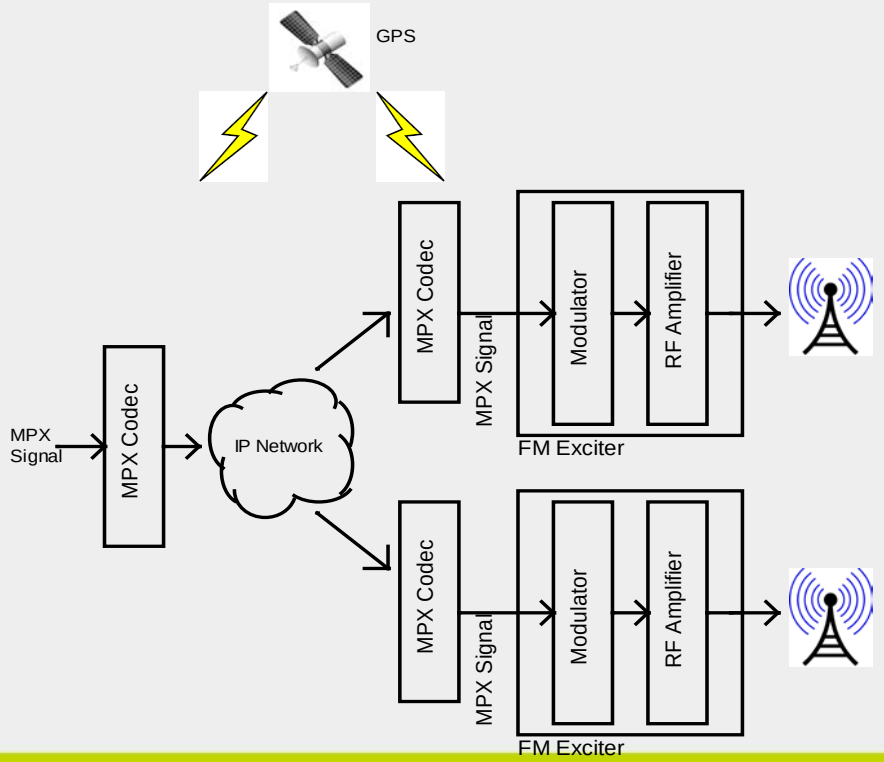






Single Frequency Simulcasting

- 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

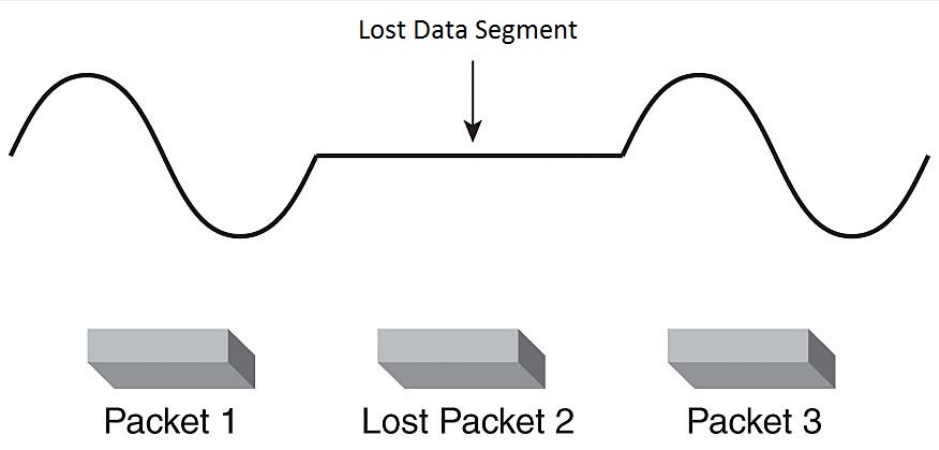


IP Packet Loss

- 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

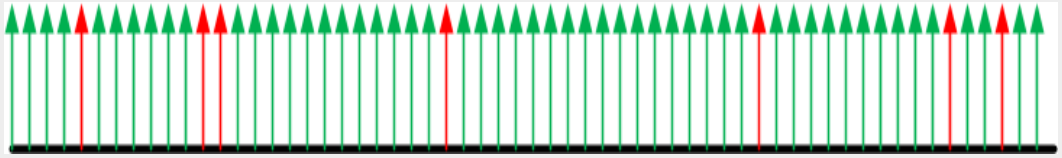
- Audio compression algorithms keep spectral information – fill in missing data segment from previous data – error concealment
- MPX codec method is PCM coding – no spectral information is computed
- MPX codec – no error concealment



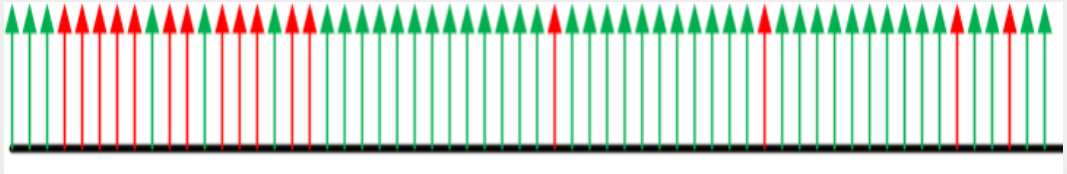
IP Packet Loss

- Random vs. Burst Packet Loss
- Random Losses
  - Uncorrelated
  - Appear to be spread out

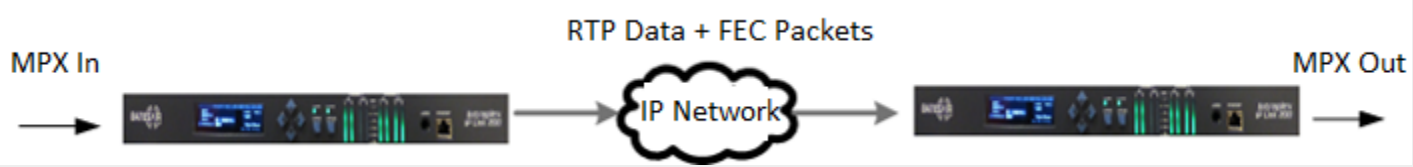
Random Loss



Burst Loss



RTP Forward Error Correction

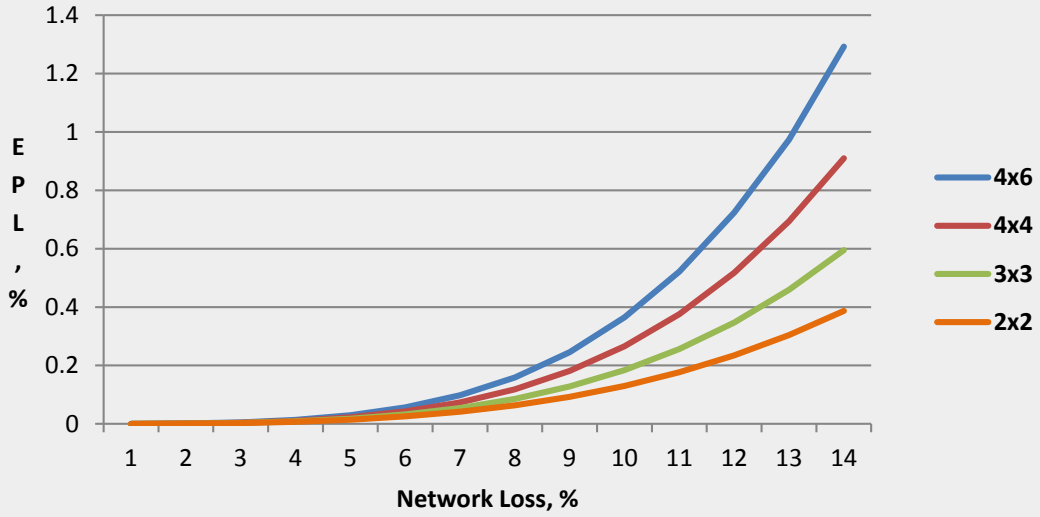


- FEC packets are generated from a matrix of RTP data packets
- Both RTP data and FEC packets are sent to the receiver
- FEC attempts recovery of lost data packets at the receiver
- Effectiveness of recovery depends on type of packet loss

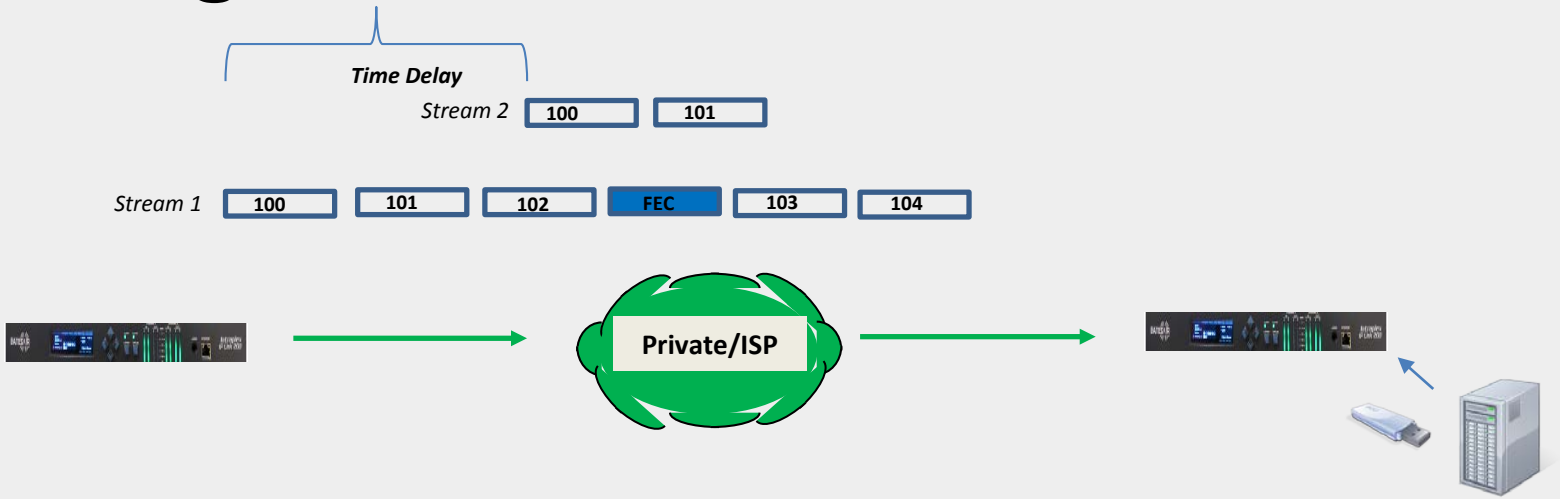
FEC Matrix

	Col 1	Col 2	Col 3	Col 4	FEC(x)
Row 1	1	2	3	4	XOR(1,2,3,4)
Row 2	5	6	7	8	XOR(5,6,7,8)
Row 3	9	10	11	12	XOR(9, 10,11,12)
Row 4	13	14	15	16	XOR(13, 14,15,16)
FEC(x)	XOR(1,5,9, 13)	XOR(2,6, 10,14)	XOR(3,7, 11,15)	XOR(4,8, 12,16)	

FEC Correction for Random Loss

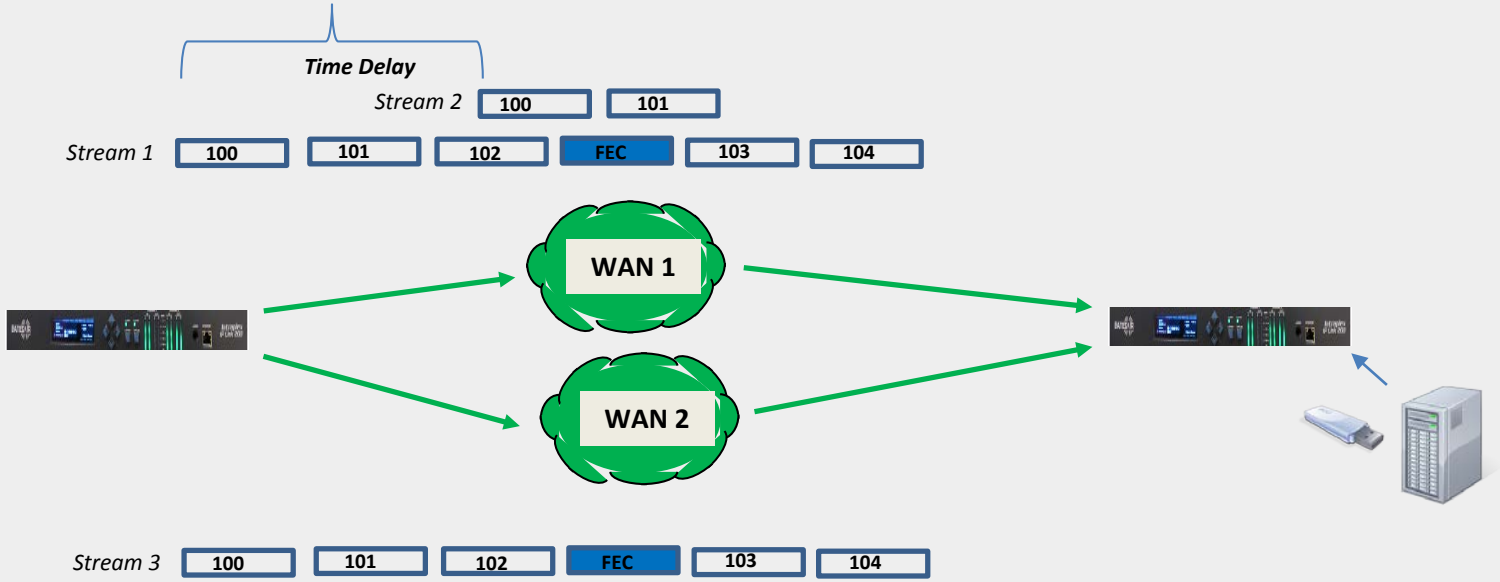


Single Network Packet Protection



- 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