UTC REGION 2 MEETING

The Effect of Digital Frame Loss on Audio Teleprotection
Introduction

Audio Teleprotection was perfected over analog communications systems

*Digital is different!!!*
Overview of Digital Transmission

- Serial versus parallel data
- Framing patterns
- Loss of frame
T1 FRAME

ONE FRAME = 24 8-BIT WORDS (192 BITS) PLUS ONE FRAMING BIT (1 BIT)
CALCULATING THE 1.544 Mbps T-1 RATE

<table>
<thead>
<tr>
<th>STEP</th>
<th>WHAT HAPPENS</th>
<th>CALCULATION</th>
</tr>
</thead>
</table>
| 1.   | The 8-bit digital samples created by PCM (voice channels only) are grouped into 24 discrete time slots created by TDM. Each group of time slots is called a *T1 frame.* | 24 samples  
X 8 bits per sample  
192 information bits per frame |
| 2.   | A framing bit is added to mark the end of one frame and the beginning of the next. | 192 information bits  
+ 1 framing bit  
193 total bits per frame |
| 3.   | T1 frames are transmitted at the rate of 8000 per second. | 8000 samples  
X 193 total bits  
1,544,000 bits per second (1.544Mbps) |
D1 Framing

- The 1.544Mb/s is organized in an orderly, understandable way. Framing provides this organization.

- A frame contains one sample (8-bits) from each of the DS-1’s 24 time slots. A framing bit is used to separate the frames and indicate the order of information arriving at the receiving end.

- A D1 frame contains 24 time slots, each carrying an eight bit word and a framing bit. Bit eight of each word is reserved for signaling information.
THE D1 FRAMING PATTERN

24 8-BIT BYTES (192 BITS) X 8000 SAMPLES = 1.536 Mbps
**D4 FRAMING/SUPERFRAME (SF)**

- 12 frames are grouped together to form a superframe. Each frame contains 8-bits of each of the 24 time slots and a framing bit (F-bit).
- The twelve framing bits are combined into a 12-digit word that provides frame and signal management.
- To share signaling bits by all 12 frames in the superframe, D4 framing uses a process called “robbed bit signaling.” The 8th bit of the DS-0’s in the 6th and 12th frames are reserved for signaling information.
- In summary, D4 framing improved signal quality by freeing more bits for customer information.
D4 SUPERFRAME (SF)

1 Superframe = 12 Frames
1.5 ms = 2316 Bits

D4 Framing
Frame # F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12

1 Frame
125 µSec., 193 Bits

Time Slot #
Bit#
EXTENDED SUPERFRAME (ESF)

- ESF expands the superframe from 12 to 24 193-bit frames. ESF was developed in order to be able to evaluate system performance without disrupting service by testing the t-1 link.
- Three fourths of the 24 control bits are reserved for evaluation of circuit performance.
- 6 control bits are reserved for cycle redundancy check (CRC), a method of detecting errors during transmittal (2kb/s);
- 12 control bits are reserved as a data link for communication between transmitting and receiving equipment at either side (4kb/s).
- 6 control bits are used to managed signaling and framing.
EXTENDED SUPERFRAME (ESF)

EXTENDED SUPERFRAME
4632 BITS (3 msec)

1 24

DS1 FRAME
193 BITS (125 µsec)

1 24

DS0 CHANNEL
8 BITS (5.18 µsec)

1 24

SIGNALING INFORMATION

8th BIT IN FRAME #
6 A
12 B
18 C (A) DUPLICATE
24 D (B) DUPLICATE

FRAMING BIT SUMMARY

F1

D C1 D 0 D C2 D 0 D C3 D 1 D C4 D 0 D C5 D 1 D C6 D 1

F24

D - FORCED TO 1 BY USER, TBD BY ATT, 4 KBPS “EMBEDDED OPERATIONS CHANNEL”
C1 - C6 = CRC6 POLYNOMIAL FOR ERROR DETECTION, 2KBPS, 98.4% OF SINGLE AND MULTIPLE ERRORS FOUND.
FRAMING PATTERN = 2 KBPS.
Serial Versus Parallel

Parallel transmission gives one character at a time with hardware boundaries.

Serial transmission has no hard boundaries.

Channel 1

1010101010101110001110110111

1010101010101110001110110111
Framing Patterns

In order to find the boundaries a framing pattern is inserted

1PPP.....PPP0PPP.....PPP1PPP.....PPP0PPP.....PPP1

Framing Bits

Payload Data Bits

T1 has 192 (24x8) Payload Bits and 1 Frame Bit = 193 Bits
Framing Patterns

However, bits are bits.
Which ones are the frame bits?

110110011100011011010111000010110111011011101101

It takes time for a receiver to find the framing pattern and it is easily lost when bits are corrupted.
Loss of Frame

When a multiplexer is unframed the start of frame pointer is pointing to the wrong bit, shifting the channel pointers to the wrong bits
Description of Problem

- What causes loss of frame
- Media considerations
- Channel hopping
- Pink noise
- Teleprotection
What Causes Loss of Frame

- Corrupted framing bits
- Change in propagation time

Any disruption to the media of equipment can cause a loss of frame.
Media Considerations

Fiber – breaks, equipment failures
When it goes it usually fails completely or switches to a good path

Digital Microwave – path fades, multipath
Comes and goes continuously
Channel Hopping

- Caused by frame misalignment
- The frame misalignment is exactly a multiple of channel time or “words”. (5.18 uS for 1 word in typical TDM muxes)
- The channel faithfully outputs data intended for another channel or time slot
Pink Noise

- Caused by frame misalignment.
- The alignment is off by less than one channel or one “word” (5.18 us)
- Output circuits reproduce a complex noise pattern including various frequency components
Teleprotection – Channel Hop

- Designed to wait for trip frequencies after losing guard frequencies
- A channel hop to another teleprotection channel with correct trip frequencies for that channel
Teleprotection – Pink Noise

- Designed to pull trip and guard frequencies out of noisy channels
- Pink Noise can mimic a noisy trip condition
- AGC circuits help bring the noise to the proper level and a trip results
Possible Solutions

- Prevention
- Detection
- Addressing
- Frequency Diversity
- Squelching
Prevention

- Build a system which has
  - Robust framing during corruption
  - Rapid detection of “Loss Of Frame”
  - Takes action before a trip can occur
Detection

- Detection time is limited by the framing pattern
- At least two frames are required for minimum detection time
- Longer the frame – slower the detection
- Don’t want to be too sensitive
Channel Addressing

- Each protection pair has a unique TX/RX address transmitted with data
- Usually limited to digital teleprotection
- Can be done with audio but not quickly enough
Frequency Diversity

- Each protection pair has unique frequencies
- Can be a maintenance problem
- Does not protect against pink noise
Squelching

The Best Protection!

- Quickly detect loss of frame and squelch output
- A relaying grade multiplexer should do this in less than 2 ms.
- Not available with channel banks
Test Results

- Pink Noise – No Squelch
- Pink Noise – With Squelch
- Channel Hopping – No Squelch
- Channel Hopping – With Squelch
Pink Noise – No Squelch

Valid Audio Tone

Pink Noise

Loss of Frame
Pink Noise - with Squelch

Valid Audio Tone  Squelched Output

Loss of Frame
Channel Hopping – No Squelch

- Major utility sanctioned test
- Telecom grade T1 Mux – 24 PCM voice cards
- 23 channels at trip frequencies, 1 channel at guard with RFL 9745 teleprotection channel receiver
- Repetitive T1 breaks
- One false trip output about every 20 minutes
Channel Hopping – With Squelch

- Major utility sanctioned test
- RFL IMUX 2000 – T1 Multiplexer with DS0 squelching enabled
- Same setup and conditions as previous test
- 17 Hours – No False Trip Outputs