SMPTE ENGINEERING GUIDELINE

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Revision of EG 34-1999

Pathological Conditions in Serial Digital Video Systems

1 Scope

This guideline presents some of the special aspects of working with digital video signals that have been serialized in accordance with ANSI/SMPTE 259M, SMPTE 292M, or SMPTE 294M.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this guideline. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this guideline are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

ANSI/SMPTE 259M-1997, Television — 10-Bit 4:2:2 Component and 4fsc Composite Digital Signals - Serial Digital Interface

SMPTE 292M-1998, Television — Bit-Serial Digital Interface for High-Definition Television Systems

SMPTE 294M-2001, Television — 720 x 483 Active Line at 59.94-Hz Progressive Scan Production — Bit-Serial Interfaces

3 Background

3.1 Serial digital data communication systems are generally optimized to have an approximately equal number of ones and zeros within a small- or medium-length string of the data stream. When it is necessary to recover clock information from the data, it is also desirable to have many signal transitions in order to improve the performance of the clock recovery system.

3.2 Standard digital video signals may have long streams of data with relatively few data transitions, and a large ratio of one-bit polarity compared to the other (e.g., many more zeros than ones).

3.3 There are many techniques used in the communications industry to take signals with poor transmission characteristics and convert them to signals with much better transmission characteristics. Many of these conversion systems increase the bit rate or bandwidth required to transmit the signal.

Self-synchronizing pseudo-random scrambling is one technique that usually improves the transmission characteristics of a digital signal without increasing the bandwidth. This technique is used in ANSI/SMPTE 259M, SMPTE 292M, and SMPTE 294M to increase the transition density and improve the balance between ones and zeros in the transmitted signal. The signal is also NRZI encoded, allowing the transmission signal to be inverted without changing the data recovery.

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3.4 Scrambler systems work well under most conditions, but they may not work properly with certain special data patterns. This can result in repeating patterns of data that have poor transmission characteristics because of reduced transition density, or a bad ratio of ones to zeros. There are three cases that have been documented in serial data transmission of television signals where the scrambling system does not give optimum operation. In general, these athological cases do not occur every time the offending input data are serialized. Since there are 511 different initial states for the scrambler when it encounters these pathological input signals, the scrambling algorithm fails about 0.2% of the possible times. The pathological conditions can last for up to the entire active scan period of a horizontal line. Usually an offending line will be followed by one or more lines without the pathological output condition, but, in some rare cases, multiple lines in sequence may have the condition.

3.4.1 The first case can occur during the vertical interval of one field in a digital video frame. In this case, there can be a period of 44 bit times without a transition in the scrambled data stream. This pathological case seldom, if ever, causes any problems.

3.4.2 The second case can occur during a flat field of several special colors. In this case, the scrambled data stream becomes a repeating pattern of 20 bits high followed by 20 bits low. This condition can stress the clock recovery phase locked loop. It is possible for the PLL to lock to the data pattern at the wrong frequency. In most cases, this condition does not cause problems with well-designed systems, since the PLL will typically be locked before this condition occurs and then remain correctly locked during this condition.

3.4.3 The third case can occur during a flat field of special colors, different from those for the condition of 3.4.2. In this case, the scrambled data stream becomes a repeating pattern of 1 bit either high or low, followed by 19 bits of the opposite polarity. This results in a signal with a 1 to 19, or a 19 to 1 ratio of ones to zeros. The scrambled signal then has a large amount of low-frequency energy. Unless otherwise specified, the remainder of this guideline discusses aspects of this condition.

3.5 This third pathological condition results in a signal with a high- or low-duty cycle. If this signal is passed through a coupling network that does not have sufficient low-frequency response, the baseline of the data stream will shift up or down. Unless the pulses have very short rise and fall times, the resulting pulse stream following the input comparator will have significant pulse-width distortion. This distortion can prevent proper recovery of the data stream.

3.6 Fiber-optic transmission systems may also be subject to pathological problems. Many laser optical transmitters have a power control circuit that keeps the optical power output at a set level. These circuits assume the data to have a constant average duty cycle of 50% over a period of time. This time period is usually in the range of 1 ms. Since the pathological condition may last for about 50 ms, the laser drive will be adjusted too high or too low, depending upon the duty cycle of the signal.

Many fiber optic receivers use ac coupled amplifiers with time constants in the range of 1 ms. This means they will not have adequate low-frequency response to properly handle a long run of a high- or low-duty cycle signal.

4 System considerations

The low-frequency components of the digital signal must be recovered or replaced in order for the serial signal to be properly recovered. The commercially available receiver chip sets for ANSI/SMPTE 259M coaxial cable systems have systems to properly recover the data. Two well-known systems are quantized feedback and clamping. These two systems function differently, but accomplish the same purpose.

SMPTE 292M specifies a maximum dc level shift over a one-line time period for coax cable line drivers, but ANSI/SMPTE 259M does not have a similar specification.

It is expected that manufacturers of integrated circuits and equipment conforming to ANSI/SMPTE 259M, SMPTE 292M, and SMPTE 294M will design their products to work in the presence of the pathological conditions.

System designers must be aware of the pathological conditions when designing systems. This is especially important when selecting fiber-optic components or other equipment that has not been designed to operate properly in the presence of the pathological conditions.

5 Prevention

The special input signals that result in the line-length pathological conditions do not usually come from cameras or other natural image sources. These inputs usually have sufficient noise, or small areas of the special signals, that any resulting pathological conditions will be short in length. Matte generators, graphics generators, and other synthetic image sources are much more likely to make signals with pathological conditions. These cases can be avoided by adding a small amount of noise or dither to the least significant bit of the digital video words. This breaks up the repeated nature of the signal feeding the scrambler, and thus prevents the repeated output. Another option is to avoid combinations known to generate pathological conditions.

Systems have been proposed and developed where the scrambling systems could be modified to prevent occurrence of the pathological conditions. Unfortunately, this would require additional circuitry or modification of the scrambling algorithms. It would not address the problem of the large amount of legacy equipment already installed in many television systems.

6 Testing

Equipment may be tested for susceptibility to pathological signals. SMPTE RP 178 describes test signals for serial digital interfaces conforming to ANSI/SMPTE 259M. SMPTE RP 198 describes similar test signals for serial digital interfaces conforming to SMPTE 292M. Users should check for the availability of test equipment, generating signals in accordance with SMPTE RP 178 and SMPTE RP 198, to facilitate testing of equipment and systems.

7 Conclusions

Digital video system designers and users should be aware of the existence of pathological signals. Generation of pathological signals should be avoided when possible by prudent system design and operation. Systems should be designed to operate correctly in the presence of pathological signals.

Annex A (informative)
Bibliography

SMPTE RP 178-1996, Serial Digital Interface Checkfield for 10-Bit 4:2:2 Component and $4f_{SC}$ Composite Digital Signals

SMPTE RP 198-1998, Bit-Serial Digital Checkfield for Use in High-Definition Interfaces