VIAVI Solutions

Application Note

Digital Quality Index (DQI)

Assessing Downstream Digital Signal Quality

Overview

Most downstream channels are transported on digital quadrature amplitude modulation (QAM) carriers. How are intermittent transport issues detected within those downstream digital services, and are customer quality expectations being met?

A patented VIAVI measurement called DQI (Digital Quality Index) concentrates on the condition of the raw information on the physical path and immediately detects intermittent issues and sustained issues within the stream. In comparison, the typical measurement used to check for these issues on a digital QAM carrier is pre and post forward error correction (FEC) bit error ratio (BER), which relies on actual errors and is relatively slow to detect many issues.

Drawback of Current Methods

Most digital field test equipment today incorporates the same digital hardware components that reception equipment uses. These components use numerous correction technologies to adjust the demodulated carrier correcting problems that were the result of transmission issues on the RF physical path. These technologies make the digital reception a superior quality service versus the older analog methods. Test instruments monitor these technologies to achieve a quantitative view of how hard the reception hardware is working to correct the physical path issues. The resultant measurements become an indicator of potential issues, not actual carrier quality. In some cases, the technologies can mask the issues since their intent is to correct issues before the user sees a problem. Utilizing the same technologies for test purposes is not as responsive as the old analog test measurements.

What is the Goal of Field Testing?

The goal of field testing is to identify network issues before services are affected and to fix the problem before the customer experiences any degradation of service. To accomplish this the technician needs to:

1. Determine there is indeed a problem
2. Segment where the problem is located
3. Fix the problem if it is determined to be in the field

Quantifying an issue with standardized measurements is always preferred, but for digital signals, traditional measurements do not necessarily excel at tracking the problem, particularly if the issue is intermittent. Marginal digital reception can be extremely frustrating for both the subscriber and the technician. A good example is the so-called “cliff effect,” in which there is a perfectly good picture one moment, and in the next moment, the picture is distorted with tiling effects or full freeze frame. A means of measuring the real-time performance of the RF digital reception is needed to see quality fluctuations and log intermittent transient issues causing momentary digital reception problems.

Development of a real-time digital quality index measurement

Two prominent digital measurements used to locate problems in the field are Modulation Error Ratio (MER) and Bit Error Rate (BER). An extension of BER is errored seconds (ES) and severely errored seconds (SES). These severity readings use the frequency of errors occurring within a second to arrive at a reading. One error within a second will count as one ES, while a specific quantity of errors within a second will count as one SES. MER is often compared to the digital equivalent of analog signal-to-noise ratio (SNR).

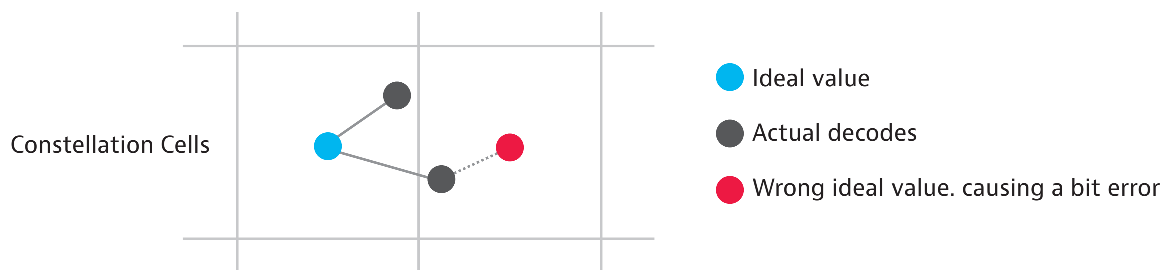

Figure 1. Distance from the ideal center target (error magnitude) equates directly to a calculated MER reading. If the error magnitude is sufficient to cause the dot (representing a received symbol) to appear in the adjacent target area, the wrong decoding will occur, and an error is generated

A received QAM carrier is demodulated to a stream of QAM symbols consisting of In-phase and Quadrature components. The QAM data stream contains a sequence of such I-Q pairs. The pairs are often plotted on a Cartesian coordinate system to analyze the quality of the received signal. This plot is referred to as a constellation display of the QAM carrier. The coordinate system is divided into squares, with the number of squares matching the QAM modulation rate. When an ideal QAM signal is received and decoded, each symbol’s I-Q pair will fall at the center of one of the squares. When a non-ideal signal is received, the impaired signal will cause each I-Q pair to fall some distance from the center of a square. The decoder assumes that the intended symbol is that of the square containing the I-Q pair, and the linear distance from the actual I-Q pair to the center of the square is the amount of error present in the signal when that symbol was received. The average signal magnitude divided by the average error magnitude is the signal-to-noise ratio (SNR). Experienced technicians use the constellation display to further help identify the source of the problem.

MER vs Error Magnitude characteristics:

- When the received signal is clean, the error magnitude is small
- Small changes in error magnitude produce large changes in MER
- The average MER is strongly affected by these large changes
- When impairments are present, the error magnitude is large
- Large changes in error magnitude produce only small changes in MER
- Short noise bursts have little effect on the average MER measurement

Digital Quality Index (DQI) is a simple indicator of the overall quality of a QAM digital stream. It reports the signal quality as a single number, with 0 being lowest quality and 10 being highest. Signal quality readings of 6 or 7 indicate that impairments are detected but are most likely corrected by FEC and interleaving. Readings of 1 to 4 indicate that subscriber service is most likely being adversely affected by the impairments. Readings of 8 and higher are typically not detected by FEC BER.

How DQI Works

DQI is a statistical measure of the signal impairments that can cause uncorrected bit errors, resulting in packet loss. It also detects impairments that have not yet caused any Pre BER errors. It provides a continuously updating measure once per second. Each update provides a statistical analysis of 98% of the QAM symbols received during the past second. It will detect and report the severity of any distortion, ingress, or other impairment to the received signal. Because it samples QAM symbols, the decoder must acquire and maintain QAM lock to obtain DQI readings.

DQI uses the raw digitized data directly from the demodulator, and is separate from the digital technology that is designed to correct the received signal. While this technology may be good for the subscriber to consume the service, it masks issues that occur on the physical distribution plant, making it difficult to locate issues that should be corrected. This raw data is essentially analog components in digital form that represent the signal-to-noise ratio (SNR) of the received carrier. The simplified diagram below illustrates where the conventional measurement data comes from versus the DQI measurement path. For example, for DQI to see narrow ingress pulses, the estimated SNR must be sampled at a higher rate than would be used to measure MER.

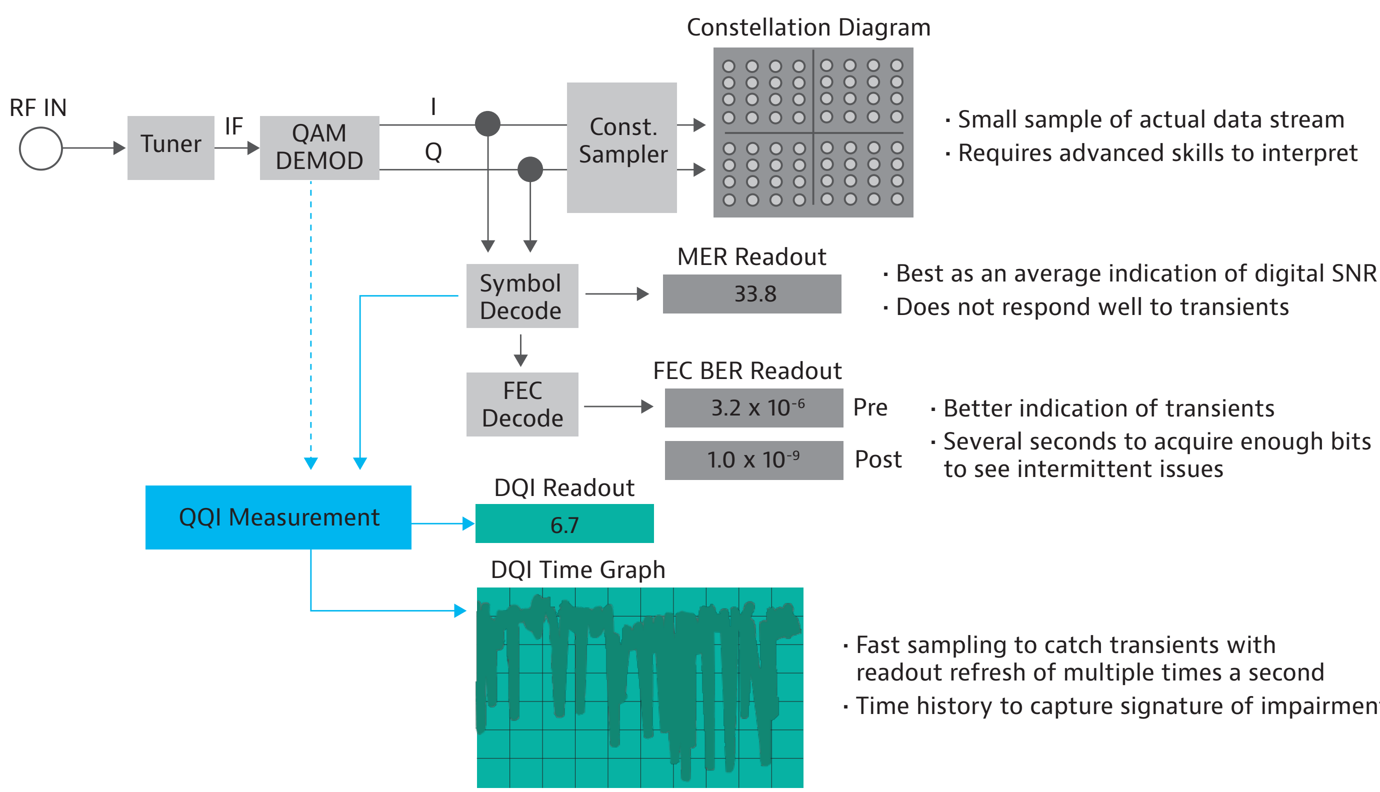

Figure 3. Simplified diagram illustrating where conventional measurement data originates versus the DQI measurement path.

Enhancing Traditional Troubleshooting with DQI

Traditional Measurement		DQI
Characteristic	***User Experience***	***User Experience***
BER		
Samples millions of bits before presenting a reliable reading	Must wait at least 10 to 30 seconds for a reliable initial reading.	Immediate: Sampling engine is less than 100 microseconds; display refresh is once a second
Displayed in scientific notation	Confusing to interpret and compare	Easy: 0 to 10 readout, 10 being highest quality
Uses results of FEC working to correct errors that are the results of constellation decision boundaries being violated	Observes FEC error correction process by noting pre- and post-error reading. Any post errors are passed to the CPE and will affect service.	Sensitive: Presents an indication of all deviations from an ideal constellation, i.e. DQI is sensitive to error magnitudes before errors occur and error magnitudes that result in errors
Constellation		
Constellation accumulates a small sample of the bit stream to show a pattern that is indicative of any source of continuous steady state impairment.	Excellent means of segmenting a sustained issue to the headend, distribution network, or drop.	Adds impulse detection: Further qualifies issue by displaying a time history which emphasizes transient issues within the steady state impairment.
Constellation is specifically very telling at the extremes of the display such as in the corners.	A zoom to the corners of the constellation can further lead one to the cause of the impairment Good pass/fail figure to test against limits for averaged steady state signal quality over time	Sensitive: DQI modeling includes corner I and Q data to increase sensitivity to the corner symbols
MER		
MER is an accumulative measurement for steady state conditions	Good pass/fail figure to test against limits for averaged steady state signal quality over time	Enhanced troubleshooting: Helps segmentation of issue with a more responsive measurement readout and time history display

Case Studies

High frequency QAMs have margin issues

An operator reported that he wanted to monitor a high frequency channel placed at the roll-off region of their 760 MHz plant. The channel was channel 121 at 777 MHz and was the guide channel on a 256 QAM carrier. This meant that the channel was more susceptible to margin issues than a channel with lesser data rate. BER readings did not reveal many, if any, errors and MER showed acceptable levels. The DQI measurement was used and consistently showed a value that stayed just above midrange of the measurement (DQI of 5 to 6). Now that the operator has a means of checking channel 121 with a measurement that is more sensitive than MER and BER, he is more confident when pushing the limits of his plant. Additionally, he noticed that there were other impairments that would be damaging to a service such as digital video (DQI dropping to 2 or lower), but with forgiving applications such as their guide data, this use of the extended spectrum was acceptable.

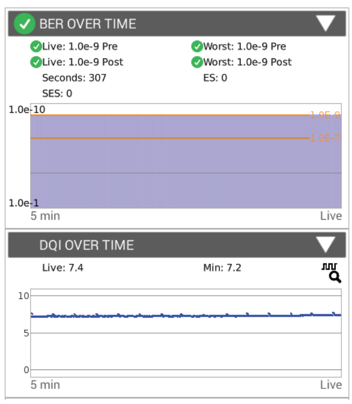

Figure 4. DQI showing a constant degradation of the signal quality because of discrete interfering signal. DQI also shows some intermittent severe issues that may not be acceptable in an application

Tiling on the digital video channels, as well as phone and HSD disruptions

An operator was experiencing intermittent issues on QAM channels causing video tiling, as well as phone service and HSD disruptions. The initial problem was detected by an installer who witnessed the issue at a customer's premises. An advanced maintenance technician was sent to the location to identify and resolve the issue. Using a variety of handheld QAM analyzers the issue with the service could not be seen with traditional MER or BER measurements. An MPEG analyzer detected occasional synch loss errors signifying an issue with the channels. The issue was finally tracked down to an event occurring in an amplifier's AGC circuitry. The event caused random signal interference but would not show up as a traditional BER issue. Testing with DQI revealed the sporadic nature of the impairment, showing a characteristic signature of the issue that will help the technician identify similar issues in the future.

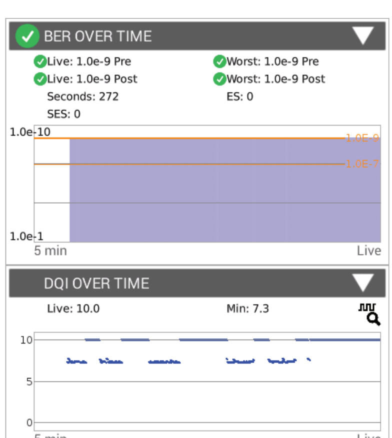

Figure 5. Plotting a time history of the DQI measurement can show a characteristic signature of the issue that will help the technician identify similar issues in the future.

Digital High Definition Video intermittently impacted

Intermittent issues are the most difficult to locate. Traditional measurements such as MER and BER are too slow to capture issues that only occasionally arise. DQI is real-time and samples 98% of the demodulated stream. The following example could occasionally be caught with BER but DQI captures it instantly when it happens and plots a time history that gives the technician a further dimension of the impairment.

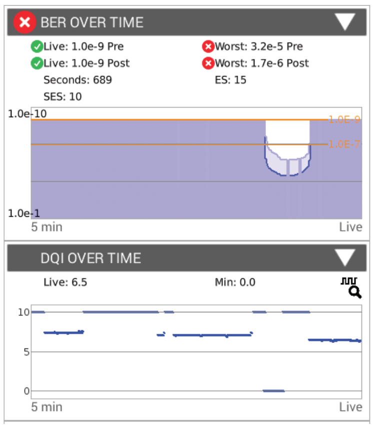

Figure 6a

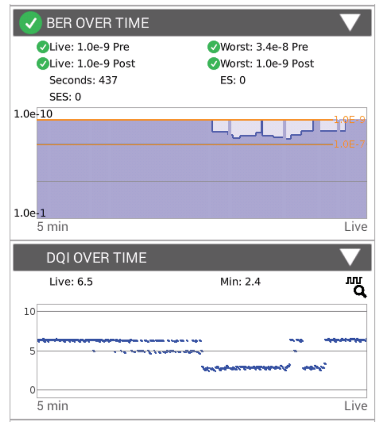

Figure 6b

Figure 6a and 6b. Displaying drop in DQI well before BER shows the issue.

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