Datacasting Over Analog Television: A Tutorial on Dotcast's dNTSC Technology

Dotcast, Inc.
20425 72nd Ave. S, Suite 200
Kent, WA 98032

Correspondence: Dr. Wonzoo Chung
wchung@dotcast.com

Digital Data on TV signals

Considered a gold mining opportunity to re-use the broadcast television infrastructure, there have been several attempts to transmit digital data on top of analog TV broadcast signals. One straightforward approach places a QPSK signal in the TV signal at a less sensitive spectral position - for example, between the color sub-carrier and audio carrier, or at the end of the vestigial sideband area. Another, more complicated solution spreads digital data and inserts it below the noise floor of the TV signal using spread spectrum or OFDM techniques.

However, none of the said solutions has managed to successfully deliver data with acceptable TV video quality - simply, the data is visible to the TV receiver. Furthermore, attempts at lowering the data power to the point of imperceptible impact on the video prevent reliable data reception in realistic settings.

Dotcast's dNTSC technology is a revolutionary approach to insert digital data without perceptible video impairment. In a nutshell, the dNTSC system inserts data as a quadrature component to the TV signal. With Dotcast's patented data insertion and extraction techniques, the dNTSC system can provide unimpaired analog television viewing while simultaneously delivering error-free, rich multi-media content to a TV station's Grade A contour—for example, about 1.7 million people in Los Angeles, CA for an ABC affiliate station.

How dNTSC puts data on the TV signal

To understand how the dNTSC system works, we need to first understand how the analog TV system works. The source video signal is real-valued, symmetric in magnitude and anti-symmetric in phase. For the sake of improved transmission efficiency, the real-valued source video signal is converted to its complex-valued form by eliminating spectral redundancy using a vestigial side-band filter, leaving 1.25 MHz of the real sub-band around DC, as illustrated in the frequency domain in Figure 1.

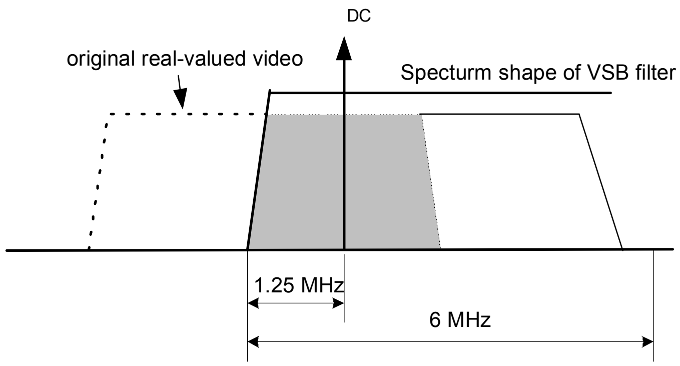

Figure 1: Shaping of the analog television signal with a VSB filter to remove spectral redundancy.

During transmission the television signal is rotated by an unknown phase. The TV receiver must correct for this phase rotation, and usually does so by using a Quasi-Synchronous Carrier Recovery (QSCR) method, that operates on a narrow bandwidth typically centered around DC, as illustrated in Figure 2.

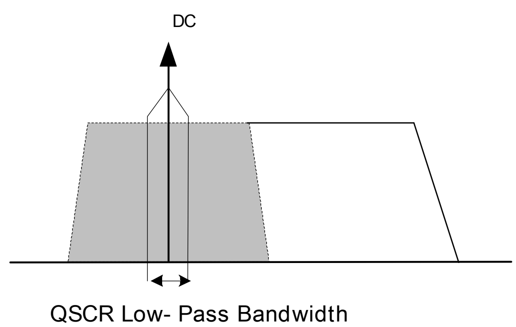

Figure 2: Synchronization of analog television signal is accomplished in TV receiver using a QSCR method centered around DC

After phase recovery in the QSCR, the real-valued video signal is restored by a Nyquist filter, which has the frequency response illustrated in Figure 3.

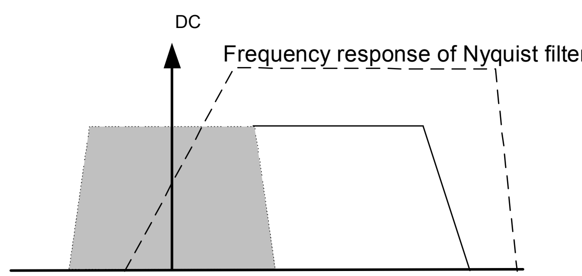

Figure 3: Restoring the real-valued video signal with a Nyquist filter in the TV receiver.

Now that we understand the analog television system basics, we can see how digital data can be communicated on top of this existing infrastructure. The dNTSC system inserts digital data in quadrature to the video signal within the 1.25MHz band around DC of its real-valued portion, using the following processes.

A. **Sub-modulation:** A QAM data signal is generated from a 4 to 128 point constellation, with a symbol rate of 0.613 MHz, producing 1-3.9 Mbps payload data rate. This signal is modulated onto a data sub-carrier whose frequency is chosen such that the resulting signal does not overlap with the QSCR bandwidth in TV receivers. Therefore, the digital data does not interfere with the synchronization in the TV receiver, as illustrated in Figure 4.

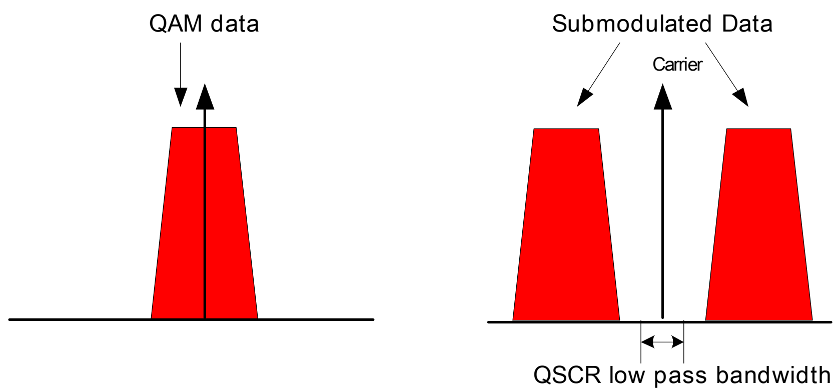

Figure 4: Baseband QAM data in the left subplot is modulated in the right sub-plot onto a sub-carrier whose frequency is chosen outside the QSCR bandwidth of the TV receiver

B. **Abatement Process:** To counteract the effect of the Nyquist filter in the TV receiver, the sub-modulated digital data is processed by an Abatement filter, which for illustrative purposes can be viewed as the complementary Nyquist filter to that which is used in the TV receiver. Since the TV receiver filters the received signal with a Nyquist filter, we desire the received data signal output from the Nyquist filter to be real valued. Hence, a complementary Nyquist filter applied to the sub-modulated data, as illustrated in Figure 5, results in a real-valued data signal from the TV receiver's Nyquist filter.

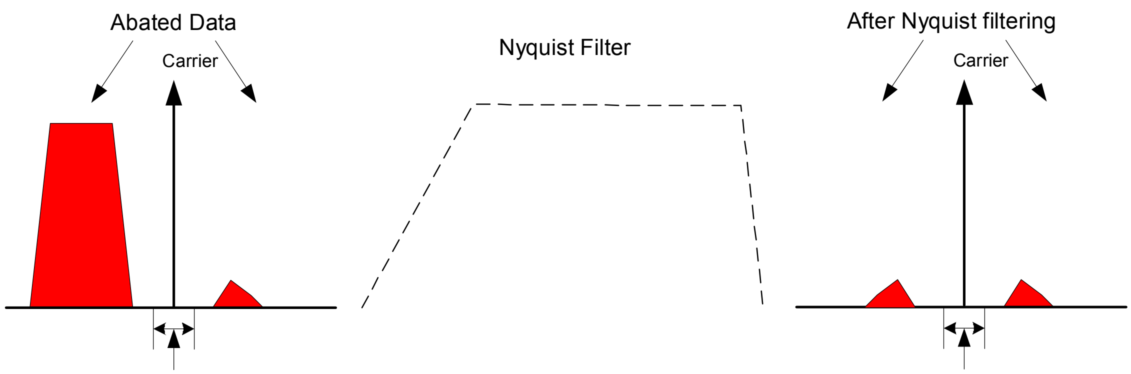

Figure 5: Sub-modulated data is first filtered by an Abatement filter to produce abated data, which when processed by a TV receiver's Nyquist filter produces real-valued digital data.

C. Data Insertion: The abated data is now inserted as a quadrature component to the video signal. Mathematically, the dNTSC output is expressed as

$$y = B(v) + jA(d)$$

where *B(v)* denotes VSB-filtered video and *A(d)* denotes abated data. This idea is conceptually illustrated in Figure 6.

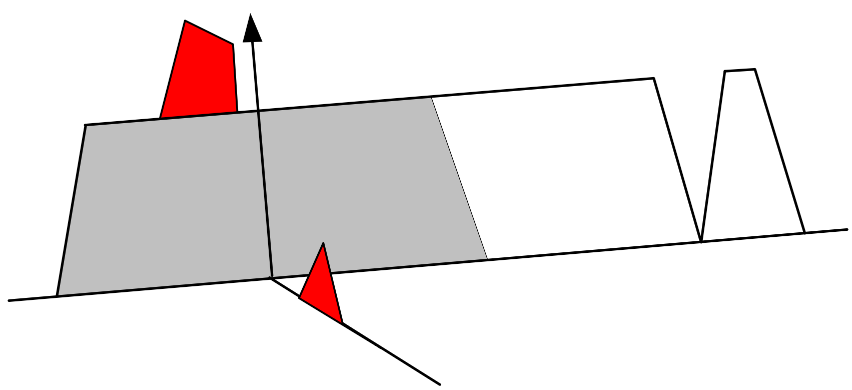

Figure 6: Digital data is inserted in quadrature to the video signal

Why TV cannot see dNTSC data

Although the data is added in quadrature to the video signal, TV receivers recover phase as if the data does not exist, since the data is not detected by the QSCR low-pass filter.

Furthermore, after Nyquist filtering in the TV receiver, the real-valued data exists purely as the imaginary component to the video signal, since the Nyquist filter makes the abated data real-valued and data is in quadrature to the video signal, i.e.,

$$\begin{aligned} N(y) &= N * B(v) + jN * A(d) \\ &= v + j\underbrace{(N * A(d))}_{real-valued} \end{aligned}$$

Since the TV receiver restores only the in-phase component, the video signal, the data does not interfere with the video signal.

Note that when *N*A(d)* is not real-valued due to mismatch between the Abatement filter and the Nyquist filter, the video is recovered with leakage from the data, which manifests as noise in the TV receiver. However, since the power of *N*A(d)* is so small from the spectral shape of the Nyquist filter and Abatement filter, the dNTSC system has inherent robustness and still achieves acceptable video impairment.

How dNTSC receiver extracts data

The dNTSC system uses state-of-the-art digital receiver technology to restore the data signal from the composite dNTSC signal. First, the quadrature component of the composite video signal is extracted by filtering one sideband of the abated data signal spectrum, as illustrated in Figure 7.

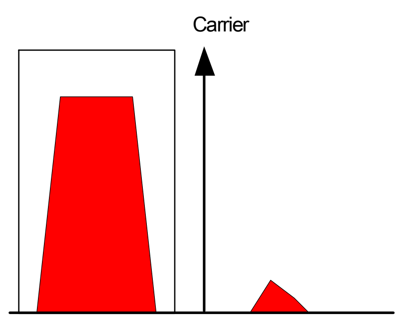

Fig 7: Single sideband filtering of the abated data spectrum to recover the digital data in the dNTSC receiver

Once this data spectrum is filtered, the major challenges of the receiver include the mitigation of multipath artifacts, such as traditional inter-symbol interference, as well as video leakage onto the data. The dNTSC receiver is equipped with cutting edge adaptive data equalization and video cancellation techniques. Furthermore, the data is channel coded using concatenated Reed Solomon and

Trellis codes, providing better than 10^{-8} error rates within a TV station's Grade A contour.

If you want to learn more about dNTSC

For a more detailed description of the dNTSC technology, please refer to:

W. Chung, T.J. Endres, and C.D. Long, "A Data Broadcasting System Expanding the Information Capacity of Existing Analog Communication Systems," to appear in *IEEE Trans. on Broadcasting*.