DVB-T and the Magic of COFDM

DVB-T on a tram in downtown Cologne

In the August issue of Australia's Broadcast Engineering News (BEN), Martin Jacklin of the DVB Project Office outlined the strengths of the DVB-T Terrestrial system. As a response, in September Craig K. Tanner of the ATSC made several comparisons between the ATSC and DVB-T digital TV systems. In this third part of the Great Terrestrial Debate, Jonathan Stott of the BBC - which has built and tested a DVB-T modem and will launch a public service in 1998 - attempts to clear up some misunderstandings.

Introduction

Because the DVB-T COFDM system is very flexible, offering a wide range of implementation choices for the broadcaster, it can be difficult to make valid comparisons between the DVB-T and ATSC systems - so it's easy to come to the wrong conclusions. This article will try to explain some of the choices and give some results to try to help BEN readers make an informed comparison.

Data rate capability

Last month's article suggested that DVB-T would provide only 14.8 Mbit/s in an Australian channel compared with 19.3 Mbit/s for ATSC. The calculation there of data rate capacity assumed a guard interval 1/4 for the DVB-T system. However, for comparison with 8-VSB, which has no guard interval, it would be more appropriate to choose the shortest guard interval of 1/32, as proposed and tested in the UK. In this case the data rate for a 6 MHz system would be 18.1 Mbit/s, not 14.8 Mbit/s as quoted.

But one of the advantages of DVB-T is that scaling for different channel bandwidths is very easy: all you have to do is change the clock frequency - there is not even a "modest effort" in developing a scaled version. In tests in Sydney in November 1996 the change was made at the flick of a switch. So in Australia's 7 MHz channels a DVB-T system with 64-QAM modulation, rate 2/3 coding and a 1/32 guard interval could be used, **giving a data capacity of 21.1 Mbit/s**.

Carrier-to-noise performance

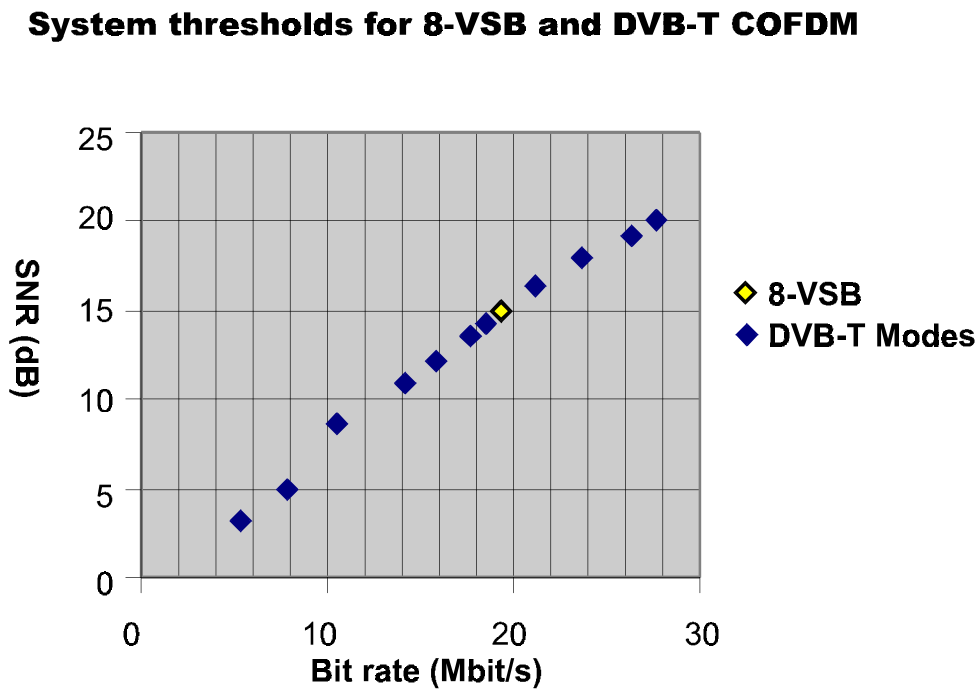
It's when you come to compare carrier-to-noise performance that you have to be most careful in comparing the two different systems - you may be comparing apples with bananas!

The first thing is to settle what you are measuring: is it the C/N for essentially error-free reception, or the C/N when the system has completely failed? The difference can be as much as 10 dB!

Last month's article said "the 8-VSB signal's threshold of reception is 15 dB, nearly 5 dB lower than the COFDM threshold of 19.8 dB ....". However, the ATSC figure is for a severely degraded signal (about 1 decoded packet per second in error) corresponding to system failure, whereas the DVB-T figure is for essentially error-free reception. Furthermore, the DVB-T result quoted was from a first-generation demodulator optimised to have an excellent performance in rapidly-varying channels. A figure of 18.1 dB has recently been published in the ITU for a more up-to-date demodulator.

With COFDM there is a wide range of possible demodulator algorithms offering different compromises between ultimate carrier-to-noise performance and the ability to track rapidly-varying channels. Now you may feel you do not require mobile reception - but a fixed receiver still lives in a changing environment, with aircraft flutter affecting even rooftop antennas while set-top antennas will 'see' passing traffic or people moving around the room.

Our first BBC receiver was optimised for ultimate carrier-to-noise ratio performance in a static flat channel, getting within 0.1 dB of the theoretical limit. Its performance in the various DVB-T modes is plotted on a graph, Fig. 1, showing the C/N for failure for each mode together with the corresponding capacity for DVB-T operated within a 7 MHz channel. For comparison it also shows the single mode available from the ATSC system, as quoted in last month's article. Clearly, there is essentially no difference between the systems in this case. Of course, if a special variant of the ATSC system were developed for the Australian market, the figure for the ATSC system would change.



But it is our experience that it is better to sacrifice a dB or so in the lab in order to have better performance in practical conditions.

It is convenient (and easily repeatable) to test in the laboratory under flat-channel (so-called "Gaussian") conditions. However, this is not always a useful indicator of the performance to be obtained in the field. Even comparing different modes of the DVB-T COFDM system itself can be difficult if this is not appreciated. For example, two DVB-T modes (16-QAM/rate-3/4 and 64-QAM/rate-1/2) convey the same bit rate. It would be easy to conclude from its superior performance on the flat channel that the 16-QAM option should be preferred. This might be wrong, however, because the 64-QAM option can perform more robustly when you really need the best performance - in a channel degraded by severe multipath and interference. Similar care is needed to distinguish cases for COFDM and 8-VSB representing conditions that are both comparable and significant.

COFDM is very robust against co-channel interference. We understand that for 8-VSB, if co-channel interference is expected a 'compatibility filter' is switched in which makes the C/N performance of 8-VSB roughly 3 dB worse.

Single Frequency Networks

A single frequency network with 0 dB echoes was demonstrated at Montreux in 1995 and again in 1997. Recently the benefits of SFN operation for **gap filling** have been shown in operational circumstances in Berlin and demonstrated at IFA in September 1997. Gap filling is a way of covering small "shadowed" areas using an on-channel repeater. Of course, the use of SFNs with COFDM is well established in Eu147 DAB.

Care is needed when interpreting C/N values in the presence of echoes. It is usual with COFDM (which effectively treats all the incoming signal as 'useful') to calculate the "C" of C/N as including the echo power. Thus suppose a receiver is served by a single transmitter with a C/N of x dB. If another transmitter on the same frequency is then switched on, as part of an SFN, the receiver now receives two signals and the C/N is increased. If we suppose the receiver is so placed that the 'echo' is equal in strength to the original signal, the C/N is now $(x + 3)$ dB. It is true that the C/N required in the presence of such a 0-dB echo is greater than for a 'flat' channel, by an amount depending primarily on the inner code rate option chosen. This increase is about

3 dB for rate 1/2 coding, or about 6 dB for rate 2/3 as cited in the previous article. But taking into account that the echo is included in the useful power, the transmitter power does not have to be increased by this full amount as implied by the article. With rate 1/2 coding no increase is needed; with rate 2/3 the increase is only about 3 dB.

While 0 dB echoes will be relatively rare with reception using rooftop antennas, they are more probable with set-top antennas.

High definition television

Both ATSC and DVB-T systems offer a 'bit-pipe' that can be used for any service offering. Both systems were demonstrated carrying HDTV at Montreux. The MPEG video decoder is unlikely to be included in the demodulator chipset in the foreseeable future. The choice of HDTV or multiple SDTV programming thus depends only on the business plans of the broadcaster and does not depend on the choice of modulation system.

Conclusions

The flexibility of DVB-T was designed to meet the surprisingly-varied commercial requirements of all the DVB members. Any broadcaster intending to offer a digital terrestrial TV service must similarly decide its requirements and what key performance factors they imply. The many options of DVB-T (which equip it so well to satisfy varied needs) make it difficult to identify relevant factors from others' published results. So, if we were to offer advice to somebody contemplating starting digital broadcasting, it would be: test the systems under the conditions you want to use them in, and with the parameter set you want to use - then make your decision based on the results of those tests.