Report of the DTTB Selection Panel

Annex E

DVB Comments on Australian Lab Tests and Field trial results

Comments compiled for DVB by Jeff Gledhill (NDS)
with assistance from Chris Nokes (BBC) and Lis Grete Møller (Tele Danmark A/S)

31/3/98

FACTS and the Communications Labs are to be congratulated on the thorough and professional organisation of both the field trial and the laboratory measurements. These tests must be among the most complete investigations of digital transmission systems made anywhere in the world.

1 Scope of the tests and choice of DVB-T system parameters

An important difference between the DVB-T and ATSC systems is that ATSC allows only one bit-rate (excluding the 16-VSB mode intended for cable) whereas DVB-T has several adjustable parameters, which allow a trade off between robustness and bit rate. The lab tests and field trial concentrated largely on tests of one mode. The mode chosen was 64 QAM with a rate 2/3 code and a 1/8 guard interval - primarily to give a similar bit rate as ATSC. Consideration was given to using 16 QAM with a 1/32 guard interval, but this was rejected on advice from NDS. This mode actually has a 2.5 dB better AWGN performance, but has significantly worse performance in non-Gaussian channels. In fact it is likely that this mode would replicate the performance of ATSC quite closely.

Because at the time equipment was only available working to the 2K variant of DVB-T, the 8K modes could not be tested. It is also worth noting that for the same absolute guard interval, the 8K variant of DVB-T delivers nearly 2 Mbit/s extra bit rate using the same modulation and coding. Alternatively, for exactly the same bit rate, four times the echo performance is possible.

1.1 Performance of DVB-T receivers

It is important to understand that there is no prescription for the implementation of a DVB-T receiver. There are a number of trade-offs that can be made - for example Doppler performance against AWGN performance. There are also cost/complexity trade-offs. Therefore in these tests “DVB-T” is not being compared with “ATSC”, but one implementation of each system is being tested.

1.2 The equipment

An important difference between the ATSC and DVB-T receivers was that the ATSC receiver appeared to be a laboratory demonstrator, whereas the DVB-T equipment was designed to be as close an emulation of a consumer unit as possible at the time. Thus the DVB-T receiver from NDS was much smaller than that from ATSC, and included an MPEG decoder (based on a PACE board from a domestic receiver). The DVB-T tuners were an “off-the-shelf” domestic design, apart from the substitution of a frequency synthesiser chip to improve phase noise (note that these tuners were manufactured by Philips, not ALPS as stated in the report on the laboratory measurements). On the other hand the ATSC receiver included no video decoding, and its tuner was believed to be a dual conversion design based on professional components.

Considerable pressure was applied by FACTS to deliver equipment as early as possible. The COFDM modulator was delivered in late 1996 followed by two receivers in February 1997. It had been expected that the ATSC would deliver a complete system before this, but as things transpired, the ATSC receiver was not actually delivered until some months after the DVB equipment.

It is not claimed that the equipment supplied by NDS was as mature as that from the ATSC - it had only been working for a short time and was not fully optimised. In fact, as originally supplied there was an error in the implementation of one of the interleavers (and corresponding de-interleaver). This was discovered as the result of inter-operability tests with a BBC modem, and fortunately was fixable with a firmware upgrade (it is not believed that this error would have significantly affected test results even if it had not been corrected). A further significant factor was that the tuners used in the receivers (one VHF and one UHF) were far from optimum. These were PAL tuners hastily substituted for the one normally used, to allow operation in 7 MHz channels. The resulting tuner / IF board was not as well screened as the original 8 MHz version resulting in significant ‘self interference’ from the digital circuitry inside the receiver. Although the communications labs made excellent efforts to improve the earthing arrangements inside the receiver, variations in the noise performance of around 1 dB were seen in the tests, probably mainly because of this effect.

Subsequently, the NDS DVB-T receiver design has been optimised in a number of ways. Important optimisations include:

- An improved channel state CCI detection algorithm
- A longer channel estimation filter
- Modifications to the UHF tuner to improve adjacent channel performance
- Use of a professional MPEG decoder with better error performance

The first of these required only a PROM to be changed, and this was supplied for the tests in Australia. Unfortunately, used alone, this does slightly worsen the noise performance, so it was not used for most of the tests. In fact a further optimisation of the values in this PROM allows the same CCI performance with negligible noise penalty. This is independently supported by tests on an entirely different DVB-T receiver, as reported in reference 3.

The second modification results in much better performance with strong echoes, but could not be supplied since it required the replacement of a 120 pin programmable gate array, soldered to the motherboard. The third and fourth modifications also would have required the return of the receiver to NDS in the U.K.

There was also a difference in the conduct of the tests, in that ATSC insisted on being present during the laboratory tests, and made adjustments to the equipment between tests, whereas DVB or NDS representatives were in general not present.

2 Observations on the Laboratory measurements

2.1 Note on failure criteria BER measurements (Report section 3.1, page 19)

ATSC and DVB-T have used different system failure criteria, which were carried through into the lab measurements. The ATSC definition of failure is a Bit Error Ratio of 3×10^{-6} at the final modem output. ATSC claim that this corresponds to ‘Threshold Of Visibility (TOV)’ on decoded pictures. Since no video decoder was provided, it was not possible to check this, however it must be said that without sophisticated concealment, this would normally correspond to a severely impaired MPEG stream. Strictly DVB does not define a failure criterion at all, but instead prefers to define a performance criterion where the system is still working, since it is this criterion which must be used for service planning. In analogue television terms, this corresponds to the difference between planning for Grade 4 services and Grade 1 services. The DVB-T limiting criterion of 2×10^{-4} at the output of the Viterbi decoder before the Reed Solomon decoder corresponds to a “Quasi Error Free (QEF)” condition - a BER of the order of 10^{-11}, at the final modem output, or around one visible picture artefact per hour.

The results based on these measurements will thus be slightly skewed in favour of ATSC. Fortunately, the difference between QEF and TOV will generally not be large, - probably around 1.5 dB, but when burst errors occur - e.g. due to impulse noise - the difference may be greater. Similarly for co-channel interference, the difference may be over 4 dB.

2.2 Digital interference into PAL (Report section 3.2, pages 20...26)

Since both the ATSC and DVB-T signals approximate to white noise, they would be expected to cause similar levels of interference into PAL. Some differences might be expected because of the slightly wider DVB-T spectrum. DVB-T would be more likely to cause interference to the sound in both co- and adjacent channel cases, but would concentrate less power in the critical parts of the vision spectrum when acting as a co-channel interferer. In fact, the measurements seemed consistently to show a small advantage for DVB-T. This is difficult to understand, but may be due to the fact that COFDM is a better approximation to Gaussian noise than 8-VSB.

2.3 PAL / CW interference into Digital (Report section 3.3 / 3.4, page 27)

Co channel Essentially two sets of measurements were made on the DVB-T receiver, one based on an early and one based on an upgraded channel state estimation PROM. The latter resulted in an improvement in the DVB-T performance, but in either case DVB-T significantly outperformed the ATSC system. In the case of the upgraded system this amounted to an 11 dB advantage at the channel centre. This must be a very significant result for any circumstances where Digital Transmissions must co-exist with PAL.

With a CW interferer, and using the upgraded channel state estimation, the differences are even more dramatic, with an advantage for DVB-T of at minimum 12 dB, and at exact channel centre a massive 23 dB.

Adjacent channel Adjacent channel results are heavily dependent on tuner performance, so care should be taken in reading too much into the results presented here. As it happens the performance of the DVB-T and ATSC receivers are rather similar, both having very large protection ratios better than –35 dB. Figure 3.3.1 shows a small advantage (~3 dB) for the ATSC receiver in the lower adjacent channel, and a very small advantage for (~1 dB) for the DVB-T receiver in the upper adjacent.

2.4 Additive White Gaussian Noise performance (Report section 3.5 p35)

Measurements of the AWGN performance of the ATSC and DVB-T receivers, working in the 64 QAM rate 2/3 mode, showed approximately a 4 dB advantage for the ATSC system, and ATSC have made much of this. However, this advantage is not as significant as it seems and it is important to understand where it comes from.

Firstly, being essentially laboratory test equipment, the ATSC receiver has a very low implementation margin compared to the theoretical 8-VSB performance. The DVB-T equipment on the other hand loses about 1 dB of performance, primarily due to the use of a domestic PAL tuner. Further, there is a trade off in the channel estimation algorithm between Doppler performance and static AWGN performance. As implemented, the NDS receiver uses a wide bandwidth temporal channel estimation filter which, according to simulation results, in good Doppler performance but loses 1.6 dB AWGN performance. By reducing the Doppler performance to a few Hz (still better than ATSC - see section 2.10) most of this 1.6 dB can be reclaimed. Thus on a fair comparison, and also taking into account the different BER criterion used in the measurements, the ATSC advantage shrinks to less than 1 dB, for this DVB-T mode.

In fact the choice of this particular mode is rather arbitrary. It is interesting to compare two other DVB-T modes - an 8K system using 64 QAM, rate 2/3 code with a 1/32 guard interval, and 16 QAM, rate 7/8 code and a 1/32 guard interval. The first of these variants would replicate the 2K variant used in most of the tests except for the Doppler performance. However, it would deliver nearly 2 Mbit/s extra data rate for the same noise performance. The 16 QAM rate 7/8 system delivers just under 1 Mbit/s less data, but theoretically has

1 dB better performance than ATSC in Gaussian channels. Of course the use of this mode would lose a lot of the advantages of DVB-T over ATSC in ability to handle strong echoes, CCI, etc.

Even if all the previous comments about differences in system performance are ignored for a moment, the minimum signal levels, exactly as measured, are extremely revealing. Table 3.6.1 shows that when the performance of the system matters most, that is at the minimum input signal level, COFDM outperforms 8-VSB by about 2 - 2.5 dB. This somewhat surprising result leads to an effective noise figure measured in Table 3.7.1 of 3 – 6 dB worse for 8-VSB. One possible explanation for this is that any self-interference (for example, from harmonics of digital signals) will be most noticeable at low signal levels. The 8-VSB system has been shown to be poor at combating CW interference, so this could explain the relatively poor effective noise figure.

It is also important to remember that unlike ATSC, DVB-T has many modes of operation so performance can be traded for bit rate. Thus operation is possible down to signal / noise ratios of under 5 dB, or bit rates of up to 27 Mbit/s.

2.5 Echo Performance (report section 3.8 p40)

Because of the lack of a channel simulator, a delayed signal was generated using either using a length of cable, or by sending the signal down a microwave link. It is probable that results using the link are somewhat pessimistic, because of various imperfections in the signal path.

Echo performance was probably the aspect of the DVB-T equipment that suffered most as a result of the equipment being an early prototype. As supplied, and in the 64 QAM rate 2/3 mode, the receiver was only just able to work with short (7.5 us) 0 dB post echoes, showing an SNR loss of around 20 dB. With a longer (17 us) 0 dB echo the system was not able to work at all, although these results may have been in part due to degradation on the microwave link. With updated interpolation filters, NDS receivers now show an S/N degradation of around 6 dB due to 0 dB echoes over most of the guard interval. Similar results are quoted in reference 3.

With weak echoes the ATSC system shows a slight advantage over the DVB-T system, but this is really just a reflection of the somewhat better Gaussian noise performance with this implementation of the DVB-T receiver (see 2.4 above).

However, as supplied, the DVB-T equipment was still able to show the ability of COFDM to function with very strong echoes in a way that the 8-VSB system cannot. 8-VSB unable to deal with 0 dB echoes under any circumstances. For post echoes, the best-achieved figure was –3 dB with a echo length of 4.2 us. Pre-echo performance was very poor, with a maximum tolerable echo of -13.8 dB with an echo as short as 4.2 us. To be fair, this could probably be improved with more complex equalisation filters.

Curiously, the DVB-T equipment actually worked better with pre-echoes than post echoes (it should be completely symmetrical). This may have in part been due to the performance of the microwave link, but was probably mainly attributable to the early version of the firmware used in these tests.

Comment regarding notches in the spectrum

The note on page 42 stating that only short 0 dB echoes produced severe notches, is describing an artefact of the bandwidth setting of the spectrum analyser. Even with long echoes the notches are still deep in reality.

2.6 Co-and adjacent channel interference from digital (report 3.10 p53)

Co – channel Since only one DVB-T modulator was available, DVB-T measurements were conducted with a delayed and frequency-shifted version of the COFDM signal. As the report points out, this is roughly equivalent to a measurement of Doppler performance. This explains the greatly superior performance of the DVB-T system with a small frequency offset with this measurement (see section 2.10). With un-correlated interferers both ATSC and DVB-T interference would be expected to act more or less as Gaussian noise, and this is confirmed by the 8-VSB measurement in figure 3.10.4, and has been confirmed for DVB-T in measurements elsewhere.

One interesting observation is that the measurements made using the microwave link as delay, and with a large frequency offset (report figures 3.10.1 and 3.10.3), both systems show some degradation compared to interference with an unimpaired DTTB signal - presumably due to imperfections in the link. In the case of DVB-T, this impairment amounts to around 2 dB, but ATSC shows 5 – 7 dB loss of performance. This is perhaps a reflection of the ability of the two signals to handle ‘real world’ impairments.

Note: in table 4, the final summary, there appears to be an error in the PAL into 8-VSB co-channel protection ratio. On the basis of figures 3.3.1 to 3.3.4, this should be 9 dB at channel centre, not 2.4 dB.

Adjacent channel In this case, the use of a frequency-shifted version of the DVB-T signal rather than independent signals would not be expected to significantly affect the result. As with the PAL interference, this measurement reflects the quality of the tuner more than the digital systems. The ATSC receiver shows an advantage of 2-4 dB, but since this is in the context of protection ratios - in the order of 30 dB, this is not a significant difference.

2.9 Impulse interference (report 3.12 page 62)

Impulse interference is the one case where ATSC may have an advantage over the 64 QAM rate 2/3 2K mode of DVB-T. However, even this needs some qualification:

Firstly the difference between the systems may not be as large as the tests seem to indicate (an average of around 8 dB). This is because the BER measurements are inevitably averaged over a long period. Even if a mean BER of $3x10^{-6}$ is accepted as the failure point for MPEG with randomly distributed errors, with bursts of errors the failure point will be significantly lower.

Secondly, the results are likely to vary depending on the nature of the interference. The interference used, a food mixer, consisted of high amplitude spikes of short duration, and a relatively infrequent repetition rate. Consequently, the ATSC error correction sees short bursts of errors, and deals with them by interleaving, which converts a short burst of errors into a larger number of even shorter bursts. The ATSC Reed Solomon outer code inherently performs well given this sort of error pattern. So long as the error bursts remain short in duration, above a certain threshold performance will be nearly independent of pulse amplitude. The interference simply erases a number of bits - this number being related primarily to pulse duration not amplitude.

DVB-T also spreads the interference, but in a different way. In this case the energy in an interference pulse is spread by the receiver FFT over a complete symbol - many thousands of bits, a much larger number than the ATSC interleaving. This energy approximates to noise the amount of noise becoming worse as the pulse amplitude increases. If the effective SNR in a symbol becomes greater than the system failure threshold, a burst of hundreds or thousands of errors may result.

However, some length of interference bursts will exceed the combined burst error correction capability of the ATSC interleaving and error correction. The amplitude of interference the system can deal with will be much reduced. In this case, the way that the DVB-T spreads the interference becomes an advantage, so for longer pulses the DVB-T system may outperform the ATSC system. This remains to be confirmed.

Thirdly, the 8K variant of DVB-T spreads the energy in an impulse over a symbol four times longer than the 2K variant. For interference pulse repetition rates significantly less than the symbol repetition rate (1 KHz) and pulse durations significantly less than a symbol (1 ms) the 8K system should have a 6 dB better performance than the 2K variant - i.e. similar to ATSC.

Having said this, the field trial results did indicate a greater sensitivity to 'real world' impulse interference for at least the 2K DVB-T mode tested compared to ATSC.

2.10 Doppler Performance (report section 3.13)

The Doppler tests were conducted using a single frequency-shifted echo. Although in the real world multiple echoes are the norm, this test gives quite a good indication of the system performance.

The Doppler tests show the most dramatic variation between the systems of all the tests. As indicated earlier, the COFDM system was optimised for mobile reception, at slight expense to the AWGN performance. The system was found to be still able to operate with strong echoes (-3 dB) with Doppler shifts of around 100 Hz. On the other hand, the ATSC system failed at around 1 Hz.

Although the ATSC system was not designed for mobile reception, there must be a worry that its Doppler performance is so poor that even portable reception may be unreliable due to slow dynamic multipath, e.g because of people walking around the room. Even fixed reception may be affected by objects moving in the wind, or reflections off vehicles.

2.11 AFC performance (Table 3.23.1)

Note that the narrow lock range of the DTTB receiver is a consequence of the use of a voltage-controlled crystal oscillator in the IF stages, it is not fundamental. Chip-based implementations of the specification have a lock range of at least +- 70 KHz.

3 Comments on the Field trial

Both NDS (DVB) and Zenith (ATSC) representatives were present as equipment was installed for the field trial. As stated in the field trial report, great care had been taken to ensure the accuracy and reliability of the measurements. This can be seen in the consistency of the results, few of which are anomalous or difficult to explain.

Although the field trial represented a very thorough trial of DTTB, the limited time available and the restriction of measurements to Sydney mean that some caution must be used in interpreting the results. In particular, the reception sites chosen were not randomly distributed, but were deliberately biased to be interesting (i.e. likely to be difficult for DTTB). This affects the percentage of sites unserved. Sydney is also in many respects quite a difficult reception environment, with multipath from tall buildings and interference from overhead power distribution. There is one exception to this, however, the absence of co-channel interference. From the laboratory measurements, CCI would be expected to disadvantage ATSC much more than DVB-T, and this could be an important factor in other locations (e.g. Melbourne) where significant interference is expected.

Comments on the results summarised in the Field Trial Data Presentation follow.

3.2 Measurements of the analogue transmissions (Presentation 13.2.4..14)

These measurements are broadly as would be expected, and represent a useful confidence check on the measurement procedures.

3.3 DTTB Field Strengths (13.2.15..21)

In general the ATSC field strength seems to be slightly higher (typically 0.5 – 1 dB) than DVB-T. In principle this would give a slight unfair advantage to 8-VSB in terms of number of sites covered, in practice the difference is probably not significant.

3.4 Threshold C/N (13.2.21..24)

These results tie up fairly well with the lab test results - under good reception conditions the DVB-T system showing an S/N failure point of around 19 dB, the ATSC showing around 15 dB. There are some slight differences in results depending on the use of a spectrum analyser or a HP Vector Signal Analyser, and system noise or noise injection methods. The combination of VSA and noise injection methods seem to give least spread, perhaps indicating that these are the most reliable, but given the difficult measurement conditions in a field trial, all the methods are surprisingly consistent.

3.5 COFDM and 8-VSB threshold C/N (13.25..31)

These show the threshold C/Ns with both ATSC and DVB-T measurements on the same figure, using the different measurement techniques. Some care should be taken in interpreting these figures. At first sight the DVB-T system seems to have more anomalously poor results. However, many of these correspond to sites where the ATSC receiver did not work at all, consequently there is no ATSC measurement on the figure.

3.6 Decoder NF (13.32)

These results show that the DVB-T had suffered a change in noise figure from 4.6 dB to 10.7 dB between the lab measurements and the field trial. It has subsequently been found on other copies of the equipment that the 75 ohm input socket can be damaged by connection to 50 ohm connectors, leading to a loss of receiver sensitivity. This is a possible explanation. Owing to the use of a mast head amplifier, this should not have in general affected the measurement results.

3.7 COFDM v 8-VSB noise threshold (13.33..38)

These show directly the difference in SNR performances shown in figures 21..31 - the same comments apply.

3.8 Service availability and Dynamic Threshold effects (13.39..44)

Figure 13.41 is one of the most significant diagrams in the report, since it shows the most important result to the consumer - whether the service is viewable. As expected, with this transmitter power, neither system fully replicates PAL coverage. Despite a slightly worse SNR performance, the DVB-T receiver was able to decode a signal at more sites than the ATSC, although the difference (2% of sites) is not large enough to be statistically significant. For this DVB-T mode, and this transmitter power, the receiver performances are in practice the same.

However, the reasons for the failure are important (figure 13.42). A major cause for both systems is multipath. Since the equipment was supplied, the DVB-T receiver’s multipath performance has been substantially improved. The option also exists of using one of the 8K DVB-T modes which would allow echoes of four times the duration to be tolerated for no loss of SNR performance or bit rate.

The other major causes of failure were impulse noise, which mainly affected DVB-T, and flutter which affected ATSC. There is an important difference between the two in that a simple increase in signal strength would help with impulse interference, but not necessarily with flutter. This partly accounts for the effects seen in 43, where most of the DVB-T failures occurred in areas of low signal strength, whereas there are significant 8-VSB failures at high signal strength. This implies that if an increase in transmitter power was possible, DVB-T coverage may significantly improve, but ATSC may not.

System failure comparisons with PAL S/N (13.2.46 .. 48)

These results are generally consistent with previous noise measurements, and reiterate the point that some degree of PAL viewing may be possible when DTTB is not.

4 Conclusion

For the laboratory measurements, a good summary is the table in section 4 of the report (page 103). For the majority of measurements, the systems as supplied actually have quite similar performance, in the DVB-T mode chosen. However, the DVB-T equipment does have a very significant advantage for co-channel interference (PAL and CW) and Doppler. On the other hand the ATSC equipment has a better ability to cope with some types of impulse noise.

An important result of the field trial is that given the transmission power used, DTTB does not fully replicate PAL coverage. However, the field trial results have shown that the DVB-T system achieves very slightly better coverage than ATSC, and confirms the better ability of DVB-T to handle time-varying channels. The ATSC advantage with impulse noise was also confirmed.

On the basis of these results alone, the DVB-T system appears to have the overall advantage. However there are at least three reasons to believe that the advantage for DVB-T is even greater than indicated by the results:

1 There is reason to believe that there is more room for improvement in the DVB-T system than for the ATSC system. Some improvements (e.g. better echo performance) have already been demonstrated.

2 At most field trial locations where DVB-T was unable to decode a signal, a simple increase in power would be sufficient to make the system work. However, because of its sensitivity to flutter, this is not the case for ATSC. There are therefore an irreducible number of unserved sites, even after, for example, the PAL services are switched off and DTTB powers can be increased substantially.

3 The DVB-T system has much greater flexibility than ATSC. The ability to use other modes of the system, and also the existence of Hierarchical modes and the ability to work in Single Frequency Networks means that implementing a real transmission system is a much more practicable proposition than with ATSC. Thus some of the coverage deficiencies found in the field trial could be remedied with low-cost on-channel repeaters with DVB-T; this is unlikely to be possible with the ATSC system.

5 References

[1] Laboratory Report 98/01 - Laboratory testing of DTTB Modulation Systems - Neil Pickford Communications LAB.

[2] Field Trial Data Presentation - Report. FACTS specialist Group Advanced Transmission.

[3] Evaluation of a DVB-T Compliant Digital Terrestrial Transmission System - C.R. Nokes, I.R. Pullen, J.E. Salter, BBC R&D. IBC conference report 1997 pp 331..336 (IEE publication).

ANNEX E (part 1a)

Geneva, 16th June 1998

Re – DTTB Selection Process

Dear Mr. Robertson and Mr. Barton,

As you know, DVB has now provided you with responses to the laboratory tests and field trials carried out in Australia on DVB-T and ATSC. I am sure that these responses, with others, are currently in front of the Evaluation Committee which is considering them before shortly making their judgement as to the technical adequacy, and indeed the long-term advantages, of DVB against ATSC.

I now refer to several informal meetings between Richard Barton and DVB representatives, particularly Peter MacAvock and David Wood. These meetings discussed the proposed selection process to be undertaken by the Committee in making a decision on the recommendation of an appropriate digital terrestrial television system for Australia. It was indicated at that time that the critical issues upon which the recommendation would be based would go beyond just the detailed technical considerations and fundamental characteristics of the respective systems, and would also include such important considerations as –

- The availability and cost of receivers, and
- The support provided by DVB, if chosen, to the implementation phase of the system in Australia

Although your committee has made no specific request on these considerations, we thought it would assist the committee’s deliberations for DVB to provide some more founded comment.

Availability of receivers

On the surface, it may seem that because DVB is not being used in some European markets to deliver HDTV, there would be a delay in DTTB implementation in Australia if DVB were chosen. This, some argue, is due to the non-availability of HDTV receivers with DVB-T front ends. As you know the major component of the receiver, and indeed the most important influence its cost, is the display device. This display device will be the same for both contending systems. The DVB manufacturers believe that the difference in the supporting electronics will have a negligible influence on either the cost or the availability of receivers. Indeed, you are already aware that DVB-T front-end chipsets exist in 2k and 8k modes and that MPEG-2 MP@HL chipsets are also available.

DVB member manufacturers that we have approached have given us their assurance that the integrated HD receivers for DVB will be made available well within the time-scale to meet your implementation commitments. They have indicated that irrespective of the preferred system, receivers complying with the chosen standard will be made available to satisfy the market and manufacturing plans will commerce once a decision is announced. I might add that we strongly feel that ATSC bears no real advantages in this respect. Quite simply Australia cannot use receivers manufactured and marketed for the US market. They will, we feel, differ significant.

The UK is planning the launch of digital terrestrial services at the end of the year. Six multinational manufacturers have been singled out to launch DTTB consumer equipment. Nokia and Pace will manufacture set-top boxes and Grundig, Panasonic, Sony and Toshiba will manufacture integrated digital terrestrial TVs. The diversity of equipment suppliers already manufacturing DVB equipment is one of the strengths of DVB and is important for a market like Australia.

Receiver Prices.

As you know the price of receivers is controlled by the economies of scale that apply at a given time to a given market. As such, we see from experience that the price of receivers will decrease in due course as the sets become more popular. However, we do not believe, and this is confirmed in our discussions with member manufacturers, that there will be any significant difference in set prices as a result of the DTTB system chosen. Indeed one could argue that if early receivers in Australia were to have a requirement to tune and display both DTTB and PAL transmissions, then, for a mixed standard, i.e. 50/60 and 6/7 MHz then price would be higher than for 50/50 and 7/7 units.

DVB Implementation Support

As you know, DVB, backed by its members, will provide support to Australia during the implementation phase of digital terrestrial TV. In this respect, please be assured that should DVB be successful as the system choice, then we recognise the important responsibility placed on us to ensure that your transition to digital HDTV is fully successful.

In addition, DVB feels that tomorrow’s digital television services will extend far beyond traditional TV to include for example: HDTV, EPGs, wide-band interactivity, and a full range of data broadcasting services. To enable these DVB includes elements such as the DVB/DAVIC cable modem, an MPEG-2 DSM-CC based data broadcasting system and the so-called Multimedia Home Platform. We feel that such a toolbox is important in bringing service concepts to the market. We would be more than happy to discuss these further at any time.

Yours faithfully,

Helmut Stein
Chairman DVB PCM

ANNEX E (part 2)

ATSC COMMENTS ON THE DRAFT AUSTRALIAN LABORATORY AND FIELD TEST REPORTS

April 24, 1998

The Advanced Television Systems Committee (ATSC) is very pleased to have the opportunity to have its 8-VSB transmission subsystem tested by the FACTS as a candidate for possible adoption and use in Australia. In addition to the independent review of our system, which has already been adopted in the United States, Canada, and South Korea, your testing provides the world's first direct comparison of the ATSC system and the system supported by the DVB.

Moreover, we appreciate the opportunity to review, ask questions and make comments about the test results prior to your evaluation process and public release of the data and your recommendations.

The ATSC has formed a small working group of people who have been intimately involved in the U.S. testing processes. Members of that working group are listed in Appendix A for your information. Keeping our group small has enabled us to maintain the confidentiality you requested.

Your testing groups are to be congratulated on the methodology and thoroughness of both the laboratory and field trials. The sheer volume of the summary and detailed data (more than one foot thick when stacked!) attests to the efforts of those doing the testing and data compilation. In fact, it is that sheer volume of data that has caused our review to take longer than any of us had anticipated -- for which we apologize and appreciate your patience.

Overall, we are very pleased with the performance of the 8-VSB transmission system. We believe that the Australian field trial data is supportive of the ever increasing data base in the U.S. Moreover, now that independent data exists on the COFDM system, we believe that our assertions of substantially better overall performance with 8-VSB are backed up by data from an apples-to-apples testing process.

We have very few comments or questions on the Laboratory Trials. We will, therefore, concentrate our comments on the data from the Field Trials.

In establishing a new digital service in the environment of existing analog service, the two most important transmission factors are: (1) the capability of the new digital service to cover as much area as possible (nominally equal to the existing analog service area) without causing interference into the existing analog service; and (2) the capability of the new digital service (at substantially lower power than the analog service) to be immune to all types of interference -- be it from existing analog services, white noise, non-white or burst noise, or self-caused reflections (multipath).

Carrier-to-noise ratio (C/N) threshold. As we anticipated based on our own extensive testing in the U.S. and the results reported from Europe, the carrier-to-noise ratio (C/N) threshold was found to be slightly more than 4 dB better (lower) for VSB. Thus, the 4 dB difference determined in the testing program is extremely significant. For coverage area equal to that of 8-VSB, a COFDM signal would have to be transmitted at 4 dB greater power. This would result in either 4 dB greater transmitter power or 4 dB greater antenna gain or some combination thereof -- all costly solutions. Moreover, the interference generated into PAL would be 4 dB more than that resulting from 8-VSB transmission. This is especially significant with COFDM, because it uses the entire 7 MHz channel with resultant high fields in the 0.5 MHz spectrum immediately adjacent to the upper and lower adjacent channel analog services. For a 6 MHz system, the 8-VSB signal, of course, is centered in the allocated 7 MHz channel. (If a 7 MHz 8-VSB system is implemented, the .5 MHz guard bands would be sacrificed in favor of a 17% higher data rate.)

Burst noise. Unlike white noise with its flat passband spectrum, burst noise is much more random in frequency, amplitude and duration. Your field testing plan was designed to evaluate the effect of burst noise on both systems. The data shows that COFDM did not function at a total of 14 sites, six of which were lost due to burst noise. The 8-VSB system performed successfully at all of these six sites Burst noise is also extremely important for indoor reception, which is discussed in Appendix B.

Multipath. Many sites were chosen to explore large amplitude multipath performance. There were only two sites (three tests) at which the 8-VSB system did not function properly due to large ghosts (tests 2, 3 and 10) but at which COFDM did function properly. Site 10 failed because the receiving antenna was aimed at a ghost, resulting in a long pre-ghost outside the range of the equalizer. [At site 1, 8-VSB had data errors greater than zero, although all of the diagnostics showed no reason for such errors.]

For completeness, there were eight sites where neither system performed successfully. This is most likely the result of very low signal strengths as well as noise.

Interference into PAL. The COFDM signal “caused up to 0.5 dB more impact” than 8-VSB. This may have been the result of COFDM using the entire 7 MHz channel.

The significant VSB to COFDM data comparison is summarized in the red/green charts of the report in two distinct ways. First, for those sites where zero errors were achieved, the carrier-to-noise ratio (C/N) threshold is plotted for each test. A good example is Chart 25, where a calculation of average C/N can readily be made. The average was shown to be about 4.0 dB. Second, at sites in which system failures actually occurred, since it is not possible to record C/N values, the failures were noted, as a function of assumed cause, for each failed test. The best example is Chart 41. [As explained in Appendix C, Chart 41 has mistakes resulting from the incorrect transfer of the raw data.] It is possible to combine the data as a function of C/N if histograms are used. Histograms, from which *median* and other percentiles can be obtained, have the additional advantage of smoothing the effects of a few outlying points (as occurred on the C/N threshold for both systems -- see Chart 25).

Figure 1 shows a histogram of the measured static carrier-to-noise ratio thresholds and the percentage of tests that were below that number. The entire data set is used, including failed sites. Failed sites have thresholds greater than 26 dB, and therefore show up at the top right corner of the histogram. The median (50 percentile) threshold for 8-VSB is 15.75 dB. The median for COFDM is 20.1 dB. Both numbers are within 1 dB of the measured white noise threshold in the laboratory tests. By design, the test sites were not statistically selected on the basis of population served or land area covered, but they were specifically aimed at sites where reception was expected to be difficult. Nevertheless, the median threshold is dominated by a single impairment -- white noise. Therefore, the difference between the performance of the two systems is slightly greater than 4 dB. To evaluate the performance of the systems under multiple impairments, the threshold for 90% or 95% of the sites would normally be used for a statistically based trial. Since this evaluation is closer to a worst-case situation, a more reasonable threshold number would be 75%. For 75% of the sites, the threshold for 8-VSB is 17.5 dB and for COFDM is it 22.75 dB. (Or read another way, at signal levels where 75% of the trial sites would be successfully received by 8-VSB, no sites would be received by COFDM.) In the case of multiple impairments (multipath and/or impulse noise in addition to white noise), an approximate 2 dB increase in threshold is required for both systems.

Figure 2 is a similar histogram of the dynamic C/N threshold. The dynamic threshold is a much more difficult case. The criteria for successful reception is zero errors for an unspecified period of time. It includes such long-term burst affects as airplane flutter and the non-stationary characteristic of impulse noise. The median thresholds for both systems have deteriorated approximately 1 dB. The difference between the two systems at both the 50 and 75 percentiles, is still slightly greater than 4 dB. There are now more sites with very large thresholds. For COFDM these represent mainly time-varying impulse noise, and for 8-VSB these sites are primarily related to airplane flutter.

The prototype VSB test-rack that was used in the trial had two modes of equalizer operation. The first, based solely on the training signal, is very accurate, but slow. The second, a blind-equalizer mode, is a data decision-directed mode which is considerably faster. There is an automatic algorithm to switch between them. Due to hardware limitations in the prototype tested, the blind-mode only operates on the feed-forward section of the equalizer, approximately the first four microseconds. This mode was not seen in the laboratory trials because the only dynamic ghost tested had a delay of 7.18 microseconds. To achieve zero errors during moderate-to-strong airplane flutter, the system would have had to be forced into the blind-mode, because relying on the automatic mode switching was too slow and errors occurred before the switching occurred. [For production receivers, the chipsets which have been developed by both LG Electronics and Lucent Technologies update all equalizer taps in one cycle so they are inherently much faster than the prototype used in the trials. Both chipsets also have training-signal and blind-equalizer modes controlled by the system microprocessor.]

Figure 3 is a worst-case C/N threshold histogram. It covers the entire test suite. At each site the higher (poorer) of dynamic or static threshold is used. The median threshold for 8-VSB is now 16.4 dB and the median threshold for COFDM is now 20.8 dB. The difference between systems at both the median point and the multiple impairment point of 75% is still in excess of 4 dB.

CONCLUSIONS

Although we have made a variety of comments and raised a number of questions, the overarching nature of the trials and the data collection/presentation is very well done.

We believe the results of the trials clearly prove the superiority of the 8-VSB system and substantiate our assertions relative to the attributes of 8-VSB compared to those of COFDM:

- The most significant difference is 8-VSB’s superior C/N threshold, in excess of 4 dB
    - 4 dB less transmitter power required with 8-VSB for equal service area, and
    - 4 dB less interference into PAL services with 8-VSB for equal service area

- Superior immunity to burst or impulse noise emanating from electric motors, vehicle ignition systems, lighting systems, power line radiation and the like
    - important with outdoor reception
    - critical with indoor reception because of much lower signal strength and the presence of many electrically noisy appliances

- Comparable real world ghost performance between the two systems (performance with severe airplane flutter has been improved in second generation pre-production 8-VSB receivers using VLSI ICs)

- Higher data rate capability with 8-VSB
    - While the 8-VSB data rate used in the trials was only slightly greater, it was achieved with a 6 MHz bandwidth compared to 7 MHz for COFDM
    - 8-VSB provides more guard band (0.5 MHz on both sides), if a 6 MHz VSB system is used
    - Opportunity for a 17% increase in data rate, if a 7 MHz VSB system is used

Again, we appreciate the opportunity to provide our comments prior to the preparation of your full report. It is hoped that you will be able to provide some answers to the questions we have raised, and we look forward to continued dialog relative to the transmission system trials.

On behalf of the ATSC, its members, and the members of the ATSC Review Committee, we offer our sincere appreciation and best regards.

Sincerely,

WAYNE C. LUPLOW,
ATSC Executive Committee
Head, ATSC Australian Test Results Review Committee