PERFORMANCE EVALUATION TESTS OF DTTB

COORDINATED BY

FACTS SPECIALIST GROUP ADVANCED TRANSMISSION

FIELD TRIALS

FIELD TRIAL DATA and ANALYSIS

SUMMARY REPORT

FACTS Summary Report for the Australian Field Trials of DVB-T and ATSC DTTB systems conducted in 1997

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The first DTTB Field Trial for Australia was conducted by FACTS in Sydney in October and November 1997. The European DVB-T 2k-COFDM and the American ATSC 8VSB systems were tested in the environment of Sydney in VHF Band III along side PAL Analogue channels.

This "Summary Report" provides a "snap shot" of the Field Trial. The report presents the data on 8VSB and COFDM as well as analogue PAL. Such data is intended to provide, along with data from the DCA Communications Laboratory tests, the foundations for the selection between the proponent systems and the predictions of DTTB coverage. Detailed information is contained in the main Test Reports :

- ***FACTS – Field Performance Evaluation Tests of DTTB, January 1998 (Data only)***
- ***FACTS - Field Performance Evaluation Tests of DTTB, 1998 (Data and Analysis)***
- ***DCA Laboratory Report 98/01 – Laboratory Testing of DTTB Modulation Systems, DMV – System 3000 COFDM, Zenith / Harris – 8VSB. January 1998***

Caution should be exercised as the measurements relate to those taken using the specific implementations of pre-production (DVB) and prototype (8VSB) receivers.

The Field trials provided :

- Testing of both ATSC and DVB-T Systems at the same time and location
- Operation of DTTB in VHF 7 MHz channels
- DTTB transmission with Analogue PAL on upper and lower adjacent channels
- Reception conditions similar to that of fixed reception of Consumers.
- Static and Dynamic (Flutter) echoes (multipath) testing
- Impulse noise testing
- Comparative Analogue PAL character records
- Development of DTTB Field Test methods

The overall objectives were :

- To provide, as <u>part</u> of the selection criteria for a choice between 8VSB and COFDM modulation systems, the difference in reception character of the two systems
- To provide, to the system planners, some of the information for the design to allow reception by the viewing public
- To use the upmost care to provide credible data

The Field Trial did not cover :

- UHF Bands IV and V
- Co-channel interference
- Long term level variations (seasonal)
- Variable weather conditions eg rain and lightening
- Performance in MATV and cabled systems
- In-door reception
- Portable and Mobile reception

The Contributing Organisations were :

- Australian Broadcasting Authority (ABA)
- DCA Communications Laboratory
- FACTS
- TEN Network
- NINE Network
- SEVEN Network
- NDS (DMV)
- ZENITH Electronics Corp.
- HARRIS Corp.
- Radio Frequency Systems (RFS)
- NEC
- Hewlett Packard
- Rohde & Schwarz

The involvement early in the initial familiarisation section of the trial, of the designers of the COFDM and 8VSB systems, proved very helpful in setting up and honing the procedures for the collection of data in the field. An independent person was hired to collect the data with the aim of providing consistency and credibility of the data collected.

The Field Trial Aims were :

In a VHF Band III transmission environment, record and study :

- Interference of DTTB into PAL analogue receivers to allow decision on DTTB power for purpose of the trial **only**
- Analogue reception character to allow comparison to DTTB reception
- Coverage of DTTB relative to Analogue PAL
- Robustness of DTTB reception compared to analogue reception
- DTTB C/N Threshold variability
- Overall field strength variability
- General multipath performance
- Performance in static environments
- Performance in dynamic environments
    - Aircraft flutter
    - Moving vehicles in receive path
- Performance in impulse noise environments
- Translator / gap filler requirements

The Field Trial Restrictions

The restricted time and the availability of DTTB equipment limited not only the total number of sites, but also unfortunately the make up of sites with different reception character. For example a different proportion of those reception sites with dynamic conditions such as impulsive noise or “flutter” mechanisms may have been more appropriate to represent the market. But although not a “statistical” trial there was more than sufficient data to satisfy the aims and the overall objectives. The data and the techniques developed can provide the base for other field trials and investigation.

FIELD TRIAL PARAMETERS

DTTB Modulation Parameters :

The two systems tested in the Sydney Field Trials were :

(A) DVB-T System to ETSI ETS 300 744 using COFDM modulation format

(B) ATSC Digital Television Standard A/53 using 8VSB modulation format

The DVB-T system with its selectable parameters was set up to closely match the transport stream bitrate and the FEC of the ATSC system, giving both systems the same HDTV capacity.

DVB-T System :

The chosen parameters were :

- 7 MHz nominal bandwidth
- 2K carrier mode
- 64QAM modulation (8 levels x 8 phases)
- FEC 2/3
- RS (204,188)
- Guard interval 1/8 (32uSec)
- Transport Stream Bitrate of 19.35Mbps
- DMV V1.0 Equaliser software used
- DMV V2.0 System software used

ATSC System :

The parameters were :

- 6 MHz nominal bandwidth
- 8VSB modulation (8 levels)
- FEC 2/3
- RS (207,187)
- Transport Stream Bitrate of 19.39Mbps
- Equaliser range of 23uSec
- Co-channel compensation not on.
- “Blue rack” decoder

Note : 1. The 8VSB system under test was optimised for the NTSC environments.

2. The term “Payload Bitrate” is sometimes used in place of “Transport Stream Bitrate”, but unfortunately has different definitions in different camps. In the ATSC context, the Payload Bitrate is the Transport Stream Bitrate less the overhead of one sync. Byte (1 in 188), which results in an ATSC Payload Bitrate of 19.28Mbps.

Transmission Parameters :

Analogue PAL transmissions occurred from the Commercial Free to Air (FTA) transmission sites at locations of Willoughby and Artarmon, which are separated by 1.5 Km. The DTTB transmissions only occurred from the Willoughby site for the field trials.

All transmissions were in Band III VHF (174 to 229MHz) on 7MHz channels :

for PAL :	CH7 with 182.25MHz Vision carrier
	CH9 with 196.25MHz Vision carrier
	CH10 with 209.25MHz Vision carrier
for DTTB :	CH6 174 to 181MHz channel - centre 177.5MHz
	CH8 188 to 195MHz channel - centre 191.5MHz

Note : All the "PAL-B" transmissions use the "System G" dual sound carrier system with the "mono" carrier at +5.5MHz and the right channel carrier at +5.742MHz from the vision carrier.

The basic parameters of these sites are :

	Willoughby	***Artarmon***
Site Ground Height :	72 m ASL	102 m ASL
Antenna Array centre :	295 m ASL	294 m ASL
Antenna Gain(nominal) :	x 10 Omni-directional	x 10 Omni-directional
Nominal ERP (for PAL):	100KW	100KW
Transmitter power (PAL) :	10KW	10KW
Nominal ERP (for DTTB):	4 KW	-
Transmitter power (DTTB) :	400 W	-

The main items of equipment used were :

(1) DMV COFDM Modulator
(2) DMV COFDM Demodulator
(3) DMV MPEG-2 ML@MP Encoders
(4) DMV Multiplexer
(5) ZENITH 8VSB Demodulator
(6) HARRIS 8VSB Modulator
(7) NEC 200W DTTB Transmitter
(8) HARRIS 1KW Transmitter
(9) RFS CH6/CH8 Combiner
(10) RFS CH8 Adjacent Channel Combiner
(11) HP VSA real time spectrum analyser
(12) R & S (Advantest) spectrum analyser

Items (1) to (8) were extensively bench tested by the DCA Communications Laboratory in Canberra.

DTTB Transmissions :

For the **interference testing** the CH6 and CH8 Combiner was used with both transmitters. The control system allowed the alternating of the modulation system between COFDM and 8VSB on CH6 and CH8.

For **all other testing** the Adjacent Channel Combiner and the CH8 transmitter was only used. Again by remote control from the survey vehicle the modulation system could selected between COFDM and 8VSB, but this time only on CH8.

Field Equipment :

Survey Vehicle :

The vehicle was a four-wheel drive Mitsubishi Express 2.4ECI constructed as a general field survey vehicle supplied by the Australian Broadcasting Authority (ABA). The power was supplied by a trailer mounted 5KVA Onan petrol generator. UPS power was available for short periods of testing.

The telescopic compressed air operated mast was extendable from 2.5m to 10m.

VHF Receive Antennas :

A calibrated high gain VHF Band III antenna ("Hills" type Y10/6A) was used for the bulk of the "Tests", and had a nominal gain of 7 dBi at CH8. The front to back ratio measured in the field was 28 dB on CH9. The antenna was turned to produce a maximum analogue level.

Some tests were also carried out using a dipole antenna. The gain was determined to be 2dBi.

When at a site, the antenna was never turned to create a reception condition. The antenna's height, up to 10m, was determined by the general height of the consumer's antennas. If the consumer's antennas were thought to be "rabbits ears", a dipole antenna was also used to obtain a comparative set of data.

Analogue Demodulator Performance :

The Plisch professional demodulator was used to measure the analogue levels existing within the vehicle system and to demodulate to vision and audio. The vision was then recorded on most tests through the Tektronix VM700, to provide an indication of the reception character at the site. The signal presented to the "Plisch" was matched to that on the inputs to the DTTB receivers and the spectrum analysers.

System Gains

The gains measured from the input of the system (antenna output) to input to each DTTB decoder, spectrum analysers, and PAL demodulator were matched within 0.1dB.

All cables used were double shielded to avoid any problems of interference within the vehicle and from outside the vehicle. As Sydney has high power FM services, a FM trap, included near the antenna, avoided any influence of FM transmissions especially in the environments near the Towers.

Amplifier Gain and NF :

The amplifiers had on nominal gain of 25 dB with a NF of 3.5 dB. Although the input overload level, with the three VHF analogue services, was better than 90 dBuV per service, the test procedure did not allow any higher than 64 dBuV per service on the input of the amplifier.

Decoder and measuring system input level :

The test procedure required that there was no greater than 80 dBuV per analogue service (CH7, CH9 or CH10) to be applied to the inputs of the measuring equipment and the DTTB decoders. This procedure avoided any possibility of overload problems affecting the accuracy of the measurements.

Measurement System Accuracy's :

A great deal of attention was paid to all the facets affecting accuracy, such as equipment calibration, connection, test method, operator procedure and overall system variability's. The resultant accuracy was determined to be :

Comparative between system accuracy :	+/- 0.25 dB
Absolute accuracy :	+/- 1 dB

SYDNEY LOCATIONS

Defined Area

The Sydney License Service area was substantially covered and aligns to the Australian Bureau of Statistics - Sydney Statistical Region. The Coverage area reasonably matches the License Service area and is defined by the 50dBuV/m curve from the main VHF transmission sites.

Site selection criteria :

The selection process was based upon the following criteria, both for the nominal and the "in the field" selection of the sites. The data from these sites was then used in the analysis of the COFDM and 8VSB systems.

Each site generally had a combination of the following characteristics. An attempt was made to have an adequate sampling of the characteristics to generate statistically accurate results for both systems under test, along with clarity of comparison to the current analogue services in Band III.

The selected sites tended towards the average character of consumer sites and were not the worst sites that could have been selected.

Sites representing :

(A) Population concentrations and centres. - representing population majority.
(B) Rural reception. - help in setting "free space" coverage power for DTTB.
(C) Urban reception - multistorey residential. - dispersed multipath examples
(D) CBD - multistorey offices. - short multipath examples.
(E) Suburban - houses up to two storey. - variable character in terrain and foliage.
(F) Suburban - industrial. - terrain and foliage variable with impulse noise.
(G) Power line interference. - impulse noise in both low to high field strength areas.
(H) Existing Translator areas. - assessment of need for DTTB Translators.
(I) Obscured reception for moderate populations - possible need for further DTTB Translators.
(J) Over water reception - eg over Sydney Harbour. - high variable multipath.
(K) Beach area reception - Northern and Southern beaches. - complex multipath
(L) Aircraft Flutter. - fast varying multipath
(M) Omni-directional antenna reception in urban and suburban environments. – to assess continued popular use of "rabbit ear" antennas.
(N) Reception through distribution systems. eg residential units, hotels and hospitals.
(O) Reception through vehicle traffic – trucks and buses for example producing flutter and or impulse noise.

General Field Trial Statistics

The following general statistics provide an idea of the extent of the trial. Future analysis can generate further statistics such as relationships to demographics, population, type of receiving system, etc.

Sydney statistics (approximate):

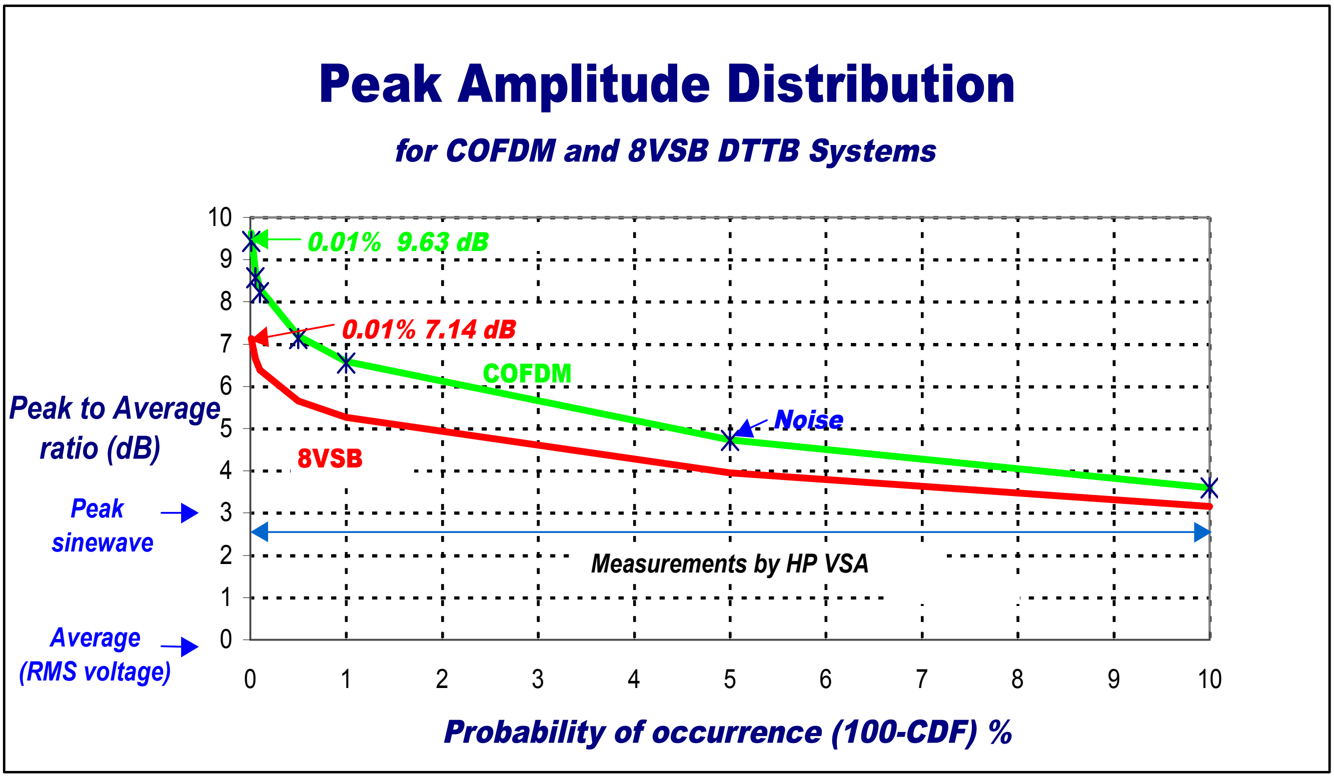
- 13,500 square Km
- 3.9 million people
- 1.3 million dwellings

Field Trials of 3 October to 14 November 1997

- 27 days of testing
- 108 Sites
- 125 Tests
- 0.4Km to 100Km
- generally distributed around the compass
- 4KW ERP DTTB (-14 dB ratio)
- 100KW ERP PAL
- PAL F/S's from ……40 to 105dBuV/m
- DTTB F/S's from…..30 to 90dBuV/m
- Average Analogue F/S of…82dBuV/m
- Average DTTB F/S of…….68dBuV/m

Peak to Average Ratio of COFDM and 8VSB modulation :

The Peak to Average ratio was checked for both COFDM and 8VSB, at the transmission site before and after the combiner, for the correct undistorted peak to average ratio. The technique used is called CDF (Cumulative Distribution Function) which is available on the HP VSA. The resultant peak amplitude distributions measured before and after the combiner was found to be the same and is represented in the plot below. The distribution produced by the noise generator used in the field for measurements is also shown. A check of the amplifier used in the field proved to add no distortion.



Measuring for a CDF @	99.90%	99.95%	99.99%
8VSB	6.5 dB	6.8 dB	7.3 dB
COFDM	8.3 dB	8.7 dB	9.6 dB
Noise	8.3 dB	8.7 dB	9.6 dB

The distribution shows that there is a higher peak to average ratio for **COFDM** compared to **8VSB** varying from **1 dB to 2.3 dB**. The COFDM distribution is near identical to “white” noise.

This test was one of the essential prerequisites before starting the Trial. Also checked was the spectrum skirts of both the 8VSB and COFDM transmitted spectrums. The “skirts” relative to the spectrum centre were lower than –35 dB at all powers used in the Trials.

DTTB into PAL Interference

As the Sydney main VHF TV transmission towers are located within a densely populated area in Sydney, extensive planning and testing occurred.

The interference into PAL, due to both CH6 and CH8 was investigated. DTTB power between 2 to 9KW ERP was transmitted from Willoughby, with the PAL transmissions coming from Artarmon 1.5Km away. The change in the "**Ratio**" between DTTB to PAL, at various distances from the Willoughby tower, was recorded along with the affect on the Video and Audio S/N unwtd ratio measured via a Plisch professional demodulator as a receiver.

The results were :

(A) Between 0.4 to 2Km the **Ratio** decreased by 0.4 to 16.7 dB (increase in DTTB ref. PAL)
(B) At 1.5Km the **Ratio** typically decreased by 6dB (increase in DTTB ref. PAL)
(C) With a resultant **-10dB Ratio** (COFDM on CH8) the **Video** S/N deteriorated :
    on CH7 from 44.6dBunwtd to 42.5dBunwtd (2dB change)
    on CH9 from 48.8dBunwtd to 47.7dbunwtd (1dB change)
(D) At a **Video** S/N of around 45dBunwtd, the "7MHz" **COFDM** signal caused up to **0.5dB more** impact than the "6MHz" **8VSB** signal on CH9 with both having similar effect on CH7. With the video S/N worse than 40 dB, there was insignificant effect or difference of the impact on PAL from either COFDM or 8VSB.
(E) With a ratio of –10dB and an **Audio** S/N of around 43dBunwtd, there was an impact of 1dB by both COFDM and 8VSB on the S/N of the right channel of CH7.
(F) This round of tests was a low sample and was meant as a pre trial check rather than quest for accurate data. Further testing must be pursued using typical or worse case consumer receivers

Viewer complaints

For the period of the DTTB transmissions, which in general remained "on" over night in peak viewing hours :

(A) No relevant complaints were taken from viewers for interference into vision, including from the area where the DTTB to PAL ratio had deteriorated significantly.

(B) Four (4) complaints were taken by CH7 complaining of sound interference on mono and stereo when broadcasting on DTTB (both COFDM or 8VSB). An investigation is occurring and will be the subject of a separate report.

FIELD TRIAL TEST PROCEDURES

General Procedures :

(1) At each site both COFDM and 8VSB was tested on CH8.

(2) The A*nalogue* PAL transmissions on CH7, CH9 and CH10 were recorded by :
   (a) "VM700" plots of "line 17 & 318" plus the noise spectrum
   (b) Level on "Plisch" demodulator

   to provide a reference for both coverage (level) and character (multipath and video S/N). This is called the *Analogue environment profile*

(3) The *8VSB Information* from the analysis computer was recorded to help to provide the *Digital environment profile.*

(4) All tests on COFDM and 8VSB were absolute measurements and are valid in isolation.

(5) The *Spectrum* information was recorded in hard copy to provide spectrum character of the DTTB and PAL signals.

(6) The DTTB *C/N Threshold* measurements were taken for both systems **after** the RS error correction.

(7) The DTTB *C/N Threshold* was taken under *static* conditions as well as under *dynamic* conditions (dynamic conditions being created by such mechanisms as fast varying level, varying multipath, interference- impulse or other, aircraft or vehicle flutter ie doppler echo, etc.)

(8) The C/N threshold figures collected at sites, chosen with the *Site Selection Criteria* section, should provide a strong guide to defining the power required for DTTB.

(9) DTTB C/N Threshold measurements were taken by both a conventional scanning Spectrum Analyser (SA) and a real time Spectrum Analyser (HP VSA).

(10) C/N Threshold was created with the aid of either :
   (a) injecting noise from a noise source and adjusting via a ***noise attenuator***. *That is* ***increasing the noise towards the signal***.
   (b) *Or* by ***reducing the signal towards the noise*** floor of the measurement system by reducing the input signal via the ***system attenuator***.

C/N Threshold BER measurement methods :

As there was a difference between the BER measurement methods used in the Field Trials as compared to the "Laboratory Tests" a description will help bridge the gap.

To allow direct comparison, without requiring any conversion, the methods used in the Field Trials were the result of an agreement between the proponent engineers to produce near equivalence of the measurement techniques to find the Threshold C/N figure.

An extract from the Communications Lab Report 98/04 defines the laboratory test method :

The majority of the digital modulation system tests were conducted using measurements of the bit error rate (BER) of pseudo random data. The systems were thus evaluated as data pipes. Unfortunately the system error threshold is defined differently for the DVB-T and ATSC systems.

- *The DVB-T system BERs are measured before the reed solomon (RS) decoder allowing a high error rate to be measured (2.1×10^{-4}). This translates to a very low error rate(10^{-11}) after RS.*
- *The ATSC system uses a BER (3.0×10^{-6}) at the transport stream system output. This output error rate has been determined to match the Threshold of Visibility (TOV) when the data is decoded and displayed.*

Comments : The basic difference between the DVB standards and the ATSC standards, besides differing philosophies, is the European standards conservatively assumes that there is no error concealment in the in MPEG processing, whereas the American standard relies upon error concealment in MPEG processing to provide at a BER of 3.0 x 10^{-6} to be able to match the Threshold of Visibility (TOV).

The important challenge in the Field Trial Measurements was to adopt a method to allow a reasonable direct comparison between the systems. It was decided, after consultation with the proponent engineers that the measurements would be carried out after Reed Solomon error correction at near, as possible to no observed errors over at least 2 minute period for "static" environments.

This conclusion was also encouraged, as the complex environments presented to the decoders in the field requires the assessment of the performance after both levels of error correction.

As the 8VSB decoder could not display pictures, this was carried out by the measurement of the BER after RS error correction with an external, to the decoder, BER meter.

As the COFDM decoder could only be set up to either measure BER before RS error correction or to produce pictures, which of course is after RS error correction, it was decided to use the picture as effectively the BER meter after RS. The "PACE" MPEG-2 decoder had no error concealment. Also to increase the picture's sensitivity to errors, the encoding compression was increased to 2 Mbps video.

Measurement Techniques and Methods :

There were two methods used to generate the Threshold C/N and two methods of measuring the power in the "carrier" and the "noise".

The power measurement methods were via :

(A) A conventional scanning Spectrum Analyser

(B) A real time Spectrum analyser in the form of a HP VSA (Vector Signal Analyser)

The Spectrum Analyser gave some unreliable figures probably related to a subjective method of reading the data from the analyser. For this reason plots sourced from this method were not used in summary report.

Very interestingly, and worthy of further analysis, the two methods used for generating Threshold C/N gave significantly and consistently different results. Both methods will be presented.

Equality in measurement :

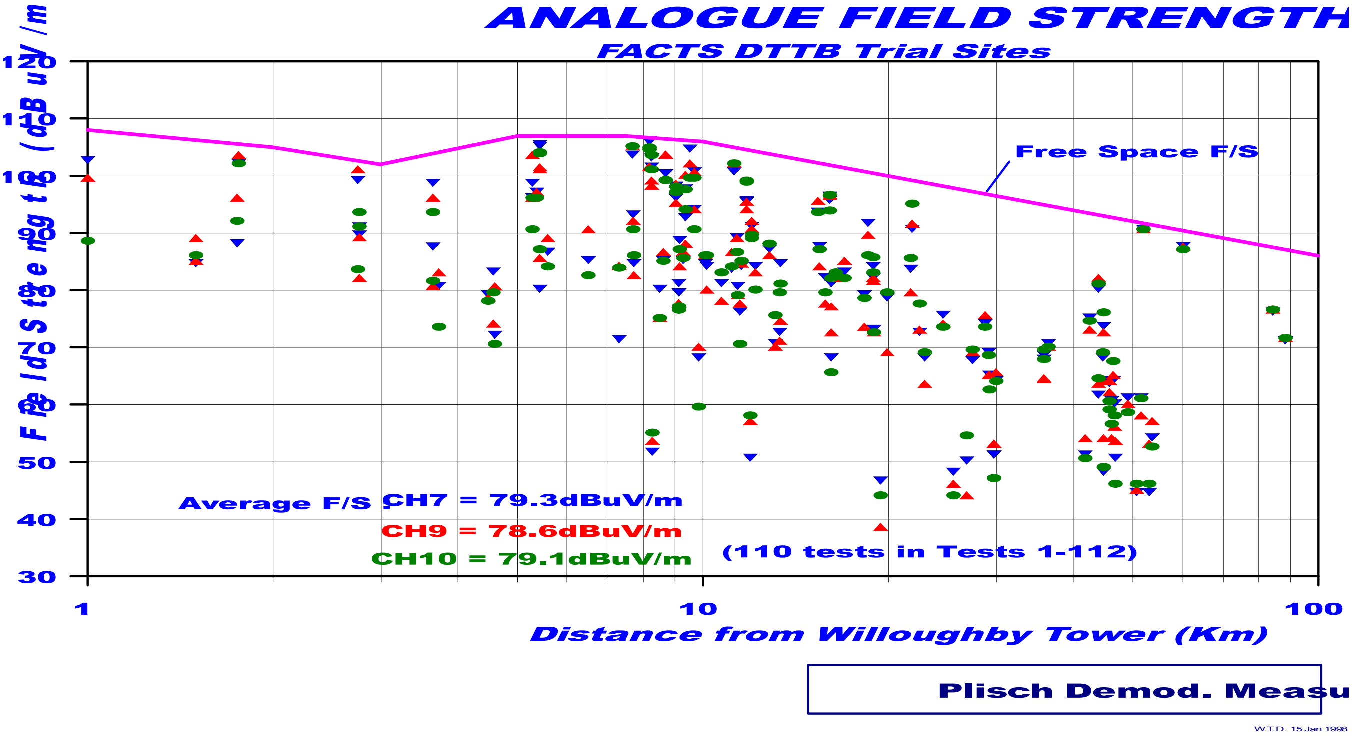
The methods and the conditions of the tests for both 8VSB and COFDM were either equivalent or identical to ensure valid comparisons. For following are examples :

- The power source was the same. ie If UPS used for COFDM low F/S tests, 8VSB tested also with UPS power.
- Antenna was never turned between tests on systems at a site.
- Observation times for judgement of errors were similar.
- One system was never tested alone without giving the other system the opportunity to function.

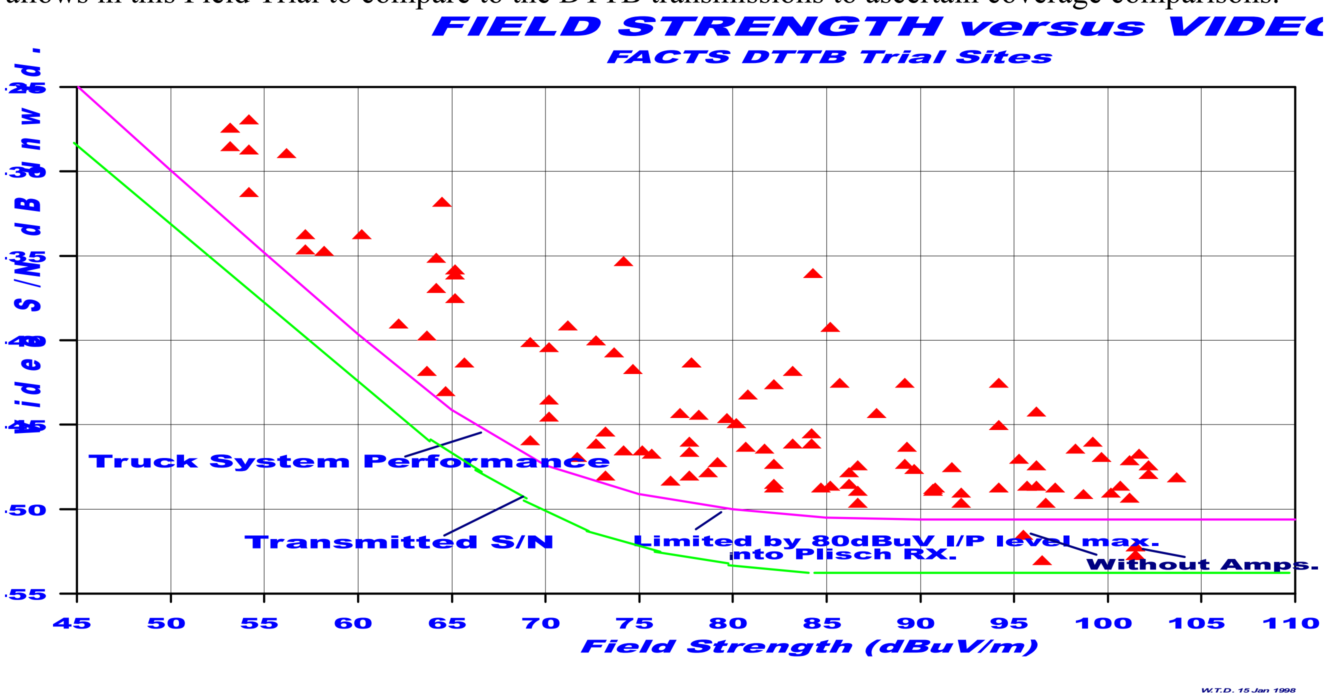
The Results :

Analogue PAL F/S and Video S/N :

CH7, CH9 and CH10 F/S are shown plotted against distance from the tower, to show the extent of variation from the free space F/S there is in the typical reception environments. The F/S is calculated using the figures provided from the calibration figures of the Antenna, system gain etc.

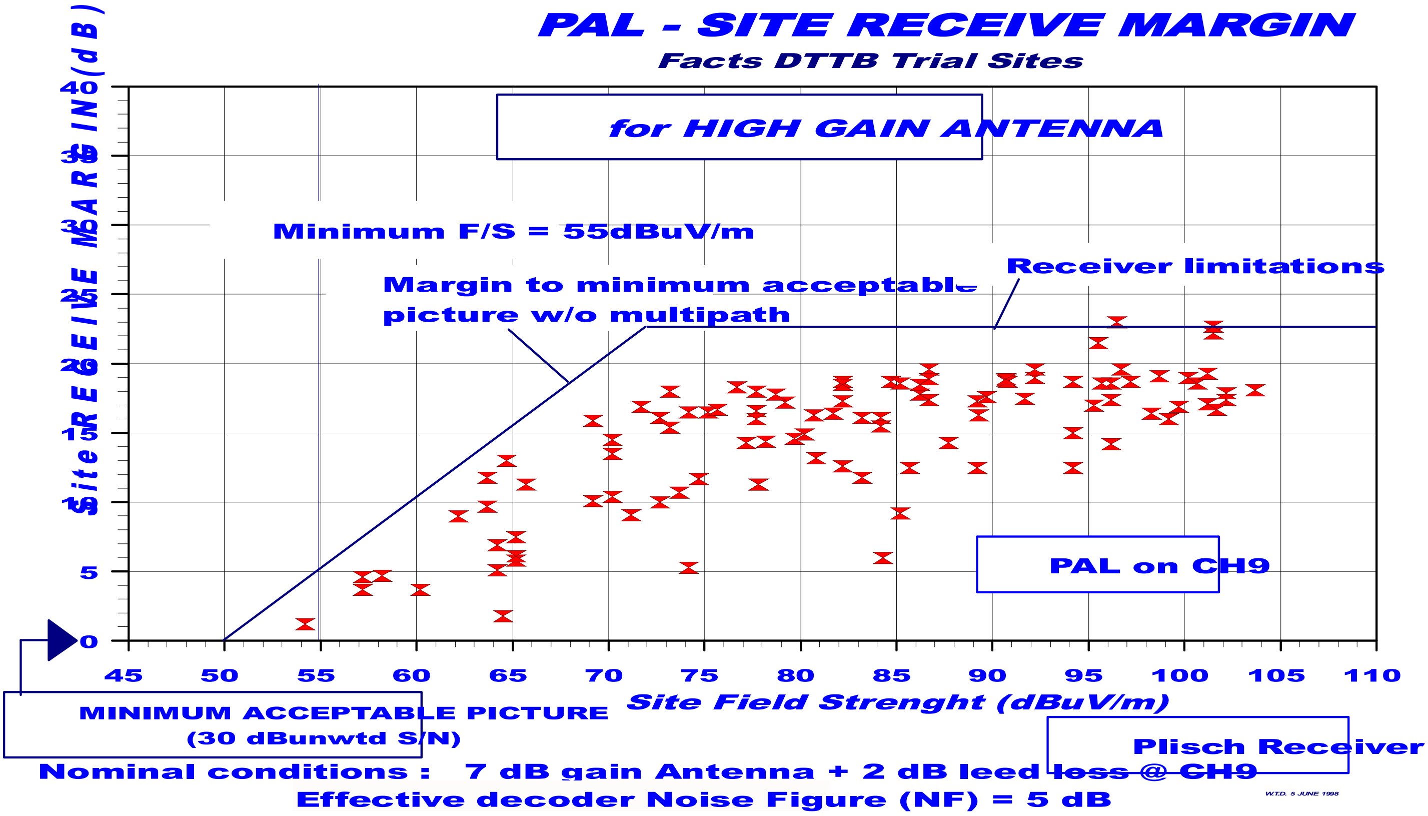


The measured Video S/N shows the relationship that F/S has to the quality of the PAL signal and allows in this Field Trial to compare to the DTTB transmissions to ascertain coverage comparisons.



PAL Receive Margin :

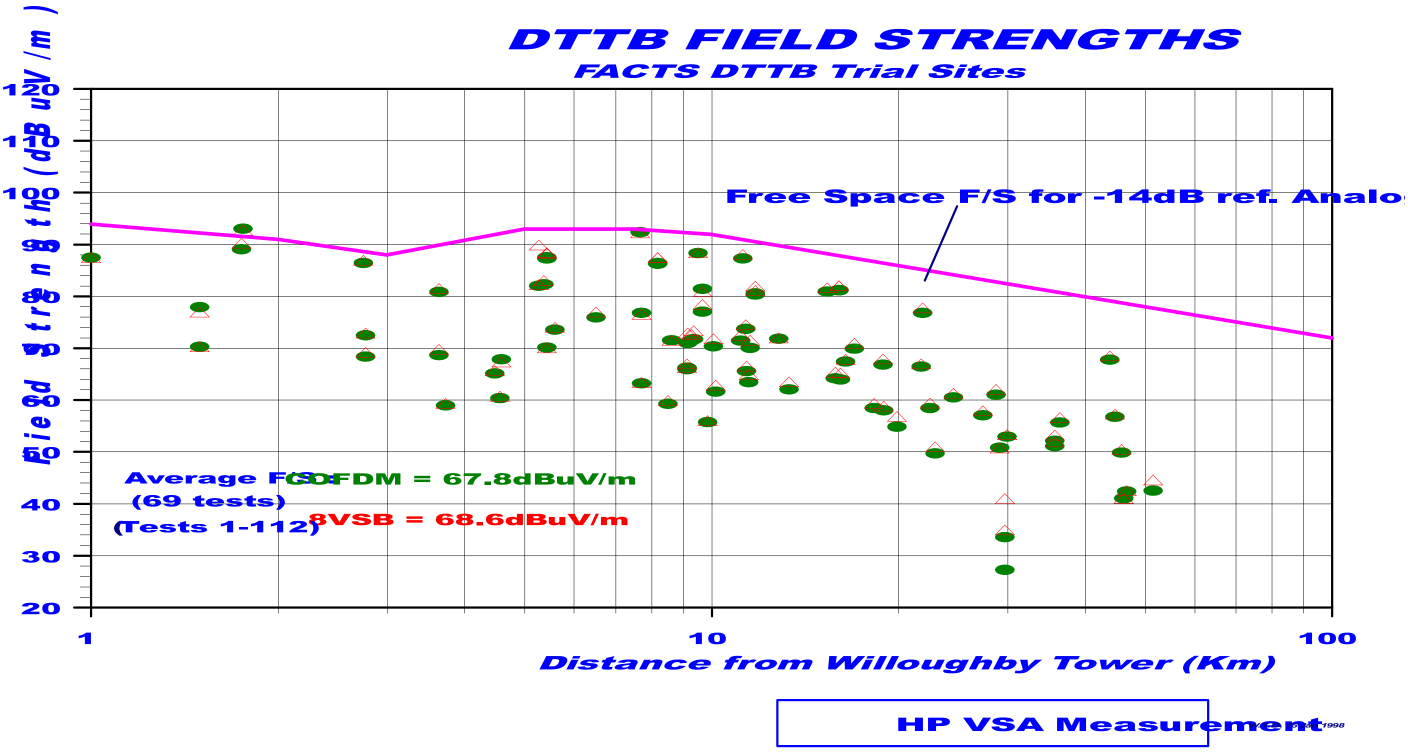
By first developing the concept of receive margin in an analogue PAL receiver, this may help the analysis of DTTB decoder margin and its relationship to the prediction of coverage of DTTB compared to PAL.



The minimum acceptable picture is defined hear as picture with a video S/N of 30 dBunwtd.

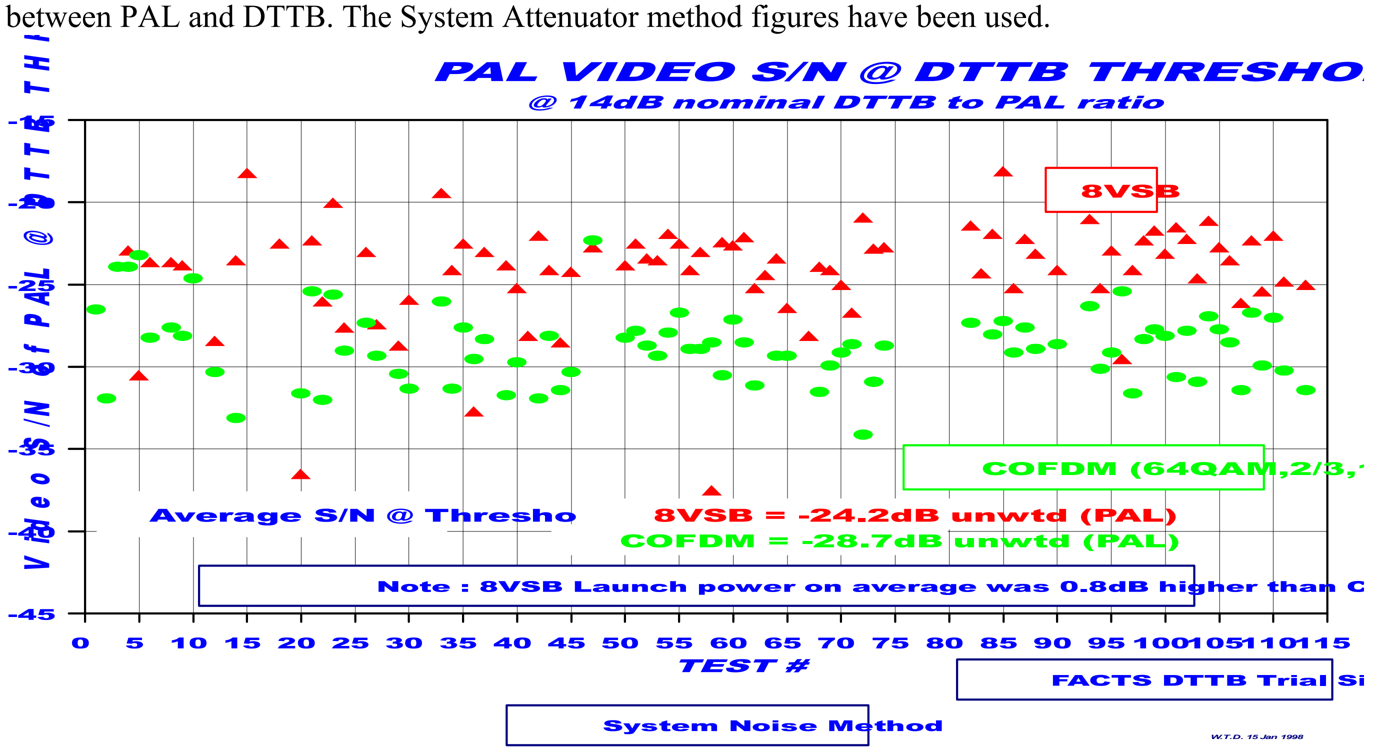
DTTB F/S for a –14dB DTTB to PAL ratio :

The distribution of the DTTB F/S across the coverage area provides some insight into the requirements for planning, and is also a reminder of range of terrain loss and ground clutter that exists.



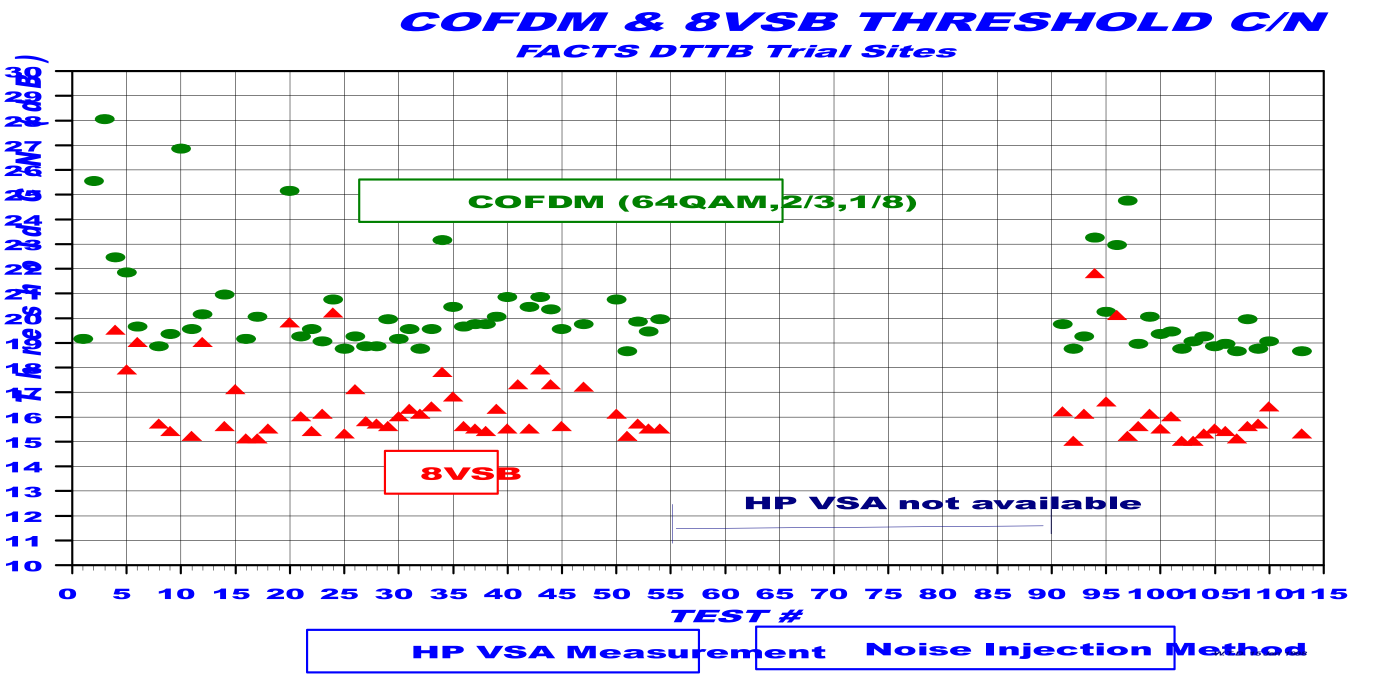
PAL Video S/N @ DTTB Threshold :

The PAL video S/N, when the DTTB C/N has been adjusted to point of threshold, is plotted against the index function of Test #. Both COFDM and 8VSB are displayed showing effectively the PAL picture quality at the DTTB threshold. This plot is valuable for ascertaining the relative coverage information between PAL and DTTB. The System Attenuator method figures have been used.

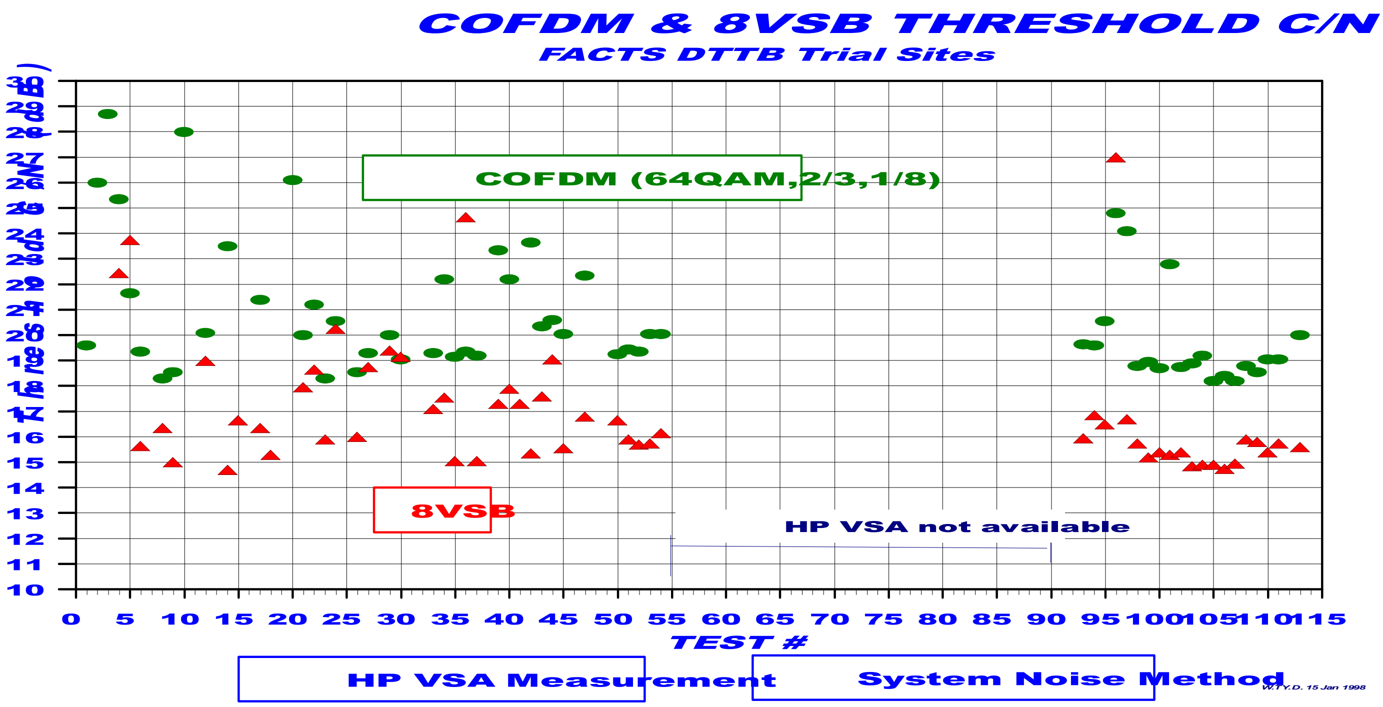


COFDM & 8VSB Threshold C/N :

To allow convenient comparisons both COFDM and 8VSB have been plotted together. The Noise Injection method was used along with measurement by HP VSA.

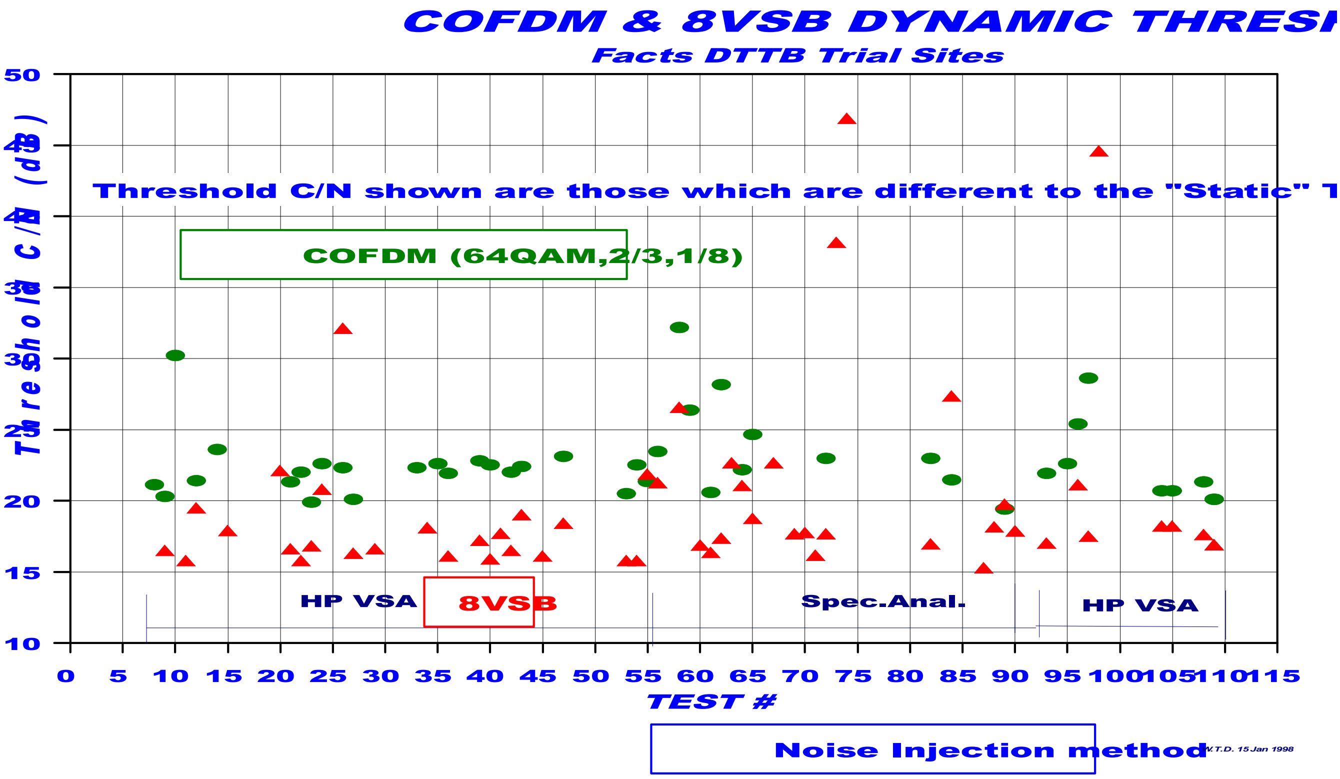


As above but using the System Attenuator method to generate the Threshold C/N. the figure shows a significant difference from that of the Noise Injection method. The system Attenuator method is closer to real environment and clearly with its higher spread of threshold C/N is the harder test.



COFDM & 8VSB Dynamic Threshold C/N :

The dynamic thresholds of both COFDM and 8VSB, measured by the noise injection method, were plotted against the Test # which provides an index to other data for further analysis. The spectrum analyser figures were used in the absence of the HP VSA. Of interest here is the tests where the 8VSB threshold C/N exceeds that of COFDM.



The dynamic threshold condition was defined as any random or periodic affect causing a variation from the static threshold. The conditions which caused this variation from the static threshold were more than obvious to the observer on all the occasions in the field trial. The PAL receiver was always observed to classify the character.

The time of observation depended upon the situation and was similar if appropriate for both systems. The times varied from 1 minute to 3 minutes for judgement of the static threshold measurements and up to hours for the dynamic threshold measurements.

The technique to measure the 5 to 10 seconds of flutter resulting from a aircraft or large road vehicles changing the reception conditions, for example, was as follows :

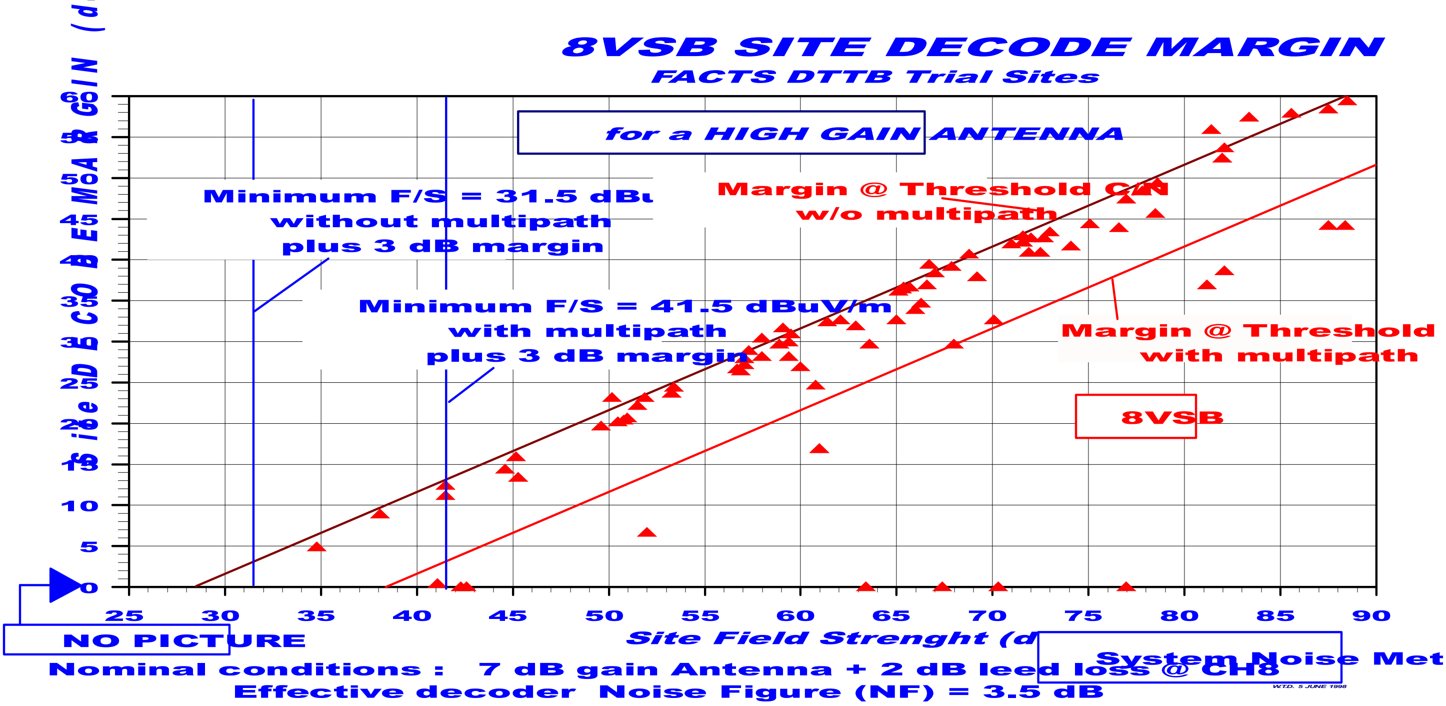
1. Between 6 to 12 flights or passes were observed.
2. Adjustment of the attenuator occurred in between the observations.
3. Flutter testing took literally hours to complete.

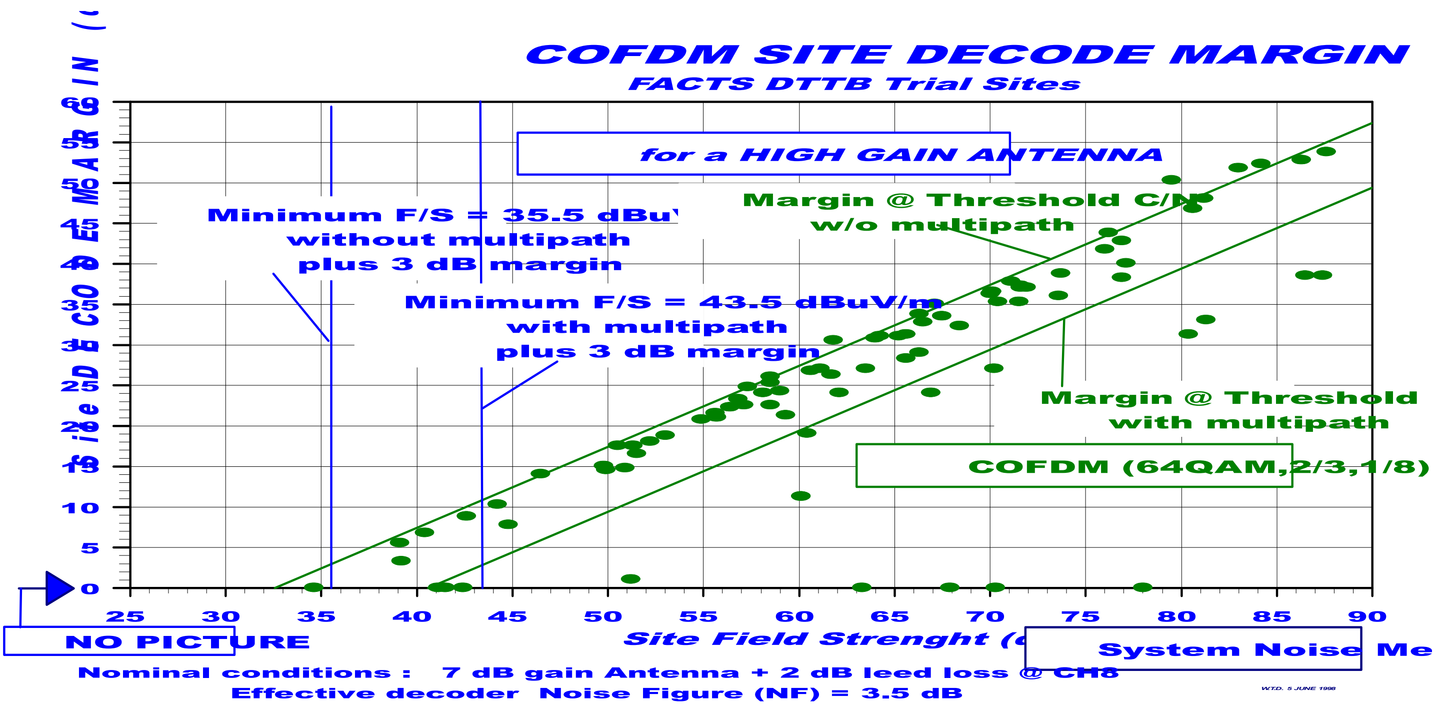
The figures plotted represent the actual affect of deterioration of the static threshold by the dynamic condition that occurred in the field.

DTTB Decoder Margins with a NF of 3.5 dB :

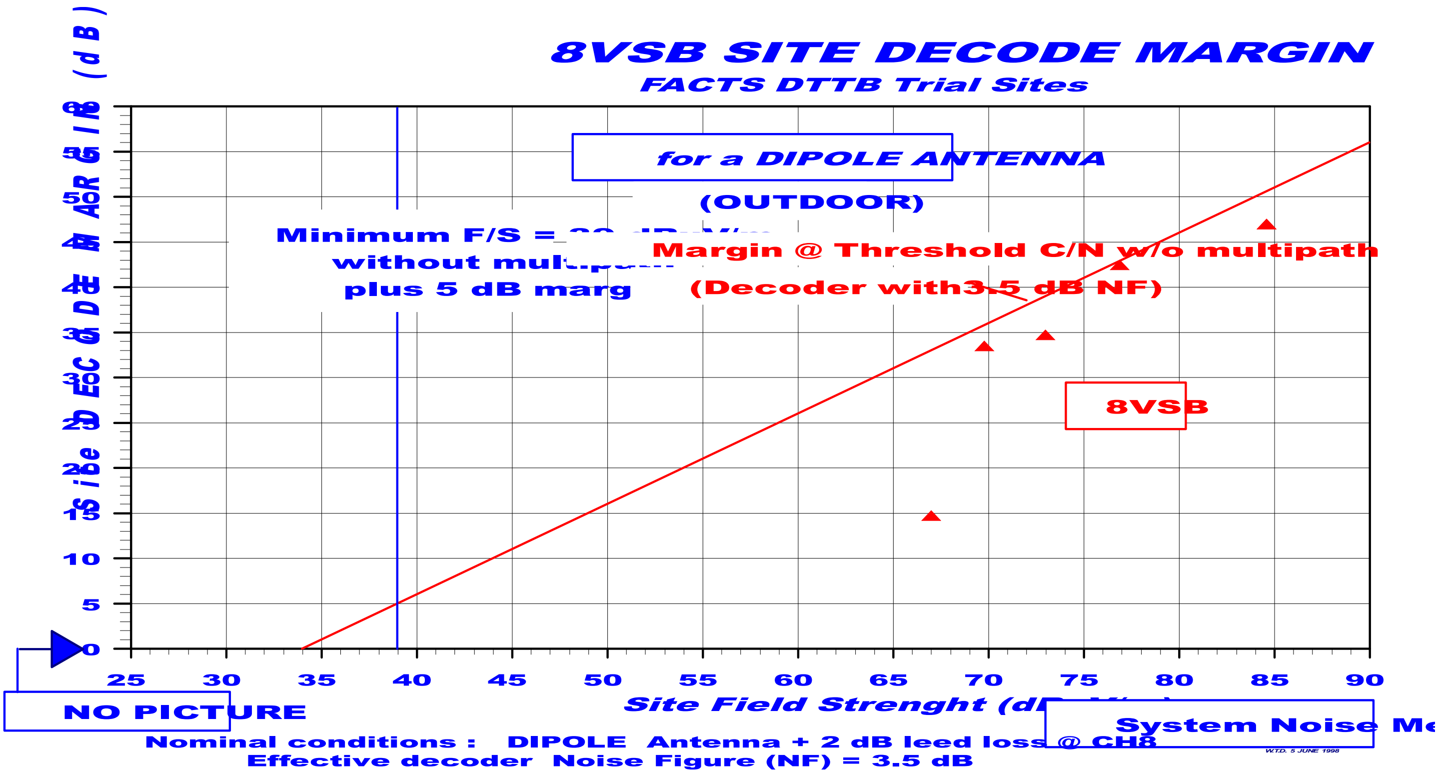
The following plots provide the decoding margin experienced at the test sites for both the "High Gain" and "Dipole" antennas in a **static multipath environment**. The System Attenuator method was used to produce these results.

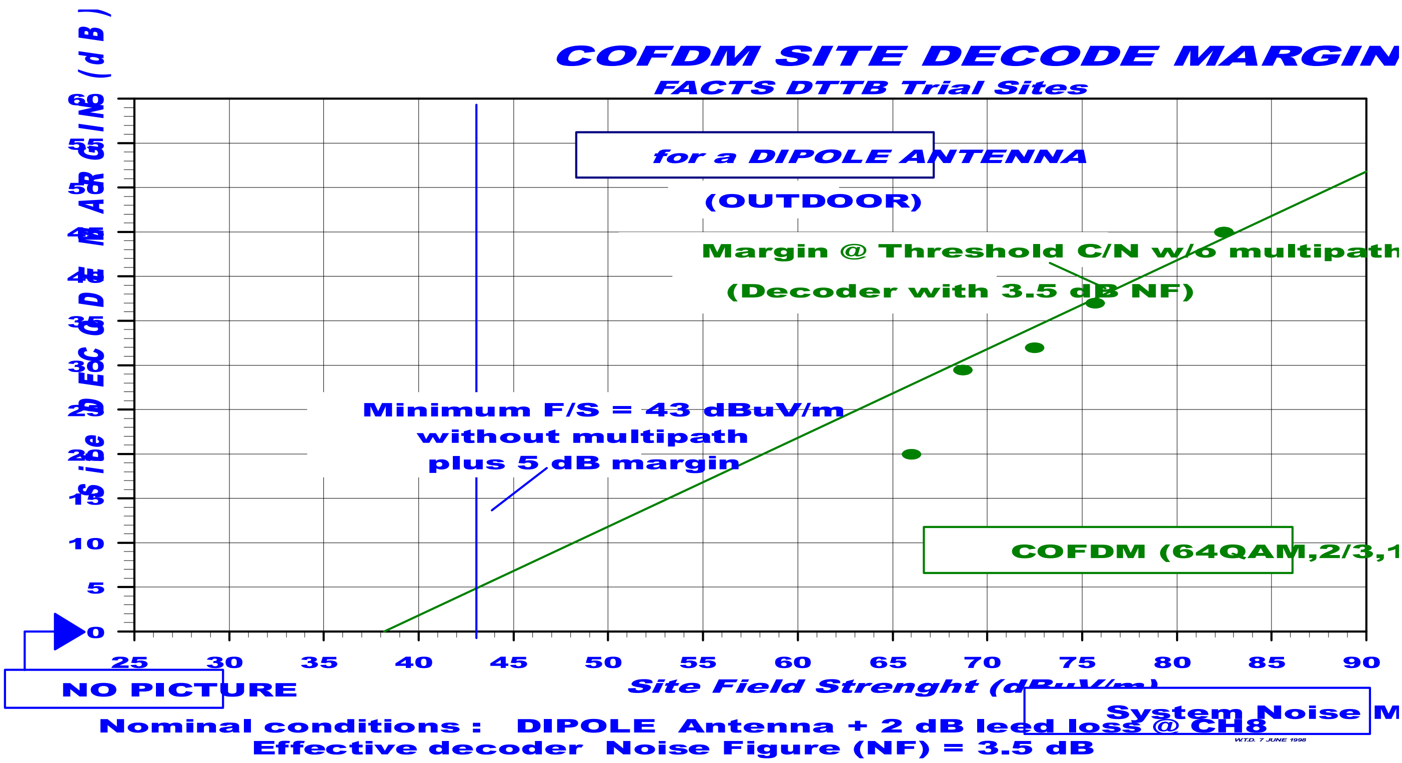
The spread of the margins from the base line is indicative of the extent of the complex multipath experienced at the site. The character of the spread is similar in both systems. Of interest are those points on the baseline representing the decoder not working. Further character analysis is required to explore the reasons for such failures to decode.





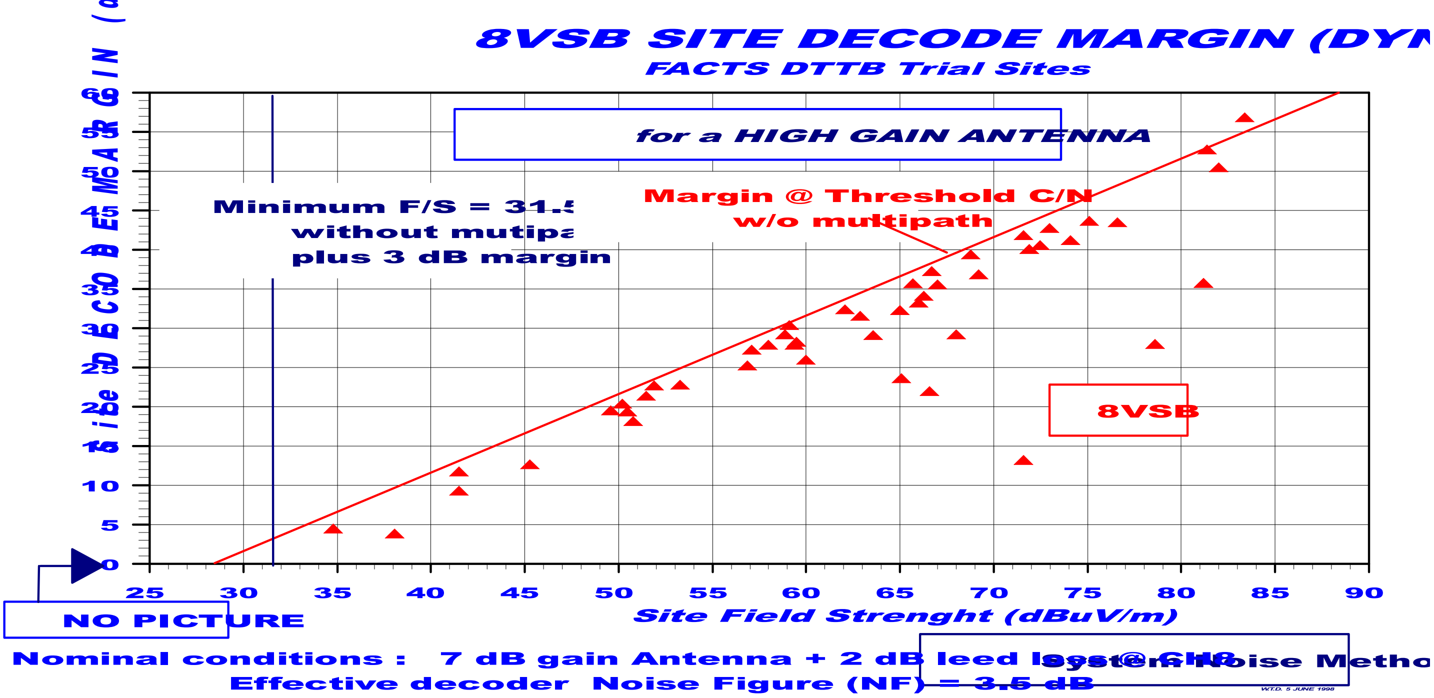
At five sites the tests were repeated with a dipole antenna. The decoder margins recorded at these sites are shown in the plots below. Although a low sample, a trend can be observed that indicated a decreased decode margin was experienced by the 8VSB decoder in this outdoor dipole reception scenario. Further testing is needed to provide more data on outdoor dipole (portable) and indoor dipole ('rabbits ears") reception.

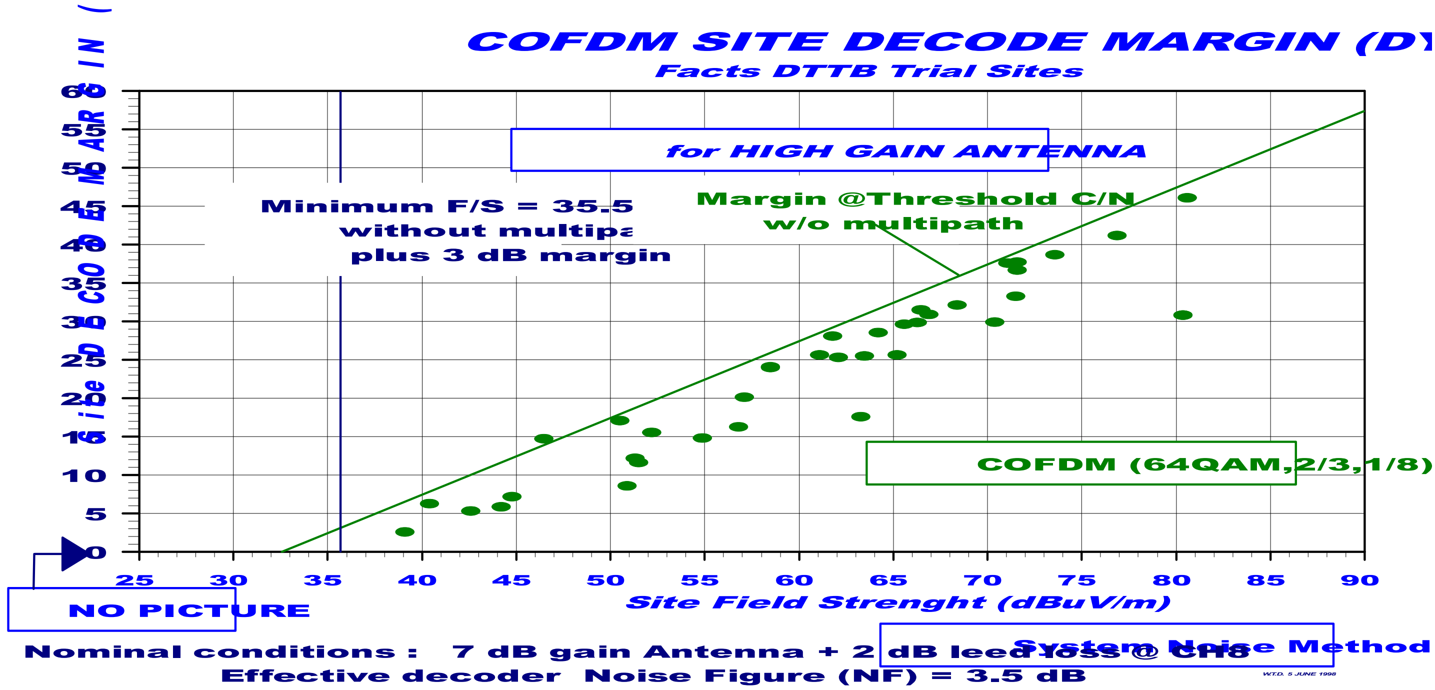




DTTB Decoder Margins with Dynamic Multipath influence

The plots below show the trend to be expected with the signal under the influence of dynamic multipath (impulse noise and flutter) with a roof top antenna. The plots do not show the failures that occurred under some of the dynamic conditions.

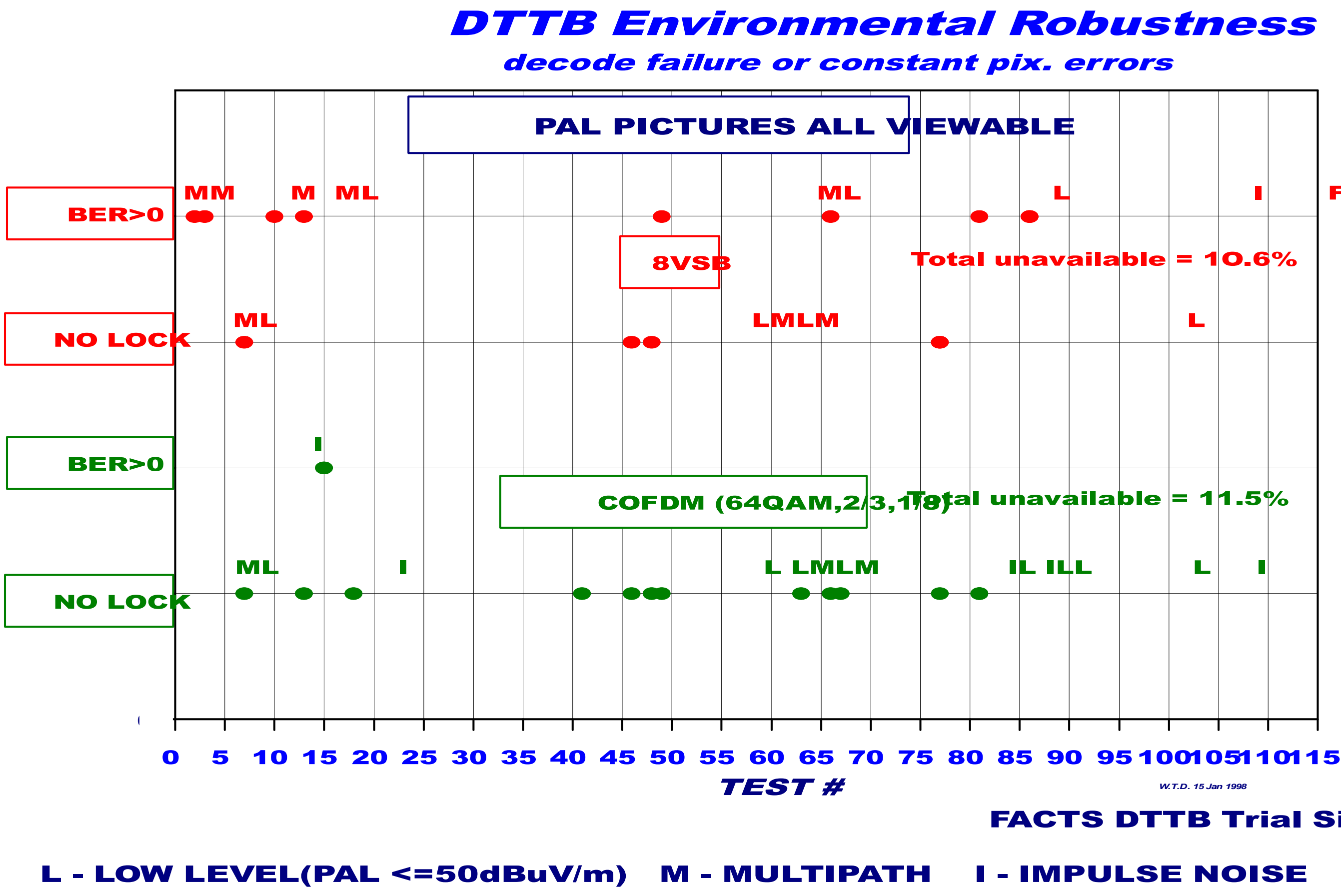




DTTB Decoding Robustness

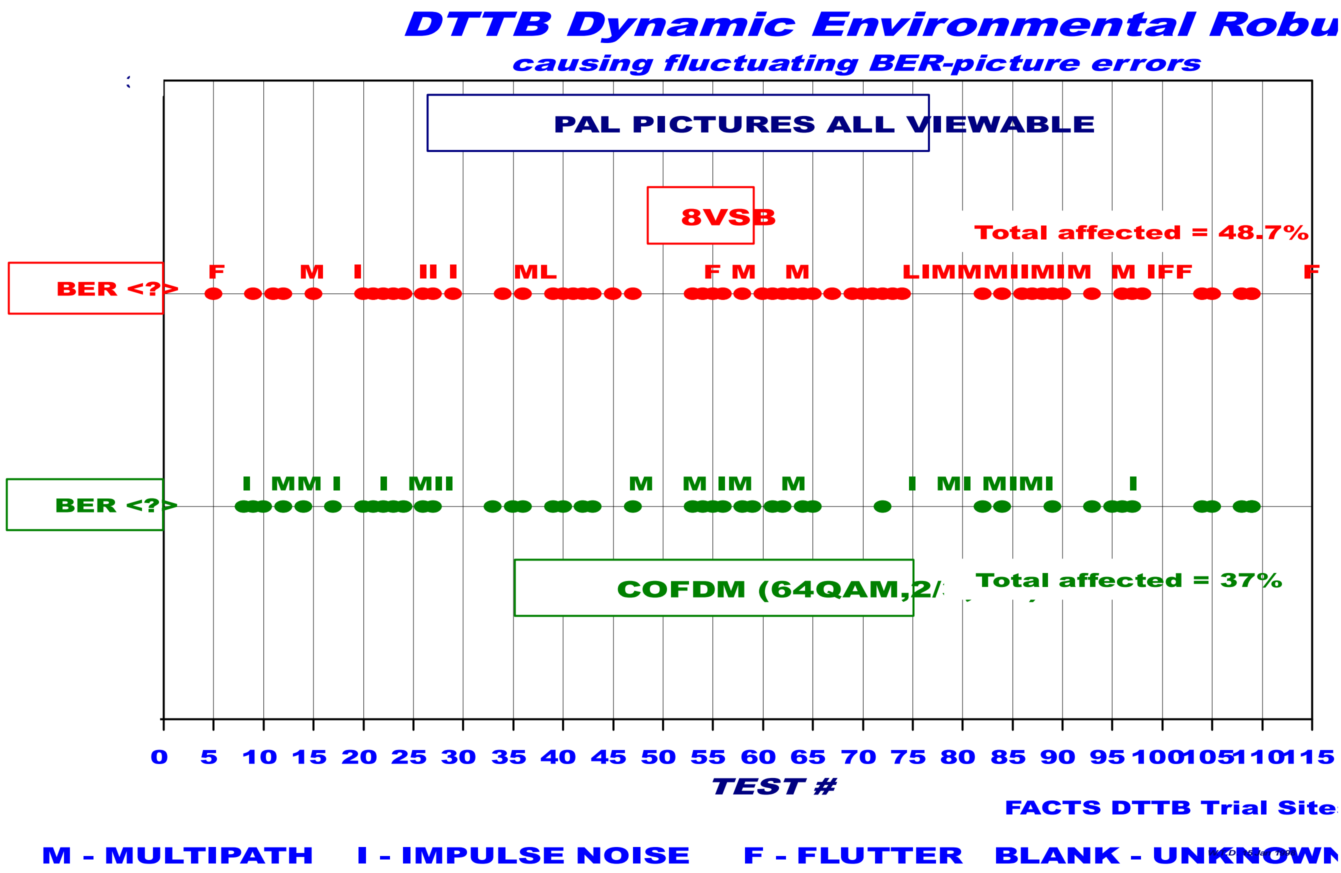
DTTB Environmental Robustness

By plotting all the cases in the field trial where the decoders either were not able to decode (ie no decoding of transport stream) or was constantly producing errors (ie unwatchable pictures), some idea of the extent of this effect can be obtained. Although this is a relatively small sample, discussion is a very worthwhile result of this presentation of the field results.



DTTB Dynamic Environmental Robustness

By plotting all the tests which showed deterioration of the static threshold, where the picture was normally ok, an idea could be provided of the extent of this "dynamic" effect. The deterioration was caused by some intermittent or occasionally occurring condition like multipath variation, impulse noise, aircraft or vehicle flutter. The term robustness is used, as the variation from the static threshold threatens the safety of the static decoder margin. Awareness is appropriate of this effect and indeed should result in an allowance to be catered for when planning services.



Note : (1) This plot does not show those tests where the decoder did not work at all. Refer to the "DTTB Environmental Robustness" plot.

(2) At some locations the power was supplied from the UPS as COFDM decoder had some problems with impulse noise from generator, whereas the 8VSB decoder did not. The plot does show any of these sites. (The use of the UPS is valid, as clearly the trial is to study the consumer's environment not an artificially created one.)

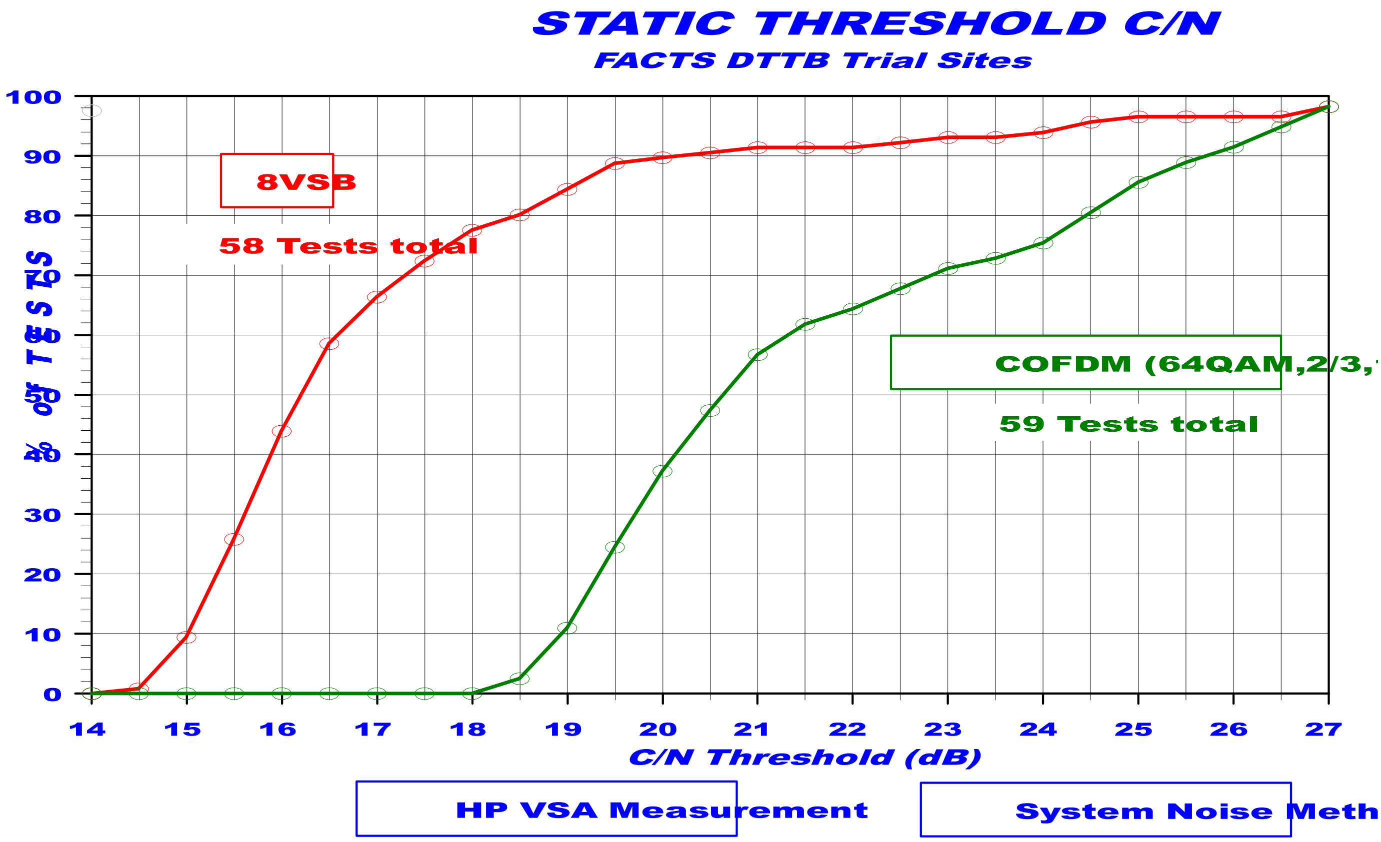
(3) The "Total affected %" could be interpreted as a trend not as an accurate figure, as the sample is low and not all environments were either present or in correct proportions to satisfactorily represent the market.

Threshold C/N Trends and Distributions :

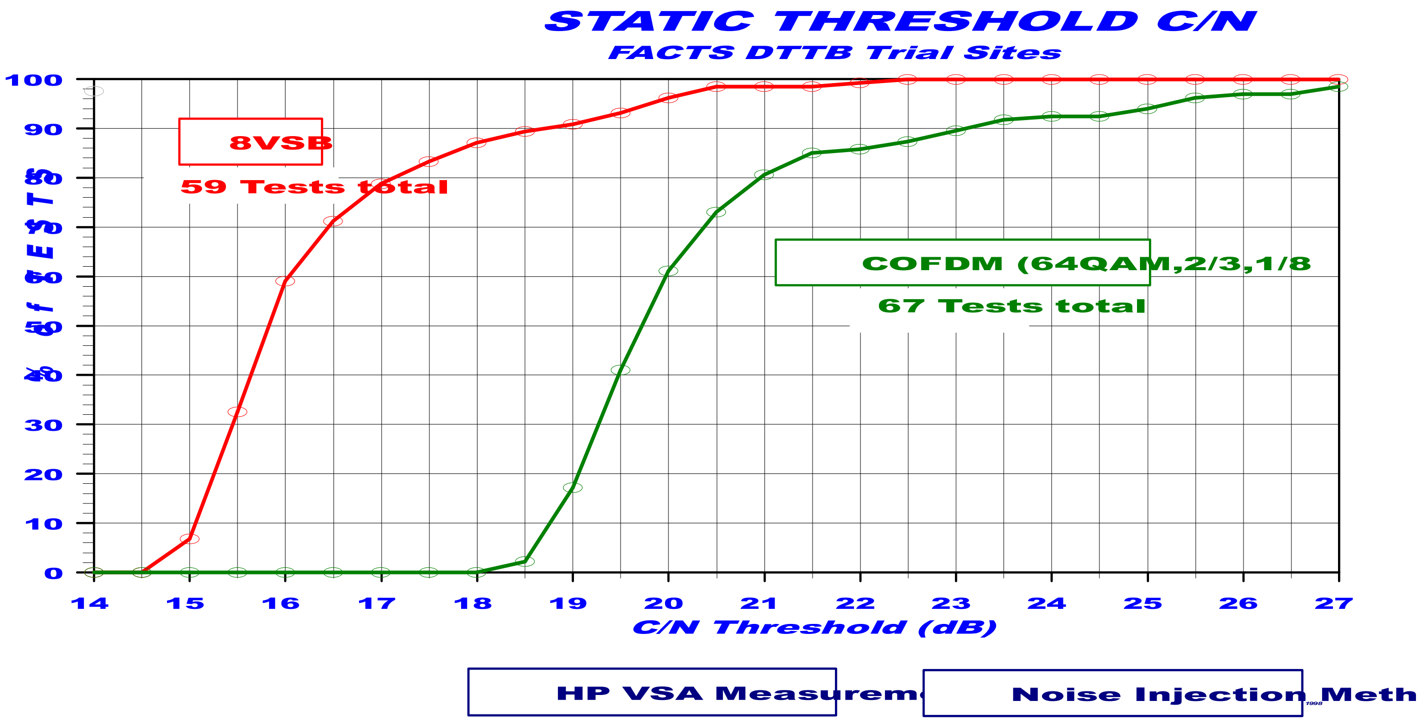
The cumulative distribution plots below provide some indication of the spread of the threshold C/N in the field Trial. The two methods used to establish the threshold C/N vary significantly in the spreads in the distributions. Further research may provide the reason. The “System Method” is perhaps the closest to the practical situation of the signal reducing towards the noise in the system, rather than artificially increasing the noise floor towards the signal in the “Noise Injection Method”.

The lack of smoothness in the curves suggests a low sample but does appear sufficient for comparison. The data above “80 % of tests” probably needs more samples, but the general trend may be a good indicator.

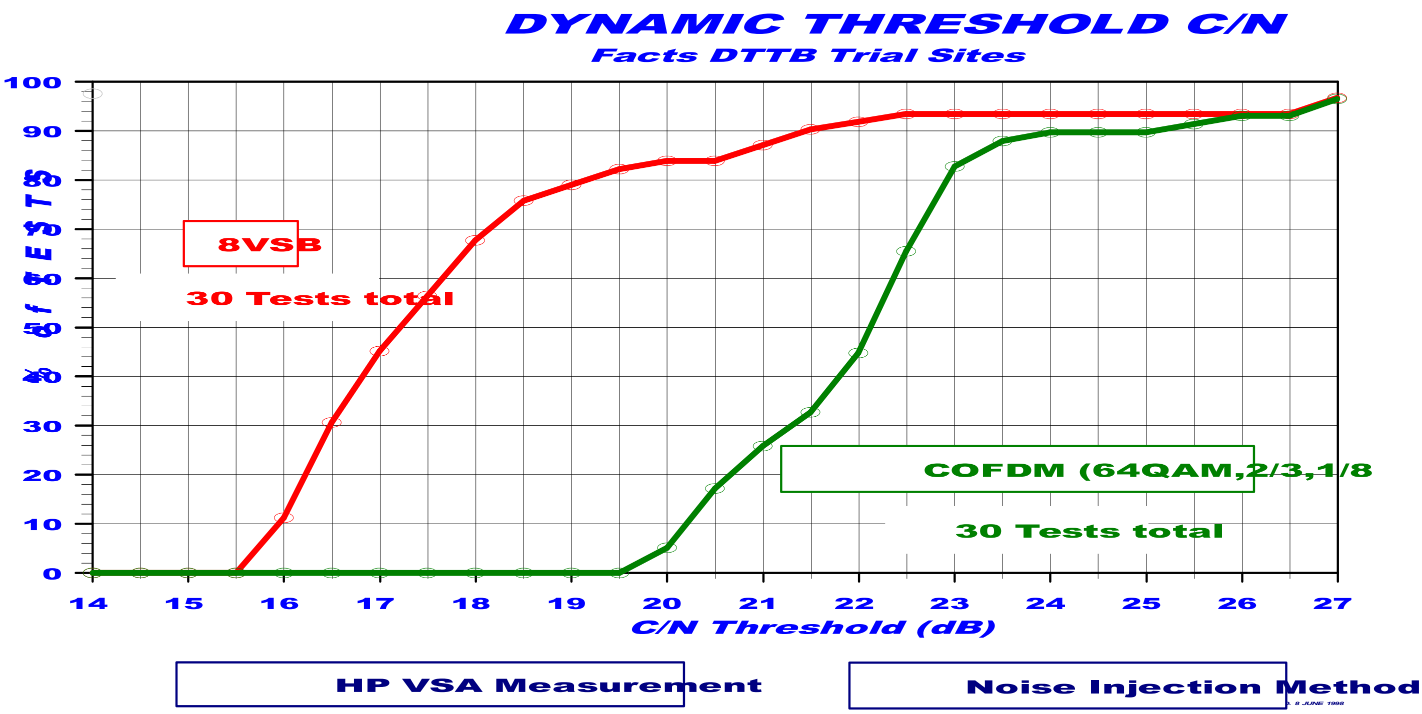
The distributions of the “Number of Tests” against “C/N Threshold” not only demonstrates the difference in character of the two C/N generating methods, but shows the influence of complex multipath upon the C/N Threshold performance of the two systems.



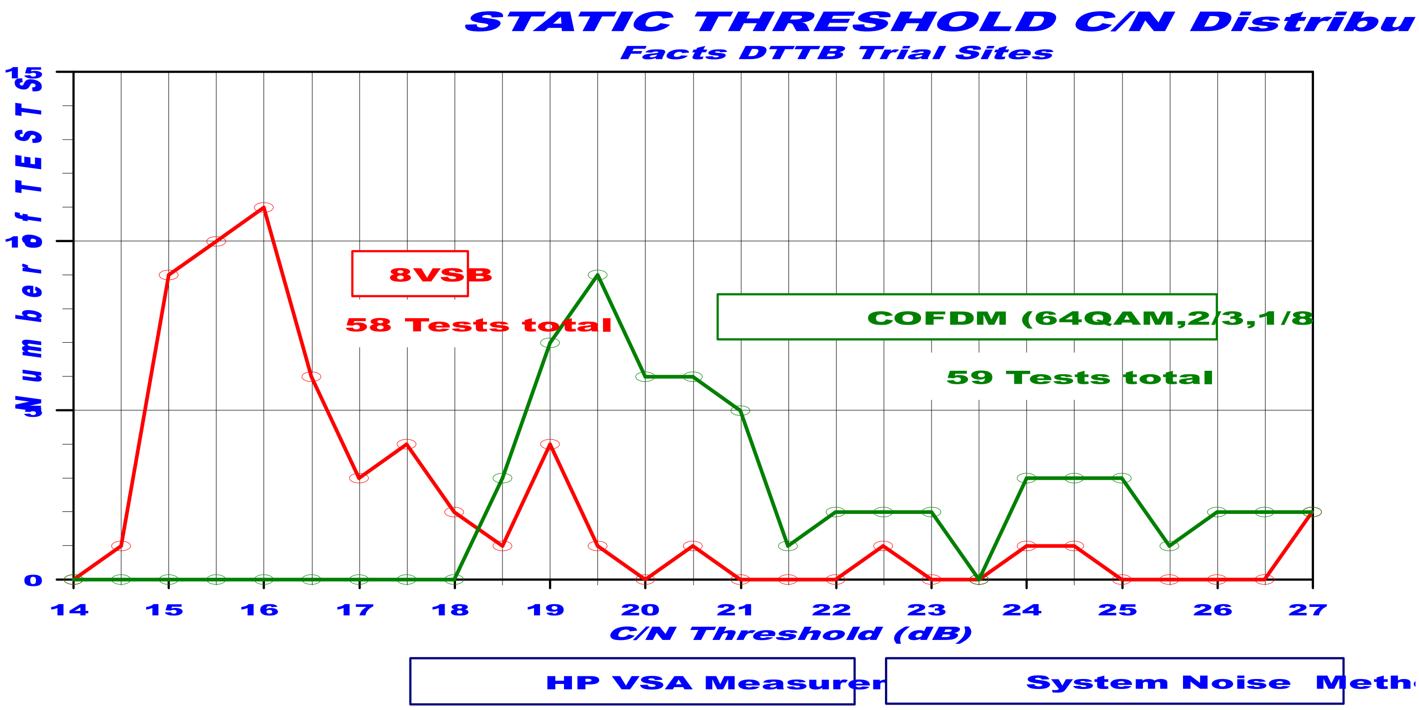
The distribution function using the Noise Injection Method is shown with its clearly different character. Further analysis and investigation will be undertaken to explain such difference in outcomes of measurement methods.



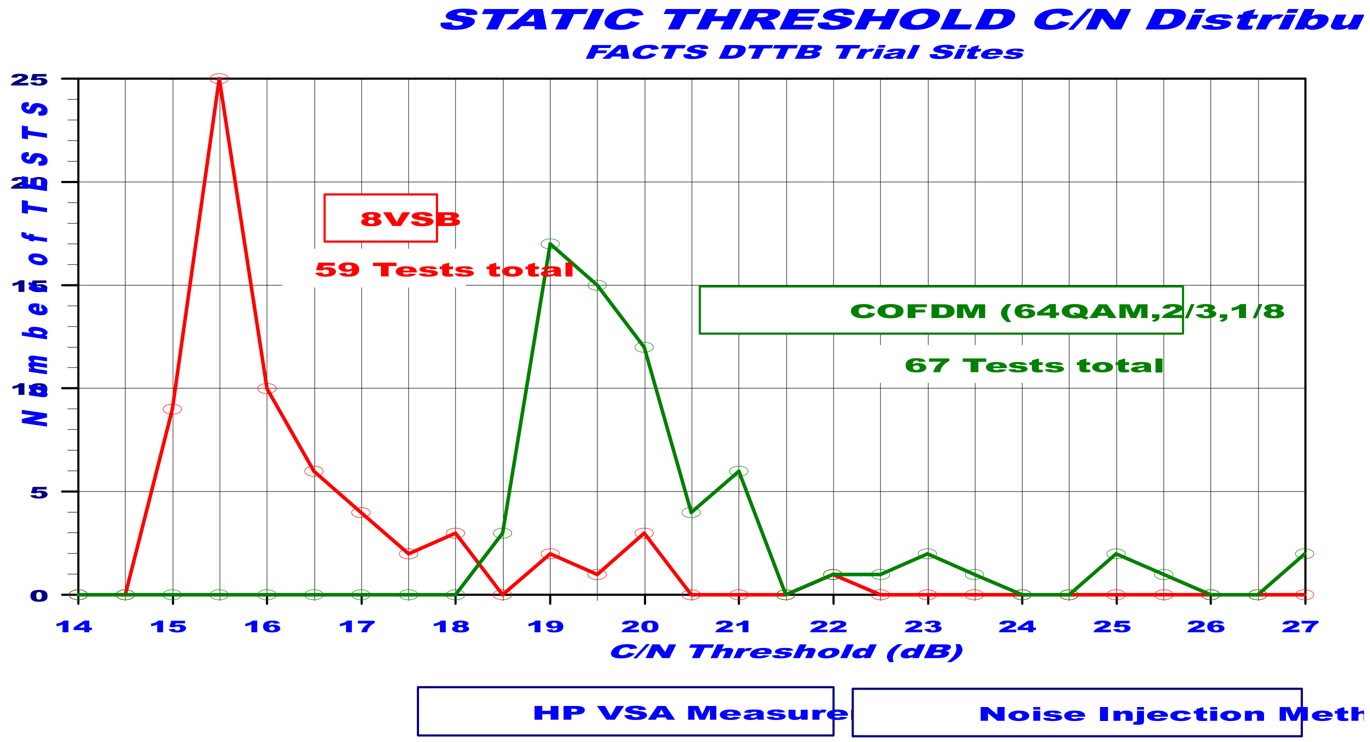
The cumulative distribution below shows the extending towards the higher threshold C/N for “dynamic” conditions. The comparison between COFDM and 8VSB may not be completely accurate as the sample is small, but it does indicates the trend of the stretching of the range of Threshold C/N to be allowed for in planning.



The distributions provide an indication of the spreads involved in C/N thresholds with particular differences between 8VSB and COFDM clear. The difference in measurement methods is reinforced.



Statistics : 8VSB : Median = 16 dB Average = 17.3 dB Minimum = 14.7 dB
COFDM : Median = 19.6 dB Average = 20.7 dB Minimum = 18.2 dB



Statistics : 8VSB : Median = 15.7 dB Average = 16.4 dB Minimum = 15 dB
COFDM : Median = 19.6 dB Average = 20.3 dB Minimum = 18.7 dB

DTTB Decoder Margin with decoder implementation variations :

The actual decoder margin is influenced by the characteristics of the receiver decoder released to the "consumer". One clear characteristic of the decoder's implementation influencing this margin is the NF of the tuner. The affect of this difference is demonstrated by the use of the NF of the supplied decoders from Zenith and NDS which could be representative of the decoders which may appear in mass-produced market. Some testing of the affect of decoder NF was completed in the field. The plots below although calculated are supported by the sample checks in the field.

Other parameters of the tuner which may also influence the decoder margin are :

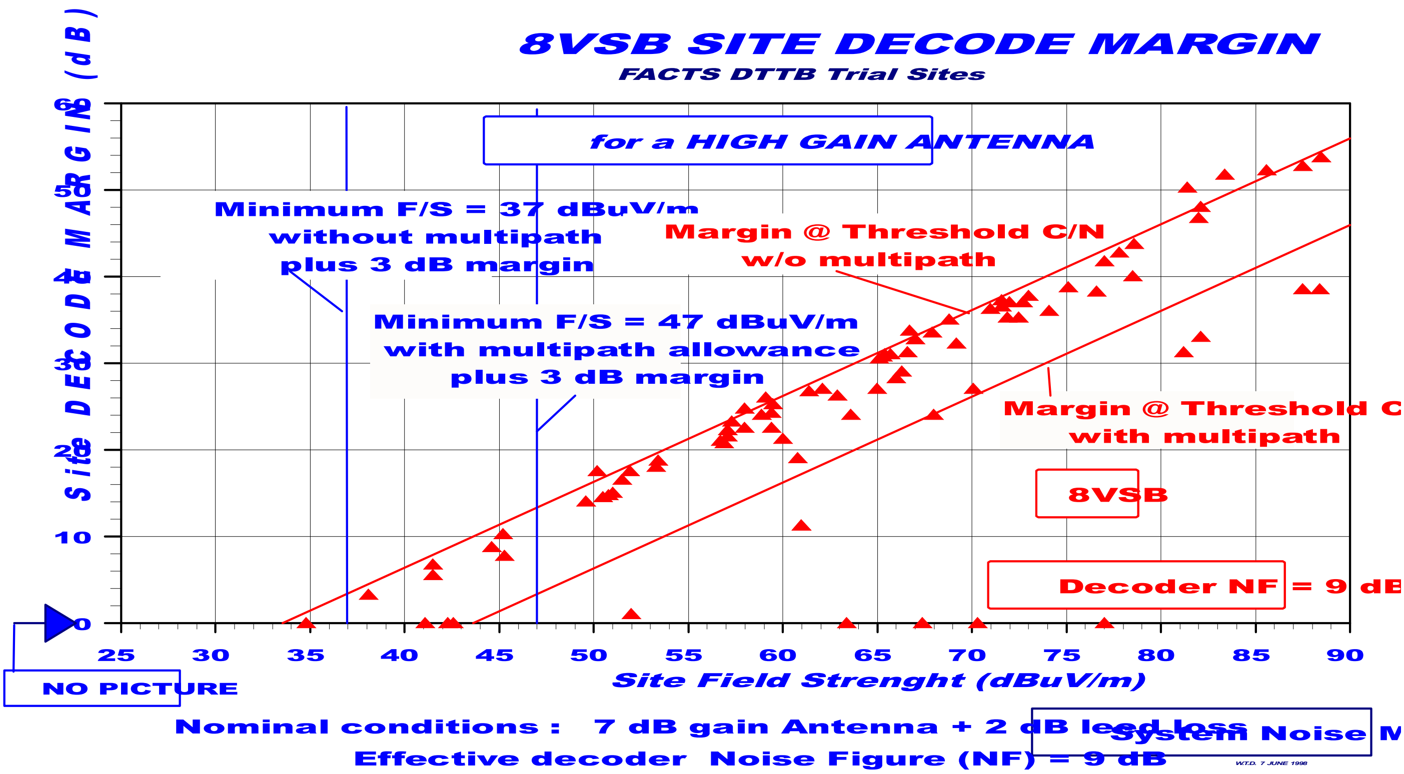
1. Phase noise
2. Group delay character
3. Amplitude response
4. Linearity
5. Maximum I/P level
6. Selectivity

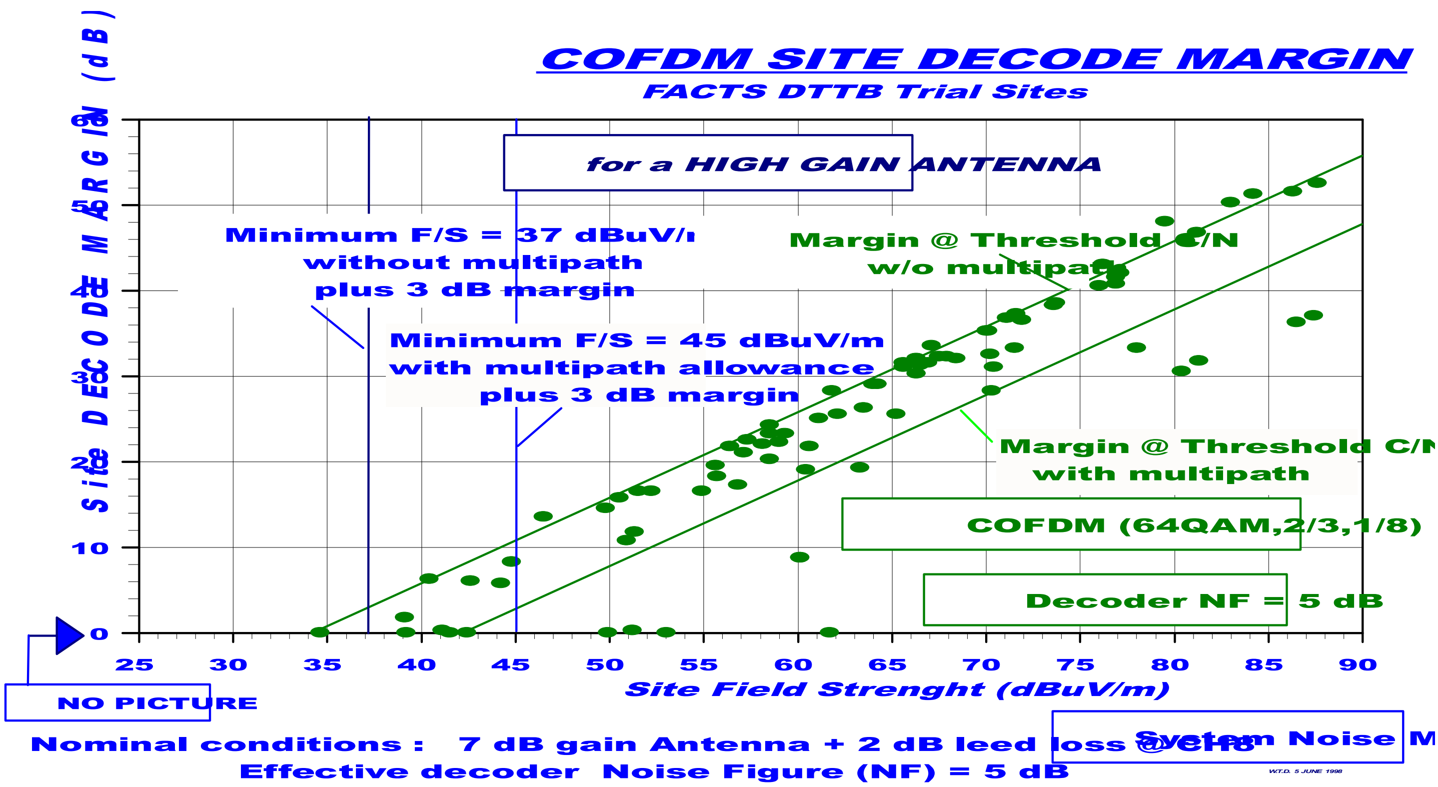
The extent to which these aspects influence the decoder margin vary significantly between 8VSB and COFDM, although the NF had a similar direct influence in both systems.

Other aspects of the system performance will change the decoder margin at the particular site and are different as recorded in the Laboratory Report and the Field Trials. Importantly these some of characteristics will vary between different implementations to be released into the market. Some of these factors are :

1. Co-channel – PAL into DTTB
2. Co-channel – CW into DTTB
3. Adjacent channel rejection
4. Multipath or ghost performance
5. Flutter performance
6. Impulse noise rejection
7. Transmission system implementation margins
8. Consumers receive antenna

Allowing for the difference between Field Trial Receiver NF and Supplied Receiver's NF :




COFDM SITE DECODE MARGIN
FACTS DTTB Trial Sites
for a HIGH GAIN ANTENNA
Minimum F/S = 37 dBuV/m
without multipath
plus 3 dB margin
Minimum F/S = 45 dBuV/m
with multipath allowance
plus 3 dB margin
Margin @ Threshold C/N
w/o multipath
Margin @ Threshold C/N
with multipath
COFDM (64QAM,2/3,1/8)
Decoder NF = 5 dB
Site DECODE MARGIN (dB)
Site Field Strenght (dBuV/m)
NO PICTURE
System Noise M
Nominal conditions : 7 dB gain Antenna + 2 dB feed loss @CH8
Effective decoder Noise Figure (NF) = 5 dB

ANALYSIS SUMMARY

Parameter		COFDM	8VSB	*Unit*	
Static Multipath :	- Median Threshold C/N (Noise inject)	19.6	15.7	dB	C/N
	- Median Threshold C/N (System Att.)	19.6	16	dB	C/N
	- Minimum Threshold C/N (Noise inject)	18.7	15	dB	C/N
	- Minimum Threshold C/N (System Att.)	18.2	14.7	dB	C/N
	- Average Threshold C/N (Noise inject)	20.3	16.4	dB	C/N
	- Average Threshold C/N (System Att.)	20.7	17.3	dB	C/N
	- 80% of tests (Noise inject) were less than	20.9	17.1	dB	C/N
	- 95% of tests (Noise inject) were less than	25.2	19.7	dB	C/N
	- 80% of tests (System Att.) were less than	24.5	18.5	dB	C/N
	- 95% of tests (System Att.) were less than	26.4	24.3	dB	C/N
	- Spread of Threshold C/N (95% Noise Inject)	6.3	4.5	dB	
	- Spread of Threshold C/N (95% System Att.)	8.2	9.6	dB	
Hi Gain Antenna :	- Minimum F/S @ 3.5 dB NF (1) (2)	35.5	31.5	dBuV/m	F/S
	- Minimum F/S for DTTB receivers supplied(1) (2) (3)	37	37	dBuV/m	F/S
	- Minimum F/S at 95% worst case (1) (3)	45.2	46.6	dBuV/m	F/S
Dipole Antenna :	- Minimum F/S @ 3.5 dB NF (5 dB safety margin) (2)	43	39	dBuV/m	F/S
	- Minimum F/S for DTTB receivers supplied (5 dB) (2)(3)	44.5	44.5	dBuV/m	F/S
	- Minimum F/S for DTTB receivers supplied(5 dB) (3) (6)	52.5	54	dBuV/m	F/S
DTTB to PAL Launch Ratio Variation of coverage area (>5Km from Tx)		+/- 2	+/- 2	dB	
PAL S/N @ DTTB C/N Threshold :	- Worse	32.5	32.5	dBunwtd	S/N
(for Hi Gain Antenna)	- Average	28.4	23.7	dBunwtd	S/N
@ -14 dB DTTB to PAL ratio	- Typical worse	32	30	dBunwtd	S/N
	- Best	20	19	dBunwtd	S/N
Typical F/S of PAL with Hi Gain Antenna for 30 dB S/N = 55 dBuV/m					
For Coverage equivalent to existing PAL Coverage requires :					
DTTB to PAL launch ratio :	- C/N Threshold study (1) (2)	-19.5	-23.5	dB	
- **Roof top** Outdoor Antenna	- C/N Threshold study 95 % worse case (1)	-11.3	-13.9	dB	
- Receiver **NF = 3.5 dB** (5)	- PAL comparisons – NO margins	-12	-14	dB	
(with RX NF as supplied) --	(- C/N threshold study 95 % worse case(1) (3))	-10	-8.5	dB	
Typical F/S of PAL with Dipole Antenna for 30 dB S/N = 60 dBuV/m					
DTTB to PAL launch ratio :	- C/N Threshold study (5 dB safety margin) (2) (4)	-17	-21	dB	
- **Dipole** Outdoor Antenna					
- Receiver **NF = 3.5 dB** (5)	- C/N Threshold study (as above + 95 % worse case)	-9	-11	dB	
(with RX NF as supplied) --	(- C/N threshold study & PAL comp.(1) (3) (6))	-7.5	-6	dB	

Notes :
1. Safety margin for reception at VHF of 3 dB allowed for in each system
2. No allowance for multipath deterioration of C/N threshold has been included.
3. Supplied DTTB receiver NF's were : COFDM NF = 5 dB nom. and 8VSB NF = 9 dB nom. from Lab. Tests.
4. Based upon PAL receiver with a dipole requiring 60 dBuV/m for 30 dB S/N - obtained from 5 dB lower antenna gain.
5. The variation in DTTB to PAL ratio in the field has not been allowed for in these ratios.
6. Uses multipath allowance for roof top antenna of 95% worst case. Dipole antenna likely to be worse.

Further analysis especially of the relationship between the complex multipath, recorded by both analogue records and 8VSB records, may provide the charts predicting the field results. The single echo with gaussian noise tests do not adequately provide these predictions. Indoor antenna testing will provide the data to extend these predictions down into the higher level multipath environments.

General Field Observations :

The observations are quite general, but do provide some feel of the performance of DTTB in the field.

With DTTB power 1/25 th (-14 dB) of PAL :

- When there was a reasonable analogue PAL picture, both 8VSB and COFDM worked at the vast majority of sites.

When there was noticeable :

- grain (noise) and some echoes (multipath) on Analogue PAL picture, 8VSB and COFDM failed.
- flutter, caused by aircraft or vehicles, on Analogue PAL picture, 8VSB failed.
- impulsive noise and some grain in the Analogue PAL picture, COFDM reception failed.

The straight noise with some multipath performance would be directly improved by increased transmission power.

The sensitivity of the COFDM system to impulse noise increased towards low field strength and would be improved by increased transmission power.

The sensitivity of 8VSB to flutter was found over the whole field strength range, with only large changes in level improving the performance. Hence increasing the transmission power is unlikely to significantly improve 8VSB sensitivity to flutter. The requirements for doppler performance and the Laboratory measured performance of both systems can be seen in the Annex.

Measurements taken in the field at a number of sites to verify the NF (Noise Figure) of the supplied receivers showed a directly translatable influence on the required minimum F/S or decoder margin. The field tests also confirmed the measurements carried out on receiver NF in the Laboratory tests. All other tests were conducted with effectively equal decoder NF's.

Overall :

The Field Trial was dominantly a study of the performance of the current implementations of the 8SVB and COFDM receivers into **fixed roof top antennas**.

The DTTB to PAL power ratio required to provide equivalent coverage to analogue PAL based upon :

- Analysis of Field Trial data
- Multipath allowance for 95% worst case
- Receivers supplied by the proponents
- No allowance for "dynamic" conditions

is : -8.5 dB for 8VSB and -10 dB for COFDM

Compiled by Wayne T Dickson
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Member of the FACTS Specialist Group Advanced Transmission

Annex

The plots below show the required range of doppler shifts of the echoes that the decoders are required to handle with various speeds of aircraft and road vehicles. The requirement as indicated changes with the TV channel of operation, hence field trials of higher Band III and Band IV / V channels should be considered.