REPORT ON
THE TECHNICAL TRIAL OF DIGITAL TERRESTRIAL TELEVISION (DTT)

Digital Terrestrial Television Steering Committee

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EXECUTIVE SUMMARY

In view of the advent of the digital broadcasting technology and the benefit it will bring to television broadcasting in Hong Kong, the Government of the HKSAR, Asia Television Limited (ATV) and Television Broadcasts Limited (TVB) agreed to jointly conduct a technical trial of digital terrestrial television (DTT) in Hong Kong. The purpose of the trial is to assess the performance of the three prevailing DTT standards, namely Advanced Television Systems Committee (ATSC), Digital Video Broadcasting - Terrestrial (DVB-T) and Integrated Services Digital Broadcasting - Terrestrial (ISDB-T), in the Hong Kong environment.

2. The technical trial consisted of two parts, the field test and the laboratory test. The field test intended to find out the performance of the three DTT systems under different reception conditions with reference to the existing PAL-I system used in Hong Kong, whereas the laboratory test measured the protection ratios required when the DTT systems were to be deployed. In order to obtain a more meaningful result for subsequent analysis, the performance of the three DTT systems were assessed by a set of identical test items under similar equipment configuration, modulation modes and test conditions, to the extent that was possible subject to the technical limitation of available test equipment and facilities. The technical trial was conducted during the period from May to November 1999 and the major findings of the trial are summarised in the following paragraphs.

3. **Improvement in Reception** - The performance of all the three DTT systems was much better than the existing PAL-I system with more stable picture and sound quality and more robust reception. The field trial demonstrated that the three DTT systems could help resolve the poor reception problems of the existing PAL-I television system. The three DTT systems were also capable of providing similar coverage to that of the existing PAL-I television system with the use of lower transmitter power.

4. **Support of Standard Definition Television (SDTV) and High Definition Television (HDTV) Modes** - The three DTT systems were able to support the transmission in both the SDTV mode and the HDTV mode in different reception conditions including fixed and indoor locations, and reception via the In-Building Coaxial Cable Distribution System (IBCCDS).

5. **Support of Mobile Reception** - Mobile reception of ISDB-T and DVB-T was good in open areas. For ATSC, as the standard was not designed for mobile reception and the relevant mobile reception equipment was not available, the test on mobile reception for ATSC was not included in the technical trial.

6. **Compatibility of DTT Signals with PAL-I Television Transmission** - Field measurements in fixed outdoor locations, in the system headends and TV outlets of the IBCCDS indicated that no adverse effect was caused to the reception of nearby PAL-I signals by the DTT signals. In general, the result indicated that the DTT signals were compatible with the PAL-I television transmission network, whereas certain specific system alignment work would be required when DTT signals were distributed via some of the IBCCDS in Hong Kong.

7. **Support of Single Frequency Network (SFN) Configuration** - Both ISDB-T and DVB-T supported Single Frequency Network (SFN) operation. For ATSC, as the standard was not designed for operating in SFN configuration and the relevant SFN equipment was not available, the test of SFN for ATSC was not included in the technical trial.

8. **Effect of Tidal Fading** - All the three DTT systems were affected by the effect of tidal fading in similar fashion as the PAL-I transmission. Precaution should be taken in aligning the receiving systems to avoid the sudden fading of the digital signals.

9. **Protection Ratios and Overall Encoding / Decoding Delay** - The protection ratios for co-channel interference, adjacent channel interference and image channel interference of the three DTT systems, and the overall encoding / decoding delay of the ISDB-T and DVB-T systems were measured and found to be consistent with the figures quoted in the respective standards.

INTRODUCTION

Digital Terrestrial Television (DTT) technology is developing fast around the world. The technology offers more channels within the same amount of spectrum with higher quality pictures and many more enhanced features to television broadcasting service. At present, there are three DTT standards, namely the Advanced Television Systems Committee (ATSC) standard from the United States, the Digital Video Broadcasting – Terrestrial (DVB-T) standard from Europe, and the Integrated Services Digital Broadcasting – Terrestrial (ISDB-T) standard from Japan.

2. The ATSC standard was adopted by the Federal Communications Commission in December 1996 as the DTT standard to be deployed in the United States. Subsequently, the DTT service has been launched since November 1998 and more than 50% of the American population now have access to DTT signals in around 120 cities of the United States [1]. Argentina, Canada, South Korea and Taiwan have announced the adoption of the ATSC standard for the DTT service. The ATSC standard is capable of supporting high quality video, audio and ancillary data in both the Standard Definition Television (SDTV) mode and the High Definition Television (HDTV) mode with the use of Vestigial Sideband (VSB) modulation schemes [2].

3. The DVB-T standard, approved by the European Telecommunications Standards Institute (ETSI) in February 1997, is capable of supporting both the SDTV and HDTV modes and is based on the Orthogonal Frequency Division Multiplexing (OFDM) technology which provides multipath immunity to the receiving system. In this regard, features like mobile reception and the Single Frequency Network (SFN) configuration can be supported. The standard also provides different options on the use of modulation schemes and number of carriers. DVB-T standard specifies the use of Quadrature Phase Shift Keying (QPSK) and different levels of Quadrature Amplitude Modulation (QAM) in order to trade bit rates against robustness. For instance, the QPSK modulation is more robust against different fading conditions but offers smaller bit rates, whereas higher level of QAM provides more bit rates but is less robust. The standard also allows the choice between the 2k carrier mode which is suitable for relatively small single frequency networks with limited transmitter power, or the 8k mode which can be used for large area single frequency networks. [3] In addition to the member countries of the European Union, other countries like Australia, India, New Zealand and Singapore have also adopted DVB-T as the DTT standard.

4. The ISDB-T standard was developed by the Association of Radio Industries and Businesses (ARIB) and approved by the Ministry of Posts and Telecommunications (MPT) of Japan. It was first publicly demonstrated in November 1997 [4]. ISDB-T can support both the

SDTV and HDTV modes. The standard is also based on the OFDM technology which improves the robustness against multipath fading. Different modulation schemes such as QPSK, DQPSK, 16-QAM and 64-QAM are supported in the ISDB-T standard. Likewise, mobile reception and the SFN configuration can also be supported [5].

5. With a view to facilitating the development of digital broadcasting technology in Hong Kong and promoting the diversity of services, it will be beneficial for the broadcasting industry in Hong Kong to perform relevant trial and to gain practical experience on the technology in the Hong Kong environment. In this connection, the Government of the HKSAR, the Asia Television Limited (ATV) and the Television Broadcasts Limited (TVB) agreed to jointly conduct a technical trial of DTT, to assess the performance of the three DTT standards, i.e. ATSC, DVB-T and ISDB-T and their variants in Hong Kong.

6. A joint Government-Industry DTT Steering Committee comprising representatives from the Information Technology and Broadcasting Bureau (ITBB), ATV, Office of the Telecommunications Authority (OFTA), Television and Entertainment Licensing Authority (TELA), and TVB was established to steer the arrangement of the technical trial of DTT. Under the DTT Steering Committee, a Technical Sub-committee led by OFTA was formed to co-ordinate and monitor the technical trial.

7. The technical trial was conducted from May to November 1999. The test reports of the technical trial are given in Appendices 1, 2 and 3. This report summarizes the results of the technical trial and presents the findings on the performance of the three DTT standards in the Hong Kong environment.

OBJECTIVES OF THE TECHNICAL TRIAL

8. The overall objective of the technical trial is to assess the performance of the 3 DTT standards in the Hong Kong environment. The scope of the trial is as follows:-

(i) the propagation behaviour and coverage of DTT transmissions;

(ii) the ability of DTT signals to be conveyed by In-Building Co-axial Cable Distribution Systems (IBCCDS) and the compatibility with the existing analogue television equipment and NICAM service;

(iii) the support for single frequency network operation;

(iv) compatibility with the existing analogue television transmission, co-channel, adjacent channel and image channel performance;

(v) picture and sound quality; and

(vi) the effect of overall encoding / decoding delay.

DETAILS OF THE TECHNICAL TRIAL

9. In the technical trial, the performance of the three DTT systems were tested individually and the details of the three trials of ISDB-T, DVB-T and ATSC are given in the trial reports in Appendices 1, 2 and 3 respectively. The trial was conducted in three stages during the following periods:

Technical trial of ISDB-T:	May 1999 to June 1999
Technical trial of DVB-T:	August 1999 to September 1999
Technical trial of ATSC:	November 1999

10. In each stage, the performance of each DTT system were assessed by a set of identical test items. In order to obtain a more meaningful result for subsequent analysis, the test items of the trial were conducted under similar equipment configuration, modulation modes and test conditions, to the extent that was possible subject to the technical limitation of available test equipment and facilities.

11. The evaluation on the DTT systems was divided into two parts, the field test and the laboratory test. The field test intended to find out the performance of the three DTT systems under different reception conditions, which included fixed reception, indoor reception, and mobile reception, in the Hong Kong environment. The relative improvement of the DTT systems over the existing PAL-I television system was also addressed. The laboratory test focused on the evaluation of the performance of the three DTT systems under different interference conditions with a view to verifying the values of the protection ratios quoted in the respective standards.

12. In the field tests for the three DTT systems, two DTT transmitting stations, namely the Master Station and the Slave Station, were established for the field measurements and for the evaluation of the Single Frequency Network capability. The following arrangement was used in the field tests of the trial:-

Main station
Location: Temple Hill
Maximum Effective Radiated Power (ERP): 100 W (note)

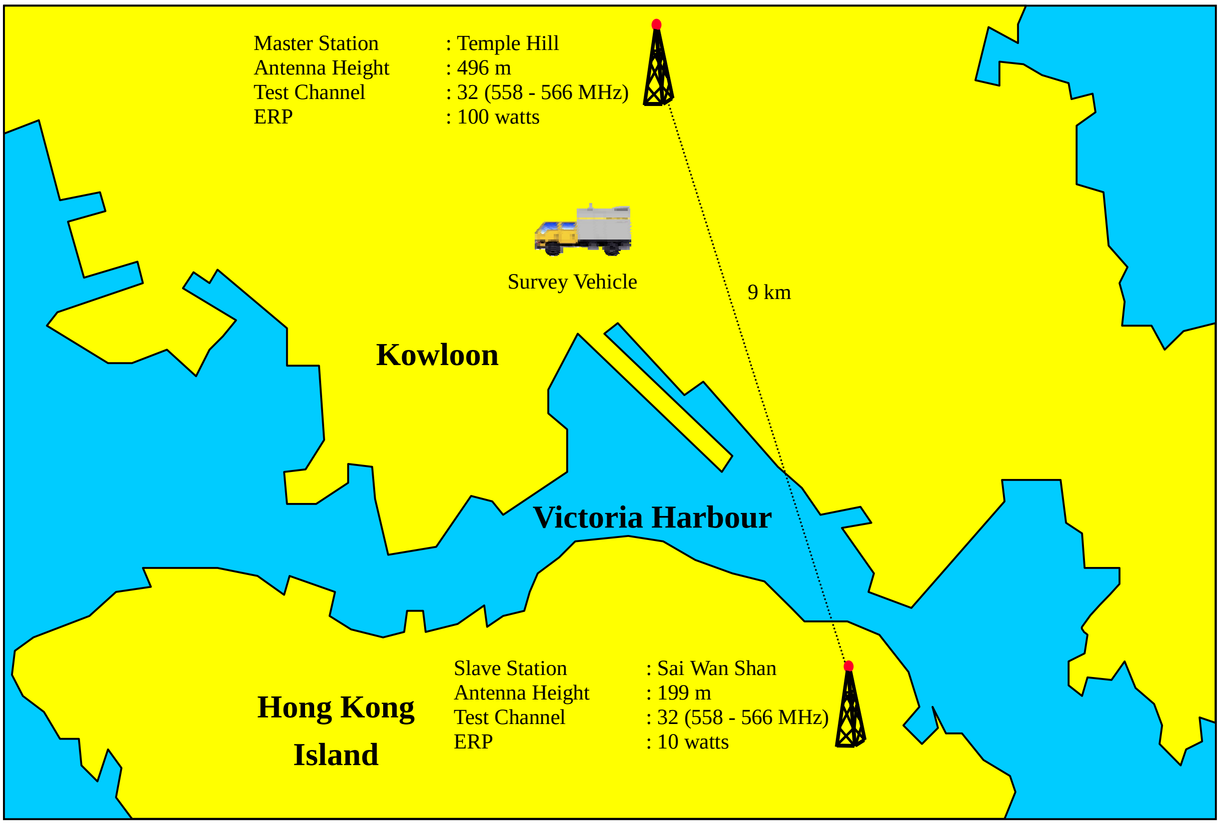
Slave station
Location: Sai Wan Shan
Maximum ERP: 10 W

Frequency Channel for Test Transmission: Channel 32 (558-566 MHz)

Coverage Area:
- Northern part of Hong Kong Island;
- Kowloon East;
- Kowloon Central; and
- Kowloon West

Note: The result of the technical trial was normally obtained with the Master Station transmitting at 100 W. Only under certain test cases, the transmitter power of the Master Station was increased to 1 kW to investigate the effect of increased transmitter power.

Figure 1 Field Test Configuration



13. An analogue (PAL-I) transmitter which also operated on Channel 32 was set up at Temple Hill as a reference. For the detailed test setup and measurement procedure, please refer to <u>Appendices 1, 2 and 3</u>.

14. The laboratory tests for the three DTT systems were carried out in the TVB Transmission Laboratory at TV City. The detailed test setup and measurement procedure are given in <u>Appendices 1, 2 and 3</u>.

15. Due to the unavailability of appropriate test systems and equipment and the limitation of time and resources, the technical trial only focused on the evaluation of the three DTT standards, and not on testing any variants of the three DTT standards.

RESULTS AND DISCUSSIONS

16. The measurement results and findings of each of the three DTT systems in the technical trial are presented in the respective interim trial reports. In the following paragraphs, the test results for the three DTT systems as obtained in the field tests and laboratory tests of the technical trial are summarised. The observations on the relative performance of the three DTT systems over the existing analogue television system are also addressed. For the detailed result of each of the following test items, please refer to the trial reports for ISDB-T, DVB-T and ATSC as given in Appendices 1, 2 and 3 respectively.

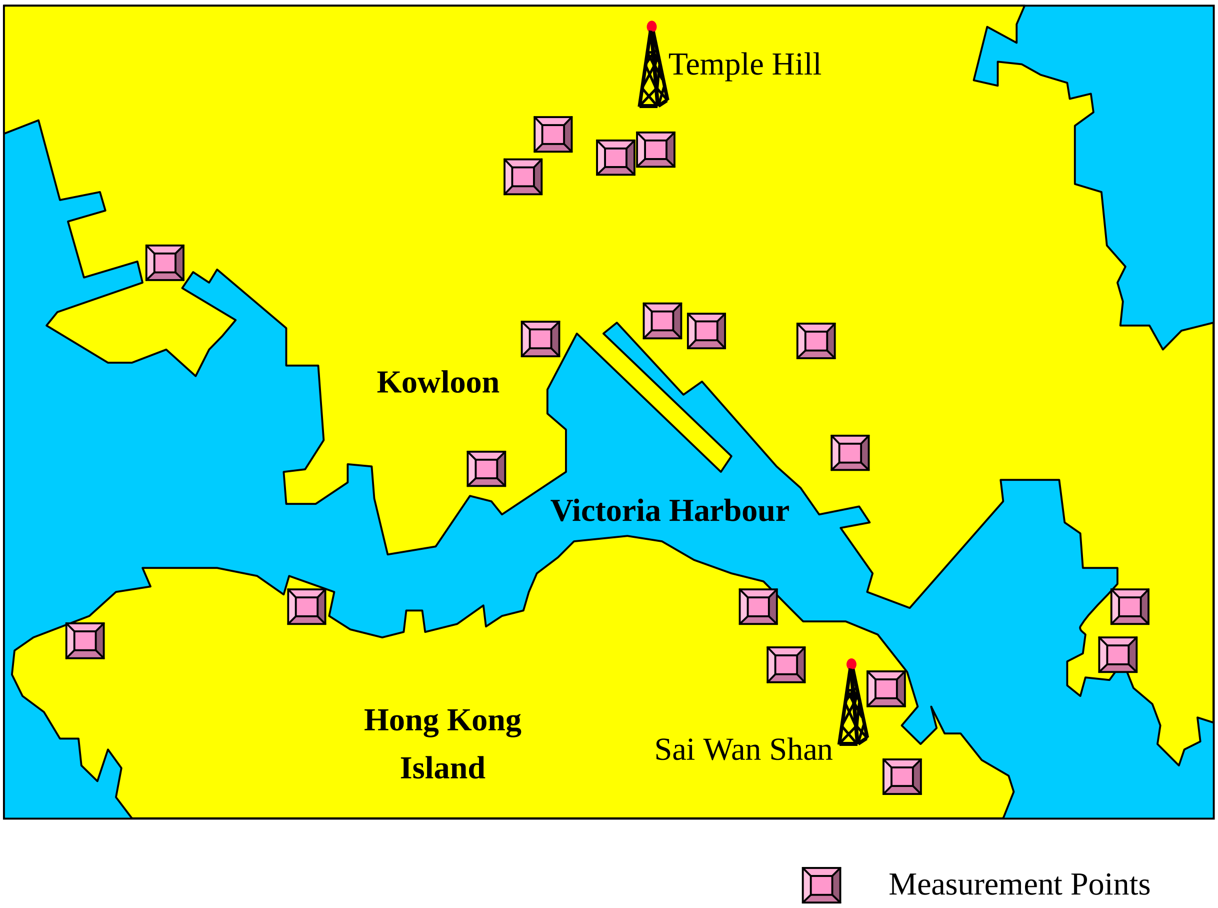
FIELD TESTS

17. Field tests were conducted to examine the performance of the three DTT systems under different reception scenarios, namely in Fixed Locations, Mobile Environment, Indoor Locations, reception via the In-Building Coaxial Cable Distribution System (IBCCDS) and reception under the Single Frequency Network (SFN) configuration. The results are presented in the following paragraphs:-

Fixed Reception of DTT Signals

18. Fixed reception of the DTT signals from the three DTT systems were measured in a number of different locations in the urban areas of Hong Kong Island and Kowloon Peninsula as shown in Figure 2. The geographical distribution of the measurement points represented the coverage area presently served by the 10 kW Temple Hill transmitter station of the analogue television network.

Figure 2 Measurement Points for Fixed Reception



19. In order to examine the performance of the DTT systems under different reception conditions, the measurement points were selected with respect to the following categories:-

i) Street Level (Line-of-Sight) Measurement;
ii) Street Level (Building Shadow & Hill Shadow) Measurement; and
iii) Rooftop (Building Shadow) Measurement.

<u>ISDB-T</u>

20. The field measurement for ISDB-T was conducted in 19 different locations using the 64-QAM modulation mode with 2k carriers. In all cases, an excellent picture and sound quality of grade 5 according to the ITU-R scale [6] was obtained for both the SDTV and HDTV modes. The test result is summarized as follows:-

	Fixed Reception of ISDB-T	Measured Field Strength / Signal Level	Margin of Threshold for SDTV Reception
a.	Street Level (Line-of-Sight) Measurement	64 to 93 dBμV/m	17 to 46 dB
b.	Street Level (Building Shadow & Hill Shadow) Measurement	62 to 77.5 dBμV/m	11 to 48.8 dB
c.	Rooftop (Building Shadow) Measurement	46.1 to 61.5 dBμV	12 to 33 dB

<u>DVB-T</u>

21. The field measurement for DVB-T was conducted in 21 different locations using the 64-QAM modulation mode with 2k carriers. In all cases, an excellent picture and sound quality of grade 5 was obtained for both the SDTV and HDTV modes. The test result is summarized as follows:-

	Fixed Reception of DVB-T	Measured Field Strength / Signal Level	Margin of Threshold for SDTV Reception
a.	Street Level (Line-of-Sight) Measurement	65 to 88 dBμV/m	27 to 52 dB
b.	Street Level (Building Shadow & Hill Shadow) Measurement	53 to 74.3 dBμV/m	7 to 35 dB
c.	Rooftop (Building Shadow) Measurement	38.5 to 44 dBμV	19 to 32 dB

<u>ATSC</u>

22. The field measurement for ATSC was conducted in 18 different locations using the 8-VSB modulation mode. In all cases, an excellent picture and sound quality of grade 5 was obtained for both the SDTV and HDTV modes. The test result is summarized as follows:-

	Fixed Reception of ATSC	Measured Field Strength / Signal Level	Margin of Threshold for SDTV Reception
a.	Street Level (Line-of-Sight) Measurement	68 to 88 dBμV/m	33 to 53 dB
b.	Street Level (Building Shadow & Hill Shadow) Measurement	56 to 76 dBμV/m	21 to 40 dB

c.	Rooftop (Building Shadow) Measurement	33.6 to 37.2 dBμV	18 to 22 dB

Observation

23. In general, all the three DTT systems provided satisfactory reception and the received picture and sound quality for both the SDTV and HDTV modes was excellent. In all the measurement points, the received signal strengths of the DTT signals from all the three DTT systems were sufficient for sustaining an excellent reception quality. During the test, the values of the margin of threshold were obtained by artificially attenuating the received DTT signals until the reception of the SDTV mode deteriorated to a certain reception threshold. It was noted that all the 3 DTT systems provided large values of the margin of threshold which contributed to enhancing the robustness of the reception of the DTT signals.

24. It was also noted that no adverse effect was caused to the reception of nearby analogue television channels and no complaint was received from the public during the duration of the technical trial.

Mobile Reception of DTT Signals

25. The capability of mobile reception of DTT signals was examined by taking measurement on a survey vehicle travelling at speeds less than 70 km/hr, which was the typical safety speed for the roads of Hong Kong. The percentage of time that a satisfactory reception was obtained was taken as the success rate of mobile reception and this figure was used to quantify the performance of the DTT systems. Mobile reception test for the following routes were conducted:-

i) Kwun Tong Bypass (Laguna City to Kowloon Bay);
ii) Diamond Hill Route (Po Kong Village Road to Hammer Hill Road to Lung Cheung Road);
iii) Whampoa Garden Route (a number of streets inside Whampoa Garden); and
iv) Eastern Corridor (Taikoo Shing to Causeway Bay).

ISDB-T

26. Mobile reception for ISDB-T was examined by using the 16-QAM and DQPSK modulation modes with 2k carriers. The test results for the 16-QAM and DQPSK modulation modes with or without SFN configuration are illustrated in Figures 3, 4, 5 and 6 respectively.

DVB-T

27. Mobile reception for DVB-T was examined by using the 16-QAM and QPSK modulation modes with 2k carriers. The test results for the 16-QAM and QPSK modulation modes with or without SFN configuration are illustrated in Figures 7, 8, 9 and 10 respectively.

ATSC

28. Given the ATSC standard was not designed for mobile reception and the relevant mobile reception equipment was not available, this item was not included in the field test for ATSC.

Observation

29. In this test, mobile reception of ISDB-T and DVB-T was demonstrated. In all the test routes, the reception of analogue television signals was unstable and the picture was also very noisy. The reception of the DTT signals was much better and a satisfactory picture quality was always obtained for the Diamond Hill Route and the Eastern Corridor for both ISDB-T and DVB-T. However, for Kwun Tong Bypass and Whampoa Garden Route, the reception of ISDB-T and DVB-T was not always possible probably due to signal blockage by the neighbouring high-rise buildings. For DVB-T, it was also found that the success rate of mobile reception actually depended on the design of the receiver and different results were obtained when receivers from 2 different manufacturers were used in the test.

30. In particular, the result of mobile reception for the Whampoa Garden Route was very poor as the average success rates for ISDB-T under DQPSK modulation and for DVB-T under QPSK modulation merely ranged from 4.5% to 36.4%. Possible reasons for the poor reception might be due to the relatively long distance from the transmitter station and the presence of a large number of dense, high-rise buildings.

31. Another observation from the result of the mobile reception test was that QPSK/DQPSK modulation scheme provided a relatively better performance advantage over the 16-QAM modulation scheme. For instance, the measurement data for the mobile reception of ISDB-T in Kwun Tong Bypass without SFN indicated that the average success rate for DQPSK modulation reached 97.2% while the average success rate for 16-QAM was only 28.6%.

Figure 3 *Mobile Reception of ISDB-T (16-QAM Modulation, No SFN)*

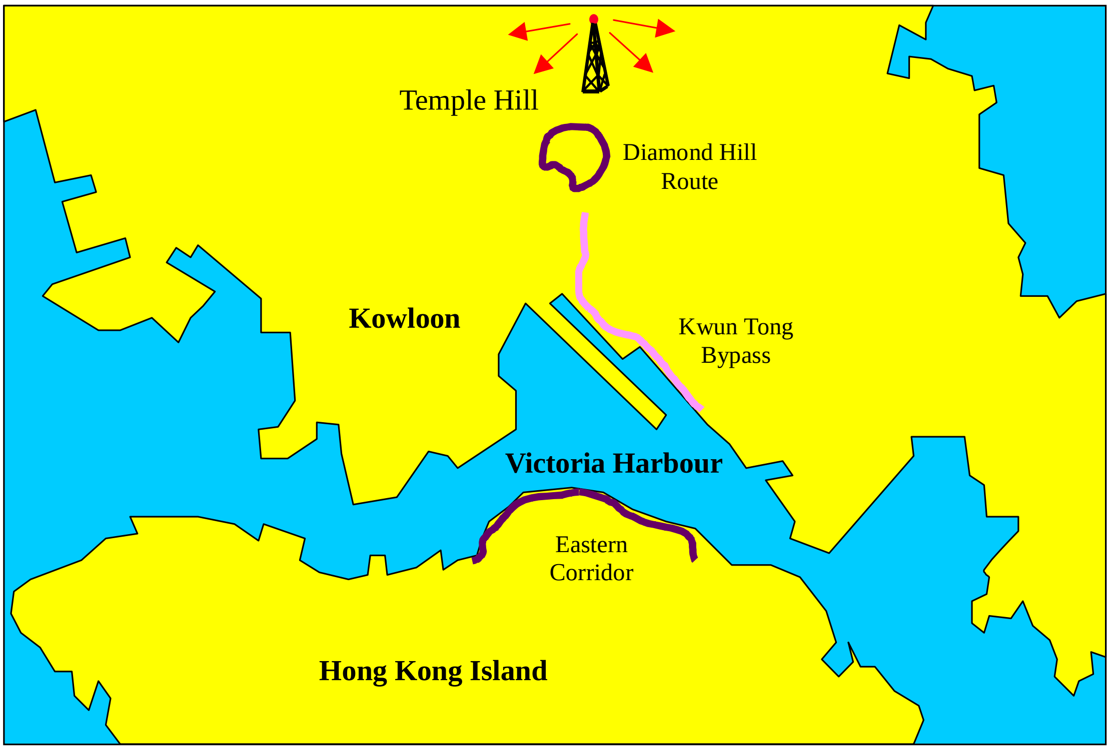
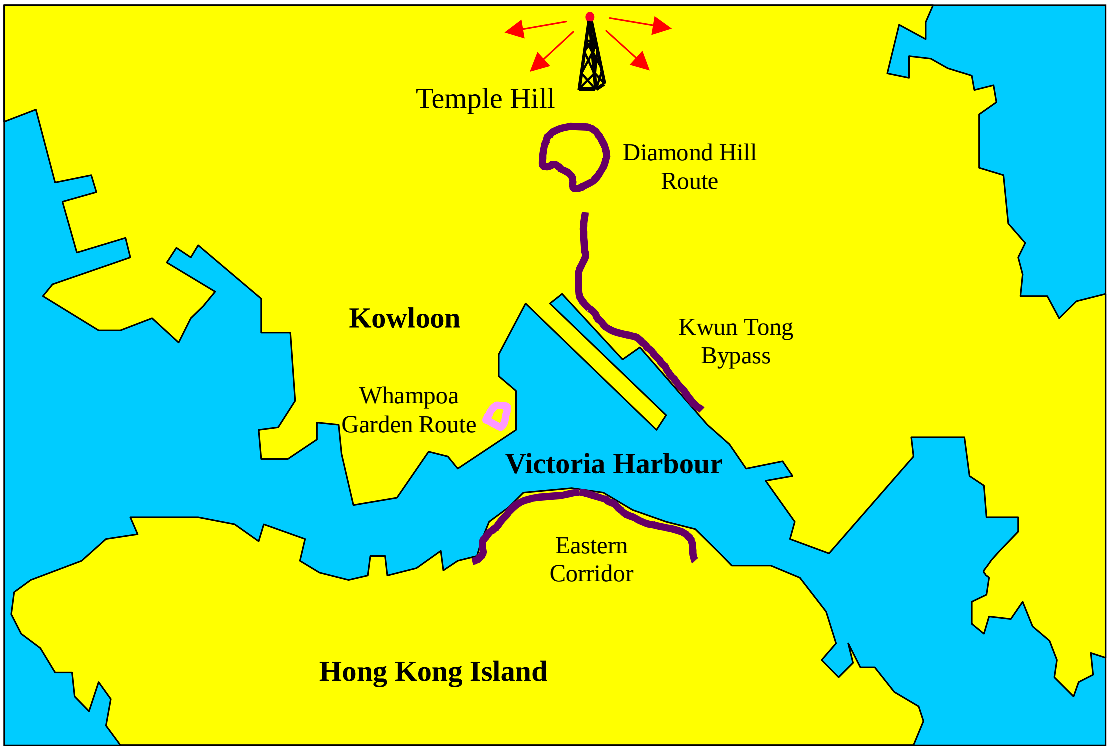


Figure 4 *Mobile Reception of ISDB-T (DQPSK Modulation, No SFN)*



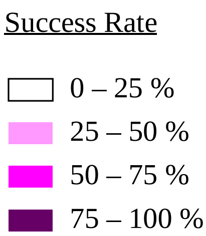


Figure 5 Mobile Reception of ISDB-T (16-QAM Modulation, SFN)

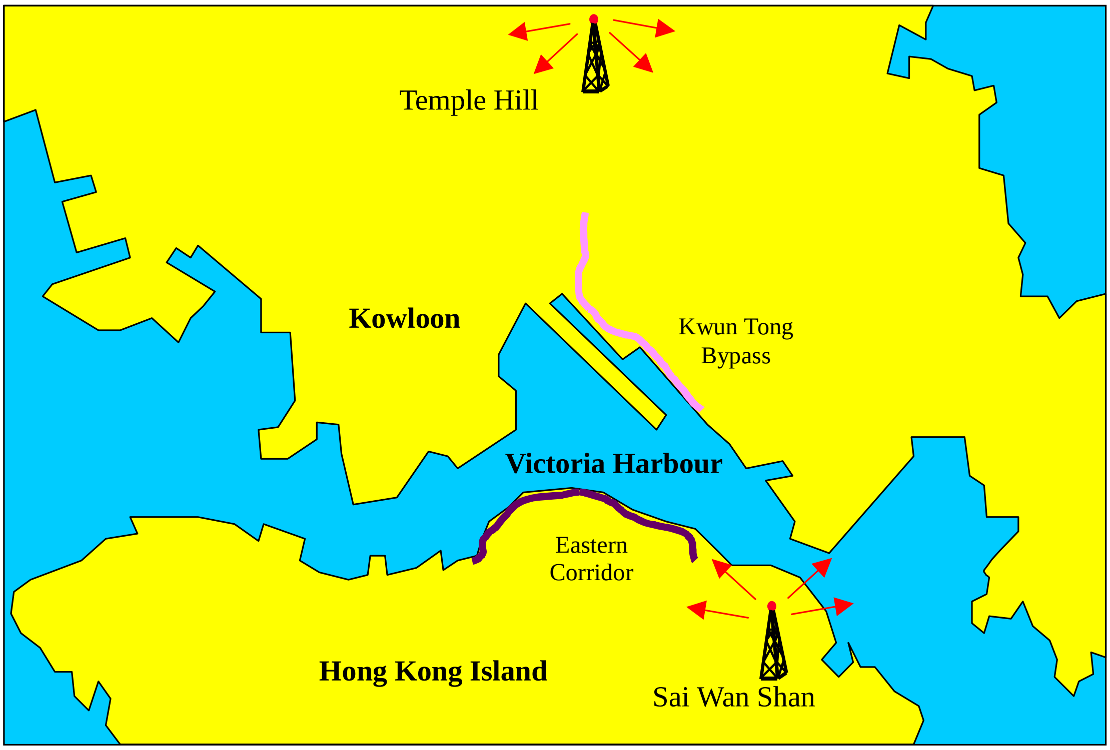
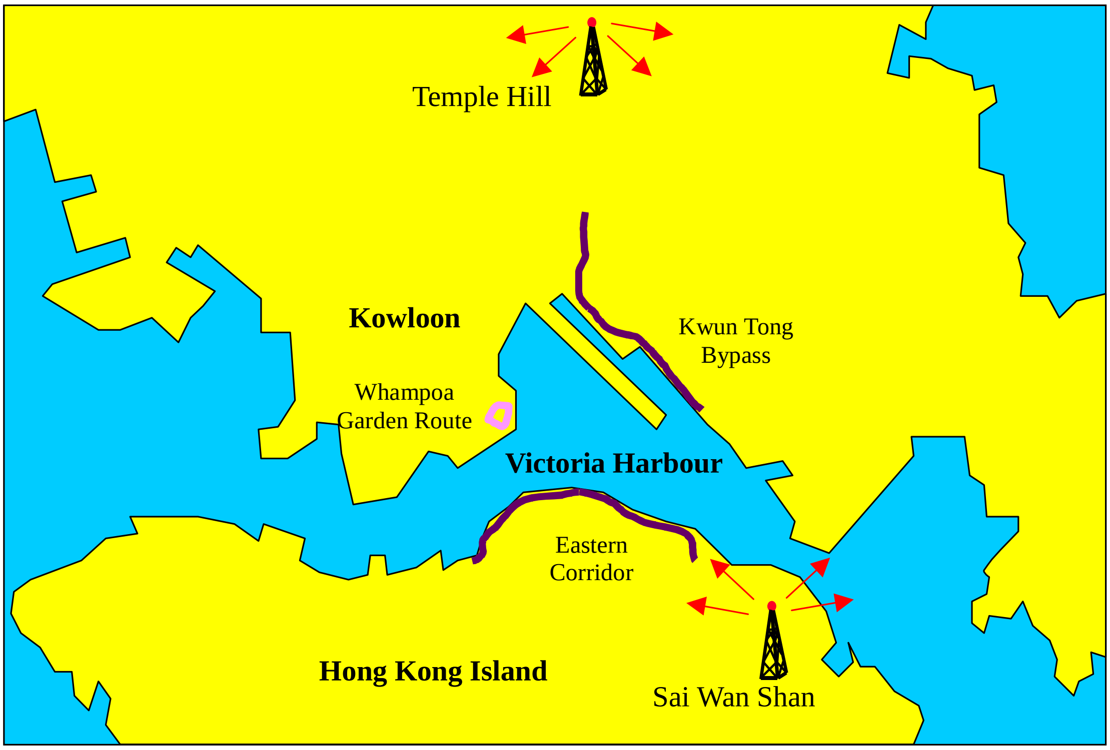


Figure 6 Mobile Reception of ISDB-T (DQPSK Modulation, SFN)



<u>Success Rate</u>

- 0 – 25 %
- 25 – 50 %
- 50 – 75 %
- 75 – 100 %

Figure 7 *Mobile Reception of DVB-T (16-QAM Modulation, No SFN)*

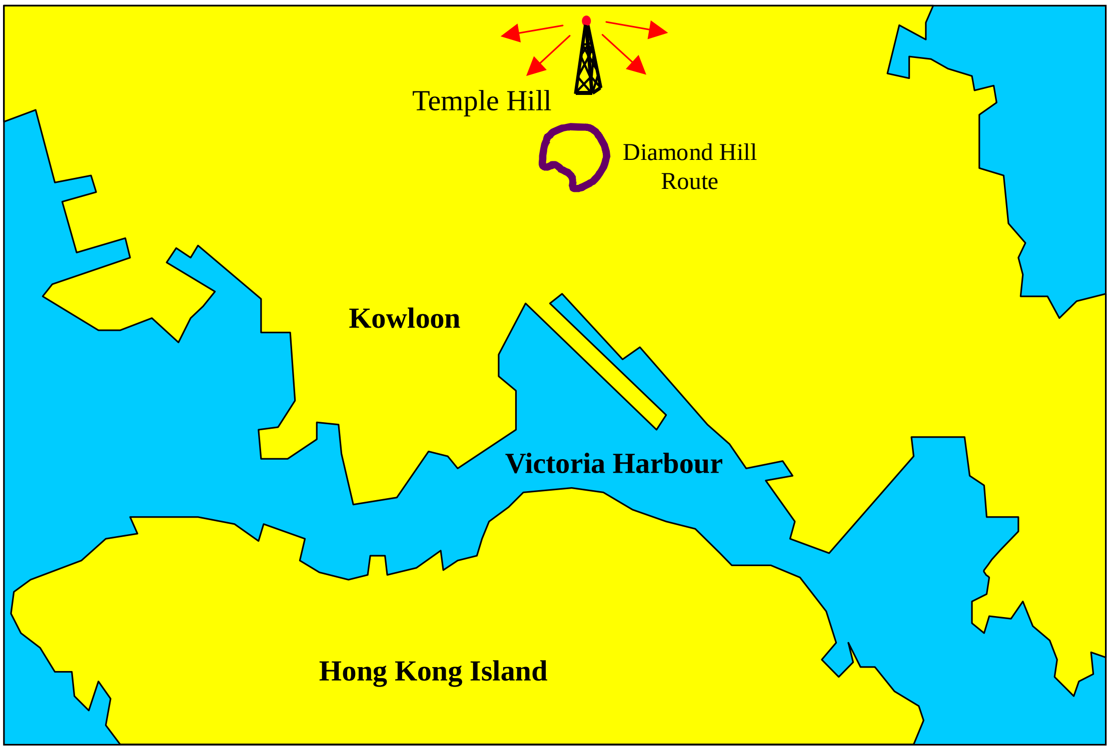


Figure 8 *Mobile Reception of DVB-T (QPSK Modulation, No SFN)*

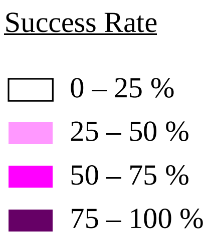


Figure 9 *Mobile Reception of DVB-T (16-QAM Modulation, SFN)*

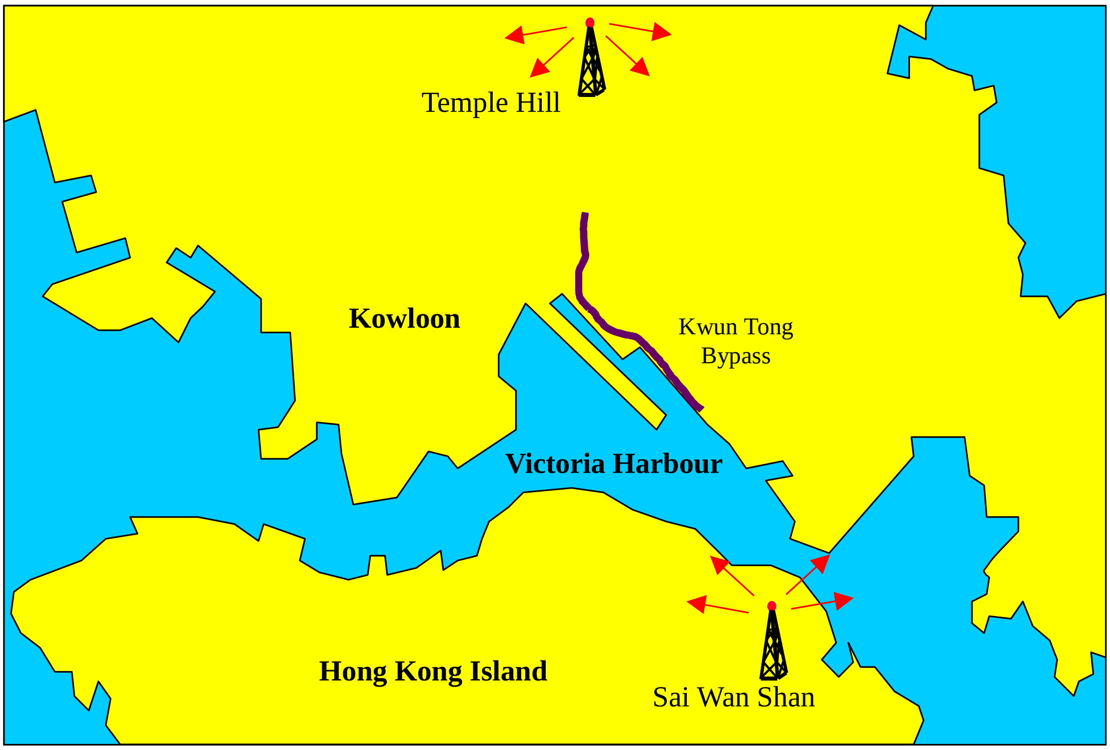
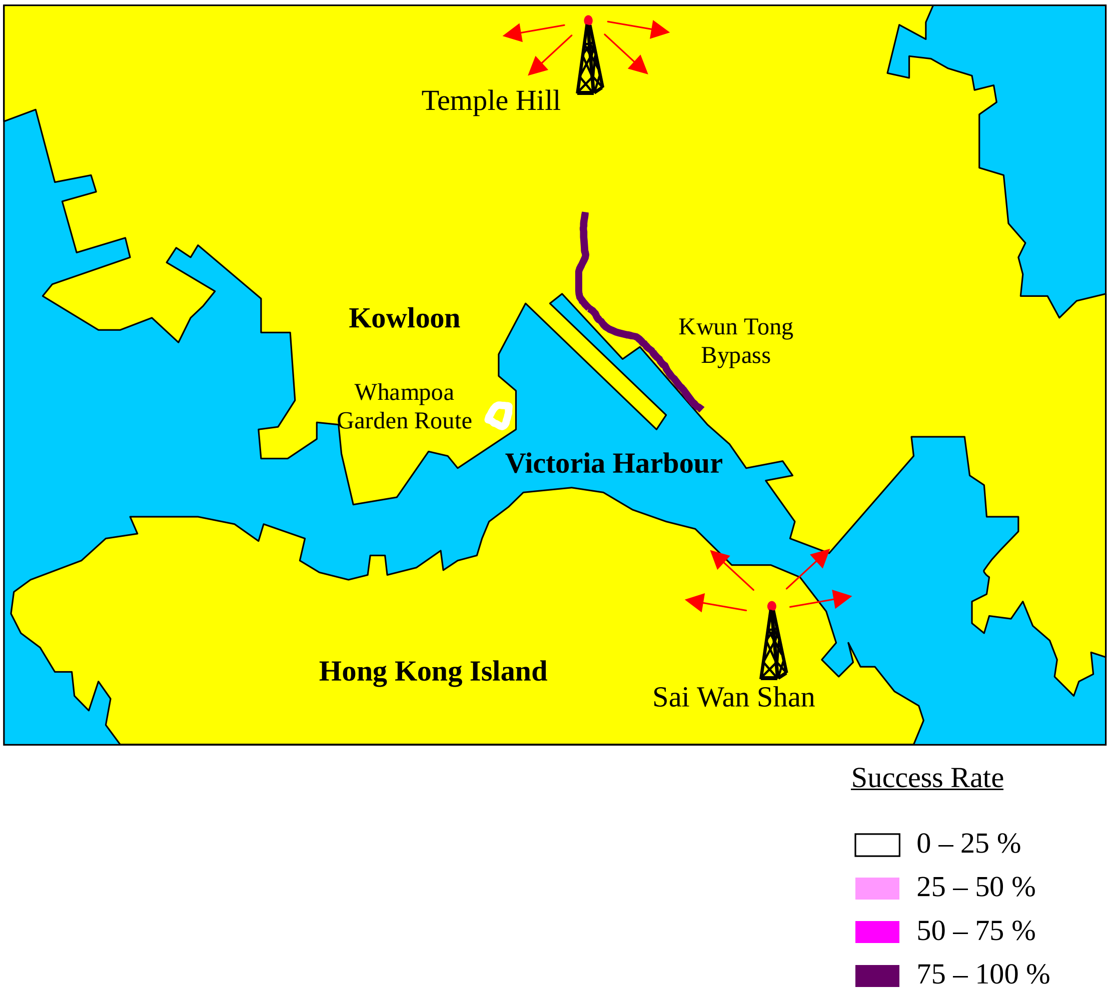


Figure 10 *Mobile Reception of DVB-T (QPSK Modulation, SFN)*



Indoor Reception of DTT Signals

32. Indoor reception of the DTT signals from the three DTT systems were measured in four typical housing estates of Hong Kong. An antenna was placed inside the flats or corridors of the housing estates for the reception of the DTT signals. The results are summarized in the following paragraphs.

<u>ISDB-T</u>

33. At all the measurement points, a satisfactory SDTV picture and sound quality of grade 5 could be obtained by using ISDB-T at 16-QAM modulation mode with 2k carriers. A margin of threshold of 6 dB to 30 dB for SDTV reception was also available. However, under the 64-QAM modulation mode, it was found that the picture froze intermittently in the SDTV and HDTV modes. The result might be due to the technical limitation of the test equipment that was used in the field test and additional technical evaluation would be required to further demonstrate the indoor reception of ISDB-T.

<u>DVB-T</u>

34. DVB-T generally performed well in the indoor reception test. The measurement was performed by using the QPSK, 16-QAM or 64-QAM modulation mode with 2k or 8k carriers. During the measurement, indoor reception of the SDTV and the HDTV modes was satisfactorily demonstrated with picture and sound quality of grade 5. A margin of threshold of about 21 dB to 43 dB was also obtained for SDTV reception.

<u>ATSC</u>

35. ATSC also had good performance in the indoor reception test. All the measurement was performed by using 8-VSB modulation. Indoor reception of the SDTV and the HDTV modes was satisfactorily demonstrated with good picture and sound quality of grade 5. A margin of threshold of about 28 dB to 42 dB for SDTV reception was also obtained in the test.

<u>Observation</u>

36. In this test, indoor reception of the three DTT systems was verified. All the three DTT systems could produce a satisfactory picture and sound quality in the SDTV mode under the indoor reception environment of the typical housing estates in Hong Kong.

Improvement in Reception

37. Reception of analogue PAL-I television signal is affected by many factors, such as the multipath interference due to reflection of signal by nearby buildings and structures, signal blockage by the neighbouring high-rise buildings and terrains, etc. It is anticipated that digital technology as employed by the DTT systems can improve the reception of the television signal. Accordingly, this technical trial also intended to verify the improvement in the reception of the three DTT systems with reference to the analogue television system. The measurement points were chosen to represent the typical television signal reception environment of Hong Kong. The measurement points also represented the coverage area presently served by the 10 kW Temple Hill transmitter station of the analogue television network.

38. For the test on fixed reception, the performance of all the three DTT systems surpassed that of the analogue television system. Under all the measurement scenarios, i.e. Street Level (Line-of-Sight) Measurement, Street Level (Building Shadow and Hill Shadow) Measurement and Rooftop (Building Shadow) Measurement, all the three DTT systems produced a much better picture and sound quality than the analogue television system. The benefits of the DTT systems were most obvious under the building shadow or hill shadow environment where the analogue television system only achieved a picture grade of 1.5 to 3.5, whereas all the DTT systems offered a consistent picture grade of 5.

39. For the test on mobile reception, the reception of DTT signals of ISDB-T and DVB-T was found to be much better than the reception of analogue television signal. When the survey vehicle was travelling on the test routes, the analogue television signal was all the way unstable and the received picture was very noisy. However, the reception of DTT signals using the ISDB-T and the DVB-T systems could produce a better result and a satisfactory picture quality could be obtained for the Diamond Hill Route and the Eastern Corridor.

40. For the test on indoor reception, the reception of DTT signals was always found to be much better than the reception of analogue television signals. At all the indoor locations, the picture received by the analogue television system was very poor with a picture grade of merely 1 to 3. The picture was very noisy and was plagued by numerous multipath signal components. However, all the three DTT systems showed a significant improvement over the analogue television system. Stable and sharp pictures having picture grade of 5 were obtained for all the three DTT systems under test.

Observation

41. In terms of general reception, the performance of the three DTT systems was found to be much better than that of the analogue television system. The picture and sound quality of the three DTT systems was found to be much better than the analogue television system. In addition, the reception of the three DTT systems was more robust. In this regard, it was anticipated that the three DTT systems could help resolve the poor reception problems of the existing analogue television system.

42. While the effective radiated power of the Master Station at Temple Hill for the three DTT systems was only 100 W, the test demonstrated that the three DTT systems could provide a coverage area similar to that of the 10 kW analogue PAL-I transmitter station at Temple Hill. In other words, the three DTT systems were capable of providing similar coverage to the existing analogue television system with the use of much smaller transmitter power.

Tidal Fading Measurement

43. Certain locations along the coastline of the Victoria Harbour of Hong Kong consistently suffer from the effect of tidal fading in the reception of existing analogue television signals. At certain time of the day, a very strong multipath component of the analogue television signal will be reflected by the sea surface and will severely affect the reception of the analogue television signal. Accordingly, this item was tested to investigate whether the effect would still adversely affect the reception of the three DTT systems.

44. For all the three DTT systems, the test result indicated that the reception of the DTT signals was also affected by the effect of tidal fading. During the time when the effect of tidal fading was most severe, the reception of both the SDTV and HDTV modes for all the three DTT systems was not satisfactory, either with blocky and annoying visual artifacts or the reception being intermittently failed with sudden loss of picture.

Observation

45. The test result indicated that all three DTT systems were affected by the effect of tidal fading in similar fashion as the analogue transmission. Given the characteristics of sudden fading of the digital signals which would make the reception fail intermittently, precaution should be taken in the receiving system design and in selecting the location of receiving antenna to minimize the effect of tidal fading.

Single Frequency Network (SFN) Reception Measurement

46. The capability of the DTT systems in supporting the SFN configuration was examined in this item. To simulate the SFN configuration, both the master and the slave stations were transmitting simultaneously using the same DTT signals.

ISDB-T

47. The measurement was performed in 2 measurement points and the result indicated a satisfactory reception of the ISDB-T signals under the SFN configuration. By using the 64-QAM modulation mode with 2k carriers, an excellent picture and sound quality of grade 5 for both the SDTV and HDTV modes was obtained consistently during the test. The corresponding margin of threshold for SDTV reception ranged from 22 to 46 dB, indicating a high robustness of reception. Even for the case when the ratio of the field strength of wanted signal to that of unwanted signal was as low as 3 dB, satisfactory reception was still achieved for both the SDTV and HDTV modes with 33 dB margin of threshold for SDTV reception.

DVB-T

48. The reception of DVB-T signals under the SFN configuration was examined in 1 measurement point in Chai Wan. By using the 64-QAM modulation mode with 2k or 8k carriers, an excellent picture and sound quality of grade 5 for both the SDTV and HDTV modes was obtained during the test. The corresponding margin of threshold for SDTV reception ranged from 44 to 54 dB, indicating a high robustness of reception. Even for the case when the ratio of the field strength of wanted signal to that of unwanted signal was as low as -1 dB, satisfactory reception was still achieved for both the SDTV and HDTV modes with 44 dB margin of threshold.

ATSC

49. Given the ATSC standard was not designed for operating in SFN configuration and the relevant SFN equipment was not available, this item was therefore not included in the field test for ATSC.

Observation

50. The result indicated that ISDB-T and DVB-T were able to support the SFN configuration. This test verified that the reception of the DTT signals remained unaffected when 2 stations transmitted at the same frequency channel. A satisfactory picture and sound quality was obtained with high margin of threshold for the SDTV mode.

51. However, the field measurements for this test were only taken in 2 different locations for two transmitting stations. Since SFN is critical to obtaining sufficient channels for DTT, further study may be required to affirm the feasibility of SFN.

Reception via IBCCDS

52. Reception of DTT signals via IBCCDS in Hong Kong was examined in this item. Common types of IBCCDS in commercial buildings, hotels and public housing estates of Hong Kong were used in this test. Measurements were taken at both the system headends and the corresponding TV outlets to study the transmission characteristics of the DTT signals via the IBCCDS.

ISDB-T

53. In this test, ISDB-T signals using 64-QAM modulation with 2k carriers were distributed via different types of IBCCDS in 6 different locations. In all cases, an excellent picture and sound quality of grade 5 was obtained for both the SDTV and HDTV modes at the system headends and the outlets. The test result is summarized as follows:-

	Reception via IBCCDS for ISDB-T	**Measured Signal Level**	**Margin of Threshold for SDTV Reception**
a.	System Headend Measurement	38 to 79 dBμV	7 to 52 dB
b.	TV Outlet Measurement	39 to 55 dBμV	7 to 24 dB

DVB-T

54. In this test, DVB-T signals using 64-QAM modulation with 2k carriers were distributed via different types of IBCCDS in 6 different locations. In all cases, an excellent picture and sound quality of grade 5 was obtained for both the SDTV and HDTV modes at the system headends and the outlets. The test result is summarized as follows:-

	Reception via IBCCDS for DVB-T	Measured Signal Level	Margin of Threshold for SDTV Reception
a.	System Headend Measurement	37 to 74 dBμV	16 to 59 dB
b.	TV Outlet Measurement	37 to 57.7 dBμV	18 to 47 dB

ATSC

55. In this test, ATSC signals using 8-VSB modulation were distributed via different types of IBCCDS in 5 different locations. In all cases, an excellent picture and sound quality of grade 5 was obtained for both the SDTV and HDTV modes at the system headends and the outlets. The test result is summarized as follows:-

	Reception via IBCCDS for ATSC	Measured Signal Level	Margin of Threshold for SDTV Reception
a.	System Headend Measurement	43.5 to 79.8 dBμV	29 to 67 dB
b.	TV Outlet Measurement	45.6 to 61.4 dBμV	32 to 49 dB

Observation

56. The measurement result indicated that satisfactory reception of DTT signals via the typical IBCCDS in Hong Kong was demonstrated. All the three DTT systems provided excellent picture and sound quality of grade 5 at all measurement points. The measured margin of threshold for SDTV reception should be sufficient to ensure robust reception. It was also noted that no adverse effect was caused to the reception of nearby analogue channels via the IBCCDS.

57. Measurements on the reception of the analogue television signals were also performed at the same system headends and TV outlets. During the test, reception of the analogue television signals via the IBCCDS was not very satisfactory and the picture grade was only around 2 to 4.5. Again the result indicated a significant improvement of the DTT signals over analogue signals.

58. In addition, it was observed that some of the existing IBCCDS used in the test required certain specific system alignment work in order to accommodate the new DTT signals. Accordingly, addition of new hardware or modification to the system headend of the existing IBCCDS may be required when the IBCCDS is to be used to carry DTT signals.

LABORATORY TESTS

59. Laboratory tests were conducted to determine the technical parameters for the DTT systems under a controlled environment for more accurate measurements. The technical parameters included the protection ratios for co-channel interference, adjacent channel interference, and image channel interference, and the overall encoding / decoding delay of the three DTT systems. The following values for the SDTV mode of the three DTT systems were obtained during the laboratory tests:-

Protection Ratio Measurement

Co-channel Interference (CCI) for ISDB-T

60. By using ISDB-T of 64-QAM modulation with 2k carriers, the following values were obtained:-

Wanted Signal	Unwanted Signal	Protection Ratios of CCI for the Wanted Signal Being Interfered by the Unwanted Signal
ISDB-T	ISDB-T	20 dB
ISDB-T	PAL-I	3 dB
ISDB-T	PAL-I1	4 dB
ISDB-T	PAL-K	4 dB
PAL-I	ISDB-T	37.7 to 47 dB
PAL-I1	ISDB-T	43.7 to 49 dB
PAL-K	ISDB-T	44.3 to 48.3 dB

Co-channel Interference (CCI) for DVB-T

61. By using DVB-T of 64-QAM modulation with 2k or 8k carriers, the following values were obtained:-

Wanted Signal	Unwanted Signal	Protection Ratios of CCI for the Wanted Signal Being Interfered by the Unwanted Signal
DVB-T	DVB-T	19 to 21 dB
DVB-T	PAL-I	4 to 9 dB
DVB-T	PAL-I1	4 to 9 dB
DVB-T	PAL-K	6 to 8 dB
PAL-I	DVB-T	46.7 dB to 59.3 dB
PAL-I1	DVB-T	45.7 dB to 54.7 dB
PAL-K	DVB-T	45 dB to 53.3 dB

62. By using DVB-T of 16-QAM modulation with 8k carriers, the following values were obtained instead:-

Wanted Signal	Unwanted Signal	Protection Ratios of CCI for the Wanted Signal Being Interfered by the Unwanted Signal
DVB-T	PAL-I	-8 to -1 dB
DVB-T	PAL-I1	-9 to -2 dB
DVB-T	PAL-K	-8 to -5 dB

Co-channel Interference (CCI) for ATSC

63. By using ATSC of 8-VSB modulation, the following values were obtained:-

Wanted Signal	Unwanted Signal	Protection Ratios of CCI for the Wanted Signal Being Interfered by the Unwanted Signal
ATSC	ATSC	16 to 19 dB
ATSC	PAL-I	-3 dB
ATSC	PAL-I1	-4 dB
ATSC	PAL-K	-3 dB
PAL-I	ATSC	37 dB to 44.7 dB

PAL-I1	ATSC	40 dB to 45.3 dB
PAL-K	ATSC	40 dB to 45 dB

<u>Adjacent Channel Interference (ACI) for ISDB-T</u>

64. By using ISDB-T of 64-QAM modulation with 2k carriers, the following values were obtained:-

Wanted Signal	Unwanted Signal	Protection Ratios of ACI for the Wanted Signal Being Interfered by the Unwanted Signal
ISDB-T	ISDB-T	-27 dB to -24 dB
ISDB-T	PAL-I	-38 dB to -31 dB
ISDB-T	PAL-I1	< -43 dB to -31 dB
ISDB-T	PAL-K	< -40 dB
PAL-I	ISDB-T	-15.7 dB to 7.7 dB
PAL-I1	ISDB-T	-11.7 dB to 7 dB
PAL-K	ISDB-T	-13.3 dB to 7.3 dB

<u>Adjacent Channel Interference (ACI) for DVB-T</u>

65. By using DVB-T of 64-QAM modulation with 2k or 8k carriers, the following values were obtained:-

Wanted Signal	Unwanted Signal	Protection Ratios of ACI for the Wanted Signal Being Interfered by the Unwanted Signal
DVB-T	DVB-T	-33 to -15 dB
DVB-T	PAL-I	-23 to -19 dB
DVB-T	PAL-I1	-24 to -20 dB
DVB-T	PAL-K	-24 to -21 dB
PAL-I	DVB-T	-13 to 12.3 dB
PAL-I1	DVB-T	-11 to 12.3 dB

PAL-K	DVB-T	-13 to 13.3 dB

66. By using DVB-T of 16-QAM modulation with 8k carriers, the following values were obtained instead:-

Wanted Signal	Unwanted Signal	Protection Ratios of ACI for the Wanted Signal Being Interfered by the Unwanted Signal
DVB-T	PAL-I	-22 to -20 dB
DVB-T	PAL-I1	-22 to -20 dB
DVB-T	PAL-K	-27 to -24 dB

Adjacent Channel Interference (ACI) for ATSC

67. By using ATSC of 8-VSB modulation, the following values were obtained:-

Wanted Signal	Unwanted Signal	Protection Ratios of ACI for the Wanted Signal Being Interfered by the Unwanted Signal
ATSC	ATSC	-33 to -30 dB
ATSC	PAL-I	-37 to -30 dB
ATSC	PAL-I1	-41 to -32 dB
ATSC	PAL-K	-45 to -40 dB
PAL-I	ATSC	-4 to 9.7 dB
PAL-I1	ATSC	-7.3 to 7.3 dB
PAL-K	ATSC	-5.7 to 6.7 dB

Image Channel Interference (ICI) for ISDB-T

68. By using ISDB-T of 64-QAM modulation with 2k carriers, the following values were obtained:-

Wanted Signal	Unwanted Signal	Protection Ratios of ICI for the Wanted Signal Being Interfered by the Unwanted Signal
ISDB-T	PAL-I	< -42 dB
ISDB-T	PAL-I1	< -42 dB
ISDB-T	PAL-K	< -41 dB
PAL-I	ISDB-T	-18.7 to -10.7 dB
PAL-I1	ISDB-T	-13.7 to -9 dB
PAL-K	ISDB-T	-15.3 to -9.7 dB

Image Channel Interference (ICI) for DVB-T

69. By using DVB-T of 64-QAM modulation with 2k or 8k carriers, the following values were obtained:-

Wanted Signal	Unwanted Signal	Protection Ratios of ICI for the Wanted Signal Being Interfered by the Unwanted Signal
DVB-T	PAL-I	< -46 dB
DVB-T	PAL-I1	< -42 dB
DVB-T	PAL-K	< -46 dB
PAL-I	DVB-T	-31 to -4.3 dB
PAL-I1	DVB-T	-32 to -5.3 dB
PAL-K	DVB-T	-29 to -6 dB

70. By using DVB-T of 16-QAM modulation with 8k carriers, the following values were obtained instead:-

Wanted Signal	Unwanted Signal	Protection Ratios of ICI for the Wanted Signal Being Interfered by the Unwanted Signal
DVB-T	PAL-I	< -46 dB
DVB-T	PAL-I1	< -42 dB
DVB-T	PAL-K	< -46 dB

Image Channel Interference (ICI) for ATSC

71. By using ATSC of 8-VSB modulation, the following values were obtained:-

Wanted Signal	Unwanted Signal	Protection Ratios of ACI for the Wanted Signal Being Interfered by the Unwanted Signal
ATSC	PAL-I	< -46 dB
ATSC	PAL-I1	< -45 dB
ATSC	PAL-K	< -45 dB
PAL-I	ATSC	-31.3 to -13 dB
PAL-I1	ATSC	-29.3 to -13.7 dB
PAL-K	ATSC	-29 to -13 dB

Observation

72. The protection ratios for co-channel interference, adjacent channel interference and image channel interference of the three DTT systems were obtained. In general, the result was consistent with the figures quoted in the respective standards. Owing to the limitation of time and resources, the result was obtained by only taking a relatively small number of samples. Consequently, the figures obtained might not be directly applicable in practical situations and special measures in the frequency planning of the DTT systems such as carrier offset might be required in the actual implementation.

Overall Encoding / Decoding Delay Measurement

73. The overall encoding and decoding delay of the three DTT systems were examined in the laboratory tests. The original video signals were fed to the encoders of the respective DTT systems and the encoded DTT signals were relayed over the whole transmission path. The DTT signals were then decoded by the corresponding receiver and the decoded video signals were obtained. The overall encoding / decoding delay were estimated by measuring the time difference between the original video signals and the decoded video signals.

<u>ISDB-T</u>

74. By using the 64-QAM modulation with 2k carriers and by using ISDB-T decoders from 2 manufacturers, namely R&S and Toshiba, the overall encoding / decoding delay of the ISDB-T system was found to be ranging from 0.67 seconds to 1.77 seconds.

<u>DVB-T</u>

75. By using the QPSK, 16-QAM or 64-QAM modulation schemes and by using DVB-T decoders from 2 manufacturers, namely ITIS and NDS, the overall encoding / decoding delay of the DVB-T system was found to be ranging from 1.00 seconds to 1.08 seconds and stayed roughly constant.

<u>ATSC</u>

76. As the ATSC system under test operated on a video server instead of an encoder, the overall encoding / decoding delay could not be determined in the laboratory test.

<u>Observation</u>

77. In the laboratory tests, the overall encoding / decoding delay of the ISDB-T and DVB-T systems were obtained. In general, the result was consistent with the figures quoted in the respective standards.

FURTHER STUDY

78. Owing to the time and resource limitations, laboratory tests on the performance of the three DTT systems under different channel bandwidth was not conducted. Where necessary, further study on this item might be required.

CONCLUSIONS

79. The findings of the technical trial are summarised as follows:-

a) Under fixed reception environment which included street level and rooftop measurements with or without direct line-of-sight to the transmitter station and without crossing waters, the reception of the three DTT systems was found to be excellent and the received picture and sound quality was very good. In general, large values of margin of threshold were also available to enable robust reception of the DTT. During the trial, it was also noted that no adverse effect was caused to the reception of nearby analogue television channels. However, in practice, careful planning of the DTT systems should be performed to ensure its compatibility with the existing analogue television systems.

b) All three DTT systems produced satisfactory picture and sound quality in the SDTV mode for indoor reception. At all test points the picture and sound quality was much better than the equivalent analogue reception. The reception of the three DTT systems was also more robust. At those locations where there was no direct line-of-sight to the transmitter stations and where the reception of the analogue television system was very poor, the reception of the three DTT systems could still provide a satisfactory picture and sound quality.

c) Consequently, it was anticipated that the three DTT systems could reduce the poor reception problems of the existing analogue television system. They should be able to achieve similar coverage to that of the existing analogue television system but with the use of smaller transmitter power.

d) Mobile reception of ISDB-T and DVB-T was demonstrated with satisfactory picture and sound quality, whereas mobile reception of analogue television system was not feasible. The result indicated that mobile reception of the ISDB-T and DVB-T signals was possible in the open areas. As ATSC was not designed for mobile reception and the relevant mobile reception equipment was not available, the test on mobile reception for ATSC was not included in the technical trial.

e) The reception of the three DTT systems, however, was still affected by the effect of tidal fading similar to the analogue systems. During the time when tidal fading was dominant, the reception of all the three DTT systems was intermittent, blocky and sometimes even failed. Given the characteristics of sudden fading of digital signals, precaution should be taken in aligning the receiving systems.

f) Both the ISDB-T and DVB-T were able to support the Single Frequency Network (SFN) configuration. It was noted that the reception of the ISDB-T and DVB-T systems remained unaffected even when 2 stations transmitted at the same frequency channel and the ratio of the field strength of wanted signal to that of unwanted signal was around -1 dB to 3 dB. As ATSC was not designed for operating in SFN configuration and the relevant SFN equipment was not available, the test on SFN for ATSC was not included in the technical trial.

g) The reception of the three DTT systems via the IBCCDS was also satisfactory. Good picture and sound quality was also achieved. It was also noted that no adverse effect was caused to the reception of nearby analogue television channels via the IBCCDS. Therefore it was expected that the DTT signals of the three DTT systems could be conveyed by the typical IBCCDS in Hong Kong.

h) The measured protection ratios of co-channel interference, adjacent channel interference and image channel interference between the three DTT systems and the analogue television system were generally consistent with the figures quoted in the respective standards.

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LIST OF ABBREVIATIONS

ACI	Adjacent Channel Interference
ATSC	Advanced Television Systems Committee
CCI	Co-Channel Interference
DQPSK	Differential Quadrature Phase Shift Keying
DTT	Digital Terrestrial Television
DVB-T	Digital Video Broadcasting - Terrestrial
ERP	Effective Radiated Power
HDTV	High Definition Television
IBCCDS	In-Building Coaxial Cable Distribution System
ICI	Image Channel Interference
ISDB-T	Integrated Services Digital Broadcasting - Terrestrial
ITU-R	International Telecommunication Union Radiocommunication Sector
OFDM	Orthogonal Frequency Division Multiplexing
PAL-I	Phase Alternation Line System I
PAL-I1	Phase Alternation Line System I with modified spectrum mask
PAL-K	Phase Alternation Line System K
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
SDTV	Standard Definition Television
SFN	Single Frequency Network
VSB	Vestigial Sideband Modulation