Report on
Initial Phase of
Digital Audio Broadcasting Technical Trial

Introduction

In February 1998, a Digital Audio Broadcasting (DAB) Steering Committee was established under the auspices Information Technology and Broadcasting Bureau (ITBB) to steer and co-ordinate the conduct of a trial on DAB. The objectives of the trial are:

- to test an experimental L-band Eureka 147 DAB network in Hong Kong,
- to find out how DAB technology may improve the existing radio broadcasting services,
- to establish the feasibility of territory-wide signal coverage using this technology, and
- to explore the application services which are available from this standard.

2. A Technical Sub-Committee (TSC) was formed to coordinate the conduction of DAB trial and to advise the Steering Committee the result of the trial. The TSC is chaired by the Office of the Telecommunications Authority (OFTA) and comprised of representatives from the Hong Kong Commercial Broadcasting Co. Ltd, Metro Broadcast Corporation Ltd, Radio Television Hong Kong and ITBB.

3. This paper is submitted by the TSC to report the findings of the first phase of the trial and recommend a way forward.

Selection of DAB Systems for the Trail

4. In accordance with the discussion of DABSC Paper no. 2/98 in the DAB Steering Committee meeting held on 14 February 1998, Eureka 147 DAB system operating in L-band was selected and a MOU

was signed by the three broadcasters on 29 May 1998 for the trail. The reasons for the selection are given below:-

- it is the most widely tested and demonstrated DAB system;
- it is the only available system meeting all the technical objectives and requirements set out by the International Telecommunication Union (ITU);
- it was recommended world-wide by the Inter-Union Technical Committee of the World Conference of Broadcasting Unions in 1992;
- It complies to ITU-R Recommendations BS.1114 and BO.1130 for both terrestrial and satellite broadcast;
- more than 30 countries across Europe and Canada have adopted and implemented the system; and
- more than ten manufacturers support the system.

Network Configuration

5. Mt. Gough and Beacon Hill were selected for installing the test transmitters for the following reasons:

- the sites can serve a large part of the urban areas;
- With a separation of about 9 km, there are some overlapping coverage which is required for testing the capability of DAB single frequency network (SFN);
- The sites are well developed with all the required facilities and space; and
- the sites are also equipped with FM transmitters and comparison of propagation and coverage is possible.

6. The network configuration is given in Annex 1(a) Details of the technical parameters of the transmitters are shown in Annex 1(b).

Mt. Gough site

7. At Mt. Gough, a stereophonic audio source from a compact disc player was fed in parallel to six channel coders. The outputs of channel coders were multiplexed and fed directly to a transmitter rack. For

comparison of reception quality at different transmission bit-rates and error protection levels, the same audio source was used for all the six audio channels of the DAB ensemble. Another output from the multiplexer was sent over an E1 leased circuit to the transmission facility at Beacon Hill.

8. To synchronize the frequency and timing of the two sites, a fixed delay of 200 microseconds was inserted at the channel encoder to compensate for the delay in the leased circuit as well as difference in processing delays at the two sites. Global Positioning System (GPS) receivers at both sites were used to provide position and timing information for transmitter synchronization. A RF power of 200 watts was fed to a power splitter supplying equal power to two sets of antennas pointing to the offset North (20° from true North) and offset South (200° from true North) respectively. Since wide beamwidth (160°) antennas were used, the combination formed a pseudo-omni-directional horizontal radiation pattern with two null points at 110° and 290°. The transmitter was expected to serve Northern and Southern parts of the Hong Kong Island and Southern part of Kowloon.

Beacon Hill site

9. The equipment set-up at Beacon Hill was similar to that at Mt. Gough except that there was no channel coder/multiplexer facilities, as the multiplexed audio bit-stream was supplied from Mt. Gough via the leased circuit. A transmitter output power of 100 watts was equally split into two sets of antennas. A narrow beamwidth (65°) antenna was pointed at 30° from true North serving the areas on both sides of Shing Mun River and a wider beamwidth (90°) antenna was pointed to the South direction serving urban areas of central and South-East Kowloon.

10. Detailed transmission parameters of the trial network are given in Annex 2.

Test Method and Set-up

Test parameters

11. The following parameters were evaluated under different error protection levels, audio bit-rates, transmission modes, fixed/ mobile receptions and indoor/outdoor receptions:

- sound quality,
- bit-error-rate, and
- field strength.

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Field measuring equipment

12. The field measuring equipment set-up is illustrated in Annex 3. It consists of a Rohde & Schwarz TS9951 measuring system with application software running on Windows95 platform, a Philips 452 DAB test receiver, a GPS receiver and a laptop computer. All equipment and accessories were installed in a vehicle. Parameters logged by the computer included time stamps, position of receiver in longitude and latitude, audio-bit-errors, fast information channel (FIC) bit errors, and audio error-flag-rates (EFRs). When the computer was loaded with bitmap files of the Hong Kong territory, a real-time display of the test route could be seen on map along with EFRs indicated by different colours. The events could be saved and played back on screen at a later stage. The recorded files could be sent to a printer in ASCII format for record keeping. Separately, to collect more field information, a Rohde & Schwarz ESVB field strength meter was used for measuring field strengths manually at intervals of approximate one minute.

Outdoor/indoor reception test set-up

13. A consumer type DAB car radio was used for both outdoor and indoor reception tests. Areas within the expected coverage of the two transmitters and some fringe areas were selected for outdoor reception test. Measurements were taken in a stationary condition with a car-mounted antenna at about 1.5 metres above ground. The audio quality was rated by human perception and was recorded in three quality

grades. Grade A indicates perfect audio reception without any noise or interruption. Grade B indicates some level of audible impairment such as short dropouts and audio garble. Grade C indicates complete muting of the radio.

14. The same car radio was used for indoor reception test conducted on different floors of selected commercial buildings and shopping malls. Field strength was measured with the assistance of an ESVB field strength meter. A number of evenly distributed test points were selected for measurement on floors of different levels. Measurements were also taken at street level surrounding the buildings and rooftops with a view to comparing outdoor and indoor receptions.

Tests

15. The following tests were conducted:

- Mobile speed test (for determining the appropriate transmission mode),
- Field measurement,
- Outdoor reception test, and
- Indoor reception test.

<u>Results</u>

Mobile speed test

16. Various transmission modes[1] of DAB signal are designed for mobile reception to cope with the multipath impairments characterized by the delay spread and Doppler spread. Theoretically, mode 4 transmission working in the L-band has the advantage of providing the greatest maximum transmitter separation of up to 37 km but it only

[1] There are four prevalent transmission modes in Eureka 147, Modes 1, 2, 3 and 4, which are designed to cope with Doppler spread and multipath echoes for different transmitters spacings and mobile speeds.

supports mobile reception at a lower speed (around 100 km/h). A mobile reception test was performed at certain sections of the Tolo Highway. The result revealed that received audio quality deteriorated seriously at a speed of 85 km/h or higher if mode 4 transmission is used. Accordingly, members of the TSC considered that mode 4 would not be suitable for operation in Hong Kong and unanimously agreed that further tests should be conducted on mode 2 (which can support mobile operation at a speed up to about 130 km/h theoretically).

Field measurement

17. Based on the system parameters in Annex 2, the reception quality of the reference programme channel 1 (encoding at an audio bit-rate of 192 kbit/s and error protection level 3) was assessed along 25 pre-selected routes covering major population districts.

18. The results of the field measurement are shown in Annex 4(a) to 4(c). The quality of the received audio signals was indicated by two colours. Green colour represents perfect audio reception without audible noise or interruption corresponding to EFRs in the range 4 to 6 whereas red colour represents some levels of audible impairment corresponding to an EFR range 0 to 3. The latter can range from on-set of short audio dropouts to complete muting of the receiver.

19. Annex 4(a) illustrates the result with only the Beacon Hill transmitter in operation. Except some minor receiving dead spots, most of the areas on both sides of Shing Mun River, in Kowloon urban districts and in waterfront of Hong Kong Island along Victoria Harbour were well served by this site. However, the received quality at Ma On Shan was not as good as expected due to considerable signal path blockage by high-rise buildings. Some sections of the route along Choi Hung, Ngau Tau Kok and Kwun Tong were also not well served due to a deviation of 55° or more from the direction of maximum radiation of the Southern beam (which had a half-power at 45° offset angle). At the route from Tai Wai to Tsuen Wan via Shing Mun Tunnel, reception was possible only at the opening section of Lower Shing Mun Reservoir and at a section right after the exit of the tunnel. Since the route was outside

the expected coverage of the Southern beam. Furthermore, the route beyond Pak Shek Kok and up to Tai Po Market was not covered due to signal blockage by Needle Hill and Grassy Hill.

20. Annex 4(b) shows the result with only Mt. Gough transmitter in operation. The three routes in Kowloon urban areas were well served by the Northern beam of this site, since direct line-of-sight exist between these areas and the transmitter. The radio signals received in the areas of Taikoo Shing and Sai Wan Ho were however attenuated by Braemar Hill. A large portion of the route from North Point to Shek O was heavily obstructed from the transmitter site by the hilly terrain of Mt. Nicholson, Mt. Bulter and Mt. Parker. Apart from that, a radiation null at 110° from true North exists. However, there were still some reception windows in the regions of North Point, junction of Chai Wan Road and Tai Tam Road and some intermittent sections of Shek O Road along Tai Tam Harbour. Probably the windows were contributed by high altitude of the receiving points and some opening gaps along the radio paths. The route from Pokfulam to Repulse Bay was adequately served by the Southern beam with a small exception in the section of Pokfulam Road near Queen Mary Hospital, which was shadowed by the knife-edge of Sai Ko Shan at its immediate vicinity.

21. Annex 4(c) shows the results when both transmitters were in operation. The benefit of single frequency network became apparent in signal overlapping areas. Most notably, improvement by overlapping of both signals could be found at the section from North Point up to the entrance of Tai Tam Road at which the signal outages caused by weak field strength were supplemented by the Southern beam from Beacon Hill. Although the Northern beam of Mt. Gough to Kwai Chung had been partially attenuated by the high terrain in Lai King, the reception in Kwai Chung had also significantly improved, especially in Kwai Shing area of higher altitude.

22. The field strength readings collected along the test routes have provided a rough indication of the required field strength under mobile reception condition. It was found that in general, for satisfactory reception, a minimum field strength of around 51 to 53 dBμV/m was required for satisfactory mobile reception at normal speed.

Outdoor reception test result

23. Annex 5 shows a table summarizing the percentages of satisfactory reception (grade A) in the outdoor reception test. Programme channel 1 was used as the reference channel throughout the test. The remaining channels 2 to 6 encoded at different bit-rates and error protection levels were for comparison purpose.

24. With only the Beacon Hill site operational, its Southern beam provided 96% satisfactory reception in the areas of Tsimshatsui to Mongkok. The areas from Kowloon Bay to Kwun Tong got a 50% reception. The narrower beam facing the Shing Mun River provided 67% reception in areas from Shatin Town Centre to Ma On Shan. This percentage is lower than expected because it was biased by the low scored result in Ma On Shan in which the points of taking measurement were critical. It depended on whether the points were near the Tolo Harbour waterfront or within high-rise residential estates. As anticipated, reception percentage in the areas of Kwai Chung and Tsuen Wan was zero since they were outside the expected coverage of Beacon Hill site.

25. When only Mt. Gough site was in operation, the percentages of reception in most of the areas in Southern part of Kowloon Peninsula, Northern parts of Hong Kong Island along Victoria Harbour and Southern parts of Hong Kong Island appeared to be well served. Percentages ranging from 74% to 100% were achieved. However, there were areas not well served from Shau Kei Wan to Chai Wan due to radio path obstruction by Mt. Butler and Mt. Parker as well as the radiation null at the East of the Mt. Gough site.

26. The third batch of data in the table shows the results with both sites in operation. Comparing with the result when either site in operation, signal overlapping areas of Kowloon Bay to Kwun Tong, Causeway Bay to North Point and Tsimshatsui to Mongkok had been enhanced in percentages of reception. Previous shadowed areas of Kwai Chung to Tsuen Wan and Shau Kei Wan to Chai Wan had been slightly improved. To collect more data so that a coverage contour of

the network can be realized, extra areas were included in this test. Areas of Mei Foo to Lai King and Tsz Wan Shan to Chuk Yuen had scored a very high percentages of reception while the score at Tsing Yi was below average.

27. Besides estimate of coverage at street level, the data collected from other audio programme channels had indicated the effects of encoding audio channels at different bit-rates and protection levels. Channels 2 and 5 were encoded at a higher error protection of level 2 in contrasting with level 3 in the case of the reference channel. The effect of higher protection level to the received quality can only be observed from the results obtained in areas of marginal reception such as Shau Kei Wan to Chai Wan and Kwai Chung to Tsuen Wan. In these areas, channels encoded at higher protection level had achieved slightly higher percentages of reception than the reference channel. On the other aspect, it was hard to tell the differences by listening among the sound quality of the channels 1 to 5 encoding at bit-rates of either 192 kbit/s or 160 kbit/s. But channel 6, which was encoded at a slower bit-rate of 64 kbit/s, had substantial loss of stereophonic separation between the left and right sound channels. At this bit-rate, the signal quality was somewhat worse than conventional FM stereophonic programme.

Indoor reception test result

28. Indoor reception test was carried out when both sites were in operation. The aim of the test is to study the building penetration characteristics of the DAB signal. The buildings and floors/levels selected for the test are listed in the following table:

Indoor reception test locations

Location	Floor/Level
An office floor in Yau Ma Tei	2*
Hollywood Plaza in Diamond Hill	G*, 1*, 3*
Commercial Radio office in Broadcast Drive	G*, 1*, 3
New Town I & II in Shatin	1, 3, 5
New Town III in Shatin	1, 3
The Center in Central	UG, 79
Whampoa Garden Site 1 shopping mall	G*
Whampoa Garden Site 2 shopping mall	B1*, G*
Whampoa Garden Site 12 shopping mall	G*
Trade Department Tower in Mongkok	5*, 10, 17
Canton Road Government Offices	3, 8, 12
Wu Chung House in Wanchai	12, 29, 36
North Point Government Offices	4, 13, 21
	*denotes less then 50% of reception

29. Unlike outdoor reception test, it was not practicable to draw statistical results, such as percentage of satisfactory reception. This is because the reception quality depends very much on a number of factors like location of the building, floor level, proximity to windows/doors/open space of the test points, direction of these windows/doors, and material of interior partition used. In general, reception on low levels, such as basements and ground floors, were relatively poor. By correlating the reception quality of different grades with their respective ranges of field strengths, 51 dBμV/m is suggested to be the minimum required field strength for satisfactory reception indoors.

30. In addition, we have found two specific properties of DAB radio working in the L-band in comparing with conventional FM radio working in the VHF band. DAB radio appears to be immune to interference caused by internal electrical office equipment and lighting even at close proximity and in concealed places where the field strengths are weak. The other property is, unlike conventional FM radio of which the background noise would progressively increase with decrease in signal strength when moving away from open space (progressive decrease in signal-to-noise ratio), the DAB radio would be muted sharply after a receivable threshold.

Contour of coverage

31. Based on the results of field measurement and outdoor reception test, two coarse contours of coverage of individual transmitter site and of the combined network are shown in Annex 6(a) and 6(b). The contours resemble slightly to the shapes of their respective antenna radiation pattern and are modified by the hilly terrain along radio paths. The combined network shows improvement in coverage to previous under-served areas at which the weak field strengths have been supplemented by signals of each other. Owing to the lacking of measurements taken at the West and South-West directions of the Hong Kong territory, the contours corresponding to that directions are incomplete.

Conclusion

32. The TSC has identified the following critical parameters and issues to assist future network planning:

Transmission mode

33. A mobile speed test has confirmed that mode 4 transmission only permits satisfactory operation at a low mobile speed not exceeding 85 km/h. In fact, its advantage of allowing the greatest maximum transmitter separation of 37 km among the other modes is not a major

concern in the relative small area of the Hong Kong territory. The TSC therefore considered that mode 4 transmission is not applicable to Hong Kong and mode 2 transmission should be adopted.

Network coverage

34. The outdoor results of this initial phase of trial indicate that majority of the areas covered by the radiation beams of the two sites can be adequately served with some exceptions of the shadowed regions in Ma On Shan, Kwai Chung and Tai Koo Shing to Sai Wan Ho. These areas could be served separately by fill-in transmitter sites in an operational network. It appears that the coverage of the trial network, for the outdoor reception aspect, is comparable to the current FM service covered by the same sites working alone.

35. However, for the indoor reception, the result revealed generally poor on floors of low level, such as ground floors and basements. The situation is very similar to existing VHF/FM reception. Theoretically, this might be due to the high radio path loss experienced by the L-band signal at 1.5GHz. As possible solutions, indoor reception at lower floors may require separate external antennas (whips of about 5 cm) installed at balconys or windows. In closed areas, such as shopping malls, low-powered repeaters would be needed to provide reasonable grade of service. Alternatively, increasing transmitter power, overlapping coverage by additional single frequency network transmitters and/or using in-house coaxial cable systems to distribute the DAB signal may be possible ways to improve the reception. Further test is required to study the performance of DAB in terms of indoor reception.

Single frequency network

36. Reception quality was found to be enhanced in areas of overlapping signals from both transmitters. The trial network with two transmitter sites had demonstrated a successful operation of DAB single frequency network. The major advantage of a single frequency network is that additional transposers may be added without the need of allocating additional radio frequency channel. Comparing with the bandwidth

(87-108 MHz) currently allocated for conventional VHF/FM (now providing seven territory-wide coverage programmes), the same bandwidth would be able to accommodate 12 DAB ensembles. In other words, a total of 72 near CD-quality stereophonic programme channels would be available. This gives a spectrum efficiency gain of more than 10 folds.

Minimum required field strengths

37. Due to the limitation of the field measuring system, the field strength readings were taken manually along the test routes. This led to inaccuracy in relating the reading to their respective measured locations. Likewise, for the indoor reception test, many variable factors, such as floor levels, direction etc., are critical to the measured results. Nevertheless, based on the performance of the receiving equipment (Philips DAB452 test receiver and a DAB car radio) used in the trial, minimum required field strengths for satisfactory reception have been identified. They are 51 to 53 dBμV/m for mobile reception and 51 dBμV/m for indoor reception. The figures would serve as references for future DAB network planning.

Audio channel encoding

38. Comparison of sound quality among different programme channels suggests that encoding at bit-rates of lower than 160 kbit/s, for transmission of music, is not practical since the stereophonic effect will be seriously deteriorated. The gain of employing higher error protection level at the expense of consuming more bandwidth in the audio multiplex could only become significant in areas of marginal reception. To strike a balance between the benefit achieved and the resource consumed, protection level[2] 3 is considered to be generally good enough for normal operations.

[2] Protection levels determine the amount of redundant bits added to the audio data stream in order to provide ruggedness against transmission distortions. The smaller the number of protection level means the higher the error protection (i.e. level 1 is the highest and level 5 is the lowest). With higher protection level, the redundancy will be higher but the number of available programme channels in a DAB multiplex will be smaller.

Indoor reception behaviour

39. The indoor reception behaviours of DAB receivers are significantly different from that of conventional FM receivers. Firstly, DAB receivers in L-band show more superior interference immunity from indoor electrical appliance. Secondly, audio output of DAB receivers in areas of weak field strength has two quite clear distinctive states, either good or completely mute. This is an inherent characteristic of digital processing of audio at which the audio is designed to be muted at significant high error rate on the audio bit stream. On the contrary, audio recovered by FM receiver tends to be progressively worsen in the increase of background noise, i.e. progressively decrease in signal-to-noise ratios. The major concern will be with audience, who get used to listening to FM receivers, will probably have less tolerance to DAB receivers under marginal reception conditions.

Way-forward

40. Based on the results obtained from this initial phase of DAB trial, the TSC considered that it is not mature at this stage to conclude whether it is technically feasible for Eureka 147 DAB system working in the L-band to be introduced into Hong Kong. It is proposed that further tests should be conducted in a second phase of trial to facilitate the decision making.

Further tests required

41. In order to have a more in-depth understanding of the mobile reception characteristics, a further field measurement should be run at narrow roads in congested populated areas with high density of buildings.

42. The effect of imposing higher error protection level to the reception quality of mobile environment has not been tested. It would be beneficial to carry out another test of the same kind by mobile in those marginal reception areas.

43. The results of indoor reception test showed that reception on floors of low levels was generally poor. It is proposed to conduct a comparison test between DAB receiver and FM receiver at previous poor reception locations.

44. To explore the application services which the DAB technology is capable of providing, a test on non-audio services, such as the transmission of text and image (or so-called the Multimedia Radio Programmes), should also be conducted.

45. Furthermore, it is necessary to compare the receiving audio quality of DAB with conventional VHF/FM receivers in real-time. A simulcast of three live FM programmes from the three broadcasters on both the DAB trial network and existing VHF/FM network is recommended.

Additional test equipment

46. The equipment used in both the outdoor and indoor reception tests was a car radio. To reflect the real situation, a few portable DAB receivers should be purchased for further test and confirmation of our results.

Technical Sub-Committee
Steering Committee for DAB Trial
March 1999

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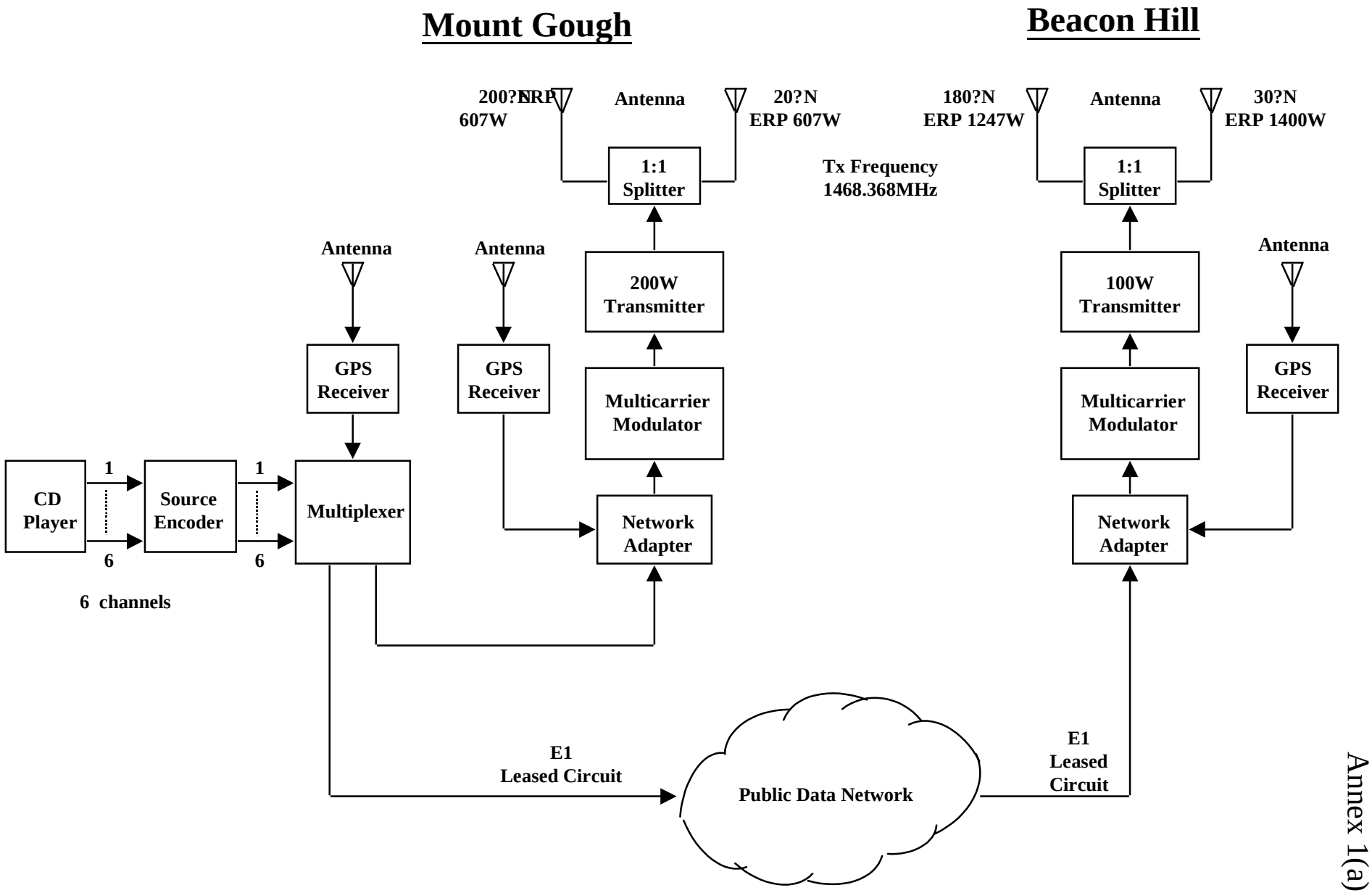
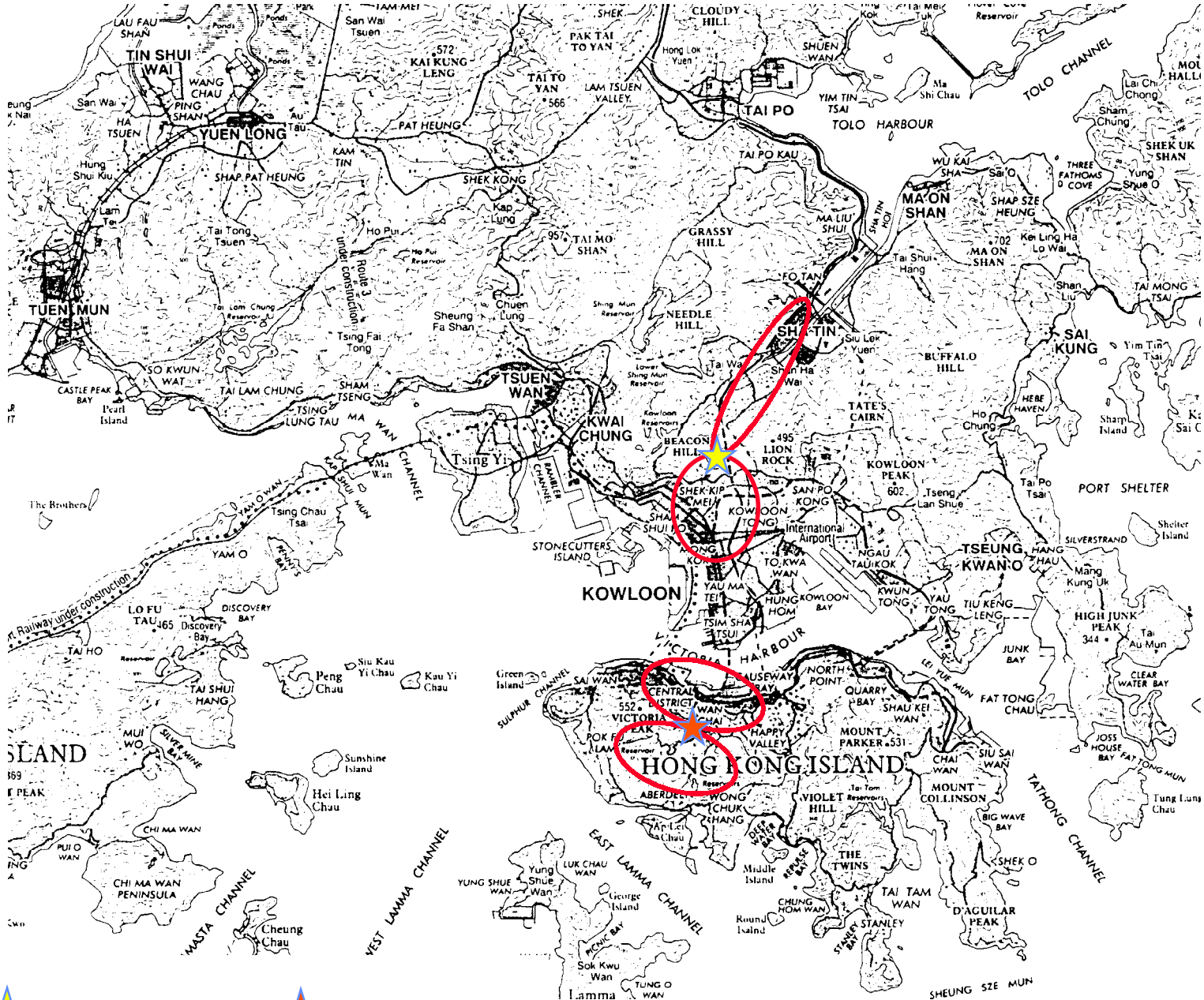
Equipment Configuration of DAB Trial Network



Annex 1(a)

Horizontal Radiation Patterns of Transmission Sites



Annex 1(b)

Annex 2

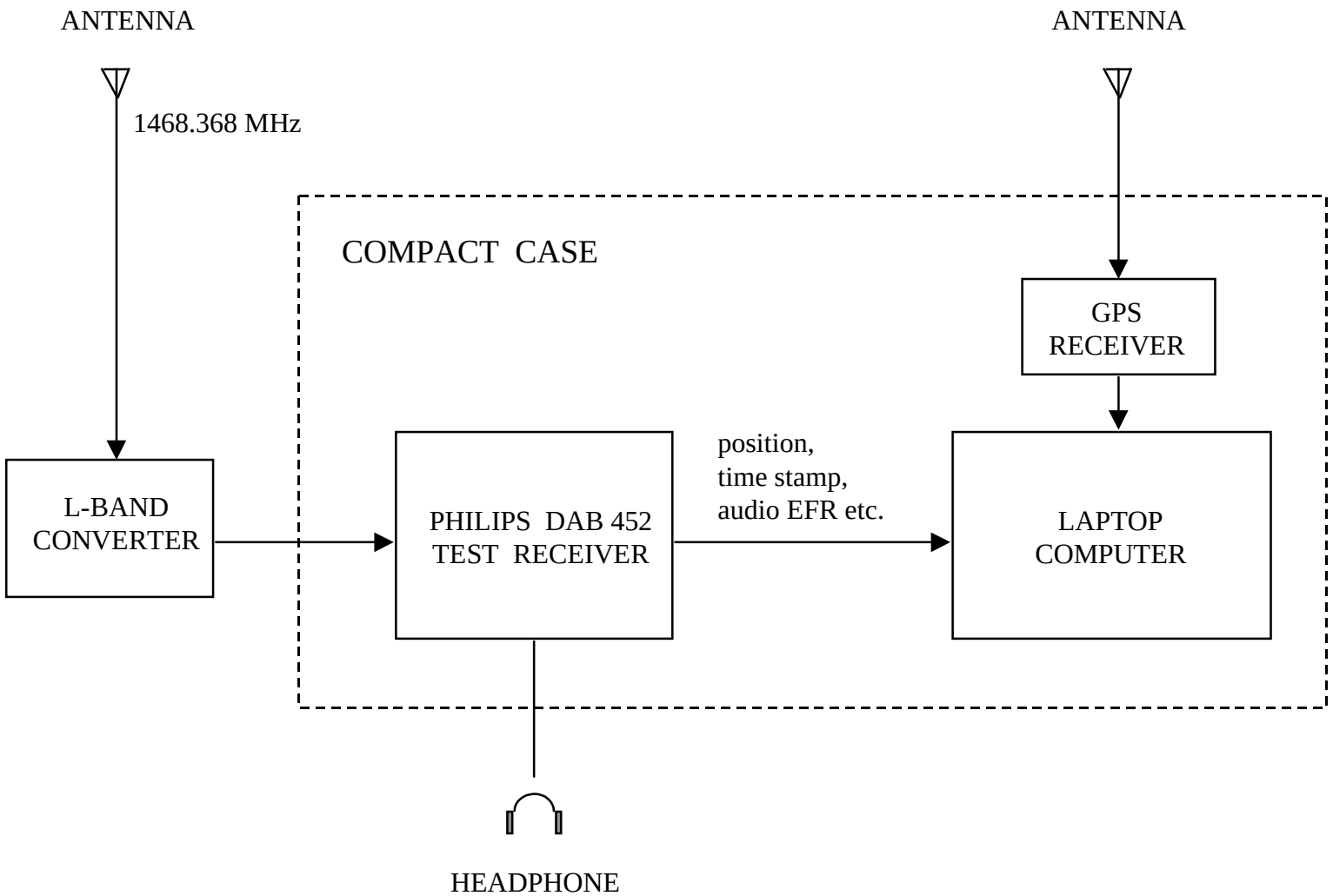
Network system transmission parameters

Parameter	**System**			
Transmit Frequency:	1468.368 MHz			
RF bandwidth of ensemble:	1.536 MHz			
Transmission mode:	either mode 2 or mode 4			
Separation between sites:	approx. 9 km			
	Mt. Gough		**Beacon Hill**	
Direction of radiation (relative to True North)	20°	200°	30°	180°
Power to antenna feeder:	100W	100W	50W	50W
(not accounting for cable & splitter losses)				
Antenna height above mean sea level:	501m	501m	480m	480m
Antenna polarization:	vertical	vertical	vertical	vertical
Horizontal beamwidth:	160°	160°	65°	90°
Vertical beamwidth:	6°	6°	4°	4°
Antenna gain :	10dBd	10dBd	16dBd	15.5dBd
Cable & splitter losses:	2.17dB	2.17dB	1.53dB	1.53dB
Effective radiated power:	607W	607W	1400W	1247W

Encoded configuration of DAB multiplex

Program channel	Audio bit-rate (kbit/s)	Error protection level
1 (ref. channel)	192	3
2	192	2
3	192	4
4	160	3
5	160	2
6	64	3

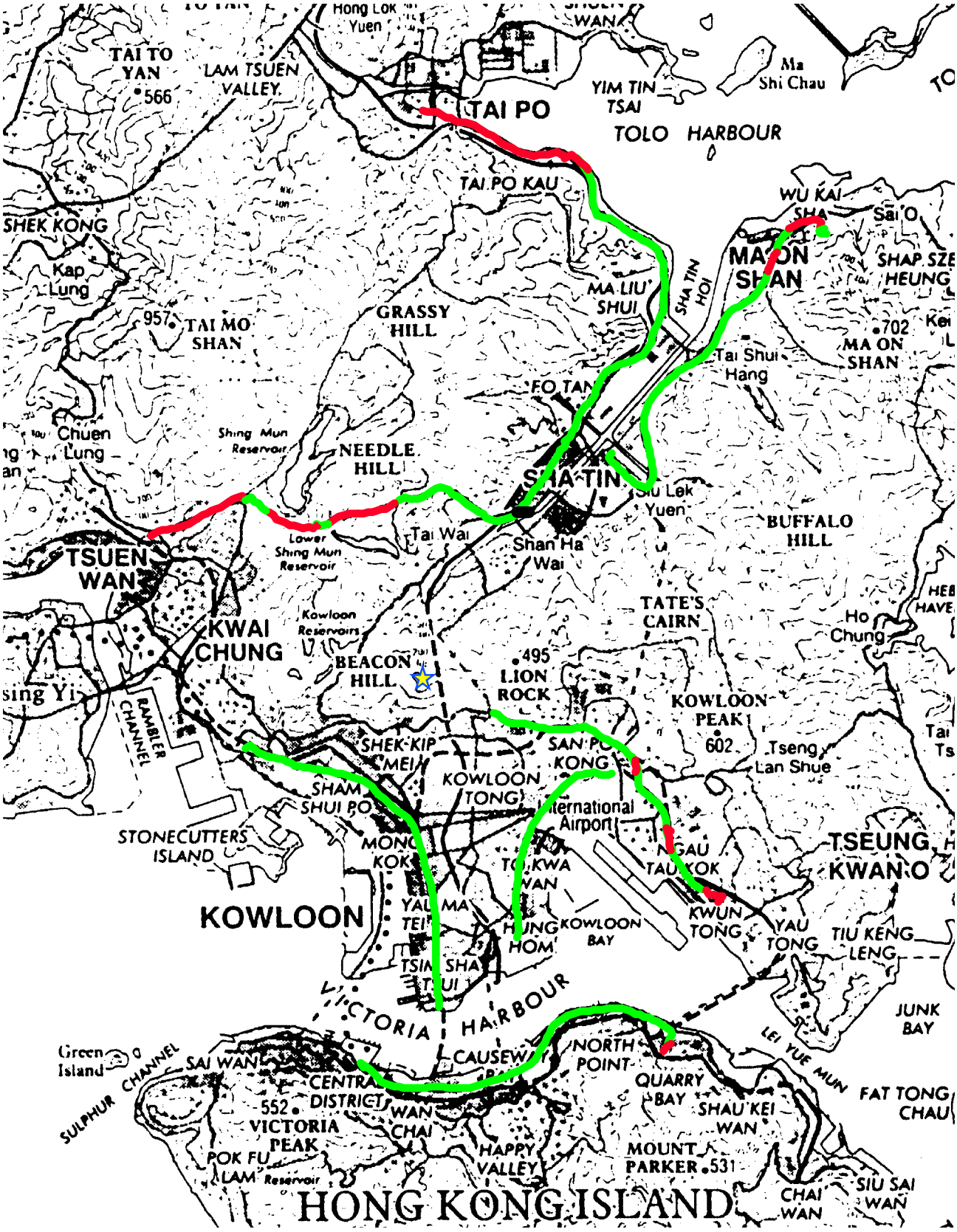
CONFIGURATION OF FIELD MEASURING SYSTEM



Annex 3

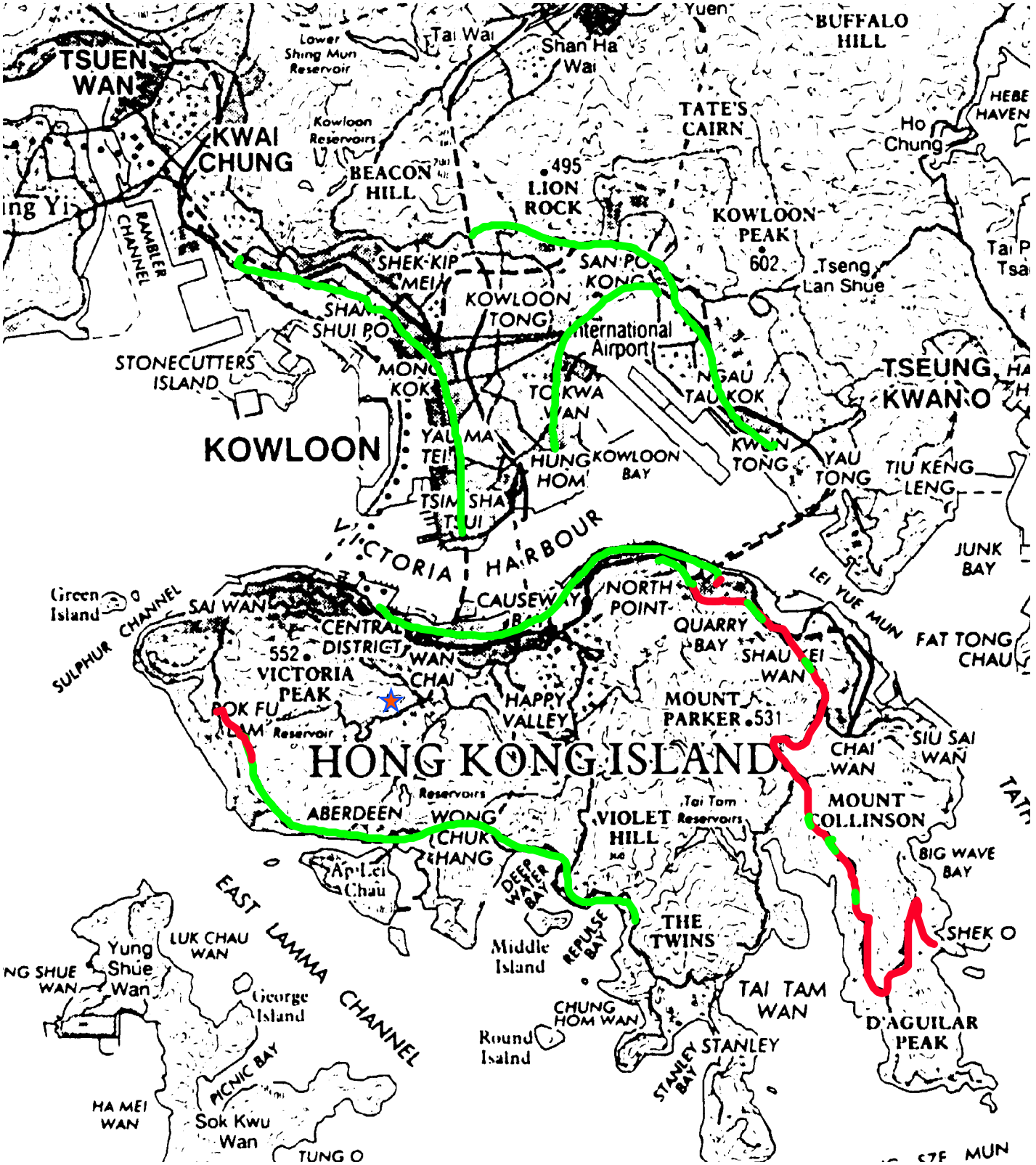
Result of Field Measurement (Beacon Hill only)

Annex 4(a)



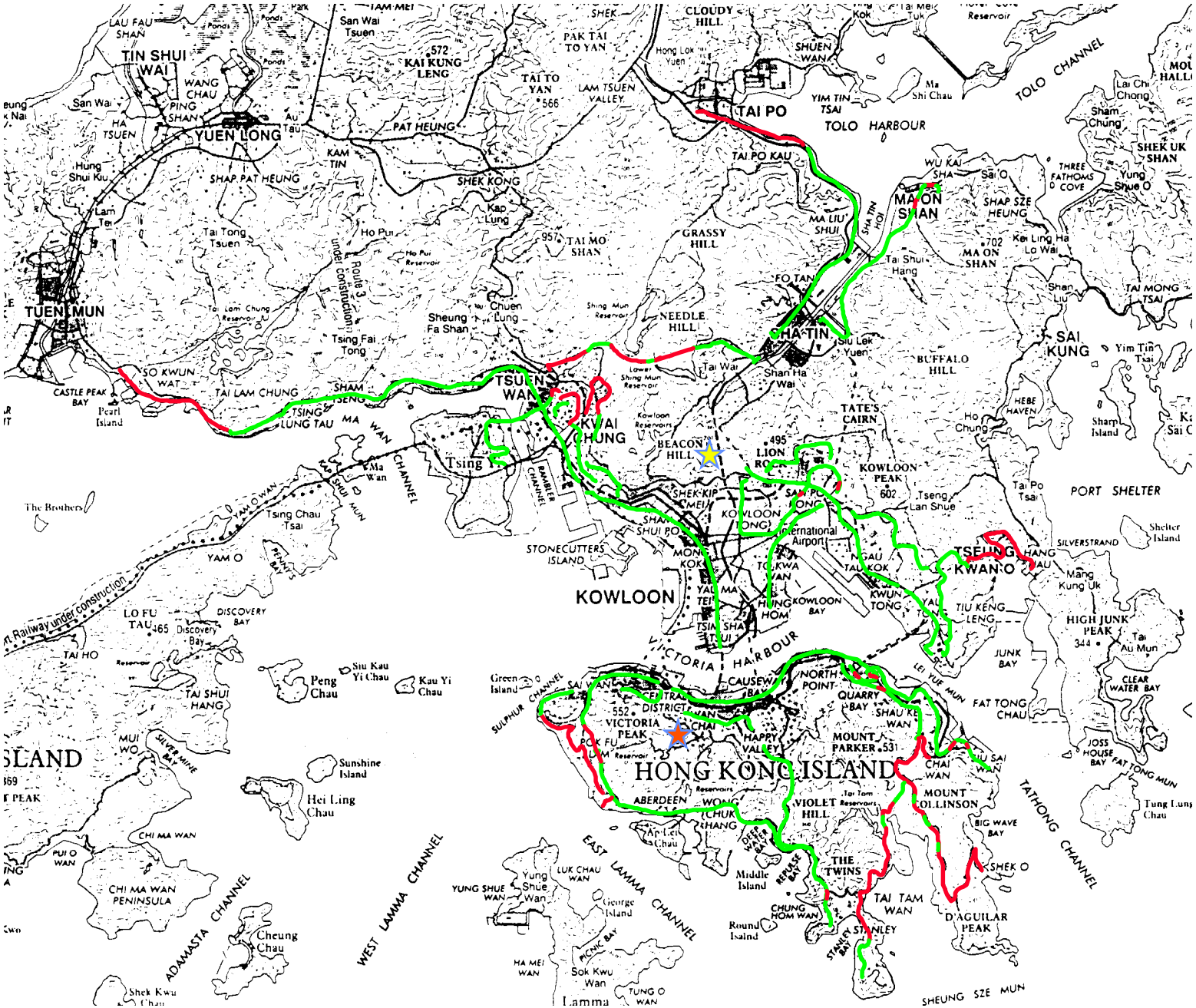
☆ Beacon Hill Site

Result of Field Measurement (Mt. Gough only)



★ Mt. Gough Site

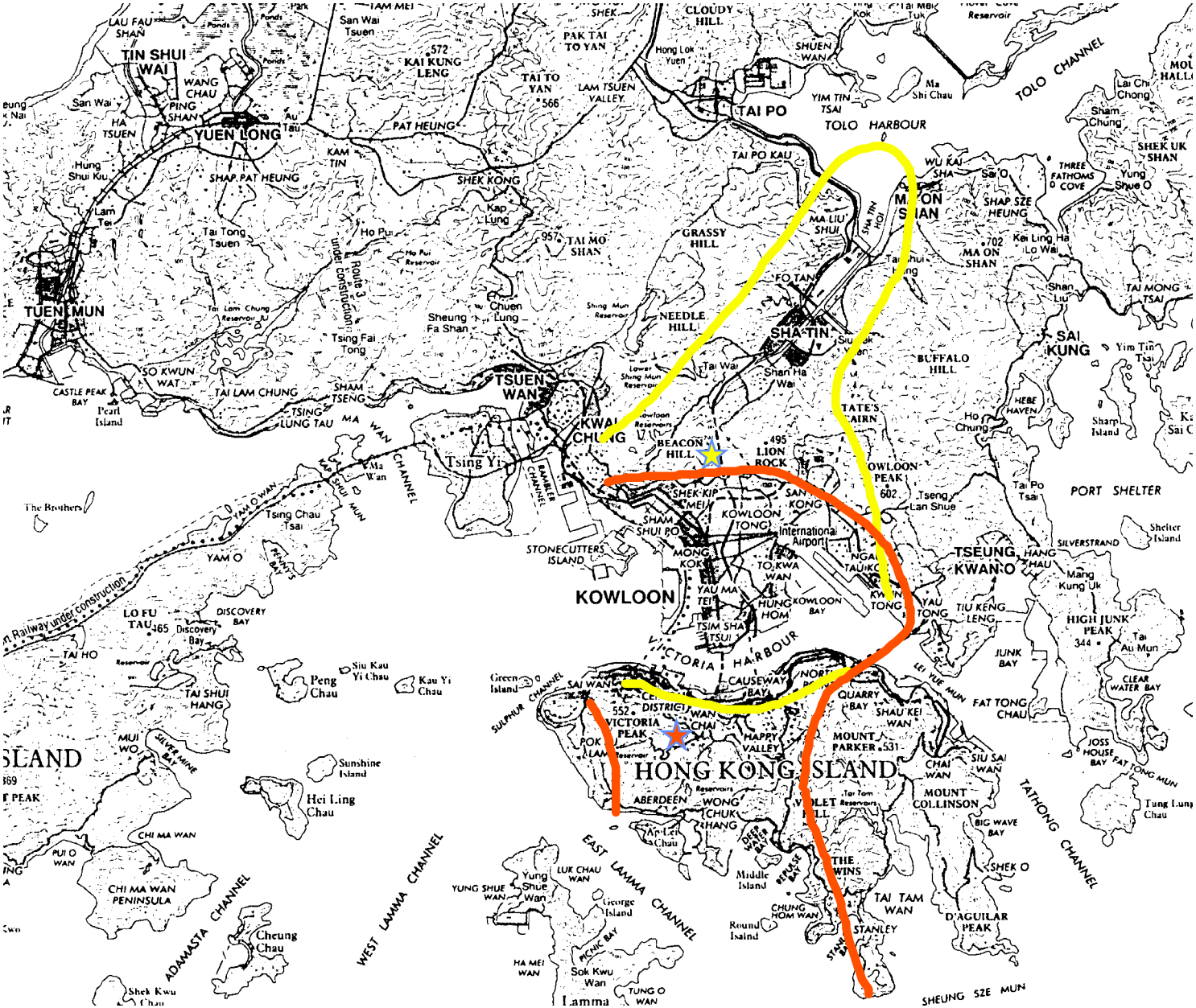
Result of Field Measurement (Beacon Hill and Mt. Gough)



Annex 4(c)

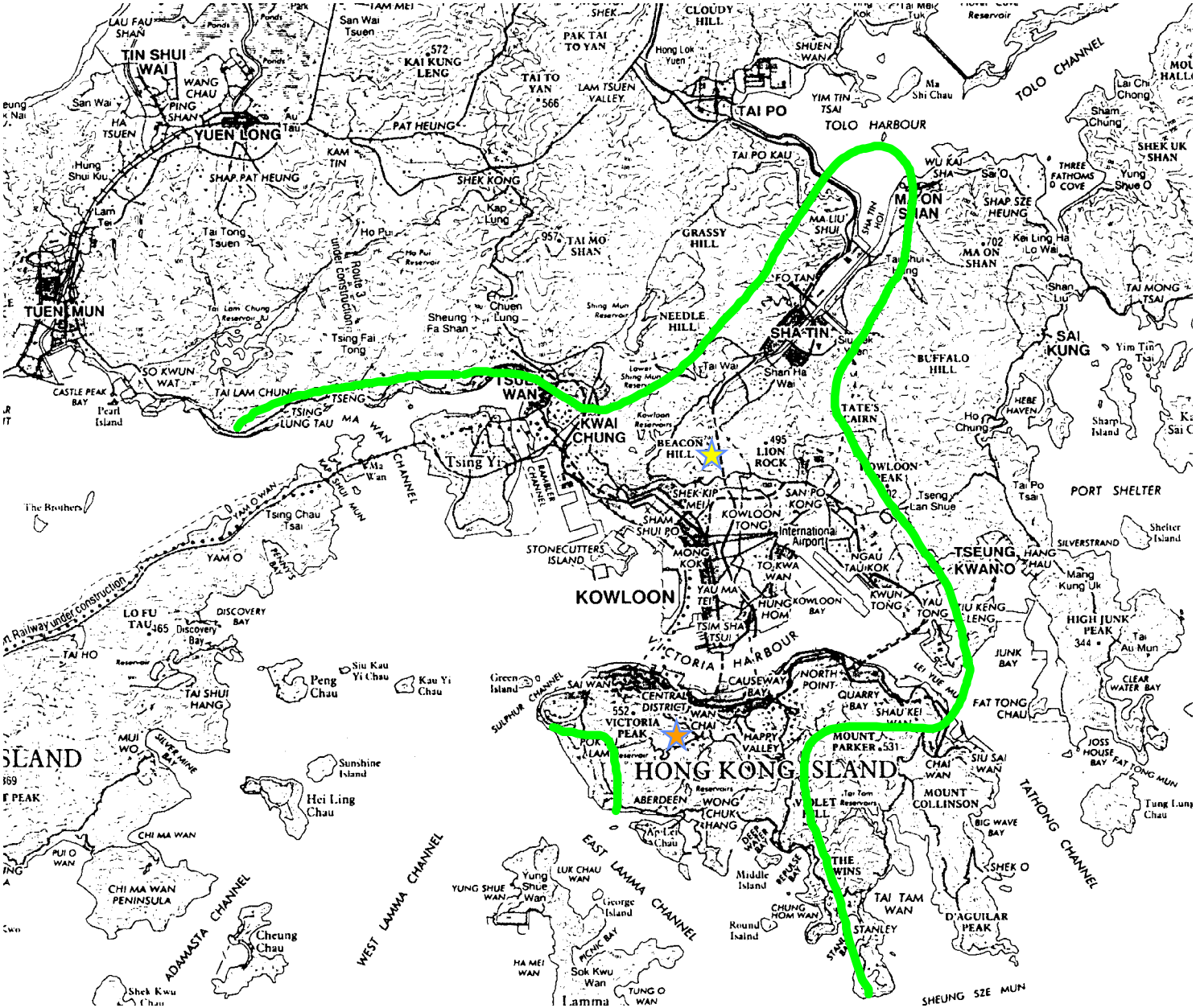
Outdoor Reception Test Result						
	Percentage of reception					
Loation	**Pgm1**	**Pgm2**	**Pgm3**	**Pgm4**	**Pgm5**	**Pgm6**
Beacon Hill only						
Tsimshatsui / Mongkok	96	96	96	96	96	100
Shatin Town Centre / Ma On Shan	67	67	62	67	67	67
Kwai Chung / Tsuen Wan	0	0	0	0	0	0
Chinese University / Tai Po	13 / 7	13 / 7	10 / 0	10 / 7	10 / 3	NA
Kowloon Bay / Kwun Tong	50	54	46	50	54	58
Mt. Gough only						
Aberdeen / Repulse Bay	74	83	63	80	83	NA
Kowloon Bay / Kwun Tong	81	88	81	81	86	70
Causeway Bay / North Point	90	93	90	93	93	71
Shau Kei Wan / Chai Wan	0	0	0	0	0	0
Tsimshatsui / Mongkok	100	100	100	100	100	100
Both						
Kowloon Bay / Kwun Tong	86	95	83	88	93	88
Aberdeen / Repulse Bay	77	82	71	80	86	NA
Causeway Bay / North Point	93	93	93	93	93	93
Shau Kei Wan / Chai Wan	27	35	23	27	35	35
Kwai Chung / Tsuen Wan	17	17	4	17	21	NA
Shatin Town Centre / Ma On Shan	78	78	78	78	78	78
Tsimshatsui / Mongkok	100	100	100	100	100	100
Chinese University / Tai Po	25	25	25	25	25	25
Tsing Yi	40	43	35	35	43	35
Mei Foo / Lai King	96	96	81	94	96	NA
Tsz Wan Shan / Chuk Yuen	100	100	100	100	100	100

Coverage Contour of Individual Site



Annex 6(a)

Coverage Contour of Combined Network



Annex 6(b)