For Discussion **SSAC Paper 3/2012**
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RADIO SPECTRUM AND TECHNICAL STANDARDS ADVISORY COMMITTEE

Review of Path Lengths of Fixed Links Operating above 10 GHz

Purpose

This paper reviews the path lengths of fixed links operating above 10 GHz in Hong Kong.

Background

2. In July 2010, the achievable path lengths of fixed links in various frequency bands were reviewed at a meeting of the Radio Spectrum Advisory Committee ("RSAC") based on RSAC Paper 4/2010[1] which referred to the then prevailing ITU Recommendations. Following the updates of some relevant ITU-R Recommendations, the achievable path lengths of fixed links operating in various frequency bands above 10 GHz are reviewed in this paper.

Calculation of Achievable Path Lengths

3. The transmit power, antenna size, modulation scheme, availability requirement and rainfall rate have deterministic effect on the achievable path lengths. For the purpose of calculating achievable path lengths at various frequency bands, reference was made to the technical parameters given at Annex 1 in RSAC Paper 4/2010. To calculate the effect of rain attenuation on the path lengths in various frequency bands, the RSAC Paper made reference to ITU-R Recommendations P.838-3, ITU-R P.837-5 and ITU-R P.530-13, which set out the parameters based on an availability of 99.99%.

[1] Discussion paper for the RSAC of the Office of the Telecommunications Authority which can be downloaded at http://tel_archives.ofca.gov.hk/en/ad-comm/rsac/paper/rsac04_2010.pdf.

4. Rain attenuation per kilometre, as defined in terms of specific rain attenuation γ_R (in dB/km), is obtained from the rainfall rate R (in mm/h) using a power law relationship $\gamma_R = kR^{\alpha}$ where k and α are coefficients of the specific rain attenuation, determined as functions of the frequency and polarisation. An availability of 99.99% corresponds to a rainfall rate exceeding 0.01% in time, $R_{0.01}$, such that $\gamma_R = kR_{0.01}^{\alpha}$. The specific rain attenuation in different frequency bands and polarisations are found from ITU-R Recommendation 838-3.

5. The rainfall rates $R_{0.01}$ given in ITU-R Recommendation P.837-5 are based on 40 years rain data gathered from individual regions, as supplied by the European Centre of medium-range Weather Forecast (ECMWF). With the rainfall data provided in ITU-R Recommendation P.837-5, the rainfall rate at Tai Mo Shan exceeding 0.01% of the average year was worked out as 86.9 mm/h.

6. To cater for the variance of rainfall rate at different parts of the fixed link path, a distance factor r is introduced by ITU-R Recommendation P.530-13. The rain attenuation exceeding 0.01% in time, $A_{0.01}$, is therefore calculated by multiplying the specific rain attenuation with the actual separation d and the distance factor r, i.e. $A_{0.01} = kR_{0.01}^{\alpha}dr$. The rain attenuation for availability of 99.999%, or rain attenuation exceeding 0.001% in time, was derived following a power law given in ITU-R P.530-13. The indicative path lengths of various frequency bands are then derived by varying the distance to a point where the received signal level is attenuated to the receiver sensitivity level by propagation loss and rain attenuation taken together. The formulas for calculating rain attenuation in RSAC Paper 4/2010 are recapitulated at Annex 1 for easy reference.

Updates of ITU-R Recommendations

7. Based on the research conducted by ITU-R over the years, ITU-R Recommendations P.837 and P.530 regarding rainfall data and rain attenuation respectively have been updated to new versions P.837-6 and P.530-14 in early 2012.

8. ITU-R Recommendation P.837-6 provides the same set of rainfall data referred by its previous version P.837-5. The new version introduces a method

to convert local rain data to a certain statistical form for fitting into the ITU-R model. Since the current local rain data do not provide sufficient statistical stability[2], the long-term rain data provided by ECMWF shall continue to be used in this review of the achievable path lengths. Accordingly, the rainfall rate exceeding 0.01% in time as derived previously, being 86.9 mm/h, continues to be applicable.

9. The calculation of distance factor r and rainfall attenuation exceeding 0.001% in time under the new Recommendation are shown below.

Calculation of distance factor r:

ITU-R Recommendation P.530-14 gives an update on the derivation of the distance factor r with a new formula given below:

$$r = \frac{1}{0.477 d^{0.633} R_{0.01}^{0.073\alpha} f^{0.123} - 10.579[1 - exp(-0.024d)]}$$

where $R_{0.01}$ is the rain rate exceeding 0.01% of the time;
d is the actual link distance;
α is the coefficient of specific rain attenuation; and
f is frequency in GHz.

Calculation of the rain attenuation exceeding 0.001% in time:

Calculation of the rain attenuation at availability of 99.999%, or rain attenuation exceeding 0.001% in time, $A_{0.001}$, ITU-R Recommendation P.530-14 introduces a new set of formulas as listed below:

$$A_{0.001} = A_{0.01} \times C_1 \times 0.001^{-(C_2 + C_3 \log_{10}(0.001))}$$

where $A_{0.01}$ is the rain attenuation exceeding 0.01% of the time

$$C_1 = (0.07^{C_0})\left[0.12^{(1-C_0)}\right]$$

$$C_2 = 0.855C_0 + 0.546(1 - C_0)$$

$$C_3 = 0.139C_0 + 0.043(1 - C_0)$$

$$C_0 = 0.12 + 0.4[\log_{10}(f/10)^{0.8}], \ f \geq 10 \text{ GHz}$$

10. In accordance with our calculation of distance factor r and $A_{0.001}$ based on ITU-R Recommendation P.530-14, it is noted that the updates of the

[2] To convert local rainfall data into long-term statistics, it requires territory-wide data collected over a long period of time. The current data on hand do not meet such requirements.

relevant recommendations would have an effect of increasing the rain attenuation on fixed links, in particular those operating in lower frequency ranges.

Indicative Path Lengths

11. The indicative path lengths applicable to the frequency bands of 11 GHz, 13 GHz, 18 GHz, 23 GHz, 28 GHz and 38 GHz have been reviewed in RSAC Paper 4/2010. Since the band 24.5 – 26.5 GHz (the "26 GHz band") is going to be released for fixed link applications (see SSAC Paper 2/2012), the path length of 26 GHz band is also reviewed in this paper.

12. The same set of technical parameters (as shown in Table 1) of microwave transceiver and antenna, as used in the calculation in RSAC Paper 4/2010 except for the 26 MHz band, are employed to work out the achievable path lengths under the new model given in ITU-R Recommendations P.530-14.

Table 1: Technical parameters of microwave systems

System parameters	**Frequency Bands**						
	11	**13**	**18**	**23**	**26**	**28**	**38**
Transmitter power (dBm)	26	22	20	20	20	19	16
Antenna size (m)	1.2	1.2	0.6	0.6	0.6	0.6	0.6
Transmitter/Receiver antenna gain (dBi)	40	42	39	40	41.6	42.5	44
Receiver sensitivity at 128 QAM and BER=10^{-6} (dBm)	-69	-68	-68	-68	-67	-67	-66

The detailed results of the calculations are given at Annex 2. The estimated achievable path lengths are summarised and tabulated at Table 2 below:

Table 2: Achievable path length based on parameters given in Table 1

Frequency band (GHz)	**11**	**13**	**18**	**23**	**26**	**28**	**38**
Path length for 99.99% availability (km) [Vertical Polarisation]	26	16	7.4	5.3	4.6	4.2	2.4
Path length for 99.99% availability (km) [Horizontal Polarisation]	19	13	5.5	3.9	3.4	3.1	2.0
Path length for 99.999% availability (km) [Vertical Polarisation]	23	15	6.7	4.8	4.2	3.8	2.2

Path length for 99.999% availability (km) [Horizontal Polarisation]	17	11	5.0	3.5	3.1	2.9	1.8

13. Having considered that the relevant ITU-R Recommendations make reference to availability of 99.99% in calculating rain attenuation of fixed links and some fade margins should be allowed in practical situation, the indicative path lengths in various frequency bands are suggested as tabulated in Table 3 below:

Table 3: Indicative path length

Frequency band (GHz)	**11**	**13**	**18**	**23**	**26/28**	**38**
Antenna size (m)	1.2	1.2	0.6	0.6	0.6	0.6
Path length (km)	16 (16)	10 (10)	5 (6)	3 (4)	3 (3)	2 (2)

Note: The indicative path lengths set out in RSAC Paper 4/2010 are given in brackets for reference

Advice Sought

14. Members are invited to offer their views and comments on the indicative path lengths, as well as the parameters for the calculation, as set out in this paper.

Office of the Communications Authority
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Annex 1

Formulas and Technical Parameters used in RSAC Paper 4/2010

1. System Parameters

System parameters	Frequency Bands					
	11	**13**	**18**	**23**	**28**	**38**
Transmitter power (dBm)	26	22	20	20	19	16
Antenna size (m)	1.2	1.2	0.6	0.6	0.6	0.6
Transmitter/Receiver antenna gain (dBi)	40	42	39	40	42.5	44
Receiver sensitivity at 128 QAM and BER=10^{-6} (dBm)	-69	-68	-68	-68	-67	-66

*BER: bit error rate

2. Rain Attenuation

2.1 According to ITU-R Recommendation P.530-13, 99.99% availability is taken as a benchmark in calculating the rain attenuation, which is found by multiplying the specific rain attenuation γ_R with the actual separation between the fixed stations, d, and with a distance factor r. The distance factor r is a fraction that depends on the rainfall rate exceeding 0.01% in time, $R_{0.01}$, and the actual separation, d, as follows:

$$r = \frac{1}{1 + d/d_o}$$

where $d_o = 35e^{-0.015R_{0.01}}$. The rain attenuation exceeding 0.01% of time (or fixed link availability of 99.99%) is therefore $A_{0.01} = \gamma_R \frac{d}{1+d/d_o}$.

2.2 Rain attenuation of other percentage of time, p, in the range 0.001% to 1% may be deduced by:

$$\frac{A_p}{A_{0.01}} = 0.07p^{-(0.855+0.139log_{10}p)}$$

For availability 99.999%, the overall path attenuation is 1.44 times the path attenuation at 99.99% due to rainfall.

Annex 2

Calculation Results for Path length of Fixed Link

Table 2A: Path Length for availability of 99.99%, Vertical Polarisation

Frequency band (GHz)	**11**	**13**	**18**	**23**	**26**	**28**	**38**
Estimated path length (km)	**26**	**16**	**7.4**	**5.3**	**4.6**	**4.2**	**2.4**
	Background calculations						
Propagation loss (dB)	141.57	138.80	134.93	134.16	134.00	133.85	131.64
Distance factor	0.409	0.494	0.614	0.669	0.696	0.716	0.890
Effective path length (km)	10.63	7.91	4.54	3.54	3.20	3.01	2.14
Rain attenuation for the whole path (dB)	32.91	33.58	30.78	33.52	35.84	37.15	37.37

Table 2B: Path Length for availability of 99.99%, Horizontal Polarisation

Frequency band (GHz)	**11**	**13**	**18**	**23**	**26**	**28**	**38**
Estimated path length (km)	**19**	**13**	**5.5**	**3.9**	**3.4**	**3.1**	**2.0**
	Background calculations						
Propagation loss (dB)	138.84	137.00	132.35	131.50	131.37	131.21	130.06
Distance factor	0.463	0.527	0.681	0.754	0.786	0.812	0.968
Effective path length (km)	8.80	6.86	3.75	2.94	2.67	2.52	1.94
Rain attenuation for the whole path (dB)	35.24	36.80	33.21	36.14	38.04	38.88	39.67

Table 2C: Path Length for availability of 99.999%, Vertical Polarisation

Frequency band (GHz)	**11**	**13**	**18**	**23**	**26**	**28**	**38**
Estimated path length (km)	**23**	**15**	**6.7**	**4.8**	**4.2**	**3.8**	**2.2**
	Background calculations						
Propagation loss (dB)	140.50	138.24	134.07	133.30	133.21	132.98	130.89
Rain attenuation at 0.01%, $A_{0.01}$ (dB)	30.70	32.13	28.83	31.53	33.92	35.01	35.65
Rain attenuation at 0.001%, $A_{0.001}$ (dB)	33.77	35.17	31.79	34.43	36.79	37.86	38.43

Table 2D: Path Length for availability of 99.999%, Horizontal Polarisation

Frequency band (GHz)	**11**	**13**	**18**	**23**	**26**	**28**	**38**
Estimated path length (km)	**17**	**11**	**5.0**	**3.5**	**3.1**	**2.9**	**1.8**
	Background calculations						
Propagation loss (dB)	137.88	135.55	131.53	130.56	130.57	130.63	129.14
Rain attenuation at 0.01%, $A_{0.01}$ (dB)	32.75	32.76	31.27	33.90	36.07	37.44	37.52
Rain attenuation at 0.001%, $A_{0.001}$ (dB)	35.83	35.79	34.22	36.80	38.94	40.29	40.30