通訊事務管理局辦公室
OFFICE OF THE COMMUNICATIONS AUTHORITY

Radio Spectrum and Technical Standards Advisory Committee

SSAC Paper 7/2012 for information: Modulation and Polarisation Schemes of Fixed Links

Office of the Communications Authority

Date: 9 October 2012

Background

- The indicative path lengths of fixed links operating above 10 GHz bands were discussed in SSAC Paper 3/2012 at the first SSAC meeting (29/6/2012)
  - Practical technical parameters are used in the calculation of indicative path lengths including:
    - Vertical and horizontal polarisations
    - modulation scheme 128 QAM

Background

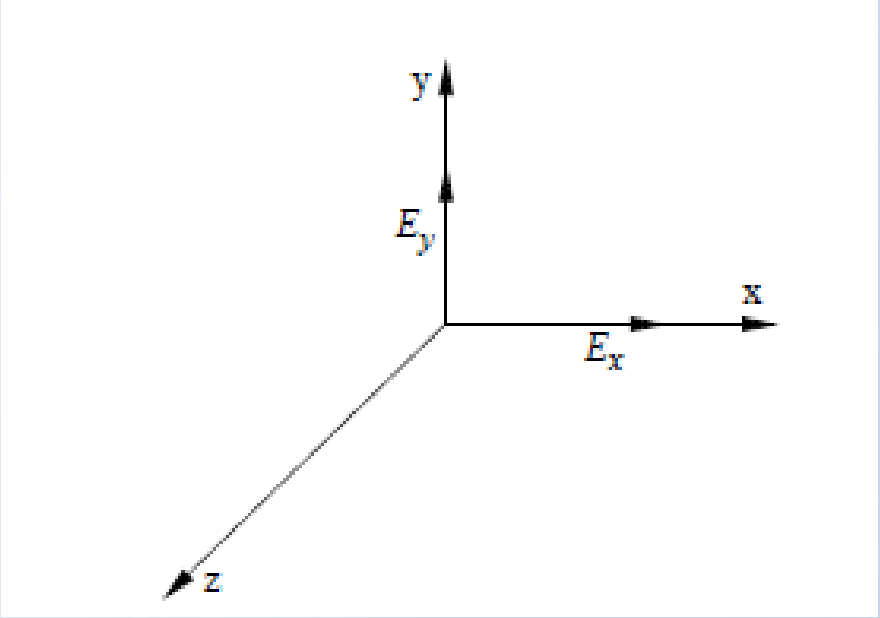
- In reviewing the SSAC Paper 3/1012, there was suggestion to consider circular polarisation and modulation scheme 256 QAM in calculating the indicative path lengths of fixed links
- While there is limited deployment of circular polarisation in Hong Kong and 256 QAM is less robust than the practical modulation scheme, they are introduced in this paper for Members' information

Forms of Polarisation

- The different forms of wave polarisation may be considered as special cases of the more general case of elliptical polarisation
- An elliptically polarised wave may be represented by two mutually perpendicular linear waves, propagating along the z-axis and having the respective electrical fields expressed by:

  $Ex = E1 \sin \omega t$

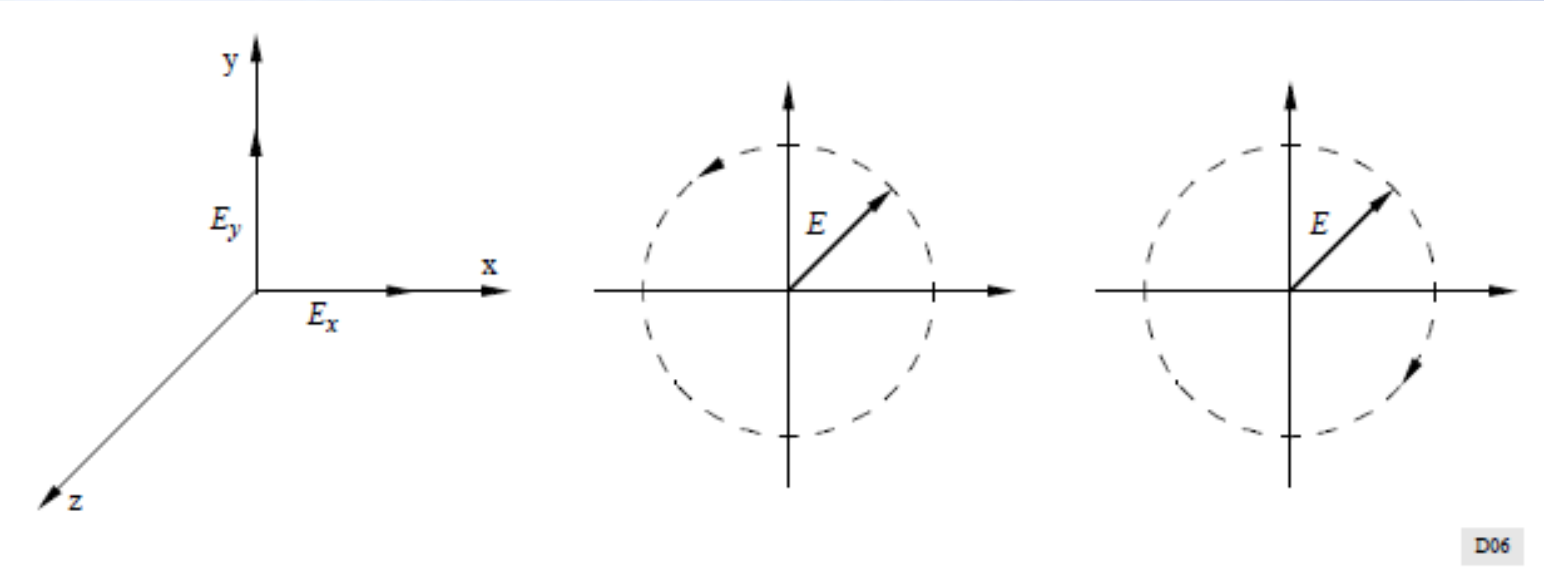
  $Ey = E2 \sin (\omega t + j)$



Source: Rec. ITU-R BS1195

Forms of Polarisation

- Linear polarisations:
  - Vertical polarisation: *Ex = 0*
  - Horizontal polarisation: *Ey = 0*
- Circular polarisation: $Ex = E \sin \omega t$ *and* $Ey = \pm E \cos \omega t$

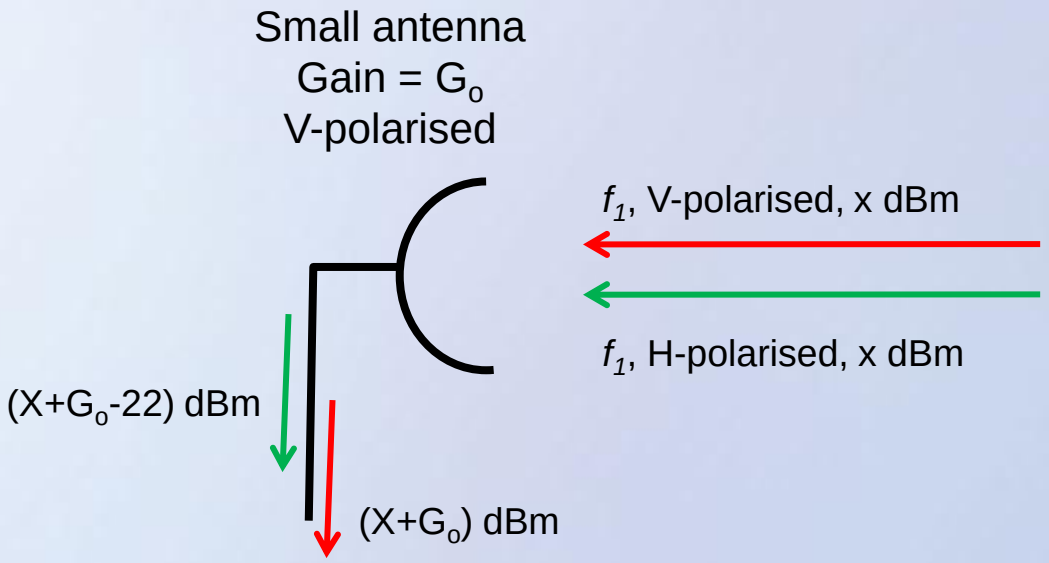


Left-hand Circular polarisation

Right-hand Circular polarisation

Use of Polarisations

- There is cross-polarisation discrimination (XPD) between vertical (V) and horizontal (H) polarisation at receiving antenna
- The XPD for small antenna (up to 1.8m) and large antenna (up to 3.5m) are 22 dB and 28 dB respectively



Source: Rec. ITU-R S.731-1

Use of Polarisations

- XPD is useful for reducing co-channel interference, hence facilitating frequency reuse:
  - the same frequency channel can be assigned to two users in V- and H-polarisation respectively provided that there is sufficient physical separation between the two users
  - maximising spectrum efficiency (frequency reuse factor)
- Dual linear polarisation scheme (employing both V- and H-polarisation) may be employed to increase the data capacity
- However, the receiving antenna is required to have accurate polarisation tracking in V- and H-polarisation scheme

Use of Polarisations

- For circular polarisation, it is suitable for mobile service due to its polarisation-tracking-free nature
- To find the estimated path lengths of circular polarisation in various bands, the effect of rain attenuation on circular polarisation, which is specified in Recommendation ITU-R 838-3, should be considered

Source: Rep. ITU-R M.2175

Use of Polarisations

- According to Recommendation ITU-R 838-3, the specific attenuation γ_R (dB/km) is obtained from the rain rate R (mm/h):

$$\gamma_R = kR^{\alpha}$$

- For circular polarisation, its coefficients are related to that of V- and H-polarisations:

$$k_c = (k_H + k_V)/2$$
$$\alpha_c = (k_H\alpha_H + k_V\alpha_V)/2k_c$$

Use of Polarisations

- The specific rain attenuation of linear and circular polarisations are then calculated and tabulated below:

Under Different Polarisations	Frequency Bands (GHz)						
	11	13	18	23	26	28	38
V (dB/km)	3.10	4.24	6.77	9.46	11.20	12.36	17.50
H (dB/km)	4.00	5.37	8.86	12.30	14.23	15.45	20.50
C (dB/km)	3.53	4.75	7.70	10.79	12.65	13.85	18.97

Use of Polarisations

- For the calculation of indicative path lengths given in SSAC Paper 3/2012, rain attenuation of both vertical and horizontal polarisations have been considered.
- As the specific rain attenuation of circular polarisation in various bands fall between that of vertical and horizontal polarisations, the indicative path lengths are applicable to circular polarisation.

Use of Polarisations

- In Hong Kong,
  - most fixed links above 10 GHz bands employ linear polarisations (either V- or H- or dual polarisation); and
  - circular polarisation is mainly used by broadcasters for Electronic News Gathering (ENG) and Outside Broadcast purpose

Modulation Schemes

- Fixed links usually employ Quadrature Amplitude Modulation (QAM) to transmit and receive data
- The higher order of QAM, the more data capacity gained
- However, the receiver sensitivity* requirement is more stringent for higher order of QAM
- The typical receiver sensitivity levels under different QAM schemes in 11-18 GHz bands are listed below for illustration purpose

** Receiver sensitivity is a measure of the minimum power level required for proper receiver operation*

Modulation Schemes

Modulation	Bit per symbol	Receiver sensitivity level at BER=10^{-6} (11-18 GHz)
16 QAM	4	-80 dBm
32 QAM	5	-76 dBm
64 QAM	6	-73 dBm
128 QAM	7	-70 dBm
256 QAM	8	-67 dBm

Source: Huawei Product Description

Modulation Schemes

- If modulation is changed from 128 QAM to 256 QAM:
  - Capacity increases by 11%
  - Sensitivity level requires 3 dB more, implying achievable path length shortened*
- For high speed data transmission, use of 128 QAM in a 28 MHz channel already supports STM-1 signals (156 Mbit/s)
- Use of 128 QAM is a good balance between data capacity and transmission distance

*Power decreases with distance travelled. To meet higher receiving power requirement, the path length is shortened.

Estimated Path Lengths above 10 GHz bands

- In SSAC Paper 3/2012, the indicative path lengths above 10 GHz bands are set based on the estimated path lengths which refer to V- and H-polarisation and a modulation scheme of 128 QAM
- For comparison, the estimated achievable path lengths of circular polarisation in various bands are calculated:
  - same technical parameters such as transmitter power, antenna gain etc. as used in SSAC Paper 3/2012;
  - **except**
    - the receiver sensitivity level in each band is added 3 dB for a modulation scheme of 256 QAM; and
    - specific rain attenuation changed to that for circular polarisation

Achievable Path Lengths above 10 GHz bands

- At availability 99.99%

Polarisation	Frequency Band (GHz)						
	11	13	18	23	26	28	38
Vertical (km)*	26	16	7.4	5.3	4.6	4.2	2.4
Horizontal (km)*	19	13	5.5	3.9	3.4	3.1	2.0
Circular (km)	20	13	5.8	4.1	3.6	3.3	2.0

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*Extracted from SSAC Paper 3/2012

Achievable Path Lengths above 10 GHz bands

- At availability 99.999%

Polarisation	Frequency Band (GHz)						
	11	13	18	23	26	28	38
Vertical (km)*	23	15	6.7	4.8	4.2	3.8	2.2
Horizontal (km)*	17	11	5.0	3.5	3.1	2.9	1.8
Circular (km)	18	12	5.2	3.7	3.2	3.0	1.8

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*Extracted from SSAC Paper 3/2012

Observations

- The specific rain attenuation (dB/km) of circular polarisation falls between that of vertical and horizontal polarisation.
- While the receiver sensitivity level of 256 QAM is increased by 3 dB in comparison with that of 128 QAM, its achievable path lengths are shorter than those of vertical polarisation but do not fall below those of horizontal polarisation.
- Therefore, the indicative path lengths as shown in SSAC Paper 3/2012 are applicable to fixed links using V-, H-polarisation, circular polarisation and modulation scheme up to 256 QAM.

Thank you!