First Semester Examination
2022/2023 Academic Session

February 2023

EEE440 – Modern Communication Systems
(Sistem Perhubungan Moden)

Duration : 2 hours
(Masa : 2 jam)

Please check that this examination paper consists of **FOURTEEN (14)** pages of printed material including appendix before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **EMPAT BELAS (14)** muka surat yang bercetak termasuk lampiran sebelum anda memulakan peperiksaan ini.]*

Instructions : This paper consists of **FOUR (4)** questions. Answer **ALL** questions.

*[**Arahan** : Kertas ini mengandungi **EMPAT (4)** soalan. Jawab **SEMUA** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. A frequency division duplexing (FDD) cellular mobile system allocates a bandwidth of 32 MHz that uses 50 kHz simplex channels for voice communication. Assume each user averages 1 call/hour and each call lasting 3 minutes. The system also uses 5 clusters with a cluster size of N = 16. On a separate note, traffic study requested from Ameritech Co. informs the cellular mobile system that the traffic intensity is too high. An alternative to this is to use sectorized cells. Therefore, the system is redesigned using 120° cell sectoring and a new cluster size of N = 4 is used. What is the blocking probability if the number of users in a cell is increased 3 times compared to the original system. Discuss the changes you have observed in the blocking probability.

Satu sistem mudah alih selular pendupleks bahagian frekuensi (FDD) menyediakan jalur lebar sebanyak 32 MHz dan menggunakan saluran simplex berfrekeunsi 50 kHz bagi perhubungan suara. Anggap setiap pengguna berpurata sebanyak 1 panggilan/jam dan setiap panggilan mengambil masa 3 minit. Sistem tersebut menggunakan 5 kelompok bersaiz, N = 16. Di samping itu, kajian lalu lintas yang diminta oleh Ameritech Co. memaklumkan kepada sistem mudah alih selular bahawa keamatan trafik adalah terlalu tinggi. Satu kaedah untuk menyelesaikan masalah ini adalah dengan menggunalan sel bersektor. Oleh itu, sistem diubahsuai dengan menggunakan sel bersektor 120° dan saiz gugus yang baru iaitu N = 4. Apakah penghalang kebarangkalian jika bilangan pengguna di dalam satu sel ditingkatkan 3 kali ganda berbanding sistem asal. Bincangkan perubahan pada penghalang kebarangkalian.

(100 marks/*markah*)

2. Table 2 shows the mechanism of communication between users (A, B and C) with the base station in CDMA receiver. Each user has been encoded with its own code respectively shown in Table 2(a). Example of the code transmission (data bit 1) from user A at base station receiver A is shown in Table 2(b). Show how the codes are transmitted and find their respective values for each code transmission, for these cases:

Jadual 2 menunjukkan mekanisma perhubungan antara pengguna (A, B dan C) dengan stesen pangkalan di dalam penerima CDMA. Setiap pengguna telah dikodkan dengan kod tersendiri seperti di dalam Jadual 2(a). Contoh penghantaran kod (bit data 1) daripada pengguna A di stesen pangkalan penerima A ditunjukkan di dalam Jadual 2(b). Tunjukkan bagaimana kod tersebut dihantar dan tentukan nilai bagi setiap penghantaran kod, bagi kes-kes ini:

a) Transmission from B, receiver attempts to recover C's transmission.

Penghantaran daripada B, percubaan penerima mendapatkan penghantaran C.

(34 marks/*markah*)

...3/-

b) Transmission from A, receiver attempts to recover C's transmission.

Penghantaran daripada A, percubaan penerima mendapatkan penghantaran C.

(33 marks/*markah*)

c) Transmission from A, receiver attempts to recover B's transmission.

Penghantaran daripada A, percubaan penerima mendapatkan penghantaran B.

(33 marks/*markah*)

Table 2. Communication between users and base station in CDMA receiver.
Jadual 2. Perhubungan antara pengguna dengan stesen pangkalan di dalam penerima CDMA.

(a) User's codes.
(a) Kod pengguna.

User A *Pengguna A*	-1	-1	-1	1	1	-1
User B *Pengguna B*	-1	1	-1	1	1	-1
User C *Pengguna C*	-1	1	-1	1	-1	1

(b) Transmission from A.
(b) Penghantaran daripada A.

Transmit (data bit = 1) *Penghantaran (bit data = 1)*	-1	-1	-1	1	1	-1	
Receiver codeword *Katakod penerima*	-1	-1	-1	1	1	-1	
Multiplication *Pendaraban*	1	1	1	1	1	1	6

...4/-

3. a) An Earth Station (ES) is located in the **southern hemisphere**. A geostationary satellite has been launched and its subsatellite is located to the **east** the earth station (ES). Figure 3 shows the four possible locations of a subsatellite (SS) relative to the earth station method having sentence followed by roman number.

*Stesen Bumi (ES) terletak di **hemisfera selatan**. Satelit geostasionari telah dilancarkan dan subsatelitnya terletak di **timur** stesen bumi (ES). Rajah 3 menunjukkan empat lokasi yang mungkin terjadi diantara subsatelit (SS) berbanding dengan stesen bumi (ES).*

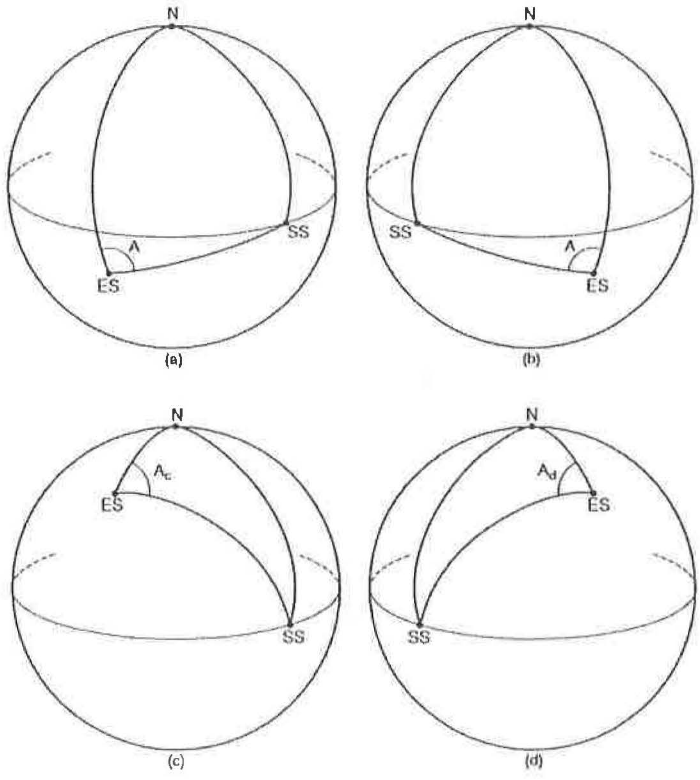

Figure 3. Four possible locations of earth station (ES) relative to subsatellite (SS).
Rajah 3. Empat kemungkinan lokasi diantara stesen bumi (ES) dengan subsatelit (SS).

Table 3. Azimuth Angles A_z from Figure 3.
Jadual 3. Sudut azimuth A_z dari Rajah 3.

Fig. 1.3	λ_E	B	A_z, degrees
a	<0	<0	A
b	<0	>0	$360° - A$
c	>0	<0	$180° - A$
d	>0	>0	$180° + A$

Based on the given information;

Berdasarkan maklumat diberikan;

(i) Find one suitable figure from the Figure 3 (a) – (d) that describes the problem above.

Cari satu rajah yang sesuai dari Rajah 3 (a) – (d) yang menerangkan masalah di atas.

(10 marks/*markah*)

(ii) Based on Table 3, determine the corresponding rule (row) suitable to be used.

Berdasarkan Jadual 3, tentukan peraturan (barisan) yang sesuai untuk digunakan.

(10 marks/*markah*)

b) Following Question 3(a), given that the Earth Station (ES) is located at latitude 20° S and longitude 120° W. The absolute angle difference between the subsatellite and the earth station (ES) is 30°. The earth radius $R = 6{,}371$ km, and distance from the earth center to the satellite $a_{GSO} = 42{,}164$ km.

Sambungan daripada Soalan 3(a), diberi Stesen Bumi (ES) terletak di latitud 20° S dan longitud 120° W. Perbezaan sudut mutlak antara subsatelit dan stesen bumi (ES) ialah 30°.Radius bumi adalah $R = 6{,}371$ km, dan jarak dari pusat bumi ke satelit $a_{GSO} = 42{,}164$ km.

(i) Determine angle B, and the longitude of subsatellite.

Tentukan sudut B dan longitude subsatelit

(20 marks/*markah*)

(ii) Determine the Azimuth angle.

Tentukan sudut Azimuth.

(20 marks/*markah*)

(iii) Find the range between earth station and the satellite.

Cari julat antara stesen bumi dan satelit.

(20 marks/*markah*)

(iv) Find the earth station antenna elevation angle.

Cari sudut kenaikan antena stesen bumi.

(20 marks/*markah*)

4. a) An Earth Station (ES) transmitting data to satellite via an uplink satellite circuit at frequency 16 GHz. The distance between earth station and the antenna is 42,000 km. The communication happens in a noisy environment with the noise bandwidth of 20 MHz. Table 4.1 shows the related parameters for the transmitter and the receiver. Table 4.2 shows the losses for the transmission. Assume the speed of light $c = 1 \times 10^{8}$ m/s, and the Boltzmann's constant $k = 1.38 \times 10^{-23}$J/K.

Stesen Bumi (ES) menghantar data ke satelit melalui litar satelit pautan keatas pada frekuensi 16 GHz. Jarak antara stesen bumi dan antena ialah 42,000 km. Perhubungan itu berlaku dalam suasana hingar dengan lebar jalur hingar adalah 20 MHz. Jadual 4.1 menunjukkan parameter yang berkaitan untuk pemancar dan penerima. Jadual 4.2 menunjukkan kehilangan pada penghantaran. Anggapkan kelajuan cahaya $c = 1 \times 10^{8}$ *m/s, dan pemalar Boltzmann* $k = 1.38 \times 10^{-23}$J/K.

Table 4.1. Parameters for satellite link circuit.
Jadual 4.1. Parameter untuk litar pautan satelit.

Transmitter (*Pemancar*)		Receiver (*Penerima*)	
Transmit Power *Kuasa penghantar*	10 W	$\left[\frac{G}{T}\right]$	19.5 dB/K
Antenna Gain *Gandaan antena*	40 dB	Antenna Gain *Gandaan antena*	50 dB
		Receiver Feeder loss *Kehilangan pada pembekal penerima*	1 dB

Table 4.2. Other transmission losses.
Jadual 4.2. Kehilangan penghantaran yang lain.

Descriptions (Penerangan)	Values (Nilai)
Atmospheric absorption loss *Kehilangan penyerapan atmosfera*	2 dB
Antenna pointing loss *Kehilangan penunjukan antena*	1 dB
Polarization loss *Kehilangan pengutuban*	0 dB

Calculate the following;

Hitungkan berikut;

(i) EIRP in dBW.

EIRP dalam dBW.

(10 marks/*markah*)

(ii) Free space loss [FSL] in dB.

Kehilangan ruang bebas.

(20 marks/*markah*)

(iii) The received power in Watt.

Kuasa yang diterima dalam in Watt.

(20 marks/*markah*)

(iv) Carrier-to-noise density ratio at the receiver.

Nisbah kepadatan pembawa kepada hingar pada penerima.

(10 marks/*markah*)

(v) Carrier-to-noise ratio at the receiver.

Nisbah pembawa kepada hingar pada penerima.

(20 marks/*markah*)

b) The same uplink satellite circuit as in Question 4(a), but the operation requires that the receiver to be in saturation. It is given that the saturation flux density at the receiver is -90 dB (W/m^2). Using all the information of losses similar to Question 4(a), determine the additional [EIRP] from Question 4(a) part (i) in Watt, required to saturate the receiver.

Litar satelit pautan keatas yang sama seperti di dalam Soalan 4(a), tetapi memerlukan penerima beroperasi dalam keadaan tepu. Diberi bahawa ketumpatan fluks tepu pada penerima adalah -90 dB (W/m^2). *Dengan menggunakan maklumat kehilangan sama seperti di dalam Soalan 4(a), tentukan tambahan [EIRP] dari Soalan 4(a) bahagian (i) dalam Watt, yang diperlukan untuk menepukan penerima.*

(20 marks/*markah*)

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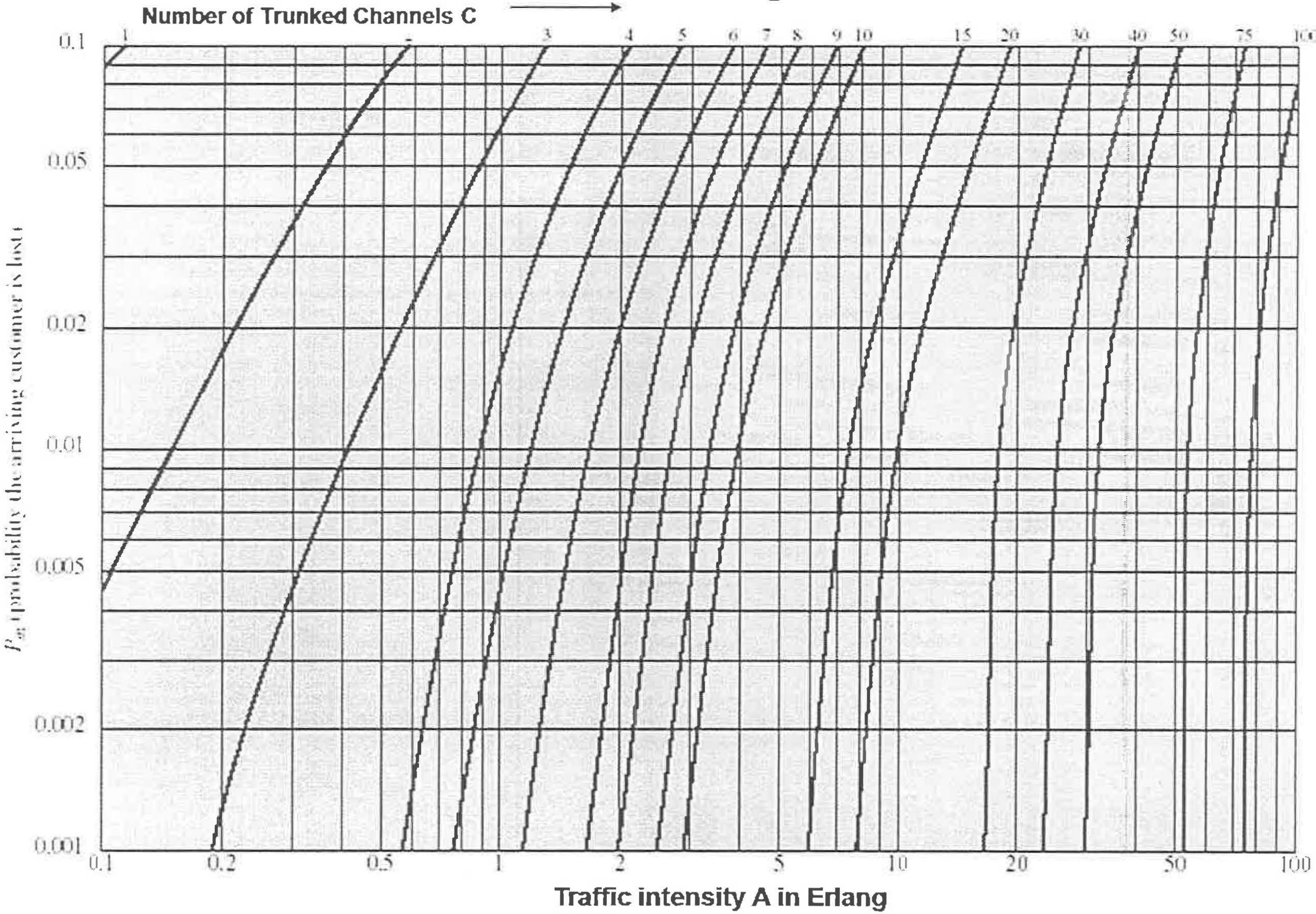
APPENDIX

LAMPIRAN

Question	Course Outcome (CO)	Programme Outcome (PO)
1	1	PO3
2	1	PO3
3	1	PO4
4	1	PO4

Erlang B Chart



CELLULAR CONCEPT – EQUATIONS:

<table>
<tr><td>1.</td><td>Area (hexagon)</td><td>$2.6R^2$</td></tr>
<tr><td>2.</td><td>Perimeter (hexagon)</td><td>6R</td></tr>
<tr><td>3.</td><td>$N = i^2 + ij + j^2$</td><td>
<table>
<tr><th>i</th><th>j</th><th>$N = (i^2 + ij + j^2)$</th><th>$Q = D/R = \sqrt{3N}$</th></tr>
<tr><td>1</td><td>0</td><td>1</td><td>1,73</td></tr>
<tr><td>1</td><td>1</td><td>3</td><td>3,00</td></tr>
<tr><td>2</td><td>0</td><td>4</td><td>3,46</td></tr>
<tr><td>2</td><td>1</td><td>7</td><td>4,58</td></tr>
<tr><td>3</td><td>0</td><td>9</td><td>5,20</td></tr>
<tr><td>2</td><td>2</td><td>12</td><td>6,00</td></tr>
<tr><td>3</td><td>1</td><td>13</td><td>6,24</td></tr>
<tr><td>4</td><td>0</td><td>16</td><td>6,93</td></tr>
<tr><td>3</td><td>2</td><td>19</td><td>7,55</td></tr>
<tr><td>4</td><td>1</td><td>21</td><td>7,94</td></tr>
<tr><td>3</td><td>3</td><td>27</td><td>9,00</td></tr>
</table>
</td></tr>
<tr><td>4.</td><td></td><td>$D = R\sqrt{3N}$</td></tr>
<tr><td>5.</td><td></td><td>$Q = D/R = 1/N$</td></tr>
<tr><td>6.</td><td>Signal to Interference Ratio</td><td>$S/I = 1/6\,(D/R)^n$ for equal distance</td></tr>
<tr><td>7.</td><td>Signal to Interference ratio (worst case)</td><td>$\frac{S}{I} = \frac{R^{-n}}{\sum D_i^{-n}} = \frac{R^{-n}}{2(D-R)^{-n} + 2(D+R)^{-n} + 2D^{-n}}$
$\frac{S}{I} = \frac{1}{2(Q-1)^{-n} + 2(Q+1)^{-n} + 2Q^{-n}}$</td></tr>
<tr><td>8.</td><td>With 120° sector</td><td>$\frac{S}{I} = \frac{R^{-n}}{D^{-n} + (D+0.7R)^{-n}} = \frac{1}{Q^{-n} + (Q+0.7)^{-n}}$</td></tr>
<tr><td>9.</td><td>With 60° sector</td><td>$\frac{S}{I} = \frac{R^{-n}}{(D+0.7R)^{-n}} = (Q+0.7)^n$</td></tr>
<tr><td>10.</td><td>Number of channels</td><td>$N = \frac{B_t - 2B_g}{B_c}$</td></tr>
<tr><td>11.</td><td>Without sector (CDMA)</td><td>$N = 1 + \frac{W/R}{E_b/N_o}$</td></tr>
<tr><td>12.</td><td>With sector (CDMA)</td><td>$N_s = 1 + (1/\alpha)\frac{W/R}{E_b/N_o}$</td></tr>
</table>

SATELLITE:

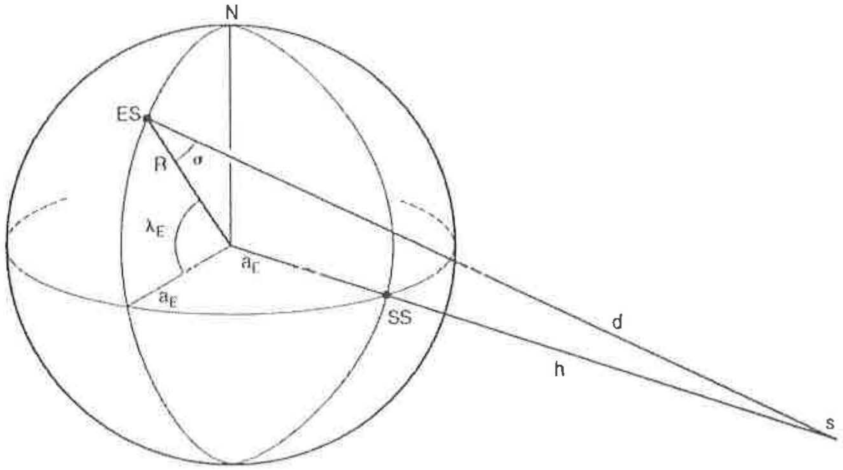


Figure A.1 The geometry used in determining the look angles for a geostationary satellite.

1. Earth station latitude - λ_E
2. Earth-station longitude - ϕ_E
3. Subsatellite point longitude - ϕ_{SS}

$a = 90^o$

$c = 90^o - \lambda_E$

$B = \phi_E$- ϕ_{SS}

Napier's rule:

$b = \cos^{-1}(\cos B \cos \lambda_E)$

$A = \sin^{-1}\left(\frac{\sin|B|}{\sin b}\right)$

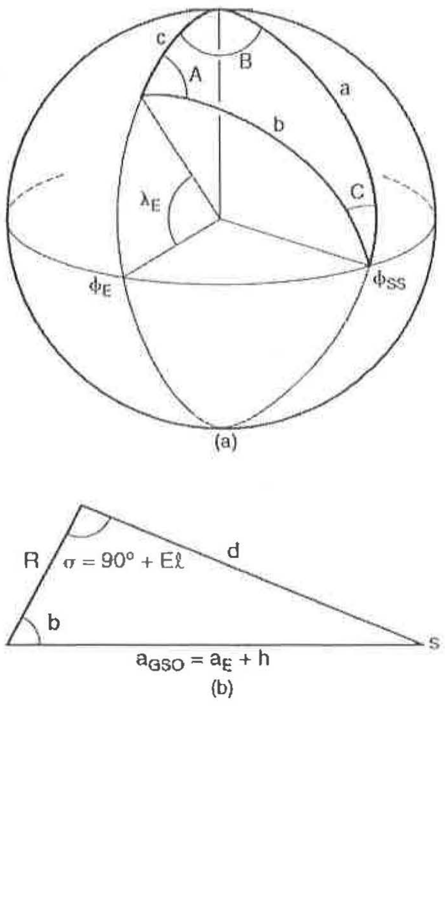


Figure A.2 (*a*) The spherical geometry and (b) The plane triangle obtained from Fig A.1.

LINK BUDGET EQUATIONS:

1	Max flux density at some distance r from transmitting antenna	$\psi_m = \frac{GP_s}{4\pi r^2}$
	Free space loss	$[FSL] = 10\log_{10}\left(\frac{4\pi r}{\lambda}\right)^2$
2	The link-power Budget Equation	$[P_R] = [EIRP] + [G_R] - [LOSSES]$
3	System Noise	
	Thermal noise	$P_N = kT_N B_N$
	Noise power spectral density	$N_0 = \frac{P_N}{B_N} = kT_N \; [J]$
	Cascade system	$T_s = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \cdots.$
	Noise factor	$T_e = (F-1)T_0$
	Noise figure	$[F] = 10\log_{10} F$
	Boltzmann's Constant	$k = 1.38 \times 10^{-23}\, J/K$
6	Carrier-to-Noise Spectral density Ratio	$\left[\frac{C}{N_o}\right] = [EIRP] + \left[\frac{G}{T}\right] - [LOSSES] - [k]$
7	Uplink (single carrier)	
	Saturation flux density	$[\psi_M] = [EIRP] - [FSL] - 10\log_{10}\left(\frac{\lambda^2}{4\pi}\right)$
		$[EIRP_S]_U = [\psi_S] + [A_o] + [LOSSES] - [RFL]$
		$[A_0] = -(21.45 + 20\log_{10} f)$ where f is in GHz
8	Downlink (single carrier)	
		$\left[\frac{C}{N_o}\right]_D = [EIRP]_D + \left[\frac{G}{T}\right]_D - [LOSSES]_D - [k]$
		$\left[\frac{C}{N_o}\right] = \left[\frac{C}{N}\right] + [B_N]$

		$[EIRP]_D = \left[\frac{C}{N}\right]_D - \left[\frac{G}{T}\right]_D + [LOSSES]_D + [k] + [B]$
8	Uplink & downlink	$\frac{N_o}{C} = \frac{P_N}{P_R} = \left(\frac{N_o}{C}\right)_U + \left(\frac{N_o}{C}\right)_D + \left(\frac{N_o}{C}\right)_{IM}$
9	Multicarrier downlink	$[\alpha] \leq [BO]_o$
		$KB = \alpha B_{TR}$