University of KwaZulu-Natal
School of Engineering

Main Examination: **2026**
Subject, course & code: **Selected Topics in Electronic Engineering I: ENEL4TA**

Duration: 2 Hours **Total Marks: 60**

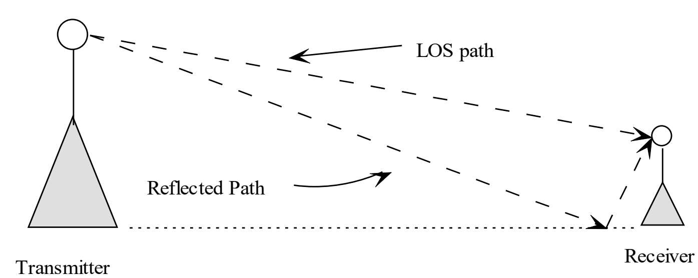
Examiner/s:	Prof. N Pillay	(Internal)
	Mr J Parker	(Internal Moderator)
	Prof. M Sumbwanyambe	(External Moderator)

Instructions:
1. This paper consists of **three** questions. ***Answer all three questions.***
2. All questions must be answered in full. All relevant assumptions must be documented clearly. Use diagrams where possible.
3. Programmable calculators may be used provided that all memory is cleared.
4. No notes of any kind are allowed. Useful data is attached at the back of the question paper

Question 1 [20]

1.1 **Derive** the formula for the numerical aperture of a fiber optical cable. **Include** a sketch showing the fiber geometry related to the numerical aperture. [6]

1.2 The illustration below depicts a transmitted wave travelling to a receiver in two ways (two paths). A line-of-sight path and a reflected path. Space (tropospheric) waves normally exhibit this property in their propagation.



A. **Write** expressions for the length of the line-of-sight path and the reflected path. [2]

B. **Using** your expressions in 1.2.A, derive the difference between these paths. Assume the range is large compared to the antenna heights. [2]

C. **Derive** an expression for the plane-earth loss model in dB using the above two-ray model by considering the ratio of the total amplitude to the direct component amplitude. Clearly **state** all assumptions. [7]

1.3 **Explain** using an illustration the meaning of average SNR in a channel with multiplicative noise due to fast fading. [3]

Question 2 **[20]**

2.1 A mobile communication system is to provide 98% successful communications at the edge of a cell. The path loss may be determined using the Okumura-Hata model for an urban area with base station height 20 m and mobile station height 1m. The carrier frequency has been set as 1500 MHz. It was found that the maximum accepted loss is 120 dB. **Determine** the range of the system if the location variability is 7 dB. [6]

2.2 Consider the following parameters for a C-Band satellite system:

Uplink:
Frequency: 6 GHz
Maximum hub earth station EIRP: 75 dBW
Fade Margin: 4dB
Total carrier-to-interference noise density ratio: 60dBHz
Multiple Access Scheme: TDM
Modulation: BPSK
Coding: Half-rate Convolutional code

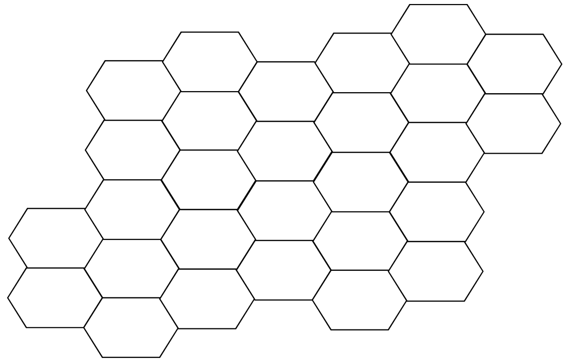
Space Segment:
Satellite location: 70°E
Elevation angle at edge of coverage: 12 degrees
Satellite *G/T*: 8 dB/K
EIRP/VSAT carrier: 50dBW
Transponder C-IM noise power density ratio: 60 dB

Downlink:
Frequency: 4 GHz
Fade margin: 5 dB
Total carrier-to-interference noise density ratio: 65 dBHz
VSAT *G/T*: 10 dB/K
VSAT antenna diameter: 1.7 m
Eb/No: 8 dBHz (BER = 10^{-7})

A. **Draw** a diagram showing the fundamental architecture of a satellite communication system. [3]
B. **Calculate** the range for this system. [2]
C. **Calculate** the uplink and downlink path loss. [2]
D. **Calculate** the bit rate for a user in this satellite system? [7]

Question 3 **[20]**

3.1 A particular area has been planned with the following cell layout.



Use the cell labelling formula to assign labels to each of the cells shown. Make use of a 7-cell cluster, while assuming the number of j cells is 1. [5]

3.2 Code division multiplexing allows for the transmission of information from multiple users by using pseudorandom sequences. Each user is assigned one or many orthogonal waveforms derived from an orthogonal code.

A. Consider 4-bit orthogonal codes generated from Hadamard matrices. **Write** out the first two sequences in time. **Use** an antipodal mapping in your solution. [3]

B. Suppose we want to transmit two messages '0 1 1' and '0 0 1'. Using the two sequences from 3.2.A, **sketch** the transmit waveform. [4]

C. **Verify** that the message '0 0 1' is recovered correctly using the transmit waveform from 3.2.B. [4]

3.3 **Show** that the worst-case noise power spectral density that can be coupled from a Johnson noise generator into the front-end of the receiver amplifier can be defined as $N_o = kT^o$, where k is the Boltzmann's constant and T^o is the Kelvin temperature. **State** all assumptions clearly. (Hint: Consider the open-circuit mean-square voltage of the noise generator). [4]

DATASHEET

$$B(S,a) = \frac{\frac{a^S}{S!}}{\sum_{k=0}^{S} \frac{a^k}{k!}}$$

$$C(S,a) = \frac{\frac{a^S}{(S-1)!(S-a)}}{\frac{a^S}{(S-1)!(S-a)} + \sum_{i=0}^{S-1} \frac{a^i}{i!}}$$

$$L_b(dB) = 42.6 + 26\log d(km) + 20 log f(MHz)\ for\ d \geq 20m$$

$$L_{PU}(dB) = 69.55 + 26.16logf_c(MHz) - 13.82logh_b(m) - \propto [h_m(m)] + [44.9 - 6.55logh_b(m)]logd(km)$$

$$L_b = \begin{cases} L_0 + L_{rts} + L_{msd} & for\ L_{rts} + L_{msd} > 0 \\ L_0 & for\ L_{rts} + L_{msd} \leq 0 \end{cases}$$

$$L_0 = L_{fs} = 32.45 + 20logf(MHz) + 20logd(km)$$

$$L_{rts} = -16.9 - 10logw(m) + 10logf(MHz) + 20log\Delta h_{Mobile}(m) + L_{Ori}$$

$$L_{Ori} = \begin{cases} -10 + 0.354\varphi(degrees) & for\ 0° \leq \varphi < 35° \\ 2.5 + 0.075(\varphi(degrees) - 35) & for\ 35° \leq \varphi < 55° \\ 4 - 0.114(\varphi(degrees) - 55) & for\ 55° \leq \varphi < 90° \end{cases}$$

$$L_{msd} = L_{bsh} + k_a + k_d logd(km) + k_f logf(MHz) - 9logb(m)$$

$$L_{bsh} = \begin{cases} -18\log(1 + \Delta h_{Base}(m) & for\ h_{Base} > h_{Roof} \\ 0 & for\ h_{Base} \leq h_{Roof} \end{cases}$$

$$k_a = \begin{cases} 54 & for\ h_{Base} > h_{Roof} \\ 54 - 0.8\Delta h_{Base}(m) & for\ d \geq 0.5km\ and\ h_{Base} \leq h_{Roof} \\ 54 - 0.8\Delta h_{Base}(m).\frac{d(km)}{0.5} & for\ d < 0.5km\ and\ h_{Base} \leq h_{Roof} \end{cases}$$

$$k_d = \begin{cases} 18 & for\ h_{Base} > h_{Roof} \\ 18 - 15\frac{\Delta h_{Base}(m)}{h_{Roof}(m)} & h_{Base} \leq h_{Roof} \end{cases}$$

$$k_f = -4 + \begin{cases} 0.7(\frac{f(MHz)}{925} - 1) & for\ medium\ sized\ city\ and\ suburban\ centres \\ 1.5(\frac{f(MHz)}{925} - 1) & for\ metropolitan\ centres \end{cases}$$

$$\eta = arctan\left(\frac{\cos(\varphi) - \sigma}{\sin(\varphi)}\right) \quad \propto [h_m(m)] = \begin{cases} 8.29[log1.54h_m(m)]^2 - 1.1, & f_c \leq 200\ MHz \\ 3.2[log11.75h_m(m)]^2 - 4.97, & f_c \geq 400MHz \end{cases}$$

$$\varphi = 90^0 - \eta - \sin^{-1}\frac{\cos(\eta)}{6.6235}$$

$$d = 35786[1 + 0.4199\{1 - \cos(\varphi)\}]^{\frac{1}{2}}$$

Urban areas	$L_{dB} = A + B \log R - E$
Suburban areas	$L_{dB} = A + B \log R - C$
Open areas	$L_{dB} = A + B \log R - D$

where

$$A = 69.55 + 26.16 \log f_c - 13.82 \log h_b$$
$$B = 44.9 - 6.55 \log h_b$$
$$C = 2(\log(f_c/28))^2 + 5.4$$
$$D = 4.78(\log f_c)^2 - 18.33 \log f_c + 40.94$$
$$E = 3.2(\log(11.75 h_m))^2 - 4.97 \text{ for large cities, } f_c \geq 300\,\text{MHz}$$
$$E = 8.29(\log(1.54 h_m))^2 - 1.1 \text{ for large cities, } f_c < 300\,\text{MHz}$$
$$E = (1.1 \log f_c - 0.7) h_m - (1.56 \log f_c - 0.8) \text{ for medium to small cities}$$