Continuous Assessments for Ning Zhen

Wireless and Satellite Networks

1. Introduction

You are asked to examine performance options for a small satellite communications system, aimed at government and military use in Ruritania, a fictitious country. A satellite and some ground terminals are available, with a number of technical and supplier constraints.

You are asked to give advice on the merits and performance of the various options available. This will involve examination of frequency bands, link budgets and capacity.

The output of the assignment will include outline link calculations, together with some comments and recommendations. You are expected to provide just a few illustrative link budgets, together with relevant comments and observations. The assignment is open-ended, and there is no "best" solution.

Your report should be not more than 10 pages maximum. It should identify areas for further study or more detailed assessment. Calculations should be as simple as possible: in general, the parameters here are not very precisely defined, so accuracy of greater than about 0.1 dB is not called for or appropriate. In many case 1 dB precision may be sufficient.

2. Procedure

Consider initially only the SHF (X-band) operation. Explore some possible communication links on the basis of the parameters given below, and draw up a few link budgets to show which options are feasible and to illustrate the constraints. In the course of this you may make any assumptions, and identify where information is missing or uncertain.

You will initially need to examine the up- and down-links separately and produce some simple link budgets. To refine these, determine whether the uplink signal is sufficient to overcome the satellite front-end thermal noise, and if not then identify the consequences in terms of downlink signal EIRP. Subsequently, you will combine the two link portions to determine overall carrier-to-noise density, C/N_0, and hence estimate supportable traffic based on the modem figures given.

Having characterised single accesses, you then need to consider roughly how many accesses may be simultaneously supported by the system: this will require consideration of how the satellite EIRP is shared between accesses. (You will also need to consider whether traffic is simplex - i.e. one-way - or duplex.)

When you have finished looking at the capacity of the SHF band and explored potentially useful links, then you can consider the Jamming Threat, and demonstrate how it might be overcome by use of spread spectrum anti-jam measures.

3. Resources and requirements

The technology and equipment under consideration involves a geostationary satellite operating in the SHF and EHF bands, together with some (old fashioned 1980's technology) ground terminals.

3.1 Available Frequency Bands

	SHF:	**EHF:**
Uplink	8 GHz	44 GHz
Downlink	7 GHz	20 GHz

3.2 Ground Terminals

Each terminal may be procured for operation in any one of the above frequency bands:

Type *A* (large):	Dish 13 m diameter Pointing accuracy 0.05° R_X noise temp 400 K (all bands) Available T_X power: 1 kW (SHF), 200 W (EHF)
Type *B* (semi-portable):	Dish 2 m diameter Pointing accuracy 0.5° R_X noise temp 500 K (all bands) Available T_X power: 10 W (all bands)
Type *C* (manpack):	Dish 60 cm diameter Pointing accuracy 2° R_X noise temp 350 K (UHF & SHF), 800 K (EHF) Available T_X power: 2 W (all bands)

3.3 Terminal Deployments and Links

The system calls for a single fixed main hub station (the "Anchor" Station), together with a number of portable/mobile tactical terminals; these are all capable of handling either frequency band. The hub station will use one large ground terminal (Type ***A***). The terminal deployment will comprise up to 10 semi-portable terminals (Type ***B***) plus up to 10 portable "Manpacks" (Type ***C***).

The communications link possibilities under examination may be summarised:

Hub to type ***B***	(Full duplex, i.e. both ways at once)
Hub to type ***C***	(Duplex or one-way as appropriate)
Type ***B*** to Type ***B***	(Duplex or one-way as appropriate)
Type ***B*** to Type ***C*** (if readily feasible)	(Duplex or one-way as appropriate)

Type ***C*** to Type ***C*** (if readily feasible)	(Duplex or one-way as appropriate)

Ideally the system should be able to handle several links between the hub station and the Type ***B*** terminals: you should attempt a rough estimate of how many. Any multiplexing will probably be done simply using FDM, and you may assume that the Multiple Access technique is FDMA. (However, determination of Intermodulation noise is beyond the scope of this exercise, and it may be ignored: only a first-order solution is required).

3.4 Traffic

The traffic options under consideration are:

T1: 64 kbit/s BPSK high-quality PCM speech or data (BER better than 10^{-5})

T2: 2.4 kbit/s BPSK compressed or vocoded speech (BER better than 10^{-3})

T3: 50 baud FSK telegraph data (BER better than 10^{-5}).

Fortunately, you are saved added calculation as the modems to be procured have defined minimum operating input signal-noise parameters (C/N_0) for each traffic type as follows:

T1: 61 dB-Hz; **T2:** 43 dB-Hz; **T3:** 30 dB-Hz.

In practice a mix of traffic rates could be employed, and the higher data rates used where possible; this will depend on feasibility (and cost).

3.5 The Satellite

This is in geostationary orbit, requiring a terminal antenna elevation angle of about 30° in Ruritania. Because the north-south station keeping is poor by modern standards, the pointing angle to the satellite varies ± 2° (roughly N-S sinusoidally, with 24 hr period). The pointing accuracy of the satellite itself due to attitude control is better than ± 0.2°.

The transponders are all transparent, and are designed with sufficient gain that they can saturate upon satellite front-end thermal noise. (You may assume that they are likely to be operated in this mode, and that output power is shared simply *pro-rata* to input powers, including noise. Small signal suppression effects may be neglected). The following transponder options are on offer:

SHF:	One channel available, 25 MHz wide. The –3dB antenna beamwidth on the satellite provides coverage of the visible earth. R_X system noise temp 1000 K (includes earth noise) T_X power is 10 W.
EHF:	One channel, bandwidth 200 MHz. Antenna coverage is one quarter of earth cover (T_X and R_X). R_X system noise temp 1500 K, T_X power is 10 W.

4. The threat and countermeasures

Hostile Arcadia is building a large ground terminal 500 km away from Ruritania's main hub station. It has been estimated that with their access to advanced technology, the Arcadians may be able to provide an EIRP of 2 x 10^{11} Watts (all bands). Ruritania does not expect its links to survive any jamming, but does wish to maintain a one-way link (i.e. broadcast) @ 2.4 kbit/s out to the Type ***B*** terminals under all circumstances. You should briefly investigate this, and suggest how it can be done and what the implications are.

Spread Spectrum (SS) techniques may be used with a de-spreading receiver either at the ground terminal or/and on the satellite. SS can provide a Processing Gain (PG) advantage over an uncorrelated signal, which may be taken as the ratio of the total spreading bandwidth to the information channel bandwidth.

You need not become involved in the details of SS design, but it is worth remembering that there are two fundamental types of Spread Spectrum:

(i) Direct Sequence (DS) involves multiplying the signal by a fast pseudo-random code (at typically several Mbit/s) prior to transmission, and then multiplying again at the receiver: this inverse operation reproduces the original signal which may be band-pass filtered. Any interference is itself spread and is rejected by this filter by an amount equivalent to the PG. Synchronisation limitations suggest a maximum code chip rate of about 40 MHz.

(ii) Frequency Hopping (FH) involves transmitting briefly on discrete frequencies in a pseudo-random pattern (typically up to 20 kHop/s). The receiver local oscillator follows this pattern, and interference is unlikely to affect all hops. Generally some forward error-correction is used (perhaps with interleaving), and you may assume that the same broad criterion for PG applies. (An advantage of FH is that a very much greater spread BW may be employed, giving greater PG).

5. Subsidiary information

The Boltzmann constant, $k = 1.38 \times 10^{-23}$ W Hz^{-1} K^{-1}

Typical antenna efficiency, η, may be taken as 60% for all dishes except the small manpack, for which 40% may be a realistic estimate.

Antenna Gain $G = 4\pi A\eta/\lambda^2$. Antenna beamwidth may be taken as 1.2 λ/D (rads).

Suggested single propagation path margins (i.e. ground-satellite or vice-versa) for weather and other normal propagation effects (in Ruritania):

SHF	3 dB	
EHF 20 GHz	4 dB	(gives 95% availability)
	10 dB	(gives 99% availability)
EHF 44 GHz	13 dB	(95%)
	45 dB	(99%)

Communications Systems

1. Queuing and Traffic Modelling

a) A big insurance company is designing a new call centre. Customers phone the call centre entirely at random, with an average of 100 calls being received per hour. Calls last for an average of five minutes, and are negatively exponentially distributed in length. You are asked to calculate how many people should be employed to answer the telephones.

Make reasonable assumptions about the quality of service (in terms of blocking and/or waiting times) for this case, and show how your assumptions lead to the result you quote. (About 500 words and any derivations required).

b) What does AIMD stand for in the context of TCP congestion control? While AIMD has been extensively used in the past, several recently proposed schemes, including Binary Increase Congestion TCP and Compound TCP have moved away from AIMD. Describe how these schemes work, and what their advantages are over the use of conventional congestion control schemes. (About 1000 words required).

2. Information Theory

a) A binary source generates the symbol '1' with probability 0.8. Find the information rate (entropy) of this source in bits/symbol.

b) The data from the source of part (a) is to be compressed using a Huffman code. Devise a suitable code, and find its compression ratio and encoded source efficiency. (You will need to choose a suitable input block length). Comment on the result in view of the information rate of the source.

c) Binary data is transmitted over a binary symmetric channel with error probability 0.08. Find the capacity of the channel in bits/symbol.

d) A Hamming (7,4) error-correcting code is used for the data on the channel of part (c). Find the decoded word and bit error probability. Comment on the result in view of the capacity of the channel.

Optical Communications

Discuss a possible architecture of an intercontinental fibre-optical link operating at an aggregate rate of 1 TBit/s.

Briefly comment on the main limitations that have to be overcome in such a system.

Comment on the design that you would expect to find in the current generation of systems.

Include in your report, explaining your choices/answers:

1) The operating wavelength
2) The type of fibre used.
3) The choice of a multiplexing scheme, if any, the number of channels, bit rate per channel, etc.
4) The choice of the transmitter and receiver components and which of their operating characteristics you think are the most important for this application
5) The presence or absence of any active booster-type elements embedded inside the fibre link.

Finally, comment on what other strategies may be used in the future to achieve the aggregate throughput of the same order or higher.

A report of around 5 or 6 pages is expected.

Personal and Mobile Communications

You have been asked to design an entirely new cellular communications system. The bandwidth you have available is not-paired, and consists of a single frequency band 400 kHz wide at 300 MHz. The system is intended to provide voice and low-rate data communications for users over a large area. A modulation scheme capable of transmitting 2 bits per symbol, and requiring a CINR of 8 dB has been selected.

You can assume that the propagation environment can be modelled by an inverse-fourth power law with 12 dB log-normal shadowing, and Rayleigh fading.

Design the system. Include in your report, explaining your choices/answers:

1) How large the cells in your system could be, and what limits this size.

2) What the maximum speed of users in your system is.

3) How your system would cope with very slowly moving users experiencing slow fades.

4) The frame and packet formats.

5) As estimate of how many voice users could be supported in each cell.

6) What control signals would be required, and how they would be multiplexed with the data.

7) How your system could be expanded in future to provide higher data rates.

Note that there is no one "right" answer - you are free to choose any technology you feel is most appropriate. It is the justifications of your choices that is of most interest.

A report of around 5 or 6 pages is expected.